New Frontiers in Agricultural Extension – Volume II

Editors

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The Cereal Systems Initiative for South Asia (CSISA) is a regional initiative to sustainably increase the productivity of cereal-based cropping systems, thus improving food security and farmers' livelihoods in Bangladesh, India and Nepal. CSISA works with public and private partners to support the widespread adoption of resource conserving and climate resilient farming technologies and practices. The initiative is led by the International Maize and Wheat Improvement Center (CIMMYT), is jointly implemented with the International Food Policy Research Institute (IFPRI), the International Rice Research Institute (IRRI) and Indian Council of Agricultural Research (ICAR) and is funded by USAID and the Bill & Melinda Gates Foundation.

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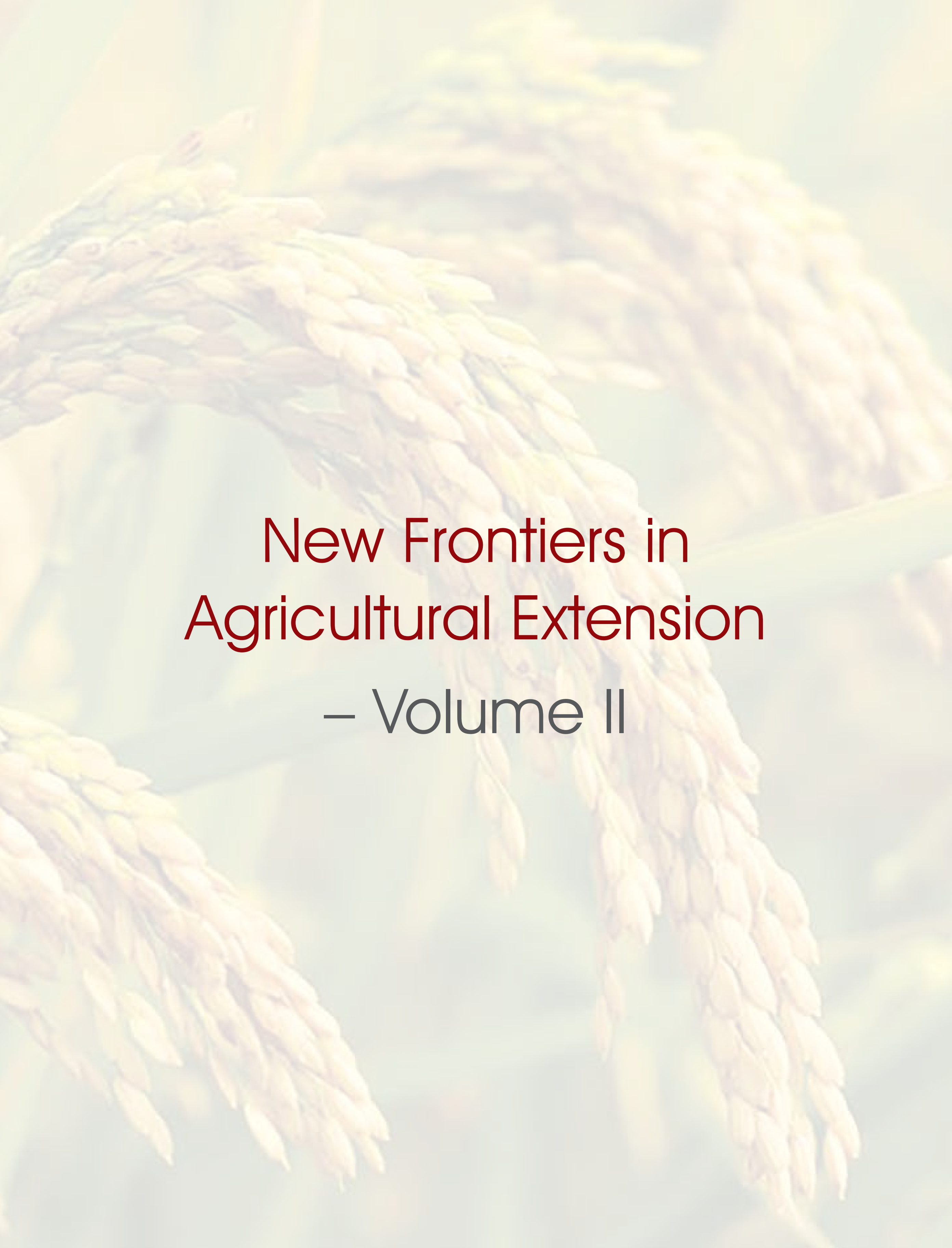

New Frontiers in Agricultural Extension

– Volume II

Contents

3. Evidence Based District Level Adoption Patterns of Technologies to Identify Future Actions

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Foreword

Cereal-based cropping systems are vital to the food security in South Asia as population increases are high in this area- a cause of concern for the livelihood of the most densely populated region of world. The year 1966 saw the start of Green Revolution (GR) based on new high yielding fertilizer responsive varieties, which initiated the expansion in food production. It was a significant milestone in the fight against the food shortages of late 1960s and 1970s. We are proud of what we have achieved in rice-wheat cropping system (RWCS) and in rice-rice cropping system (RRCS) so far, but this success is not uniform across the region. Rice has been the center of significance as far as the cropping system productivity is concerned. Now that milestone has to be sustained, especially in view of climate change. Creation of infrastructure for irrigation made the GR easier in Punjab, Haryana and Southern states. By and large the impact of GR in eastern states is small compared to regions with assured irrigation. However, regions of assured irrigation are now facing the second-generation problem of falling water tables, whereas eastern states have lower adoption of new technologies. The agronomic management gaps between stronger North-west and Southern states and weaker Eastern states have remained as such. Furthermore, productivity growth did not result in an increase in earning or wealth by farmers across all states. New technologies require scaling, which is not happening. The focus has to shift from a top-down approach to developing and scaling farmer-led innovative research and their transformation or adaptation of recommended technologies. At a time when yield gaps within and between states are large, it is important to understand why farmers' interest (or incentive) does not necessarily align with scientists' solutions.

The impact of climate change across South Asia, second generation problems in some states, and slow growth in other states are now shaping the research and extension agenda in rice. There has to be a focused attention on setting priorities to tackle these problems. The lesson learnt is that the major breakthrough does not come from the top-down approach and through isolated approaches based on commodity crops. Hence, there is a need to shift the perspective to systems and build on the lessons learnt so far, and requirement is of new initiatives in the form of big data analytics on – what works, what does not work and why. The priority setting should now be based on a strong feedback mechanism, backward integration, bottom-up approach, big data generation, data analytics and its digitization and evidence-based scaling approach. The KVK system, which operates at district level, needs to: (i) up-grade knowledge base of their scientists within their specialization; and (ii) equip them with the skills in digital data collection and analytics, which will become a key part of their activities in future. If modern varieties powered the GR, crop and system management are required to play a greater role in the second GR. Yield gaps can be handled effectively only if these become evident through a sound data-base and the prioritization of rapid monitoring, evaluation, and learning (ME&L) processes. This publication reveals how this can be achieved.

This publication brings together the status of technology adoption patterns of rice-based technologies across eight states–Andhra Pradesh, Bihar, Chhattisgarh, Haryana, Odisha, Punjab, Uttar Pradesh (mostly Eastern Uttar Pradesh) and West Bengal. Such data sets should be regularly gathered through the well-connected KVK system and used at district, state and national levels for developing of research and extension plans. Since such data sets need to be more granular and detail oriented, ATARIs are the best institutions to provide a base line and monitor the progress in the adoption of technologies to narrow the yield gaps in crops and cropping systems. The research institutions and state agricultural universities can use this information in developing the technical programs and then expand in a broader farming system framework. In the long run, such data sets can be used to understand adoption patterns and making strategic decisions on seasonal planning by the department of agriculture (DoA) in states. Eventually it could be a logical next step towards big data and machine learning as part of new frontiers in agricultural extension.

The primary objective of the publication *New Frontiers in Agricultural Extension,* Volume II, is to understand the opportunities to align the rice-based cropping system research and extension from the ground-up rather than top-down approach. I hope, with greater need for a strong data base used in this publication, the prospects of setting evidence-based research and extension priorities and ME&L will improve efficiency in National Agricultural Research, Education and Extension System.

(T. Mohapatra)

Date: 15th December 2020
Place: New Delhi 110 001

Preface

The growth in rice production is primarily due to increase in yields made possible through gradual replacement of old varieties with new varieties developed in research institutions, improving the access to irrigation and use of external inputs. This helped in poverty alleviation and improvement in food security. Such growth of rice production also generated a sense of complacency, which considerably slackened the growth of rice production. Farm mechanization and hybrid technology on one hand and on the other hand changing climate in the form of monsoon variability and depletion of natural resources, are affecting the research and extension needs in rice. The eastern regions are having good potential to produce high rice yield due to sufficient rains, but the rice productivity is still low. There are yield gaps within and between states. If the research and extension managers are keen to bridge the yield gaps, the National Agricultural Research and Extension system (NARES) has to develop the most predictable and practical technical solutions based on the evidence generated through strong data base generated at the grassroots level. The excellent KVK network can be used to find a systematic way to bridge the yield gaps. The land scape diagnostic survey (LDS) can help in identifying sources across states to bridge these yield gaps. Data presented in the publication *New Frontiers in Agricultural Extension*, Volume II, will provide the ability to explain clearly as to why some technologies were accepted and others not. Once it is done the researchers will fully understand the need of the market including farmers and private sector, and help targeting areas of research and extension to bridge the yield gaps. The grassroots level of evidence-based adoption patterns is expected to evolve new ways of real time extension which in the long run depends on digitization of agriculture and machine learning.

After publishing the first volume of *New Frontiers in Agricultural Extension*, the *Volume* II contains 15,434 data points on the adoption patterns of new technologies in rice across eight states in India. This is the first systematic survey that covered wheat in volume I and now covers rice in volume II. Data sets were comprehensively analyzed and presented in three broad categories including methodology, thematic areas related to varieties, crop establishment, irrigation, nutrients and weed management and district-wise technology adoption patterns. The digitization will eventually lead to a dynamic shift towards machine learning.

This is an exciting field in which scientists continually learn new approaches to monitor, evaluate and learn (ME&L) the technology adoption process more effectively and efficiently. Dynamic aspects of preferences of farmers are well presented in the book and it further builds on the excellent institutional arrangement of KVK system having professional experience on most disciplines in agriculture. Data collected from farmers provided useful insights like –need to operate at different time scale in thinking. The write-ups indicated that linking and analyzing data within and between states would help measuring effectiveness of recommendations made by NARES. In the long-run attempts like this will induce the system towards adoption digital system of real time extension.

This publication will help research and extension organizations to re-invent and come up with programs for generating recommendations and to fast track the cycle of research and extension, support KVKs and DoA in states to facilitate adoption. It will help in– identifying actionable steps through ME&L, ensuring a proper feedback to research institutes and extension agencies of states at regional level for making informed decisions, and finally aggregating the feedback information at central level for an effective planning of technical programs.

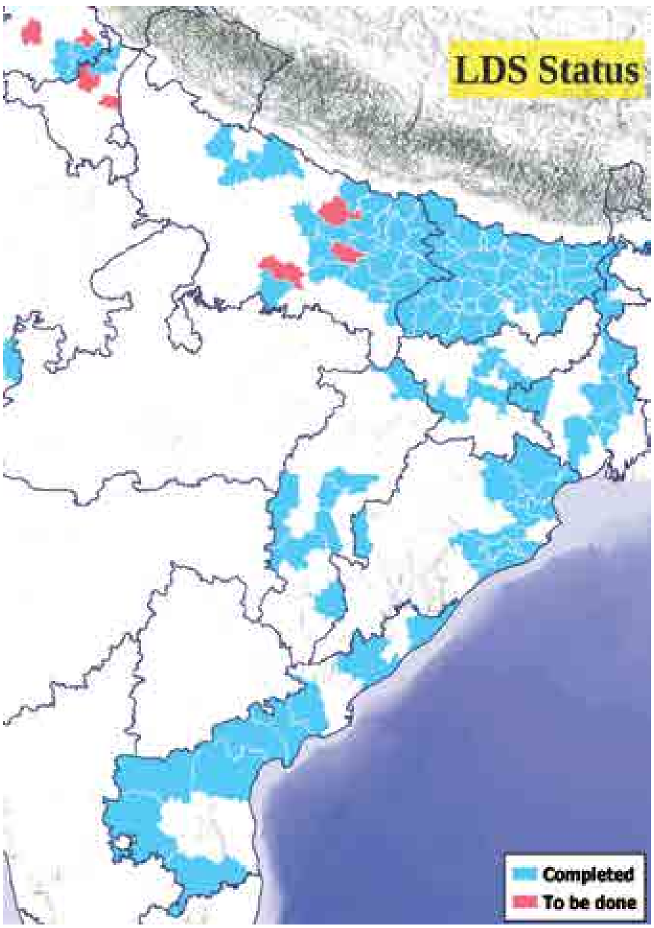
This publication is based on the contributions from Arindam Samaddar, Ashok Yadav, Ashok Rai, Anurag Ajay, Sachin Sharma, Harshit Rajan, Umesh Yadav, Gokul Paudel and colleagues from Indian Agricultural Statistics Research Institute (IASRI) for methodology, data management and capacity development of KVK and project staff. Cynthia Carmona Reyes, Nima Chodon, Ajay Kumar, Shishpal Poonia, Anurag Kumar, Madhulika Singh, Pankaj Kumar, Shahnawaz Dar, Prabhat Kumar, Deepak Kumar Singh, Moben Ignatius, Sugandha Munshi, Peramaiyan Panneerselvam, Wasim Iftikar, Bidhan Mohapatra, Nabakishore Parida and Narayan Chandra Banik Principal Investigators and Co-Principal Investigators of participating KVKs for conducting the surveys and analysing the data. Directors of extension and Directors of ATARIs helped providing facilities.

Editors

Executive Summary

Peter Craufurd

The green revolution significantly improved rice and wheat productivity in South Asia that enhanced the income of cereal farmers and lowered prices for consumers. The increase in food production alleviated hunger and poverty across South Asia. Rice cultivation in the country is mostly dependent on monsoon-rain but also includes pockets with assured irrigation. Rice yield growth has slowed considerably in recent years. The green revolution has not been a sustainable event with some regions, including the North west states and Southern states, which benefitted more than many eastern states. With yield growth still being flat in Eastern Gangetic Plains and in places like Odisha, the stage is now set for a debate on why yield growth is stagnant in these ecologies where climatic, hydrologic, and edaphic conditions are much suitable for high yield potential. This weakness is a cause of concern for livelihoods in the most densely populated region of South Asia. Punjab and Haryana states, having high productivity levels struggling to manage their falling water table and potentially facing a



significant crisis. In most places attempts to diversify rice have not been successful. There are options to diversify within rice by replacing long duration rice varieties (LDRVs) with medium or short duration rice varieties, but their yield levels are not matching the yield levels of LDRVs. The uncertainties in both scenarios are increasing by extreme weather conditions frequented due to climate change. This has brought about the need for change and the quest to understand status of agronomic practices as part of monitoring, evaluation, and learning (ME&L) to set research and extension priorities. The critical need is to save irrigation water in the NWIGP, to make joint response to climate change, to avoid drought like situation in Eastern Indo-Gangetic Plains (EIGP), and to facilitate sustainable intensification of farming systems to improve the profits of farmers.

The landscape diagnostic survey (LDS) was conducted to understand what technologies are being accepted by farmers and to identify factors, which will help improve the productivity of rice. The LDS will provide key insights on trends for overall adoption and performance of technologies recommended over time, i.e. whether technology adoption is on track or whether may have to change the track. The data analysis and results presented in this publication represent an early stage in the evolution of a new frontier or ecosystem for agricultural research and extension system. New advances foundedon Open Data Kit (ODK)-based electronically collected big data and R-based advanced analytics offered possibilities of rapidly tracking the challenges in the adoption of technologies and location-specific best suited agronomy. The LDS also shows the power of bigger data. The LDS analysis can identify mega or large trends across regions (e.g. variety/hybrid use), interactions and more local or ecology specific contexts (e.g. the performance of long vs medium duration varieties in different ecologies), and importantly identify new categories or groupings to target and understand adoption (e.g. by types and number of irrigations). This ecosystem requires an integrated effort on the part of biological and social scientists to diagnose issues faster and find solutions accordingly.

The LDS was conducted in all 102 districts from 10 states (Bihar (n=7,136), Uttar Pradesh (n=2,546), Odisha (n=1,193), West Bengal (n=1,876), Chhattisgarh (n=685), Andhra Pradesh (n=,), Haryana (n=415), and Punjab (n=388)) covering eight ATARIs and 110 KVKs. These data sets are accessible at Indian Agricultural Statistics Research (IASRI) and offer big benefits to support the division of Extension, ICAR for regular monitoring, evaluation and learning (ME&L) from the adoption patterns of different technologies across states. Results suggested that on average, farmers view yield and profits more favorably while adopting new technologies. Following points have emerged.

- Data on varietal adoption in rice highlights the widest spread of MTU 7029, a long duration rice variety (LDRV) released in 1982, with its adoption by 9.4, 26.6, 35.6, 37.6, 21.1, and 35.1% households (HHs) in Andhra Pradesh, Bihar, Chhattisgarh, Odisha, Uttar Pradesh, and West Bengal, respectively. If we also consider more than 50% HHs adopting Pusa 44, a LDRV in Punjab, the share of LDRVs is higher than any other group. The adoption of BPT 5204, a medium duration rice variety (MDRV) maturing in 140-145 days released in 1986, is still widespread with 41.8, 4.1, and 19.8% HHs in Andhra Pradesh, Bihar, and eastern Uttar Pradesh, respectively. Among short duration varieties Sarju 52, an old variety released in 1980s, was adopted by 5.4 and 5.9% HHs in Bihar and eastern UP, respectively. The adoption of hybrids became evident with 36, 35, 11 and 11% of surveyed HHs in Bihar, Haryana, Chhattisgarh, and eastern UP, respectively, using hybrids. Among hybrids, Arize 6444 Gold was adopted by 64.8, 63.3, 11.6 and 56.5% HHs in Bihar, Haryana, Chhattisgarh and eastern UP, respectively. The continued adoption of old varieties showed that these varieties have endured uncertain and variable monsoon more than the new varieties and/or have valued taste and other organoleptic properties. The adoption of new varieties was visible in Punjab, Haryana, and Andhra Pradesh, but not in the eastern states.

- Hybrids are more popular in Bihar and Haryana. Within Bihar, these are more popular in upland ecologies. The adoption of hybrids by 50 to 98% of HHs from 11 districts in a sample of 42 districts with hybrids in Bihar, eastern UP and Haryana showed that the high frequency is either because of water stress or due to prevalence of intensified cropping system in these districts. Such evidence also showed that hybrids and/or basmati rice can be targeted for diversification if it is difficult to popularize alternate crops in Haryana and Punjab. Hybrids, therefore, provide a pathway for cropping system intensification, which is the only way to increase the income of small holders. The estimates also showed adoption of new basmati varieties in Haryana. The emphasis on more profits from intensification would encourage farmers to consider the adoption of hybrids. This trend seems long lasting.

- High seed cost was considered a deterrent for adoption of hybrids. Farmers innovated the use of one-third less seed and made it economically viable for small and marginal farmers. Data also suggested that adoption of hybrids is almost same in all categories of farmers and the social factor (e.g. farm size) did not determine adoption. We should leverage this into an opportunity. Hybrid rice also accelerated the adoption of early wheat sowing in many districts of Bihar and eastern UP.

- Although more than 350 varieties were reported to be cultivated in farmers' fields in the western and eastern ecologies, just five to nine varieties/hybrids are grown by more than 80% HHs. The most preferred varieties in Punjab, Haryana and Andhra Pradesh are those, which were developed in the region; whereas in eastern India, popular varieties are those which were imported from other regions.

- The rainfall in the Eastern states is more than that in Punjab, Haryana, and Andhra Pradesh, but the underlying problem of access to electricity-based tube-well irrigation is still unresolved. This problem gets more serious in years when the rainfall is delayed or when the number of rainy days is less, a regular feature now with the advent of climate change. The high cost of irrigation and the resultant low yields changed the underlying economics of rice cultivation, which is less profitable in these ecologies than that in Punjab, Haryana, and Andhra Pradesh with assured irrigation. With low cost irrigation farmers can ensure flexibility in the management cycle of their rice crop. The lower water productivity in different states is a consequence of lack of access to low cost irrigation in the eastern states as well as the variable and uncertain monsoon rains.

- Transplanting of rice at optimum time – mid-June to mid-July – is central to better yield performance of rice in the North-west Indo-Gangetic Plains (NWIGP), and similarly in the Eastern Indo-Gangetic Plains (EIGP). The improving paddy yield due to timely transplanting has its own logic. For translating the lessons learned from high yield producing states like Punjab and Haryana, the policies in the eastern states should focus on timely transplanting and services needed to achieve that goal. The fundamental assumption is that the farmers have access to electricity up to their field and if so, farmers will install tube wells according to their intensification needs. When the transplanting period is stretched too much, system productivity and profit margins decline. Time management, therefore, is big incentive to optimize of rice-based cropping systems. Even a small change in transplanting will help harnessing best out of long duration varieties, which were found dominating in all surveyed states

- The work on the introduction of new crop establishment (CE) methods was found less impactful. Efforts to replace puddled transplanted rice (PTR) with direct-seeded rice (DSR) could be more successful if it is drill seeded in a conventionally tilled field after pre-sowing irrigation or sufficient rainfall. Because of soil mulch created by proper field preparation, the moisture does not escape from the dry soil, and irrigation is not needed for 2 to 3 weeks after sowing; saving water. The dry upper surface as a consequence would reduce the weed emergence. The state-run schemes should recognize the fact that some CE methods like direct broadcast seeding of rice (DBSR) followed by *beushening* (DBSRB), a common practice in Chhattisgarh and Odisha, is less productive and getting costly. Direct drill seeded rice could be an alternative option.

- In Punjab, paddy yields are increasing for almost 50 years with no or very limited addition of P and K. In contrast, farmers in Eastern UP, Bihar and Andhra Pradesh are using more NPK without looking at the rate of return. This progression and the survey contain hints that perhaps issues like NPK ratio need to be resolved for creating a platform for improved nutrient management and optimization of cropping systems in the Eastern States. Soil-test values are the drivers of change in the recommendations; however, the challenge is how to generate better rate of return and increase factor productivity though agronomic management. The access to soil-test values alone is insufficient in decision making. These data sets indicated that the combination of soil test values with crop responses and the landscape data analytics cannot be overlooked. The agronomic management is the foundation and should be made an integral part of nutrient management.

- Early weed competition is crucial and the cropping system played its role. There is dominance of weeds like *Cynadon dactylon* in rice-fallow cropping system (RFCS) and rice-pulse cropping system (RPCS) in Odisha, Andhra Pradesh and Chhattisgarh; *Cyperus rotundus* and *Cynadon dactylon*, in Bihar; *Echinochloa colonum* in Eastern UP, and *Echinochloa crus-galli* and *Cyperus iria* in Punjab and Haryana. These dominant weeds affected the demand for herbicides differently in different states. In Odisha and Bihar, sole hand weeding-based weed control was found to be the most dominant method, practiced by >65 % of households. The use of herbicide-based weed control methods (herbicide alone or herbicide + hand weeding) were the lowest in Odisha and Bihar (24-29 % of households), followed by Andhra Pradesh, West Bengal, and Chhattisgarh (52-55 % of households), and EUP (66 % of households). The use of herbicides was the highest in Haryana and Punjab with 80 % and 100 % of households, respectively.

With growing uncertainty due to climate change and the increased role of the private sector, especially in respect of new seeds and external inputs, every institution or organization in the research and extension or R4D system should collaborate to make research and the extension system more pluralistic and more demand or solution-led. The initial LDS results presented in this publication, revealed that what works (and what does not work) at farm level, i.e. the priority solutions. The need is, collectively and inter-disciplinarily, to understand both the underlying causes of low productivity and sustained improvement in the cropping systems productivity, as well as understand the 'why', especially the context, and hence how to more effectively promote that works. To do this the system should rely on the evidence generated through data, not only in each crop but also on the whole range of farming systems, acknowledging the knock-on effects or trade-offs inherent in decisions that farmers have to make. The big data link of this nature is equivalent of a systemic ME&L and can be used planning of technical programs and extension agenda.

1. Data Collection and its Processing Methods

1.1 Sampling methodology for landscape diagnostic survey for rice in India

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Sampling method, one of the important factors, determines the correctness of survey results. There are many ways of drawing survey samples depending upon the need and situation. Survey results get distorted if anything goes wrong in selecting samples. Cereal System Initiative for South Asia (CSISA) in collaboration with Indian Council of Agricultural Research (ICAR) in India planned to gather information about rice crop production practices at large scale. This electronically enabled survey was implemented through *Krishi Vigyan Kendra* (KVK) of each district. In 2019, the survey was implemented in 70 districts across eight Indian states (Bihar, Uttar Pradesh, Odisha, Andhra Pradesh, West Bengal, Chhattisgarh, Haryana and Punjab). Approximately 14,000 farmers were interviewed. The objectives of this electronically enabled survey were to fill existing data gaps, generate recent data-based evidences, derive better insights and facilitate informed decisions by policy makers. Sampling methods used for the survey are given in detail in this article.

Data Collection

There are several methods of data collection that can be applied in field surveys. These methods fall into two broad categories :

Quantitative Methods

Data are collected in a random sample of observation units i.e. farm households. Random sampling is required to ensure that the sample is representative of a larger underlying population e.g. farm households in a district. From each observation unit, the same set of information is elicited using a structured questionnaire. If the observation unit is a farm household, this means that each respondent farmer is asked exactly the same set of questions. Appropriate statistical methods are used for data analysis. For example, we collect data on rice yields from a random sample of farm households in district X. If our sample is sufficiently large, the average yield we find in our sample will be an adequate estimate of the average yield that farmers in the district X attain overall.

Qualitative Method

This approach is commonly used when the research topic is complex and requires deeper understanding. Focus group discussion (FGD) and key informant interviews (KII) are some of the popular methods to collect qualitative data. Other than in the quantitative approach, we will prepare an interview guideline for data collection, rather than a questionnaire with fully formulated questions and potential response options. The guideline helps us ensure that we cover all the relevant aspects during the interviews/discussions, but each such event will differ from the other. For instance, when a given topic is discussed with two groups of farmers separately, the two groups will almost certainly give different reactions and inputs, leading the discussion in different directions. The researcher is to react flexibly and follow up on such diverse inputs, rather than sticking to a list of pre-defined questions, as is done in a quantitative survey.

The quantitative and qualitative methods both have their own merits and limitations. None is better than the other; rather, the two approaches complement each other, and which of the two provides appropriate results depends on the research question to be addressed. If we want to get a representative picture of what practices farmers are using, how these technologies are performing, and what are the perceptions of farmers regarding benefits of these practices and constraints to their adoption, the quantitative approach is to be used. If the aim is to delve into great depth or get farmers' views on sensitive or highly complex issues, or to investigate particularly contrasting cases/settings, the qualitative approach should be pursued. When we follow a qualitative approach, we often select the villages where we conduct FGDs (focus group discussions) or KIIs (key informative interviews) according to certain criteria, e.g. villages with good market access versus very remote villages; this means that, in contrast to quantitative approach, we often use purposive sampling rather than random sampling to select our research villages. Findings from qualitative research cannot be generalized to a population, but they can be used to highlight (contrasting) cases or conditions that require further investigations. Consequently, the sample size (e.g. number of selected villages) in a qualitative research is usually very small.

Often, a mixed-methods approach is recommended, combining the strengths of both quantitative as well as qualitative approaches. An overview of the advantages and disadvantages of the two approaches is given in Table 1.

Table 1. Advantages and disadvantages of the quantitative and qualitative approaches.

	Quantitative	Qualitative
Advantages	• Results can be extrapolated to a larger, underlying population • Efficient and easy digital data collection using structured questionnaire • Relatively quick basic statistical data analysis	• Information can be obtained relatively quickly and inexpensively • It is more suitable for sensitive or complex issues compared to quantitative approach • Flexibility to follow up on unexpected aspects as they arise during data collection
Disadvantages	• Relatively costly and time-consuming, depending on sample size • Less suitable for sensitive or highly complex issues (e.g. power relations etc.)	• Results cannot be extrapolated to a larger population (e.g., each FGD represents a case study) • Data collection and analysis require greater skill than applying a structured questionnaire

Sampling

In sampling during field surveys a predetermined number of respondents is selected from a larger population. The methodology used for selecting respondents from a larger population depends on the type of analysis being performed. All sampling methods can broadly be categorized into two :

- Probability sampling
- Non-probability sampling

The difference between the above two is whether the sample selection is based on randomization or not. In randomization, every element gets equal chance/ probability to be selected in the sample and to be part of survey. Before start, it is important to understand basic terminologies used in sampling.

1. **Element (or observation unit) :** The unit about which information is sought.
2. **Sampling unit :** The element or elements available for selection at a given stage in the sampling process.
3. **Sampling frame :** The list of sampling units available for selection.
4. **Population (or universe) :** The aggregate of all the elements defined prior to selection of the sample.

The ongoing landscape diagnostic survey (LDS) of rice crop used single stage cluster sampling (Fig. 1), a type of probability/random sampling method.

Probability sampling ⟶ Cluster sampling ⟶ Single stage cluster sampling

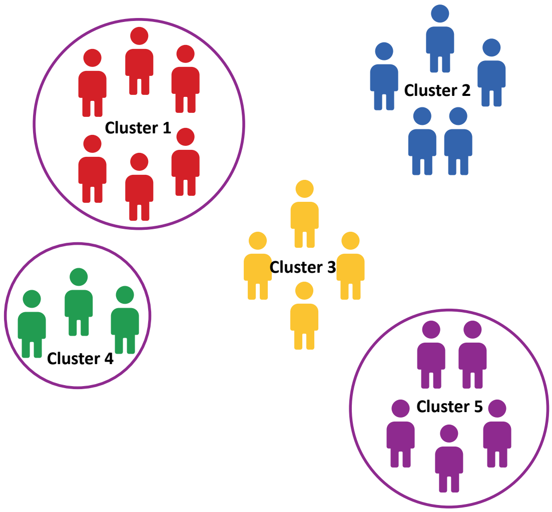

Fig. 1. Landscape diagnostic survey of rice crop used single stage cluster sampling.

In cluster sampling, entire population is divided into clusters and the clusters are randomly selected. This sampling plan is used when mutually homogeneous yet internally heterogeneous groupings are evident in a population. To apply single stage cluster sampling, samples are drawn randomly from the selected clusters. All the elements of the cluster are used for sampling (Singh, 2018).

Probability proportional to size (PPS) sampling is a method of sampling from a finite population in which a size measure is available for each population unit before sampling and where probability of selecting a unit is proportional to its size (Skinner, 2016). Accordingly, PPS selected villages within a district considering village as one cluster then selected farm households within each cluster/village. So, in our perspective, the above terminologies refer to:

Population : All villages of a district and then all households of the village

Sampling frame : Rural villages with >50 and <5,000 households then all households of the village

Sampling units : Villages first then farm households

Elements : Farm households

In broad terms, the sampling process comprises the following five steps :

- Step 1 : Define the population
- Step 2 : Select a sampling procedure
- Step 3 : Construct the sampling frame
- Step 4 : Determine the sample size
- Step 5 : Select the sample

Sample Size

Before we start determining sample size, we need to consider the population size and the level of accuracy we need. The larger the sample size the more the precise estimates will be, such as average yields or the percentage of farmers using a given technology. In other words, with a larger sample, we can be more confident that our results will be relatively close to what we would find in the population as a whole. Related to this, the larger the sample size the more likely to detect statistically significant differences between groups (e.g., differences in rice yields among farmers who applied direct seeding, random transplanting and line transplanting). However, the gains in precision decrease quickly at the margin with increasing sample size.

We suggested that KVKs aim at a sample size of 210 randomly selected farm households in their district to assess farmers' current practices; for most purposes, this sample size achieves a good balance between data precision on the one hand and cost of data collection on the other. We further suggested that sample households be spread across 30 randomly selected villages to capture an adequate degree of across-village variation, e.g. in terms of soil conditions, infrastructure, and market access (factors, which may influence the outcomes that we are interested in).

Village Selection

Probability proportional to size (PPS) method of random sampling was used to select villages. It refers to a sampling technique where the probability that a particular sampling unit will be chosen in the sample is proportional to some known variable such as number of households. It can also be called unequal-probability sampling because you are actually increasing the odds that a subject will be chosen in the sample based on its size. It is used when the populations of sampling units vary in size. If the sampling units are selected with equal probability, the likelihood of a sampling unit with a large population being selected for the survey is actually lesser than the likelihood of elements from a sampling unit with a small population.

This reduces standard error and bias by increasing the likelihood that a sampling unit from a larger population will be chosen over a sampling unit from a smaller population. To illustrate this method, consider the example of four villages of varying sizes given in Table 2.

Table 2. Probability proportional to size (PPS) method of random sampling to select villages.

Village name	Number of households (HHs)	Cumulative number of HHs	HH ID range	Probability of selection
A	200	200	1 – 200	200/1000 = 20%
B	300	500	201 – 500	300/1000 = 30%
C	100	600	501 – 600	100/1000 = 10%
D	400	1000	601 – 1000	400/1000 = 40%

To select villages using probability proportional to size method, we generate random numbers within the range 1 – max. HH ID. In the example above, we would type the formula =randbetween (1, 1000) into Excel; a village is selected if the random number falls within its HH ID range, thus making the probability of its selection proportionate to its size. For example, the random number 461 would fall into village B (HH ID range 201 – 500); hence, village B would be selected. We would continue generating random numbers (pressing the F9 key) until the desired number of villages is selected. If a random number falls within an already selected village, we simply continue pressing F9 until we get a random number that falls within a new village. This method for selection of villages was done based on the 2011 census data, which contained the number of resident households in each village of a given district.

Household Selection

Once the 30 villages are selected using PPS method, 7 households in each village need to be selected through simple random sampling. In the simple random sample, there is only one type of sampling unit, for instance all households residing in one village. Simple random sampling is a sampling technique where every item in the population has an equal chance of being selected in the sample.

This means that we need a complete list of households in that one village. This is our sampling frame for household selection. LDS used voter list of respective village to construct sampling frame. These voter lists of villages were downloaded from election commission websites of the respective states. These lists are generally available in PDF version. Unique house numbers were treated as single household. Using ‘R’ software, these PDF type voter lists were processed in batch to generate random house numbers. The output was available as single excel file with 30 worksheets (one sheet per village) having desired random numbers for survey. This is an efficient way of doing household level randomization.

The process can also be done alternatively using MS Excel. But, then one needs to enlist all unique house numbers of a village. Once, it is compiled, number the households consecutively from 1 to max, where max stands for the total number of households in the village. For example, if there are 150 households in the village, the numbers would run from 1 through 150. Open an MS Excel spreadsheet and select cell A1. Use the function 'randbetween' to create a random number that lies between a specified minimum and maximum value. The minimum is usually '1', i.e. the first element in our sampling frame. The maximum depends on the number of elements in our list. In our example it is 150; we therefore type :

=randbetween (1,150) and press Enter

Assume that you want to select 7 households randomly : select cell A1, click on the lower right corner of cell A1 and drag it down until you reach cell A7. You now have a list of 7 random numbers available, which all lie between 1 and 150. Now simply copy the random numbers and paste them in column B as values. Now, tick off all the households that have been selected according to the list of random numbers.

Household was identified from the house number of the sampled villages during the implementation of the survey. If in one house, three households were found, the eldest household was selected for the survey from the sampled villages. A total of 210 HHs were interviewed in each district through electronically enabled survey

Plot Selection for Crop-Cut

Follow these 10 steps :

1. Refer to the selected 7 households in the village
2. Select the farmer whom you meet first out of these selected 7
3. Ask him for his largest rice plot – consider this largest plot for crop-cut
4. Take farmer's consent for crop-cut
5. Crop-cut has to be taken from two spots in the selected largest plot
6. Size of each of these two spots (quadrants) is 2 m × 2 m
7. Get on the corner of the plot, move diagonally for almost 5 m and select your first spot here for taking samples

8. Similarly, repeat the procedure from the another corner of this plot and mark second spot
9. Finish crop-cut from these two spots and record
   - Total above ground biomass
   - Grain weight and
   - Moisture per cent
10. Use Open Data Kit (ODK) Form – 'Crop Cut Form' to enter these readings along with other basic information asked in this form

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1.2 Application of open data kit in landscape diagnostic survey for rice in India

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Technology advancements are bringing a great change in data collection, storage and analysis. Digital data collection (DDC) is a process of collecting data electronically using smart phones, tablets and net-books. This version has significantly improved data quality and reduced resource requirement for field surveys in past few years. Several DDC tools (Kobo, Collect, SurveyCTO, Magpi, Cogo, Insyt, GoSurvey, etc.) were recently developed and are available for use. Each of them is having its own benefits and limitations in the context of utility and deployment by users. Cereal System Initiative for South Asia (CSISA) in collaboration with Indian Council of Agricultural Research (ICAR)-Indian Agricultural Statistics Research Institute (IASRI) in India used Open Data Kit (ODK) for diagnostic survey of rice production practices. In 2019, the survey was conducted in 70 districts across nine Indian states (Bihar, Uttar Pradesh, Odisha, Andhra Pradesh, West Bengal, Chhattisgarh, Jharkhand, Haryana and Punjab) through *Krishi Vigyan Kendra* (KVK) of each district. The survey intended to capture detail information on current rice production practices being applied by farmers. From each district, 210 randomly selected farmers were interviewed in depth for their rice crop production practices; approximately 14,000 data points were gathered. The objectives of this electronically enabled survey were to fill existing data gaps, generate recent data-based evidences, derive better insights and facilitate informed decisions by policy makers.

About Open Data Kit (ODK)

Developers and researchers at Department of Computer Science and Engineering, University of Washington had developed ODK. ODK began as a Google sponsored sabbatical project in April 2008. The first two deployments of the tool happened in Uganda and Brazil (https://docs.opendatakit.org/). ODK is an open-source tool – the source code is available for free– and is licensed to permit customization by users. These are generally developed as a public collaboration and made freely available. Compared to conventional paper based data collection, ODK provides great ease by automating data compilation. In a large scale survey, data compilation itself requires huge resources, and the task is very much error-prone; whereas, the ODK is easy to use and easy to scale even in resource-constrained environments.

There are three major components (Build, Collect & Aggregate) that jointly form the data ecosystem in ODK (Fig. 1).

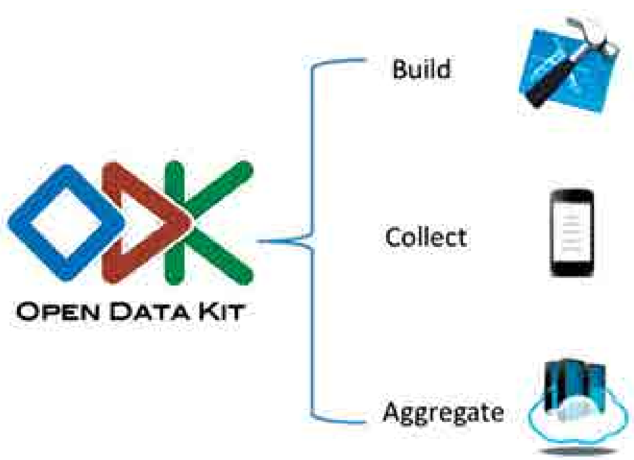

Fig. 1. Components of ODK platform.

ODK Build

This is used for designing a questionnaire for ODK. ODK Build is a form designer with a drag-and-drop user interface. Build is an HTML web application and works best for designing simple forms. Alternatively, XLSForm is a form standard created to help simplify the authoring of forms in Excel. XLSForms are simple to get started with but allow for the authoring of complex forms. Forms designed with Excel can be converted to XForms, the .xml version readable by the ODK server as digital questionnaire and used by ODK Collect.

ODK Collect

It is an Android app that is used in survey-based data gathering. It supports a wide range of question and answers types, and is designed to work well without network connectivity. ODK Collect renders forms into a sequence of input prompts. Users work through the prompts and can save the submission at any point. Finalized submissions can be sent to a server. Collect supports location, audio, images, video, barcodes, signatures, multiple-choice, free text, and numeric answers.

ODK Aggregate

It is a Java application that stores, analyzes, and presents XForm survey data collected using ODK Collect. It supports a wide range of data types, and is designed to work well in any hosting environment. With Aggregate, data collection teams can :

- Host blank XForms used by ODK Collect
- Store and manage XForm submission data
- Visualize collected data using maps and simple graphs
- Export and publish data in a variety of formats.

Accordingly, the workflow for data collection through ODK system is as follows :

i. Design the form (questionnaire)

ii. Download a questionnaire for data collection

iii. Collect the data, **even if device is offline**

iv. Submit collected data to ODK Aggregate

v. Access aggregated data for use

The mobile app i.e. ODK Collect, to be used by enumerators can be downloaded from Google Play Store. The updated version (v1.29.1) of the app contains six buttons and their functions are self-explanatory. Once the mobile app gets linked with the hosting server, these buttons rightly perform following functions.

Get Blank Form – It is used to download desired survey forms in the data collection device from server. Internet connectivity is required.

***Fill Blank Form* –** It is used to fill-in the information in the form while conducting the survey. It works offline.

Edit Saved Form – If enumerator wishes to add/ change some information in the surveyed form before sending to the server, it can be saved in the device. This button can be used for doing edits.

Send Finalized Form – It is used to send single or multiple surveyed forms from collection device to the server. Internet connectivity is required.

View Sent Form – If you wish to see how many forms you have sent through a particular device, it generates the list of sent forms.

Delete Saved Form – It is used to delete blank form, if the current form is obsolete or an updated version of blank form has to be used. This button can also be used to delete filled-in forms if users do not want to submit it on server. It mostly happens in case of form testing.

Benefits of ODK

There were several reasons for preferring ODK in the current rice production practices survey. As the diagnostic survey is quite large in terms of sample size, spread and length of questionnaire, manual data compilation would have been extremely difficult to handle. The respondents of this survey are farmers and they are mostly located in hinterlands. So, we wanted a tool that can work uninterrupted in such setting. Another factor of choosing ODK was the confidence of CSISA's technical team in handling the tool. CSISA had been using ODK for almost five years for collecting monitoring data. Considering these factors, it was decided to go with ODK for the current landscape survey. In general, ODK provides another benefits over conventional paper based survey system. The key benefits are as follows :

Cost : There are many elements of cost. Electronic devices cost more than paper but, when we factor in the requirement of hiring, training and employing data entry staff for the paper processes, in addition to buying and setting up the data entry machines, it ends up being costlier.

Speed and efficiency : This is the most obvious advantage of digital data collection over paper-based system. Digital data collection reduces both data collection time and also the time required for analyzing and distributing results. One of the main issues with paper version is its in-field administration if changes arise. While digital forms can be updated and pushed to enumerators quickly and automatically.

Data quality : Digital data collection reduces the possibility of error at the point of in-field collection, and can also automate data correction. Paper can be lost, destroyed, or mishandled in a number of ways, which can create problems later if the data need to be re-accessed. Digital data, on the other hand, can be easily and inexpensively stored, copied, backed up.

Visibility and tracking : Another important advantage of digital data collection is tracking. Paper process does not tell us anything about what is going on in real time, but with a digital platform, as soon as an enumerator completes and submits a form, the data are accessible to all stakeholders. We can check who has sent this, from where it has come and is there any discrepancy. Data managers can contact back the data collector if required.

Functionalities

ODK provides wide range of functionalities right at the time of questionnaire designing that improve data quality and restrict users to enter incorrect data (ODK Documentation, 2017). Some of these features are discussed here.

Skip patterns : A question with skip patterns is very common in any form of survey. For example, we may only want to ask respondents about irrigation frequency, if their response to a previous question on whether they have irrigation facility is "yes". These types of skip patterns can only be enforced on digital surveys, with a conditional question only appearing based on the response to a previous question. An example of a skip pattern question is as below :

Do you have irrigation facility?	[ ] Yes / [ ] No
If Yes to question above, how many times you irrigated your crop	[Number Entry_____]

For paper based questionnaires, proper recording of such skip pattern kinds of questions is entirely reliant on the enumerator skills, knowledge of the questionnaire and keenness, leaving plenty of room for error.

Entry limits : This kind of restriction is usually vital especially for numeric types of questions. For digital surveys, it is possible to restrict entries, by having minimum and maximum values. For example, when taking the second split of urea applied in days after seeding, it cannot be less than the value of days (10-30) entered for first split. We can restrict conditional entry to higher value of first split in days. Any entry below that is therefore rejected.

Type of questions : Survey questions happen to be of different types. These can be numeric, alpha-numeric, and dates, among other types. ODK ensures that entries are limited to their type, so we do not have a text response for a numeric question. Form developer is also able to control date format through pop-up calendar, furnishing options as single select or multiple select, pre-populating basic information such as area details, etc.

Optional vs mandatory questions : In digital data collection, we have control over whether a question is mandatory or optional. In this case, enumerator does not miss responses for questions that are considered essential for the survey. For example, you cannot move forward with the interview unless you fill the response about variety type. This means that the data available for analysis are usually pretty clean and ready for analysis.

Geo-tagging : One of the best features of ODK-based survey is geo-referencing. Currently available mobile hand-sets can capture geo-location even without having internet and mobile connectivity. It adds great credibility to data we collect through ODK. All the locations (largest plot of respondents) of production practice survey

Operational model of ODK has been furnished in following schematic diagram

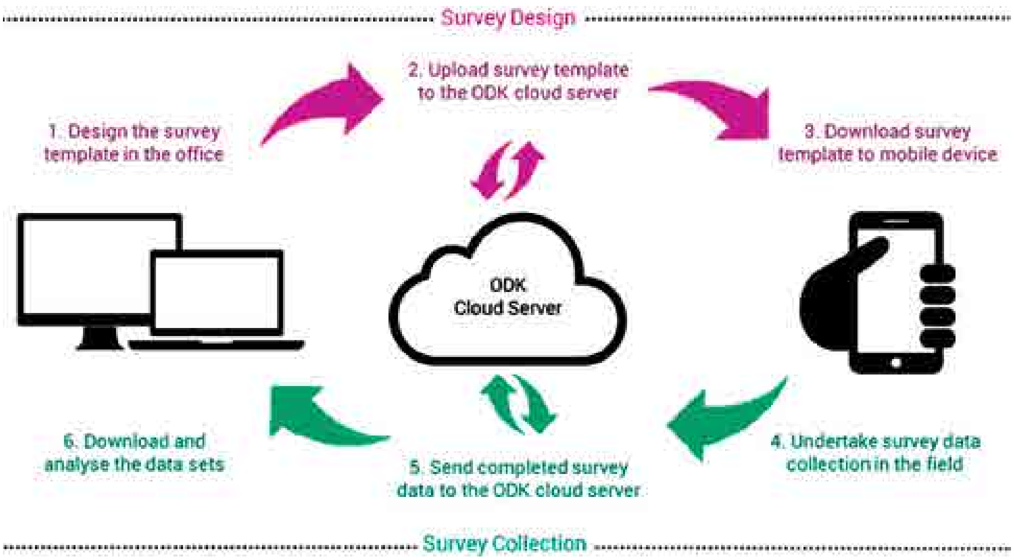

Fig. 2. Operational model of ODK.

henceforth are geo-tagged. It further allows us to layer this data with other parameters such as, soil profile, weather condition, etc.

Extracting of dataset : After data collection is complete, the compiled dataset of the survey is extracted from the ODK server. ODK Aggregate component is used for data transfer on the server. A server has been hosted in ICAR Data Center at ICAR-IASRI with the domain https://csd.icar.gov.in/, to transfer the curated data collected in surveys in the Indian region. Data extraction, a simple and easily executable task, can be performed any time after the collection process starts. Personnel having access of server should log-in and choose dataset from the FORM box option as shown on the left of Fig. 3. Once a particular dataset (Form) is selected, the user has to tap on EXPORT button as depicted on the right side of Fig. 3. ODK server starts generating desired dataset and the same can be downloaded. Data can be extracted in excel file and the same can be shared using

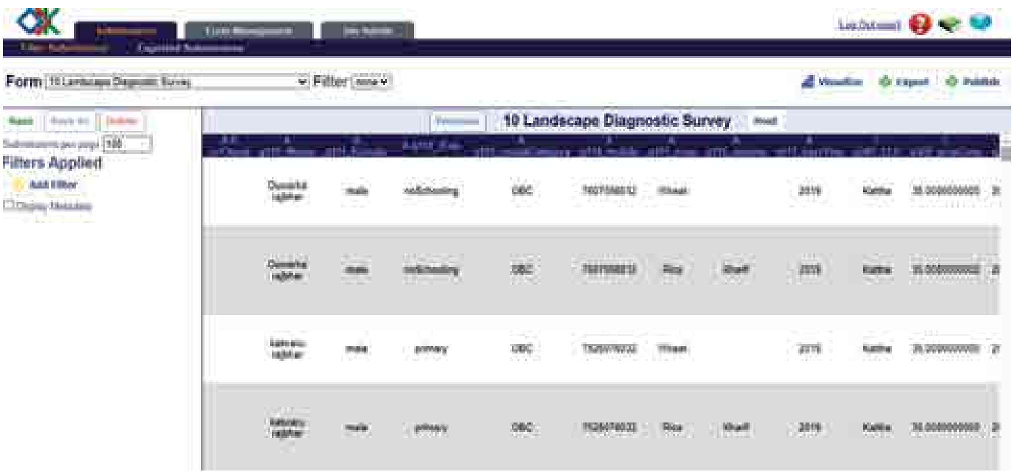

Fig. 3. Snapshot of ODK server showing aggregated data points of individual surveys in rows.

email, Google Drive or Dropbox. Data can be transferred to database for further processing.

Data diagnostics : ODK Aggregate provides pie chart, bar graph and map to diagnose the datasets. In LDS survey, user can see the distribution of dataset with respect to states, crop and other attributes. An example of diagnostics is shown for distribution of data from different states in Fig. 4. This type of data diagnosis helps in understanding the larger picture of the dataset. Such data driven findings can also form the basis of refining analytics and help to streamline the internal learning process.

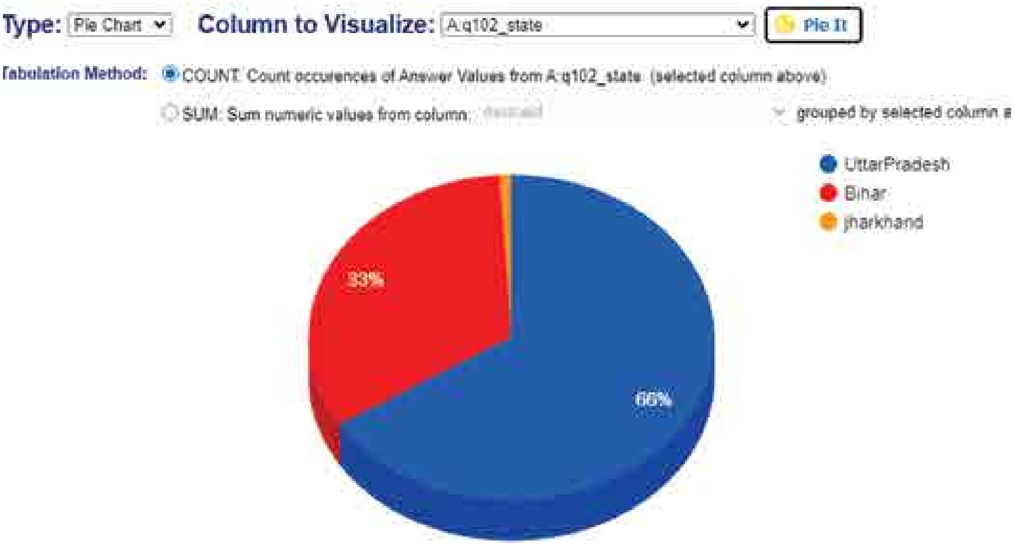

Fig. 4. Data visualization on ODK server.

Conclusion

ODK (Design, Collect and Aggregate) is completely self-reliant system for mobile based surveys. The surveys can be carried out in an efficient and affluence way using ODK. Data can be collected using mobile devices and easily converted to an excel file or seamlessly integrated with database. This makes it possible to deliver results of complex surveys in minimized time frame.

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1.3 Visualizing landscape diagnostic survey data of rice on Krishi Vigyan Kendra knowledge network

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Introduction

Under Cereal System Initiative for South Asia (CSISA), data on farmer's current crop production practices called Landscape Diagnostic Survey (LDS) have been collected through Open Data Kit (ODK), an Android based digital data collection tool. LDS has so far been deployed in eight Indian states covering more than 100 districts for detailed diagnosis of current production practices and yields. These data are aggregated and stored at ICAR Data Centre of ICAR-Indian Agricultural Statistics Research Institute (IASRI). There were altogether 14491 data points including data from rice, wheat and maize crops. With these data, a dashboard has been created for showcasing information which can be used for further analysis. The dashboard is linked with *Krishi Vigyan Kendra Knowledge Network* or KVK Portal (ICAR-IASRI 2016) and hosted at https://kvk.icar.gov.in/CSISA.aspx. A number of reports, graphics and map views have been developed and integrated into this dashboard. In this chapter, the dashboard based on the production practices survey data of rice crop (number of data points = 6824) is discussed. This dashboard has been developed using ASP.NET framework 3.5 (Walther, 2011). For database designing and development, Microsoft SQL Server 2012 (LeBlanc, 2013) has been used.

Dashboard Layout

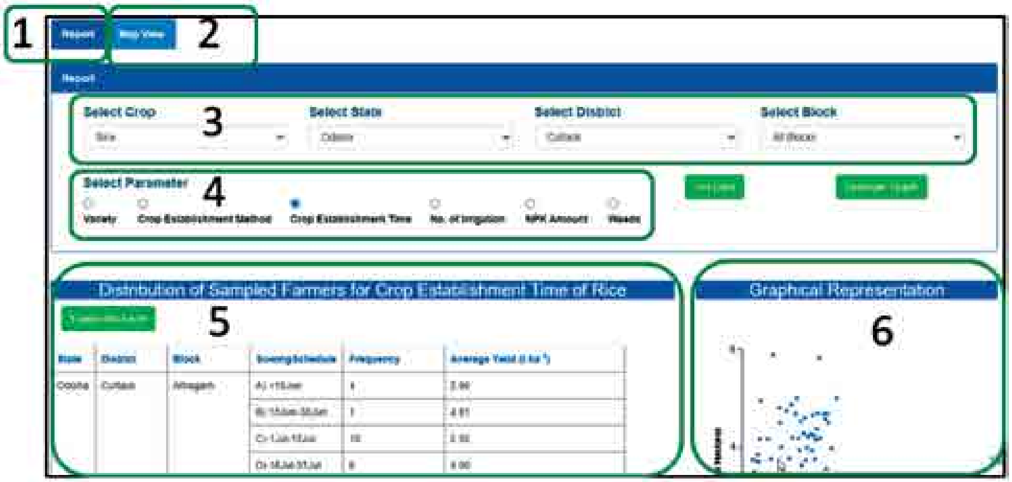

Fig. 1. LDS dashboard layout.

The LDS dashboard has two tabs viz. Report and Map View. In the Report tab, there are four different panes. Following is the description for the tabs as well as the panes.

1. Tab for reports in tabular and graphical format : In this tab, reports are generated in tabular format based on crop, state, district, block and parameter selected. For selective parameters at district level, graphs are also generated.
2. Tab for map view : Maps are generated based on crop, state, district, block and parameter selected.
3. Levels of aggregation for analysis : Selection pane for crop, state, district and block.
4. Data description : Selection pane for parameter (one parameter at a time).
5. Pane for tabular report : All the reports can be exported into MS-Excel file.
6. Pane for graphical representation.

Reports and Graphics in Dashboard

A number of reports, based on the selection of the parameters, can be generated in the dashboard. Reports can be generated based on various parameters selected from the dropdown menu provided for State, District and Block level. The list of parameters and the corresponding reports (for rice crop) have been depicted in the below table :

Parameter	Report in tabular form	Report in graphical form
Variety	Distribution of sampled farmers and respective yield (average, maximum and minimum) state-wise, district-wise and block-wise with respect to different varieties and for a particular variety	Distribution of sampled farmers district-wise with respect to different varieties
Crop Establishment Method	Distribution of sampled farmers and respective yield (average, maximum and minimum) state-wise, district-wise and block-wise with respect to different crop establishment methods and for a particular crop establishment method	Distribution of sampled farmers district-wise with respect to different crop establishment methods
Crop Establishment Time	Distribution of sampled farmers and yield (average, maximum and minimum) state-wise, district-wise and block-wise with respect to different sowing schedules and for a particular sowing schedule	Average yield with respect to different sowing dates
Number of Irrigation	Distribution of sampled farmers and yield (average, maximum and minimum) state-wise, district-wise and block-wise with respect to different number of irrigations and for a particular number of irrigation	Distribution of sampled farmers district-wise with respect to different number of irrigations
NPK Amount	Distribution of sampled farmers and yield (average, maximum and minimum) state-wise, district-wise and block-wise with respect to average N, average P_2O_5 and average K_2O	
Weeds	Distribution of sampled farmers state-wise, district-wise and block-wise with respect to top 10 weeds	

Some screen shots of the above mentioned reports are depicted below:

In Fig. 2, distribution of sampled farmers (n=192) for different varieties in rice for all the blocks of Rohtas district in Bihar state is captured. It is evident from the graph (Fig. 3) that ‘MTU 7029’ variety of rice is dominant in this district.

Distribution of sampled farmers (n=116) for different crop establishment methods in rice for all the blocks of Deoria district in Uttar Pradesh state is captured in Fig. 4. In this case, it is clear that most of the farmers in different blocks of Deoria district are using the ‘Manual Puddled Random’ Method for rice crop establishment. The same inference can also be drawn from the corresponding graph (Fig. 5).

In Fig. 6, there is depiction on distribution of sampled farmers (n=188) for different transplanting schedules in rice for all the blocks of Gaya district in Bihar

State	District	Block	Variety	Frequency	Average yield (t ha^{-1})	Max	Min
Bihar	Rohtas	Bikramganj	BhagalpurKatarni	1	5	5	5
			BPT5204	1	5.5	5.5	5.5
			MTU_7029	17	5.23	7.2	2.88
			NK5251_hybrid	1	4.8	4.8	4.8
			RajendraMansoori1	1	4.8	4.8	4.8
			Sonam	1	4.33	4.33	4.33
		Chenari	MTU_7029	10	4.69	5.66	2.4
			SuperMoti	1	3.2	3.2	3.2
		Dawath	BPT5204	5	4.7	6	2.72
			MTU_7029	4	6.2	6.8	5.6
		Dinara	MTU_7029	5	5.82	7.2	4
		Karakat	BPT5204	10	5.02	6.4	2
			MTU_7029	41	4.8	7.2	2
		Kargahar	BPT5204	1	6.28	6.28	6.28
			MTU_7029	3	5.07	6	3.2
		Kochas	MTU_7029	7	4.66	7.2	3
		Nasriganj	MTU_7029	8	5.11	7.52	2.52
		Nauhatta	BhagalpurKatarni	1	4.8	4.8	4.8
			MTU_7029	3	4.63	5.5	3.6
			Other	1	4	4	4
			Sahabhagi	1	4.67	4.67	4.67
			Sonam	1	4.8	4.8	4.8
		Nokha	BPT5204	1	3.2	3.2	3.2
			MTU_7029	13	5.66	7.2	3.04
		Rajpur	MTU_7029	1	4.8	4.8	4.8
		Rohtas	MTU_7029	12	4.73	6	2.4
		Sanjhauli	MTU_7029	14	6.02	7.44	3.6
		Sasaram	BPT5204	2	4.5	4.8	4.2
			MTU_7029	5	4.18	4.5	4
		Sheosagar	MTU_7029	4	4.68	5.01	4
			Sonam	2	5.02	6.03	4
		Tilouthu	MTU_7029	14	5.74	7.2	2.88

Fig. 2. Report on distribution of farmers and average yield for different varieties in rice.

state. There is provision to rank the tabular data based on certain parameter(s). If the data can be ranked (descending order) based on frequency, in this particular case, it is evident that most farmers have sown the crop in the month of July (Fig. 7). The ranking/sorting feature is elaborated in the *Sorting* section. From the graph, as shown in Fig. 8, a decreasing trend of average yield is observed as the date of transplanting is delayed.

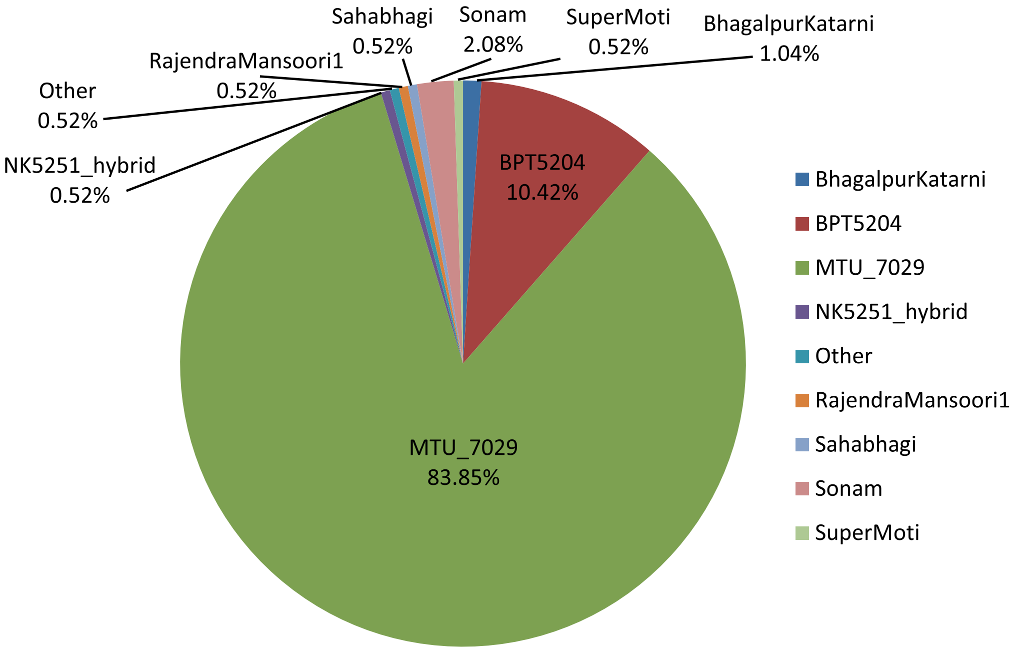

Fig. 3. Graph on distribution of farmers for different varieties in rice (sample size =192).

State	District	Block	Crop establishment method	Frequency	Average yield (t ha^{-1})	Max	Min
Uttar Pradesh	Deoria	Baitalpur	ManualPuddled_Random	32	3.89	5.62	1.87
		Barhaj	ManualPuddled_Random	1	6.57	6.57	6.57
		Bhagalpur	ManualPuddled_Random	8	3.64	4.51	2
		Bhaluani	ManualPuddled_Random	4	3.51	3.79	3
		Bhatani	ManualPuddled_Random	9	3.9	5	1.75
		Bhatparani	ManualPuddled_Random	1	6.75	6.75	6.75
		Deoria	ManualPuddled_Random	13	3.53	5	2.21
		DesaiDeoria	ManualPuddled_Random	6	3.8	5	2.12
		GauriBazar	ManualPuddled_Random	13	3.76	5.5	1.49
		Pathardeva	ManualPuddled_Line	3	5.31	6.25	4.69
			ManualPuddled_Random	7	3.81	4.69	2.25
		RampurKarkhana	ManualPuddled_Random	5	4.63	4.85	4.25
		Salempur	ManualPuddled_Random	14	4.32	6.55	3

Fig. 4. Report on distribution of farmers and average yield for different crop establishment methods in rice.

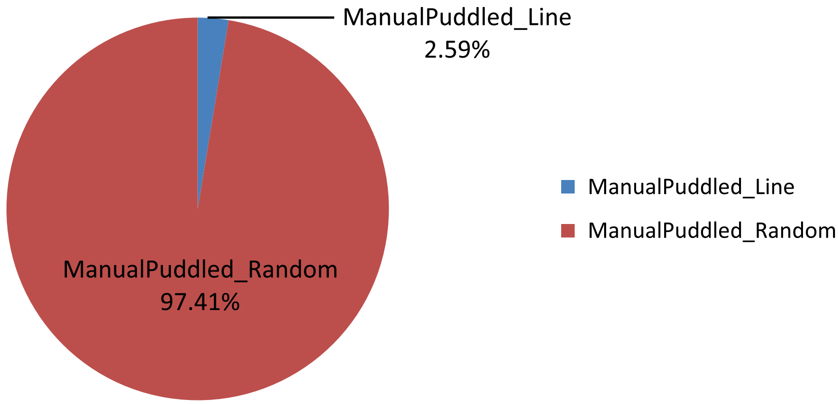

Fig. 5. Graph on distribution of farmers for different crop establishment methods in rice (sample size = 116).

State	District	Block	Crop establishment time	Frequency	Average yield (t ha^{-1})	Max	Min
Bihar	Gaya	Atri	16Jul-31Jul	6	4.5	5.4	3.83
			1Aug-15Aug	1	3.38	3.38	3.38
		Barachatti	1Jul-15Jul	2	4.2	5	3.4
			16Jul-31Jul	5	4.33	5.2	2.8
		Belaganj	15Jun-30Jun	3	6.41	7.59	5.22
			1Jul-15Jul	32	4.31	6.75	3.22
		BodhGaya	1Jul-15Jul	13	3.42	5.4	2.5
			16Jul-31Jul	1	3	3	3
			1Aug-15Aug	1	2.7	2.7	2.7
		Dobhi	16Jul-31Jul	7	2.81	4.05	2.03
		Gurua	16Jul-31Jul	7	4.19	5.16	2.75
		Khizirsarai	1Jul-15Jul	4	3.21	4.32	2.5
			16Jul-31Jul	2	4.78	4.78	4.78
		Konch	1Jul-15Jul	2	7.05	7.2	6.9
			16Jul-31Jul	2	3.55	3.55	3.55
		Manpur	15Jun-30Jun	1	3.15	3.15	3.15
			1Jul-15Jul	36	4.47	6.08	3.38
			16Jul-31Jul	13	4.58	5.25	3.75
			1Aug-15Aug	3	3.47	4.2	2.8
		Mohanpur	1Jul-15Jul	4	4.54	5.62	3.45
			16Jul-31Jul	1	5.4	5.4	5.4
		NeemChakBathani	16Jul-31Jul	4	4.73	5.4	4.05
		Sherghati	1Jul-15Jul	18	4.04	4.8	2.76
			16Jul-31Jul	4	4.65	4.94	4.28
		Tikari	1Jul-15Jul	6	4.79	6.4	3.2
			16Jul-31Jul	10	4.49	5.6	3.73

Fig. 6. Report on distribution of farmers and average yield for different sowing schedules in rice.

State	District	Block	Crop establishment time	Frequency	Average yield (t ha^{-1})	Max	Min
Bihar	Gaya	Manpur	1Jul-15Jul	36	4.47	6.08	3.38
			1Jul-15Jul	32	4.31	6.75	3.22
			1Jul-15Jul	18	4.04	4.8	2.76
			1Jul-15Jul	13	3.42	5.4	2.5
			16Jul-31Jul	13	4.58	5.25	3.75
			16Jul-31Jul	10	4.49	5.6	3.73
		Dobhi	16Jul-31Jul	7	2.81	4.05	2.03
			16Jul-31Jul	7	4.19	5.16	2.75
		Atri	16Jul-31Jul	6	4.5	5.4	3.83
			1Jul-15Jul	6	4.79	6.4	3.2
		Barachatti	16Jul-31Jul	5	4.33	5.2	2.8
		Khizirsarai	1Jul-15Jul	4	3.21	4.32	2.5
			1Jul-15Jul	4	4.54	5.62	3.45
		NeemChakBathani	16Jul-31Jul	4	4.73	5.4	4.05
			16Jul-31Jul	4	4.65	4.94	4.28
		Belaganj	15Jun-30Jun	3	6.41	7.59	5.22
		Manpur	1Aug-15Aug	3	3.47	4.2	2.8
		Barachatti	1Jul-15Jul	2	4.2	5	3.4
			16Jul-31Jul	2	4.78	4.78	4.78
			1Jul-15Jul	2	7.05	7.2	6.9
			16Jul-31Jul	2	3.55	3.55	3.55
			1Aug-15Aug	1	3.38	3.38	3.38
		BodhGaya	16Jul-31Jul	1	3	3	3
			1Aug-15Aug	1	2.7	2.7	2.7
		Manpur	15Jun-30Jun	1	3.15	3.15	3.15
		Mohanpur	16Jul-31Jul	1	5.4	5.4	5.4

Fig. 7. Report on distribution of farmers ranked by frequency (descending order) for different sowing schedules in rice.

Fig. 9 is related to distribution of sampled farmers (n=200) for different number of irrigations applied in rice crop for all blocks of Mau district in Uttar Pradesh state. This screenshot depicts the number of times farmers have applied irrigation in rice field. In this particular case, maximum farmers have applied irrigation five times in their fields. This fact is more prominent from Fig. 10.

Fig. 11 captures the screenshot for distribution of sampled farmers (n=1588) for use of average NPK amount in rice in Uttar Pradesh state for all of its districts. This tabular data depicts the number of farmers using/not using the respective quantities of nitrogen (N), phosphorous (P_2O_5) and potash (K_2O) in the rice crop. In this particular case it can be stated that most farmers are not using potash fertilizer.

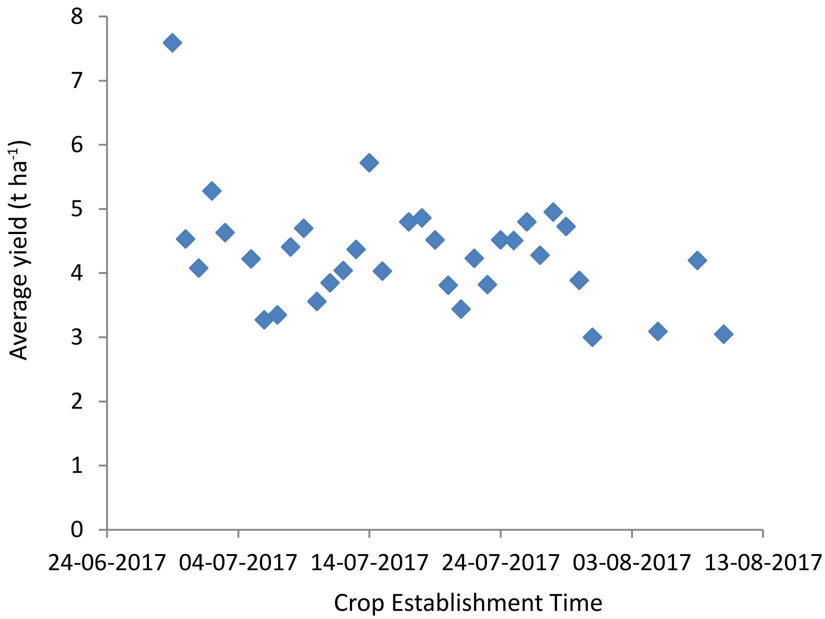

Fig. 8. Graph on average yield for different crop establishment dates in rice

Distribution of sampled farmers for 10 common weeds in rice is shown in Fig. 12. It depicts the frequency, as mentioned by the farmers in the survey, of the 10 common weeds in Pandarak block of Bihar's Patna district. All the reports which are generated in tabular form can further be sorted and searched (for some of the parameters).

Sorting

All the columns in the above mentioned reports (in tabular form) can further be sorted alphabetically (for state, district, block, variety, etc.) or ascending/descending (frequency, average yield, etc.) order as depicted in Fig. 13. Here data are sorted on the basis of average yield in descending order.

Searching

Report can be searched based on selected value from dropdown as shown in Fig. 14. Here, for example, the variety 'Ankur' has been searched in Bihar.

Map View in Dashboard

A GPS based report, for rice crop, has been created in which the survey data points can either be located in map view or satellite view for specific state, district,

State	District	Block	No. of irrigation	Frequency	Average yield (t ha^{-1})	Max	Min
Uttar Pradesh	Mau	Badraon	2	1	4.8	4.8	4.8
			3	2	3.27	3.94	2.59
			4	4	2.7	3.94	2.19
			5	5	4.09	5.25	2.63
			6	1	3.07	3.07	3.07
		DohriGhat	4	1	2.19	2.19	2.19
			5	2	2.85	3.07	2.63
			6	2	2.77	3.2	2.33
		FatehpurMadraun	3	12	3.58	4.8	1.98
			4	7	3.26	5.25	1.98
			5	14	3.57	6.4	2.33
			6	13	3.81	5.69	2.62
		Ghosi	2	2	5.48	6.57	4.38
			3	3	4.52	4.82	4.37
			4	9	4.17	6.13	2.33
			5	16	3.4	4.8	2.19
			6	12	3.94	5.25	3.15
			8	1	4.8	4.8	4.8
		MuhammadabadGohana	1	2	3.6	4	3.2
			2	6	3.86	5.6	2.93
			3	1	3.5	3.5	3.5
			4	3	4.49	4.8	3.99
			5	1	4.4	4.4	4.4
			6	1	4	4	4
			7	1	2.22	2.22	2.22
		Pardaha	3	2	3.18	3.35	3
			4	8	3.44	4.8	2.48
			5	6	2.71	3.32	2.2
			6	4	3.62	4.8	2.62
		Ranipur	1	3	2.68	3.59	2
			2	1	4.26	4.26	4.26
			3	3	3.23	3.5	3.01
			4	6	3.01	5.33	2
			5	5	3.66	4.38	2.3
		Ratanpura	2	1	2.62	2.62	2.62
			3	1	2.62	2.62	2.62
			4	3	3.25	4	2.24
			5	24	3.54	4.8	2
			6	9	3.11	4.37	2.19
			7	2	2.75	3.5	2

Fig. 9. Report on distribution of farmers and average yield for different number of irrigations in rice.

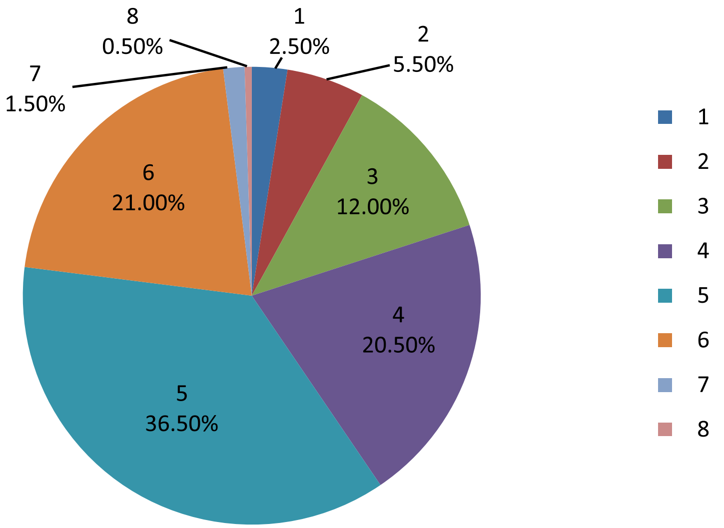

Fig. 10. Graph on distribution of farmers for different number of irrigations in rice (sample size = 200).

State	District	Avg. N (kgha-[1])	Frequency of N	Avg. P_2O_5 (kgha^{-1})	Frequency of P_2O_5 (kgha^{-1})	Avg. K_2O (kgha^{-1})	Frequency of K_2O (kgha^{-1})	Average yield (tha^{-1})	Max	Min
Uttar Pradesh	Balia	141.95	Using = 180, Not Using = 0	57.12	Using = 174, Not Using = 6	20.16	Using = 92, Not Using = 88	3.69	6.4	2.24
	Chandauli	119.84	Using = 204, Not Using = 0	57.73	Using = 203, Not Using = 1	3.11	Using = 29, Not Using = 175	4.65	6.58	2
	Deoria	126.76	Using = 115, Not Using = 1	47.87	Using = 107, Not Using = 9	9.02	Using = 48, Not Using = 68	3.96	6.75	1.49
	Gazipur	154.61	Using = 187, Not Using = 0	57.15	Using = 165, Not Using = 22	5.44	Using = 29, Not Using = 158	3.91	6.4	1.99
	Gorakhpur	139.2	Using = 181, Not Using = 0	44.05	Using = 147, Not Using = 34	5.13	Using = 41, Not Using = 140	4.23	6.5	1.5
	Kushinagar	121.83	Using = 140, Not Using = 0	43.06	Using = 120, Not Using = 20	15.9	Using = 93,Not Using = 47	3.97	6.67	1.25
	Maharajganj	149.23	Using = 199, Not Using = 0	54.32	Using = 182, Not Using = 17	5.89	Using = 51, Not Using = 148	4.9	6.75	2
	Mau	128.03	Using = 199, Not Using = 1	50.16	Using = 182, Not Using = 18	10.53	Using = 73, Not Using = 127	3.54	6.57	1.98
	Siddharthnagar	136.75	Using = 181, Not Using = 0	47.34	Using = 155, Not Using = 26	6.19	Using = 39, Not Using = 142	4.51	6.74	1.26

Fig. 11. Report on distribution of farmers and average yield for average NPK amount in rice.

State	District	Block	Top 10 weeds	Frequency
Bihar	Patna	Pandarak	Rc_Echinochloa_crusgalli	4
			Rc_Euphorbia_hirta	3
			Rc_Paspalum_distichium	3
			Rc_Rottboellia_cochinchinensis	2
			Rc_Sphenochlea_zeylanica	2
			Rc_Eragrostis_japonica	2
			Rc_Leersia_hexandra	2
			Rc_Leptochloa_species	2
			Rc_Lindernia_species	1
			Rc_Ludwigia_octovalvis	1
			Rc_Marsilea_minuta	1
			Rc_Ageratum_conyzoides	1
			Rc_Commelina_diffusa	1
			Rc_Cyperus_iria	1
			Rc_Scirpus_juncoides	1
			Rc_Pistia_stratiotes	1
			Rc_Fimbristylis_spp	1

Fig. 12. Report on distribution of farmers for 10 common weeds of rice.

State	No. of irrigation	Frequency	Average yield (t ha^{-1})	Max	Min
Uttar Pradesh	13	1	5.81	5.81	5.81
Bihar	10	83	5.09	7.2	2.2
	12	76	5.02	7.59	2.76
	13	127	4.89	7.2	2
	11	34	4.85	7.44	2.5
Odisha	7	1	4.85	4.85	4.85
Bihar	7	121	4.58	6.9	1.78
	6	241	4.57	7.2	0.8
	9	42	4.51	7	1.71
	8	130	4.43	7.2	2.4
Odisha	0	1	4.38	4.38	4.38
Bihar	5	367	4.36	6.8	0.68
Uttar Pradesh	4	323	4.35	6.58	1.87
	5	323	4.32	6.75	1.5
Odisha	4	32	4.24	5.83	2.5
	5	15	4.23	5.94	2.61
Uttar Pradesh	3	394	4.17	6.75	1.75
Odisha	3	22	4.13	6.25	2.19
Uttar Pradesh	10	2	4.13	4.5	3.75
Bihar	4	916	4.09	7.2	1.06
Uttar Pradesh	2	278	4.07	6.57	1.26
	7	21	4.05	6.4	2

State	No. of irrigation	Frequency	Average yield (t ha^{-1})	Max	Min
Odisha	10	6	4.01	5.42	1.5
	2	29	3.97	6.25	1.67
Uttar Pradesh	6	81	3.9	6.74	2.19
	1	146	3.87	6.64	1.25
	9	2	3.84	3.92	3.75
	8	18	3.75	4.8	2.39
Bihar	3	1289	3.73	7.52	0.67
Odisha	8	3	3.69	4.06	3.25
Bihar	2	968	3.6	6.75	1.1
Odisha	1	26	3.56	5.7	1.38
Bihar	1	318	3.42	6	1.1
Odisha	6	4	3.12	4.69	1.94
	12	1	2.59	2.59	2.59

Fig. 13. Sorting of data on the basis of average yield in descending order.

State	District	Variety	Frequency	Average yield (t ha^{-1})	Max	Min
Bihar	Arah	Ankur	1	4	4	4
	Banka	Ankur	1	1.75	1.75	1.75
	Bhagalpur	Ankur	1	3	3	3
	Samastipur	Ankur	1	5.5	5.5	5.5
	Siwan	Ankur	4	2.64	3.38	1.89

Fig. 14. Result of searching for a particular variety.

block and also based on certain parameters viz., Variety, Crop Establishment Method, Crop Establishment Time and Number of Irrigations. For example, as shown in Fig. 15, all the data points (number of data points = 180) of Balia districts in Uttar Pradesh have been chosen for viewing. The corresponding satellite view is shown in Fig. 16 for some cluster points. In Fig. 17, a particular variety viz., Sampoorna is selected to show all data points where it is cultivated as reported by farmers in the survey. The result of this selection is shown in Fig. 18. There are altogether 36 such data points. On clicking a particular point, the information on following parameters is shown : state, district, block, village and average yield. In Fig. 19, 'manual puddled random' method has been selected as crop establishment method in Patna district of Bihar and the corresponding map view (number of data points = 187) is depicted in Fig. 20. On clicking of cluster of data points, individual data points can be viewed. Similarly, map view can be generated for the other two parameters viz., Crop Establishment Time and Number of Irrigations also.

Fig. 15. Selection of parameter for GPS view of survey data points.

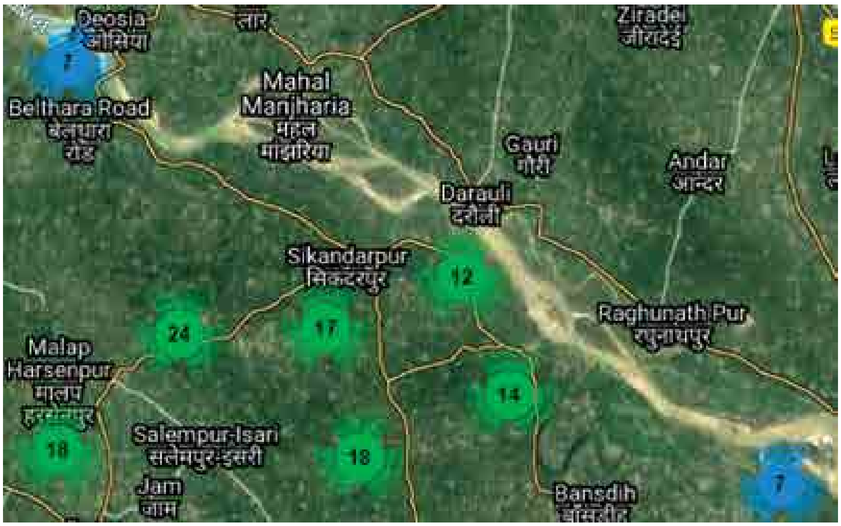

Fig. 16. Satellite view of survey data points.

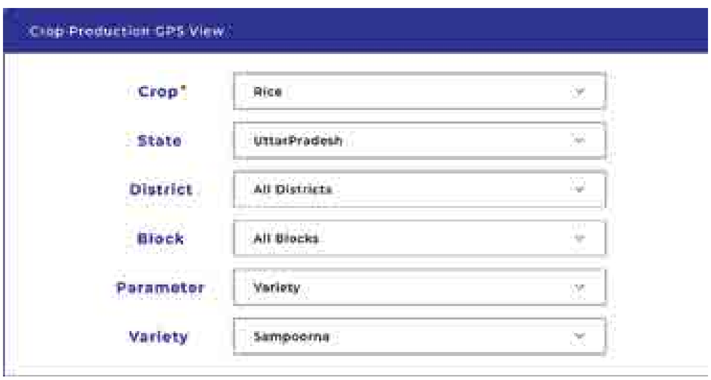

Fig. 17. Selection of a particular variety for map view of respective data points.

Fig. 18. Map view of survey data points for 'Sampoorna' variety of rice in all districts of Uttar Pradesh.

Fig. 19. Selection of a particular crop establishment method for map view of respective data points.

Fig. 20. Map view of survey data points based on 'Manual Puddled Random' crop establishment method of rice in Patna district of Bihar.

Conclusion

In India, the KVKs are the main extension body at the district level. This dashboard will help the KVK extension personnel understand better what production practices are being followed in their respective districts. It will help them find out the gap between extension of technologies and adoption of the same by the farmers. This dashboard can help them in finding out the key areas where traditional technologies are still prevailing over the ones which were already introduced to the farmers through demonstration. In this way, this dashboard can provide strong backing with up to date, real (observed) data that can either support or challenge myths or assumptions prevailing over the period in the area under study. This should help in identifying the thrust or target areas where intensive extension or revised extension recommendations are required. This can also help the policy makers to frame effective and accurate planning for Indian agriculture.

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1.4 Management of Landscape Diagnostic Survey data in India

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To make best use of data, systematic data management is extremely important for researchers and policy makers. It involves good design of the survey instrument, efficient collection using digital methods, careful curation, detail description or meta-data, secure storage, broad summarization and timely sharing. Data from the Landscape Diagnostic Survey (LDS) is collected digitally in a way that enumeration errors are minimized. Raw data undergoes multi-layer curation by concerned enumerators and scientists and the clean data file gets stored separately on a local server. Metadata is generated that details variables captured, collection related protocols, summary statistics and coverage map. Data, with attached metadata, is shared internally with key project people through cloud storage system. Finally, main data file along with associated metadata[1] files are uploaded on institute's Dataverse page and hence published. Normally, the process from collection to publication takes about 12 months for each dataset.

Emerging data infrastructure demands a concrete data management plan and dissemination of data to the public. FAIR Data Principles, first published in 2016 in *Scientific Data,* provide guidelines to improve the Findability, Accessibility, Interoperability and Reuse (FAIR) of data. These principles are not ultimate standards but broadly refer to: 'Findability' as data with globally unique and persistent digital identifier; 'Accessibility' as data that is open and free; 'Interoperability' as data with broadly applicable language; and 'Reuse' as data with clear and accessible usage licence (Wilkinson *et al*., 2016). Compliance to these guiding principles is the aim to be achieved with LDS data.

[1]Metadata is "data that provides information about other data". In other words, it is "data about data".

About the survey

LDS has been deployed by CSISA[2] and Extension Division of ICAR[3] jointly since 2018. The survey captures production practices applied by farmers in rice and wheat crops. Predetermined number of randomly selected farmers (N=210) are surveyed in each district for two major cropping seasons (rainy and winter). The first surveyed crop of LDS was rice in 2017 followed by wheat from the 2018 harvest that had covered 31 districts of Bihar, nine districts of Uttar Pradesh and three districts of Odisha. In the following years, LDS gradually expanded within and outside these three states. It now covers approximately 120 districts spread across Bihar, Uttar Pradesh, Odisha, Andhra Pradesh, Chhattisgarh, West Bengal, Jharkhand, Punjab and Haryana.

Based on crop, a single interview consists of 200 to 250 questions. These production practice questions are appropriately detailed and are related to land preparation, variety used, seeding time, fertilizer use, weed infestation, irrigation, diseases and pest management. Besides collecting these essential agronomic data, the survey briefly touches through social and economic angels of respondent. The data is collected using ODK[4] platform that saves collection time, automates data compilation, imposes internal checks and provides instant access to raw data. So far, approximately 25,000 data points have been gathered through LDS in India.

Data management procedure

The Fig. 1 illustrates LDS data management procedure from 'collection using ODK' to 'publication through Dataverse repository'.

A. **Data collection:** ODK version of digital questionnaire allows several functionalities to control and check potential errors during data collection, as well as improving the data collection process. Prepopulating possible responses (e.g. districts, blocks, varieties, planting methods, fertilizer names, harvesting methods, etc.) completely takes out chance of input errors (typos). It saves collection time and brings accuracy in responses. Questions are programmed in a way that the questionnaire remains extremely dynamic. For example, a question about timing of third manual weeding appears on the collection device only if farmer's response for the 'number of manual weeding' was three or more in the previous question.

[2]The project, Cereal Systems Initiative for South Asia (CSISA), is led by the International Maize and Wheat Improvement Center (CIMMYT) and implemented jointly with the International Food Policy Research Institute (IFPRI) and the International Rice Research Institute (IRRI).

[3]The Indian Council of Agricultural Research (ICAR) is an autonomous body responsible for co-ordinating agricultural education and research in India.

[4]Open Data Kit (ODK) is a free, open-source suite of tools that allows data collection using Android mobile devices and data submission to an online server, even without an Internet connection or mobile carrier service at the time of data collection.

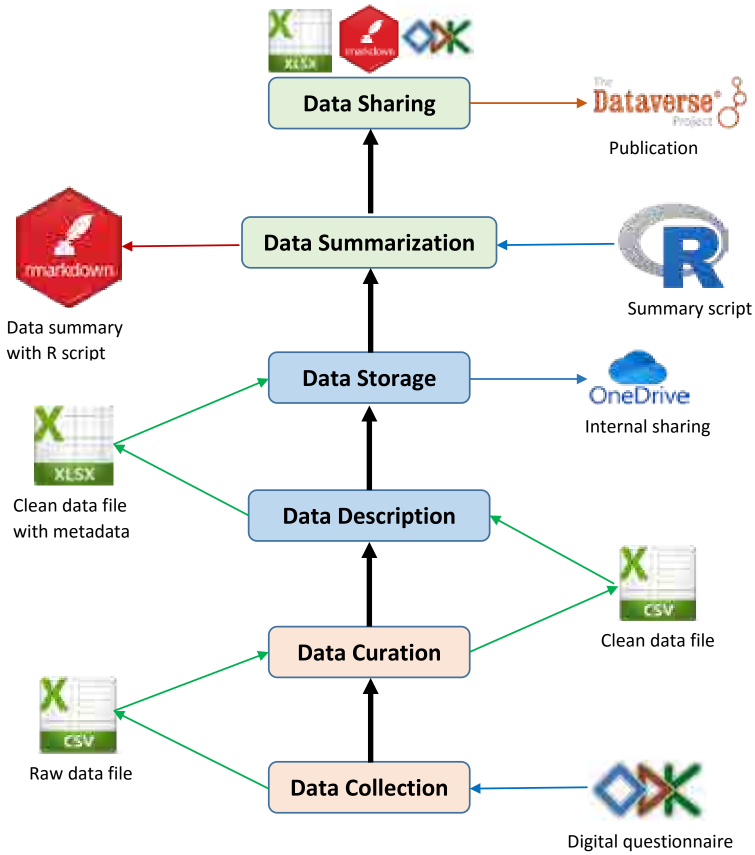

Fig. 1. Data management procedure

Entry limits are set to ensure that values entered lie within the permissible range (e.g. wheat yields > 8,000 kgha^{-1} cannot be accepted). Most of the responses are made mandatory so that important variables are not missed out. Even after a full-proof digital design, enumeration errors can only be minimized and cannot be ruled out completely. Another advantage of using this digital platform is that the raw data (.csv) of surveyed farmers is available in real-time.

B. **Data curation:** Raw data in .csv format is scrutinized row-wise by concerned enumerator first. In the second round, the enumerator checked file is further verified by senior agronomists and monitoring team jointly. A few columns (e.g. land unit conversion factor, dates, varieties, fertilizer doses, yields, etc.) are checked minutely as error chances are experienced high in these areas. Summary tables of different combination are prepared to check result's range. If some value is found to be too high or low, these are again verified from the field team. If rectification seems valid, it is modified and kept; otherwise the complete row gets deleted. Curation consumes the highest amount of time but ultimately generates a clean data file that users can have confidence in.

C. **Data description:** Adding information about the survey data (creating metadata) is the most important part of this work. The data file format changes from .csv to .xlsx as multiple worksheets are required in one single file. These sheets contain a detailed description of the data.

- *Sheet-1 (Basic information)* – This worksheet gives the purpose of collecting the data and institutions involved. It contains information such as the number of variables in the data, the number of samples surveyed, data collection tenure, geography covered and individuals involved.
- *Sheet-2 (Protocol)* – Methods and tools of data collection are briefly described on this sheet. Using the MS Excel feature of 'insert object', the original document related to survey methodology and digital data collection tool is made available for users. This document thoroughly describes about village and farmer selection, application of ODK tool and questions of the survey.
- *Sheet-3 (Process)* – The steps involved in generating this data are described here covering from 'questionnaire development' to 'data sharing'. This sheet also provides users with print and digital versions of the survey questionnaires inserted as objects.
- *Sheet-4 (Variables)* – This is the most informative sheet of the metadata file as it describes each variable captured in the survey. Corresponding to each coded variable name, their actual meaning, type (text/numeric) and measurement unit are mentioned. Additionally, there are statistical information (mean, median, minimum, maximum, standard deviation and missing values) provided for numeral variables.
- *Sheet-5&6 (Raw data & Clean data)* – Two worksheets next to variable sheet, are pure data sheets. As name suggests, one contains uncleaned data and the other one having curated data. The clean data TAB is used for any analytical work in future.
- *Sheet-7 (Districts)* – This sheet gives information about area/districts covered and corresponding number of samples surveyed. It also illustrates location of the survey and coverage through maps.
- *Sheet-8 (R File)* – Basic summary statistics of the data can be viewed through R script made available on this sheet. The sheet also provides steps about how to run this script. This should significantly increase the usability of the data and reduce the amount of 'data wrangling'.

D. **Data storage:** A copy of clean data file is uploaded on the ODK server hosted by IASRI[5] where those with administrative access can download this. Another copy with metadata sheets are kept on cloud storage of CGIAR[6] OneDrive and shared among key individuals of CSISA. Access to cloud storage can be permitted to project partners upon signing the data sharing agreement.

E. **Data summarization:** Using R Studio[7], clean data file is summarized allowing users to get an idea about distribution of values of majority of variables, basic statistical (mean, median and quartile) values of important numerical variables and some linear relationships of major independent variables (seeding time, planting method, number of irrigation, fertilizer rates, varieties, etc.) on crop yield. These summary results are knit together with R codes to generate R Markdown[8]. This file is one of the metadata files so is shared wherever the clean data goes.

F. **Data sharing:** Clean data file along with associated metadata files are made public through CIMMYT Research Data & Software Repository Network, the Dataverse (https://data.cimmyt.org/) after 12 months from the time of data curation. This final step tags the dataset with a persistent digital identifier. Before public sharing, data is anonymized to ensure that all personal information of surveyed farmers are rightly protected. Name of farmer and their contact details are deleted while geo-coordinates of their surveyed plots are truncated.

The first round of LDS was conducted in summer of 2018 and covered 31 districts of Bihar, nine of eastern Uttar Pradesh and three in Odisha. The first round created two datasets – Rice 2017 and Wheat 2018. The following rounds were extended to wider geographies within and outside these three states (Andhra Pradesh, Chhattisgarh, Jharkhand, Haryana, Punjab and West Bengal) and generated seasonal datasets for Rice 2018 and Wheat 2019. As far as the status of LDS data management is concerned, all the above steps have been completed for data of Rice 2017 and Wheat 2018. The work is under process for remaining two other datasets. Systematic and standardized process of data management in LDS would provide greater ease to data users and support the project adhere to FAIR principles in data management.

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[5]*The Indian Agricultural Statistics Research Institute (IASRI) is an institute under the Indian Council of Agricultural Research with the mandate for developing new techniques for the design of agricultural experiments as well as to analyse data in agriculture.*

[6]*Consultative Group on International Agricultural Research (CGIAR) is a global partnership that unites international organizations engaged in research about food security.*

[7]*R Studio is an integrated development environment for R, a programming language for statistical computing and graphics.*

[8]*R Markdown is a file format for making dynamic documents with R containing embedded R code.*

1.5 Rice yield and its determinants in Eastern Uttar Pradesh of India

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ABSTRACT

A diagnostic survey was conducted in nine districts of Eastern Uttar Pradesh (India) under Cereal Systems Initiative for South Asia (CSISA) through *Krishi Vigyan Kendra* (KVK) of each district. The survey data consisted of observations from farmer's field on different variables encompassing crop yield, inputs and management practices. Information in the survey was collected from a total of 1218 farmers following two stage sampling designs from all the districts. A total of nine varieties were observed to be cultivated in the surveyed districts. The four dominant rice varieties/hybrids preferred by majority of households (HHs) were MTU7029, BPT5204, Moti and Arize6444Gold. On an average, the highest yield was observed in Maharajgang district and the lowest was in Mau and Balia districts. The highest average yield (across the districts) was observed for MTU7029 and lowest was for Moti, and there were significant variety X district interactions. For yield determinants, multiple linear regression (MLR) model with stepwise selection technique (SST) was applied, with twelve regressors covering both quantitative as well as qualitative variables. Across districts and varieties simultaneously, regressors could not explain much of the variability in yield. However, on carrying out the analysis by variety across districts (i.e. fixing genotypic as well as the climatic/environmental effects and looking for the contribution of management variables for determining yield), the value of R^2 ranged from 20 to 85 % for different variety-district combinations. This analysis revealed that transplanting date, number of irrigations, farm size, drainage class and amount of N and K applied were the most significant yield determinants.

Introduction

According to the fourth advanced estimate for the year 2018-19 by Directorate of Economics & Statistics, DAC&FW, in India rice is grown in 43.79 million ha, with total production of 116.42 million tonnes and the productivity is about 2659 $kgha^{-1}$ (Agricultural Statistics at a Glance- 2019). It is grown under diverse soil and climatic conditions. The productivity level of rice is low compared to the productivity levels of many countries in the world. All regions have shared interest in increasing the productivity of rice and need to pool their research and innovations so that scaling of the best technologies is possible. In general, rice crop has more options for choosing varieties than any other crop. More than 1100 varieties have been released and list is getting larger every year. Every year we are adding about 10 varieties, but the concern is how many of newly released varieties are matching the strength of old varieties released in 1980s. Whether the release of new varieties (except hybrids) has translated into increased productivity of rice is an important question that need to be answered.

Dataset and Preliminary Investigation

For the present analysis, districts in Eastern Uttar Pradesh, India have been considered for identifying major yield determinants in rice. Total twelve variables have been considered for determining yield of rice and they are : variety, date of transplanting, previous crop grown, crop estimation techniques, seed rate, drainage class, farm size, no. of irrigations, largest crop area, and the amount of NPK. Among these twelve regressor variables, first seven regressors are qualitative in nature and last three are quantitative in nature. The summary statistics of rice yield in different districts covering all the varieties are presented in Table 1. A perusal of Table 1

Table 1. Summary statistics of rice yield (t ha^{-1}) in different districts considering all the varieties

Districts	N	Mean	SD	CV	Median	Min	Max	Range	Skewness	Kurtosis
Balia	94	3.85	0.89	23.12	3.75	2.25	6.40	4.15	0.72	0.13
Chandauli	190	4.66	0.90	19.31	4.75	2.00	6.58	4.58	-0.36	0.04
Deoria	87	4.12	1.11	26.94	4.25	1.49	6.75	5.26	-0.03	-0.23
Gazipur	142	3.93	0.84	21.37	4.00	1.99	6.40	4.41	0.12	0.14
Gorakhpur	171	4.20	1.18	28.10	4.38	1.50	6.50	5.00	-0.32	-0.48
Kushinagar	115	4.00	1.25	31.25	4.17	1.25	6.67	5.42	-0.18	-0.80
Maharajganj	180	4.92	0.89	18.09	5.00	2.00	6.75	4.75	-0.57	0.64
Mau	99	3.72	1.11	29.84	3.62	1.98	6.57	4.59	0.31	-0.56
Siddharthnagar	140	4.48	1.09	24.33	4.61	1.26	6.74	5.48	-0.31	-0.20

reveals that the Skewness and Kurtosis are not much deviated from zero indicating that the yield is distributed as normal distribution. The districts, varieties, number of farmers and the average yield for the studied locations are given in Table 2. In the last five years, there is a sharp increase in production of rice in Uttar Pradesh as

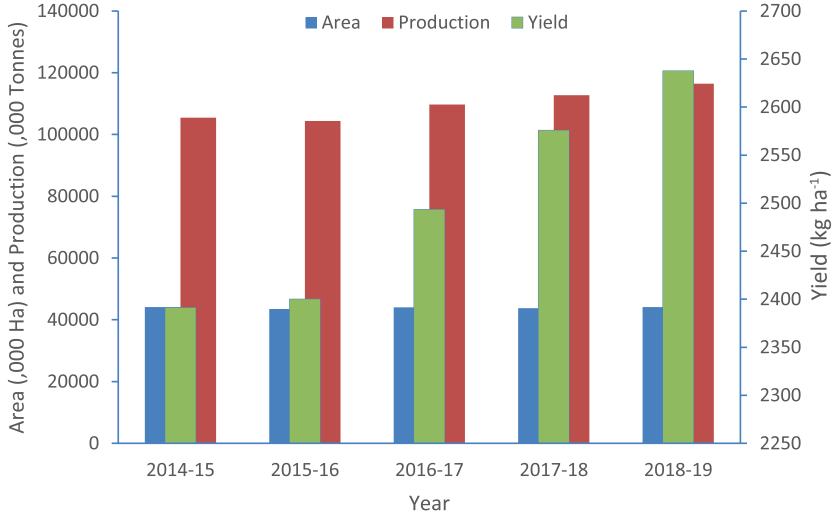

Fig. 1. All India area, production and yield of rice.

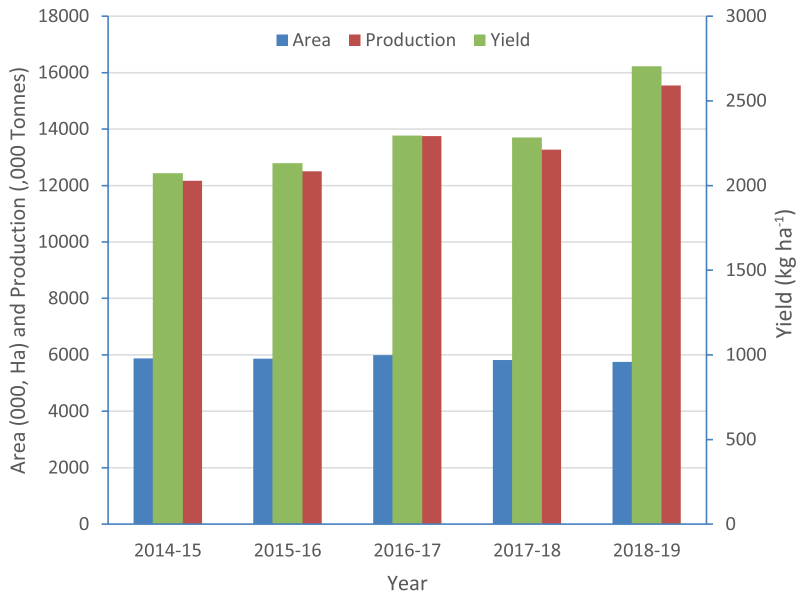

Fig. 2. Area, production and yield of rice in Uttar Pradesh.

Table 2. Average yield of rice (t ha^{-1}) from different varieties in surveyed districts.

District	Varieties	Frequency	Average yield
Balia	Other	66	3.55
	Moti	37	3.59
	MTU7029	34	4.29
Chandauli	Moti	72	4.23
	MTU 7029	76	5.12
Deoria	MotiGold	21	3.49
	Arize6444Gold	24	4.34
	BPT5204	23	4.36
Gazipur	Other	33	3.86
	Moti	102	3.94
Gorakhpur	BPT5204	65	3.8
	MTU7029	36	4.32
	Arize6444Gold	43	4.72
Kushinagar	Sarju52	42	3.41
	BPT5204	36	4.06
	MTU7029	28	4.74
Maharajganj	BPT5204	40	4.35
	MTU7029	122	5.2
Mau	Chintu	21	3.19
	Other	93	3.33
	Moti	32	3.35
	MTU7029	27	4.7
Siddharthnagar	Gorakhnath-509	26	4.08
	BPT5204	40	4.39
	MTU7029	30	4.63
	Sampoorna	23	4.67
	Arize6444Gold	21	4.73

compared to national level (Figs. 1 and 2). Though the area under rice and yield of rice have remained almost stagnant during 2014-15 to 2018-19.

Among the above varieties, four major varieties, namely, MTU7029, BPT5204, Moti and Arize6444Gold which are grown in maximum number of districts are selected for the further analysis.

The distribution of yield in different districts considering all the varieties and also considering the four major varieties as mentioned above have been presented in terms of boxplot in Fig. 3. Here, X-axis denotes the yield and Y axis denotes the districts.

Methodology

Multiple linear regression (MLR) model and one-way ANOVA with pairwise multiple comparison tests have been used for the present study.

Multiple linear regression (MLR) model, which can accommodate many regressors, has been applied. The model can be written as :

$$Y_i = \beta_0 + \sum_{j=1}^{p} \beta_j X_{ji} + \varepsilon_i$$

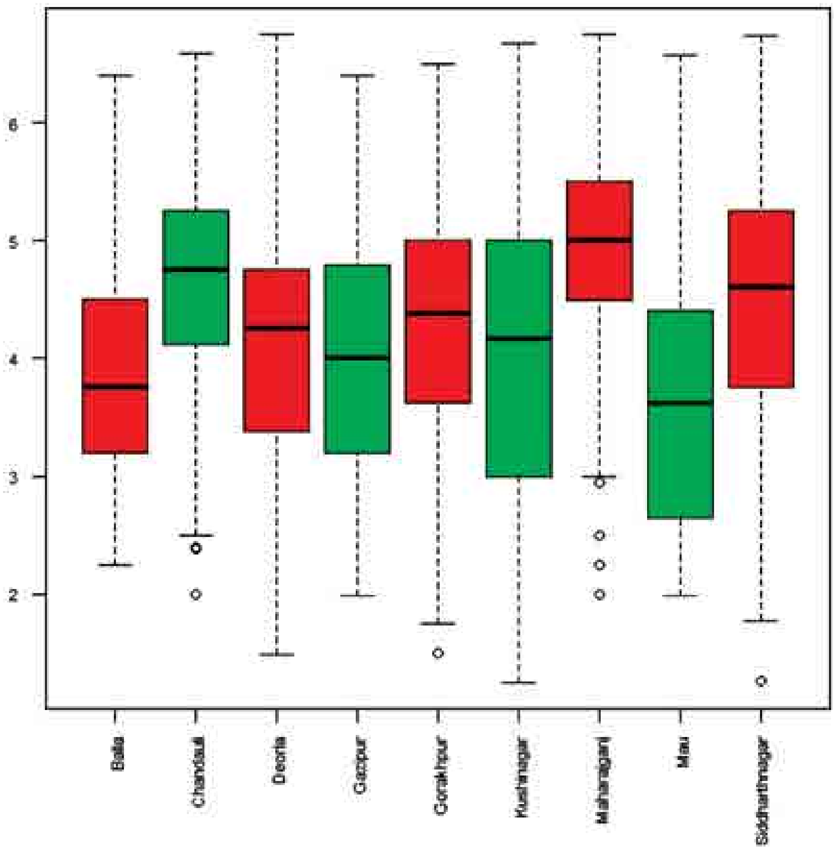

Fig. 3. Boxplot of rice yield (t ha^{-1}) for different districts in eastern UP, India covering four major varieties of rice.

Here Y_i is the value of the response variable corresponding to i^{th} observation, β_0 is the intercept term and β_j is the regression coefficient corresponding to j^{th} regressor variable. X_{ji} is the value of the j^{th} predictor variable for the i^{th} observation, ε_i is error term and it follows identically independently normally distributed (IIDN) with mean zero and constant variance σ^2 i.e. ε_i ~IIDN $(0, \sigma^2)$, covariance $(\varepsilon_i, \varepsilon_j)=0$ for $(i \neq j)$.

The main difficulty in using MLR is in choosing appropriate variables (regressors) in the model. In this regard, there exists three variable selection techniques namely forward selection, backward selection and stepwise selection. In the present analysis, stepwise selection technique has been implemented for variable selection in MLR model.

The stepwise regression procedure starts by choosing the single best X variable and then attempts to build up with subsequent additions of X's one at a time as long as these additions are worthwhile. The order of addition is decided by using the partial F-test values to select which variable should enter next (Paul and Bhar, 2019).

The basic procedure is as follows. First, we select the regressor variable (X) most correlated with response variable (Y) (suppose it is X_1) and find the first-order, linear regression equation. Next, this variable is checked for its significance. If it is not, we quit and adopt the model as best; otherwise we search for the second predictor variable to enter the regression. For details of the methodology of application of MLR with variable selection technique one may refer to Kleinbaum and Kupper (1978), Draper and Smith (1998) and Montgomery *et al*. (2003).

Results and Discussion

The MLR has been applied with stepwise selection technique for selecting appropriate regressors in the model. In the first step, attempt was made to identify the yield determinants in the states by considering all the varieties and districts as reported in Table 2. Data show that varietal turnover of new varieties is very low as the old varieties (MTU 7029, BPT 5204, Moti and *Sarju* 52) released before 1990s are still popular among farmers. This evidence shows that, most probably new varieties except hybrids might have not met the expectations of farmers for high yields. Paddy yields reported by surveyed households (HHs) from 9 districts trended to remain high in the order of long duration variety (MTU 7029), medium duration varieties (BPT 5204 and Moti), medium duration hybrid (Arize 6444) and short duration variety (Sarju 52). The best among the varieties (MTU 7029) has maintained higher yield than any other variety. It is evident from the data that yield growth was a function of the duration of a variety. In the absence of an alternative for high yield, hybrid rice is occupying the space in districts like Deoria, Gorakhpur and

Siddharthnagar. The efforts to reduce the maturity time are not making the situation better.

Overall, the significant variables to determine rice yield are found out to be : frequency of irrigation, transplanting date, dose of K, crop establishment method, dose of N, farm size, seed rate (kgha-^{1}) and dose of P are statistically significant in determining yield of the crop.

In the second step, modelling has been carried out for prediction of yield based on different regressors both variety wise as well as district wise. The main input variables entered in the variety wise analysis for respective districts are reported in Table 3. For the variety Arize6444Gold, the significant regressors entered in the model are : frequency of irrigation, transplanting date and dose of K with the value of R^2 as 11.87. When the same procedure was followed for district wise as well as variety wise, it is observed that in Deoria district, for the hybrid rice Arize6444Gold (Table 3), transplanting date, frequency of irrigation, dose of N, farm size, dose of K and drainage class are found to be significant with R^2 as 85.18. Whereas, in Gorakhpur district, for the same variety, frequency of irrigation is the only variable found significant with explanation of 41.78 % of variability of yield. In Siddharthnagar district, frequency of irrigation and dose of N explained more than 60 % of the variability in yield for the variety Arize6444Gold.

Similarly, for variety BPT5204 in overall districts, frequency of irrigation, dose of P, dose of K, transplanting date, farm size, crop estimation technique and drainage class are significant in determining rice yield. In district wise analysis of the variety BPT5204 (Table 3) the significant regressors were found as follows : in Deoria distrct frequency of irrigation, dose of N and dose of K; in district Gorakhpur, transplanting date and crop estimation technique; in district Kushinagar, drainage class and dose of P; in district Maharajganj, largest crop area, transplanting date, drainage class and dose of P and N; in Siddharthnagar, dose of N.

For variety Moti in overall districts, dose of K, dose of P, farm size and drainage class are observed to be significant in deterring rice yield. On analyzing the data district wise for the variety Moti (Table 3), it is observed that in Balia, largest crop area and dose of P; for Chandauli, transplanting date, frequency of irrigation, previous crop and dose of K; in Ghazipur, farm size, transplanting date, largest crop area, transplanting date, dose of K and P; in Mau, transplanting date and dose of P are significant.

In overall districts for the variety MTU7029, largest area of crop, farm size and frequency of irrigation contribute significantly toward explaining the variability of yield. In district wise analysis (Table 3), it may be seen that in Chandauli, previous

Table 3. Per cent contribution to R^2 by each of the input variables for each of the varieties

Districts	Transplanting date	Previous crop	No of irrigation	Seed rate	Drainage class	Crop largest area	Farm size	Amount of nitrogen (N)	Amount of phosphorous (P)	Amount of potassium (K)	Total
Variety: Arize6444Gold (Sample size: 88)											
Deoria	43.76	--	13.95	--	3.04	--	9.14	11.82	--	3.47	85.18
Gorakhpur	--	--	41.78	--	--	--	--	--	--	--	41.78
Siddharthnagar	--	--	44.22	--	--	--	--	16.31	--	--	60.54
Variety: BPT5204 (Sample size: 204)											
Deoria	--	--	35.71	--	--	--	--	12.90	--	10.19	58.80
Gorakhpur	8.08	--	13.34	--	--	--	--	--	--	--	21.42
Kushinagar	--	--	--	--	10.97	--	--	--	12.61	--	23.58
Maharajganj	5.99	--	--	--	8.32	7.24		9.19	8.82	--	39.56
Siddharthnagar	--	--	--	--	--	--	--	17.36	--	--	17.36
Variety: Moti (Sample size: 243)											
Balia	--	--	--	--	--	12.03	--	--	5.88	--	17.91
Chandauli	4.90	7.49	5.42	--	--	--	--	--	--	2.98	20.80
Gazipur	2.19	--	--	--	6.87	2.57	13.88		5.23	4.68	35.41
Mau	14.98	--	--	--	--	--	--	--	10.69	--	25.67
Variety: MTU7029 (Sample size: 353)											
Chandauli	--	3.65	--	--	--	--	3.48	--	--	3.17	10.30
Deoria	--	--	19.60	15.23	28.66	--	--	--	--	--	63.49
Gazipur	--	--	--	--	14.71	--	--	8.39	43.73	--	66.82
Kushinagar	16.17	--	--	--	9.68	--	--	--	--	--	25.85
Maharajganj	3.61	--	19.53	--	--	2.94	2.28	--	--	--	28.36
Mau	15.56	--	--	--	--	--	--	--	--	--	15.56

crop grown, farm size and dose of K; in Kushinagar, transplanting date and drainage class; in Maharajganj, frequency of irrigation, largest crop area, transplanting date and farm size; in Mau, transplanting date are found to be significant.

To this end, one-way ANOVA was carried out for testing the significant difference among the varietal yield. The pairwise comparison of yield from four varieties was also carried out using least significant difference. It is found that, the yield of four varieties differ significantly (Fig. 4) and all possible pairwise comparisons are statistically significant at 5 % level of significance. Moreover, even the performance of a single-fixed-variety differs significantly over different districts (Figs. 5A to D) implying thereby that the climatic/environmental conditions (represented by different districts) also play an important role in determining rice yield. In Figs. 4 and 5, the X-axis denotes the yield and Y axis denotes the districts.

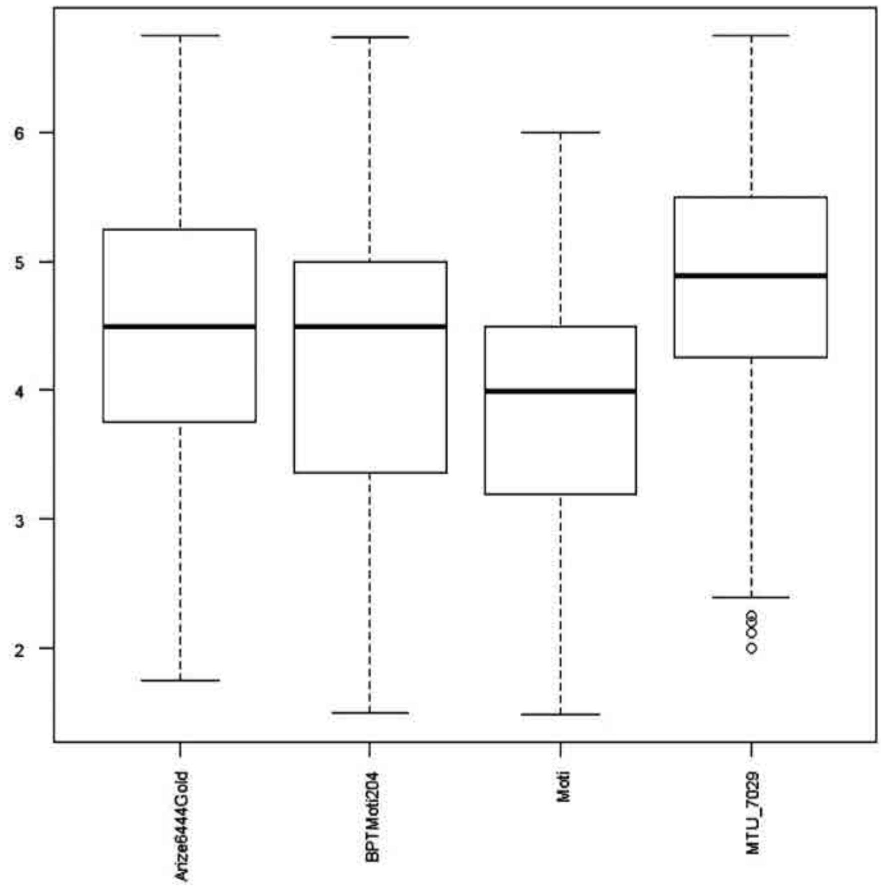

Fig. 4. Variations in rice yield for four major varieties (found dominant in all surveyed districts).

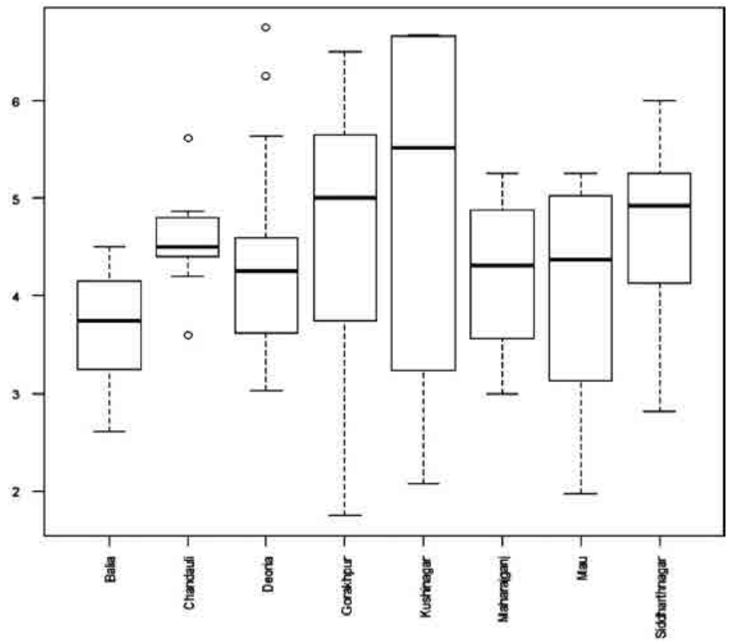

Fig. 5A. Variations in rice yield for the variety Arize6444Gold over different districts.

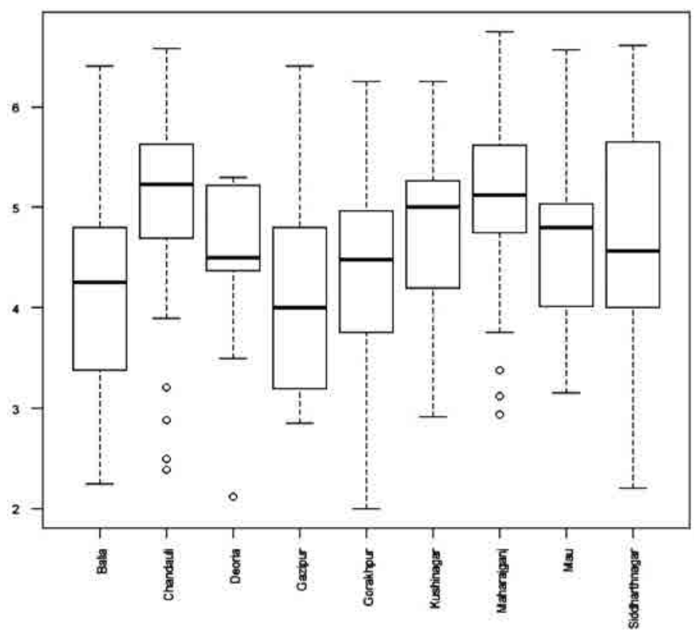

Fig. 5B. Variations in rice yield for the variety MTU7029 over different districts.

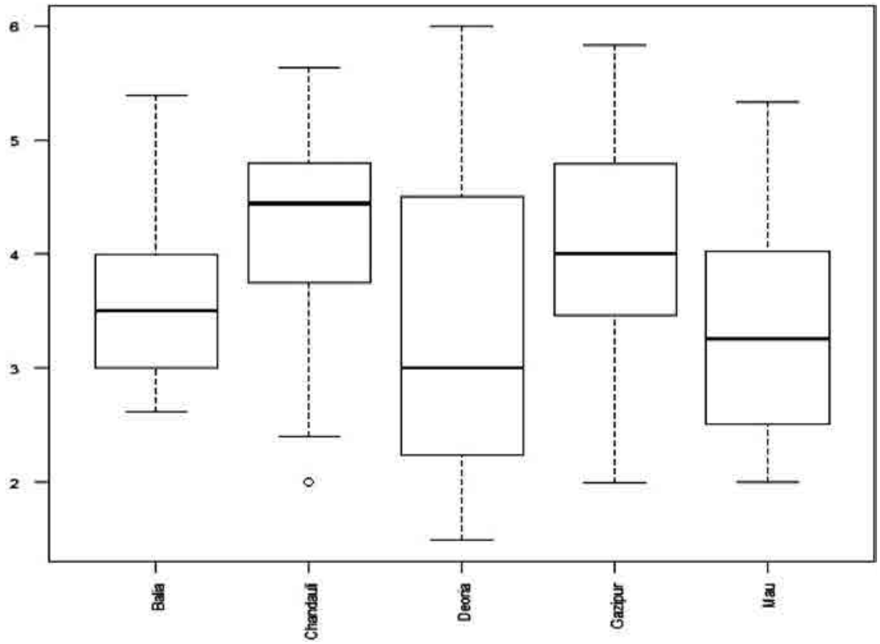

Fig. 5C. Variations in rice yield for the variety Moti over different districts.

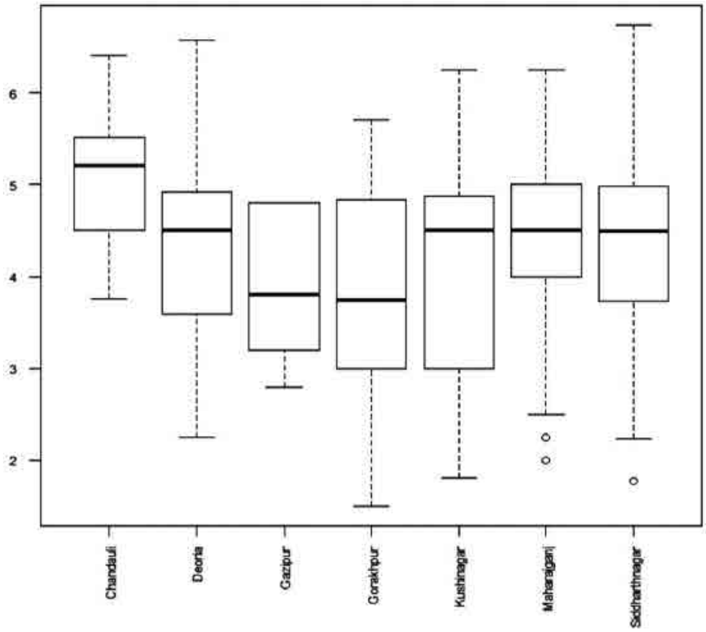

Fig. 5D. Variations in rice yield for the variety BPT5204 over different districts.

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2. Learnings and Priority Setting from Landscape Diagnostic Survey Database

2.1 Understanding and mapping rice variety spread

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KEY MESSAGES

- Older varieties, such as MTU 7029 (Swarna) released in 1982, and BPT 5204 (Samba Mahsuri) released in 1986, continue to dominate the eastern India region.
- The most preferred varieties in Punjab, Haryana and Andhra Pradesh are those that were developed in the region, whereas in eastern India, popular varieties are those which were imported from other regions.
- Although more than 350 varieties were reported to be cultivated in farmers' fields in the western and eastern ecologies, just five to nine varieties/hybrids are grown by more than 80% HHs.
- Paddy yields in Bihar and Eastern UP were just half to that of Punjab and Haryana within the same maturity class.
- In districts where hybrids were significantly adopted, yield of hybrid varieties was about 10% higher than that of inbred varieties.
- Adoption of rice hybrids in Bihar predominantly occurred in upland or medium land ecologies - those districts having risk of mild water stress, whereas adoption of hybrids was very low in districts with lowland ecologies.

- The variety BPT 5204 was very successful. Relatively high yield, fine grain type and excellent cooking and eating quality are important factors helping this variety to get a premium price to stay ahead of other varieties within medium duration maturity group.
- Kalachamapa, Dudheswar and Chaitali varieties are promising landraces/farmer varieties in Odisha and West Bengal.

1. Introduction

After the success of Mexican wheat, the Ford and Rockefeller Foundations established the International Rice Research Institute (IRRI) in the Philippines in 1960. The release of high-yielding semi-dwarf variety IR 8 by IRRI was the beginning of the green revolution in rice. According to the website of National Rice Research Institute (NRRI; updated in March 2020) 1,200 rice varieties have been released in India. Before the beginning of the Green Revolution in the late 1960s, Indian paddy yield was static at 1.5–1.6 t ha^{-1}. By 1980, Indian paddy yield reached 2 t ha^{-1} (FAOSTAT, www.fao.org/nr/water/aquastat/main/index.stm). The yield increased further by another 30% to 2.6 t ha^{-1} by 1990. By 2000, paddy yield was hovering around 3 t ha^{-1} (Zeigler and Mohanty, 2010). Progress has been excellent since the establishment of the breeding program in 1911 in Dhaka (now in Bangladesh), the establishment of ICAR in 1929 and Central Rice Research Institute (CRRI), now National Rice Research Institute (NRRI) in Cuttack in 1946. The initial but limited success came from inter-racial hybridization program between *japonicas* and *indicas* of ICAR in 1950-54. The major success came after the work on the nutrient responsive semi-dwarf high yielding varieties was started in NRRI and in the newly established International Rice Research Institute (IRRI) in 1960. The evolution of Padma and Jaya varieties marks the beginning of the more productive and intensive All India Coordinated Research Projects (AICRP) in 1965. During the following 12 years, 123 varieties were released compared to 51 varieties during the preceding 30 years. The hybrid rice program started in 1970 with no success for 20 years; the first four hybrids were released only in 1994.

The major breakthrough came after the release of IR 64 (Khush and Virk, 2005) and this variety is still found in some pockets of Chhattisgarh. Presently the system owes a lot to MTU 7029 in Andhra Pradesh (AP), released in 1982; since then, none of the newer varieties have surpassed the yield, stability and area under it till date.

Since the Green Revolution days, many technological changes have happened, but the solution for the stagnant yield growth in the eastern Indo-Gangetic Plains (EIGP) is not clear. On the whole, the yield growth in these ecologies has not endured since the start of the Green Revolution. Most new varieties promise farmers about increasing the yield. On farm trials are also conducted to facilitate the adoption of new varieties. However, in the EIGP new varieties were not adopted as per the expected scope at the time of the release of varieties. Although some new varieties and hybrids were adopted in Punjab, Haryana and AP, the majority of farmers are still favoring older varieties like Pusa 44, BPT 5204, and MTU 7029. If the variety in question is not accepted, even after a subsidy based incentive, that means there may be some underlying issues with the variety, recommendations, communication or dissemination process.

Yield growth in the eastern sector is necessary to sustain rice production and to reduce the area, currently 43 million ha, under rice. There is a need to consolidate the genetic yield potential of the currently available high yielding varieties and raising the ceiling of yield through hybrid technology and new plant type varieties (Siddiq, 1999).

The consensus was on giving more emphasis on varietal improvement in rainfed ecologies. But even after full-scale efforts, the yield growth was slow and adoption of new varieties released after late 1990s is even slower.

The LDS was conducted to build on the insights into the preferences of farmers in their constant struggle to sustainably increase the yield of rice. The objective is to develop a database related to the adoption of rice varieties and hybrids to help public and private sector decision making in research, set extension priorities and help policymakers in designing strategies for faster varietal turnover in the field. This survey will help the National Agricultural Research and Extension System (NARES) partners to plan their district level extension based on the factual status of adoption of varieties in the district. Data so generated will reflect changes in farmers' requirement for varieties/hybrids of rice grown under diverse soil and climatic conditions. This survey covered eastern regions (Bihar, Eastern UP, Chhattisgarh, Jharkhand, Odisha and West Bengal) with a regional rainfall of 1,526 mm, northern region with regional rainfall of 650 mm (Punjab and Haryana) and southern region (Andhra Pradesh) with an annual rainfall of 966 mm.

2. Methodology

CSISA-KVKs network surveyed 16,512 HHs across 8 states covering representative districts dominated by rice-wheat or rice-rice or rice-fallow cropping systems during 2019-20. There were 30 villages with 7 HHs (selected randomly based on 2011 Census) in each village in the district. Each respondent was asked questions on the adoption pattern of varieties already listed in consultation with each participating KVK. All randomly selected farmers responded for their preferences.

Supply-oriented varietal dissemination is usually arrived at based on the breeder seed intend of each variety. This has serious limitations while assessing adoption pattern of different varieties as the approach does not account for the use of farm-saved seeds and assumes that all breeder seeds is converted into the foundation and then to certified/truthfully labelled seeds[1]. The current survey gave an idea on the demand side of varietal adoption pattern of varieties across districts in eight states representing North West, the EIGP, Odisha, Chhattisgarh and Andhra Pradesh (AP) in Southern part. The Landscape Diagnostic Survey (LDS) data-based evidence argued that although the research and extension agenda for varieties are mostly set by a top-down approach, an informal system of bottom-up approach should be developed by seeking the opinion of farmers or market options.

Based on the International Rice Testing Program (IRTP) trials of the International Rice Research Institute (IRRI) varieties/hybrids were also broadly grouped according to total duration into four groups (IRTP Reports, 1985) as very early (90 – 105 days), early (105 – 120 days), medium (120 – 140 days) and late maturing (> 140 days). In this volume, three groups were kept including; short duration (90-125 days), medium duration (126 -145 days) and long duration (above 145 days). Data for eight states gathered by CSISA-KVKs network accounts for 35 districts in Bihar, 18 districts in the Eastern UP, seven districts in Odisha, three districts in Chhattisgarh, nine districts in West Bengal, nine districts in AP, and two districts each in Punjab and Haryana.

3. Results and Discussion

3.1 Rice yield

The rice landscape in India is very diverse and one would expect significant variation in terms of its productivity across these landscapes. Southern and north west India are the most productive regions (more than 5 t ha^{-1}), whereas significant variation is observed in eastern India; hence we confine our focus within the eastern geography (Haryana, Punjab, EUP, Bihar). Four districts (Rohtas, Bhojpur, Lakhisarai and Mahraganj) are highly productive, yielding more than 5 t ha^{-1}, whereas, Vaishali and Darbhanga are least productive with less than 3 t ha^{-1}. Most southern districts are highly productive (4 to 5 t ha^{-1}) except Buxar, which produced 3 to 4 t ha^{-1} (Fig. 1). Several north and north eastern region districts are less productive (3 to 4 t ha^{-1}), but three districts (Madhubani, Sitamarhi and Sheohar) have yield of 4 to 5 t ha^{-1}.

[1]Otherwise, the proportion of breeder seeds finally converting into certified or truthfully labelled seeds required to be estimated. Alternatively, final sale volume of each variety by different seed companies, public and other agencies are required to be collated, and to our knowledge such database at variety level is not available.

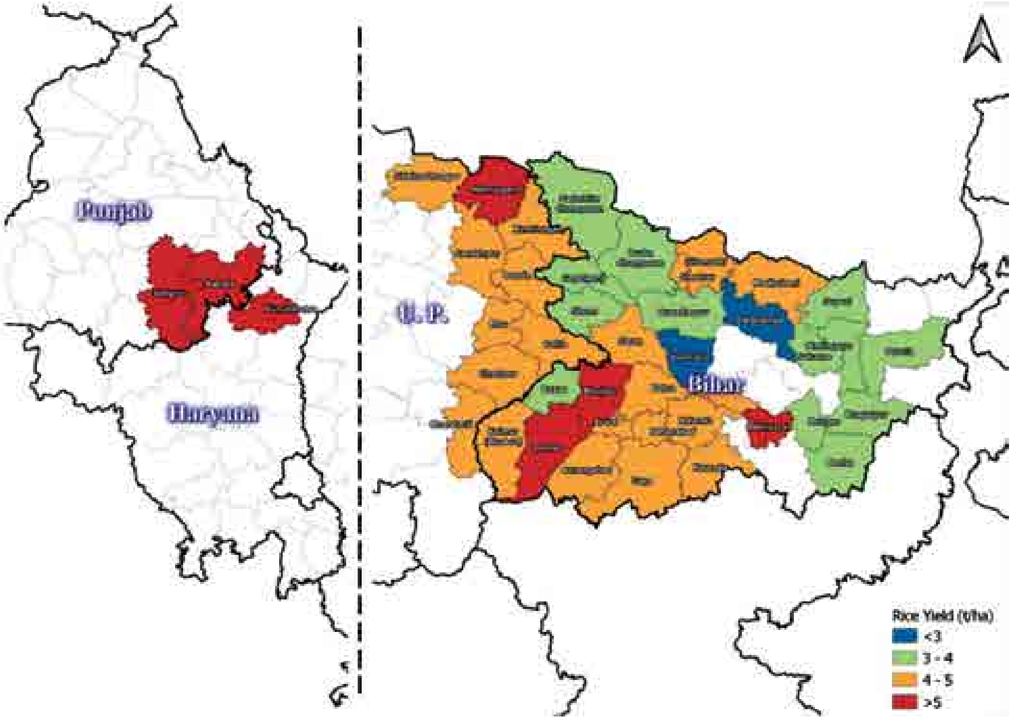

Fig. 1. Mapping rice productivity in eastern India

Yield is the most significant attribute, followed by taste, when farmers' make their choice on varieties (Table 1). Farmers clearly indicated their preference for adding traits such as drought resistance and more fertilizer responsive varieties. With this backdrop, the next sections primarily explored the variety spread *vis-a-vis* the yield.

3.2 Variety spectrum and geographical spread of major varieties

The spread of varieties across surveyed states showed (Fig. 2) that MTU7029 (Swarna) is the top variety in five out of eight states and it occupied the second position in AP. The short duration PR126 is the top variety in Haryana districts and long duration Pusa 44 occupied the first position in Punjab districts. Samba Mahsuri (BPT 5204) also has dominance in AP (first position), and UP (second position), whereas the hybrid variety Arize 644 Gold is the second variety in Bihar and Haryana. The top 10 varieties constitute more than 80 % of the total rice cultivation in the region, hence this session is confined to understand the spread of those varieties. It seems that the yield and the stability determine how well a variety will be accepted and how long it will stay as a preffered variety. The preference of few

Table 1. Preferences about traits of major rice varieties during *kharif* 2016 in Eastern India.

Location	Variety	More yield	Disease resistant	Pest resistant	Flood tolerant	Drought tolerant	Affordable	More marketable	High germination rate	Good taste	Good for cooking	Good straw quality	Easily available	Shorter duration	Needs less fertilizer	Easily threshed	No lodging problem	Panicle weight
Stress prone	Arize 6444	(±)				–		(±)		+								
	Kalachampa	(±)		–						+		+					–	
	Khandagiri	(±)		–		–				+						+		
	Lalat	(±)	–			–				+	+							
	Mahsuri	(±)				–		+		+					–			
	Moti	(±)				–		+		+					–			
	MTU 1001	(±)		–		–		+		+								
	MTU 1010	(±)					–	–			+		+					
	Pratikshya	(±)	+			–		–		+								
	Puja	(±)		–						+	+				–			
	Sahbhagi Dhan	(±)				+				+				–	–			
	Sambha Mahsori	(±)	–					+		+					–			
	Sarju 52	(±)				–		(±)		+								
	Swarna	(±)	–					+		+					–			
	Swarna Sub1	(±)			+			+						–	–			
Non-stress prone	Arize 6444	(±)	–				–	+		+								
	Kalachampa	(±)				–			–	+								+
	Khandagiri	(±)								+	–		(±)					
	Lalat	(±)				–				+	+			–				
	Mahsuri	(±)				–		+		+				–				
	Moti	(±)				–	–	+		+								
	MTU 1001	(±)				–	+	–		+								
	MTU 1010	(±)					(±)			+	–							
	Pratikshya	(±)						(±)		+				–				

Location	Variety	More yield	Disease resistant	Pest resistant	Flood tolerant	Drought tolerant	Affordable	More marketable	High germination rate	Good taste	Good for cooking	Good straw quality	Easily available	Shorter duration	Needs less fertilizer	Easily threshed	No lodging problem	Panicle weight
	Puja	(±)				–		(±)		+								
	Sahbhagi Dhan	(±)		+				+						–		–		
	Sambha Mahsori	(±)	–			–		+		+								
	Sarju 52	(±)				–		(±)		+								
	Swarna	(±)						(±)		+					–			
	Swarna Sub1	(±)			+			–						–			+	

+ good traits, – needs improvement, (±) good traits but still needs improvement (Source: RMS, 2018)

varieties across states also showed that how well the seed market is connected across states.

Several studies showed that the most important trait when farmers make a decision on a variety is its yield. Accounting this strong preference association, the dominant mega-varieties were plotted in each district against the average district yield of rice (Fig. 3). Following top ten varieties were found the most predominant in the region: MTU 7029 (Swarna), BPT 5204 (Samba Mahsuri), Arize 6444 Gold, Binadhan 11, Moti, Damini, PR126, Pusa 44, Rajendra Mahsuri, and Sarju 52. Fifteen districts in eastern UP and Bihar are dominated by the hybrid Arize 6444 Gold, followed by the old variety Swarna (10 districts), Sarju 52 (four districts), Samba Mahsuri (three districts) and other varieties in two districts (Damini, Bina Dhan 11, Pusa 44, Moti). Rajendra Mahsuri and PR 126 are the most widespread varieties in Madhubani and Kurukshetra districts, respectively. As evident from Fig. 3, three districts (Rhotas, Bhojpur and Lakhisarai) in Bihar, two districts in Haryana (Kurukhetra and Ambala) and two districts in Punjab (Patiala and Sangrur) harvested rice with more than 5 t ha^{-1} average yield. The dominant mega-varieties in these districts are Swarna in Bihar, PR 126 and Arize 6444 Gold in Kurukhetra and Ambala, Haryana, respectively, and Pusa 44 in Sangrur and Patiala in Punjab. Though only one district is having hybrid (Arize 6444 Gold) yielding more than 5 t ha^{-1}, it is inconclusive to conclude the performance of the hybrid in the region. Please refer the session 3.2 for more discussion on hybrids versus inbreds. Only one district, Darbhanga in Bihar, has reported an average yield of less than 3 t ha^{-1}.

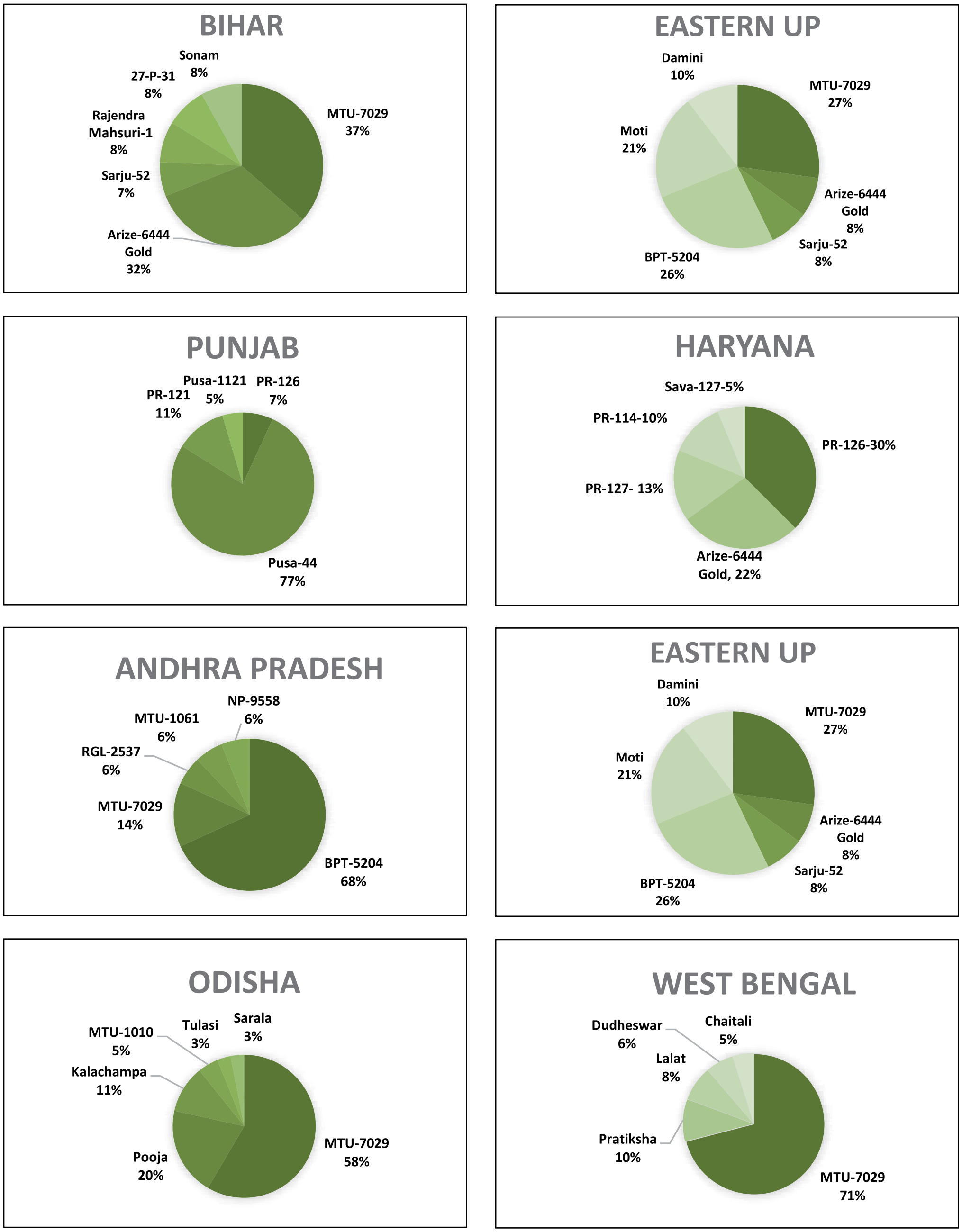

Fig. 2. Spread of major varieties across different states (varieties with 3 % household each in Andhra Pradesh include NLR 3041, NLR 34449, MTU 1001, MTU 1064); varieties with small area are given in Annexure 1.

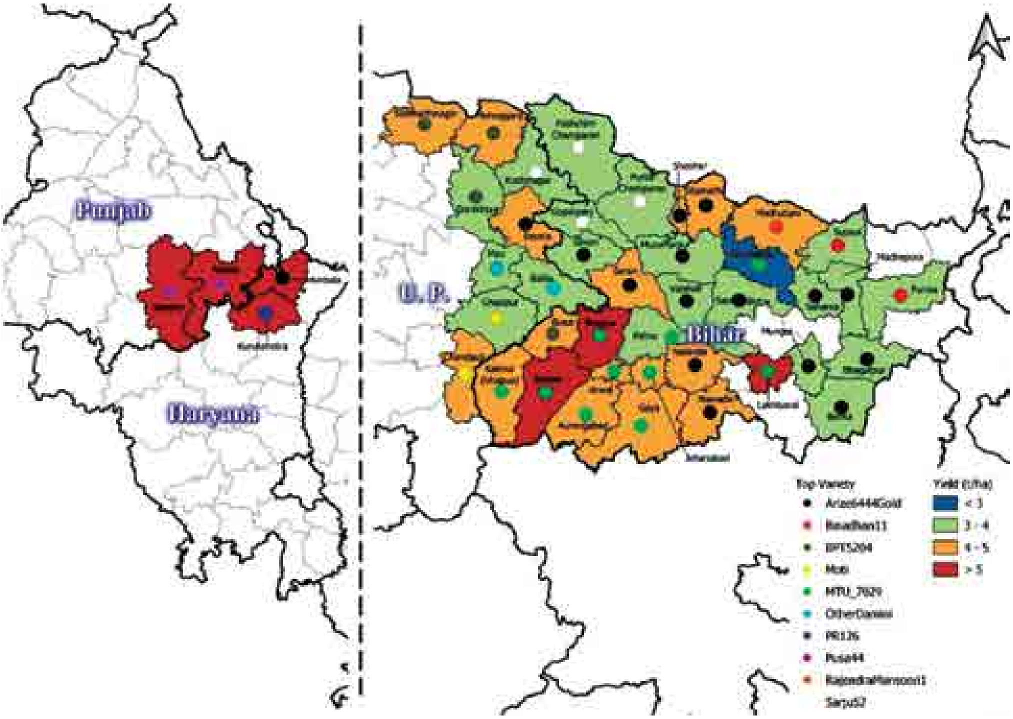

Fig. 3. Spread of mega-varieties in the region plotted against the district rice yield

The dominant variety in this district is Swarna. Most districts (45 %) fall under the second lowest yield category, 3 to 4 t ha^{-1}. Out of 20 districts, nine are dominated by hybrid (Arize 6444 Gold). Varieties in remaining districts are Sarju 52 (four districts), Damini and Binadhan 11 (two districts each), and Swarna, Samba Mahsuri and Moti (one district each). Sixteen districts belong to the second highest yield group (4 to 5 t ha^{-1}), of which Arize 6444 Gold is wide spread in six districts, followed by Swarna in five districts and Sambha Mahsuri in three districts. In summary, in the best performing districts in Bihar and eastern UP, two varieties are outstanding – Swarna followed by Arize 6444 Gold. It might also be noted that in certain geographic areas some varieties dominate; for example, Sarju 52 and Sambha Mahsuri in north Bihar and adjacent areas of UP, Pusa 44 in Punjab etc. A detailed variety list along with the spread of Swarna and Arize 6444 Gold is provided in the Appendix 1.

The spread of the top three varieties was now carefully evaluated – two inbreds (Swarna and Samba Mahsuri) and a hybrid (Arize 6444 Gold). Swarna is reported to be cultivated very widely in UP, Bihar, West Bengal, Odisha, Chattisgarh and AP. In Bihar, more than 75 % farmers in Rohtas cultivate Swarna, and it is important to note that this district is among the most productive regions. It is important to note that the districts where Swarna is adopted significantly large proportion of farmers are yielding on average more than 4 t ha^{-1}. The adoption of Swarna is high (60 to 75% of farmers) in Mahraganj, Kaimur, Aurangabad and Arwal. Samba Mahsuri is very common in AP districts as more than 75% farmers have adopted Samba Mahsuri in two districts of AP. In UP-Bihar region, Buxar is reportedly having high adoption, around 45 to 60%, and Deoria 15 to 30% adoption. The spread of hybrid Arize 6444 Gold is confined within Bihar and UP region. The majority of farmers in Madhepura (>75%), Saran, Sheohar and Samastipur (60 to 75%) cultivate the hybrid. Among these districts, Madhepura and Samastipur had yield lower (3 to 4 t ha^{-1}) than Sarana and Sheohar (4 to 5 t ha^{-1}). In short, though mega-varieties spread across different geographies, they concentrated in a few districts. This requires further investigation specifically taking account of resource availability, agricultural extension and information services, machine intensity, institutional development along with the ecosystem suitability and exposure to abiotic or biotic stresses.

3.3 Hybrid versus inbreds

In the earlier session, the spread of mega varieties in the region was primarily looked at and here the inbred and hybrid adoption is discussed. In Bihar and eastern UP the central tract is dominated by hybrids, whereas the north and south region are primarily inbred areas (Fig. 4). In majority of these districts rice experiences some level of mild water stress because of medium or upland ecology and soil with relatively low water holding capacity. The adoption of hybrids is less in lowland ecologies and soil with high water holding capacity as farmers can grow long-duration varieties. Punjab is mostly growing inbred varieties whereas Haryana districts are mostly into

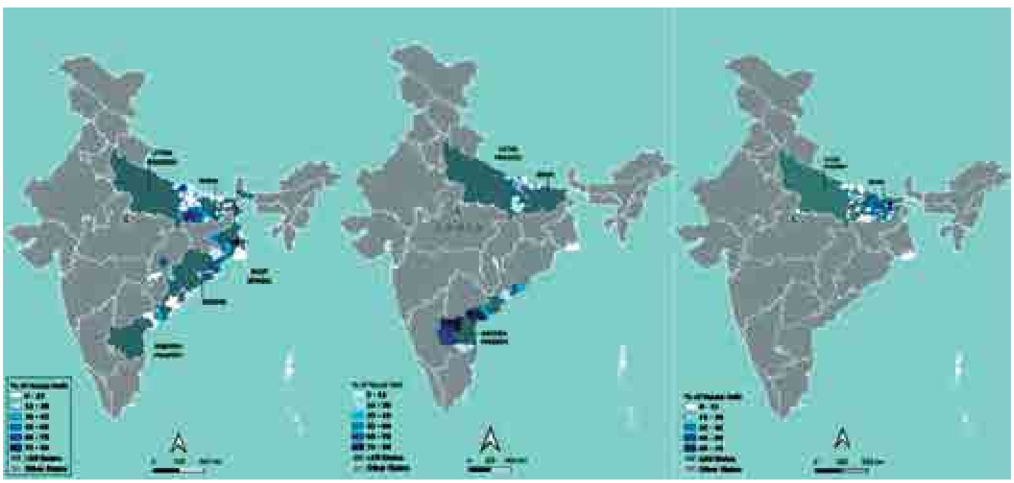

Fig. 4. Adoption of top three varieties (Swarna, Samba Mahsuri and Arize 6444 Gold) in the region

hybrids. The adoption of hybrid/inbred and the average district yield in t ha^{-1} is given in Fig. 5. Adoption of hybrids is low in districts where yields are high (> 5 t ha^{-1}) (Lakhisarai, Rohtas, Bhojpur and Mahraganj) and inbreds are preferred by farmers in these areas (Fig. 4). The Fig. 4 also showed farmers' preference, and adoption of hybrids was found more in districts with relatively lower yield. For example, in 15 districts of Bihar where yields were relatively low (ranged between 3 and 4 t ha^{-1}), in 11 districts (Purnia, Banka, Munger, Bhagalpur, Shahrasa, Madhepura, Samastipur, Vaishali, Muzaffarpur, Siwan, Deoria) adoption of hybrid dominated, whereas inbred adoption was high in four out of 15 districts (Darbhanga, Purba Champaran, Paschim Champaran and Supaul). Among the districts having 4 to 5 t ha^{-1} yield, farmers in 12 out of 19 districts (Madhubani, Gaya, Aurangabad, Arwal, Jehanabad, Patna, Kaimur, Chandauli, Ghazipur, Ballia, Mau and Kushinagar) mainly cultivated inbreds, whereas in the remaining seven districts (Nawada, Nalanda, Sheohar, Sitamarhi, Gopalganj, Saran Gorakpur and Siddharthnagar) cultivated hybrids.

The yield of inbreds and hybrids in Bihar for districts having reasonable percentage of households adopting both categories of rice cultivars (at least 15% households of either category), were compared (Table 2). Overall, hybrid gave 0.35 t ha^{-1} (10%)

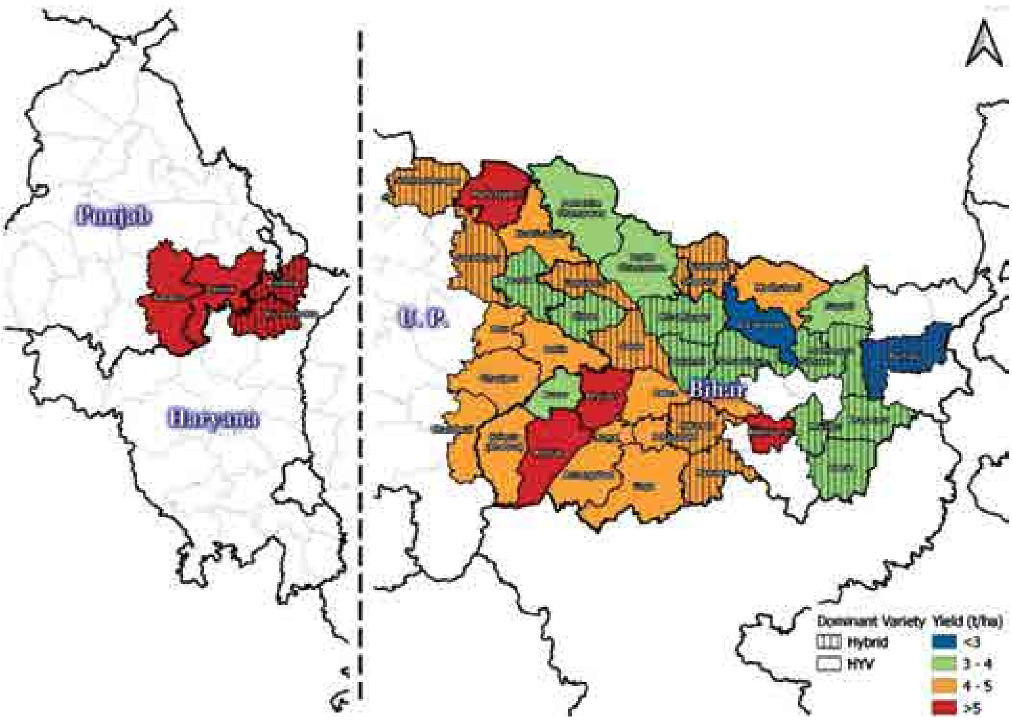

Fig. 5. Farmers choice of varieties – yield of hybrid versus inbreds

Table 2. Yield comparision of hybrid and inbred cultivars in 18 districts of Bihar where at least 15% of surveyed household adopted hybrids

District	Total HH (#)	Inbred		Hybrid		Yield change with hybrid over inbred	
		Yield (t ha^{-1})	% HHs	Yield (t ha^{-1})	% HHs	t ha^{-1}	%
Banka	365	3.37	66.03	3.44	33.97	0.07	2.1
Bhagalpur	279	3.60	42.35	3.95	56.94	0.35	9.7
Darbhanga	168	2.40	65.48	3.29	34.52	0.89	37.1
East Champaran	377	3.70	78.16	4.57	21.05	0.87	23.5
Gopalganj	195	3.69	70.65	4.11	26.37	0.42	11.4
Lakhisarai	273	5.31	59.34	5.15	40.66	-0.16	-3.0
Madhepura	258	3.42	34.88	3.72	65.12	0.30	8.8
Madhubani	207	4.70	68.12	5.49	31.88	0.79	16.8
Munger	358	3.51	48.61	3.88	50.83	0.37	10.5
Nalanda	393	4.30	61.17	4.23	38.58	-0.07	-1.6
Nawada	211	4.43	65.57	4.39	33.96	-0.04	-0.9
Patna	196	3.99	82.23	4.20	17.26	0.21	5.3
Saharsa	217	3.15	48.62	3.55	50.92	0.40	12.7
Saran	199	4.13	27.14	4.34	72.86	0.21	5.1
Sheohar	208	3.85	41.83	4.04	58.17	0.19	4.9
Sitamarhi	191	4.33	63.35	4.99	36.65	0.66	15.2
Siwan	162	2.85	47.88	3.03	50.3	0.18	6.3
West Champaran	208	3.30	85.1	3.74	14.9	0.44	13.3
Average						0.35	9.8

higher yield than that of inbred varieties. In four districts (Lakhisarai, Nalanda, Nawada and Banka) yields of hybrid and inbred did not differ. However, in all other districts the yield gain from hybrid over inbred ranged from 5 to 37% (0.18 – 0.89 t ha^{-1}). In Dharbhanga and East Champaran districts yield gain from hybrid over inbred was high.

3.4 Duration and rice yield

The variety adoption data showed that inbreds belong to all three duration categories, namely short duration (<125 days) inbred (SDV), medium duration (125 to 135 days) inbred (MDV), and long duration (>135 days) inbred (LDV), whereas hybrids belong to two categories - short duration hybrids (SDH) and medium duration hybrids (MDH). In Bihar nearly equal proportion of farmers (Fig. 6) cultivate long-duration inbreds (35 %) and medium duration hybrids (34 %), followed by medium duration inbreds (20 %). UP is dominated by medium duration inbreds (58 %) followed by long duration inbreds (24 %). Hybrid was found cultivated by only 11 % of UP farmers. There is an yield advantage with long duration inbreds in both Bihar and UP, but a more detailed investigation is needed taking account of the system performance. In UP the hybrids (both MDH and SDH) outperformed medium and short duration inbreds. Though a similar observation is found with farmers in Bihar, the yield advantage is relatively lower for hybrids when compared with the medium duration inbreds.

Each group of varieties or hybrids are well adapted to varied agro-climate across states. It is hard to know how exactly the interaction of G × E is taking place, but there is large scale adoption of varieties originating from AP to all over the EIGP, often with same or higher yields compared to their place of origin. In Figs. 7, 8, the spread of different duration varieties across districts in Bihar and UP is presented. South and North east districts of Bihar mostly cultivate long duration varieties, whereas in West Champaran, Gopalganj and Supaul, short duration varieties dominate. Interestingly, except Gopalganj, all other districts are dominated by inbreds and most of these districts, except Darbhanga and West Champaran, are high performing districts in

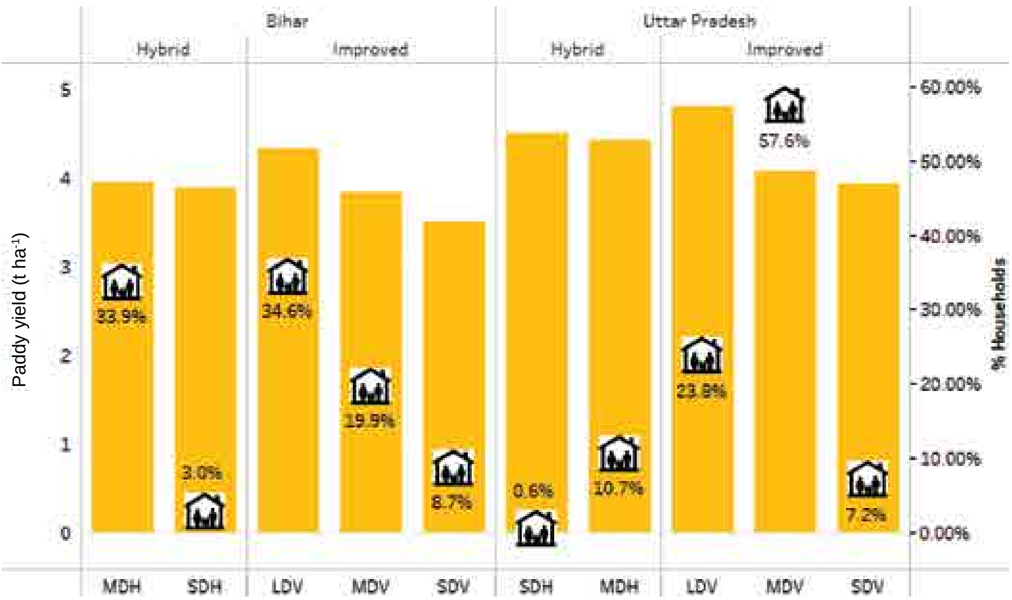

Fig. 6. Adoption of rice inbreds and hybrids of different maturity periods and their effects on paddy yield in Bihar and Uttar Pradesh

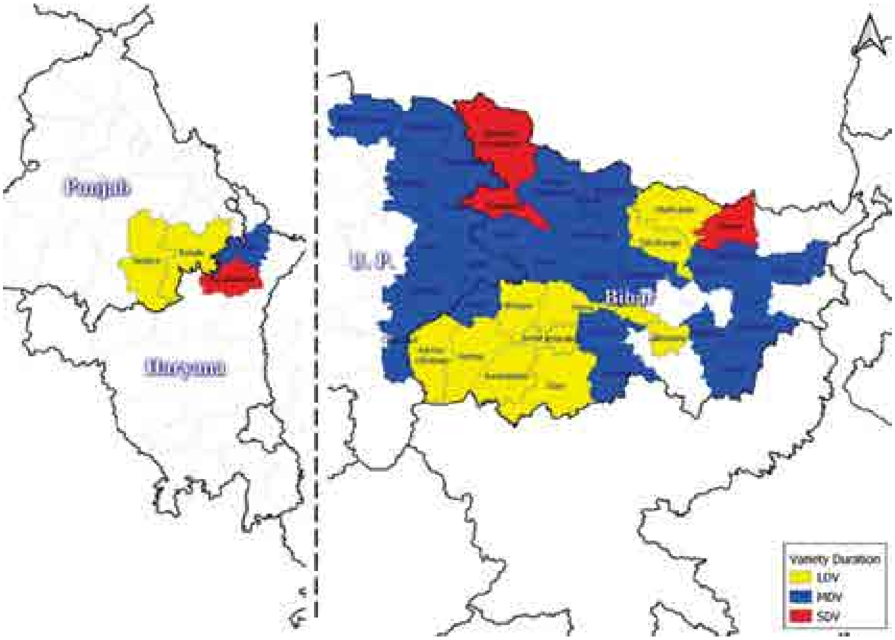

Fig. 7. Farmers choice of short, medium and long duration varieties

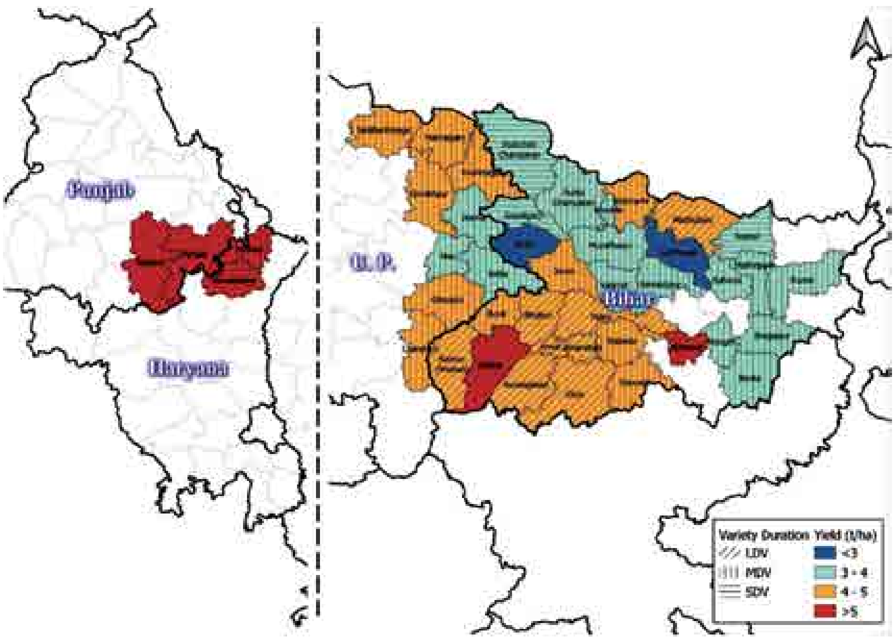

Fig. 8. Duration of rice varieties and yield

terms of yield (average yield of > 4 t ha^{-1}). It may be also concluded that most hybrid dominating areas fall under medium duration rice varieties.

3.5 Small holders and hybrid adoption

High cost of hybrid seed, which is 10 times the cost of inbreds, was expected to act as a barrier for small and marginal farmers to adopt hybrid rice in ecologies like Bihar. In contrast, the study did not show any evidence of such scale discrimination towards marginal and smallholding vis-a-vis adoption of hybrid (Table 3). Bihar and Eastern UP, which are dominated by small and medium farmers are now attractive markets for hybrids. Among adopters, a significantly higher proportion of marginal farmers were found adopting hybrids than large farmers (Table 3). This scale neutrality of hybrids is mostly attributed to farmers' innovation with respect to seed rate, which reduces the cost of seed. The LDS data and work on rice nursery

Table 3. Hybrids adoption in the surveyed states

State	Farmer type	Yield (t ha^{-1})	No. of households adopting hybrids	% households
Bihar	Marginal	3.9	1739	24
	Small	4.0	587	8
	Semi-medium	4.1	216	3
	Medium	3.9	46	1
	Large	3.5	3	>0.1
Haryana	Marginal	6.8	16	4
	Small	6.9	33	8
	Semi-medium	7.0	52	12
	Medium	7.1	40	10
	Large	6.5	6	1
Punjab	Small	8.5	2	0.5
	Semi-medium	7.1	3	0.8
	Medium	7.7	1	0.3
Uttar Pradesh	Marginal	4.3	159	6.2
	Small	4.6	77	3
	Semi-medium	4.3	37	1.4
	Medium	5.0	12	0.5
	Large	4.7	2	0.1

enterprise showed that the farmers reduced seed rate of hybrids to 4 kg/acre from 12 kg/acre (a 67 % reduction). The quantity of complementary inputs required is almost the same as in inbreds. Dr Hari Prasad from the Directorate of Rice Research, India, while talking about the status of hybrid rice on Expert Consultative Group meeting in July 2014 said that 95 % hybrid seed production is done by private sector, which increased it from 200 tons in 1995 to 40,000 tons in 2014. The innovation of reduced seed rate of hybrids by farmers resolved the issue of high seed cost, and helped the concept of seed saved is seed produced. It also increased the confidence and trust of farmers in technology. A study on adoption of hybrids in rice showed decision of farmers to adopt any variety depends on their frequent interactions with their peers (Ward and Pede, 2015), and the trust they generate through these interactions.

The scaling of hybrids was much better in the upland ecologies than that in the shallow low land ecologies in the EIGP, and where farmers worry about drought-like situation. It was also better in the intensified cropping systems like Ambala in Haryana and the six districts in Bihar where adoption is high. In future, more consolidation may happen in these ecologies. Adoption may increase further even in shallow low lands if the maturity time of new hybrids can be extended up to 145-150 days. Short duration hybrids, though, can fit well with potato or toria/raya as a third crop and cropping intensity can be increased to 300 %. A high response rate of farmers towards hybrids itself supports our argument about the scale neutrality of hybrids.

It is reasonable to assume that relatively high adoption rates of hybrids in early season or late season drought situations that existed in Bihar may be due to their better tolerance to stress. State policymakers in Bihar and Haryana were quicker to respond to the need of hybrids especially in the stressed environment of delayed and uncertain monsoon. In districts like Ambala, the intensified cropping system of three crops in some blocks favors the adoption of hybrids. In Punjab, millers were skeptical about the problem of broken rice in hybrids. Moreover, the yield advantage of hybrid rice is not as high in Punjab as in Bihar, mainly because there is no water stress scenarios in Punjab. There is no yield advantage of hybrids against MTU 7029 in Bihar or Pusa 44 in Punjab. Key considerations like seed cost may not matter if the performance of hybrids is better than varieties in any given situation.

The degree of confidence that farmers of Bihar and Haryana have in hybrids provided enough evidence that hybrids now will challenge MDRVs and SDRVs, but not the LDRVs. The continued growth in private sector as evident now is central to yield growth in rice as well as for intensifying cropping systems.

3.6 Premium rice adoption

Small and marginal farmers generate too little profit to pay for daily expenses and risk-taking capacity is low, therefore, they adopt only those technologies which give them guaranteed cash for everyday life. This argument is again supported by data on Rajender Bhagwati, a variety released in Bihar for high quality. The success of BPT 5204 is basically because it does not have a yield penalty for better quality. However, it has not happened with Ragender Bhagwati because the yield penalty is more than the premium for quality. The adoption of this variety did not happen except in few locations near the Pusa campus of DRPCAU, Pusa, Bihar. For the adoption of quality based varieties, there has to be price premium as is happening in basmati rice.

Even for basmati, the focus on yield enhancement is paying dividend with large scale adoption of the newest basmati varieties such as Pusa 1121 and Pusa 1509. Quality attracted attention, but within quality based varieties like basmati rice, the adoption was more for varieties with high yields. Having seen the sustainability with high adoption rates of old long duration varieties like MTU 7029 in EIGP, BPT 5204 in AP, and PUSA 44 in Punjab, the adoptions trends are clearly favour high yield. New research for nutrient-rich high protein or varieties with moderately high levels of zinc should take a clue from BPT 5204 or Pusa 1121.

3.7 Stress tolerant varieties and hybrids

Many farmers in the EIGP are frequently exposed to uncertain and variable monsoons. Nonetheless, data showed very limited adoption of stress-tolerant rice varieties (STRVs) in all the surveyed districts. Trade-offs between high yield and stress tolerance is a complex issue. Most of these varieties provided an edge when the stress happens, but not if the targeted stress does not happen. The question is how to plan for STRVs beyond the abiotic stresses, which is quite common with the district level or village level. The STRVs like Swarna-Sub1 (2.1 % HHs in Chhattisgarh, 0.4 % HHs in Bihar, 0.1 % HHs in eastern UP, 0.6 % HHs in Odisha, and 1.0 % HHs in West Bengal), Sahbhagi dhan (0.1 % HHs in Bihar and 0.1 % HHs in Odisha), were partially adopted in very few districts in stress-prone ecologies. These STRVs released in the last decade do promise better performance, but often under stress conditions only, which may not occur every year in the same location. The coastal districts of Odisha showed a higher adoption of STRVs; 14 % flood prone area adopted the Swarna-Sub1 with an yield advantage of 0.6 t ha^{-1} (Veettil *et al.*, 2020). The first STRVs, namely Swarna-Sub1 was released in 2009 with the flash flood tolerance of up to 14 days, and the second namely Sahbhagi dhan was released in 2010 for drought tolerance (Gregorio *et al.*, 2013; Das *et al.*, 2009, Singh *et al.*, 2009; Ismail *et al.*, 2013). Shanghai dhan produced double grain yield (2.8 t ha^{-1}) than that of the popular rice varieties like Damini, Moti, Sarju 52, and Swarna when faced 15-20 days of total water deficit at the active tillering stage (Dar *et al.*, 2020). Moreover, many areas in rainfed lowlands often experience both flood and drought at different times within the same cropping season. Considering this, both the drought and submergence tolerant genes were recently introgressed into the two popular lowland Sub1 varieties, Swarna-Sub1 and Samba-Sub1, and were released in India as CR dhan 801 and DRR dhan 50, respectively, to enhance and stabilize rice productivity in the areas that are prone to both submergence and drought (Maheshwari *et al.*, 2019).

The State Governments also responded by increasing the seed production of STRVs. Seed distribution was significantly expanded when the National Food Security Mission (NFSM) was implemented from 2010 onwards. This variety (SS1) was well received by farmers and extension agencies. Worries about yield penalty under normal conditions should be weighed against substantial benefits these varieties provide under specific stress conditions (Septiningsih *et al.*, 2009). For instance, the Sub1 varieties failed to exhibit good results if the flash flood duration exceeded 2 weeks or if complete submergence was followed by a partial long term stagnant flooding (Singh *et al.*, 2011). Floods or droughts do not occur every year and are probabilistic in nature, it was hard for farmers to plan the choice of STRV seeds ahead of the season.

Private companies expanded their market share of hybrids by aggressive marketting strategies, including door to door visit and awareness creation, and IT enabled media campaigns. The same is true in drought-tolerant varieties, which are competing with hybrids in specific stress-prone areas. The scale of adoption of hybrids in water stress or drought-like situations is high, with MDHs adopted by 33% HHs and SDHs adopted by only 3% HHs (Table 4). The magnitude of high adoption rates of hybrids in upland and medium land ecologies of Bihar, and Chhattisgarh (the Kanker district) showed potential for hybrids to tolerate moderate

Table 4. Stress tolerant varieties vs. medium and short duration hybrids

Variety	Yield (t ha^{-1})	HHs	% HHS
MDRHs	4.1	2,383	33.4
SDRHs	4.5	208	2.9
Sahabhagi dhan	3.4	4	0.06
Sukha dhan 1	2.3	1	0.01
Sukha dhan 2	1.6	1	0.01
Swarna-Sub 1	3.6	30	0.42

stress without significant yield penalty. The adoption of SS1 in submergence-prone areas is understandable, which is situation-specific, but the low adoption of drought-tolerant varieties reflected their lower yield potential compared to hybrids under moderate water stress conditions. The challenge to scaling STRVs attributes to yield disadvantage compared to the alternative varieties in the localities of same maturirty duration.

The data from some representative upland ecologies in Bihar showed that hybrids have occupied more than 50% area in seven districts. In some districts like Vaishali and Samastipur, farmers are growing only hybrids. The data provided enough evidence to suggest that the spread of hybrids in some states, especially during the last 10 years, is much wider than expected. The relative yield advantage of rice hybrids in irrigated (Virmani *et al.*, 1982; Janaiah and Hossain, 2003) and in a drought-like situation (Villa *et al.*, 2012) is a noteworthy development. The significant development happened in the breeding programs with obtaining the ability to lock in hybrid vigour in respect of plant height, tiller number and grain yield. Hybrid rice varieties due to its heterosis effects increased yield by 15-20% over inbred varieties, grown in similar conditions. The baseline survey conducted by CSISA (Spielman *et al.*, 2013) showed that the interest in the technology remains significant as hybrid rice can be considered as means of boosting stagnant yield growth, improving national food security, raising incomes and as a means of sustainable intensification of production on a smaller area of land. The strong correlation exists between yield and superior alleles in hybrid rice (Xiao *et al.*, 1995; Huang *et al.*, 2015) but not in inbred lines, which could be the important factor for their superior performance under normal and under a light to moderate drought-like situation in these states. Hybrid rice varieties due to the heterosis effects could increase yield by 15-20% over inbred varieties, grown in similar conditions. The baseline survey conducted by CSISA (Spielman *et al.*, 2013) showed that interest in technology remains significant as hybrid rice can be considered as means of boosting stagnant yield growth, improving national food security, raising incomes and as a means of sustainable intensification of production on a smaller area of land.

Farmers in the stress-prone areas have supported hybrids or the existing varieties. When compared to hybrids, the adoption of STRVs has remained hard. The STRVs must be packaged with the same or consistently more yield than the existing varieties both in the years of stress and the normal years.

4. Conclusions

The LDS data covered eight states with wide variation in the natural resource base ranging from assured irrigation to rainfed ecologies with diesel based irrigation. Based on 15,540 data points, farmers in shallow lowland ecologies of Bihar, Eastern UP, Chhattisgarh, West Bengal, Odisha, and to some extent AP, still favour the 37 year old variety MTU 7029. Since release in 1982, its adoption has shifted from AP (9% HHs) to Bihar (27% HHs), Eastern UP (21% HHs), West Bengal (44% HHs), Chhattisgarh (39% HHs), and Odisha (38% HHs). Evidence also showed that preference for quality parameters like fine grain and cooking quality still existed with another 35-year-old variety, BPT 5204, grown by 45, 20, 4, and 3% HHs in AP, Eastern UP, Bihar, and Chhattisgarh farmers, respectively. MDRHs were adopted by 33% HHs in Bihar and 25% HHs in Haryana with corresponding paddy yields of 4.0 t ha^{-1} and 7.0 t ha^{-1} against the paddy yields of 3.8 t ha^{-1} and 6.7 t ha^{-1} from MDRVs, respectively. In Punjab and Haryana, the replacement of new varieties is happening at regular intervals, but this is not happening in other states except AP. In AP, new varieties are being accepted, but more than 55% HHs still grow old varieties dominated by BPT 5204.

Results from this survey revealed the value of having up-to-date (digital) information on the trends of adoption for both production of seeds and placement of seeds by seed companies and parastatals for distribution among farmers. The information and insights can help breeders sharpen their focus on identifying the traits and developing varieties, which can compete with the top performers from old varieties. Another important question is how to increase the yield potential of stress-tolerant varieties, especially in the years when that particular stress (e.g. flood or drought) does not occur at the farm level. Probably, the shorter duration inbreds varieties with multi-stress tolerance can provide some serious challenge to the growing popularity of the hybrids in stress-prone areas in the future.

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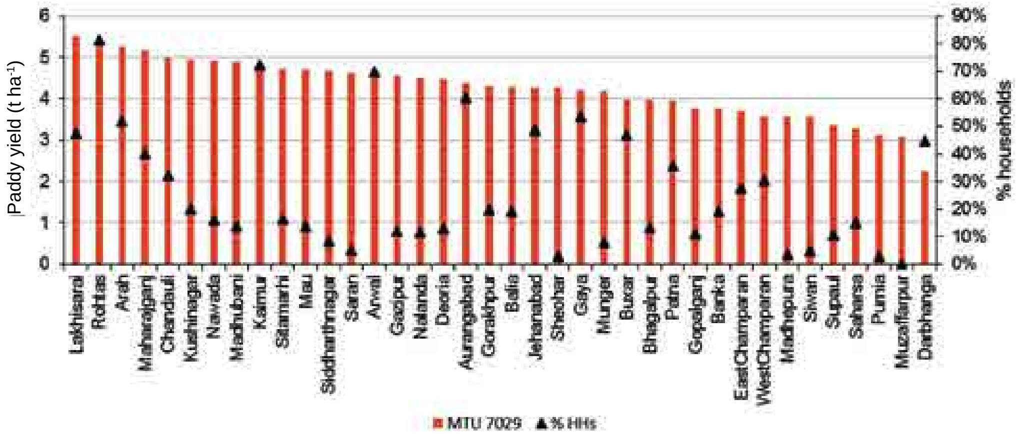

Fig. A1: Performance and adoption rate of MTU 7029 across the surveyed districts in Bihar and EUP

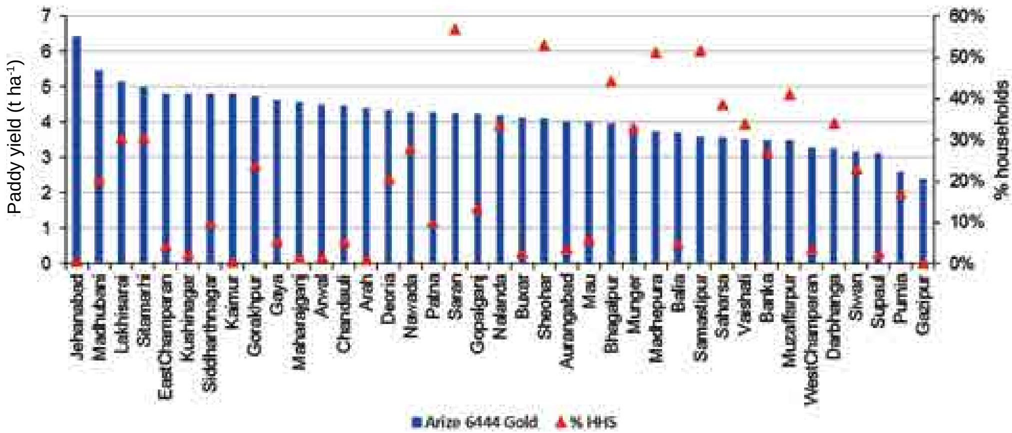

Fig. A2: Performance and adoption rate of Arize 6444 across the surveyed districts in Bihar and EUP

Table A1. Other varieties/hybrids in Bihar, Haryana, Punjab and Uttar Pradesh

Variety/hybrid	Bihar*	Haryana**	Punjab***	Uttar Pradesh****
Binadhan11	1.15 %			
BPT 5204	4.10 %			
Chintu				1.41 %

(contd...)

Table A1 (concluded)

Variety/hybrid	Bihar*	Haryana**	Punjab***	Uttar Pradesh****
CSR 30		1.68 %		
Dhanya 775	1.44 %			
Gorakhnath 509				2.86 %
Jaya	1.18 %			
JK-Dhanyarekha				1.06 %
Moti	0.97 %			
Moti Gold	1.39 %			3.13 %
PAC835		1.20 %		
PHB71	2.39 %			
Pioneer 25P35		3.36 %		
Pioneer 27P31				0.90 %
Pioneer 27P63				1.80 %
PR 114			1.80 %	
PR 118			1.80 %	
PR 121		1.44 %		
PR 122			2.84 %	
PR 124		1.20 %		
PR 127			1.03 %	
Prasanna				1.96 %
Pusa 1121		1.92 %		
Pusa 1509		0.96 %		
Rajendra Shweta	1.48 %			
Sampoorna				2.31 %
Super Moti	1.02 %			

***Bihar-** Loknath 505 (0.74 %), NK 5251 (0.71 %), Pioneer 27P63 (0.64 %), MTU 1001 (0.52 %), Mugdha (0.42 %), Swarna Sub1 (0.42 %), Rajendra Bhagwati (0.39 %), Sonali (0.39 %), Damini (0.36 %), Sita (0.31 %), US 312 (0.31 %), BR 11 (0.29 %), MTU 1001 (0.29 %), Basmati (0.27 %), Kaveri (0.25 %), Rupali (0.25 %), Bhagalpur Katarni (0.24 %), JK 401 (0.24 %), Ankur (0.22 %), Sabour Sampann (0.21 %), Kranti (0.2 %), Janaki (0.17 %), Kanchan (0.17 %), Gutraj (0.15 %), JK-Dhanyarekha (0.15 %), Shri Ram505 (0.15 %), Aghani (0.14 %), Gautam (0.14 %), Supreme Sona (0.14 %), Krishna (0.13 %), ShushkSamrat (0.13 %), Gangotri (0.11 %), Nano (0.11 %), Rajendra Saraswati (0.11 %), Rajendra Suhasini (0.11 %), Ranjit (0.11 %), Chandan (0.08 %), PAC 835 (0.08 %), Sankar (0.08 %), Silky 277 (0.08 %), Sudha (0.08 %), Diamond (0.07 %), Laxmi (0.07 %), Local (0.07 %), Pioneer 27P37 (0.07 %), Sabour Surbhit (0.07 %), Sampada (0.07 %), Tez Arize (0.07 %), Bakoui (0.06 %), Dhaulagiri (0.06 %), Garima (0.06 %), Poonam (0.06 %), Sahabhagi (0.06 %), sonamorda (0.06 %), Unknown (0.06 %), Arize 6129 (0.04 %), Bengal Tiger (0.04 %), BH 21 (0.04 %), Binadhan 10 (0.04 %), BL 4341 (0.04 %), BR 23 (0.04 %), Dhusri (0.04 %), Mahima Gold (0.04 %), Pooja (0.04 %), Prabhat (0.04 %), Prasanna (0.04 %), Rajshree (0.04 %), Bioseed (0.03 %), Iratom 24 (0.03 %), JK

2082 (0.03%), Kamini (0.03%), Komal (0.03%), KP 108 (0.03%), MTU 1010 (0.03%), NHR 31 (0.03%), Pusa Sugandh 5 (0.03%), S 301 (0.03%), Sabour Shri (0.03%), Sampoorna (0.03%), Star Gold (0.03%), Sufala (0.03%), Sujata (0.03%), Vijay (0.03%), Yamuna Gold (0.03%), Aditya (0.01%), Aman (0.01%), Bhasar (0.01%), Binayak (0.01%), BR26 (0.01%), BRRI Dhan 33 (0.01%), Champion (0.01%), Daftari-Omshri 125 (0.01%), Dhanwan (0.01%), Gaurav (0.01%), Gorakhnath 509 (0.01%), Jaishree (0.01%), Jera (0.01%), K 9090 (0.01%), Kala Namak (0.01%), Laxmi gold (0.01%), Maina (0.01%), MP 3030 (0.01%), MTU 7026 (0.01%), NK 6302 (0.01%), Pachpan (0.01%), Pan Ganga (0.01%), Parvati (0.01%), Radha 9 (0.01%), Raghunath (0.01%), Sabitri (0.01%), Sabour Harshit (0.01%), Sabour Shresth (0.01%), Sarwada (0.01%), Sato kanma (0.01%), Sheetal (0.01%), Sukha Dhan 1 (0.01%), Sukha Dhan 2 (0.01%), Swanam (0.01%), Swargadwari (0.01%), Upaj (0.01%), VNR (0.01%)

****Haryana**- HKR 126 (0.72%), Swift Gold (0.72%), Arize 8433 (0.48%), HKR 127 (0.48%), ND 359 (0.48%), PB 1 (0.48%), PR 125 (0.48%), Sava 134 (0.48%), 888 (0.24%), Arize 6129 (0.24%), K 9090 (0.24%), PHB 71 (0.24%), Pioneer 27P31 (0.24%), Pioneer 27P63 (0.24%), PR 122 (0.24%), Pusa 1718 (0.24%), Pusa 44 (0.24%), Rasi (0.24%), RHM 406 (0.24%), Signet Raja 45 (0.24%), Sri Ram 432 (0.24%), Sri Ram 505 (0.24%), Supreme Sona (0.24%), Tata 001 (0.24%)

*****Punjab**- PAU 201 (0.77%), Pusa 1509 (0.77%), Sri Ram 432 (0.77%), 6162 (0.52%), MTU 7029 (0.52%), PR 124 (0.52%), 625 (0.26%), CR 212 (0.26%), JK 2082 (0.26%), PR 134 (0.26%), WGL 915 (0.26%)

******Uttar Pradesh**- Shri Ram 505 (0.82%), Ganesh (0.63%), Super Moti (0.51%), Basmati (0.47%), Sonam (0.39%), JK 2082 (0.35%), Kaveri (0.35%), Arize 6129 (0.31%), JK 401 (0.31%), Komal (0.31%), PHB 71 (0.27%), Diamond (0.16%), Sankar (0.16%), PAC 835 (0.12%), Poonam (0.12%), Sonali (0.12%), Bhagalpur Katarni (0.08%), Dhanwan (0.08%), K9090 (0.08%), Kanak (0.08%), Mahyco-Maheen (0.08%), Radhika (0.08%), Sabour Sampann (0.08%), Shushk Samrat (0.08%), Swarna Sub1 (0.08%), US 382 (0.08%), Ajooba (0.04%), Ankur (0.04%), Arize 6633 (0.04%), Chandan (0.04%), CR Dhan 501 (0.04%), Dhanya 775 (0.04%), Dilkhush (0.04%), Fine rice (0.04%), Godawari (0.04%), Govind bhog (0.04%), Heena (0.04%), Jaya (0.04%), Jera (0.04%), Laxmi (0.04%), Madhuri (0.04%), MTU 1010 (0.04%), Nano (0.04%), NK 6302 (0.04%), NPH 909 (0.04%), Parsana (0.04%), Pusa Basmati (0.04%), Pusa Sugandh 5 (0.04%), Rajendra Shweta (0.04%), Rukmani (0.04%), Sabour Samriddhi (0.04%), Sampada (0.04%), Samriddhi 555 (0.04%), Supreme Sona (0.04%), Tahalaka (0.04%), US 312 (0.04%), Vedaplus (0.04%), Yamuna Gold (0.04%)

Table A2. Other varieties/hybrids in Andhra Pradesh, Chhattisgarh, Odisha, and West Bengal

Variety/hybrid	Chhattisgarh^	Odisha^^	West Bengal^^^	Andhra Pradesh^^^^
Swarna Sub-1	2.1%			
Balwan	2.0%			
HMT	0.9%			
VNR 2228	0.6%			
MTU 1009		1.3%		
Deradun		1.2%		
Lalat		0.9%		
Barsha		0.8%		
MTU 1010		0.8%		
Pradhan Dhan		0.8%		
Bankei		0.8%		
Niranjan		0.6%		

(contd...)

Variety/hybrid	Chhattisgarh^	Odisha^^	West Bengal^^^	Andhra Pradesh^^^^
Raspanjar		0.6%		
Swarna Sub-1		0.6%		
Balibhajana		0.6%		
Sabita Patnai			2.5%	
IR 64			1.8%	
Super Shyamali			1.4%	
Jamuna			1.3%	
MTU 1001			1.3%	
Bangabandhu			1.2%	
1000 BB			1.0%	
Ranjana			1.0%	
Nilanjana			1.0%	
MTU 1075				2.5%
MTU 1010				2.3%
BPT 3291				2.0%
RNR 15048				1.8%
NLR 9674				1.5%
BPT 2231				1.2%
NDLR-8				0.8%
BPT 2270				0.6%

^**Chhattisgarh** - MTU 1001 (0.59%), IR 36 (0.40%), MTU 1075 (0.40%), Durgeswari (0.40%), Hira gold (0.40%), Kirtiman (0.40%), Arize 6129 (0.20%), Chandan (0.20%), Kolam 101 (0.20%), Nirmal (0.20%) and Amit (0.20%).

^^**Odisha** – Khandagiri (0.60%), Malabati (0.59%), Naveen (0.59%), Udaygiri (0.55%), Bakuri (0.35%), Kalabali (0.35%), Kaveri (0.35%), PusaSugandh5 (0.28%), Gayatri (0.21%), Moti (0.21%), Gadichampa (0.14%), Gitanjali (0.14%), HMT (0.14%), RajendraMahsuri1 (0.14%), Sonam (0.14%), Arize 6444 (0.07%), Baisnabi (0.07%), BH 21 (0.07%), Bhuban (0.07%), Biswajeet (0.07%), Champeswar (0.07%), CR 1014 (0.07%), Dharitri (0.07%), Lalchampa (0.07%), Lalita (0.07%), Laxmi (0.07%), Manoj (0.07%), Parijat (0.07%), Prasanna (0.07%), Pratiksha (0.07%), Sahbhagi (0.07%), Saktiman (0.07%), Sampada (0.07%), Sindhu (0.07%) and Sundarbhajana (0.07%)

^^^**West Bengal** - SwarnaSub1 (0.95%), Jaya (0.83%), MTU 1010 (0.82%), Dhanraj (0.7%), Nayanmoni (0.7%), BR-11 (0.6%), Ranjit (0.47%), Gitanjali (0.36%), Madhuri (0.36%), CR Pankaj (0.24%), Pooja (0.24%), Rajlakshmi (0.24%), Uttam (0.24%), Sonali (0.24%), Ankur (0.12%), Arize6129 (0.12%), BhagalpurKatarni (0.12%), BR 23 (0.12%), Jamuna (0.12%), Khandagiri (0.12%), Pollishree (0.12%), Prathik (0.12%), Satabdi (0.12%), Saurav (0.12%) and Sujala (0.09%)

^^^^**Andhra Pradesh** - Sreeram gold (0.55%), MTU 1121 (0.37%), Sampath (0.31%), MTU 1156 (0.31%), MTU 2077 (0.24%), MTU 1140 (0.18%), Jaya (0.18%), Apoorva (0.12%), MTU 2067 (0.12%), Krishna (0.12%), MTU 1224 (0.12%), NLR 28523 (0.12%), Kaveri Sona (0.11%), Sadhana (0.06%), MTU 1166 (0.06%), MTU 1229 (0.06%), Omkar (0.06%), Pooja (0.06%), Vijaya (0.06%) and NLR 145 (0.06%)

2.2 Nutrient management in rice challenges on different use rates and ratios across states in India

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KEY MESSAGES

- While generating recommendations on nutrients, the long-term soil quality is very important, but greater emphasis must also be put on maximizing – yield, use efficiency of externally added nutrients and balance between soil quality and improved profit margins of farmers.
- The ratios of NPK in rice are distorted across states. Some states though have even maintained recommended NPK ratio, yet have not attained higher yields, therefore, ending with low partial factor productivity (PFP). The PFP has remained high with nutrient management dominated by N application in Punjab (46.7 kg/kg NPK) and Haryana (38.7 kg/kg NPK). On the contrary, the average PFP of Punjab was 47% more than Andhra Pradesh (AP) and that of Odisha 33% more than AP. The low PFP in AP was because of high NPK rates without any proportionate increase in yield.
- Out of 16,161 respondents only 0.3. 0.5, 0.52, 0.79, 1.2, 1.42, 7.24% and 7.84% HHs in Bihar, Odisha, Punjab, West Bengal, Haryana, Eastern Uttar Pradesh (EUP), Chhattisgarh and AP used soil health card (SHCs) for applying NPK, respectively.

- Soil test values are the drivers of changes in the recommendations, however, the agronomic management, which brings about these changes is not a part of nutrient management models. The agronomic management is the foundation and should be made an integral part of nutrient management. Data on nutrient management showed that in the Eastern States, the legacy issues on crop management should be resolved, and focus be on expanding the work on agronomic management – especially irrigation, weed management and mechanization–, and integrate these with nutrient management.
- In Punjab, paddy yields are increasing for almost 50 years with no addition of P and K. This progression and the survey hinted that perhaps issues like NPK ratio need to be resolved for creating a platform for improved nutrient management and optimization of cropping systems in the Eastern States. Advantages of scale accrued by SHCs are not visible. More time is to be spent on working with farmers and create trust in them.

1.0 Introduction

Cultivation of rice, the staple food of India, consists mostly of monsoon-rain dependent ecologies and also includes regions of assured irrigation. At the first stage of Green Revolution (GR), all regions shared interest in increasing productivity of rice with a focus on new varieties, fertilizer use and creation of irrigation infrastructure. To achieve higher yields, the GR era varieties required adequate amount of externally added essential crop nutrients. With the result, the fertilizer uses in Asian countries increased markedly in the last few decades. In India, the NPK use is lesser than many Asian countries and the variations among Indian states are still very large. The problem is much more severe in the frontline GR states of Punjab, Haryana, and Andhra Pradesh, where NPK use is 200 kg/ ha to 264 $kgha^{-1}$ compared with very low rates in Odisha. Scientists from the beginning, have used soil test values for generating recommendations. It is tried and tested option for long but still widespread use is not happening. It is still far away from integrated- and balanced- nutrient management even after a massive investment in soil health card (SHC) based recommendations. There is a lot of variation among states and within states with some states use high nitrogen application, some are nearing recommendation of well-balanced NPK ratios, while few others use high rates of phosphorus and potash. Variation in the paddy yield across states is very high even when the fertilizer application rates are more than the state recommendations, which showed that the farmers' decision-making process, however, is not merely driven by the soil test values but by a whole set of factors cutting across the agronomic management, socio-economic and profit margins. This whole situation brings out the question that how to bring changes in nutrient management according to real farm situations.

The nutrient management practices in rice depend both on – crop demand and to replenish soil fertility levels. Research results showed that despite the use of best variety and full recommended dose of NPK, farmers are not able to bridge the yield gaps in rice. The expected yield increases due to varieties and nutrient management do not really add up; that needs integration of soil test values and crop responses with all other variables that affect growth and development of crop.

All recommendations for nutrient management are made by the State Agricultural Universities (SAUs). In all states, recommendations are based on commodity crops with limited or no variation for different cropping systems, soil types, and other management options. There was not much effort to tailor the nutrients needs depending on local conditions. However, states are not fully independent of Central Government for fertilizer related policy interventions. Overall, most nutrient management solutions are based on top-down solutions with little feed-back loop from farmers. The understanding of the response of farmers is more important than recommendation itself. It is hard to decipher that whether the driving force behind adoption of different NPK ratios is soil quality or the desire of farmers to get higher yields. The focus of top-down approach is to find solutions within the nutrient management without looking at the factors affecting performance of added nutrients. In fact, it is undermining the real goal of integrated nutrient management (INM) itself in different cropping systems. There are pioneers in generating INM recommendations across states to meet the future needs of soil quality. The recommendation on INM based solutions needs very long-term studies, which are already in place but a feed-back mechanism from the stakeholders including farmers is not happening. In the present study a feed-back mechanism was discussed by conducting landscape diagnostic survey (LDS) across eight states of India.

The LDS was conducted to (i) evaluate NPK use rates within and between states; (ii) look at the scope of reducing NPK rates under sub-optimal crop management practices; and (iii) share nutrient management adoption by farmers with research institutes including SAUs and the DoA to introduce possible changes in policies and priorities.

2.0 Methodology

The survey was conducted in eight states of India representing North-western states (Punjab and Haryana), Eastern states (Eastern Uttar Pradesh, Bihar, West Bengal, Chhattisgarh, and Odisha) and Southern state (Andhra Pradesh). To understand how farmers are applying fertilizer and organic manures, CSISA-KVKs network interviewed farmers based on the complete randomization process for the selection of farmers in each village. The team selected 30 villages in each district and organised these interviews with seven households (HHs) per village to collect data on the fertilizer use pattern and other production practices adopted by them. The nutrient use patterns, based on the above randomization process, were analysed for each surveyed district. The adoption of nutrient management recommendations represents actual field situation and highlights fairly accurate use rates and adoption rates by surveyed HHs. Since HHs were selected at random, the data so generated are reflective of views of farmers in the district in terms of farm size, education and other social background. The surveyed districts in Punjab, Haryana, EUP and Bihar are dominated by rice-wheat cropping system (RWCS). In other states the study area is dominated by rice-fallow or rice-rice in Odisha and Chhattisgarh while rice-rice, rice-pulses, or rice-rice- pulses are the dominant cropping systems in Andhra Pradesh. In most surveyed states, farmers are growing long duration rice varieties (LDRVs), medium duration rice hybrids/varieties (MDRVs/ MDRHs) and short duration hybrids/varieties (SDRHs/SDRVs) in that order. The NPK status across surveyed states was mapped (Figs. 1-3).

The status of NPK was taken from two sites including– www.krishi.bih.nic.in https://www.soilhealth.dac.gov.in/PublicReports/ComparativereportPercentageGraph; and https://farmer.gov.in/soilfertilitymaps.aspx. The data on the recommendations of NPK for different states (Table 1) were picked up from different sources (Anonymous, 2020; Patra and Das, 2019; Kaushik, 2019). The surveyed areas in Punjab, Haryana and AP were irrigated. Most Eastern states were overlapped with limited irrigation or no irrigation. Press information bureau (PIB), Government of

Table 1. Recommendations of nutrient management in different states

State	NPK recommendations (kgha-^{1})		
	N	P	K
Andhra Pradesh[a]	85	60	50
Bihar[b]	100	40	20
Chhattisgarh	100	60	40
Haryana [c]	150	60	60
Odisha	80	40	40
Punjab	105	30	30
Uttar Pradesh	150	60	60
West Bengal	80	40	40

[a]Scarce rainfall zone (Kurnool and Anantapur) NPK recommendation is 240, 80, 80 kg/ ha
[b]NPK recommendation for early maturing varieties is 80, 40, 20 kgha-^{1} in Bihar
[c]NPK recommendation for basmati varieties is less than other varieties

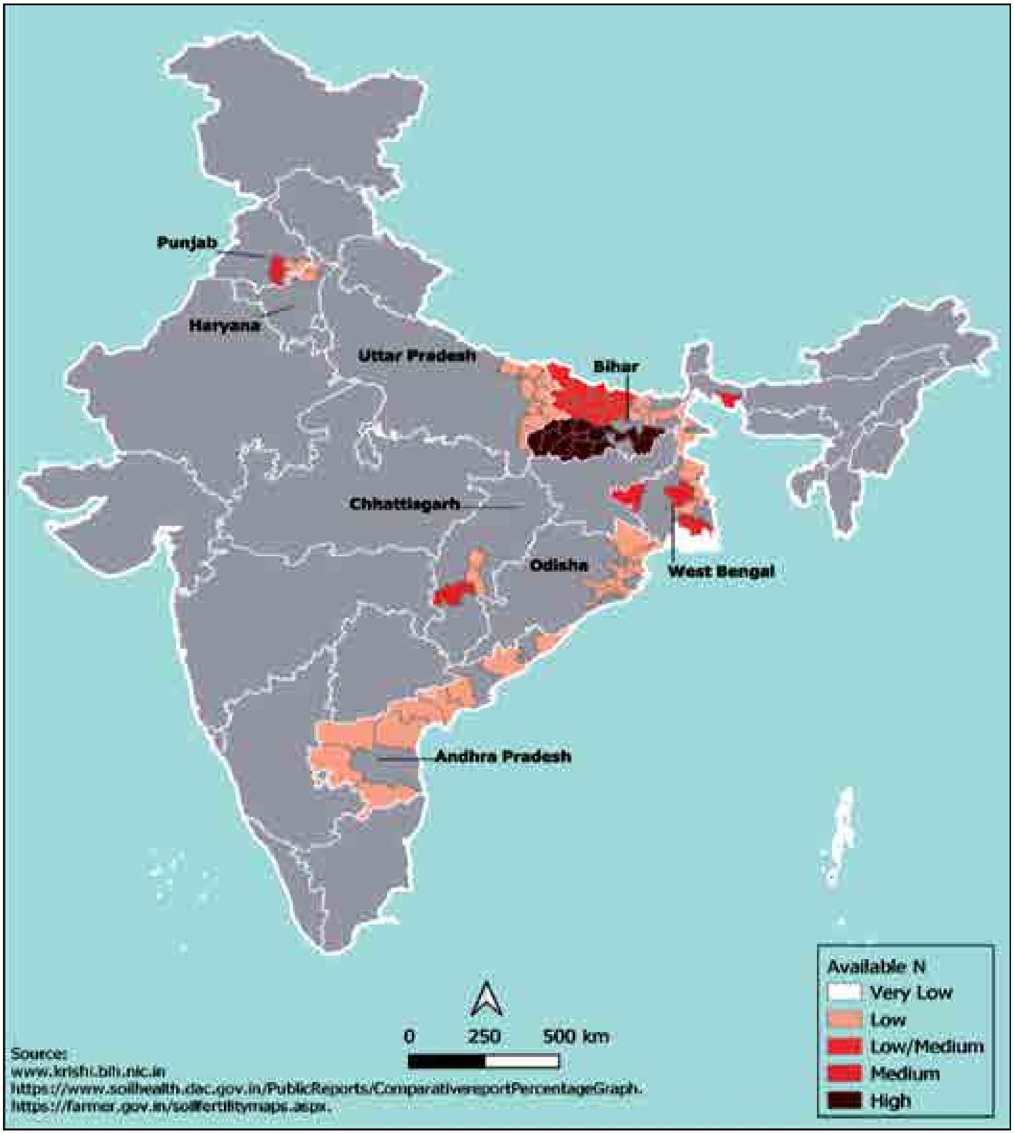

Fig. 1. Status of available nitrogen in surveyed districts across eight states in India

India 2019 (https://pib.gov.in/newsite/PrintRelease.aspx?relid=188051) was used as a criteria for categorization of farmers. It includes marginal below 1 ha, small 1-2 ha, semi medium 2-4 ha, medium 4-10 ha and large 10 ha and above. Total operational land holdings of surveyed HHs were considered. The average land holding size of farmers based on PIB in eight states varied between 0.4 and 3.62 ha–Bihar (0.4 ha),

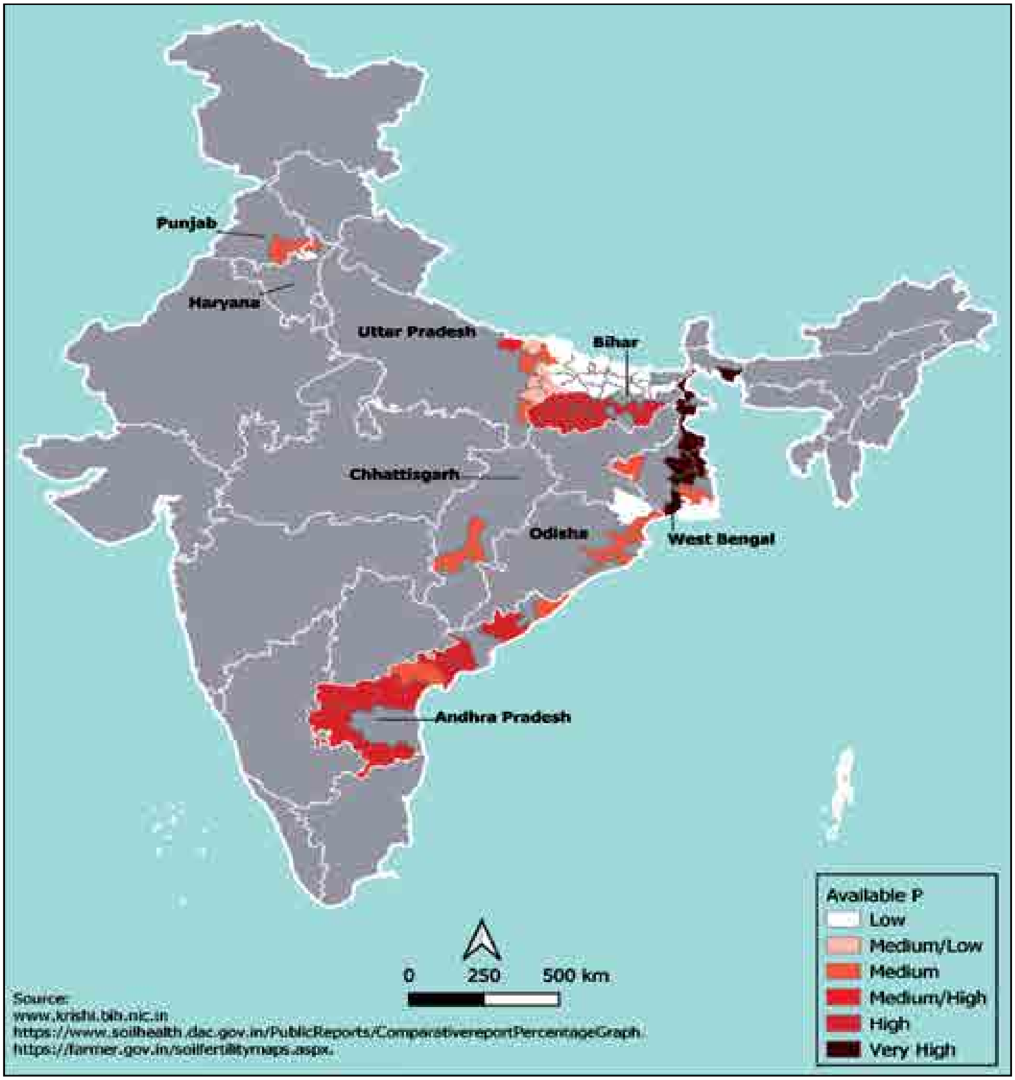

Fig. 2. Status of available phosphorus in surveyed districts across eight states in India

UP (0.7 ha), Haryana (2.2 ha), Punjab (3.62), Odisha (1.0 ha), West Bengal (0.8 ha), AP (0.9 ha), and Chhattisgarh (1.25 ha).

The structured questions on production practices ranged from seed to harvest and marketing of the produce. Assessing the farmers' response on how they are using fertilizer is crucial to understand the use pattern of NPK. Data analytics can help modelling the NPK use patterns in different states and in different districts within states.

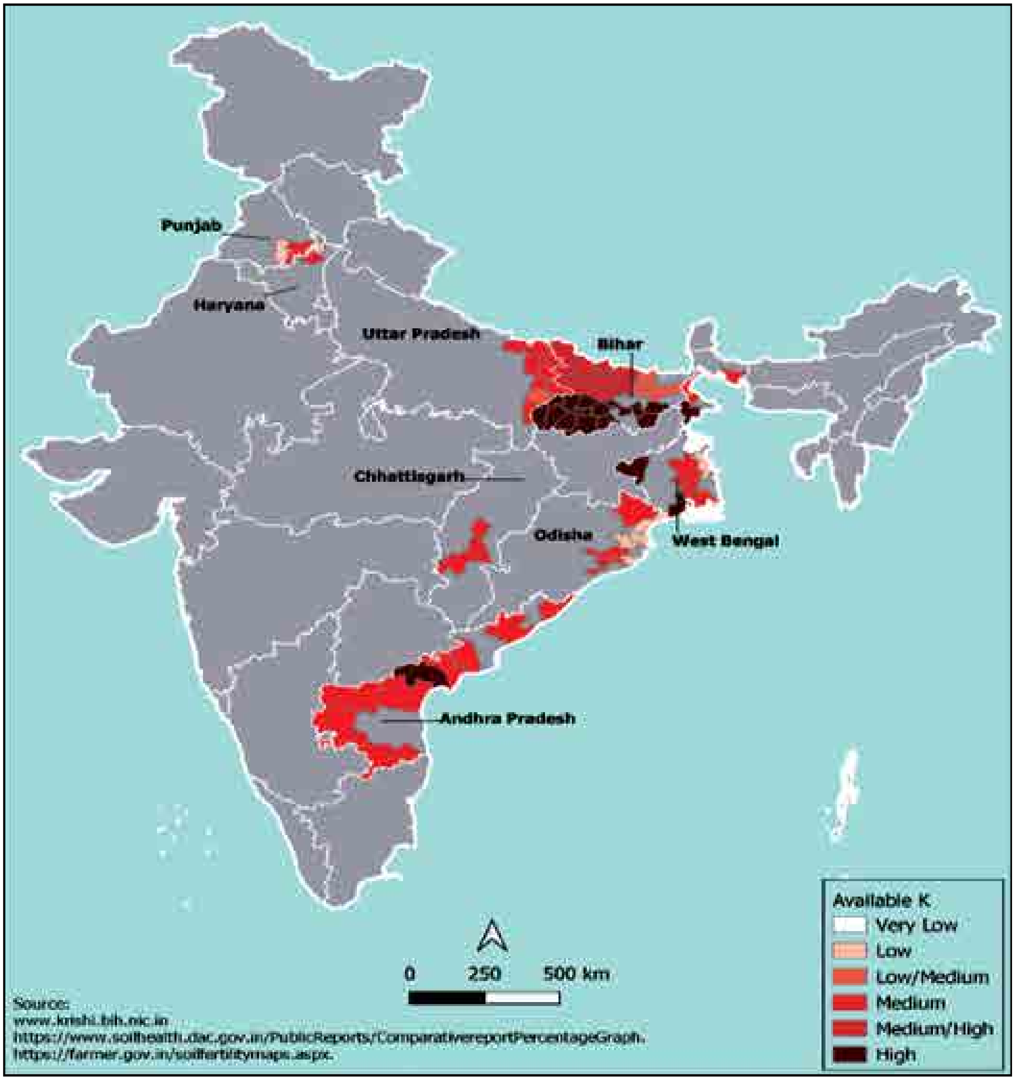

Fig. 3. Status of available potash in surveyed districts across eight states in India

The next step was to extend the use of other production practices and soil test values to determine the dose of each element in the crop as part of site-specific recommendation. The knowledge gained from this survey will help setting priorities for an INM relevant to local conditions. The results of this survey represented most variations in ecologies and cropping systems across states. It also represented regions with assured irrigation, which add to the effect of nutrients, and the regions where variable monsoon added to the cause of poor responses to provided inputs.

The results were sent to IASRI server where data could be crunched for different set of analytics. The stakeholders in the SAUs, ICAR Institutes, KVKs at district level and the DoA can use data-based evidence from such a KVKs portal managed by IASRI.

3.0 Results and Discussion

3.1 Nitrogen use rates roughly aligned with paddy yield

The contrasting use pattern of nitrogen (N) between states and within states emerged from the survey. Presumably, it could be correct if it was applied based on soil test values. In some states high N use rate matched the yield levels but, in many cases, yield levels were too low to match the N rates. The surveyed districts from Andhra Pradesh including, Krishna, Chittoor, Visakhapatnam, Prakasam, and Guntur (Fig. 4) used 147, 159, 153,182 and 164 kg N/ha. The average N use rate of user HHs in AP was 137 kgha^{-1} and that the overall use rate of all HHs was 132 kgha^{-1}.

In Haryana (Fig. 5), the N use was 145 (Ambala) and 147 kgha^{-1} (Kurukshetra) and in Punjab 155 kgha^{-1} in Sangrur and 177 kgha^{-1} in Patiala (Fig. 5). The average use rates in Haryana and Punjab were 147 and 165 kgha^{-1}, respectively (Fig. 4).

In Haryana, the respective average yield levels were 7.0 (Ambala) and 6.3 t ha^{-1} (Kurukshetra), which are matching the N rates. The Kurukshetra district grows more

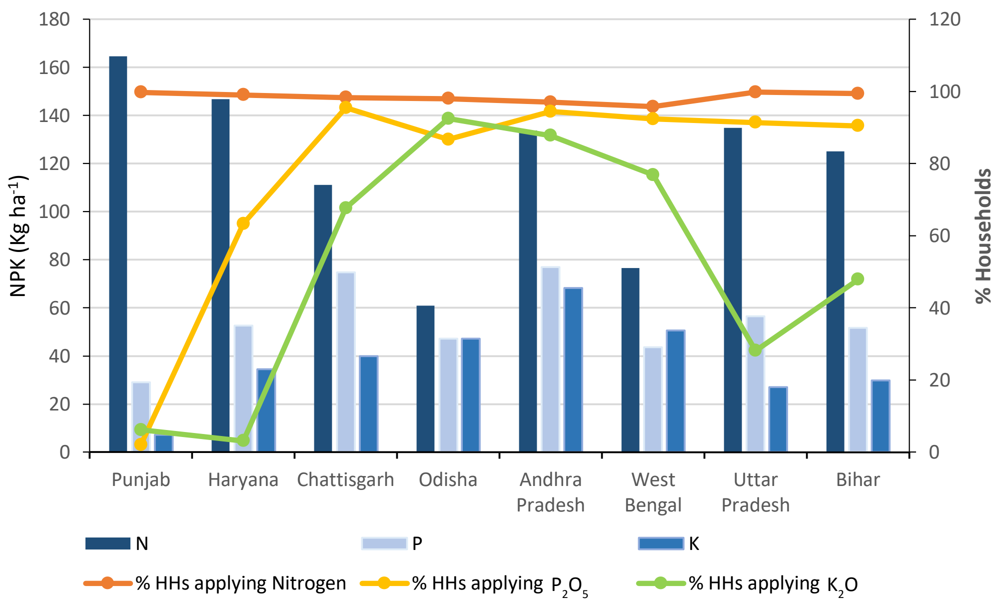

Fig. 4. Various NPK doses and percent household using NPK across eight states (n=16,161)

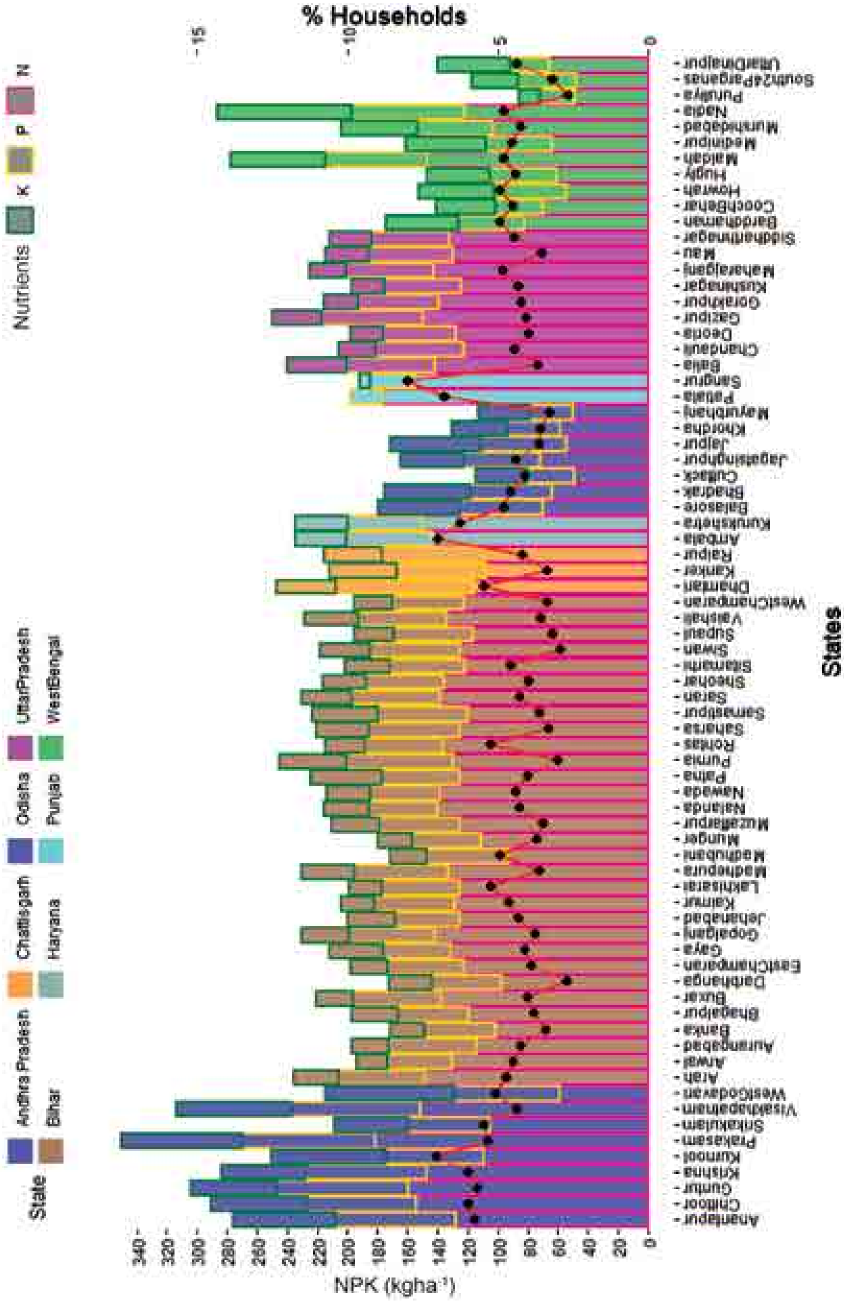

Fig. 5. Effect of various doses of NPK used by household on the paddy yield across surveyed districts of Andhra Pradesh (n=1,647), Bihar (n=7,141), Chhattisgarh (n=773), Haryana (n=417), Odisha (n=1,207), Punjab (n=388), West Bengal (n=2,035), and Uttar Pradesh (n=2,553)

basmati varieties, which are low yielders and Ambala grows more hybrids, which are relatively high yielders than basmati varieties. The district Sangrur had an average paddy yield of 8.0 t ha^{-1} and Patiala 6.8 t ha^{-1}. It can also be due to frequent use of Pusa 44 - a high yielding LDRV in Sangrur. Nitrogen (N) is one of the main factors affecting rice yield and these use rates are much less than that in China, where the national average was 300 $kgha^{-1}$ in 2006. Like China (Zhang *et al.*, 2000), low N fertilizer prices have further increased N inputs. Some measures like adjusting the N rate based on chlorophyll readings (Hu *et al.*, 2007) were unsuccessful in India (Shukla *et al.*, 2004). These results suggested that AP also has boosted its rice productivity with high N rates but with more investment in P and K (Fig. 4). Despite high cost of P and K, their use rate in AP is highest among the surveyed states. The farmers in Haryana had been using same rates of P and K since last survey done in 2007-08 (Singh *et al.*, 2010). Punjab farmers are not using P because they are using it in the preceding wheat crop. The increased P use in AP did not reflect available P levels, which were more than Punjab and Haryana. The build-up in available phosphorus was reported in districts Chittoor, AP (Govardhan *et al.*, 2017) and Amritsar, Punjab (Sharma *et al.*, 2007).

These use patterns seemed to be a deviation from soil test figures (Fig. 2). Establishing these trends of P is difficult in Punjab and Haryana even if the available P levels are in the medium range in three surveyed districts and low in one district (Fig. 2). Poor response of rice to P and K may override the recommendations. In rice (*Oryza sativa* L.)-rapeseed (*Brassica napus* L.) rotation, the rice yield increased 19-41% and such yield responses were ranked as NPK>NP>NK>PK, illustrating that N deficiency was the most limiting condition in a rice-rapeseed rotation, followed by P and K deficiencies (Yousaf *et al.*, 2017). In AP, the pulses in rotation, where P requirement may be more, could have encouraged more P use in rice. In this study, P and K accumulation was greater in NPK treated sites than that in PK treated sites, which clearly indicated the synergistic effect of N on P and K uptake. The data from Punjab and Haryana showed that residual P and K uptake from soil might be greater with higher levels of N. In all three cases, the N deficiency was the most limiting condition for crop yields followed by P and K (Wang *et al.*, 2012) deficiencies.

The use of high N rates might sound like an opportunity to increase rice yield at low investment. But poor management and access to low cost irrigation can change this equation like what happens in different districts of Bihar and EUP (Fig. 5). A comprehensive picture of relatively low yields at better NPK rates in EUP and Bihar has emerged.

Farmers in Punjab with preference for N (Punjab) over P and K also have better agronomic management (sowing date, irrigation, weed management) than farmers in Bihar and EUP with additional support for P and K. Such agronomic factors, in general, improve the efficiency of nutrients,e.g., there might be no shortening of crop development duration due to transplanting done in June in Punjab (Lobell and Gourdji, 2012). In addition to frequently delayed transplanting-based effects, weed competition, and the stress induced by inappropriate field management (Waddington *et al.*, 2010) may not allow the realization of benefits of high NPK application in these two states (Bihar and EUP).

In Bihar, the evidence showed that the rice crop seemed less responsive to added nitrogen compared to Punjab, Haryana and AP. In Ara, Vaishali, Buxar, Gaya, Arwal, Saran, Gopalganj, Sheohar, Nawada, Madhepura, Rohtas, and Nalanda districts, respective, N rates at 147, 133, 137, 132, 130, 138, 147, 136, 138, 132, 136, and 139 kgha-^{1} provided an average yield of 4.7, 3.6, 4.0, 4.1, 4.5, 4.3, 3.8, 4.0, 4.4, 3.6, 5.3 and 4.3 t ha^{-1} (Fig. 5). Farmers in these districts apparently did not adjust their N use rates with the paddy yields as has happened in Punjab and Haryana.

Whatever may be the long term consequences, the survey reflects good economics for farmers in Punjab and Haryana than for farmers of EUP and Bihar. The farmers in EUP and Bihar with much better natural resources and much better-balanced use of NPK lag behind farmers of Punjab and Haryana in paddy yield. It appeared that good agronomic management is adding more to the effect of applied fertilizer in Punjab than that in Bihar or EUP.

In Eastern Utter Pradesh, the N dose exceeding 130 kgha-^{1} in Ballia (143 kgha-^{1}), Gorakhpur (139 kgha-^{1}), Gazipur (150 kgha-^{1}), Siddharthnagar (133 kgha-^{1}) and Maharajganj (142 kgha-^{1}) provided an average paddy yield ranging from 4.1 t ha^{-1} in Gazipur to 4.8 t ha^{-1} in Maharajganj district. The trend indicated that N use is getting quite close to places like Haryana, but the paddy yields are not matching in the same proportion even if small percentage of farmers are growing basmati rice, traditionally low yielding varieties in Haryana (Fig. 5). Even the highest yield level of 4.8 t ha^{-1} at 142 kg N/ha is no match to the 7.0 t ha^{-1} in Ambala district of Haryana.

Most surveyed farmers from three districts of Chhattisgarh including Raipur, Dhamtari, and Kanker reported similar N use rates in the range of 110 to 116 kg / ha. But the yield gaps between Raipur (4.2 t ha^{-1}) and Kanker (3.4 t ha^{-1}) were wider and still wider when compared with Dhamtari at 5.5 t ha^{-1} with an average N rate at 116 kgha-^{1} (Fig. 5). Among these districts, Kanker is more exposed to vulnerability of variable monsoon especially water stress during the active growth of rice. The differences within state again raises the question of developing synergies between agronomic interventions and nutrient management.

Except for Malda, the N use is less in West Bengal than that in most other states except Odisha. The use of N is highest in Malda district at 157 kgha^{-1} compared to 83, 54, 104, 74, 122, 74, 62, 65, 48 and 72 kgha^{-1} in Bardhman, Howrah, Murshidabad, Nadia, Purulia, Hooghly, Uttar Dinajpur, South 24 Pagana, and Cooch Behar, respectively. In high use N districts (104-157 kgha^{-1}), the paddy yields were in a range of 5.5 t ha^{-1} in Medinipur district and 2.6 t ha^{-1} in Purulia district (Fig. 5). Here again the question of using N as per crop response or soil test recommendation is not resolved. Earlier also the use rates in nitrogen (N) increased from 21.84 kg in 1980-81 to 80.66 kg in 2010-11 (Datta *et al.*, 2015). With much better soil test facilities now than that in the past, the research and extension agencies need to develop a consensus within West Bengal.

The management of NPK in Odisha is different as farmers are using more P and K without intensifying the rice-fallow cropping system. Odisha soils are low in nitrogen, medium in phosphorus and low to medium in potash (Figs. 1-3). There is unusual strength in the form of more use of FYM and less use of N in Odisha. With more use of P and K, there is scope of stimulating the crop growth by using more N, which is much lower than that in other states (Fig. 4). Nutrient management plays a large role in helping optimize crop response to inputs (Bruulsema *et al.*, 2009) and should be included as a component of the overall cropping system management plan in Odisha.

3.2. Farmers are more selective about phosphorus use in rice

Since independence, the Government of India (GoI) has been regulating the sale, price, and quality of fertilizers. The GoI declared fertilizers as an essential commodity, and issued the Fertilizer Control Order (FCO) under the Essential Commodities Act, 1957. The GoI introduced subsidy schemes including N fertilizer subsidy in 1977, which later also included P and K; and also decontrolled all phosphatic and potassic (P and K) fertilizers namely DAP, MOP, NPK complex fertilizers, and SSP (Single Super Phosphate) in 1992. This increased the prices of P and K. With this, the use of P and K got reduced and that of N increased. During 1997-98, difference in the delivered price of fertilizers at the farm gate and the MRP was compensated by the Government as a subsidy to the manufacturers/importers. The GoI introduced the Nutrient Based Subsidy (NBS) Policy with effect from 2010, for P and K fertilizers (MOP, DAP, etc.). Despite so many positive steps, the use pattern of NPK remained same in Punjab and Haryana. The use pattern of P has increased in more states, and K has increased only in few states.

The use of phosphorus is popular in AP with application rate ranging from 56 kgha^{-1} in Srikakulam to 101 kgha^{-1} in Guntur. Most farmers (90 to 99%) use P in AP (Fig. 5). More use of P in AP can be, to some extent, ascribed to the adoption of rice -pulses rotation by more farmers in this state. According to current survey, which interviewed 16,166 HHs, the P use is trending towards an increase in 6 out of 8 states. That can be seen from the contrasting situation in Punjab where farmers do not use P in rice. The earlier studies indicated that continued use of inadequate P application would worsen P deficiency (Saleque *et al.*, 2006). Kolar and Grewal (1989) reported that the residual effect of P on the subsequent rice crop is inferior to direct application. Dobermann *et al.* (1996) suggested that a rice crop depleted about 7-8 kg /ha when P fertilizer was not used. Most of these studies and other reports suggested that P applied to any one crop in rotation contributes to the available P pool to the succeeding crop. With progressively high yields since GR, data showed a cut in P use in Punjab as against an increasing focus on P use in other states.

Strategies that only aim at increasing P application rates without considering the indigenous supply from soil reserves are inefficient; they may not sustain yield increases to meet rice demand (Dobermann *et al.*, 1998). The P is used in three districts of Chhattisgarh by almost all farmers (99 -100 %) in a range of 57 to 94 kgha-^{1}. In West Bengal, the use rate ranges from 26 kg in Uttar Dinajpur to 72 kgha-^{1} in Malda. Here also most farmers (86 to 96 %) use P in rice. In Odisha, the use rate of P is from 22 kgha-^{1} to 56 kgha-^{1} and is used by 93 to 98 % farmers in 8 surveyed districts. In Odisha, it is expected because P in Odisha soils is in low to medium range (Fig. 2). The survey of HHs in Punjab found something different – almost no use of P in Patiala (0.56 % HHs) and small percentage of HHs (3.3 %) in Sangrur with top 10 % farmers harvesting an average paddy yield of 8.9 t ha^{-1}. The average P rate of even these small number of users is in a range of 21 to 30 kgha-^{1}. The general practice is to apply P to wheat and raise rice on residual P fertility (Rajendera Prasad, 2007). In that case the high N use in these states is justified because it may enhance the P uptake from the residual P in soil. In other words, P accumulated soil had the ability to provide enough P to satisfy the rice requirement according to the nitrogen availability (Doberman *et al.*, 1996; Nagumo *et al.*, 2013); but this appeared happening in Punjab but not in Bihar and Eastern UP. The removal of nutrients such as P with harvested rice grain and straw increased markedly with the greater yields in the new systems. This trend is contrary to the arguments in 1980s. An issue is whether current P management strategies are enough to support yields near 8 to 10 t ha^{-1} (Tandon and Sekhon, 1988; Mohanty and Mandal, 1989). In Haryana, use of P is less (72-77 % HHs) than most other states. These users apply P in a range of 44 to 49 kgha-^{1}. In Punjab and Haryana farmers are applying P in wheat in rice-wheat cropping system (RWCS), and flooding of fields with irrigation water may increase its supply to rice crop. Since the yield response to P mainly depends on the effective P supply from the soil, its enough quantity might have remained available for rice crop in rotation. If the use of P has fallen out of favour in Punjab, partly because of its full use in wheat, then why 70 % plus farmers are using P in rice in Haryana with same ecology and with recommended dose in wheat. Assuming Punjab farmers are correct, scientists in Haryana may have to revisit the recommendation on P application. Flooding a dry soil initially increases the P concentration in soil solution because of reduction of Fe (III) compounds that liberate adsorbed and co-precipitated P. It was generally thought that the availability of soil P was higher under flooded conditions than that under upland conditions on the same soil (De Datta, 1983; Diamond, 1985). The comparison of results from Punjab on one hand and on the other hand the results of Bihar and EUP brought forward the question why even with much better NPK use scenario, the average paddy yield is almost half to that of Punjab. Like irrigation, the high cost of P may have raised the problem in Bihar where most farmers are small and marginal, but P is used by 98 -100 % HHs. High cost of P is one-time event, but irrigation must be applied frequently. The use rates of P in Bihar are in the range of 43 $kgha^{-1}$ in Arwal district to 63 kg /ha in Madhepura district. Such use rates may be genuine as these are based on the recommendation of the state, which is less than these rates. Similarly, the P use in EUP district is pervasive (100 %) and it ranged from 49 to 66 $kgha^{-1}$. This is one part of argument because this survey did not consider the soil test data, which may show some long-term gains in term of soil enrichment with P.

More complete nutrient balance studies are required to verify such varied use of P across states. Incorporating the rice stubble into the soil or on the surface may return most of P and K. Burning straw causes P losses of about 25 %, and K losses of 20 % (Ponnamperuma, 1984). The requirement is of a precise and evidence-based recommendation on phosphorus management in rice, which is tailored to a cropping system approach rather than a commodity-based approach as is the situation now.

3.3 Potash use not as pervasive as expected

This survey took a broad-based approach with random survey across each district in eight states, and found some striking results on use pattern of potash in rice. Data showed that farmers in AP use the highest amount of K and farmers in Punjab and Haryana use the lowest amount of K (Fig. 4). Farmers' decision to use K is influenced by the crop response they get from the addition of K, which depends on the availability of K in the soil. Except in Ambala district of Haryana where available K is low, the available K in the surveyed districts of these three states is medium to high. Farmers in these ecologies did not increase their K application even after such high paddy yield for such a long time. That means there is no long-term decline in K level in these soils. Part of long-run decline in K levels in high K soil can be explained from the fact that such trends of limited K use were reported from the survey conducted in early 2007-08 (Singh *et al.*, 2010) from Haryana. The dose (50 to 84 $kgha^{-1}$) and the frequency (77 to 97% HHs) of K use among all surveyed states is the highest in AP. The frequency of K use in Odisha is high with 81 to 98% HHs using K but the use rates are slightly less than that in AP at 34 $kgha^{-1}$ in Mayurbhanj to 62 $kgha^{-1}$ in Jaipur district. The use rates in these two states might be affected, to a large extent, on K status in the soil.

The frequency of K use in Bihar showed a large variation from 10% HHs in Arah district to 96% HHs in Madhepura district. The use rate by those HHs who are using K varied from 20 to 44 kg /ha across all surveyed districts of Bihar. In EUP, the frequency of K use ranged from 10-11% in Ghazipur and Chandauli district to as high as 62% HHs in Kushinagar district. In Chhattisgarh also the use of K was less attractive with 30 to 35% HHs not using potash and the use rate of those who applied K ranged from 34 in Raipur district to 48 $kgha^{-1}$ in Kanker district. Except for Hooghli and Nadia district of West Bengal, the use rate of K and its dose was quite comparable to AP and Odisha.

Based on the response from farmers, K was not found central to nutrient management in rice to a large extent in Punjab and Haryana, and to some extent in Bihar and EUP. The soil test data from 1990s- few districts from Punjab (Muktsar), Haryana (Ambala, Sonipat, Faridabad, Hisar, Sirsa, Kurukshetra), Bihar (Sitamarhi , Madhubani, Gopalganj) and EUP (Gorakhpur and Mirzapur) of Uttar Pradesh, West Bengal (West Dinajpur, Malda, Mursidabad, Medinipur and 24 Parganas) showed medium to high K (Sharma, 2003). Districts Guntur, Krishna, Prakasam, Srikakulam, Visakhapatnam, Anantapur, Chittoor and Kurnool of AP also showed medium to high K (Naidu *et al.*, 2002; Naidu *et al.*, 2009). Most soils of the great alluvial floodplains in Asia are generally regarded as high in extractable K. The additional K supply from irrigation water would make it a rare limiting factor in irrigated rice systems (Bajwa, 1994). Reports also showed that considerable area was converted into low K status (Motsari, 2002; Hasan and Tiwari, 2002). The trend of change in available K from medium to high (in year 1976) to medium to low (in year 2002) was also reported earlier (Bansal *et al.*, 2002; Sekhon, 1999). Since most farmers are removing or burning both rice and wheat straw from the field, the K exhaustion might have been more rapid. How farmers in Punjab and Haryana and few districts in EUP and Bihar are coping with this situation is a challenging question. Farmers cannot be solely blamed for not using K. They might have not seen the advantage from the K application as the relationship between K and harvest index was much poorer than that for N or P (van Keulen, 1986).

Many scientists argued that K application is essential for profitable cultivation of rice-wheat cropping system (RWCS) in India (Tiwari *et al.*, 1992; Singh *et al.*, 2013).

This was not reflected in this survey because there is almost zero K use in high yielding ecologies of Punjab and Haryana. Though the contrasting ecologies of Bihar and EUP have relatively better K management yet yields are much lower than that of these states. The different expectations across states may be because the substantial and variable quantities of the K can also originate from irrigation water and crop residues retained in the field (Buresh *et al.*, 2010). The K levels may be high in some ecologies like Punjab and Haryana. The plough back of lot of residue of cereal may be maintaining K levels in some ecologies. High crop removal coupled with less K additions may result in large scale depletion of soil potassium. Chatterjee and Sanyal (2007) outlined an approach for the site-specific K recommendations based on the soil test results to maintain balance between K mining and a productivity target. Even if the studies showed the potential deficit in K balance, farmers are always looking at the response of their crop from the added K. They may not be ready to make commitment for the future K balance.

3.4 Conflict of interest for NPK use

The response of farmers for the rates and extent of N use is somewhat uniform across all states and all surveyed districts within the state. Farmers are convinced that the N application helps them get higher yield. However, the response towards P and K is split with farmers in some states did not favour either P or K or both. High use rate of P in AP, Bihar and EUP even at a high cost showed that cost was not the major factor of using or not using P. These results may, therefore, be interpreted in terms of best yield advantage each element provided in each situation. How to resolve the potential conflict of interest on the need to maintain proper ratio of 4:2:1 for NPK or a proper balance for soil test values and the crop responses are the challenge. In view of low yield scenarios, high cost of irrigation, uncertainties associated with monsoon rains, much better NPK ratio and much better overall soil health compared to Punjab, the existing NPK rates especially P rates appeared to be on the higher side in some states. The mix of economic gains with high yields and nutrient balance in Punjab, which seemed to have sustained, may have favoured this distorted NPK ratio in Punjab. The NPK ratio of 4:2:1 is applicable to one ecology (Bihar). The ambiguity should be resolved through better understanding of cropping systems, soil- plant relationships, crop responses and the ecology rather than depending solely on soil test values. The framework of understanding the problem is lost if focus diverted only to the soil test rather than to factors improving the efficiency. How the scientists would handle these problems is going to depend on the evidences created through such surveys and data analyzed by using soil test and crop responses as part of machine learning.

3.5 Wider shift in partial factor productivity across states

The application of NPK at different use rates and ratios threw light on the partial factor productivity (PFP) in rice across eight states surveyed. Data on PFP revealed that whether NPK ratio- a typical measure of good nutrient management- was affecting the decision of farmers in different states. The PFP from applied nutrient (NPK) is a useful tool to measure nutrient use efficiency because it provides integrative index that quantifies total economic output related to utilization of all nutrient resource in the system (Cassman *et al.*, 1996). Data on the partial factor productivity showed clear difference between different states (Fig. 6). Punjab farmers used 24 % less NPK but harvested 25% higher yield than that of AP farmers. Similarly, Odisha farmers used 41% less NPK but also harvested 26% less paddy yield. On the contrary, the average PFP of Punjab was 47% more than that of AP, and that of Odisha it was 33% more than AP. The low PFP in AP was because of high NPK rates without any proportionate increase in the yield. Data in this survey showed that each state or region confronted a different set of conditions or circumstances affecting the PFP differently. The PFP was changing in different ways with highest level at 46.3 kg/kg of NPK in Punjab, closely followed by Haryana (38.7 kgha^{-1}) and Odisha (36.8 kg/kg NPK). Data from Punjab suggested a strong link between agronomic management and fertilizer response, which is even better than China. This example showed that plants exposed to good growing condition using best management practices are tuned differently towards the response of added nutrients. A well-managed crop is optimised for much better response from the nutrients than that from a poorly managed crop.

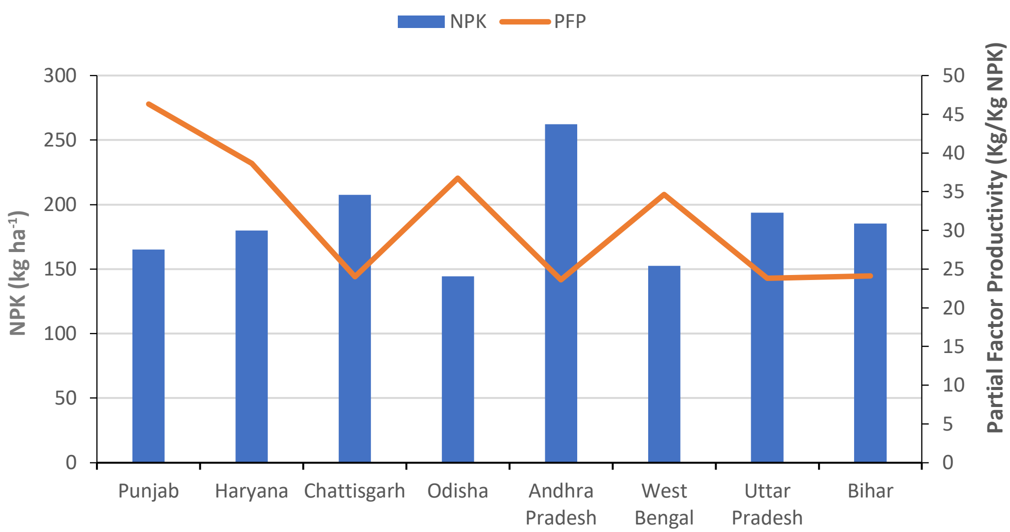

Fig. 6. Effect of total NPK use rates on the average partial factor of productivity across the eight states (n=16,161)

The farmers in AP have gone a step further with best NPK scenario with an average paddy yield of 5.6 t ha^{-1} (Fig. 7) but with less PFP at 24.5 kg yield/kg NPK, which was on par with Bihar and EUP (Fig. 6) but 89 and 60% less than that in Punjab and Haryana, respectively. Paddy yield levels in Punjab (7.4 t ha^{-1}) and Haryana (6.6 t ha^{-1}) were realized mostly at higher use rates of N but coupled with more irrigations (11-13) compared to other states (Fig. 8). In Chhattisgarh, EUP

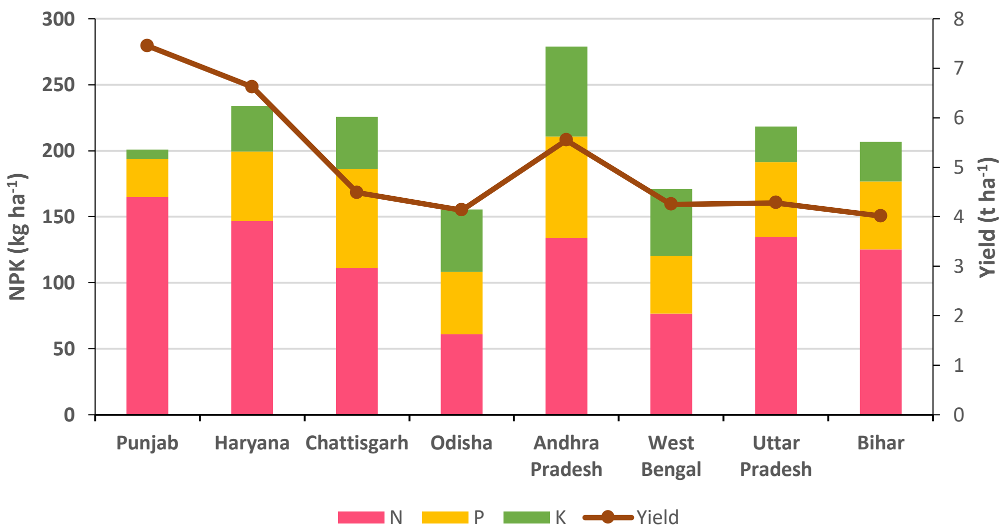

Fig. 7. Average paddy yield and the ratio of total NPK uses by surveyed HHs across eight rice growing states in India (n=16,161)

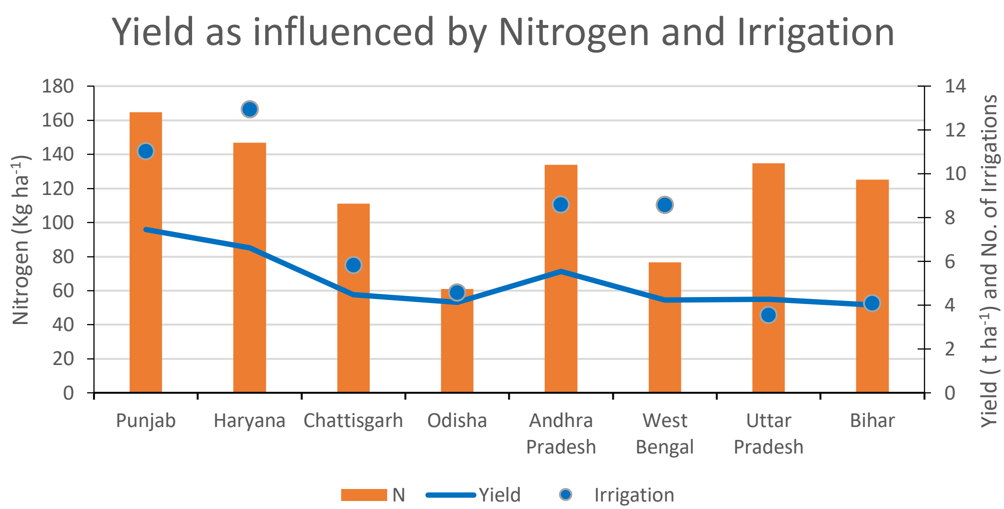

Fig. 8. Effect of nitrogen and irrigation level of the paddy yield across surveyed states (n=16,161)

and Bihar, with the N use rate of 111-135 kgha-[1] and irrigation 3.5-5.8, the paddy yields were much lower (4.0-4.6 t ha^{-1}). In AP, at 134 kg N/ha and 8.6 irrigations, the yield was 5.5 t ha^{-1} higher than these three states but still much lower than that of Punjab and Haryana. Whereas, in WB, even with similar irrigations, the yield was lower than that in AP owing to lower use rates of applied N in WB. That means both N application as well as irrigation are integral parts of crop management to realize higher yields.

Present survey data sets also showed that even under assured irrigation, there seems to be complex relationship of June transplanting in Punjab and Haryana on one hand and on the other hand the staggered transplanting from June to August in AP. The lower PFP in EUP and Bihar with limited irrigation and AP with assured irrigation indicated how agronomic management changes the performance of added NPK. The high P application rates in some districts across Eastern states only increased the cost with not much yield gain (Fig. 9).

But farmers in Odisha used very low rates of N and relatively high rates of P and K. In the same scenario, the PFP of WB farmers as reported by respondents was higher at 34.8 kg/kg NPK.

Even if we assume an efficiency of 20 kg grain yield increase per kg N applied (Witt *et al.*, 2007), the use efficiency in Bihar and EUP could be extremely low.

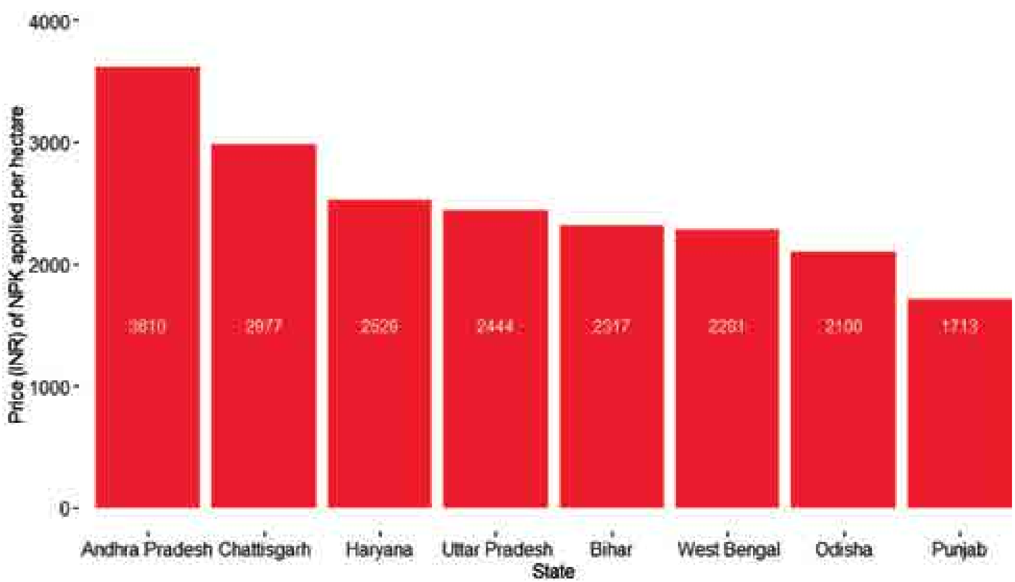

Fig. 9. Average price (INR) of NPK fertilizer used in eight surveyed states (n=16,161)

Total NPK applied in different proportion and their cumulative effect on paddy yield is given in Fig. 7. When the paddy yield is compared, the distorted NPK ratios showed success to a large extent in Punjab (7.4 t ha^{-1}) and to some extent in Haryana (6.6 t ha^{-1}) but gave no advantage in Bihar (4.0 t ha^{-1}) and EUP (4.3 t ha^{-1}) despite much better NPK ratios. Compared to Punjab, with NPK applied at 124:47:14 $kgha^{-1}$ in Bihar, the yield gaps were 3.5 t ha^{-1}. In EUP, this gap was 3.2 t ha^{-1}. Farmers in AP were too cautious about rates and ratios of NPK, but the average yield was still 5.5 t ha^{-1}. The issue is how to maximize value within these adoption patterns rather than looking for changes within NPK use. There are reasons for poor yield realization in the Eastern states (Fig. 7). The lack of timely irrigation had made rice more vulnerable to delayed transplanting and poor weed management. The lack of mechanization might have discouraged heavy puddling leading to a situation where there was no standing water in the first half of rice growth. In the eastern states the crop remained more sensitive to stress in the early phases of growth cycle. Moreover, very small size of holding deterred the farmers from investments in other inputs. On the contrary, Punjab farmers are just-on-time in transplanting, shield their crop from losses from weeds with 100% herbicide use, and practice heavy puddling, which helped maintaining at least 2-3 cm water during the early stages of crop growth. Most of these agronomic management practices may be prerequisite to the efficient use of nutrients.

Another survey done in Haryana also showed that the balance has remained in favour of N since last 10 years (Singh *et al.*, 2010). Access to soil information alone is insufficient to support change through improved decision making. Soil health management recommendations should be developed by combining soil test values, crop response values and other agronomic management factors through machine learning data analytics. It requires broader discussions at the state and national levels about the importance of robust data systems and data integration. The question is how to come out with a profitable recommendation, which is acceptable by the farmers. Farmers in states with higher yields are further supported by low cost of fertiliser input (Fig. 9). The nutrient management built around costly inputs like P and K in Odisha and WB showed that cost matters but not much as it is thought be. It is the response that the crop gets matters the most.

Clearly the objective is to maintain the soil health with profits to farmers who use the recommendations. In this context, the soil health does not mean soil health cards (SHCs). It must be a full integration of all management factors in cropping system mode rather than for individual crops. Contrary to the general perception, the estimates cited by Pathak (2011) showed that there has not been much depletion of soil fertility of agricultural soils of the country over the years. Panda *et al.* (2007) observed positive balances of N and P and negative balance of K in the long-term experiments in rice-rice systems in treatments with N and P application. The use pattern showed that it may not be possible to balance the interest of farmers and the overall soil health without showing the evidence like the one which was brought out in this LDS. The goal is beyond yield and profit maximization to long-term outlook on soil health. Innovative tools and techniques like Nutrient Expert (NE), or Green-Seeker Sensor showed potential for prescription of site- specific nutrient management (Pampolino *et al.*, 2012; Singh *et al.*, 2015). Two approaches; one nutrient expert (Dutta *et al.*, 2014) and the other Crop Manager (Sharma *et al.*, 2019) propagated during last 10 years emphasised balanced nutrient with a focus on K but it did not work out the way these were argued in the studies. The success would depend on digitization of whole process that integrates a cropping system, intensification and optimization of cropping system and broader set of agronomic management rather than depending only on soil test-based fertilizer recommendation.

3.6 Irrigation and nutrient management

Districts Anantapur and Visakhapatnam in AP, Vaishali, Gopalganj, Sheohar, Madhepura, Muzaffarpur, Purnia, Supaul, Saharsa and Siwan in Bihar, Kanker in Chhattisgarh, and Nadia in West Bengal showed poor responses to the applied NPK. The water stress in some of these districts at some or the other stages of rice might have led to such inconsistencies. Data on the effect of irrigation are summarized in Fig. 8. In districts like Mayurbhanj in Odisha and Purulia in West Bengal, higher PFP (more than 40 kg/kg NPK) was found associated with low rates of NPK. Although there could be inconsistencies in this argument, yet these data sets put the irrigation management (Fig. 8) ahead of nutrient management for improving the efficiency of applied NPK. Very low yield of rice even under quite high N doses was because of water stress at any of the growth and development stages of rice; supporting the argument that the root distribution was shallower (Angus *et al.*, 1983) and the rice growth in terms of shoot dry weight, especially at higher N levels was found clearly more affected by severe stress. This meant that the root/shoot ratio get affected adversely making it difficult to ensure adequate water supply to shoots. Even higher N application did not change the ratio under water stress (Motohiko *et al.*, 2000). Connecting these factors to the response of applied nutrients was necessary for proper supply of assimilates from source to sink. This is because the optimum growth of rice owing to these factors embodies the photosynthesis potential of rice at jointing to heading stage and from heading to maturity stage, which sequentially assists NPK to harness their full potential. The effect of nutrients would be less if any of these factors inhibit pre-anthesis growth of rice. As indicated earlier, irrigation has a powerful influence on the response of applied NPK. In fact, many of these factors were excluded while looking at the inefficacies of applied N (Okafor and De Datta, 1976).

The poor access to low cost irrigation represents large areas in rice across India, especially in the Eastern States. It showed that the nutrient response was more in states where water limitation was minimal. However, farmers in the Eastern states, might be using more NPK to prolong the adverse effect of short-term drought. The addition of nutrients would help stressed rice to maintain growth. Therefore, the nutrient management could be an important component to manage moderate drought. Lower moisture reduces nutrient diffusion to the roots. The change from anaerobic to aerobic soil may reduce the availability of N and P. Because of reduced transpiration and nutrient uptake root growth is reduced. The restricted root growth further checks the uptake of water and nutrients. In that situation nutrient may become limiting factor (Wade *et al.*, 1999). The improved nutrition may moderate the negative effect of drought on the growth and development of rice. Improved growth and canopy cover may reduce evaporation and increase transpiration resulting into more dry matter accumulation (Hafele *et al.*, 2009). All these changes happen in moderate drought situation, which is more common in the Eastern states. Therefore, studies on irrigation and nutrient interactions are important (Boling *et al.*, 2007). However, in many cases, the application of recommended NPK in relatively right ratio is not increasing the rice yield substantially in the Eastern states owing to less application of irrigation. To attain higher yield, these ecologies may require more nitrogen but not P as in Punjab. When the data was compared within districts in Bihar, the magnitude of N response was more in Rohtas district where water was not a limiting factor compared to other districts having water as a limiting factor.

3.7 Use of FYM and other management practices as part of INM

Data also suggested that even the best of NPK ratio did little if other agronomic practices were not precise. The growth rate of fertilizer in rice levelled off in most regions except in Odisha and to some extent in West Bengal. The use of new varieties is plateauing. The task of producing additional rice must come from hybrids and factors other than nutrients management. The challenge now is that the past work gave a platform to have excellent infrastructure for soil testing; it happened on very high level of scale during SHCs scheme. The digital transformation was adopted that included soil test values and most actions which affect the crop response to externally added nutrients. Here the need is to completely recalibrate the recommendations; that would need even more emphasis on data analytics. Data also revealed that almost 22 to 26% farmers use farmyard manure (FYM) in Bihar and EUP (Fig. 10) against an average of 43% in Punjab; but it is quite good (42% HHs) in AP. Small differences between states except Odisha may not be viewed as an important variable as far as the efficiency is concerned. The submergence of rice itself makes the rice to respond differently to the addition of FYM. The submergence

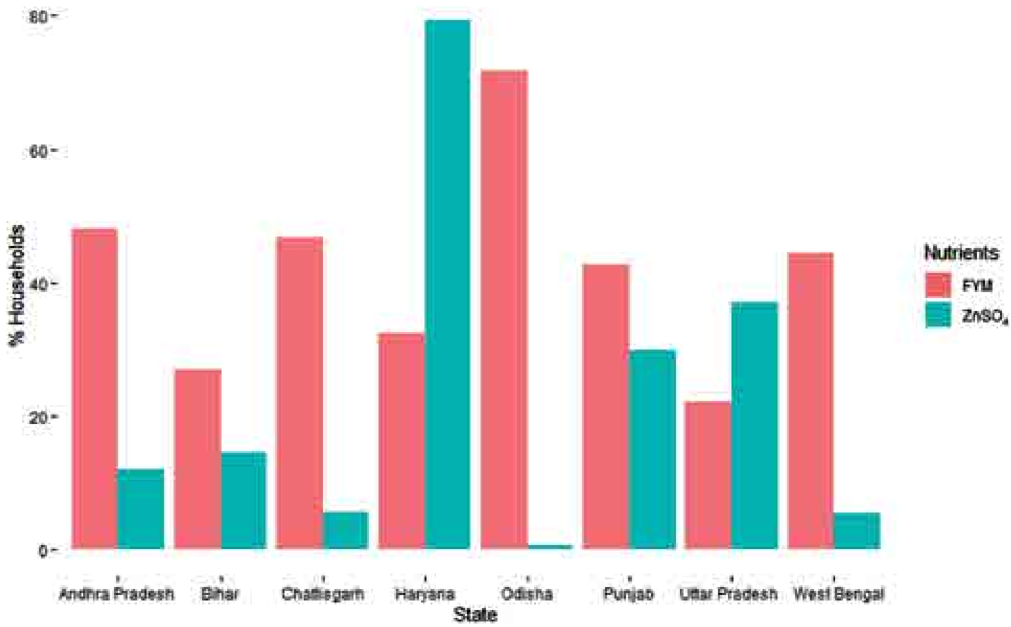

Fig. 10. Response of percent household using FYM and Zn across eight surveyed states

and management of rice soils results in biological and chemical processes leading to uniquely different nutrient cycling, nutrient supply to crops, and decomposition of organic materials than that in well-drained, aerobic soils. Organic materials typically have less benefit on the physical, biological, and chemical properties of submerged rice soils than on well-drained, aerobic soils (Buresh and Dobermann, 2010). Decomposition of organic matter (OM) in submerged soils needed for rice cultivation is slower than well drained soils (Buresh *et al.*, 2008). Low nutrient supply and fertilizer use efficiency were considered as main contributors to this trend (Dobermann and Smith, 1999).

The tillage of submerged soil called puddling reduces the downward movement of water. Rice soils are typically kept saturated with water through the growing season depleting soil oxygen, and replacing aerobic organisms by anaerobic organisms. The decomposition of organic matter, therefore, is much slower in the rice soils (Buresh *et al.*, 2008).

Added organic materials may stimulate activity of aerobes in well-drained soils but not anaerobes in submerged soil. The effect of organic materials on soil chemical properties is also less in submerged soils of rice. Submergence also reduces decomposition of native soil organic matter (Ponnamperuma, 1972). Organic materials in sufficient amounts can potentially meet much or all of the K and even P needs of rice, but they seldom meet the N needs of a high-yielding rice crop. Moreover, P is added in sufficient quantity in all states except Punjab and Haryana. Therefore, applying sufficient N from synthetic manufactured fertilizer to meet the needs of the crop for supplemental N (Buresh and Dobermann. 2010) is a must.

3.8 N response and agronomic practices

Data in Fig. 11, showed that the paddy yield tended to increase with increase in level of N. In most cases increase in yields are aligned with increase in the doses of N but relationship was quite weak. There was lot of variation between states when the comparison of N response was compared across states having assured irrigation (Punjab, Haryana and AP) and the regions having limited irrigation (EUP and Bihar) and the regions with relatively high rainfall (Odisha, West Bengal and Chhattisgarh), data revealed the interplay between irrigation, hydrology, soil test values and cropping systems and response of added N to rice. The correlation was not significant because there were so many factors, which might have affected the response of N across different ecologies.

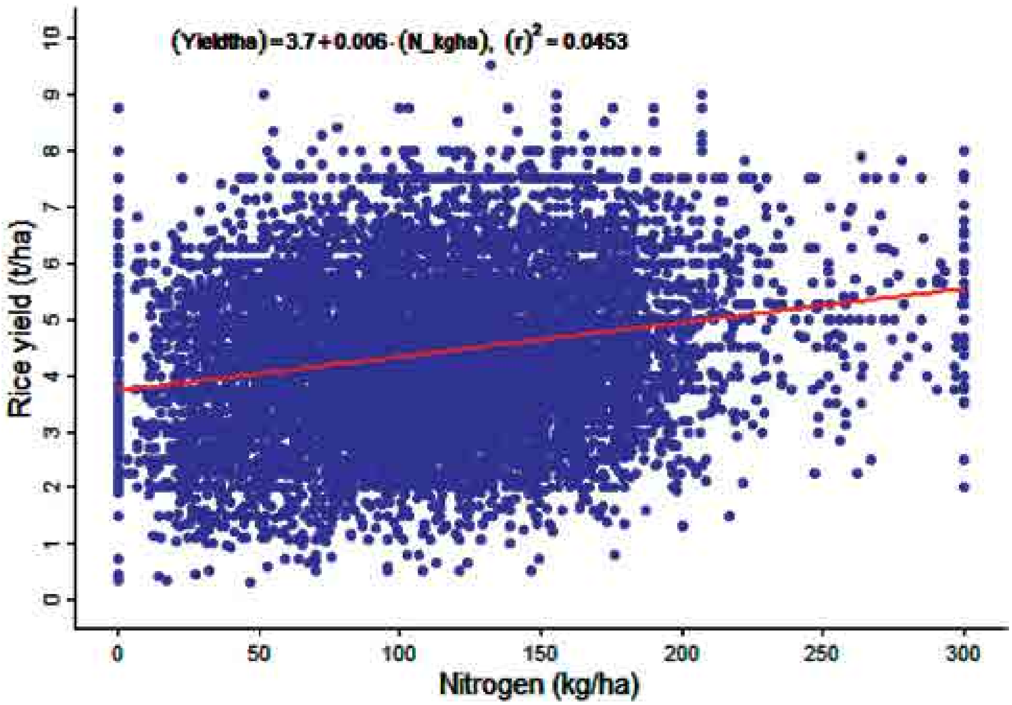

Fig. 11. Relationship between rice yield and nitrogen application rate across eight states (n = 16,161) (Correlation = 0.206, r^2 = 0.0425)

The states which ranked high in terms of paddy yield also had more use rates for N. Among Bihar and EUP the yield margins due to added N might have not improved despite the use of recommended P and K rates because– irrigation was not given as per need of the crop, or there was a lack of acceptable weed control due to dominance of difficult to control weeds. Moreover, herbicides like pretilachlor or butachlor applied pre-emergence might were less effective due to requirement of 2-3 cm standing water after their application. In addition, during last 10 years there was delayed monsoon, added to the drought like situation during the peak growth stage of rice. Overall, two things standout– (i) the costly irrigation, and (ii) unacceptable weed management from existing methods. In addition, the response of rice to added N on Odisha was probably less than that to P. Overall, the response to added N was less in Eastern states and much of that was basically because of factors other than nutrient management. In addition, to above factors there may be N losses due to leaching, and runoff owing to heavy rains leading to high weather risk (Scharf, 2015). That is why relationship between yield and optimum N rates was usually weak (Puntel *et al.*, 2018). There is a need for digital soil mapping to refine regional soil data base (Nawar *et al.*, 2017).

As a result, farmers in the Eastern states have a yield gap of more than 3.0 t ha^{-1}; and are increasingly seeking solutions of low yield through nutrient management. Among them N fertilizer is preferred. Even the fertilizer recommendations (Table 1) are not tailored to the expected response of plants to changes in the agronomic practices, e.g., high fertilizer rates to offset possible losses due to delayed crop establishment does not work that way. If the change in the paddy yield is examined at different N application levels, there is no significant correlation although there is an increase in yield with increase in N rates. The N input to yield output ratio is high in Punjab but very low in EUP and Bihar and even in AP. A surplus N balance leads to NH_3, N_2O, NO_3^-, and or NO pollution while a deficit N balance leads to low soil fertility from depleting soil nutrient pools, resulting in poor crop yield (Bouwman *et al.*, 2005). The GoI successfully implemented N reduction program by reducing the package size to 45 kg bag of urea from 50 kg but it still needs a review in terms of ratio of NPK and interaction effects of other factors. Overall, it is important to understand how N use can be reduced by using better agronomic management (Olesen *et al.*, 2004) including varieties (Mishima *et al.*, 2006). Use of N at later stages, applying controlled release fertilizer, using urease inhibitors, or combining organic and inorganic sources are other parts of management. In the EIGP, it is more to do with other management practices that are playing around nitrogen. The N applied in rice cannot harness its potential if it is not appropriately integrated with other management factors like transplanting time, age of seedling, irrigation and weed management, which affect growth and carbohydrates in leaves, stem, and sheath. The dry matter remobilization done by the effect of nutrients especially N will decrease if above factors are not properly managed.

Green manures with a relatively high N concentration and low C : N ratio decompose rapidly in submerged soil and readily release plant-available forms of N and other nutrients. Therefore, the solution to poor efficiency of applied fertilizer is not necessarily to make changes within the fertiliser rates, or source. Similarly, the poor yield is not always due to poor soil health, which does not seem to be the case for EIGP. Better utilization of inputs brightens the scope of growth and better utilization will come from growing plants in the most suitable environment, which can be set only by time management. Some of these agronomic issues cannot be resolved easily, therefore it may remain a protracted point. Earlier studies also showed that the rice crop yield can be improved at reduced N application rate through integrated soil-crop system management (Liang *et al.*, 2016).

3.9 Soil health cards (SHCs)

Farmers may be adding NPK as needed based on soil test value but the data showed that only few farmers are applying fertilizer based on recommendations given in the SHCs. The fertilizer use pattern of farmers was not influenced by soil testing values as only 0.3. 0.5, 0.52, 0.79, 1.2, 1.42, 7.24 % and 7.84 % HHs in Bihar, Odisha, Punjab, West Bengal, Haryana, EUP, Chhattisgarh and AP used SHCs for applying NPK. A maximum of 21 % HHs received SHCs in Chhattisgarh and 7.2 % HHs used the information given in the SHCs. In other states 92 to 99 % HHs had not received SHCs. Data showed large variation among states with best case scenarios in AP, but overall, there is clear sign of non-adoption of soil test recommendations by the farmers. These data sets reasonably indicated that soil tests, even if done accurately led to a very narrow way of generating recommendations (Table 2). The trend towards extremely low rates of acceptance also suggested that already burdened soil testing labs cannot maintain quality of outcome. These data sets also suggested that trends of adoption reported by the KVK system from time to time can help generating evidences on the trends in fertilizer use, which are mostly based on crop responses.

In fact, fertilizer should be applied as per the response rather than a fixed rate typically recommended by any state. These data sets showed that focus should be not only on tracking the soil test values for site specific nutrient management but also on crop responses to each element and all other relevant information on other agronomic management factors especially the role of water in rice. The system needs large scale digitization from the existing data sets and use of analytics to segregate the effect of factors other than nutrients. Given the so called distorted

Table 2. Status of soil health cards in the surveyed states (n=16,161)

State	Soil Health Card status	Yield ($t\ ha^{-1}$)	Households (%)
Andhra Pradesh (n=1,647)	No soil health card	5.5	92.0
	Available and information used	5.9	7.9
Bihar (n=7,141)	No soil health card	4.0	99.1
	Available and information used	3.9	0.3
	Available and information not used	4.4	0.6
Chhattisgarh (n=773)	No soil health card	4.4	71.8
	Available and information used	4.8	7.2
	Available and information not used	4.8	20.9
Haryana (n=417)	No soil health card	6.6	96.4
	Available and information used	6.6	1.2
	Available and information not used	5.7	2.4
Odisha (n=1,207)	No soil health card	4.1	98.9
	Available and information used	4.2	0.5
	Available and information not used	5.3	0.6
Punjab (n=388)	No soil health card	7.4	99.2
	Available and information used	8.0	0.5
	Available and information not used	8.0	0.3
Uttar Pradesh (n=2,553)	No soil health card	4.3	97.7
	Available and information used	4.9	1.41
	Available and information not used	4.6	0.8
West Bengal (n=2,035)	No soil health card	4.2	98.4
	Available and information used	4.6	0.8
	Available and information not used	3.8	0.8

NPK ratio with lowest fertiliser use (201 $kgha^{-1}$) but highest average yield of rice (7.5 $t\ ha^{-1}$) in Punjab and with highest NPK use (264 $kgha^{-1}$) and an average yield of 5.6 $t\ ha^{-1}$ in AP, it may be better to use the soil test services to examine the case for nutrient recycling. It should focus bulk of services on how different cropping systems are maintaining the nutrient balance. A high dry matter recycling scenario seen through management options other than nutrient management might have helped maintaining the soil quality indirectly. Since data reflected the opinion of farmers in each district, views and practical implications of soil test values should be analysed. This warrants a thorough review of whether system depended solely on the soil test recommendations or reoriented the whole program by involving factors like crop responses and associated factors, which affected such crop responses. Farmers in Punjab and Haryana are benefitting more from existing NPK use rates while farmers in Eastern states are struggling to harness best from relatively better NPK ratios. The benefits of better outcomes from existing NPK rates in the first case are primarily driven by much better management of crop (Chu *et al.*, 2016). The survey also found that majority farmers are with less education background and could be less trustful of extension agencies on soil test recommendation even after they were issued SHCs. The consensus should be based on the convergence of ideas of all stakeholders so that the polarising issues can be captured and distilled with proper data analytics. The intensive rice-wheat cropping system (RWCS) or rice-rice cropping system (RRCS) or rice-pulse cropping system (RPCS) with high dry matter turnover might generate large nutrient surplus in the mechanised farms as was observed in Punjab. Therefore, it can happen in other states, if the recycling of crop residues is made more effective. The convergence platform may be created and must follow certain guidelines by including the data for adoption by farmers like the one reported in this survey or data from farmers' field trials. These convergence platforms should be a state level and focus on specific questions on the recommendations on soil health issues. Such convergence platform should not be just for the endorsement of ideas without evidence, which is bottom-up and not always top-down. The system should be willing to listen to the point of view of users of technologies including farmers, private sector, and extension agencies. The real situation of soil health may not be as it is made out. The real case of overuse may also be not as bad as it is made out to be. That needs data, its analytic, digitization, and machine learning as a futuristic approach to find solution for integrated nutrient management.

Conclusion

The HHs in different states exhibited varied level of support for P and K but uniform support (92-100%) for nitrogen. The order of support for adoption of phosphorus was 2 and 63% in Punjab and Haryana, respectively, while in other states it ranged from 87 to 95%. The support for potash was only 3 to 6% in Punjab and Haryana, but the order of support was 28, 48, 68, 77, 88 and 92% from EUP, Bihar, Chhattisgarh, West Bengal, AP, and Odisha, respectively.

When compare the parallel of Punjab with Bihar, the survey result from Punjab showed that the average NPK rates, paddy yields and partial factor productivity of farmers were 201 $kgha^{-1}$, 7.45 t ha^{-1} and 46.8 kg/kg NPK, respectively. The average NPK rates, paddy yield and PFP of farmers in Bihar were 234 $kgha^{-1}$, 4.0 t ha^{-1} and 24.6 kg/kg NPK, respectively. Even in Odisha, the corresponding results were of the order of 156 kgha-^{1}, 4.1 t ha^{-1} and 44.3 kg/kg NPK. Data across all surveyed states showed that fertilizer use efficiencies can only improve if nutrient management at field levels is fully integrated with agronomic management (INM). The INM and agronomic practices are connected and that is why differential responses were noticed across states. Looking at the high total NPK dose, relatively better NPK ratios and the high cost of added NPK, it appeared that paddy yields were not matching the farmers' expectations in AP, Bihar and EUP. Comparison of the similar data from other states, revealed that in aggregate, Punjab and Haryana farmers could harvest high yield (7.4 and 6.6 t ha^{-1}, respectively) and much better PFP with distorted ratio in favour of N and at much lower cost of fertilizer. The integrated nutrient management requires a paradigm shift with focus on more data analytics that include other management factors, weather forecasting, hydrology, and socio-economic factors as a central theme. Data across states showed that it is one thing to maintain the balance between nutrient mining and a productivity target, but it is quite another to dispute to role of factors other than nutrient management and the interest of farmers to maintain profit margins.

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2.3 Irrigation management - a catalyst for sustained yield growth of rice

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KEY MESSAGES

- The rainfall in the Eastern states is more than that in Punjab, Haryana, and Andhra Pradesh, but the underlying problem of access to electricity-based tube-well irrigation is still unresolved. This problem is more serious in years with a delayed rainfall or when the number of rainy days is less– a regular feature now with the advent of climate change. The high cost of irrigation and the resultant low yields changed the underlying economics of rice cultivation, which is less profitable in these ecologies than that in Punjab, Haryana, and Andhra Pradesh with assured irrigation. The lower water productivity in different states is a consequence of lack of access to low-cost irrigation in the eastern states as well as the variable and uncertain monsoon rains. It is easier to implement it by encouraging rice nursery enterprises (RNEs) instead of community nursery.
- Rice farmers need to make the best use of monsoon rainwater whenever the rains arrive, so that they can transplant (or direct drill) in a timely manner. More emphasis should be given to pre-season preparation and nursery management to ensure supply of healthy seedlings of the right age. It is better if farmers make themselves ready by raising nursery wherever irrigation water is available.
- Accurate weather forecasting can help planning the transplanting time of rice. The automated weather forecasting service can be further improved by

including agronomic management data and studying interactions for developing messages. Transplanting should be done when farmers are confident to maintain 2 to 3 cm water immediately after transplanting to support early growth and suppress weed emergence. Irrigation at the time of transplanting becomes the priority activity.

- The extensive investments in irrigation, electricity infrastructure and government subsidies on water and power consumption have made rice cultivation risk free in Punjab, Haryana, and Andhra Pradesh. In view of lower risk and lower cost irrigation due to free electricity, diversification from rice to other crops did not happen. So, research should focus on options within rice, such as replacing long duration rice varieties (LDRVs) with short duration rice hybrids (SDRHs) or basmati rice, or explore the possibility of precision irrigation from conventional practice of puddled transplanting to drip irrigation.
- There is ample evidence that hybrids need same or a lesser number of irrigations in the upland ecologies across Eastern states. The yield stability, both under stress and normal conditions, is an important variable for stress tolerance in hybrids.
- Farmers, especially the small and marginal ones who dominate this survey, will not compromise with yield. So, alternate wetting and drying should be tested in simple formats which farmers can understand. Perhaps there are some stages where deficit irrigation help crop to achieve high yields.
- Technologies that decrease water use and increase profitability through intensification of cropping systems, with 300% cropping intensity, should be identified. For example, farmers in district Ambala of Haryana and Samastipur of Bihar intensified cropping system with dominance of hybrid rice.

1.0 Introduction

The year 1966 is the beginning of green revolution based on new high yielding fertilizer and irrigation responsive varieties. A new boost to development came in 1989 when hybrid rice was brought on the agenda. Irrigation related yield gaps across India still exist between states and within states. Since, to produce 1 kg rough rice the crop requires 2,500 litres of water, it plays pivotal role in the cultivation of rice. This includes all supply side including rainfall and/or irrigation (Bouman, 2009). A recent study published in the *Nutrients* (e) showed that two slices of whole grain bread had a much lower water-scarcity footprints (0.9 litres/kg) than a cup of cooked rice (124 litres /kg). The proportion of irrigated rice is about 22.0 million ha. Out of 8 surveyed states the rice cultivation in three states including Punjab, Haryana and Andhra Pradesh (AP) is irrigated. Small area in AP is also under coastal saline areas. About 13.5% area is in the uplands where yield is low because there is no standing water in the field few hours after rains; parts of Bihar, Eastern Uttar

Pradesh, Chhattisgarh, West Bengal, and Odisha fall in this category. The low land rice covers about 32 % area, mostly found in the Eastern states, and was covered in this survey. The rice production is highly correlated with the amount of summer monsoon rainfall (Krishna Kumar *et al.*, 2004). Farmers in high rainfall ecologies are unable to access low-cost irrigation. The recurrent floods and drought like situation also have a great influence on rice cultivation in the Eastern states. The decrease in number of rainy days and frequency of long-rainy spells during 1951-2004 (Dash *et al.*, 2009) highlights worries about variable monsoon and climate change. The drought like situation has greater impact than the extreme rainfall situation (Auffhammer *et al.*, 2012). Overall, farmers in the Eastern states face most risks associated with loss in productivity and reduced water productivity (Bhattarai and Narayanamoorthy, 2003). Some of these extreme moments brought by climate change require the access of farmers to low-cost irrigation to support rice growth during this phase. Better access to irrigation can help realising the dual aim of improving rice yield and water productivity. In states like Odisha and West Bengal, sometimes very heavy rainfall at the time of crop establishment threatens the transplanted rice. All these scenarios need advance preparation. Small and marginal farmers in the eastern states, on average, produce half the yield than that of relatively bigger farmers getting in Punjab. This happens even if one take into consideration the adoption of high percentage of high yielding long duration rice varieties (LDRVs) in the eastern states. The positive impact of new technologies (varieties and external inputs) on paddy yield is still unrealised in these states compared to irrigated ecologies. There are two contrasting scenarios– in one farmers are getting yields as per the capacity of natural resources and in the other farmers are not getting yield according to what their natural resources can support. One system is facing an unsustainability of intensive system of agriculture (e.g., rice-wheat system in North-western India and rice-pulses or rice-rice in AP) as it has reached its plateau in Punjab but not in Haryana or AP. This system has overexploited the groundwater. The other system that includes eastern states, which is supposed to perform better due to high rainfall but has not done so owing to lack of access to irrigation. Among eastern states, Bihar and Eastern Uttar Pradesh (EUP) can be called as typical limited irrigated ecologies because network of diesel-pump based bore-wells is available, but it is costly irrigation. These regions also have some districts with canal irrigation. The small and marginal farmers in these states cannot take advantage of irrigation because it is costly. Moreover, applying irrigation is associated with socio-economic factors as it is not a onetime event. There are two questions– would the farmers (i) in Punjab and Haryana still have used excess water if the irrigation was costly; (ii) in eastern states have increased the rice productivity with better access to low cost irrigation with high rainfall? Landscape Diagnostic Survey (LDS) was conducted to understand the process of monitoring, evaluation and learnings (ME&L) so that individual Krishi Vigyan Kendra (KVK) can anticipate the changing preferences of farmers and communicate the same to the parent institutions as a feedback mechanism for research and extension agencies for policy changes in the scaling process of irrigation management in any given year.

2.0 Methodology

The dynamics in respect of irrigation management in rice have not changed much in many states. To understand these variations and the yield responses, LDS was conducted in 2017 and 2018. The LDS covered eight states including Andhra Pradesh (AP), Bihar, Chhattisgarh, Eastern Uttar Pradesh (EUP), Haryana, Punjab, Odisha, and West Bengal representing approximately 28 million ha rice area in India. The survey broadly covered three areas of influence: (i) irrigated ecosystem in Punjab, Haryana and Andhra Pradesh, (ii) limited and costly irrigated ecosystem in EUP, and Bihar, and (iii) rain-fed rice in Chhattisgarh, Odisha and West Bengal.

The survey schedule covered most of the crop production practices in rice. The randomization was followed having every element of getting equal chance/probability to be selected and to be part of the survey. The well represented data collection in this survey will not make any bias in the algorithms. The response is based on very broad group of households (HHs) who were selected randomly.

Data collected through this survey can pick up the differences in ecologies and the responses of rice to rainfall and irrigation patterns. The accumulated rainfall for 2019 across eight surveyed states is given in Fig. 1. Cereal Systems Initiative for South Asia (CSISA)-KVKs network used mobile based Open Data Kit (ODK) to record observations instead of time-consuming conventional paper-based system. Capacity and understanding of the survey process was developed through nine training sessions on hands-on training. These training sessions on the methodology, were conducted at regional level to enable KVK network to conduct rigorous diagnostics on their own programming, and also to understand the adoption behaviour of farmers. The data enlisted range of factors that decide the emerging scaling process and limitations that may reset the research agenda through research groups in different states or in the Indian Council of Agricultural Research (ICAR) institutions.

The survey allowed to pick up large variations ranging from– upland ecologies to very lowland ecologies, drought prone areas to flood affected areas, single monsoon to double monsoon areas and rice-wheat cropping system (RWCS) to rice-rice cropping system (RRCS) or rice-fallow cropping system (RFCS). Data generated though this survey was deployed on the Indian Agricultural Statistics Research Institute (IASRI) server and used to develop digital system, which helped looking at the trends on the effect of irrigation or monsoon rains on rice at national, state and district levels. A total of 16,162 data points were used from HHs, randomly selected across states so that each district and each ecology in a district is represented equally.

The randomized villages were broadly representative of districts and in the same way farmers in each village were broadly representative of a village. Data were analysed and compared within and between states to explain why the yield levels were different when the best performers and worst performers among the respondents were compared. These data sets were compared across states to open new avenues on irrigation management in rice and how to integrate irrigation with other variables. This analysis was done to study that why technologies are differentially adopted by farmers. Within states, it is to give an idea of local ecologies affecting the adoption pattern and whether site specific recommendations are needed or not as an effective alternative for each technology evolved by the National Agricultural Research and Extension System (NARES). The accumulated rain-fall from June to October over eight surveyed states is given in Fig. 1.

This approach is to guide us to shift the traditional commodity-based approach by allowing extension staff in KVKs to spend more time in collecting data and engaging with farmers across the whole district rather than the domain area of few villages and few farmers. After proper data analytics, it will provide exact information and clear ways to assess whether technology adoption is on the right track or have to change the track itself.

3.0. Results and Discussion

The yield gaps between and within states are decisively on account of water management and its effect on the precision with which the crop is managed. This is because the crop requires near submergence environment, with daily consumptive use of 6-10 mm, 2,000-3,000 liter water/kg rice and total water requirement of 1,200-1,400 mm (http://agropedia.iitk.ac.in/category/location/india?page=186-aipictuasdharwad 2009). Theoretically eastern states are perfectly suited to rice cultivation, but in practice the system is not harnessing best out of this natural resource. Since water management is the core of any future research and extension, region-specific interpretations are presented here. Clustering was, therefore, used to first look at grouping the survey sites into different typologies for irrigation and other key factors (Fig. 2). The data of 15,627 farmers from eight surveyed states were taken to partition the observations into six Clusters with nearest mean. For achieving this K-means

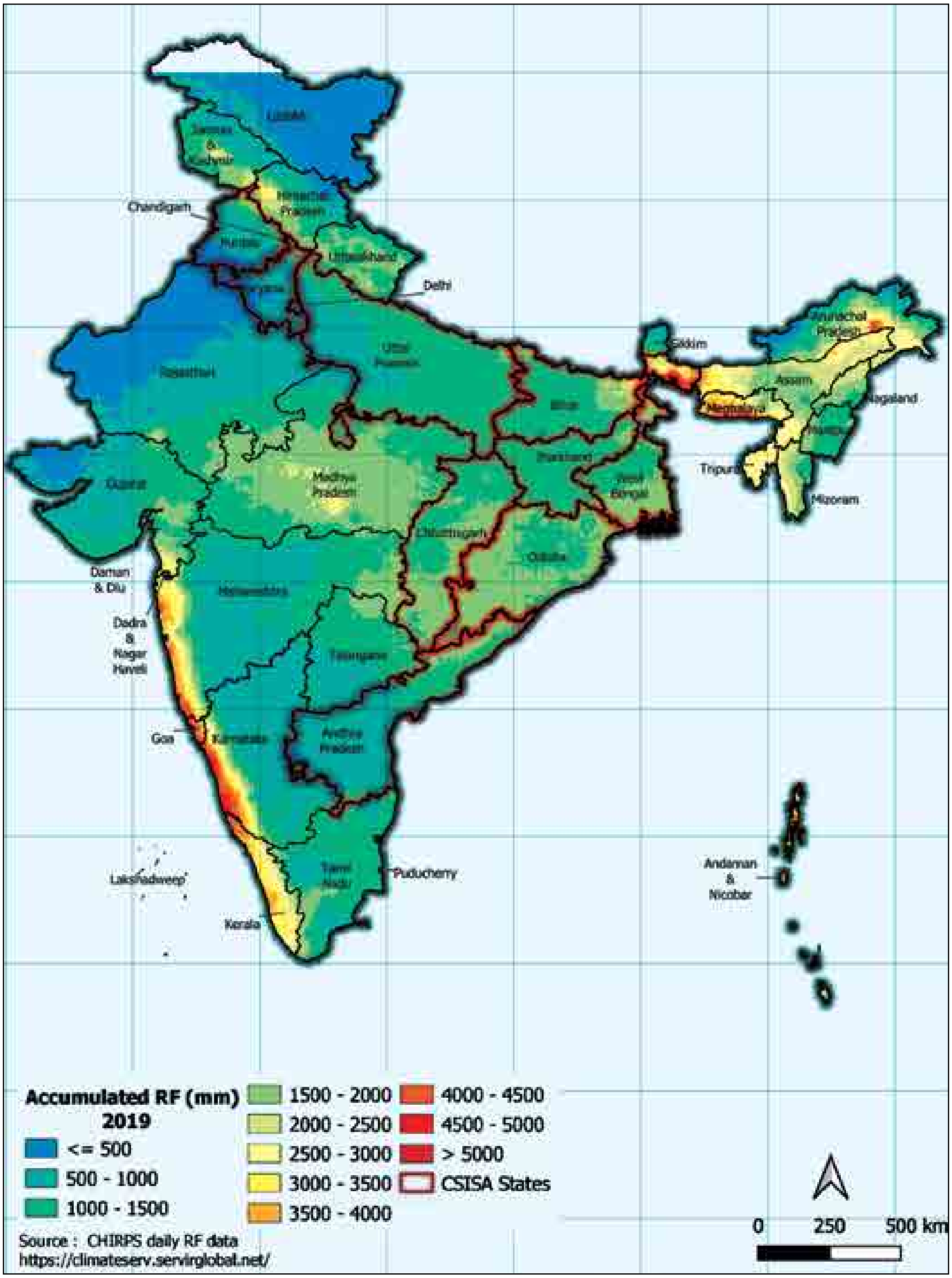

Fig. 1. Distribution of average annual rainfall during June-October 2019 (surveyed states are marked by red boundary)

Clustering algorithm was used to classify the data points into different Clusters. The Clusters were formed based on the agronomic and economic practices followed by the farmers. The accumulated rainfall data (June-October) was also included to classify the Clusters in the surveyed states. The variables considered in the Clustering algorithm were: nursery establishment date, transplanting date, seed rate, farm yard manure application, nitrogen application, phosphorus application, potash application, number of days of first top dressing of urea, number of days of second top dressing of urea, number of irrigations, number of manual weeding, lodging in the field, total number of members in the family, marketable surplus, share of agricultural income, share of rice crop in agricultural income, distance of market from household, and coordinates (latitude and longitude) of the largest plot. The accumulated rainfall (Fig. 1) was included in these Clusters as part of total water requirement.

The paddy yield trends in the six Clusters given in Fig. 2, showed that yield trends are not dependent solely on the amount of rainfall. The representation of surveyed states in different Clusters include: Cluster 1- Andhra Pradesh and parts of West Bengal; Cluster 2- parts of Bihar, parts of West Bengal, and Eastern Uttar Pradesh; Cluster 3- Haryana and Punjab; Cluster 4- parts of Bihar and Eastern Uttar Pradesh; Cluster 5- Odisha, West Bengal and Chhattisgarh; and Cluster 6 -parts of Bihar, West Bengal, Eastern Uttar Pradesh. Clusters 1, 3 and 5 were therefore

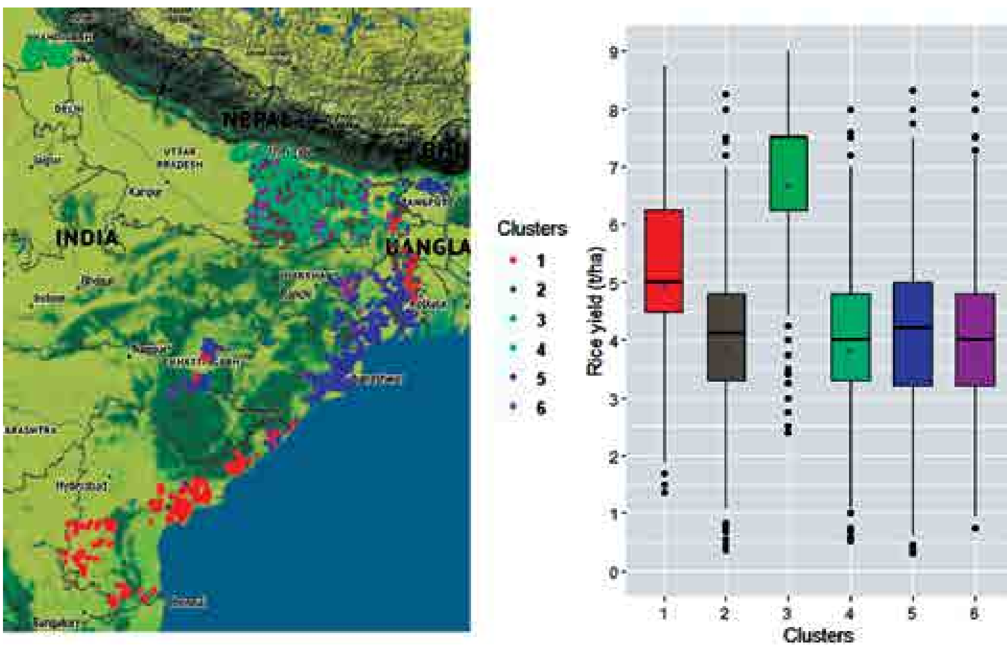

Fig. 2. Paddy yield trends in six clusters.

distinct geographically, while Bihar was predominantly Cluster 4 but with many areas of Cluster 2 and Cluster 6. The total accumulated rainfall in the eastern states (Clusters 2, 4, 5, and 6) is close to the total water requirement of rice. Farmers in these states continued to get much lower yield than that of the farmers in Punjab, Haryana and AP. These trends did not show any evidence to support the argument that rice cultivation in India should be shifted to eastern states.

3.1. Irrigation management–A game changer in rice

The paddy yield in Cluster 1, which represents Andhra Pradesh and small part of West Bengal, was 5.0 tha^{-1} while the yield levels in Clusters 2, 4, 5 and 6 representing most of the eastern states were significantly less (4.1 to 4.3 tha^{-1}) than that of Clusters 1 and 3. Farmers in Cluster 3 (Punjab and Haryana) outperformed farmers in all Clusters with an average paddy yield of 6.3 tha^{-1}. The management options might have followed the rainfall patterns, which are changing over the years with number of rainy days being lower now than that in the past (Dash *et al.*, 2009),i.e. high rainfall in the eastern states would provide good results only in conjunction with irrigation and the associated management practices. Why there is low yield realization with relatively more total rainfall was explained for different Clusters representing different states. The explanation for the responses in Clusters data representing the number of irrigation and paddy yield is given in Fig. 3. Data on number of irrigations implied that almost all HHs in these states applied at least one irrigation. Even with good rainfall, farmers in these states are highly dependent on irrigation with around 50 % HHs using 1-3 irrigations in rice. Some of differences in the paddy yields in Cluster 3 (Punjab and Haryana) and Cluster 1 (AP and parts of West Bengal) on one hand, and on the other hand the eastern states (Clusters 5, 2, 4, 6 in that order), can also be attributed to the differences in the hydrological conditions (Virk *et al.*, 2003) and the time of continuous flooding. More broadly, the trends indicated that higher rainfall regions are showing low yields across Clusters 2, 4, 5 and 6. One explanation for such trends is the tendency of policy makers and farmers to depend heavily on monsoon rains. In Punjab and Haryana, intermittent irrigation is very well maintained during the early stages to maintain heavy tillers per hill. In the eastern states, especially in the shallow lowland ecologies, heading occurs at faster rate due to continuous flooding in the second half of rice growing cycle compared to Punjab and Haryana, where water regimes are maintained by intermittent irrigation and no irrigation is given during the last 3-weeks of crop cycle. There could be higher percentage of decayed roots (Thakur *et al.*, 2011) in the eastern ecologies than that in the ecologies of well-regulated and assured irrigation. Greater root volume and longer roots (Ascha *et al.*, 2005) by maintaining near flooding conditions in the early stages and keeping the fields without flooding during last few weeks near crop maturity seem to help

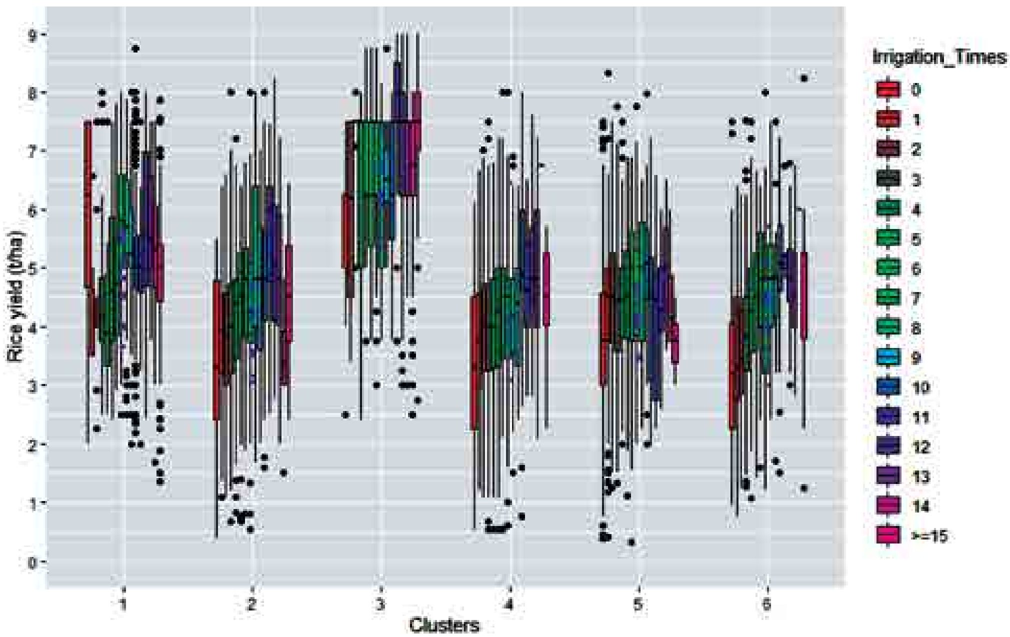

Fig. 3. Effect of number of irrigations on the farmers reported paddy yield in Clusters of surveyed states (Cluster 1- Andhra Pradesh, West Bengal; Cluster 2- Bihar, West Bengal, Uttar Pradesh; Cluster 3- Haryana, Punjab; Cluster 4- part of Bihar and Eastern Uttar Pradesh; Cluster 5- Odisha, West Bengal, Chhattisgarh; Cluster 6- Bihar, part of West Bengal, part of Eastern Uttar Pradesh). Sample size-Andhra Pradesh (n=1,647), Bihar (n=7,141), Uttar Pradesh (n=2,553), Chhattisgarh (n=773), Haryana (417), Punjab (388), Odisha (n=1,207), West Bengal (n=2,035).

plants to maximize water capture and its access at greater depths. For better crop management the orderly and conjunctive use of irrigation (Fig. 3) and rainfall (Fig. 1) and their effects on rice yields were explained for each surveyed Clusters separately. The yield gap between Cluster 1 and 3 itself is 25 %, and that between majority (Fig. 2) eastern states (Clusters 2, 4, 5 and 6) and Cluster 3 ranged from 48 to 55 %, respectively. The realized yield gains from rainfall have remained low. The interactive data in Fig. 3 indicated that the access to irrigation is at the core of getting high yields and making best use of natural resource like rainfall. These data sets offered a case for providing access to low-cost irrigation to make best use of rainfall as a natural resource of water in these ecologies. In fact, the lack of low-cost irrigation is depriving farmers of these ecologies to make best use of rainfall even if it meets more than 80 % water requirement of rice.

When data on agronomic management and the accumulated rainfall data from June to October were combined, three broad scenarios emerged. Data in Fig. 3 provided the evidence that there is a positive response to irrigation level across

Clusters. This finding coupled with general yield data contained in Fig. 2 found that the eastern states with best growth conditions for rice did not show much growth in its yield. Review of the literature (Nene and Nalini, 1997; Nene 2002) on Indian summer monsoon (ISM) since Vedic time's revealed that one-sixth rains occur during the beginning and the end of monsoon and two-thirds in the middle of rainy months. Even with a network of canal water and large number of private owned diesel-pumps there is no orderly use of monsoon rains in the eastern states. With such a known distribution, farmers can only manage high yield if the rainfall is fully utilised. It is also clear that the effective use of rainwater is less than the expected use. With relatively high rainfall, the use of irrigation in these ecologies will still keep the water table sustainable. The Punjab and Haryana and AP did much better than the eastern states as these states created irrigation facilities. Even yield in these states was steadily increasing more than eastern states. As farmers in these states increase the water use in rice, the system could lose their major advantage in the long run. There is a dilemma– in Punjab and Haryana farmers are not willing to diversify while in the eastern states are not willing to pay for irrigation. Can the yield of rice be increased with the current rainfall scenario? Data showed that it cannot, if supplementary irrigation is not given. The data showed that it should not be the way to proceed. Enough has not been done to provide low cost irrigation even if the water table is not so deep, and there is a little or no worry for decline in water table.

According to a 2019 study (https://www.bloombergquint.com/economy-finance/india-must-shift-rice-growing-east-from-punjab-and-haryana-to-prevent-desertification) done by the National Bank of Agriculture and rural development (NABARD) and Indian Council of Research and International Economic Relations (ICRIER), Punjab (including Haryana at that time) was a desert until the 1800s. The major shift in favour of rice in Punjab and Haryana happened with the increase in the distribution of number of electricity-based tube-wells. The availability of low-cost irrigation water allowed innovations in best management practices which improved the productivity. Irrigation network in AP can also be described as good as these states but in ecology it is different with the dominance of rice-rice cropping system (RRCS) or rice-pulse cropping system (RPCS). The Punjab and Haryana represent almost double paddy yield to that obtained by HHs in eastern states. Compared to eastern states, the irrigation is not the major cost towards the cost of cultivation. Depth of each irrigation is also more here than that in the eastern UP and Bihar where the irrigation water is distributed in the field through plastic pipes. Since the effective rainfall during the season is roughly 500 mm in these two states, irrigation allows long-term protection against shortage of water; but it may not last long as excess use of water is causing a drop in the water table.

The currently expanded rice area in Punjab and Haryana was previously dominated by non-rice crops and this became possible due to creation of electricity-based tube-well oriented irrigation infrastructure. The use of groundwater has increased many folds as private tube-wells in Punjab increased to 1.41 million in 2015-16. The water is extracted faster than it is replenished. According to a report in *The Economist* (22 May 2010), farmers in Bhutal Kalan (Punjab) reported 2 m decline in water table after two years and also increased fluorosis content. The Government is subsidizing the electricity for tube-wells. According to data given by *The Economist* (5 January 2019), the share of agriculture in the total energy use went up from 10 % in 1970 to 30 % in 1995. Using subsidized electricity, farmers pump more groundwater than that needed by the crop. The water table is falling on average by 0.3 m and at some places water table is falling by 4.0 m/year (*The Economist*, 25 May 2016). In addition, the electricity worth INR 14.4 billion is supplied free of cost in Punjab, which makes the supply unsustainable (Hira, 2009). Diversification as the only way to solve the problem (Johl, 1986) of declining water table, is not finding the favour of farmers. The other angle for not adopting the diversification is that the alternatives are less profitable and not supported by assured market price and procurement as for rice and wheat crop. Even if diversification happens, there could be another long-term issue. In salt affected areas of Punjab and Haryana, paddy also served the function of soil amendment in managing the alkali soils. Poor physical conditions leading to low infiltration rate and poor air permeability make these soils ideal for rice cultivation but unfit for raising other crops. Rice once established helps reclaiming alkali soils (Chhabra and Abrol, 1977). Since rice crop helped managing the alkali soils in 1970s and 1980s, the diversification that makes sense for managing water table decline, may prove risky, if alkali soil issue resurfaces in the long run. Who knows? The legacy of problem soils may return. That can happen and has not yet been studied. Proper regulation of water and its combination with optimum time of transplanting determines the growth and development of rice plant. If proper water depth is maintained at transplanting, this interaction will have a direct impact on the rate of establishment of rice seedlings (Tashiro *et al.*, 1999), leaf area index (Rai and Kushwaha, 2008), and length and number of grains including filled grains per panicle (Shah and Bhurer, 2005). Adoption of water-deficit irrigation strategy with an appropriate irrigation threshold can help save water and increase water productivity (Anjani Kumar *et al.*, 2017). With supply of required water at the time of transplanting, the rice plant sets well for producing high tiller number and shapes the development process in such a way that it makes fullest use of maturity time.

The experience of diversification programs with so many incentives also showed that new opportunities can happen only when there are enough returns. There were policy interventions (Johl, 1986) but the adoption has remained inconsistent. What will be the disincentives associated with going back to non-rice crops as diversification is also a question for innovative research. To go beyond these yield levels without any further decline in water table will require new technology (*The Economist*, 2016). The priority for now could be diversification within rice, and innovations in drip irrigation system that were demonstrated at BISA farm in Ludhiana.

3.2. Diversification within rice

The work on the adoption of varieties was analysed and included in this volume. The share of long duration rice varieties (LDRVs) has not fallen; in fact, it is still rising. Farmers in Bihar successfully used hybrids in water stress-prone areas. Here the scrutiny of varieties was done in response to irrigation levels used in three broad categories of Clusters representing Punjab and Haryana (Cluster 3), Andhra Pradesh with few districts of West Bengal (Cluster 1) and the eastern states (Clusters 2, 4, 5 and 6).

The survey showed that in Cluster 3, LDRVs represented by Pusa 44 provided an average consolidated paddy yield of 7.9 tha^{-1}. The average paddy yields of medium duration rice varieties (MDRVs) and short duration rice varieties (SDRVs) were 6.8 and 6.4 tha^{-1}, respectively, but needed 11 irrigations to reach that level (Fig. 4). Data suggested that Pusa 44 variety maintained its highest yield with the margin of only an irrigation. For getting paddy yield of 7.9 tha^{-1} from LDRVs (like Pusa 44), the farmers in Cluster 3 used 12.5 irrigations while for getting yield of 4.4 tha^{-1} from LDRVs (MTU 7029) farmers in Bihar and Eastern UP used 4.7 irrigations. Similarly, farmers growing MDRHs (Arize 6444 Gold) applied 12.9 irrigations in Cluster 3 and 3.5 irrigations in Bihar and EUP. The farmers from Punjab and Haryana had an incentive of 2.7 times more irrigations in LDRVs and 3.7 times more irrigations in MDRHs than that in Bihar and EUP (Fig. 4). Assuming the rainfall of 500 mm in Cluster 3 and 1,000 mm in Bihar and EUP, the total water flow is almost the same. If irrigation depth is same in both scenarios, the yield levels in Bihar and Eastern UP are much lower at almost same water use. That means farmers in Cluster 3 managed uncertainty better than farmers in parts of Clusters 2, 4, 5 and 6.

Despite the scope of introducing MDRVs or MDRHs, the maintenance of highest yield by Pusa 44 means that it could utilize its full potential under best management practices facilitated by assured irrigation. Reduction in water-table is seen in all the rice dominated districts across both states, which means fall in water-table might have not been caused by LDRVs alone. The adoption of Pusa 44 has remained unchanged since 1995. Very high paddy yields with 12-13 irrigations in Punjab and Haryana also suggested that rice does not require continuous submergence, if adequate water is provided at critical stages.

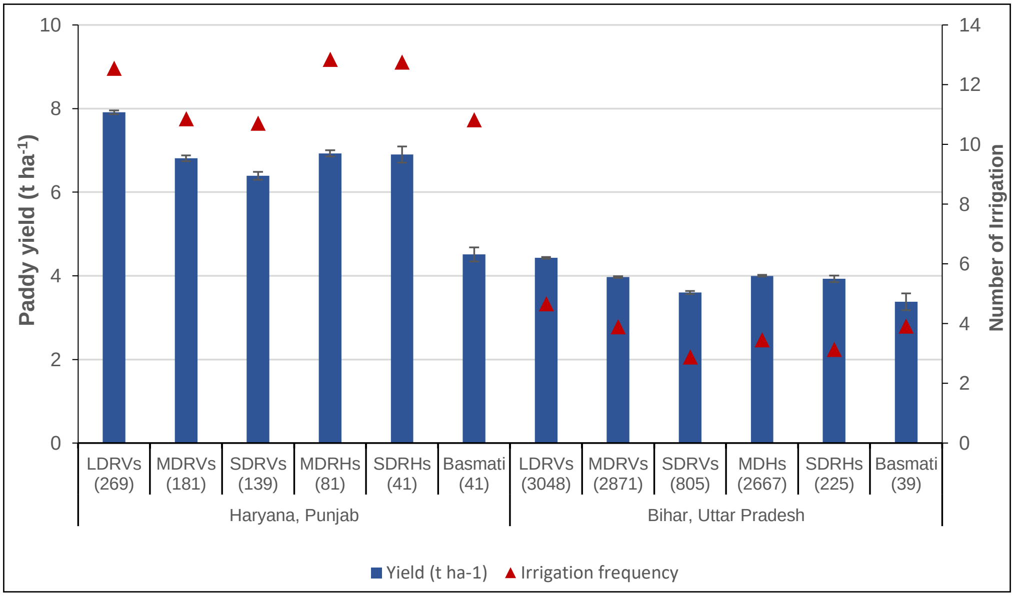

Fig. 4. Effect of number of irrigations on paddy varieties/hybrids yield (Bihar and EUP-n=9,694; Punjab and Haryana-n=805)

The variety related causes and effects could be seen in bottom 10 % HHs who had grown potentially low yielders basmati varieties (CSR 30/Pusa 1121). In this case, the profit margins due to their quality premium compensate for their low yield levels. In Clusters 2, 4, 5 and 6 survey results showed much wider adaptability of MTU 7029 (data not given), data from AP and Bihar were discussed (Fig. 5 and 6). Data did not establish whether MTU 7029, an LDRV, need more irrigation because ecologies in AP are similar. The yield levels of BPT 5204 are even better than that of MTU 7029. So, it is better to promote varieties belonging to the maturity group of BPT 5204. The difference in the number of irrigation between top 10 % and bottom 10 % was 26 % for BPT 5204 to 28 % for MTU 7029. The paddy yields of top 10 % performer HHs was 42 to 44 % more than bottom 30 % performer HHs across varieties but the difference in the irrigation frequencies was only 9-10 %. That means the differences in the irrigation levels is an issue with small percentage of farmers (10 %) but not with majority of farmers in AP (Fig. 5).

The gap between the best and worst performer HHs growing MTU 7029 or Arize 6444 is given in Fig. 6. The survey showed two distinct scenarios where the average yield of the same variety (MTU 7029) was 6.6 tha^{-1} with 10 % top performers HHs and half of that (2.1 tha^{-1}) by 10 % bottom performers. Same trend was recorded when comparisons were made between top and bottom 10 % performers (5.8 tha^{-1}

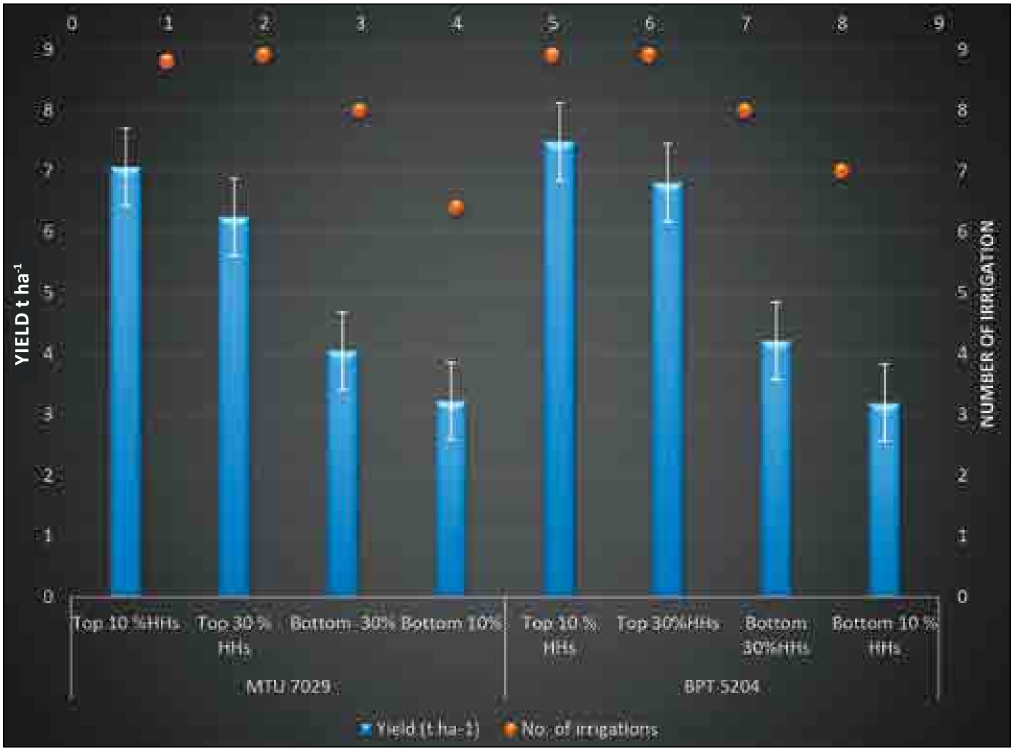

Fig. 5. Average paddy yield of two most widely spread varieties as affected by frequency of irrigation in Andhra Pradesh (n=652)

vs 2.3 tha^{-1}) growing hybrid rice. Data from the two widely spread variety/hybrids showed that in MTU 7029 the top 10% performer HHs applied 8 irrigations and bottom 10% performer HHs applied 4 irrigations - a gap of 50%. The corresponding irrigation numbers of top 10% performer HHs of Arize 6444 were 4.2 and 3.0 irrigations, a gap of 29%. Such gaps in the top and bottom 30% HHs were 39 and 25% for MTU 7029 and Arize 6444, respectively, suggesting that when the top 10 performer HHs were compared with the bottom 10% performer HHs within each varieties/hybrid, paddy yield showed large differences due to irrigation regimes. The reason for high yields of MTU 7029 compared to Arize 6444 may be associated with hydrological issues (shallow low land ecologies vs upland ecology) and maturity durations. Data on large scale yield reduction of 10 or 30% bottom performers due to less number of irrigations showed that water regimes are the most important contributing factors in realising the yield potentials of varieties or hybrids. Hybrid (Arize 6444 Gold) showed more resilience with paddy yield of 5.2 and 5.8 tha^{-1} at 4.2 and 4.3 irrigations in upland ecologies uncertainties resulting from late rains in

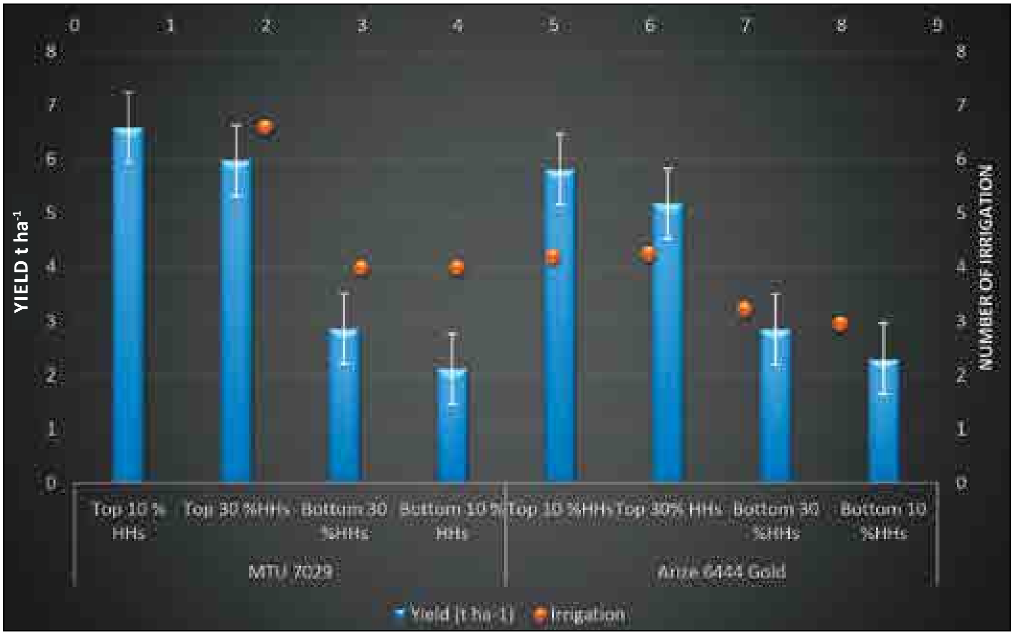

Fig. 6. Average paddy yield of MTU 7029 (LDV) and Arize 6444 (MDRH) reported by top and bottom performer HHs as affected by different irrigation frequencies in Bihar

Bihar (Fig. 6). The availability of water shaped the balance of varieties or hybrids of different maturity classes according to their genetic potential. That means irrigation is a catalyst, which if well regulated, can help make best use of genetic material and natural resources like rainfall.

Regardless of access to irrigation, the use of LDRVs will stay in the shallow land ecologies of eastern states because water remains standing till crop maturity. Farmers are unable to frequently irrigate the crop during early stages of crop growth. The yield potential of LDRVs is not harnessed because the crop remains under water stress during the early stages. That is why the difference in paddy yields between Clusters 1 and 3 on one hand and on the other hand the Clusters 2, 4, 5 and 6 is very high and the irrigation as such explains it. The relatively less average yields of LDRVs underlines a striking feature–that the same yield potential is not harnessed in eastern states.

These results revealed that the supplementary irrigation is important to both varieties and hybrids and more so for LDRVs owing to water stress-based decline in the net photosynthesis, reduced growth, and decreased number of panicles per hill (Pirdashti *et al.*, 2009). The yield gap between Arize 6444 - hybrid and MTU

7029 in the top 10% performers HHs was only 12% but this gap was 48% with a smaller number of irrigations in hybrid compared to LDRV like MTU 7029. Villa *et al.* (2012) indicated that under drought stress condition, harvest index of hybrids was more than that of the varieties suggesting that resource allocation in hybrids under water stress conditions is better than varieties. The key is to go beyond varieties to hybrids or agronomic management within rice. Silva *et al.* (2020) explained such types of yield gaps. Farmers need to cut losses in growth and development at all stages because the sink -size (Jinagchang *et al.*, 2001) is important to improve the accumulation of assimilated products in grain. Irrigation mediated effective agronomic management is required to maintain a source and sink balance for high production growth in the mid and late tiller stages of rice (Pu *et al.*, 2007).

Although long duration varieties (LDRVs) as a group, with adoption by largest number of HHs in Bihar and EUP, has highest paddy yield (4.4 tha^{-1}) but these may seem resilient because yield levels are at the highest irrigation frequency of 4.7. These types of irrigation-based responses are different in Punjab where the paddy yield of Pusa 44 (LDRV) is double to that in Bihar or EUP. With high irrigation cost, LDRVs may produce more at less profit. For most of upland ecologies especially in Bihar, medium duration rice hybrids (MDRHs) have dominated with an average paddy yield of 4.0 tha^{-1} at an irrigation frequency of 3.5. Same group of LDRVs and hybrids produced an average yield of more than 8.0 and 7.0 tha^{-1} with higher irrigation frequencies in Punjab and Haryana. The high yields from a same group of varieties or hybrids (Figs 4-6) owe much to irrigation than any other factor. The long-term path of varietal development (Das, 2012) explains that the initial trends in the varieties released by NRRI or OUAT were for high yield and adaptability for irrigated and favorable rain-fed medium lands in the *kharif*. Except for hybrids, the subsequent emphasis on early duration and stress tolerance varieties (STVs) have not produced desired results. There is very low distribution of SDRHs and SDRVs at their respective paddy yields of 3.9 and 3.6 tha^{-1} with corresponding irrigation levels of 3.1 and 2.9. The access to irrigation is vital to the future of rice especially when the climate change is causing the extremes in the rainfall patterns.

The average yield of 5.0 to 5.8 tha^{-1} was recorded with 10 or more irrigations, but the number of respondents did not exceed 5% even in Bihar. According to an article in India climate change (https://indiaclimatedialogue.net/2019/01/16/declining-rainfall-places-farming-at-risk-in-bihar/), the declining rainfall with reduction in rainy days is a serious concern in Bihar. The state has recorded less than normal rainfall in the past seven years. Out of about 1,100 mm rainfall, it received 21, 30, 17, 28, 3 and 9% deficient rainfall in 2012, 2013, 2014, 2015, 2016 and 2017, respectively. Rainy days in the state have reduced to 37-40 from the long-term average of fifty-five

(55); that means number of dry days increased over the years. This is more serious when small and marginal farmers purchase water for irrigation by hiring diesel or electric pump sets. Irrigation, therefore, is the critical constraint that increases the cost of cultivation. Rainfall is more than 1,000 mm and studies showed that the decline in water-table is not a major issue. Therefore, the groundwater sources are not depleting as fast as in other ecologies of IGP.

Data from these two states indicated that a small push to improve the access to irrigation though electricity-based tube-wells or making the fuel cheaper can provide a strong leverage for making other management options more feasible. That would help transitioning late transplanting to early transplanting and supporting initial rice growth.

With saving in irrigation, SDRHs also have the advantage of intensifying the rice-based cropping systems in the IGP. With SDRHs or even MDRHs, both yield per unit area and the cropping intensity that depend on the accumulated rainfall and irrigation from the beginning (Naylor *et al.*, 2001; Koide *et al.*, 2013) to harvest of rice, also contribute to food security (Schnepf *et al.*, 2001) especially in the EIGP. Farmers in Clusters 1 and 3 were able to deliver best results even under extreme climate (Dash *et al.*, 2009), but not in the Eastern states. The yield levels from the same group of varieties or hybrids in Eastern states (mostly in Clusters 2, 4, 5 and 6) are much lower than that in Clusters 3 and 1. It will not reach to the level of Cluster 3 or even Cluster 1 until low-cost irrigation is made available to farmers. Alternate crops still have high degree of uncertainty about sustainable profits. Diversification within rice can help. Following four interventions would need further research for irrigation management in rice-based cropping systems.

- Introducing SDRHs in upland ecologies with limited irrigation as in Bihar, and EUP with better scope of intensive cropping systems like rice-mustard-moong bean at less irrigation cost. The SDRHs with assured irrigation as in parts of Haryana and Punjab have better scope of rice-potato-wheat or rice-mustard-mung bean or rice-wheat-moong bean.
- Continued adoption of LDRVs in eastern states is expected. The agronomic management, if properly applied would result in improved water productivity and paddy yield. MDRHs offer opportunities to cope with water scarcity under water stress based upland ecologies.
- Basmati rice will provide some protection against decline in water-table in Haryana and Punjab because of low water use. In addition these varieties need lesser nutrients and even lesser use of herbicides because of their high competitive ability against weeds.

3.3 Improving water productivity in rice

The data from this survey revealed that varieties released before 1995 are still performing better than that of newly released varieties. However, with same yield potential of best performing varieties farmers could manage to get high yields in Clusters 3 and 1 but not in Clusters 2, 4, 5 and 6. The valuation between Cluster 3 and Clusters 2, 4, 5 and 6 or between Clusters 1 and 3 is quite different. The uncertainties associated with rainfall are unavoidable in all Clusters. Assuming no difference in the use of best of varieties, which is almost same in both scenarios, 31 % less yield among top 10 % performers in the eastern states is because of poor access or costly irrigation. Irrigation is prerequisite for facilitating other management options which in turn stimulate growth (Jinagchang *et al.*, 2001; Pu *et al.*, 2007; Pirdashti *et al.*, 2009) leading to large yield variations. The irrigation facilitated agronomic management can help lifting the yield potential of existing varieties or hybrids. On an average, the paddy yields of top 10 %, top 30 %, bottom 30 % and bottom 10 % HHs in Cluster 1 at 9.9, 10.1, 10.2 and 9.3 irrigations were 7.6, 6.7, 3.7 and 2.9 tha^{-1}. The corresponding yield levels in Cluster 3 at 14.3, 13.6, 10.4 and 9.3 irrigation levels were at 8.7, 8.2, 5.4 and 4.2 tha^{-1}, respectively. In Clusters 2, 4, 5, and 6 at the irrigation levels 5.3, 4.8, 3.4 and 3.3 (Fig. 7) yields were 6.1, 5.4, 2.8, and 2.1 tha^{-1}, respectively. Top 10 % performers in Cluster 3 produced 15 % higher paddy yield than top 10 % performers in Cluster 1, and 42 % higher yield than the top 10 % performers in Clusters 2, 4, 5, and 6. This corresponding difference was 19 and 45 % in top 30 % performers. The difference between top 30 % best performers and bottom 30 % performers was 84 % when compared within Cluster 1 but it was almost 150 % when compared with 4 Clusters (2, 4, 5 and 6) of eastern states. The corresponding yield levels within 30 % top and bottom performers in Cluster 3 had a margin of 51 % but this margin was almost 200 % when compared with 30 % bottom performers in Clusters representing eastern states (Fig. 7). The amount of rainfall is accounted for water inflow but its distribution is not accounted.

The survey also found that yield gaps are more due to interaction of irrigation and N levels with low paddy yield of bottom 10 % HHs; it was owing to a smaller number of irrigation and less dose of N. These interactions do not appear to be consistent across Clusters. A relook at the interaction of water and nutrient management is required. The favourable productivity gaps happened from the benefits of assured irrigation in Punjab and Haryana, and because of timely transplanting and timely application of fertilizer but it did not happen in the eastern states (Fig. 8). The water management and addition of more nitrogen rather than P and K improves the growth of rice serves as an important asset when the monsoon rains are at their peak (July-August). This part of crop management sets the stage and is validated in Figs. 7 and 8. The approach of finding water management solutions through varieties alone did

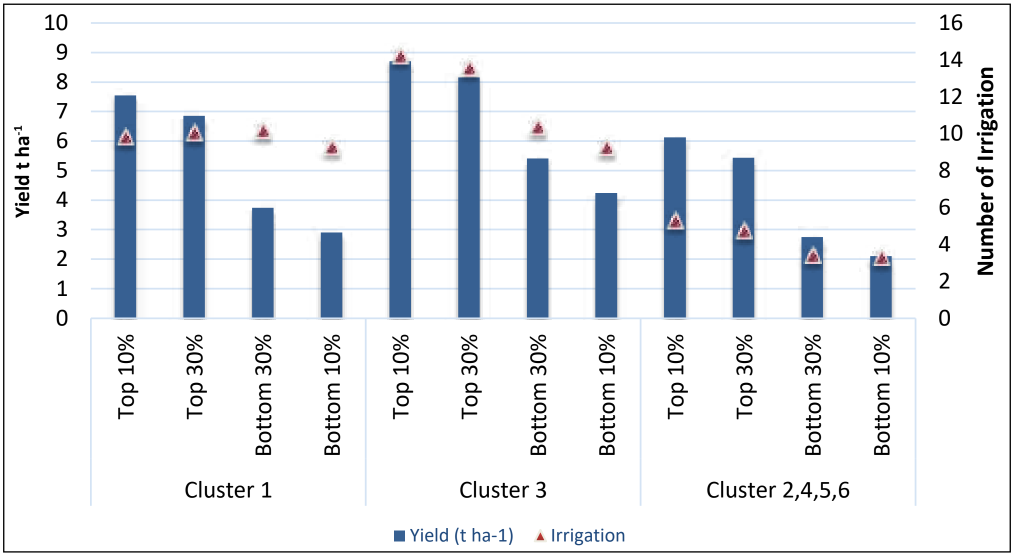

Fig. 7. Influence of number of irrigations on average paddy yield in various Clusters

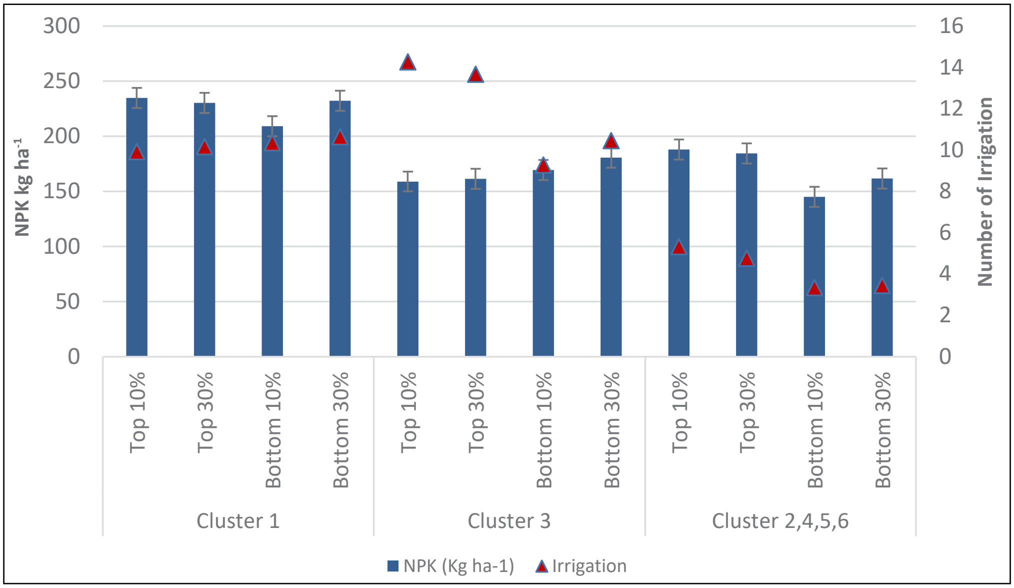

Fig. 8. NPK application rates and number of irrigations applied by different households in various Clusters

not work well (Figs 4-6). Keeping rice fields in flood like situation that exists in Cluster 1 showed beneficial effect on soil organic matter build up, P and Zn availability and biological N fixation (Kirk, 2004).

Underperformance of the best varieties in the eastern states even with the best-case scenarios– having better access to canal irrigation conditions– is because most of the water flows during a short season when it is usually needed less. The water productivity can be increased by focusing on the bottom half HHs in two Clusters (1 and 3) and all HHs in Clusters 2, 4, 5 and 6. Moreover, the canal irrigation, wherever available, is very well regulated in Punjab, Haryana, and AP but it is unregulated plot to plot irrigation in eastern regions. For example, farmers wait for the arrival of monsoon rains before seeding rice nurseries and start transplanting late in the season that is already late for LDRVs or MDRVs of 140-145 days maturity, which are more suitable for these regions. Even after transplanting, 2-3 cm water is not maintained for better establishment of nurseries and reduction in weed emergence. This leads to poor early growth and dominance of weeds from the beginning of growth cycle.

If affordable irrigation is made available, one or two extra supplementary irrigations will be needed because these ecologies already have excellent water resource base and enough rains to grow a healthy rice crop. For example, one or two supplementary irrigations will allow timely transplanting. It ensures that vegetative growth occurs during a period of satisfactory temperatures and high levels of solar radiation, ensuring that the grain filling occurs at right temperature during day and night (Farrell *et al.*, 2003). Drought at vegetative stages delays flowering, reduces tiller number and the dry matter production (Lafitte *et al.*, 2006). Since water in Bihar and EUP is applied through plastic pipes, the depth of irrigation is also always lower than the application of water by gravity flow.

Rainfall from June to September accounts for over 75 % of the annual precipitation (Chand and Raju, 2009). In one study (Aryal, 2012) conducted in Nepal, the total amount of rainfall in the study area over study period (23 June to 30 September 2005) was 549.6 mm. The total crop water requirement of rice for the same period in the same area was 711.5 mm. These data sets also suggested the need for early and late season irrigations. The rate of evapotranspiration showed an increasing order from June to September ranging from 3.43 mm/day in June to 19.57 mm/day for September, respectively. The water required by crop was in an increasing order reflecting that more water is required with the advances in crop growth after transplanting. The rice crop in many cases struggles to make up the growth affected by shortage of irrigation in the beginning of crop and at successive developmental stages of rice. In September, the amount of rainfall was lesser than the crop water required for rice (Aryal, 2012). Almost similar trends were reported from Pakistan. The gross inflow (sum of canal water, groundwater and rainfall) may be 1,458 mm. The crop evapotranspiration was 534 mm indicating a large excess in water supply. This was due to large volume of deep percolation and then in ponded water conditions, which are common in the second half of rice season; it showed that about 60 % of water flow was not used as evapotranspiration (Jehangir *et al.*, 2007).

Another way is to synchronize growing cycle with low water demand (Chahal *et al.*, 2007). Irrigation here forms a buffer against rainfall variability, and it can help improving the water productivity, i.e. peak growth and development should happen in July and August when two-thirds monsoon rainfall occurs (Seckler, 1996; Nene and Nalini, 1997).

The water productivity (WP) is very low in Bihar. This happens even under good soil and water resources. Based on panel data of 20 years (1991-2010), the WP of 11 Bihar districts was 0.22 kg/m^3, it is very low (Sharma *et al.*, 2018) compared to Haryana (0.40 kg/m^3), and Punjab (0.57 kg/m^3). More rice must be produced from the viable water resources. In WP these differences are due to a combination of socioeconomic conditions, irrigation facilities, access to low cost electricity-based irrigation, credit, and market facilities. The intensity of puddling is low in Bihar than that in Punjab or Haryana. Mean water-input-based productivity under one, two and three puddlings under Punjab conditions were 0.32, 0.39, and 0.43 kg/m^3 (Arora *et al.*, 2006). In well-regulated conditions in Echuca, Australia, it ranges from 0.70 to 0.75 kg/m^3, and in USA 0.88 to 1.44 kg/m^3 (Zwart and Bastiaanssen, 2004). The contrast in water productivity is not solely because of variable and uncertain monsoon rains but a consequence of lack of access to low cost irrigation in the eastern states.

Data showed that in the best (Cluster 3) and worst performing Clusters (2, 4, 5 and 6) there is a contest between annual grasses and perennials with dominance of *Cyperus rotundus* and *Cynodon dactylon* in case of bottom performers. These two weeds still dominate in Cluster 3 because of poor crop growth due to less frequency of irrigation and relatively less dose of nitrogen but more dose of P and K. The dominance of annual grasses like *E. cruss-galli* and *Echinochloa colona* is outcome of good irrigation management with support of enough nitrogen that favoured growth of rice at the cost of low-growing perennials. In the ecologies of AP and Odisha conditions of high temperature, *Cynodon dactylon,* being a C4 plant, always gets a competitive advantage over rice (Ziska and Bunce, 1997). Specific to these ecologies, this weed is putting up fierce competition during pulse phase in rice-pulse cropping system (RPCS) or rice-fallow cropping system (RFCS). In addition to cropping system, the simple weed flora (Zhang *et al.*, 2017) is dominated by these two annual weeds (Table 1) on account of frequent irrigations and more use of nitrogen (Fig. 8). As the season advances, the initial set back on the growth of rice multiplies with farmers adding fertilizer in a weedy situation and it is further compounded with early cessation of rains during the grain filling stage. Overall, biotic losses in agricultural systems can be substantial, and can exceed 50% depending on the cropping systems (Oerke, 2006). The water management is considered as the part of weed management as the ponded water prevents weed development. This will help reducing herbicide use and the labour use. Less number of irrigations may add to the weed pressure of different types, which is difficult to control by herbicides. In practice this is not happening in the eastern states because the maintenance of ponding water is difficult at the time of crop establishment. The inherent strength of rainfall in this Cluster is not captured by a small push towards supplementary irrigation in the early stages.

The question is what supplementary irrigation means to these farmers vis-a-vis timely transplanting, nutrient management, weed management and the whole set of IPM issues.

- Increased emphasis on providing field level electricity will solve this problem in the long run because farmers will start investing in tube-wells. It has started happening now in Bihar.
- Irrigation facilities and irrigation depth need to be improved so that farmers can increase the area under early transplanting when there is no risk of flood like situation and the growing conditions for rice are better. The aim is to reduce the cost of cultivation and improve the precision in agronomic management in rice where water management is the key variable. Some water saving practices like field bunds have better water control and improving rainfall productivity especially in shallow low land ecologies.
- In addition timely release of canal water, financial support for farmers especially during the crop establishment and initial growth phase, creating surface irrigation infrastructure, facilitating water storage facilities or lifting water from the overflowing canals during rainy season are some other initiatives, which can help improving rainfall productivity.
- In Clusters 1 and 3, the micro irrigation can also be matched with supplementary irrigation. The success of micro irrigation in rice was demonstrated at BISA farm in Ludhiana. It could be a part of future agenda for well-developed ecologies like Punjab, Haryana, and AP.
- The crop establishment methods including direct seeded rice (DSR) under conventional tillage and machine transplanted rice (MTR) offer better scope (Madhulika Singh *et al.*, 2020; Komboj *et al.*, 2014) of improving the water productivity in rice by utilizing pre-monsoon rainfall

or supplemental irrigation (Kar *et al.*, 2018). Water saving from DSR comes only if pre-sowing irrigation is given and followed by good seedbed preparation. The soil mulch created by tillage helps saving water loss.

- The conjunctive management of rain, surface water and groundwater are some other important priorities especially at the crop establishment. The water productivity can be increased by conserving the rainwater (Joshi and Kar, 2009) on one side and improving its productivity by agronomic management of rice on the other side. Transferring of responsibility for the operation and maintenance (O&M) of irrigation schemes to groups of farmers including Water Users Associations (WUAs) has brought obvious benefits in AP (Peter, 2001). This should be adopted by other states as well.
- Alternate wetting and drying should be tested in simple formats, which farmers can understand. System should support efforts to reduce excess use of water by drawing up a plan to decrease number of irrigations by identifying stages where rice is least affected by deficit irrigation. The system can endure, if the water productivity is improved by producing "more from less water" by focusing on time management for supporting intensification, diversification, and drip irrigation. System must give a serious thought on strategies, which can be practiced by farmers without sacrificing the profit margins.
- The ecologies of eastern states must push the concept of cropping system intensification. The rice crop must create more space for other crops. The residual moisture from rice phase should be effectively used for intensification.

3.4 Improving access to irrigation in Eastern states

In India, 58% of the rice area (Mandal *et al.*, 2019) is irrigated out of a net irrigated area of 66.1 mha in 2012–13. Rice in the eastern region is either rainfed or irrigation facilities are poor and costly. Despite the presence of ample resources like good soil quality and water resources, the productivity of rice is quite low (Najmuddin *et al.*, 2018). Based on the article in *Groundwater Yearbook* (GWYB) published in 2014, groundwater development in the eastern Indian states, viz. Bihar, Chhattisgarh, Odisha and West Bengal, remains low (22–43%), which should be enhanced to the level of the country's average (61%). Some HHs are applying irrigation by purchasing it at the cost of INR 100-120/hr from other farmers (Singh and Singh, 2000; Bhattarai, and Narayanamoorthy, 2003) having diesel pump-based bore-wells. Hydrological conditions in Bihar and in other eastern states can support considerable area under irrigation (Wood, 1999). According to the statistics provided by the Ministry of Water Resources, a total of 22.94 billion cubic meters (BCM) of water is potentially available annually for irrigation in Bihar, while the net draught is around 10.63 BCM/year (Chatterjee and Purohit, 2009; Rajmohan and Prathapar, 2013). One-acre irrigation may take 10 -12 hours. The estimates of National Sample Survey Organisation (NSSO, 1999) of 1999 showed that 40% HHs depend on their wells, 27.2% HHs on purchased irrigation and 32.8% on Government sources including canal irrigation. Overall, tube-wells account for approximately 62% of the total irrigated area. Poor infrastructure, inequitable distribution of irrigation water, inadequate numbers of tube-wells, and ineffective use of rainwater (Sharma *et al.*, 2018) are some reasons for low yields in rice. Despite abundant water resources, the ratio of gross irrigated area (GIA) to gross cropped area (GCA) on an average was only 12% per year during 1980- 81 to 2004-05 in eastern states, compared to 36% at the all India level, 93% in Punjab, 40% in Andhra Pradesh, and 29% in West Bengal during the same period (Goyari, 2008). The irrigation potential is different in Odisha, West Bengal, and Chhattisgarh. Very small percentage of farmers are involved in rainfed agriculture in Bihar and EUP but in other Eastern states about 28 to 57% HHs are having rainfed farming. Even with highest rainfall ranging from 1,350 mm to more than 1,500 mm in Odisha, the average paddy yield without any irrigation was 3.8 tha^{-1}. In West Bengal and Chhattisgarh, the corresponding paddy yield was 3.5 and 4.0 tha^{-1}, respectively. Even with sufficient rains, this cannot provide high yield as a standalone water resource for rice. The spread of tube-well/bore-well irrigation can make a big difference. Farmers who applied 1 to 3 irrigations could get an increase in paddy yield by 0.5 tha^{-1} in Odisha and Chhattisgarh and by 0.9 tha^{-1} in West Bengal.

As discussed earlier the decrease in water productivity is attributed to insufficient irrigation resulting from underutilization of canal and groundwater (Figs 9-13) due to limited access to electricity at field level. For example, the response of rice with large difference in the paddy yields of best (Clusters 3 and 1) and worst performing HHs (Clusters 2,4,5, 6) indicated that irrigation is central to achieve enhanced rice productivity because there is no orderly use of rainfall in the eastern states, which is almost equal to the total water requirement of rice. According to CGWB (2011), the groundwater development of Bihar (43%), and West Bengal (40%) are not exceeding 50%. The overall average annual rainfall of this state is 1,232 mm but the average productivity is low (Behera *et al.*, 2013). The northern part of Bihar receives a maximum rainfall of 1,400 mm. West Bengal receives an average annual rainfall varying from 1,211 mm (Bankura district) to 3,067 mm (Cooch Behar district) (GWIB-CGWB 2007). As an example of eastern states, Bihar has extensive network of canal (Fig. 9) and the number of tube- wells (Fig. 11). The length of canal in each district of Bihar is given in Fig. 10. The groundwater in Bihar is developed through dug wells and shallow tube-wells (CGWB 2006). According to MoEF (2007), surface water irrigation contributed to 2.6 Mha and groundwater irrigation to 0.96 Mha in Bihar

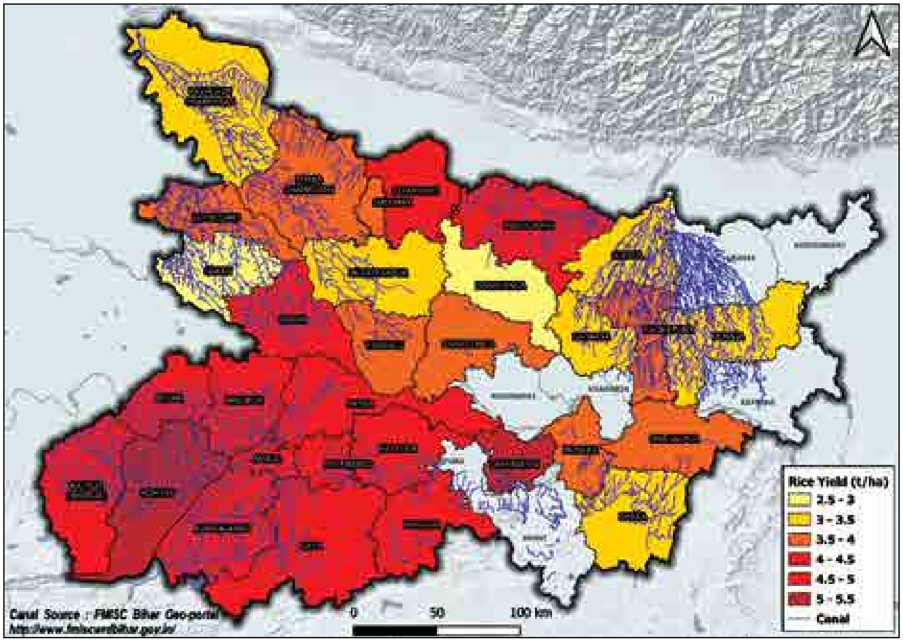

Fig. 9. Representative map of canal irrigation and the paddy yield trends across Bihar state (n=7,141)

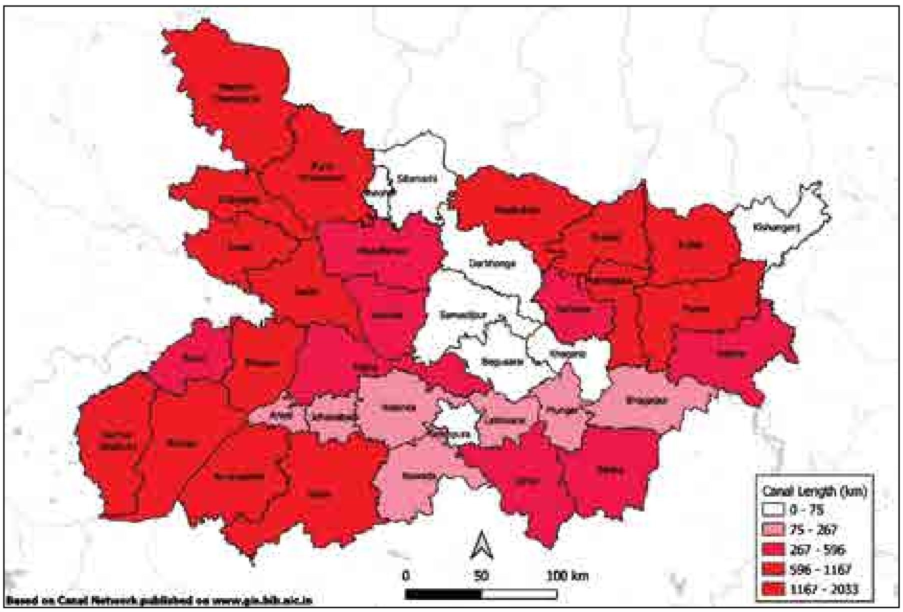

Fig. 10. District wise total canal length based on the GIS data given on www.gis.bih.nic.in

until 1991. The canals and tube-wells contribute 38 and 31%, respectively. Even with an extensive water resource distribution of canal water needs improvement. The Rohtas and Aurungabad districts in Bihar are co-sharer of water of seasonal canal but land under Rohtas district gets regular water because of its low land ecologies, and Aurangabd gets lesser water because the command area is elevated, and water does not reach regularly. Similarly, in the East and West Champaran district, Gandak Area Development Agency (GADA), Bihar, was created in 1975 for integrated development of the Command area of the Gandak project in north-Bihar. Despite the creation of massive irrigation facilities, productivity of major crops and in turn the economic benefits to farmers in the Command area, did not commensurate with the irrigation potential. In areas where water is made available (head), the farmers tend to apply excessive irrigation while water is not available to the tail-end areas. The Gandak river water is diverted into three canals Trivani, Trihut and Doon depending on the rainfall. There is a need to develop catchment area for the area in Balmikinagar on the Nepal border. The Araria, Purnia, Madhepura and Supaul districts are linked with river but the canal link system is not systematic. There is a problem of excess water

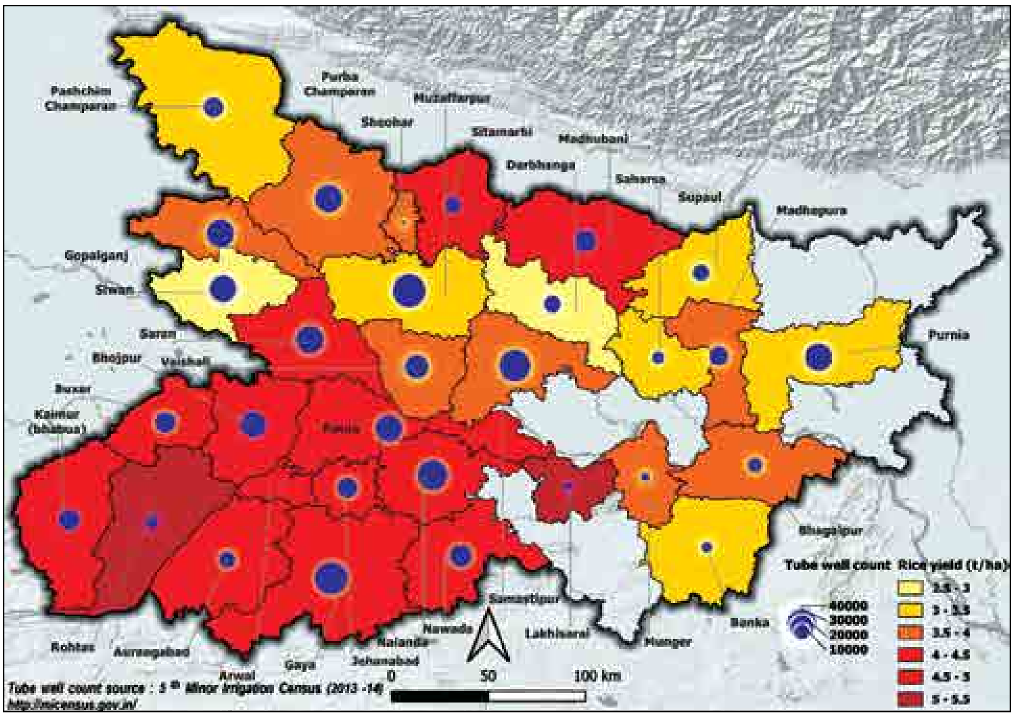

Fig. 11. Development of groundwater based on installation of number of shallow tube-wells and bore-wells in different Bihar districts and the paddy yields ranges of surveyed farmers (n=7,141).

in some areas and of shortage in some areas. This explains why Rohtas district is the rice bowl of Bihar with highest yield. There is a huge network of canal irrigation but the operation, maintenance and modernization including de-silting of canals and distribution channels is necessary to avoid flooding and to improve the distribution of water (Fig. 10). Owing to very small holdings and poor economic conditions of farmers (Bhattarai and Naraynamoorthy, 2003; Alauddin and Sharma, 2013), the groundwater irrigation will depend on access to low cost energy for pumping water. The high energy price discourages them to extract sufficient groundwater for irrigation, leading to low water productivity (Anonymous, 2008).

Rodell *et al.* (2009) concluded that groundwater use for irrigation in North-western India (Fig. 12) is not sustainable. The water-table over this part of India is declining by 4 cm/year.

The yield gap between and within states is huge. In Punjab top 10 % performers HHs have reached a yield of 8.9 tha^{-1}. On the contrary, the paddy yield of bottom 10 % HHs is 2.1 tha^{-1} in Bihar, which is 4 times lesser than that of the best Punjab farmers. However, this gap is only 1.45 times when top 10 % farmers are compared between Punjab and Bihar. Despite favourable water resource base in Clusters 2, 4, 5, and 6, it is not possible to distract attention from the weakness of low rice at high rainfall.

According to Prasuma *et al.* (2018) the state of AP is divided into 13 administrative districts spread across two unofficial regions namely Coastal Andhra and Rayalaseema. Coastal Andhra is divided into nine districts viz. Srikakulam, Vizianagaram, Visakhapatnam, East Godavari, West Godavari, Krishna, Guntur, Prakasam, Sri Potti Sri Ramulu Nellore. Rayalaseema comprises 4 districts, viz., Chittoor, Kadapa and Anantapur. Three districts from Rayalaseema and 6 districts from Coastal Andhra were included in this survey. The irrigation sector was canal irrigation till 1980s. The distribution of canals and the average paddy yield trends are given in Fig. 13. The transformation to alternate sources of irrigation started happening after 1990s. Now groundwater including tube-wells and wells is the major source of irrigation which covers 49 % of net irrigation (tanks - 0.3 million ha, canal - 1.4 million ha, groundwater -1.1 million ha). The state created the irrigation potential of 4.84 million ha through 90 irrigation projects and approximately 13,000 tanks.

According to Jana (2017) in West Bengal the canal irrigation covers 0.25 Mha in Birbhum, Murshidabad, and Burdwan in Mayurakshi project, 0.48 million ha in Birbhum, Bankura, Midnapur and Howrah, 0.35 million ha in Bankura in Damodar Valley project, Midnapur and Hooghly in Kangsabati project. In addition, 0.92 million ha is expected in Coochbehar, Jalpaigur, Uttar Dinajpur, Dakshin Dinajpur, Malda

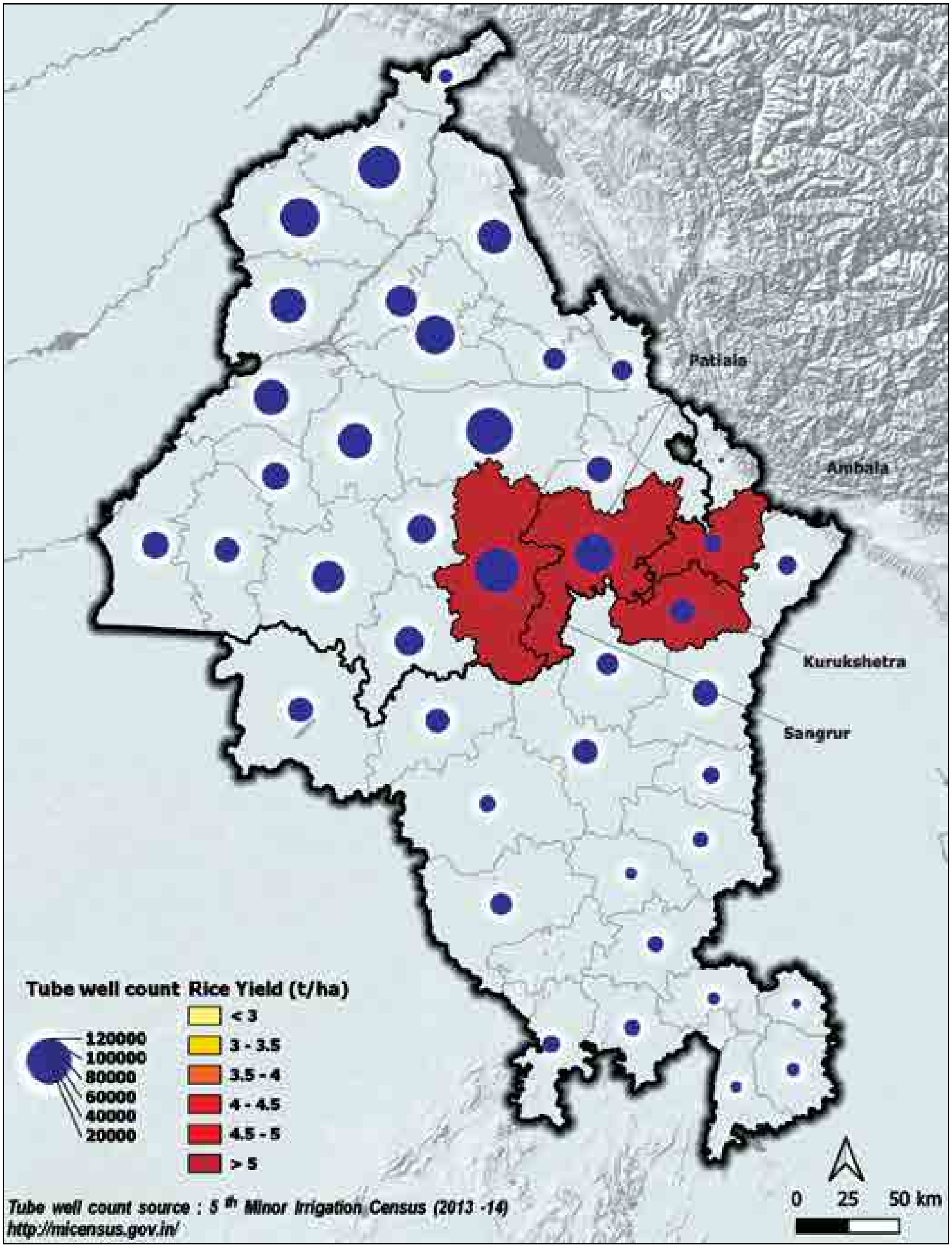

Fig. 12. Number of electricity-based tube-wells including shallow, medium and deep tube-wells in different districts of Punjab and Haryana. The bigger the circle the more the number of tube-wells.

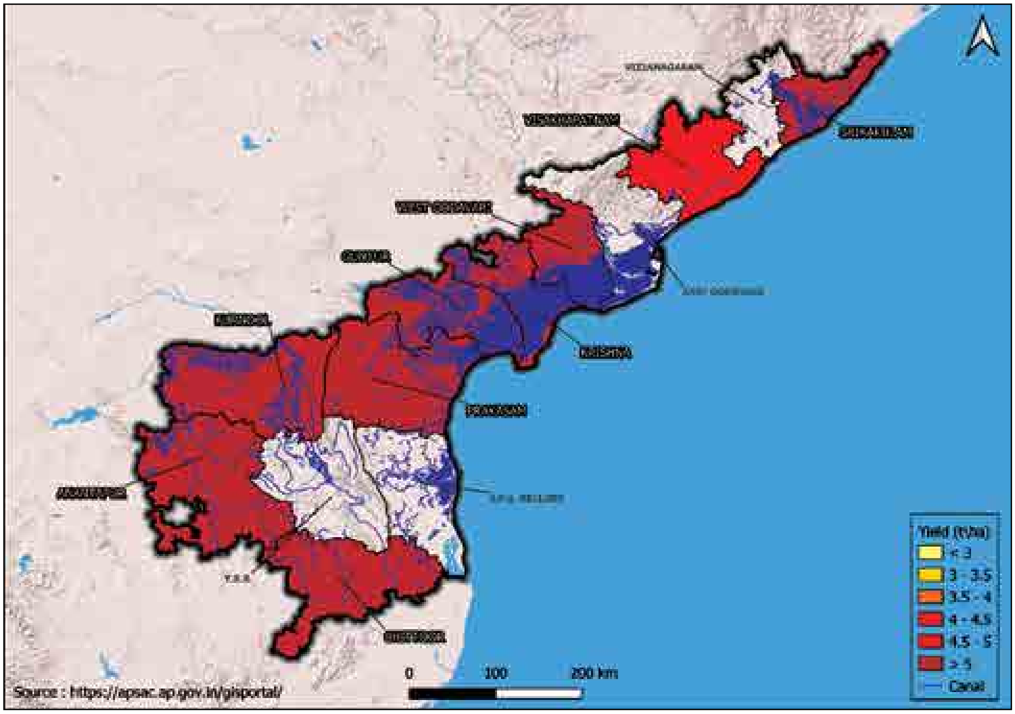

Fig. 13. Canal distribution in different surveyed districts and paddy yield in AP

and Darjeeling in Teesta Barrage project. Per capita irrigated area in West Bengal is 36 ha/1,000 population against 51 ha/1,000 population on All India basis. In West Bengal 54 % of gross cropped area is irrigated and out of which 55 % is irrigated by wells. Owing to poor electrification, the development of tube-well irrigation is 39 % compared to 53 % on All India basis. Based on all major and minor irrigation projects in West Bengal, 1.1 million ha is canal irrigated, 1.2 million ha is tube-well irrigated, and 0.25 million ha is tank irrigated.

In Odisha, the district of Puri tops the list with an irrigation intensity of 80.8 followed by Bhadrak district with 71.9. The Balasore district is at the third position (66.9) while the district of Balangir has the lowest intensity value (20.6). About 59.0 % of the net area sown is benefited by irrigation. The gross irrigation potential created till 2013-14 from all the sources is 3.6 million ha during *kharif* with potential of 5.0 million for *kharif* and 2.4 million ha for *rabi*. Its climate has a temperature suitable for year-round cropping, but still rice-fallow cropping system is more prevalent. Compared to irrigation sector growth, the agriculture growth is slow in Odisha. There is a gap between the potential created and its utilization. The total cultivated land of the state is 6.2 million ha, out of which 2.9 million ha (47%) is high land, 1.6

million ha (28 %) medium land and 1.2 million ha (25 %) low land. The normal rainfall is 1,451 mm. It is frequently susceptible to floods and cyclones. Tanks, an important source of irrigation, are mostly rainfed. Out of surveyed districts, Puri, Bhadrak and Balasore are well irrigated whereas Nuapada is the least irrigated (Pattanayak and Mallick, 2018). The average rainfall of Chhattisgarh is 1,300 mm. The variability of rainfall directly affects paddy yield. The irrigated area is 34 %. The *beushening* (*biasi* in Chhattisgarh) method of crop establishment is quite common but the highest yield was reported from puddled transplanted method.

Conclusions

In 2017 and 2018, the landscape diagnostic survey (LDS) was conducted across eight states covering Northwest (Punjab, Haryana), Eastern states (Bihar, Eastern UP, West Bengal, Odisha, and Chhattisgarh) and Southern state (Andhra Pradesh). Data on the adoption of irrigation practices and their effects on rice were collected by covering 16,162 data points. Punjab and Haryana with rice -wheat cropping system (RWCS) and Andhra Pradesh with rice-rice (RRCS) or rice-pulse cropping system (RPCS) but have assured irrigation as common factor with each other. All eastern states (Bihar, EUP, West Bengal, Odisha and Chhattisgarh) have limited access to low cost irrigation and practice rice based cropping systems. All eight surveyed states were divided into 6 Clusters based on the agronomic and economic practices followed by the farmers. The accumulated rainfall data (June-October) was also included to classify the Clusters in the surveyed states. The eastern states representing 4 Clusters (Clusters 2, 4, 5 and 6) have not performed well with an average paddy yield ranging from 4.0 to 4.3 tha^{-1} compared to an average yield of 6.3 in Cluster 3 (Punjab and Haryana) and 5.0 tha^{-1} in Cluster 1 (Andhra Pradesh and part of West Bengal). There was no positive link between high rainfall and more paddy yield. The contrast in water productivity in different states is not solely because of variable and uncertain monsoon rains but a consequence of lack of access to low-cost irrigation in the eastern states. High productivity and risk-free rice cultivation in Punjab, Haryana and AP has brought in the second-generation problem of falling ground water-table. All these states need to rebalance their water use by embracing diversification, which is also not risk-free. Diversification within rice and efficient irrigation management with new technologies should be taken up in these states. In the eastern states, the poor access and the high cost of irrigation made farmers more vulnerable to variable monsoons. If the shallow low land ecologies in these states have better access to low cost irrigation, they could be more productive than states with assured irrigation and low rainfall. Lack of irrigation disrupts all agronomic management factors, which may help improving yield and water productivity. The reassessment of irrigation network, digitization of services that links the canal irrigation network, prediction models for monsoon arrivals and crop insurance can help farmers target management options. The best agronomic management, which is catalysed by irrigation, is the most important factor in addressing the yield gaps and water productivity between the eastern states including Bihar, EUP, West Bengal, Odisha, and Chhattisgarh on one hand and Punjab, Haryana, and AP on the other hand.

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2.4 Implications of techniques of crop establishment on rice cultivation across states

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KEY MESSAGES

- The work on the introduction of new crop establishment (CE) methods was not highly impactful. It reflects a pattern where the paddy yields were not more than the existing method of puddled transplanted rice (PTR).
- Efforts to replace PTR with DSR (direct seeded rice) can be more successful if it is drill seeded in a conventionally tilled field after pre-sowing irrigation or sufficient rainfall. Soil mulch created by proper field preparation, does not let moisture escape from the dry soil. Enough moisture stays underneath topsoil. Farmers do not need irrigation for 2 to 3 weeks after sowing, saving on water. If upper surface stays dry, the weed emergence will also reduce, as a consequence.
- The state-run schemes should recognize the fact that some CE methods like direct broadcast seeding of rice (DBSR) followed by *beushening* (DBSRB) is less productive and getting costly. Direct drill seeded rice could be an alternative option.
- Transplanting of appropriate/optimum-age rice seedlings, is conducive for production of tillers, which is a basis of yield determination in rice. In general, transplanting of 16- to 20-day old seedlings results in better crop growth and higher paddy yield.
- Monsoon uncertainty leaves farmers indecisive and unprepared for preparation of rice nurseries. As a result, they fail to raise nurseries "Just-in-time". On the

onset of monsoon i.e., sudden rain, nursery availability is limited due to too much demand thus, affecting timely establishment of rice. Therefore, the need is to focus on timing and rationalising the way nurseries are raised. It can be aptly managed through creation of private service providers (PSPs) and/or promotion of rice nursery entrepreneurs (RNEs) to ensure quality nursery at affordable price for timely crop establishment.

- Based on data of few states, the seed-rate required for rice nursery is much lower than that recommended by most state agricultural universities (SAUs). This is an exemplary learning from farmer-led innovation and practice based on consistent and wide-scale field evidence. Such favorable and cost-saving changes that can be implemented and may lead to departure from the prescriptions, need to be identified and widely demonstrated by the KVKs as a part of bottom-up approach for technology development.

1.0 Introduction

Rice is traditionally grown by transplanting 4- to 6-week-old seedlings into puddled fields, which are prepared by ploughing under ponded water conditions. Puddling, a soil management operation, reduces soil permeability, controls weeds, facilitates transplanting of rice seedlings, reduces the deep percolation losses of water to maintain anaerobic conditions (Kalita *et al.*, 2020) that increases the availability of iron and phosphorus required for growth of rice. Results of several studies (Anonymous 2006) indicated that nearly 30% of the total water used (1,400-1,800 mm) in rice culture is consumed mainly in puddling and transplanting operations. A key concern, therefore, is –how to reduce the water requirement in rice culture.

In India water is increasingly becoming scarce and seasonality of transplanting operations also creates labour shortages. The continued puddling over decades has led to deterioration of soil physical properties (Kukal and Aggarwal, 2003) through structural breakdown of soil aggregates and capillary pores, and clay dispersion. Puddling forms a compacted layer (plough-pan) that resists root penetration and growth of the crops such as wheat or other crops in rotation. Relying heavily on manual labour, which is getting scare and costly, there is a need to shift the focus towards mechanical methods of CE. These issues are there since late 1990s.

One way to reduce water and labour demand is to grow direct-seeded rice (DSR) instead of the conventional puddled transplanted rice (PTR). In current DSR practices farmers face several problems such as of poor germination, high early seedling mortality during a rainfall event requiring gap-filling in uneven fields, weed infestation, non-availability of effective post–emergence herbicide molecules for complex weed flora, and shifts in weed flora in favor of some annual grasses not controlled by existing postemergence herbicides. In this system rice is grown like any other upland crop with seed placed in the soil by seed-cum-fertilizer drill with or without seed bed preparation. Zero-till DSR was attempted in the beginning but it is not sustainable in the long run. Direct seeding has advantages of faster and easier planting, reduced labour, earlier crop maturity by 7-10 days, and higher profits in areas with an assured water supply. The water saving generally comes with conventional DSR, where soil mulch is created after pre-sowing irrigation and field preparation.

2.0 Methodology

Rice establishment methods were surveyed to check several changes in the manual crop establishment methods from *beushening* to manual PTR to mechanized system involving DSR sown with machine, and the machine transplanted methods with or without puddling. The survey covered rainfed single crop system in Odisha and Chhattisgarh to multiple cropping system in states with limited or assured irrigation. Two contrasting CE methods– direct seeding or transplanting and their improved versions– were surveyed across eight states. The new approaches evolving through research and extension efforts were surveyed to understand the yield responses under different methods. Closing yield gaps by shifting CE from random crop establishment to line CE were also evaluated to assimilate whether the change has happened or not. A total of 7 HHs were surveyed from 30 villages in each district. These respondents were from all socio-economic categories including marginal, small, medium, and large farmers based on land holdings. The interventions like seed rate and nursery management facilitating better adoption of above CE methods were also included in the survey to explain how some of these interventions may reduce cost and facilitate adoption. The KVK network had already participated in the concept of community nursery introduced by different state Governments schemes like Bringing Green Revolution in Eastern India scheme of Government of India (BGREI). The CSISA -KVK network team had the experience of handling the questions related to these interventions. Hands-on training was provided to each participating KVK on the methodology involved in the electronic survey. Other details of the methodology are given in the paper on the time of crop establishment in this volume.

3.0 Results and discussion

Data showed that improved CE methods have not yet made any significant impact either on the expansion of new CE methods or on the effect of new methods on the crop yield. Although the proportion of farmers with improved methods of CE is rising but the dissemination is much slower than expected. Efforts were also made to identify interventions which help better adoption of the improved CE methods. This survey also highlighted some other interventions like the possibilities of reduced seed rate to facilitate the adoption of hybrids for DSR or introduce the concept of private service providers (PSPs) for raising quality nursery to facilitate timely transplanting or mechanized transplanting.

3.1 Nursey management

There are opportunities around nursery management, which can support the time management especially when the focus is on the contingency plan for monsoon variability. One reason for the success of system of rice intensification (SRI) was the transplanting of young seedlings. Therefore, the nursery management is kept as the part of CE. Majority of Andhra Pradesh (AP) farmers transplant rice seedlings at the age ranging from 16 to 40 days, with the yield advantage trending towards young seedlings. The highest paddy yield of 5.7 t ha^{-1} was recorded when 21-to 25-day old seedlings were used for transplanting. The paddy yield started declining when seedlings older than 35 days were transplanted (Fig. 1). The young seedlings will produce early and more tillers with high impact under dry conditions (Pasuquin *et al.*, 2004). Rajesh and Thanunathan (2003) also indicated that growth of rice improves by transplanting young seedlings. The prevailing weather conditions of high temperature marks poor health of nursery at young stage in Punjab and Haryana. In very early transplanting young seedlings did not support better growth as the harsh climate at the time of transplanting compounded the problem. More

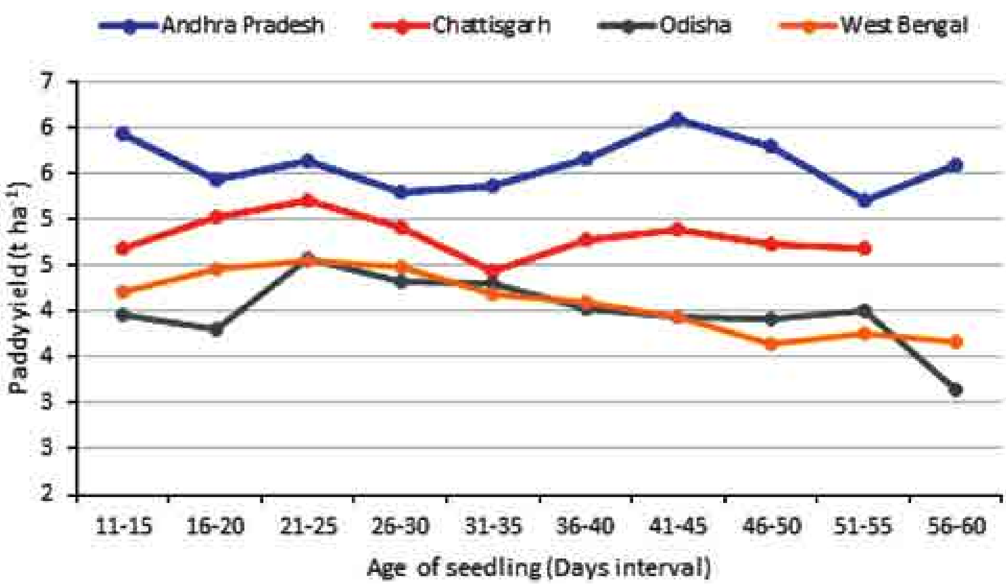

Fig. 1. Effect of age of seeding (days) on the average paddy yield (t ha^{-1}) of surveyed farmers from Andhra Pradesh, Odisha, Chhatisgarh, and West Bengal (n=5662).

aberrant weather with hot and desiccating winds did not allow rice to initiate tillering as efficiently as expected.

A similar trend was recorded in Chhattisgarh with a maximum paddy yield of 5.1 t ha^{-1} recorded from 21- to 25-day old seeding; and the paddy yields declined with seedlings older than 35-days. Similar trends were recorded in West Bengal, where the paddy yields started declining with transplanting of seedling of more than 30 days. Best yield of 5.0 t ha^{-1} was recorded with seedlings of 16-20 days. Evidence of shifting trend in favor of young seeding in this survey with 48.0, 75.5, 63.0, and 34.0 % HHs in AP, Chhattisgarh, Odisha, and West Bengal, respectively, showed some impact of Government program on puddled transplanting of rice in line (PTRL). Among 5,662 respondents, 5 % HHs in Chhattisgarh to 20 % HHs in AP, who transplanted seedling older than 40 days, reported a yield loss of 0.5 to 1.0 t ha^{-1} (Fig. 1). The transplanting of young seedling at the most appropriate time help withstand the early season water stress due to increased root length and root density.

The use of old seedlings is often caused by non-availability of labor in Punjab and Haryana or lack of irrigation in the eastern regions. Moreover, the use of still older seedlings in Punjab and Haryana has less impact on yield (Fig. 2). Because some farmers are growing Pusa 44 (LDRV) in Punjab, there is always a comparative element like this to explain this discrepancy as to why the option for 36- to 40-day old seeding is producing high paddy yield. In the same context, the lower paddy yield from 31- to 35-day old seedling is because most of these HHs had grown basmati premium varieties, which have lower yield potential (Fig. 2). In Punjab, there was no effect of early transplanting up to July 5 on paddy yield of LDRVs, but water productivity was the highest when transplanting was done on July 5 (Brar *et al.*, 2012).

Except for these two yield-based extreme cases of Pusa 44 with high yields, and basmati group with lower yield in Punjab and Haryana, which affected the average yield, young seedlings did well enough to make a case for its integration with the CE time and method. In addition, farmers in Punjab and Haryana are slow to embrace the concept of young seeding because of very high and hot desiccating wind at the time of nursery raising.

In Bihar and to some extent in EUP, meaningful adoption of the concept of young seedlings is taking roots. With the adoption of hybrid rice, despite its costly seed, farmers are more open to the adoption of the practice of young seedlings as part of good agronomy. The relative success of young seedling was considered due to introduction of hybrids, but the CSISA team claimed that this success is owing to its efforts on machine transplanting of rice (MTR) introduced in 2011-12. Lessons

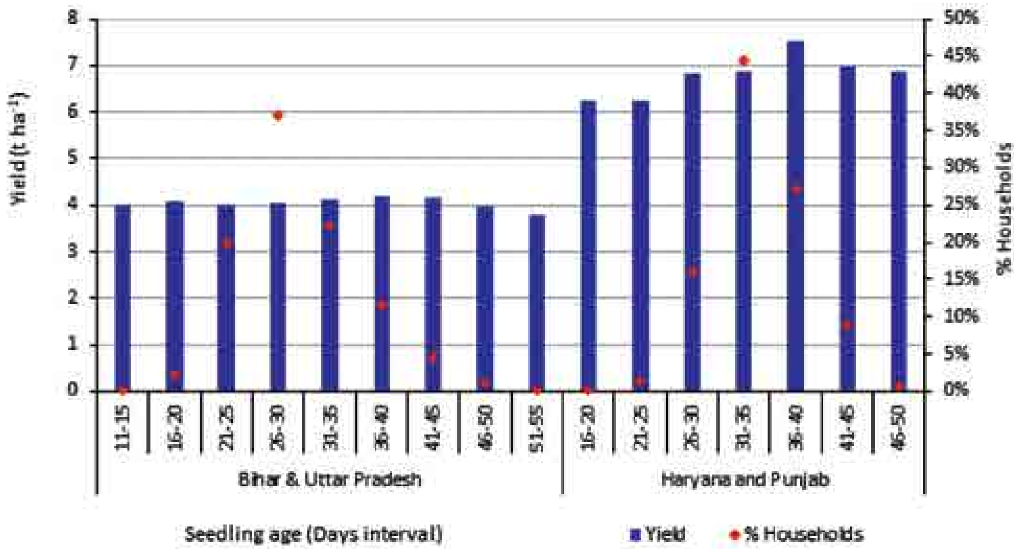

Fig. 2. Effect of seedling age on paddy yields (t ha^{-1}) in two contrasting ecologies of Eastern Indo-Gangetic Plains (Eastern UP and Bihar, n=9,694) and Northwest –IGP (Punjab and Haryana, n=805).

can also be learnt from some attempts made for introducing SRI, which advocated the use of young seedlings, across many states except Punjab and Haryana. Young seedlings, the basic component of agronomy, had practical implications, and its transplantation represents the major contributing factor (McDonald *et al.*, 2006) for high yields from SRI. While the attitude regarding SRI is unlikely to change, the change towards adoption of young seedling is happening. Whatever might be the reason, the concept of transplanting young seedling seems more convincing. The time of transplanting cannot be disconnected from the age of seeding. This is because young seedlings cannot settle well due to high temperature and too much sun light in April- May. It may not be easy for a very young seedling to weather the shocks of transplanting when water is a limiting factor immediately after transplanting. However, the right age of seedling, somewhere between 20 and 35 days, can harness the benefits of timely transplanting. The yield gaps can be bridged by integrating optimum seedling age with the time and method of CE. These are important factors for higher tiller numbers that lay a foundation for heralding higher yield (Chahal *et al.*, 2007). The supply of photosynthetic assimilates from source (leaf + stem and sheath) to sink (grain) is lowered for rice plants by using old seedlings (Katsura *et al.*, 2007) and late transplanting.

The advantage of the 20- to 25-days young seedling is associated with the rapid generation of more tillers and better recovery from the transplanting shock (De Datta *et al.*, 1998). Occasionally, however, the competition for light causes old seedlings to grow taller with reduced potential to generate more tillers. The young seedlings will produce early and more tillers with high impact under dry conditions (Pasuquin *et al.*, 2008) but may also die due to extremely high temperature (Mobasser *et al.*, 2007).

3.2 Create private service providers (PSPs) for timely nursery supply

Data on differential response of age of seedlings across states can be resolved by looking at business case for nursery supply, because the time of transplanting falls in a narrow window (end of June to 15th July). The labor required for transplanting is scarce and costly. The plan revolves around the concept of nursery management and how to do it by supporting private service providers (PSPs) or nursery enterprises.

Department of Agriculture and Farmers Welfare, Government of Bihar, launched a scheme for promoting farmer-managed community nurseries under assured irrigation to make available paddy seedlings for transplanting to meet out the contingent situations. Under the scheme, a community nursery in 5 acre/panchayat (local governing body in a village) and 150 acre in each district are taken up. The subsidy for each nursery is Rs 6,500/acre to cover the cost of production and Rs 1,000/acre for purchasing seedlings for transplanting in 10 acres from 1 acre of the nursery area. Thus, the total subsidy support by the department for 1 acre of community nursery works out to Rs 16,500. Instead of a community nursery, the Government should see this as a business opportunity for small farmers. In the long run, it could lead to a platform where the rice nursery is at low cost and of better quality, which may also reduce the seed requirement in rice. Our experience in the CSISA-KVK network also showed that PSPs can prepare rice nurseries and sell seedlings to other farmers as service providers. However, all this will need multi-institutional support to materialize.

The capability of farmers must be increased to take up service provisions in the supply of good quality rice nursery so that the transplanting is not delayed due to the non-availability of the nursery. Once the business proposition is made profitable, it will provide the capability for the timely availability of nursery on the day of arrival of monsoon across regions where variable monsoon (Kyuma, 1973) is a common issue. If the nursery raising is made a small business, the seed rate could be reduced significantly. The cost-analysis based on the discussion from farmers of Rohtas district, Bihar, is presented in Table 1, which reflects the averages from farmers who were PSPs, and from farmers who were nursery buyers. Based on the average of eight participants (PSPs + KVK), the cost of raising nursery, including a 20% risk premium for one-acre transplanted area, was INR 800.

For example, farmers in district Rohtas showed how they have made it a profitable proposition. This is an opportunity for all categories of farmers because

Table 1. Economic analysis per acre (4,000 m²) of rice nursery area

Particular	Detail	Cost (INR)
Seed quantity	176 kg × INR 40/kg	7,040
Seed treatment	-	336
Tillage	INR 800/hr × 4 hour	3,200
Irrigation	25.66 hr × INR 150/hr	3,840
Fertilizer	DAP and urea	1,760
Labour	INR 300/day × 5.33 man days	1,600
Land rental value	One-month rental value	1,600
Plant protection	Insecticides and fungicides	384
Herbicides	Pyrazosulfuron (for *Cyperus* spp.)	448
Others	Risk premium 20 % of nursey raising cost	4,042
Total cost	Including risk premium	24,250
Gross return*	50-acre × INR 800 (sale price for nursery)	40,000
Net profit		15,750
B:C		1.64

*Expected area-coverage by one-acre nursery = 50 transplanted acres, Nursery sale price @ INR 800/acre

only the good quality of the nursery will create value. On interacting with buyers and sellers of the nursery, data showed that the farmers who raised nursery tended to be more innovative and could raise nursery in the ratio of 1:50 (1 acre nursery is transplanted in 50 acres) or more, against the recommended ratio of 1:10 or 1:12. One of the participating farmers, a leading PSP, said that this business could be even more successful if the same PSP takes the contract of raising nursery and transplanting of rice on a custom hire service basis. The skill of transplanting of one seedling per hill is another important point that led to a significant saving of seed and the area under nursery. Instead of raising their own nursery, farmers may cut their cost by outsourcing the nursery-raising to PSPs in the same village or the adjoining villages.

Given the seriousness of problem that occurs year after year, time is to be allocated besides resources to prepare for staggered nursery raising. The preparation is to be at a scale that allows the supply of rice nursery to many farmers when rain arrives.

The outlook for efficient prediction of short-term monsoon variability has improved, but the outlook for long-term variability is still an issue. Moreover, it is hard to shake the belief of farmers that PTR is the best method of CE. Data presented here also proved this fact. The solution, as of now, lies with manual transplanting. The studies showed that 2, 3, or 4 seedlings/hill had large, medium, and small panicles, respectively (Qian *et al.*, 2009). The high seed-cost of hybrid rice forced farmers of Bihar to innovate this technique. In some of the best performing districts like Rohtas, farmers transplant even one seedling per hill.

The evidence of a viable nursery enterprise exists, and women farmers may be safely targeted as well. Having identified this as a scalable option for improving rice productivity, the KVKs and DoA should take up special campaigns on this issue and modify the scheme from community nursery to the concept of PSPs. This will also resolve the issue of seed quality because farmers will buy nursery of a target variety rather than the possibility of seed mixture when they buy seed.

3.3 Merit in hybrid technology and innovation in seed rate reduction to cut cost

Farmers saw merit in hybrid rice. This survey proved that hybrids were accepted on large scale in some states. The paddy yields in water stress prone areas are the same or more than the existing varieties suitable for those areas. Since the introduction of hybrid rice, farmers have become more innovative and significantly reduced the seed rate of rice from more than 30-60 $kgha^{-1}$ to only 15 $kgha^{-1}$ (Fig. 3). The seed rate in Haryana is still even less than Bihar at 9.0 $kgha^{-1}$.

Farmers have further innovated the process of seed saving by establishing only one seedling per hill. This has started happening in a few cases, especially where hybrids are used. There is an upcoming wave of using very less seed compared to what farmers used in the past and what is recommended in the most package of practices. However, this has not happened in Odisha, where the average seed rate across different methods of crop establishments is 67 $kgha^{-1}$. This is because of inefficient methods like seed broadcasting, followed by *beushening* with a seed rate of 102 $kgha^{-1}$ (Fig. 3).

Farmers may still be paying a higher seed cost for hybrids, but with a higher yield than that in the MDRVs or SDRVs (Fig. 4). With reduced seed rate under drought-like situation, farmers will earn more than varieties anyway. The reduction in seed rate will save a lot of money which the governments spend on seed subsidy schemes. The seed cost of hybrids will stay high because of high production costs and lower seed yield. This reduction in seed rate will also ensure sufficient seed supply because the seed saved is seed produced. Farmers using such low seed rates still get high yields.

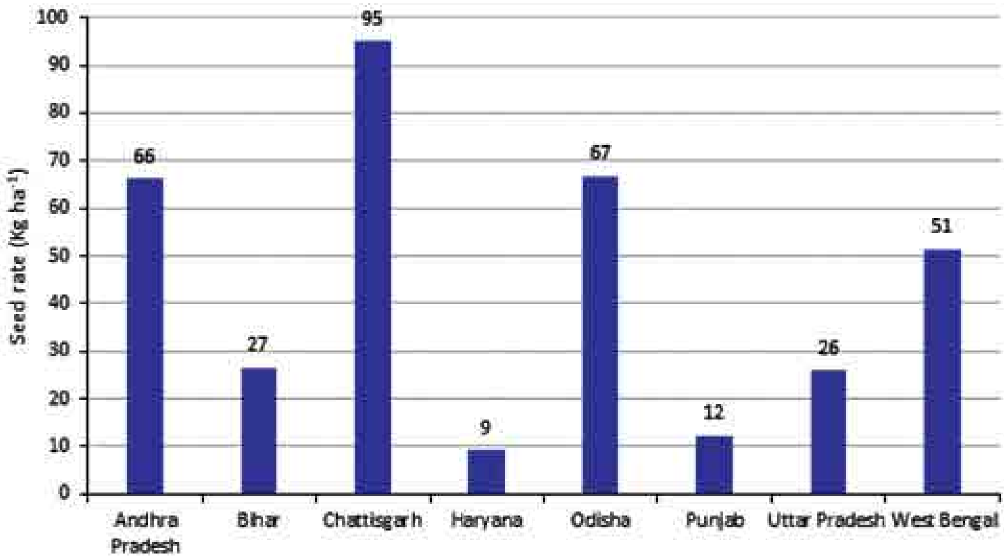

Fig. 3. Average seed rate of rice across all surveyed states, including Punjab, Haryana, Bihar, EUP, Chhattisgarh, Odisha, and West Bengal (n=16,161).

The practice of using a reduced seed rate has gained momentum from Haryana to EUP and Bihar. The lower the seed rate the larger the area it facilitates, and the larger the net returns of each hybrid seed user. That means a good deal can be struck by growing hybrids with high yield at less cost. In the absence of strong competition from new varieties, it is an easy walkover by hybrids for the healthy breakthrough. Overall, the farmers' attitude towards hybrids is changing. The ability to make best use of monsoon rains now rests on hybrids, and the hybrids with shorter duration than LDRVs will intensify the cropping system- a win- win situation for farmers.

3.4 Methods of crop establishment (CE)

Government agencies and the researchers made efforts to change the old CE method of *beushening* since long. The changes in CE method were attempted for managing new and emerging problems, often with improved yield. In the existing random transplanting method of crop establishment, seedlings are transplanted without maintaining a definite distance. Transplanting in rows facilitates manual weeding or mechanical weeding, and a uniform application of fertilizers and pesticides. The adoption patterns of different CE methods (Fig. 5) were studied for the possibility of future way ahead. Data from the current survey showed a little difference in the adoption patterns of new CE methods from random puddled transplanted rice (PTRR). These results must also be compared with other facts. Restrained by different times of CE across states, the CE methods also enable

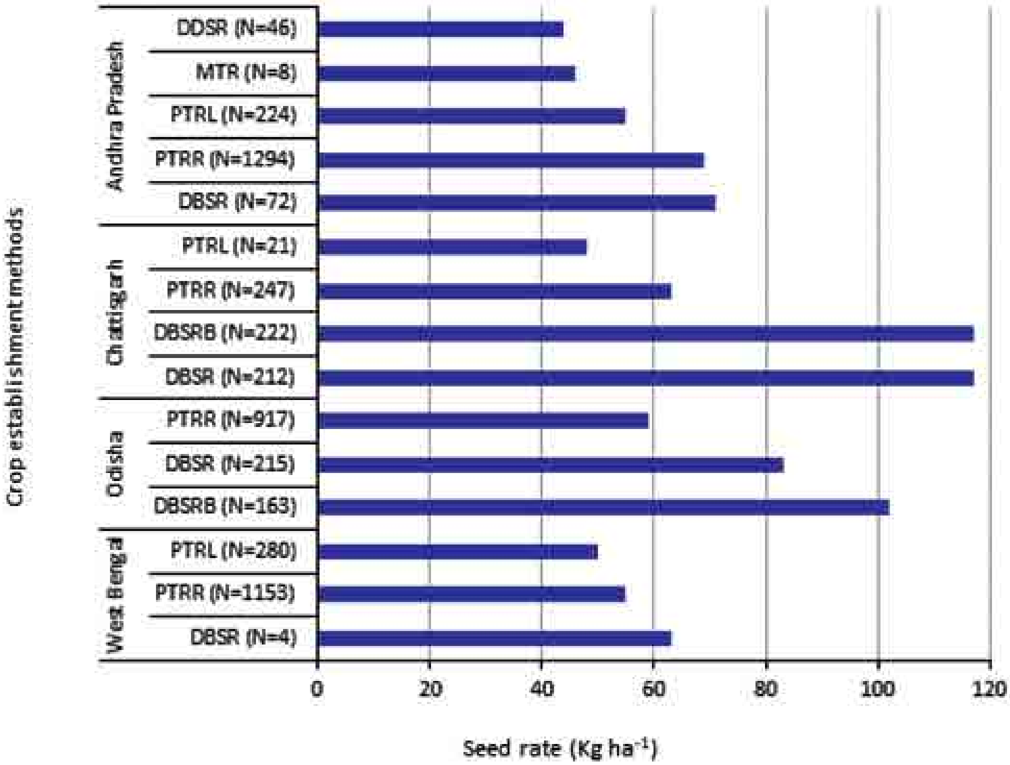

Fig. 4. Seed rate of rice under different methods of CE across Andhra Pradesh, Bihar, Chhattisgarh, and West Bengal (n=5,662).

plants to make use of resources differently. Except for Odisha and West Bengal, where transplanting of rice seedlings in-line under puddled condition (PTRL) has small edge over PTRR, the PTRR has provided highest yield. Other methods including, direct broadcast seeding of rice (DBSR), DBSR followed by *beushening* (DBSRB) provided less yield than that of PTRR or PPRL or even MTR, in Odisha. The direct drill seeding of rice (DDSR) in AP (6.2 t ha^{-1}), Bihar (4.3 t ha^{-1}) and EUP (5.0 t ha^{-1}) showed similar yields to other transplanting methods, but the adoption is very limited (up to 2.4% HHs in AP). So far DBSR or DBSRB has catered to the need of small and marginal farmers in Odisha and Chhattisgarh, but now DDSR may emerge as an alternative to this method. In recent years, rural labor has become increasingly insufficient and expensive, mainly due to Mahatma Gandhi Rural Employment Guarantee Act (MNREGA), 2005.

The DSR was recommended in almost all states but the acceptance by farmers is patchy. Published work showed a great promise in DSR technology, but there are still many ifs and buts which need resolution from the research groups (Kumar and Ladha

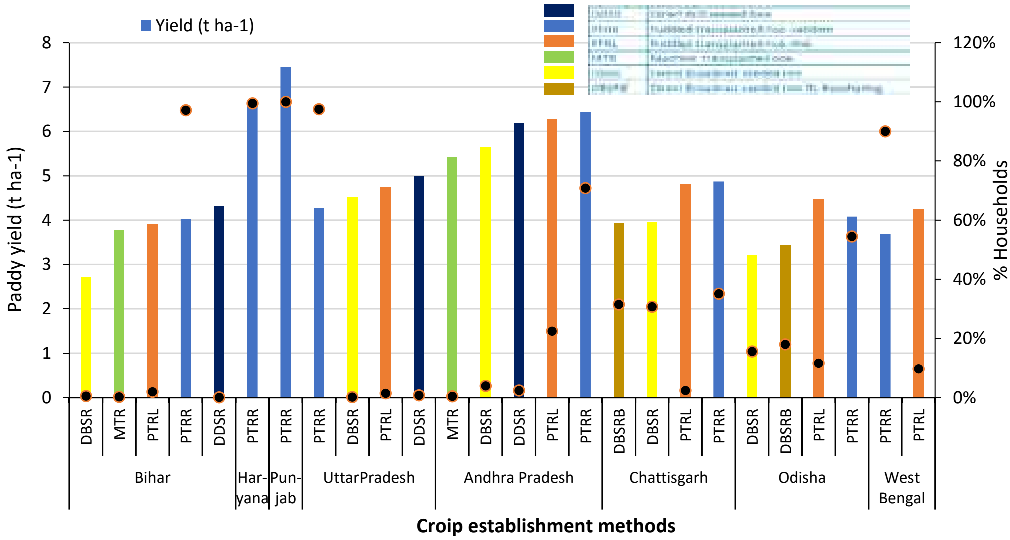

Fig. 5. The performance of various crop establishment methods across Punjab, Haryana, EUP, Bihar, Odisha, Chhattisgarh, West Bengal and AP. Data on the magnitude of adoption (% HHs) and paddy yield are presented with 16,161 data points.

2011), in the light of farmers' feedback. It is hard to think what researchers would have done to avoid these questions. Work of CSISA-KVK network showed that, perhaps, DDSR with soil mulch (sowing on a fine seed bed prepared after pre-sowing irrigation) may help solving the problem of scarce and costly labor. With national attention diverted towards COVID 19 in 2020, the labour problem forced farmers to adopt DSR on a large scale in Punjab and Haryana. The plan to introduce soil-mulch-based DSR or conventional DSR where the seeding is done after pre-sowing irrigation, followed by conventional tillage and direct drilling did much better job in avoiding the risk associated with weeds and also in conservation of soil moisture. The shifting from DBSR to CDSR is much easier than shifting from transplanting to CDSR, especially where water is not at the command of farmers. Machine transplanting can solve immediate problem of labor shortage without any yield penalty (Kamboj *et al.*, 2013; Bhavani *et al.*, 2017), but machines are costly and business models are not in place. This is one of the weaknesses in this technology. This can be resolved by combining MTR with PSPs by taking up both activities, raising nursery and transplanting, on contract basis.

MTR is more productive but needs one-time high investment. With only 20% rainfall in the end of June, and a very high cost of diesel pump-based irrigation, these ecologies are not well positioned for shifting from PTR to DSR. It is believed that creating a soil mulch by conventional-tillage-based sowing will be the key factor for shifting the rice establishment from PTR to DSR. The soil mulch will save post-sowing irrigation and help avoiding loss of water through evaporation due to breaking of soil capillary after tillage or soil mulch. It will also help decreasing weed population because of lack of moisture in the top 3.0 -5.0 cm soil profile where most weeds emerge. When integrated with new technologies and practicing DSR under conventional tillage by creating soil mulch, soil moisture loss will be reduced, and the crop will withstand water stress for initial 2-3 weeks leading to better weed management and huge water saving. The shift to CDSR would mean better way of saving water (Madhulika Singh, 2020). DSR as such has shown great promise against DBSRB in Odisha. With increasing scarcity of rural labor force, machine transplanting or direct seeding of rice (DSR) will become a prevalent method of rice establishment.

The purpose of promoting MTR now is to help farmers struggling with labor scarcity at the time of rice transplanting. This might turn out to be a natural order of adoption of new technologies. The major constraint in the adoption of MTR is the availability of quality machines and the relative cost. Leveraging the private sector for placement of machines in the marketplace at competitive price should be focused. But this also has its problems associated with raising of special type of nursery, called as mat-type nursery. Critical analysis of all available options suggested that profit margin is obviously an important variable in rice cultivation but the process of delivering these technologies may require solutions for missing parts in MTR as well as DSR. This opens possibilities for further research in these technologies.

Conclusion

Of the HHs practicing transplanting, more than 90% HHs favored manual puddled transplanted rice-random (PTRR) having a yield parity with puddled transplanted rice-in line (PTRL). Owing to a host of benefits, changing over to alternate crop establishment (CE) methods is enchanting the development agencies and policy makers for long, but their adoption at scale has not yet picked up, despite the sustained efforts for the last 2-3 decades. Manual puddled transplanting is still ruling the roost, with a limited success achieved towards its re-orientation to attain geometric perfection by transplanting in lines (PTRL). The rising labor shortage is likely to propel farmers towards adoption of alternate CE methods in the imminent future. The data showed that there is no immediate solution to the problem associated with water and labor. The solution now is left to drill seeded conventional direct seeded rice (CDSR), The availability of quality rice nursery ‘just-in-time’ at affordable price, is still a matter of concern, particularly in the eastern ecologies, where crop establishment, at large, is dependent on the timely arrival of monsoon.

The plan for private nursery business must be prioritized through private service providers rather than the community nursery-based concept.

The data on the age of seedling at transplanting, manifested a trend underlining the role of younger seedling in increasing rice yield. However, in Punjab and Haryana, the age of seedlings was not an issue, because raising of irrigated nursery well before monsoon is a common practice there, and appropriately aged seedlings are timely transplanted in irrigated puddled lands. In Odisha and Chhattisgarh, the single-most important cause of low paddy yields was the broadcast method of seed, adopted by majority of households (HHs).

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2.5 Management of crop growth cycle as the frontier of yield growth in rice

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KEY MESSAGES

- Transplanting of rice at optimum time, mid-June to mid-July, is central to better yield performance of rice in the North-west Indo-Gangetic Plains (NWIGP), and similarly in the Eastern Indo-Gangetic Plains (EIGP).
- Timely transplanting of rice confers stability to the rice-based cropping system. It helps to cope with the uncertain monsoon for the *kharif* rice crop, because of which there is timely/early harvest of rice facilitating utilisation of residual soil-moisture by the succeeding crops at seeding, thus minimising requirement of pre-sowing irrigation.
- Inclusion of hybrids in the upland and medium lands, and service-based mechanization from seed to harvest, can help improving the sustainability of intensified rice-based cropping systems across states.
- The improvement in the paddy yield due to timely transplanting has its own logic. For translating the lesson learned from high yield producing states like Punjab and Haryana, is that the policies in the eastern states should focus on timely transplanting and services needed to achieve that goal. Such data sets are more useful than small experiments in each state.
- The National Agricultural Research and Extension System (NARES), during its technical program formulation and planning meetings for priority setting, policy

making and state level contingency plan, should consider the database captured by Landscape Diagnostic Survey (LDS) through monitoring, evaluation, and learnings (ME&L) process as evidence based on the farmer feedback mechanism.

1. Introduction

Rice, the staple food of India, is cultivated mostly in the monsoon-rain dependent regions but is also cultivated in regions with assured irrigation. The Orissa Famine of 1866 and the Bengal Famine of 1943, which resulted in the death of millions of people, showed that the effect of uncertain and variable monsoons, especially in the eastern states, and that climate change had added on to this problem. However, system is better equipped to avoid catastrophes now owing to the work done during and after the Green Revolution (GR) of the 1960s and 1970s, which focused on 'seed-based' technology interventions. (https://geneticliteracyproject.org/2020/10/30/norman-borlaug-nobel-prize-winning-agronomist-saved-a-billion-lives-and-almost-banished-hunger/--)

The contribution of varieties towards productivity growth after the 1980s was less than that in the preceding years, though the use of rice hybrids and some long duration rice varieties (LDRVs) improved productivity. Rice productivity in the eastern states with high rainfall is less than the Northern and the Southern states where farm sizes are larger. Furthermore, the yield gap is still widening. The question is how to narrow this widening gap. Most of the varieties in the eastern states mature in more than 140 days, therefore, need timely planting (~longer growing season). The eastern sub-regions also have problems of poor water control and flooding. However, among all rice-growing regions, the eastern states are a paradox, with plenty of natural resources and yet low productivity. The main reason for stagnant growth in these states is delayed transplanting leading to contraction in the available time for such varieties to complete their maturity cycle. These varieties are not allowed to grow according to their maturity time. That means, farmers need to apply management options to allow these varieties to achieve their fullest yield potential by transplanting rice on time. The problem of time management in rice is more complicated than it appears. When crop establishment is delayed farmers are less confident about profit outlook. Hence, they invest less time and energy in managing their crop. Farmers need extra yield to cover the increasing cost of labour and inputs. Time management is a non-cash input. In addition, the profits of small farmers can increase if they intensify their cropping systems to get higher rate of return on the investment (ROI).

Rice has been the center of significance as far as the cropping system productivity is concerned. So, the need is to keep focus on time management in rice to determine the time of sowing of succeeding crops. The variability in the onset of the monsoon is also expected to become more frequent in all regions as climate change gets more pervasive. The adoption patterns of varieties given in this volume show that farmers are much likelier to prefer LDRVs due to their high yield potential. That means the varietal balance has moved in favor of LDRVs and MDRHs. According to this survey one in three households have started growing hybrids in states like Bihar and Haryana. The time of crop establishment also depended on which method of crop establishment was followed. Electricity-based and low cost irrigation helped farmers to be flexible enough in managing time in some ecologies. By comparison, the dependency on costly diesel pump-based irrigation delayed crop establishment, leading to low yields from long duration rice varieties (LDRVs).

The experience of the GR suggested that now the need is of cropping-system based management options. Overall, the time management in a cropping system, especially during rainy reason, is among the most demanding and complex activities, which require networking across disciplines of crop improvement, crop management and farm mechanization. There also has to be an increased emphasis on climate change. Since farmers know their vulnerability better than outsiders, the work of this nature is far beyond each crop in the system and can be done efficiently at farmer's field rather than on research farms. Since the system has to deal with a system approach comprising rice-wheat cropping system (RWCS), rice-rice cropping system (RRCS) or rice-fallow cropping system (RFCS) in different ecologies, an increased emphasis on time management may be a way to harness maximum benefit from varieties and other external inputs used by farmers.

2. Methodology

In total 16,161 data points were included in the LDS survey, which covered households (HH) in 64 districts in the states of Punjab (2 districts), Haryana (2), EUP (18), Bihar (30), Odisha (7), Chhattisgarh (3), West Bengal (3), and AP (9). All selected states represent different ecologies with rice-based cropping systems in common. The survey represented different land types including uplands and lowlands. The upland ecologies are those where all the water drains off once there is cessation of rainfall/ irrigation. Lowland ecologies are categorized as shallow lowlands (0-30 cm), intermediate lowlands (30-50 cm) where standing water is less than 50 cm, semi-deep and deep lowlands with 50-100 cm and more than 100 cm water depth, respectively (Mohanty *et al.*, 1996). Land holding categories include marginal farmers with landholding below 1 ha; small, 1-2 ha; semi-medium, 2-4 ha; medium, 4-10 ha; and large, above 10 ha. Total operational landholding of surveyed HHs was considered. The average landholding size of HHs in the present survey was 0.4 ha for Bihar, 0.7 ha UP, 2.2 ha Haryana, 3.6 ha Punjab, 1.0 ha Odisha, 0.8 ha West Bengal, 0.9 ha AP, and 1.3 ha Chhattisgarh.

The LDS survey was designed to find out the current trends in the adoption of agronomic practices by farmers, and their preferences for improving the productivity of rice. Data were aggregated over the states; and differences within and between states were evaluated to get a broader view of yield growth of individual HHs, districts, and the state.

The National Agriculture Research and Extension System (NARES) made efforts to close the yield gaps in different states. The survey carried out across states estimated the extent of spread of different management-based recommendations. The impact of adopted technologies was estimated by recording yield levels reported by the surveyed farmers. This is the first attempt to understand the impact of adopted technologies across states and across districts in the surveyed states to show the evidence how the technologies were accepted in the randomized population representing most ecologies. This will resolve the biggest obstacle in getting the message across policy makers and institutions responsible for generating and disseminating crop management-based recommendations. Data so generated can be used time and again by multi-stakeholders. The updated datasets will be shared with State Agricultural Universities (SAUs) and the concerned state Departments of Agriculture (DoA) for strategic convergence between all stakeholders for setting priorities for evolving and promoting new technologies. It will also be useful to finalize the package of practices that are based on the farmers' feedback, and allow independent verifications of different recommendations which were accepted by the farmers. The data collection method also brings out the real picture from the representative HHs in any given ecology, rather than the selected pockets of chosen and often unrepresentative farmers. Therefore, more districts were covered from the eastern states (Bihar, Eastern UP, West Bengal, and Odisha) and southern state AP, and few representative districts were covered from NW states of Punjab and Haryana, and central Indian state like Chhattisgarh. This will help NARES to recalibrate existing work plans, not only to innovate and bring systemic change, but also to show the impact at scale. The focus was on how to fully integrate with KVK system and the rest of NARES. The Indian Agricultural Statistics Research Institute (IASRI) was involved in data analytics, data management, and developing a dashboard on behalf of the Directorate of Extension Education, KAB-1, New Delhi. The LDS and its outcomes can form a part of monitoring, evaluation, and learning (ME&L), which will lead to huge data generation and also reflect a management system in India for a much larger transformation in the research and extension.

During the process of randomization, the emphasis was laid on increased transparency so that the views adequately reflect and represent the interests of all categories of farming community. LDS covered many households (HHs) that represent entirely different ecologies from north-west to the east and south Indian states where rice is the center to any intensification program. Based on the feedback mechanism designed in the LDS, the research institutions on the one hand and on the other the DoA can improve their services and the outcomes.

3. Results and Discussion

Extension agencies and farmers are keen promotors and users of new varieties almost every year, hence the GR is the success story of rice in India. A news release in Chicago News on 6 July 1968, highlighted that International Rice Research Institute (IRRI) had developed rice varieties which gave paddy yield in a range of 5.0 to 7.0 tha^{-1} compared to an average of 2.0 tha^{-1} in Asia (Georgie 1968). The new varieties created the demand for fertilizer, which expectedly rose from 0.6 million tons in 1968 to 4.0 million tons in 1970-1971 (David *et al.*, 1970). Since then, the investment in research and extension has tilted towards two important components – varieties and nutrient management. The adoption pattern of new varieties and nutrients are discussed separately in this volume. However, the yield growth is still not happening as expected. There is a need to revitalize yield growth, though there are differences in how to go about achieving this objective (Zeigler and Mohanty 2010). Factors like time management have emerged as fundamental to harness more from varieties and fertilizer use. The evidence for a need to change has emerged from this survey. Now the debate needs to be shifted towards time management to find solutions of specific vulnerabilities that uncertain monsoons have created.

3.1 Time management

The uncertain and variable monsoon is a common problem in rice cultivation. Within Indian states with limited or no irrigation farmers face serious problem of late crop establishment (CE). From among farmers within states and between states, the best performers among them still manage their crop well and in a timely manner, and get rice yields that are close to the best farmers of states with assured irrigation. Many of the best varieties released in the past are still showing consistently better performance even in these changed scenarios of variable monsoon and climate change. Data (Fig. 1) indicated a marked change in the crop management practices with best performers maintaining good yield in the eastern states, which can almost match the yield in states with assured irrigation.

Farmers have to be in a situation that helps them to establish their crop just-in-time on the arrival of monsoon rains. The groundwork of managing the time can be done by mechanization. The optimum time of CE is expected to influence the overall management cycle towards better use of resources including seed, nutrient, irrigation

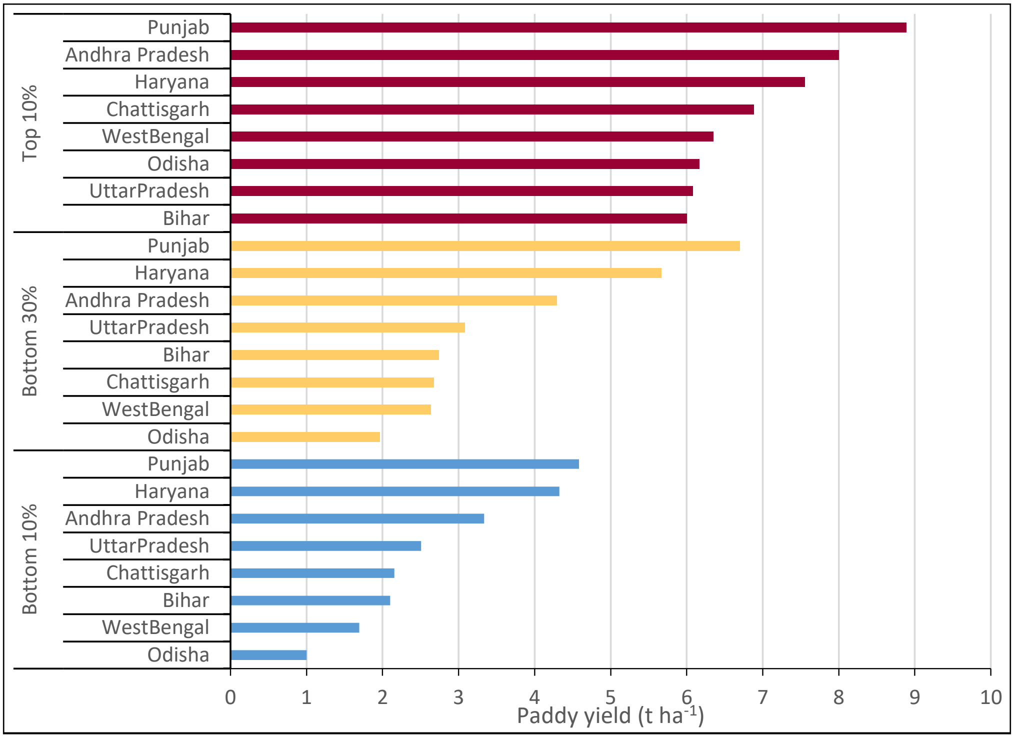

Fig. 1. Paddy yields of 10 % top performer and bottom performer households across 8 states (n=16,161)

and weed management. Technologies like big data analytics can explain the factors that might have resulted in better performance by 10 % top performing farmers and what might be the causes for poor performance by 10 or 30 % bottom performers among farmers. Farmers and extension agencies can use both monsoon prediction models and such data sets to see why yields are so high in Punjab and Haryana and how timely transplanting have changed the whole yield scenarios across states. There are lessons that can be learnt between states and within states (Fig. 1).

Data are now trending towards the need for more focus on CE time to harness maximum from any given ecology. In relative terms, the inconsistent weather limited the yield growth of rice in the eastern states like EUP, Bihar, and West Bengal, Odisha, and Chhattisgarh, but not in Punjab, Haryana, and AP. The expectation of high yield from 10 % top performers in each state was met with an average paddy yield ranging from 6.0 tha^{-1} in Bihar to 8.9 tha^{-1} in Punjab with a yield difference of 3.9 tha^{-1}. However, the paddy yields of bottom 10 % performers ranged from 1.0 tha^{-1} in Odisha to 4.6 tha^{-1} in Punjab, having a yield difference of 3.6 tha^{-1}. Similarly, in the bottom 30 % performers recorded a yield difference of 4.7 tha^{-1} between Odisha and Punjab. Within states, the yield gap between 10 % top and bottom performers were 95 % in Punjab and 186 % in Bihar. However, the yield gap between the top 10 % (8.9 tha^{-1}) and bottom 30 % (6.7 tha^{-1}) in Punjab is only 33 % (Fig. 1). Although there are large variations in the natural resource base in different ecologies, the CE schedule presented in Figs 2 and 4 showed what looks like a major role of time management. The timely CE has contributed to the realization of yield potential of best of varieties and other inputs in Punjab, Haryana, and to some extent in AP but not so much in the eastern states. Data (Fig. 2) supported the need for Bihar and for that matter all eastern states to establish the rice crop in the end of June as is being done in Punjab. The crop may respond differently in different regions and reflected the reality of growth conditions, which is a function of time of CE and how the crop was managed till harvesting. Hence, the time management is the fundamental factor to harness the best out of any variety. For explaining the transplanting schedule, the results are presented in two distinct scenarios. One scenario covers Punjab, Haryana, Eastern UP, and Bihar (Fig. 2), which is dominated by RWCS, and the other scenario covers Odisha, Chhattisgarh, West Bengal, and Andhra Pradesh (Fig. 4), which is dominated by rice-fallow cropping system (RFCS - mostly Odisha) and rice-rice cropping system (RRCS) or rice-pulse cropping system (RPCS).

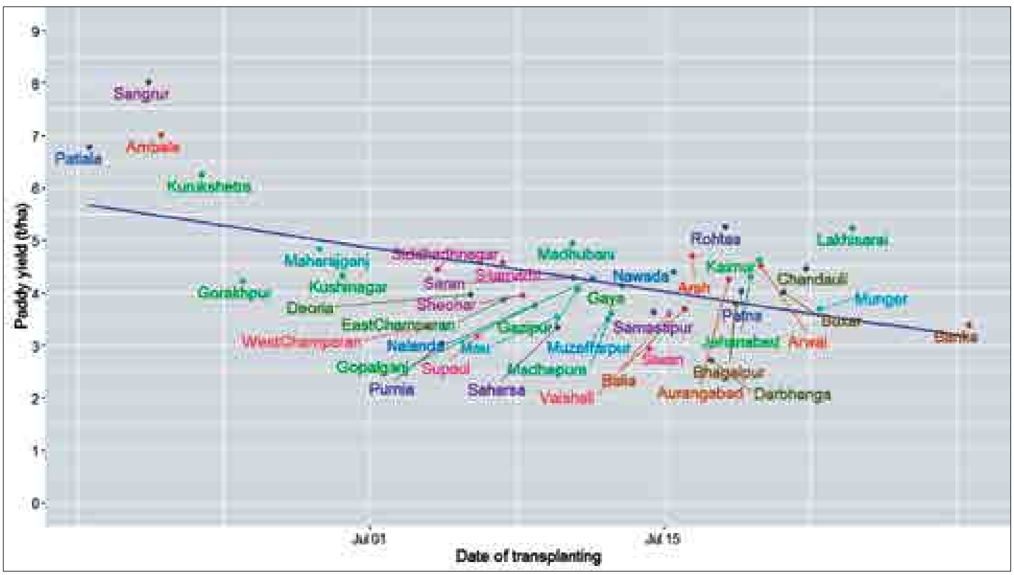

Fig. 2. District-wise average paddy yield (tha^{-1}) against the average date of transplanting across Punjab, Haryana, Eastern UP and Bihar dominated by rice-wheat cropping system (RWCS), n=10,499

3.1.1 Time of crop establishment in rice-wheat cropping system (RWCS)

There was a lot of intensification in the RWCS and RRCS after the evolution of short-statured varieties during the GR era (Parayil, 1992). That seemed to be the mainstay for sustaining the livelihood of farmers in South Asia. One-sixth of rains occur at the beginning and the end of monsoon, and two-thirds in the middle of rainy months. The mean rainfall has been higher from 1906 to 1965, thereafter getting lower between 1966 and 2005 (Subash and Ram Mohan, 2011). Similarly, the number of rainy days declined sequentially from 1951 to 2004 (Dash *et al.*, 2009). Climate models predict that the monsoon will continue to weaken (Kripalani *et al*., 2007) and the global area affected by drought is likely to increase in the future, with the frequency of heavy precipitation events very likely to increase over most areas (Pachauri and Reisinger, 2007). Such historical perspective showed that the rainfall patterns have more or less remained the same, but the climate change-based events created new problems.

Historically, this is also the primary reason to prefer CE according to established summer monsoon pattern. The prediction of monsoon is now more stressful and needs much more data sets for improving the accuracy of models. That is necessary because the rice transplanting should be aligned more closely with the peak monsoon rains in any given ecology. The crop responds more favorably when the active tillering coincides with monsoon rains. The transplanting of rice in Sangrur and Patiala in Punjab (Fig. 2) starts from June 15, and in most cases, it is completed within June. The highest paddy yield inspires most farmers in Punjab to finish the transplanting at the earliest. The dominance of Pusa 44, a LDRV also favors early transplanting in Punjab. That is why the adjacent two districts from Haryana follow the same pattern and try to finish the transplanting around 10 days later than these two districts (Fig.2). Basmati rice, which is transplanted a bit late, also draws the attention of farmers in Haryana due to high market value. The delay of 10 to 15 days in Haryana is, therefore, because of the mix of medium duration varieties (MDRVs), hybrids and basmati rice.

With limited irrigation available in the eastern states, transplanting must be tailored in accordance with rainfall aimed at improving the rainfall productivity. As such this reflected the genuine concern on the part of farmers. In our datasets from eastern states, maximum paddy yield was recorded when transplanting was scheduled in July rather than in June. This is different from the best-case scenario with assured irrigation in Punjab. In these ecologies, farmers must make choices ranging from the time of transplanting and all factors related to that, choice of a variety, and access to irrigation. Field experiences have to be applied depending on the ecologies. Since monsoon variability has its maximum influence on the time of transplanting, the role of irrigation becomes critical. The lack of access to irrigation infrastructure is discussed separately in this volume. Farmers will achieve high yields if this benefit is harnessed by managing the time properly.

Data suggested that an irrigation facility is the biggest asset in some districts of shallow lowland ecologies in Bihar and eastern UP. Data (Fig. 2) collectively indicated that supplementary irrigation is seen as a path to increase rainfall productivity. Data from Bihar and eastern UP showed large variations in the response to time of CE from upland ecologies to shallow low land ecologies. In some districts like Rohtas, Lakhisarai, Kaimur, Arwal, Buxar, and Arah in Bihar, and Chandauli in EUP, paddy yields are higher even when the transplanting was done after July 15. Districts Rohtas and Lakhisarai, are leading the pack with an average paddy yield of 5.5 tha^{-1}. Both districts are dominated by shallow lowland ecologies and have canal irrigation facilities. With the very old practice of late transplanting and still reliably high yields (Fig. 3) compared to other districts, irrigation can add value to such ecologies, which are highly favorable for rice cultivation. The timely transplanting in such ecologies held the promise of high yields in a much larger area (Fig. 3). Owing to late release of canal water most transplanting operations are done in July and that is why there is no yield difference in Rohtas and Lakhsarai. The concern for farmers is costly irrigation. If there are some policy interventions for subsidy on diesel, farmers may transplant early and make fullest use of high yield potential of LDRVs as in Punjab because there is no problem of water after mid-July. Once the crop is established earlier than the existing time, the distinctive advantage of ecology with shallow water level can be leveraged for yield gains. These are the ecologies which can match the standards of Punjab once transplanting can be advanced. Based on the limited data in this survey the most popular variety LDRV–Pusa 44 yielded more than 8.0 tha^{-1} in Punjab where the transplanting is finished in June. The margin of yield advantage from another LDRV- MTU 7029 with same yield potential transplanted early in the season seems realistic (Fig. 3) in Rohtas and Lakhisarai but it was not realized. Early transplanting will realize the synergistic benefits of shallow lowland ecologies to LDRVs, which are still popular and will remain so in these districts. Broadly speaking varieties in Rohtas and Lakhisai districts of Bihar, which represent shallow land ecologies of Bihar and in Punjab are of same yield potential. Given the same yield potential, it provides a link between time of transplanting and the paddy yield. The only major difference is the time of CE. There is no large yield difference within each state (Fig. 4) but the difference between two contrasting ecologies is large enough to explain the role of time management. That means farmers need to reorient themselves by managing the time in the presence of varieties of same yield potential. Once the CE is delayed farmers become more sensitive to yield reductions rather than rewards, they get from timely CE as happens in Punjab and Haryana but not in the eastern states. It is important to understand such adaptations across states.

Madhubani is the *Terai* area bordering Nepal. Water from Nepal flows (does not stagnate) through this district. Nawada district is mostly lowland with limited irrigation. Both districts are better placed than many other districts because of timely transplanting. Few districts like Supaul, Madhepura, Darbhanga, and Saharsa, with an average paddy yield of less than 3.4 tha^{-1}, have problem of stagnant water. If an early transplanting is ensured, the crop can escape the adverse effect of floods in these ecologies. This is where the state needs to position farmers to transplant early and insulate the crop from damage from floods. This would need small push for developing rice nursery enterprise among farmers who have the irrigation at their command. That is discussed in another chapter in this book. Similarly, district Muzaffarpur has two distinct ecologies: (i) upland ecology in Sakara, Mushahri, Muraul, and Kudhani blocks, and (ii) flooded area in Bandra, Katra, Aurai, and Minapur blocks. In upland parts of these districts, farmers grow hybrids, which can withstand the adverse effect of water stress. Here also the paddy yield of 4.0 tha-1 was achieved because of timely transplanting and use of hybrids.

In some cases, the time of transplanting does not fully explain the yield differences. There are differences within similar ecologies as Sidharthnagar, Kushinagar, Maharajganj, and Gorakhpur districts in EUP on one hand and on the other hand Rohtas, Lakhisarai, Kaimur, Arwal, Buxar, Arah districts in Bihar and Chandauli (in EUP). In the first case transplanting is done on time while in the second case transplanting is done late. Within these districts, Rohtas with highest paddy yields has more plain and shallow low land area than that in Arah district. In the second scenario the paddy yield is higher due to irrigation support as the crop does not remain in stress.

It implies that shallow lowland ecologies of Rohtas, Lakhisarai, Kaimur, Arwal, Buxar, Arah, and Chandauli may yield at par with Punjab and Haryana if access to tube-well irrigation is further improved, and transplanting is advanced. Already in Sidharthnagar, Kushinagar, Maharajganj, and Gorakhpur transplanting is done timely, supply of irrigation may improve the rice productivity. Overall, early transplanting will add value to the advantage of shallow lowland ecologies of EIGP states.

In most other districts, including Saran, Sitamarhi, Gaya, Jehanabad, Bhagalpur, Samastipur, East Champaran, and Vaishali in Bihar and Deoria in EUP, the transplanting is done in mid-July, yet the yield levels are more than other districts (Fig. 2). Data from within such surveys could be used. The access to MDRHs increased in some of these districts. Application of one or two extra irrigation, and its combination with MDRHs, may solve part of the problem associated with low paddy yield. Understanding why paddy yields are low in certain districts with same variety hints at complex interaction of different factors and their effects on the growth and development of rice. Overall, shallow low land ecologies are shielded from the water stress except during CE phase when transplanted early but upland ecologies suffer water stress even during the later stages of crop cycle. The upland ecologies are not protected by saturated soil conditions and the CE time can be adjusted with peak rainy days by using hybrids. The ecology itself helps explain why farmers are preferring hybrids. The ecological issues must be balanced by using data analytics for suggesting CE time and associated agronomic management for different ecologies. Following two examples of CE time seem to have shaped the response of LDRVs (Fig. 3) and hybrids (Table 1) to the combination of ecologies across states.

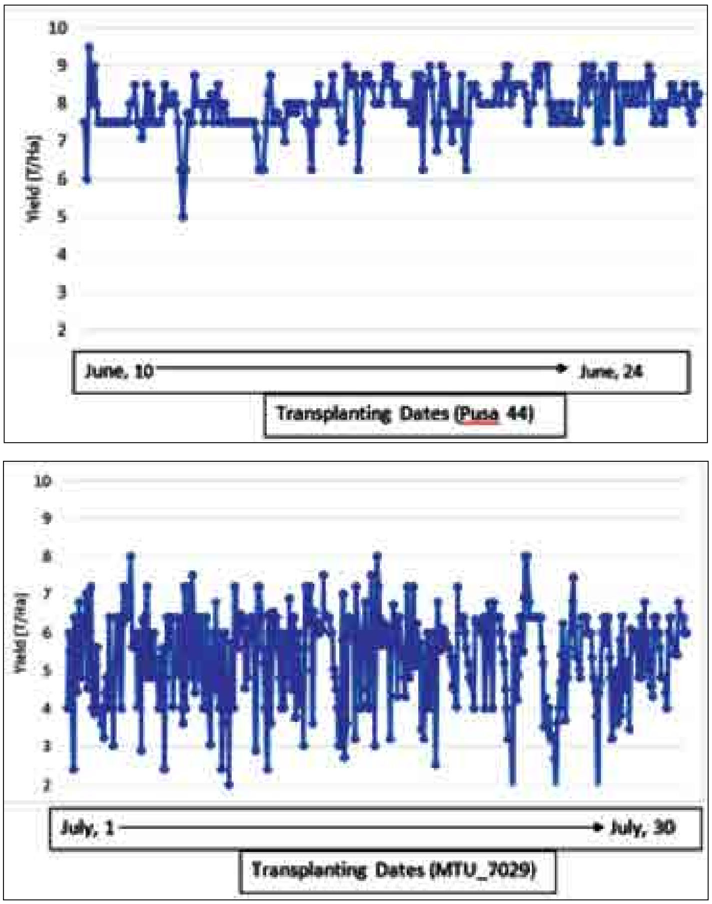

Fig. 3. Long duration rice varieties in Rohtas and Lakhisarai (MTU 7029) in Bihar and in Punjab (Pusa 44) and their response to the time of transplanting

Table 1. Effect of time of transplanting on the paddy yield of Arize 6444 in Haryana and Bihar where the adoption of hybrids is around 30%

State	Date of transplanting	Yield ($kgha^{-1}$)	Yield/day ($kgha^{-1}$)	No. households	SD	% households
Bihar	16 June- 30 June	4030	28.8	32	1.02	0.45%
Bihar	01 July- 15 July	4060	29.0	990	1.01	13.87%
Bihar	16 July- 31 July	3840	27.4	555	1.02	7.78%
Bihar	01 August- 15 August	3860	27.6	90	0.84	1.26%
Bihar	After 15 August	3860	27.6	10	0.59	0.14%
Haryana	Till 15 June	6930	49.5	15	0.55	3.61%
Haryana	16 June- 30 June	7040	50.3	73	0.55	17.59%
Haryana	01 July- 15 July	6750	48.2	5	0.53	1.20%

Compared to Punjab and Haryana, the eastern states with RWCS have much better attributes in terms of shallow lowland ecologies for producing very high paddy yields. The extra time-period is needed to harness maximum benefits from the LDRVs and MDRVs or MDRHs. Data (Table 1) indicated that timely transplanting helps but it is hard to get maximum benefit in Bihar if irrigation is costly.

3.1.2. Time of crop establishment in rice-rice, rice-fallow, and rice-pulse cropping systems

There is little ecological difference among Odisha, West Bengal, and surveyed districts of Chhattisgarh. In Odisha, transplanting started from June (Nayagarh) and continued till 15 July. Paddy yield was higher at 4.3 tha^{-1} in Jagatsinghpur districts where transplanting or direct seeding was done in the second half of July. The lower yields in Mayurbhanj, Khorda, and Jajpur were because of direct broadcast seeding of rice followed by *beushening* (DBSRB) in some areas, which reduced yields, and due to lack of irrigation. Balasore and Bhadrak were the best performing districts with paddy yields ranging from 4.5 to 4.7 tha^{-1}. Time of transplanting and assured irrigation supply are inter-linked to improve rice productivity.

The transplanting in three districts of Chhattisgarh is mostly on time; however, other landscape and poor management related issues, including CE, weed and irrigation management, lead to lower rice yields. The Kanker district of Chhattisgarh showed the lowest average yield even under timely sowing because of the prevalence of broadcast direct seeding methods of establishment and more area under upland and rain-fed ecology. That means timely transplanting is the key to attain higher yields, but it also warrants for assured irrigation.

In addition to time of planting, suitable soil texture is also very important to harvest a good rice crop. For an example, a larger share of poor yields from districts like Mayurbhanj, Naupada, and Keonjhar in Odisha, Kanker in Chhattisgarh, and Purliya in West Bengal was majorly because of their light-textured soils along with full dependence on rains, and occurrence of drought-like situation during tillering or grain filling stages of rice. Rainfall is the dominant weather factor that determines yield in West Bengal and other eastern regions. The high mean minimum and maximum temperature at the time of flowering at the end of August and/or September may reduce rice yield if rainfall withdrawal starts early.

Another group of top performing respondents is in AP, where rice cultivation was typically done under irrigated conditions (Fig. 4). Rice cultivation in AP was under irrigated conditions, but still, the dependence on monsoon is very high. The report submitted by the National Bank of Agriculture and Rural Development Bank (NABARD) also highlighted that rice cultivation in erstwhile AP was unprofitable under unirrigated conditions (Chakarborty and Murray, 2015). More data such as this will help understanding which intervention is likely to be more effective.

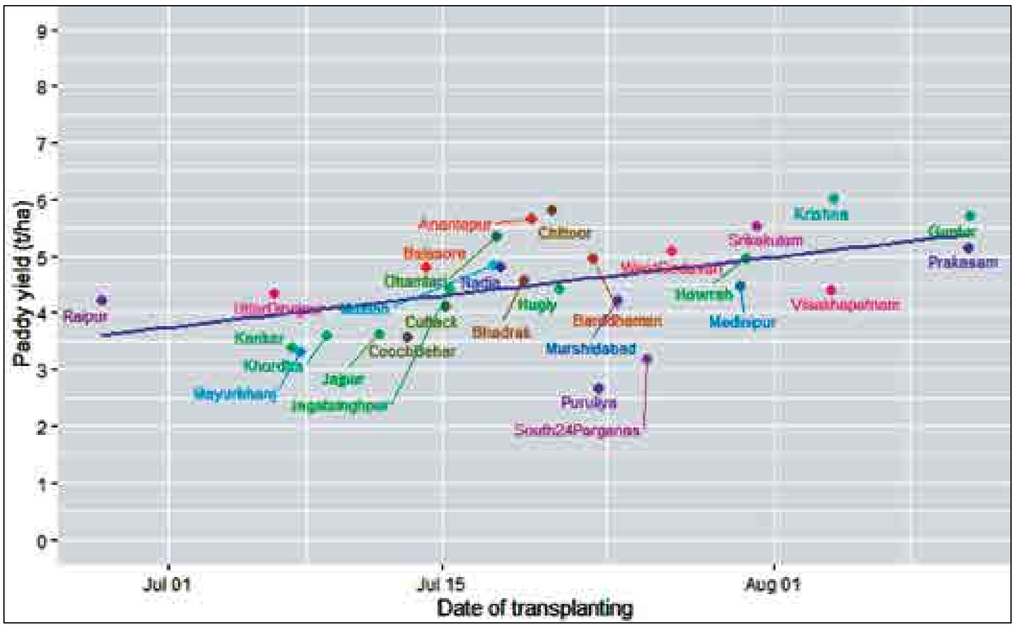

Fig. 4. District-wise average paddy yield (tha^{-1}) against average date of transplanting across Andhra Pradesh, Odisha, Chhattisgarh, and West Bengal dominated by rice-rice cropping system (RRCS) and rice-fallow cropping systems (RFCS) (n=5,662)

Recommended rice transplanting schedule is July–August in Krishna-Godavari (Guntur, Krishna, and Prakhasham), AP, but the average transplanting schedule reported by surveyed farmers is in August. The highest yield (6.1 tha^{-1}) was recorded in Krishna district where transplanting is done in the first week of August, almost 10 days earlier than Guntur and Prakasham. Late transplanting in these districts is because the canal water is not released in the June. Another reason is that in November, farmers tend to skip harvesting due to the probability of occasional cyclones in November. The earliest transplanting happens in Anantapur, which is a lower rainfall region in AP. Farmers here irrigate their crops with the help of bore-wells so that crop completes its life cycle within monsoon rains. Here the yield level of 5.5 tha^{-1} is realized. Vishakhapatnam, part of the North Coastal zone, follows the recommended transplanting schedule, but yields are less than that of other districts. Overall, Andhra Pradesh has a very well-developed irrigation system. The state is mostly irrigated and has a similar problem associated with a decline in water table as observed in NWIGP.

The average productivity of rice in AP is still low at 2.9 tha^{-1} where RRCS and RPCS are the main cropping system; soils are fertile deltaic alluvial, and the irrigation system is assured through canals, clearly indicating that the uncertain rainfall is still the most important variable. Despite assured irrigation there is a large variation in the time of CE across AP. The decreasing trend in the June rainfall delays the transplanting in most states in these cropping systems. Despite 60 % rice area being under irrigation in India, 48 % contribution of monsoon rainfall to productivity indicated the importance of monsoon rainfall in rice cultivation (Subash and Gangwar, 2014). Low average yield is because some districts in AP are more exposed to drought-like situation due to irregular supply of canal water and delayed transplanting due to scarcity of rains. Unlike Punjab where CE is complete within two weeks in June, the staggered CE in AP reflected the fear of poor time management. The level of mechanization is low.

3.1.3. Timely crop establishment means more intensification and more profits

Data (Fig. 1) showed that the paddy yields of bottom 10 % HHs in AP, Eastern UP, Chhattisgarh, Bihar, West Bengal, and Odisha are correspondingly 3.2, 2.5, 2.2, 2.1, 1.7, and 1.0 tha^{-1} in the descending order. The magnitude of yield gap between the best performer HHs and the lowest performer HHs is much more in the above states than that in Punjab and Haryana. As the problem of variable monsoon is further compounded by climate change, the bottom 10 to 30 % performers may have to adopt similar management strategies, as adopted by the top 10 % performers in their respective states. The LDS found two broad trends, indicating the need for time management. The trends indicated no displacement of LDRVs or MDRVs of 140 days or more. The data filter on the basis of duration revealed that profits can be improved by intensifying the cropping systems through time management across all ecologies. These data sets across states help in finding the core issues that affect the productivity. Farmers in Punjab and Haryana could take two rice crops, and still maintained high productivity. In fact, farmers in Punjab and Haryana used to start the process of rice cultivation right from April with summer rice followed by *kharif* rice. With the availability of a very short duration variety called Govind, the farmers then could complete two rice crop cycles in one *kharif* (April-October). Sensing the danger of falling groundwater level, the Punjab and Haryana Governments have since 2008 and 2009 prevented farmers from sowing rice nursery before 10th May and transplanting before 15th June. Data on time management matches perfectly within a short window in Punjab and Haryana but not in any other states. Based on present LDS data, it is evident that the majority of the HHs in EUP and Bihar transplant rice 4 to 6 weeks later compared to Punjab and Haryana. Overall picture indicated that early/timely transplanting is most crucial to attain higher yields because it allows the crop to spend more time in the field before maturity. Mechanization from seed to harvest can be used to facilitate timely transplanting. In fact, the comparative data from Northwest and Eastern States with rice-wheat cropping system showed that both LDRVs and MDRHs got major gains in the paddy yield due to transplanting done in mid-June. In addition, there is a scope of higher wheat grain yield. Overall data sets from Bihar and eastern UP exposed this weakness of delayed transplanting. To find out rainfall pattern over Bihar CHIRPS daily rainfall data between June to October were analyzed over the period of nine years (2011 - 2019). In terms of rainfall patterns during last nine years, the distribution of rains was normal only in two years - 2016 and 2019 (Fig. 5). Also, it is evident (Fig. 5) that south western part of Bihar is receiving less rainfall than the other parts of the state and this may be one of the causes of low productivity in this region. Historically, in Bihar and eastern UP, the focus has been more on rice than on wheat, while in Northwest this focus has been more on wheat than on rice. That is why the responses of both farmers and governments have remained concentrated on rice with little or no effort to look at the succeeding wheat crop. Now the use of big data sets like this is necessary to help farmers and the extension agencies to understand how predictive modelling and algorithms can support them with cropping system optimization-based options. Therefore, the time management should be viewed from the framework of a cropping system (Tilman *et al*., 2011; Ray *et al*., 2012) rather than a single component crop. The fundamental assumption is that the farmers have access to electricity up to their field and if so, farmers will install tube-wells according to their intensification needs.

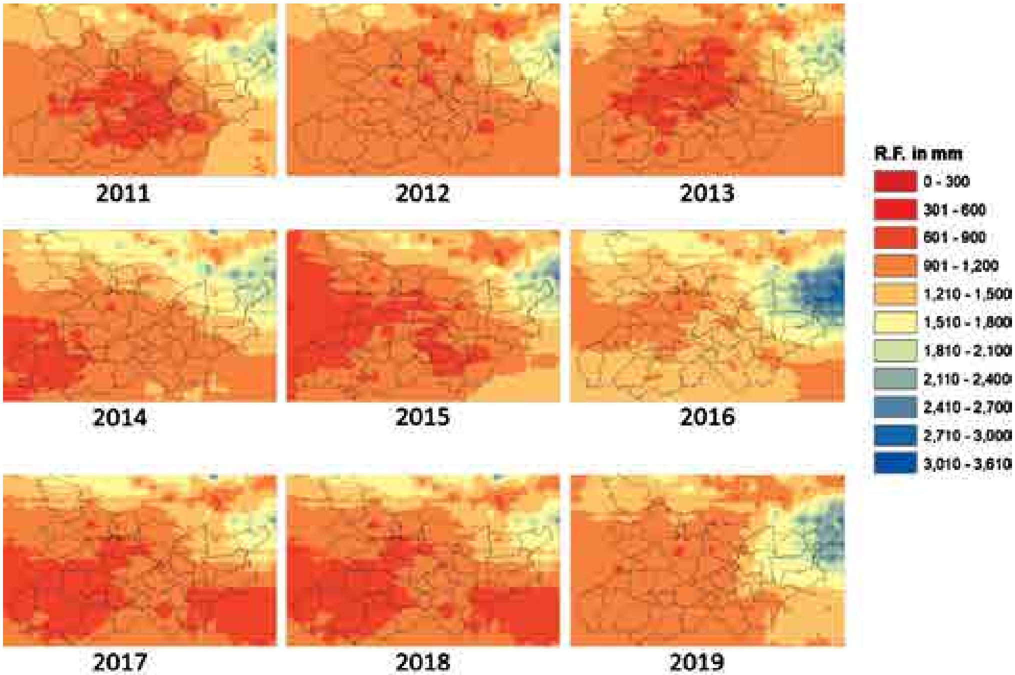

Fig. 5. Accumulated rainfall since 2011 over Bihar between June to October

The early transplanting itself can be attributed to better access to irrigation but the apparent shift towards early transplanting in Punjab and Haryana is consistent with high yield of rice itself. Additionally, the crops in rotation with rice are more likely to gain in the process where the system itself is optimized. The risk of losing yield of succeeding crops is real. This approach also applies to RRCS or RPCS in South India and RFCS in Odisha or Chhattisgarh where we must advance the current CE schedule to match the needs of crops in rotation. Similar uncertainties associated with monsoon rains existed earlier (Subash and Ram Mohan, 2011) and would likely to reveal similar patterns. The best hope for intensification remains with the framework of optimization of cropping system (through advancement in CE, with access to low cost irrigation in all ecologies covered in this survey. It is important not only to educate farmers but also spend more time and energy on cropping system research than on commodity crops as such.

Therefore, the intervention on time management is powerful enough to make a dramatic difference in the overall management of cropping systems across states. To support more area under RPCS and RRCS, and to cover fallow land in states like Odisha, time management becomes even more important. This has become more relevant in places like AP, where maize area is likely to come down due to the problem of Fall Armyworm. Optimization is very relevant where the time management is possible through mechanization from seed to harvest. This logic stands between harnessing the fullest growth cycle of the best high yielding LDRVs or the MDRVs maturing in more than 140 days, and the irrigation levels. Similarly, most upland ecologies (Figs 2, 4) will require the continued introduction of hybrids and MDRVs, with some increase in number of irrigations at establishment and development phase of a crop cycle. The time management can offer an advantage over stress tolerant varieties by making best use of rainfall patterns across ecologies and by ensuring proper sink and source relationship in the rice plant, thus optimizing the duration and time of grain filling (Gangwar and Ahamedi, 1990; Khakwani *et al*., 2006) and transferring more photosynthetic products from the leaf, stem, and sheath to the panicle (Liu *et al*., 2015).

The transitioning from *kharif* to *rabi* crops will need residual moisture to cover more areas and better time management. In the absence of cropping system productivity gains, the income of farmers will be constrained. The delayed transplanting and late harvesting of rice in these ecologies reduced the area under pulses in AP and in Odisha. Some districts like Visakhapatnam have the potential for three rice crops, but the release of canal water is a problem. Similarly, in Anantapur, where rice-groundnut is the main cropping system, time management is an important issue. Coastal areas, and the areas with better access to irrigation, including East/West Godavari and Krishna, have a much better scope of sustainable intensification. The combination of two factors, climate change (Ranuzzi and Srivastava, 2012), and the trends in technological feedbacks such as this survey, has made it necessary to revise recommendations. This dataset will be useful for effective decision making and introducing the concept of the digital agricultural advisory system (Fabregas *et al*., 2019) at the level of Agricultural Technology Application Research Institutes (ATARIs). Given the awareness coming from this survey, it will help scientists down the line to pick up new and different ideas. This survey, in a way, challenged the *status quo* and the ways priorities are to set in the research and extension work within each state.

3.6 Conclusion

A critical assessment of the data affirmed that time of transplanting, is the prime management factors influencing rice yield without incurring extra cost, across all ecologies. The granular distinctions about advantages and risks associated with timely transplanting made in this survey clearly demonstrated the need to providing enough space of each variety or a hybrid to make fullest use of their yield potential In the Krishna district of Andhra Pradesh, where the farmers transplant rice seedlings in the first fortnight of August, harvested paddy yields are 6.1 tha^{-1}. Also, in some shallow lowland ecologies of Bihar, where rice is transplanted after July 15, the average paddy yields were realized at 5.2 tha^{-1}. In West Bengal (Malda district), Chhattisgarh (Dhamtari district) and Odisha's Balasore district, the highest yielding localities were those where the rice was transplanted around July 15. Such ecologies have the enduring ability to produce very high paddy yield if the transplanting times are corrected in favor of early transplanting. The higher cost of irrigation is hindering the spread of area under timely transplanting. Punjab and Haryana, representing assured irrigated ecologies, and preferring early transplanting (till the end of June), also have two distinct performance scenarios of long duration rice varieties in Punjab (paddy yields of 7.9 tha^{-1}) and MDRVs or hybrids (paddy yields of 6.5 tha^{-1}) in Haryana get the targeted paddy yields by making fullest use of yield potential according to maturity class. Although the ecologies of surveyed states or clusters within each Eastern state are different yet the potential of harnessing the yield advantage from early transplanting is huge and should be harnessed. The time management should be viewed from the framework of a cropping system rather than a single component crop. The early transplanting itself can be attributed to better access to irrigation but the apparent shift towards early transplanting in Punjab and Haryana is consistent with high yield of rice itself. Additionally, the crops in rotation with rice are more likely to gain in the process where the system itself is optimized. The risk of losing yield of succeeding crops is real. This approach also applies to RRCS or RPCS in South India and RFCS in Odisha or Chhattisgarh where the current CE schedule must be advanced to match the needs of crops in rotation. Therefore, the benefits of time management and associated agronomic management should be utilized, for harnessing the potential of varieties or enhancing efficiency of nutrients used and also in intensification of rice-based cropping systems.

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2.6 Weed flora and weed management practices of smallholder rice farmers in key rice growing states of India

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KEY MESSAGES

- *Echinochloa* spp (either *E. colona* or *E. crus-galli*) was reported as the most common and the most troublesome weed of rice in Andhra Pradesh, Bihar, Eastern Uttar Pradesh (EUP), Chhattisgarh, Punjab and Haryana. In Odisha and West Bengal, *Cynodon dactylon* and *Marsilea minuta* were reported as the most common and troublesome weeds, respectively.
- Both *Echinochloa* group (either *E. colona* or *E. crus-galli*) and *Cyperus* group (*C. difformis* or *C. iria*) were reported among the top five most troublesome weeds in all the surveyed States. *C. dactylon* is also identified as one of the top five troublesome weeds in Andhra Pradesh, Bihar, Odisha, and West Bengal, but not in Northwestern states (Punjab and Haryana), EUP, and Chhattisgarh. Other problematic weeds reported in specific states include: *Ischaemum rugosum* in Chhattisgarh and Haryana, *Dactyloctenium aegyptium* in Haryana and EUP, *Fimbristylis* spp in Odisha, *Scirpus juncoides* in EUP, *Cyperus rotundus* in Bihar, and weedy rice in Chhattisgarh.
- The spatial distribution of the top 12 most common and top five most troublesome weeds of rice in 31 districts of Bihar and nine districts of EUP were identified. In addition, the spatial distribution of key perennial weeds (*C. dactylon* and

C. rotundus) and some emerging weeds such as weedy rice, and *M. minuta* were identified across districts in all surveyed states. This spatial information will help in developing and deploying appropriate weed management products in specific districts as per weed flora.

- In some selected districts in Bihar, EUP, Chhattisgarh, Odisha, and Andhra Pradesh, weedy rice was identified as an emerging difficult-to-control weed in rice. Therefore, there is a need to: (a) increase farmers' awareness about the threat imposed by this species, and (b) highlight the importance of closer watch so that its invasion can be checked in new areas. Its eradication is possible at an early stage by (a) rouging out upon its initial appearance in the field, and (b) developing integrated options for its management before it becomes a major problem. In addition, perennial weeds such as *C. dactylon* and *C. rotundus* are becoming a major problem widely in rainfed states and this warrants the need to develop effective strategies to manage perennial weed problems in rice production.
- Majority of the farmers (>95 % households) used various methods to control weeds in their rice fields, with the exception in Chhattisgarh where 36 % of households did not practice any weed control in their rice fields.
- Farmers practiced different types of weed control across states. In Odisha and Bihar, sole hand weeding based weed control is the most dominant method with >65 % of households. The use of herbicide-based weed control methods (herbicide alone or herbicide + hand weeding) were lowest in Odisha and Bihar (24-29 % of households), followed by Andhra Pradesh, West Bengal and Chhattisgarh (52-55 % of households), and EUP (66 % of households). The use of these methods was the highest in Haryana and Punjab with 80 % and 100 % of households, respectively.
- In Buxar, Samastipur, and Gaya districts of Bihar, about 30 %, 15 %, and 30 % surveyed farmers did not practice any weed control in their rice fields. These districts can be targeted to increase awareness about yield losses due to weeds, and rice productivity can be increased by demonstrating the benefits of integrated weed management practices.
- Herbicide + hand weeding based weed control resulted in yield gain of 0.33 – 0.75 t ha^{-1} (6 – 19 %) compared to sole hand weeding method – the most dominant weed control method in most of the surveyed states. The yield increase was 0.33 t ha^{-1} (6 %) in Andhra Pradesh, 0.38 t ha^{-1} (10 %) in Bihar, 0.45 t ha^{-1} (8 %) in Haryana, 0.6 t ha^{-1} (15 %) in Odisha, 0.41 t ha^{-1} (10 %) in EUP, and 0.75 t ha^{-1} (19 %) in West Bengal.
- These results suggested that there is a scope to increase rice yields in these states by reducing yield gaps caused by weed competition. Switching to a combination of herbicide + hand weeding based weed control, instead of relying on either sole hand weeding or herbicide-based weed control, can increase yield. Clearly, first of all, districts can be targeted where adoption of herbicide + hand weeding

based weed control is low and expected yield gain is high. Reliance on sole hand weeding or herbicides is less sustainable as sole dependence on herbicides can lead to the development of herbicide resistance in weeds, and sole dependence on hand weeding is becoming uneconomical because of rising labor shortage and labor wages. Therefore, integration of herbicide with hand weeding is more sustainable, productive and profitable option to overcome the risks of herbicide resistance development, and to reduce weed control costs besides achieving more effective weed management.

1.0 Introduction

Rice *(Oryza sativa* L.) is an important food crop for global food security being a staple cereal for more than half of the world's population (GRiSP, 2013). India, the world's top rice-producing country with 44 million ha area, is ranked second in production with 113 million metric tons (Mt) milled rice (IASRI, 2019), accounting for 25% of global rice area and 21% of global rice production (FAO, 2018). These data suggested the importance of the sustainability of Indian rice production for the country and global food security. To meet the future rice demand of the burgeoning population in India, it is projected that 140 million Mt milled rice would be needed by 2050 (Pathak *et al.*, 2018). To achieve this target, rice production has to increase by 1.5 Mt/year and national average rice productivity should increase to 3.25 t ha^{-1} by 2050. The challenges are that this extra rice in the future is required to be produced with reduced environmental footprint using fewer resources (labor, water, agrochemicals, etc.) to ensure food, economic, and environmental sustainability.

India made significant progress in improving rice productivity overtime with yield increased from 668 $kgha^{-1}$ in 1950-51 to 2,578 kg/ ha in 2017-18 (MoA, 2018). This progress in productivity gain was witnessed more in northwest India (Punjab and Haryana) and Southern India (e.g. Tamil Nadu), whereas states in Eastern India (e.g. Odisha, Eastern Uttar Pradesh, Bihar, West Bengal) lag behind in attaining the same level of yield gain during this period. In India, the rice yield gap in irrigated systems ranged from 16 to 76%, while in rainfed lowland it ranged from 33 to 66% (Siddiq, 2000). Eastern India is characterized by large cereal yield gaps including rice, hence, for large scale rural poverty and food insecurity.

The exploitable rice yield gap can partially be reduced by minimizing yield losses caused by weeds. Weeds are one of the key biological constraints in rice in attaining full yield potential and economic benefit. Based on All-India Coordinated Research Project on Weed management (AICRIP-WM), actual yield losses due to weeds in transplanted rice and direct-seed rice were 13.8% (range 3 to 30%) and 21.4% (range 6 to 50%), respectively (Gharde *et al.*, 2018). The economic losses caused by weeds in rice are estimated to the tune of USD 4,420 million (Gharde *et al.*, 2018).

Changes in crop management practices owing to different drivers of rural change can have implications on weed population dynamics and weed management practices. Therefore, it is important to document farmers' current weed management practices. For example, to cope with labor scarcity, farmers are transitioning from hand-weeding to herbicide-based weed management and from manual transplanting to mechanical transplanting or direct-seeding of rice. Household studies covering major rice-growing environments are a useful approach to characterize farmers' weed management practices, identify major and problematic weeds at the landscape level, characterize the agronomic practices influencing weed management and yield, and identify farmers' knowledge gaps in weed management.

The overall aim of this study was to take stock of the current situation of weed management in rice production environments of eastern India (Bihar, Chhattisgarh, eastern Uttar Pradesh (EUP), Jharkhand, Odisha, and West Bengal), northwestern India (Punjab and Haryana), and southern India (Andhra Pradesh). The specific objectives were to: (i) generate the spatial information on the distribution of most common and troublesome weeds of rice, (ii) document farmers' current weed management practices in rice, (iii) identify key knowledge gaps in their current weed management practices, and (iv) assess the association of weed flora with crop management practices and biophysical environments.

2.0 Methods

2.1 Study sites

The study was conducted in eight states of India covering eastern (31 districts of Bihar, nine districts of eastern Uttar Pradesh, seven districts of Odisha, 11 districts of West Bengal, and four districts of Chhattisgarh), northwestern (two districts each of Punjab and Haryana), and southern India (nine districts of Andhra Pradesh). The survey tried to cover the following rice-based cropping systems: rice-rice, rice-wheat, rice-fallow, and rice-non-cereal, and covered almost all rice environments. Overall, the study covered a total of 70 districts of India.

2.2 Household survey of rice farmers

The household survey of 14,408 randomly selected farmers was conducted in 2017-18 and 2018-19 (one-third of the surveyed districts in 2017) using a structured survey questionnaire with 30 randomly selected villages in each district and seven random rice farmers in each village (a total of 210 farmers per district). The data were collected digitally using Open Data Kit (ODK), open-source software for collecting and managing data (*see* Chapter 1.1). The survey questionnaire collected information on: farmer's profile and socio-demographic characteristics, farm characteristics, farmer's current agronomic practices, major weeds invading their rice farms, and their current weed management practices. To identify the major weeds invading their fields, farmers were shown posters with photos of 46 weed species commonly associated with rice (https://drive.google.com/open?id=1LdNN87eX6L4arZX_DLhlbv1MAuN6SWXb). The names along with their abbreviations are given in Table 1. From the poster, surveyed farmers were asked to list the major species present in their field (most common) and to rank the top five most troublesome weeds – those that are difficult to control and their infestation level is severe causing major yield losses.

Table 1. Rice weed species which were included in a weed poster for weed identification by farmers during the survey in 2017-18 and 2018-19

Sr. #	Weed Code	Weed name	Sr. #	Weed Code	Weed name
1	AESIN	*Aeschynomene indica*	24	EUPTH	*Euphorbia thymifolia*
2	AGECO	*Ageratum conyzoides*	25	FIMMI	*Fimbristylis* spp
3	ALTPH	*Alternenthera philoxeroides*	26	ISCRU	*Ischaemum rugosum*
4	ALTSE	*Alternenthera sessilis*	27	IPOAQ	*Ipomoea aquatica*
5	AMM	*Ammania* spp	28	LEEHE	*Leersia hexandra*
6	BRARE	*Brachiaria reptans*	29	LEPCH	*Leptochloa chinensis*
7	CAEAX	*Caesulia axillaris*	30	LUDAD	*Ludwigia adscendens*
8	COMBE	*Commelina benghalensis*	31	LUDHY	*Ludwigia hyssopifolia*
9	COMDI	*Commelina diffusa*	32	LUDOC	*Ludwigia octovalvis*
10	CYPDI	*Cyperus difformis*	33	LIN	*Lindernia* spp
11	CYPIR	*Cyperus iria*	34	MONVA	*Monochoria vaginalis*
12	CYPRO	Cyperus rotundus	35	MARMI	*Marsilea minuta*
13	CYNDA	*Cynodon dactylon*	36	Weedy rice	*Oryza sativa* f. *spontanea*
14	DACAE	*Dactyloctenium aegyptium*	37	PASDI	*Paspalum distichum*
15	DIGCI	*Digitaria ciliaris*	38	PISST	*Pistia stratiotes*
16	ECHCG	*Echinochloa crus-galli*	39	PHYMI	*Physalis micrantha*
17	ECHCO	*Echinochloa colona*	40	PHYNI	*Phyllanthus niruri*
18	ECLPR	*Eclipta prostrata*	41	POOL	*Portulaca oleracea*
19	EICCR	*Eichhornia crassipes*	42	ROTCO	*Rottboellia cochinchinensis*
20	ELEIN	*Eleusine indica*	43	SAG	*Sagittaria* spp
21	ERAJA	*Eragrostis japonica*	44	SCIJUN	*Scirpus juncoides*
22	ERATE	*Eragrostis tenella*	45	SPHZE	*Sphenoclea zeylanica*
23	EUPHI	*Euphorbia hirta*	46	TRIPO	*Trianthema portulacastrum*

3.0 Results and Discussion

3.1 Spatial distribution of most common and troublesome (Top 5 and 10) weeds of rice

3.1.1 Most common weeds

The 12 most common (the dirty dozen) weeds invading rice fields in eight Indian States are given in Fig. 1. Among the top 12 most common weeds, some species were the same across all states, some were common in the majority of states, and some were unique to specific states. For example, *E. colona* and *C. iria* were among the top 12 most common weeds in all the eight surveyed states; whereas *E. crus-galli*, *C. difformis* and *C. dactylon* were among the top 12 common weeds in seven out of eight states, and *C. rotundus, D. aegyptium, S. juncoides* were among the top 12 most common weeds in six out of eight states. *L. chinensis* and *M. minuta* were among the top 12 most common weeds in five surveyed states, and *Fimbristylis* spp and *I. rugosum* in four states out of eight surveyed states. The rest of the weed species (18 species) were among the top 12 most common weeds in either one or two states. For example, weedy rice was among the top 12 most common weeds in Chhattisgarh and eastern UP only; *S. zeylanica* in Odisha

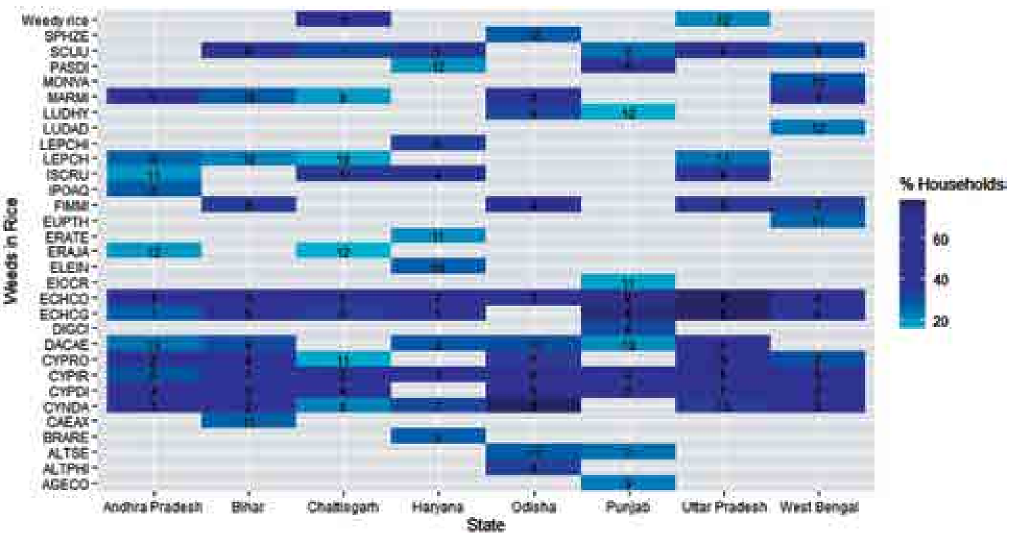

Fig. 1. Heat map of the 12 most common (dirty dozen) weeds of rice invading farmer's fields in Andhra Pradesh (n=1,647), Bihar (n=7,141), Chhattisgarh (n=773), Odisha (n=1,207), Haryana (n=417), Punjab (n=388), Uttar Pradesh (n=2,553), and West Bengal (n=2,035).

Note: Refer Table 1 for weed abbreviations; Ranking number given based on frequency (% farmers reported); Ranking 1= highest frequency; Raking 12:=lowest frequency only; *A. conyzoides*, *E. crassipes*, *D. ciliaris* and *L. hyssopifolia* in Punjab only; *B. reptans, E. indica,* and *E. tenella* in Haryana only; *C. axillaris* in Bihar only*; M. vaginalis* and *L. adscendens* in West Bengal only; *P. distichum* in Punjab and Haryana only; *E. japonica* in Chhattisgarh and Andhra Pradesh only, and *I. aquatic* in Andhra Pradesh only.

This difference in weed flora could be owing to differences in biophysical and environmental conditions, and agronomic practices. In general, grasses and sedges were more dominant in the top 12 most common weeds. Broadleaf weeds were less in the top 12 common weeds in most states except Odisha, West Bengal, and Punjab where four or five out of 12 were broadleaved weeds. The presence of these broadleaf weeds in West Bengal and Odisha could be due to water stagnation conditions in the surveyed districts as these weeds are more prevalent in lowland or water stagnation conditions. Among grasses, the dominant species were *E. colona*, *E. crus-galli*, *C. dactylon*, *D. aegyptium*, *L. chinensis,* and *I. rugosum,* whereas, among sedges, the dominant species were *C. iria, C. difformis, C. rotundus, F. miliacea,* and *S. juncoides.*

Out of the top 12 most common weeds, *E. colona* was ranked the most common weed in Andhra Pradesh, Bihar, and Chhattisgarh, whereas in Haryana, Punjab, and EUP, *E. crus-galli* was reported the most common and *E. colona* as the second most common weed. In Odisha, *C. dactylon* and in West Bengal *M. minuta* were reported as the most common weeds among the top 12.

The top 12 most important weeds of rice in each district reported by farmers from 31 districts of Bihar and nine districts of EUP are presented in Figs. 2 and 3, respectively. In Bihar, *E. colona* and *C. dactylon* were reported as the most cosmopolitan weeds as farmers from all the 31 surveyed districts selected these weeds among the top 12 most common weeds in their rice fields (Fig. 2). However, *E. colona* ranked among the top one to three in most of the districts. In addition, sedges such as *C. diformis*, *S. juncoides*, *C. iria*, *C. rotundus and Fimbristylis* spp and grasses such as *E. crus-galli* and *D. aegyptium* were also reported as widespread and most common weed species across two-thirds of surveyed districts. Weeds such as *C. axillaris*, *M. minuta*, *Leptochloa* spp, and *E. indica* were reported in almost 50 % of the surveyed districts. Other species were more common in specific districts. For example, weedy rice was more common in southern districts of Bihar (Arah, Buxar, Rohtas, Nawada, Arwal, Kaimur, Lakhisarai) except Darbhanga, and in two districts (Arah and Rohtash) it ranked as the second most common weed. *Trianthema portulacastrum* was reported only in Arah district as the ninth most common weed; *Monochoria vaginalis* and *Sagittaria* spp only in Rohtash district; *Sphenochlea zeylenica* in Kaimur and Nawada only; *Physalis micrantha* only in Samastipur and

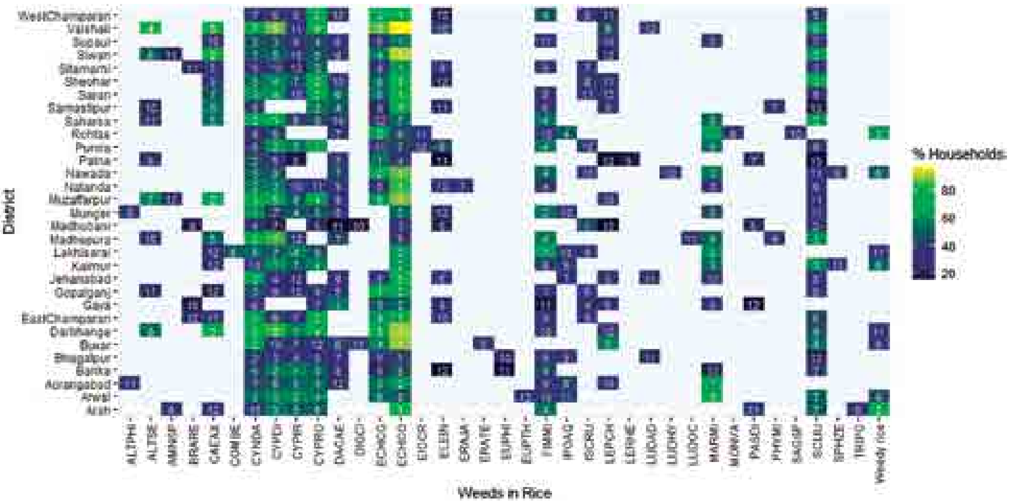

Fig. 2. Heat map of the top 12 major weeds invading farmers' rice fields in 31 districts of Bihar

Note: Refer Table 1 for weed abbreviations. Ranking number given based on frequency (% farmers reported). Ranking 1= highest frequency; Raking 12= lowest frequency.

Madhepura; *Ludwigia adscendens* in Bhagalpur, Jehanabad, and Vaishali*; Ammania* spp in Muzaffarpur, Siwan and Arah*; Paspalum distichum* in Patna, Madhubani, Gaya and Arah*; Leersia hexandra* in Patna only*; Euphorbia hirta* in Bhagalpur and Banka districts*; Commelina benghalensis* in Lakhisarai only*;* and *Bracharia reptan* in East Champaran, Gaya, Madhubani, and Sitamarhi districts.

In Eastern Uttar Pradesh, *Echinochloa* group (*E. crus-galli* or *E. colona*) was reported as the most common weeds across all surveyed districts (Fig. 3). Other weed species, which were reported as among the top 12 most common weeds by farmers of all surveyed districts include *C. rotundus*, *D. aegyptium*, and *S. juncoides*. So these five weed species were common in all the surveyed districts. *C. iria* and *C. difformis* were the other two most common weeds widely spread over eight out of nine surveyed districts. *Fimbristylis* spp and *C. dactylon* were reported by all surveyed districts except Gazipur and Deoria, and Gorakhpur and Mau, respectively. *I. rugosum* was found among the top 12 common weeds in northern districts (Sidharthnagar, Mau, Maharajganj, Kushinagar, Gorkhpur, and Gazipur) and was not reported by farmers in southern districts (Chandhuli, Ballia, and Ghazipur). Similarly, *Leptochloa* was more common in northern districts of eastern Uttar Pradesh. In contrast, *C. axillaris,* weedy rice, and *T. portulacstrum* were more common in the southern districts of Eastern Uttar Pradesh (Ballia, Chandauli, Gazipur, and Mau).

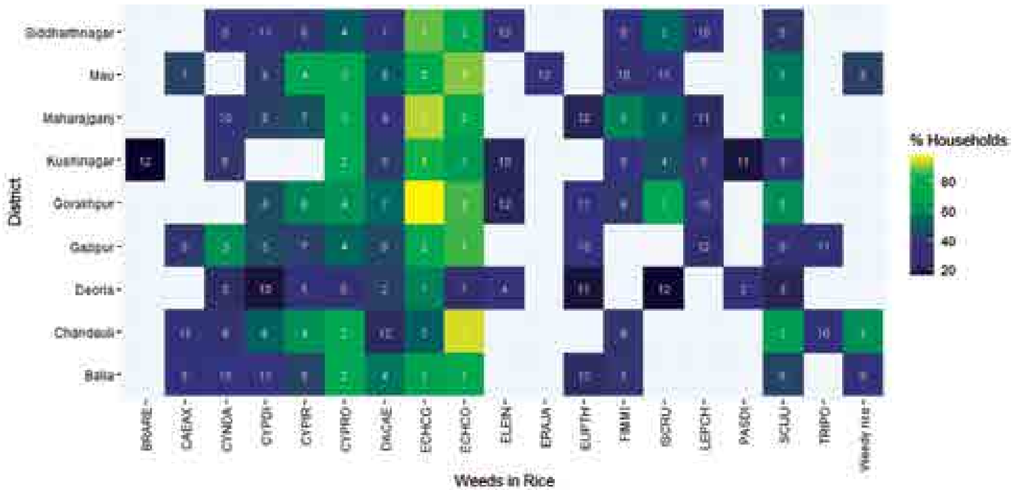

Fig. 3. Heat map of the top 12 major weeds invading farmers' rice fields in 9 districts of the eastern Uttar Pradesh

Note: Refer Table 1 for weed abbreviations. Ranking number given based on frequency (% farmers reported). Ranking 1= highest frequency; Raking 12= lowest frequency.

The weed spectrum can be influenced by crop establishment methods because of change in tillage, water management, and weed management with the establishment method (Kumar *et al.* 2013). For example, in Odisha, Chhattisgarh, and Andhra Pradesh, the ranking, as well as the type of weed species in the top 12 most common weeds, differed in DSR and PTR (Fig. 4). In Odisha, weedy rice, *B. reptans,* and *I. aquatic* were among the top 12 most common weeds in DSR but were not in PTR. In contrast, in PTR*, L. hyssopifolia*, *S. zeylanica*, and *M. vaginalis* were more common. The rest of the nine weed species were common in both DSR and PTR but ranking varied with crop establishment methods. In Andhra Pradesh, out of the top 12 most common weed species, eight were similar but 4 weed species differed in DSR and PTR, and in Chhattisgarh, two weed species varied in DSR and PTR.

3.1.2 Top five troublesome weeds

Either *E. colona* or *E. crus-galli* was reported as the most troublesome weed in all surveyed states except in Odisha and West Bengal (Fig. 5). *M. minuta* and *C. dactylon* were reported as the most troublesome weeds in West Bengal and Odisha, respectively. Both *Echinochloa* group (either *E. colona* or *E. crus-galli*) and *Cyperus* group (*C. difformis* or *C. iria*) were reported as one of the top five most troublesome weeds in all the surveyed states. *C. dactylon* was among top three troublesome weeds in Andhra Pradesh, Bihar, Odisha, and West Bengal but was not reported

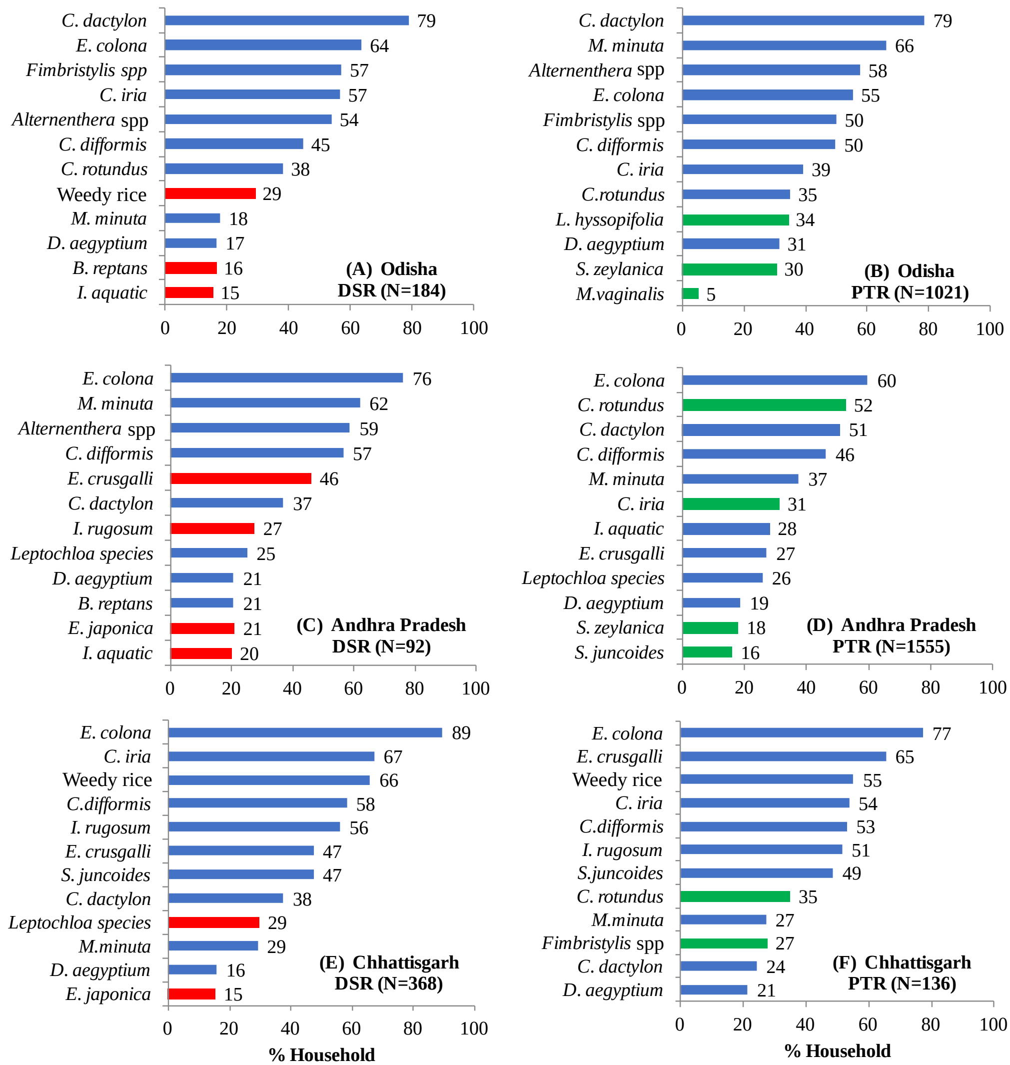

Fig. 4. Top 12 most common weeds as influenced by crop establishment methods in Odisha (A-B), Andhra Pradesh (C-D), and Chhattisgarh (E-F).

Note: Weed species with red and green color bars are the species which differ under direct-seeded (DSR) and puddled transplanted rice (PTR).

as troublesome weeds by farmers from Northwestern states (Punjab and Haryana), eastern Uttar Pradesh and Chhattisgarh. There were few other troublesome weeds, which were specific to particular state/s. For example, *I. rugosum* in Chhattisgarh and Haryana, *D. aegyptium* in Haryana and Eastern Uttar Pradesh, *Fimbristylis* spp

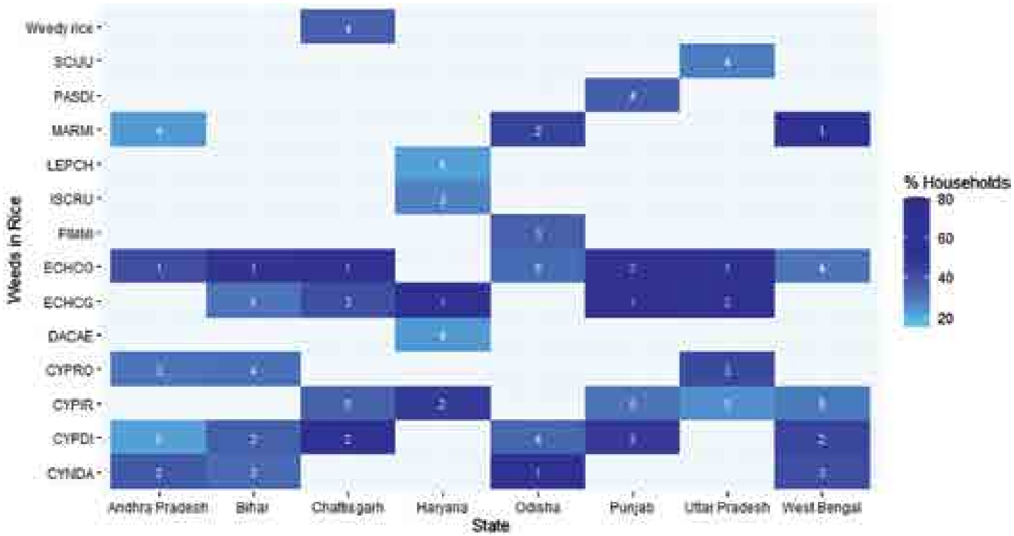

Fig. 5. Heat map of five most troublesome weeds of rice in Andhra Pradesh (n=1,647), Bihar (n=7,141), Chhattisgarh (n=773), Odisha (n=1,207), Haryana (n=417), Punjab (n=388), Uttar Pradesh (n=2,553), and West Bengal (n=2,035).

Note: Refer Table 1 for weed abbreviations; Ranking number given based on frequency (% farmers reported); Ranking 1= highest frequency; Raking 5= lowest frequency.

in Odisha, *S. juncoides* in Eastern Uttar Pradesh, *C. rotundus* in Bihar and Andhra Pradesh, *P. distichum* in Punjab, and weedy rice (*Oryza sativa*) in Chhattisgarh were reported among the top five troublesome weeds.

These top five troublesome weeds of rice varied with districts and are presented in Fig. 6 for Bihar and Fig. 7 for Eastern Uttar Pradesh and depicted in a map (Fig. 8 A-D). In Bihar, *E. colona* was reported as one of the most troublesome weeds in most of the districts followed by *C. difformis* and *C. rotundus* reported in 19-22 districts and *E. crus-galli,* and *C. dactylon* reported in 14-16 districts out of 31 surveyed districts (Fig. 6). *S. juncoides* was another most troublesome weed reported by farmers from 8 districts in north Bihar (Sharsa, Saran, Sheohar, Sitamarhi, Siwan, Vaishali, Madhubani and Madhepura) and only one district in South Bihar (Banka). Similarly, *C. axillaris* was also reported as troublesome weeds by farmers of 5 districts in north Bihar. In contrast, *M. minuta* (6 districts), weedy rice (4 districts), *Leptochloa* spp (3 districts), and *C. iria* (6 districts) were reported as troublesome weeds in districts in south Bihar. *Fimbristylis* spp were reported as troublesome weeds in a cluster of eastern districts of Bihar.

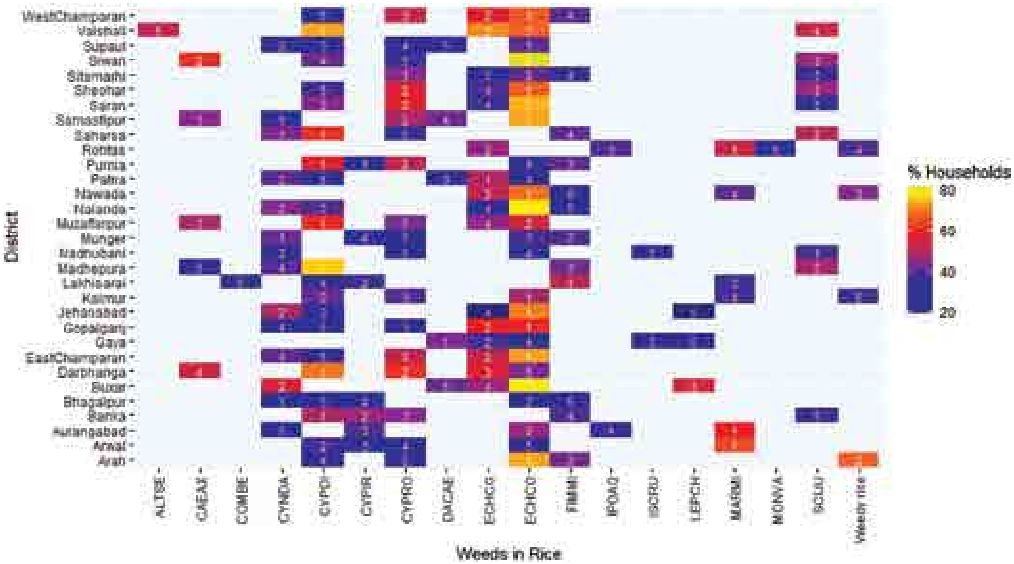

Fig. 6. Heat map of top five troublesome weeds of rice in 31 districts of Bihar.

Ranking number given based on frequency (% farmers reported); Ranking 1= highest frequency; Raking 5= lowest frequency.

In the eastern Uttar Pradesh, *Echinochloa* complex (*E. crus-galli* and *E. colona*) was the most troublesome weed in all the nine surveyed districts (Fig. 7). *C. rotundus* is another widespread troublesome weed reported by farmers from seven out of nine surveyed districts. Other weed species were also reported as troublesome weeds in specific districts; for example, *S. juncoides* in Sidharthnagar, Maharajganj and Chandhuli districts; *I. rugosum* in Sidharthnagar, Gorkhpur, and Kushinagar; *Fimbristylis* spp in Maharajganj, Mau, and Ballia; *D. aegyptium* in Gorkhpur, Deoria and Ballia. Similarly, *P. distichum* and *E. indica* were reported as troublesome weeds in Deoria and weedy rice in Chandauli district only. Although, weedy rice was not reported as a common weed in Chandauli (Fig. 3) but reported as troublesome and difficult-to-control weed. It suggested that this is an emerging weed in Chandauli, and awareness program should be focused on eradication and prevention of spread of this difficult-to-control weed.

This information on spatial distribution of troublesome weeds at the district level will help in developing and deploying effective district specific integrated weed management strategies as per weed flora by both public and private sector partners.

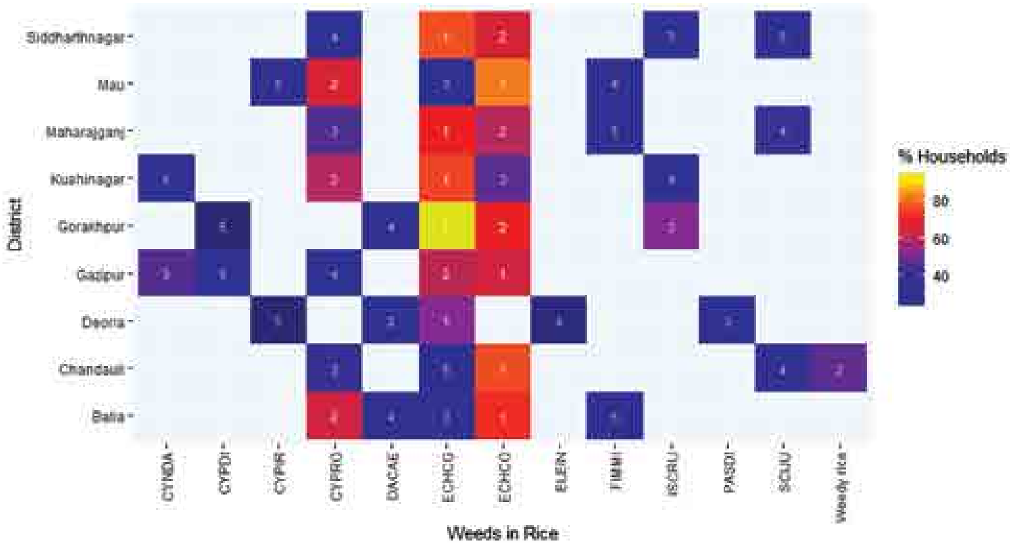

Fig. 7. Heat map of top five troublesome weeds of rice in 9 surveyed districts of eastern Uttar Pradesh

Ranking number given based on frequency (% farmers reported); Ranking 1= highest frequency; Raking 5:= lowest frequency

3.1.3 Variation is spatial distribution of key weed species

a) Echinochloa complex

The dominance of *E. crus-galli* and *E. colona* across states in this survey study demonstrated their close association with rice because of their similarity to rice in terms of growth habits, phenology, and adaptation to ecologies where rice is grown and to rice agronomic/cultural practices (Holm *et al*., 1977). The possible cause of variation in the dominance of *E. crus-galli* over *E. colona* or vice versa could be due to their differential competitiveness with rice and response to flooding depth. *E. colona* is relatively more sensitive to flooding depth than *E. crus-galli* (Rao *et al*., 2017). Also, *E. crus-galli* is more competitive to rice than *E. colona* (Chin, 2001). Therefore, it is likely that *E. crus-galli* may dominate over *E. colona* under an irrigated system where flooding can be effectively used for weed control, and rice yields are higher where more competitive weeds such *E. crus-galli* can adapt better. In other words, *E. crus-galli* may be more associated with high yielding areas with thick rice canopy because of its high competitiveness. This could be the reason that *E. crus-galli* is the top-ranked most common and troublesome weed in irrigated high yielding ecologies of Punjab and Haryana (average yield 6.62 tha^{-1} in Haryana and 7.45 tha^{-1} in Punjab) and *E. colona* is more dominant in rainfed states (EUP, Bihar, Chhattisgarh, and

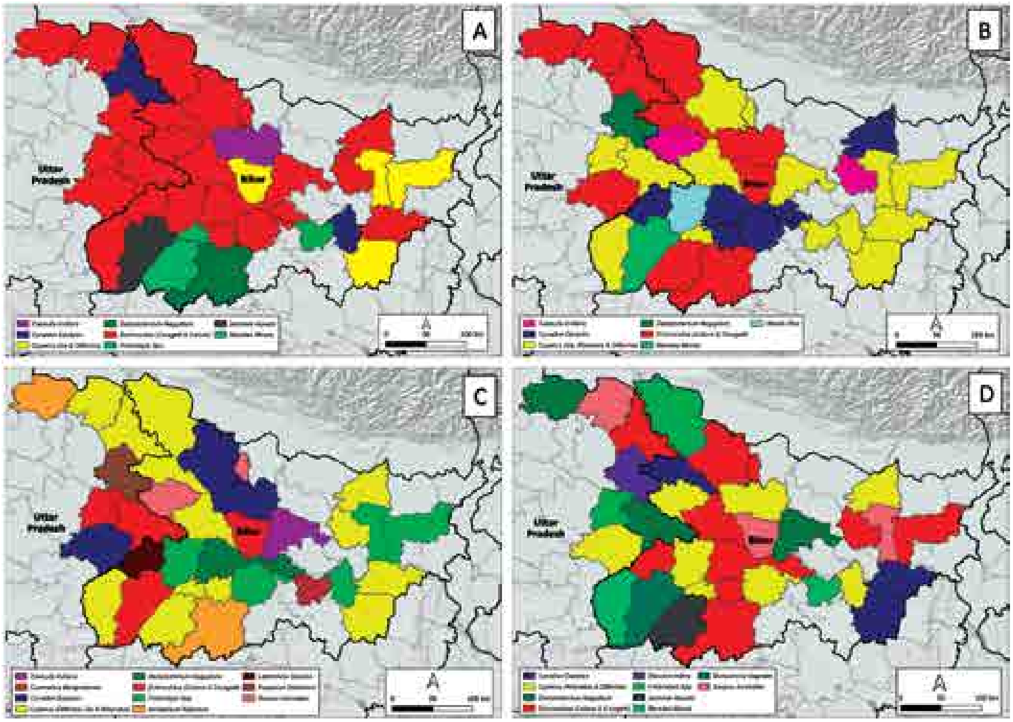

Fig. 8. (A-D). Spatial distribution of first (A), second (B), third (C), and fourth (D) most troublesome weeds of rice in districts of Bihar and Eastern Uttar Pradesh

Andhra Pradesh) with poor water control and relatively lower yields (4.01 to 4.48 t ha^{-1} in the eastern states and 5.55 t ha^{-1} in Andhra Pradesh) than Punjab and Haryana (Figs. 1, 5). This argument is further supported in the eastern UP and Bihar with more dominance of *E. crus-galli* in high yielding districts and *E. colona* in relatively low yielding districts (Fig. 9); for example, in eastern UP, *E. crus-galli* was more common and most troublesome weed in Siddharthnagar, Maharajganj, Kushinagar, Gorakhpur and Deoria where yield levels were higher (average yield 4.36 t ha^{-1}), whereas *E. colona* was more common in districts like Ballia, Mau and Gazipur where yield levels were lower (average yield 3.94 t ha^{-1}) (Table 2; Fig. 3). In Bihar, in districts with high yields like Rohtas (5.25 t ha^{-1}), and Patna (4.0 t ha^{-1}), *E. crus-galli* was ranked higher than *E. colona*, whereas, it was reversed in other majority of districts with relatively lower yields.

b) Perennial weeds such as *Cynodon dactylon* and *Cyperus rotundus*

Both *C. dactylon* and *C. rotundus* are considered as the world's worst weeds (Holm et al. 1977). The dominance of these perennials weeds in the eastern states

Table 2. Association of *Echinochloa* complex with rice yields in Eastern Uttar Pradesh

District dominated with *E. crus-galli*	Yield (tha^{-1})	District dominated with *E. colona*	Yield (tha^{-1})
Siddharthnagar	4.45	Ballia	3.69
Maharajganj	4.84	Mau	3.54
Kushinagar	4.33	Gazipur	4.06
Gorkhpur	4.23	Chandauli	4.47
Deoria	3.96		
Average yield	**4.36**	**Average yield**	**3.94**

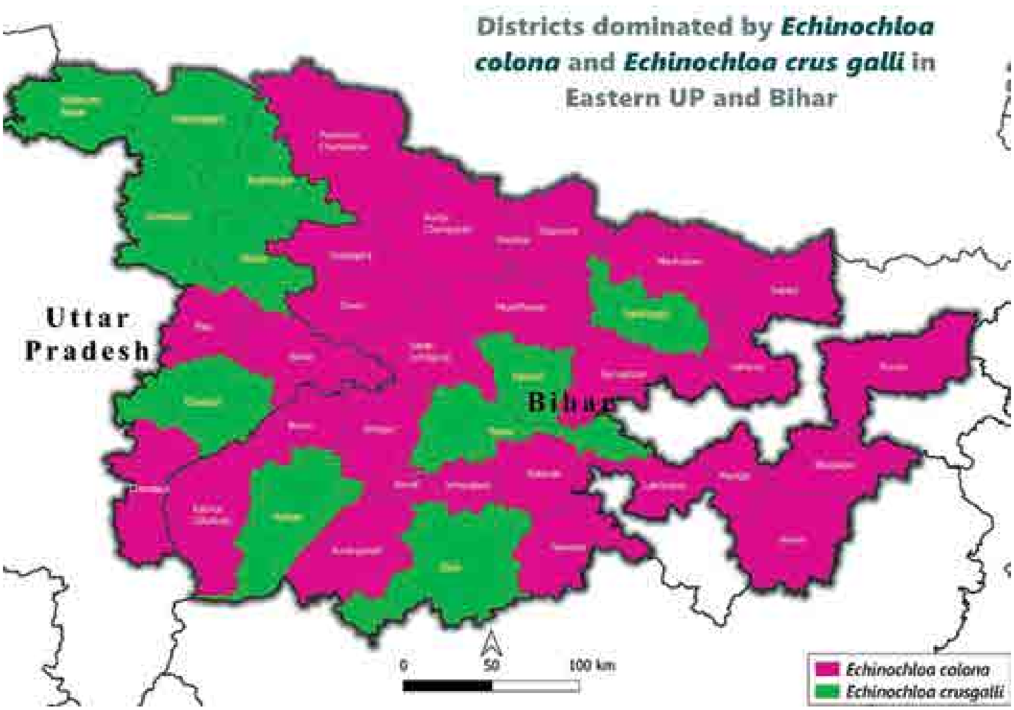

Fig. 9. Districts dominated by *Echinochloa colona* and *Echinochloa crus-galli* in Bihar and eastern Uttar Pradesh (EUP)

(Bihar, EUP, Odisha, West Bengal, and Chhattisgarh) and southern state (Andhra Pradesh) as shown in Figs. 1-3, Figs. 6-7, and in spatial distribution map (Fig. 10 A-B) could be because of following reasons: (i) tillage is not widely used to disrupt perennation during the summer fallow period between cropping systems or long fallow in single cropping systems (rice-fallow) especially in the eastern states,

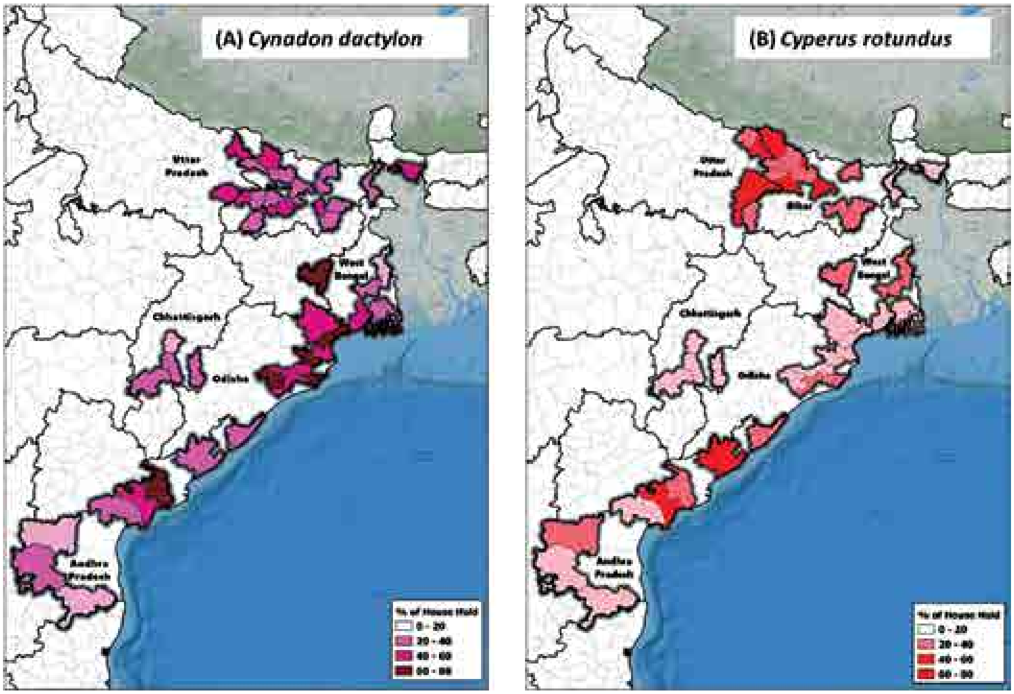

Fig. 10. A-B. Percentage of households reported *Cynodon dactylon* (A) and *Cyperus rotundus* (B) as troublesome weed in districts of Bihar, EUP, AP, Chhattisgarh, Odisha and WB

and (ii) inadequate/poor crop to out-compete as a result of overall poor agronomic practices, which allows these perennial weeds to accumulate food material for the whole season and even for their potential to carry over in the wheat crop seeded immediately after rice (Kumar *et al*., 2013; Kumar *et al*., 2019). In addition, in Odisha, Chhattisgarh and Andhra Pradesh (Fig. 10 A-B), the dominance of these weeds may also be because of common practice of direct seeded rice (DSR). These two weeds are generally common in dry to moist conditions in upland to lowland ecologies (Kent *et al.*, 2001; Caton *et al*., 2010). The top position of *C. dactylon* in Odisha as the most common and most troublesome weed also confirmed that it can tolerate extended periods of flooding during wet-season (Cook *et al.*, 2005) as well as drought during dry-season (Roy *et al.*, 2018).

In these ecologies, the presence of *C. dactylon* can also be a predictor/indicator of low yield of rice because the risk for its high population is more under stress prone environments than the conditions which favor rice growth. That is how it is more troublesome in Bihar, Odisha and West Bengal but not in EUP (Fig. 10 A). That would also mean that it is more a problem in low yield scenarios. This argument is supported by absence of these weeds in high yielding states Punjab and Haryana.

C. rotundus did not feature in the top 12 common weeds and in the top five troublesome weeds in Punjab and Haryana because of high yields and thick crop canopy. Similarly, *C. dactylon* did not feature in the top five troublesome weeds in both Punjab and in Haryana. It only featured as the seventh most common weed of rice reported by 30% farm households in Haryana only and did not feature in Punjab among the top 12 most common weeds. Keeping in view the fact that rice crop is much better in Andhra Pradesh (average yield 5.55 tha^{-1}) conditions; the higher population of weeds like *C. dactylon* and *C. rotundus* (Fig. 10 A-B) could be associated with summer-sown preceding crops or fallow land suggesting the spillover effect from one crop to another in the system (Bohan *et al*., 2011). In Andhra Pradesh, black gram is grown after rice where these perennial weeds may survive.

The variable monsoon with drought like situation in 7 out of 10 years since 2009 in Bihar indicated that such weeds may increase in the proportion, if best agronomic management like timely transplanting, early good water management, tillage and land preparation, optimal nutrient and weed management that help improve the growth of rice crop, are not focused. The uncertain and variable monsoon in the eastern Indo-Gangetic Plains poses a significant risk in the beginning of rice growing season as it adversely affects the initial rice growth providing enough space for weeds like *C. dactylon* and *C. rotundus* to grow and compete out the rice crop for resources like nutrients, water and light. In addition, sub-optimal agronomic practices such as poor land preparation and water stress at the early crop establishment can shift crop-weed competition in favor of weed. Therefore, practices which help achieving rapid canopy closure and reducing light availability to weeds can shift crop-weed competition in favor of rice especially for *C. rotundus* and *C. dactylon* suppression (Chauhan and Johnson, 2011; Chauhan and Opena, 2012). The increased prevalence of these perennial weeds in eastern and southern states warrants the need to develop and deploy both non-chemical (better bet cultural/agronomic practices which favor good early crop growth) and chemical methods adapted to these ecologies to keep these weeds under check.

c) Weedy rice

Some ecologies in Bihar and EUP (8 districts in Bihar and 3 districts in EUP) were found vulnerable to the infestation of weedy rice (*O. sativa*) (Figs. 2, 3, 11-A), however, it was reported as one of the top 5 troublesome weeds only in 4 districts of Bihar and one district in EUP (Figs. 6-7, Fig. 11-A). In Chhattisgarh, weedy rice was ranked the fifth most common weed and reported as among the top five troublesome weeds in rice in Dhantari, Kanker and Raipur districts (Fig. 11-A). In Odisha, farmers from Mayurbhanj district reported this as among the top 12 most common weeds but Cuttack farmers reported this among the top five most troublesome weeds

(Fig. 11-A). In Andhra Pradesh, it was reported as one of the most common weeds among top 12 in Chittoor and Anantapur districts and one of the most troublesome weeds among top 5 in Anantapur and Srikakulam districts. Weedy rice is known as a problematic weed in direct-seeded rice (DSR) (Singh *et al*., 2013) and emerged as a major threat for rice production in many countries where rice is established by DSR. It is generally found in lowland ecology (Caton *et al*., 2010). In Odisha, weedy rice is more associated with DSR (Fig. 4A). In Bihar and EUP, it was reported in transplanted rice, whereas in Chhattisgarh, it was reported by farmers doing both DSR and transplanted rice (Fig. 4C). This observation can be extrapolated for a possibility of weedy rice being a problem in low land ecologies across states and also where DSR is practiced as the majority of the weedy rice reported districts are

(A) Weedy rice **(B) *Marsilea minuta***

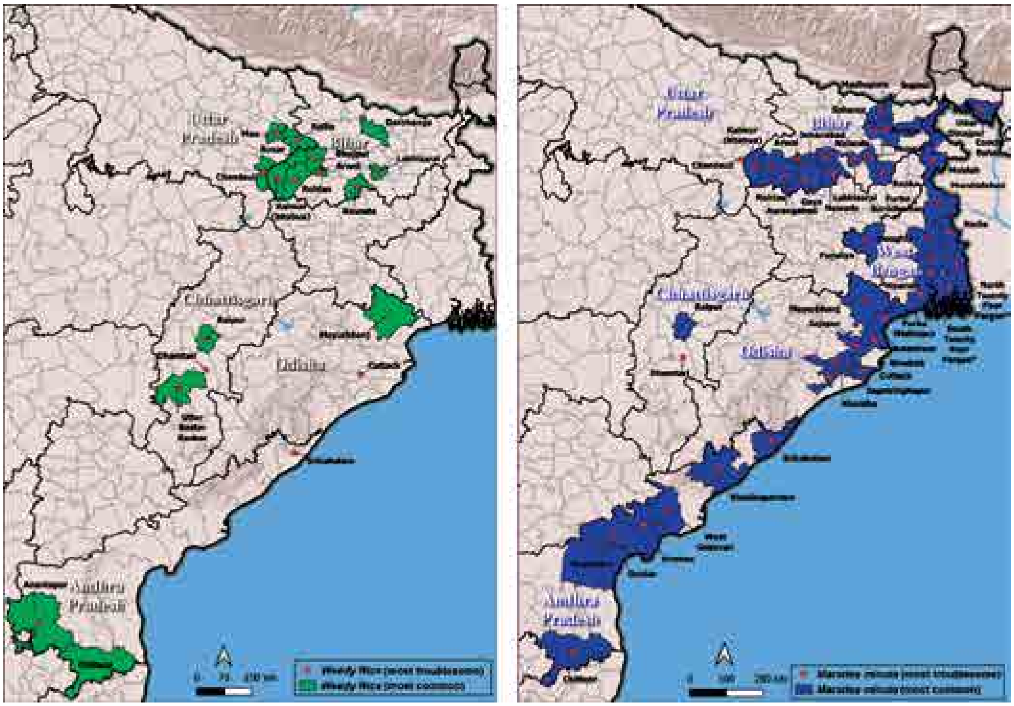

Fig. 11. A-B. Distribution of weedy rice (A) and *Marsilea minuta* (B) across districts in surveyed states of Andhra Pradesh, Odisha, Chhattisgarh, Bihar and Eastern Uttar Pradesh

Note:

1. Districts shaded with green–weedy rice was reported among the top 12 most common weeds; districts with red asterisk– it was reported as among the top 5 most troublesome weed.
2. Districts shaded with blue– *M. minuta* was reported among the top 12 most common weeds; districts with red asterisk–it was reported as among top 5 most troublesome weed.

in lowland ecologies or where DSR is practiced (Fig. 11-A). Weedy rice is difficult-to-control weed in rice because of its morphological, phenological and genetic similarities with cultivated rice and limited selective in-crop control options. This is an emerging weed and limited to few districts, an awareness campaign about the potential risks and problems imposed by weedy rice and the importance of its prevention is the first important step to develop successful strategies to manage and combat its spread.

d) *Marsilea minuta*

M. minuta, a perennial fern, spreads with puddling by dispersing the rhizomes over the entire field. It is very troublesome weed in the low land rice fields, which remain temporarily submerged. This species is spreading and has become a noxious weed in paddy fields, mainly because of frequent flooding (Yaduraju and Kathiresan, 2003). *M. minuta* also called dwarf water clover is a very competitive broadleaf weed (Rabbani *et al.*, 2011) and is a problem in districts where water remains stagnant. The paddy yield reduction up to 70 % was recorded due to such weeds (Ampong-Nyarko and de Datta, 1991).

M. minuta is reported 1st, 2nd, 5th, 9th, and 8th most common weed in West Bengal, Odisha, Andhra Pradesh, Chhattisgarh, and Bihar (Fig. 1). It is also reported as the 1st, 2nd, and 4th most troublesome weeds in West Bengal, Odisha and Andhra Pradesh (Fig. 5). The distribution of this weed reported as among the top 12 most common and among top 5 troublesome weeds across districts in the surveyed states is shown in Fig. 11-B. Farmers reported it as mostly in surveyed districts of West Bengal, Odisha, Andhra Pradesh and some selected districts of Bihar. It may be because of more water stagnant situation in these districts owing to lowland ecologies where it was reported in these states as this species is more common in frequent flood/ stagnant water conditions (Yaduraju and Kathiresan, 2003). In districts like Rohtas and Lakhisarai where the unregulated canal water keeps the fields almost under flooded condition may be the reason for its presence. Most of the areas in Andhra Pradesh where this weed is reported are irrigated and in most cases, it also remains continuously flooded. In few districts of Bihar, WB and in most cases in Odisha, the rice crop remains intermittently flooded.

e) Other weeds

Weed species such as *M. vaginalis*, *Sagittaria* spp, *E. crassipes*, *L. adscendens*, *I. aquatic,* and *S. zaylenica*, are aquatic weeds and generally found in lowland ecology with moisture conditions flooded to wet (Caton *et al*., 2010). These species are limited to few districts where water is stagnant for a longer time. *T. portulacastrum*, *B. reptans*, *C. benghalensis*, and *E. hirta* are more common in upland fields with more aerobic conditions. They are also more problem in DSR systems or in transplanted systems in upland ecology. Sedges such as *C. iria*, *C. difformis*, *Fimbristyllis* spp, and *C. rotundus* are adapted to diverse conditions in rice cultivation, *C. difformis* better adapted under lowland conditions and prefers wet to moist conditions, whereas *C. iria* and *Fimbristyllis* spp prefer moist to wet conditions and adapted to both lowland and upland conditions (Caton *et al*., 2010). *S. juncoides* is also more prevalent under lowland/water stagnant conditions. Weeds such as *I. rugosum*, *D. aegyptium*, and *E. japonica* are emerging problematic weeds in areas where DSR was introduced or practiced and also in transplanted rice areas where water control was uncertain (Kumar *et al*., 2013). *I. rugosum* is more adapted to lowland conditions as once it is established, it can tolerate water stagnation. *Leptochloa* spp, *D. aegyptium*, and *E. japonica* prefer moist conditions but not flooded conditions (aerobic conditions). Based on their adaptation to hydrological conditions, their distribution varied across districts within a state or across states.

4. Weed management in rice

4.1 Types of weed management practices

Types of hand weeding practiced by farmers are divided into four types: (i) sole hand weeding only, (ii) sole herbicide only, (iii) combination of herbicide + hand weeding, and (iv) none (no in-crop weed management after crop establishment). In almost all surveyed states, the majority of the farmers controlled weeds in their rice fields by various methods, except in Chhattisgarh where 36 % of farmers did not do anything for controlling weeds. In other states, <4 % farmers did not control weeds in the rice fields.

Types of weed control practiced by farmers in their rice fields varied with state (Fig. 12); for example, sole hand weeding was the most dominant method of weed control in Odisha and Bihar with 74 % and 67 % of surveyed farmers, respectively. In Andhra Pradesh and West Bengal, about 43-45 % of surveyed farmers controlled weeds by sole hand weeding, whereas in eastern Uttar Pradesh, Haryana, and Chhattisgarh, hand weeding was practiced by 33, 20, and 12 % of surveyed farmers, respectively. In Punjab, sole hand weeding was not practiced by any of the surveyed farmers. Herbicide-based weed control (herbicide alone or herbicide + hand weeding) was the lowest in Odisha and Bihar (24-29 % farmers) followed by Andhra Pradesh, West Bengal and Chhattisgarh with 52-55 % of farmers. In EUP, Haryana, and Punjab, herbicide-based weed control was the dominant method of weed control. About 66 % of surveyed farmers in EUP, 80 % in Haryana, and 100 % in Punjab followed herbicide-based options for controlling weeds in their rice fields.

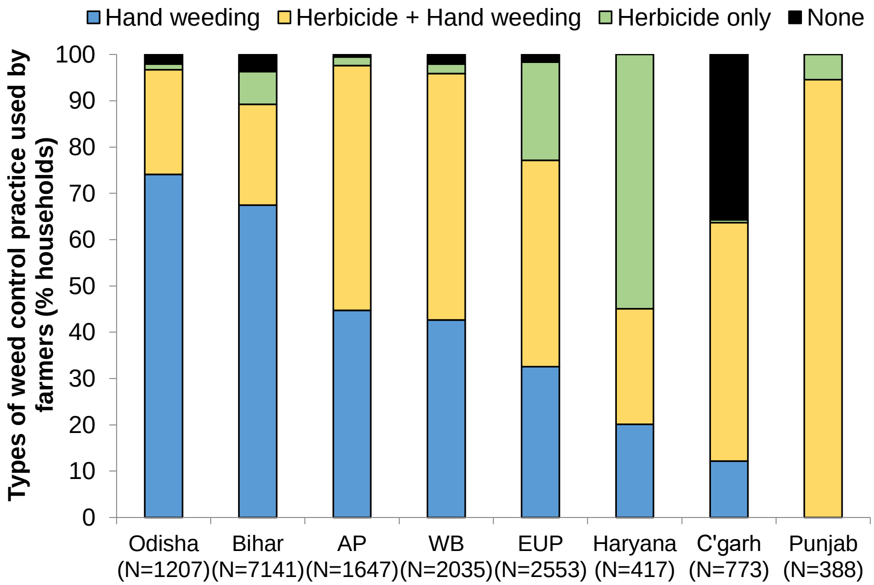

Fig. 12. Types of weed control practices (%) used by farmers for weed control in rice in Odisha, Bihar, Andhra Pradesh (AP), West Bengal (WB), Eastern Uttar Pradesh (EUP), Haryana, Chhattisgarh (C'garh), and Punjab during 2017 and 2018

The type of weed management practices used by rice farmers in Bihar, EUP and Odisha varied a lot with districts (Fig. 13). In general, the majority of the farmers in all the districts in these states control weeds either by hand weeding or by herbicide-based methods (herbicide alone or herbicide + hand weeding) except Buxar, Samastipur and Gaya districts in Bihar where about 30 %, 15 %, and 30 % of surveyed farmers, respectively, did not practice any weed control in their rice fields. These results suggested that these districts can be targeted to increase awareness about yield losses caused by weeds and rice productivity can be increased with deployment of weed management practices. In other districts, the proportion of farmers not controlling weeds in their rice fields was low, between 0-7 %. These results are in contrast to wheat where 31 % farmers in Bihar (ranging from 15 to 68 % across districts) did not practice any weed control in their wheat fields (Kumar et al., 2019).

In Bihar, farmers in seven districts (Munger, Madhubani, Banka, Lakhisarai, Bhagalpur, Vaishali, and Patna) are heavily dependent on hand weeding for weed control (80-95 % households) and use of herbicide-based (herbicide alone or herbicide + hand weeding) method was very limited in these districts (3-14 % households) (Fig. 13). In the other 21 districts, >50 % surveyed households (range: 52 to 77 %) relied on sole hand weeding; and herbicide-based weed control was practiced by

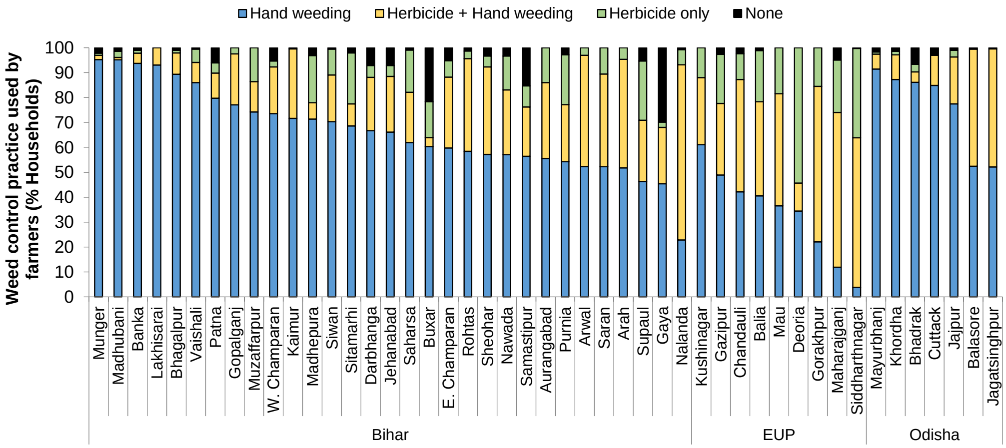

Fig 13. Types of weed control practices (% households) used by farmers for weed control in rice in different districts of Bihar, Eastern Uttar Pradesh (EUP) and Odisha

18-48 % households. Majority of farmers in Nalanda only used herbicide-based weed control methods (76 %).

In the EUP also, districts varied in types of weed control practices used by farmers; Siddharthnagar, Maharajganj, and Gorkhpur used more herbicide-based weed control methods (78-96 % farmers; Fig. 13). In Kushinagar, hand weeding was more dominant (61 %) compared with herbicide-based weed control methods (39 %). In remaining surveyed districts (Ballia, Chanduli, and Gazipur), herbicide-based methods and hand weeding were used in almost equal proportion. Five out of seven surveyed districts in Odisha, farmers heavily relying on hand weeding for weed control in their rice fields (78-91 % farmers), and in two districts (Balasore and Jagatsinghpur), the use of hand weeding and herbicide-based weed control methods were used almost in equal proportion.

4.2 Impact of weed management practices on rice yields

Rice yield was found higher when farmers used herbicide-based (herbicide + hand weeding) weed control compared to when farmers controlled weeds by hand weeding (Fig. 14). Rice yield was either similar or higher when weeds were controlled with herbicides as compared to hand weeding based weed control. In Andhra Pradesh, rice yield was 0.33 t ha^{-1} (6 %) higher when farmers used herbicide + hand weeding method for weed control compared to when used hand weeding. In Bihar, yield gain was 0.26 to 0.77 t ha^{-1} (7-22 %) higher with weed control either by hand weeding or herbicide or herbicide + hand weeding as compared to no weed control. Yields were almost similar when weeds were controlled with hand

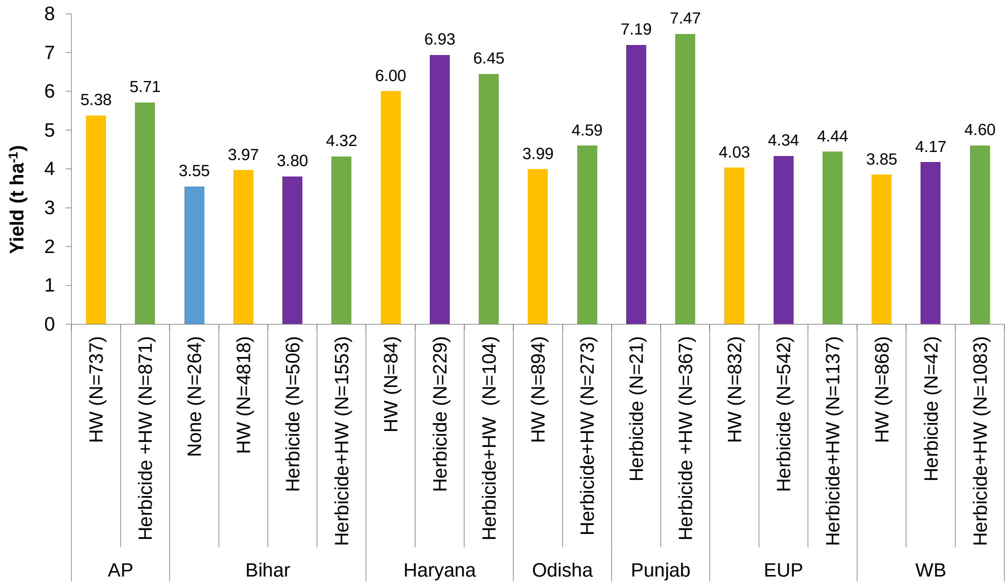

Fig 14. Grain yield of rice under different weed management practices in Andhra Pradesh, Bihar, Haryana, Odisha, Punjab, Eastern Uttar Pradesh and West Bengal states of India; each state is shown with different color

weeding or herbicides, but yield increased in herbicide + hand weeding method by 0.35 to 0.51 t ha^{-1} (9-13 %) compared to hand weeding and herbicide only methods. In Haryana, as compared to hand weeding based weed control, rice yield was 0.45 to 0.94 t ha^{-1} (7.5 to 15.6 %) higher in herbicide-based weed control methods (herbicide only or herbicide + hand weeding). In Odisha, yield gain with herbicide + hand weeding method was 0.60 (15 %) as compared to dominant method of hand weeding. In Punjab, yield was higher in herbicide + hand weeding method (0.28 t ha^{-1}; 4 %) than that in herbicide only method. In the EUP and West Bengal, rice yield increased in the following order: Herbicide + hand weeding > herbicide > hand weeding. In EUP, yield was 0.31 t ha^{-1} (8 %) and 0.41 t ha^{-1} (10 %) higher in herbicide + hand weeding and herbicide only method, respectively, than that in hand weeding based weed control method. Similarly, in West Bengal, yield gain in herbicide only and herbicide + hand weeding method observed was 0.32 t ha^{-1} (8 %) and 0.75 t ha^{-1} (19 %), respectively, as compared to hand weeding based method.

These results suggested that there is a clear scope to increase rice yields in these states by closing yield gaps caused by weed competition by switching to integration of herbicide and hand weeding instead of relying on either sole hand weeding or herbicide. Reliance on sole hand weeding or herbicides is less sustainable as sole dependence on herbicides can lead to evolution of herbicide resistance in weeds and sole dependence on hand weeding is becoming uneconomical and sub-optimal because of shortage of timely availability of labor leading to sub-optimal weed control and rising labor scarcity and consequently rising labor wages making hand weeding uneconomical. Therefore, integration of herbicide with hand weeding is more sustainable, productive and profitable option to overcome the risks of herbicide resistance development and to reduce weed control costs.

The district-wise survey results from Bihar, EUP and Odisha also showed huge scope to improve rice yields in these states by deploying herbicide + HW based integrated weed management and targeting those districts where the potential gain in terms of yield gain and adoption scope is high (Figs. 13, 14). The yield gain with herbicide + HW method compared to hand weeding based method varied across districts. In districts like Gaya, the potential of yield gain with use of herbicide + hand weeding based management observed was 23% compared to hand weeding based weed control. In this district, significant percent of farmers (30%) either did not practice weed control or were practicing hand weeding only (45%), so 75% farmers can be benefitted from herbicide + hand weeding. In Arah, the yield gain from herbicide + hand weeding was 27%, where, only 44% farmers are adopting herbicide + weed control practice, and about 52% farmers are still dependent on hand weeding based weed control. In Banka, the yield gain with herbicide + hand weeding method was 15%, and only 4% farmers are currently practicing herbicide + hand weeding while majority (94%) relying on hand weeding only which can be targeted for herbicide + hand weeding based weed control for improving productivity and profitability of the farmers. In Gopalganj, Muzzaffarpur, Siwan, Kaimur, Sithmarhi and West Champaran, rice yield was 8 to 16% higher than hand weeding based weed control method, which is practiced by 69-94% farmers in these districts. In districts such as Madhubani, Munger, and Bhaglpur where yield gain with herbicide + HW based method was 5-6% but adoption of this practice was only 1-9%, hence, majority of farmers can be benefited with herbicide +HW based integrated weed management.

In the EUP, districts like Deoria, Mau, and Kushinagar, where yield was 33, 26, and 13% higher, respectively, in herbicide + hand weeding than that in hand weeding only and adoption of herbicide + hand weeding was low (Figs. 13, 15). These results suggested that weed control is sub-optimal in these districts with hand weeding based weed control. In Maharajganj and Gorakhpur, yield gain with herbicide + hand weeding was around 8% and about 62% farmers have already adopted herbicide + hand weeding. In remaining surveyed districts (Gazipur, Ballia, and Chandauli), the yield in herbicide + hand weeding was only 2-4% higher than hand weeding method suggesting that farmers are effectively managing weeds with hand weeding but weed control cost probably can be reduced by integrating

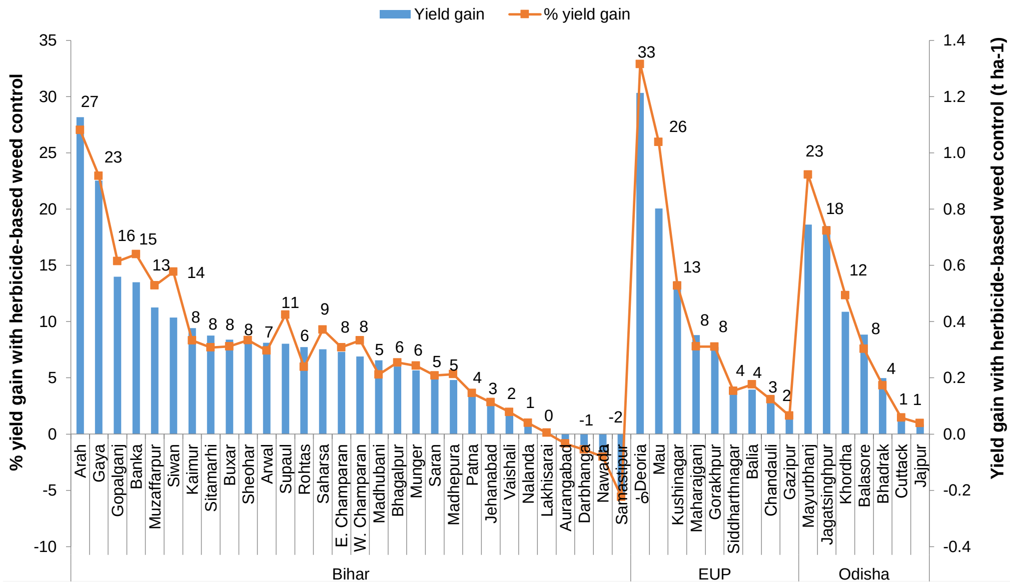

Fig. 15. Gain in yield in t ha^{-1} and in percent with herbicide-based weed control compared to hand weeding based weed control from different districts in Bihar, EUP and Odisha

hand weeding with herbicide use keeping in view rising labor scarcity and labor wages.

In Odisha also, yield gain with herbicide + hand weeding based integrated weed management compared to hand weeding based weed control varied among surveyed districts (Fig. 15). Out of 7 surveyed districts, yield was higher by 23 % in Mayurbhanj, 18 % in Jagatsinghpur, and 8 % in Khurda districts when farmers used herbicide + hand weeding method of weed control compared to when farmers relied only on hand weeding method. In these districts, the adoption of herbicide + hand weeding based weed control was also very low (6 % in Mayurbhanj and 10 % in Khurda) except Jagatsinghpur (47 surveyed farmers used herbicide + hand weeding) and farmers largely relied on hand weeding for weed control in these districts. These results suggesting that weed control with hand weeding in these districts are sub-optimal and integration of herbicide + hand weeding can significantly improve productivity and profitability of farmers in these districts. In other districts (Bhadrak, Cuttack, and Jajpur), hand weeding is dominant method of weed control (77-86 % surveyed farmers) and yield of farmers using hand weeding was only 1-4 % higher than farmers using herbicide + hand weeding suggesting that farmers were effectively controlling weeds with hand weeding. However, herbicide + hand weeding can significantly reduce weed control cost, hence, can improve profitability of farms in these districts.

4.3 Herbicide used for weed control in rice

Herbicides used for weed control also varied with states; for example, pre-emergence herbicides like butachlor and pretilachlor are used by 100 % farmers in Punjab and 80 % farmers in Haryana (data not shown). Because both states are fully irrigated, so pre-emergence application of any of these herbicides combined with early flooding can effectively control weeds. Andhra Pradesh is also significantly irrigated, therefore, farmers rely heavily on pre-emergence herbicides (75 % of farmers used herbicides), and remaining 25 % herbicide using farmers used post emergence (18.5 % bispyribac, 4 % bispyribac + pretilachlor, 3.5 % 2,4-D and fenoxaprop). In rainfed states such as Bihar, EUP, and Chhattisgarh, because of non reliability of standing water at an early stage, there was less use of pre-emergence herbicides and more use of post-emergence herbicides (Table 3); for example, out of herbicide

Table 3. Herbicides used for weed control in rice (% households) in Andhra Pradesh, Bihar, Chhattisgarh, Odisha, eastern Uttar Pradesh (EUP), and West Bengal

Herbicide	Andhra Pradesh	Bihar	Chhattisgarh	Odisha	EUP	West Bengal
	% households					
Butachlor	16	3	2	<1	3	4
Oxadiargyl	9	<1				<1
Bispyribac Sodium	9	10	17	1	44	
Pretilachlor	7	6	1	10	8	17
Alachlor	3					
Pretilachlor + Safener	1					
Bensulfuron	1					
Pyrazosulfuron	1	<1	14	7		7
2, 4-D	1	9	2	1	10	1
Fenoxaprop	1					<1
Pretilachlor + Bispyribac sodium	2					
Bispyribac sodium + Pyrazosulfuron		<1	4			
Bispyribac sodium + Oxadiargyl		<1	4	2		19
Bispyribac sodium + 2,4-D			1			
Bispyribac sodium + Almix			1			
Bispyribac + pyrazosulfuron + almix			<1			

(Contd...)

Table 3 (Concluded)

Herbicide	Andhra Pradesh	Bihar	Chhattisgarh	Odisha	EUP	West Bengal
	% households					
Bispyribac + butachlor					<1	
Pretilachlor + pyrazosulfuron						1
Bispyribac + oxadiargyl + pyrazosulfuron						<1
2, 4-D + Pyrazosulfuron			1			
2,4-D + pretilachlor						< 1
Metsulfuron + Chlorimuron (Almix)			2		1	

using farmers, 66 % used post-emergence herbicides (32 % bispyribac-sodium, 30 % 2,4-D, and 4 % tank mix of bispyribac-sodium + pyrazosulfuron/oxadiargyl) and remaining 34 % used pre-emergence herbicides such as pretilachlor (20 %), butachlor (11 %), pyrazosulfuron (1 %), and oxadiargyl (2 %). In Chhattisgarh, out of herbicide using farmers, only 6 % farmers used butachlor or pretilachlor, whereas 28 % used pyrazosulfuron, 34 % used bispyribac-sodium, 24 % used bispyribac-based mixtures (bispyribac + pyrazosulfuron/oxadiargyl/2,4-D/Almix), and 8 % used other post-emergence herbicides (2,4-D 3 %; 2,4-D + pyrazosulfuron 2 %; Almix 3 %). Similarly, in EUP, out of herbicide using farmers, 85 % farmers used post-emergence (bispyribac-sodium 66 %; 2,4-D 16 %, Almix 2 %, and bispyribac-sodium + butachlor 1 %) and remaining 15 % used pre-emergence herbicides (12 % pretilachlor and 4 % butachlor) for weed control in their rice fields.

In Odisha, because of sufficient rain, use of pre-emergence herbicides was reported as the major herbicides for weed control in rice (Table 3). Among herbicide using farmers, 81 % used pre-emergence (pretilachlor 45 %, pyrazosulfuron 33 %, butachlor 3 %) and remaining 19 % farmers used post-emergence, primarily bispyribac-sodium based mixture (bispyribac-sodium + oxadiargyl 10 %; bispyribac-sodium 5 %, 2,4-D 4 %). In West Bengal, out of herbicide users, post-emergence application of bispyribac-sodium + oxadiargyl had the highest use with 37 % of farmers followed by pretilachlor (32 %), pyrazosulfuron (14 %), and butachlor (7 %).

Conclusions

This survey clearly demonstrated that there are few cosmopolitan weed species closely associated with rice, such as *Echinochloa* group and *Cyperus* group. These were reported among the top 12 most common and the top five troublesome weeds across all surveyed states, whereas other weeds were more specific to a particular state or district depending on rice environment (lowland or upland or irrigated), hydrology (water stagnation or not), and crop management practices. The spatial distributions of the top 12 most common and top five troublesome weeds district-wise were identified. This spatial information will help public and private sectors in developing and deploying appropriate weed management practices in specific districts as per weed flora. In some selected districts of surveyed states, weedy rice has emerged as difficult-to-control weed, which warrants the need for awareness campaigns to prevent its spread, and to develop and deploy integrated options for its management. The problem of perennial weeds such as *C. dactylon* and *C. rotundus* is also becoming severe in rainfed states, and therefore, special efforts are needed to develop effective management strategies against these perennial weeds. Results also demonstrated that rice yields were 0.33 – 0.75 t ha^{-1} (6-19 %) higher when weeds were controlled using the integration of herbicide + hand weeding based weed control method as compared to dominant farmers' practice of hand weeding method. States like Bihar and Odisha, where the majority of farmers (>65 %) rely on hand-weeding for weed control, can greatly benefit from herbicide + hand weeding based weed control method. Herbicide + hand weeding based weed management along with other best crop management practices would be more economically and environmentally sustainable than relying on any single weed control method such as herbicide only or hand weeding only. In future, more efforts are needed to develop, demonstrate, and deploy herbicide-based integrated weed management practices to improve farm yields and to avoid/delay evolution of herbicide resistance in weeds where farmers are increasingly relying solely on herbicides only for weed control in rice.

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3. Evidence Based District Level Adoption Patterns of Technologies to Identify Future Actions

3.1 Timings of transplanting and irrigation practices can increase grain yield in Anantapur district, Andhra Pradesh

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Introduction

Anantapur is the only arid district of Andhra Pradesh with annual rainfall of 536 mm and suffers frequent drought with high monsoon variability. The cropping intensity is only 107 % and 11 % of area is under irrigation with groundnut occupying maximum area under rainfed condition accounting for over 75 % of the cropped area (Gopinath *et al.*, 2013). Other important crops are chickpea (6.3 %), rice (5.07 %), sunflower (3.7 %), pigeon pea (3.0 %) and sorghum (1.2 %). Paddy is the fourth important food grain crop cultivated in Anantapur district. Due to lack of irrigation facilities, the crop is confined to only 5.07 per cent to the total cropped area of the district. It is predominantly cultivated as an irrigated crop. The rice cultivated area was lowest in the last ten years due to severe drought conditions with the annual rainfall of 334 mm for the particular period (CPO, 2019). Based on the trends of area and production, farmers in specific blocks of Anantapur district are interested to cultivate the paddy crop despite the rainfall pattern. The majority of the spatial distribution of paddy farming in Anantapur district was distributed in the following blocks, Kanekal with highest paddy cultivated area (5308 ha) followed by Garladinne (3550 ha), Singanamala (1722 ha), Pamidi (1411 ha) and Bukkarayasamudram (1242 ha) which covers 41.8 per cent of total paddy cultivable area among 63 blocks of Anantapur district (Anjaneyulu, 2016).

Hence, KVK in collaboration with CSISA aimed at generating quantitative information on rice through digital tool to make relevant, location-specific and need-based suggestions.

Methodology and Sample Distribution

Diagnostic surveys for production practices and yield assessment were conducted in Anantapur district from 220 farmers of 28 villages with the coverage of 18 blocks. The data on rice production practices were collected using digital tool-Open Data Kit (ODK)-based survey deployed on smartphones. Details of methodology found in Chapter 1.

Blocks Covered : Atmakur, Beluguppa, Brahmasamudram, Bukkaraya Samudram, Chennekothapalle, Dhirehal, Garladinne, Kadiri, Kanaganapalle, Kanekal, Kudair, Kundurpi, Narpala, Pamidi, Penukonda, Ramagiri, Singanamala and Yellanur.

Villages surveyed (Fig. 1) : Aravakuru, Bodaganidoddi, Brahmasamudram, Chelamakuru, Chenampalli, Chilamakuru, Eragunta, Ganthimarri, Gundiganihalli, Gutturu, Kalluru, Kannepalle, Karutlapalli, Kesipalli, Koppalakonda, Kothapalli, Kudulur, Mukthapuram, Penakacharala, Ramasagaram, Reddypalli, Serivaram, Singampalli, Sodanapalli, Tagarakunta, Thimmapuram, Y. Kothapalli and Yeluru.

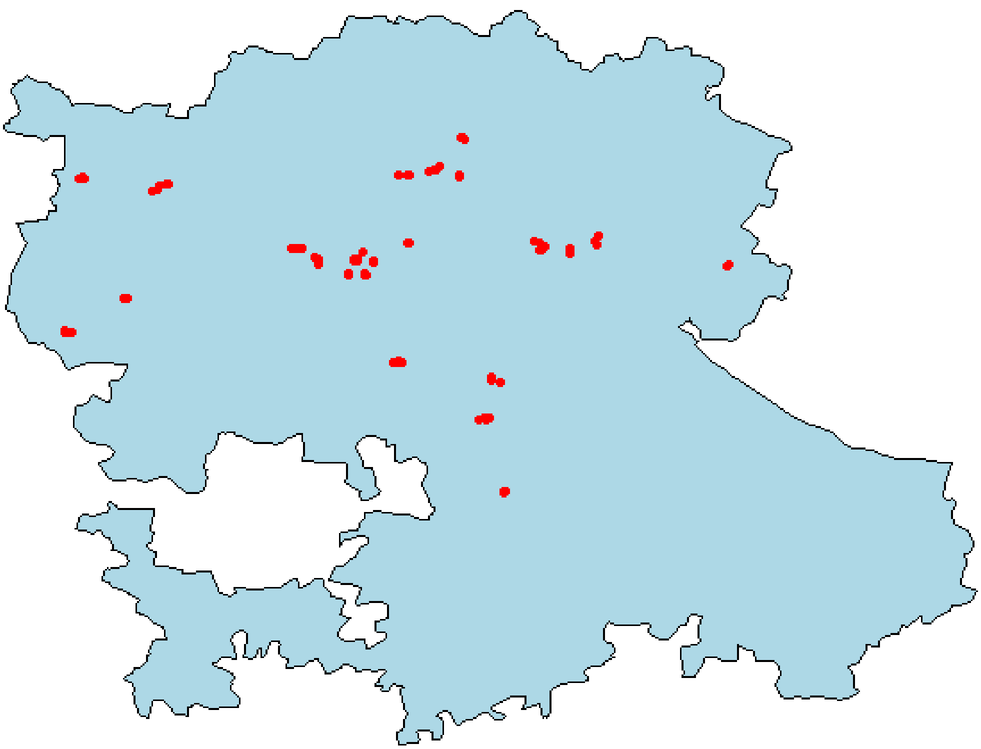

Fig. 1. GPS points of surveyed farms in Anantapur district, Andhra Pradesh.

Results and Discussion

Our survey shows that more than 85 % farmers grew nursery during first fortnight of June (Fig. 2) and all the surveyed farmers transplanted rice manually under puddled soil conditions. The district is lacking mechanization in rice crop establishment like other districts in Andhra Pradesh as survey shows that none of the farmers adopted either mechanical transplanting or direct seeding by using seed drill as this might be due to non-availability of machinery like transplanter or seed drill for crop establishment.

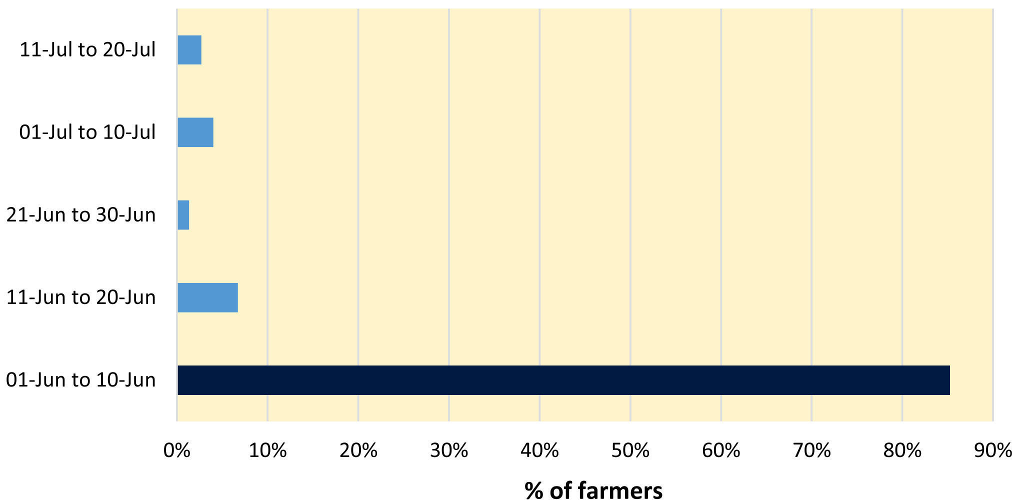

Fig. 2. Timing of nursery establishment in Anantapur district.

The surveyed farmers have access to irrigation and applied 4 to 10 number of irrigations for growing rice. The rice grain yield increases with increase in number of irrigations from 3.14 tha^{-1} under four irrigations to 6.85 tha^{-1} under 10 irrigations (Fig. 3). But, the rate of increase in yield is decreasing after 7^{th} irrigation and it suggests that 7 irrigations might give the economical yield in Anantapur condition. Deep tube well is the source of irrigation for 76 % farmers. Majority of farmers (40 %) applied 8 irrigations followed by 32 % of farmers who applied 6 irrigations in the district.

The results were in line with the findings of Solieng (2010) in which he reported that, paddy cultivation is a mainly influenced by the water resources available in that particular area and the sector is by far the predominant off-stream water user. In such cases, water resources management and water-related development planning play crucial role in increasing the production of paddy.

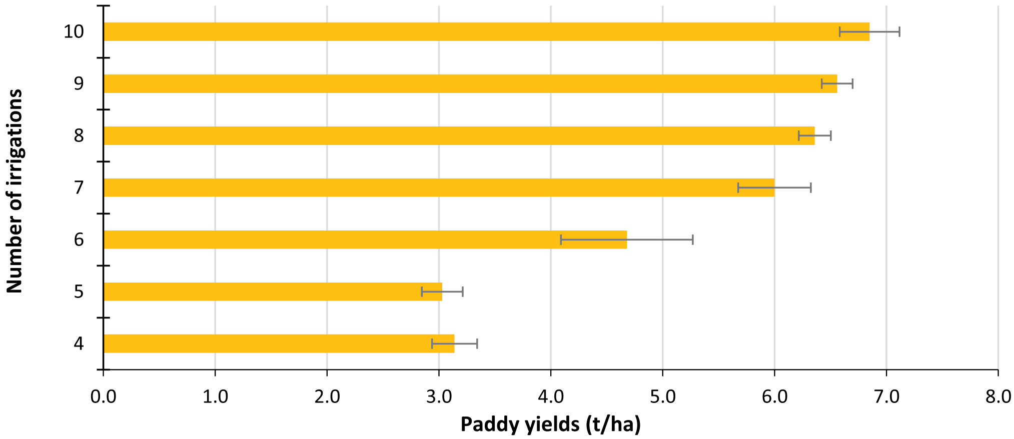

Fig. 3. Rice grain yield under different irrigations.

Since most of the farmers grew nursery in June, transplanting was completed mostly in July or August. However, the grain yield was high in the fields which transplanted in August (6.9 tha^{-1}) compared to July (5.6 tha^{-1}) and September (5.5 tha^{-1}) (Fig. 4). Late transplanting in September resulted in yield reduction of more than 1.4 tha^{-1} in the district.

Two rice varieties, BPT5204 and MTU1010, grown by 68 and 19 % of surveyed farmers in the district (Fig. 5) suggest that still old varieties are preferred by farmers due to higher yield and better cooking quality. However, MTU1010 had higher grain

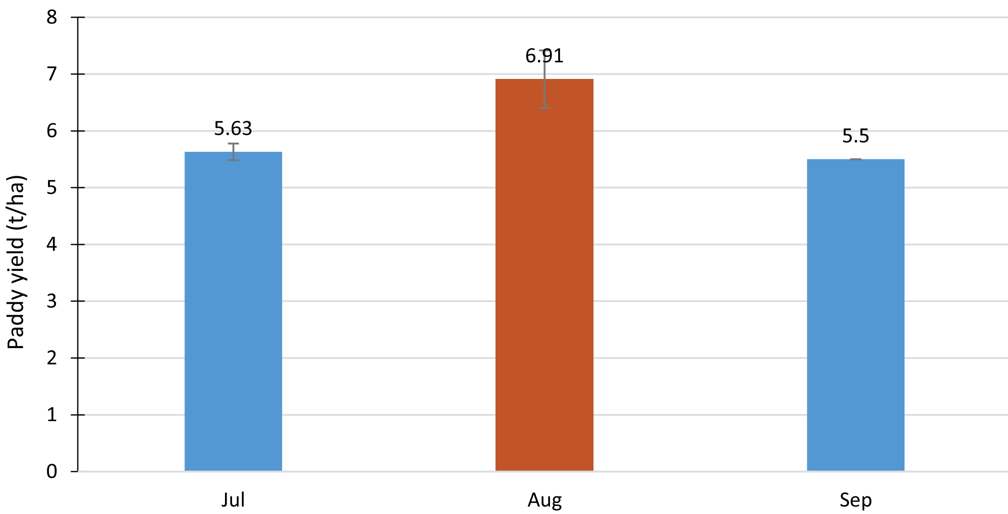

Fig. 4. Rice grain yield at different months of transplanting in Anantapur district.

yield (6.15 t ha^{-1}) than BPT5204 (5.68 t ha^{-1}) from the surveyed farmers (data not reported here).

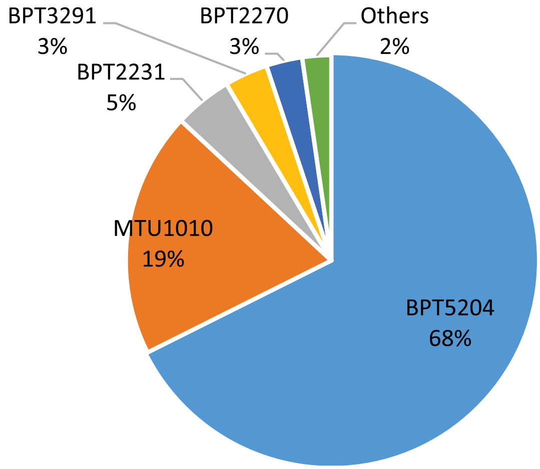

Fig. 5. The major rice varieties used in Anantapur district.

The box plot (Fig. 6) shows that rice farmers in Anantapur district applied nitrogen an average of 138 kgha^{-1} (ranging from 0 to 245 kgha^{-1}). They also applied phosphorus at the rate of 65 kgha^{-1} (ranging from 0 to 176 kgha^{-1}) and potassium at 75 kgha^{-1} (ranging from 0 to 215 kgha^{-1}). The results were justified with the findings of Singh *et al.* (2013) in which they reported that, low input use, inappropriate plant spacing, late sowing and selection of wrong cultivars were some of the technical constraints, which can be effectively reduced through the diffusion of relevant technologies among the farmers.

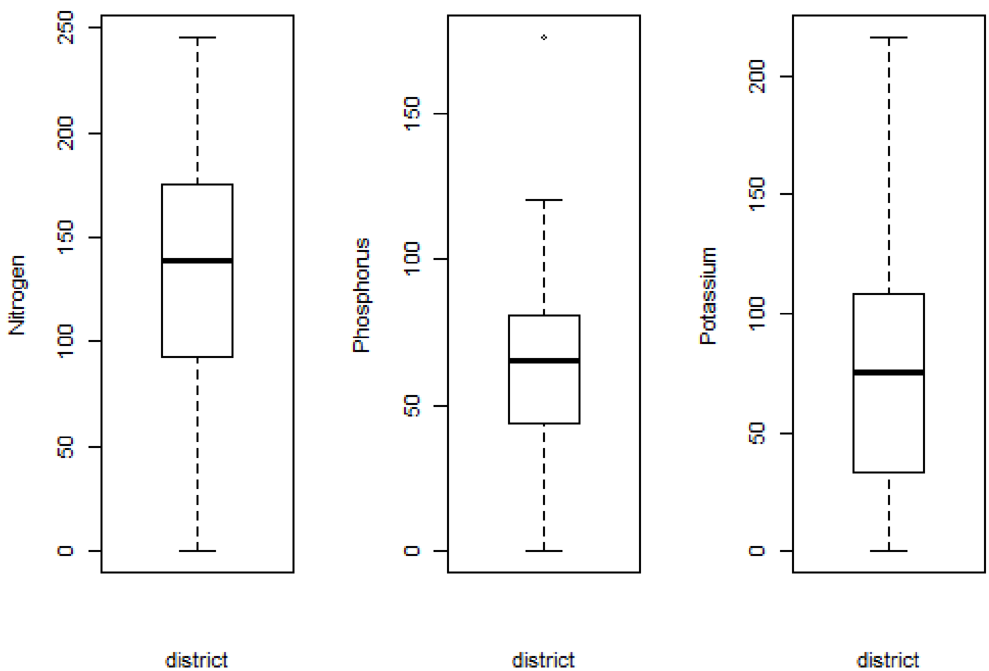

Fig. 6. Fertilizer NPK (kgha^{-1}) application in rice in Anantapur district.

Conclusion

The results from diagnostic survey show that rice farmers in the district grew only few rice varieties and hence variety replacement rate might be low. Also, mechanization in rice crop establishment is nil. For achieving higher grain yield, farmers should complete transplanting in August and apply 7 to 8 irrigations in the district. The major rice production constraints and priority research problem areas of rainfed rice production in Anantapur district are drought, leaf blast, weeds, brown plant hopper and poor soil fertility. Hence, it would be logical to prioritize rice research on the basis of prevailing constraints under rainfed areas of Anantapur district.

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3.2 Increasing the rice grain yield through improved crop establishment methods in Guntur

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Introduction

Guntur district receives 881 mm of rainfall annually, which includes 545 mm from south-west monsoon and 251 mm from north-east monsoon (Anonymous, 2012). The major soil types are black cotton soils (72 %), red soils (17 %), coastal sandy soils (9 %), and alluvial soils (2 %). The district's net sown area is 5, 97,000 ha with a cropping intensity of 135 %. Around 62 % of the cultivated area in the district is irrigated. Canal irrigation (80 %) is the major source of irrigation. The major crops are rice, cotton, maize, pulses and chilli. Cyclone, heavy rainfall in a short period and outbreak of pest and disease due to unseasonal rains are the major problems in the district. Lack of adoption of best management practices, improved varieties/hybrids, high labour costs, and high weed intensity are other problems faced by the farmers (Sowjanya, 2016).

Methodology and Sample Distribution

Diagnostic survey for production practices and yield assessment was conducted in Guntur district by KVK, with backstopping and technical guidance provided by the CSISA team. A total of 251 farmers were selected randomly from 34 villages across the district, and data on rice production practices were collected using digital tool-Open Data Kit (ODK)-based survey deployed on smartphones. Details of methodology found in Chapter 1.

Blocks covered : Bapatla, Chebrolu, Guntur, Mangalagiri, Narasaraopet, Piduguralla, Ponnur, Rentachintala, Repalle, Sattenapalle and Tenali.

Villages surveyed (Fig. 1) : Abburu, Appikatla, Barthipadi, Bethapudi, Brahmana kodur, Cheruvu, Chinnaravuru, Chodayapalem, Choudapallam, Dandamudi, Dhulipalla, Gorantla, Gudipudi, Isakapalle, Jannulapalem, Janapadu, Jonnalagadda, Katevaram, Kollakalluru, Konanki, Lakkarajugarlapadu, Mannava, Mulapalem, Mulukuduru, Nelapadu, Pakalapadu, Palapadu, Pedaravuru, Penumudi, Penupadu, Poondla, Ramachandrapuram, Ravipadu and Vellalur.

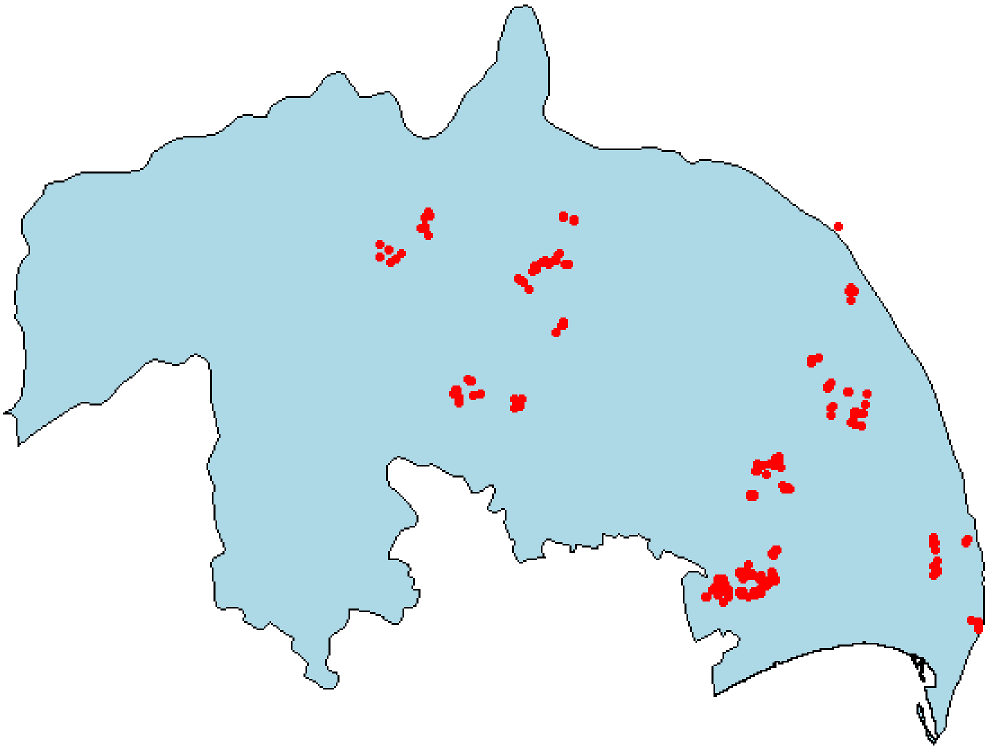

Fig. 1. GPS points of surveyed farms in Guntur district, Andhra Pradesh.

Results and Discussion

Rice is grown in the irrigated condition during the *kharif* season in Guntur district. The major cropping systems are rice-pulses (41%), rice-maize, rice-sorghum, and rice-rice (Fig. 2). Hence, cropping intensity is high in rice-based cropping systems, despite the overall cropping intensity of the district is around 135% which might be due to single cropping of rainfed cotton in many areas.

The rice variety, Samba Mahsuri (BPT-5204), 140-145 days of duration, is still occupying 86% of the rice area in the district despite it was released from 1986

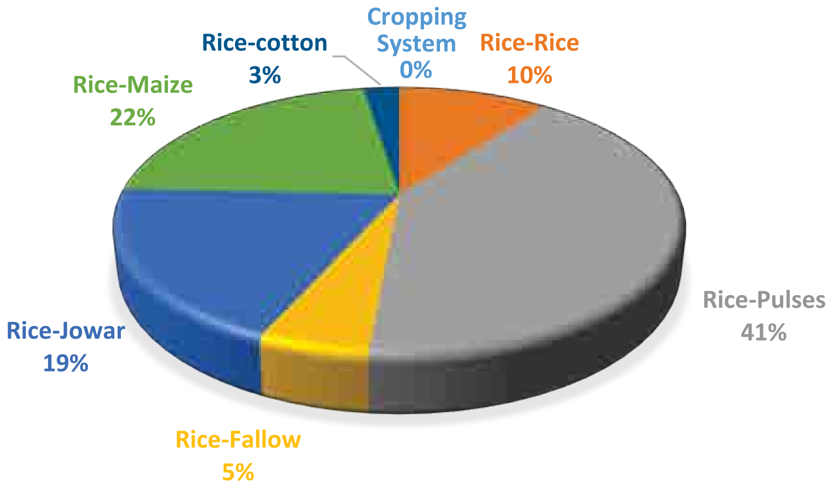

Fig. 2. Major cropping system in Guntur, Andhra Pradesh.

(Fig. 3). This might be due to good grain and cooking quality. Other varieties are grown in less area.

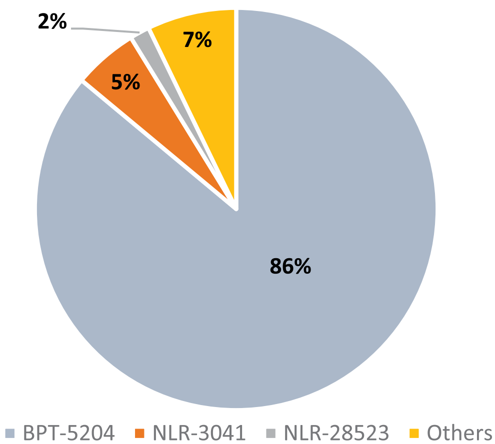

Fig. 3. Major rice varieties in Guntur, Andhra Pradesh.

Our results show that only 10% of the surveyed farmers have a soil health cards (SHC) and only 3% of farmers used the SHC information for fertilizer management (Fig. 4). Surprisingly, 97% surveyed farmers neither had SHC nor used SHC's information for fertilizer management. There is a need for improvement in field-specific fertilizer recommendations and a need for developing a simple way of communication to farmers through SHCs.

The histogram of NPK application in Guntur shows that majority of the farmers either apply 100 to 150 kg N per ha or 150 to 200 kg N per ha (Fig. 5) and trends more on over-application of nitrogen. Most surveyed farmers applied phosphorus either 30 to 40 $kgha^{-1}$ or 50 to 75 $kgha^{-1}$. Most of the farms received potassium from 25 to 75 kg per ha despite few farmers applied more than 100 $kgha^{-1}$.

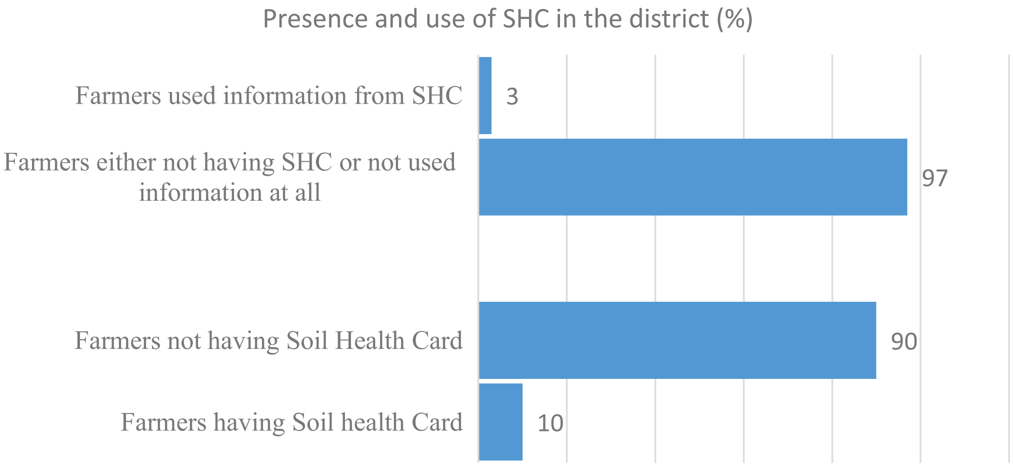

Fig. 4. Status of soil health card use in Guntur, Andhra Pradesh.

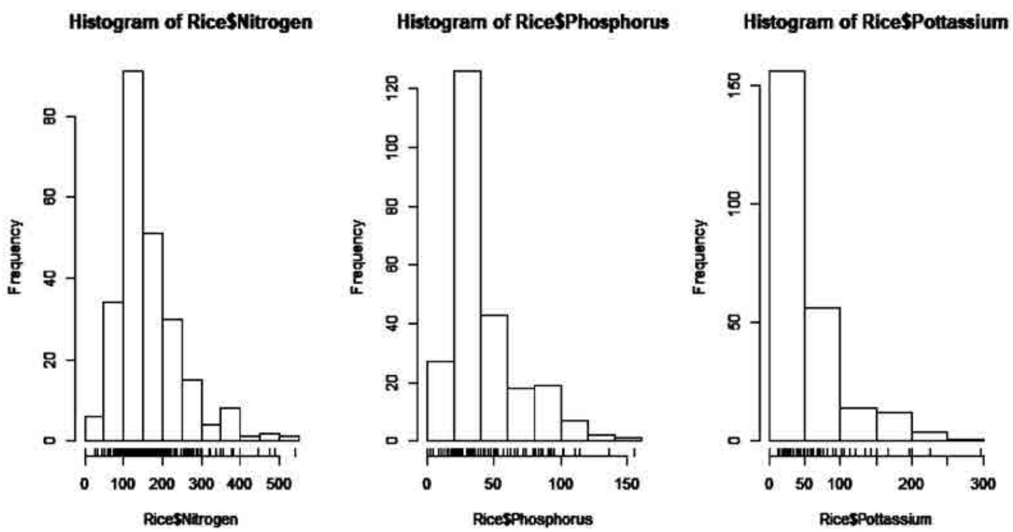

Fig. 5. NPK (kgha^{-1}) application in rice in Guntur, Andhra Pradesh.

Most of the surveyed farmers reported that weed was one of the major problems in rice cultivation in the district. The major weeds in *kharif* rice are *Echinochloa colona* (39 % of the surveyed farmers reported this as the topmost weed in their fields), *Echinochloa crus-galli* (20 %), and *Cyperus* spp. (15 %) and others (Fig. 6). To manage these weeds, farmers use both manual weeding and herbicides (Fig. 7). A one-time application of pre-emergence herbicides followed by two manual hand weedings are the major methods of weed control in most of the rice fields.

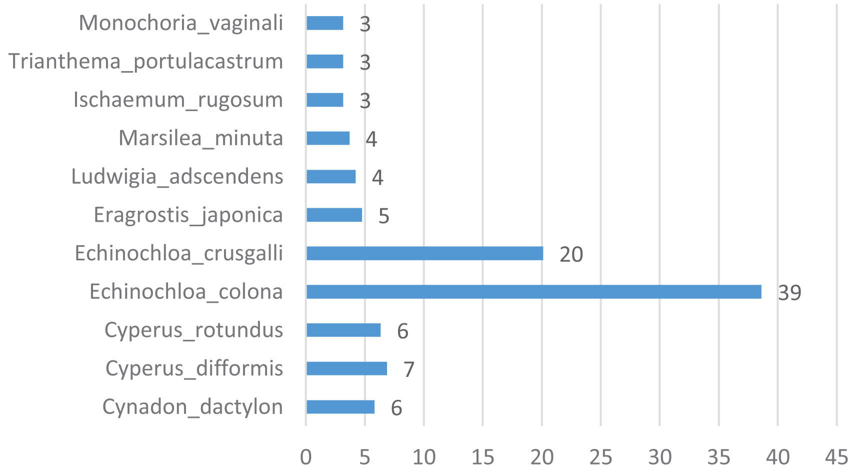

Fig. 6. Major weeds in rice in Guntur, Andhra Pradesh.

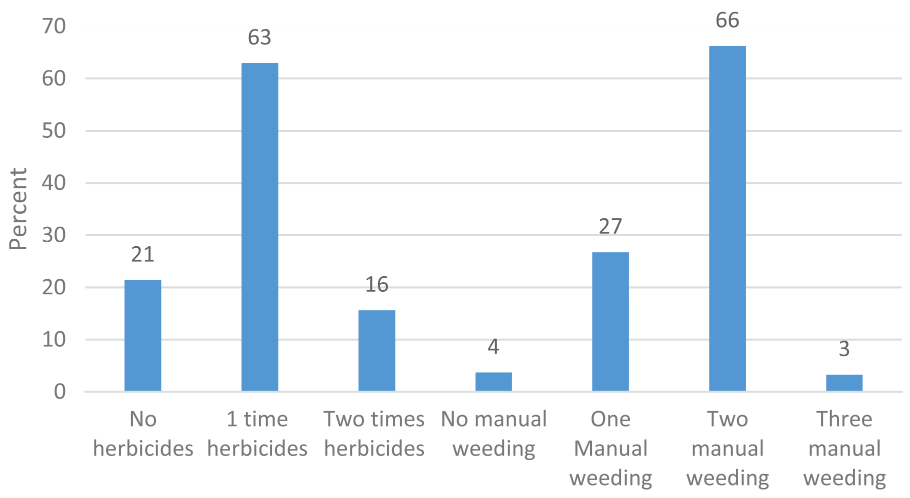

Fig. 7. Weed management practices in Guntur.

Interestingly, around 79 % of the surveyed rice farmers used herbicides. Almost all farmers used manual weeding (96 %) and 66 % of them did two times manual weeding.

Most of the farmers reported that they had a rice yield of 5 to 7 tha^{-1} (Fig. 8) with the present management practices. Results show that there is still a lot of potential for improving the yield by adopting best management practices and mechanization. Since lack of labour availability and associated higher cost of labour in the district is the major issue, the introduction of mechanization in rice cultivation could benefit both farmers and the environment. Our survey shows that still, machine transplanting has not reached farmers which could be the best alternative method for manual transplanting in terms of labor, water, timeliness, yield, and profit for the Guntur region and the benefit of machine transplanting proved in eastern India (Singh *et al.*, 2020).

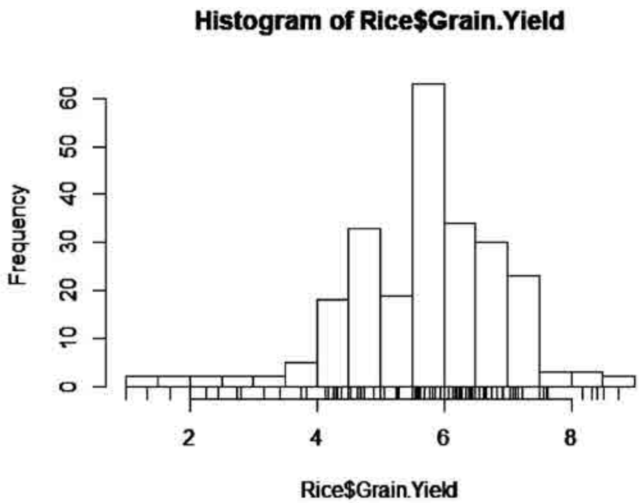

Fig. 8. Rice grain yield (tha^{-1}) in Guntur, Andhra Pradesh.

Our results show that manual line puddled transplanted rice had higher grain yield (5.9 tha^{-1}) than manual random puddled transplanted rice (5.0 tha^{-1}) (Fig. 9). Similarly, direct-sown rice by seed drill resulted in higher grain yield (5.8 tha^{-1}) than the manual broadcasting method (5.24 tha^{-1}). Manual random transplanting produced a lower yield with high variability. We also recorded that most of the farmers adopted manual line transplanting in the district (63 %). Our results also show that 48 % of farmers still do manual harvesting and threshing and only 35 % of farmers use combine harvester.

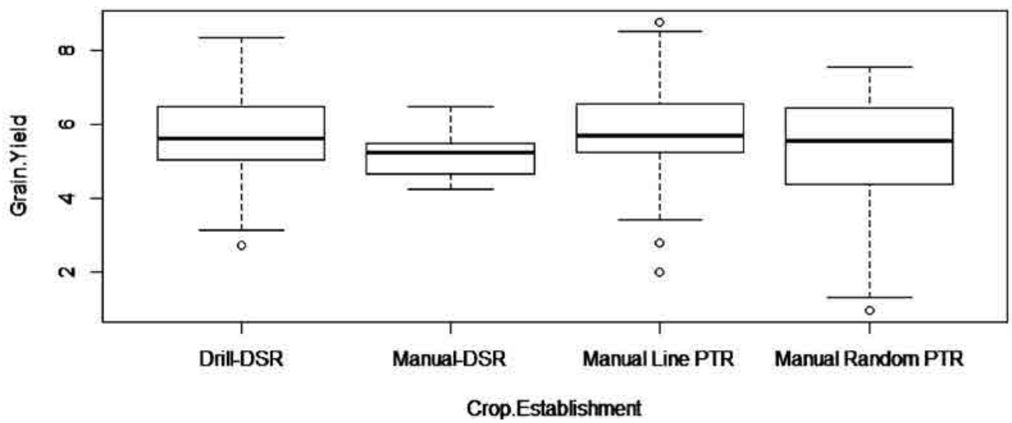

Fig. 9. Grain yield in different rice crop establishment methods in Guntur.

Conclusion

The tracking of adoption patterns showed that there was still one variety and manual transplanting was practiced by most farmers. Farmers are using more fertilizer but the yield is not increasing in that proportion. Factors other than nutrient management should be prioritized to harness maximum out of externally added fertilizers. The current practice of soil health card based nutrient management should be improved to win the trust of farmers. Hence, field-specific nutrient management decision support tools should be developed as part of digital farming. Mechanization in rice cultivation is not popular but has the potential to address the issue including labour, water, costs and timeliness of operations.

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3.3 Mechanization from seed to harvest and improved varieties can increase the yield potential of rice in Krishna district

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Introduction

Krishna district is a coastal district of Andhra Pradesh, with an annual rainfall of 1034 mm with 66% of rainfall received from south-west monsoon and 24% from north-east monsoon (CRIDA, 2012). The major soils are black cotton soils (57.6%), sandy clay loams (22.3%), red loamy (19.4%), and sandy on the fringes of sea coast constitute 0.7% (Hand Book of Statistics, 2018). The net sown area of the district is 4,63,000 ha and cropping intensity is 155%. Around 66% of the cultivated area is under irrigation and 72% of irrigated area by canal irrigations and 17% by borewells. Major crops grown in the district are rice, black gram, cotton, maize, green gram, sugarcane, chilli groundnut and tobacco. Rice grown under irrigated conditions both in *kharif* (2,73,000 ha) and *rabi* (1,20,000 ha) seasons. Monsoon variability (cyclone and heavy rainfall in a short span of time) within the season is the major issue despite rice cultivated in irrigated situations. Lack of mechanization and lack of adoption of improved management practices are other issues for increasing yield potential in the district (Sowjanya, 2016).

Methodology and Sample Distribution

Diagnostic surveys for production practices and yield assessment were conducted in Krishna district from 206 farmers from 32 villages. The data on rice production practices were collected using digital tool-Open Data Kit (ODK)-based survey deployed on smartphones. Details of methodology found in Chapter 1.

Blocks covered : Bapulapadu, Kaikalur, Musunuru, Vuyyuru, Nuzvid, Kalidindi, Challapalle, Gannavaram, Kankipadu, Pamidimukkala, GKonduru, Gudlavalleru, Jaggayyapeta, Machilipatnam, Mopidevi, Mudinepalle, Pedaparupudi, Unguturu and Vatsavai.

Villages surveyed (Fig. 1) : Annavaram, Arugolanu, Bandipalem, Challapalli, Chegireddypa, Chevendra, Choragudi, Chwgireddypadu, Edpugallu, Edupugallu, Ganginenipalem, Gannavaa, Gollanapalli, Gowravaram, Korukollu, Lopudi, Malkapuram, Mudinepalli, Mudunuru, Mukkollupadu, Padda avutupalli, Pedagonnuru, Peddaavutupalli, Pochavaram, Polampalli, Sana Rudravaram, Singavaram, Sn Gollapalem, Vedurupavuluru, Vemavarappadu, Venturumilli and Vinjarampadu.

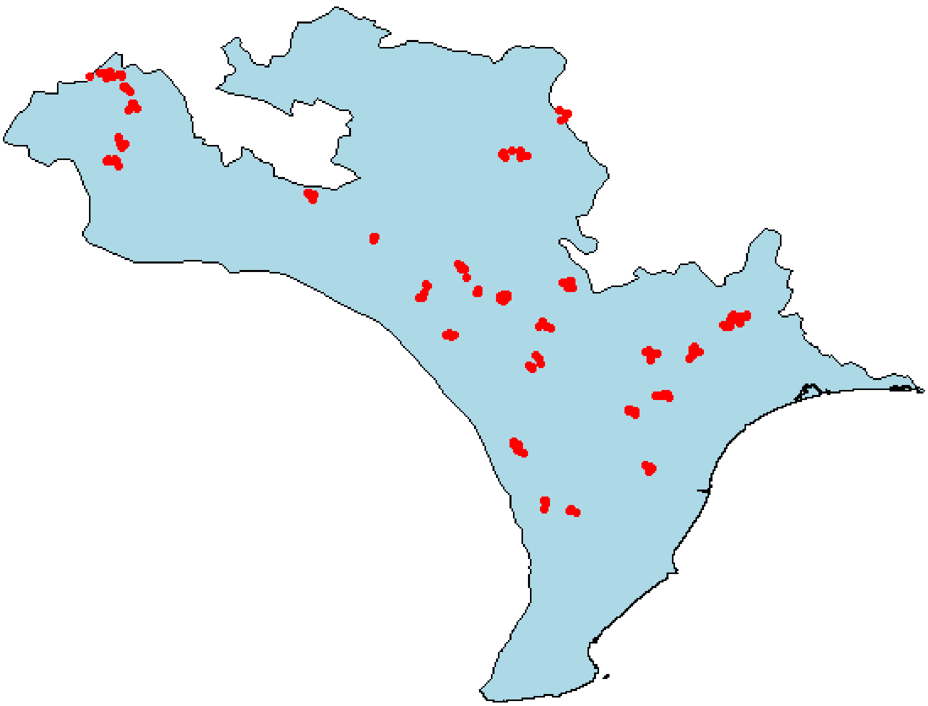

Fig. 1. GPS points of surveyed farms in Krishna district, Andhra Pradesh.

Results and Discussion

The major cropping sequence is rice in *kharif* season followed by the black gram in *rabi* season (40% of the area), rice (17%), maize (11%), other crops (20%), green gram (5%) and 7% of area left as fallow (Fig. 2). Hence, cropping intensity is high in rice-based cropping systems in the Krishna district. Most of the surveyed HHs are using improved rice varieties in the district. Samba Mahsuri (BPT-5204), occupied 41 % of the rice area followed by 26 % of the area by Indra (MTU-1061), a 10 % area by Pushyami (MTU-1075), 5 % each by Pujitha and Akshaya (BPT-2231) and 4 % by Swarna (MTU-7029). The highest rice yield was recorded with Pujitha (7.6 tha^{-1}) which was on par with Akshya (7.2 tha^{-1}) but it was significantly higher than other varieties (Fig. 3). The average yield from other varieties was 5.7, 6.0, 6.1 and 6.5 from BPT-5204, Indra, Swarna and Pushyami, respectively.

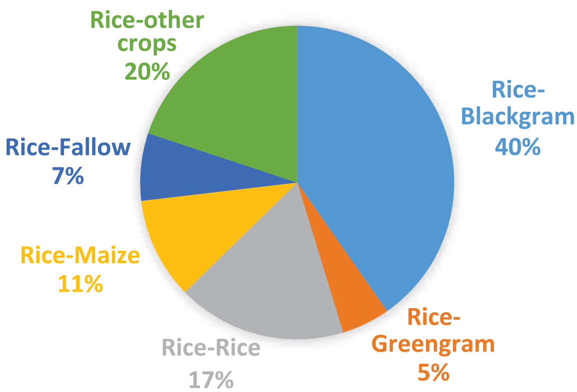

Fig. 2. Major rice-based cropping systems in the district.

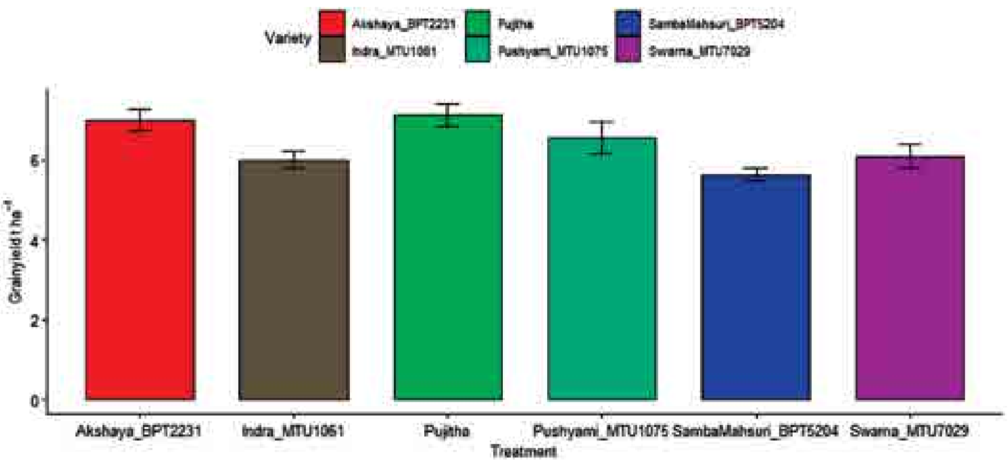

Fig. 3. Major rice varieties grown in Krishna district, Andhra Pradesh.

Almost 80 % of the households (HHs) established rice by manual random transplanting followed by 17.5 % of rice established by direct broadcasting and 2.5 % by direct seeding using a seed drill. Direct seeding using seed drill produced higher grain yield (7.1 tha^{-1}) compared to broadcasting (6.1 tha^{-1}) and manual random transplanting method (6.0 tha^{-1}) (Fig. 4). Mechanical transplanting was not observed among the surveyed farmers and villages. Our survey also shows that 57 % of surveyed HHs still do manual harvesting and threshing. Mechanization is lacking in crop establishment in Krishna district and there was no machine transplanting and only a few farmers

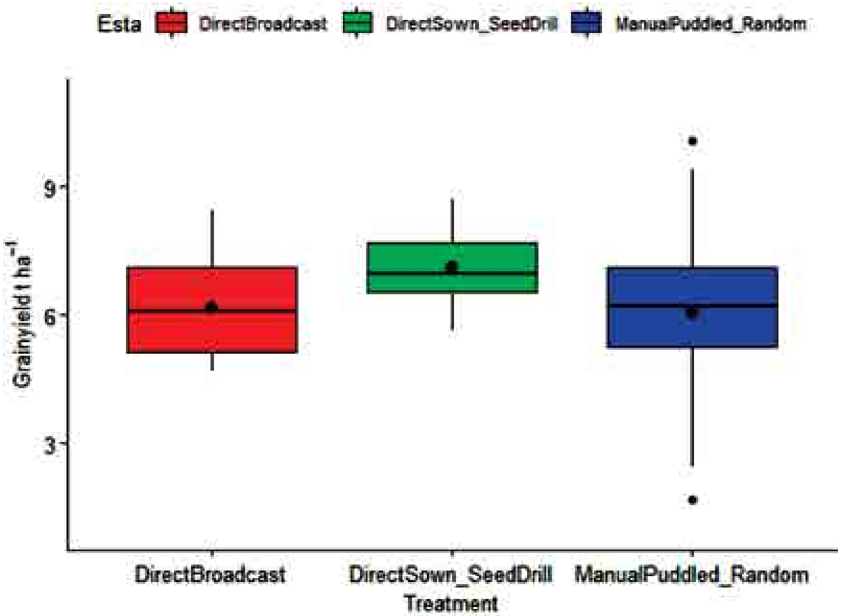

Fig. 4. Major rice crop establishment methods in Krishna district, Andhra Pradesh.

used seed drill for sowing. There is a lot of scope for mechanization due to a shortage of labour and a higher cost of labour during the peak cropping season.

Forty-eight per cent of the surveyed farmers have soil health cards (SHC) but only 3 % of farmers used the SHC information for fertilizer management (Fig. 5).

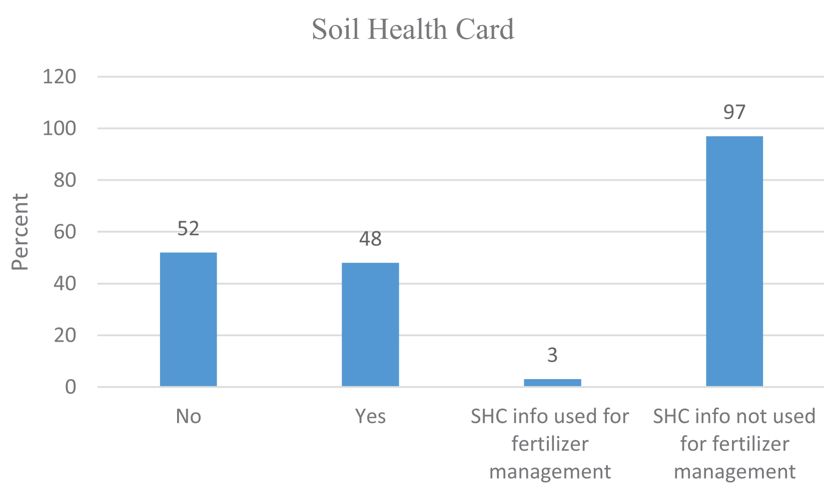

Fig. 5. Status of soil health card usage in Krishna district.

Similar to Guntur district, 97 % surveyed farmers did not use SHC's information for fertilizer management. The state government provides a subsidy for $ZnSo_4$ for those farms deficient in Zn, but the subsidy is provided based on Zn content printed on SHC. Our results show that 22 % of farmers applied $ZnSo_4$ which is still low despite 100 % subsidy provided by the state government and the majority of farmers apply $ZnSo_4$ purchased from the dealer.

The histogram of NPK application shows that the average application of nitrogen was 127 kg per ha (the majority of farmers apply 100 to 180 kg N per ha), phosphorus 55 kg per ha (30 to 100 kg per ha), and potassium 53 kg per ha (30 to 80) (Fig. 6). The results indicate that farmers, on an average, apply NPK at the recommended rate except in a few cases in the district.

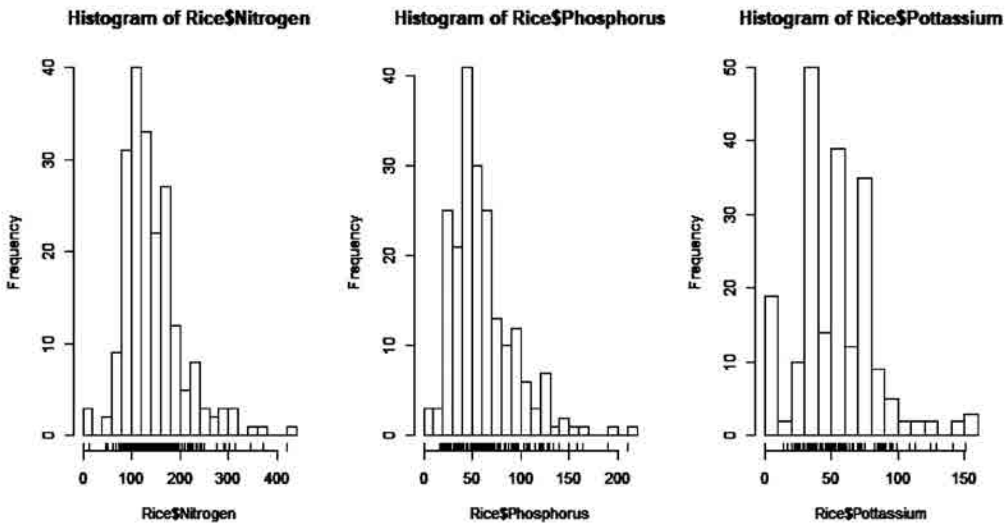

Fig. 6. The application of NPK ($kgha^{-1}$) in rice in Krishna district.

Weeds are one of the major constraints in rice cultivation in the district. The major weeds in *kharif* rice are *Echinochloa colona* (35 % of the surveyed farmers reported this as topmost weed in their fields), *Cynadon dactylon* (12 %), *Leptochloa* spp. (10 %), *Cyperus rotundus* (9 %) and *Marsilea minuta* (9 %) (Fig. 7). To manage these weeds, farmers use both manual weeding and herbicides (Fig. 8). Around 36 % of farmers managed weeds only by manual weeding and 10 % of farmers managed weeds only by the application of herbicides. However, 64 % of surveyed farmers used both manual weeding and herbicides for managing weeds in their rice fields. Application of pre-emergence herbicides was followed by one manual weeding adopted by 30 % of farmers.

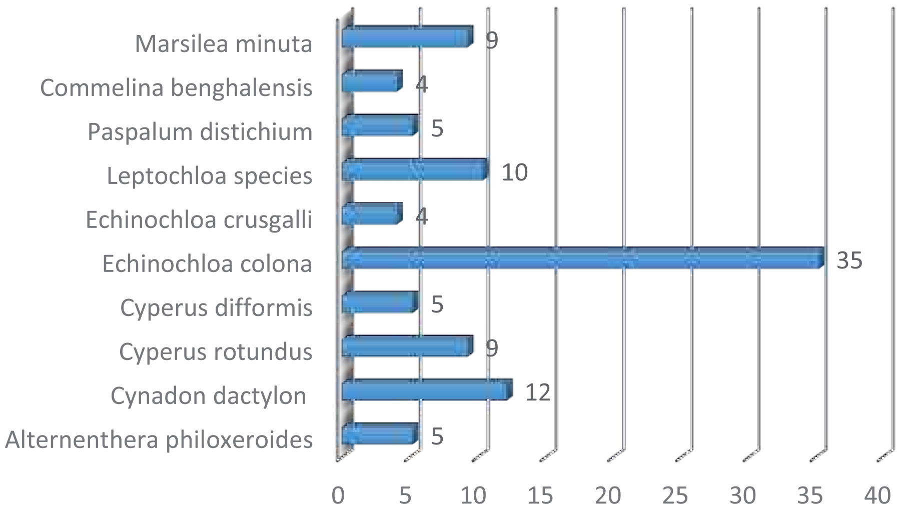

Fig. 7. Major weeds perceived by the farmers in rice fields.

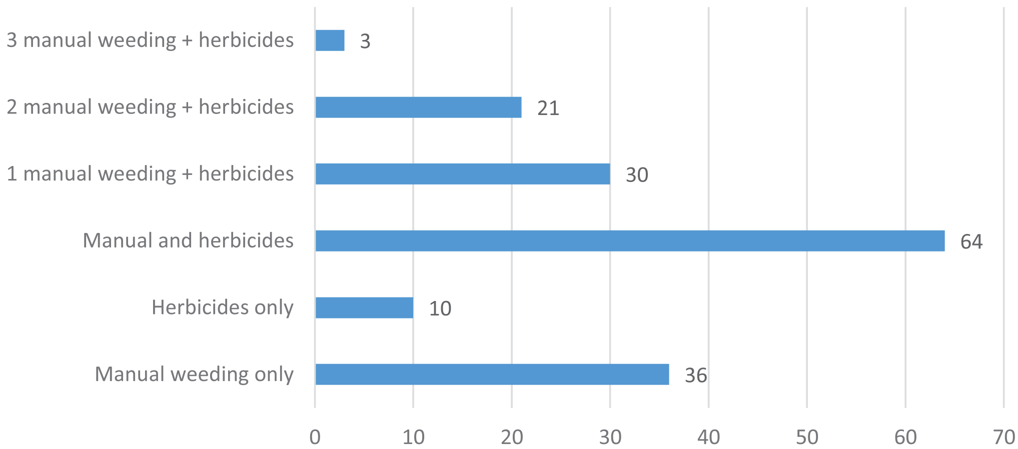

Fig. 8. Weed control methods adopted by rice farmers in Krishna district.

Since rice is grown in irrigated conditions, the yield obtained is comparatively better than in other regions. The average paddy yield from surveyed farms was 6.0 tha^{-1} (most farms yield ranged from 5 to 7 tha^{-1} with the present management practices) (Fig. 9). Our results also show that yield increased with an increased number of irrigations from 5-7 to 8-10 but further increase in yield was not observed with further increase in the number of irrigations to 11-14 (Fig. 10). Results show that there is still a lot of potential for improving the yield by adopting best management practices and mechanization.

Conclusion

Tracking of production practices shows that farmers still establish the rice crop with manual transplanting method despite a labour shortage. Varietal spectrum is still dominated by some old varieties like BPT 5204. Lack of awareness on the best management practices based on system approach is needed. Mechanization from seed to harvest can help intensifying the cropping system and profits of farmers.

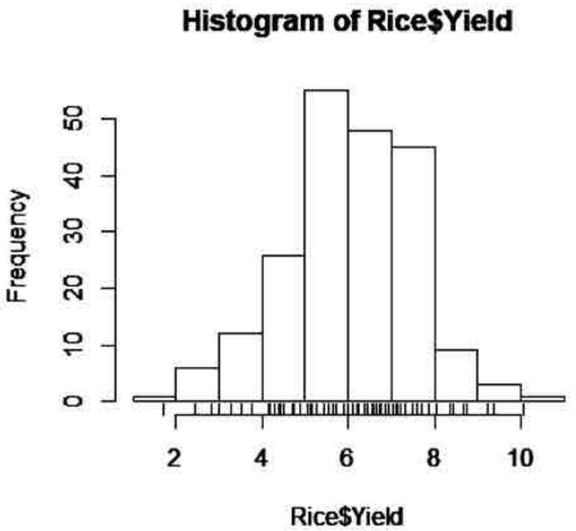

Fig. 9. Rice grain yield obtained by farmers in Krishna district.

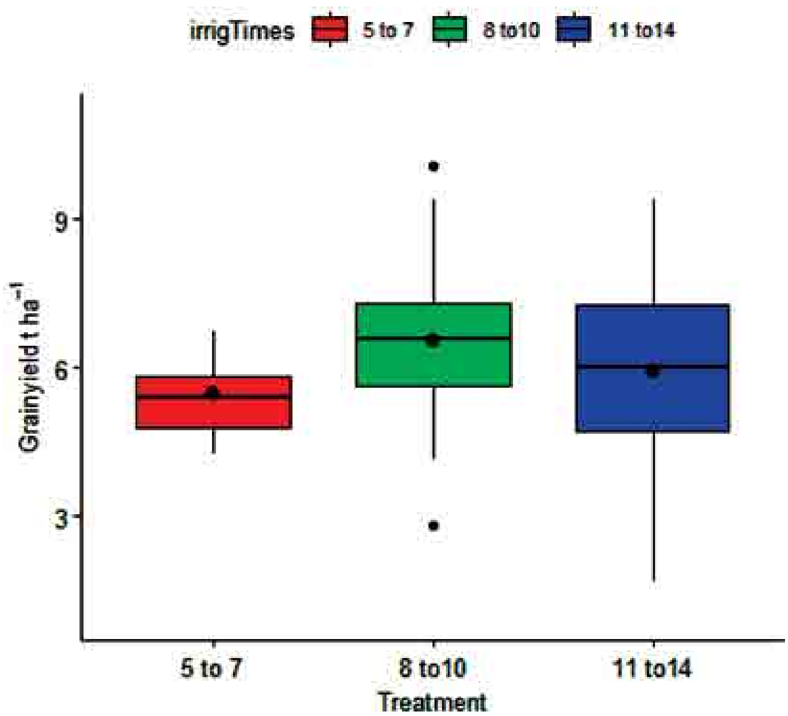

Fig. 10. Rice grain yield influenced by number of irrigations.

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3.4 Timely transplanting and integrated weed management offer best scope to increase rice yield in Chittoor, Andhra Pradesh

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Introduction

The annual rainfall of the district is 934 mm, equally received from both South West Monsoon (438 mm) and North East Monsoon (396 mm). Mono-cropping of groundnut prevails asthe major crop in dry areas, while double-cropping (rice-groundnut) in irrigated areas (Anonymous, 2020). Chittoor district is one of the chronic drought-affected Rayalaseema districts of Andhra Pradesh. The main crops are groundnut, rice, sugarcane, pulses and vegetables. The rice area in this district is 61,577 ha, and groundnut is 1, 61,957 ha during 2014 (Govardhan *et al.*, 2015). The tendency for not adopting any technology may be because of lack of confidence or in some cases farmers do not know what their preferences are.We need landscape diagnostic survey (LDS) to monitor, evaluate and learn the system that reflects the views and represents the interests of farmers. Chittoor KVK in collaboration with CSISA aimed to collect data from farmers on prevailing management practices and performances of new technologies in rice through digital data collection tools.

Methodology and sample distribution

Diagnostic surveys for production practices and yield assessment were conducted in Chittoor district from 213 farmers from 42 villages. The data on rice production practices were collected using digital tool-Open Data Kit (ODK)-based survey deployed on smartphones. Details of methodology found in Chapter 1.

Blocks covered : Buchinaidu Kandriga, Chandragiri, Chinnagottigallu, Chowdepalle, Gangavaram, Kambhamvaripalle, Karvetinagar, Mulakalacheruvu, Narayanavanam, Nindra, Pakala, Peddapanjani, Pulicherla, Punganur, Renigunta, Rompicherla, Sodam, Srikalahasti, Srirangarajapuram, Thottambedu, Varadaiahpalem, and Vedurukuppam.

Villages surveyed (Fig. 1) : Agasthapalli, Allamadugu, Appinapalle, Ayyavandlapalli, Bandarauvaripalli, Bayareddigaripalli, Bestapalli, Chinnagorniguntа, Chintamakulapalli, Dandapalle, Diguvapalli, Elakatur, Etavakili, Gandrajupalle, Garnimitta, Gopichettipalle, Gutturu, Ingalur, Kallivettu, Karuvuru, Kateperi, Kodekambhamvaripalli, Kumaripalli, Mangalapalli, Mittapalem, Mulakalacheruvu, Nadigadda, Nethigutlapalli, P L Kothuru, Prasannaayyagaripalli, Pullur, Romphicherla, Rompicherla, Sankarayalapeta, Santhavellure, Sodum, Thippireddigaripalli, Thiruvatyam, Vagavedu, Vallivedu, Vankireddigaripalli and Yerrathivaripalli.

Results and Discussion

Most of the rice cultivation in the district comes from medium land (80%) followed by low land (17 %) and only 3 % from upland (Fig. 2). Our survey shows that many rice varieties are grown by farmers in this district compared to the dominance of one

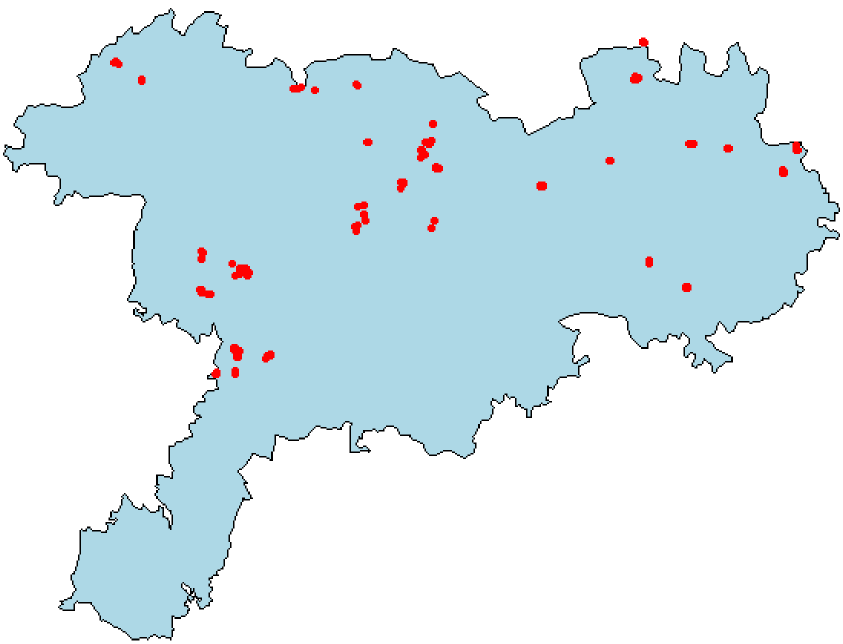

Fig. 1. GPS points of surveyed farms in Chittoor district, Andhra Pradesh

or two varieties in other districts. Hybrid rice is also grown by farmers in the Chittoor district. NLR34449 produced the highest paddy yield of 8.94 tha^{-1} (N=54) followed by other NLR series (6.6tha^{-1}), BPT-5204, and Sriram Gold hybrid rice (Table 1).

However, the lowest grain yield was obtained with RNR 15048 (5.6 tha^{-1}).

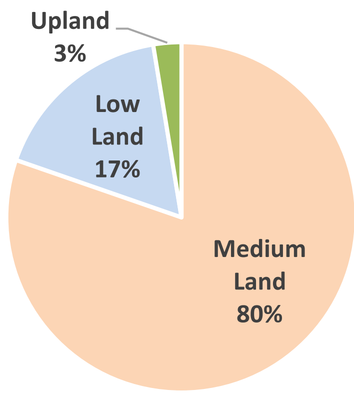

Fig. 2. Rice ecology in Chittoor district.

Most of the farmers established rice with manual puddled random transplanting (95%) followed by a small proportion of other methods like direct seeding and manual line transplanting methods (Table 1). Grain yield was less under the direct seeding (4.0 tha^{-1}) than manual transplanting methods (6.6 to 7.0 tha^{-1}). The district lack in mechanization in rice crop establishment and no farmers established crop with the machine, despite there is a potential for mechanization due to double rice cropping systems and shortage of labor. The average grain yield from surveyed farms was 7.0 t per ha with yield ranging from 4 to 10 tha^{-1} among many farmers with the current management practices (Fig. 3).

Table 1. Grain yield among the varieties and crop establishment methods.

	Number of farmers adopted	Grain yield (tha-1)
Varieties		
NLR34449	54	8.94 a
NLR3041	36	6.65 b
NLR9674	21	6.66 b
RNR 15048	28	5.60 c
Samba Mashuri (BPT-5204)	30	6.61 bc
Sreeram Gold	12	6.61 bc
Crop establishment methods		
Direct broadcasting	3	4.0 b
Manual puddled random transplanting	202	7.0 a
Manual puddled line transplanting	7	6.6 a

Means within a column for a variable followed by the same letter are not different using *LSD test* at $P \leq 0.05$

Our result shows that paddy yield was highest in the fields transplanted during June (8 t ha^{-1}) and yield decreases with a delay of transplanting from July to Aug (Fig. 4).

This highlights that when the irrigation is available, farmers should start nursery in May or early June to transplant in time to harvest more with high resource use efficiency.

The rice farmers in the district also use pre-emergence herbicides followed by one hand weeding to manage weeds effectively which resulted in the highest grain yield compared to one hand weeding alone or two manual weeding (Fig. 5). The grain yield under the combination of herbicides and one hand weeding was higher by

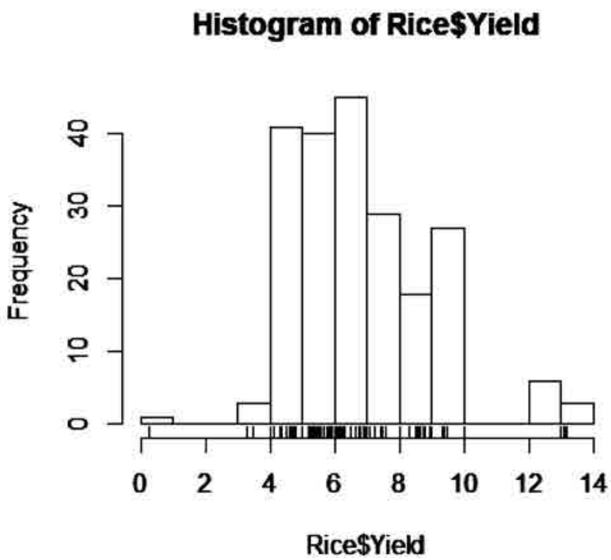

Fig. 3. Histogram of rice grain yield from the surveyed farms in Chittoor district.

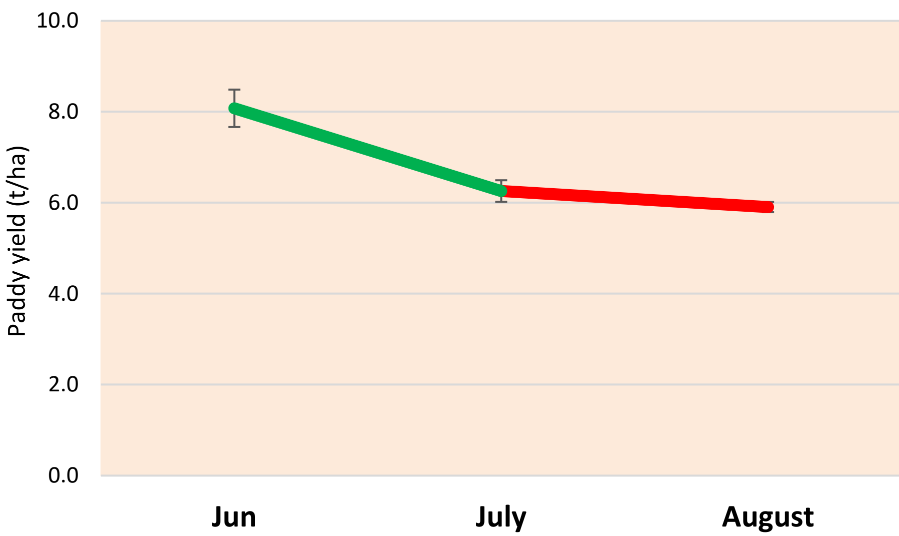

Fig. 4. Grain yield in different months of transplanting.

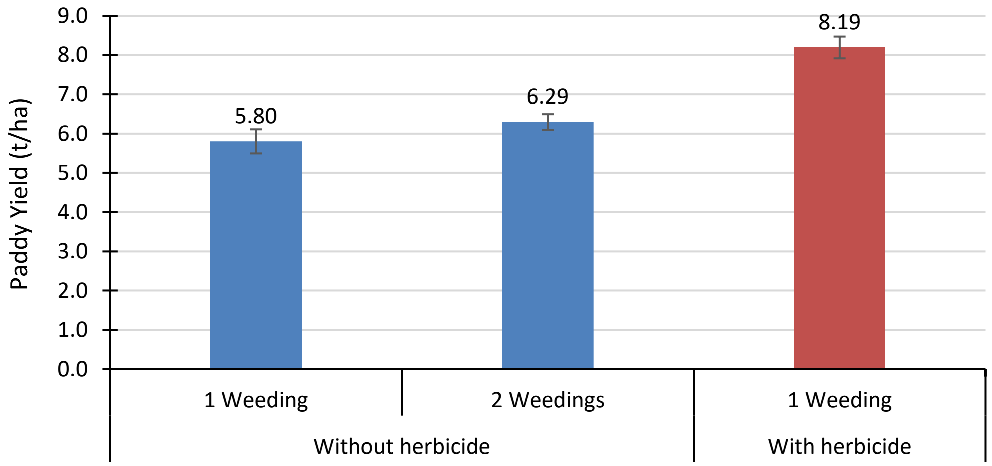

Fig. 5. Grain yield under different weed control methods in Chittoor district.

2.39 and 1.9 tha^{-1} compared to one or two hand weeding. However, most of the farmers in the district lacked knowledge on herbicides usages, and hence imparting knowledge and training for farmers and input dealers is important for rice production in Chittoor district.

Conclusion

Better adoption of relatively new varieties calls for KVK system to see how to match the new varieties with the yield and quality of old varieties. Hybrid rice and early transplanting can help reshaping the intensification of rice-rice cropping system. Scarce labour shortage has increased the cost of manual transplanting, herbicide use with better water management should be promoted

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3.5 Irrigation and improved varieties can increase rice yield in Prakasam district

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Introduction

Prakasam district receives an annual rainfall of 871 mm. This includes 390 mm rainfall each from south-west monsoon and north-east monsoon (CRIDA, 2012). Major soil in the district is red (51%) and black cotton soil (41%). The net sown area is 5,48,000 ha with a cropping intensity of 108% only. Moreover, only 32% of the cultivated area is under irrigation and the main sources of irrigation in the district are borewells (43%) and canals (34%) (CRIDA, 2012). The major crops are rice, chickpea, red gram, cotton, maize and sunflower. Rice is grown in irrigated conditions and mostly sown from the 2nd week of Aug to the 3rd week of September depending on the release of water from canals. Drought, delayed and limited release of water from canals, and lack of adoption of best management practices including mechanization in rice cultivation are the major issues in the district.

Methodology and Sample Distribution

Diagnostic surveys for production practices and yield assessment were conducted in Prakasam district from 216 farmers from 30 villages. The data on rice production practices were collected using digital tool-Open Data Kit (ODK)-based survey deployed on smartphones. Details of methodology found in Chapter 1.

Blocks covered : Addanki, Bestawaripeta, Chandrasekhara Puram, Chimakurthi, Chinaganjam, Darsi, Donakonda, Karamchedu, Konakanamitla, Kondapi, Kotha Patnam, Maddipadu, Mundlamuru, Parchur, Pedacherlo Palle, Ponnaluru, Santhanuthala Padu, Tripuranthakam, Veligandla, Yerragondapalem and Zarugumilli.

Villages surveyed (Fig. 1) : Badapuram, Bhusarapalle, Darsi, Edara, Edugundlapadu, Gurapasala, Jagarlamudi, Kadavakudur, Kotapadu, Kothareddy palem, Kunkalamaru, Madipi, Pachala venkatapuram, Padarthi, Papayapalle, Pasupugallu, Pedagogulapalle, Pedarikatla, Pulipadu, Rajupalem, Ramalingapuram, Ravulakollu, Rudravaram, Sivajinager, Talakondapadu, Thumadu, Vemparala, Vemula, Vennuru and Zarugumilli.

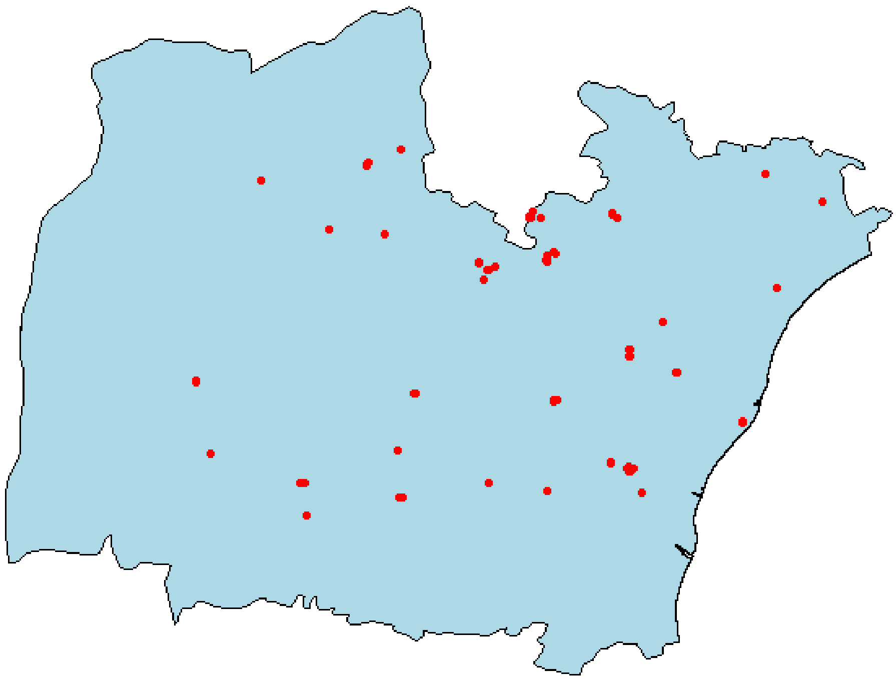

Fig. 1. GPS points of surveyed farms in Prakasam district, Andhra Pradesh.

Results and Discussion

Around 80 % of the farmers in the district preferred growing BPT-5204 than other rice varieties (Table 1). However, rice grain yield was high with NLR-145 and NLR-33892 but only a few farmers grew these varieties compared to BPT-5204. The grain yield from BPT-5204 fairly represents the average yield and consistent than other varieties due to many samples. Most of the farmers grow rice under irrigated conditions and many farmers irrigate 8-10 times and 11-15 times in this district (Table 1). Grain yield was increased with an increase in the number of irrigations from 2-7 to 14-15. However, grain yield was on par at 8 to 13 irrigations (Table 1). Grain yield was almost double from no irrigation to 14-15 irrigations in the district.

Table 1. Influence of variety and irrigations on grain yield.

	Number of farmers adopted	Grain yield (tha^{-1})
Variety		
NLR-145	7	7.0 a
NLR-33892	14	6.0 b
BPT-5204	168	5.2 c
NLR-9674	7	5.2 c
NLR-34449	12	5.0 c
Number of irrigations		
0	15	3.5 d
2-7	39	5.0 c
8-10	64	5.3 b
11-13	49	5.4 b
14-15	49	6.0 a

Means within a column for a variable followed by the same letter are not different using *LSD test* at $P \leq 0.05$.

Among the surveyed farmers, 81 % of them mentioned that drought was not a severe issue for rice cultivation (Fig. 2). Similarly, 91 % of surveyed farmers felt floods not a severe issue for rice cultivation in the district. This might be due to rice cultivated in the irrigated condition in Prakasam district with canal and borewells. However, 92 % of farmers mentioned insects and 83 % of farmers mentioned diseases are the major issues in the region (Fig. 2). In the case of weeds, only 19 %

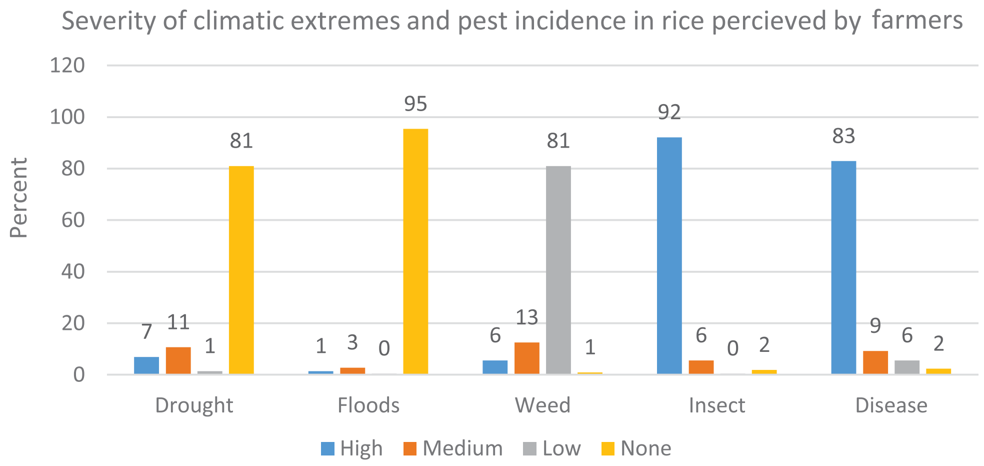

Fig. 2. Severity of climatic extremes and pest incidence in rice.

mentioned weeds are severe or medium in their rice fields, but the majority (81 %) of the farmers felt that weeds were less or easily managed in their fields. This could be due to rice cultivated in well puddled transplanted conditions (all surveyed farmers manually transplanted rice in puddled conditions, data not shown here). According to farmers' perception and experience, the top most weeds in rice fields in the districts are *Cyperus rotundus*, *Portulaca oleracea*, *Echinochloa colona, Leptochloa* spp. and *Cynadon dactylon* (Fig. 3).

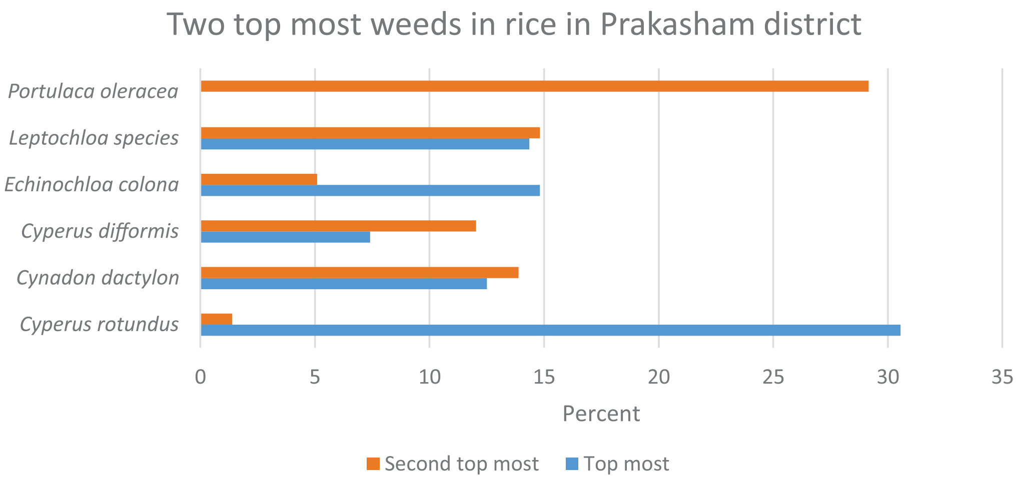

Fig. 3. Top most weeds in rice in Prakasam district.

The histogram of NPK application shows that the average application of nitrogen among the surveyed farmers in the district was 180 $kgha^{-1}$ (the majority of farmers applied 150 to 250 kg N ha^{-1}), phosphorus 45 kg per ha (30 to 80 $kgha^{-1}$), and potassium 80 $kgha^{-1}$ (60 to 100) (Fig. 4). The results indicate that farmers on an average apply the recommended dose of phosphorus but over-application of nitrogen. Survey also reported that only 32 % of farmers applied farmyard manure and 41 % of farmers grew green manure in the district (data not reported). We also found that input dealers were the major source of fertilizer recommendations for farmers.

However, around 16 % of farmers approached MPEOs or Mandal Agricultural Officers for Zn-sulfate. Zn sulfate is provided with 100 % subsidy by the state government, so MPEOs or agricultural officers play a vital role as a source of information for micronutrients under the subsidy program. But, still, only around 16 % of farmers approached/applied Zn despite 100 % subsidy and this might be due to lack of knowledge or complication in obtaining subsidy using a soil health card.

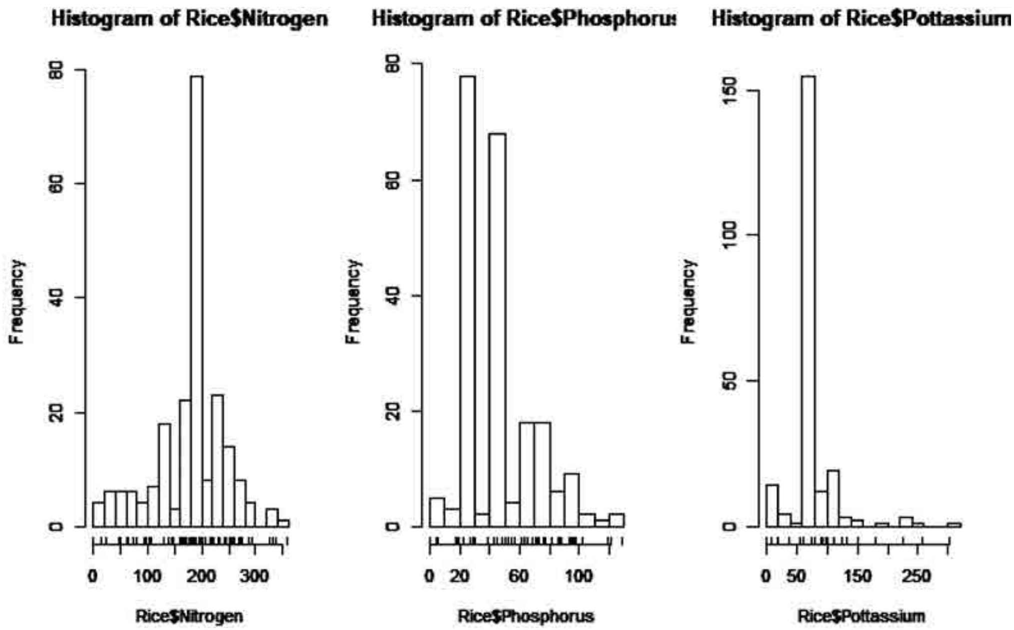

Fig. 4. NPK (kgha^{-1}) application in rice across the surveyed farms in Prakasam district.

Conclusion

Data from this survey have ascertained that the only the best variety (BPT 5204) among the lot survives for a long period. Varieties with maturity duration of 140 days or higher have higher yield potential than varieties with lower range. All surveyed farmers transplanted rice manually and 98 % of them harvested manually despite lack of labour and increased labour costs. Mechanization should be promoted to intensify the cropping systems in Prakasam district. Creating awareness on agronomic management practices to leverage best out of varieties and nutrient management should be prioritized in Prakasam district.

Reference

CRIDA (2012). Agriculture contingency plan for Prakasam. http://www.crida.in/CP-2012/statewiseplans/Andhra%20pradesh%20(Pdf)/ANGRAU,%20Hyderabad/AP17%20Prakasam%2031.1.2011.pdf.

3.6 Rice cultivation needs to expand into mechanization from crop establishment to harvesting to intensify the rice-pulse cropping system in Srikakulam district

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Introduction

Srikakulam is one of the coastal districts that lie on the extreme north-east in Andhra Pradesh. The total annual rainfall is 1162 mm, and 60 % received from south-west monsoon and 24 % from the north-east monsoon. Sixty per cent of soil is red soil followed by brown forest soil (15 %), alluvial soil (10.3 %), and black soil (5 %) (CRIDA, 2012). Frequent floods and intermittent drought during crop season are common climatic shocks in the district. The cropping intensity tends to be 140 %. Around 60 % of the net sown area is under irrigation and the major sources of irrigation are canals (53 %) and tanks (35 %). Rice, groundnut, black gram, green gram, sugarcane, sesame, coconut and cashew are the major crops cultivated in Srikakulam. Rice is the major crop contributing to household income and food security in the region. Monsoon variability (long dry spell in the season and delay onset of monsoon) and lack of adoption of best management practices are the major issues for rice cultivation in Srikakulam district.

Methodology and Sample Distribution

Diagnostic surveys for production practices and yield assessment were conducted in Srikakulam district from 184 farmers from 33 villages. The data on rice production practices were collected using digital Tool-Open Data Kit

(ODK)-based survey deployed on smartphones. Details of methodology found in Chapter 1.

Blocks covered : Bhamini, Burja, Etcherla, Hiramandalam, Jalumuru, Kanchili, Kaviti, Kotabommali, Kothuru, Lakshminarsupeta, Mandasa, Narasannapeta, Palasa, Pathapatnam, Polaki, Ponduru, Rajam, Saravakota, Sarubujjili and Seethampeta.

Villages surveyed (Fig. 1) : Allada, Anthili, Aravasariapalli, Avatarabad, Baddupadu, Belagaam, Challabandha, Chintada, Kindruwada, Sunnamguda, Dallavalasa, Gorribanda, Jammu, Kalaparthi, Kinruvada, Kojjiria, Kondavalasa, Kongaram, Korasavada, Kusumapolavalasa, Maniga, Pogiri, Samantaramachandrapuram, Saravakota, Singupuram, Sabakota, Sirusuvada, Edupuram, Loddaputti, Manikyapuram, Govindapuram, Venkatapuram and Theemara.

Results and Discussion

Our survey shows that 32 and 25% of the rice area in the district is occupied by BPT-5204 and Swarna (MTU 7029), respectively. Two-third HHs have adopted

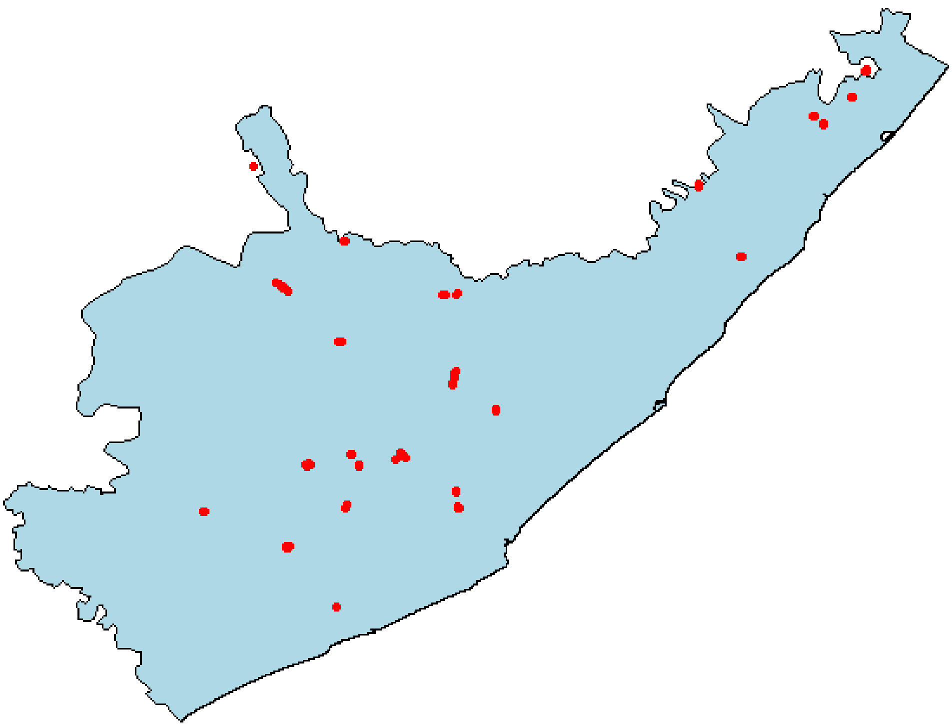

Fig. 1. GPS points of surveyed farms in Srikakulam district, Andhra Pradesh.

old varieties recommended in 1980s. Other varieties such as Indra, BPT-3291, Vijetha and Pushyami occupied approximately 8 % of the rice area (Table 1). However, grain yield among the cultivated varieties did not vary much, despite the higher grain yield obtained with BPT and Indra (Table 1). The average grain yield from surveyed farms was 5.5 tha^{-1} with grain yield ranging from 4 to 6 tha^{-1} among many farmers with the current management practices (Fig. 2). The majority of the farmers established rice with manual puddled random transplanting (79 %) followed by direct seeding and a small proportion of other methods like machine transplanting, manual line transplanting, and drum

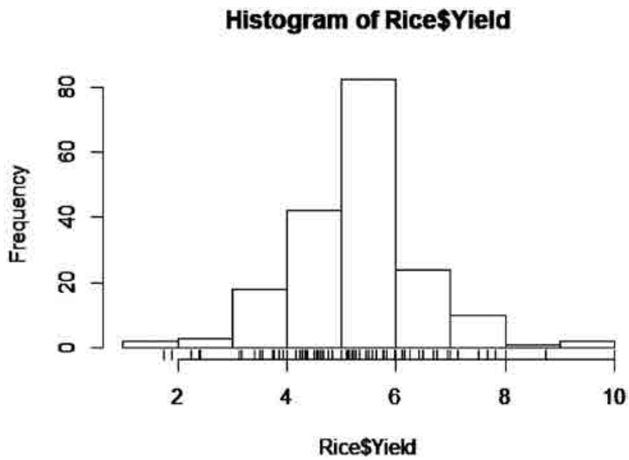

Fig. 2. Histogram of rice grain yield from the surveyed farms in Srikakulam.

Table 1. Grain yield among the varieties and crop establishment methods

	Number of farmers adopted	Grain yield (tha^{-1})
Varieties		
Indra (MTU-1061)	15	6.1 a
SonaMashuri (BPT-3291)	14	6.0 a
Samba Mashuri (BPT-5204)	59	5.9 a
Vijetha (MTU-1001)	15	5.3 ab
Swarna (MTU-7029)	47	4.9 b
Pushyami (MTU-1075)	13	4.9 b
Crop establishment methods		
Direct broadcasting	20	5.1
Manual puddled random transplanting	145	5.4
Manual puddled line transplanting	15	5.4
Machine puddled transplanting	4	5.6
		NS

Means within a column for a variable followed by the same letter are not different using *LSD test* at P ≤ 0.05.

seeding methods. Farmers in the district lack in the adoption of mechanization in rice crop establishment. Our analysis shows that grain yield from different crop establishment methods did not vary significantly in the district (Table 1).

Weeds are the major constraints in rice cultivation in the district. Around 19 % of the surveyed HHs mentioned *Marsilea minuta* as topmost weed in their fields, followed by *Cynadon dactylon* (13 %), *Cyperus* spp., *Ischaemim rugosum,* etc. (Fig. 3). To manage these weeds, farmers use both manual weeding and herbicides (Fig. 4). Among the surveyed HHs, 92 % manage weeds with the application of herbicides with one or two manual weedings, while 7 % of farmers manage weeds

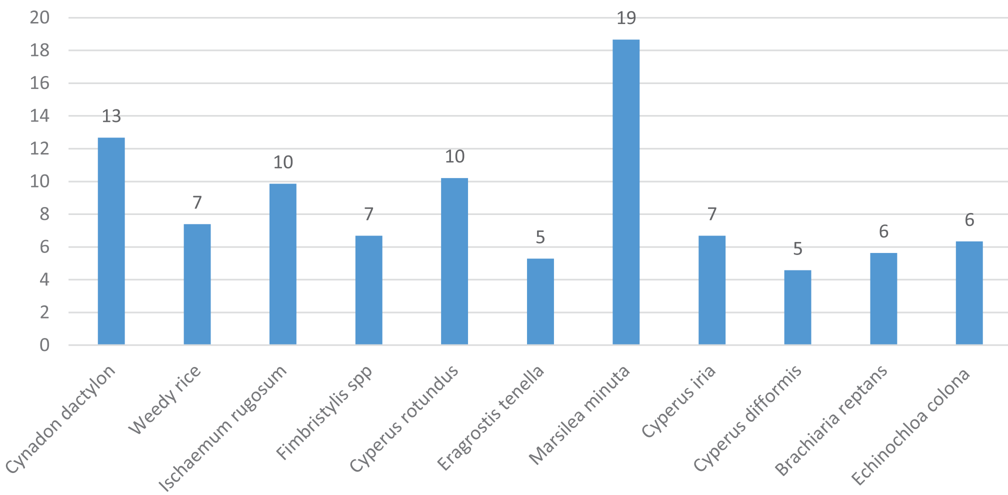

Fig. 3. Top most weeds in rice fields perceived by farmers in district Srikakulam.

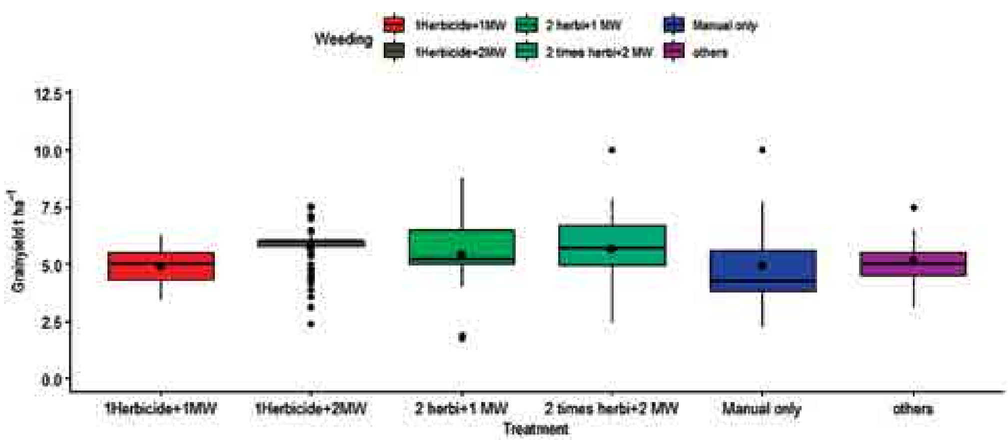

Fig. 4. Weed management practices and their effect on rice yield in Srikakulam.

only with manual weeding. However, one pre- or post-emergence herbicide application followed by two hand weeding methods was adopted by 50 % HHs (data not reported here). One manual weeding with one herbicide was adopted by 15 % of the farmers. The box plot shows that grain yield was high with the application of one pre-emergence herbicide followed by two manual weedings (average 5.8 tha^{-1}) and 2 times of herbicides (pre followed by post) application plus two manual weedings (5.7 tha^{-1}) compared to other weeding methods (Fig. 4). The lowest yield was obtained with manual weeding only or one-time herbicide plus one manual weeding (average 4.9 tha^{-1}).

Our results from the surveyed farms indicated that the average application of NPK was 102:22:45 $kgha^{-1}$. The histogram of NPK application shows that more than 50 % of HHs applied nitrogen in a range of 70 to 80 $kgha^{-1}$ (Fig. 5). Similarly, more than 60 % HHs applied phosphorus 10 to 20 $kgha^{-1}$ and potassium 30 to 40

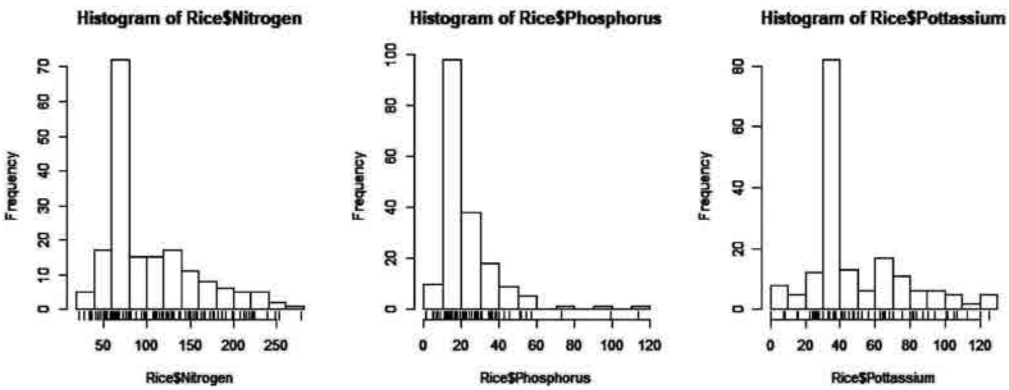

Fig. 5. NPK applications in rice in Srikakulam district.

kgha-^{1}. The results indicate that farmers in this district apply fertilizer lower than the recommended dose. Hence, there is a need to improve location-specific best management practices for increasing the grain yield.

The mechanization in rice crop establishment in the district is low, and only four farmers out of 184 farmers established rice with machine transplanting (Table 1). Similarly, mechanization in harvesting also low- 2 % of farmers harvested with reaper and 8 % by combined harvester (Fig. 6). However, 40 % of the farmers threshed manually, 52 % with the reaper/machine, and 8 % with combined harvester (Fig. 6). Mechanization in rice cultivation is not popular in the district and has the potential to address issues including labour, water, costs, and timeliness of operations.

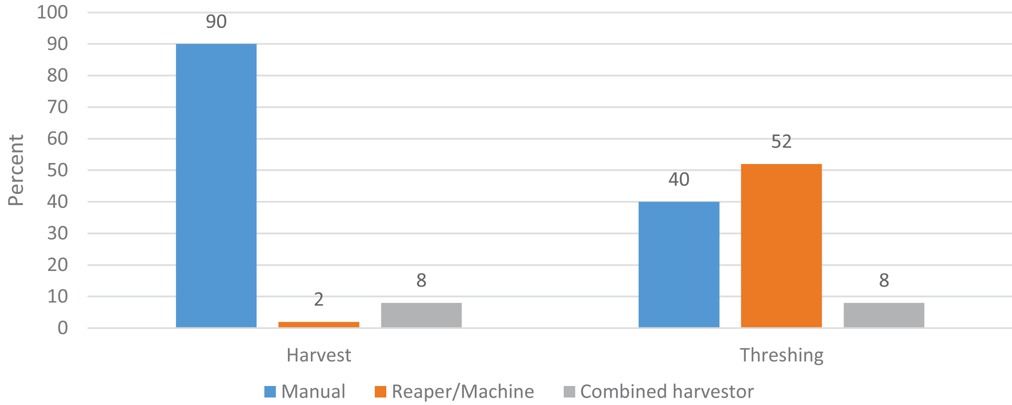

Fig. 6. Harvesting and threshing methods in Srikakulam.

Farmers take many crops after harvesting of *kharif* rice depending on their resources and soil moisture availability/irrigation source. The main succeeding crops after rice season in the district are black gram (46 %) and green gram (32 %), and other crops are taken by a few farmers (Fig. 7).

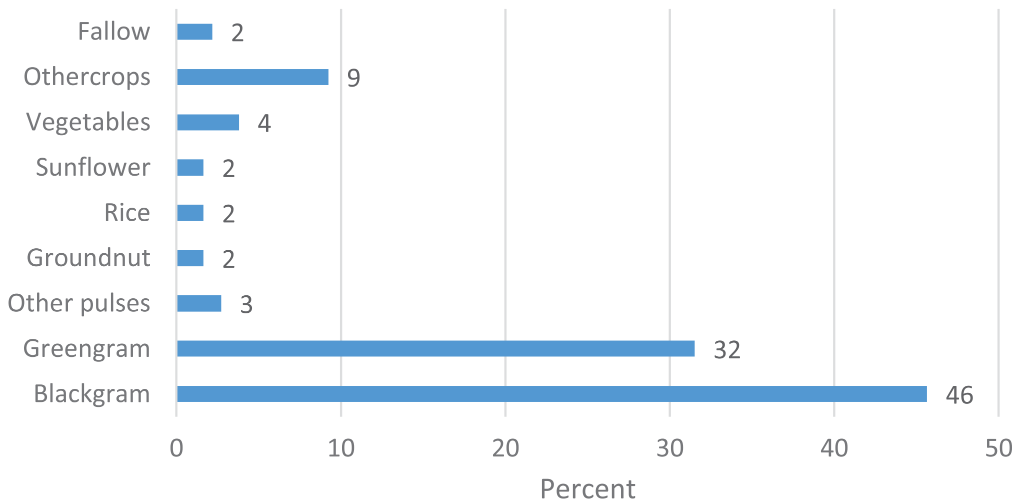

Fig. 7. Rice-based cropping systems in Srikakulam (succeeding crop after main rice system).

However, rice followed by fallow was 2 %, hence, cropping intensity is high in rice-based cropping systems in Srikakulam district.

Conclusion

Data show that new varieties could not sustain the competition from old varieties like BPT 5204 and MTU 7029 released in 1980s. The best way for regular cash flow is to work around the intensification of the rice-pulse cropping system. The mechanization of rice cultivation from seed to harvest should be given the top priority to cut cost and to intensify the cropping system. The dominance of *Cynadon dactylon* shows that weed management in pulses is as important as in rice.

Reference

CRIDA (2012). Agriculture contingency plan for Srikakulam. http://www.crida.in/CP-2012/statewiseplans/Andhra%20pradesh%20(Pdf)/ANGRAU,%20Hyderabad/AP13-Srikakulam%2031.1.2011.pdf.

3.7 Line transplanting and improved varieties are the key for increasing rice yield in Visakhapatnam district, Andhra Pradesh

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Introduction

Visakhapatnam district is one of the north-eastern coastal districts in Andhra Pradesh. It is located between 17°15’ and 18°32’ north latitudes and between 81°54’ and 83°30’ eastern longitudes. The geographical area of Visakhapatnam district is 11.34 lakh ha out of which 4.24 lakh ha is cropped area (District Survey Report, 2018). The district receives an annual normal rainfall of 1202 mm. The contribution of south-west monsoon is 55.6 % of the normal rainfall, while north-east monsoon contributes 11.9 % of the normal rainfall. The rest is shared by summer showers and winter showers. Agency and plain mandals receive larger share of rainfall from the south-west monsoon, while coastal mandals get larger share of rainfall from the north-east monsoon.

Visakhapatnam district consists of three types of soils, namely, red loamy soils, coastal sands and alluvial soils. Red loamy soils predominate with a share of 69.9 %. Sandy loam soils cover an extent of 19.2 % of the area and are largely confined to the coastal area. Alluvial soils come next, with sizeable areas in some of the mandals. The average size of land holding in the district is 0.91 ha.

The productivity of rice (2075 kgha^{-1}) in the district is very low (Cheralu, 2018). Less adoption of green manuring/lack of rotation with legume crops preceding rice in *kharif*, in discriminate use of nitrogenous fertilizers and top dressing of complex fertilizers containing phosphorus, improper nursery management, low plant population and use of over-aged seedlings besides the Zn deficiency (micro nutrients), are common factors in the district, limiting the productivity.

Methodology and Sample Distribution

Diagnostic surveys for production practices and yield assessment were conducted in Visakhapatnam district from 219 farmers from 34 villages. The data on rice production practices were collected using digital tool-Open Data Kit (ODK)-based survey deployed on smartphones. Details of methodology found in Chapter 1.

Blocks covered : Atchutapuram, Butchayyapeta, Cheedikada, Chodavaram, Golugonda, Kasimkota, Kotauratla, Madugula, Makavarapalem, Nathavaram, Paderu, Padmanabham, Paravada, Ravikamatam, Rolugunta, Sabbavaram, Visakhapatnam and Yelamanchili.

Villages surveyed (Fig. 1) : Lakshimi Puram Agency, Ankupalem, Bapirajrtallavalasa, Baranikam, Chakipalle, Chammachinta, Digumodaputtu, Etikoppaka, Gadirai, Giduthuru, Golugondapeta, Kailasapatnam, Kanchugummala, Khajipalem, Kodavatipudi, Konam, Lopudi, M K Vallapuram, M kotapadu, Marupaka, Mogalipuram, Mungarlapalem, Ponnavulu, Panduru, Pulakanda, Pydipala, Seethakandi, Sundarayyapeta, Sunkapur, Tangudupalli, Venkayyagaripeta, Yarrannapalem and Yetikopaka.

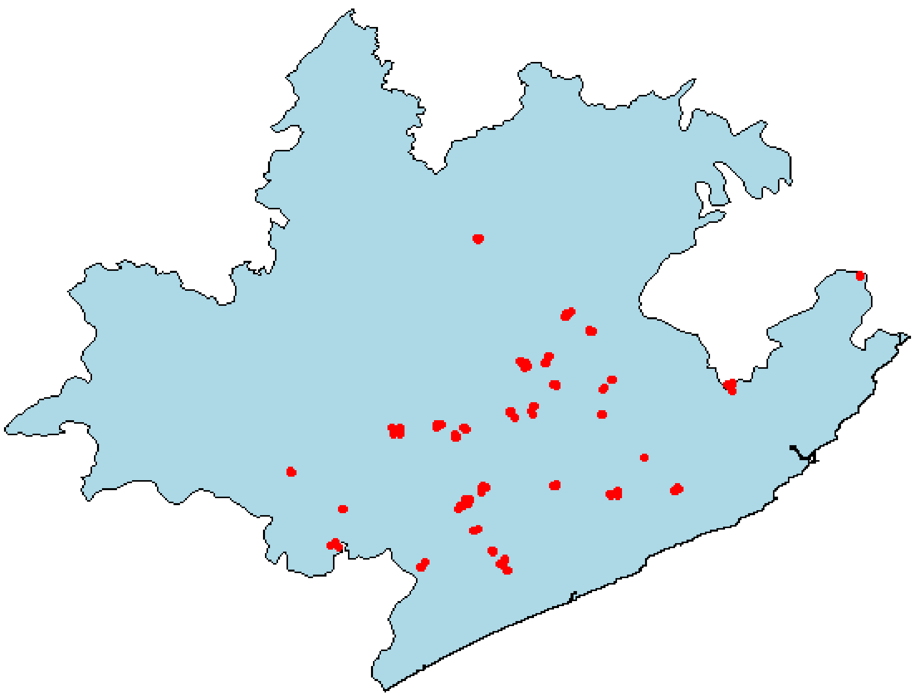

Fig. 1. GPS points of surveyed farms in Visakhapatnam district, Andhra Pradesh.

Results and Discussion

Most of the surveyed farmers in Visakhapatnam district apply FYM (94 %), fertilizers (90 %), grow green manure (30 %), and have access to some kind of irrigation (84 %) for growing rice (Fig. 2). The major rice varieties grown are RGL-2537 (48 % of farmers), followed by Amara (19 % of farmers), Samba Mahsuri (16 %), Swarna (6 %) and Sona Mahsuri (5 %) (Fig. 3). However, still, manual transplanted rice is the major crop establishment method, and neither direct seeding nor machine transplanting was found among the surveyed farmers in the district. All the farmers practiced manual harvesting and threshing unlike at least 20 to 40 % of farmers used machines in other districts.

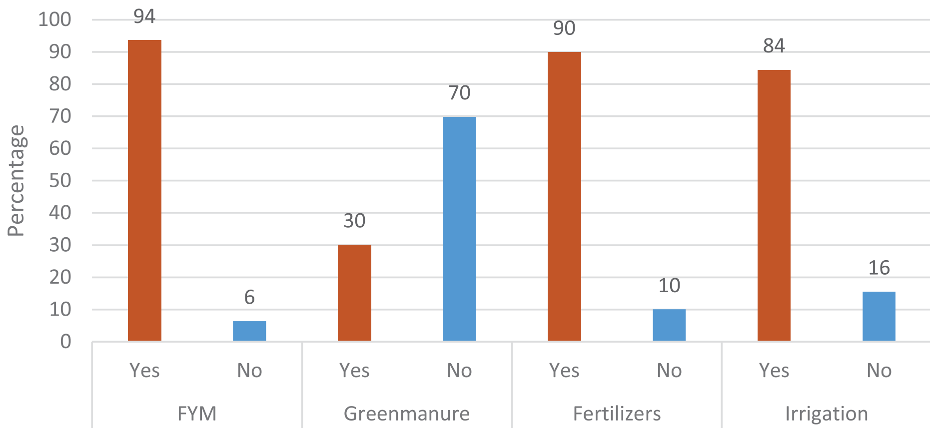

Fig. 2. Percentage of farms applied or access to various inputs.

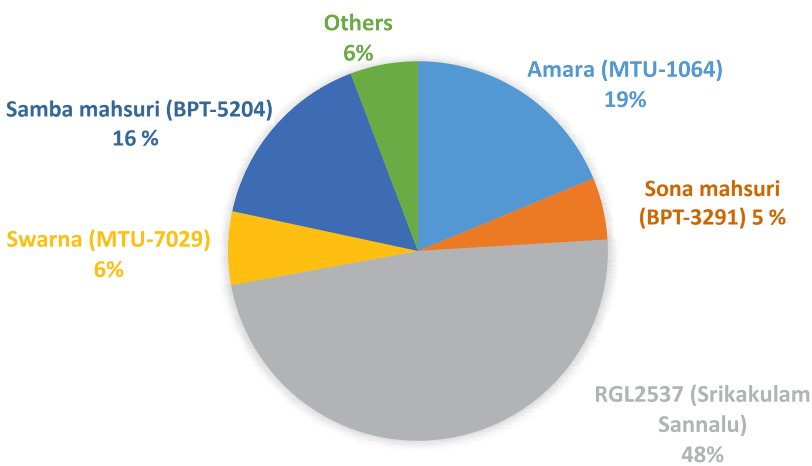

Fig. 3. Major rice varieties grown in the district.

The grain yield was higher in manual line transplanted rice (5 tha^{-1}) than manual random transplanted rice (4.31 tha^{-1}) (Fig. 4). Nevertheless, 87% of the farmers established crops with manual random transplanting. The average rice grain in the district was 4.2 tha^{-1} with most of the farmers harvested from 3 to 6 tha^{-1} (Fig. 5).

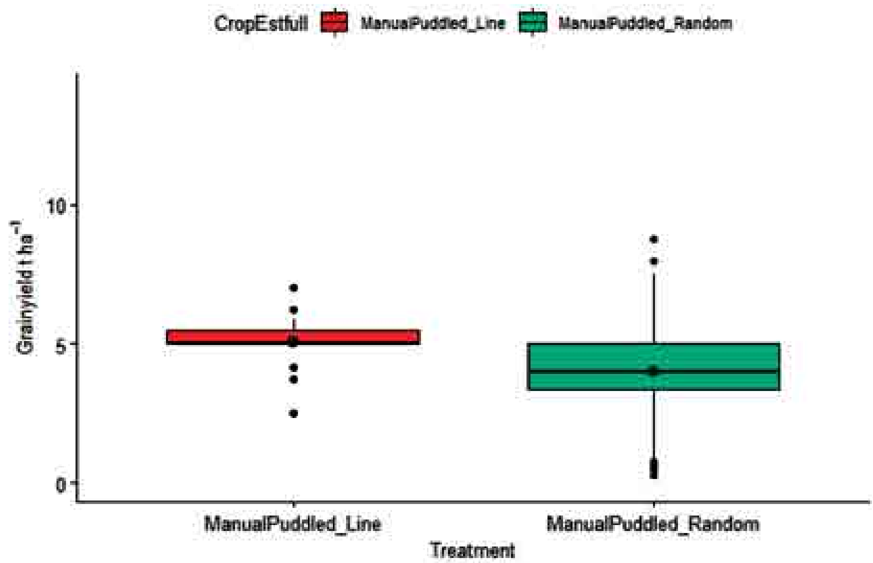

Fig. 4. Rice grain yield among the crop establishment methods.

Rice grain yield was also higher in heavy texture soil than medium or light texture soils (Fig. 6).

Thirty-eight per cent of surveyed farmers expressed *Cyperus rotundus* was the top most weeds in rice in their farms followed by *Echinochloa colona* (16%), *Marsilea minuta* (13%), *Cynadon dactlylon* (Fig. 7). Surveys conducted by several researchers (Nagaraju *et al.*, 2014; Murthy and Venkaiah,

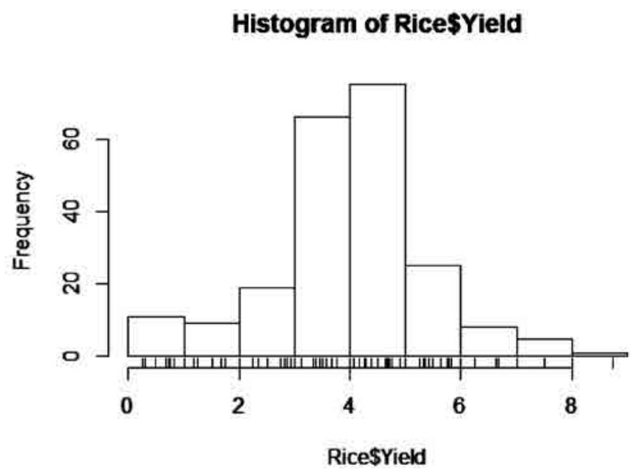

Fig. 5. Rice grain yield (tha^{-1}) from the Visakhapatnam district.

2012) also indicated that *Cyperus rotundus* (35 %) was the most frequent weed in the Visakhapatnam district. None of the farmers applied herbicides for managing weeds so manual weeding (one to three times) is the major method of weed management in rice. Average fertilizers N, P, K applied in rice were 138, 34 and 64 kgha^{-1}, respectively.

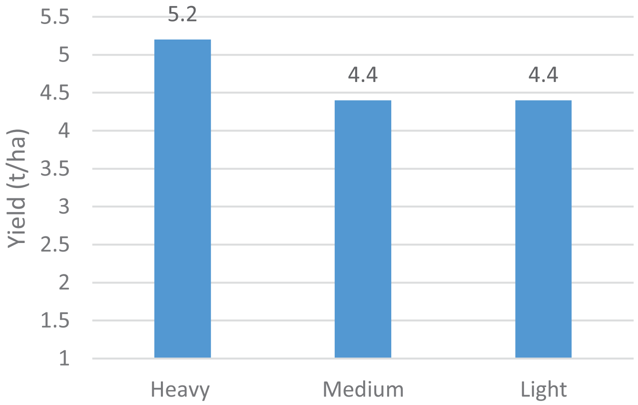

Fig. 6. Grain yield across the soil texture in Visakhapatnam district.

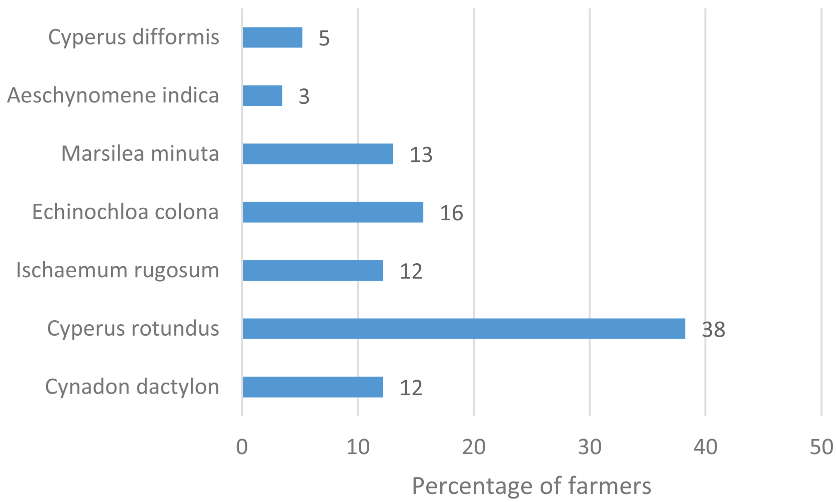

Fig. 7. Top most weeds in rice fields in Visakhapatnam district.

Conclusion

The results from the diagnostic survey show that there was lack of adoption of new varieties/hybrids, mechanizations and best management practices among the farmers. There is a lot of potential in increasing the paddy yield by adopting best management practices including choosing the right variety, timely transplanting through mechanization and proper weed control methods targeting major weed species in the regions. Therefore, the research and extension efforts will have to focus on maximizing the output through scientific crop production and protection technologies.

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3.8 Improved weed management and crop establishment have potential to increase the rice yield in West Godavari district, Andhra Pradesh

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Introduction

Sixty-three per cent of farmers are marginal and small in West Godavari district and the net sown area constitutes 46 % of the geographical area of the district (Department of Agriculture, 2020). The major soil types are alluvial (33 %) followed by sandy alluvial (30 %) and deltaic alluvial (24 %). The annual rainfall of the district is 1153 mm and 68 % of it is received through south-west monsoon (CRIDA, 2012). Rice is the major crop both in *kharif* and *rabi* seasons. Maize, black gram, tobacco and sugarcane are other major crops grown in West Godavari. The major portion of the irrigated area in the district is by Godavari irrigation system and the remaining area by a network of irrigation canals and bore-wells. The cropping intensity of the district is 162 %. However, the district is prone to vagaries of monsoon variability like high rainfall in a short span of time, cyclone and drought during the critical period of crop growth.

Methodology and Sample Distribution

Diagnostic surveys for production practices and yield assessment were conducted in West Godavari district from 210 farmers from 30 villages. The data on rice production practices were collected using digital tool-Open Data Kit (ODK)-based survey deployed on smartphones. Details of methodology found in Chapter 1.

Blocks covered : Akividu, Attili, Bhimadole, Bhimavaram, Buttayagudem, Chintalapudi, Dwaraka, Tirumala, Kovvur, Koyyalagudem, Lingapalem, Nidadavole, Nidamarru, Palacole, Peravali, Polavaram, Tallapudi, Tanuku, Undi, Undrajavaram and Ungutur.

Villages surveyed (Fig. 1) : Antarvedigudem, Bavayapalem, Bayyanagudem, Choparamanngudem, Errampalle, Kaldhari, Kapavaram, Kodurupadu, Korupalle, Kovvada, Kothapalle, Kukunuru, Maddurulanka, Madiwada, Mahadevipatnam, Malleswaram, Manchili, Mandapaka, Mattagudem, Nallamadu, Palangi, Siddapuram, Surappagudem, Suryaraopalem, Uttasamdram, Vaduluru, Velivennu, Vempadu, Venkatakrishnapuram and Vinjaram.

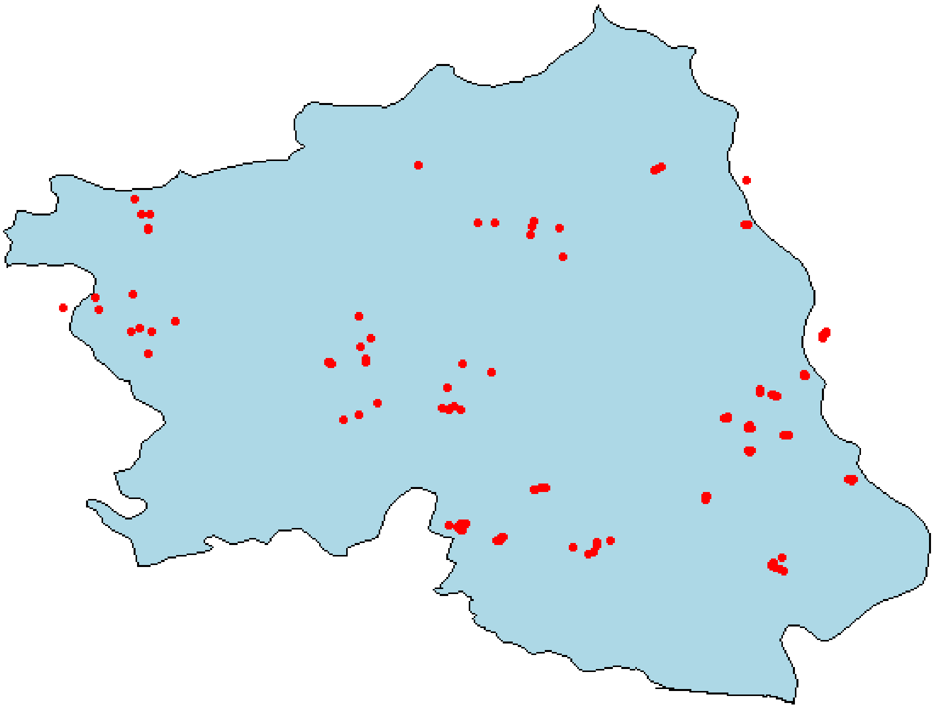

Fig. 1. GPS points of surveyed farms in West Godavari district, Andhra Pradesh.

Results and Discussion

Our survey shows that 34 and 30% of the rice area in the district is occupied by Swarna (MTU-7029) and Sampada, respectively (Table 1). Other varieties such as Vijetha, Pushyami, and Amara, occupied 15, 9 and 4% of the rice area, respectively (Table 1). However, Vijetha produced lower grain yield than other varieties, and grain yield was on par among the other cultivated varieties (Table 1).

Table 1. Grain yield among the major varieties grown in the district (*Kharif* 2018).

Varieties	Number of farmers adopted	Grain yield (tha^{-1})
Amara (MTU-1064)	9	5.07 ab
Sampada	61	5.16 a
Pushyami (MTU-1075)	19	5.15 a
Swarna (MTU-7029)	70	5.14 a
Vijetha (MTU-1001)	31	4.72 b

Means within a column for a variable followed by the same letter are not different using *LSD test* at $P \leq 0.05$.

The average grain yield from surveyed farms was 5.1 t per ha with yield ranging from 2.5 to 10.6 tha^{-1} (Fig. 2). However, around 62% of farmers produced 5 tha^{-1} with the present management practices and there is still a great potential to increase the rice yield with improved best management practices.

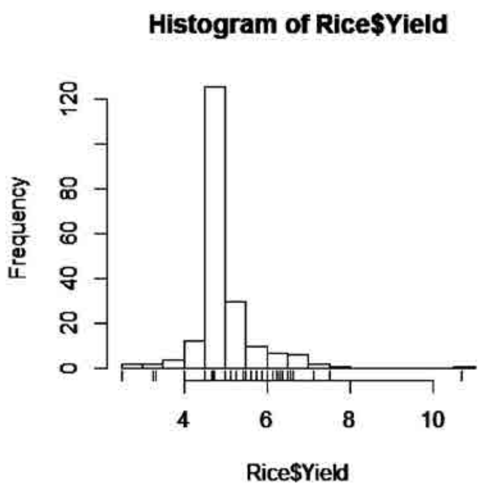

Fig. 2. Histogram of rice grain yield from the surveyed farms in West Godavari district.

The box plot shows that grain yield was higher by 1.3 tha^{-1} in manual line transplanting method (average 6.3 tha^{-1}) than the manual random transplanting method (average 5.0 tha^{-1}) (Fig. 3). However, only five farmers established rice with manual line transplanting method compared to 197 farmers with manual random transplanting. Though all the farmers used combined harvester for harvesting and threshing no farmers used seed drill or machine for transplanting (data not presented). The mechanization in crop establishment in the district is poor despite increased labour cost and shortage of labour during the peak crop season.

Rice-rice is the major cropping system in West Godavari district and weeds are the major constraints for rice cultivation. *Cynadon dactylon*, *Sphenochlea* spp. and *Echinochloa colona* are the top most weeds in rice fields mentioned by farmers (Fig. 4). *Digitaria* spp., *Eragrostis japonica* and *Lindernia* spp. are the second top most weeds in the West Godavari. To manage weeds, farmers use both manual weeding and herbicides. Surprisingly, all the surveyed farmers applied herbicides along with one or two manual weedings to manage the weeds. Among surveyed farmers, 93%

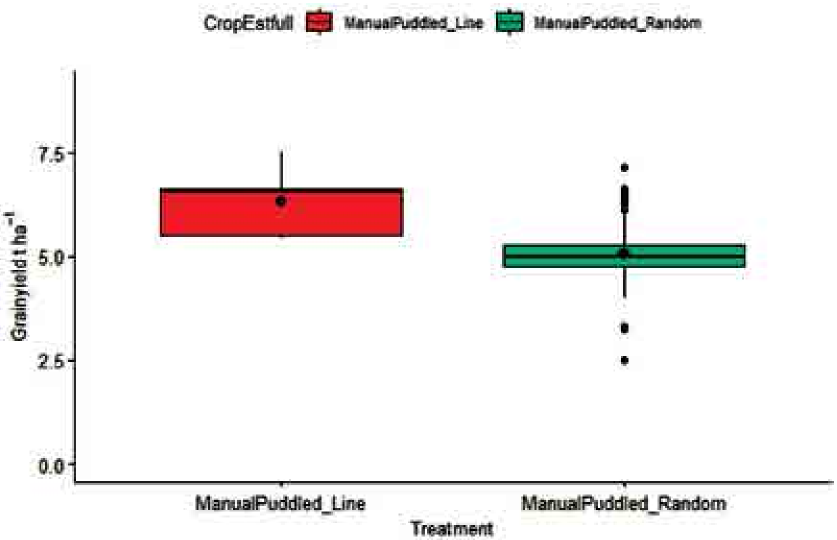

Fig. 3. Grain yield among the crop establishment methods.

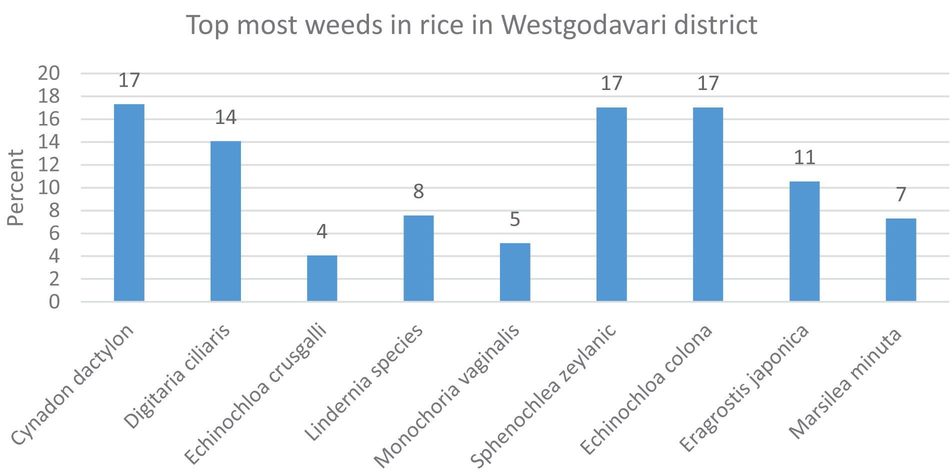

Fig. 4. Top most weeds in rice fields perceived by farmers.

applied pre-emergence herbicides and rest 7 % of farmers applied post-emergence herbicides along with one or two manual weedings (data not shown here).

The box plot (Fig. 5) shows that application of one pre-emergence herbicide followed by two manual weedings (15 to 30 days after transplanting and 40 to 60 days after transplanting) produced higher grain yield (average 6 tha^{-1}) than the application of one pre-emergence herbicide followed by one manual weeding (20 to 40 days after

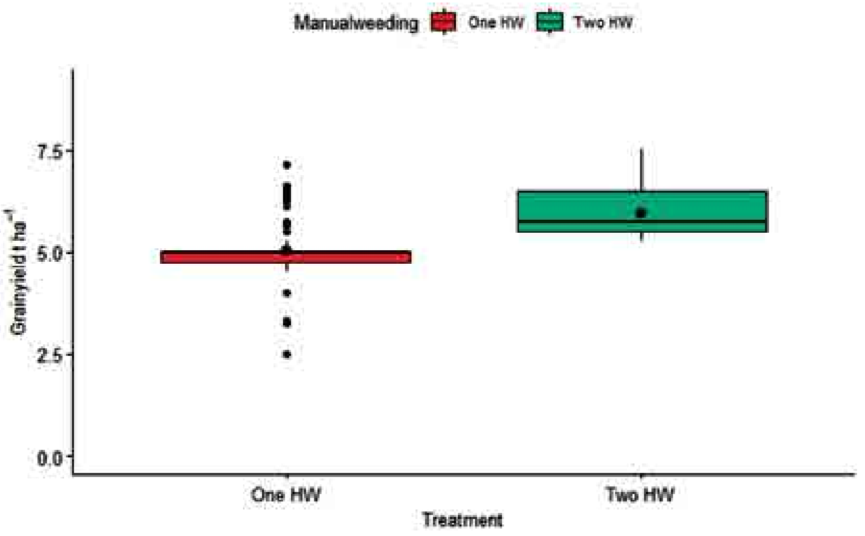

Fig. 5. Effect of hand weeding with one pre-emergence herbicides on rice yield.

transplanting) (average 5 tha^{-1}). If labour is cheaper and available on time, then farmers may go for two-manual weedings after pre-emergence application of herbicides considering the yield advantages of 1.0 tha^{-1}.

Conclusion

Like neighbouring districts, the manual random transplanting method is predominant among the surveyed farms despite a labour shortage and increased wages in West Godavari district. Mechanization in crop establishment is low or none despite 100% mechanized harvesting and threshing. Application of herbicides is common among the rice farmers along with one hand weeding, but two hand weedings had yield benefit over one hand weeding. There is a lot of potential in increasing the rice production in the districts through improved management practices including proper weed management and improved varieties in addition to the promotion of mechanization in rice crop establishment.

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3.9 Traditional varieties and delayed planting along with complex weed flora and poor nutrition are major constraints for realizing higher paddy yield in Patna district of Bihar

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Introduction

The district of Patna falls in agro-climatic zone IIIB. The soil type varies from alluvial sandy loam to clay. There are areas of *diara* and *taal*. Zone III has 76.3% of cultivable area with assured means of irrigation. Despite its high gross irrigated area, the cropping intensity is as low as 135.1% mainly due to water stagnation in *kharif* in low lying areas.

Methodology

Villages (30) were randomly selected from the 2011 census data on the basis of probability proportionate to size (PPS) method. Villages and farmers within the villages were randomized (Fig. 1) and samples properly reflected farmers' population in the district. Randomly 7 farmers were selected from each village, and interviewed regarding prevailing agronomic practices for the rice crop. The randomization process makes it easy to assess the adoption pattern of different technologies in the district.

The questionnaire for the landscape diagnostic survey was prepared in a mobile application based digital data collection format of Open Data Kit (ODK) which is capable of transferring real time data to the server or cloud.

Blocks covered : Belchi, Dinapur cum Khagaul, Maner, Patna Rural, Dulhin Bazar, Naubatpur, Sampatchak, Masaudhi, Phulwarisharif, Paliganj, Punpun, Fatuha, Khushrupur and Pandarak.

Village surveyed : Adampur, Baank, Babupur, Andauli, Bahuwara, Bhadaura, Bhusaula Danapur, Chesi, Dalanichak, Dhibra Jamsaut, Dumri (Bihta), Faridpur, Fatehpur, Haibatpur, Jamsaut, Kamarji, Khapura, Lodipur, Mohammadpur, Naraina, Nizampur, Painapur, Pali, Panapur, Raili, Saksohra, Sarsi, Sikanderpur, Simra and Wazirpur (Fig. 1).

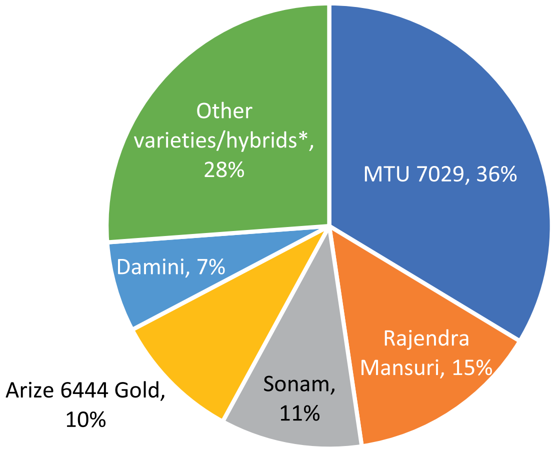
Fig. 1. GPS points of surveyed farms in Patna.

Results and Discussion

The landholding size of the surveyed farmers showed that 63 % were marginal, 22 % small, 12 % semi-medium and 3 % medium. The data on drainage class revealed that 83.8 % plots were medium land, 11.7 % low land and 4.6 % upland. The data on soil texture indicated that 66.5 % soils were medium type, 29.4 % heavy and 4.1 % light type. The major cropping system with the surveyed farmers was rice-wheat with 98.5 %, rice-other crops 1 % and rice-fallow 0.5 %.

The varietal spectrum revealed that 36 % farmers cultivated MTU7029, 15 % Rajendra Mahsuri, 11 % Sonam, 10 % Arize 6444 Gold, 7 % Damini and 28 % other varieties (Fig. 2).

Yield of Rajendra Mahsuri was at par with Arize 6444 Gold i.e. 4.33 and 4.27 tha^{-1}, respectively; while that of Damini was the lowest with 3.74 tha^{-1} (Fig. 3).



*Other varieties/hybrids-Dhaulagiri, Gangotri, Krishna, PAC835, Pioneer 27P63, Radha9, Rajendra Bhagwati, Super Moti, Supreme Sona, Swarna Sub1, US312, Bengal Tiger, Chandan, Moti Gold, Mugdha, S301, Sonali, Yamuna Gold, PHB71, BPT5204, Loknath 505

Fig. 2. Varietal spectrum of the surveyed farmers in Patna district.

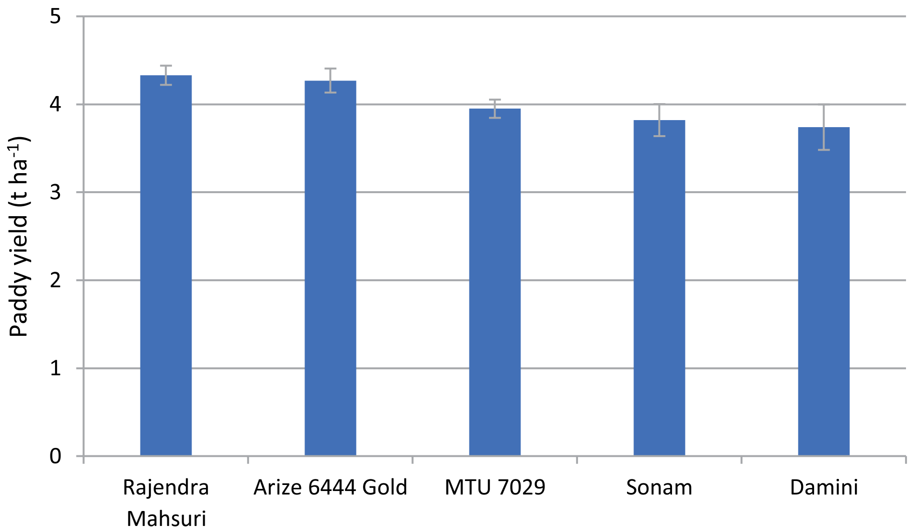


Fig. 3. Varietal performance of the surveyed farmers in Patna district.

The yield declined with corresponding delay in date of transplanting for both hybrids and varieties (Fig. 4).

Hybrids outperformed varieties by an average yield of 0.3 tha^{-1}. There was an additional input of N by 10 $kgha^{-1}$ in hybrids, whereas P&K and irrigation were almost at par (Table 1).

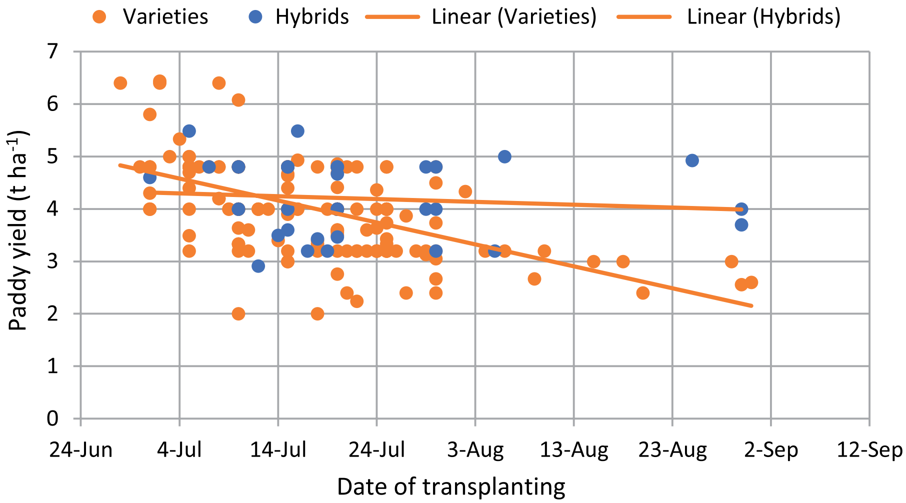


Fig. 4. Effect of dates of transplanting on paddy yield in Patna district.

Table 1. Nutrients and irrigation application pattern in improved and hybrids in Patna

Particulars	Hybrid	Improved varieties
Average yield (tha^{-1})	4.2	3.9
Average nitrogen application (kgha^{-1})	131.7	123.5
Average phosphorus application (kgha^{-1})	52.5	51.4
Average potash application (kgha^{-1})	48.3	47.3
Average irrigations applied	5.5	5.7
Total households	34	162
% households applying nitrogen	100%	100%
% households applying phosphorus	100%	97%
% households applying potash	44%	37%
% of households applying irrigation	100%	100%

The two most common weeds were *Echinochloa crus-galli* with 54.3% and *Cynadon dactylon* with 44.7% HHs' response. The troublesome weeds were *Echinochloa crus-galli* and *Cynadon dactylon* with 49.2 and 39.6% HHs (Table 2). Chemical herbicides are the most efficient way to control weeds (Adeosun *et al.*, 2009).

Table 2. Five most common and troublesome weeds and yield of paddy in Patna district

Rank	Common weeds	% HHS	Troublesome weeds	% HHs
Weed 1	*Echinochloa crus-galli*	54.3	*Echinochloa crus-galli*	49.2
Weed 2	*Cynadon dactylon*	44.7	*Cynadon dactylon*	39.6
Weed 3	*Dactyloctenium aegyptium*	37.1	*Dactyloctenium aegyptium*	32.9
Weed 4	*Echinochloa colona*	33.5	*Echinochloa colona*	27.9
Weed 5	*Cyperus difformis*	29.4	*Cyperus difformis*	23.8

Conclusion

Paddy yield in Patna district of Bihar can be improved by timely transplanting, replacing varieties with potential hybrids, and integrated management of complex weed flora. *Cynadon dactylon* should be managed by good tillage during summer.

Reference

Adeosun, J. O. *et al.* (2009). On-farm weed management in upland rice in three villages of Katsina State of Nigeria. *Afr. Crop Sci. Conf. Proc*. 9 : 625-629.

3.10 Access to cheap irrigation to facilitate timely rice transplanting - the key to improve paddy yield in Siwan district of Bihar

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Introduction

Agro-climatically, district Siwan falls under North West Alluvial Zone (B1-1) between 25° 53' to 26° 23' N latitude and 84° 01' to 84° 47' E longitude at an altitude of 77 m above MSL. Its geographical area is 222,000 ha, of which 172,300 ha is the net sown area with 132% cropping intensity. Net irrigated area is 122,700 ha mainly through canals (18.4%) and bore wells (31.4%). Annual rainfall in the district is 1,130 mm mainly received through SW monsoons. Soils are black (18.4%), sandy (14.5%), sandy loam (30.0%), alluvial (5.5%) and *Diara* (14.9%). Rice (80,100 ha) and wheat (104,100 ha) are two main crops in the district. The low rice productivity in the district is not new. The effect of rapidly changing technology should be reflected in yield and profits of farmers. The landscape diagnostic survey (LDS) was conducted to gather data on adoption patterns of technologies for further analytics. It will provide key insights on trends for overall performance of technologies recommended over time.

Methodology

Villages (30) were randomly selected from the 2011 Census data based on probability proportionate to size (PPS) method. Details of villages are given in Fig. 1. Seven farmers were randomly selected from each village. They were interviewed regarding the prevailing agronomic practices for the rice crop they have grown in *kharif* 2018. The questionnaire for the Landscape Diagnostic

Survey (LDS) was prepared in a mobile application based digital data collection format of Open Data Kit (ODK), which is capable of transferring real time data to the server or cloud. Out of total 210 households surveyed, majority of them were marginal (71%) and small (25%) as per their landholding size. As per drainage classification, the topography was mainly medium land (86.1%), whereas upland and lowland were only 7.9 and 6.1%, respectively. The soil texture is 73.4% medium, 10.9% heavy and 15.2% light. All the surveyed HHs (100%) adopted rice-wheat cropping system.

Blocks covered : Bhagwanpur Haat, Basantpur, Siwan, Barharia, Andar, Mairwa, Darauli, Raghunathpur, Guthani, Hussainganj, Pachrukhi, Lakri Nabiganj, Goriakothi, Maharajganj.

Villages surveyed : Bherwaniya, Karahi khurd, Murwar, Lakri, Sani bagahi, Haraipur,Bagahi, Dewariya, Fajilpur Deowria, Sirsiya, Tari, Babhnauli, Piparpati, Rajpur, Pachnerui, Kujhwa, Sirsiyan, Amarpur, Gopalpur, Ukhai Bichla Tola, Sareya srikant, Pratappur, Alapur, Akopur, Shikatiya, Vabhanauli, Barhoga jaddu, Shikatiya Dumara, Balia, Kasdevara bagara and Sareya Srikant.

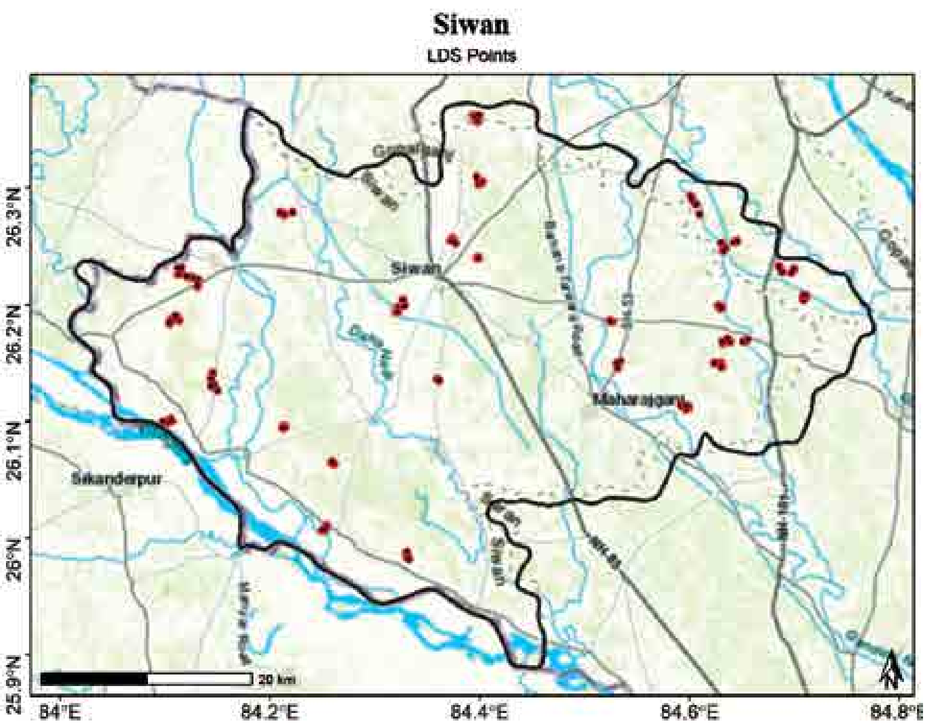
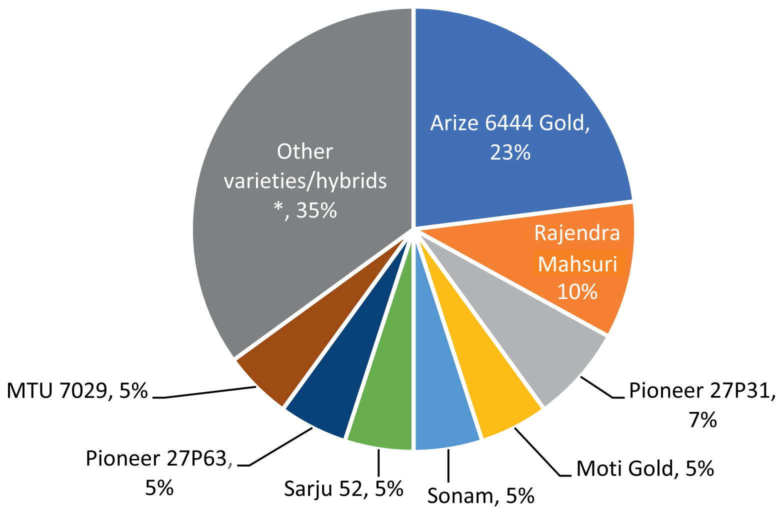


Fig. 1. GPS coordinates of the largest plot of the surveyed farmers in Siwan.

Results and Discussion

Among popular varieties/hybrids, Arize 6444 Gold, Rajendra Mahsuri, Pioneer 27P31 were preferred by 23, 10 and 7 % HHs (Fig. 2). Moti Gold, Sonam, Sarju 52, Pioneer 27P63 and MTU 7029 each was used by 5 % HHs. In addition to these, there were also few other popular varieties/hybrids (35 % HHs) in the district. LDS gathered enough data to show that among the new interventions, it is only the hybrids, which farmers accepted. Among varieties the most preferred varieties are old varieties. It is enough to challenge the strategy of evolving new varieties that could compete with old varieties in their respective maturity classes.



*Other Vareities/hybrids- Arize Tez, Dhanya 775, Dhanyarekha, Kaveri, Moti, MTU 1001, NHR 31, NK 6302, Poonam, Sonali, Bhagalpur Katarni, Garima, JK 401, MTU 1010, NK 5251

Fig. 2. Varietal spectrum of rice varieties/hybrids based on surveyed farmers (210) in Siwan.

Among the eight most preferred varieties/hybrids (Fig. 3), yield of MTU 7029 (3.56 tha^{-1}), Pioneer 27P63 (3.26 tha^{-1}) and Arize 6444 Gold (3.18 tha^{-1}) was a bit higher than Sonam , Rajendra Mahsuri, Moti Gold and Pioneer 27P31 attaining yield ranging from 2.44 to 3.0 tha^{-1}. Grain yield of Sarju 52 was the lowest in this group (2.1 tha^{-1}).

Grain yield of rice across hybrids/varieties was higher when transplanting was done either between 16-30 June (2.93 tha^{-1}), 01-15 July (3.01 tha^{-1}) and latest by 16-31 July (2.88 tha^{-1}) (Fig. 4). A sharp decline was observed if transplanting was done thereafter (01-15 August). This indicated that an early or timely transplanting will help attaining higher productivity in Siwan. In general, the yield level of rice

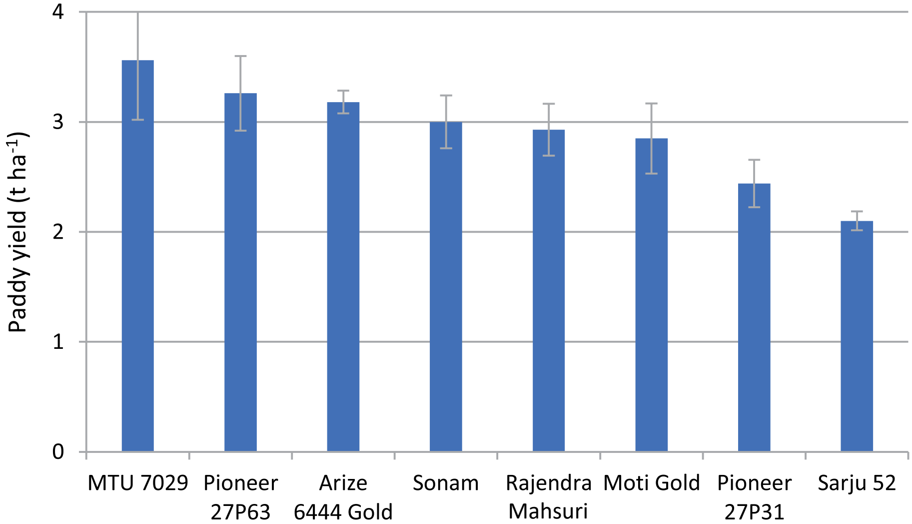


Fig. 3. Performance of most preferred rice varieties/hybrids by the surveyed farmers in Siwan.

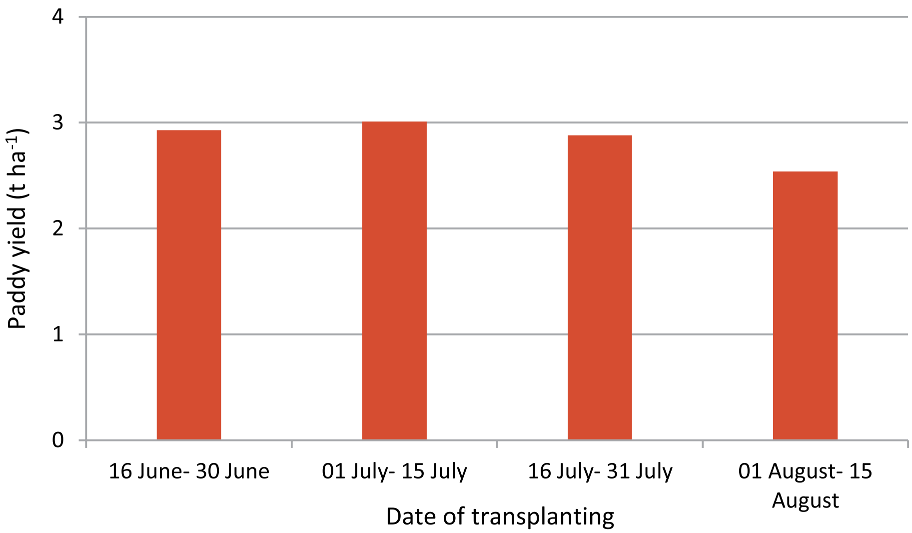


Fig. 4. Effect of time of transplanting on grain yield of rice varieties/hybrids (165) in Siwan.

was low in this district. The variation in monsoon rains and resultant droughts and floods are the threats to rice with a marked impact on rice yield and water productivity (Bhattarai and Narayanamoorthy, 2003). Better access to low-cost irrigation can help realizing the dual aim of improving rice yield as well as rainfall productivity.

A total of 79 and 83 HHs who grew improved rice varieties and hybrids, respectively, harvested an average yield of 2.9 and 3.0 tha^{-1} with close to recommended dose of N (120.4 and 128.8 $kgha^{-1}$), P_2O_5 (60.3 and 58.2 $kgha^{-1}$) and K_2O (36.6 and 29.2 $kgha^{-1}$) (Table 1). Irrigation level was also almost similar in varieties and hybrids (3.1 and 3.4) and all HHs applied irrigation. N, P_2O_5 and K_2O were applied by 100, 72 and 27 % HHs in rice varieties, respectively, and the corresponding figures in hybrids were 99, 87 and 33 %. There is a need to emphasize on recommended use of potash across different HHs in the district.

Table 1. Nutrients and irrigation application pattern in varieties and hybrids in Siwan.

Particulars	Improved varieties	Hybrids
Average yield (tha^{-1})	2.85	3.03
Average nitrogen application ($kgha^{-1}$)	120.4	128.8
Average phosphorus application ($kgha^{-1}$)	60.3	58.2
Average potash application ($kgha^{-1}$)	36.6	29.2
Average irrigations applied	3.1	3.4
Total households	79	83
% households applying nitrogen	100 %	99 %
% households applying phosphorus	72 %	87 %
% households applying potash	27 %	33 %
% of households applying irrigation	100 %	100 %

Among five top most troublesome weeds infesting rice crop in Siwan (Table 2), 81.2, 61.2, 46.7, 41.8 and 35.1 % HHs ranked *Echinochloa colona, Caesulia axillaris, Scirpus juncoides, Cyperus difformis* and *Cyperus rotundus* at rank 1, 2, 3, 4 and 5, respectively. Similarly, *Echinochloa colona, Caesulia axillaris, Scirpus juncoides, E.*

Table 2. Top five troublesome and common weeds in Siwan.

Rank	Top 5 troublesome weeds	% HHs	Top 5 common weeds	% HHs
Weed 1	*Echinochloa colona*	81.2	*Echinochloa colona*	92.1
Weed 2	*Caesulia axillaris*	61.2	*Caesulia axillaris*	81.8
Weed 3	*Scirpus juncoides*	46.7	*Scirpus juncoides*	64.2
Weed 4	*Cyperus difformis*	41.8	*Echinochloa crusgalli*	57.6
Weed 5	*Cyperus rotundus*	35.1	*Cyperus difformis*	52.7

crus-galli and *C. difformis* were adjudged as the five most common weeds by 92.1, 81.8, 64.2, 57.6 and 52.7% HHs. This clearly indicated pronounced dominance of sedges along with other grass and broadleaf weeds in the district, which warrants for effective and integrated weed management including relevant herbicides.

Conclusion

Siwan district, predominantly a medium land ecology (86.1%), is dominated by marginal and small landholding farmers (96%) who mainly follow rice-wheat cropping system (100% HHs). MTU7029, Pioneer 27P63 and Arize 6444 Gold were high yielding cultivars in the district. LDS has enough data to show that among the new interventions, it is only the hybrids which farmers have accepted. Among varieties, the most preferred varieties are old varieties. It is enough to challenge the strategy of evolving new varieties that could compete with old varieties in their respective maturity classes. An early (15-30 June) or timely transplanting (01-31 July) was found the most congenial action to attain higher grain yield in the district. Access to low-cost irrigation is the another critical input to enhance rice yield in the district Siwan.

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3.11 Explore the time management as part of a strategy to improve paddy yield in Rohtas district of Bihar

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Introduction

Agro-climatically, district Rohtas falls under South Bihar Alluvial Plain Zone (B1-3) between 24°30’ to 25°20’ N latitude and 83°14’ to 84°02’ E longitude at an altitude of 107.8 m above mean sea level. Its geographical area is 337,690 ha, of which 231,880 ha is the net sown area with 167 % cropping intensity. Net irrigated area is 79,000 ha mainly through canals (85.7 %) and bore wells (11.5 %). The average annual rainfall in the district is around 1,000 mm mainly received through SW monsoons. Soils are loamy (43.9 %), clay loam (30.3 %) and sandy loam (18.9 %). Rice (195,000 ha) and wheat (140,000 ha) are two main crops in the district.

Methodology

Villages (30) were randomly selected from the 2011 Census data on the basis of probability proportionate to size (PPS) method. Seven farmers were randomly selected from each village. They were interviewed regarding the prevailing agronomic practices for the rice crop they had grown in *kharif* 2018. The questionnaire for the Landscape Diagnostic Survey (LDS) was prepared in a mobile application based digital data collection format of Open Data Kit (ODK), which is capable of transferring the real time data to server or cloud. Out of total 210 households surveyed, majority of them were marginal (60 %), small (21 %), semi-medium (11 %) and medium (7 %) as per their landholding size. As per drainage classification, the topography comprised medium land, lowland and upland to the tune of 90.2, 5.7 and 2.1%, respectively. As per soil texture, it is 97.4% medium, 1.0% heavy and 1.6% as light soil. About 98.4% of the surveyed farmers followed the rice-wheat cropping system, whereas 1.6% opted for rice-other crops.

Blocks covered : Rohtas, Sanjhauli, Dawath, Kargahar, Karakat, Bikramganj, Sasaram, Nauhatta, Kochas, Dinara, Nasriganj, Chenari, Nokha, Tilouthu and Sheosagar.

Villages surveyed : Akbarpur, Amardah, Bahuara, Baknaura, Bamahan Barahatta, Baradih, Baratha, Belarhi, Bhadara, Bhadkgudia, Buknawan, Chitawan, Dhanwar, Derhgaon, Dinara, Dumri, Eghara, Gorakh Parasi, Hariharpur, Jabra, Jaishree, Jonhi, Karma, Khiriawan, Lawara, Nariwa, Nonahar, Panjar, Pewandi, Ramdiayara and Sonhar (Fig. 1).

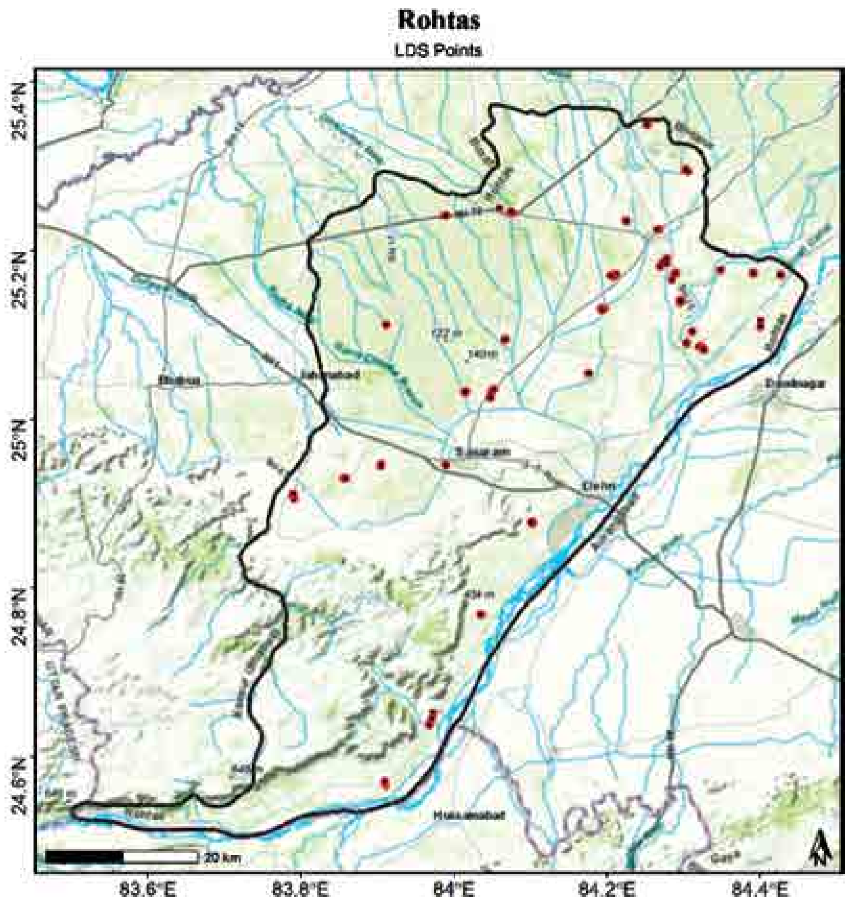

Fig. 1. GPS coordinates of the largest plot of the surveyed farmers in Rohtas.

Results and Discussion

The data (Fig. 2) clearly revealed that 84 % farmers still preferred MTU 7029, a very old, high yielding and long duration variety of rice. Other popular varieties were BPT 5201 (10 %), Sonam (2 %), Bhagalpur Katami, Super Moti, Sahbhagi, Rajendra Mahsuri, Krishna and NK 5251. The variety MTU 7029 can be considered as naturally superior variety because of its ability to consistently produce high yield across all eastern states. BPT 5204 is the second most widely grown variety with same consistency in yield performance. If this is the finding of this survey, it is the management which can improve the yield growth of rice because these two varieties are in the system for last 30 years.

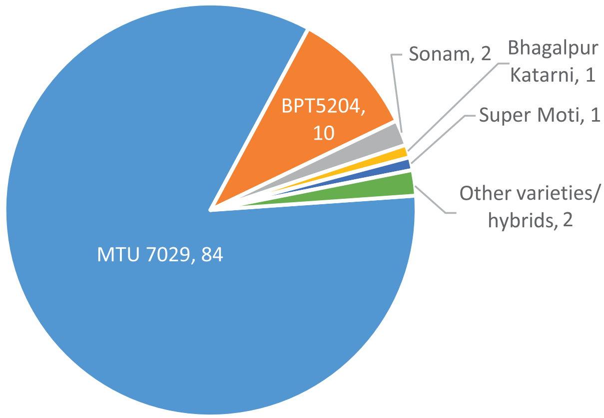

Fig. 2. Varietal spectrum of rice varieties/hybrids based on the data of surveyed farmers (210) in district Rohtas.

Among nine most preferred varieties, grain yield of MTU 7029 (5.14 tha^{-1}) was the highest, however, it was closely followed by Bhagalpur Katami, BPT 5204, NK 5251, and Sonam (4.79-4.90 tha^{-1}) (Fig. 3). Sahabhagi (4.67 tha^{-1}) also performed fairly well in the district. Grain yields of Krishna (4.0 tha^{-1}) and Super Moti (3.2 tha^{-1}) were towards lower side.

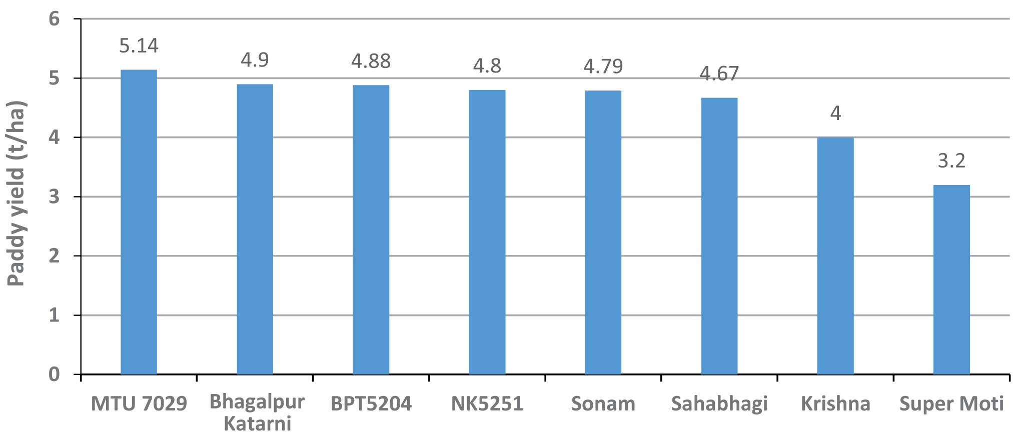

Fig. 3. Performance of most preferred rice varieties/hybrids by the surveyed farmers in district Rohtas.

Grain yield of rice across varieties was higher when these were transplanted between 16 and 31 July (5.33 tha^{-1}), however, it was also very close to other dates of transplanting between 16 and 30 June (early) (4.93 tha^{-1}), 01-15 July (4.96 tha^{-1}) and even 01-15 August (4.91 tha^{-1}) (delayed) (Fig. 4). This provides wide window for rice transplanting to the farmers without much sacrificing on yield i.e. varieties with a longer life span are associated with higher yield (Li *et al.,* 2019) and it is the time management (Siddiq, 1999) and not the varieties that will help improving paddy yield in Rohtas.

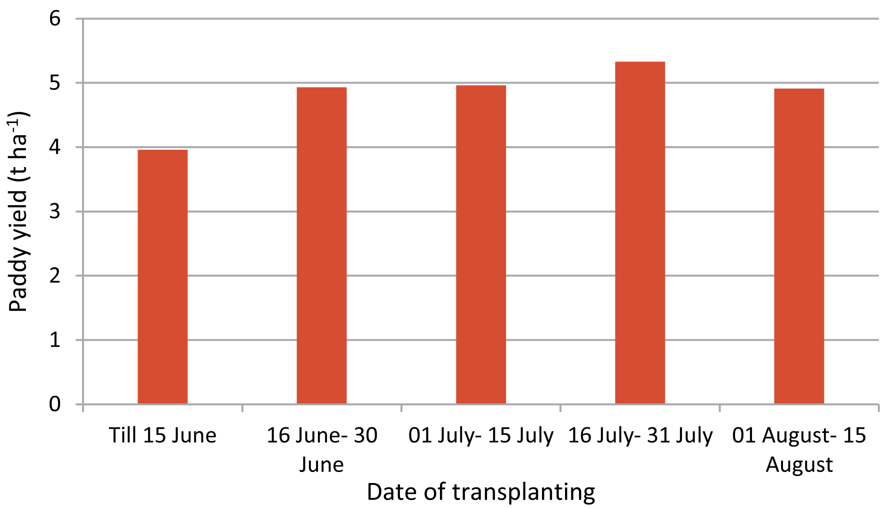

Fig. 4. Effect of time of transplanting on grain yield of rice varieties/hybrids (192) in district Rohtas.

Farmers (191) growing improved rice varieties harvested an average yield of 5.09 tha^{-1} with N at 132.2 $kgha^{-1}$ (little more than that of the recommended), 52.3 $kgha^{-1}$ P_2O_5 (close to recommended dose) and sub-optimal dose of K_2O (29.8 $kgha^{-1}$) (Table 1) along with 8.9 irrigations by all HHs. N, P_2O_5 and K_2O were applied by 99, 97 and 24 % HHs in rice varieties, respectively. Grain yield of hybrid (only one HH) was less (4.8 tha^{-1}) even with higher N, P_2O_5 and irrigations. Looking into better performance of varieties mainly MTU 7029, farmers prefer it to grow in Rohtas district of Bihar.

Among five top most troublesome weeds infesting rice crop in Rohtas (Table 2), 58.8 % HHs indicated *Ipomoea aquatica* as the most serious weed (rank 1) followed by *Marsilea minuta* (rank 2; 58.8 % HHs), *Echinochloa crus-galli* (rank 3; 56.7 % HHs), *Monochoria vaginalis* (rank 4; 40.6 % HHs) and *Pistia stratiotes* (rank 5; 35.4 % HHs). Likewise, among top five common weeds of transplanted rice crop, *E*.

Table 1. Nutrients and irrigation application pattern in varieties and hybrids in Rohtas.

Particulars	Improved varieties	Hybrids
Average yield (tha^{-1})	5.09	4.80
Average nitrogen application ($kgha^{-1}$)	132.2	176.0
Average phosphorus application ($kgha^{-1}$)	52.3	73.6
Average potash application ($kgha^{-1}$)	29.8	0.0
Average irrigations applied	8.9	13.0
Total households	191	01
% households applying nitrogen	99 %	100 %
% households applying phosphorus	97 %	100 %
% households applying potash	24 %	0 %
% of households applying irrigation	100 %	100 %

Table 2. Top five troublesome and common weeds in Rohtas district.

Rank	Top 5 troublesome weeds	% HHs	Top 5 common weeds	% HHs
Weed 1	*Ipomoea aquatica*	58.8	*Echinochloa crus-galli*	73.9
Weed 2	*Marsilea minuta*	58.8	*Marsilea minuta*	67.7
Weed 3	*Echinochloa crusgalli*	56.8	*Ipomoea aquatic*	66.1
Weed 4	*Monochoria vaginalis*	40.6	Weedy rice	57.3
Weed 5	*Pistia stratiotes*	35.4	*Cyperus difformis*	54.7

crus-galli, *M. minuta*, *I. aquatica*, weedy rice and *C. difformis* were reported by 73.9, 67.7, 66.1, 57.3 and 54.7 % HHs, respectively. This clearly indicated infestation of complex weed flora in the district, which warrants for an effective and integrated weed management including use of relevant herbicides.

Conclusion

Marginal and small landholding HHs (81 %), medium land and rice-wheat cropping system are the main features of Rohtas district. MTU7029, a traditional long duration rice variety was grown by majority of the HHs (84 %) yielding around 5.14 tha^{-1}. K_2O used was sub-optimal, and it needs focussed attention.

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3.12 Hybrids are more resilient to water stress in upland intensive rice based cropping system in Samastipur district of Bihar

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Introduction

Samastipur district of Bihar is in North West Alluvial Plain Zone (B1-1) with 25°46’ N latitude and 86°90’ E longitude at an altitude of 53 m above mean sea level (MSL). Its geographical area is 262,400 ha of which 184,100 ha is the net sown area with 137 % cropping intensity. Net irrigated area is 66,100 ha mainly through open wells/ bore wells (25 %). Annual rainfall in the district is 1,234 mm mainly received through SW monsoons. Rice (68,800 ha) is the main crop of the district grown in *kharif*, whereas wheat area is 58,900 ha in the district. Farmers are frequently losing yield because they have limited access to irrigation and as such the irrigation is costly. The expectation for increasing the rice productivity is too high which, in fact, is not being fulfilled. We need to understand why the yields are below expectations; to do that landscape diagnostic survey (LDS) was conducted for devising strategies and setting priorities to manage moisture stress in the upland ecologies of the district.

Methodology

Villages (30) were randomly selected from the 2011 Census data on the basis of probability proportionate to size (PPS) method. Seven farmers were randomly selected from each village. They were interviewed regarding the prevailing agronomic practices for the rice crop they had grown harvested in *kharif* 2018. The questionnaire for the LDS was prepared in a mobile application based digital data collection format of Open Data Kit (ODK), which is capable of transferring real time data to the server or cloud. Out of 210 households surveyed, marginal, small, semi-medium and medium HHs were 59, 24, 13 and 3 %, respectively. As per drainage classification, the topography of the district has 57.4 % medium land, 32.7 % lowland and only 9.9 % upland and as per soil texture also it largely falls into medium (73.8 %), heavy (24.3 %) and light (2.0 %) categories. Majority of the HHs (99.5 %) adopted rice-wheat cropping system in the district and few followed rice-maize also (0.5 %).

Blocks covered : Kalyanpur, Pusa, Tajpur, Morwa, Patori, Mohanpur, Jitwarpur, Waris Nagar, Khanpur, Sarairanjan, Mohuiuddinagar, Vidyapatinagar, Dalsinghsarai, Ujiyarpur, Bibhutipur, Rosra, Shivayanagar, Hasanpur, Bitthon and Singhia.

Villages surveyed : Bathua Bujurg, Bhagwatpur, Bibhutipur, Chak tulsi, Chandarpur, Charo, Gadopur, Gohda, Kariyam, Keothar, Kesopatti, Kishanpur, Kothia, Kusaia, Kyotha, Mahara, Mahe singhia, Mehsi, Paridah, Parwana, patpara, Ramauli, Rampur siwan, Rariyahi, Rupauli bujurg, Sahpur Baghauni, Sakmohan, Somnaha, Sormar, Sripur, Tajpur, Ujiarpur and Wirshinghpur (Fig. 1).

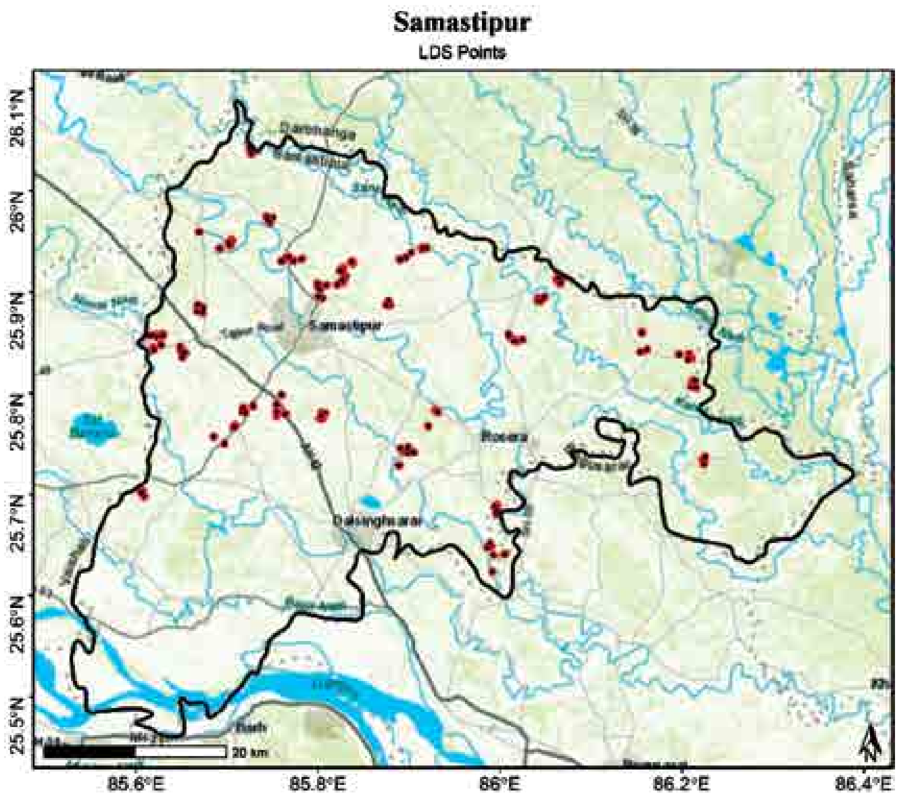
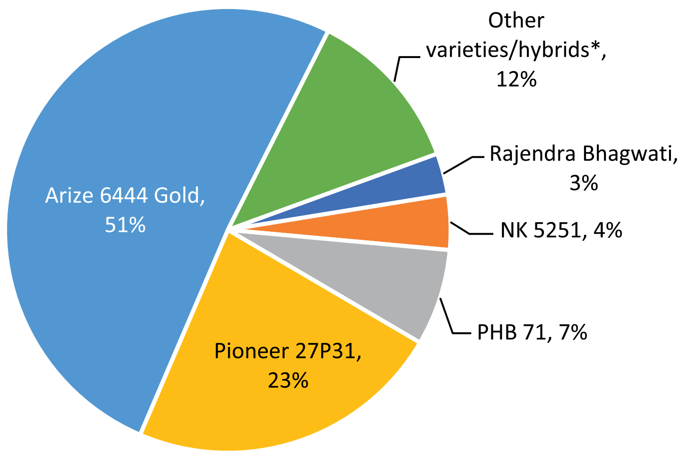


Fig. 1. GPS coordinates of the largest plot of the surveyed farmers in district Samastipur.

Results and Discussion

The data (Fig. 2) revealed that majority of the HHs preferred hybrids including Arize 6444 Gold (51%), Pioneer 27P31 (23%) and PBH 71 (7%). NK 5251 (3%), Rajendra Bhagwati (3%) and few other varieties/hybrids (12%) were also grown in Samastipur district.



*Other varieties/hybrids- Aghani, Ankur, JK 2082, JK 401, Kaveri, Loknath 505, MTU 1001, PAC 835, Pusa Sugandh 5, Sabitri, Sankar, Arize 6129, US 312, Pioneer 27P63, Sarju 52

Fig. 2. Varietal spectrum of rice varieties/hybrids based on the data of surveyed farmers (210) in district Samastipur.

Five most preferred rice varieties/hybrids viz., NK 5251, Rajendra Bhagwati, Arize6444 Gold, PBH 71 and Pioneer 27P31 yielded on an average 4.34, 3.63, 3.60, 3.60 and 3.45 tha^{-1}, respectively (Fig. 3), indicating higher yield in NK 5251. Data was suggested that the spread of hybrids in this

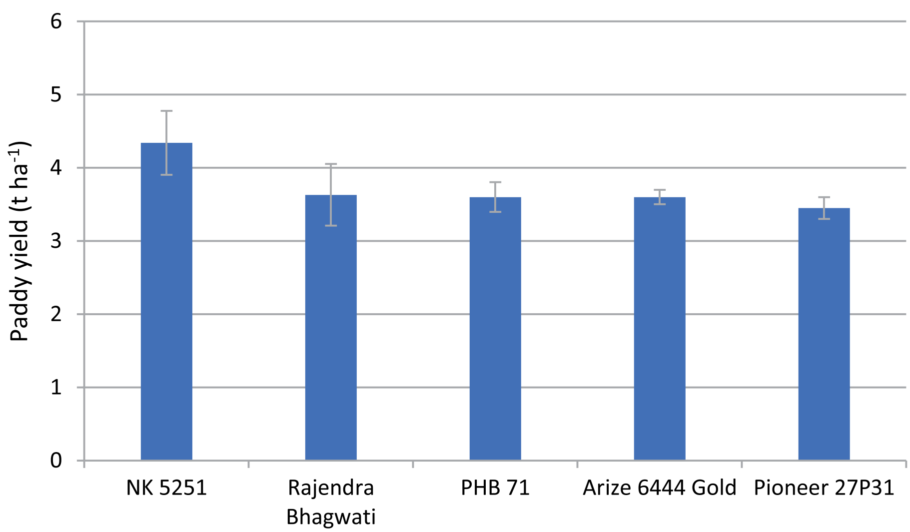


Fig. 3. Performance of most preferred rice varieties/hybrids by the surveyed farmers in district Samastipur.

district much wider than expected. This is because hybrids have the yield advantage both in the irrigated (Janaiah and Hossain, 2003) and in drought like situation (Villa *et al.*, 2012).

Grain yield across rice varieties/hybrids was almost similar ranging from 3.60 to 3.68 tha^{-1} when transplanting was accomplished any time ranging till 15 July to 16-31 July (Fig. 4). When the transplanting is done in mid-July, greater reduction in evapo-transpiration (ET) without any yield penalty will enhance water productivity (Seckler, 1996).

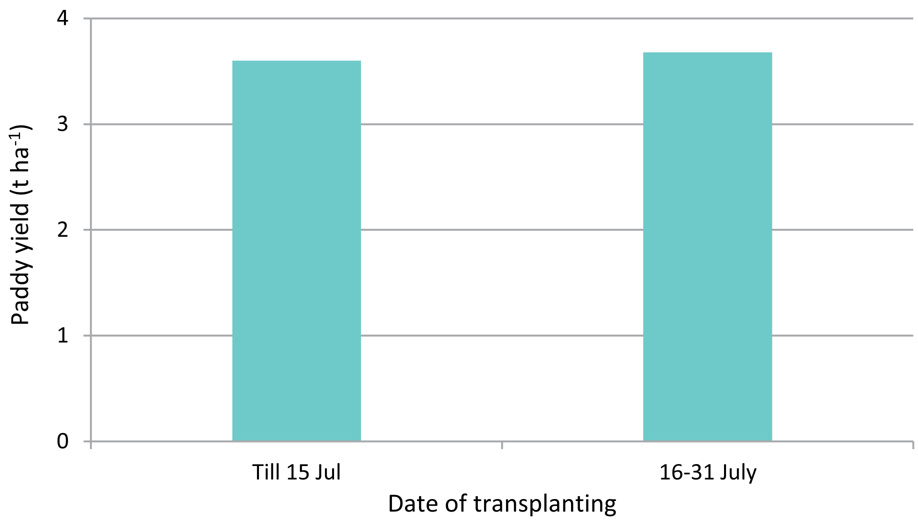


Fig. 4. Effect of time of transplanting on grain yield of rice varieties/hybrids (202) in district Samastipur.

A total of 13 and 187 HHs who grew improved rice varieties and hybrids, respectively, harvested an average yield of 3.75 and 3.64 tha^{-1} with almost similar to the recommended level of N (118.5 and 119.4 $kgha^{-1}$), P_2O_5 (52.7 and 60.3 $kgha^{-1}$) and even K_2O (41.2 and 43.5 $kgha^{-1}$) and little higher level of irrigation in hybrids (2.51) compared to varieties (1.92) but all HHs applied irrigation (Table 1). N, P_2O_5 and K_2O were applied by 100, 77 and 69 % HHs in rice varieties, respectively, and the corresponding figures in hybrids were 99, 63 and 66 %. But still yield levels were low, and there appears the possible and potential role of number of irrigations.

Among five top most troublesome weeds infesting rice crop in Samastipur (Table 2), 73.7 % HHs indicated *Echinochloa colona* as the most serious weed (rank 1) closely followed by *Cyperus rotundus* ranking 2 (48.0 % HHs), *Caesulia axillaris* (rank 3; 45.0 % HHs), *Dactyloctenium aegyptium* (rank 4; 42.1 % HHs) and *Cynadon*

Table 1. Nutrients and irrigation application pattern in varieties and hybrids in Samastipur.

Particulars	Improved varieties	Hybrids
Average yield (tha^{-1})	3.7	3.6
Average nitrogen application ($kgha^{-1}$)	118.8	119.4
Average phosphorus application ($kgha^{-1}$)	52.7	60.3
Average potash application ($kgha^{-1}$)	41.2	43.5
Average irrigations applied	1.9	2.5
Total households	13	187
% households applying nitrogen	100	99
% households applying phosphorus	77	63
% households applying potash	69	66
% of households applying irrigation	100	100

Table 2. Top five troublesome and common weeds in Samastipur.

Rank	Troublesome weeds	% HHs	Common weeds	% HHs
Weed 1	*Echinochloa colona*	73.7	*Echinochloa colona*	81.2
Weed 2	*Cyperus rotundus*	48.0	*Cyperus rotundus*	56.9
Weed 3	*Caesulia axillaris*	45.0	*Caesulia axillaris*	55.9
Weed 4	*Dactyloctenium aegyptium*	42.1	*Dactyloctenium aegyptium*	50.5
Weed 5	*Cynadon dactylon*	32.2	*Cynadon dactylon*	43.1

dactylon (rank 5; 32.2 % HHs). The top five common weeds of transplanted rice crop were *Echinochloa colona*, *Cyperus rotundus, Caesulia axillaris, Dactyloctenium aegyptium* and *Cynadon dactylon* as reported by 81.2, 56.9, 55.9, 50.5 and 43.1 % HHs, respectively. This indicated infestation of prominent grassy weeds along with few sedges in the district, which warrants for their timely and effective management.

Conclusion

Samastipur district of Bihar is having huge number of respondents with medium lands and dwells majorly marginal (59 %) and small landholding HHs (26 %). Rice-wheat (99.5 %) is the major cropping system along with very few farmers growing rice-maize (0.5 %) in the district. Hybrids (Arize 6444 Gold, Pioneer 27P31 and PBH 71) are preferably grown by the majority of HHs (81 %). Transplanting time till 15 July to the schedule of 16-31 July across varieties/hybrids resulted in similar yield levels (3.60-3.68 tha^{-1}). Increased number of irrigations may still result in higher productivity.

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3.13 Delayed rice transplanting of long duration varieties is a challenge in Banka district of Bihar

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Introduction

Agro-climatically, district Banka falls under South Bihar Alluvial Plain Zone (B1-3) between 24°30' and 25°08' N latitude and 86°30' and 87°12' E longitude at an altitude of 43 m above MSL. Its geographical area is 305,620 ha, of which 152,300 ha is the net sown area with 106 % cropping intensity. Net irrigated area is 115,000 ha mainly through bore wells. Annual rainfall in the district is 1,170 mm mainly received through SW monsoons. Soils vary from fine sandy loam (38.45 %) to clayey (32.25 %). Rice (99,420 ha) is the main crop of the district grown in *kharif*. The objective of this survey is to develop a data base on the production practices of rice to help decision making in short and long term research, and set extension priorities for policy makers in allocating funds in the annual planning meetings.

Methodology

Villages (30) were randomly selected from the 2011 Census data on the basis of probability proportionate to size (PPS) method. Seven farmers were randomly selected from each village. They were interviewed regarding the prevailing agronomic practices for the rice crop they had grown in *kharif* 2018. The questionnaire for the Landscape Diagnostic Survey (LDS) was prepared in a mobile application based digital data collection format of Open Data Kit (ODK), which is capable of transferring real time data to the server or cloud. Out of 210 households surveyed, majority of them were marginal (73 %) and small (18 %) as per their landholding size. The GPS coordinates of the surveyed farmers in Banka are presented in Fig. 1. As per drainage classification, the topography comprised upland, medium land, lowland and very low land to the tune of 53.7, 33.3, 12.4 and 0.5 %, respectively. As per soil texture, it was 50.2 % medium, 36.3 % heavy and 13.4 % as light soil. About 80.6 % of the surveyed farmers followed the rice-wheat cropping system, whereas 9.5, 9.0 and 1.0 % opted for rice-other crops, rice-fallow and rice-maize, respectively.

Blocks covered : Amarpur, Banka, Barahat, Eblhar, Chanan, Dhuraiya, katoria Fulidumar, Rajaun, Shambhuganj.

Villages surveyed : Babarchak, Babhangama, Badlichak, Badariya Khurd, Baliyash, Banshipur, Badi mohani, Bastar, Beldiha, Bhadariya Khurd, Bhaluar, Biharotari, Birchak, Chandpur, Domsarni, Dudhari, Gobardaba, Hatnema, Jamdaha, Jotha, Kadli Chak, Kateli Mohariya, Kemsar, Khamari, Kharhara, Khardori Balwa, Kodarkatta, Kojhi, Lakrikola, Lilagora, Maohani, Narayanpur, Neema, Nonia Basar, Parsautipur, Fulidumar, Pindra, Rukanpura, Subhanpur, Sujalkorama, Supaha and Uprama (Fig. 1).

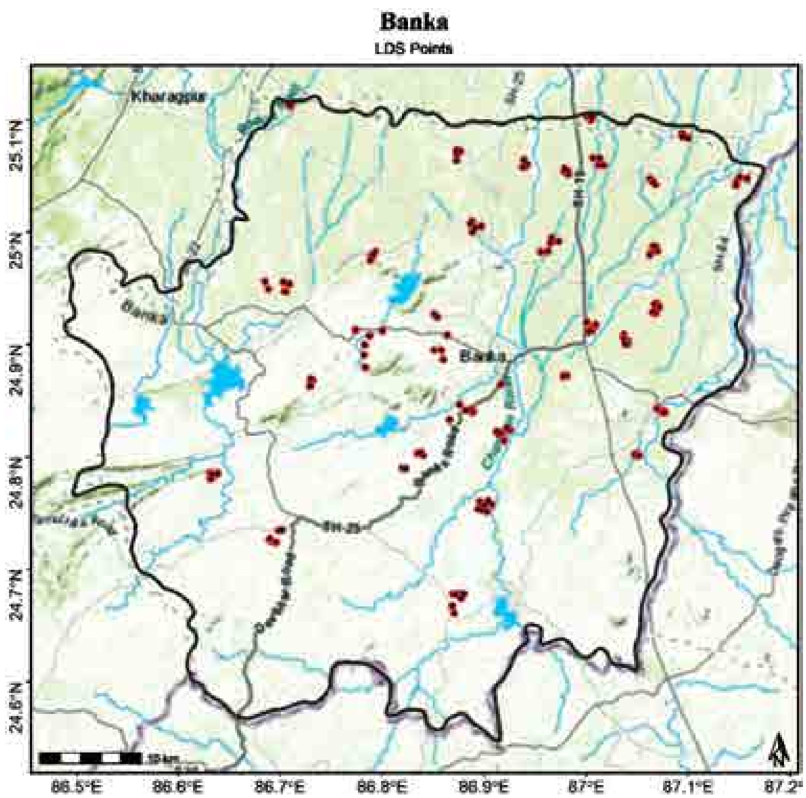
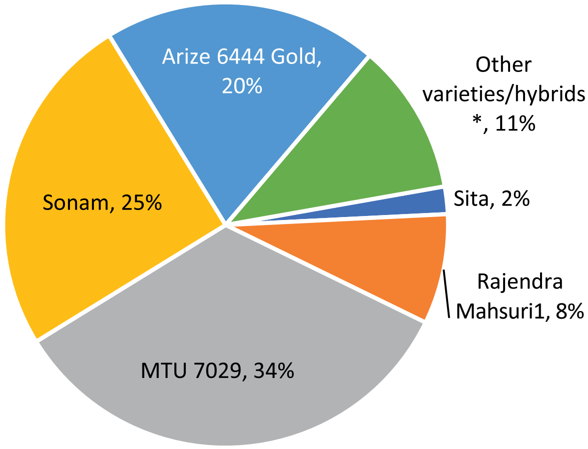


Fig. 1. GPS coordinates of the surveyed farmers in Banka district.

Results and Discussion

The data (Fig. 2) revealed that 34% HHs preferred MTU 7029, while 25% Sonam and 20% hybrids (Arize 6444 Gold). Farmers still like MTU 7029 even though it is a very old and long duration rice variety (LDRV). MTU 7029 may be one of the rare varieties to stay as most preferred variety ever. Some shift is happening in favour of medium duration hybrids. It should continue because late transplanting decreases the dry matter accumulation due to less tillering and shortens vegetative growth cycle (Lampayan *et al.*, 2015) in this variety.



*Other Varieties/hybrids- Ankur, K 9090, Kranti, Loknath 505, Mugdha, PAC 835, PHB 71, Rajendra Shweta, Sita, Sabour Harshit, Shushk Samrat, Sudha, Pioneer 27P31, BPT 5204, Sankar

Fig. 2. Varietal spectrum of rice varieties/hybrids based on the data of surveyed farmers (210) in district Banka.

Among five most preferred varieties/hybrids, MTU 7029 yielded highest (3.7 tha^{-1}), however, it was at par with Arize 6444 Gold (3.6 tha^{-1}) but both were superior to Sita, Sonam and Rajendra Mahsuri (Fig. 3).

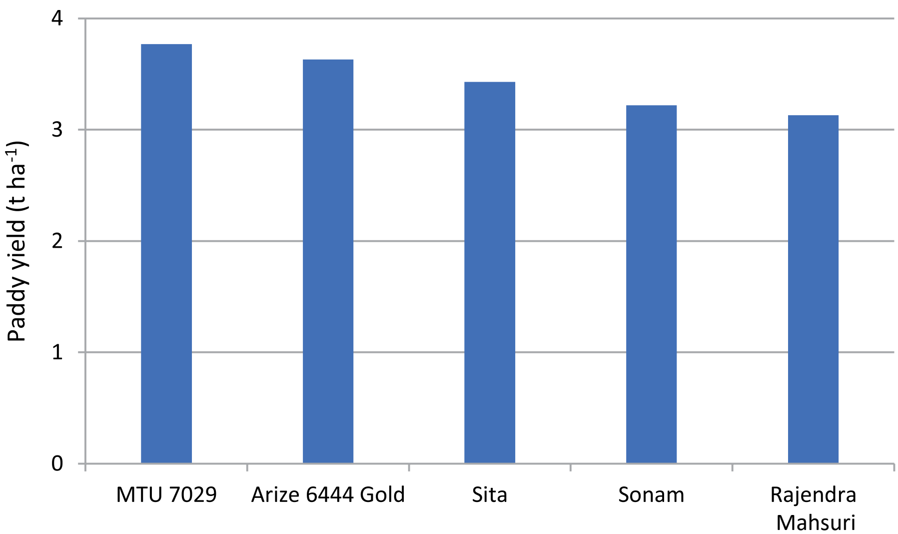


Fig. 3. Performance of most preferred rice varieties/hybrids by the surveyed farmers in district Banka.

Grain yield of rice was at par when it was transplanted from 01 July to 15 July (3.5 tha^{-1}) and 16 July to 31 July (3.6 tha^{-1}) but significantly higher than when transplanted thereafter (01 to 31 August) (Table 1). This clearly indicated that an early or optimal time of transplanting was the most crucial factor to improve rice yields in Banka district. Similar results were realized at other places in South Asia (Muhammad *et al.,* 2018).

Table 1. Effect of time of transplanting on grain yield of rice varieties/hybrids (201).

Date of transplanting	Yield (tha^{-1})	sd	HHs
01 July-15 July	3.5	1.1	19
16 July-31 July	3.6	0.9	69
01 Aug-15 Aug	3.4	0.9	106
15 Aug- 31 Aug	3.3	1	7

A total of 150 and 51 HHs who grew improved rice varieties and hybrids, respectively, and harvested an average yield of 3.4 and 3.6 tha^{-1} with almost similar dose of N (91.8 and 104.8 $kgha^{-1}$) (Table 2). Rates of P_2O_5 (46.9 and 39.7 $kgha^{-1}$) and K_2O (24.8 and 22.0 $kgha^{-1}$) application were lower than the recommended doses both in varieties and hybrids. The irrigation level of 3.4 in varieties was bit lower than that in hybrids (3.8) and it was followed by all the HHs. N, P_2O_5 and K_2O were applied by 100, 97 and 75 % HHs in rice varieties, respectively, and the corresponding figures in hybrids were 100, 98 and 90 %. On an average, farmers used bit higher N in hybrids than that in varieties.

Table 2. Nutrients and irrigation application pattern in varieties and hybrids in Banka district.

Particulars	Improved varieties	Hybrids
Average yield (tha^{-1})	3.4	3.6
Average nitrogen application ($kgha^{-1}$)	91.8	104.8
Average phosphorus application ($kgha^{-1}$)	46.8	39.6
Average potash application ($kgha^{-1}$)	24.8	22.0
Average irrigations applied	3.4	3.8
Total households	150	51
% households applying nitrogen	100	100
% households applying phosphorus	97	98
% households applying potash	75	90
% of households applying irrigation	100	100

Among five top most troublesome weeds infesting rice crop in Banka (Table 3), 55.7% HHs indicated *Cyperus iria* as the most serious weed (rank 1) closely followed by *Cyperus difformis* (rank 2; 51.7% HHs), *Cyperus rotundus* (rank 3; 39.3% HHs), *Cynadon dactylon* (rank 4; 36.3% HHs) and *Echinochloa colona* (rank 5; 29.2% HHs). Likewise, among top five common weeds of transplanted rice crop, *E. colona*, *C. rotundus*, *E. crus-galli, D. aegyptium* and *C. iria* were reported by 75.0, 71.1, 66.7, 56.7 and 45.0% HHs, respectively. This clearly indicated pronounced dominance of sedges along with grassy weeds in the district.

Table 3. Top five troublesome and common weeds in Banka district.

Rank	Troublesome weeds	% HHs	Common weeds	% HHs
Weed 1	*Cyperus iria*	55.7	*Echinochloa colona*	75.0
Weed 2	*Cyperus difformis*	51.7	*Cyperus rotundus*	71.1
Weed 3	*Cyperus rotundus*	39.3	*Echinochloa crus-galli*	66.7
Weed 4	*Cynadon dactylon*	36.3	*Dactyloctenium aegyptium*	56.7
Weed 5	*Echinochloa colona*	29.3	*Cyperus iria*	45.0

Conclusion

The varietal turnover is poor but still the old varieties are doing much better. Hybrids are with 20% HHs. Improving rice yield calls for more than varieties and the nutrient use. Delayed transplanting, access to low-cost irrigation and weed management are some important constraints.

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3.14 Hybrids and herbicide use can help in improving paddy yield in Bhagalpur district of Bihar

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Introduction

Agro-climatically, district Bhagalpur falls under South Bihar Alluvial Plain Zone (B1-3) between 25°07' and 25°30' N latitude and 86°37' and 87°30' E longitude at an altitude of 42.9 m above MSL. Its geographical area is 248,200 ha, of which 153,600 ha is the net sown area with 125% cropping intensity. Net irrigated area is 54,000 ha mainly through open and bore-wells. Annual rainfall in the district is 1,208 mm mainly received through SW monsoons. Soils vary from sandy and coarse/fine sandy loam to clayey and saline/calcareous. The survey was conducted to collect data sets and analyze thoroughly to generate critical insights into how the technologies are accepted by farmers. The aim of the landscape diagnostic survey (LDS) is to monitor, evaluate and learn the system that reflects views and represents interests of farmers.

Methodology

Villages (30) were randomly selected from the 2011 Census data on the basis of probability proportionate to size (PPS) method. Seven farmers were randomly selected from each village. They were interviewed regarding the prevailing agronomic practices for the rice crop they had grown in *kharif* 2018. The questionnaire for the LDS was prepared in a mobile application based digital data collection format of Open Data Kit (ODK), which is capable of transferring real time data to the server or cloud. Out of total 210 households surveyed, majority of them were marginal (73%) and small (17%) as per the landholding size. GPS coordinates of the largest plot of the surveyed farmers in Bhagalpur are depicted in Fig. 1. As per drainage classification, the topography comprised medium land, lowland and upland to the tune of 70.2, 16.8 and 13.0 %, respectively. As per soil texture, it was 75.8 % medium, 20.5 % heavy and 3.7 % as light soil. About 81.4 % of the surveyed farmers followed the rice-wheat cropping system.

Blocks covered : Bihpur, Colgong, Gopalpur, Goradih, Jagdishpur, Narayanpur, Nathnagar, Pirpainti, Rangra chawk, Shahkund, Sonhaula and Sultanganj.

Villages surveyed : Azimabad, Beernaudh, Belsira, Bhandarwan, Bimkitta, Bhuria, Bhuwalpur, Bihpur, Daharpur, Dewari, Dhauri, Dhoradih, Ekchari, Gobrain, Ifadpur, Imadpur, Kamarganj, Khutaha, Kumaitha, Mahisamunda, Maknpur, Malikpur, Narayanpur, Parshuramchak, Payalpur, Rampur khurd, Rangra, Rifadpur, Shadipur, Sajaur, Saraha, Srirampur Dariyachak, Siwanpur and Taradiha (Fig. 1).

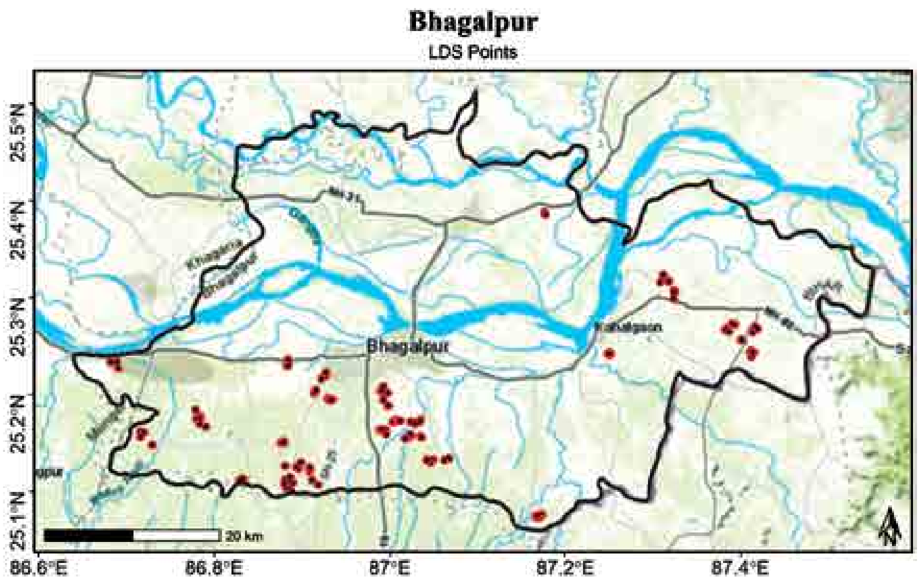

Fig. 1. GPS coordinates of the largest plot of the surveyed farmers in Bhagalpur.

Results and Discussion

The data (Fig. 2) revealed that two long duration varieties (MTU 7029 -21 % HHs; Rajendra Mahsuri 1-6 % HHs) and two medium duration hybrids (Arize- 30 % HHs; Pioneer 27P31-7 % HHs) covered 64 % HHs in this district. Other popular varieties were Sonam (9 %), and Sita (6 %) along with few miscellaneous ones.

Among six most preferred varieties/hybrids, Arize 6444 Gold was highest yielder (4.2 tha^{-1}), however, it was at par with Rajendra Mahsuri (4.0 tha^{-1}) and MTU

7029 (3.9 tha^{-1}). Performance of other three varieties was poor and Sonam was lowest yielder in this group (Fig. 3). The incremental competition from new varieties across different groups is almost zero. Since rice is the centre of significance for sustainable intensification of the dominating cropping system, hybrids seem to have better scope in this district. Huang *et al.* (2015) described the superiority of hybrids.

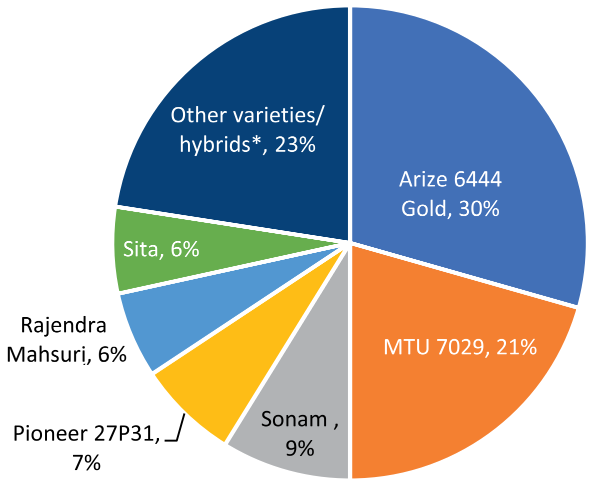

Fig. 2. Varietal spectrum of rice varieties/hybrids based on the data of surveyed farmers in Bhagalpur.

Grain yield of rice was at par when it was transplanted up to 30th June and between 01 and 15th July compared to delayed transplanting thereafter (Fig. 4) indicating the importance of an early or optimal time of transplanting in the surveyed area. The effect could be more in the long duration varieties. Longer growth duration within the maturity class enhances the translocation of assimilates from source to sink (Yoshida, 1993).

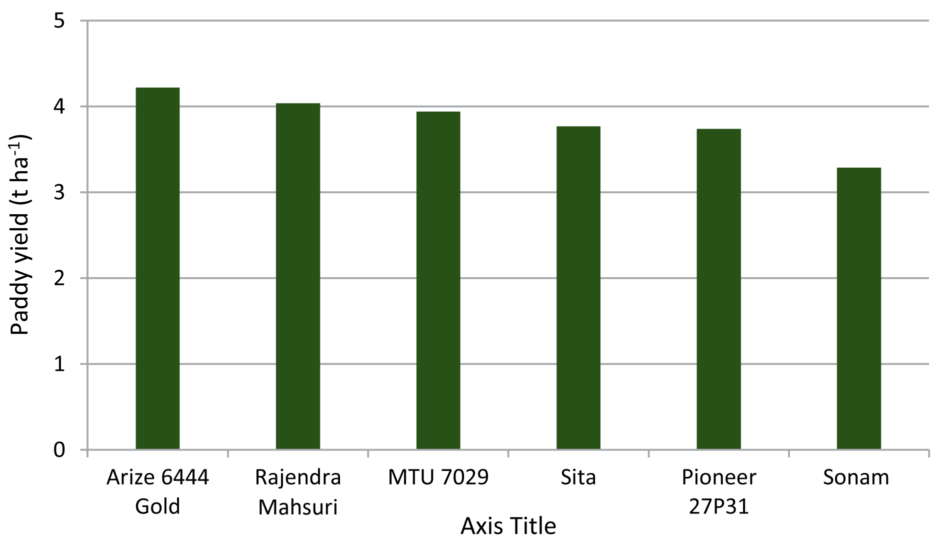

Fig. 3. Performance of most preferred rice varieties/hybrids by the surveyed farmers in Bhagalpur.

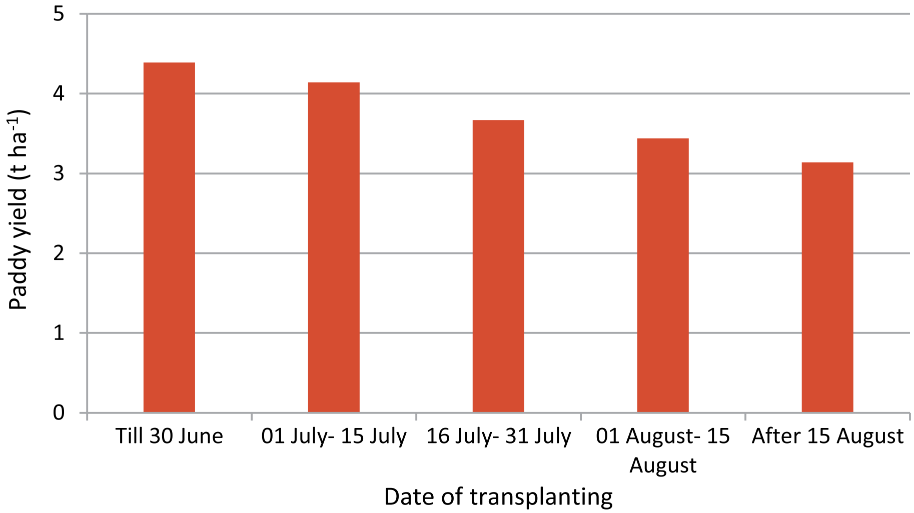

Fig. 4. Effect of time of transplanting on grain yield of rice varieties/hybrids in Bhagalpur.

A total of 89 and 71 HHs who grew improved rice varieties and hybrids, respectively, harvested an average yield of 3.7 and 4.1 tha^{-1} with almost similar dose of N (118 and 127 $kgha^{-1}$), which was also close to the recommended one (120 $kgha^{-1}$) (Table 1). Rates of P_2O_5 (50 and 51 $kgha^{-1}$) and K_2O (26 and 32 $kgha^{-1}$) application were bit lower than the recommended doses both in varieties as well as hybrids, however, the irrigation level (3.3) was equal in both the cases and it was applied by all the HHs. N, P_2O_5 and K_2O were applied by 99, 93 and 65 % HHs in rice varieties,

Table 1. Nutrients and irrigation application pattern in varieties and hybrids in Bhagalpur.

Particulars	Improved varieties	Hybrids
Average yield (tha^{-1})	3.7	4.1
Average nitrogen application ($kgha^{-1}$)	118	127
Average phosphorus application ($kgha^{-1}$)	50	51
Average potash application ($kgha^{-1}$)	26	32
Average irrigations applied	3.3	3.3
Total households	89	71
% households applying nitrogen	99 %	99 %
% households applying phosphorus	93 %	97 %
% households applying potash	65 %	83 %
% of households applying irrigation	100 %	100 %

respectively, and the corresponding figures in hybrids were 99, 97 and 83 %. Overall picture indicated that farmers used a bit higher inputs (nutrients) in hybrids compared to varieties and also ended up with an edge in terms of yield gain.

Among five top most troublesome weeds infesting rice crop in Bhagalpur (Table 2), 39 % HHs indicated *Echinochloa colona* as the most serious weed (rank 1) followed by *Cyperus difformis* (rank 2; 37 % HHs), *Cyperus iria* (rank 3; 32 % HHs), *Cynadon dactylon* (rank 4; 29 % HHs) and *Cyperus rotundus* (rank 5; 23 % HHs). Likewise, among top five common weeds of transplanted rice crop, *E. colona*, *C. difformis*, *C. dactylon*, *C. iria* and *E. crus-galli* were reported by 53, 44, 43, 40 and 39 % HHs, respectively. This clearly indicated pronounced dominance of grassy weeds and sedges in the district, which warrants for effective and integrated weed management including relevant herbicides.

Table 2. Top five troublesome and common weeds in Bhagalpur.

Rank	Top 5 troublesome weeds	% HHs	Top 5 common weeds	% HHs
Weed 1	*Echinochloa colona*	39	*Echinochloa colona*	53
Weed 2	*Cyperus difformis*	37	*Cyperus difformis*	44
Weed 3	*Cyperus iria*	32	*Cynadon dactylon*	43
Weed 4	*Cynadon dactylon*	29	*Cyperus iria*	40
Weed 5	*Cyperus rotundus*	23	*Echinochloa crus-galli*	39

Conclusion

Bhagalpur district, a medium land ecology, dwells mainly marginal and small landholding farmers adopting rice-wheat cropping system. Arize 6444 Gold, Rajendra Mahsuri and MTU 7029 were found to be more promising. Delayed transplanting of rice after 15 July significantly reduced the grain yield. An early or timely transplanting before or up to 15th July and effective management of sedges and grass weeds may help raise the existing rice productivity.

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3.15 Timely irrigation and weed management are key variables for improving rice yields in Buxar

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Introduction

Buxar is one of the agriculturally advanced districts of Bihar. The important rivers flowing through the district are the Ganga, Thora, Dharmawati and Karmnasha. The Ganga forms the northern boundary of the district, while river Karmnasha joins the Ganga near Chausa. Agriculture remains the basis of survival for most of the population. It covers the total area of 1,703 km^2. The district has a population density of 1,003 inhabitants per square kilometre (2,600/sq mile).The major cropping system prevailing in the district is rice-wheat. Landscape diagnostic survey (LDS) was conducted for deep engagement with researchers in the ICAR system and the DoA based on the evidences and scope of new intervention that emerged from the survey.

Methodology

Villages (30) were randomly selected from the 2011 census data on the basis of probability proportionate to size (PPS) method. The villages and farmers within villages were randomized (Fig. 1) and the sample properly reflects farmers' population in the district. Seven farmers were randomly selected from each village. They were interviewed regarding the prevailing agronomic practices for the rice crop. The randomization process makes it easy to assess the adoption pattern of different technologies in the district.

The questionnaire for the landscape diagnostic survey was prepared in a mobile application based digital data collection format of Open Data Kit (ODK), which is capable of transferring real time data to the server or cloud.

Blocks covered : Brahmpur, Buxar, Chausa, Dumraon, Itarhi, Kesath, Nawanagar, Rajpur and Simri.

Village surveyed : Waina, Sonpa, Purana Bhojpur, Bhatauli, Harikishunpur, Bhatauli, Nimej, Bairia, Ariaon, Ahirauli, Akodhi, Baghipatti, Chakhaura, Chilbili, Dumri, Jalilpur, Chotki Basauli, Diwanpura, Gaayghat, Haroja, Kasath, Kharhatand, Khutaha, Lalchak, Lalganj, Sondhila, Sahiyar, Rajapur, Dehariya and Padaria (Fig. 1).

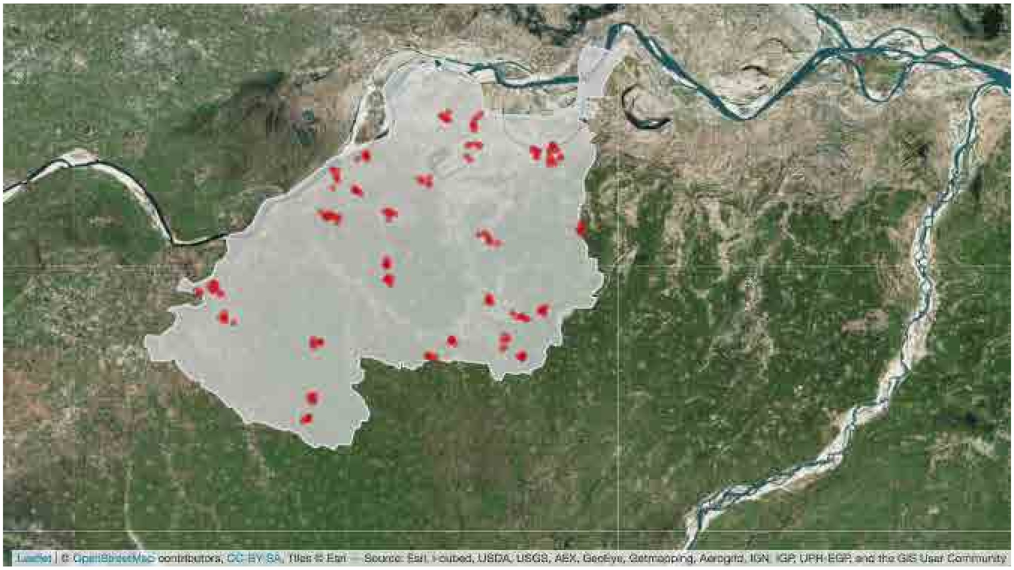

Fig. 1. GPS points of surveyed farms in Buxar.

Results and Discussion

In Bihar, majorly farmers are in the small and marginal category. The data from the surveyed farmers of Buxar gave a similar trend with almost 79 % of the surveyed population falling in this category; whereas only 2 % farmers are in the large category. The drainage class data revealed that 85 % of the surveyed HHs were in medium and low land category. The surveyed HHs had farm land with soil type where 85 % of the 82 % falling in the medium category, 15.5 % in the light category and 2.6 % in heavy category. Light textured soils are not well suited to grow paddy due to lesser water holding capacity (WHC) and demand for higher irrigation. Data showed that 100 % of surveyed HHs followed rice-wheat cropping system.

Rice varieties BPT5204 and MTU7029 occupy almost 97 % of the total cultivated area of rice with the surveyed farmers (Fig. 2). That means most varieties with maturity duration of 140 days plus will stay a favourite of farmers in this district. This is the reason that the 35 years old varieties are still dominating in the district. Newly released rice varieties are not finding any space in this district.

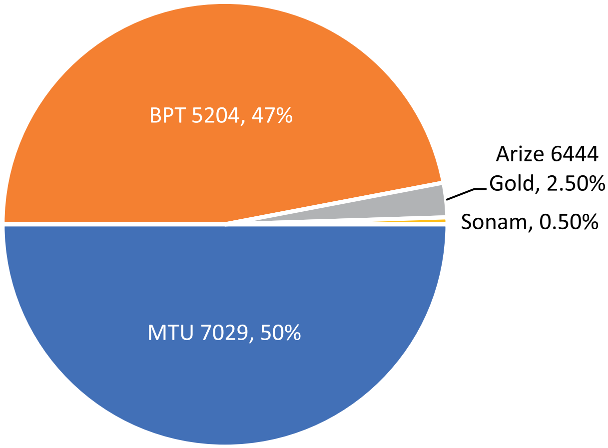

Fig. 2. Varietal spectrum of the surveyed farmers in the district of Buxar.

Results highlighted that variety Sonam recorded a highest yield but the data are from very limited number of farmers (Fig. 3).

The observations on date of transplanting of varieties that

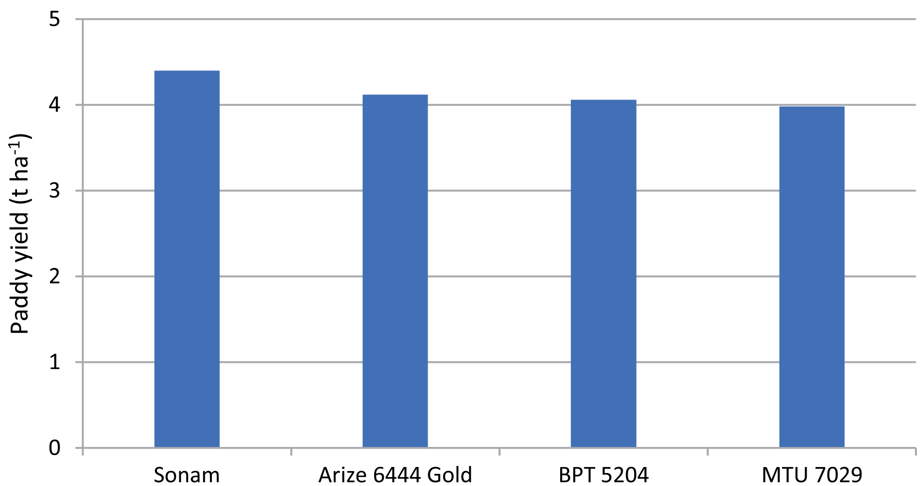

Fig. 3. Varietal performance of the surveyed farmers in the district of Buxar.

cover almost 98% of the total area with the surveyed farmers, revealed that varieties performed better than hybrids. This may be attributed to the use of high yielding varieties i.e. BPT 5204 and MTU 7029 and also use of better irrigation in the area owing to presence of canal based irrigation system (Fig. 4).

With dominance of old varieties and high N use, the question is how to harness more from varieties and nutrient management with a focus on agronomic management.

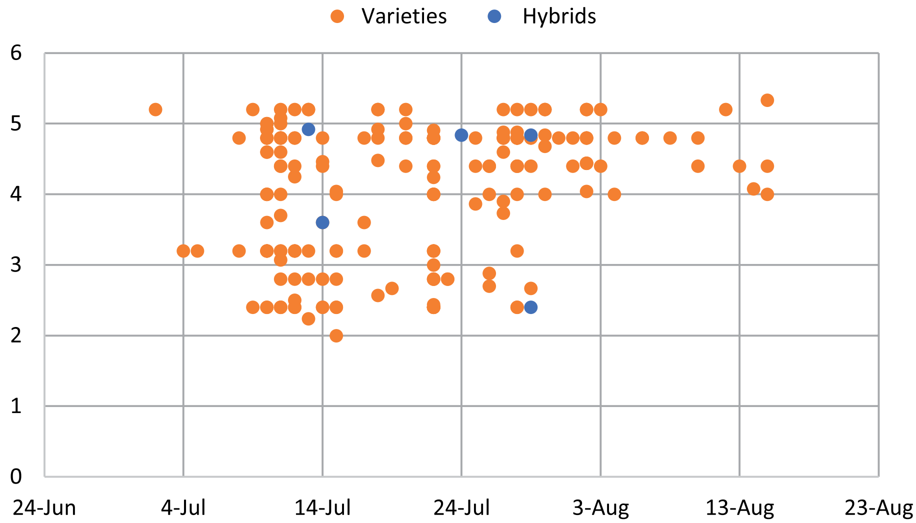

Fig. 4. Effect of dates of transplanting on paddy yield in the district of Buxar.

Increasing the number of split applications may have a greater effect on increasing yield than the increase in the amount of N applied (Dobermann and Fairhurst, 2000). Rice is cultivated here in areas that are mostly monsoon-rain dependent but also in regions of assured irrigation.

The number of irrigation applied was also at par for both hybrids and varieties (Table 1). Irrigation determines rice yield to a very large extent (Bhattacharya, 2008).

Table 1. Nutrients and irrigation application pattern of hybrids and improved varieties in Buxar district.

Particulars	Improved varieties	Hybrids
Average yield (tha^{-1})	4.0	4.1
Average nitrogen application ($kgha^{-1}$)	137.2	130.2
Average phosphorus application ($kgha^{-1}$)	58.8	69.0
Average potash application ($kgha^{-1}$)	24.7	24.0
Average irrigations applied	3.3	3.6
Total households	189	5
% households applying nitrogen	100	100
% households applying phosphorus	95	80
% households applying potash	33	40
% of households applying irrigation	100	100

Managing weeds have been really a serious problem in rice cultivation. Puddling is thought to be a solution to this (Das *et al.*, 2014) but still weeds remain a nuisance for which either manual weeding is required or certain chemical molecules are sprayed at particular growth stages to control them and prevent decline in yield. The surveyed data on weeds from the district revealed that *Echinochloa colona* and *Cynadon dactylon* are the two most important troublesome weeds affecting almost 79 and 55 % households, respectively (Table 2). Summer cultivation is necessary for suppressing *Cynadon dactylon.*

Table 2. Five most common and troublesome weeds and yield of paddy in Buxar district

Rank	Troublesome weeds	% HHs	Common weeds	% HHs
Weed 1	*Echinochloa colona*	78.8	*Echinochloa colona*	89.7
Weed 2	*Cynadon dactylon*	55.1	*Cynadon dactylon*	65.9
Weed 3	*Leptochloa* species	53.6	*Leptochloa* species	59.3
Weed 4	*Echinochloa crus-galli*	45.9	*Echinochloa crus-galli*	58.7
Weed 5	*Dactyloctenium aegyptium*	40.7	*Scirpus juncoides*	53.1

Conclusion

Rice cultivation is done in areas, which are mostly monsoon-rain dependent but also includes regions of assured irrigation. Timely establishment of long duration rice or medium duration varieties or medium duration hybrids with proper weed management and timely irrigation are the three most important factors that need focused attention.

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3.16 Old varieties or hybrids still dominate in East Champaran: Scope for better agronomic management

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Introduction

East Champaran district of Bihar falls into North West Alluvial Plain Zone (B1-1) between 26°38'N latitude and 84°54'E longitude at an altitude of 62 m above MSL. Its geographical area is 398,600 ha, of which 266,200 ha is the net sown area with 174 % cropping intensity. Net irrigated area is 121,600 ha mainly through bore-wells (55.9 %) and canals (26.4 %). Annual rainfall in the district is 1,202 mm mainly received through SW monsoons. Soils of the district are fine sandy loam (50.1 %) and saline/calcareous (28.6 %). Rice (177,000 ha) is the main crop of the district grown in *kharif*, whereas wheat area is 121,000 ha in the district. The landscape diagnostic survey (LDS) promises to monitor the adoption of technologies across the district. The NARES can use the resulting data to monitor the technology adoption process and to manage the technical program of research and extension including the planning part of DoA.

Methodology

Villages (30) were randomly selected from the 2011 Census data on the basis of probability proportionate to size (PPS) method. Seven farmers were randomly selected from each village. They were interviewed regarding the prevailing agronomic practices for the rice crop they had grown in *kharif* 2018. The questionnaire for the Landscape Diagnostic Survey (LDS) was prepared in a mobile application based digital data collection format of Open Data Kit (ODK), which is capable of transferring real time data to the server or cloud. GPS coordinates of the largest plot of the surveyed farmers in East Champaran are shown in Fig. 1. Out of total 210 households surveyed, majority of them were marginal (63%) and small (19%) as per their landholding size. Others were semi-medium (14%) and medium (4%). As per drainage classification, the topography comprised medium land, lowland and upland to the tune of 69.7, 28.3 and 2.0%, respectively. As per soil texture, it was 59.6% medium, 16.7% heavy and 23.7% as light soil. Almost 82.8% follow the rice-wheat cropping system, 14.1% rice-fallow, and 3.0% rice-other crops.

Blocks covered : Piprakothi, Narkatia, Banjaria, Madhuban, Chiraia, Paharpur, Sangrampur, Areraj, Sugauli, Motihari, Kalyanpur, Harsidhi, Dhaka, Ramgarhwa, Kotwa, Tetaria, Mehsi and Raxaul.

Villages surveyed : Salempur, Shripur, Pachrukha, Rupani, Khartari, Noniya, Madhubani, Radhiya, Inarwabhar, Chiljhapti, Barwa, Lakshmipur, Bakhari, Bishunpur, Nanhkar, Mamarkha, Guranawa, Bhawanipur, Jaitapur, Jitpur, Harajpur, Raghunathpur, Bhatawa, Jasauli, Singhasani, Kataha, Naurangia, Mahmadpur Sagar, Harnahi, Semrahia and Jatwa (Fig. 1).

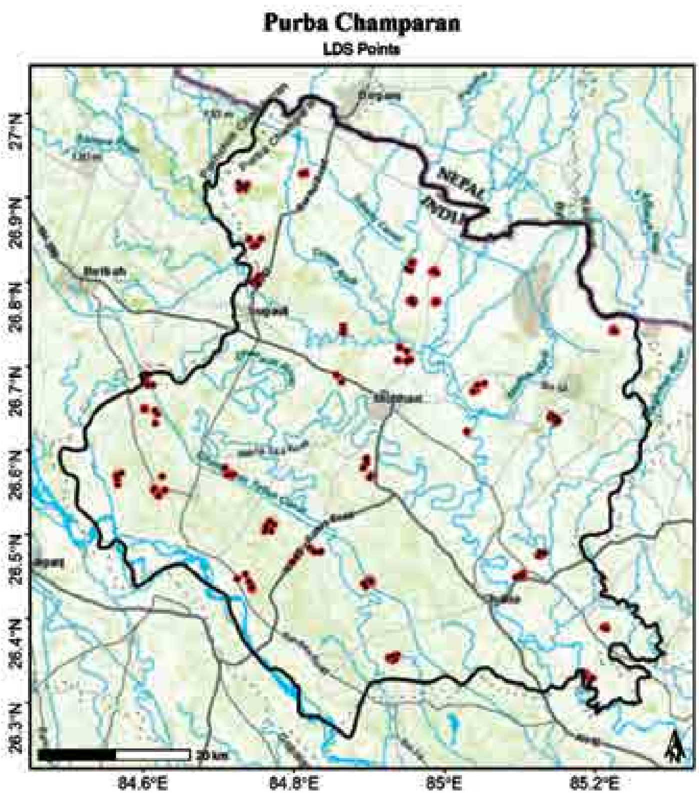
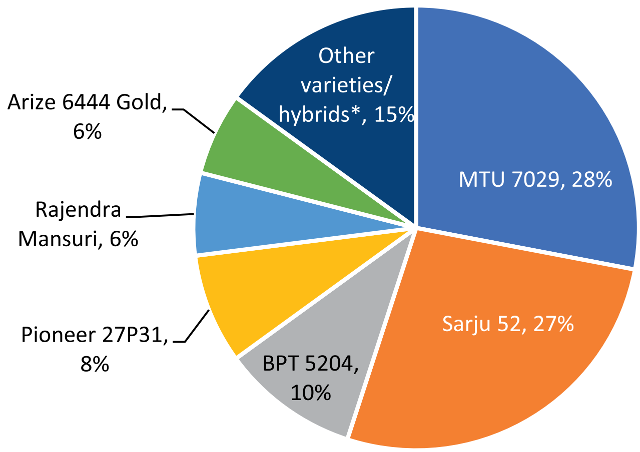


Fig. 1. GPS coordinates of the largest plot of the surveyed farmers in East Champaran.

Results and Discussion

The data (Fig. 2) revealed that 28, 27, 10, 8, 6, 6 and 15% HHs preferred MTU 7029, Sarju 52, BPT 5204, Pioneer 27P31, Rajendra Mahsuri, Arize 6444Gold, and other varieties/hybrids, respectively. Other varieties grown by few HHs were Dhanya 775, Gangotri, JK4015, Pan Ganga, Pioneer27P63, Supreme Sona, MTU 1001, Rajendra Bhagwati, Sonam, Aghani, Moti Gold, Kaveri, NK 5251 and PHB 715. More than 70% HHs adopted old varieties and the rest adopted varieties from private sector.



*Other varieties/hybrids- Dhanya 775, Gangotri, JK 401, Pan Ganga, Pioneer 27P63, Supreme Sona, MTU 1001, Rajendra Bhagwati, Sonam, Aghani, Moti Gold, Kaveri, NK 5251, PHB71

Fig. 2. Varietal spectrum of rice varieties/hybrids based on the data of surveyed farmers (194) in East Champaran.

Among six most preferred varieties/hybrids, Pioneer 27P31 (4.61 tha^{-1}) being at par with Arize 6444Gold (4.57 tha^{-1}) yielded significantly higher than BPT 5204, Rajendra Mahsuri, Sarju 52 and MTU 7029 (Fig. 3). Hybrids have emerged strongly in this district with yields of LDRVs unexpectedly lower than expectations.

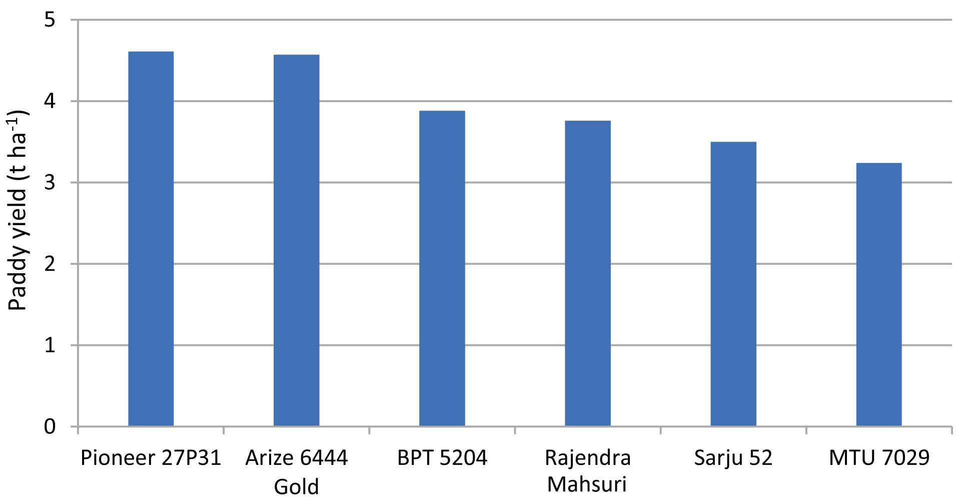


Fig. 3. Performance of most preferred rice varieties/hybrids by the surveyed farmers in East Champaran.

Grain yields of rice variety MTU 7029 as well as hybrids were higher when these were transplanted between 15 and 30 June (more precisely during last week of June) and then started declining significantly thereafter (Fig. 4). In general, grain yield of hybrids was more than MTU 7029 with each date of transplanting up to 15 July, however, the magnitude of decline in grain yield was also higher in hybrids than MTU 7029. It clearly indicated that an early transplanting was the key to achieve higher rice yields in E-Champaran. Similar results were realized earlier also (Lampayan *et al.*, 2015).

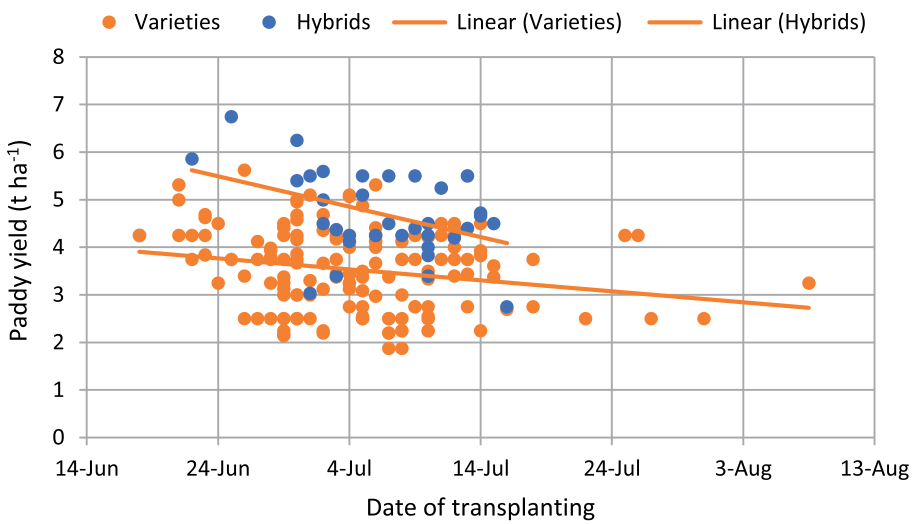


Fig. 4. Effect of time of transplanting on grain yield of rice varieties/hybrids in East Champaran.

A total of 156 and 39 HHs who grew improved rice varieties and hybrids, respectively, harvested an average yield of 3.5 and 4.7 tha^{-1} with 118.8 and 134.8 kgha^{-1} N in that order (Table 1). Use rate of P_2O_5 in hybrids was 65.4 kgha^{-1}, which was higher than varieties (49.4 kgha^{-1}). K_2O use at 24.4 kgha^{-1} in varieties was also lower than its use in hybrids (35.1 kgha^{-1}). However, the irrigation level was similar in both cases (2.27 in varieties and 2.49 in hybrids) and it was applied by all the HHs. N, P_2O_5 and K_2O were applied by 98, 75 and 45 % HHs in rice varieties, respectively, and the corresponding figures in hybrids were 100, 74 and 28 %. Rice can take up near 30 % of the P applied as fertilizer (Buresh *et al.,* 2010).

Among the five top most troublesome weeds infesting rice crop in E. Champaran (Table 2), 66.7 % HHs indicated *Echinochloa colona* as the most serious weed (rank 1) closely followed by *Cyperus rotundus* ranking 2 (51.0 % HHs), *Cynadon dactylon* (rank 3; 44.4 % HHs), *Echinochloa crus-galli* (rank 4; 32.8 % HHs) and *Cyperus*

Table 1. Nutrients and irrigation application pattern in varieties and hybrids in East Champaran.

Particulars	Improved varieties	Hybrids
Average yield (tha^{-1})	3.5	4.7
Average nitrogen application ($kgha^{-1}$)	118.8	134.8
Average phosphorus application ($kgha^{-1}$)	49.4	65.4
Average potash application ($kgha^{-1}$)	24.4	35.1
Average irrigations applied	2.3	2.5
Total households	156	39
% households applying nitrogen	98	100
% households applying phosphorus	75	74
% households applying potash	45	28
% of households applying irrigation	100	100

Table 2. Top five troublesome and common weeds in East Champaran.

Rank	Top 5 Troublesome weeds	% HHs	Top 5 common weeds	% HHs
Weed 1	*Echinochloa colona*	66.7	*Echinochloa colona*	74.7
Weed 2	*Cyperus rotundus*	51.0	*Cyperus rotundus*	70.2
Weed 3	*Cynadon dactylon*	44.4	*Cynadon dactylon*	62.1
Weed 4	*Echinochloa crus-galli*	32.8	*Echinochloa crus-galli*	43.4
Weed 5	*Cyperus difformis*	27.8	*Cyperus difformis*	38.9

difformis (rank 5; 27.8 % HHs). Among top five common weeds of transplanted rice crop were also *E. colona*, *C. rotundus*, *C. dactylon*, *E. crus-galli* and *C. difformis* as reported by 74.7, 70.2, 62.1, 43.4 and 38.9 % HHs, respectively. This indicated infestation of grassy weeds along with sedges in the district, which warrants effective and integrated weed management including relevant herbicides.

Conclusion

Hybrids (Pioneer 27P31 and Arize 6444 Gold) showed significantly higher yield than many popular varieties (BPT 5204, Rajendra Mahsuri, Sarju 52 and MTU 7029) in East Champaran. It is a medium and low land ecology populated mainly with marginal and small landholding HHs (82 %) adopting mainly rice-wheat cropping system (83 %). An early transplanting 15 June-30 June or up to first week of July both in varieties and hybrids, and increased use rate of phosphorus in varieties and potash in both varieties as well as hybrids may enhance the rice productivity in the district.

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3.17 Time management is a must to harness the yield potential of existing varietal spectrum of rice in Gaya

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Introduction

District Gaya is located on the southern part of Bihar state. It is spread in an area of 4,976 Sq. km. It has heavy to medium textured soil that generally lacks in macro- and micro-nutrients like zinc and boron. District receives an average rainfall of 944 mm. The paddy is grown in 177,472 ha followed by wheat on 81,430 ha of land. The landscape diagnostic survey (LDS) was conducted by CSISA-KVK network to understand the prevailing production practices for both rice and wheat crops. This chapter focuses on rice crop that is one of the most important staple foods.

Methodology

Villages (30) were randomly selected from the 2011 census data based on probability proportionate to size (PPS) method. The villages and the farmers within villages were randomized (Fig. 1) and the sample properly reflected the farmers' population in the district. Seven farmers were randomly selected from each village. They were interviewed regarding the prevailing agronomic practices for the rice crop. The randomization process makes it easy to assess the adoption pattern of different technologies in the district.

The questionnaire for the landscape diagnostic survey was prepared in a mobile application based digital data collection format of Open Data Kit (ODK) which can transfer real time data to the server or cloud.

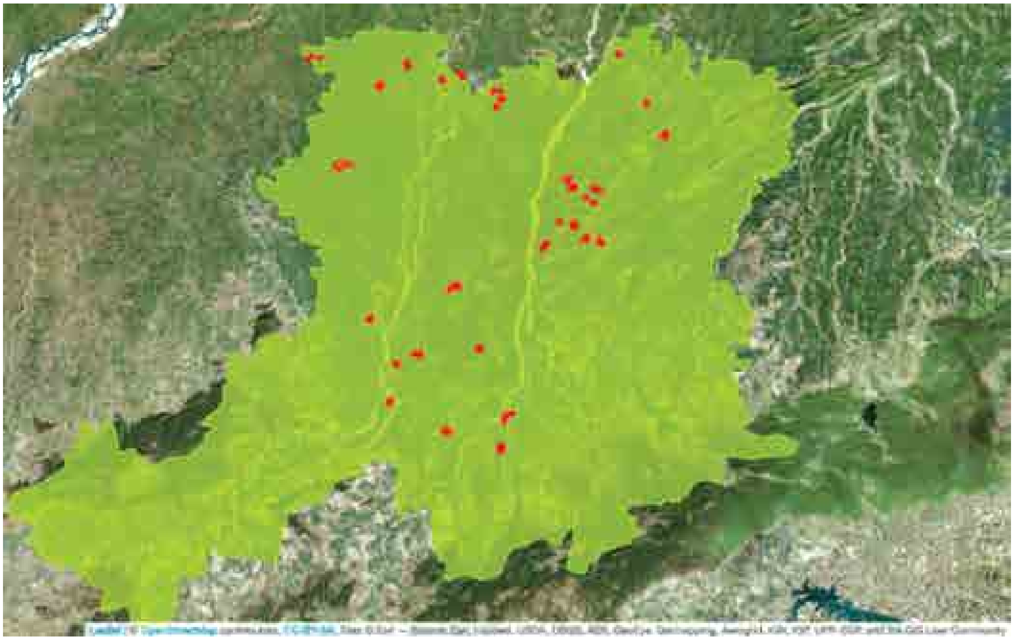


Fig. 1. GPS points of surveyed farms in Gaya district.

Blocks covered : Atri, Barachatti, Belaganj, BodhGaya, Mohanpur, Neem Chak Bathani, Sherghati, Tikari, Dobhi, Gurua, Khizirsarai, Konch and Manpur.

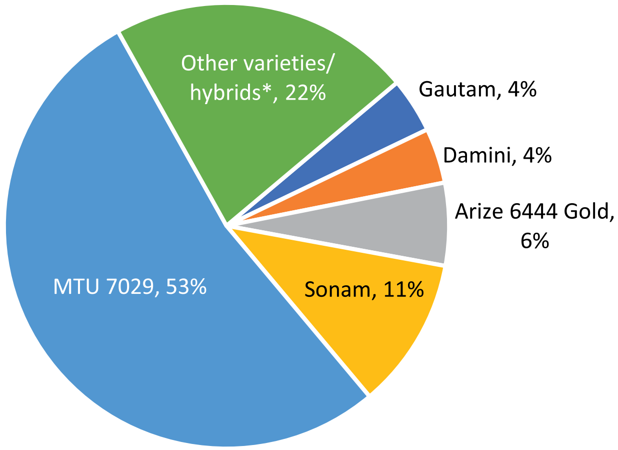
Villages surveyed : Tetua, Lodipur, Chhatni, Dahiyar, Korma, Vajitpur, Kormathu, Khaneta, Jamdi/jamri, Burhi, Gohti, Angra, Matua, Rajan, Hasanpur, Murera, Singhra, Bheriya, Lodipur, Goga, Badahpur, Mastalipur, Turi, Bara, Bhore, Naundhariya, Khandail, Choari, Khandail, Majhanpur, Kamat, Tuturkhi, Alipur and Mau (Fig. 1).

Results and Discussion

Evaluation of the data on size of landholding, put almost 86% of the surveyed households (HHs) in the small and marginal category. Farmers having large landholding were only 1%; and rest 13% were in the category with medium and semi-medium landholdings. Regarding the drainage class 68, 23 and 9% HHs had medium land, upland and lowland farm categories, respectively. Looking at the data on soil texture, 75.8% of farmers have land with medium type of soil, whereas 12.9% of farmers have heavy soil. The rice-wheat is the dominant cropping system of 97.4% HHs.

More than half of the surveyed population transplanted MTU 7029, which is an old variety but still a high yielding one. Sonam was cultivated by 11% HHs, Arize 6444 Gold by 6% and Gautam and Damini by 4% each (Fig. 2).

It is evident from the data that Arize 6444 Gold performed the best with a grain yield of 4.62 tha^{-1}, followed by Damini and Sonam with 4.3 and 4.2 tha^{-1} (Fig. 3). MTU 7029 has sustained despite release of so many varieties during the intervening period from 1982 till date. Transplanting in the middle of season would need focused attention on medium duration varieties or hybrids. If this does not happen, the transplanting must be advanced to make fullest use of growth duration of long duration varieties. Same argument was put forward by Siddiq (1999).



*Other varieties/hybrids- Aman, Moti Gold, Pooja, Rajendra Shweta, Shushk Samrat, Super Moti, US312, BL4341, BPT 5204, Dhaulagiri, Kamini, Moti, Sonali, Diamond, PHB71, Rajendra Mansuri, Kanchan

Fig. 2. Varietal spectrum of the surveyed farmers in district Gaya.

The grain yield of paddy declined when transplanted in August in comparison to one that transplanted in June and July (Fig. 4).

The comparative account of improved varieties vs hybrids showed that the average grain yield was 4.2 and 4.3 tha^{-1}, respectively. The NPK applied in both the cases were

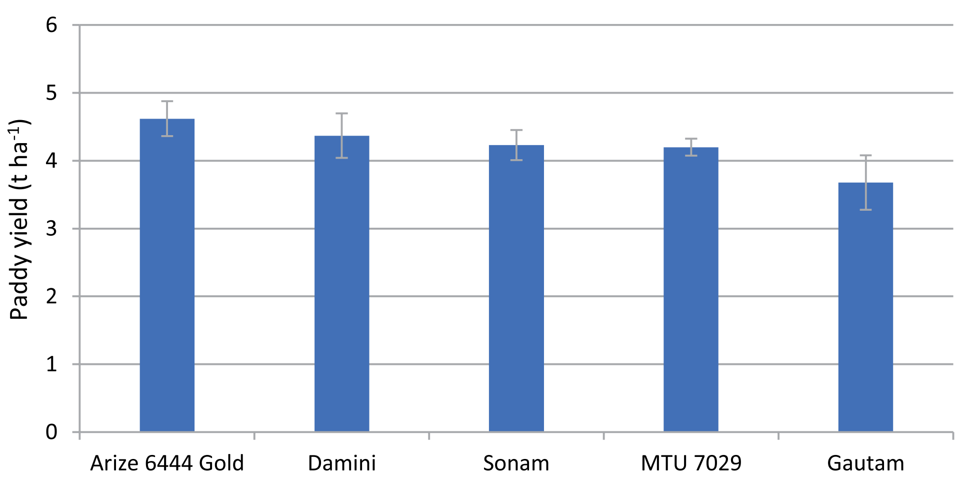


Fig. 3. Varietal performance of the surveyed farmers in district Gaya.

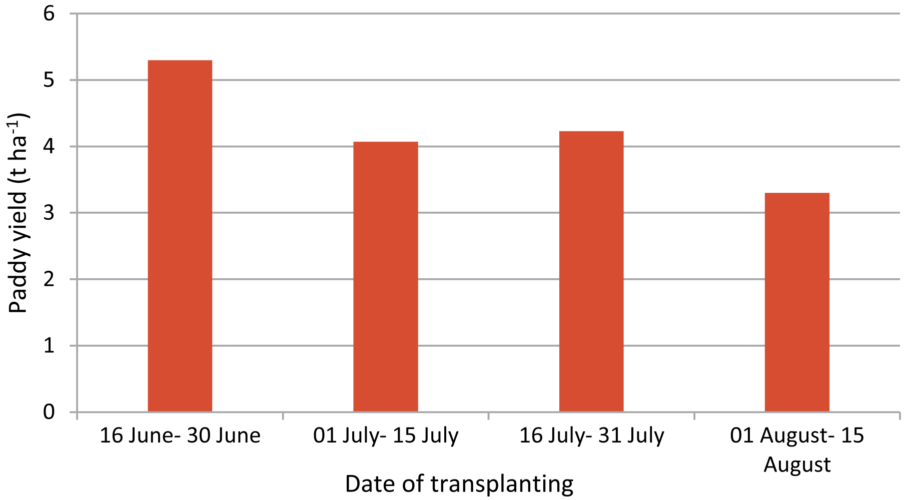


Fig. 4. Effect of dates of transplanting on paddy yield in district Gaya.

at par, whereas the average irrigation applied was 6.1 in improved varieties and 7.6 in case of hybrids (Table 1).

Weeds are the most crucial factor of concern in paddy. Two most prevalent and troublesome weeds in the area were *Dactyloctenium aegyptium* and *Echinochloa* spp. (Table 2). Puddling practice helps in quickly establishing the seedlings, controls weeds due to anaerobic condition and also leads to better utilization of nutrients (De-Datta, 1981).

Table 1. Nutrients and irrigation application pattern in hybrids and varieties in Gaya

Particulars	Improved varieties	Hybrids
Average yield (tha^{-1})	4.2	4.3
Average nitrogen application ($kgha^{-1}$)	128.4	131.3
Average phosphorus application ($kgha^{-1}$)	44.2	41.6
Average potash application ($kgha^{-1}$)	35.6	33.2
Average irrigations applied	6.1	7.6
Total households	157	18
% households applying nitrogen	100	100
% households applying phosphorus	99	100
% households applying potash	22	56
% of households applying irrigation	100	100

Table 2. Five most common and troublesome weeds and yield of paddy in Gaya district

District	Troublesome weeds	% HHs	Common weeds	% HHs
Weed 1	*Dactyloctenium aegyptium*	43.3	*Dactyloctenium aegyptium*	56.2
Weed 2	*Echinochloa crus-galli*	37.6	*Echinochloa colona*	51.5
Weed 3	*Ischaemum rugosum*	32.9	*Echinochloa crus-galli*	47.9
Weed 4	*Echinochloa colona*	32.5	*Ischaemum rugosum*	38.1
Weed 5	*Leptochloa* spp.	28.3	*Leptochloa* spp.	37.1

Conclusion

Arize 6444 Gold, Damini and Sonam performed better than MTU 7029 in the medium and low land ecology of Gaya district in Bihar. An early transplanting from 15 to 30 June, and increased use rate of phosphorus along with improved weed management may enhance the rice productivity in the district.

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3.18 Better access to irrigation and hybrids, and weed management are best options to improve rice yield in Gopalganj district

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Introduction

The Gopalganj district is a part of Middle Gangetic Plain Region and its average rainfall is 1,009 mm. The irrigation facilities are not sufficient and the total net irrigated area is 98,352 ha. Net sown area is 16,000 with crop intensity of 150%. Farmers depend upon monsoon rains or on bore-well based irrigation, which is costly. There is, however, strong possibility of yield growth, if more emphasis is given on management of crop cycle. There are inconsistencies in adoption of recommendation generated over time. Landscape diagnostic survey (LDS) discussed in the paper has allowed independent verification of how the recommendations were accepted by farmers.

The LDS carried out during 2018 is aimed at understanding the existing production practices in rice-wheat cropping system.

Methodology

Villages (30) were randomly selected from the 2011 census data on the basis of probability proportionate to size (PPS) method. The villages and the farmers within villages were randomized (Fig. 1) and the sample properly reflects farmers' population in the district. Seven farmers were randomly selected from each village. They were interviewed regarding the prevailing agronomic practices for the rice crop. The randomization process makes it easy to assess the adoption pattern of different technologies in the district.

The questionnaire for the landscape diagnostic survey was prepared in a mobile application based digital data collection format of Open Data Kit (ODK), which is capable of transferring real time data to the server or cloud.

Blocks covered : Kuchaikot, Gopalganj, Thawe, Uchkagaon, Hathua, Sidhwalia, Barauli, Manjha, Panchdewari, Phulwaria, Baikunthpur and Bijaipur.

Villages surveyed : Mathiya Hardo, Galimpur, Jadopur Dukhran, Sughar Tola, Chotka Sakha, Maksudpur Ghoraghat, Hatta Kodara, Jigna Gopal, Phuluguni, Bhojpurwa, Haluwar, Semra, Sangawadih, Chitu Tola, Narayanpur, Larauli, Madhopur, Neuri, Tola Guman Ray, Rampur Jiwdhar, Bhawaniganj, Khushal Chhapar, Kapuri, Balepur, Rajpur, Ushri, Mathya, Sudama Chak, Pyarepur and Bakhari (Fig. 1).

Results and Discussion

In district Gopalganj, 88% HHs are in the marginal category, 8% in small and 3% in semi-medium category. Based on the survey data, it is evident that majority of farmers had their farmland under the medium land category i.e. 77% followed by 11% of upland and lowland each. Rice-wheat is the dominant cropping system in the district with 65.2% of the surveyed HHs followed by rice-fallow with 34.3% HHs.

The most prevalent variety in the district was Sarju 52 with 41% stakeholders followed by Arize 6444 Gold with 13% and MTU 7029 with 11% (Fig. 2). With 1,000

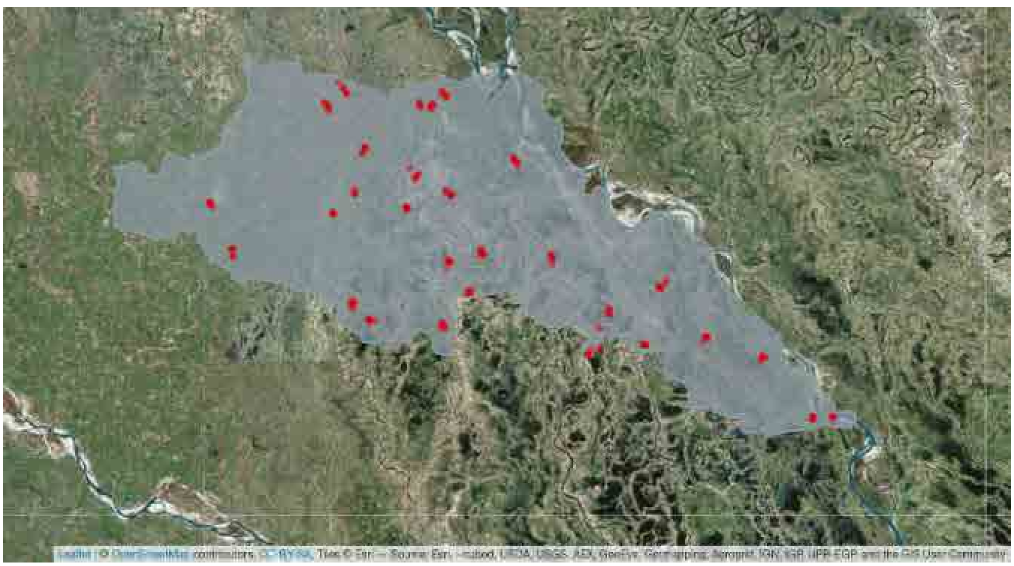
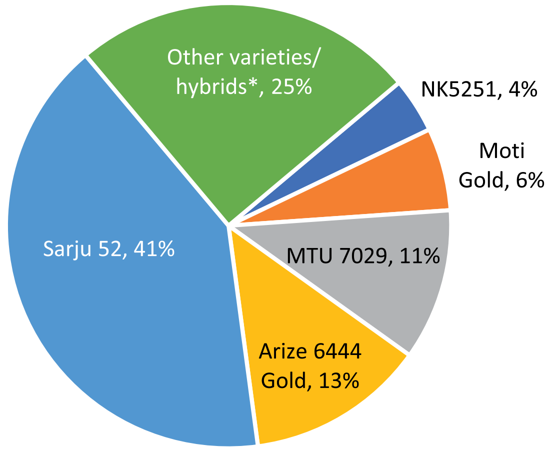


Fig. 1. GPS points of surveyed farms in Gopalganj.

mm rainfall, the area seems to stay under water stress during rice season as the average number of irrigations is relatively lesser than other districts. Aiming for high yield is a matter of concern for the farmers which cannot be resolved by short duration varieties like Sarju 52.

Arize 6444 Gold was among the best performing in whole spectrum with an average paddy yield of 4.22 tha^{-1} followed by Moti Gold with an average yield of 4.16 tha^{-1} (Fig. 3). Like other districts, data suggested that medium duration varieties or hybrids will have better scope in this district. The water stress environment has already reduced the adoption of long duration varieties like MTU 7029.



*Other varieties/hybrids- BPT 5204, Dhaulagiri, Gangotri, Komal, MTU 1001, Raghunath, Upaj, Rajendra Mansuri, Sonam, Sudha, Rupali, JK Dhanyarekha, US 312, Aghani, Moti, Pioneer 27P31, Pioneer 27P35

Fig. 2. Current scenario of varietal adoption of the surveyed farmers in Gopalganj district.

From the data of hybrids and varieties, there is a slight decrease in yield observed with delay in date of transplanting (Fig. 4). This is expected because the district is dominated by SDRVs or hybrids.

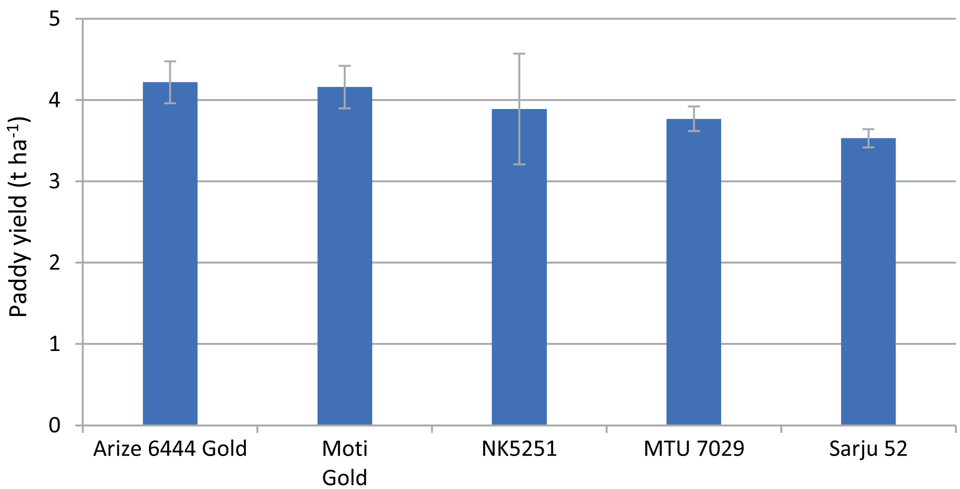


Fig. 3. Varietal performance of the surveyed farmers in district Gopalganj.

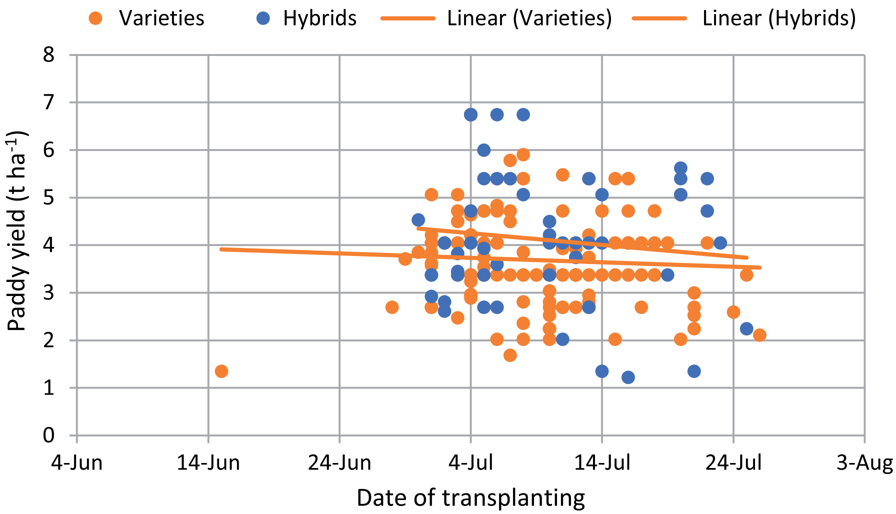


Fig. 4. Effect of dates of transplanting on paddy yield in district Gopalganj.

Across all varieties or hybrids, hybrids showed better yield with 4.1 tha^{-1} compared to 3.7 tha^{-1} from improved varieties. It is because dominating variety is of short duration and cannot compete with hybrids. The NPK usage and irrigation frequency were same for both the situations. The percentage of HHs applying NPK and irrigation was also almost at par (Table 1). At current yield level, the NPK dose seems to be on the higher side. It makes a better case for other agronomic practices that include weed management, use of hybrids, and better access to low-cost irrigation.

Table 1. Nutrients and irrigation application pattern in improved varieties and hybrids in Gopalganj.

Particulars	Improved varieties	Hybrids
Average yield (tha^{-1})	3.7	4.1
Average nitrogen application (kgha^{-1})	145.0	141.6
Average phosphorus application (kgha^{-1})	56.2	58.4
Average potash application (kgha^{-1})	30.5	33.9
Average irrigations applied	2.1	2.0
Total households	142	53
% households applying nitrogen	98	96
% households applying phosphorus	83	83
% households applying potash	70	68
% of households applying irrigation	100	100

The major troublesome weeds are *Echinochloa colona* with 60.4 % HHs claiming to be in their rice fields followed by *Echinochloa crus-galli* in 58.91 % of HHs (Table 2). Both are very competitive weeds and yield setbacks are expected (Rao *et al.*, 2015).

Table 2. Five most common and troublesome weeds and yield of paddy in Gopalganj district

Rank	Troublesome weeds	% HHs	Common weeds	% HHs
Weed 1	*Echinochloa colona*	60.4	*Echinochloa crus-galli*	73.3
Weed 2	*Echinochloa crus-galli*	58.9	*Echinochloa colona*	66.3
Weed 3	*Cyperus rotundus*	32.7	*Cynadon dactylon*	46.5
Weed 4	*Cynadon dactylon*	31.2	*Cyperus rotundus*	41.1
Weed 5	*Cyperus difformis*	22.8	*Dactyloctenium aegyptium*	29.7

Conclusion

The Gopalganj survey gives hybrids a better chance to sustainably increase the yield of rice. Owing to lack of low-cost irrigation, weed competition is the second most important variable that adversely affects the yield of rice. *Echinochloa* spp. are best controlled by herbicides but *Cynadon dactylon* control will need summer tillage and early ground cover by the crop.

Reference

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3.19 Timely transplanting and weed management are critical part of rice production system in Jehanabad district

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[1]Krishi Vigyan Kendra, Jehanabad, Bihar
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Introduction

The Jehanabad district is under zone-III (B) of South Bihar. Soil type is mainly loamy, clay in texture with low to moderately high organic matter content. The rice-wheat cropping system is practiced by most farmers. Even with relatively high organic matter, farmers are still using recommended P both in rice and wheat, which is a big issue and they are still using old varieties is another issue. The Landscape Diagnostic Survey (LDS) was conducted to understand the shift towards data-driven process for the development of technical program in research institutions and investment proposal from extension agencies (subsidy allocation, seed distribution) and private sector for market intelligence.

Methodology

Villages (30) were randomly selected from the 2011 census data on the basis of probability proportionate to size (PPS) method. The villages and farmers within villages were randomized (Fig. 1) and the sample properly reflects farmers' population in the district. Seven farmers were randomly selected from each village. They were interviewed regarding the prevailing agronomic practices for the rice crop. The randomization process makes it easy to assess the adoption pattern of different technologies in the district.

The questionnaire for the landscape diagnostic survey was prepared in a mobile application based digital data collection format of Open Data Kit (ODK), which is capable of transferring real time data to the server or cloud.

Blocks covered : Ghoshi, Hulasganj, Jehanabad, Kako, Makhdumpur, Modanganj and Ratni Faridpur.

Villages selected : Akhtiyarpur, Balwa, Bandhuganj, Bauri, Beldari, Bhore, Dhuriyari, Fauladpur, Gangapur, Gaurapur, Ghoshi, Godiha, Kora, Korma, Kurre, Lakhawar, Maheva, Makhdumpur, Mirzapur, Nandanpura, Tetha, Narawan, Narwayn milik, Nerthua Tola, Mudera, Owa, Pandui, Parasbigha, Rasulpur, Saidabad, Saidabad Parsain, Sugawan, Sulemanpur, Sumera, Surka and Tehta (Fig. 1).

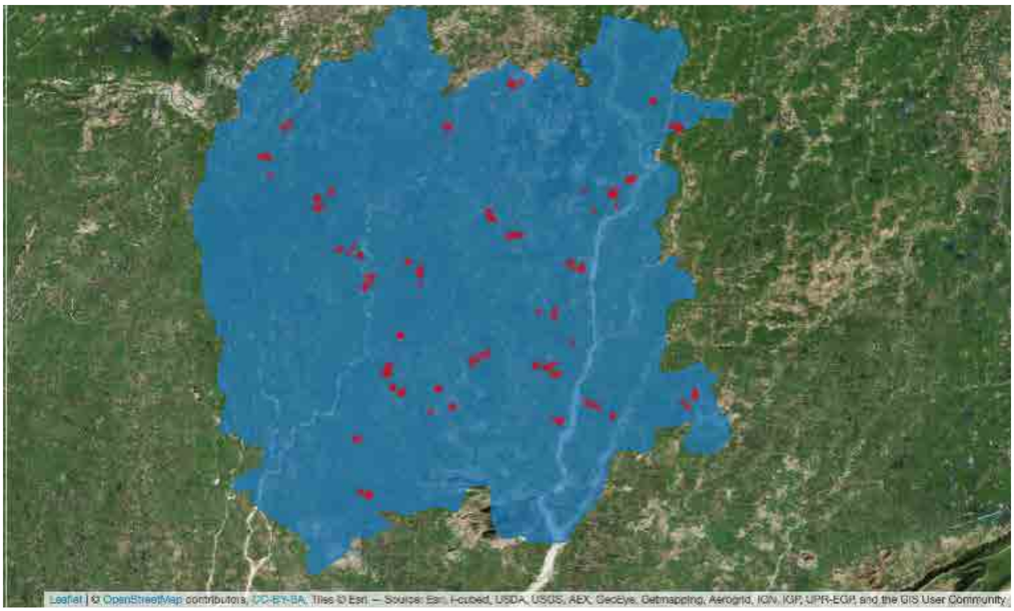


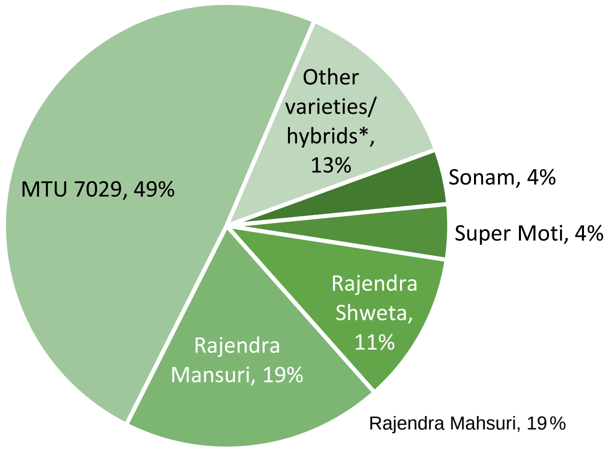
Fig. 1. GPS points of surveyed farms in Jehanabad.

Results and Discussion

Data from the surveyed HHs showed that 70% of the HHs were marginal, 23% small, 5% semi-medium and 2% medium on the basis of landholding size. The data on the drainage class constituted 59.6% medium type, 21.3% lowlands, 14.8% uplands and 4.4% very lowlands. The soil texture included 42.1% medium category, 35.5% light and 22.4% heavy category. The cropping system was dominated by rice-wheat (94% HHs), with only 3.8% practiced rice-maize and 2.2% practiced rice-other crops system.

The varietal spectrum showed that 49% farmers cultivated MTU 7029, 19% cultivated Rajendra Mahsuri and 11% Rajendra Shweta (Fig. 2).

The variety Rajendra Shweta outperformed all the other varieties cultivated by the respondents with yield of 4.6 tha^{-1} (Fig. 3). High yield of Rajendra Shweta at very low adoption showed that another variable, which affected the spread was the ecology, with more adoption of MTU 7029 in low land ecologies (Saha *et al.*, 2008).



*Other Varieties/hybrids- Arize 6444 Gold, Daftari-Omshri 125, Komal, Loknath 505, PHB71, Rajendra Saraswati, Sahabhagi, Kranti, Laxmi, Moti, Moti Gold, Poonam, Sonali

Fig. 2. The varietal spectrum of the surveyed HHs in district Jehanabad.

The data of transplanting dates revealed that grain yield declined with delay in transplanting (Fig. 4). In the June transplanted crop, the less yield may be due to water stress in the early stages of crop growth as the monsoon rains were received late.

NPK and irrigation applied in hybrids were more than that of improved varieties (Table 1). Phosphorus is applied both in rice and wheat but rice can take

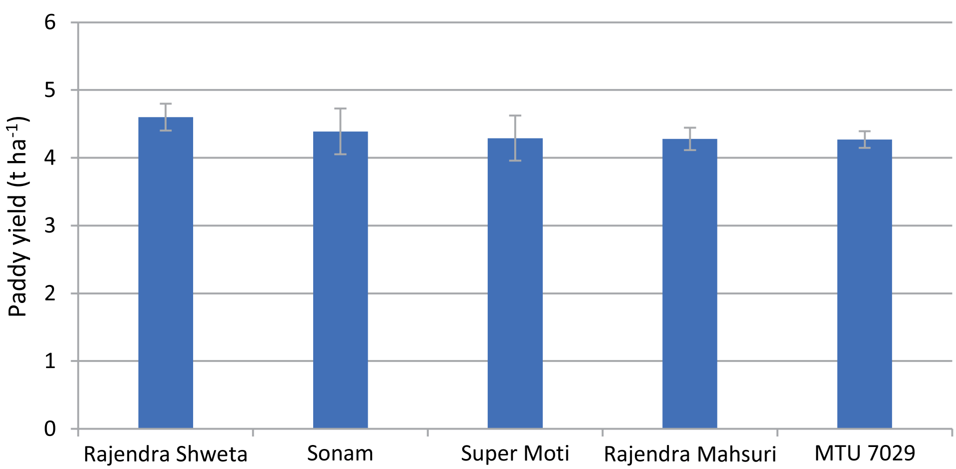


Fig. 3. Paddy yield of different varieties among surveyed farmers in district Jehanabad.

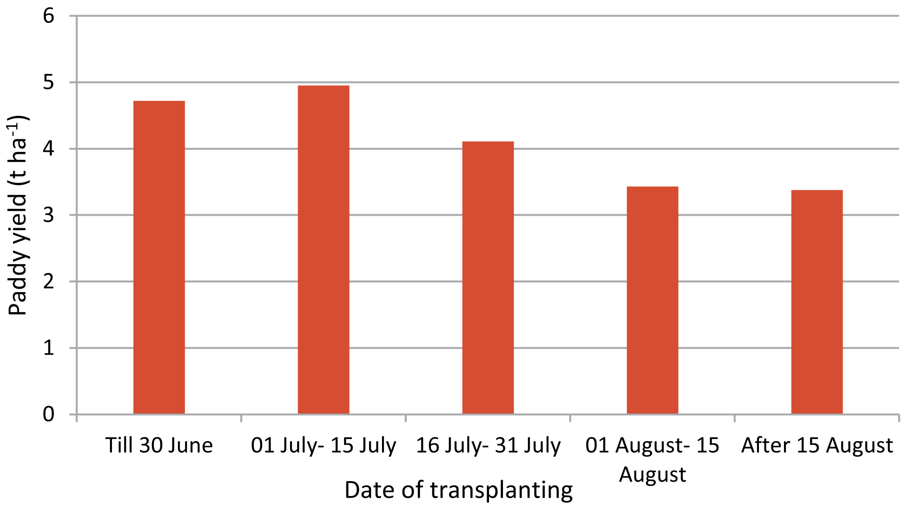


Fig. 4. Effect of dates of transplanting on paddy yield in district Jehanabad.

Table 1. Nutrients and irrigation application pattern in improved varieties and hybrids in Jehanabad.

Particulars	Improved varieties	Hybrids
Average yield (tha^{-1})	4.3	5.5
Average nitrogen application ($kgha^{-1}$)	124.7	134.1
Average phosphorus application ($kgha^{-1}$)	43.1	51.4
Average potash application ($kgha^{-1}$)	31.8	32.2
Average irrigations applied	4.6	5.6
Total households	180	3
% households applying nitrogen	100	100
% households applying phosphorus	98	100
% households applying potash	42	67
% of households applying irrigation	100	100

up near 30 % of the P applied as fertilizer (Buresh *et al.*, 2010). The continuous use of organic materials does not lead to significantly higher rice yields than the judicious and balanced use of synthetic manufactured fertilizers (Dawe *et al.*, 2003).

Echinochloa colona and *Cynadon dactylon* are the most important weeds of the district (Table 2). Summer tillage is important for suppressing this weed.

Table 2. Five most common and troublesome weeds and yield of paddy in Jehanabad district

Weeds	Troublesome weeds	% HHs	Common weeds	% HHs
Weed 1	*Echinochloa colona*	70.5	*Echinochloa colona*	82.5
Weed 2	*Cynadon dactylon*	48.6	*Cynadon dactylon*	65.0
Weed 3	*Cyperus difformis*	31.7	*Leptochloa* species	39.3
Weed 4	*Echinochloa crus-galli*	19.1	*Cyperus difformis*	37.2
Weed 5	*Leptochloa* species	19.1	*Echinochloa crus-galli*	30.6

Conclusion

The main concentration on long duration varieties (LDRVs) and varieties in upper range of medium duration and adoption of full recommendation of P and K does not reflect the expected paddy yield. Delayed transplanting along with heavy infestation of weeds is the main cause of low yield. Even relatively good irrigation levels may not compensate the losses during early growth.

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3.20 Hybrid rice and improved agronomy with scale appropriate mechanization will enhance farm income in Sitamarhi district of Bihar

Rameswar Prasad[1], Pankaj Kumar[2], Prabhat Kumar[2], Randhir Kumar[1] and Sachchidanand Prasad[1]

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[2]International Maize and Wheat Improvement Center (CIMMYT)

Introduction

The agro climate zone of Sitamarhi district falls under Middle Gangetic Plain Region. Annual rainfall received is between 1100-1300 mm. Cropping intensity is 110 %. This area is generally low lying and prone to floods. Due to Bagmati river most soils are fine sandy loam which are very rich and fertile for *rabi* crops. Paddy, wheat, maize, sugarcane and lentils are the main crops of the district. Irrigation is through open wells and tube-wells. Frequent floods are seen in the district in the *kharif* season.

Methodology

In total, 30 villages were randomly selected from the 2011 census data on the basis of probability proportionate to size (PPS) method. The villages and the farmers within villages were randomized (Fig. 1) and the sample properly reflects the farmer's population in the district. Seven farmers were randomly selected from each village. They were interviewed regarding the prevailing agronomic practices for the rice crop. The randomization process makes it easy to assess the adoption pattern of different technologies in the district.

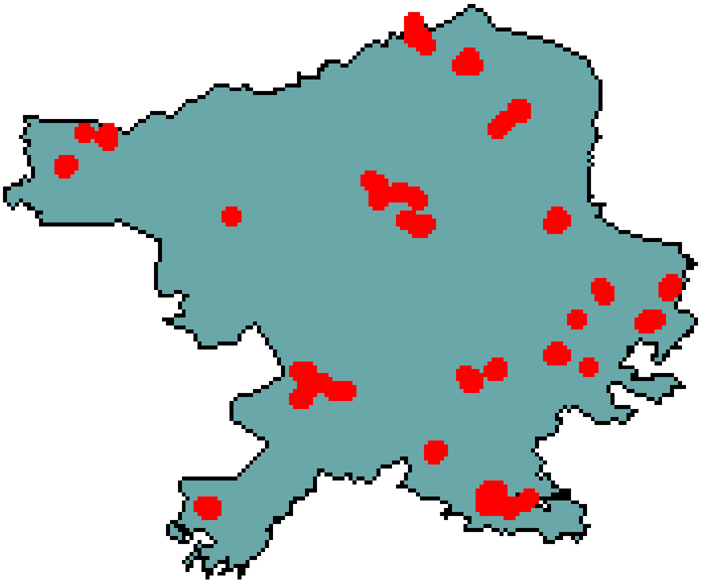


Fig. 1. Village-wise representation of surveyed area in Sitamarhi.

The questionnaire for the landscape diagnostic survey was prepared in a mobile application based digital data collection format of Open Data Kit (ODK) which is capable of transferring real time data to the server or cloud.

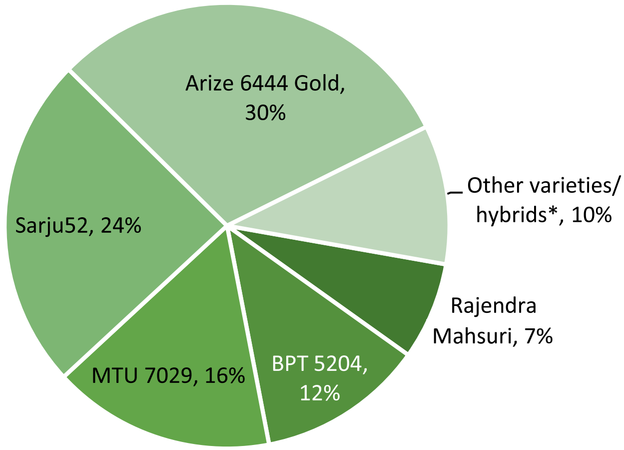
Blocks covered : Bokhara, Charaut, Runisaidpur, Bajpatti, Nanpur, Pupri, Bathnaha, Sursand, Sonbarsa, Bairgania, Parihar, Riga

Villages surveyed : Bhaur, Simari, Dhanushi, Mirjapur, Bajitpur Bhaur, Mohni, Bishunpur, Bathnaha Purvi Tola, Dhanukhi, Gadha, Latipur, Bokhara, Banauli, Bhathnaha puravi Tola, Sonbarsa, Puran Daha, Masaha Alam, Baya, Pachtaki, Bhusulwa, Parsa, Mohani Skrauli, Charaut, Bathnaha purvi Tola, Sater Jhitki, Khopi, Mohani skrauli, Rudauli, Chikna, Majhaulia, Sater jhitki, Majroha, Simri, Mohni Sakrauli, Riga and Manjroha (Fig. 1).

Results and Discussion

Data found four categories of farmers including 55 % marginal, 28 % small, 2 % medium, 14 % semi-medium farmers and 0.5 % large farmers. Rice is mostly grown in medium land (64.4 %) and lowland (35.6 %). Soils are mostly medium soil type. The dominant cropping system is rice-wheat with 72 % respondents followed by rice-fallow with 25 % respondents. The varietal spectrum is mix of hybrids Arize6444 (30 %)

followed by old varieties like MTU7029 (16 %), Sarju52 (24 %), BPT5204 (12 %) and Rajendra Mahsuri (7 %). Other 10 % HHs used other varieties listed in Fig. 2.



Other varieties/hybrids- Ankur, Jaya, Kaveri, Sarwada, Super Moti, Swarna Sub1, Bhagalpur Katarni, Pioneer 27P35

Fig. 2. Varietal spectrum of the surveyed farmers in district Sitamarhi.

The best performing cultivar was Arize 6444 with an average paddy yield of 4.99 tha^{-1} followed by MTU 7029 with 4.72 tha^{-1}. Sarju 52 was the poorest performer with 4.0 tha^{-1} (Fig. 3). Mostly old varieties released in 1980s are sustaining the yield under continued uncertain rains. There is a need to consolidate the genetic yield potential of the currently available high yielding varieties and raising the ceiling of yield through hybrid technology and new plant type varieties (Siddiq,1999).

Households who grew improved rice varieties harvested an average yield of 4.72 tha^{-1} with N at the rate 123 $kgha^{-1}$, P_2O_5 at the rate 49 and potash at the rate 30 $kgha^{-1}$ (Table 1). On an average 2.4 irrigations were applied in rice. N, P_2O_5 and K_2O were

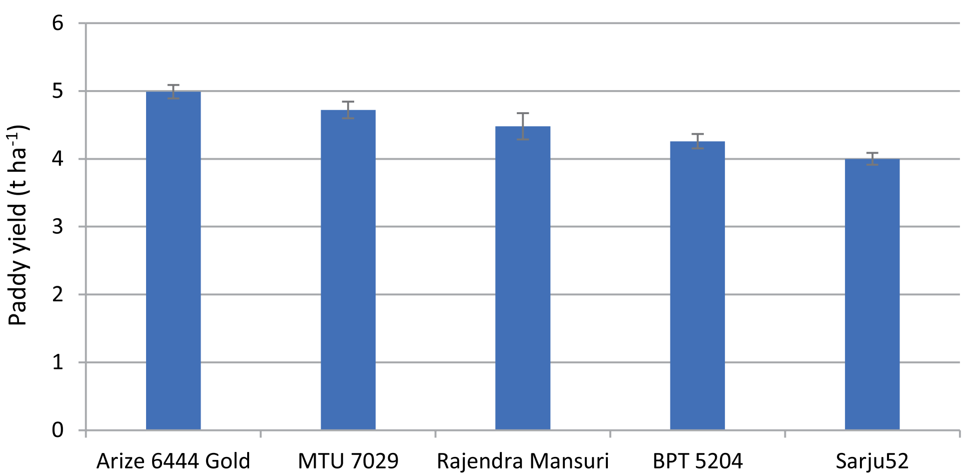


Fig. 3. Varietal performance of the surveyed farmers in the district of Sitamarhi.

Table 1. Nutrients and irrigation application pattern in improved varieties and hybrids in Sitamarhi.

Particulars	Hybrid	Improved varieties
Average yield (t ha^{-1})	4.99	4.72
Average Nitrogen application ($kgha^{-1}$)	119	123
Average Phosphorus application ($kgha^{-1}$)	51	49
Average Potash application ($kgha^{-1}$)	30	30
Average Irrigations applied	2.81	2.40
Total households	70	121
% households applying Nitrogen	100	100
% households applying Phosphorus	71.4	61.9
% households applying Potash	58.6	42.1
% of households applying Irrigation	100	100

applied by 100, 62 and 42 % HHs, respectively. HHs which grew hybrids harvested an average grain yield of 4.99 tha^{-1}. On an average, 2.81 irrigations were applied in hybrids. N, P_2O_5 and K_2O were applied by 100, 71 and 59 % HHs, respectively (Table 1).

The two most common weeds were *Echinochloa colona* with 62.3 % and *Cyperus rotundus* with 52.36 % household responding for them (Table 2). The most troublesome weeds were *Echinochloa colona* and *Cynadon dactylon* with 40.4 % and

Table 2. Five most common and troublesome weeds and yield of paddy in Sitamarhi district.

Rank	Common weeds	% HHs	Troublesome weeds	% HHs
Weed 1	*Echinochloa colona*	62.3	*Echinochloa colona*	40.4
Weed 2	*Cyperus rotundus*	52.4	*Cynadon dactylon*	34.4
Weed 3	*Scirpus juncoides*	38.7	*Cyperus difformis*	28.5
Weed 4	*Echinochloa crus-galli*	37.2	*Cyperus rotundus*	26.5
Weed 5	*Caesulia axillaris*	34.5	*Dactyloctenium aegyptium*	23.2

34.4 % respondents. In conventional tilled paddy field, with puddling of 10-15 cm is effective to control *Echinochloa* sp. and other hygrophytic weed species (Shibayama, 2001).

Conclusion

Sitamarhi district is largely represented by marginal farmers with medium (64.4 %) and lowlands (35.6 %) where 72 % HHs grow rice-wheat and 25 % rice-fallow. The varietal spectrum essentially involves three old varieties like MTU7029, Sarju52 and BPT5204 released in 1980s. Hybrids are occupying some space and may have some niche in this district. Improved agronomy including weed management and scale appropriate mechanization will further increase rice productivity and profitability of old varieties.

Reference

Siddiq, E.A (1999). Bridging rice yield gaps in India. Expert Consultation on "Bridging the Rice Yield Gap in Asia and the Pacific", held in Bangkok, Thailand, 5-7 October, 1999. http://www.fao.org/3/x6905e/x6905e09.htm.

3.21 Hybrid rice, timely transplanting and improved agronomy with scale appropriate mechanization will help increase productivity and farm-income in West Champaran, Bihar

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[2]International Maize and Wheat Improvement Center (CIMMYT)

Introduction

Soils in district West Champaran are sandy loam, clay loam and saline. It has 18 blocks, 315 gram panchayats and 1,507 revenue villages. The district has 2,71,000 ha cultivable area with a population of 3.91 million (2011 census). The cropping intensity is 145 %. The net irrigated area is 76.4 %. The total area under rice is 90,000 ha and total area under wheat is 95,000 ha. The KVK and CSISA team surveyed the farmers and studied the existing production practices followed by them.

Methodology

The crop production practices survey (CPPS) was carried out by Open Data Kit (ODK), an open-source data collection software compatible to android phones or tabs. The survey was conducted in 30 villages in West Champaran district and the villages were selected by the randomization process of probability proportionate to size (PPS). The population selected was from census data of 2011. The details of village and HHs are given in Fig. 1. The choice of questions asked from the farmers was based around agronomic practices they follow from seed to harvest. Questions asked were from the farmer's largest plot of which the geo-coordinates were recorded from the center of the plot.

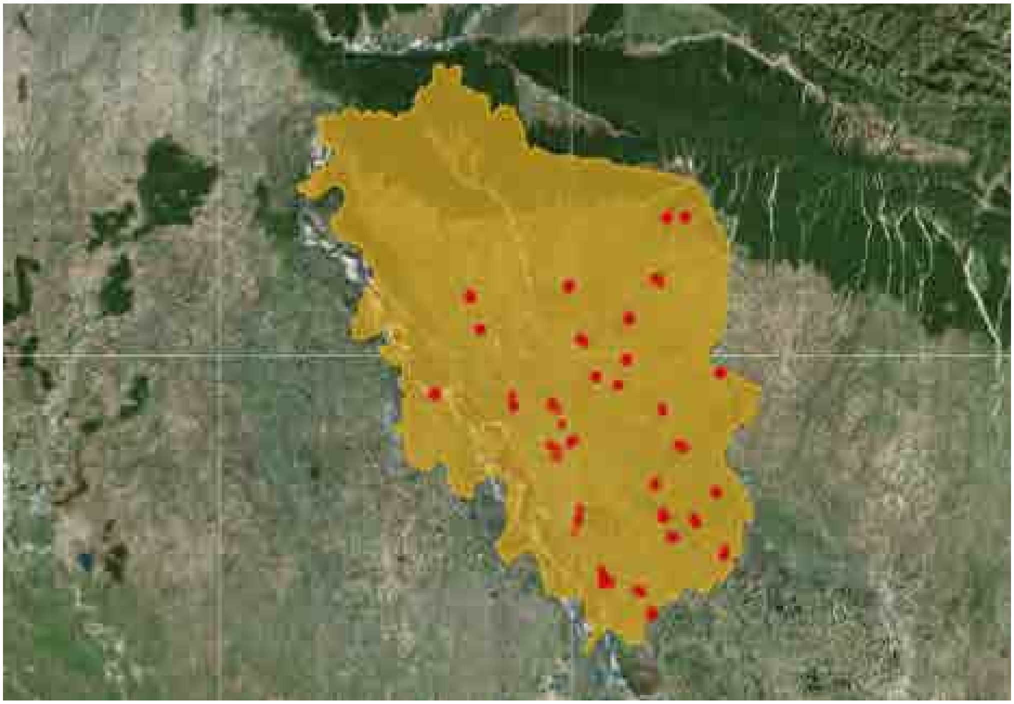


Fig. 1. Village wise representation of surveyed area in West Champaran.

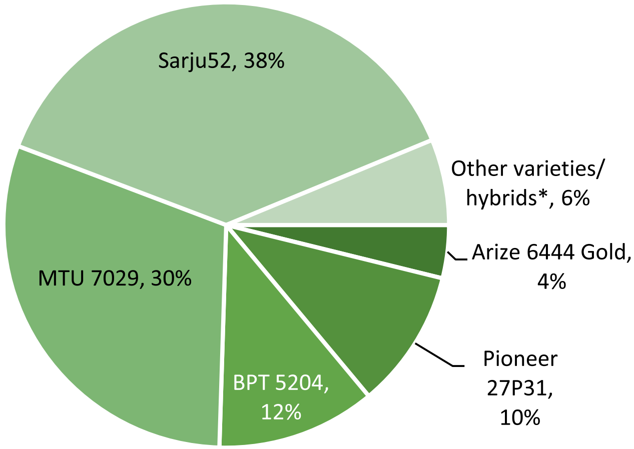
Blocks covered : Ramnagar, Majhaulia, Lauriya, Chanpatia, Narkatiaganj, Bairia, Nautan, Jogapatti, Bagaha, Madhubani, Bettiah, Gaunaha and Sikta.

Villages surveyed : Singri Murili, Harpur, Basantpur, Ghogha, Tika Chapar, Musharwa, Mansa Dubey, Sihuliya, Patjirwa, Fatuchhapar, Gahiri, Amaithiya, Patkhauli, Khairatiya, Matiyariya, Bargajwa, Ajuwa, Bahuwarwa, Piprahi, Amwaliya, Madhubani, Tesrahiya, Senuwaria, Singachhapar, Jamuniya, Kukura, Pipara pakari, Majhaulia, Parsauni Parsa and Parsa (Fig. 1).

Results and Discussion

Out of surveyed HHs, 73% were marginal, 18% small, 4% medium, 5% semi-medium and 1% large. Data from drainage class recorded showed that 73% respondents had medium land, 19% lowland, 7% upland and 0.5% very lowland. The dominant cropping system is rice-wheat with 77% respondents followed by rice-fallow with 21% HHs. The adoption of old varieties like Sarju52 (30%), MTU 7029 (30%), BPT5204 (11%) is quite common as in other districts of Bihar. The hybrid rice adoption was reported by 14% HHs (Fig. 2).

The maximum paddy yield was reported for Pioneer27P31 at (3.95 tha^{-1}) followed by MTU7029 (3.58 tha^{-1}) followed by BPT5204 and Sarju52 at 3.15 and 3.16 tha^{-1} respectively (Fig. 3). The low yield of MTU 7029 is because of late transplanting. It implies that the proper time of transplanting is necessary for optimizing the duration and time of grain filling (Khakwani *et al*., 2006).



*Other varieties/hybrids- Jaya, MTU 1001, PHB71, Rajendra Bhagwati, Rajendra Mansuri, Sonam

Fig. 2. Varietal spectrum of the surveyed farmers in district West Champaran.

Average grain yield was 3.95 tha^{-1} for hybrids and 3.58 tha^{-1} for improved varieties (Table 1). NPK applied in case of hybrids were 124:50:32 kgha^{-1} and for improved varieties it was 123 : 46 : 25 kgha^{-1}. Number of irrigations applied was 1.52 in hybrids, whereas 2.58 in improved varieties. Approximately 100% HHs applied NP and irrigation whereas K was applied by 65% in case of hybrids, and 77% farmers in case of improved varieties.

The two most common weeds were *Echinochloa colona* with 78.37% and *Cyperus rotundus* with 71.1% household responding for them (Table 2). The most troublesome weeds were *Echinochloa colona* as reported by 66.3% HHs and *Echinochloa crus-galli* by 55.77% HHs.

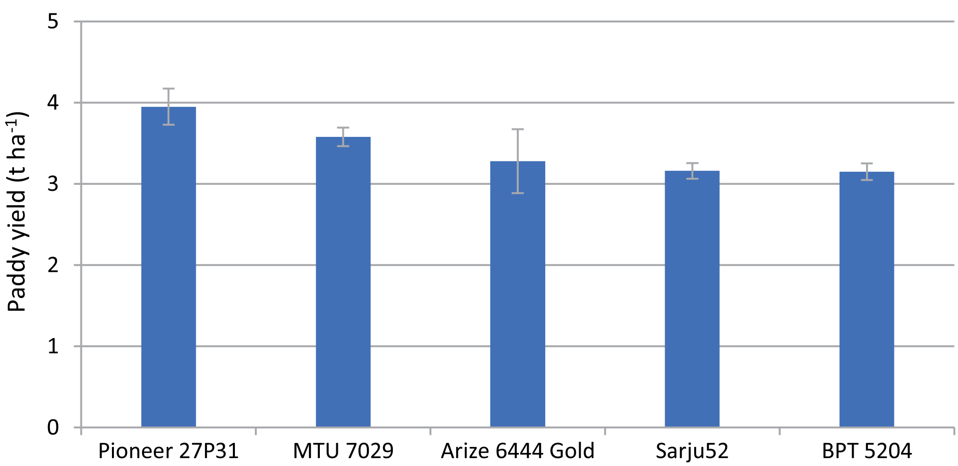


Fig. 3. Varietal performance of the surveyed farmers in district West Champaran.

Table 1. Nutrients and irrigation application pattern in Improved and Hybrids in West Champaran.

Particulars	Hybrid	Improved varieties
Average yield (tha^{-1})	3.95	3.58
Average Nitrogen application $kgha^{-1}$	124	123
Average Phosphorus application $kgha^{-1}$	50	46
Average Potash application $kgha^{-1}$	32	25
Average Irrigations applied	1.52	2.58
Total households	31	177
% households applying Nitrogen	100	98.8
% households applying Phosphorus	96.7	92.6
% households applying Potash	64.5	76.8
% of households applying Irrigation	100	100

Table 2. Five most common and troublesome weeds and yield of paddy in West Champaran district.

Rank	Common weeds	% HHS	Troublesome weeds	% HHs
Weed 1	*Echinochloa colona*	78.4	*Echinochloa colona*	66.3
Weed 2	*Cyperus rotundus*	71.1	*Echinochloa crus-galli*	55.7
Weed 3	*Echinochloa crus-galli*	67.8	*Cyperus rotundus*	52.4
Weed 4	*Fimbristylis* spp.	49.5	*Fimbristylis* spp.	39.4
Weed 5	*Scirpus juncoides*	41.3	*Cyperus difformis*	27.8

Conclusion

Data found rice-wheat was the most common rotation with 77% HHs Despite the release of so many new varieties, 68% HHs have adopted old varieties like Sarju52, MTU7029 and BPT5204 released in 1980s. Hybrids (14% HHs) are also catching interest of farmers owing to their higher yields. There is added urgency to improve the access to cheap irrigation so that farmers can adopt improved crop management including early transplanting.

Reference

Khakwani, A.A., Zubair, M., Mansoor, M., Naveed, K., Shah, I.H., Wahab, A., Ilyas, M. and Ahmed, I. (2006). Agronomic and morphological parameters of rice crop as affected by date of transplanting. *J. Agron*. 5(2) : 248-250.

3.22 Improved agronomy and inclusion of potential hybrids in the system are two key factors to raise rice productivity in Supaul district of Bihar

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[2]International Maize and Wheat Improvement Center (CIMMYT)

Introduction

The agro-climate zone of Supaul district of Bihar falls under Middle Gangetic Plain Region. Population of this district is 2.23 million. Soils are mostly sandy and coarse sandy loam type. Annual rainfall is between 1200-1300 mm. Cropping intensity is 173%. Irrigation is through canals and tube-wells. Frequent floods are seen in the district in the *kharif* season.

Methodology

In total, 30 villages were randomly selected from the 2011 census data based on probability proportionate to size (PPS) method. The villages and the farmers within villages were randomized (Fig. 1) and the sample properly reflects the farmer's population in the district. Seven farmers were randomly selected from each village. They were interviewed regarding the prevailing agronomic practices for the rice crop. The randomization process makes it easy to assess the adoption pattern of different technologies in the district.

The questionnaire for the landscape diagnostic survey (LDS) was prepared in a mobile application based digital data collection format of Open Data Kit (ODK) which is capable of transferring real time data to the server or cloud.

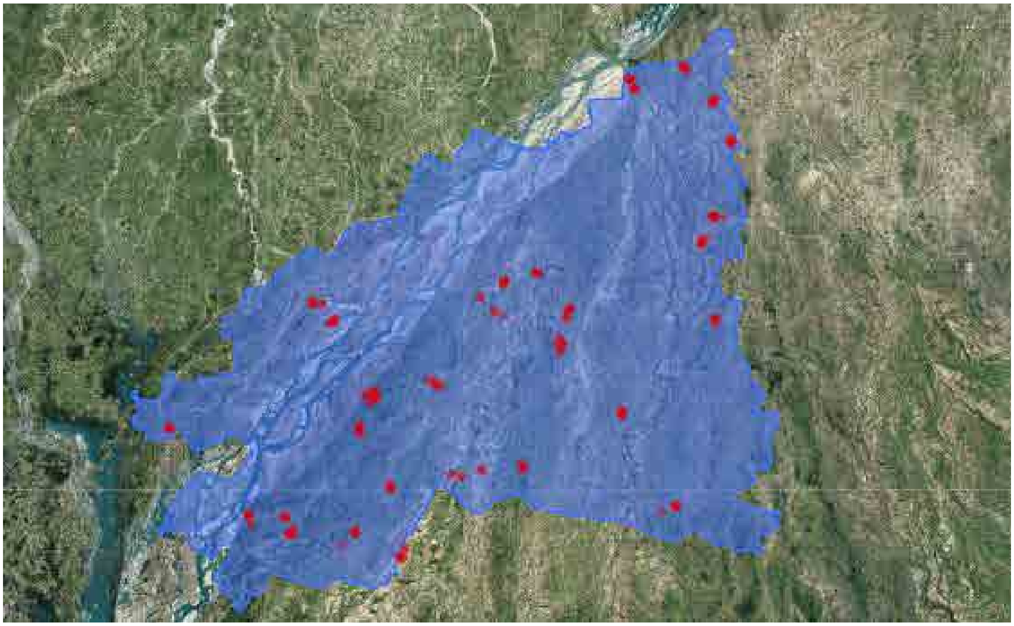


Fig. 1. Village-wise representation of surveyed area in Supaul.

Blocks covered : Basantpur, Chattapur, Kishanpur, Marauna, Nirmali, Pipra, Raghopur, Saraiganj Bhaptiyahi, Supaul, Triveniganj.

Villages surveyed : Hatwaria, Chainpur, Bela, Chandail, Piprahipatti Golari, Bairia Kamal, Parsa Madho, Hariharpur, Mohanpur, Keola, Hardi, Morauna, Jadia, Murli, Bhimnagar, Itahari, Naraenpur, Dhakhargaru, Kamalpur, Simrahi, Rasuar, Shivnagar, Bairo, Singiawan, Bishunpur, Dhurgawan, Telwa, Orlaha, Amha, Mahesua, Bina, Kishunpur and Khokhaha (Fig. 1).

Results and Discussion

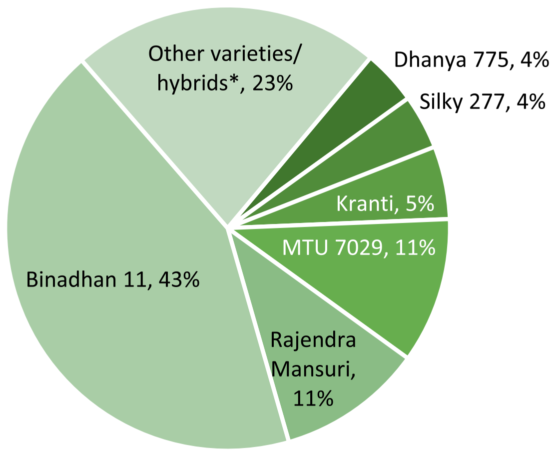
There were 63% marginal, 20% small, 3% medium and 13% semi-medium farmers based on the surveyed data. Data show that 62.3% respondents had medium land, 22.5% lowland and 15.2% to be upland. The dominant cropping system was rice-wheat with 95% respondents. This district has its own varietal preference with the dominance of Binadhan11 (43% HHs) . The second preference is for Rajendra Mahsuri and MTU 7029 with 10.6% HHs in each case. Rest of HHs have mix of varieties and hybrids (Fig. 2).

The highest paddy yield was reported from Dhanya775 at 4.25 tha^{-1} followed by Rajendra Mahsuri and MTU7029 at 3.4 tha^{-1}, respectively. Binadhan11, Kranti and

Silky227 were found to have yield in the range of 3.0 to 3.4 tha^{-1} (Fig. 3).

Grain yield recorded for hybrid was 4.25 tha^{-1} whereas for improved varieties it was 3.4 tha^{-1} (Table 1). The average NPK applied for hybrid was 124 : 64 : 35 $kgha^{-1}$ and for improved varieties, it was 117 : 51 : 26 $kgha^{-1}$ and irrigation applied was 2.92 and 3.12, respectively.

The two most common weeds were *Echinochloa colona* with 87% and *Cynadon dactylon* with 74% households responding for them (Table 2). The most troublesome weeds were *Echinochloa colona* and *Cynadon dactylon* as reported by 61 and 52% HHs, respectively. These two weeds are more common in dry conditions in upland crops (Kent *et al.*, 2001) and *Cynadon dactylon* is tolerant to drought.



*Other varieties/hybrids- Gutraj, Kaveri, Nano, PHB71, Pioneer 27P31, Rajendra Shweta, Sabour Shresth, Sarju52, Shriram 505, Shushk Samrat, Sita, SukhaDhan, Swarna Sub1, Binadhan10, JK-Dhanyarekha, Ranjit, Sufala, Arize 6444

Fig. 2. Varietal spectrum of the surveyed farmers in district Supaul.

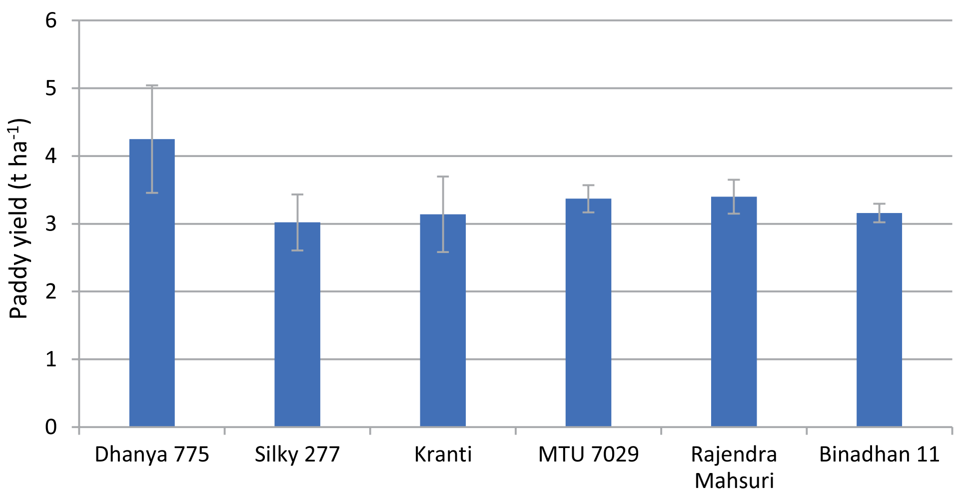


Fig. 3. Varietal performance of the surveyed farmers in district Supaul.

Table 1. Nutrients and irrigation application pattern in improved varieties and hybrids in Supaul.

Particulars	Hybrid	Improved varieties
Average yield (tha^{-1})	4.25	3.40
Average Nitrogen application ($kgha^{-1}$)	124	117
Average Phosphorus application ($kgha^{-1}$)	64	51
Average Potash application ($kgha^{-1}$)	35	26
Average Irrigations applied	2.92	3.12
Total households	13	135
% households applying Nitrogen	100	98.5
% households applying Phosphorus	100	97.8
% households applying Potash	100	94.8
% of households applying Irrigation	100	100

Table 2. Five most common and troublesome weeds of paddy in Supaul district.

Rank	Common weeds	% HHS	Troublesome weeds	% HHs
Weed 1	*Echinochloa colona*	87	*Echinochloa colona*	61
Weed 2	*Cynadon dactylon*	74	*Cynadon dactylon*	52
Weed 3	*Cyperus difformis*	67	*Cyperus difformis*	43
Weed 4	*Cyperus rotundus*	67	*Cyperus rotundus*	40
Weed 5	*Echinochloa crus-galli*	57	*Dactyloctenium aegyptium*	35

Conclusion

Supaul district of Bihar is dominated by marginal farmers and the landscape is mainly medium land (62%) and lowland (22.5%). Rice-wheat is the predominating cropping system in the district with 95% HHs. Binadhan 11 is the dominant variety but the paddy yield is low at 3.4 tha^{-1}. Weed spectrum is dominated by low growing weeds like *Echinochloa colona* and *Cynadon dactylon* which would need focused attention on summer tillage and puddling.

Reference

Kent, R, Johnson, D.E. and Becker, M. 2001. The influences of cropping system on weed communities of rice in Côte d'Ivoire, West Africa. *Agriculture, Ecosystem and Environment* 87 : 299-307.

3.23 Hybrid rice technology broadens the prospective by better yield of paddy in district Saran, Bihar

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[1]Krishi Vigyan Kendra, Saran, Bihar
[2]International Maize and Wheat Improvement Center (CIMMYT)

Introduction

Saran district lies between 25°36” and 26°13” N latitude and 84022” and 85012” E longitude at an altitude of 36 m amsl. It lies in the middle-Gangetic Plains with subtropical climate characterized by hot summer, wet monsoon, and dry winter. The average annual rainfall is 1,140 mm. The total cropped area in the district is 232,691 ha. The net sown area is 192,285 ha and 40,406 ha of land is sown more than once. The temperature varies from 10 to 35°C but during summer the temperature may go up to 45°C or even more with hot westerly winds from March to June. The landscape diagnostic survey (LDS) was conducted to measure inventory of recommendations and use analytics to identify issues and set priorities.

Methodology

Villages (30) were randomly selected from the 2011 census data based on probability proportionate to size (PPS) method. The villages and the farmers within villages were randomized (Fig. 1) and the sample properly reflects farmers' population in the district. Seven farmers were randomly selected from each village. They were interviewed regarding the prevailing agronomic practices for the rice crop. The randomization process makes it easy to assess the adoption pattern of different technologies in the district.

The questionnaire for the landscape diagnostic survey was prepared in a mobile application based digital data collection format of Open Data Kit (ODK), which can transfer real time data to the server or cloud.

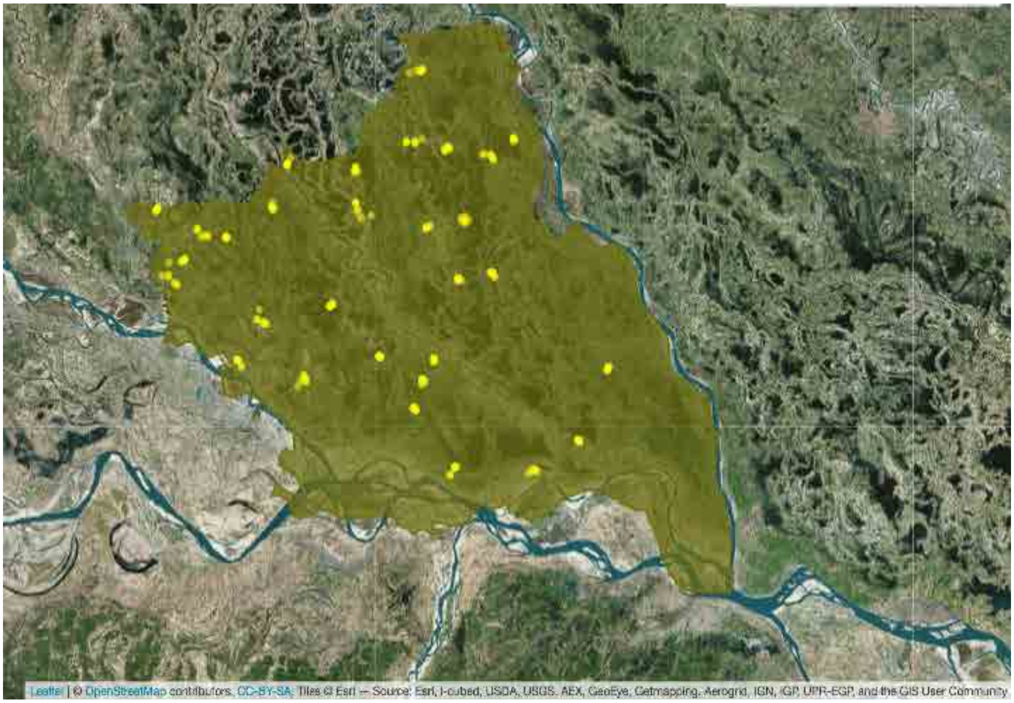


Fig. 1. GPS points of surveyed farms in Saran.

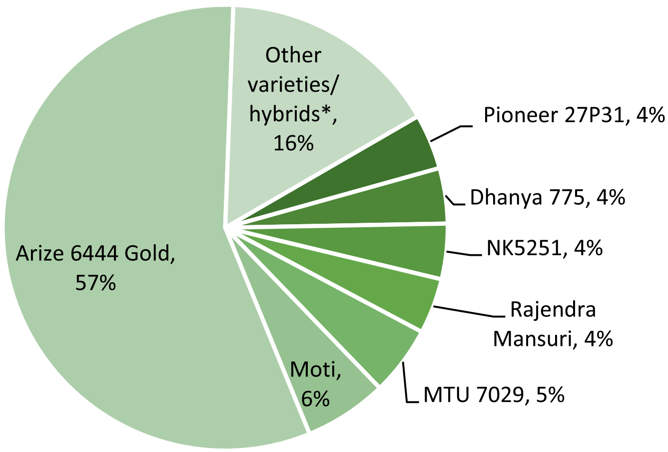
Blocks covered : Mashrakh, Ishuapur, Marhaura, Chapra, Nagra, Ekma, Manjhi, Baniapur, Jalalpur, Lahladpur, Dighwara, Dariapur and Taraiya.

Villages surveyed : Pachkhanda, Galimapur, Agauthar Nanda, Silhauri, Badlu Tola, Lohari, Takiya, Rith, Darwa, Dumari, Jaitapur, Najba, Dhangaraha, Dohar, Kopa, Nawada, Bhajuna, Mahammadpur, Kishunpur Lauwar, Jhaua, Dharampur, Padmaul, Khanpur, Natha Chapra, Usari, Fuchati Kala, Rasulpur and Kharauni (Fig. 1).

Results and Discussion

More than 54 % of the cultivable area is covered by wheat in *rabi* and 36 % by paddy in *kharif*. The data from the LDS very clearly showed that majority of farmers (95 %) fell in the small and marginal category whereas the rest 5 % fell in medium and semi-medium category. The drainage class data revealed that the major existing drainage class was medium land with 58.8 % respondents followed by upland and lowland with 22.1 and 19.1 % respondents, respectively. The soil texture data for the surveyed farmers showed that 69.3 % farmers had rice fields with medium soil, 13.1% with heavy and 17.6% with light soil. Rice-wheat is the major cropping system.

The share of hybrids as a whole in the varietal spectrum is more than 75% with Arize 6444 being preferred by 57% HHs (Fig. 2). This shift seems to reflect a response towards water stress during one or the other stage of crop growth. Better scope of intensification may also have contributed for preference of farmers towards hybrids.



Other Varieties/hybrids- JK 401, MTU 1001, BPT 5204, Sonali, Mahima Gold, Pioneer 27P63, Rupali Sonam, US 312, Gangotri, Moti Gold

Fig. 2. Varietal spectrum favours hybrids in district Saran.

The trends indicated that interests of farmers did not necessarily align with scientists' interest while accepting varieties or hybrids. Hybrids provided better yields than inbreds in rice (Khalifa, 2009).

The data on varietal performance revealed that Rajendra Mahsuri and NK5251 had yield advantage over MTU7029 due to better agronomic management (Fig. 3).

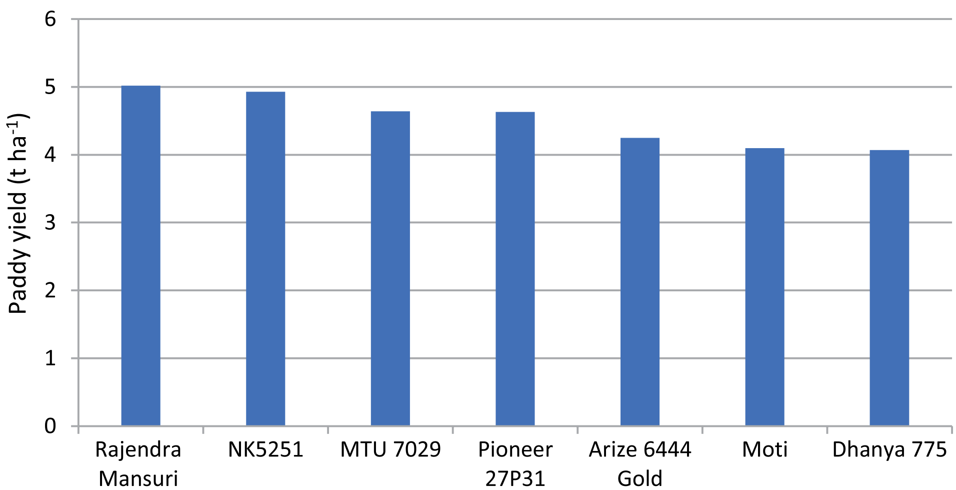


Fig. 3. Paddy yield of different improved varieties and hybrids in district Saran.

Moreover, in Saran district lot of area is with lowland ecologies where the performance of long duration varieties is better than hybrids. The availability of several competing hybrids like NK 5251 or Pioneer 27P31 with better yield than that of Arize 6444 is a good sign. The more the rice hybrids the more the choices for farmers.

Delay in paddy transplanting caused a slight decline in yield due to a short window of transplanting in July. Similar trend of yield decline was realized for hybrids as well as varieties (Fig. 4). This also hints at the fact that there is a general trend of delayed transplanting, hybrids or medium duration varieties are better option than long duration varieties.

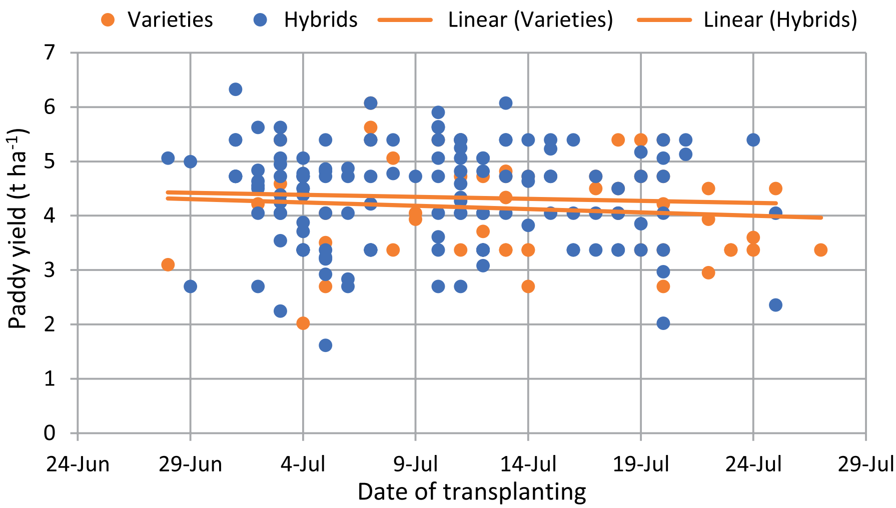


Fig. 4. Effect of dates of transplanting on paddy yield in district Saran.

In Saran, the number of HHs applying P and K is higher in hybrids but the N application is same both in hybrids and varieties. N application at paddy yield of 4.1 to 4.3 tha^{-1} is on the higher side (Table 1). The efficiency of N must be improved (Bowman *et al.,* 2009) and the use of P and K must be revisited in hybrids. In RWCS, data also signals the need for using P in one crop, preferably in wheat not always in rice. This warrants further research.

Cynadon dactylon and *Cyperus rotundus* two troublesome weeds, perennial in nature, grow in rice (Table 2) because of relatively low yields in this district. There is no alternative of bispyribac-sodium against complex weed flora dominated by *Cyperus rotundus*.

Table 1. Nutrients and irrigation application pattern in hybrids and improved varieties in Saran.

Particulars	Hybrids	Improved varieties
Average yield (tha^{-1})	4.34	4.1
Average nitrogen application ($kgha^{-1}$)	139.8	135.7
Average phosphorus application ($kgha^{-1}$)	59.1	56.2
Average potash application ($kgha^{-1}$)	33.1	34.0
Average irrigations applied	3.1	2.7
Total households	145	54
% households applying nitrogen	144	54
% households applying phosphorus	116	39
% households applying potash	88	18
% households applying irrigation	145	54

Table 2. Five most common and troublesome weeds affecting yield of paddy in Saran district.

Rank	Troublesome weed	% HHs	Common weed	% HHs
Weed 1	*Echinochloa colona*	74.5	*Echinochloa colona*	79.5
Weed 2	*Cyperus rotundus*	56.5	*Cyperus rotundus*	72.0
Weed 3	*Cyperus difformis*	44.5	*Cynadon dactylon*	62.5
Weed 4	*Echinochloa crus-galli*	36.5	*Cyperus difformis*	61.5
Weed 5	*Caesulia axillaris*	31.5	*Echinochloa crus-galli*	55.0

Conclusion

The varietal spectrum is dominated by hybrids with similar paddy yield to that reported from long duration varieties. The preference for hybrids may resolve the genuine problem of late transplanting, water stress and climate change with little or no yield penalty. The access to low cost irrigation needs improvement for long-term yield gains and improved crop management.

References

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Khalifa, A. A. B. A. (2009). Physiological evaluation of some hybrid rice varieties under different sowing dates. *Australian Journal of Crop Science*. 3(3) : 178-183.

3.24 Hybrids and old varieties dominate the rice cultivation in Sheohar district of Bihar

Ram Niwas Singh[1], Prabhat Kumar[2], Rajendra Prasad[1] and Manoj Kumar[1]

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[2]International Maize and Wheat Improvement Center (CIMMYT)

Introduction

Sheohar is the smallest district of Bihar with an area of 0.65 million ha. The district is situated between 26°33’ N latitude and 85°17’ E longitude. The soil type is fine sandy loam to saline calcareous. The cropping intensity is 145%. The net irrigated area is 45%. The total area under rice remains around 20,000 ha and wheat 17000 ha. Other crops include sugarcane, maize, pulses and oilseeds.

The aim of this survey was to understand the expectations of farmers and build these expectations in research and extension.

Methodology

The Landscape Diagnostic Survey (LDS) was carried out by Open Data Kit (ODK) in open source data collection software compatible to android phones or tabs. The survey was conducted in 30 villages in Sheohar district which were selected by the randomization process of probability proportionate to size (PPS). The details of village and household level randomization are given in Fig. 1. Most of the questions asked were from the farmer’s largest plot of which the geo-coordinates were recorded from the center of the plot. The district represents rice-wheat cropping system (RWCS) as a major cropping system.

Blocks covered : Sheohar, Dumari Katsari, Piprahi, Purnahiya and Tariyani Chowk.

Villages surveyed : Garahiya, Kushhar, Bishunpur Maniyari, Harnahi, Chamanpur, Kanwani Kalyanpur, Singahi Indarwa, Narkatia Bandobasti, Bakhar Chandiha,

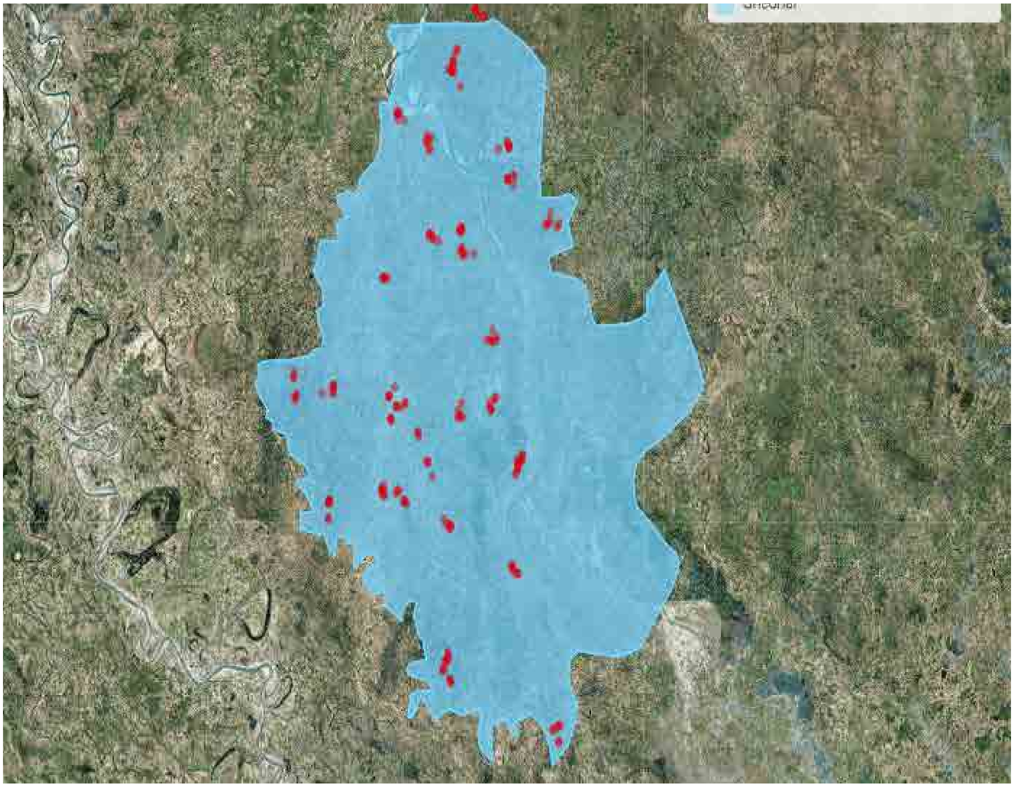


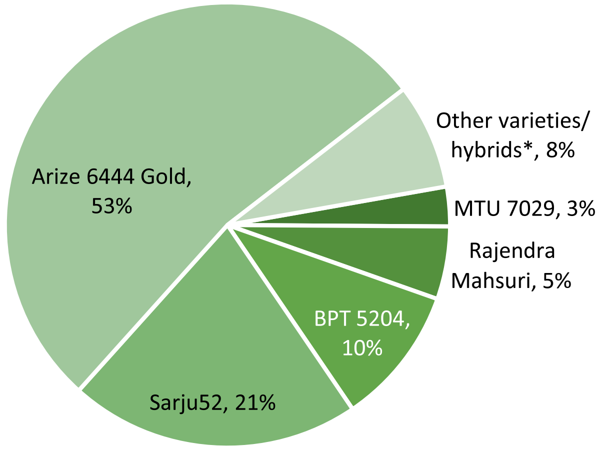
Fig. 1. Village wise representation of surveyed area in Sheohar.

Shyampur, Pachara Ghot, Madhopur anant, Sultanpur Bhim, Kishanpur, Hirauta, Duma, Kamrauli Jangali, Ghorha Punarwas, Naya Gaon, Tajpur, Maksudpur Karaiya, Kishunpur Narwara, Jagdispur Kotiya, Phulkaha, Chiraiya, Barahi Mohan, Bairia, Mesauda, Ashopur and Sankarpur Bindhi (Fig. 1).

Results and Discussion

There were 61% marginal, 28% small, 0.4% medium, 10% semi-medium farmers and 0.5% large farmers based on the surveyed data. Data from drainage class recorded reveals that 87% respondents having medium land, 5% upland and 9% lowland. Data on soil texture revealed that 80% of plots were with medium, 20% with light and rest 0.5% with heavy soil type. The dominant cropping system was rice-wheat with 76% respondents, followed by rice-fallow with 16%. Data on varietal spectrum showed that almost 53% farmers cultivated hybrid rice Arize 6444 (52.9%) followed by most common variety Sarju (21%), BPT5204 (10%), Rajendra Mahsuri (5%) and MTU7029 (3%), and 7% farmers used other varieties which included Jaya, JK401, PHB71, Pioneer 27P63, Rajshree, Sankar, Pioneer27P31, Sonam and Dhanya7755 (Fig. 2).

The best performing cultivated variety was MTU 7029 with an average grain yield of 4.27 tha^{-1} followed by Arize 6444 with 4.09 tha^{-1}, while Sarju 52 recorded the lowest yield with 3.76 tha^{-1} (Fig. 3). Since drought like situation is a major problem (Lafitte *et al.*, 2006), hybrids should be promoted in the district.



Other varieties/hybrids- Jaya, JK 401, PHB71, Pioneer 27P63, Rajshree, Sankar, Pioneer 27P31, Sonam, Dhanya775

Fig. 2. Varietal spectrum of the surveyed farmers in district Sheohar.

There was yield decline in case of varieties with respect to delay in transplanting date. Most of the transplanting date concentrated in between 1-15 July (Fig. 4).

Average NPK applied in case of hybrids were 131 : 52 : 29 whereas in improved varieties it was 142 : 51 : 30 fetching grain yield of 4.9 and 4.3 tha^{-1}, respectively. The grain yield, NPK and irrigation application for both hybrids and improved varieties were at par (Table 1).

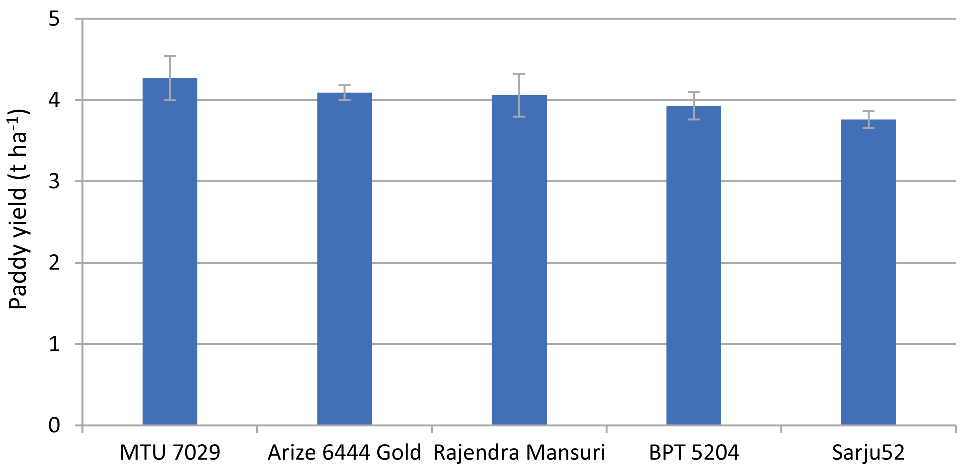


Fig. 3. Varietal performance of the surveyed farmers in district Sheohar.

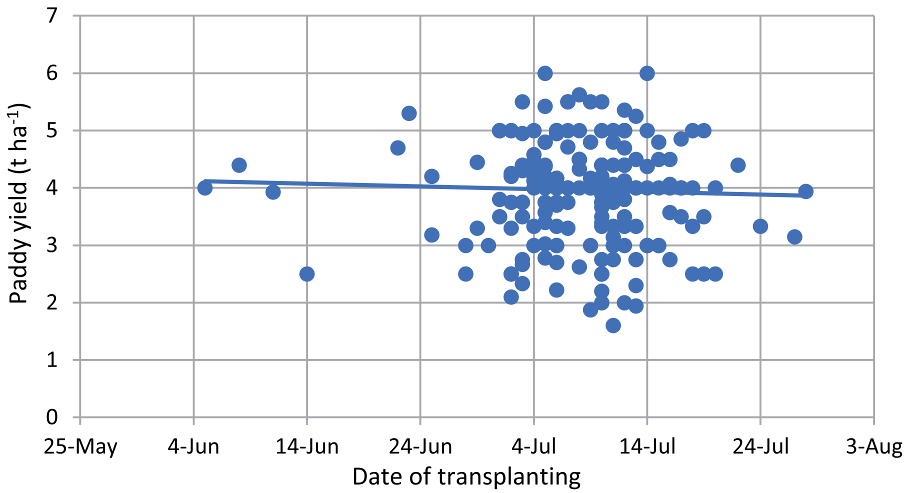


Fig. 4. Effect of dates of transplanting on paddy yield in district Sheohar.

Table 1. Nutrients and irrigation application pattern in improved varieties and hybrids in Sheohar

Particulars	Hybrids	Improved varieties
Average yield (t ha^{-1})	4.9	4.3
Average Nitrogen application	131	142
Average Phosphorus application	52	51
Average Potash application	29	30
Average Irrigations applied	2.36	2.40
Total households	121	87
% households applying Nitrogen	100	100
% households applying Phosphorus	96.7	3
% households applying Potash	71.1	71.3
% of households applying Irrigation	100	100

The two most common weeds were *Echinochloa colona* with 81.7% and *Cyperus rotundus* with 76.9% households responding for them. The most troublesome weeds were *Echinochloa colona* and *Cyperus rotundus* with 66.8 and 55.2% respondents, respectively (Table 2).

Table 2. Five most common and troublesome weeds and yield of paddy in Sheohar district

Rank	Common weeds	% HHs	Troublesome weeds	% HHs
Weed 1	*Echinochloa colona*	81.7	*Echinochloa colona*	66.8
Weed 2	*Cyperus rotundus*	76.9	*Cyperus rotundus*	55.3
Weed 3	*Scirpus juncoides*	66.8	*Scirpus juncoides*	46.6
Weed 4	*Cyperus difformis*	60.1	*Echinochloa crus-galli*	37.5
Weed 5	*Cynadon dactylon*	53.4	*Cyperus difformis*	36.5

Conclusion

Sheohar district of Bihar is dominated by marginal farmers with medium lands. Data show the dominance of hybrids and it could be useful by a turning point in improving the productivity of rice-wheat cropping system. The timely transplanting until mid-July is very important to attain higher productivity.

Reference

Lafitte, H.R., Z.K. Li, C.H.M. Vijayakumar, Y.M. Gao, Y. Shi, J.L. Xu, B.Y. Fu, S.B. Yu, A.J. Ali, J. Domingo, R. Maghirang, R. Torres, and D. Mackill (2006). Improvement of rice drought tolerance through backcross breeding : evaluation of donors and selection in drought nurseries. *Field Crops Res*. 97 : 77-86.

3.25 Hybrid rice along with improved irrigation and fertilizer management is the key for higher productivity in Muzaffarpur district of Bihar

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[3]International Rice Research Institute (IRRI)

Introduction

District Muzaffarpur of Bihar falls in agro-climatic zone I (Northern-West) and comprise 16 blocks and 1,811 villages. The total geographical area is 3,17,591 ha. Total cultivable area in the district is 2,47,721 ha and net sown area is 2,19,963 ha, whereas 82,964 ha is irrigated. The overall land situation in the district is 58,825 ha upland, 83,778 ha medium land and 72, 212 ha lowland.

Methodology

In total, 30 villages were randomly selected from the 2011 census data based on probability proportionate to size (PPS) method. The villages and the farmers within villages were randomized (Fig. 1) and the sample properly reflects the farmers' population in the district. Seven farmers were randomly selected from each village. They were interviewed regarding the prevailing agronomic practices for the rice crop. The questionnaire for the landscape diagnostic survey was prepared in a mobile application based digital data collection format of Open Data Kit (ODK) which can transfer real time data to the server or cloud.

Blocks covered : Saheganj, Motipur, Bandra, Salrav, Puroo, Saraiya, Kudhani, Kanti, Morwan, Minapur, Mushahri, Bochahan, Aurai, Katra, Gaighat and Muraul.

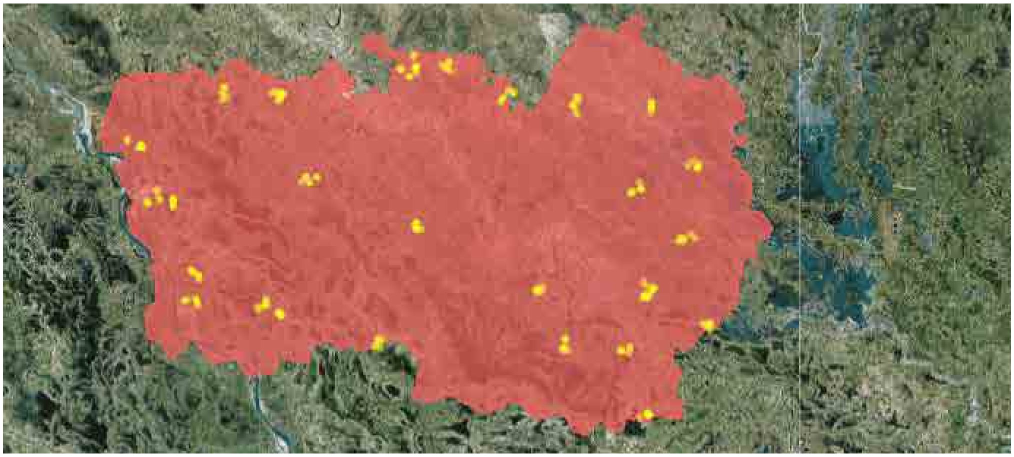
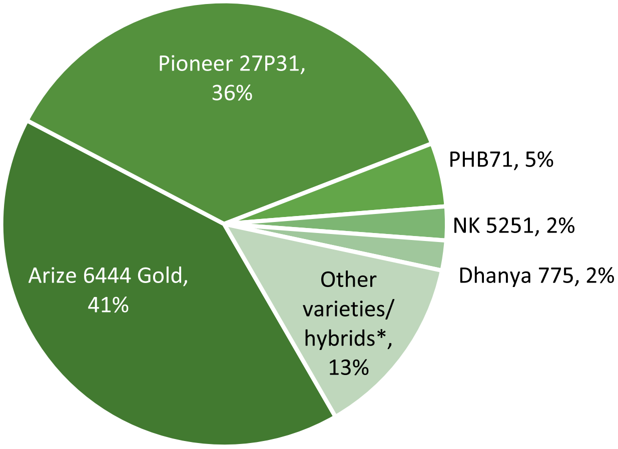


Fig. 1. GPS points of surveyed farms in Muzaffarpur district, Bihar.

Villages surveyed : Bahilwara, Chaturshi, Tengharhi, Belahi Lacchi, Jarang Dih, Bisanpurmehsi, Dihjiwar, Dhasna, Bangara Nizmat, Prahladpur, Baghakhal, Gyaspur, Thikaho, Bariyarpur, Kuahin, Husepur rati, Dubuali, Puran Pakri Rampur Rattan, Laxmipur arar, Susta, Narsinghpur, Katra, Bagahi, Pandeh, Chakbajo, Rajepur and Sukhwara (Fig. 1).

Results and Discussion

The survey data showed that all farmers followed rice-wheat cropping system. Data showed that 63.6% of farmers fell in the category of marginal farmers based on landholding size, 22.0% in small, 10.6 in semi-medium and 3.8% in medium category. Data further showed that 84% HHs had medium land, 12.8% low and 3.3% as upland. The soil texture was 92.9% medium soil type, 6.4% light and 2.4% heavy. It is clear from the data on varietal spectrum (Fig. 2) that 41.03% of HHs preferred



*Other varieties/hybrids- Arize 6129, Bhasar, Kaveri, MP3030, MTU 7029, Pusa Sugandh5, Sukha Dhan2, Arize Tez, Kranti, Rajshree, Dhusri, Rajendra Mansuri, Bakoui, Pioneer 27P37, JK 401, Rajendra Bhagwati, Rajendra Shweta, Sarju 52

Fig. 2. Varietal spectrum of rice varieties/hybrids based on the data of surveyed farmers.

hybrid Arize6444 followed by 36.41% of Pioneer 27P31, 4.62% HHs grew PHB71, 2.45% NK5251, 2.71% Dhanya775 and 13.31% grew a few varieties/ hybrids. Similar spread of hybrids rice in irrigated (Janaiah and Hossain, 2003) and in a drought-like situation (Villa *et al*., 2012) has been reported earlier.

It is evident from the data (Fig. 3) that among the five most preferred hybrids, Pioneer 27P31 and PHB71 were at par with 3.64 and 3.63 tha^{-1} of paddy yield, followed by Arize 6444 with 3.5 tha^{-1}, NK5251 at 3.42 and Dhanya775 with 3.35 tha^{-1}.

There was not much correlation seen with respect to date of transplanting and yield as most of the data points concentrated in between 1-30 July, however, still more peaks were visible around mid-July (Fig. 4). This is because of more hybrids in the system.

The farmers who grew improved varieties harvested 3.6 tha^{-1}, whereas those who grew hybrids harvested 3.0 tha^{-1}. There was less use of N in case of hybrids i.e. 105 kgha^{-1}, whereas in case of improved varieties it was 127 kgha^{-1}. Phosphorus and potassium use was almost at par to state recommendation (Table 1).

Among five top most troublesome weeds infesting rice crop in Muzaffarpur (Table 2), 60.3% HHs indicated *Cyperus difformis* as the most serious weed (rank 1) closely followed by *Echinochloa colona* ranking 2 (53.8% HHs), *Caesulia axillaris* (rank 3; 48.6% HHs), *Echinochloa crusgalli* (rank 4; 45.4% HHs) and *Cyperus rotundus* (rank 5; 42.9% HHs). Among top five common weeds of transplanted rice crop were, *Echinochloa colona*, *Caesulia axillaris, Cynadon dactylon, Cyperus rotundus* and *Cyperus difformis* reported by 88.8, 75.3, 70, 68.7 and 66.0% HHs, respectively.

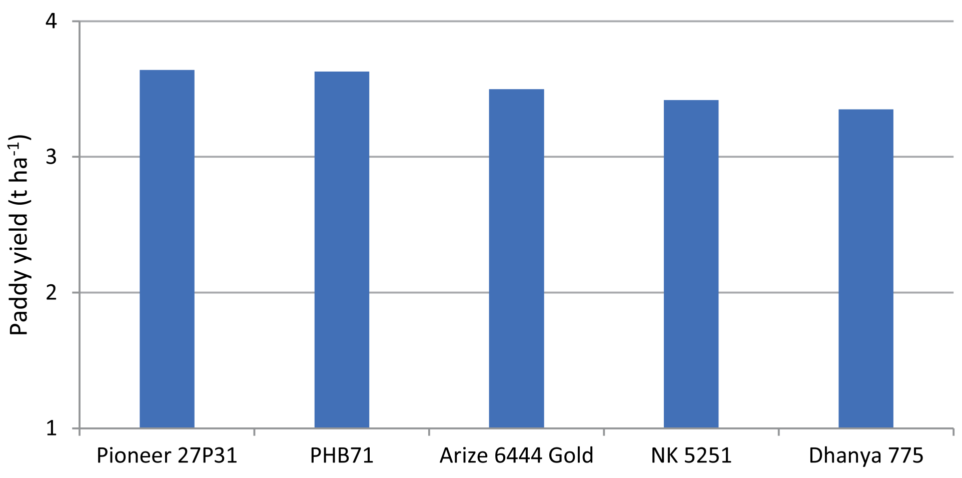


Fig. 3. Performance of the most preferred rice varieties and hybrids in Muzaffarpur.

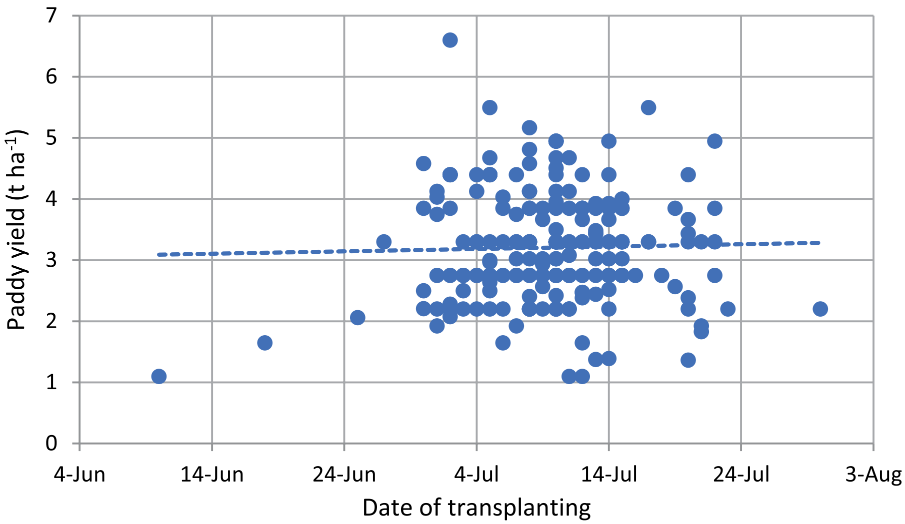


Fig. 4. Effect of time of transplanting on grain yield of rice varieties/hybrids (n=210).

Table 1. Nutrients and irrigation application pattern in varieties and hybrids in Muzaffarpur

Particulars	Improved varieties	Hybrids
Average yield (t ha^{-1})	3.6	3.0
Average nitrogen application kgha^{-1}	127	105
Average phosphorus application kgha^{-1}	54	52
Average potash application kgha^{-1}	32	31
Average no. of irrigations applied	3.41	2.54
% households applying nitrogen	98.8	100
% households applying phosphorus	90.6	82.1
% households applying potash	45.9	64.3
% of households applying irrigation	100	100

Table 2. Top five troublesome and common weeds in Muzaffarpur.

Rank	Troublesome weeds	% HHs	Common weeds	% HHs
Weed 1	*Cyperus difformis*	60.3	*Echinochloa colona*	88.8
Weed 2	*Echinochloa colona*	53.8	*Caesulia axillaris*	75.3
Weed 3	*Caesulia axillaris*	48.6	*Cynadon dactylon*	70.6
Weed 4	*Echinochloa crus-galli*	45.4	*Cyperus rotundus*	68.7
Weed 5	*Cyperus rotundus*	42.9	*Cyperus difformis*	66.0

Conclusion

Majority of farmers (>99%) in Muzaffarpur district of Bihar follow rice-wheat cropping system and is dominated by marginal farmers with medium lands (84%). This district has its own preferences with the dominance of hybrids. This technology need to be leveraged with better agronomic management with a push for access to cheap irrigation at transplanting time.

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3.26 Varietal spectrum marks beginning of hybrids and medium duration varieties in Nalanda district

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[3]Krishi Vigyan Kendra, Lakhisarai, Bihar

Introduction

The district of Nalanda is situated at 24°15'N to 25°27'N and 85°10'E to 85°56'E. The total geographical area is 2.34 thousand hectare of which 1.81 thousand hectares is cultivable. The soil type is majorly sandy loam to clay loam. The average annual rainfall is 904 mm. The major cropping systems include – rice-potato and vegetables, rice-pulses and rice-wheat. Owing to increase in electricity facilities, the district has potential for sustainable intensification and diversification of cropping systems. Evidence of differentiated adoption patterns of diversified cropping system demands resetting priorities based on the demand from farmers rather than supply based on top-down approach. The KVK in collaboration with CSISA Project, therefore, conducted landscape diagnostic survey (LDS) to support the future needs of intensified cropping system in the district.

Methodology

Villages (30) were randomly selected from the 2011 census data based on probability proportionate to size (PPS) method. The villages and the farmers within villages were randomized (Fig. 1) and the sample properly reflects farmers' population in the district. Seven farmers were randomly selected from each village. They were interviewed regarding the prevailing agronomic practices for the rice crop. The randomization process makes it easy to assess the adoption pattern of different technologies in the district.

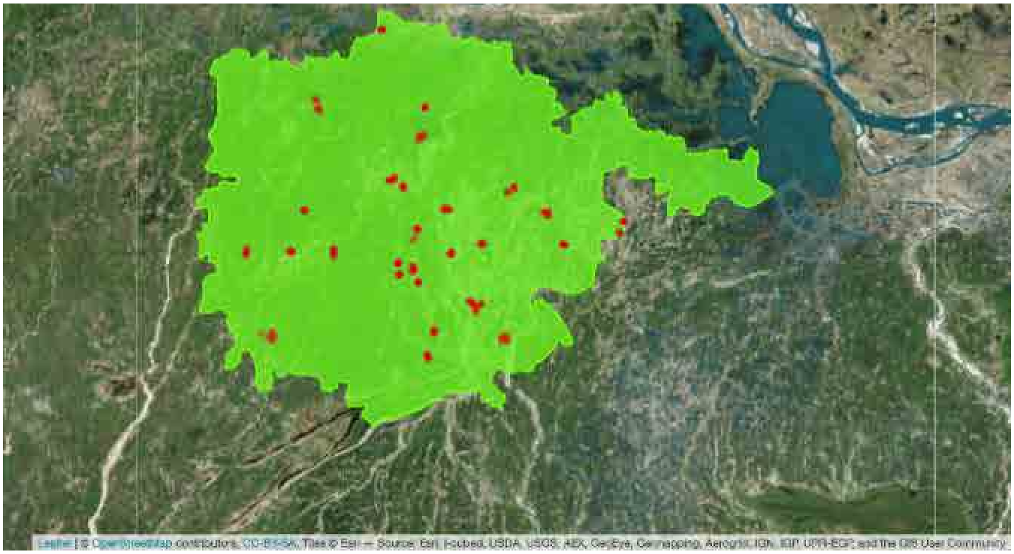


Fig. 1. GPS points of surveyed wheat farms in Nalanda.

The questionnaire for the landscape diagnostic survey was prepared in a mobile application based digital data collection format of Open Data Kit (ODK), which can transfer real time data to the server or cloud.

Blocks covered : Asthawan, Bihar, Chandi, Noorsarai, Giriak, Islampur, Nagar Nausa, Silao, Ekangsarai, Harnaut, Prabalpur, Rahui and Tharthari.

Villages surveyed : Asthawan, Bada Khurd, Bakra, Bhobhi, Bauridih, Chorsua, Gobindpur, Jiar, Khetalpura, Khorampur, Mohammadpur, Mohsinpur, Mustafapur 1, Mustafapur 2, Narari, Ghustawan, Pachauri, Shahpur, Shivnagar, Surajpur, Takiakalan, Jagdishpur Tiari, Jiar, Khakhra, Khorampur, Lodhipur, Muragawan, Pyarepur, Utra and Uttarnawan (Fig. 1).

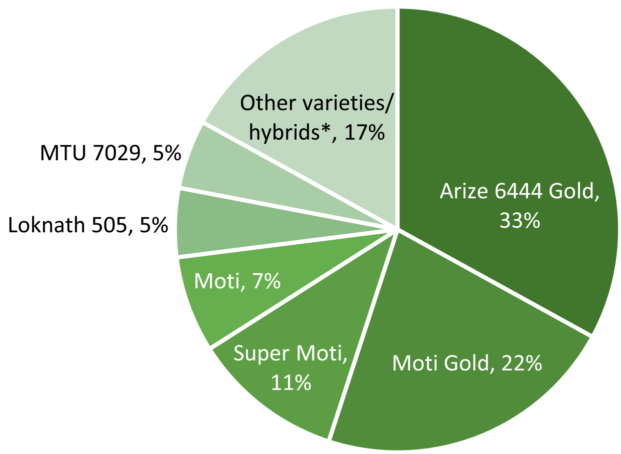
Results and Discussion

The data from the ODK based survey showed that 64% of HHs were marginal farmers, 25% small, 7% semi-medium and 4% medium farmers. The drainage class of the surveyed plots showed that 98.15% were having rice sown on medium land and 1.5% on lowland. Based on the soil texture 99.5% farmers plots were having medium type of soil and 0.5% heavy type. The cropping system is dominated by rice-wheat with 91.3% respondents.

The varietal spectrum data showed that 33% cultivated Arize 6444 Gold, 22% Moti Gold, 11% Super Moti, 7% Moti and 5% each Loknath 505 and MTU 7029 (Fig. 2).

Loknath 505 was the best performing variety with a paddy yield of 4.85 tha^{-1} followed by MTU 7029 with 4.76 tha^{-1}, whereas, Moti Gold was the lowest yielder with a grain yield of 4.12 tha^{-1} (Fig. 3).

Data on yield response found that early or timely transplanting was the key driver in realizing the yield potential (Khakwani *et al.*, 2006; Liu *et al.*, 2015) of varieties or hybrids. The long duration varieties are good for increasing the yield of rice, but medium duration varieties or hybrids are good for intensifying the cropping system without any yield penalty (Fig. 4).



*Other varieties/hybrids- Bhagalpur Katarni, Laxmi Gold, Nano, Parvati, Pioneer 27P31, Rajendra Saraswati, Chandan, Laxmi, PHB71, Sonam, Rajendra Shweta, Kanchan, Rupali, Rajendra Mansuri

Fig. 2. Varietal spectrum of the surveyed farmers in district Nalanda.

The grain yield, NPK and irrigation application for both hybrids and improved varieties were almost at par (Table 1).

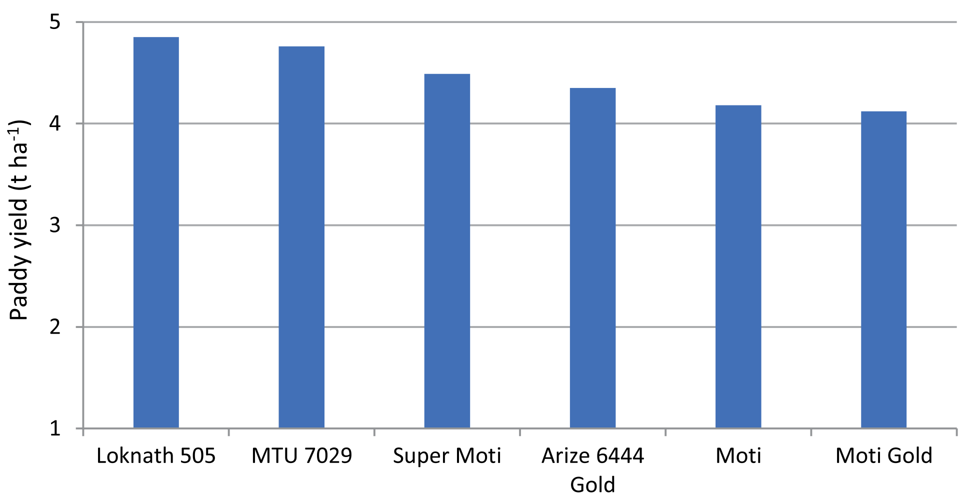


Fig. 3. Varietal performance of the surveyed farmers in district Nalanda.

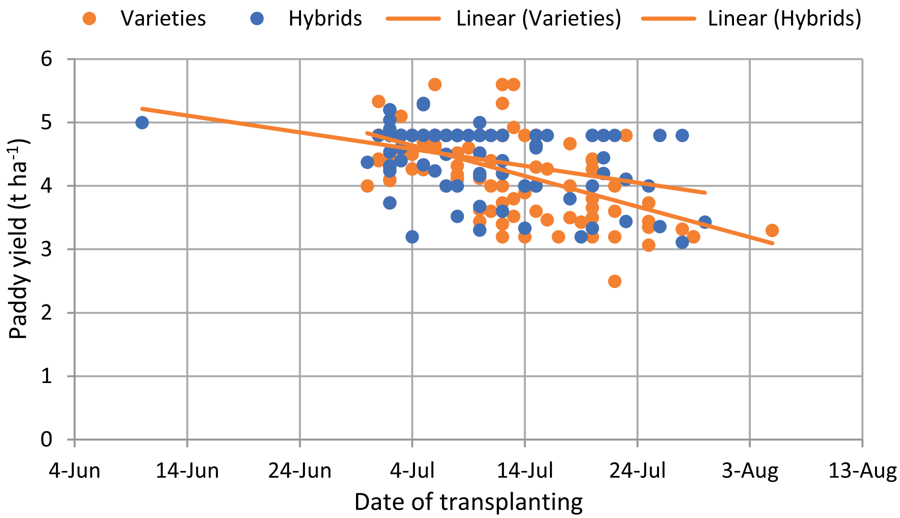


Fig. 4. Effect of dates of transplanting on paddy yield in district Nalanda.

Table 1. Nutrients and irrigation application pattern in improved varieties and hybrids in Nalanda

Particulars	Hybrid	Improved varieties
Average yield (tha^{-1})	4.41	4.32
Average nitrogen application ($kgha^{-1}$)	148.95	143.41
Average phosphorus application ($kgha^{-1}$)	44.95	41.01
Average potash application ($kgha^{-1}$)	35.24	29.5
Average irrigations applied ($kgha^{-1}$)	6.48	6.05
Total households	79	117
% households applying nitrogen	100	100
% households applying phosphorus	94	89
% households applying potash	48	44
% of households applying irrigation	100	100

The two most common weeds were *Echinochloa colona* with 78.57 % and *Cynadon dactylon* with 50.51 % households responding for them. The most troublesome weeds were *Echinochloa colona* and *Cynadon dactylon* with 75 and 47.45 % each (Table 2).

Table 2. Five most common and troublesome weeds and yield of paddy in Nalanda district

Rank	Common weeds	% HHs	Troublesome weeds	% HHs
Weed 1	*Echinochloa colona*	78.57	*Echinochloa colona*	75.0
Weed 2	*Cynadon dactylon*	50.51	*Cynadon dactylon*	47.45
Weed 3	*Fimbristylis* spp.	49.49	*Fimbristylis* spp.	44.9
Weed 4	*Cyperus difformis*	41.84	*Cyperus difformis*	37.24
Weed 5	*Eragrostis japonica*	31.63	*Eragrostis japonica*	31.12

Conclusion

Data linked medium duration varieties (MDRVs) or hybrids (MDRHs) with cropping system intensification. The possibility of intensified cropping system supported the case for timely transplanting of rice. The increased infestation of *Cynadon dactylon* can be effectively managed by summer tillage. Other weeds can be controlled by herbicides.

References

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Liu, Q., Wu, X., Ma, J., Chen, B. and Xin, C. (2015). Effects of delaying transplanting on agronomic traits and grain yield of rice under mechanical transplantation pattern. *PLoS ONE* 10 (4).

3.27 Nutrient and weed management-two most important factors to enhance rice yields in Lakhisarai district of Bihar

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[2]International Maize and Wheat Improvement Center (CIMMYT)

Introduction

Lakhisarai district of Bihar falls into South Bihar Alluvial Plain Zone (B1-3) with 25°10' N latitude and 86°41' E longitude at an altitude of 22.2 m above MSL. Its geographical area is 1,28,100 ha, of which 77,200 ha is the net sown area with 166 % cropping intensity. Net irrigated area is 42,100 ha mainly through bore-wells (36 %), canals (18 %) and tanks (15 %). Annual rainfall in the district is 1,095 mm mainly received through SW monsoons. Soils of the district are fine sandy loam (41 %) and clayey (42 %). Average productivity of rice and wheat in the district is 2,014 and 2,205 kgha^{-1}, respectively. Nutrients and weed management are the two most serious factors for lower rice yields in the district, and therefore, it needs to be addressed accordingly. The KVK initiated a process of monitoring, evaluation and learning where the data collected from farmers were analyzed and articulated so that the best technologies preferred are highlighted and shared with research and extension system.

Methodology

Villages (30) were randomly selected from the 2011 census data based on probability proportionate to size (PPS) method. Seven farmers were randomly selected from each village. They were interviewed regarding the prevailing agronomic practices for the rice crop they had grown in *kharif* 2018. The questionnaire for the Landscape Diagnostic Survey (LDS) was prepared in a mobile application based

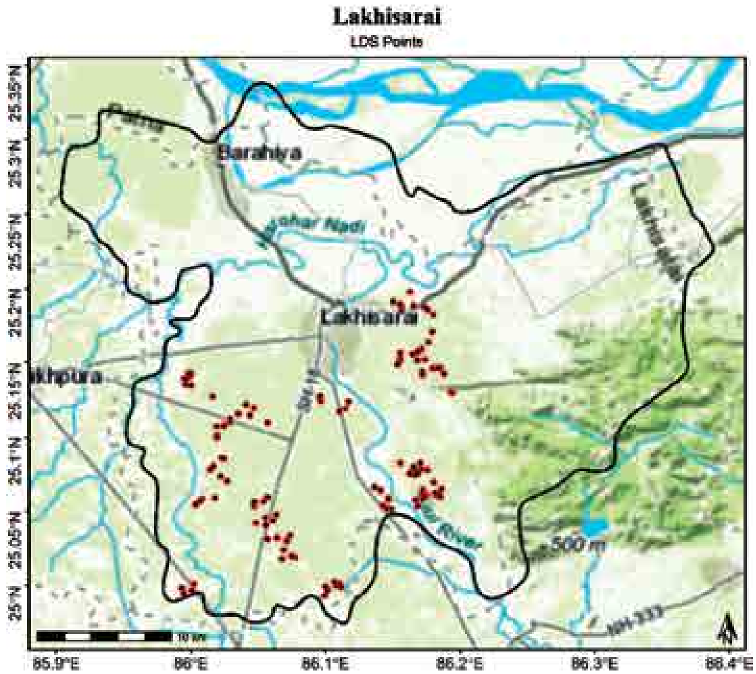


Fig. 1. GPS coordinates of the largest plot of the surveyed farmers in Lakhisarai.

digital data collection format of Open Data Kit (ODK), which can transfer real time data to the server or cloud. Out of total 210 households surveyed, majority of them were marginal (57%) and small (25%) as per their landholding size. Others were semi-medium (14%), medium (2%) and large (1%). As per the drainage classification, topography comprised medium land, lowland, and upland to the tune of 72.4, 22.4 and 5.2%, respectively. As per soil texture, it was 56.7% medium, 33.6% heavy and 9.7% as light soil. In Lakhisarai district, almost 93% HHs follow the RWCS, 3.0% rice-other crop and 4% rice-fallow.

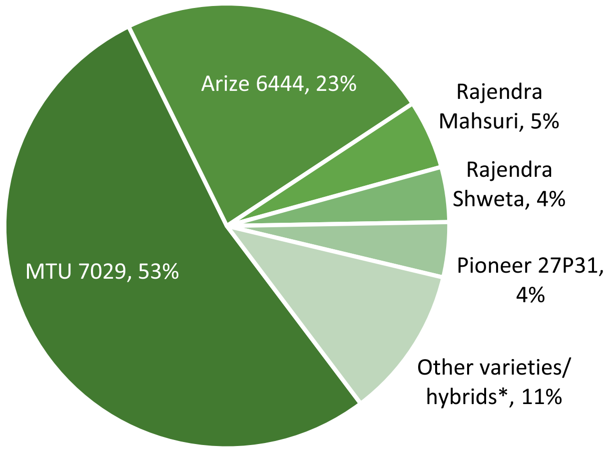
Blocks covered : Barhaiya, Chanan, Halsi, Lakhisarai, Pipariya, Ramgarh Chawk and Suryagarha.

Villages surveyed : Aurai, Basmatia, Bhalui, Billo, Chandanpura, Dumri, Etown, Halsi, Kachhiana, Kaindi, Katehar, Khutaha, Lahuara, Laxmipur, Losghani, Mahisona, Mano, Matasi, Mohanpur, Mohiuudinnagar, piparia, pratappur, Ramshir, Saithna-salunja, Salempur, Sangrampur, Satsanda, Toralpur and Walipur (Fig. 1).

Results and Discussion

The data (Fig. 2) revealed that 53, 23 and 9% HHs preferred MTU 7029, Arize

6444 Gold and other varieties/hybrids, respectively. Rajendra Mahsuri (5%), Rajendra Shweta (4%) and Pioneer 27P31 (4%) were few other popular varieties/hybrids in the district.



*Other Varieties/hybrids- BRRI Dhan33, PAC 835, Rupali, Loknath 505, PHB 71, Sita, Sonam, Dhanya 775

Fig. 2. Varietal spectrum of rice varieties/hybrids based on the data of surveyed farmers (210) in Lakhisarai.

Among the five most preferred varieties/hybrids, Pioneer 27P31 (5.85 tha^{-1}), MTU 7029 (5.5 tha^{-1}) and Arize 6444 Gold (5.4 tha^{-1}) yielded higher than Rajendra Mahsuri (4.9 tha^{-1}) and Rajendra Shweta (4.0 tha^{-1}) (Fig. 3). That means varieties with a longer life span are associated with higher yield (Li *et al.*, 2019). MTU 7029 being high yielding variety is still the first preference of majority of the HHs.

Grain yield across rice variety/hybrids was bit higher when transplanted up to 15 July (5.6 tha^{-1}) or at the most between 16 and 31 July (5.3 tha^{-1}) and then it decreased drastically (4.8 tha^{-1} when transplanted between 01 and 15 August) (Fig. 4). This calls for an early or timely transplanting to attain higher yield.

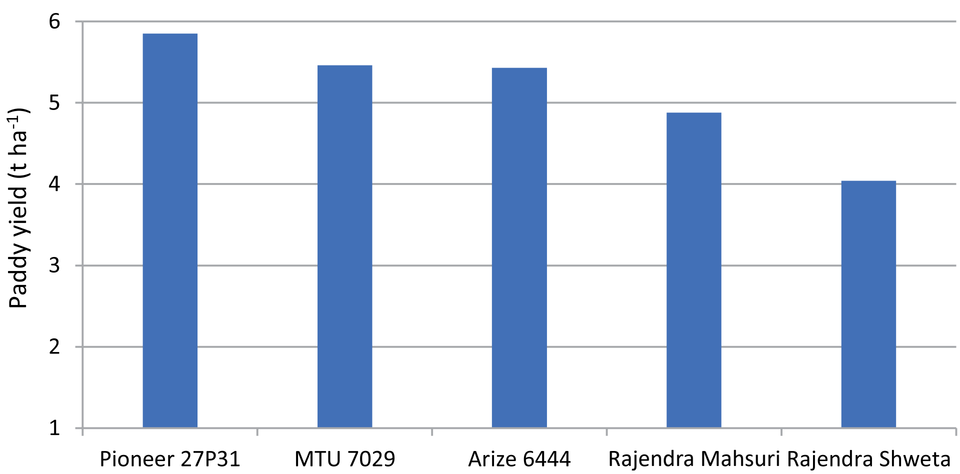


Fig. 3. Performance of most preferred rice varieties/hybrids by the surveyed farmers in Lakhisarai.

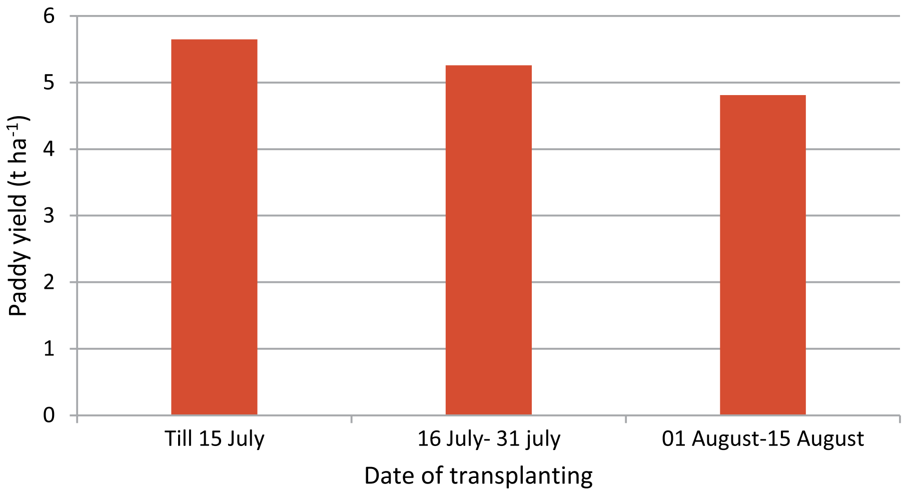


Fig. 4. Effect of time of transplanting on grain yield of rice varieties/hybrids (134) in Lakhisarai.

A total of 90 and 44 HHs who grew improved rice varieties and hybrids, respectively, harvested an average yield of 5.2 and 5.4 tha^{-1} with N, P_2O_5 and K_2O application @ 109.8, 49.5 and 22.1 $kgha^{-1}$, respectively, in improved varieties and correspondingly 119.5, 49.7 and 26.4 $kgha^{-1}$ in hybrids (Table 1). The irrigation level was higher in varieties (6.87) compared to hybrids (5.64), and it was applied by all the HHs. N, P_2O_5 and K_2O were applied by 100, 97 and 39% HHs in rice varieties, respectively, and the corresponding figures in hybrids were 100, 93 and 41%. Compared to some ecologies with very high paddy yields, farmers are relying too heavily on P application. It warrants

Table 1. Nutrients and irrigation application pattern in varieties and hybrids in Lakhisarai

Particulars	Improved varieties	Hybrids
Average yield (tha^{-1})	5.2	5.4
Average nitrogen application ($kgha^{-1}$)	109.7	119.5
Average phosphorus application ($kgha^{-1}$)	49.5	49.6
Average potash application ($kgha^{-1}$)	22.1	26.4
Average irrigations applied	6.8	5.6
Total households	90	44
% households applying nitrogen	100	100
% households applying phosphorus	97	93
% households applying potash	39	41
% of households applying irrigation	100	100

further studies especially when it has already been applied in wheat. Improved irrigation supply may also be instrumental to increase yield levels further in hybrids.

Among the five top most troublesome weeds infesting rice crop in Lakhisarai (Table 2), 47.0% HHs indicated *Fimbristylis* spp. as the most serious weed (rank 1) closely followed by *Cyperus iria* (ranking 2; 38.1% HHs), *Commelina benghalensis* (rank 3; 37.3% HHs), *Marsilea minuta* (rank 4; 35.8% HHs) and *Cyperus rotundus* (rank 5; 34.3% HHs). Among the top five common weeds of transplanted rice crop, were, *M. minuta*, *E. colona, C. iria, Fimbristylis* spp. and *Ischaemun rugosum* as reported by 69.4, 64.2, 61.2, 60.4 and 58.2% HHs, respectively. This indicated infestation of complex weed flora in the district, which warrants for effective and integrated weed management including relevant herbicides.

Table 2. Top five troublesome and common weeds in Lakhisarai

Rank	Troublesome weeds	% HHs	Common weeds	% HHs
Weed 1	*Fimbristylis* spp.	47.0	*Marsilea minuta*	69.4
Weed 2	*Cyperus iria*	38.1	*Echinochloa colona*	64.2
Weed 3	*Commelina benghalensis*	37.3	*Cyperus iria*	61.2
Weed 4	*Marsilea minuta*	35.8	*Fimbristylis* spp.	60.4
Weed 5	*Cyperus rotundus*	34.3	*Ischaemum rugosum*	58.2

Conclusion

MTU 7029 a long duration variety released in 1982 and Arize 6444 Gold a medium duration hybrid cover larger area and perform better than many other popular varieties grown in the district except Pioneer 27P31. The increased rice productivity in the uplands and medium lands through inclusion of hybrids in the system, and creation of opportunities for service-based mechanization round-the-year from seed to harvest should be the top priorities for this district.

Timely transplanting (01-31 July) of varieties and hybrids needs increasing emphasis along with optimal use of P_2O_5 and K_2O in varieties as well as hybrids, and even N in varieties along with integrated weed management.

Reference

Li, Ronghua, Meijuan Li, Umair Ashraf, Shiwei Liu and Jiaen Zhang (2019) Exploring the relationships between yield and yield-related traits for rice varieties released in China from 1978 to 2017 Front. *Plant Sci.*, 07 May 2019 | https://doi.org/10.3389/fpls.2019.00543.

3.28 Promotion of hybrids, timely transplanting and effective management of weeds are the three major factors to increase rice productivity in Madhepura district of Bihar

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[2]International Maize and Wheat Improvement Center (CIMMYT)

Introduction

The district of Madhepura spreads across 1,788 sq. km. There are 13 blocks. Paddy and jute are the major crops grown in the district. River Kosi is one of the main rivers that flow across the district. Having area of 2,570 sq. km, Madhepura district has two sub-divisions, 13 blocks, 176 Panchayat and 439 villages. It is surrounded by Araria and Supaul in north, Khagaria and Bhagalpur in south, Purnia in east and Saharsa in the west. The total geographical area of this district is 179,589 ha of which 136,484.75 ha is only cultivable. Being a rice and wheat consuming district, Madhepura, rice is cultivated in 79,640 ha followed by wheat and maize in 48 and 36 thousand ha, respectively. The area covered under irrigation is 1.39 lakh ha. The average annual rainfall is around 1,300 mm having humid and sub-humid conditions. The maximum temperature of the district ranges from 35 to 40°C in respect of minimum temperature ranges from 5 to 7°C.

Methodology

Villages (30) were randomly selected from the 2011 census data on the basis of probability proportionate to size (PPS) method. The villages and farmers within villages were randomized (Fig. 1) and the sample properly reflected farmers' population in the district. Seven farmers were randomly selected from each village.

They were interviewed regarding the prevailing agronomic practices for the rice crop. The randomization process makes it easy to assess the adoption pattern of different technologies in the district.

The questionnaire for the landscape diagnostic survey was prepared in a mobile application based digital data collection format of Open Data Kit (ODK), which is capable of transferring real time data to the server or cloud.

Blocks covered : Bihariganj, Chausa, Gailarh, Gwalpara, Kishanganj, Kumarkhand, Madhepura, Murliganj, Puraini, Shankarpur, Singheshwar.

Villages surveyed : Barahi, Bishunpur Arar, Nayanagar, Novtol, Bidi Ranpal, Pararia, Bawantikhti, Bhatati, Pokhram, Matahi, Budhma Nakhraj, Muhro, Bishanpur, Korlahi, Maura, Madhuban, Bardaha, Sahugarh, Basantpur, Kherho, Ghosai, Budhawe, Basantpur, Sahugarh and Garthan (Fig. 1).

Results and Discussion

The data on landholding size of the surveyed farmers showed that there were 60 % marginal, 27 % small, 11 % semi medium and 2 % medium. Based on the drainage class of the surveyed plots 58.7 % were medium land, 27.4 % lowland and 12 % upland. The soil texture surveyed of plots revealed that 85.5 % plots were of medium type, 11.3 % light and 3.2 % with heavy type of soil. The data recorded showed that

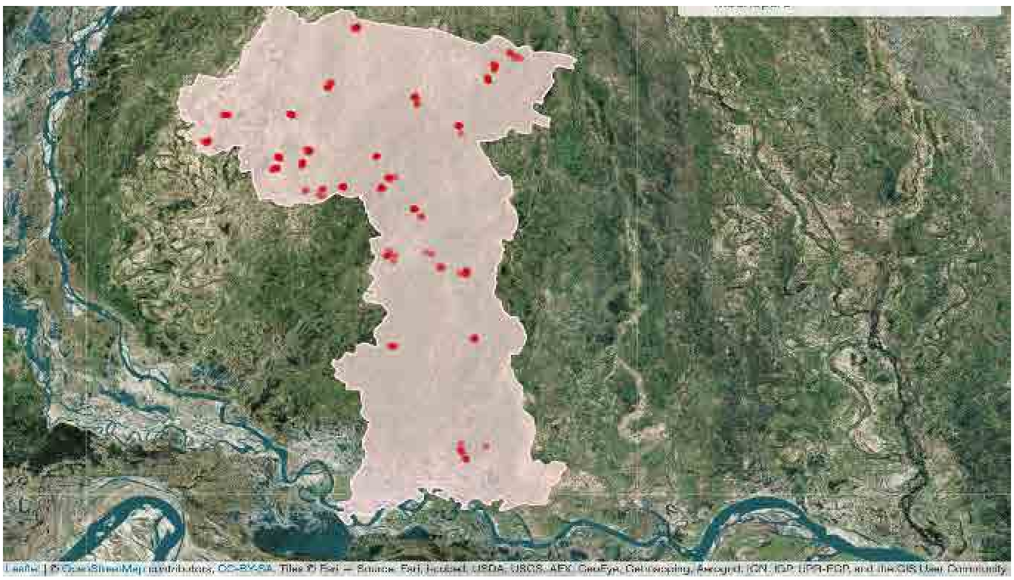
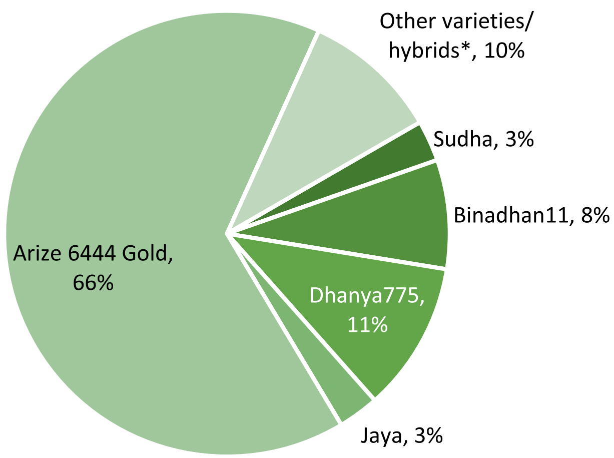


Fig. 1. GPS points of surveyed farms in Madhepura.

51.6 % farmers had rice-wheat cropping system, 17.7 % rice-maize and rest followed rice-fallow.

The varietal spectrum showed that 66 % farmers cultivated hybrid Arize 6444 Gold, 11 % Dhanya, 8 % Binadhan 11, 3 % each Sudha and Jaya, and 10 % other varieties (Fig. 2).

Arize 6444 Gold was the best performing variety followed by Dhanya 775 with 3.7 and 3.4 tha^{-1}, respectively, whereas Jaya was the lowest yielder with 2.4 tha^{-1} (Fig. 3).



*Other varieties/hybrids- BR11, PHB71, Rajendra Mansuri, Ranjit, Vijay

Fig. 2. Varietal spectrum of the surveyed farmers in district of Madhepura.

On observing the yield data of hybrids with respect to transplanting dates, it showed a negative correlation (Fig. 4).

The hybrids had an yield edge of 0.5 tha^{-1} in comparison to improved varieties. The amount of N, K and irrigations applied were at par, whereas an additional average 10 $kgha^{-1}$ of P was added in hybrids (Table 1).

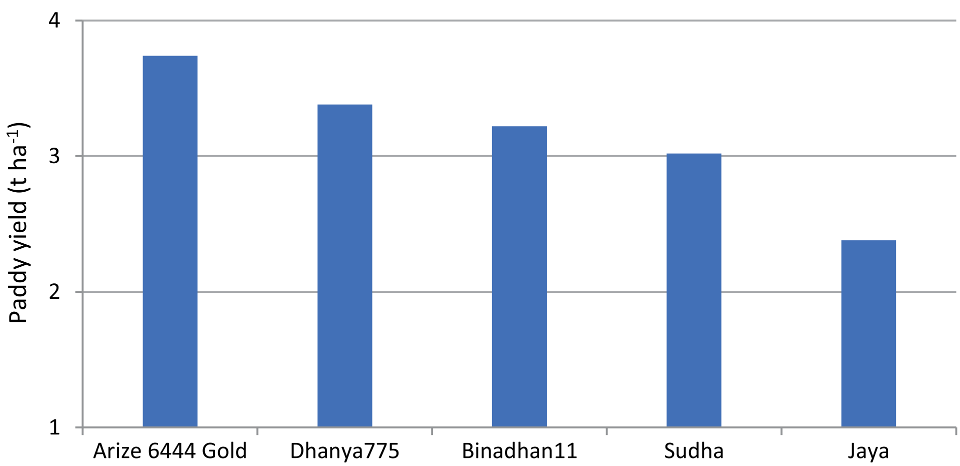


Fig. 3. Varietal performance of the surveyed farmers in district Madhepura.

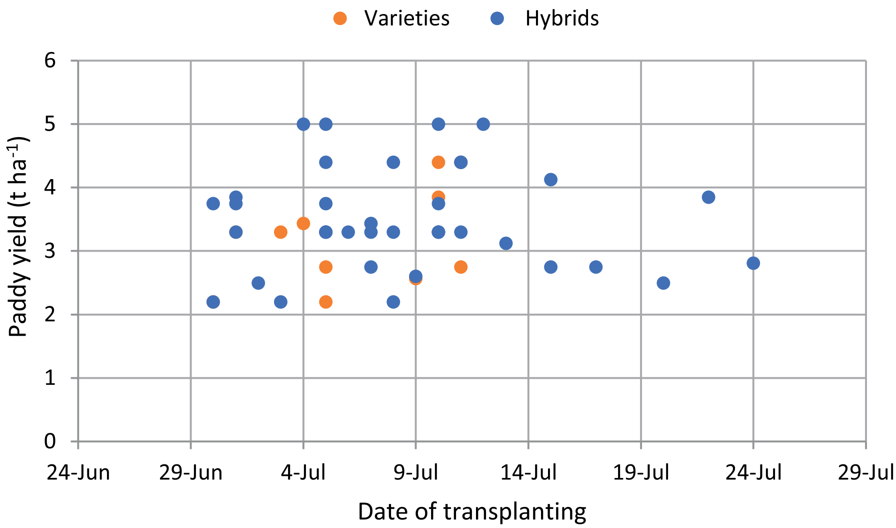


Fig. 4. Effect of dates of transplanting on paddy yield in district Madhepura.

Table 1. Nutrients and irrigation application pattern in improved varieties and hybrids in Madhepura.

Particulars	Hybrids	Improved varieties
Average yield (tha^{-1})	3.7	3.2
Average nitrogen application ($kgha^{-1}$)	123.8	120.2
Average phosphorus application ($kgha^{-1}$)	55.9	66.8
Average potash application ($kgha^{-1}$)	34.0	34.5
Average irrigations applied	2.8	2.8
Total households	49	13
% households applying nitrogen	98	100
% households applying phosphorus	88	92
% households applying potash	86	92
% of households applying irrigation	100	100

Weeds affect the rice yields to a major extent (Paul *et al.*, 2014). There can be an average yield reduction of 40-60% by weeds which may even go to as high as 94% under uncontrolled condition (Chauhan and Johnson, 2011). The two most common weeds were *Cyperus difformis* with 72.6% and *Fimbristylis* spp. with 70.9% households responding for them. The most troublesome weeds were *Cyperus difformis* and *Cyperus rotundus* with 56.4 and 43.5% respondent HHs for each (Table 2).

Table 2. Five most common and troublesome weeds and yield of paddy in Madhepura district.

Rank	Common weeds	% HHs	Troublesome weeds	% HHs
Weed 1	*Cyperus difformis*	72.6	*Cyperus difformis*	56.4
Weed 2	*Fimbristylis* spp.	70.9	*Cyperus rotundus*	43.5
Weed 3	*Caesulia axillaris*	53.2	*Fimbristylis* spp.	37.1
Weed 4	*Cyperus rotundus*	51.6	*Scirpus juncoides*	30.6
Weed 5	*Cynadon dactylon*	48.4	*Cyperus iria*	27.4

Conclusion

Madhepura district is majorly dominated by marginal and small landholding HHs and has medium (59%) and low lands (27%). Hybrids are increasingly grown by majority of the farmers most obviously owing to higher yields. Delayed transplanting and infestation of sedges are the two most important reasons for lower yields. Therefore, extension efforts are required for early/timely planting, integrated weed management and even more irrigation applications.

References

Chauhan, B.S. and Johnson, D.E. (2011). Ecological studies on *Echinochloa crus-galli* and the implications for weed management in direct-seeded rice. *Crop Protection*, Volume 30, Issue 11, November 2011. 1385-1391.

Paul, J., Kumar, A., Choudhary, V.K., Suri, A.K., Sharma, V.K. and Shobhna (2014). Bioresource nutrient recycling and its relationship with biofertility indicators of soil health and nutrient dynamics in rice–wheat cropping system. *Communications in Soil Science and Plant Analysis* 45 (7) : 912-924.

3.29 Maximise the yield potential of long duration varieties by leveraging time of transplanting in Kaimur

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Introduction

Kaimur district of Bihar falls into South Bihar Alluvial Plain Zone (B1-3) between 25-26°N latitude and 83-84°E longitude at an altitude of 548 m above MSL. Its geographical area is 3,40,400 ha, of which 1,76,700 ha is the net sown area with 136 % cropping intensity. Net irrigated area is 71,700 ha mainly through canals (68.3 %) and bore wells (12 %). Annual rainfall in the district is 1,095 mm mainly received through SW monsoons. Soils of the district are clay loam (46 %) and sandy loam (31 %). Rice (81,700 ha) is the main crop of the district grown in *kharif* season, whereas wheat area is 68,400 ha in the district. The objective of the survey was to identify most important factors to bridge the yield gaps, check the effect of leading technologies on yield of rice and putting more efforts of the emerging research and extension agenda.

Methodology

In total 30 villages were randomly selected from the 2011 census data on the basis of probability proportionate to size (PPS) method. Seven farmers were randomly selected from each village. They were interviewed regarding the prevailing agronomic practices for the rice crop they had grown by harvested last year (*kharif* 2018). The questionnaire for the Landscape Diagnostic Survey (LDS) was prepared in a mobile application based digital data collection format of Open Data Kit (ODK) which is capable of transferring real time data to the server or cloud. GPS coordinates of the largest plot of the surveyed farmers in Kaimur have been shown in Fig. 1. Out of total 210 households surveyed, majority of them were marginal (55%) and small (20%) as per their landholding size. Others were semi-medium (13%), medium (10%) and large (2%). As per drainage classification, the topography comprised medium land, lowland and upland to the tune of 93.0, 3.5 and 3.5%, respectively. As per soil texture, it was 72.1% medium, 25.9% heavy and 2.0% as light soil. Almost 100% HHs follow the rice-wheat cropping system.

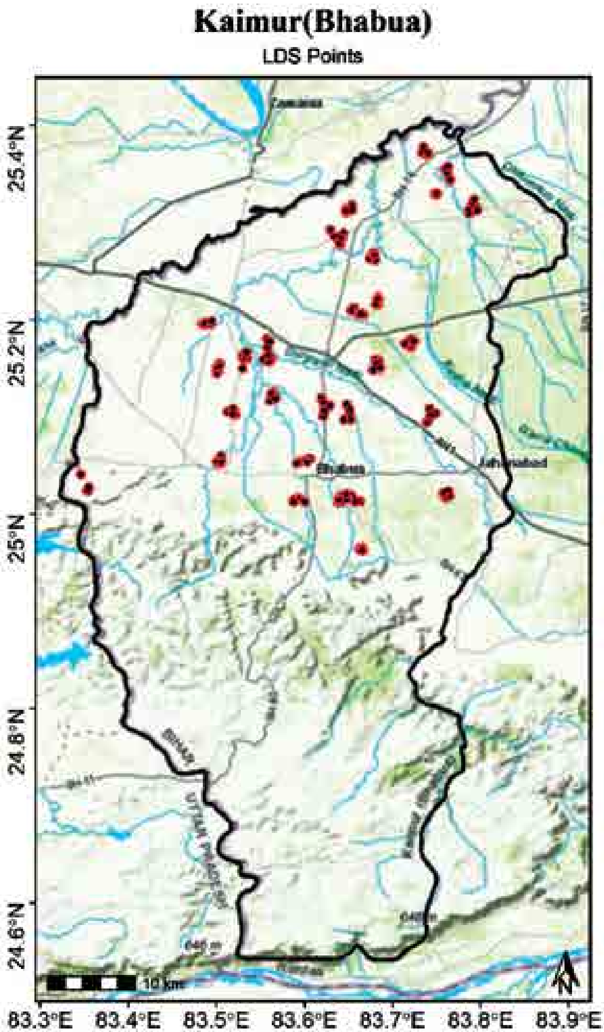


Fig. 1. GPS coordinates of the largest plot of the surveyed farmers in Kaimur.

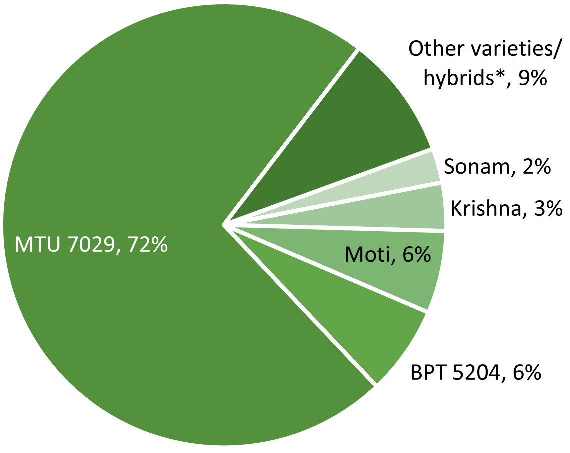
Blocks covered : Bhabua, Bhagwanpur, Ramgarh, Nuaon, Kudra, Mohania, Durgawati, Chainpur and Chand.

Villages surveyed : Burhwalia, Sahbazpur, Bare, Dharak, Ramgarh, Chhewari, Bahera, Kathej, Baghani, Bhadari, Sarai, chandesh, Jharkhande, Palka, Dhedvr, Biddi, Sapnautia, Akhlaspur, Itarhi, Harinathpur, Hariharpur, Chaprang, Saintha, Kohri, Dovre, Gorar, Dobhri, Ghosa, Dhedhua, Ghosa, Amarhi, pain, Shabajpur, Bhera, Mubarakpur and Baddha (Fig. 1).

Results and Discussion

It is clearly evident from the data (Fig. 2) that 72% HHs still preferred MTU7029. BPT5204 (6%), Moti (6%), Krishna (3%), Sonam (2%) and few other varieties/hybrids (9%) were also popular in the district.

Among five most preferred varieties/hybrids, MTU7029 (4.8 tha^{-1}), Moti (4.4 tha^{-1}) and BPT5204 (4.0 tha^{-1}) yielded higher than Krishna (3.8 tha^{-1}) and Sonam (3.7 tha^{-1}) (Fig.3). MTU 7029 being high yielding variety is still at the first preference by majority of the farmers.



*Other varieties/hybrids- Arize 6444 Gold, Binayak, Diamond, Garima, JK Dhanyarekha, Rajendra Shweta, Swanam, Swargdwari, Bioseed, Moti Gold, Pooja, Super Moti, Kaveri

Fig. 2. Varietal spectrum of rice varieties/hybrids based on the data of surveyed farmers.

Grain yield across rice variety/ hybrids was bit higher when transplanted early till 30 June (4.8 tha^{-1}), between 01-15 July (4.8 tha^{-1}) or at the most between 16-31 July (4.6 tha^{-1}) and then it decreased to some extent (4.1 tha^{-1}) thereafter (01-31 August) (Fig. 4). This calls for timely transplanting during the month of July. What makes this district different from other districts except Rohtas is the dominance of highest yielder variety (MTU 7029). To bridge the gap between its yield potential and the current yield, the time management is critical (Khalifa, 2009).

A total of 197 and 02 HHs who grew improved rice varieties and hybrids, respectively harvested an average yield of 4.6 and 4.2 tha^{-1} with N, P_2O_5 and K_2O

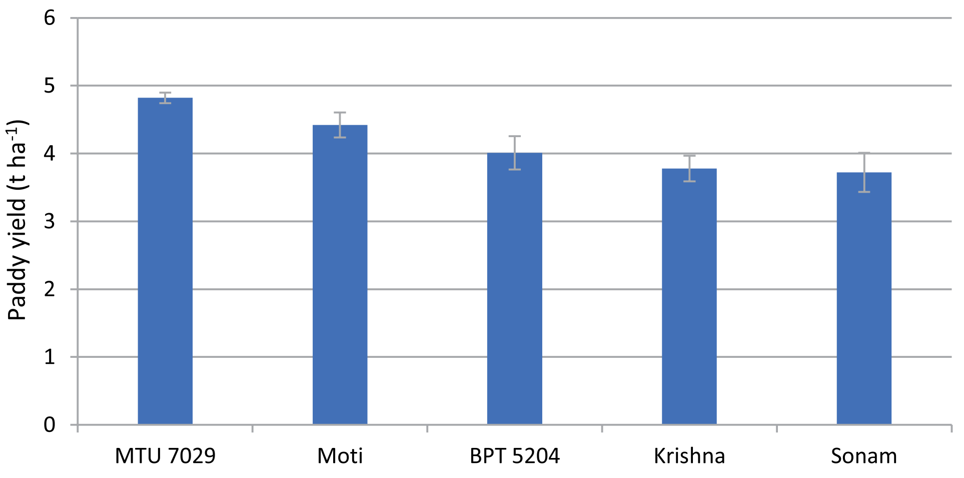


Fig. 3. Performance of most preferred rice varieties/hybrids by the surveyed farmers.

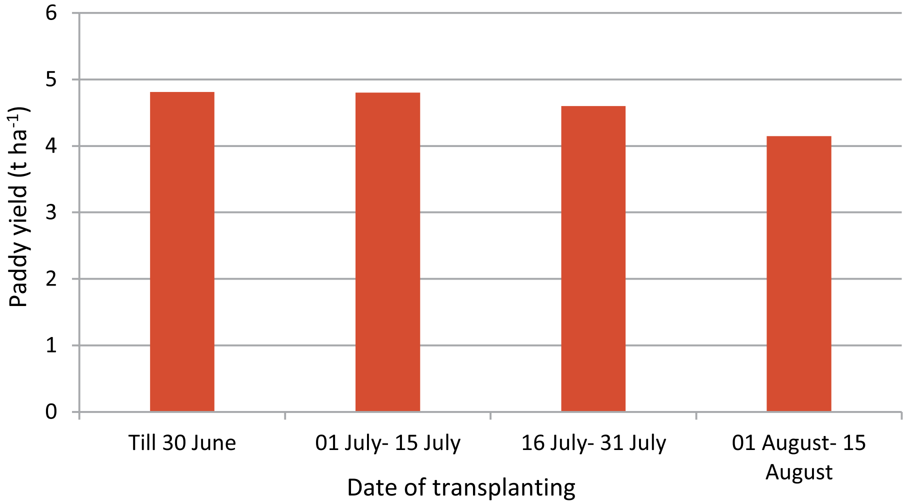


Fig. 4. Effect of time of transplanting on grain yield of rice varieties/hybrids (n=201).

application @ 128.7, 53.5 and 22.1 $kgha^{-1}$, respectively in improved varieties and correspondingly 92.6, 36.8 and 12.0 $kgha^{-1}$ in hybrids (Table 1). That means use rate of all the three nutrients was lower than recommended in hybrids and use of K_2O was also lower in varieties. The irrigation level was higher in varieties (4.58) compared to hybrids (4.0) and it was applied by all the HHs. N, P_2O_5 and K_2O were applied by 100, 97 and 24 % HHs in rice varieties, respectively and the corresponding figures in hybrids were 100, 100 and 50 %. This clearly indicates that timely transplanting and an enhanced dose of potash in varieties, and also nitrogen, phosphorus and potash in

Table 1. Nutrients and irrigation application pattern in varieties and hybrids in Kaimur.

Particulars	Improved varieties	Hybrids
Average yield (tha^{-1})	4.6	4.2
Average nitrogen application ($kgha^{-1}$)	128.7	92.6
Average phosphorus application ($kgha^{-1}$)	53.5	36.8
Average potash application ($kgha^{-1}$)	22.1	12
Average irrigations applied	4.7	4
Total households	197	2
% households applying nitrogen	99	100
% households applying phosphorus	99	100
% households applying potash	24	50
% of households applying irrigation	100	100

hybrids could further enhance the rice yield. It is also needed to educate the growers to use potash widely in whole rice area.

Among five top most troublesome weeds infesting rice crop in Kaimur (Table 2), 48.7 % HHs indicated *Echinochloa colona* as the most serious weed (rank 1) closely followed by *Cyperus difformis* ranking 2 (41.3 % HHs), *Cyperus rotundus* (rank 3; 39.3 % HHs), *Marselia minuta* (rank 4; 37.8 % HHs) and weedy rice (rank 5; 3.32 %

Table 2. Top five troublesome and common weeds in Kaimur.

Rank	Troublesome weeds	% HHs	Common weeds	% HHs
Weed 1	*Echinochloa colona*	48.7	*Cyperus difformis*	62.7
Weed 2	*Cyperus difformis*	41.3	*Echinochloa colona*	62.7
Weed 3	*Cyperus rotundus*	39.3	*Scirpus juncoides*	60.7
Weed 4	*Marsilea minuta*	37.8	*Cyperus rotundus*	59.2
Weed 5	Weedy rice	36.3	*Marsilea minuta*	54.2

HHs). Among top five common weeds of transplanted rice crop were, *C. difformis*, *E. colona, Scirpus juncoides*, *C. rotundus* and *Marselia minuta* as reported by 62.7, 62.7, 60.7, 59.2 and 54.2 % HHs, respectively. This indicates infestation of complex weed flora in the district, which warrants for effective and integrated weed management including relevant herbicides.

Conclusion

Marginal (55 %) and small landholding HHs (20 %), medium land and solely rice-wheat cropping system (100 %) are the prominent features of Kaimur. MTU7029, the traditional long duration rice variety occupies 72 % rice area in Kaimur due to higher yield. To achieve higher rice productivity, timely transplanting of rice preferably between 01-15 July needs focused attention along with optimal use of nutrients in hybrids. Weed spectrum warrants both herbicide use and manual weeding.

Reference

Khalifa, A.A. (2009). Physiological evaluation of some hybrid rice varieties under different sowing dates.” *Australian Journal of Crop Science*, vol. 3 (3) : 178-183.

3.30 Difficult to control weeds and late transplanting are key constraints for improving rice productivity in Munger

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[2]International Maize and Wheat Improvement Center (CIMMYT)

Introduction

The district Munger falls in the Agro-climatic zone IIIA with major soil type including sandy loam, clay loam and loam. The range of pH is 6.5 to 8, organic carbon 0.5 to 1 %, and available N: P: K (kgha^{-1}) range is 200 to 400 : 10 to 100 : 150 to 300. The district has 4- types of agro- ecological situation like *diara, taal*, hilly and hilly plain, which vary in their availability of resources.

Methodology

Villages (30) were randomly selected from the 2011 census data based on probability proportionate to size (PPS) method. The villages and the farmers within villages were randomized (Fig. 1) and the sample properly reflects farmers' population in the district. Seven farmers were randomly selected from each village. They were interviewed regarding the prevailing agronomic practices for the rice crop. The randomization process makes it easy to assess the adoption pattern of different technologies in the district.

The questionnaire for the landscape diagnostic survey was prepared in a mobile application based digital data collection format of Open Data Kit (ODK), which can transfer real time data to the server or cloud.

Blocks covered : Asarganj, Dharhara, Jamalpur, Kharagpur, Munger, Sangrampur, Tarapur, Titiha and Bambor.

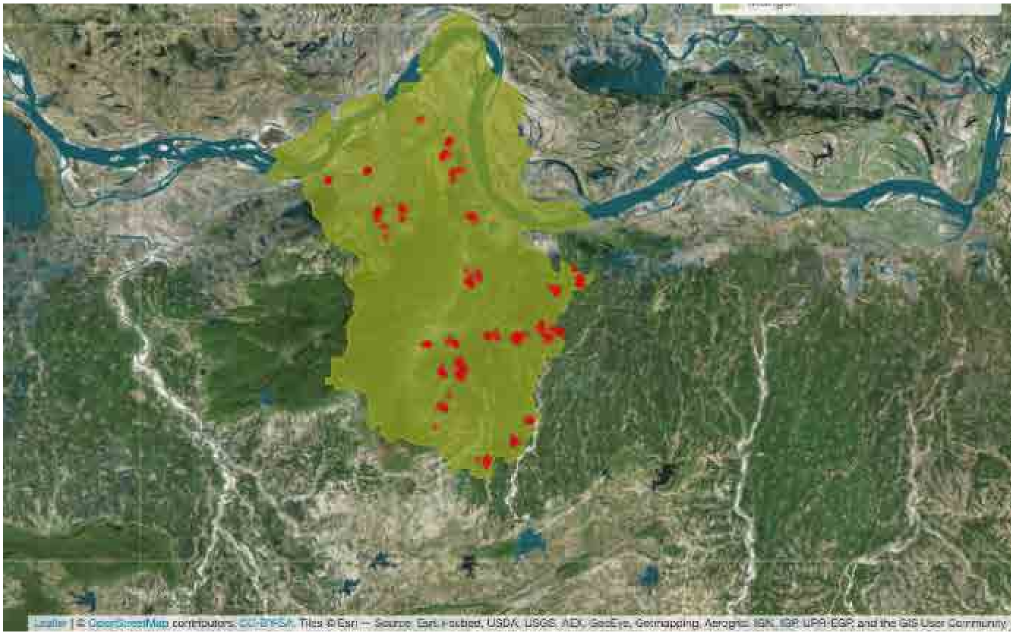


Fig. 1. GPS points of surveyed wheat farms in Munger.

Villages surveyed : Adalpur, Adras, Amari, Barui, Chamachak, Dariyapur, Dashrathi, Gobadda hemzapur, Itarhi, Jagarnathpur, Jhikuli, Kahua, Kamrain, Kathana, Lohchi, Maheshpur, Mohmadda, Manjhgaon, Mangakharbe, Manikpur, Masumganj, Murade, Nauagarhi, Parbhara, Rangaon, Rangapatal, Raunakabad, Shankarpur, Shivpur Lugaen and Teghra Jagirdari (Fig. 1).

Results and Discussion

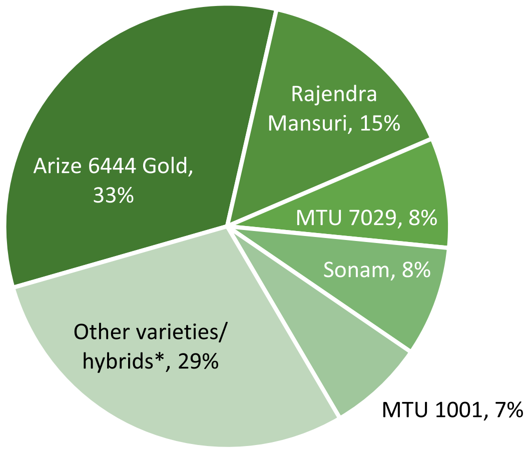
The landholding size of the surveyed HHs was: 76% in marginal category, 17% in small, whereas, 4% each in medium and semi medium category. Based on survey, 93% farmers had medium lands, 6% lowlands and 1.1% upland. Data showed that 84.2% HHs had medium soil, 9.2% heavy soil and 6.5% of light soil. The rice-wheat cropping system is the dominant one with 95% of surveyed farmers, 4.3% farmers had rice-fallow and 0.5% rice-maize cropping system. The varietal spectrum revealed that 33% of the farmers cultivated Arize 6444 Gold followed by 15% Rajendra Mahsuri, 8% MTU 7029 and Sonam each, 7% MTU 1001, and 29% HHs with other varieties or hybrids (comprise of mostly hybrids) (Fig. 2).

MTU 7029 was the best performing variety among all the varieties and hybrid cultivated by the surveyed farmers with paddy yield of 4.3 tha^{-1} followed by Arize

6444 Gold with 3.9 tha^{-1} (Fig. 3). Most farmers tend to rely on the monsoon rains for transplanting rice. Some use costly irrigation for early transplanting of long duration varieties. Owing to this, hybrid rice is the best option.

There was a decline in yield with corresponding delay in date of transplanting for both hybrids and varieties (Fig. 4).

The grain yield, NPK and irrigation application for both hybrid and improved varieties were at par (Table 1).



*Other varieties/hybrids- BL4341, Dhanya 775, JK401, NK 5251, PAC 835, Rajendra Saraswati, Shushk Samrat, Vijay, Loknath 505, Rajendra Shweta, Sita, Pioneer 27P31, Rajendra Bhagwati, PHB71, Pioneer 27P63

Fig. 2. Varietal spectrum of the surveyed farmers in district Munger.

The two most common weeds were *Cynadon dactylon* with 64.7 % HHs and *Cyperus iria* with 63.6 % HHs responding for them (Table 2). The *Cynodon dactylon* is mostly dominant under stressed environment and when the crop is not growing well (Rao and Kiran, 2014; Roy *et al.*, 2018). It must be managed by best agronomic management. The deep summer tillage is not common due to limited number of tractors in the area.

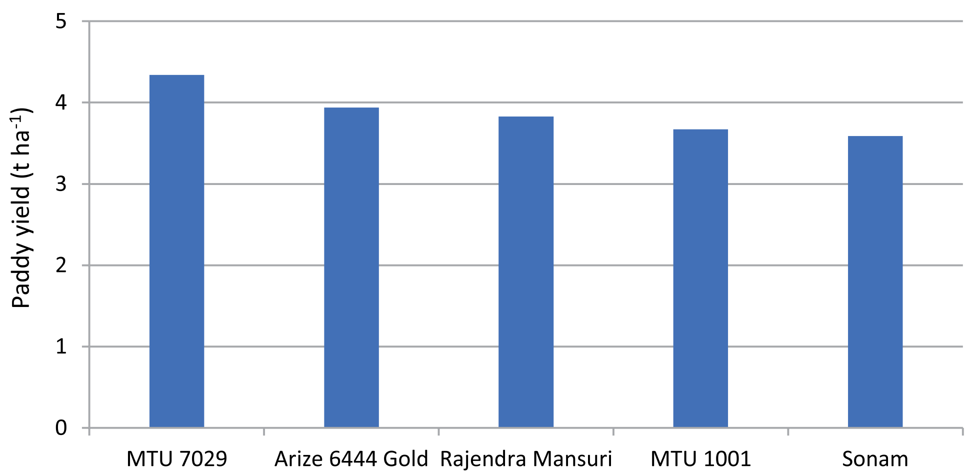


Fig. 3. Varietal performance of the surveyed farmers in district Munger.

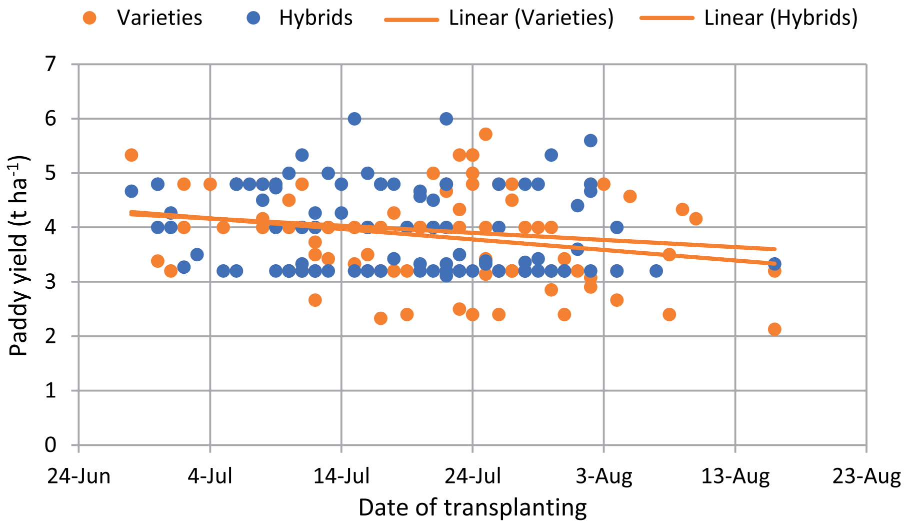


Fig. 4. Effect of time of transplanting on paddy yield in district Munger.

Table 1. Nutrients and irrigation application pattern in improved varieties and hybrids in Munger.

Particulars	Hybrids	Improved varieties
Average yield (tha^{-1})	3.9	3.8
Average nitrogen application (kgha^{-1})	116.6	114.1
Average phosphorus application (kgha^{-1})	42.9	46.4
Average potash application (kgha^{-1})	21.7	24.8
Average irrigations applied	3.2	3.2
Total households	94	88
% households applying nitrogen	100	100
% households applying phosphorus	100	99
% households applying potash	70	77
% of households applying irrigation	100	100

Table 2. Five most common and troublesome weeds and yield of paddy in Munger district.

Rank	Common weeds	% HHs	Troublesome weeds	% HHs
Weed 1	*Cynadon dactylon*	64.7	*Cynadon dactylon*	40.7
Weed 2	*Cyperus iria*	63.6	*Cyperus iria*	40.2
Weed 3	*Cyperus rotundus*	59.2	*Fimbristylis* spp.	40.2
Weed 4	*Echinochloa colona*	55.9	*Cyperus rotundus*	39.1
Weed 5	*Fimbristylis* spp.	54.9	*Echinochloa colona*	38.6

Conclusion

The use of hybrids is increasing. MTU 7029 is still the best performer among varieties and hybrids. With delayed transplanting scenario the benefit is going to hybrids but not to medium duration varieties. Meanwhile, *Cynodon dactylon* has emerged as the most dominating weed, which indicated that proper agronomy is not in place especially in the early stages of crop growth. Future yield growth will be decided by provisions for timely transplanting, summer tillage, weed management and better access to irrigation.

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3.31 Hybrids and old varieties have the potential to enhance rice yields: Timely transplanting is crucial in Saharsa district of Bihar

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Introduction

Agro-climatically, district Saharsa falls under North East Alluvial Zone (II) with 25° 22' 55'' N latitude and 27° 48' 56'' E longitude at an altitude of 44 m above MSL. Its geographical area is 164,559 ha, of which 107,143 ha is the net sown area with 177 % cropping intensity. Net irrigated area is 55,330 ha mainly through canals (18.4 %) and bore wells (31.4 %). Annual rainfall in the district is 1,326 mm mainly received through SW monsoons. Soils are loamy to silt loam (32.1 %), loamy to loamy clay (27.6 %), clay loam, loam to silt loam (24.9 %). Despite sufficient rains, the paddy yields are low. The efforts were to find out the reasons for low yields and inconsistencies in the recommendations generated over time and their adoption patterns. Overall, there has been very little data to allow independent verifications on how the recommendations were accepted by farmers. Therefore, landscape diagnostic survey (LDS) was conducted to understand this process and to suggest possible action points.

Methodology

Villages (30) were randomly selected from the 2011 Census data based on probability proportionate to size (PPS) method (Fig. 1). Seven farmers were randomly selected from each village. They were interviewed regarding the prevailing agronomic practices for the rice crop they have grown in *kharif* 2018. The questionnaire for the Landscape Diagnostic Survey (LDS) was prepared in a mobile application based digital data collection format of Open Data Kit (ODK) which can transfer real time

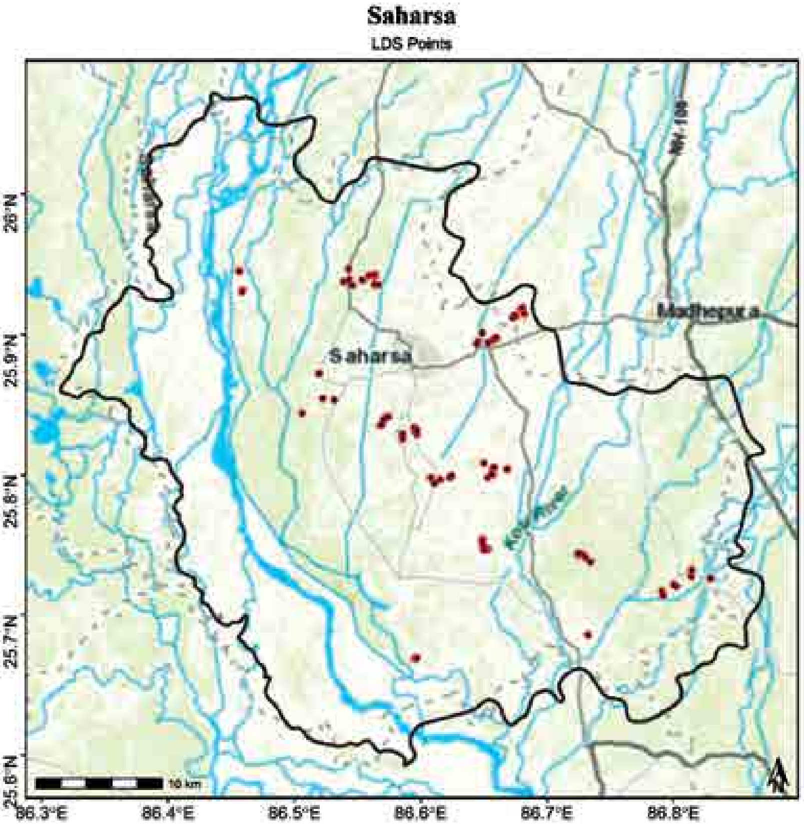


Fig. 1. GPS coordinates of the largest plot of the surveyed farmers in Saharsa.

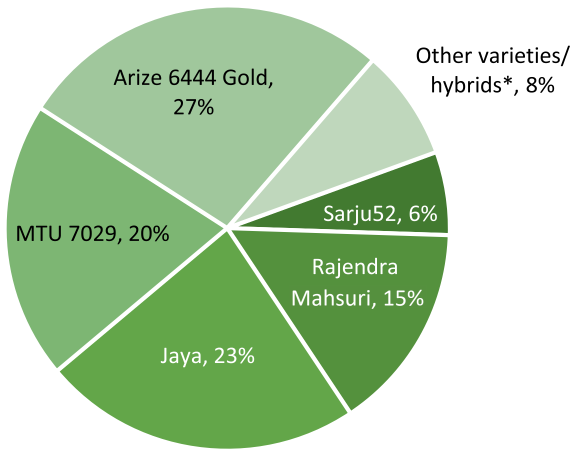
data to the server or cloud. Out of total 210 households surveyed, majority of them were marginal (55%) and small (36%) as per their landholding size. As per drainage classification, the topography comprised medium land, lowland, and upland to the tune of 30.2, 30.2 and 37.2%, respectively. The soil texture was 55.8% medium, 24.4% heavy and 19.8% light soil. Majority of the HHs (80.2%) adopted rice-wheat cropping system. However, 11.6, 3.5 and 4.7% also opted for rice-other crops, rice-fallow and rice-maize, respectively.

Blocks covered : Ban Matiahari, Kharahara, Mahishi, Nauhatta, Salkhua, Satarkatiya, Saubazar, Simri Bakhtiyarpur and Sonbarsa.

Villages surveyed : Amarpur, Thanwar, Bhanthi, Rasalpur, Muradpur, Sihaul, Bangaon, Basauna, Aukahi, Parminiya, Nado, Gwalpara, Dahad, Ghamaria, Nanauti, Manjhawa, Khajuri, Lagma, Behat, Bhatnaha, Salkhua, Mangrauni, Jhara and Tariyawan (Fig. 1).

Results and Discussion

The data (Fig. 2) revealed that 27, 23, 20 and 15% HHs preferred Arize 6444 Gold, Jaya, MTU 7029 and Rajendra Mahsuri, respectively. Sarju 52 (6%) and few other varieties and hybrids were grown by some HHs in the district. It seems farmers indeed may have remained convinced that old varieties are more stable with more yield than the new varieties. Explaining the preference for a hybrid (Arize 6444 Gold) is easy because the yields are higher (Fig. 3).



*Other varieties/hybrids- Aghani, BPT 5204, Jaishree, PHB71, Shriram 505, Dhanya 775

Fig. 2. Varietal spectrum of rice varieties/hybrids based on the data of surveyed farmers (86) in Saharsa.

Among the yields of five most preferred varieties/hybrids, Arize 6444 Gold (3.60 tha^{-1}) and MTU 7029 (3.25 tha^{-1}) showed a bit more than Jaya (2.95 tha^{-1}), Rajendra Mahsuri (2.92 tha^{-1}), and Sarju 52 (2.64 tha^{-1}) (Fig. 3).

Grain yield of rice was realized more in hybrids/varieties which were transplanted between 01 and 15th July compared to early transplanting (15-30 June) (Fig. 4);

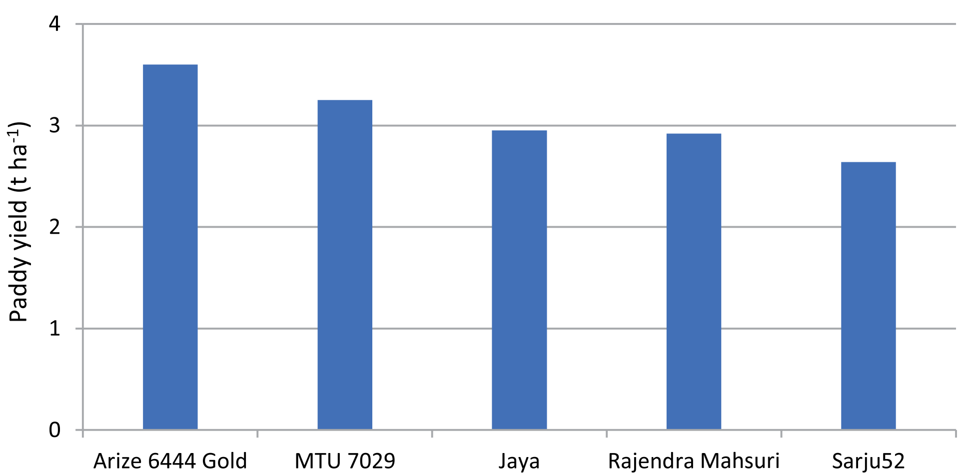


Fig. 3. Performance of most preferred rice varieties/hybrids by the surveyed farmers in Saharsa.

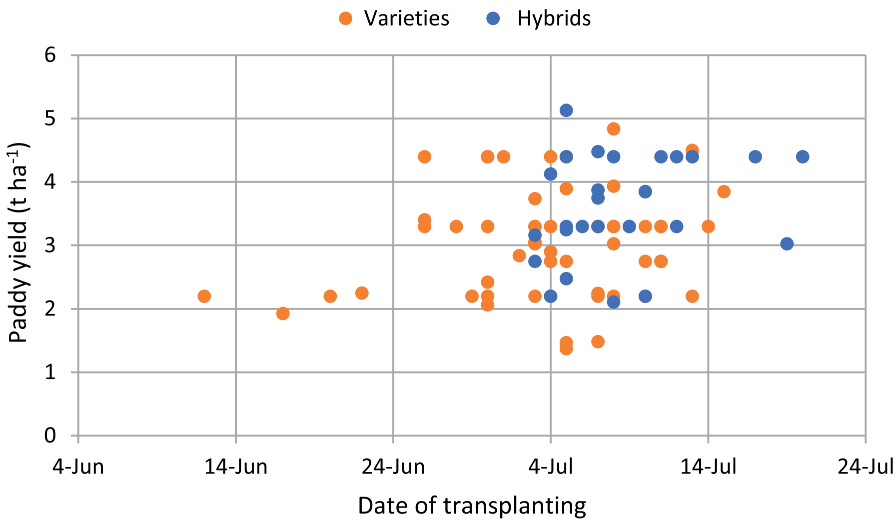


Fig. 4. Effect of time of transplanting on grain yield of rice varieties/hybrids in Saharsa.

and hybrids yielded more than varieties. This indicated for timely transplanting and choosing hybrids for attaining higher productivity in Saharsa. In general, the yield of rice was lower in this district. Similar results were realized earlier also either way either due to transplanting time or the use of hybrids (Huang *et al.*, 2015; Rishi Raj *et al.,* 2016).

A total of 58 and 27 HHs who grew improved rice varieties and hybrids, respectively, harvested an average yield of 3.04 and 3.61 tha^{-1} with close to recommended dose of N (107.6 and 125.1 $kgha^{-1}$), P_2O_5 (54.9 and 63.9 $kgha^{-1}$) and K_2O (26.9 and 40.8 $kgha^{-1}$), however, all these nutrients use was less in varieties than in hybrids and even less than recommended (Table 1). Irrigation level was also lower in varieties (1.9) than that in hybrids (2.3), however it was applied by all HHs. N, P_2O_5 and K_2O were applied by 97, 91 and 93 % HHs in rice varieties, respectively, and the corresponding figures in hybrids were 96, 96 and 85 % indicating wider use of these three nutrients across surveyed HHs. Overall picture indicated that farmers used a bit higher inputs (nutrients as well as irrigation) in hybrids compared to varieties and also ended up with an edge in terms of yield gain.

Among the five top most troublesome weeds infesting rice crop in Saharsa (Table 2), 44.2, 34.9, 34.9, 26.7 and 25.6 % HHs ranked *Echinochloa colona, Caesulia axillaris, Cyperus difformis, Echinochloa crus-galli* and *Cynadon dactylon* at rank 1, 2, 3, 4 and 5, respectively. Similarly, these five weeds were adjudged as the five most common weeds with the same order by 55.8, 53.5, 53.5, 44.2 and 43.0 %

Table 1. Nutrients and irrigation application pattern in varieties and hybrids in Saharsa.

Particulars	Improved varieties	Hybrids
Average yield (tha^{-1})	3.04	3.61
Average nitrogen application ($kgha^{-1}$)	107.6	125.1
Average phosphorus application ($kgha^{-1}$)	54.9	63.8
Average potash application ($kgha^{-1}$)	26.9	40.9
Average irrigations applied	1.9	2.3
Total households	58	27
% households applying nitrogen	97	96
% households applying phosphorus	91	96
% households applying potash	93	85
% of households applying irrigation	100	100

Table 2. Top five troublesome and common weeds in Saharsa

Rank	Top 5 troublesome weeds	% HHs	Top 5 common weeds	% HHs
Weed 1	*Echinochloa colona*	44.2	*Echinochloa colona*	55.8
Weed 2	*Caesulia axillaris*	34.9	*Caesulia axillaris*	53.5
Weed 3	*Cyperus difformis*	34.9	*Cyperus difformis*	53.5
Weed 4	*Echinochloa crus-galli*	26.7	*Echinochloa crus-galli*	44.2
Weed 5	*Cynadon dactylon*	25.6	*Cynadon dactylon*	43.0

HHs. This clearly indicated pronounced dominance of grassy weeds and sedges in the district, which warrants for effective and integrated weed management including relevant herbicides.

Conclusion

Saharsa district is with around one-third each of medium, lowland and upland ecologies. It is dominated by marginal and small landholding farmers (91%), 80% of them mainly follow rice-wheat cropping system (RWCS). Arize 6444 Gold and MTU 7029 performed better and the transplanting between 01 and 15 July was found the most optimal.

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3.32 Better access to low-cost irrigation coupled with hybrid technology can improve paddy yields in Vaishali district of Bihar

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Introduction

Vaishali district of Bihar falls in North West Alluvial Plain Zone (B1-1) with 25° 30' N latitude and 84° 85' E longitude at an altitude of 58 m above MSL. Its geographical area is 201,700 ha, of which 150,200 ha is the net sown area with 135 % cropping intensity. Net irrigated area is 39,800 ha mainly through bore wells/open wells/ shallow bores. Annual rainfall in the district is 1,014 mm mainly received through SW monsoons. Soils of the district are coarse sandy loam (14.8 %), fine sandy loam (8.2 %), clayey 27.9 % and saline/calcareous (46.6 %). Despite timely transplanting of high yielding rice varieties/hybrids and raising the crop with recommended package of practices, the yield level is lower in the district. Landscape Diagnostic Survey (LDS) was conducted to help processing the adoption patterns of technologies so that information flows to research and extension system for developing impact pathways.

Methodology

Villages (30) were randomly selected from the 2011 Census data on the basis of probability proportionate to size (PPS) method. Seven farmers were randomly selected from each village (Fig. 1). They were interviewed regarding the prevailing agronomic practices for the rice crop they have grown in *kharif* 2018. The questionnaire for the LDS was prepared in a mobile application based digital

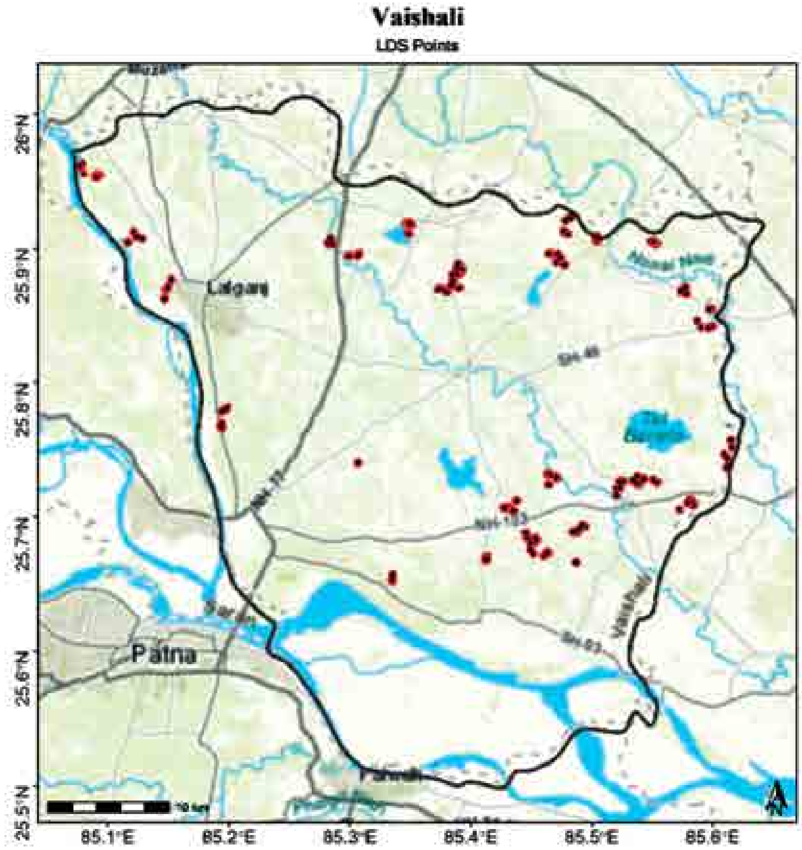
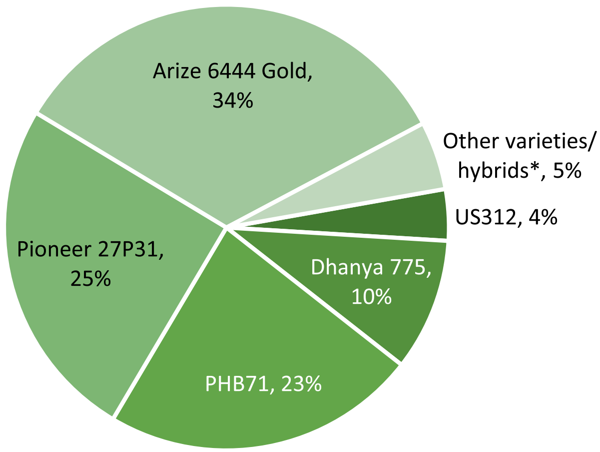


Fig. 1. GPS coordinates of the largest plot of the surveyed farmers in Vaishali.

data collection format of Open Data Kit (ODK), which is capable of transferring real time data to the server or cloud. Out of total 210 households surveyed, marginal, small, semi-medium and medium HHs were 71, 23, 5 and 1%, respectively. As per drainage classification, the topography of the district has 83.3% medium land, 11.3% lowland and only 5.4% upland and as per soil texture also it largely falls into medium (93.5%) and heavy (6.5%) categories. Most of the HHs (100%) adopted rice-what cropping system in the district.

Blocks covered : Hajipur, Patepur, Mahua, Jandaha, Biddupur, Lalganj, Raghopur, Bhagwanpur, Vaishali, Mahnar, Goraul, Raja Pakar, Chehrakalan, Sahdai Bujurg, Paterhi Belsar and Desri.

Villages surveyed : Desri, Jafrabad, Hasanpur, Bahuara, Belwar, Godia Chaman, Jagdishpur, Pohiyar Buzurg, Harlochan Sukki, Saray Dhanesh, Sohrathi, Nawachak, Bhusahi, Majhrohi, Bishunpatti, Chahrakalan, Sondho rathi, Baksama, Shahbazpur puraina, Chakmadhin, Mathurapur, Vishnupatti, Chaksaid, Bhulan Sarai, Sitalpura, Bhagwanpur Khajuri, Simra, Jalalpur, Bodiachaman and Harauli (Fig. 1).



*Other varieties/hybrids- Arize Tez, Pioneer 27P63, Rajendra Bhagwati, Swarna Sub1, JK401, NK 5251

Fig. 2. Varietal spectrum of rice varieties/hybrids based on the data of surveyed farmers (210) in Vaishali.

Results and Discussion

The data (Fig. 2) revealed that majority of the HHs preferred hybrids including Arize 6444 Gold (34%), Pioneer 27P31 (25%) and PBH 71 (23%). Dhanya 775 (10%), US 312 (4%) and few other varieties/hybrids (5%) were also grown in the district.

The yield of five most preferred rice varieties/hybrids, viz., US 312, PHB 71, Dhanya 775, Pioneer 27P31 and Arize 6444 Gold was on an average to the extent of 4.4, 3.7, 3.6, 3.5 and 3.5 tha^{-1}, respectively (Fig. 3), indicating higher yield in US 312.

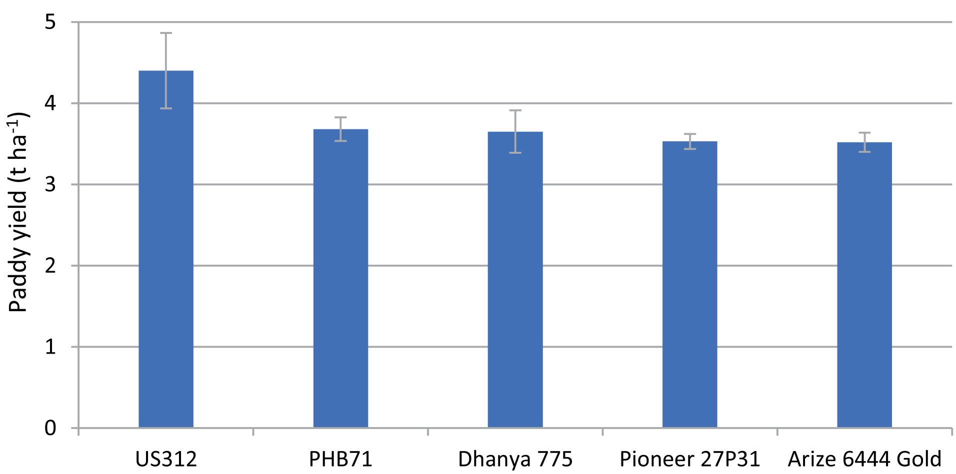


Fig. 3. Performance of most preferred rice varieties/hybrids by the surveyed farmers in Vaishali.

Grain yield across rice variety/hybrids was almost similar ranging from 3.4 to 3.8 tha^{-1} when transplanting was accomplished any time ranging from 15 July to 16-31 July (Fig. 4), indicating little edge under early transplanting.

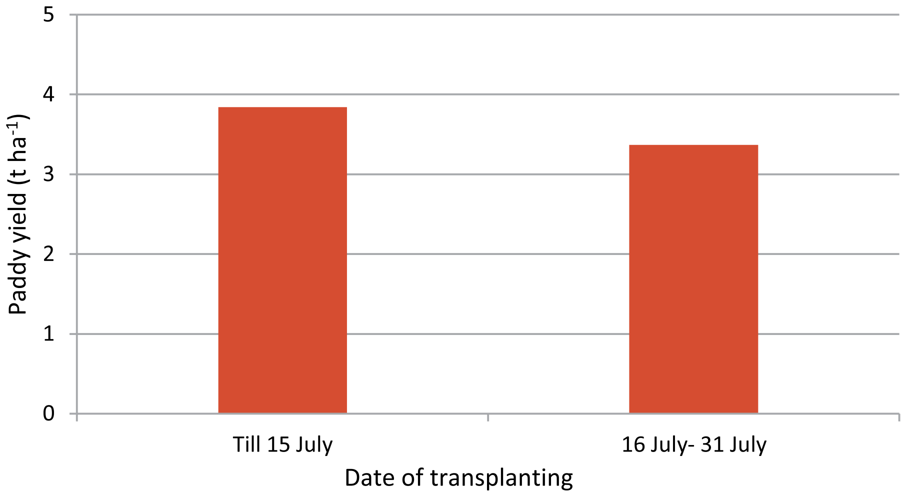


Fig. 4. Effect of time of transplanting on grain yield of rice varieties/hybrids (186) in Vaishali.

There is a need for more private investment in the development of hybrids and provisions to subsidize hybrid rice seed as is done for inbred lines (Spielman *et al.*, 2013). The lower yields even with hybrids is owing to water stress-based decline in the net photosynthesis, reduced growth, and decreased number of panicles per hill (Pirdashti *et al.,* 2009). Here, the availability of low cost irrigation will be crucial.

A total of 02 and 184 HHs who grew improved rice varieties and hybrids, respectively, harvested an average yield of 3.0 and 3.6 tha^{-1} with almost similar to the recommended level of N in varieties (117.4 $kgha^{-1}$) and bit higher with hybrids (133.9 $kgha^{-1}$), P_2O_5 (50.6 and 59.1 $kgha^{-1}$) and even K_2O (33.0 and 35.3 $kgha^{-1}$) and similar level of irrigation (3.0 and 3.3), however, all HHs applied irrigation (Table 1). N, P_2O_5 and K_2O were applied by 100, 50 and 50 % HHs in rice varieties, respectively, and the corresponding figures in hybrids were 98, 88 and 43 %. This indicated that transplanting time and fertilizer application practiced by the majority of HHs farmers were optimal in the district except sub-optimal application of K_2O. But still yield levels were low, and there appears the possible and potential role of more number of irrigations plus wider use of potash.

Among five top most troublesome weeds infesting rice crop in Vaishali (Table 2), 73.6 % HHs indicated *Cyperus difformis* as the most serious weed (rank 1) closely

Table 1. Nutrients and irrigation application pattern in varieties and hybrids in Vaishali.

Particulars	Improved varieties	Hybrids
Average yield (tha^{-1})	3.0	3.6
Average nitrogen application ($kgha^{-1}$)	117.4	133.9
Average phosphorus application ($kgha^{-1}$)	50.6	59.07
Average potash application ($kgha^{-1}$)	33.0	35.3
Average irrigations applied	3.0	3.34
Total households	2	184
% households applying nitrogen	100	98
% households applying phosphorus	50	88
% households applying potash	50	43
% of households applying irrigation	100	100

Table 2. Top five troublesome and common weeds in Vaishali.

Rank	Troublesome weeds	% HHs	Common weeds	% HHs
Weed 1	*Cyperus difformis*	73.6	*Echinochloa colona*	96.7
Weed 2	*Echinochloa crus-galli*	71.5	*Cyperus difformis*	87.6
Weed 3	*Echinochloa colona*	67.2	*Echinochloa crus-galli*	86.6
Weed 4	*Scirpus juncoides*	52.7	*Alternenthera sessilis*	82.8
Weed 5	*Aletrnenthera sessilis*	52.61	*Caesulia axillaris*	82.3

followed by *Echinochloa crus-galli* ranking 2 (71.5% HHs), *Echinochloa colona* (rank 3; 67. 2% HHs), *Scirpus juncoides* (rank 4; 52.7% HHs) and *Alternenthera sessilis* (rank 5; 51.6% HHs). Among top five common weeds of transplanted rice crop were, *Echinochloa colona*, *Cyperus difformis, Echinochloa crus-galli, Alternenthera sessilis* and *Caesulia axillaris* as reported by 96.7, 87.6, 86.6, 82.3 and 82.3% HHs, respectively. This indicated infestation of prominent grassy weeds along with few sedges in the district, warranting their timely and effective management.

Conclusion

Vaishali district of Bihar is having the medium lands with majorly marginal (71%) and small landholding HHs (23%). Hybrids (Arize 6444 Gold, Pioneer 27P31 and PBH 71) are preferably grown by the majority of HHs (82%). However, yield of US 312 hybrid was higher (4.40 tha^{-1}) compared to other hybrids (3.5-3.7 tha^{-1}). Transplanting time till 15 July across varieties/hybrids resulted into higher paddy yield (3.8 tha^{-1}) compared to the schedule of 16-31 July transplanting (3.4 tha^{-1}). Emphasis is also required to ensure effective weed management in this district.

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3.33 Agronomic management is the key for bridging the yield gaps in Arah district of Bihar

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Introduction

The district of Arah lies in between 83° 45' to 84° 45' East latitude and 25° 10' to 25° 40' longitude at an altitude of 192.9 metre above sea level. There are 14 blocks, 249 Panchayats and 1244 villages in the district. It is surrounded by river Ganga in the North and River Sone in the East. It spreads in 233.7 thousand ha out of which 186.5 thousand hectare of land is cultivable. The district falls under Zone III B (South Bihar Alluvial Plain) Agro-climatic Zone where soils vary from heavy clay to sandy clay. The average annual rainfall is about 1200 mm and temperature varies from 9°C to 40°C. Canal and private tube wells are the major source of irrigation in the district. Paddy is the main crop grown over here.

Methodology

In total 30 villages were randomly selected from the 2011 census data on the basis of probability proportionate to size (PPS) method. The villages and the farmers within villages were randomized (Fig. 1) and the sample properly reflects the farmers' population in the district. Seven farmers were randomly selected from each village. They were interviewed regarding the prevailing agronomic practices for the rice crop. The randomization process makes it easy to assess the adoption pattern of different technologies in the district. The questionnaire for the landscape diagnostic survey was prepared in a mobile application based digital data collection format of Open Data Kit (ODK) which is capable of transferring real time data to the server or cloud.

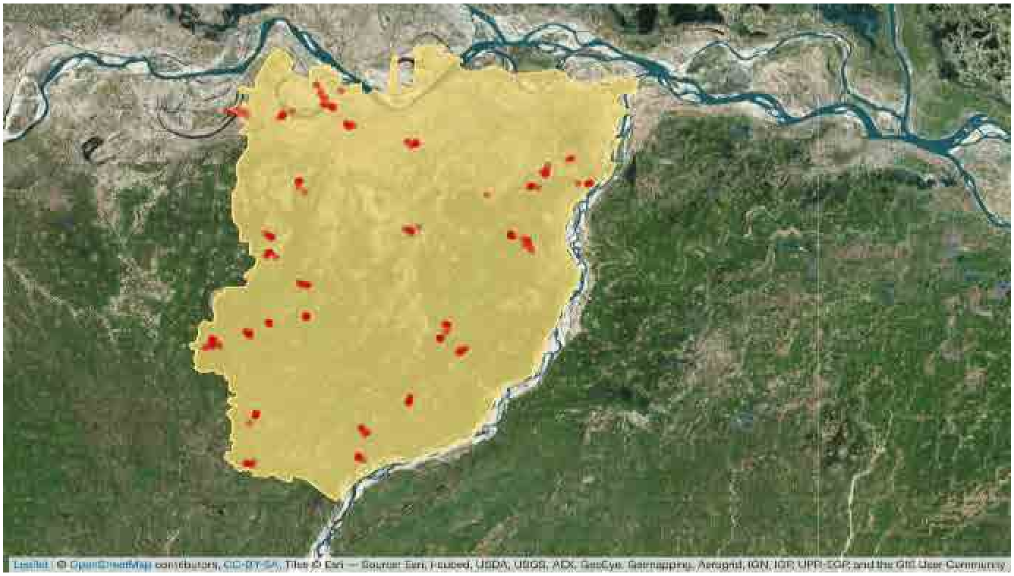


Fig. 1. GPS points of surveyed farms in Arah district, Bihar.

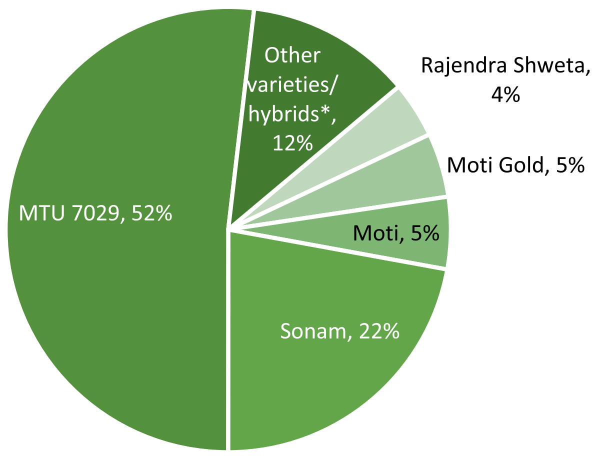
Blocks covered : Agiaon, Arah, Bihiyan, Koilwar, Jagdishpur, Piro, Sahar, Shahpur, Tarari and Udvantnagar.

Villages surveyed : Akaura, Araila, Banauli, Bhakura, Bichla Jangal Mahal, Damodarpur, Devmalpur, Dhandiha, Dhanpura, Dumaria, Imadhpur, Dumaria, Giddha, Harigaon, Hanumannagar, Jamira, Jogata, Katar, Kayam Nagar, Khagraha, Khalisha, Khutaha, Kosiar, Laharpa, Osain, Parariya, Sanaya, Shivpur, Singhitala and Suhiya (Fig. 1).

Results and Discussion

It's evident from data of size of landholding possessed by the surveyed farmers that 89 % of the farmers fall in the small and marginal category whereas only 1 % farmers fall in the category with large landholding. If we look at the drainage class based on the 210 farmers under study, a major population i.e. 90.7 % of farmers falls in the category possessing medium land whereas the percentage of farmers with low land were 5.8, and upland and very low lands were possessed by a meagre 2.9 and 0.6 % HHs, respectively. The study revealed that about 98.8 % of farmers surveyed followed the rice-wheat cropping system whereas 1.2 % fields were under rice-fallow.

It is clearly visible from the data (Fig. 2) that within varieties, there is an extraordinary expansion (52 % HHs) in the area under MTU 7029, a long duration rice variety (LDRV) in Arah district. It means that this >35 years old variety is still not vulnerable to dis-adoption, as many newly developed varieties have already seen/encountered. On evaluating the varietal performance (Fig. 3) it is clear that there is still no new variety near to the high yielding LDRV, MTU 7029 with an average yield of 5.26 tha^{-1} among the surveyed farmers whereas Moti Gold marked an average yield of 4.7 tha^{-1} followed by Sonam, Moti and Rajendra Shweta with 4.10, 3.84 and 3.15 tha^{-1}, respectively.



*Other varieties/hybrids- Aditya, Ankur, Rajendra Mansuri, Sheetal, Super Moti, Arize 6444 Gold, Kaveri, Rupali, Sonali, BPT 5204

Fig. 2. Varietal spectrum of the surveyed farmers in district Arah

Looking at the transplanting date, it is very much evident from the data that paddy transplanted in July had a yield advantage of more than 1.0 tha^{-1} in comparison to that transplanted in August (Fig. 4).

High N application levels and low yields recorded in Arah district (Table 1) suggest that low efficiencies lead to notable nitrogen losses (Eickhout *et al.*, 2006). Use of recommended N and P_2O_5 and irrigations were opted by 100 % farmers but

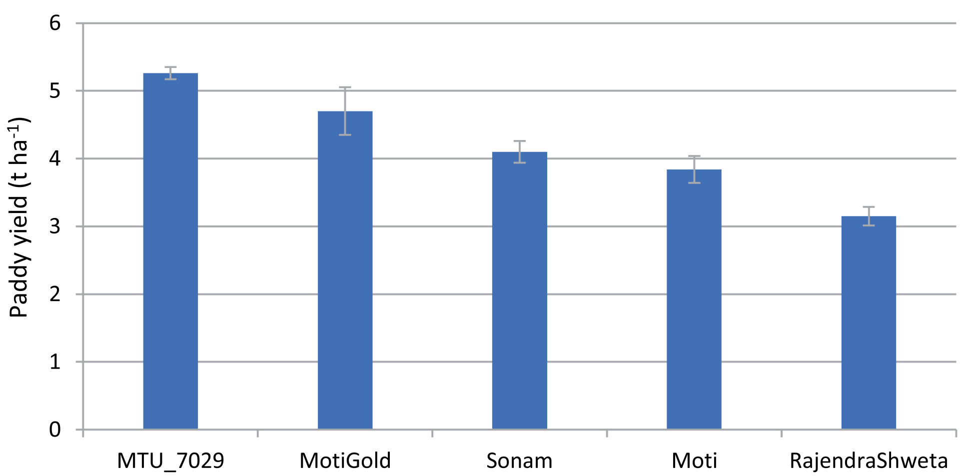


Fig. 3. Varietal performance of the surveyed farmers in district Arah.

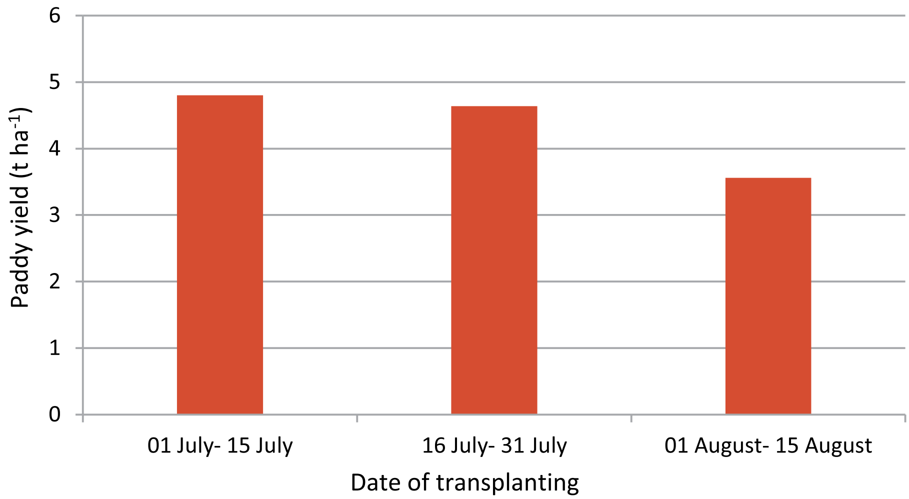


Fig. 4. Effect of dates of transplanting on paddy yield in district Arah.

Table 1. Nutrients and irrigation application pattern in MTU 7029 and Sonam varieties in Arah.

Particulars	MTU 7029	Sonam
Average yield (tha^{-1})	5.3	4.1
Average nitrogen application ($kgha^{-1}$)	148.7	152.8
Average phosphorus application ($kgha^{-1}$)	60.0	57.1
Average potash application ($kgha^{-1}$)	29.9	24.0
Average irrigations applied	2.9	3.4
Total households	89	38
% households applying nitrogen	100	100
% households applying phosphorus	99	100
% households applying potash	13	3
% households applying irrigation	100	100

use of K_2O was not only lower than recommended but also opted by 3-13 % farmers only (Table 1).

Weeds have been a major nuisance for crop production and rice is also not an exception. There has been a major yield decline attributed to severity of weeds. Based on the weed data of the surveyed farmers, it was found that 74 % HHs found *Echinochloa colona* as the most troublesome weed followed by weedy rice (67 % HHs), *Fimbristylis* spp. (42.2 % HHs), *Cyperus difformis* (26.6 % HHs) and *Cynadon* *dactylon* (24 % HHs) in Arah district (Table 2). *Echinochloa colona*, Weedy rice and *Cyperus difformis* were the three most common weeds in the district.

Table 2. Five most common and troublesome weeds and yield of paddy in Arah district.

Rank	Common weeds	% HHs	Troublesome weeds	% HHs
Weed 1	*Echinochloa colona*	80.3	*Echinochloa colona*	74.0
Weed 2	Weedy rice	76.9	Weedy rice	67.0
Weed 3	*Cyperus difformis*	55.5	*Fimbristylis* spp.	42.2
Weed 4	*Cyperus iria*	49.7	*Cyperus difformis*	26.6
Weed 5	*Scirpus juncoides*	48.5	*Cynadon dactylon*	24.3

Conclusion

The district is dominated by long duration and medium duration rice varieties due to its shallow low land ecologies. The efficiency of inputs is low. The varietal replacement is also low. The best way to bridge up the yield gap is through agronomic management with a focus on time of transplanting and weed management.

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3.34 Delayed rice transplanting and sub-optimal nutrient use– Two most serious factors for lower rice yield in Arwal district of Bihar

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Introduction

Agro-climatically, district Arwal falls under South Bihar Alluvial Plain Zone between 25° to 25° 15' N latitude and 84° to 85° 15' E longitude at an altitude of 67.9 m above MSL. Its geographical area is 63400 ha, of which 43100 ha is the net sown area with 197 % cropping intensity. Net irrigated area is 26500 ha mainly through bore wells/deep tube-wells (38 %), dry & shallow wells (46 %) and canals (16 %). Annual rainfall in the district is 1014 mm mainly received through SW monsoons. Soils largely are clayey (55.5 %) and fine sandy loam (19.8 %). Rice (44100 ha) is the main crop whereas wheat area is 15000 ha. In order to ensure the proper adoption of technologies, the production practices survey of adoption pattern was undertaken to understand the preferences of farmers.

Methodology

In total 30 villages were randomly selected from the 2011 Census data on the basis of probability proportionate to size (PPS) method. Seven farmers were randomly selected from each village. They were interviewed regarding the prevailing agronomic practices for the rice crop they had grown in *kharif* 2018. The questionnaire for the Landscape Diagnostic Survey (LDS) was prepared in a mobile application based digital data collection format of Open Data Kit (ODK), which is capable of transferring real time data to the server or cloud. Out of total 210 households surveyed, majority of them were marginal (59 %) and small (27 %). The GPS Coordinates of the largest

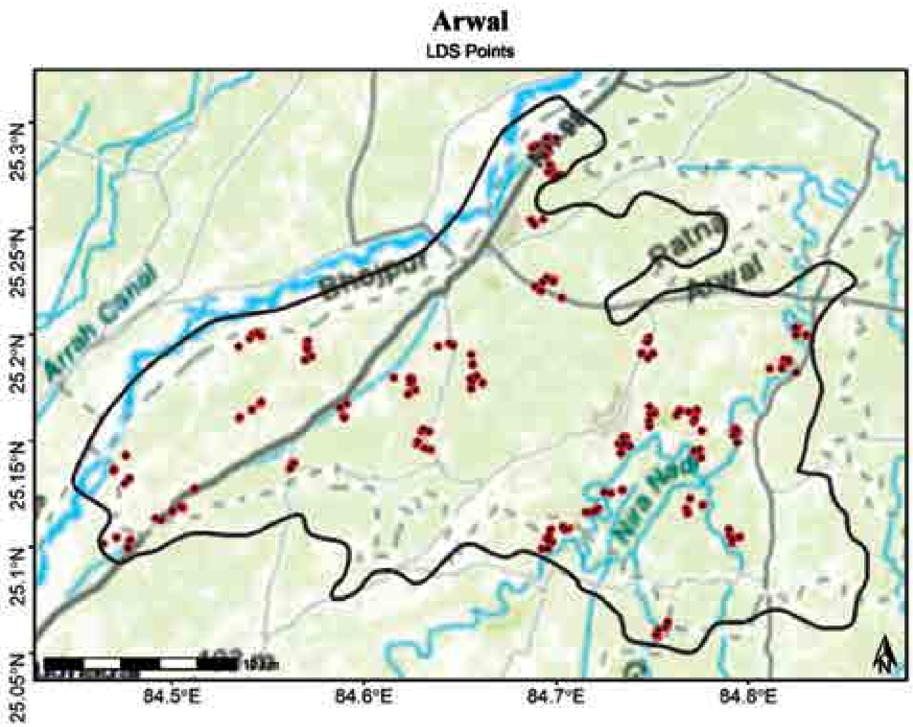


Fig. 1. GPS coordinates of the largest plot of the surveyed farmers in Arwal.

plot of the surveyed farmers in Arwal have been depicted in Fig. 1. As per drainage classification, the topography comprised medium land, lowland and upland to the tune of 92.3, 5.1 and 2.6 %, respectively. As per soil texture, it was 71.3 % medium, 26.7 % heavy and 2.1 % as light soil. About 91 % of the surveyed farmers followed the rice-wheat cropping system.

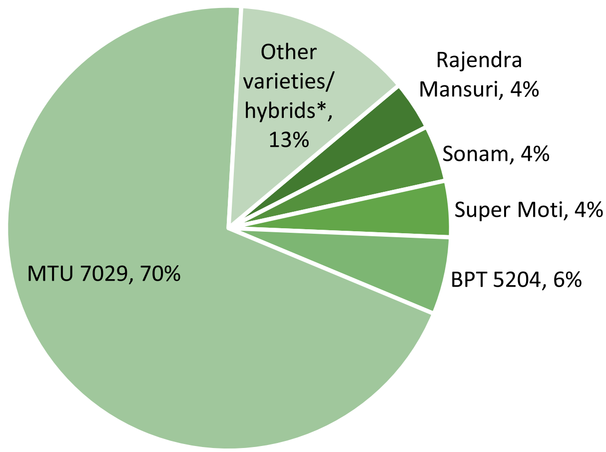
Blocks covered : Arwal, Kahar, Karpi, Khutaha, Sonbhadra, Banshi and Suryapur.

Villages surveyed : Chamandih, Narhi, Khaira, Ibrahimpur, Khatangi, Turuk telpa, Narga, Kusre, Belkharas, Chakia, Agnur, Belawaon, Khushdihra, Hardiya, Konika, Laxmanpur Bath, Bhadasi, Jaipur, Laxmanpur Bath, Sonbarsa, Kaler, Khamhaini, Rampur chauram, Khvahaini, Itawa, Bhusura, Balkhara, Kodmarai, Khara, Belaw, Badasi and Bazitpur (Fig. 1).

Results and Discussion

It is clearly evident from the data (Fig. 2) that 70 % HHs preferred MTU 7029, while 16 % other varieties/hybrids. Other popular varieties in the district were BPT

5204 (6%), Super Moti (4%), Sonam (4%) and Rajendra Mahsuri (4%) besides few others.



*Other varieties/hybrids- Laxmi, Sabour Sampann, Sampoorna, Sarju52, Damini, Moti, Rupali, Swarna Sub1, Arize 6444 Gold, JK Dhanyarekha, Kanchan, Rajendra Shweta

Fig. 2. Varietal spectrum of rice varieties/hybrids based on the data of surveyed farmers (n=210).

Among five most preferred varieties/hybrids, MTU 7029 yielded highest (4.6 tha^{-1}), however it was at par with Sonam (4.4 tha^{-1}), Super Moti (4.4 tha^{-1}) and BPT 5204 (4.4 tha^{-1}), but all these were superior to Rajendra Mahsuri (3.7 tha^{-1}) (Fig. 3). Most preferred varieties are those which have shown resilience over long period of time and which are in the either long duration or in the upper range of medium duration. That means any agronomic management that help these varieties to make fullest use of duration will increase the productivity in the district. This is because the higher yield from these varieties needs a longer growth period so that the production rate of carbohydrate via photosynthesis is not restricted (Ross *et al.*, 2015)

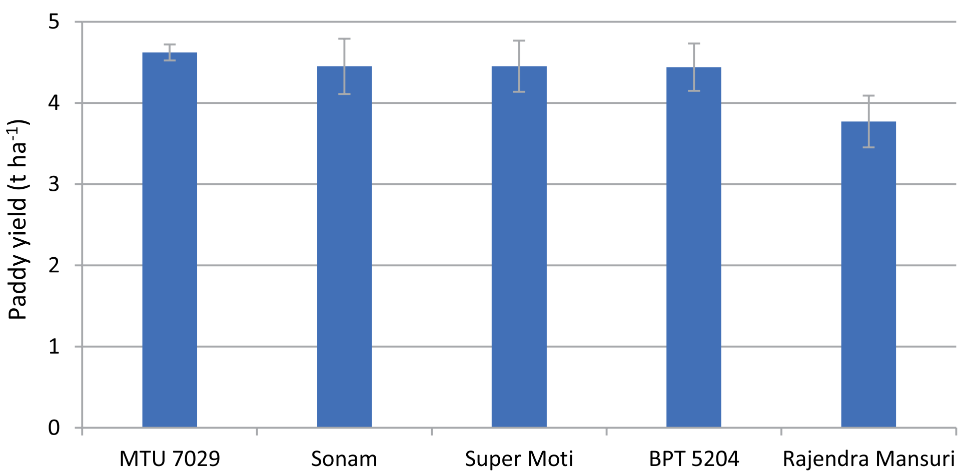


Fig. 3. Performance of most preferred rice varieties/hybrids by the surveyed farmers.

Grain yield of rice was higher when it was transplanted early (01 to 15 July) and declined thereafter, and the magnitude in the yield decline was more in varieties compared to hybrids (Fig. 4). This is obviously due to more area under MTU 7029 which is very long duration variety and yield reduction due to any such delay after 15 July is expected. Therefore, an early transplanting is the most crucial factor to improve rice yields in Arwal district of Bihar. Delayed transplanting decrease the dry matter accumulation due to less tillering and shorter vegetative growth cycle(Lampayan *et al.,* 2015).

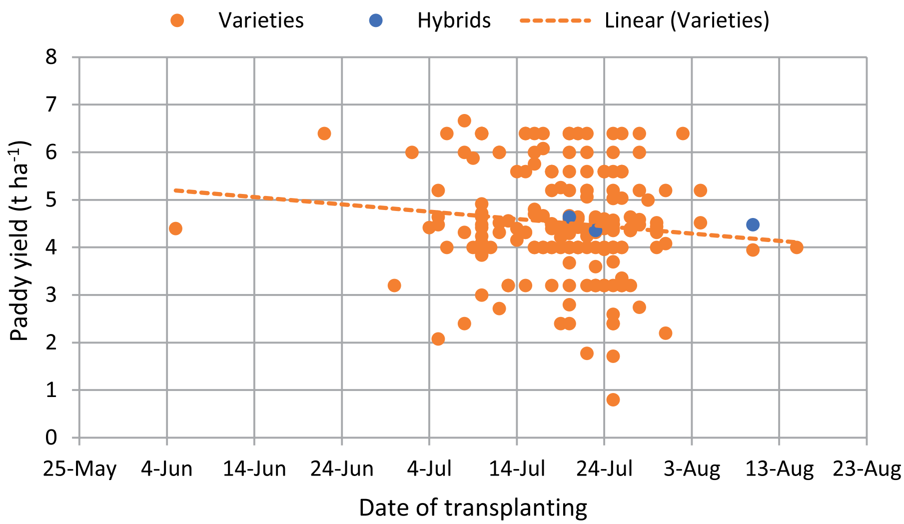


Fig. 4. Effect of time of transplanting on grain yield of rice varieties/hybrids (n=210).

A total of 192 and 03 HHs who grew improved rice varieties and hybrids, respectively harvested an average yield of 4.5 tha^{-1} with almost similar dose of N (130.7 & 129.6 kgha^{-1}) (Table 1). Rates of P_2O_5 (42.4 & 49.0 kgha^{-1}) and K_2O (20.1 kgha^{-1} in varieties & no potash in hybrids) application reflects under dose than the recommended doses both in varieties as well as hybrids, however the irrigation level (8.7 in varieties) was bit higher than the hybrids (7.7) but it was applied by all the HHs. N, P_2O_5 and K_2O were applied by 100, 97 and 31% HHs in rice varieties, respectively and the corresponding figures in hybrids were 100, 100 and 0%. An early or timely transplanting (latest by 15 July) and recommended dose of P_2O_5 and K_2O may further enhance rice yield in the district.

Among five top most troublesome weeds infesting rice crop in Arwal (Table 2), 64.6% HHs indicated *Marsilea minuta* as the most serious weed (rank 1) closely followed by *Cyperus difformis* at rank 2 (36.9 HHs), *Cyperus iria* (rank 3; 32.8% HHs), *Cyperus rotundus* (rank 4; 29.2% HHs) and *Echinochloa colona* (rank 5;

Table 1. Nutrients and irrigation application pattern in varieties and hybrids in Arwal.

Particulars	Improved varieties	Hybrids
Average yield (tha^{-1})	4.5	4.5
Average nitrogen application ($kgha^{-1}$)	130.7	129.6
Average phosphorus application ($kgha^{-1}$)	42.4	49.1
Average potash application ($kgha^{-1}$)	20.1	0.0
Average irrigations applied	8.7	7.7
Total households	192	3
% households applying nitrogen	100	100
% households applying phosphorus	95	100
% households applying potash	31	0
% of households applying irrigation	100	100

Table 2. Top five troublesome and common weeds in Arwal.

Rank	Troublesome weeds	% HHs	Common weeds	% HHs
Weed 1	*Marsilea minuta*	64.6	*Marsilea minuta*	81.5
Weed 2	*Cyperus difformis*	36.9	*Cyperus iria*	58.9
Weed 3	*Cyperus iria*	32.8	*Cyperus difformis*	58.5
Weed 4	*Cyperus rotundus*	29.2	*Cyperus rotundus*	56.9
Weed 5	*Echinochloa colona*	28.7	*Cynadon dactylon*	52.8

28.7 %HHs). Likewise, among top five common weeds of transplanted rice crop, *M. minuta*, *C. iria*, *C. difformis*, *C. rotundus, and Cynadon dactylon* were reported by 81.5, 59.0, 58.5, 56.9 and 52.8 % HHs, respectively. This clearly indicates pronounced dominance of complex weed flora. This type of weed flora would need more emphasis on cultural practices.

Conclusion

The varietal turnover is very low. The yield decline due delay in transplanting has to be resolved by replacing long duration rice varieties (LDRVs) with medium duration rice varieties (LDRVs) or hybrids. Rice variety MTU 7029 is still preferred by the 70 % HHs as it yields higher than other varieties/hybrids. Delayed transplanting and lack of effective management strategy for sedges and grass weeds is also important. Choice for weed management depends on weed communities which is very complex as per low land ecologies.

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3.35 Delayed transplanting of long duration varieties is the main cause of low rice yield in Aurangabad

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Introduction

District of Aurangabad lies at the bank of river Adri. There are few other rivers that endows the agrarian economy of Aurangabad in the rainy season. These include, Sone being the largest, Punpun, Madaar, Auranga, Morhar and Bataane others. It is located between 24.75° N and 84.37° E. The temperature varies from 5 to 50° C during winters and summers. The soil of this district is highly suitable for growing of paddy, wheat and sugarcane. The total district area is 330.01 thousand ha with a net sown area of 173.71 thousand ha. A total of 155.62 thousand ha is covered under paddy crop with a productivity of 3.6 t per ha.

Methodology

In total 30 villages were randomly selected from the 2011 census data on the basis of probability proportionate to size (PPS) method. The villages and the farmers within villages were randomized (Fig. 1) and the sample properly reflects the farmers' population in the district. Seven farmers were randomly selected from each village. They were interviewed regarding the prevailing agronomic practices for the rice crop. The randomization process makes it easy to assess the adoption pattern of different technologies in the district.

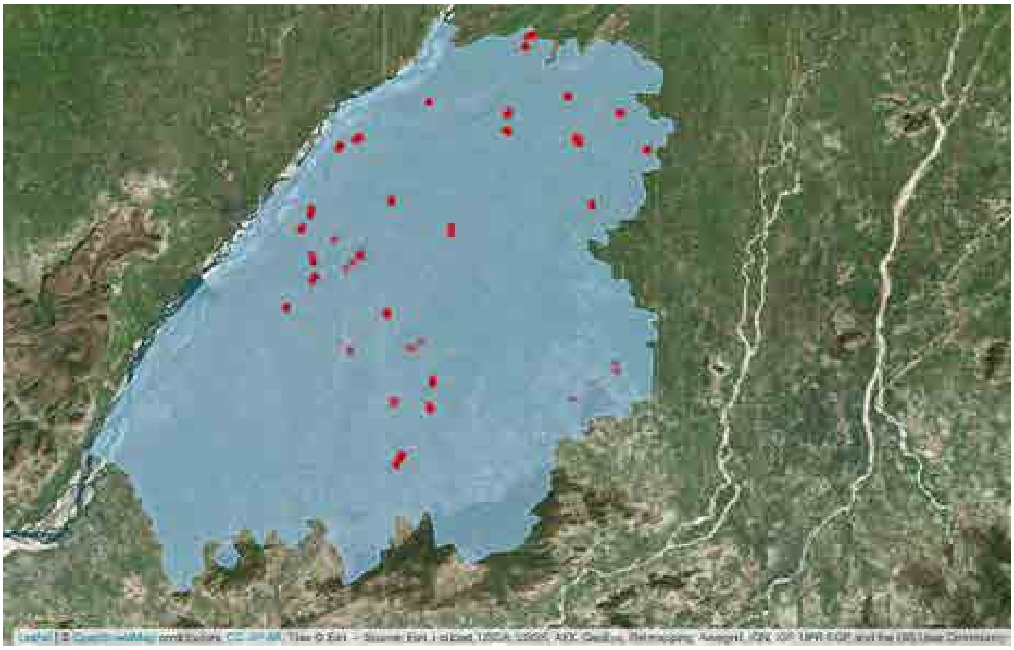


Fig. 1. GPS points of surveyed farms in Aurangabad.

The questionnaire for the landscape diagnostic survey was prepared in a mobile application based digital data collection format of Open Data Kit (ODK) which is capable of transferring real time data to the server or cloud.

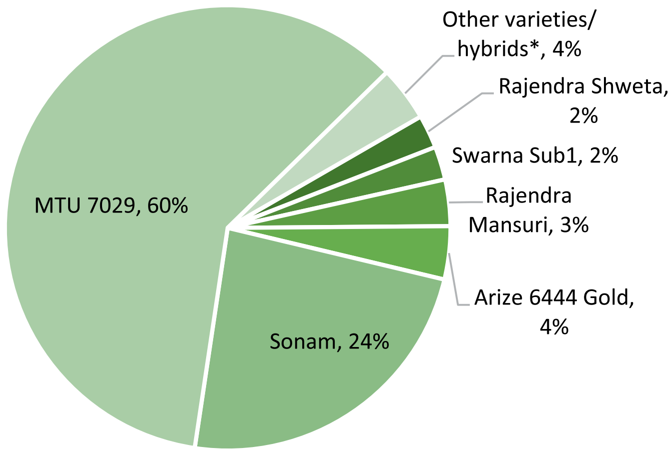
Blocks covered : Aurangabad, Barun, Deo, Haspura, Goh, Obra, Rafiganj and Daudnagar.

Villages surveyed : Dhanauti, Sarsauli, Jhari, Majhgawan, Karman, Jamuhara, Dabura Khurd, Sadikpur, Dehuli, Bharthauli, Piru, Akorha, Jakhaura, Rukndi, Gorari, Kachanpur, Sarakar, Tamoli, Khutaha, Simra Kalan, Sewahi, Ahiyapur, Jamhaur, Inguna, Ratan Khap, Dihuri, Dihra, Sihunri, Dadhpi, Munrawa and Kantari (Fig. 1).

Results and Discussion

The Landscape Diagnostic Survey (LDS) data, show that 63 % HHs fall in the category of marginal followed by small, semi medium and medium category with 20, 12 and 4 % HHs, respectively. Based on the drainage class, a majority of HHs i.e. 91 % had medium land, 5.8 % lowland and 3.4 % upland. Looking at the data for soil texture from the LDS survey farm land, the farmers with medium soil were 94.7 % followed by heavy with 3.9 % and light with the rest 1.4 %. Majority of HHs practice rice-wheat cropping system (94.2%) with a meagre 3.9% practice rice-fallow and 1.9% practice rice-other.

Data reveal that MTU 7029 is still the most popular variety with 60% HHs. The adoption is followed by *Sonam* with 24% HHs (Fig. 2). Few varieties adopted by HHs in a range of 2-4% HHs were; Arize6444 Gold, Rajendra Mahsuri, Swarna Sub1 and Rajendra Shweta.



*Other varieties/hybrids- Bengal Tiger, Gautam, Moti, BPT 5204

Fig. 2. Varietal spectrum of the surveyed farmers in district Aurangabad.

The high adoption rate of MTU 7029 and *Sonam* seems to be connected with relatively high paddy yield of Sonam and MTU7029 at 4.42 and 4.39 tha^{-1}, respectively whereas Swarna- Sub1 yielded only 2.48 tha^{-1} (Fig. 3). Hence, the yield disparities in the data describe how farmers have adopted older varieties like MTU 7029 with some competition from *Sonam*, a variety from private sector.

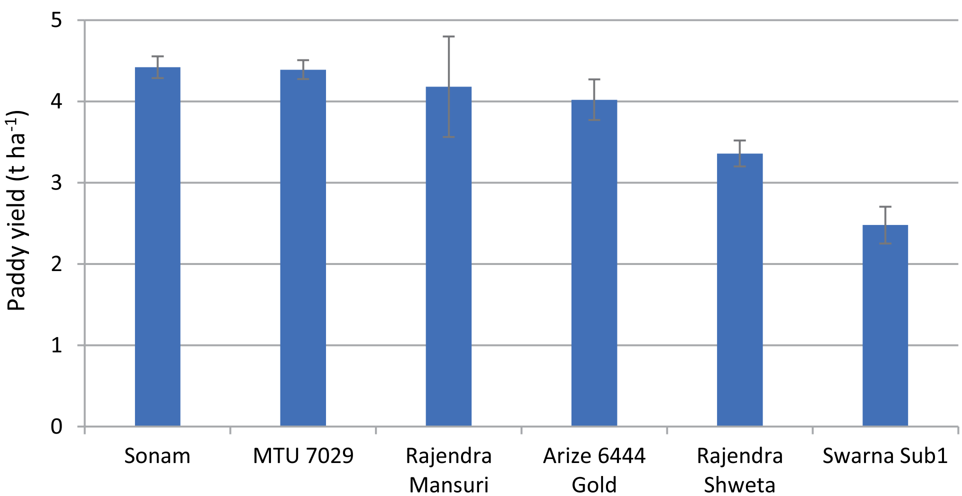


Fig. 3. Grain yield of varieties and hybrids of the surveyed farmers in district Aurangabad.

There was consistent yield decline in MTU 7029 with each delay in transplanting across July 1st to August 1st (Fig. 4). Delayed transplanting decrease the dry matter accumulation due to less tillering and shorter vegetative growth cycle (Lampayan *et al.,* 2015).

Based on data in Table 1, it's clear that average yield of both MTU7029 and Sonam was at par, the NPK & irrigation applied were also at par. The percentage HH

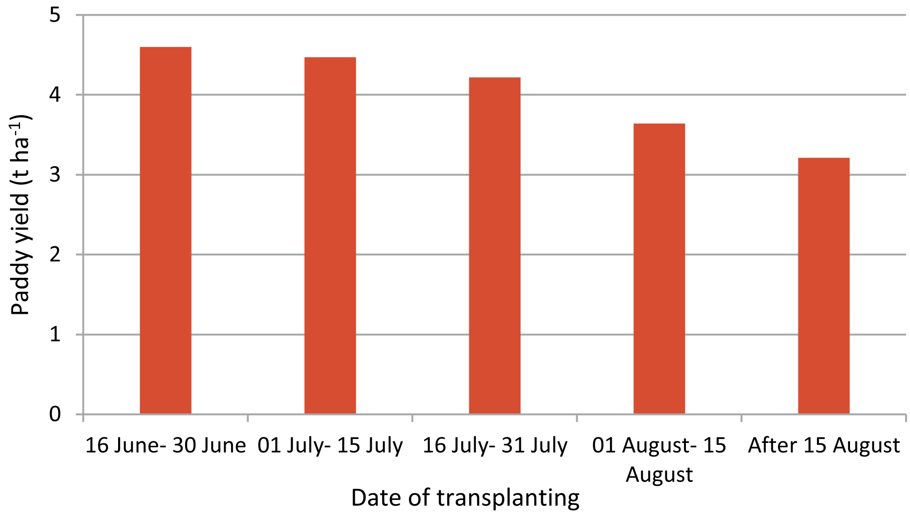


Fig. 4. Effect of dates of transplanting on paddy yield in district Aurangabad.

Table 1. Nutrients and irrigation application pattern in varieties and hybrids in Aurangabad

Particulars	MTU7029	Sonam
Average yield (tha^{-1})	4.4	4.4
Average nitrogen application ($kgha^{-1}$)	113.7	106.5
Average phosphorus application ($kgha^{-1}$)	58.5	60.6
Average potash application ($kgha^{-1}$)	24.0	21.0
Average irrigations applied	4.0	4.1
Total households	125	49
% households applying nitrogen	100	100
% households applying phosphorus	98	100
% households applying potash	19	12
% of households applying irrigation	100	100

applying N and P are 100 % whereas only 19 % of the surveyed population who used MTU7029 and 12 % who used Sonam variety applied potash.

Weeds are one of the most serious cause of concern in rice fields (De Datta and Baltazar, 1996). There are a number of chemical molecules developed to control this menace but still the problem persists. Two of the major troublesome weeds in the district of Aurangabad are *Marsilea minuta* (59 %) followed by *Echinochloa colona* (46 %) (Table 2).

Table 2. Five most common and troublesome weeds and yield of paddy in Aurangabad district

Rank	Troublesome weeds	% HHs	Common weeds	% HHs
Weed 1	*Marsilea minuta*	58.9	*Marsilea minuta*	58.9
Weed 2	*Echinochloa colona*	46.4	*Echinochloa colona*	46.4
Weed 3	*Cyperus iria*	38.6	*Echinochloa crus-galli*	38.6
Weed 4	*Ipomoea aquatic*	34.8	*Cyperus rotundus*	34.8
Weed 5	*Cynadon dactylon*	31.9	*Cyperus iria*	31.9

Delayed transplanting leads to slow growth including less tillers formation. Farmers struggle to improve growth by adding N but even low growing weeds like *Marsilea* start dominating the rice crop which leads to decrease in input use efficiency.

Conclusion

Traditional variety MTU7029 still dominates in the district and varietal replacement is very low. Delayed transplanting is the two most important factor for lower yields, which call for replacing long duration rice varieties with medium duration varieties or hybrids in the district. An effective management of complex weed flora is also equally important to realize better yield potential in the district.

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3.36 Mechanization from seed to harvest can help improve the rice yield and optimize the rice-fallow cropping system in Raipur district of Chhattisgarh

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Introduction

Raipur district is a part of Eastern Plateau and Hills Region and situated in the fertile land of Chhattisgarh region. This district is situated between 22°33' N to 21°14'N latitude and 82°6' to 81°38'E longitude. Total population of Raipur is 40,63,872 & population density is 328 per sq. km. District is having gross sown area of 2,17,507 ha. Cultivators and agricultural labourers form about 24.89 % & 50.69 %, respectively. Inceptisol (39 %), Alfisols (27 %), Vertisols (21 %) and Entisol (12 %) are the major soil types and the district received a rainfall of 1,197.1 mm. Total 1,28,965 ha land is under irrigated during *kharif* (80 %) and 27,501 ha during *rabi* season (49 %). The yield momentum since first phase of green revolution is slow. Assessing the impact of specific technologies like varieties is nothing new. 'How do farmers respond to new recommendations of varieties or the agronomic practices' is important to understand the preferences of farmers. To resolve the issue of stagnant yield growth in rice, land scape diagnostic survey (LDS) of agronomic practices was conducted and its results are presented here.

Methodology

In total 30 villages were randomly selected from the 2011 census data based on probability proportionate to size (PPS) method. The villages and the farmers within

villages were randomized (Fig. 1) and the sample properly reflects the farmers' population in the district.

Seven farmers were randomly selected from each village. They were interviewed regarding the prevailing agronomic practices for the rice crop.

CSISA-KVK network used mobile based Open Data Kit (ODK) to record observations instead of time-consuming conventional paper-based system which takes lot of time with high cost. The randomization process makes it easy to assess the adoption pattern of different technologies in the district map (Fig. 1). The questionnaire for the landscape diagnostic survey was prepared in a mobile application based digital data collection format of Open Data Kit (ODK) which can transfer real time data to the server or cloud.

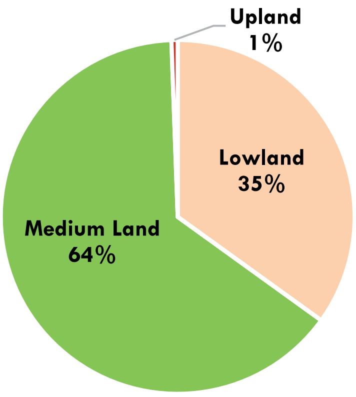

Fig. 2. Land types of surveyed farmers based on drainage class in Raipur (N=352).

Results and Discussion

Based on the drainage class, 64% HHs from the LDS data (352 HHs) had medium lands, 35% lowland and only 1% upland (Fig. 2). These data

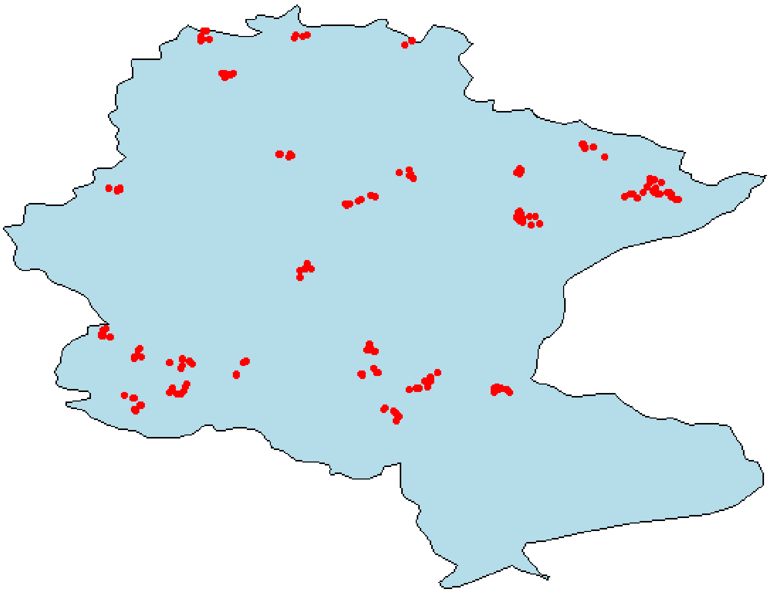

Fig. 1. LDS points of HHs survey in different villages in Raipur (N=355).

sets point to the future need for long duration or medium duration rice varieties or hybrids rather than the short duration varieties.

Prior to *kharif* season, 92 % area remains as fallows and rest 5 and 3 % is covered by rice and pulses, respectively (Fig. 3). Among the total surveyed HHs in Raipur (352), rice is majorly grown as direct seeded comprising *beushening* (44 %), broadcasting (35 % and drill seeding (1 %), while rest 20 % is transplanted (Fig. 4). These two issues are inter-related. Rabi fallow require irrigation or residual moisture for seeding, emergence and early growth of crops that follow rice. These crops may be pulses (green gram or black gram or oilseeds. The crop may need one or two post sowing irrigation to take the crop to maturity. Access to cheap irrigation is one issue which needs immediate attention. To make use of residual moisture, farmers need to ensure that rice fields are vacated immediately after harvesting so that the residual moisture is secured. That would need mechanization. *Beushening* is a problem as it requires lot of labour and seed with no yield gain. Even if farmers reduce their dependence on *beushening* direct seeding by broadcast method is another problem which may have to be resolved for getting high yields. The improvement in the crop establishment methods will have to be put in the frontline to sustainably increase rice productivity in Raipur district. Comparison of different methods given by Madhulika *et al*. (2020) can be used as reference point.

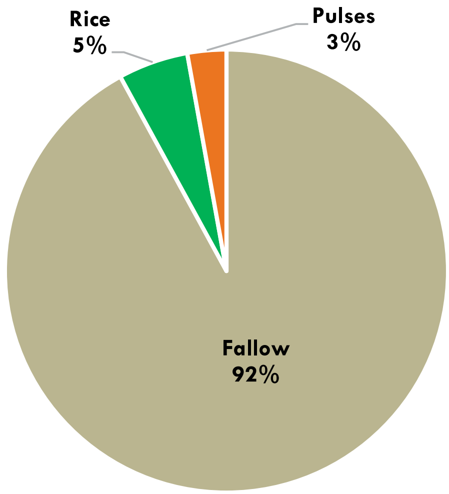

Fig. 3. Land use by surveyed farmers prior to *kharif* season in Raipur (N=352).

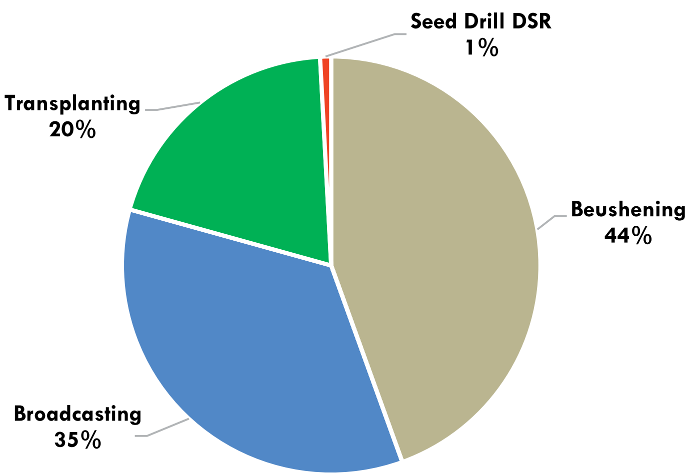

Fig. 4. Method of crop establishment applied by surveyed farmers in Raipur (N=352).

Based on LDS survey of 282 HHs, it was found that direct seeding in Raipur starts from 7th June and continues up to 4th July with a peak sowing time ranging between 21st to 29th June (Fig. 5). Paddy yield varied between 4.1 to 5.2 tha^{-1} between 7th June to 4th July but then it was reduced drastically thereafter (Fig. 6).

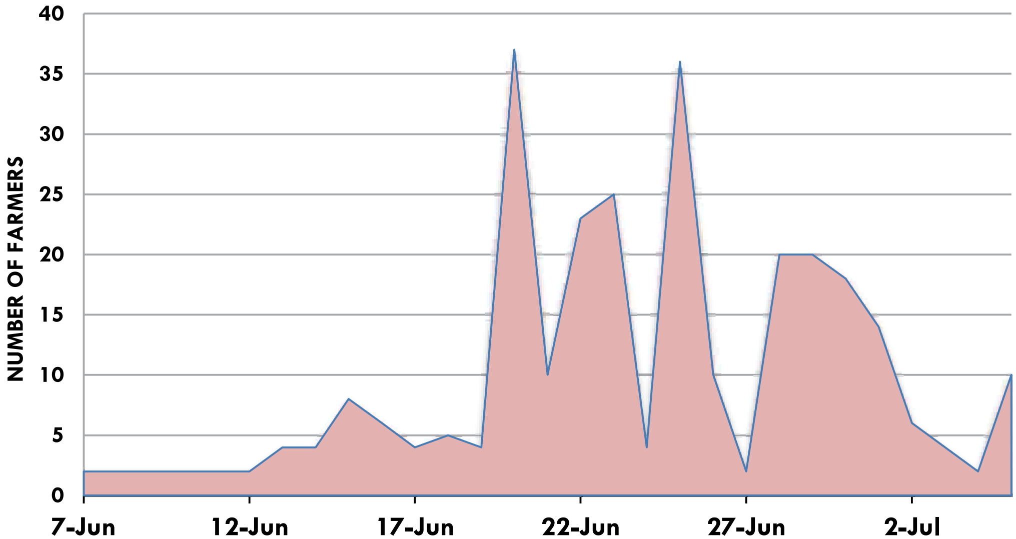

Fig. 5. Sowing schedule of DSR in Raipur (N=282).

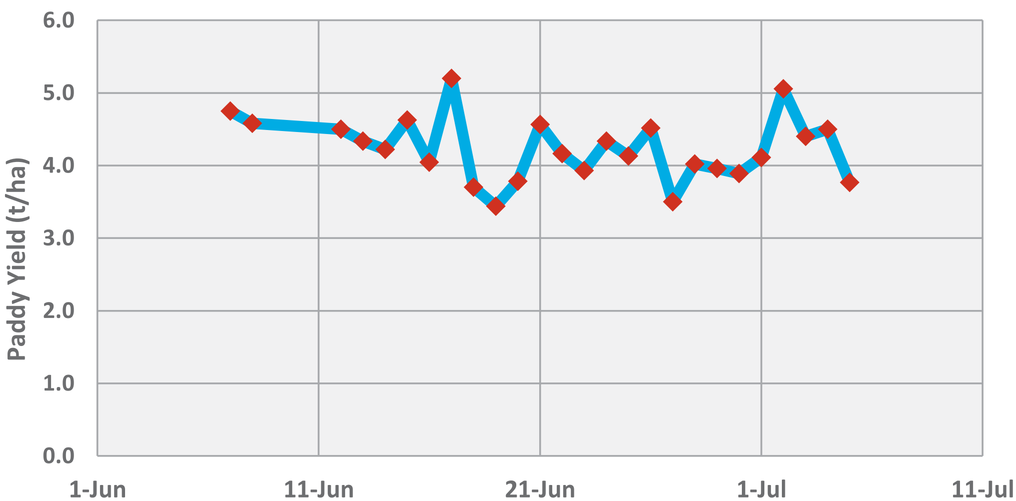

Fig. 6. Paddy yield under DSR methods along with the sowing dates in Raipur (N=282).

Based on 352 HHs LDS based data, MTU7029 was the most preferred rice variety (80 %) among the five top most preferred rice varieties in the district (Fig. 7). Other varieties Mahamaya, MTU1010, HMT and VNT2228 were preferred by 11, 6, 2 and 1 % farmers, respectively. The average yield reported for MTU7029, Mahamaya, MTU1010, HMT and VNT2228 were 4.10, 4.21, 4.50, 3.59 and 6.09 t ha^{-1}, respectively.

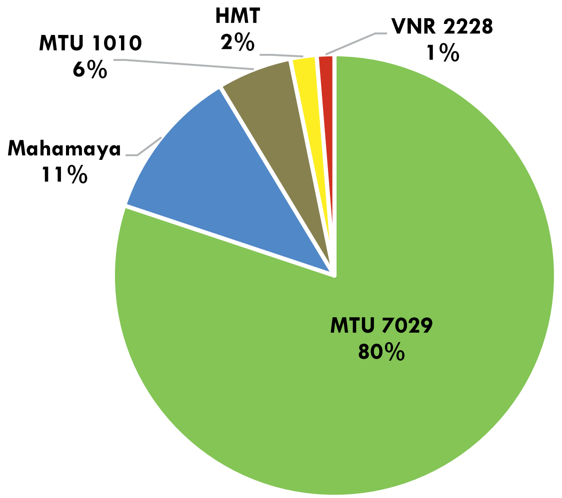

Fig. 7. Five most preferred varieties by surveyed farmers in Raipur (N=352).

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3.37 Hybrid technology coupled with weed management is very crucial to achieve higher paddy yield in Kanker district of Chhattisgarh

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Introduction

Kanker district is located in the southern region of Chhattisgarh under Agro Climatic Zone of Chhattisgarh Plains & Bastar Plateau. It is located at the 20.6° to 20.24° N longitude and 80.48° to 81.48° E latitude. Total geographical area of Kanker is 6.4 lakh ha including a vast forest area of 2.8 lakh ha. (44%). Net sown area of the district is about 2.1 lakh ha and cropping intensity is 122%. On an average, the district receives an annual rainfall of 1492 mm. There are three major field crops of the district i.e. rice, minor millet and maize. Total area under cereals is a 201659 ha, pulses 18735 ha and among crops paddy covered a major area of 174398 ha. Farmers in the district are grappling with stagnant productivity growth of rice and are not attempting to intensify the rice-fallow cropping system To understand the factors affecting these problems, CSISA-KVK attempted to track the adoption patterns of recommended technologies.

Methodology

In total 30 villages were randomly selected from the 2011 census data based on probability proportionate to size (PPS) method. The villages and the farmers within villages were randomized and the sample properly reflects the farmers' population in the district. Seven farmers were randomly selected from each village. They were interviewed regarding the prevailing agronomic practices for the rice crop.

The randomization process makes it easy to assess the adoption pattern of different technologies in the district. The questionnaire for the landscape diagnostic survey was prepared in a mobile application based digital data collection format of Open Data Kit (ODK) which can transfer real time data to the server or cloud.

Results and Discussion

According to data from the LDS survey 71% HHs had medium lands, 24% lowland and 5% had upland (Fig. 1).

Prior to *kharif* season, 75% HHs had rice-fallow and the rest 17, 6 and 2% had rice-rice, rice-maize and other cropping systems, respectively (Fig. 2). Heavy dependence on monsoon rains has made farmers more vulnerable especially when it comes to intensify the cropping system. Due to very high cost of irrigation, the soil moisture is too low to raise the succeeding crop profitably. Access to cost effective irrigation facility would help intensify rice-fallow cropping system in Kanker.

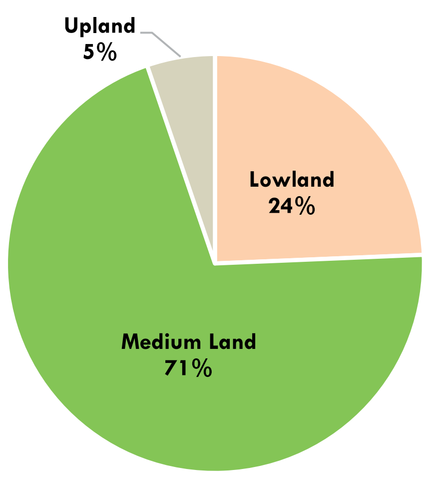

Fig. 1. Land types of surveyed farmers based on drainage class in Kanker (N=152).

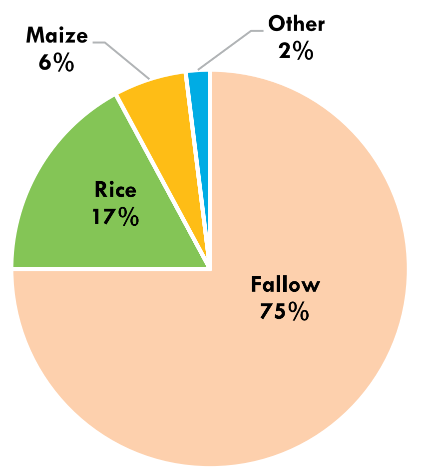

Fig. 2. Land use by surveyed farmers prior to *kharif* season in Kanker (N=152).

Among 152 surveyed HHs in the district, 21, 23, 30, 15, 8 and 3% HHS had a largest plot size of 0-1, 1-2. 2-3, 3-4, 4-5 and > 5 acres, respectively (Fig. 3).

Among the total surveyed HHs in Kanker district (N=152), rice is majorly grown as direct seeded comprising broadcasting (33%) and *beushening* (24%), while random and line transplanting was done by 33 and 10% HHs, respectively (Fig. 4). The crop establishment methods are overlapping with some of these are reducing the

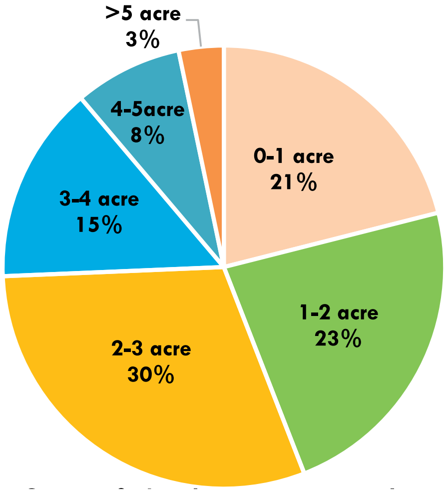

Fig. 3. Size of the largest rice plots of surveyed farmers in Kanker (N=152).

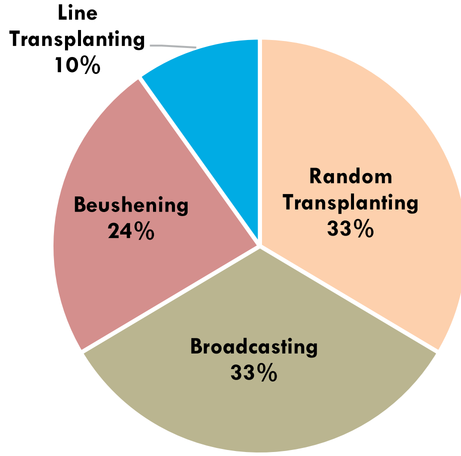

Fig. 4. Method of crop establishment applied by surveyed farmers in Kanker (N=152).

performance of varieties or external inputs. Among topmost five rice varieties, MTU 1010 was the most preferred one (34%) followed by rice hybrid Arize 6444 (21%) in the district (Fig. 5). Other varieties IR64, MTU7029 and Balwan were preferred by 17, 14 and 14% farmers, respectively.

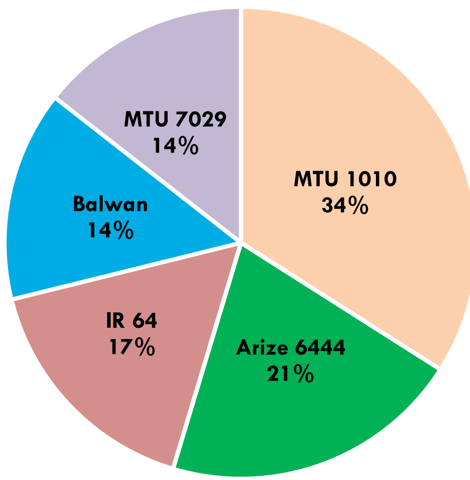

Fig. 5. Five most preferred varieties by surveyed farmers in Kanker (N=152).

Swarna (MTU 7029) is the most extensively cultivated variety of rice (Saha *et al*., 2008). Hybrids could (Janaiah, 2002; Janaiah, et al., 2006) be a potential option.

The study found that MTU 7029 from LDRVs and Balwan or Arize 6444) from MDRH group had almost same yield in a range of 3.9 and 4.0 t ha^{-1} (Fig. 6). These were followed by SDRVs including MTU1010 (3.63 tha^{-1}) and IR64 (3.26 tha^{-1}).

Majority of the famers (70%) opted for only one spray of herbicides and attained paddy yield of 3.48 tha^{-1} (Table 1). Those farmers (7%) who employed two sprays got paddy yield of 3.90 tha^{-1} but without spray (23% farmers), the paddy yield was lowest (2.96 tha^{-1}). This clearly indicated the importance of effective weed management through herbicides. It is important for researchers to identify

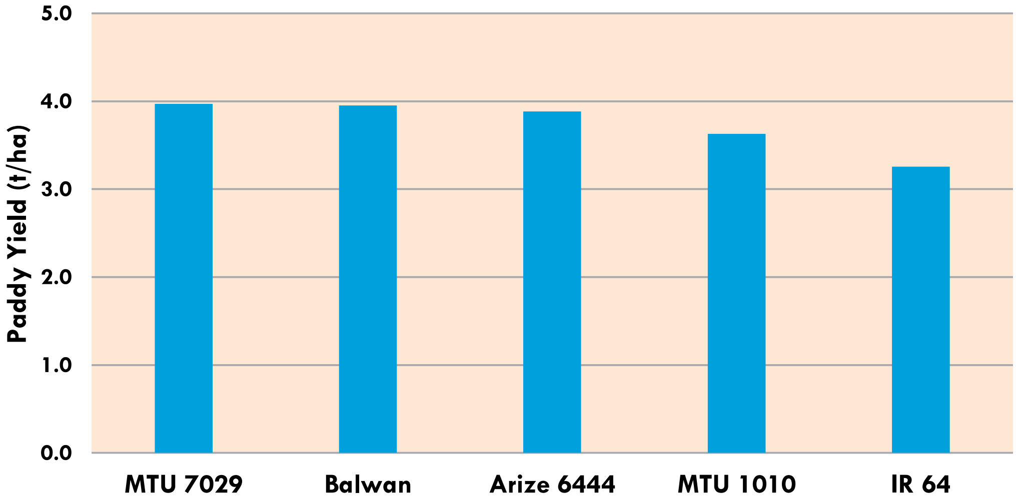

Fig. 6. Paddy yield of five most preferred rice varieties by surveyed farmers in Kanker (N=97).

and address the factors which prevent farmers to adopt new technologies (Hu et al., 2005). In Kanker, the broadcasting based DSR should be discouraged and weed management work should be initiated.

Table 1. Effect of number of herbicide sprays on paddy yield in Kanker (N=152).

Herbicide application times	Percentage of farmers	Paddy yield (t ha^{-1})
No spray	23	2.96
1 spray	70	3.48
2 sprays	7	3.90

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3.38 Effective weed management and proper crop establishment methods can further improve rice productivity in Dhamtari district of Chhattisgarh

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Introduction

Dhamtari district lies in southern region of Chhattisgarh and situated between 20°42' N latitude and 81°33' E longitude. Out of total 408190 ha geographical area of the district, the forest covers is 2.14 %. It receives an annual rainfall is 1372 mm. Gross cropped area of the district is 218425 ha and cropping intensity is 161 %. Entisol, Inceptisol, Alfisols & Vertisols ae the 4 major soil type of the district. Agriculture plays a very important role in the economic development of the district. KVK is the most important central extension system that helps disseminating technologies in a sustainable and reliable way. We have seen the shift in the process of adoption of new technologies, but more work is needed to understand the process so that KVK becomes knowledge centre for an evidence-based feedback to researchers and extension agencies. Land scape diagnostic (LDS) survey was conducted to understand the preferences of farmers.

Methodology

In total 30 villages were randomly selected from the 2011 census data based on probability proportionate to size (PPS) method. The villages and the farmers within

villages were randomized (Fig. 1) and the sample properly reflects the farmers' population in the district. Seven farmers were randomly selected from each village. They were interviewed regarding the prevailing agronomic practices for the rice crop.

The randomization process makes it easy to assess the adoption pattern of different technologies in the district. The questionnaire for the LDS was prepared in a mobile application based digital data collection format of Open Data Kit (ODK) which can transfer real time data to the cloud server.

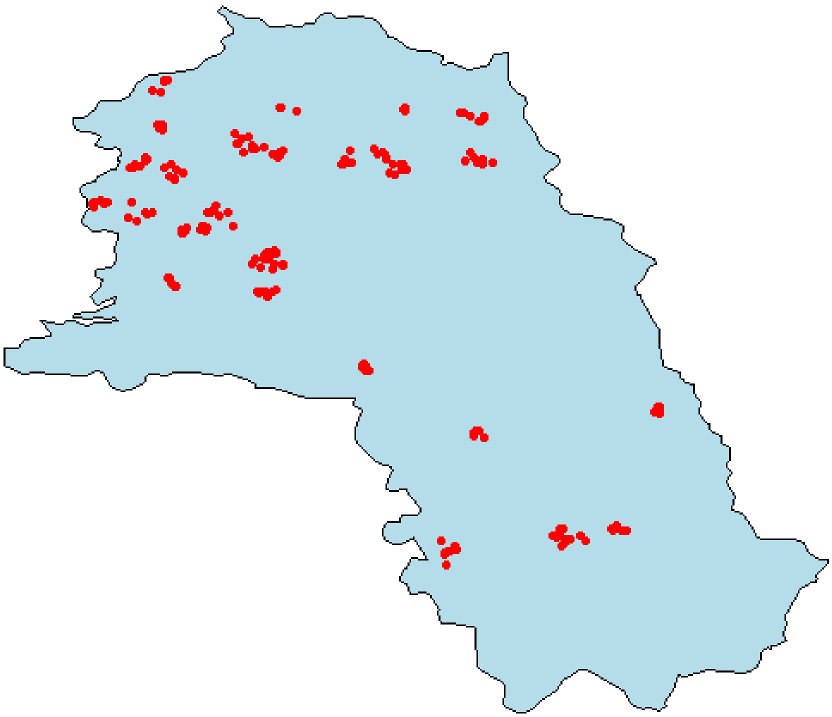

Fig. 1. LDS points of HHs survey in different villages in Dhamtari (N=185).

Results and Discussion

Based on the drainage class among 200 HHs in Dhamtari district of Chhattisgarh, most of the farmers (N=172) HHs had their rice crop in medium lands producing an average paddy yield of 5.46 tha^{-1} (Fig. 2). While farmers with lowland (N=3) and upland (N=25) attained a yield of 4.61 and 3.88 tha^{-1}, respectively. The dominance of this district with medium land can help deriving larger value and that would need more efforts to intensify the cropping system.

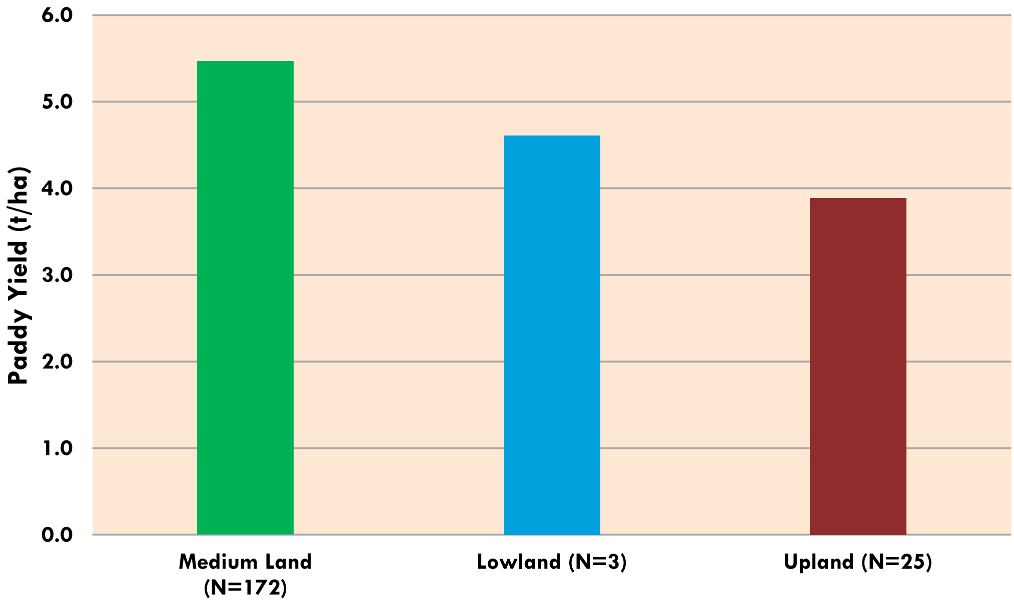

Fig. 2. Paddy yield of surveyed farmers in Dhamtari (N=200) on various land types.

Prior to *kharif* season, 40% area remains as fallows and rest 49, 9 and 2% is covered by rice, chickpea and other crops, respectively (Fig. 3). This district has built up insights into rice-rice cropping system but 40% HHs still follow RFCS. This RFCS can also be intensified by making best use of residual moisture of rice. Among the total surveyed HHs in Dhamtari district (N=200), rice is majorly grown by random transplanting (64%) followed by broadcasting (19%) and *beushening* (15%) (Fig. 4). Line transplanting is done only by 2% farmers.

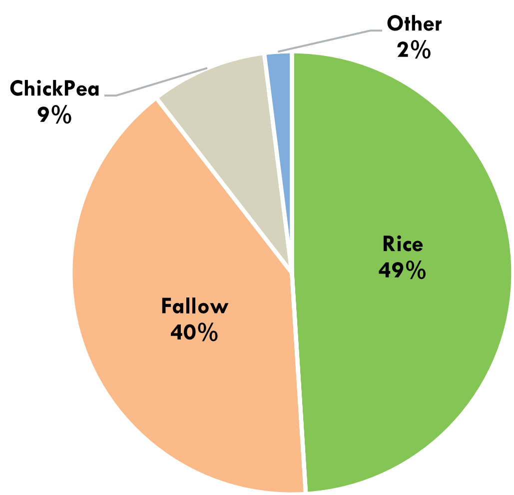

Fig. 3. Land use by surveyed farmers prior to *kharif* season in Dhamtari (N=200).

Those who opted for random and line transplanting produced an average yield of 5.47 and 5.30 tha^{-1} (Fig. 5). Whereas, the paddy yield among the surveyed HHs (N=200) was lower in broadcasting (4.85 tha^{-1}) and *beushening* (3.95 tha^{-1}). Published work has shown a great promise in DSR technology but there are still many ifs and buts which need resolution from research groups (Kumar *et al.*, 2011). Delayed transplanting decreases the dry accumulation due to less tillering and shorter vegetative growth cycle (Liu *et al.*, 2015). The mean dates of line transplanting was 23-July, for random transplanting was 19-July, for broadcasting was 5-July and for *beushening* was 3-July.

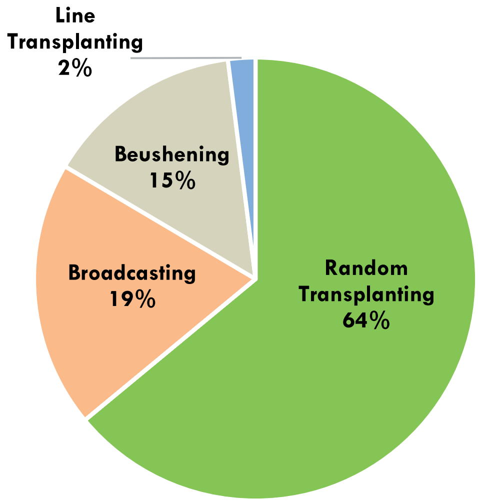

Fig. 4. Method of crop establishment applied by surveyed farmers in Dhamtari (N=200).

Among topmost five rice varieties, MTU 1010 was the most preferred one (33 %) followed by IR 64 (24 %) and BPT 5204 (20 %) in the district (Fig. 6). Other varieties Swarna Sub-1 and MTU 7029 were preferred by 14 and 9 % farmers, respectively. Beside yield advantage these varieties these varieties particularly BPT 5204 have better quality which results in clear contrast in respect of better market price for farmers.

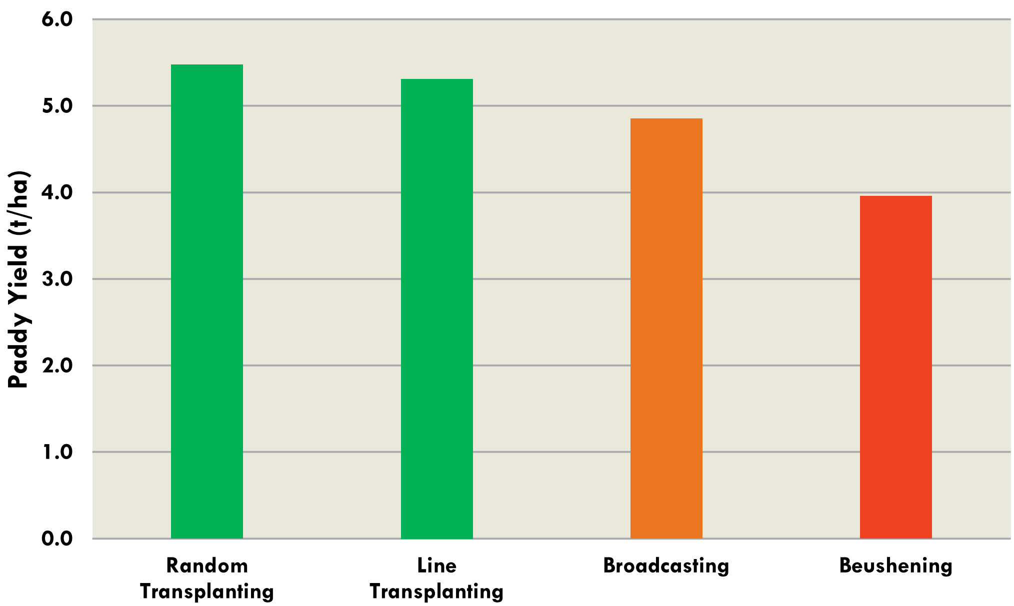

Fig. 5. Paddy yield by crop establishment methods in Dhamtari (N=200).

Majority of the famers (53%) opted for two weeding and attained paddy yield of 5.18 tha^{-1} (Table 1). Those farmers (42%) who employed only one hand weeding also harvested equally good yield (5.12 tha^{-1}). Yield realized by 4% HHs with three weeding was very high (7.0 tha^{-1} and with no weeding (2% HH), it was very low (3.67 tha^{-1}). This indicated about clear cut importance of effective weed management to attain high paddy yield in the Dhamtari district of Chhattisgarh.

Table 1. Effect of number of hand weedings on paddy yields in Dhamtari (N=200).

Number of hand weeding	Percent of farmers	Paddy yield (t ha^{-1})
No weeding	2	3.67
1 weeding	42	5.12
2 weeding	53	5.18
3 weeding	4	7.00

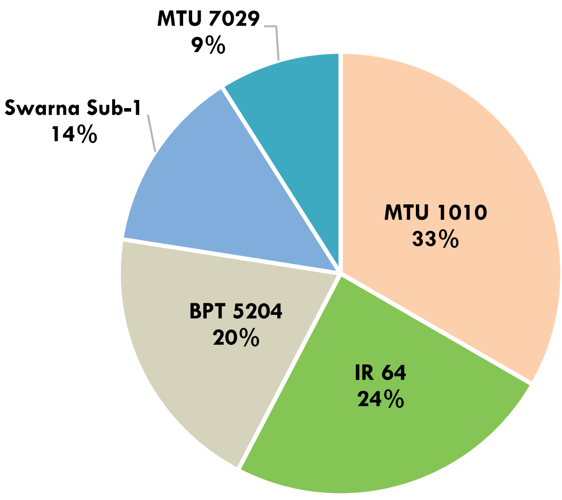

Fig. 6. Five most preferred varieties by surveyed farmers in Dhamtari (N=200).

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3.39 Status of production technologies of rice in Kurukshetra district of Haryana

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Introduction

Kurukshetra district of Haryana falls in Eastern Zone (HR-1) with 29°57' 58.52''N latitude and 76°49' 42.79''E longitude at an altitude of 283 m above MSL. Its geographical area is 168,000 ha, of which 150,000 ha is the net sown area with 177% cropping intensity. Net irrigated area is 150,000 ha mainly through electric tube-wells (82%) and partly by canals (18%). Annual rainfall in the district is 646 mm mainly received through SW monsoons. Soils of the district are loamy (alluvial) (46%) and remove and with, sandy loam (37.5%) and others (16.5%). In the district rice (109,000 ha) is the main crop in *kharif*, and wheat area is 110,300 ha. Average productivity of rice and wheat is 4,038 and 4,672 $kgha^{-1}$, respectively, in the district. Timely transplanting of high yielding rice varieties/hybrids and raising the crop with recommended package of practices along with suitable agro-ecology are the main factors contributing for higher grain yield in the district. Variations in adoption of recommended package of practices are generally observed at farmers' field. Many farmers are using inputs above the recommended doses. So, it becomes necessary to have latest status of package of practices adopted by the farmers.

Methodology

Villages (30) were randomly selected from the 2011 Census data based on probability proportionate to size (PPS) method. Seven farmers were randomly selected from each village. They were interviewed regarding the prevailing agronomic practices for the rice crop they have grown in *kharif* 2018. The questionnaire for the

Landscape Diagnostic Survey (LDS) was prepared in a mobile application based digital data collection format of Open Data Kit (ODK), which can transfer real time data to the server or cloud. GPS coordinates of the largest plot of the surveyed farmers in Kurukshetra is shown in Fig. 1. Out of total 210 households surveyed, large, medium, semi-medium, small and marginal HHs were 10, 30, 21, 26 and

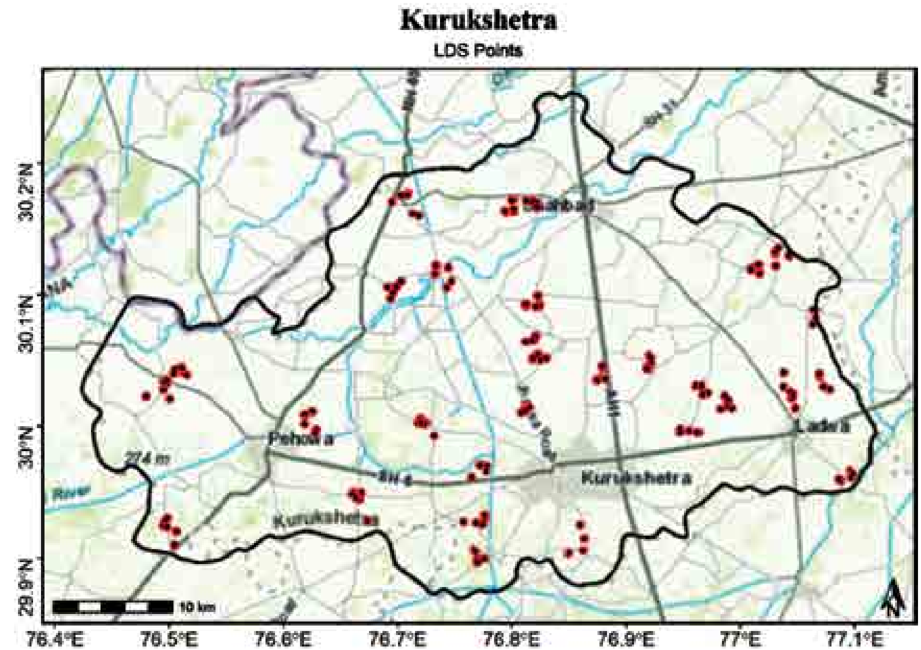


Fig. 1. GPS coordinates of the largest plot of the surveyed farmers in Kurukshetra.

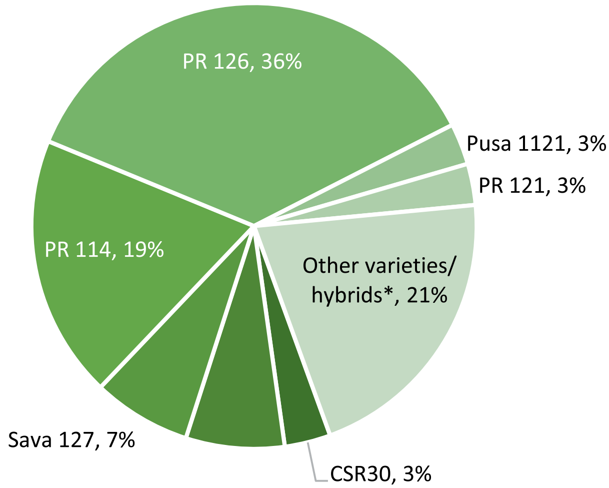
13 %, respectively. As per drainage classification, the topography of the district has 96.7 % medium land and only 3.3 % upland; and as per soil texture it largely falls into medium (95.2 %), light (2.9 %) and heavy (1.9 %) categories. Besides, rice and wheat, sugarcane, maize and other vegetable and horticultural crops are also grown in the district.

Blocks covered : Shahzadpur, Pehowa, Shahbad, Ladwa, Babain, Pipli, Thanesar, Ismailabad.

Village surveyed : Taraura khurd, Todarwal, Dandrala Kharaur, Randall, Mansurpur, Sangatpur, Tarkheri khurd, Sekhan, Salempur, Dadher, Kami kalan,, Shekhpura, Lang, Seel, Bagora, Rurki, Pharipur, Khansan, Mahadipur, Madhopur, Assarpur, Kahanghar Bhutna, Kheri Nagahiya, Barkatpur, Bakipur, Guram, Ghanaur, Nangal Kalan, Bhunerheri (Fig. 1).

Results and Discussion

The data revealed that majority of the HHs still prefer high yielding rice varieties namely PR 126 (37%), PR 114 (19%), PR 127 (7%), PR 121 (3%) and other varieties/ hybrids (13%) (Fig. 2). New hybrid Sava 127 (7%) and basmati rice varieties CSR 30 (3%) and Pusa 1121 (3%) are also popular in the district. Besides this, many new varieties/hybrids were introduced.



*Other varieties/hybrids- Arize 6129, K9090, Pioneer 27P31, PR 122, Pusa 1718, Pusa 44, Rasi, RHM 406, Sava 134, Signet Raja 45, ShriRam 432, Supreme Sona, Tata 001, HKR 127

Fig. 2. Varietal spectrum of rice varieties/hybrids based on the data of surveyed farmers in district Kurukshetra.

Four most preferred coarse rice varieties viz., PR 114, PR 121, PR 127 and PR 126 and one hybrid Sava 127 showed almost similar yield ranging from 6.4 to 6.7 tha^{-1} in the district (Fig. 3); whereas grain yield of scented rice (basmati) varieties CSR 30 and Pusa 1121 was 4.1 and 3.8 tha^{-1}, respectively.

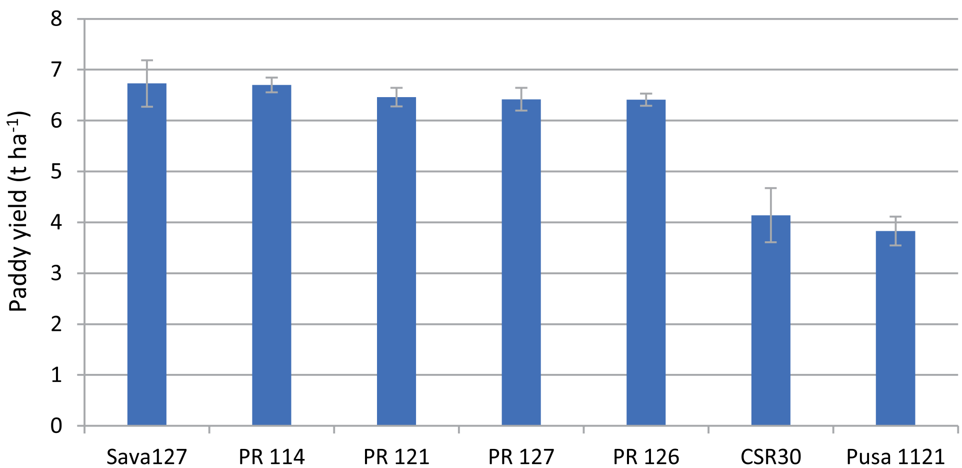


Fig. 3. Performance of most preferred rice varieties/hybrids by the surveyed farmers in Kurekshetra.

Grain yield across rice variety/hybrids was almost similar ranging from 6.0 to 6.2 tha^{-1} when transplanting was accomplished any time ranging till 15 June to 30 June (as there were only 2 cases of transplanting after 30 June in the time slot of 16 June to 31 July) (Fig. 4). That means these varieties/hybrids transplanted at an early date (by the end of June) by the farmers and attained higher yields.

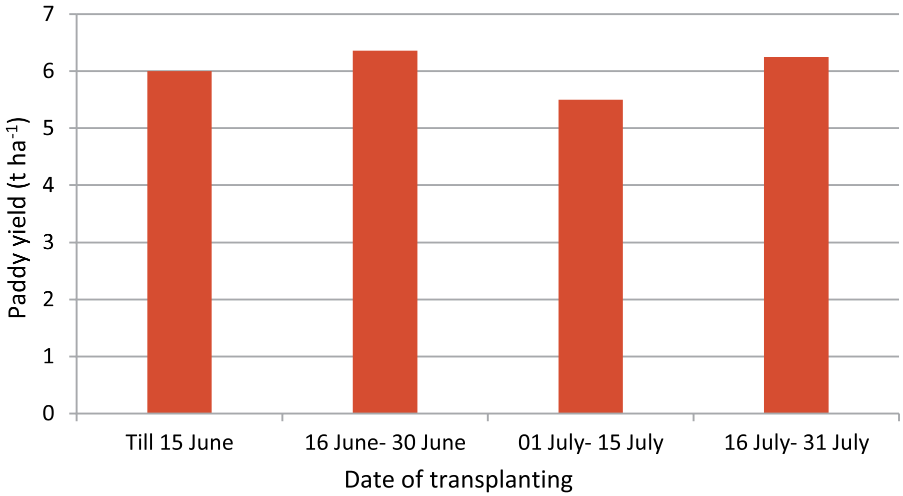


Fig. 4. Effect of time of transplanting on grain yield of rice varieties/hybrids in Kurukshetra.

Obviously, this could be possible due to assured groundwater supply not only at the time of transplanting but throughout the crop season in addition to normal rains (646 mm) in the district. However, in response to falling water table, the state is focusing on diversification from rice to other crops. To avoid a gradual fall in water table, the diversification within rice is important because diversification from rice to other crops is not profitable (Rangi, 2004).

A total of 155 and 34 HHs who grew improved rice varieties and hybrids, respectively, harvested an average yield of 6.4 and 6.6 tha^{-1} with almost similar and more than recommended level of N (154.6 and 140.4 $kgha^{-1}$), similar P_2O_5 (49.8 and 47.5 $kgha^{-1}$) and K_2O though sub-optimal in varieties only (33.7 and 0.0 $kgha^{-1}$) and similar level of irrigation (12.2 and 12.1) applications (Table 1). However, phosphorus application was lower both in varieties as well as hybrids. K_2O use rate was also lower in varieties and it was not used by any HH in hybrids, which requires attention of all stakeholders. N, P_2O_5 and K_2O were applied by 99, 72 and 3 % HHs in rice varieties, respectively, and the corresponding figures in hybrids were 100, 79 and 0 %. This clearly indicated that transplanting time practiced by the farmers is appropriate. Use of K may be increased.

Table 1. Nutrients and irrigation application pattern in rice varieties and hybrids in Kurukshetra.

Particulars	Improved varieties	Hybrids
Average yield (tha^{-1})	6.4	6.6
Average nitrogen application ($kgha^{-1}$)	154.6	140.4
Average phosphorus application ($kgha^{-1}$)	49.8	47.5
Average potash application ($kgha^{-1}$)	33.7	0.0
Average irrigations applied	12.2	12.19
Total households	155	34
% households applying nitrogen	99	100
% households applying phosphorus	72	79
% households applying potash	3	0
% of households applying irrigation	99	100

Among the five top most troublesome weeds infesting rice crop in Kurukshetra (Table 2), 50.9 % HHs indicated *Echinochloa crus-galli* as the most serious weed (rank 1) closely followed by *Ischaemum rugosum* ranking 2 (36.7 % HHs), *Dactyloctenium aegyptium* (rank 3; 32.4 % HHs), *Cynadon dactylon* (rank 4; 31.9 % HHs) and *Bracharia*

Table 2. Top five troublesome and common weeds in Kurukshetra

Rank	Troublesome weeds	% HHs	Common weeds	% HHs
Weed 1	*Echinochloa crus-galli*	50.9	*Echinochloa crus-galli*	53.3
Weed 2	*Ischaemum rugosum*	36.7	*Ischaemum rugosum*	43.8
Weed 3	*Dactyloctenium aegyptium*	32.4	*Cynadon dactylon*	35.7
Weed 4	*Cynadon dactylon*	31.9	*Dactyloctenium aegyptium*	35.7
Weed 5	*Brachiaria reptans*	29.5	*Brachiaria reptans*	32.4

reptans (rank 5; 29.5 % HHs). Among top five common weeds of transplanted rice crop were, *Echinochloa crus-galli*, *Ischaemum rugosum, Cynadon dactylon, Dactyloctenium aegyptium* and *Bracharia reptans* as reported by 53.3, 43.8, 35.7, 35.7 and 32.4 % HHs, respectively. This indicated infestation of prominent grassy weeds along with few sedges in the district, which warrants their timely and effective management.

Conclusion

Kurukshetra district of Haryana is having medium lands and majorly dwell in medium (30 %), semi-medium (21 %) and small landholding HHs (26 %) along with some large (10%) and marginal ones (13%). PR126, PR114, PR127 and PR121 yielding 6.4-6.7 tha^{-1} are the most preferred rice varieties along with new hybrids like Sava 127 (6.7 tha^{-1}) and scented rice varieties CSR 30 and Pusa 1121 (3.8-4.1 tha^{-1}). Most of the HHs completed rice transplanting by the end of 30 June in the district, which is a key for attaining higher yield. Need further emphasis to convince the farmers to use potash besides ensuring effective weed management.

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3.40 Cropping system productivity is interconnected: hybrid rice is an important chain in Ambala

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Introduction

Ambala district of Haryana falls in the Eastern Zone (HR-1) with 30°20' 59.14''N latitude and 76°50' 01.26''E longitude at an altitude of 301 m above MSL. Its geographical area is 1,54,000 ha, of which 1,32,000 ha is the net sown area with 156 % cropping intensity. Net irrigated area is 1,12,000 ha mainly through electricity based tube- wells (86 %) and partly by canals (14 %). Annual rainfall in the district is 834 mm mainly received through SW monsoons. Soils of the district are sandy loam (78 %) and loam (22 %). The paper presents data on the adoption patterns of technologies. This could be a lead indicator for technologies preferred by farmers and where the research and extension system should make more investment in this district.

Methodology

In total 30 villages were randomly selected from the 2011 Census data on the basis of probability proportionate to size (PPS) method. Seven farmers were randomly selected from each village. They were interviewed regarding the prevailing agronomic practices for the rice crop they had grown in *kharif* 2018. The questionnaire for the Landscape Diagnostic Survey (LDS) was prepared in a mobile application based digital data collection format of Open Data Kit (ODK), which is capable of transferring real time data to the server or cloud. Out of total 210 households surveyed, large, medium, semi-medium, small and marginal HHs were 5, 24, 34, 30 and 6 %, respectively. The GPS Coordinates of the largest plot of the surveyed farmers in Ambala district have been depicted in Fig. 1. As per drainage classification, the topography of the district is 100 % medium land and as per soil texture also it

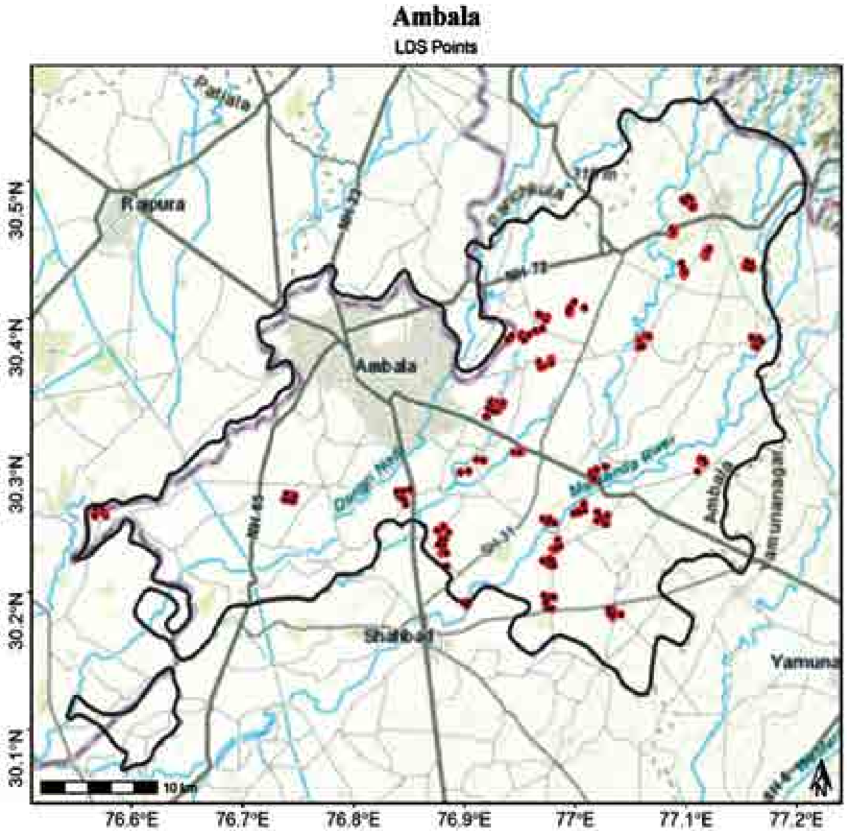


Fig. 1. GPS coordinates of the largest plot of the surveyed farmers in Ambala.

also falls into medium category (100 %). Rice-wheat (98.5 %) is the predominating cropping system in the district, however, rice-fallow (1 %) and rice-maize (0.5 %) is also adopted by few HHs.

Blocks surveyed : Saha, Barara, Ambala I, Shahzadpur, Naraingarh, Ambala II.

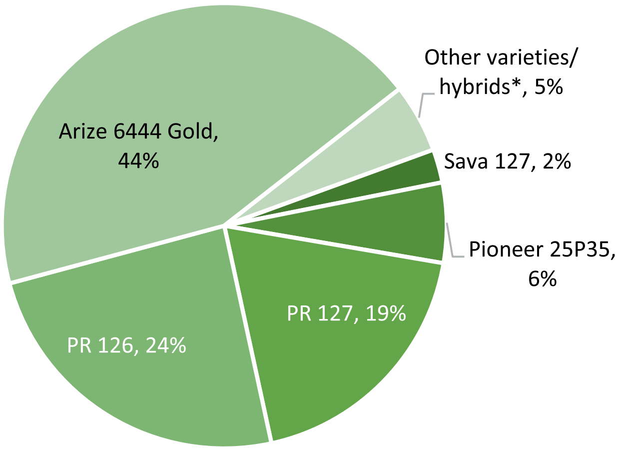
Village surveyed : Samalkha, Adhoya, Dhanora, Hema majra, Sohana, Nanyola, Landha, Dubli, Paplotha, Nangawan, Gharouli, Barheri badi, Tandwali, Baroli, Chotti bassi, Kodwa khurd, Nanhera, Tejjamohri, Gadhouli, Harra, Sapeda, Rachedi, Kapuri, Bhraman majra, Hasanpur, Tepla, Ugala, Mohra and Nagla (Fig. 1).

Results and Discussion

It is clearly evident from the data (Fig. 2) that 43 % HHs preferred the hybrid Arize6444Gold. The varieties including PR126 and PR127 were grown by 24 and

19% HHs. A few other popular hybrids in the district were Pioneer 25P35 (6%) and Sava127 (2%).

Among five most preferred varieties/hybrids in the district were PR127, Sava 127, Arize 6444 Gold, Pioneer25P35 and PR126 yielding to the extent of 7.3, 7.3, 7.0, 7.0 and 6.8 tha^{-1} respectively (Fig. 3). Paddy yield level of these five varieties/hybrids in the Ambala district of Haryana is high compared to the other rice growing areas in the eastern ecology of India and that also at much lower overall use of P and K.



*Other varieties/hybrids- PHB71, Pioneer 27P63, Sava 134, ShriRam 505, Swift gold, Arize 8433, ND359, Pusa 1121

Fig. 2. Varietal spectrum of rice varieties/hybrids based on the data of surveyed farmers (n=210).

The paddy yield across rice variety/hybrids was almost similar ranging from 6.9 to 7.2 tha^{-1} when transplanting was accomplished any time ranging till 15 June to 16-30 June, 01-15 July and even 16-31 July (Fig. 4). However, the transplanting in 16-31 July schedule was finished by 21 July and the sample size was only 4 HHs. High paddy yields even under late transplanting obviously were due to assured

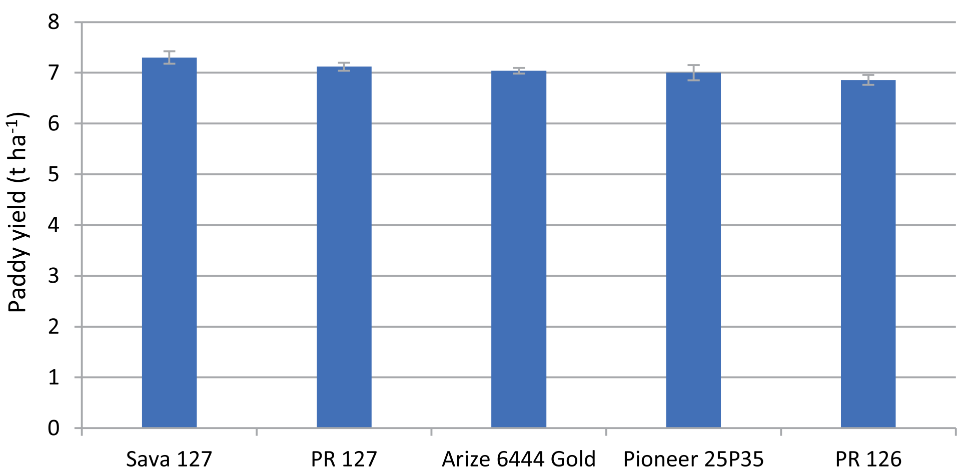


Fig. 3. Performance of the most preferred rice varieties and hybrids in Ambala.

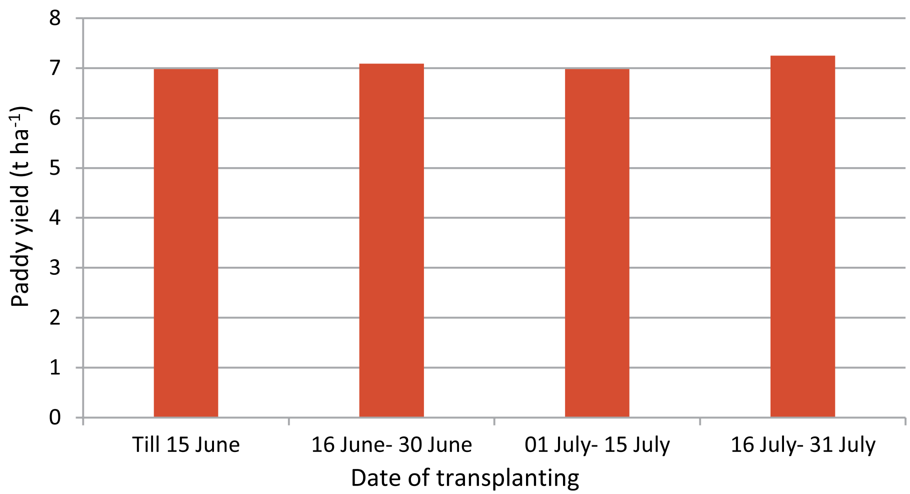


Fig. 4. Effect of time of transplanting on grain yield of rice varieties/hybrids (n=207).

ground water supply not only at the time of transplanting but throughout the crop season in addition to normal rains (845 mm) in the district. Duration of hybrids also played its role.

A total of 92 and 113 HHs who grew improved rice varieties and hybrids, respectively harvested an average yield of 7.0 tha^{-1} with almost similar and recommended level of N (147.2 & 141.4 $kgha^{-1}$), P_2O_5 (57.3& 56.4 $kgha^{-1}$) and K_2O (37.5 & 33.4 $kgha^{-1}$) and irrigation (13.8 & 13.5) applications (Table 1). However,

Table 1. Nutrients and irrigation application pattern in varieties and hybrids in Ambala.

Particulars	Improved varieties	Hybrids
Average yield (tha^{-1})	7.1	7.0
Average nitrogen application ($kgha^{-1}$)	147.2	141.4
Average phosphorus application ($kgha^{-1}$)	57.3	56.4
Average potash application ($kgha^{-1}$)	37.5	33.4
Average irrigations applied	13.8	13.5
Total households	92	113
% households applying nitrogen	99	100
% households applying phosphorus	51	57
% households applying potash	1	5
% of households applying irrigation	99	98

these application rates are from the user farmers. The potash application was lower both in varieties as well as hybrids. The response was based mostly on N application as P_2O_5 and K_2O were applied by only 5 and 1% HHs in rice varieties and 57 and 5% HHs in hybrids. This clearly indicates that transplanting time practiced by the farmers is optimal. But to further enhance the paddy yield potential or to bridge up the yield gaps, farmers may use K more frequently. Hybrids can further help improving paddy yield (Huang *et al.*, 2015) and intensifying the cropping system in Ambala.

Among five top most troublesome weeds infesting rice crop in Ambala (Table 2), 93.7% HHs indicated *Cyperus iria* as the most serious weed (rank 1) closely followed

Table 2. Top five troublesome and common weeds in Ambala

Rank	Troublesome weeds	% HHs	Common weeds	% HHs
Weed 1	*Cyperus iria*	93.7	*Cyperus iria*	95.6
Weed 2	*Echinochloa crus-galli*	74.8	*Echinochloa crusgalli*	77.8
Weed 3	*Ischaemum rugosum*	17.8	*Echinochloa colona*	70.5
Weed 4	*Leptochloa* spp.	14.5	*Scirpus juncoides*	69.6
Weed 5	*Dactyloctenium aegyptium*	14.0	*Leptochloa* spp.	34.8

by *Echinochloa crusgalli* ranking 2 (74.8% HHs), *Ischaemum rugosum* (rank 3; 17.8% HHs), *Leptochloa* spp (rank 4; 14.5% HHs) and *Dactyloctenium aegyptium* (rank 5; 14.0% HHs). Among top five common weeds of transplanted rice crop were, *C. iria*, *E. crussgalli, E. colona, Scirpus juncoides and Leptochloa* spp. as reported by 95.6, 77.8, 70.5, 69.6 and 34.8% HHs, respectively. Two top rankers can be controlled by butachlor or pretilachlor which should be used in rotation.

Conclusion

Varieties that cannot compete with hybrids in terms of yield are vulnerable. Diversification within rice varieties particularly basmati rice is important. Hybrids can help intensifying the cropping system with no extra input cost as seen in the survey.

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3.41 Long duration high yielding rice varieties and early transplanting– Two key factors for high productivity in district Patiala, Punjab

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Introduction

Patiala district of Punjab falls in undulating Plain (PB-2)/ Central Plain (PB-3)/ Western Plain (PB-4) Zone with 29° 19' 49.59'' N latitude and 76° 23' 44.23''E longitude at an altitude of 280 m above MSL. Its geographical area is 322,299 ha, of which 254,000 ha is the net sown area with 204% cropping intensity. Net irrigated area is 253,200 ha mainly through bore-wells/ tube wells and partly by canals (5%). Annual rainfall in the district is 788 mm mainly received through SW monsoons. Soils of the district are fine loamy (55%), coarse loam and fine loamy (35%) and coarse loam (10%). Rice (234,000 ha) is the main crop of the district grown in *kharif*. The wheat area is 235,000 ha. The exploitation of groundwater is a serious problem. In the absence of any technological breakthrough, the highest priority should be given to identify factors responsible for productivity variations in rice and to bridge the gaps in Patiala. Evidence of differentiated adoption patterns of technologies allows for setting priorities based on demand by farmers rather than the supply based on top-down approach. A landscape diagnostic survey was conducted to understand the whole process.

Methodology

Villages (30) were randomly selected from the 2011 Census data based on probability proportionate to size (PPS) method. Seven farmers were randomly selected from each village. They were interviewed regarding the prevailing agronomic practices for the rice crop they have grown in *kharif* 2018. The questionnaire for the Landscape Diagnostic Survey (LDS) was prepared in a mobile application based digital data collection format of Open Data Kit (ODK), which can transfer real time data to the server or cloud. Out of total 210 households surveyed, larger segment comprised small (33 %), medium (25 %) and semi-medium (26 %) HHs. Marginal and large HHs were 10 and 6 %, respectively. As per drainage classification, the topography of the district has 89.9 % medium land, and upland, lowland and very lowland represent only 5.1, 2.2 and 2.8 %, respectively and as per soil texture also it largely falls into medium (51.1 %), heavy (46.6 %) and light (2.2 %) categories. Almost all HHs (100 %) adopted rice-wheat cropping system in Patiala.

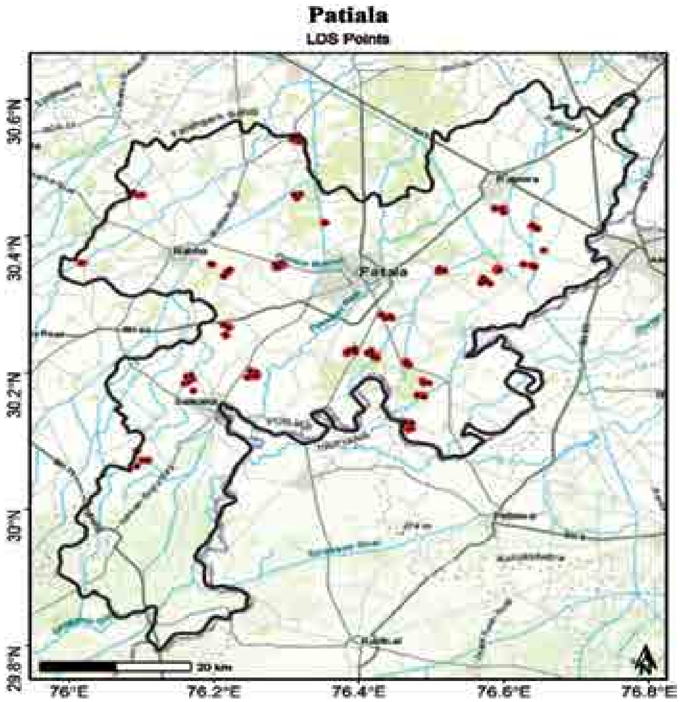


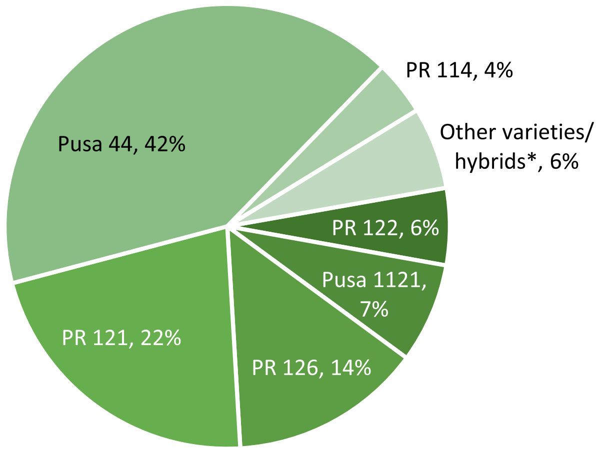
Fig. 1. GPS coordinates of the largest plot of the surveyed farmers in Patiala.

Blocks covered : Patiala, Nabha, Samana, Ghanaur, Bhunerheri and Sanaur.

Villages surveyed : Taraura khurd, Todarwal, Dandrala Kharaur, Randall, Mansurpur, sangatpur, Tarkheri khurd, Sekhan, Salempur, Dadher, Kami Kalan, Shekhpura, Lang, Seel, Bagora, Rurki, Pharipur, Khansan, Mahadipur, Madhopur, Assarpur, Kahanghar Bhutna, Kheri Nagahiya, Barkatpur, Bakipur, Guram, Ghanaur, Nangal Kalan and Bhunerheri (Fig. 1).

Results and Discussion

The data (Fig. 2) revealed that majority of the HHs still prefer high yielding and long duration rice varieties (LDRVs) namely Pusa 44 (42 %) and PR 122 (4 %), medium duration rice varieties (MDRVs) like PR 121 (22 %), and PR 114 (4 %), and SDRVs like PR 126 (14%), and other varieties/hybrids (6%) (Fig. 5). Scented rice variety Pusa 1121 was also grown by 7% HHs.



*Other varieties/hybrids- PR 124, PR 127, 6162, Pusa 1509, PAU 201, PR 118

Fig. 2. Varietal spectrum of rice varieties/hybrids based on the data of surveyed farmers (210) in Patiala.

Among the five most preferred coarse rice varieties viz., Pusa 44 (7.43 tha^{-1}) and PR 114 (7.32 tha^{-1}) the yield was higher closely followed by PR 122 (7.05 tha^{-1}) and PR 121 (6.87 tha^{-1}); while PR 126 yield was the lowest (5.64 tha^{-1}) in this group (Fig. 3). The paddy yield of Pusa 1121 was 4.37 tha^{-1}. Yield levels of these popular varieties/hybrids in Patiala are very high compared to the other rice growing areas in the eastern ecology of India.

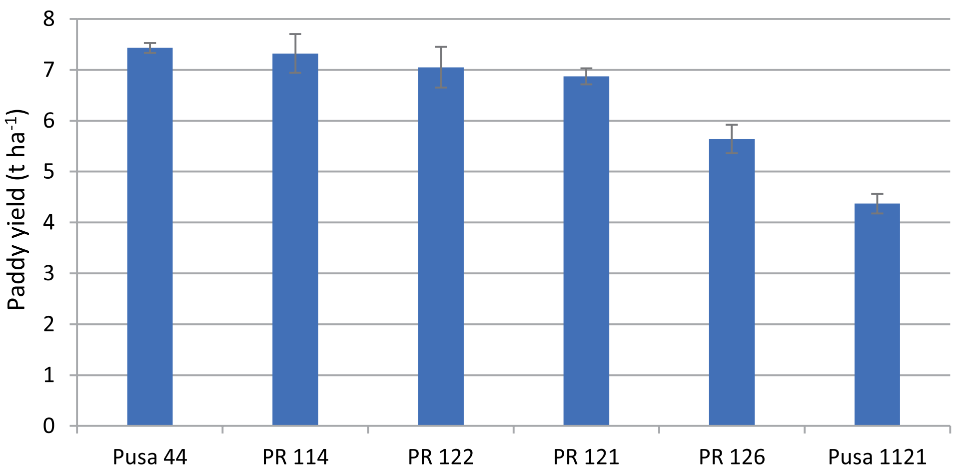


Fig. 3. Performance of most preferred rice varieties/hybrids by the surveyed farmers in district Patiala.

LDRVS are still favourite of farmers, which give higher yields compared to MDRVs or hybrids. The preference of farmers has not shifted from Pusa 44 to other varieties within LDRVs or even in favour of newly released MDRVs. The long-term solution lies in developing MDRVs or hybrids, which can match the yield levels of

LDRVs. The early maturing cultivars usually have low yield due to shortening of maturity duration. The LDRVs produced higher yield because production rate of carbohydrate via photosynthesis is not restricted due to early maturity (Rossi *et al.*, 2015).

The paddy yield across rice variety/hybrids was higher (7.40 tha^{-1}) when transplanting was accomplished from 15 June to 30 June and then it decreased by 9.2 % when transplanting was done between 16 and 30 June (6.72 tha^{-1}). But this reduction was significant (32.7 %) when transplanting was further delayed (01-31 July) yielding only 4.98 tha^{-1} (Fig. 4). It means that an early transplanting results in much higher yield in Patiala. This could be possible obviously due to assured ground water supply not only at the time of transplanting but throughout the crop season in addition to normal rains (788 mm) in the district.

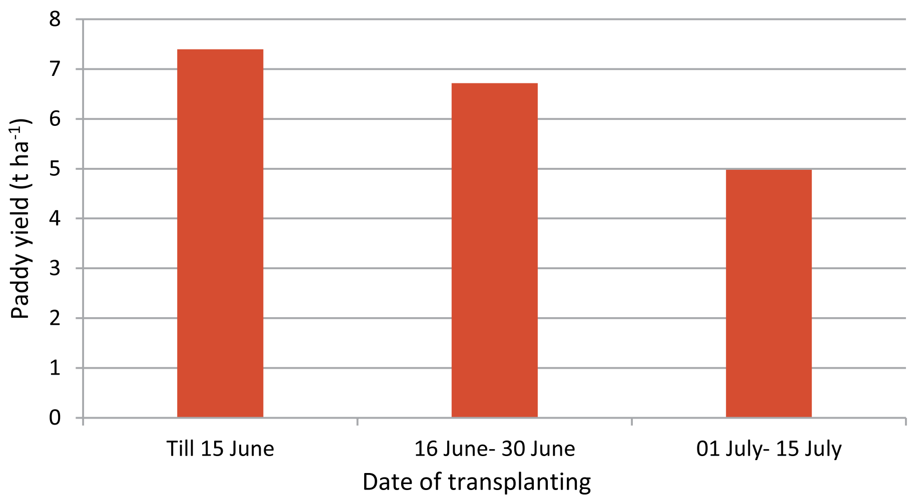


Fig. 4. Effect of time of transplanting on grain yield of rice varieties/hybrids (n=178) in Patiala.

The HHs (161) who grew improved rice varieties harvested an average yield of 6.96 tha^{-1} with N @ 176.4 $kgha^{-1}$, P_2O_5 sub-optimal (21.6 $kgha^{-1}$) and no use of potash (Table 1). On an average 5.52 irrigations were applied by 98 % HHs. N, P_2O_5 and K_2O were applied by 100, 1 and 0 % HHs, respectively. Hybrids have not become popular in the district so far. The opportunities for better nutrient use and from paddy yield standpoint, June planting should be preferred. The residual phosphorus uptake and utilization may be efficient with timely transplanting of rice.

Bates and Lynch (2001) suggested that increased root growth is associated with improved plant performance under low P by exploring a larger volume of soil.

Table 1. Nutrients and irrigation application pattern in improved varieties and hybrids in Patiala.

Particulars	Improved varieties	Hybrids
Average yield (tha^{-1})	6.96	-
Average nitrogen application ($kgha^{-1}$)	176.45	-
Average phosphorus application ($kgha^{-1}$)	21.56	-
Average potash application ($kgha^{-1}$)	0.0	-
Average irrigations applied	5.52	-
Total households	161	-
% households applying nitrogen	100	-
% households applying phosphorus	1	-
% households applying potash	0	-
% of households applying irrigation	98	-

Among the five top most troublesome weeds infesting rice crop in Patiala (Table 2), 66.8 % HHs indicated *Echinochloa colona* as the most serious weed (rank 1) closely followed by *Scirpus juncoides* ranking 2 (46.6 % HHs), *Cyperus rotundus* (rank 3; 43.8 % HHs), *Cyperus difformis* (rank 4; 30.9 % HHs) and *Cyperus iria* (rank 5; 26.9 % HHs). Among top five common weeds of transplanted rice crop were, *Echinochloa colona*, *Scirpus juncoides*, *Cyperus rotundus*, *Cyperus difformis* and *Cyperus iria* as reported by 76.9, 45.7, 44.4, 35.9 and 30.9 % HHs, respectively.

Table 2. Top five troublesome and common weeds in Patiala.

Rank	Troublesome weeds	% HHs	Common weeds	% HHs
Weed 1	*Echinochloa colona*	66.85	*Echinochloa colona*	76.97
Weed 2	*Scirpus juncoides*	46.63	*Scirpus juncoides*	47.75
Weed 3	*Cyperus rotundus*	43.82	*Cyperus rotundus*	44.38
Weed 4	*Cyperus difformis*	30.90	*Cyperus difformis*	35.96
Weed 5	*Cyperus iria*	26.97	*Cyperus iria*	30.90

Conclusion

Variety Pusa 44 with its highest yield is still the favourite of farmers in Patiala. Most of the HHs completed rice transplanting by the end of 30th June in the district, which is a key for attaining higher yield.

References

Bates, T.R. and Lynch, J.P. (2001). Root hairs confer a competitive advantage under low P availability. *Plant Soil.* **236** : 243-250.

Rossi, M, Bermudez, L. and Carrari, F. (2015). Crop yield: Challenges from a metabolic perspective. *Curr. Opin. Plant Biol*. **25** : 79-89

3.42 Evidence of farmers' preference for long duration rice varieties and nutrient management in favour of nitrogen in district Sangrur, Punjab

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Introduction

Sangrur district of Punjab falls into Western Plain Zone (PB-4) with 30°14' 25.51''N latitude and 75°50' 34.32''E longitude at an altitude of 257 m above mean sea level (MSL). Its geographical area is 361,000 ha, of which 311,000 ha is the net sown area with 198% cropping intensity. Net irrigated area is 311,000 ha mainly through tube wells and partly by canals (10%). Rice (267,000 ha) and wheat (286,000 ha) are the main crops. There has been very little data to allow independent verifications on how the recommendations are accepted by paddy cultivators. It is important to bring out the real picture based on data from the representative households (HHs) in any given ecology rather than the selected pockets or selected farmers. The KVK system can help in unlocking the new potential of innovating and disseminating new technologies to farmers based on preferences of farmers; and to do that landscape diagnostic survey was conducted.

Methodology

Villages (30) were randomly selected from the 2011 Census data based on probability proportionate to size (PPS) method. Seven farmers were randomly selected from each village. They were interviewed regarding the prevailing agronomic practices for the rice crop which they had grown during *kharif* 2018. The questionnaire for the Landscape Diagnostic Survey (LDS) was prepared in a mobile application based digital data collection format of Open Data Kit (ODK), which can transfer real time data to the server or cloud. Out of total 210 households surveyed, semi-medium, medium, and small landholding HHs in Sangrur district were 43, 30 and 20%, respectively, and rest 3% each comprised marginal and large landholding households. As per drainage classification, the topography of the district has 91.4% medium land and only 6.7% was Upland and 1.9% Lowland; and as per soil texture also it largely falls into medium (58.1%), heavy (32.4%) and light (9.5%) categories. All the surveyed HHs (100%) adopted rice-wheat cropping system in the district.

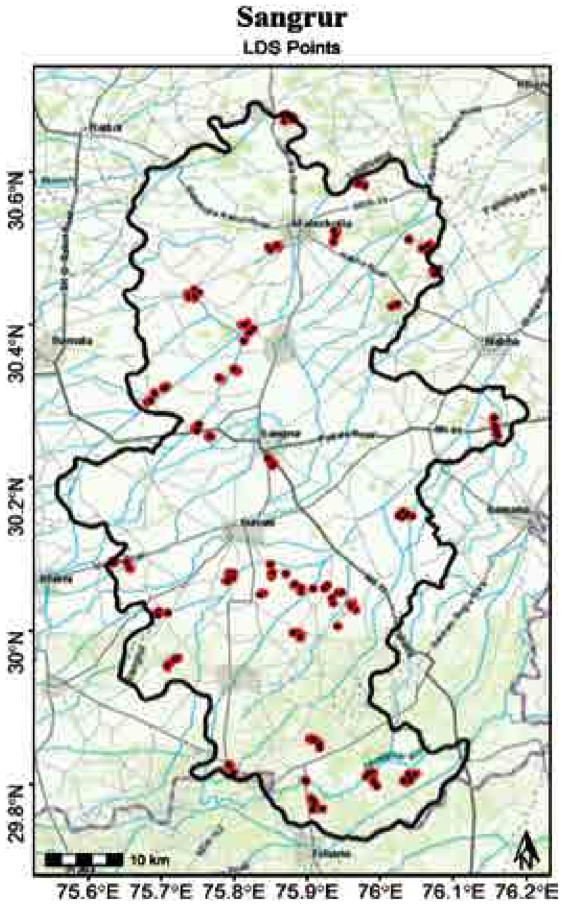

Fig. 1. GPS coordinates of the largest plot of the surveyed farmers in Sangrur.

Blocks covered : Sunam, Bhawanigarh, Sangrur, Dhuri, Sherpur, Malerkotla I, Malerkotla II, Lehragaga, Andana.

Villages surveyed : Dhandoli Kalan, Chatha Nanhera, Chhajli, Bir Kalan, Rogla, Ramgarh Jawanda, Kanakwal Bhangwan, Nilowal, Basiarkh, Bahadarpur, Jahangir, Kalajhar, Ramnagar Sibian, Katron, Chaunda, Bagrian, Salempur, Balian, Momnabad, Mehdevi, Pishore bhaike, Pishore, Haryau, Binjoki Kalan, Chural Khurd, Bhattian, Punnawal, Moranwali, Mandvi, Andana and Babangarh Alias Ghamur Ghat (Fig. 1).

Results and Discussion

The data (Fig. 2) revealed that majority of the HHs preferred high yielding and long duration rice variety Pusa 44 (79%) and Pili Pusa 9% (another name of Pusa 44) (combined 88%). Other improved varieties (recently introduced by the system) which were grown by few HHs were PR 118, PR 122, PR 127, Sri Ram 432, Pusa 1121, etc.

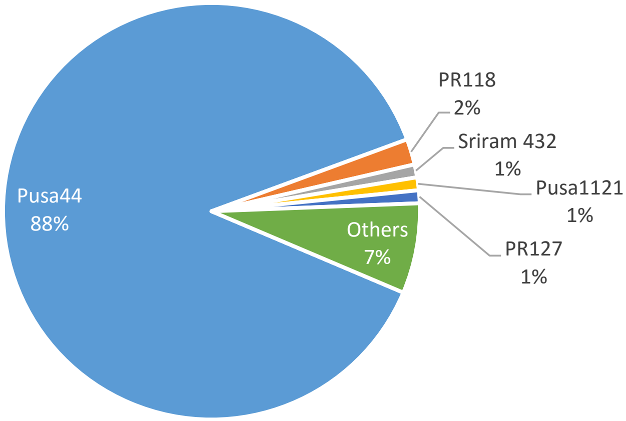

Fig. 2. Varietal spectrum of rice varieties/hybrids based on the data of surveyed farmers (210) in Sangrur.

Among seven most preferred coarse rice high yielding and long duration varieties viz., Pusa 44, and PR 118 yielded 7.88 -8.11 tha^{-1}, and these were very close to Sri Ram 432 (8.25 tha^{-1}) (Fig. 3). Other two varieties PR 122 (7.91 tha^{-1}) and PR 127 (7.0 tha^{-1}) also yielding in the higher range. Scented rice Pusa1121 also resulted into quite higher grain yield (5.0 tha^{-1}). Given that most HHs favored varieties trended towards longer duration, further strain on water table is expected. But the variety Pusa 44 alone may not be central to that argument because farmers are applying almost same number of irrigations in other varieties (except Pusa 1121) or P 126. Yield levels of these popular varieties in the Sangrur district are quite high as compared to the other rice growing areas in India (Joshi *et al.*, 2018).

Grain yield across rice variety/hybrids was almost similar ranging from 8.05 to 8.12 tha^{-1} when the transplanting was accomplished any time till 15 June and in another transplanting schedule of 16- 30 June, and the it reduced drastically to the

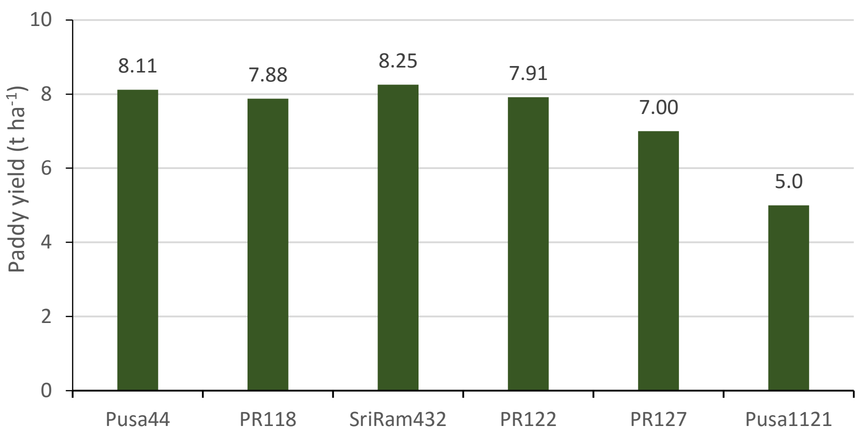

Fig. 3. Performance of most preferred rice varieties/hybrids by the surveyed farmers in district Sangrur.

level of 6.75 tha^{-1} thereafter from 01-31 July (Fig. 4). It means that transplanting varieties/hybrids at an early date (by the end of June) by the farmers is the key to attain higher yields. This is obviously due to assured groundwater supply not only at the time of transplanting but also throughout the crop season.

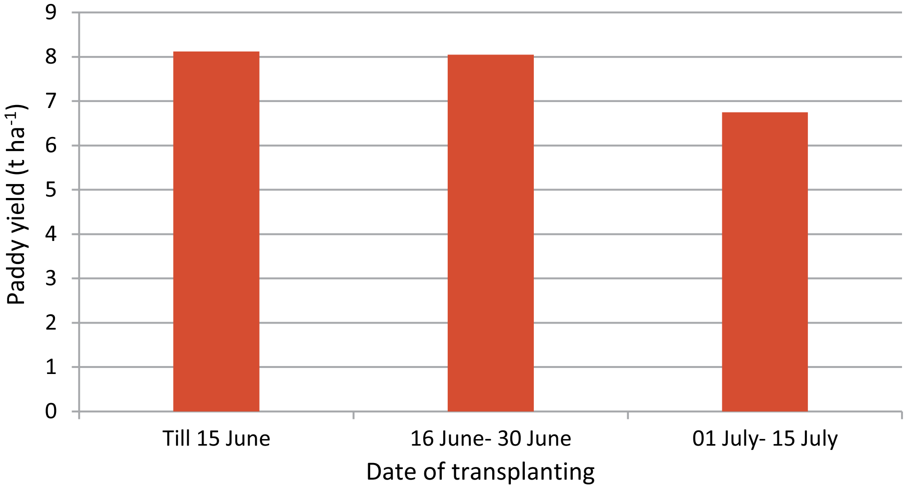

Fig. 4. Effect of time of transplanting on grain yield of rice varieties/hybrids (210) in district Sangrur.

A total of 199 and 06 HHs who grew improved rice varieties and hybrids, respectively, harvested an average yield of 8.09 and 7.67 tha^{-1} with more than recommended level of N (155.6 and 155.2 $kgha^{-1}$), sub-optimal P_2O_5 (30.1 $kgha^{-1}$) and also sub-optimal K_2O (6.9 and 15.0 $kgha^{-1}$) by users only. Similar level of irrigations (15.6 and 16.8) were given by farmers (Table 1). The N, P_2O_5 and K_2O were applied by 99, 4 and 12 % HHs in rice varieties, respectively, and the corresponding figures in hybrids were 100, 0 and 17 %. Compared to other states especially the states with low paddy yields, there is a glaring deviation in NPK ratio with no use of P and K in this district. This trend looks more positive if long-term effects are correctly judged by the researchers on NPK balance in rice-wheat cropping system. It can be a guiding principal for other states too. It is difficult to reverse this trend in the use of Pusa 44 (Joshi *et al*., 2018) or NPK ratio because farmers may not compromise on profit margins. This clearly indicated that an early transplanting time practiced by farmers is the key to attain higher yields in the district. But to further enhance the grain yield of rice or to bridge up the yield gaps amongst different farmers, mechanization in crop establishment should be prioritized. Mechanization can intensify the cropping system with more profit margins.

Table 1. Nutrients and irrigation application pattern in improved varieties and hybrids in Sangrur.

Particulars	Improved varieties	Hybrids
Average yield (tha^{-1})	8.09	7.67
Average nitrogen application ($kgha^{-1}$)	155.66	155.25
Average phosphorus application ($kgha^{-1}$)	30.07	0.0
Average potash application ($kgha^{-1}$)	6.91	15.0
Average irrigations applied	15.56	16.8
Total households	199	6
% households applying nitrogen	99	100
% households applying phosphorus	4	0
% households applying potash	12	17
% of households applying irrigation	100	83

Among the five top most troublesome weeds infesting rice crop in Sangrur (Table 2), 81.9 % HHs indicated *Echinochloa crus-galli* as the most serious weed (rank 1) closely followed by *Echinochloa colona* ranking 2 (80.5 % HHs), *Paspalum distichum* (rank 3; 6.43 % HHs), *Cyperus difformis* (rank 4; 6.9 % HHs) and *Alternanthera sessilis* (rank 5; 37.6 % HHs). Among top five common weeds of transplanted rice crop were, *Echinochloa colona*, *E. crus-galli, C. difformis, Cyperus iria* and *Paspalum distichum* as reported by 81.9, 81.9, 78.1, 67.1 and 66.7 % HHs, respectively. This indicated infestation of mainly grass weeds along with few sedges like *Cyperus difformis* in the district, which warrants for their timely and effective management.

Table 2. Top five troublesome and common weeds in Sangrur.

Rank	Troublesome weeds	% HHs	Common weeds	% HHs
Weed 1	*Echinochloa crus-galli*	81.90	*Echinochloa colona*	81.90
Weed 2	*Echinochloa colona*	80.48	*Echinochloa crus-galli*	81.90
Weed 3	*Paspalum distichum*	61.43	*Cyperus difformis*	78.10
Weed 4	*Cyperus difformis*	60.95	*Cyperus iria*	67.14
Weed 5	*Alternanthera sessilis*	37.62	*Paspalum distichum*	66.67

Conclusion

The survey of farmers found that 79 % respondents preferred Pusa 44 a long duration rice variety. The average yield of Pusa 44 reported by respondents was 8.1

tha^{-1}. Other varieties adopted by respondents include Sri Ram 432, Pusa 44 (*Pili Pusa*), PR 122 and PR 118 and Pusa 1121. Another variety locally known as *Pili Pusa* is also considered as Pusa 44. These LDRVs represented by Pusa 44 provided high paddy yield when transplanted in June. The paddy yield levels of 7.7 to 8.1 tha^{-1} are being achieved by 156 kg N /ha with negligible use of P and K.

Reference

Joshi, K., Joshi, P.K., Khan, M.T. and Kishore, A. (2018). Sticky Rice: Variety Inertia in a Technologically Progressive State of India, 2018 Conference, July 28-August 2, 2018, Vancouver, British Columbia 277529. International Association of Agricultural Economists.

3.43 Timely transplanting– Very crucial to raise rice productivity in Puri district of Odisha

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[3]International Maize and Wheat Improvement Center (CIMMYT)

Introduction

Puri district (19.8510° N, 85.7256° E) of Odisha falls in East and South Eastern Coastal Plain with hot and humid climate. The soils are saline, lateritic, alluvial, red, and mixed red & black (DES-P&C-GoO, 2017). The district agriculture has faced 17 floods, 5 cyclones and 4 droughts during 1990-2019 (DDMP-Puri, 2019). Total population is 1,697,983 and population density is 488 per sq.km. Majority of the farmers (94.4 %) in the district are marginal, and average land holding of 0.77 ha (DA&FP-GoO, 2020). Rice-Fallow, rice-pulses and rice-oilseeds are three major cropping systems. It receives an average rainfall of 1,409 mm majorly through monsoon rains. The minimum and maximum temperature varies between 18 and 27°C. The cultivated area is 1,89,000 ha (11.64 % upland, 30.69 % medium land and 57.67 % lowland) and total cropped area 2,04,620 ha (98,490 ha in *kharif* and 1,06,130 ha in *rabi* season) with a cropping intensity of 164 %. Rice, pulses, oilseeds and vegetables comprise 47.2, 26.2, 9.5 and 6.1 % of gross cropped area, respectively. Fallow area (current + other) in the district is 26,000 ha. Rice is largely grown on lowland (96.8 %). Gross irrigated area is 1,53,830 ha and net irrigated area is 93,990 ha (DA&FP-GoO, 2020). There are inconsistencies in the recommendations generated over time and their adoption patterns. Landscape diagnostic survey (LDS) has been proposed to allow independent verifications how the recommendations were accepted by farmers.

Methodology

In total 30 villages were randomly selected from the 2011 census data based on probability proportionate to size (PPS) method. The villages and the farmers within villages were randomized (Fig. 1) and the sample properly reflects the farmers' population in the district.

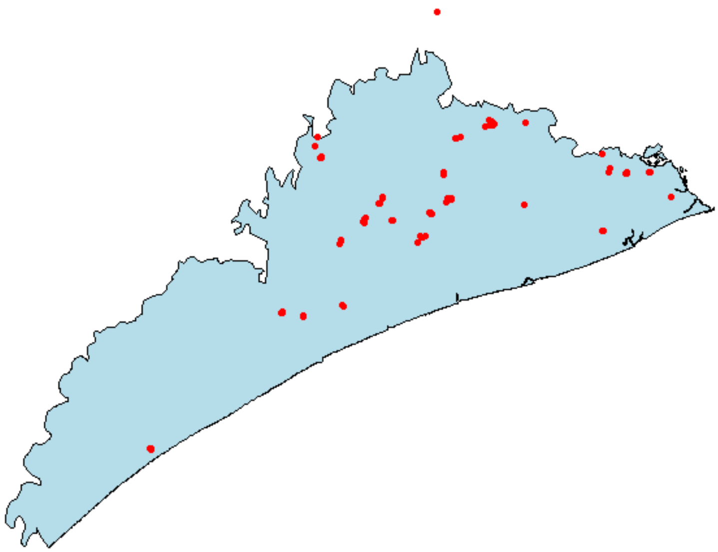

Fig. 1. LDS points of HHs survey in different villages in Puri (N=185).

Seven farmers were randomly selected from each village. They were interviewed regarding the prevailing agronomic practices for the rice crop. The randomization process makes it easy to assess the adoption pattern of different technologies in the district map (Fig. 1).

The questionnaire for the landscape diagnostic survey was prepared in a mobile application based digital data collection format of Open Data Kit (ODK) which can transfer real time data to the server or cloud.

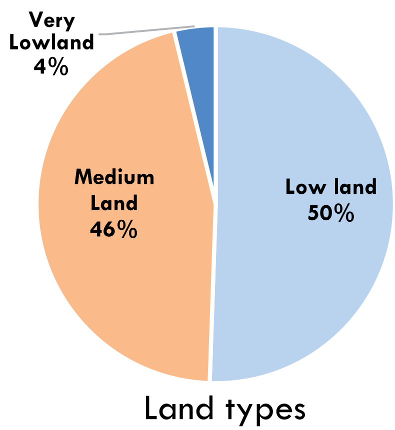

Fig. 2. Land types based on LDS data in Puri district (N=185).

Results and Discussion

Based on the drainage class, 54 % HHs from the LDS had their rice crop in lowlands (including 4 % in very low land) and 46 % in medium land (Fig. 2).

Based on the response of surveyed HHs, *rabi* fallow accounts for 49% area, and other crops grown before rice are green gram (29%), black gram (11%), groundnut (6%), *rabi* rice (3%) and vegetables (2%) (Fig. 3). Based on the data on adoption of rice varieties in the district from 118 surveyed farmers, it is evident that among five top rice varieties, MTU 7029 is still popular with 44% HHs followed by Swarna sub-1 (13%) and Pooja (11%) (Table 1). Binadhan 11 and Suma Gold (NP9308) were grown by 4 and 3% HHs, respectively. There has been strategic shift in the focus of evolving varieties after 1990s (Das, 2012) but that seems to have not worked.

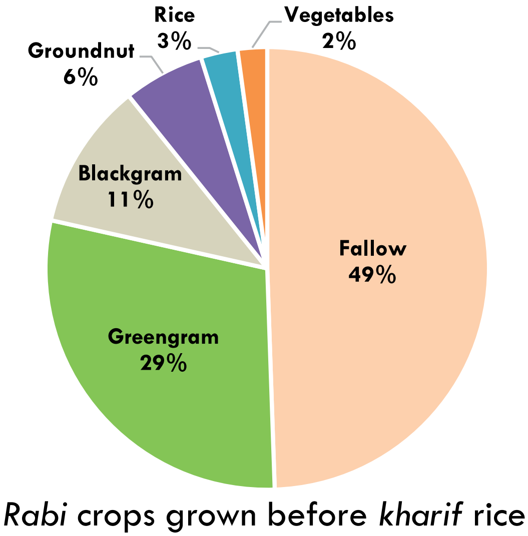

Fig. 3. Percent area under *rabi* crops based on LDS data in Puri district (N=185).

On evaluating the trend for the preferred planting methods among the surveyed farmers, it was found that transplanting of rice (88%) comprising random transplanting (58%) and line transplanting (30%) is still the most popular crop establishment method (Fig. 4). Broadcasting, *beushening* and seed drill DSR were merely adopted by 9, 2 and 1% HHs.

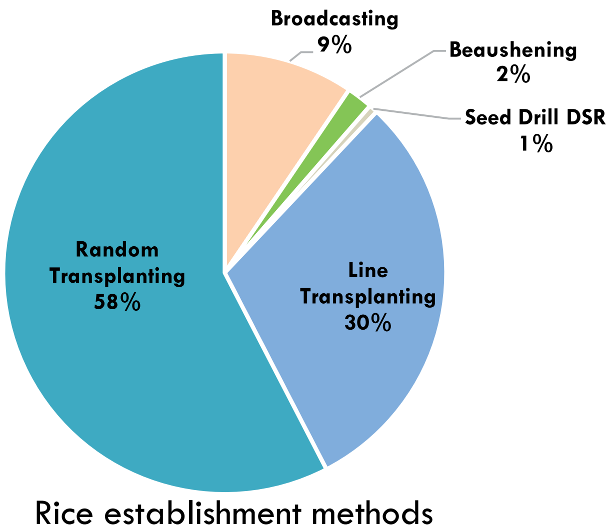

Fig. 4. Rice establishment methods among surveyed HHs in Puri district (N=185).

Among a sample of 128 farmers, it was found that transplanting of rice starts from 08th June and prolongs even up to 31st August (Fig. 5). However, majority of the farmers planted rice between mid-July and mid-August.

Looking at the transplanting date, it is very much evident from the data that paddy transplanted in June had a yield advantage of 0.62 and 0.81 tha^{-1} in comparison to that one transplanted in July and August, respectively (Fig. 6).

Table 1. Top five most popular rice varieties grown by the surveyed farmers.

Rice varieties	Number of users	% of users
MTU 7029	69	44
Swarna sub-1	21	13
Pooja	18	11
Binadhan11	6	4
Suma Gold (NP 9308)	4	3

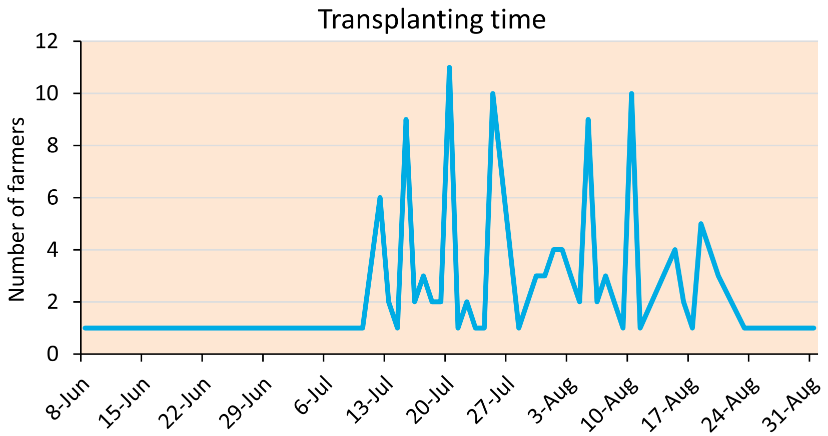

Fig. 5. Transplanting time of rice in a sample of surveyed farmers in Puri district (N=128).

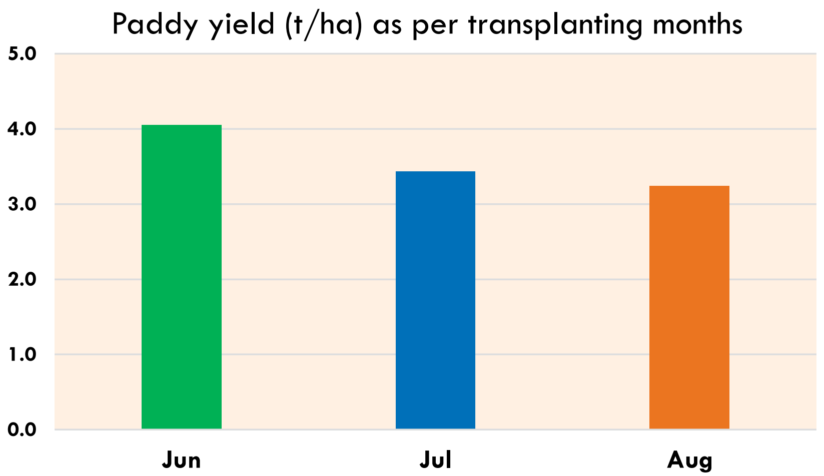

Fig. 6. Paddy yield as affected by transplanting time in a sample of surveyed farmers in Puri district.

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3.44 Seedling age and transplanting time– Two key factors for raising rice productivity in Jagatsinghpur district of Odisha

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Introduction

District Jagatsinghpur (20.1976° N, 86.3377° E) falls in East and South Coastal Plains with hot and humid climate. The soils are broadly saline, lateritic, alluvial, red and mixed red & black (DES-P&C-GoO, 2017). The district enjoys rich fertile soil of the Mahanadi. There are frequent floods, cyclones and submergence of lowland rice (Pasupalak *et al.* 2018). With a population density of 681 per sq. km (Census 2011), majority of the farmers (97%) are marginal (83%) and small (14%), with an average land holding of 0.61 ha (DA&FP-GoO, 2020). Rice-fallow, rice-pulses and pulses-vegetables are three major cropping systems. It receives an average rainfall of 1514.6 mm majorly through monsoon rains. It has total cultivated area of 104000 ha and total cropped area of 179330 ha (92330 ha in *kharif* and 87000 ha in *rabi* season). It has highest cropping intensity in the state. Fallow area (current + other) in the district is 23000 ha. Rice is largely grown on medium land (42.05%) and lowlands (52.3%) (DA&FP-GoO, 2020). Landscape diagnostic survey (LDS) has been conducted to narrow the gap between what is recommended and what is accepted. That is why farmers must be involved to identify problems and then provide solution.

Methodology

In total 30 villages were randomly selected from the 2011 census data based on probability proportionate to size (PPS) method. The villages and the farmers within

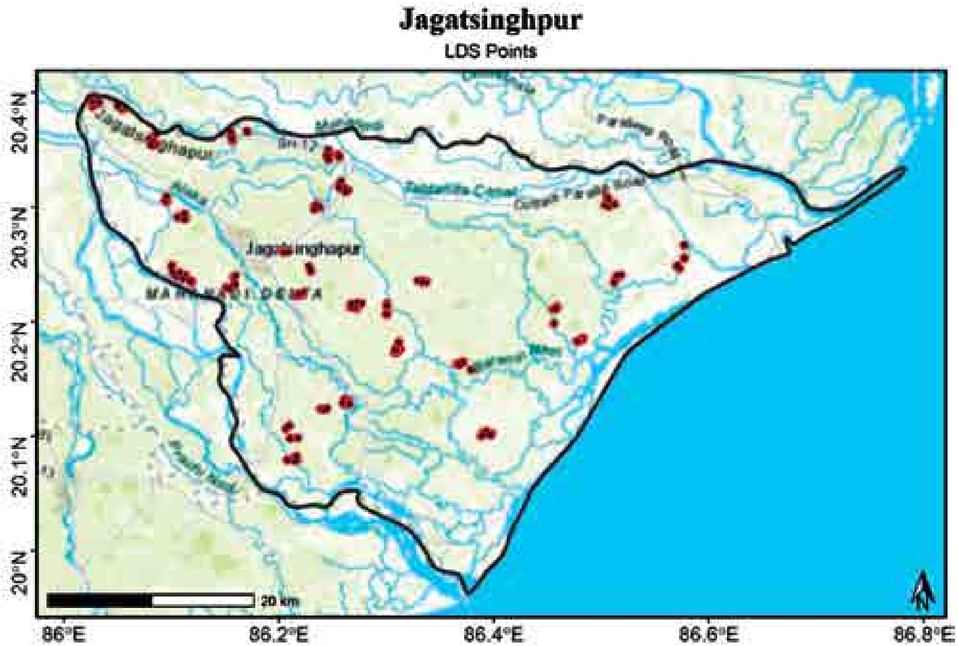

Fig. 1. LDS points of HHs survey in different villages in Jagatsinghpur (N=217).

villages were randomized (Fig. 1) and the sample properly reflects the farmers' population in the district. Seven farmers were randomly selected from each village. They were interviewed regarding the prevailing agronomic practices for the rice crop. The randomization process makes it easy to assess the adoption pattern of different technologies in the district map (Fig. 1).

The questionnaire for the landscape diagnostic survey was prepared in a mobile application based digital data collection format of Open Data Kit (ODK) which can transfer real time data to the server or cloud.

Results and Discussion

LDS data on education status revealed that most of the farmers were of 5th standard (48%) followed by 10th (26%) and bachelor (21%) (Fig. 2). Farmers with no schooling were 5% and none attained master's degree.

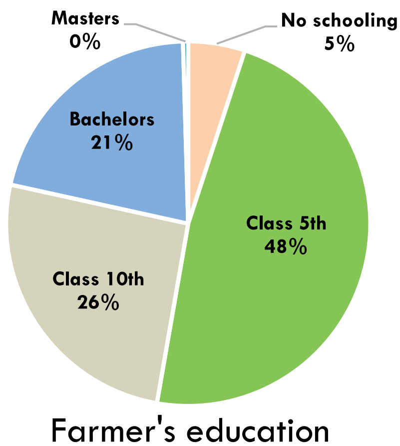

Fig. 2. Status of farmers' education based on LDS survey data in Jagatsinghpur (N=217).

Out of 181 surveyed HHs, majority of the farmers (43%) still grow Pooja followed by Sarala (14%), Kalachampa (13%), Barsha (7%) and MTU7029 (6%) (Table 1).

Table 1. Top five rice varieties grown by the surveyed farmers

Rice varieties	Number of users	% of users
Pooja	94	43
Sarala	31	14
Kalachampa	29	13
Barsha	15	7
MTU 7029	12	6

It is also evident that among the surveyed farmers (N=216), 75% have raised green gram during *rabi* season and 23% kept the land as fallow in sequence with rice (Fig. 3).

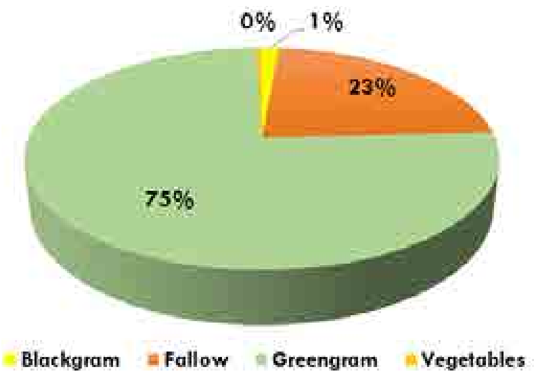

Fig. 3. *Rabi* season crops in sequence with rice grown by the surveyed farmers in Jagatsinghpur, Odisha (N = 216).

LDS based data on seedling age and rice yield (N=216) clearly revealed that transplanting of 17-23 days old seedlings resulted into highest yield (4.78 tha^{-1}) closely followed by 24-30 days old seedlings (4.53 tha^{-1}) (Fig. 4). Transplanting of 31-37, 38-44- and 45-51-days old seedlings produced drastically lower yields (2.51-2.98 tha^{-1}). Young seedlings help maintaining good source-sink relationship in rice (Katsura et al, 2007).

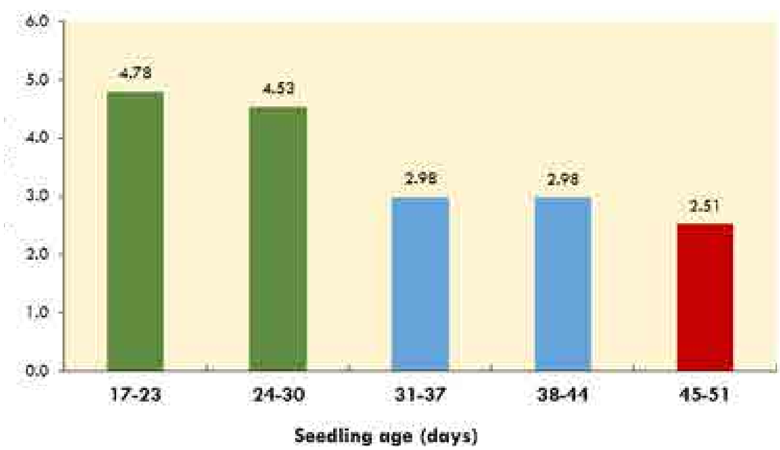

Fig. 4. Effect of the seedling age on the grain yield of rice in Jagatsinghpur.

Looking at the transplanting date, it is very much evident from the LDS based data that paddy transplanted between 9th to 23rd July had a yield advantage in comparison to that transplanted before (24th June to 8th July) and after this interval (24th July to 21st August) (Fig. 5). With more area under pulse crops in this districts, the evidence of dominance of long duration varieties, a revision of varietal spectrum is warranted to further intensify the cropping system in this district. This district has heavy dependence on monsoon rains with little support from diesel-pump based costly irrigation. Some support for supplementary irrigation at the time of crop establishment can harness best of long duration varieties and leave enough space for seeding pulses on the residual moisture immediately after rice harvest or fully rain-fed in many districts of Odisha.

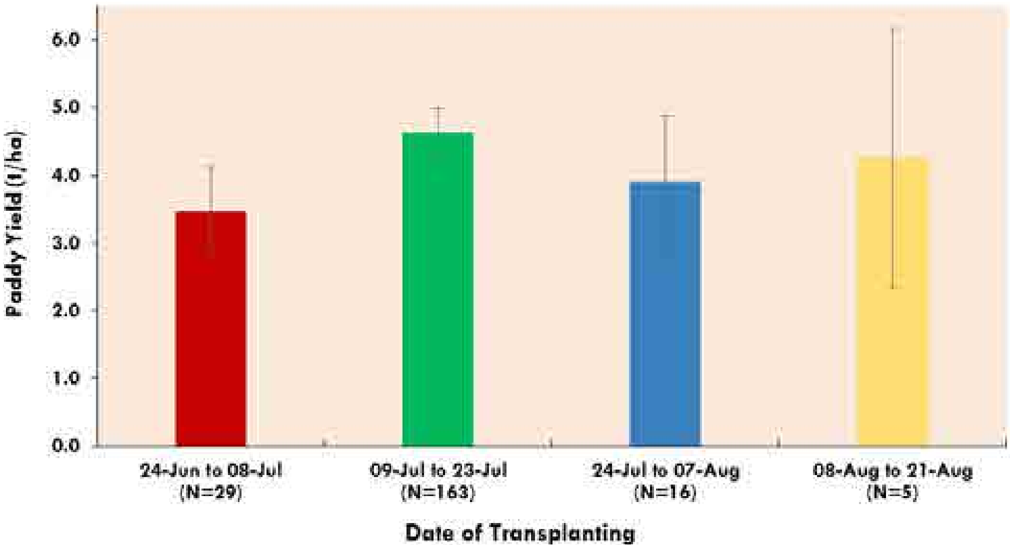

Fig. 5. Effect of date of transplanting on grain yield of rice in Jagatsinghpur (N=213).

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3.45 Dealing with agronomic management is the best element for sustained yield growth in Nuapada district of Odisha

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Introduction

Nuapada district (20.5071° N, 82.6051° E) of Odisha falls in Western Undulating Zone with warm and moist climate. The soils are red, mixed red & black. Total population of the district is 610382. The district agriculture faces frequent risk and uncertainties with drought, and acidic soils. The district has faced 3 floods, 4 unseasonal rain, ten droughts during 2007-2018 (DDMP-Nuapada, 2019). Majority of the farmers (90.1 %) in the district are marginal (69.5 %) and small (20.6 %), and average land holding of 1.1 ha (DA&FP-GoO, 2020). Rice-fallow, pulse-fallow and rice- pulses are major cropping systems. It receives an average rainfall of 1286 mm majorly through monsoon rains. The summer is extremely hot and the temperature may go up to 48^0 C (DDMP-Nuapada, 2019). Cultivated area 189000 ha (70 % upland, 15 % medium land and 15 % lowland) and total cropped area 264560 ha (200280 ha in *kharif* and 64280 ha in *rabi* season) with a cropping intensity of 146 %. Rice is grown on uplands (40 %), medium lands (30 %) and lowlands (30 %) with an average productivity of 2209 $kgha^{-1}$ (DA&FP-GoO, 2020). To understand the rice based sustainability issues, the landscape diagnostic survey (LDS) has been compared across districts. This will give the reflection of why some technologies fly and why some technologies flop across districts.

Methodology

In total 30 villages were randomly selected from the 2011 census data based on probability proportionate to size (PPS) method. The villages and the farmers within villages were randomized (Fig. 1) and the sample properly reflects the farmers' population in the district. Seven farmers were randomly selected from each village. They were interviewed regarding the prevailing agronomic practices for the rice crop.

The randomization process makes it easy to assess the adoption pattern of different technologies in the district map (Fig. 1). The questionnaire for the landscape diagnostic survey was prepared in a mobile application based digital data collection format of Open Data Kit (ODK) which can transfer real time data to the server or cloud.

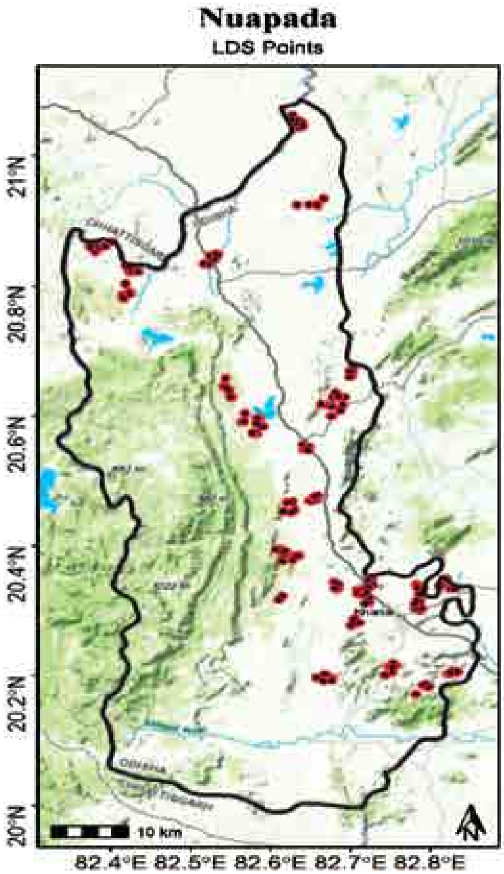

Fig. 1. LDS points of HHs survey in different villages in Nuapada (N=211).

Results and Discussion

If we look at the drainage class based on the 189 farmers under study, 64% of farmers fall in the category possessing low land whereas the farmers with medium land were 35.4%, and upland were only 0.5% (Fig. 2). The study revealed that about 65% of farmers surveyed followed *beushening*, 28% random transplanting, 2%-line transplanting and 5% broadcasting method of rice establishment (Fig. 3).

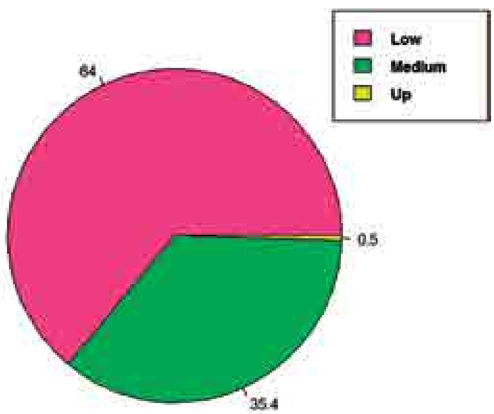

Fig. 2. Land typology based on LDS data in Nuapada, Odisha (N = 189).

It is clearly visible from the data (N = 189) (Fig. 4) that transplanting provided comparatively more paddy yield than DSR (broadcast) with and without *beushening* whereas DSR (broadcast) with *beushening* yielded more than its counterpart without *beushening*.

Among top five most preferred rice varieties, MTU1001, MTU1010, Pooja, MTU7029 and Lalat were adopted by 7, 7, 17, 42 and 7 % HHs respectively (Fig. 5). And the corresponding figures for their yields were 3.85, 3.48. 3.13. 2.95 and 2.0 t ha^{-1}, respectively. Whereas among five top high yielding rice varieties (Fig. 6) including HMT, Sampada, MTU1156, Prasama and MTU1001 with yield of 5.0, 5.0, 4.13, 4.0 and 3.85 tha^{-1}, respectively were grown only by 1, 1,2,1 and 7 % farmers, respectively.

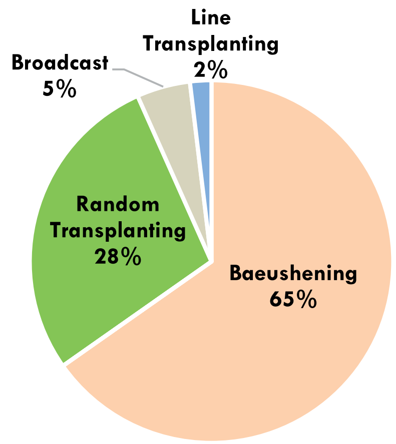

Fig. 3. Status of rice establishment methods among surveyed farmers in Nuapada.

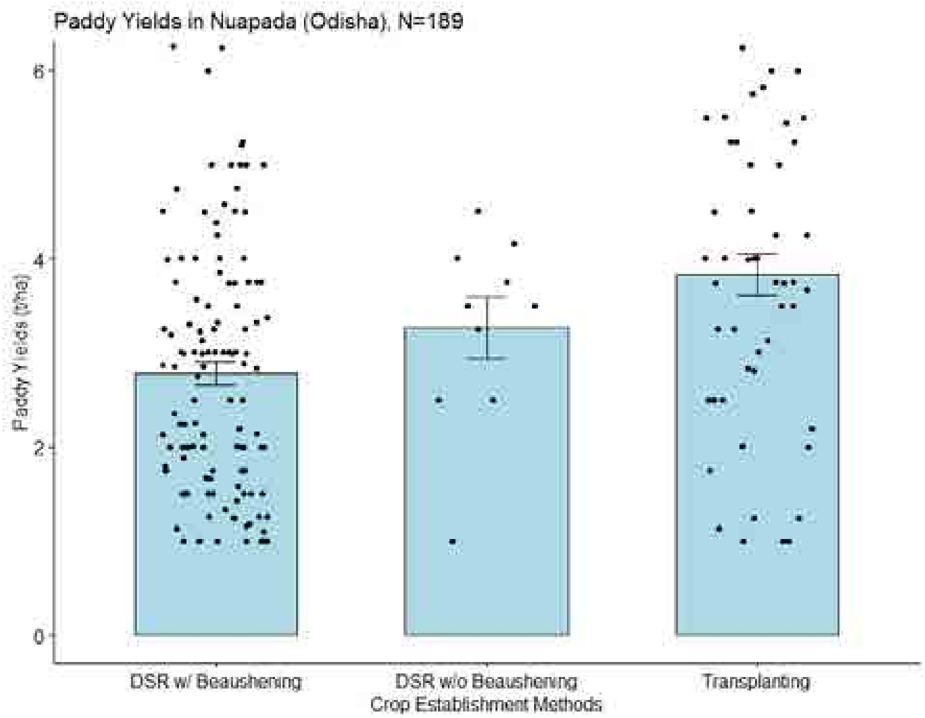

Fig. 4. Grain yield of rice as affected by different crop establishment methods in Nuapada, Odisha.

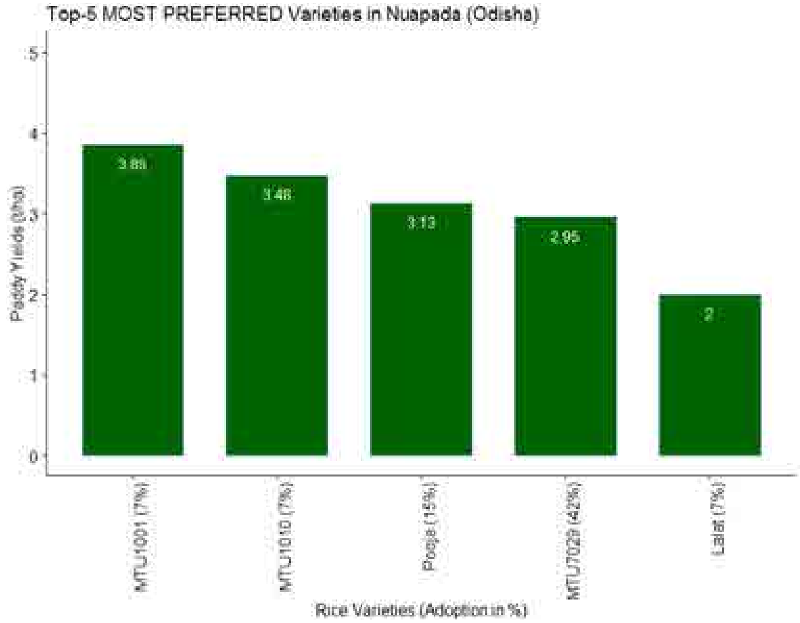

Fig. 5. Top five most preferred rice varieties based on LDS data in Nuapada, Odisha.

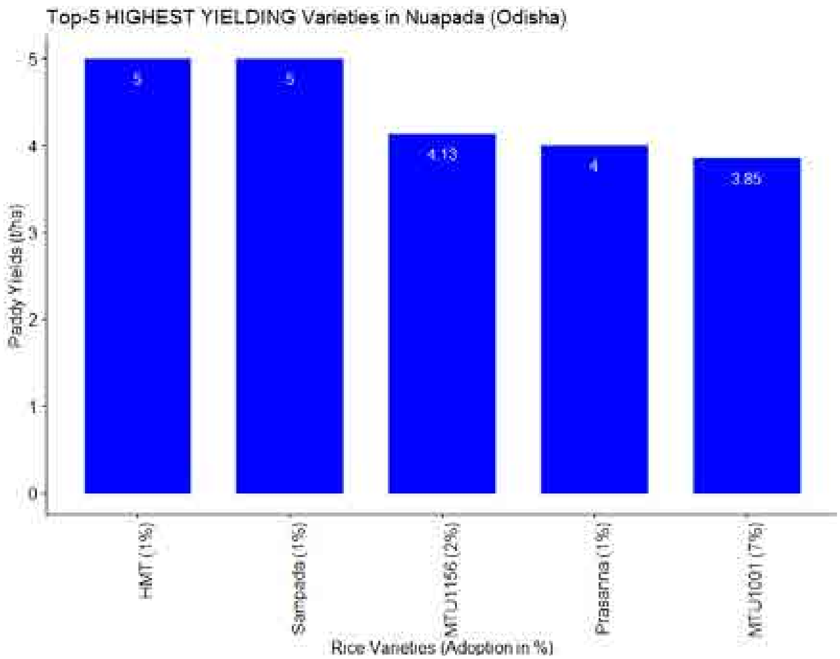

Fig. 6. Top five highest yielding rice varieties based on LDS data in Nuapada, Odisha.

Old varieties released in 1980s were more popular than the new modern varieties (Janaiah *et al.*, 2006). In the related ecologies few hybrids were found better with paddy yield of more than 10.0 $t ha^{-1}$ against 7.4 $t ha^{-1}$ from MTU 7029 (Chamling and Basu, 2012). Some of these interventions did not find a place in Odisha. It can help improving productivity in this district because of water stress at some stage especially in the terminal phase. Several other factors like Government policy may not have worked in favour of hybrids.

Based on LDS data, we found that 53% farmers used their self –saved rice seed, while 42% purchased from seed dealers (Fig. 7). Rest 2, 2 and 1% farmers used rice seed sourced from cooperatives, neighbours and Govt agencies, respectively.

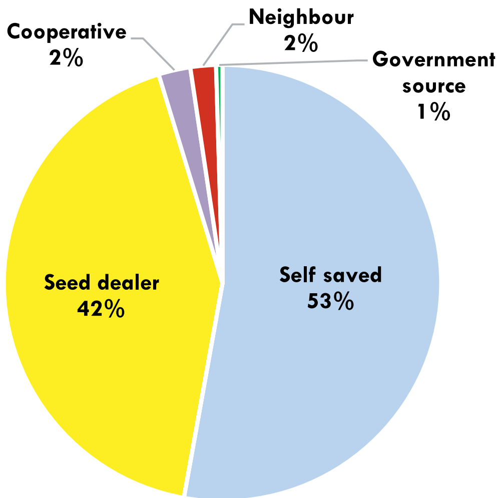

Fig. 7. Rice seed sources for the surveyed farmers in Nuapada, Odisha.

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3.46 Broadcasting and poor weed management in rice-Two key factors for lower yields in Nayagarh district of Odisha

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Introduction

Nayagarh district (20.1654° N, 85.0233° E) of Odisha falls in East and South Eastern Coastal Plain with hot and humid climate. The soils are saline, lateritic, alluvial, red and mixed red & black (DES-P&C-GoO, 2017). The district has also witnessed floods (12 nos.), flash flood (2 nos.), cyclone (5 nos.), unseasonal cyclonic rains (2 nos.) and droughts (4 nos.) during 1999-2019 (DM Plan-Nayagarh, 2019). Total population of the district is 962789 dominated by marginal (85.6 %) and small (11.6 %). The average land holding is 0.74 ha with Rice-fallow, rice-pulses and rice-vegetables are three major cropping systems. It receives an average rainfall of 1354 mm majorly through monsoon rains. Total cultivated area is 134000 ha (33.58 % upland, 36.57 medium land and 29.85 low land). The cropping intensity of the district is 173 % (DA&FP-GoO, 2020). The landscape diagnostic survey (LDS) has been conducted to address the monitoring, and evaluation part of technology adoption patterns. Once we convert the data into actionable points through data analytics, it will be new source of learning for our KVK system.

Methodology

In total 30 villages were randomly selected from the 2011 census data based on probability proportionate to size (PPS) method.

The villages and the farmers within villages were randomized (Fig. 1) and the sample properly reflects the farmers' population in the district. Seven farmers were randomly selected from each village. They were interviewed regarding the prevailing agronomic practices for the rice crop. The randomization process makes it easy to assess the adoption pattern of different technologies in the district map (Fig. 1).

The questionnaire for the landscape diagnostic survey was prepared in a mobile application based digital data collection format of Open Data Kit (ODK) which can transfer real time data to the server or cloud.

Results and Discussion

If we look at the drainage class based on the 210 farmers under study, 57 % of HHs fall in the category possessing medium land whereas the farmers with low land, upland and very low land were 21, 20 and 2 %, respectively (Fig. 2).

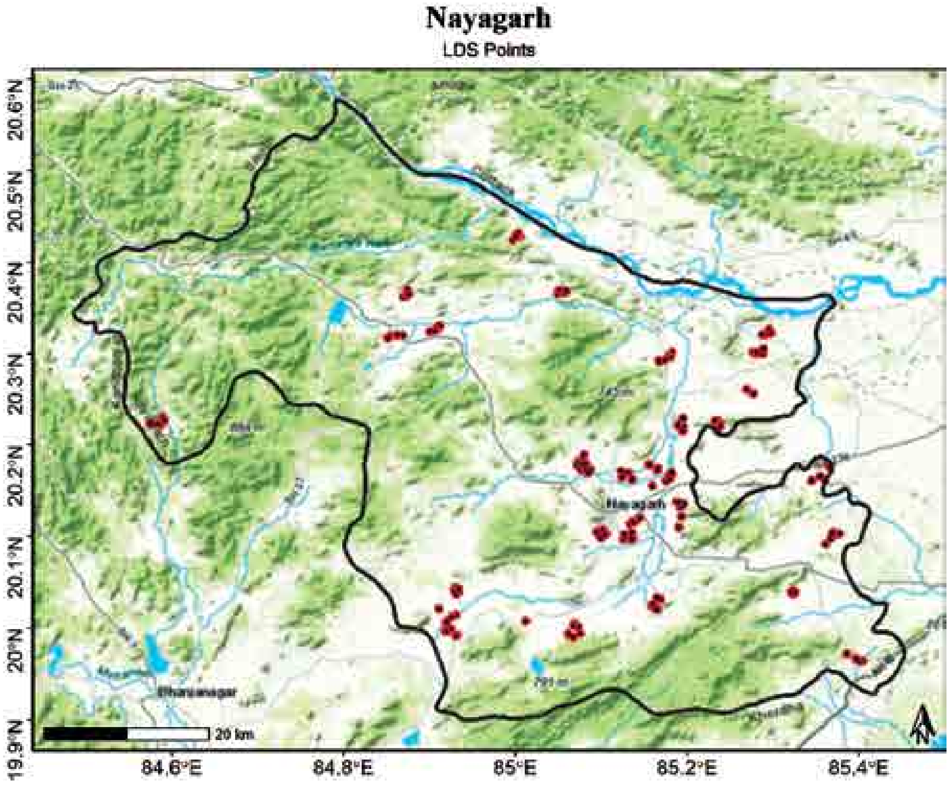

Fig. 1. LDS points of HHs survey in different villages in Nayagarh (N=210).

The study revealed that about 64.9 % of farmers surveyed followed broadcasting, 17.3 % random transplanting, 15.3 %-line transplanting and 2.5 % *beushening* method of rice establishment (Fig. 3).

Out of 165 surveyed respondents, MTU 7029, Pooja and Tulasi were grown by 25, 23 and 21 % farmers (Table 1). These three varieties were released in 1982, 1999, 1988, respectively. Rest two among five top rice varieties were MTU 1001 and Pusa Sugandh-5 with 7 and 2 % adopters, respectively. The adoption of old varieties in Odisha was also highlighted by Bahura et al., (2012). Most varieties adopted by farmers are of long duration with high yields as the priority. If farmer's views are centred on yield performance and the ecology does not allow medium or short duration varieties, the situation calls for focused attention on replacing existing methods associated with *beushening*.

Table 1. Top five rice varieties grown by the surveyed farmers

Top-5 rice varieties	Number of users	% of users
MTU 7029	52	25
Pooja	49	23
Tulasi	45	21
MTU 1001	15	7
Pusa Sugandh-5	4	2

Based on the LDS survey data, five most troublesome weeds infesting rice crop were *Echinochloa colona*, weedy rice, *Cynadon dactylon*, *Fimbristylis* spp and *Cyperus difformis* as responded by 75, 73, 65, 35 and 27 % HHs, respectively (Fig. 4). In broadcasted rice, with the increase in number of manual weeding from 1 to 3, there was a corresponding increase in the paddy yield, and 3 manual weeding yielded significantly more than 1 weeding (Fig. 5).

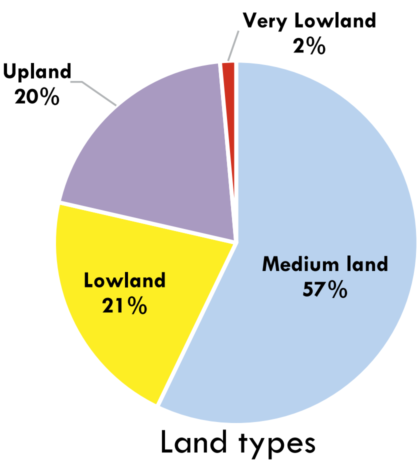

Fig. 2. Land typology based on LDS data in Nayagarh, Odisha.

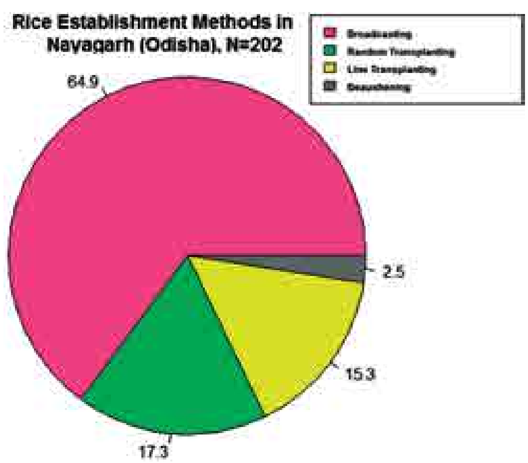

Fig. 3. Status of rice establishment methods among surveyed farmers in Nayagarh.

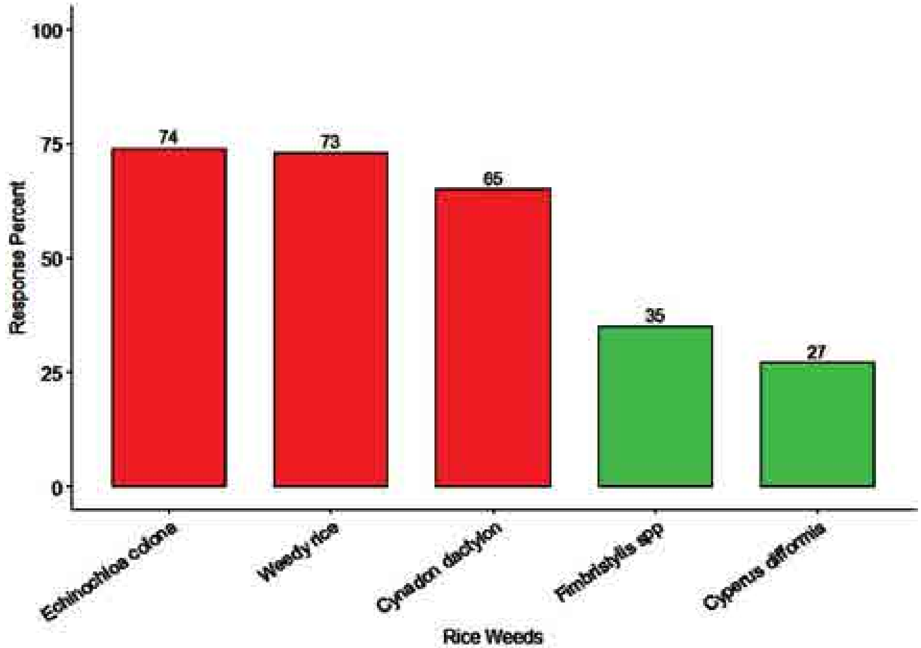

Fig. 4. Top five weeds infesting rice crop in Nayagarh district of Odisha.

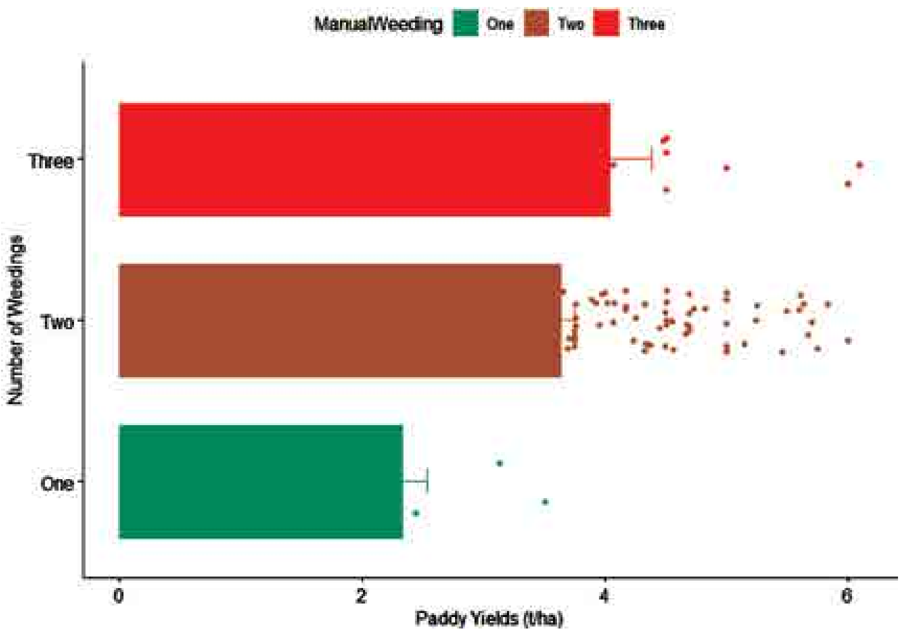

Fig. 5. Response of 'number of manual weeding' on yield in Nayagarh district of Odisha.

However, the differences in yield between 2 and 3 weeding were comparatively less.

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3.47 Improved nitrogen management and line transplanting are key elements to increase rice yields in Balasore district of Odisha

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Introduction

District Balasore (21.3469° N, 86.6611° E) of Odisha falls in North Eastern Coastal Plain with moist sub- humid climate intersected by the perennial rivers, which collectively provides conducive infrastructure for the growth of agriculture in the region. The soils are red, lateritic, deltaic, alluvial, coastal alluvial and saline. Like other districts floods, cyclones, and submergence are quite common. The district has faced 4 floods, 3 cyclones, 3 hailstorms, 4 droughts, 38 heatwaves, etc. during 2007-2016 (DDMP-Balasore, 2019). Total population of the district is 2,320,529 (Census 2011). Majority of the farmers (99 %) in the district are marginal (87 %) and small (11 %), and the average land holding of 0.75 ha (DA&FP-GoO, 2020). Rice-fallow, rice-rice, rice-pulses and rice-vegetables the major cropping systems. It receives an average rainfall of 1592 mm majorly through monsoon rains. The cultivated area is 250000 ha (16 % upland, 42 % medium land and 43 % lowland) and total cropped area 293310 ha (197480 ha in *kharif* and 95830 ha in *rabi* season) with a cropping intensity of 155 % (DA&FP-GoO, 2020). Being a top performing district in rice, we need landscape diagnostic survey (LDS) to monitor, evaluate and learn system that reflects the views and represents the interests of farmers. Increased transparency and accountability would help shortlisting technologies which are not accepted by farmers.

Methodology

In total 30 villages were randomly selected from the 2011 census data based on probability proportionate to size (PPS) method. The villages and the farmers within villages were randomized (Fig. 1) and the sample properly reflects the farmers' population in the district.

Seven farmers were randomly selected from each village. They were interviewed regarding the prevailing agronomic practices for the rice crop. The randomization process makes it easy to assess the adoption pattern of different technologies in the district map (Fig. 1). The questionnaire for the landscape diagnostic survey was prepared in a mobile application based digital data collection format of Open Data Kit (ODK) which can transfer real time data to the server or cloud.

Results and Discussion

According to survey of 306 HHs, 61% say that they practice single rice crop while 39% practice double rice (Fig. 2). Transplanting is the most common method

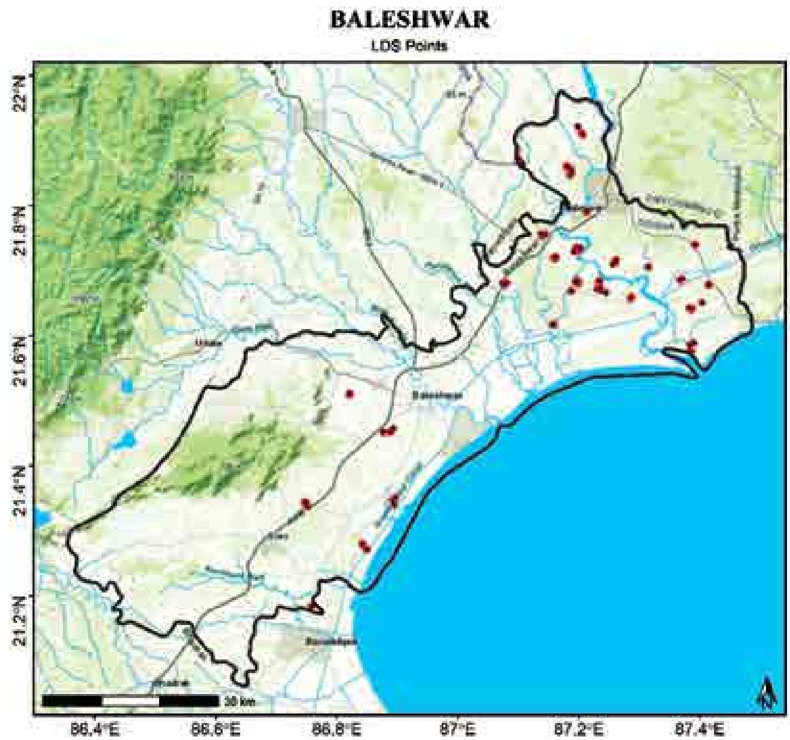

Fig. 1. LDS points of HHs survey in different villages in Balasore (N=319).

of transplanting: 88% of them followed random transplanting and 12% followed line transplanting (Fig. 3).

Out of 174 surveyed HHs, 71, 5, 5, 5, and 4% during *kharif* season preferred MTU 7029, Kalachampa, Niranjan, Raspanjar and MTU 1001, respectively (Table 1). Whereas, during rabi season, out of 106 surveyed HHs, MTU1010, Parijat, Kaveri 264, MTU1001 and MTU 7029 were the choice of 50, 19, 7, 4 and 3% farmers. That means majority HHs grow MTU 7029 in the *Kharif* season and MTU 1010 in the *rabi* season.

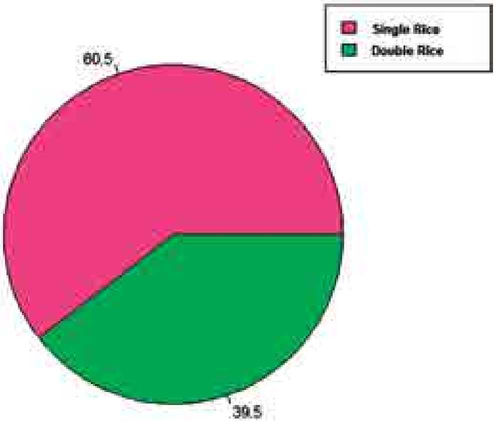

Fig. 2. Rice cropping intensity based on LDS data in Balasore (N=306).

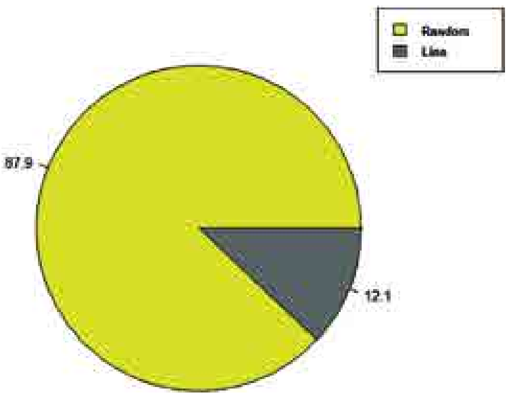

Fig. 3. Status of rice transplanting methods based on LDS data in Balasore (N=306).

Data depicted in Fig. 4 reveals that there was a drastic variation in the grain yield of rice during *kharif* and *rabi* seasons and between random and line transplanting. The paddy yield was higher in *rabi* season compared to *kharif* season both under line as well as random transplanting.

Line transplanting influence the paddy yield with better results from line transplanting compared to random transplanting during both seasons. The grain yield of rice (5.21 tha^{-1}) was higher

Table 1. Top five rice varieties grown by the surveyed farmers during *kharif* & *rabi* seasons.

Kharif			***Rabi***		
Top-5 rice varieties	**Number of users**	**% of users**	**Top-5 rice varieties**	**Number of users**	**% of users**
MTU 7029	137	71	MTU 1010	64	50
Kalachampa	10	5	Parijat	24	19
Niranjan	10	5	Kaveri 264	9	7
Raspanjar	10	5	MTU 1001	5	4
MTU 1001	7	4	MTU 7029	4	3

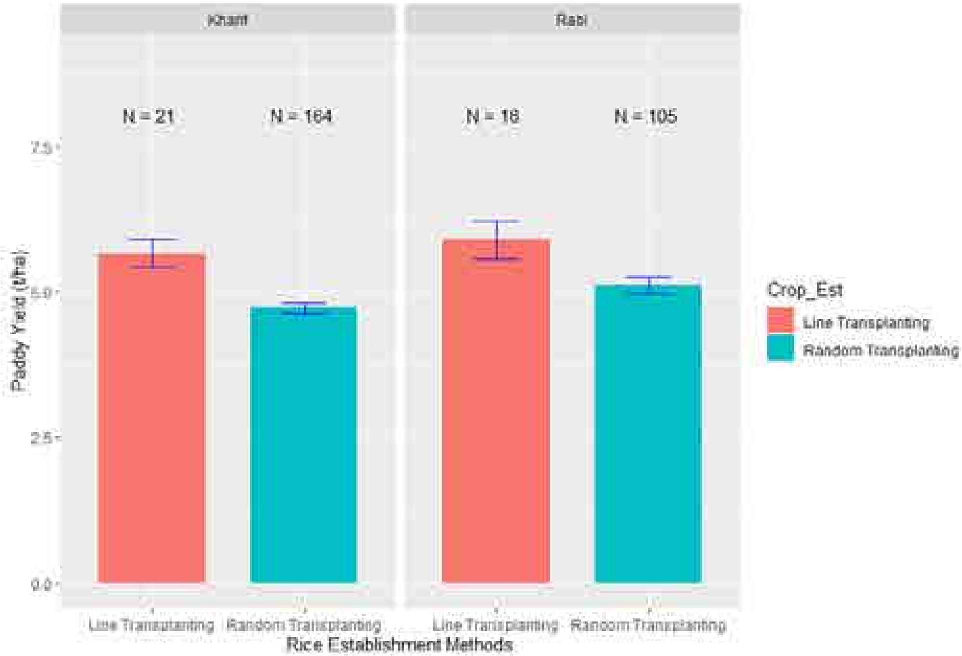

Fig. 4. Seasonal yield variation in transplanted rice based on LDS data in Balasore (N=306).

during *rabi* (N=121) compared to the *kharif* season (N=185) in spite of almost similar fertilizer use (N: P_2O_5: K_2O at 70-72, 42-46 and 54-56 $kgha^{-1}$) during both seasons (Table 2). However, with the increase in the dose of nitrogen from 0 to 200 $kgha^{-1}$, there was a corresponding increase in the paddy yield (Fig. 5). The N use rates are much lower than 165 $Kgha^{-1}$ reported by Punjab farmers with paddy yield of 8.9 t ha^{-1} from long duration variety (Pusa 44) which matches the duration of MTU 7029. Substantial increase in the rice growth rates will come only from increase in the N supply (Lloyd Evans, 2001). That will also provide opportunity for better management of indigenous N resources (Cassman et al., 1998). This clearly indicates that it will be advisable to use still higher dose of nitrogen to attain higher rice yield in Balasore.

Table 2. Status of fertilizer application by the surveyed farmers and grain yield of rice during *kharif* & *rabi* seasons.

Season	Fertilizers applied ($kgha^{-1}$)			Yield (t ha^{-1})
	Nitrogen	P_2O_5	K_2O	
Kharif (N=185)	70	42	54	4.81
Rabi (N=121)	72	46	56	5.21
Total (N=306)	71	43	55	4.97

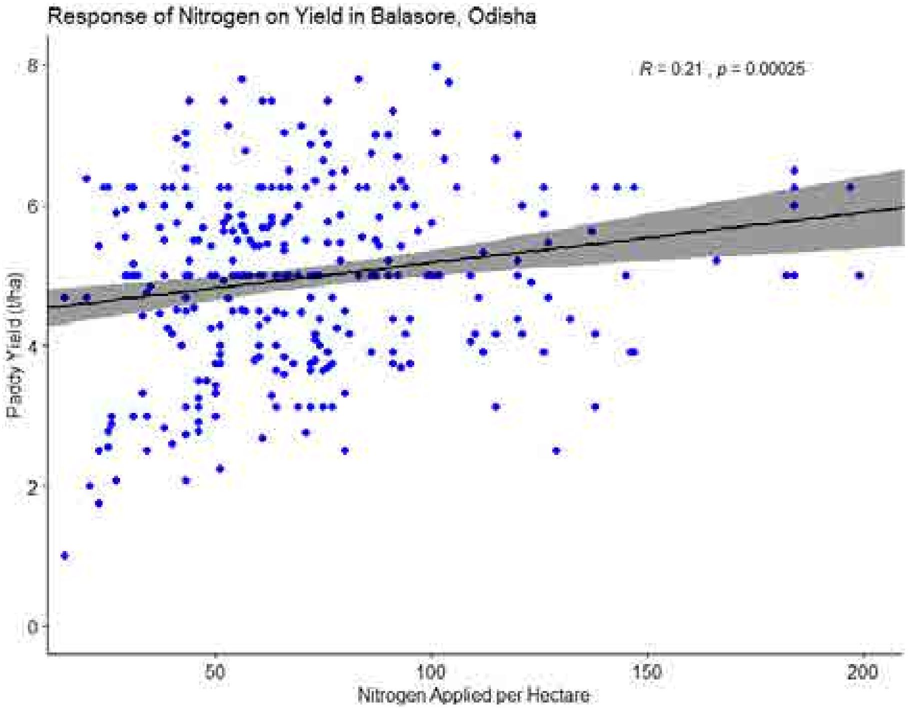

Fig. 5. Response of nitrogen application rate on the grain yield of rice based on LDS data in Balasore.

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3.48 Improved varieties and optimum transplanting time can enhance rice yield in Bhadrak district of Odisha

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Introduction

Bhadrak district (21.0574° N, 86.4963° E) of Odisha falls in East and South Coastal Plain with hot and humid climate. The soils are red, lateritic, deltaic, alluvial, coastal alluvial and saline (DES-P&C-GoO, 2017). The district agriculture faces frequent risk and uncertainties with flood, cyclone, saline soils, and submergence of lowland rice. The district has faced 8 floods, 3 cyclones, 4 droughts, 13 heatwaves, etc. during 2007-2018 (DDMP-Bhadrak, 2019). Total population of the district is 15,06,337 (Census 2011). Majority of the farmers (96 %) in the district are marginal (79.4 %) and small (16.3 %), with an average land holding of 0.77 ha (DA&FP-GoO, 2020). Rice-fallow, rice- pulses and rice-vegetables are three major cropping systems. It receives an average rainfall of 1428 mm majorly through monsoon rains. Total geographical area of the district is 250000 ha, cultivated area 176000 ha (7 % upland, 36 % medium land and 57 % lowland) and total cropped area 197870 ha (172880 ha in *kharif* and 29490 ha in *rabi* season) with a cropping intensity of 128 %. Rice is largely grown on medium land (36 %) and lowlands (64 %) (DA&FP-GoO, 2020). Lot of work has been done by KVK for improving the system productivity in this district. Landscape diagnostic survey (LDS) has been conducted to plan short term delivery and long-term strategy for adoption of technologies at the level of KVK. Data so generated will tell us if there is any kind of mismatch between what farmers prefer what we recommend.

Methodology

In total 30 villages were randomly selected from the 2011 census data based on probability proportionate to size (PPS) method. The villages and the farmers within villages were randomized (Fig. 1) and the sample properly reflects the farmers' population in the district.

Seven farmers were randomly selected from each village. They were interviewed regarding the prevailing agronomic practices for the rice crop.

The randomization process makes it easy to assess the adoption pattern of different technologies in the district map (Fig. 1). The questionnaire for the landscape diagnostic survey was prepared in a mobile application based digital data collection format of Open Data Kit (ODK) which can transfer real time data to the server or cloud.

Results and Discussion

Based on the response of the landscape diagnostic surveyed farmers', 94 % HHs informed that rabi- fallow cropping system is main cropping system. Small percentage of HHs also grow green gram (3 %), black gram (1 %), and vegetables (2 %) in the *rabi* season (Fig. 2) There are three main reasons for such a cropping system; the access to supplementary irrigation, lack of residual moisture after rice

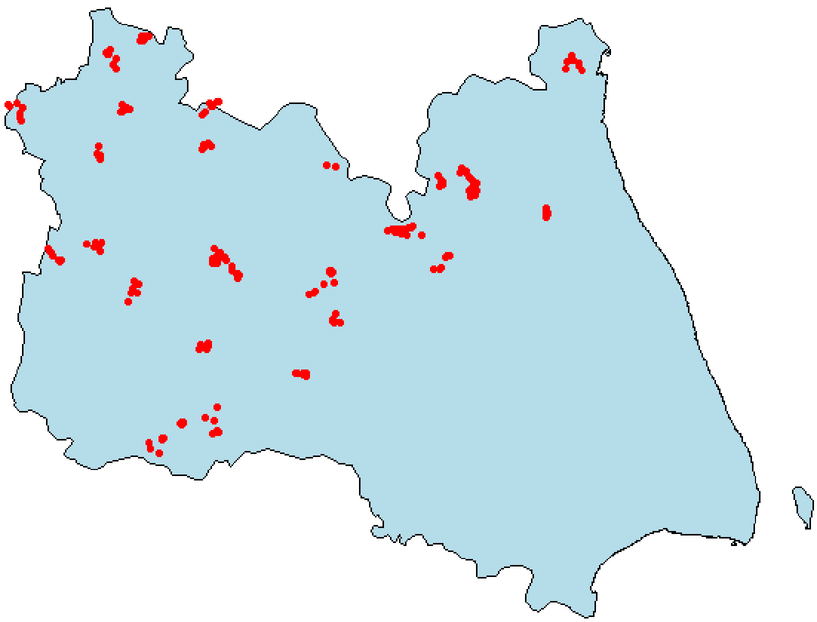

Fig. 1. LDS points of HHs survey in different villages in Bhadrak (N=206).

harvest, and very low yields of pulses. Some short duration crops of pulses can be grown successfully after harvest of rice with efficient utilization of residual soil moisture (Ali and Kumar, 2009). Since dry *rabi* season one or two supplemental irrigation can help sustaining rice-toria and rice-pulses cropping system.

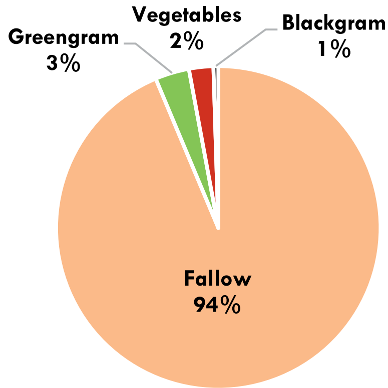

Fig. 2. Land use pattern before *kharif* rice based on LDS data in Bhadrak (N=206).

Based on the data on adoption of rice varieties in the district from the surveyed farmers (N=170), it is evident that among five top rice varieties, MTU 7029 is still popular with 35 % HHs followed by Kalachampa (19 %), MTU 1009 (11 %), Deradun (10 %) and MTU1001 (8 %) (Table 1).

Table 1. Five top most preferred rice varieties based on LDS data in Bhadrak (N=170).

Top-5 rice varieties	Number of users	% of users
MTU 7029	70	35
Kalachampa	39	19
MTU 1009	23	11
Deradun	21	10
MTU 1001	17	8

When surveyed HHs were compared for two rice establishment methods i.e. *beushening* (N=9) and transplanting (N=173), the grain yield of rice was more under transplanting (4.44 tha^{-1}) than *beushening* (4.20 tha^{-1}) (Fig. 3).

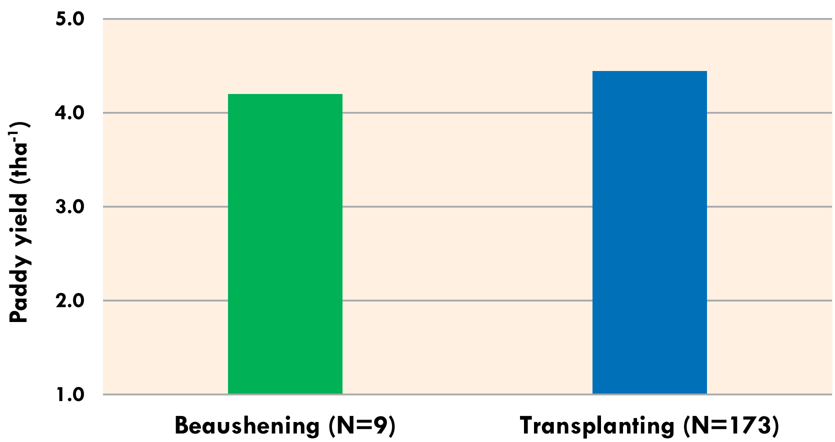

Fig. 3. Paddy yield in two establishment methods based on LDS data in Bhadrak.

The peak rice transplanting time among the surveyed farmers was between 10th to 17th July followed by 17th to 24th July and 24th to 31st July in that order (Fig. 4).

Data was also recorded to plot grain yield against each day of time of transplanting starting from 26th June to 18th August (Fig. 5). It is evident that there was not a definite trend or consistency between time of transplanting and yield but more peaks in yield (4.65 to 5.31 tha^{-1}) in the month of July transplanted crop were attained on 18, 21 & 26 July, and similarly it ranged between 4.90 to 6.25 tha^{-1} when transplanted on 4, 8.10, 13 and 15 August.

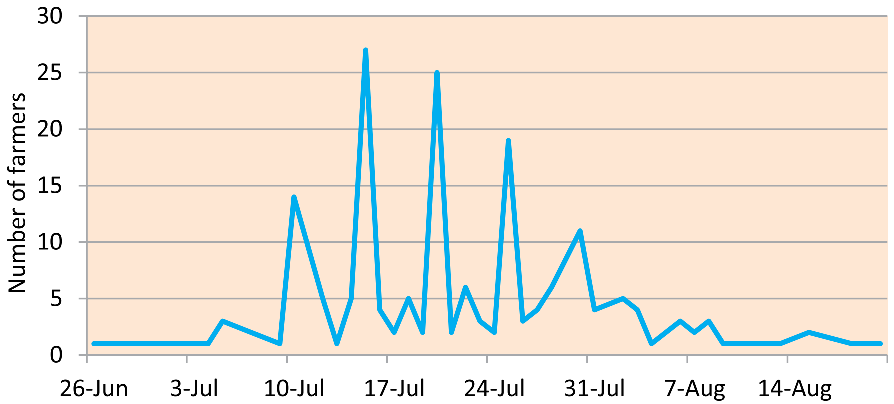

Fig. 4. Number of farmers opted for rice transplanting based on LDS data in Bhadrak.

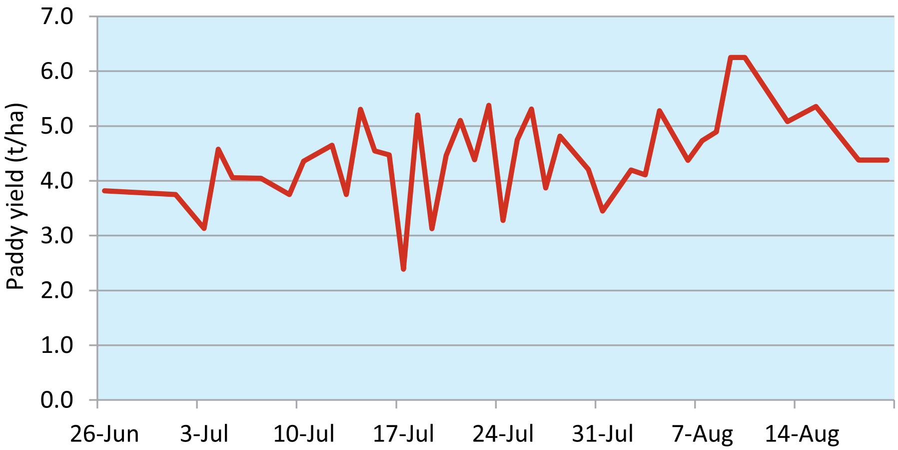

Fig. 5. Paddy yield as affected by transplanting time in Bhadrak district of Odisha.

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3.49 Long duration varieties and improved method of crop establishment– Need of time to raise rice productivity in Jajpur district of Odisha

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Introduction

District Jajpur (20.7652° N, 86.1752° E) is part of North Eastern Coastal Plain with moist sub- humid climate. The soils are red, lateritic, deltaic alluvial, coastal alluvial and saline. Like other districts, it has more distinct features of lowland rice, frequent hazards like flood (17 nos.), cyclone (2 nos.), drought (2 nos.), heatwave (8 nos.), and whirlwind (250 nos.), etc. during 2008-2017 (DDP-Jajpur, 2019). This district has a total population of 1827192 (Census 2011) with majority of the HHs (93%) in the district are marginal (77%) and small (16%), with an average land holding of 0.88 ha (DA&FP-GoO, 2020). Rice-fallow, rice-pulses and rice-oilseeds are the major cropping systems. It receives an average rainfall of 1560 mm. Total cultivated area 145000 ha (36% upland, 33% medium land and 31% lowland). The cropping intensity of the district is 178%. It is important to understand farmers and what they need. Landscape diagnostic survey (LDS) has been proposed to provide feedback to researchers to develop recommendations.

Methodology

In total 30 villages were randomly selected from the 2011 census data based on probability proportionate to size (PPS) method. The villages and the farmers within

villages were randomized (Fig. 1) and the sample properly reflects the farmers' population in the district.

Seven farmers were randomly selected from each village. They were interviewed regarding the prevailing agronomic practices for the rice crop.

The randomization process makes it easy to assess the adoption pattern of different technologies in the district map (Fig. 1). The questionnaire for the landscape diagnostic survey was prepared in a mobile application based digital data collection format of Open Data Kit (ODK) which can transfer real time data to the server or cloud.

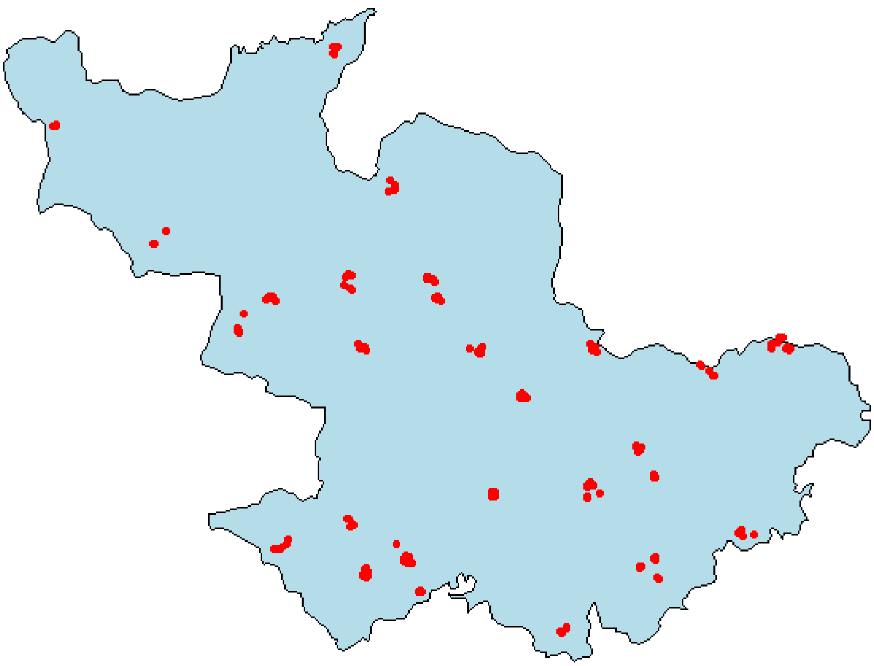

Fig. 1. LDS points of HHs survey in different villages in Jajpur (N=210).

Results and Discussion

If we look at the drainage class based on the 210 farmers under study, 92 % of HHs fall in the category possessing medium land whereas the HHs with upland and lowland were 5 and 3 %, respectively (Fig. 2).

Rice-fallow constitutes the major cropping system with 85 %. The intensification is limited to green gram (9 %), black gram (3 %), vegetables (2 %) and groundnut

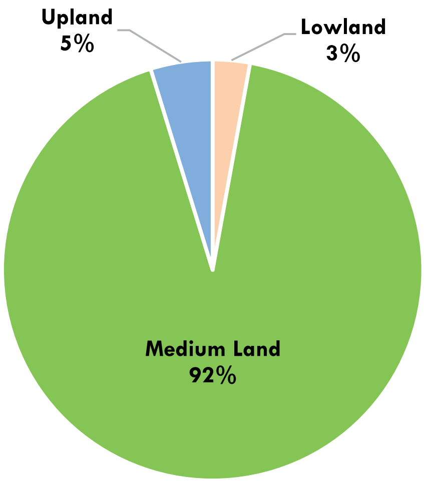

Fig. 2. Land typology based on LDS data in Jajpur, Odisha (N=210).

(1%) (Fig. 3). *Rabi* crops face the question of supplementary irrigation. There is however, enough residual moisture at the time of rice maturity. The extension agencies should consider helping famers in vacating the rice fields at the earliest so that *rabi* crops can be seeded on the residual moisture.

Based on the data on adoption of rice varieties in the district from the surveyed farmers (N=174), it is evident that among five top rice varieties, MTU 7029 is still popular with 68% farmers followed by Kalachampa (5%), Udaigiri (4%), Mugudhi (3%) and Pooja (3%) (Table 1). That shows that the adoption pattern is affected by hydrological conditions and yield performance. Old variety like MTU 7029 is still popular because the contradiction between "high yielding" and "early maturing" hampers further improvement of rice yield (Fang et al., 2019). This is because plants with higher yield needs a longer growth period so that the production rate of carbohydrate via photosynthesis is not restricted (Ross et al., 2015).

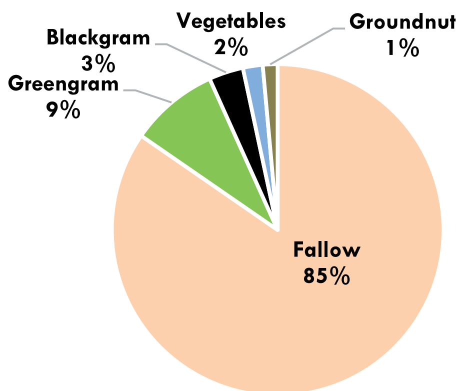

Fig. 3. Land use pattern before *kharif* rice based on LDS data in Jajpur (N=210).

When surveyed HHs were compared for different establishment methods, the grain yields under random transplanting (3.68 tha^{-1}) being similar to line transplanting (3.66 tha^{-1}) were more than *beushening* (3.29 tha^{-1}) and broadcasting (3.0 tha^{-1}) as well (Fig. 4).

Table 1. Five top most preferred rice varieties based on LDS data in Jajpur (N=174).

Top-5 rice varieties	Number of users	% of users
MTU 7029	143	68
Kalachampa	11	5
Udaygiri	8	4
Mugudhi	6	3
Pooja	6	3

The top five weeds infesting the rice crop were *Cynadon dactylon*, *Marsilea minuta*, *Brachiaria reptans*, *Echinochloa*

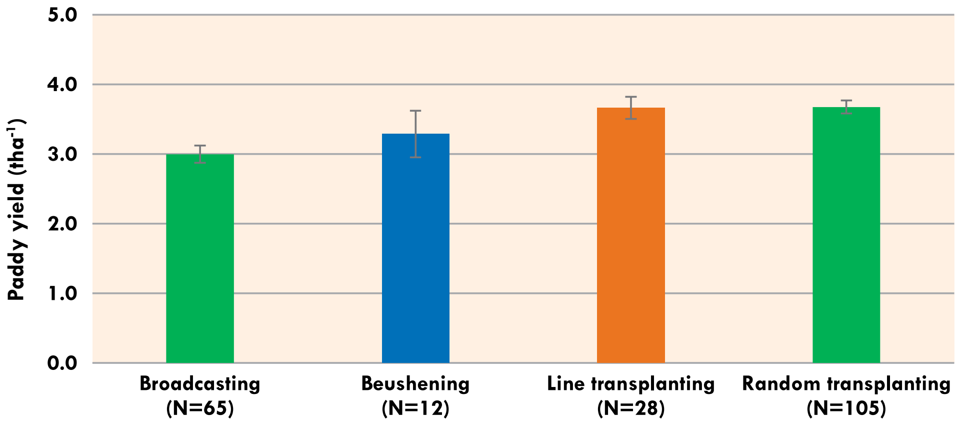

Fig. 4. Paddy yield in different establishment methods based on LDS data in Jajpur.

colona and *Dactyloctenium aegyptium* as informed by 76, 33, 28, 22 and 7% respondents, respectively (Fig. 5).

Based on LDS data of 174 HHs, it was found that in broadcasted and transplanted rice 65 and 84% farmers did not use any herbicide, 29 and 15% did one herbicide spray and 6 and 1% did two herbicide sprays, respectively (Table 2). It clearly indicated that herbicide use was comparatively more in broadcasted rice compare to transplanted one. This could be obviously due to more weed pressure in broadcasted rice. Farmers who used 0, 1, 2 and 3 weeding were 0, 39, 58 and 3% in broadcasted rice, respectively (Table 3). However, the corresponding figures in transplanted rice were 0, 47, 51 and 2%, respectively.

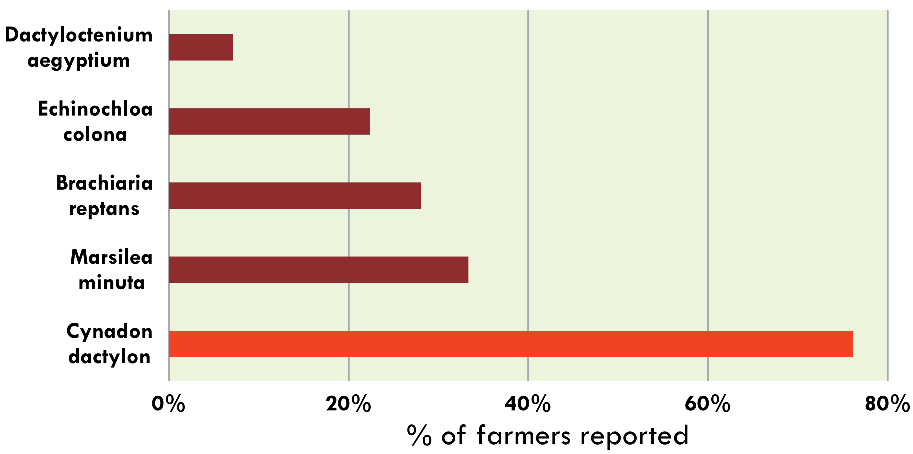

Fig. 5. Top five weeds infesting rice crop in Jajpur district of Odisha.

Table 2. Pattern of herbicide application in rice based on LDS data in Jajpur (N=174)

Herbicide use	In broadcasting (% of farmers)	In transplanting (% of farmers)
No herbicide applied	65	84
1 herbicide spray	29	15
2 herbicide sprays	6	1

Table 3. Pattern of manual weeding in rice based on LDS data in Jajpur (N=174)

Manual weeding	In Broadcasting (% of farmers)	In Transplanting (% of farmers)
No weeding	0	0
1 weeding	39	47
2 weedings	58	51
3 weedings	3	2

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3.50 Hybrid rice can break the yield barriers in Keonjhar district of Odisha

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Introduction

Keonjhar district (21.5151° N, 85.6846° E) falls in North Central Plateau with hot and moist sub-humid climate. The soils are lateritic, red & yellow, mixed red & black. Floods, droughts, and cyclones, are quite common. During 2008-2018, the district has faced 7 floods, 2 droughts, 2 cyclones, 1 hailstorm, etc. (DDMP-Keonjhar, 2020). Total population of Keonjhar district is 18,01,733. Majority of the farmers (95%) in the district are marginal (76.8%) and small (18.1%) with average land holding of 0.95 ha (DA&FP-GoO, 2020). Rice-fallow, rice-pulses, and rice -vegetables are the major cropping systems. It receives an average rainfall of 1488 mm majorly through monsoon rains. Rice is largely grown on medium land (52.1%) followed by upland (27.6%) and lowlands (20.3%) (DA&FP-GoO, 2020).

Landscape diagnostic survey (LDS) proposed in this study will help processing the adoption patterns of technologies so that information flows to research and extension system for better return on investment.

Methodology

In total 30 villages were randomly selected from the 2011 census data based on probability proportionate to size (PPS) method. The villages and the farmers within villages were randomized (Fig. 1) and the sample properly reflects the farmers' population in the district. Seven farmers were randomly selected from each village.

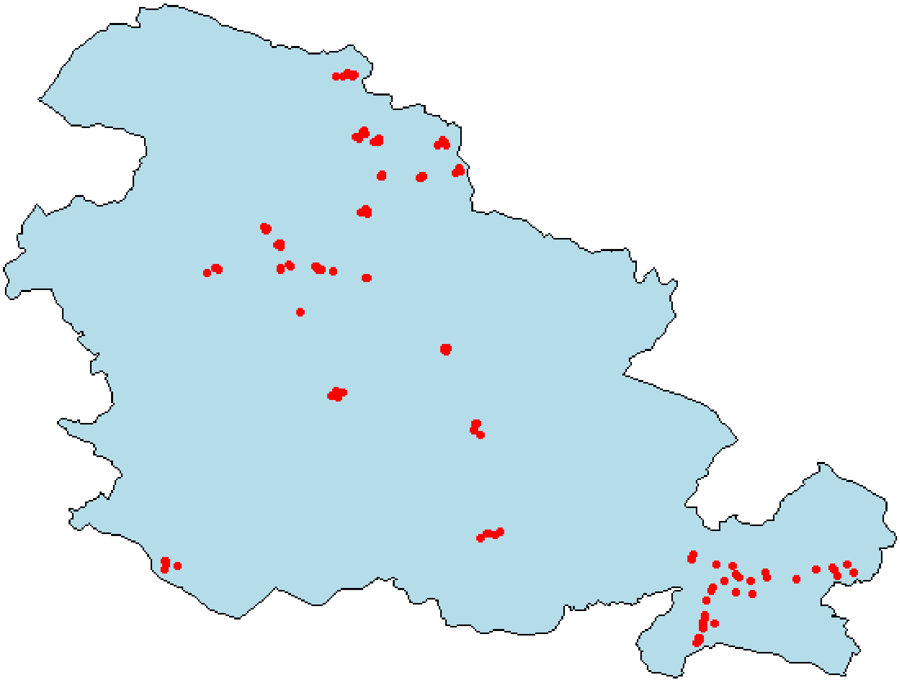

Fig. 1. LDS points of HHs survey in different villages in Keonjhar (N=184).

They were interviewed regarding the prevailing agronomic practices for the rice crop. The randomization process makes it easy to assess the adoption pattern of different technologies in the district map (Fig. 1). The questionnaire for the landscape diagnostic survey was prepared in a mobile application based digital data collection format of Open Data Kit (ODK) which can transfer real time data to the server or cloud.

Results and Discussion

The survey showed that more than HHs had medium land whereas the HHs with lowland and upland were 11 and 8%, respectively (Fig. 2).

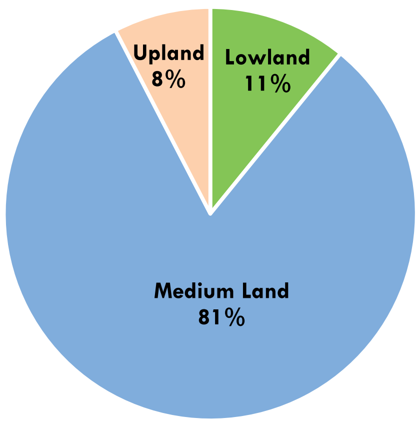

Fig. 2. Land typology based on LDS data in Keonjhar, Odisha (N=184).

Very high-count of rice-fallow HHs (93%) reflects the urgency for intensification of rice-fallow (RF) cropping system. More area under vegetables in the rabi season reflects the need for introducing high value crops (Fig. 3).

Based on the data on adoption of rice varieties in the district from the surveyed farmers (N=184), it is evident that MTU 7029, Kalachampa, Lalat, MC13, 27 P31, Dhanya 775, Sahabhagi, Swarna Sub-1 and Arize 6444 Gold were the popular rice varieties used by 16, 11, 10, 7, 7, 5, 4, 3 and 2% farmers, respectively (Fig. 4).

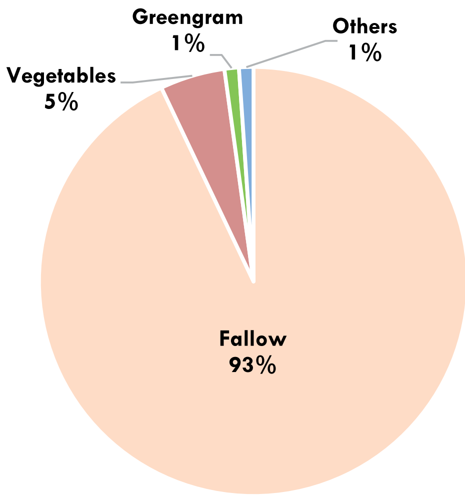

Fig. 3. Land use pattern before *kharif* rice based on LDS data in Keonjhar (N=184).

Hybrid rice varieties 27P31 (4.99 tha^{-1}) and Arize 6444Gold (4.83 tha^{-1}) yielded more than MTU 7029 (4.45 tha^{-1}), Swarna Sub-1(4.33 tha^{-1}), Dhanya 775(4.31 tha^{-1}), MC13 (4.15 tha^{-1}), Kalachampa (4.13 tha^{-1}), Lalat (3.52 tha^{-1}) and Sahabhagi (3.34 tha^{-1}) (Fig. 5).

Although biotic or abiotic stresses has shifted the priorities from high yields focused varieties to more resilient varieties (Das, 2012) but the development of hybrids and provisions to subsidize hybrid rice seed could be better option.

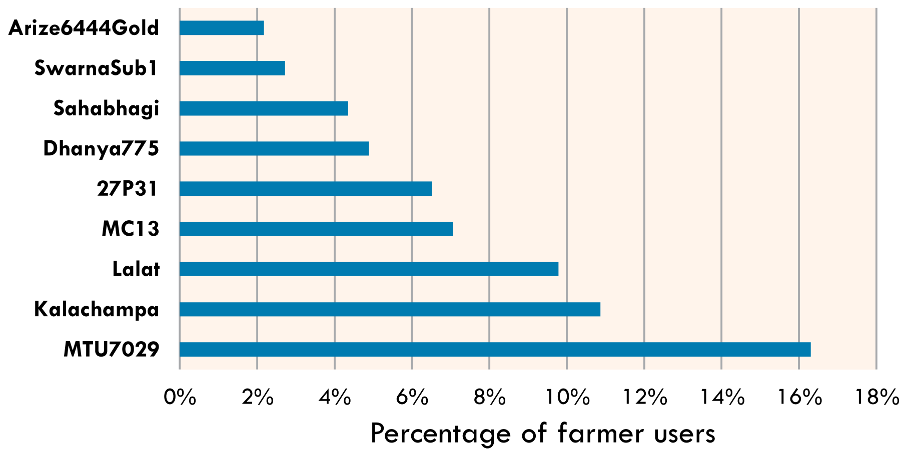

Fig. 4. Major rice varieties used by the farmers based on LDS data in Keonjhar (N=184).

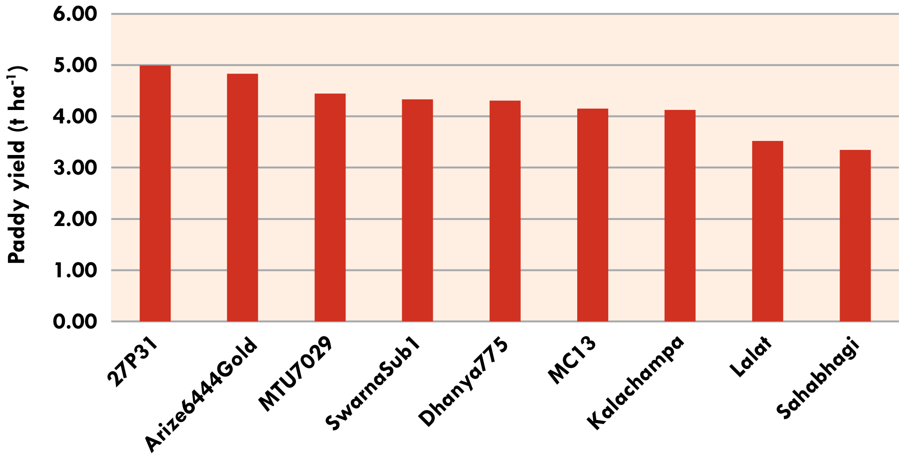

Fig. 5. Grain yield of rice varieties based on LDS data in Keonjhar (N=184).

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3.51 Hybrid rice and improved methods of crop establishment need focused attention to counter water stress in Mayurbhanj district of Odisha

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Introduction

Mayurbhanj district (22.0087° N, 86.4187° E) of Odisha falls in North Central Plateau with hot and moist sub- humid climate. The soils are sandy loam, lateritic, red & yellow, mixed red & black and light textured with low water retentive capacity and acidic in reaction. Total population of the district is 25,19,738 with a population density of 241 per sq.km. The intermittent droughts and the lack of life saving irrigation disrupts the crop growth every season. Surprisingly, disaster history shows that during 2004-2015 the district has faced droughts (3 years), heat wave (6 years), flood (7 years) and cyclone (2 years) (DDMP-Mayurbhanj, 2015). Majority of the farmers in the district are marginal (88 %) and average land holding is 0.88 ha (DA&FP-GoO, 2020). Rice-fallow, rice-pulses and pulses-fallow are the major cropping systems. It receives an average rainfall of 1601 mm majorly through monsoon rains. Total cultivated area is 437000 ha (42.56 % upland, 28.06 % medium land and 28.84 % low land) and total cropped area 435740 ha (359200 ha in *kharif* and 76540 ha in *rabi* season) with a cropping intensity of 121 %. Rice is largely grown on upland (21.38 %) medium land (37.17 %) and lowlands (41.45 %) (DA&FP-GoO, 2020). While there has been decrease in the coverage of *kharif* paddy in uplands, the area under pulses, oil seeds and maize has been showing an increasing trend.

The KVK and CSISA project has done lot of work on intensifying the *kharif* fallow with maize which has been largely successful. The rice crop is not doing well in this district. Landscape diagnostic survey (LDS) conducted in this study reflects changes in farmer's requirement for new technologies in rice.

Methodology

In total 30 villages were randomly selected from the 2011 census data based on probability proportionate to size (PPS) method. The villages and the farmers within villages were randomized (Fig. 1) and the sample properly reflects the farmers' population in the district. Seven farmers were randomly selected from each village. They were interviewed regarding the prevailing agronomic practices for the rice crop. The randomization process makes it easy to assess the adoption pattern of different technologies in the district map (Fig. 1).

The questionnaire for the landscape diagnostic survey was prepared in a mobile application based digital data collection format of Open Data Kit (ODK) which can transfer real time data to the server or cloud.

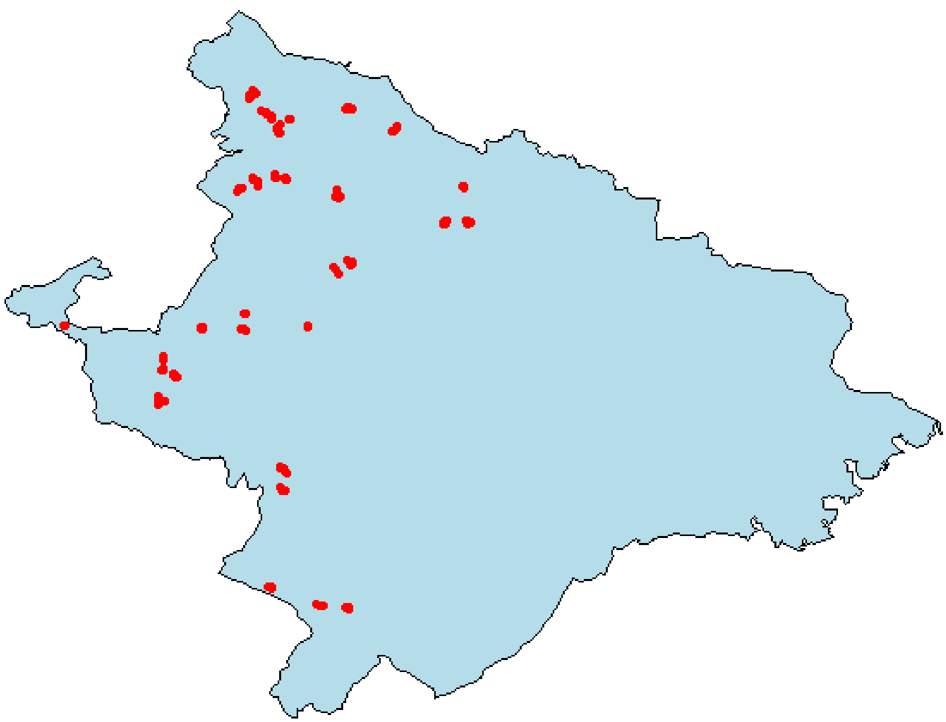

Fig. 1. LDS points of HHs survey in different villages in Mayurbhanj (N=205).

Results and Discussion

The district has large variation in the drainage class with 46% of HHs from a sample 205 fall each in the category possessing medium land and lowland. Farmers with upland ecology are only 8% in this survey (Fig. 2).

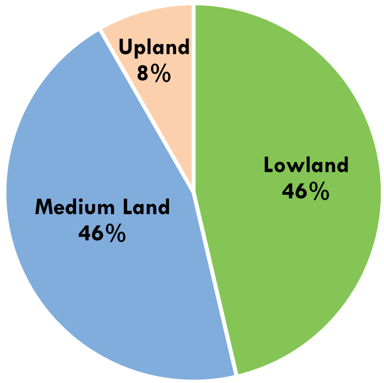

Fig. 2. Land typology based on LDS data in Mayurbhanj-II, Odisha (N=205).

Based on the response of the landscape diagnostic surveyed farmers regarding rice establishment methods; *beushening*, broadcasting, random transplanting and line transplanting were adopted by47, 4, 39 and 10% HHs, respectively (Fig. 3).

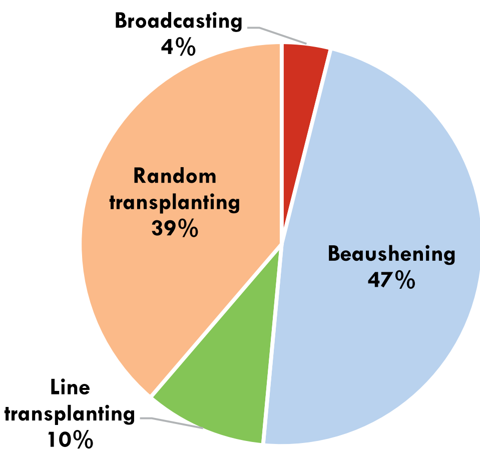

Fig. 3. Status of rice establishment methods based on LDS data in Mayurbhanj-II, Odisha (N=205).

Based on the data on adoption of rice varieties in the district from the surveyed farmers (N=96), it is evident that among five top rice varieties, MTU 7029 was preferred by 29% farmers followed by Pooja (15%), Kalachampa (9%), Balibhaina (7%) and Naveen (8%) (Table 1). Among these varieties Naveen is the latest variety released in 2006 and Kalachampa is a farmer variety. The stress for which the varieties have been developed does not happen every year in the same location even in the same district. Some varieties like Shahbhagi dhan were not accepted by farmers. While making decision for adoption,

Table 1. Five top most preferred rice varieties based on LDS data in Mayurbhanj-II (N=96)

Top-5 rice varieties	Number of users	% of users
MTU 7029	43	29
Pooja	22	15
Kalachampa	13	9
Balibhajana	10	7
Naveen	8	5

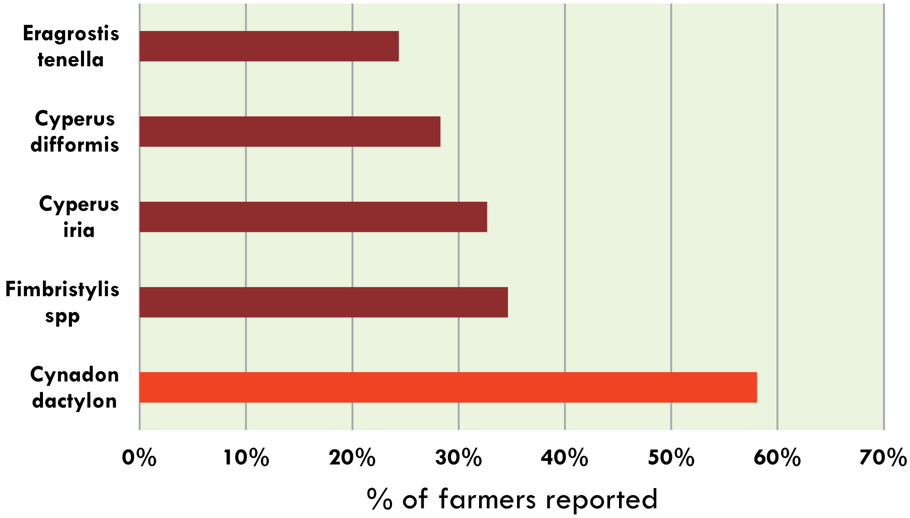

Fig. 4. Top five weeds infesting rice crop in Mayurbhanj-II district of Odisha

farmers do not like yield penalty of any kind. The yield advantage of drought tolerant varieties must be extended even for normal years. Such advantage cannot be extended in the normal or in the optimal conditions (Patrick et al., 2013). The relative yield advantage of rice hybrids in irrigated (Janaiah and Hossain, 2003) and in drought like situation (Villa et al., 2012) can fill up this gap. Therefore, hybrids which may satisfy these conditions should be promoted.

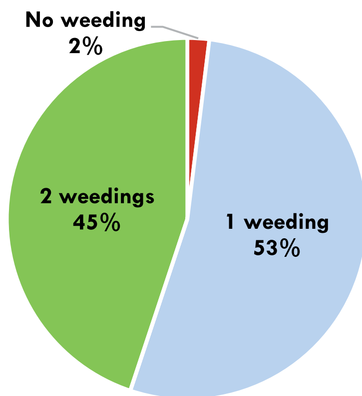

Fig. 5. Pattern of manual weeding in rice based on LDS data in Mayurbhanj-II

The top five weeds infesting the rice crop were *Cynadon dactylon*, *Fimberstylis spp*, *Cyperus iria*, *Cyperus difformis* and *Eragrostis tenella* as informed by 58, 35, 33, 28 and 24 % respondents, respectively (Fig. 4).

Farmers who used 1 and 2 weeding in rice were 53 and 45 %, respectively (Fig.5). Only 2 % farmers did not opt any weeding and herbicide was applied by just 6 % farmers.

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3.52 Complex weed flora and the lack of access to irrigation at transplanting time are the two key constraints for enhancing rice yields in Chandauli district of Uttar Pradesh

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Introduction

Chandauli, Agro climatically falls into Vidyan Zone (UP-10) with 25° 16’ N latitude and 84°16’ E longitude at an altitude of 70 m above MSL. Its geographical area is 253400 ha, of which 135600 ha is the net sown area with 187 % cropping intensity. Net irrigated area is 126500 ha mainly through canal (83 %) and bore wells (16 %). Annual rainfall in the district is 1056 mm mainly received through SW monsoons. Soils largely are loamy sand (48 %) and clay loam (21 %). Rice (114200 ha) is the main crop of the district grown in *kharif* season, whereas wheat area is 102100 ha in the district. There are inconsistencies in the recommendations generated over time and their adoption patterns. On the whole, there has been very little data to allow independent verifications how the recommendations were accepted by farmers. It is important to bring out the real picture based on the ground data from the representative households in any given ecology rather than the selected pockets or selected farmers.

Methodology

In total 30 villages were randomly selected from the 2011 Census data on the basis of probability proportionate to size (PPS) method. Seven farmers were randomly selected from each village. The questionnaire for the Landscape Diagnostic Survey (LDS) was prepared in a mobile application based digital data collection format of Open Data Kit (ODK), which is capable of transferring real time data to the server or cloud. Out of total 210 households surveyed (2018), majority of them were marginal (65%) and small (24%) as per their landholding size. The GPS coordinates of the largest plot of the surveyed farmers in Chandauli have been depicted in Fig.1. The topography comprised medium land, upland and lowland to the tune of 73.0, 16.7 and 10.3%, respectively. As per soil texture, it was 81.9% medium, 4.4% heavy and 13.7% as light soil. About 91.7% of the surveyed farmers followed the rice-wheat cropping system whereas 8.3% opted for rice-fallow.

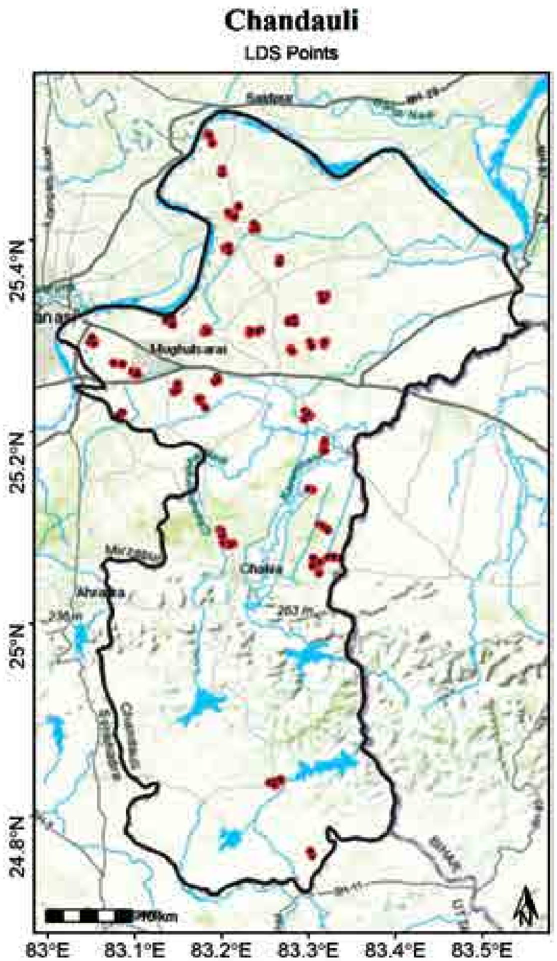


Fig. 1. GPS coordinates of the largest plot of the surveyed farmers in Chandauli.

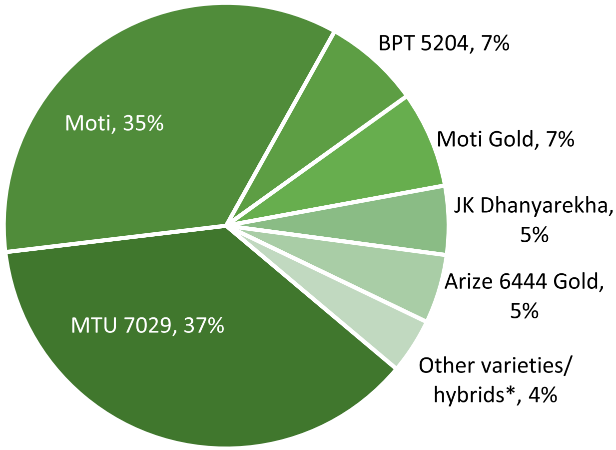
Blocks selected : Naugarh, Sakaldeeha, Niyamtabad, Chandauli, Chahaniya, Sahabganj, Chakiya and Sahabganj.

Villages covered : Baghi, Baharbani, Bakhraha, Ben, Bhadahi, Bhorsar, Bijaipurwa, Chuppepur, Dandaspur, Fatehpur, Guas, Hata, Hridayapur, Jafarpur, Jalalpur, Jamunipur, Jeewanpur, Jigna, Kailawar, Kesar, Khajur Gaon, Kundaliya, Lakshmangarh, Londha Mohammadpur, Madhuwawan, Mazadiha, Mohanpur, Naraina, Rauna, Sarauli, Shivpur, Singha and Wakhra (Fig. 1).

Results and Discussion

It is clearly evident from the data (Fig. 2) that 37, 35, 7, 7% HHs preferred MTU 7029, Moti, BPT5204, and Moti Gold. The dominance of MTU 7029 remains intact since its release in 1982. The degree of reliance on Moti which is in the upper range of MDRVs group is very high. Other varieties in the district were Arize 6444 Gold, Arize 6129, Chintu, Kaveri, Rajendra Shweta, Super Moti and Sampoorna, etc.

Among six most preferred varieties/hybrids, MTU 7029 yielded highest (5.1 tha^{-1}), however it was at par with BPT5204, Arize 6444 Gold and JK Dhanyarekha, but Moti (4.2 tha^{-1}) and Moti Gold (4.1 tha^{-1}) yielded lower (Fig.3).



*Other varieties/hybrids- Arize 6129, Chintu, Kaveri, Rajendra Shweta, Super Moti, Sampoorna

Fig. 2. Varietal spectrum of rice varieties/hybrids based on the data of surveyed farmers (N=210).

Grain yield of rice was higher but at par when it was transplanted timely between 01 to 15 July (4.8 tha^{-1}) or 16-31 July (4.7 tha^{-1}) and declined thereafter yielding 4.1 tha^{-1} when transplanted between 01-15 August and 3.8 tha^{-1} between 16-31 August) (Fig.4). Therefore, an early or optimal transplanting time is the most crucial factor to improve rice yields in Chandauli district of Uttar Pradesh. Similar results have

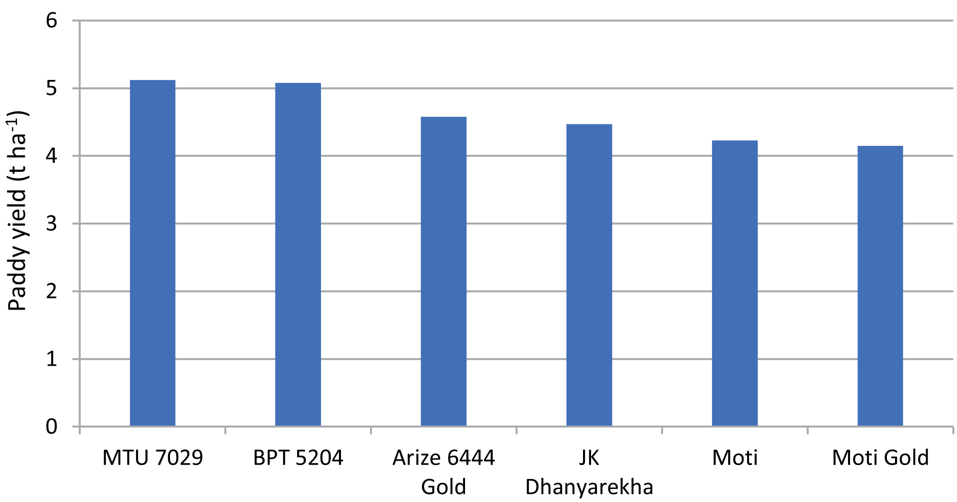


Fig. 3. Performance of most preferred rice varieties/hybrids by the surveyed farmers.

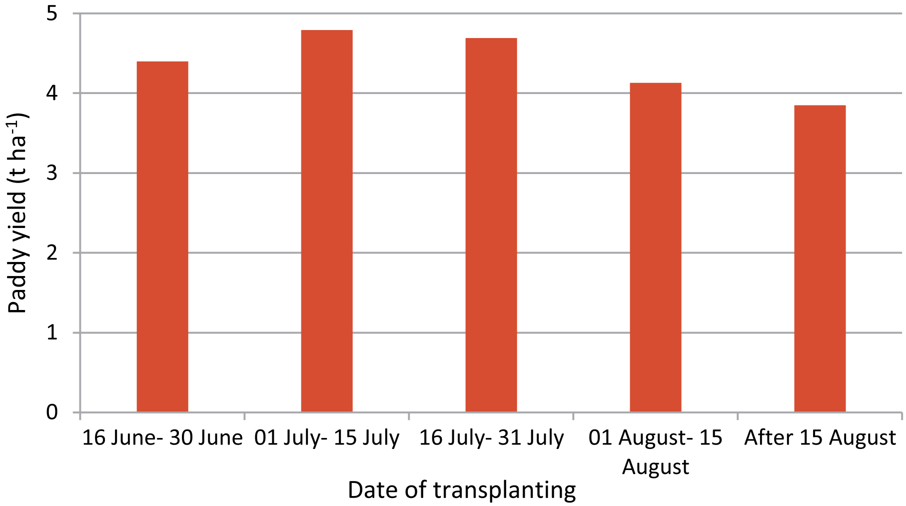


Fig. 4. Effect of time of transplanting on grain yield of rice varieties/hybrids (n=204).

been realized earlier also. Delayed transplanting is one of the most serious factor for lower rice yields in the district (Kushwaha, 2018).

A total of 193 and 11 HHs who grew improved rice varieties and hybrids, respectively harvested an average yield of 4.7 and 4.6 tha^{-1} with almost similar dose of N (119.8 & 125.9 $kgha^{-1}$), which was almost similar to the recommended one (120 $kgha^{-1}$) (Table 1). Application rate of P_2O_5 (58.8 & 46.7 $kgha^{-1}$) was lower for hybrids. Similarly, K_2O (22.5 $kgha^{-1}$ in varieties & 0.6 $kgha^{-1}$ in hybrids) was also lower in

Table 1. Nutrients and irrigation application pattern in varieties and hybrids in Chandauli.

Particulars	Improved varieties	Hybrids
Average yield (tha^{-1})	4.7	4.6
Average nitrogen application ($kgha^{-1}$)	119.8	125.9
Average phosphorus application ($kgha^{-1}$)	58.8	46.7
Average potash application ($kgha^{-1}$)	22.5	6
Average irrigations applied	4.4	4.4
Total households	193	11
% households applying nitrogen	100	100
% households applying phosphorus	99	100
% households applying potash	15	9
% of households applying irrigation	100	100

hybrids, however the irrigation level was similar (4.4 in varieties and hybrids as well) and it was applied by all the HHs. N, P_2O_5 and K_2O were applied by 100, 99 and 15% HHs in rice varieties, respectively and the corresponding figures in hybrids were 100, 100 and 9%. This indicates that timely transplanting and recommended dose of K application may be crucial for achieving higher yield particularly through hybrids.

Among five top most troublesome weeds infesting rice crop in Chandauli (Table 2), 83.3% HHs indicated *Echinochloa colona* as the most serious weed (rank 1) closely followed by weedy rice ranking 2 (61.7HHs), *Cyperus rotundus* (rank 3; 56.8% HHs), *Fimristylis* spp (rank 4; 54.9% HHs) and *Scirpus juncoides* (rank 5; 50.5%HHs). Among top five common weeds of transplanted rice crop were, *E. colona*, *C. rotundus*, Weedy rice, *S. juncoides and C. iria* as reported by 94.1, 87.2, 72.6, 71.6 and 63.7% HHs, respectively. This clearly indicates infestation of sedges along with grassy weeds and even weedy rice in the district, which warrants for effective and integrated weed management including relevant herbicides.

Table 2. Top five troublesome and common weeds in Chandauli.

Rank	Troublesome weeds	% HHs	Common weeds	% HHs
Weed 1	*Echinochloa colona*	83.3	*Echinochloa colona*	94.1
Weed 2	Weedy rice	61.7	*Cyperus rotundus*	87.2
Weed 3	*Cyperus rotundus*	56.8	Weedy rice	72.6
Weed 4	*Fimbristylis* spp.	54.9	*Scirpus juncoides*	71.6
Weed 5	*Scirpus juncoides*	50.5	*Cyperus iria*	63.7

Conclusion

Chandauli district with a medium land and upland ecology, where mainly dwells mainly marginal and small landholding farmers adopting rice-wheat cropping system exists. MTU7029, Moti and BPT 5204 were found to be more promising than hybrids. Grain yield of rice was higher when transplanted timely between 01 to 15 July or 16-31 July and declined thereafter. Therefore, an early or optimal transplanting is the most crucial factor to improve rice yields. Use of recommended dose of P_2O_5 and K_2O in hybrids and effective management of sedges and grassy weeds including weedy rice may help raise the existing rice productivity.

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3.53 Improve rice productivity through timely weed management and use of hybrids in Deoria district of Uttar Pradesh

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Introduction

Agro- climatically, Deoria district falls into Eastern Plain Zone (UP-9) with 26° 30' 16''N latitude and 83° 47' 13'' E longitude at an altitude of 68 m above MSL. Its geographical area is 249,400 ha, of which 190,200 ha is the net sown area with 163 % cropping intensity. Net irrigated area is 153,200 ha mainly through canal and bore wells. Annual rainfall in the district is 1,145 mm mainly received through SW monsoons. Rice (129,400 ha) is the main crop of the district grown in *kharif*, whereas wheat sown is 140,300 ha in *rabi* season. Landscape diagnostic survey (LDS) will help measure inventory of recommendations and use analytics to identify issues and set priorities.

Methodology

Villages (30) were randomly selected from the 2011 Census data on the basis of probability proportionate to size (PPS) method. Seven farmers were randomly selected from each village. They were interviewed regarding the prevailing agronomic practices for the rice crop which they have grown in *Kharif* 2018. The questionnaire for the Landscape Diagnostic Survey (LDS) was prepared in a mobile application based digital data collection format of Open Data Kit (ODK), which is capable of transferring real time data to the server or cloud. GPS coordinates of the largest plot of the surveyed farmers in Deoria are shown in Fig. 1. Out of total 210 households surveyed, majority of them were marginal (83 %) and small (12 %) as per their landholding size. As per drainage classification, the topography comprised medium land, lowland, upland and very lowland to the tune of 73.3, 16.4, 9.5 and 0.9 %, respectively. As per soil texture, it was 82.8 % medium and 17.2 % light soil. Almost all surveyed HHs (100 %) followed the rice-wheat cropping system.

Blocks covered : Baitalpur, Bankata, Barhaj, Bhagalpur, Baluhani, Bhatani, Bhatparrani, Deoria, Desai Deoria, Lar, Gauri Bazar, Patherdeva and Salempur.

Villages surveyed : Jaspar, Lagahra, Mathia, Pakauli, Bhanspar, Golautha, Jadupur, Barwoa, Koilgarha, Batulahi, Chhithi, Mathpalgir, Baitalpur, Amethi, Patharhat, Amawahiraman Dubey, Harimhuawa, Bikaram Bishunpura, Sahwa, Jogam, Churiya, Baraipar pandey, Siswa, Chauthia, Parasia bhagwati, Demura, Kanhav, Bhaglpur and Boliya Pandey (Fig. 1).

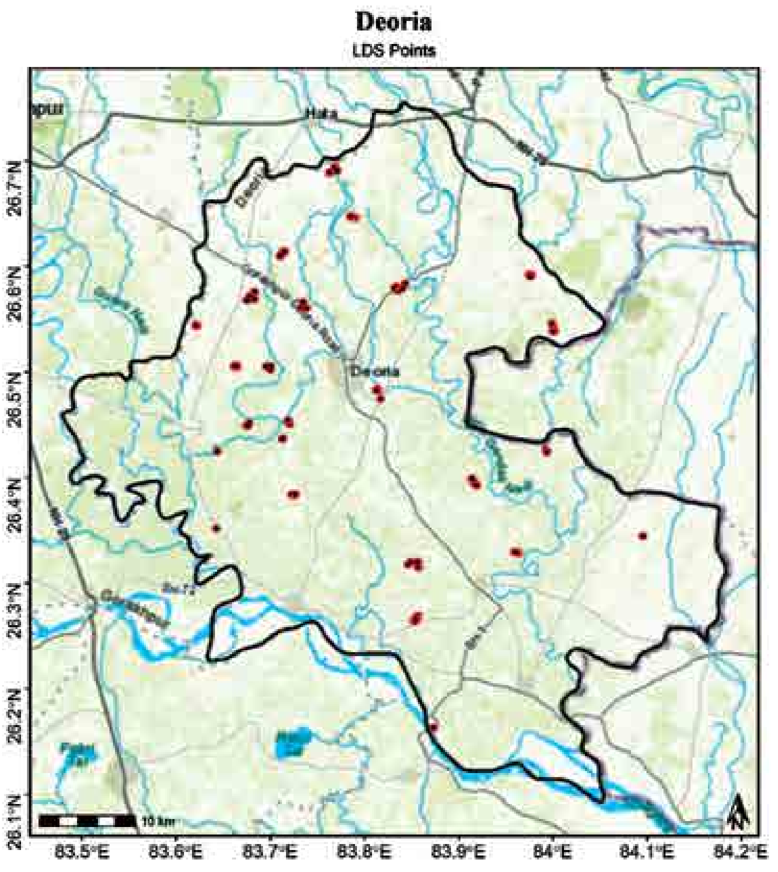
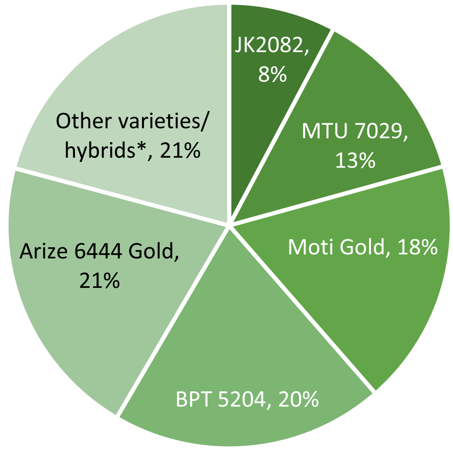


Fig. 1. GPS coordinates of the largest plot of the surveyed farmers in Deoria.

Results and Discussion

The data (Fig. 2) revealed that 21, 20, 18, 13, 8 and 21% HHs preferred Arize 6444Gold, BPT 5204, Moti Gold, MTU 7029, JK 2082 and other varieties/ hybrids, respectively. Other varieties grown by few HHs were Arize 6129, Pioneer 27P63, Sonam, Super, Moti, Pioneer 27P31, Moti, Prasanna and JK 4015.



*Other varieties/hybrids- Arize 6129, Pioneer 27P63, Sonam, Super Moti, Pioneer 27P31, Moti, Prasanna, JK 401

Fig. 2. Varietal spectrum of rice varieties/ hybrids based on the data of surveyed farmers in Deoria.

Among the five most preferred varieties/ hybrids, yield of MTU 7029 was the highest (4.5 tha^{-1}), however, at par with BPT 5204 (4.4 tha^{-1}) and Arize 6444 Gold (4.3 tha^{-1}) but of Moti Gold (4.2 tha^{-1}) and JK 2082 (3.2 tha^{-1}) was lower (Fig. 3).

Grain yield of rice was higher and at par when it was transplanted early i.e. till 15 June (4.3 tha^{-1}) or 16-30 June (4.5 tha^{-1}) but it declined significantly thereafter between 01 and 15 July (3.9 tha^{-1}) or 16-31 July (3.5 tha^{-1}) (Fig. 4). Therefore, an early transplanting is the key to improve rice yields in Deoria district of Uttar Pradesh. Similar results were realized earlier also. With MTU 7029 and BPT 5204 accounting for more than 33% adoptions by HHs, the stability and the high yield continues to be the source of satisfaction of farmers. The implication is that these varieties still

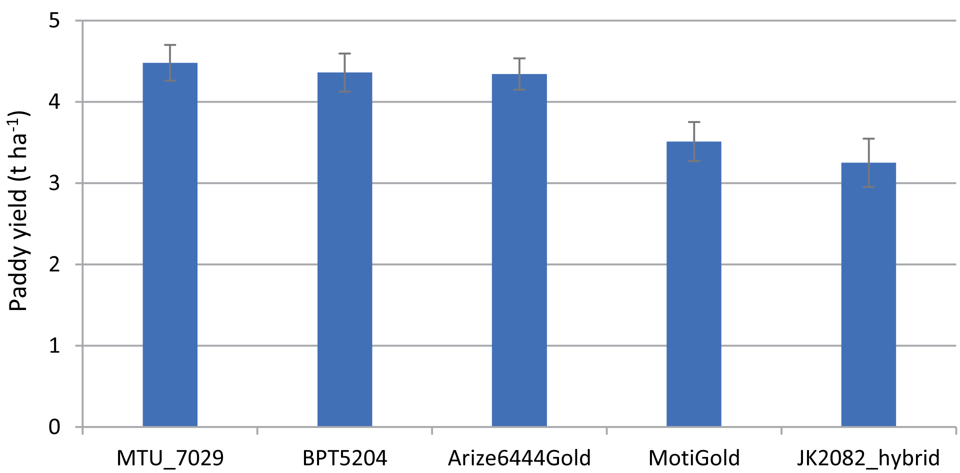


Fig. 3. Performance of most preferred rice varieties/hybrids by the surveyed farmers in Deoria.

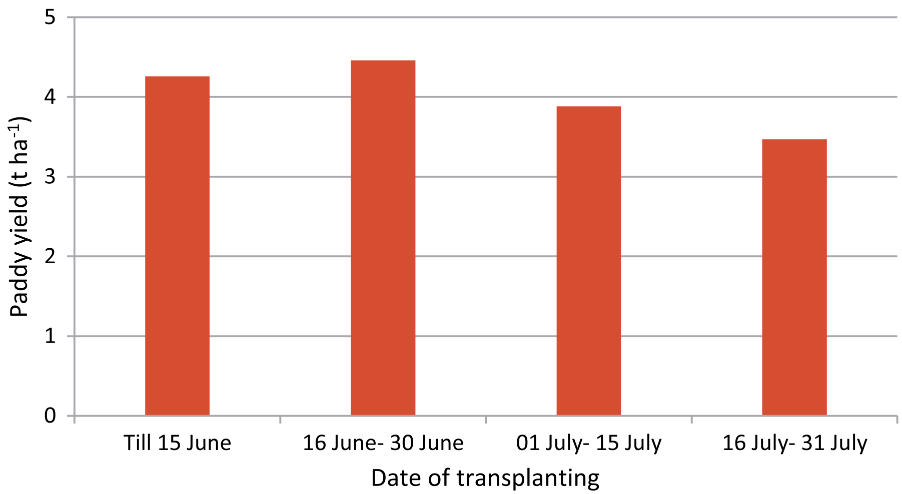


Fig. 4. Effect of time of transplanting on grain yield of rice varieties/hybrids (118) in Deoria.

have the scope to be in use till an alternative is made available. Whatever happens, it must be ensured that the new medium duration varieties are as good as these varieties both in the yield as well as quality. In the absence of an alternative, hybrids will occupy the space as is happening now. Early transplanting dates increase the physiological parameter and grain of rice as compared to late planting (Khalifa 2009; Farrel *et al*., 2013).

A total of 71 and 45 HHs growing improved rice varieties and hybrids, respectively, harvested an average yield of each equivalent to 3.9 tha^{-1} with almost similar dose of N (129.4 and 125.4 kgha^{-1}), which was marginally higher than that of

Table 1. Nutrients and irrigation application pattern in varieties and hybrids in Deoria.

Particulars	Improved varieties	Hybrids
Average yield (tha^{-1})	3.9	3.9
Average nitrogen application (kgha^{-1})	129.4	125.4
Average phosphorus application (kgha^{-1})	46.2	50.4
Average potash application (kgha^{-1})	20.9	25
Average irrigations applied	2.8	2.6
Total households	71	45
% households applying nitrogen	99	100
% households applying phosphorus	93	91
% households applying potash	54	22
% of households applying irrigation	100	100

the recommended one (120 kgha^{-1}) (Table 1). Application rate of P_2O_5 (46.2 and 50.4 kgha^{-1}) was also similar in both cases but 10-14 kgha^{-1} lower than the recommended. K_2O (20.9 and 25.0 kgha^{-1}) use was also almost similar in varieties and hybrids and it was lower than the recommended. However, the irrigation level was similar in both cases (2.8 in varieties and 2.6 in hybrids) and it was applied by all the HHs. N, P_2O_5 and K_2O were applied by 99, 93 and 54 % HHs in rice varieties, respectively, and the corresponding figures in hybrids were 100, 91 and 22 %. This indicated that an early transplanting and an enhanced dose of K application may be crucial for achieving a higher yield.

Among the five top most troublesome weeds infesting rice crop in Deoria (Table 2), 52.6 % HHs indicated *Echinochloa crus-galli as* the most serious weed

Table 2. Top five troublesome and common weeds in Deoria.

Rank	Troublesome weeds	% HHs	Common weeds	% HHs
Weed 1	*Echinochloa crus-galli*	52.6	*Echinochloa crus-galli*	59.5
Weed 2	*Dactyloctenium aegyptium*	38.8	*Dactyloctenium aegyptium*	43.9
Weed 3	*Paspalum distichum*	31.9	*Paspalum distichum*	32.7
Weed 4	*Eleusine indica*	25.0	*Eleusine indica*	28.4
Weed 5	*Cyperus iria*	24.1	*Cyperus iria*	27.6

(rank 1) closely followed by *Dactyloctenium aegyptium* ranking 2 (38.8HHs), *Paspalum distichum* (rank 3; 31.9 % HHs), *Eleusine indica* (rank 4; 25.0 % HHs) and *Cyperus iria* (rank 5; 24.4 % HHs). Among the top five common weeds of transplanted rice crop were also, *E crus-galli*, *Dactyloctenium aegyptium, Paspalum distichum, Eleusine indica* and *C. iria* as reported by 59.5, 43.9, 32.7, 28.4 and 27.6 % HHs, respectively. This clearly indicated more infestation of grassy weeds along with sedges in the district, which warrants for effective and integrated weed management including relevant herbicides.

Conclusion

The lack of timely irrigation encourages grasses and sedges. Owing to increased labour cost farmers should use herbicides to avoid early weed competition. Medium duration hybrids or long duration varieties provided higher paddy yields than short duration varieties. The paddy yield levels were higher when transplanting was done between 16 and 30 June.

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3.54 Timely transplanting and weed management are critical for breaking yield barriers in Ghazipur

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Introduction

Rice cultivation is mostly monsoon-rain dependent but is also done in regions with diesel-based assured irrigation. The irrigation is costly. The district of Ghazipur has 254,711 ha as cultivable land. The net irrigated area is 218,402 ha whereas the area under rice remains 82,300 ha and under wheat it is 80,500 ha. The popularity of some very old varieties showed that the priority of farmers for high yield has not changed. New varieties except hybrids released during last 20 years were not accepted as per the expectation. The issue is how to turn the natural resource of monsoon rains into an asset by getting higher yield from the same variety. In Ghazipur, rice-wheat cropping system is possible but large scale diversification is not possible. To narrow the yield gap we need to understand the factors which are game changer to improve the yield. There is also a need to understand how recommendations are accepted by farmers and how to set priorities. The Landscape Diagnostic Survey (LDS) was conducted to convert the adoption data into actionable points through data analytics.

Methodology

Villages (30) were randomly selected from the 2011 census data on the basis of probability proportionate to size (PPS) method. The villages and the farmers within villages were randomized (Fig. 1), and the sample properly reflects farmers' population in the district. Seven farmers were randomly selected from each village. They were interviewed regarding the prevailing agronomic practices for the rice crop. The randomization process makes it easy to assess the adoption pattern of different technologies in the district. The questionnaire for the landscape diagnostic survey was prepared in a mobile application based digital data collection format of Open Data Kit (ODK), which is capable of transferring real time data to the server or cloud.

Blocks covered : Bhawarkol, Deokali, Jakhania, Maniahari, Karanda, Kasimabad, Muhammadabad, Sadat, Saidpur and Jamania.

Village surveyed : Baberi, Barahpur, Barhat, Bhitari, Chakmubarakpur Janjirpur, Chochakpur, Dhitua, Domanpura, Fatehpur, Fauladpur, Jafarpur, Karamchandpur, Karbadeeh, Khempur, Madhiya, Mohammadpur, Mahepur, Manjha, Mehdipur, Mirpur Tirwah, Mubarakpur, Paharpur Kala, Saitapatti Uparwar, Shabazpur, Shahpur Sommerai, Shakkarpur, Sherpur Kala, Sokani, Surtapur Khas and Tamalpura (Fig. 1).

Results and Discussion

As observed from the LDS data, in district Ghazipur, 89% of farmers had farmlands that fell in the marginal and small category whereas only 1% farmer fell in the large category. A total of 70.6% of surveyed HHs owned land that fell in the medium category, 17.6% in upland, 10.7% lowland and 1.1% in very low land category. Soil texture was with medium soil 62%, heavy soil 23.5% and light soil 14.4%.The major dominant cropping system is rice-wheat (76.5%) followed by rice-fallow with 23% and rice-vegetables with 0.5% area.

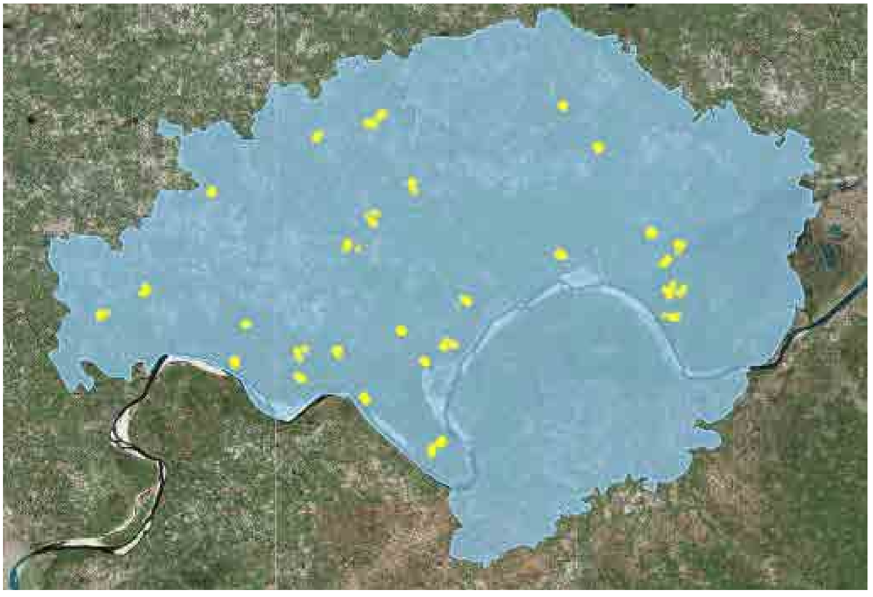
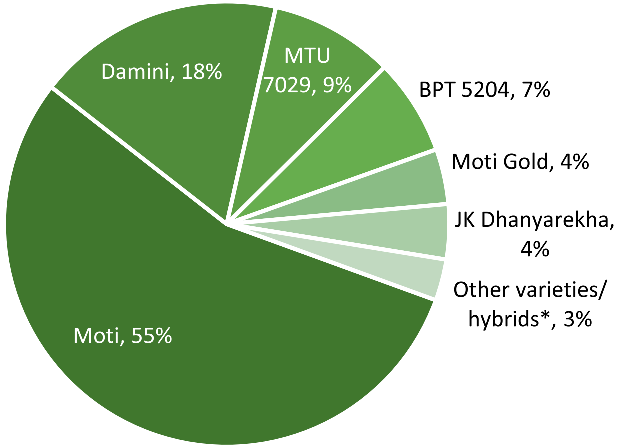


Fig. 1. GPS points of surveyed farms in Ghazipur.

The old variety Moti has survived for a long time with 55 % HHs, and has competed with MTU 7029 released in 1982 with 9 % HHs. Variety Damini has been adopted by 18 % HHs (Fig. 2).



*Other varieties/hybrids- Arize 6444, Chintu, Super Moti, Kaveri

Fig. 2. Varietal spectrum of the surveyed farmers in district Ghazipur.

The best performing variety in the district among the surveyed farmers is MTU 7029 with a yield of 4.19 t ha^{-1} (Fig. 3). Medium duration rice variety (MDRVs) like Moti is replacing MTU 7029. This variety also matures in 140 days plus. The assessment of progress towards new varieties suggested that there is a scope for replacing long duration rice varieties (LDRVs) with MDRVs varieties only if their yield levels are matching the yield levels of MTU 7029. So far there are no bright spots in new varieties and only varieties of 140 days plus will survive in this district. The varieties of such duration will survive only if transplanted early in the season. It implies that the proper time of transplanting is necessary for optimizing the duration and time of grain filling (Reddy and Narayana 1984; Gangwar and Ahamedi, 1990).

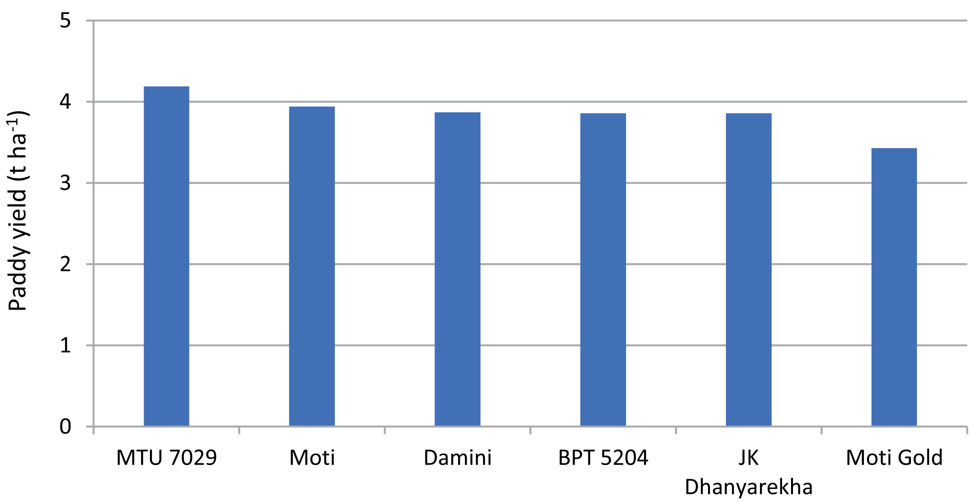


Fig. 3. Varietal performance of the surveyed farmers in district Ghazipur.

Looking at the data from date of transplanting, a slight increase in the grain yield was recorded across the date of transplanting (Fig. 4).

Evaluating average data on hybrid vs improved varieties, it is clear that there is just one entry of hybrid and in that too the NPK applied per hectare is meagre, moreover the number of irrigation applied is also one that affects grain yield of rice (Table 1).

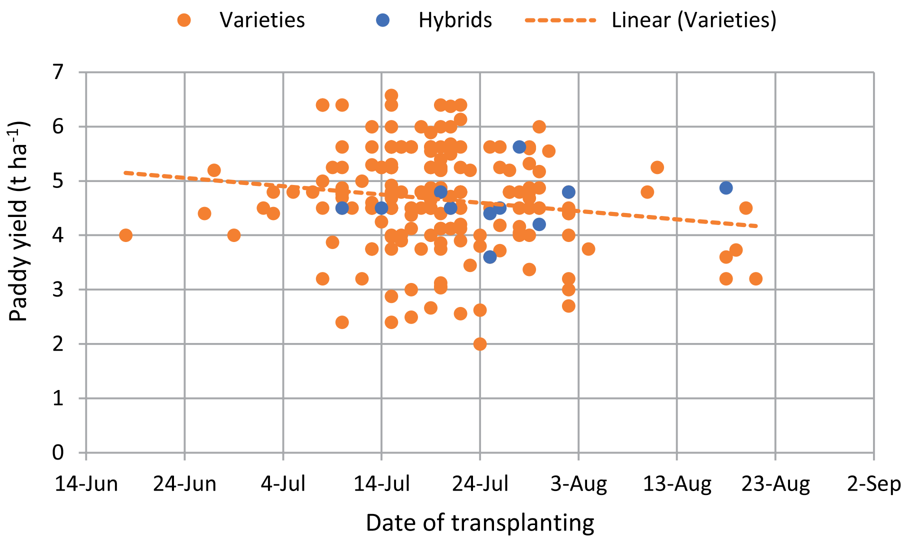


Fig. 4. Effect of dates of transplanting on paddy yield in district Ghazipur.

Table 1. Nutrients and irrigation application pattern in improved varieties and hybrids in Ghazipur.

Particulars	Improved varieties	Hybrids
Average yield (tha^{-1})	3.9	2.4
Average nitrogen application (kgha^{-1})	156.2	30.7
Average phosphorus application (kgha^{-1})	65	NA
Average potash application (kgha^{-1})	35.4	NA
Average irrigations applied	3.4	1
Total households	186	1
% households applying nitrogen	100	100
% households applying phosphorus	89	0
% households applying potash	16	0
% of households applying irrigation	100	100

The two major weeds present in the district as troublesome weeds are *Echinochloa crus-galli* and *Echinochloa colona* with a major dominance of 93.6 and 66 %, respectively (Table 2).

Table 2. Five most common and troublesome weeds and yield of paddy in Ghazipur district.

District	Troublesome weeds	% HHs	Common weeds	% HHs
Weed 1	*Echinochloa crus-galli*	93.6	*Echinochloa crus-galli*	95.2
Weed 2	*Echinochloa colona*	66.3	*Echinochloa colona*	88.8
Weed 3	*Cynadon dactylon*	50.3	*Cynadon dactylon*	69.5
Weed 4	*Cyperus rotundus*	41.7	*Cyperus rotundus*	63.6
Weed 5	*Caesulia axillaris*	31.0	*Dactyloctenium aegyptium*	59.9

Dominance of *Echinochloa crus-galli* it itself showed the need for timely weed management for the most competitive weed of rice which dominates only when yield has reached at more than 4.9 tha^{-1}. Some details are given by Rao *et al*. (2015).

Conclusion

The current varietal spectrum showed that the scope of short duration varieties is limited in this district. A separate analysis of time of transplanting suggested that transplanting should be completed by 25^{th} July. The fields dominated by *Echinochloa crus-galli* should be sprayed with herbicides while that with *Cynadon dactylon* need tillage in the summer.

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3.55 Adoption of hybrids with better irrigation and weed management are critical factors for enhancing productivity in Gorakhpur district

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Introduction

In Uttar Pradesh, rice is cultivated in 70 districts of which 7 districts fall in the highly productive, 29 in the medium productive, 26 in the medium low productive, and 3 under very low productive group. The average area of the high productivity comprises 10.4% of the total area with an average yield of 2.6 tha^{-1} whereas the average productivity of the state remains to be 2.0 tha^{-1}. The district of Gorakhpur falls in the medium low productive districts with an average productivity of 1.7 tha^{-1}. The major soil types of the district are sandy loam (70%), silty loam (20%) and clay (10%). Total area under paddy cultivation is 152,497 ha. To get an in depth insight of the reasons for low paddy yields and understanding the farmers' practices for further improvement, the Landscape Diagnostic Survey was planned by CSISA - KVK network.

Methodology

Villages (30) were randomly selected from the 2011 census data on the basis of probability proportionate to size (PPS) method. The villages and farmers within villages were randomized (Fig. 1) and the sample properly reflects farmers' population in the district. Seven farmers were randomly selected from each village. They were interviewed regarding the prevailing agronomic practices for the rice crop. The randomization process makes it easy to assess the adoption pattern of different technologies in the district.

The questionnaire for the landscape diagnostic survey was prepared in a mobile application based digital data collection format of Open Data Kit (ODK), which is capable of transferring real time data to the server or cloud.

Blocks covered : Bansgaon, Barhalganj, Belghat, Bhathat, Brahmpur, Chargawan, Gagha, Gola, Jangalkudia, Kauriram, Khajani, Pali, Piprainch, Sahjanwa, Sardarnagar and Uruwa.

Villages surveyed : Kasba Sangrampur, Matihani, Hatwa, Badhani, Bailo, Parmeshwarpur, Madaria, Jangal pakri, Mathia urf pachper, UskaJogi chak, Bharpahi, Bangaon, Jangalkudia, Jungle Rasoolpur 2, Tarang chak, Bhaisaha, Madariya, Mahopar, Sakari, Gonar, Jagdishpur, Bankati bujurga, Hariharpur, Bistoli khurd, Mahraji, Dhanaura khurd, Imlidiha Bujurg, Unolla , Majhiri, Matihania, Chhapra mansoor and Gagha (Fig. 1).

Results and Discussion

The data on size of landholding revealed that 58% of farmers were marginal, 24% small, 14% semi-medium, 3% medium and 1% large. On the basis of the data from the surveyed HHs, 73.5% of them had medium land, 23.2% upland and 3.3% lowland

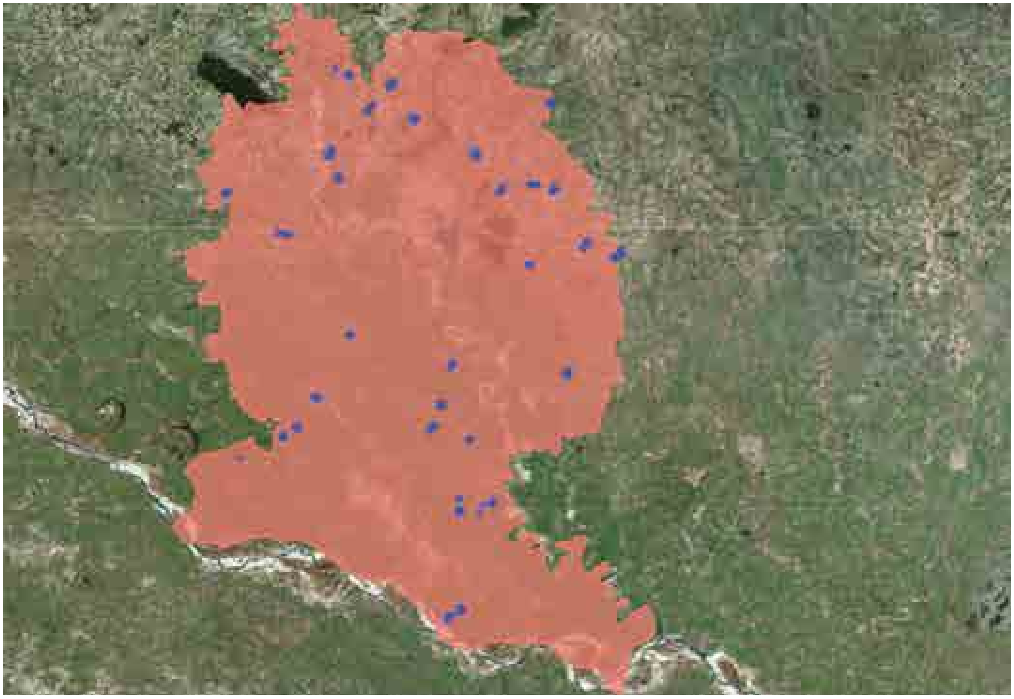
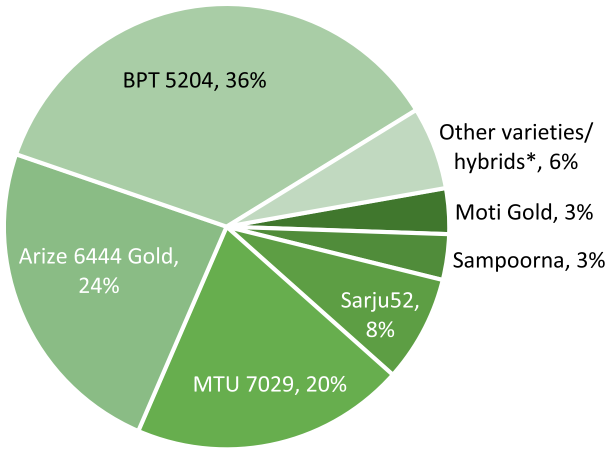


Fig. 1. GPS points of surveyed farms in Gorakhpur.

farms. The data on soil texture of surveyed HHs field revealed that 95% soils were medium textured, 3.9% light textured and 1.1% heavy textured soil. According to the data from the surveyed farmers 100% farmers responded to follow rice-wheat cropping system.

The data made it evident that 36% of farmer used BPT 5204, 24% used Arize 6444 Gold, and 20% used MTU7029 in their fields (Fig. 2).



*Other varieties/hybrids- Gorakhnath 509, Kaveri, Laxmi, Pusa Sugandh 5, Supreme Sona, US 382, Arize 6129, Komal

Fig. 2. Varietal spectrum of the surveyed farmers in district Gorakhpur.

The varietal performance revealed that Arize 6444 Gold was the best performer among all the varieties cultivated by the surveyed farmers with an average yield of 4.72 tha^{-1} followed by Sampoorna and MTU 7029 with 4.47 tha^{-1} and 4.32 tha^{-1}, respectively (Fig. 3).

There was not much synchrony seen in delay in transplanting and yield loss in the district (Table 1). BPT 5204 and MTU 7029, two good old varieties of 1980s

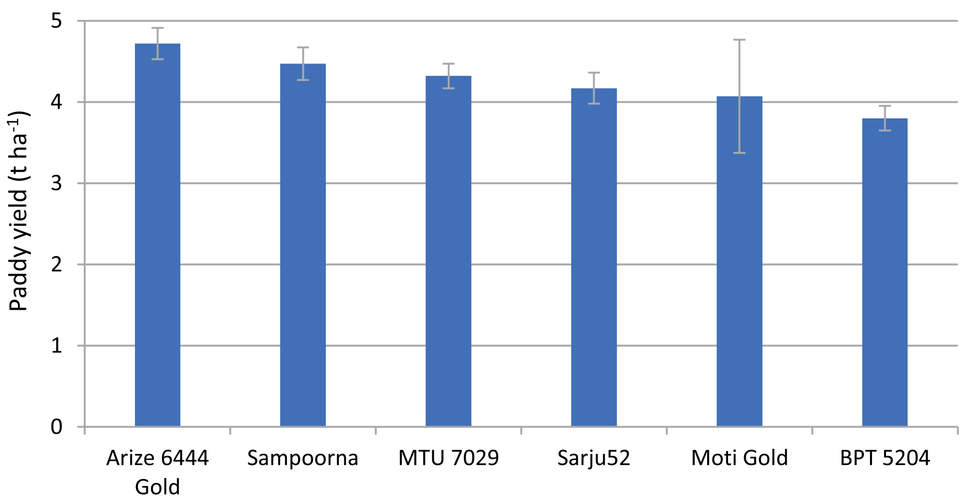


Fig. 3. Varietal performance of the surveyed farmers in district Gorakhpur.

Table 1. Effect of dates of transplanting on paddy yield in Gorakhpur district

Date of transplanting	Yield (tha^{-1})	sd	HHs
Till 15 Jun	4.22	1.1	9
16 Jun-30 Jun	4.19	1.2	150
01 Jul-15 Jul	4.54	0.9	19
16 Jul-31 Jul	4.50	0.6	3

have become a brand and are used for incorporating new genes in stress tolerant varieties. BPT 5204 is gaining interest of farmers because of its better quality. Hybrids like Azize 6444 Gold is a new entry, which is gaining more area at the cost of MTU 7029 and Sarju 52. Based on the yield data, the only answer for better adoption of new varieties is to match the paddy yield of current varieties with old varieties. It seems old varieties have done well and will probably keep the momentum in future. The best way to increase rice yields is to adopt better agronomy.

The average grain yield for hybrids was 4.72 tha^{-1}, which was almost 0.65 tha^{-1} higher than that recorded by improved varieties. The NPK and irrigation application was almost similar in both the cases (Table 2). Agronomic practices like weed management and irrigation are required to maintain a source and sink balance for high production growth of hybrids and medium duration varieties in the mid and late tiller stages of rice (Khalifa, 2009)

Table 2. Nutrients and irrigation application pattern in improved varieties and hybrids in Gorakhpur.

Particulars	Improved varieties	Hybrids
Average yield (tha^{-1})	4.1	4.7
Average nitrogen application ($kgha^{-1}$)	138.3	142.6
Average phosphorus application ($kgha^{-1}$)	52.8	54.9
Average potash application($kgha^{-1}$)	23.1	20.8
Average irrigations applied	3.1	3.4
Total households	133	46
% households applying nitrogen	100	100
% households applying phosphorus	79	87
% households applying potash	25	17
% of households applying irrigation	100	100

Weed management is important to attain better growth and the development in rice crop. *Echinochloa colona* and *E*. *crus-galli* are two most troublesome and common weeds in the district (Table 3).

Table 3. Five most common and troublesome weeds and yield of paddy in Gorakhpur district

Rank	Troublesome weeds	% HHs	Common weeds	% HHs
Weed 1	*Echinochloa crus-galli*	95.0	*Echinochloa crus-galli*	97.8
Weed 2	*Echinochloa colona*	69.6	*Echinochloa colona*	86.2
Weed 3	*Ischaemum rugosum*	51.9	*Ischaemum rugosum*	68.5
Weed 4	*Dactyloctenium aegyptium*	40.3	*Cyperus rotundus*	61.9
Weed 5	*Cyperus difformis*	23.7	*Scirpus juncoides*	61.9

Conclusion

Yield advantage along with shorter duration has led farmers to adopt hybrids in the district. However, still old varieties prevail in the district. The evidences have brought into focus factors like irrigation and weed management for breaking the yield barriers in rice.

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3.56 Technology adoption trends indicate limited adoption of new varieties : Focus should be on time of transplanting, irrigation and weed management in district Balia, Uttar Pradesh

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Introduction

District of Balia covers a total area of 299,265 ha of which the net sown area in *kharif*, *rabi* and *zaid* crops is 74.9, 83.3 and 3.0 %, respectively, of which 80 % area is irrigated. The district perennially gets affected by floods in almost 30 % of its area. It has many water bodies/ponds/river Ganga, Ghagara, Tounce and other small tributaries. In the landscape diagnostic survey (LDS), CSISA and KVKs tried covering the present production practices prevalent in the district. The LDS will monitor, evaluate, and learn the system that reflects the views and represents the interests of farmers while accepting or rejecting recommendations on rice crop in the district.

Methodology

Villages (30) were randomly selected from the 2011 census data based on probability proportionate to size (PPS) method. The villages and the farmers within villages were randomized (Fig. 1) and the sample properly reflects farmers' population in the district. Seven farmers were randomly selected from each village.

They were interviewed regarding the prevailing agronomic practices for the rice crop. The randomization process makes it easy to assess the adoption pattern of different technologies in the district.

The questionnaire for the landscape diagnostic survey was prepared in a mobile application based digital data collection format of Open Data Kit (ODK) which can transfer real time data to the server or cloud.

Blocks covered : Beruarwari, Garwar, Navanagar, Pandah, Chilkahar, Maniyar, Nagra, Siar, Rasra, Bansdih, Murli Chapra, Bairiya, Belhari, Hanumanganj and Sohaon.

Villages covered : Aaschoora, Abhaipur, Babhnouli, Bachchapur, Badsari, Bijlipur, Bishunpura, Chakra Kolhua, Chandravar Dougouli, Chandrar Walipur, Dugai, Duhi Bhasi, Ibrahimabad, Gonia Chapra, Haldi, Hasanpur urf Bichaipur, Jagooli Ramji, Jeera Basti, Khadsara, Kotwa, Maharajpur, Narayanpur Chitwanwara, Rampur, Shivrampur, Sisotar Diyara, Sohaon 1, Sohaon 2, Nauka Gaon and Narai (Fig. 1).

Results and Discussion

The surveyed data revealed that 56 % of farmers fell in the marginal category, 28 % in small, 12 % in semi medium, and 3 % in medium. No farmer represented the

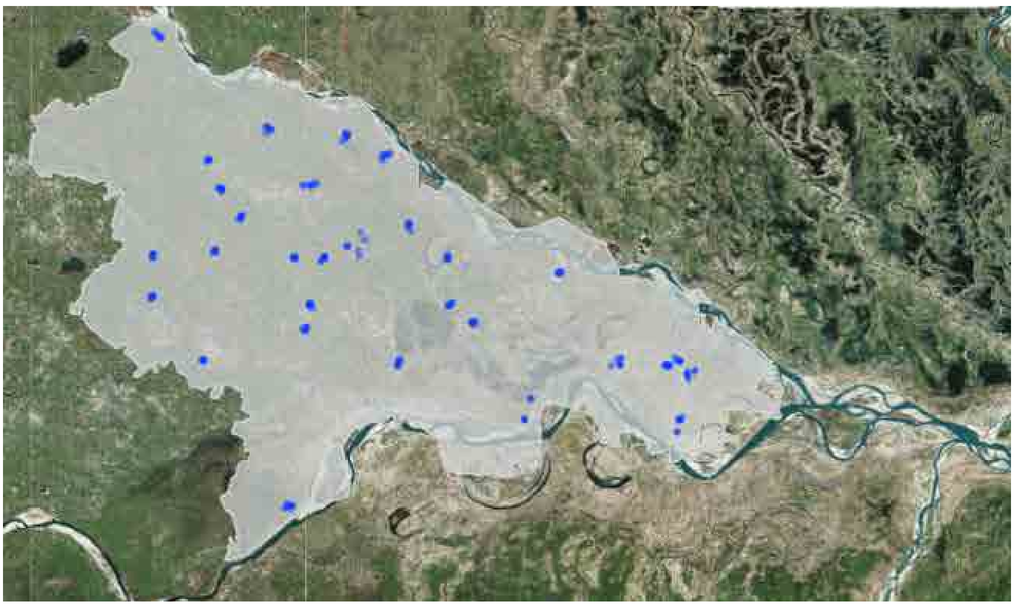
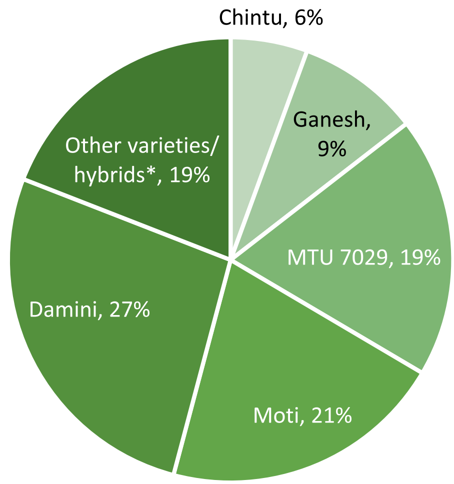


Fig. 1. GPS points of surveyed farms in Balia.

large category. The 74% HHs had medium land, 18% upland, 8% low land and 0.6% very low land. The major soil types found on the surveyed farms were 82% medium type of soil, 6.7% heavy soils and the rest was light soil. The dominant cropping system in the area is rice-wheat (79%). It was also evident from the LDS data that as high as 19% farmers had rice-fallow system.

The district showed a uniform distribution of Damini, Moti and MTU 7029 with 27%, 21% and 19%, respectively, in the area (Fig. 2). Varieties Ganesh and Chintu are were more specific to this district.



*Other Varieties/hybrids- Ajooba, Arize 6129, Dilkhush, Moti Gold, PHB71, Sampoorna, Sankar, Sarju52, Pioneer 27P31, ShriRam 505, Arize 6444 Gold, Pioneer 27P35

Fig. 2. Dominant varieties of the surveyed farmers in district Balia.

Based on LDS data, MTU 7029 outperformed all other varieties with paddy yield of 4.3 tha^{-1} (Fig. 3). The breakthrough came after the release of IR 64 (Khush and Virk, 2005), but new varieties are still not competing with old varieties. Similarly, in Bangladesh the highest-yielding variety is BR 11; released in 1980 but its yield potential still stays at the top (Hossian *et al.*, 2006).

Data showed that till date none of the varieties have surpassed the yield, stability, and area under MTU 7029.

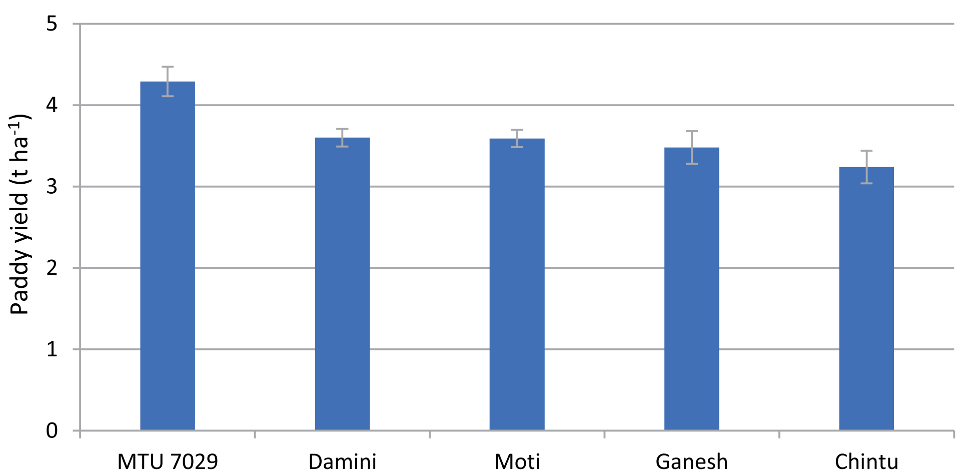


Fig. 3. Paddy yield of the surveyed farmers across five major varieties in district Balia.

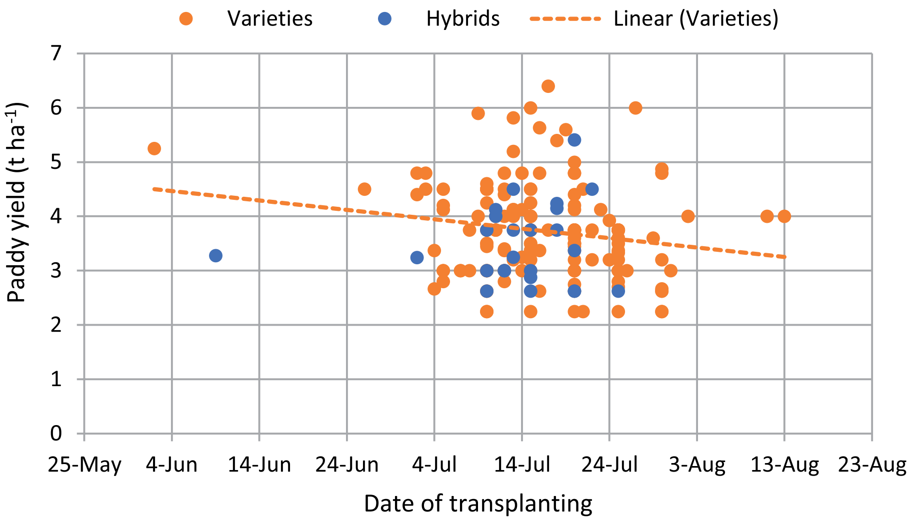


Fig. 4. Effect of dates of transplanting on paddy yield in district Balia.

A dip in yield was observed across the date of transplanting from July to August in varieties. There were not much hybrids placed here; moreover the transplanting ended in July itself so the trends were different (Fig. 4).

There was not much variation in the fertilizer inputs and irrigations applied in both hybrids and varieties (Table 1). Slightly high yield of varieties is because of

Table 1. Nutrients and irrigation application pattern in improved varieties and hybrids in Balia district.

Particulars	Improved varieties	Hybrids
Average yield (tha^{-1})	3.7	3.5
Average nitrogen application ($kgha^{-1}$)	141.6	143.0
Average phosphorus application ($kgha^{-1}$)	58.8	59.6
Average potash application ($kgha^{-1}$)	38.7	44.1
Average irrigations applied	4.8	5.3
Total households	154	25
% households applying nitrogen	100	100
% households applying phosphorus	96	100
% households applying potash	52	48
% of households applying irrigation	100	100

their longer duration than the hybrids. The efficiency of nutrients seemed low and it should be increased through agronomic interventions (Buresh *et al.,* 2008).

Echinochloa colona and *Cyperus rotundus* were two most troublesome as well as common weeds infesting rice crop in Balia district (Table 2).

Table 2. Five most common and troublesome weeds as per HHs in Balia district.

Rank	Troublesome weeds	% HHs	Common weeds	% HHs
Weed 1	*Echinochloa colona*	71.7	*Echinochloa colona*	75.0
Weed 2	*Cyperus rotundus*	63.3	*Cyperus rotundus*	71.1
Weed 3	*Echinochloa crus-galli*	40.6	*Echinochloa crus-galli*	66.7
Weed 4	*Dactyloctenium aegyptium*	30.0	*Dactyloctenium aegyptium*	56.7
Weed 5	*Fimbristylis* spp.	27.2	*Cyperus iria*	45.0

Conclusion

Evidence of prevalence of old varieties and differentiated adoption patterns of transplanting time and other agronomic practices guide us to reset the priorities to demand by the farmers rather than the supply based on top-down approach of varieties or even fertilizer. The emphasis should be on early transplanting and weed management.

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3.57 Weed and irrigation management are key variables for improving paddy yield in Kushinagar district of Uttar Pradesh

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Introduction

Kushinagar district of Uttar Pradesh falls into North Eastern Plain Zone (B1-3) with 26° 30’ 16’’N latitude and 83°47’ 13’’E longitude at an altitude of 75 m above MSL. Its geographical area is 291,500 ha, of which 224,900 ha is the net sown area with 153 % cropping intensity. Net irrigated area is 184,500 ha mainly through borewells (56.8 %), canals (29.5 %) and open wells (13.5 %). Annual rainfall in the district is 1,145 mm mainly received through SW monsoons. In the district, rice (122,500 ha) is the main crop in *kharif*, and wheat area is 114,300 ha.

Methodology

Villages (30) were randomly selected from the 2011 Census data based on probability proportionate to size (PPS) method. Seven farmers were randomly selected from each village. They were interviewed regarding the prevailing agronomic practices for the rice crop they have grown in *kharif* 2018. The questionnaire for the Landscape Diagnostic Survey (LDS) was prepared in a mobile application based digital data collection format of Open Data Kit (ODK), which can transfer real time data to the server or cloud. GPS coordinates of the largest plot of the surveyed farmers in Kushinagar are shown in Fig. 1. Out of total 210 households surveyed, majority of them were marginal (73 %) and small (21 %) as per their landholding size. Others were semi-medium (4 %) and medium (2 %). As per drainage classification, the topography comprised medium land, upland, lowland and very lowland to the

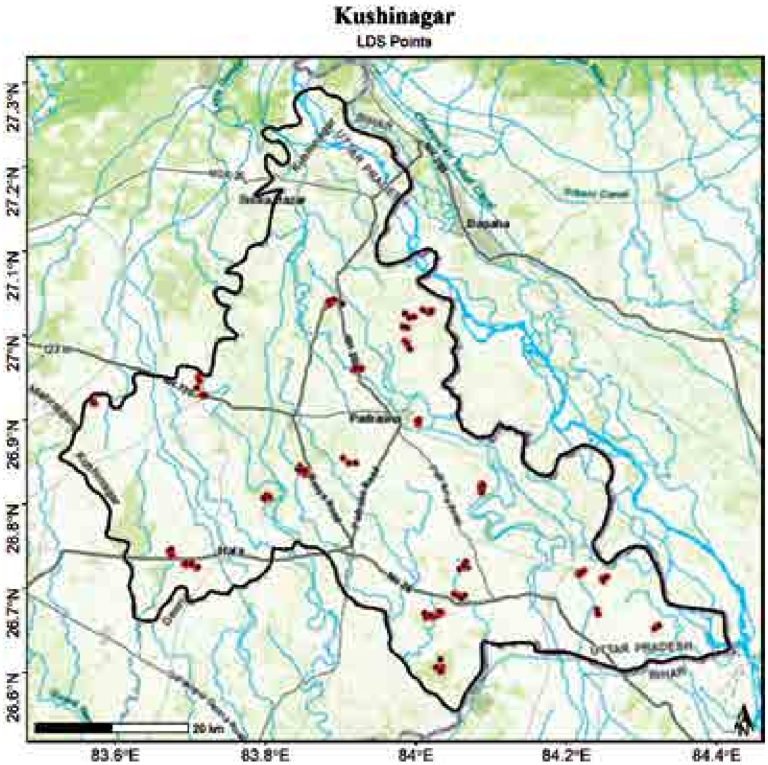


Fig. 1. GPS coordinates of the largest plot of the surveyed farmers in Kushinagar.

tune of 67.1, 17.9, 13.6 and 1.4 %, respectively. As per soil texture, it was 66.4 % medium, 12.1 % heavy and 21.4 % as light soil.

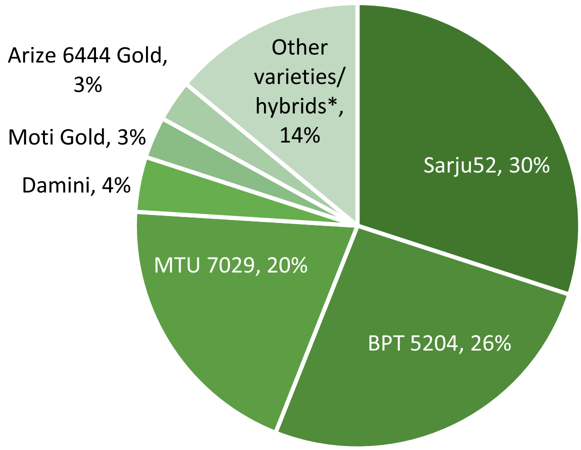
Blocks covered : Dudhahi, Fazilnagar, Hata, Kaptanganj, Khada, Motichak, Nebua Naurangiya, Padrauna, Ramkola, Sewarhi, Sukrauli, Tamkuhiraj and Vishunpura.

Villages surveyed : Basdila, Basdila Durjan, Bandaliganj, Aadharpatti chilgoda, Captanganj, Champapur, Belwa, Chirgoda, Chirgora khas, Jungal shukhapur, Hashanganj, Dhanwji khurd, Madhopur, Dondiya, Kataibharpurwa, Jungal Lala chhapra, Maghi Kothiwal, Siktya, Nada Mahartha, Pipara Mishra, Purnaha Mishra, Parsaun, Pakadihar Purab patti, Patkhuli, Naurangia, Pipra titla, Rampur maharath, Thari bhar, Shyam patti, Tekuatar, Sarpatahi khurd, Sondiya and Shahpur (Fig. 1).

Results and Discussion

The data (Fig. 2) showed that 30, 26, 20 and 18 % HHs preferred Sarju 52, BPT 5204, MTU 7029 and other varieties/hybrids, respectively. Other varieties getting popularity in the district are Damini (4 % HHs), Moti Gold (3 % HHs) and Arize 6444 Gold (3 % HHs). Data reflected the combination of 76 % old varieties (released before 1990) from public sector institutions and rest from the private sector.

Among six most preferred varieties/hybrids, Arize 6444 Gold (4.9 tha^{-1}) and MTU 7029 (4.7 tha^{-1}) yielded higher than Damini, BPT 5204, Moti Gold and Sarju 52 (Fig.3). Since new varieties are not adding any value, the improvement in rice productivity will depend on agronomic management and optimization of the cropping system.



*Other varieties/hybrids- Ankur, Arize 6129, Chandan, Heena, Jaya, K9090, Kaveri, Komal, Moti, Prasanna, Rukmani, Sankar, Sonali, Tahalka, Super Moti, Diamond

Fig. 2. Varietal spectrum of rice varieties/hybrids based on the data of surveyed farmers in Kushinagar.

Grain yield across rice variety/hybrids was bit higher when transplanted between 01 and 31 July (4.2 tha^{-1}) compared to time of transplanting till 15 June (4.1 tha^{-1}) or between 16 and 30 June (3.9 tha^{-1}) (Fig. 4). The monsoon rain is important for

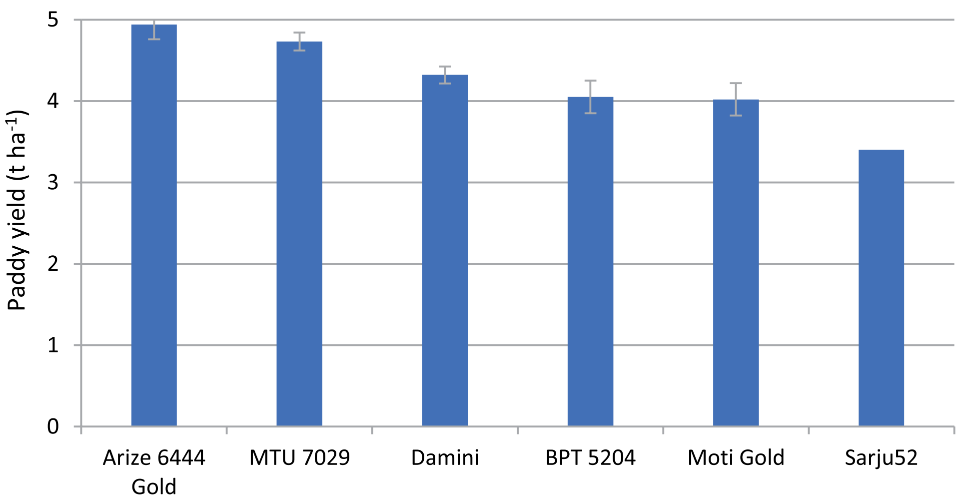


Fig. 3. Performance of most preferred rice varieties/hybrids by the surveyed farmers in Kushinagar.

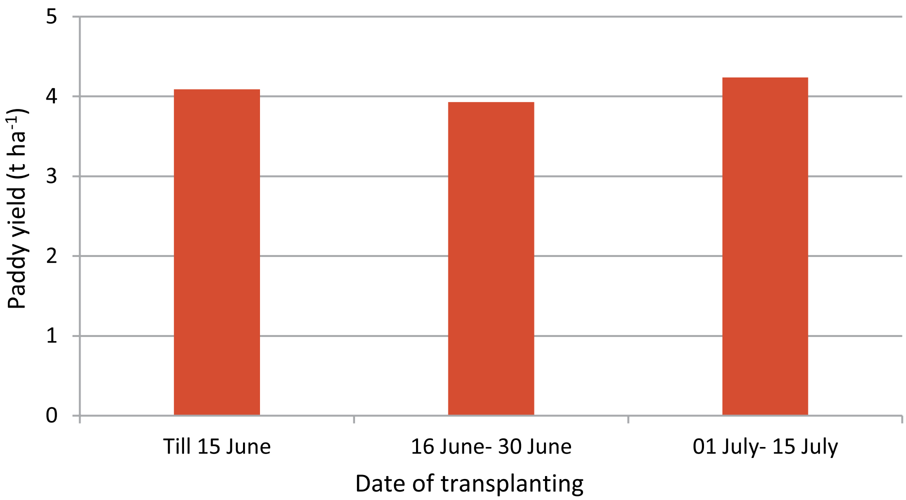


Fig. 4. Effect of time of transplanting on grain yield of rice varieties/hybrids in Kushinagar.

this region (Subash and Gangwar, 2014). Delayed monsoon during last few years affected the yield from early transplanting.

Improved varieties and hybrids had same level of N application (Table 1). Use of P_2O_5 in hybrids (68.6 kgha^{-1}) was higher than varieties (46.6 kgha^{-1}). K_2O use at 23.4 kgha^{-1} in varieties and 29.6 kgha^{-1} in hybrids was lower than recommended dose. However, the irrigation level was similar in both cases (2.36 in varieties and 2.45 in hybrids) and it was applied by all the HHs. N, P_2O_5 and K_2O were applied by

Table 1. Nutrients and irrigation application pattern in varieties and hybrids in Kushinagar

Particulars	Improved varieties	Hybrids
Average yield (tha^{-1})	3.9	4.6
Average nitrogen application (kgha^{-1})	121.2	125.2
Average phosphorus application (kgha^{-1})	46.6	68.6
Average potash application (kgha^{-1})	23.4	29.6
Average irrigations applied	2.36	2.45
Total households	126	11
% households applying nitrogen	100	100
% households applying phosphorus	87	91
% households applying potash	67	55
% of households applying irrigation	100	100

100, 87 and 67 % HHs in rice varieties, respectively, and the corresponding figures in hybrids were 100, 91 and 55 %.

Among the five top most troublesome weeds infesting rice crop in Kushinagar (Table 2), 62 % HHs indicated *Cynadon dactylon* as the most serious weed (rank 1) closely followed by *Echinochloa crus-galli* (ranking 2; 60 % HHs), *Cyperus rotundus* (rank 3; 50 % HHs), *Echinochloa colona* (rank 4; 45 % HHs) and *Dactyloctenium aegyptium* (rank 5; 29 % HHs). Among the top five common weeds of transplanted rice crop were, *C. dactylon*, *E. crus-galli, E. colona, C. rotundus* and *Dactyloctenium aegyptium* as reported by 70.21, 68.09, 57.45, 54.61 and 41.13 % HHs, respectively. This indicated infestation of grassy weeds along with sedges in the district, which warrants effective

Table 2. Top five troublesome and common weeds in Kushinagar

Rank	Troublesome weeds	% HHs	Common weeds	% HHs
Weed 1	*Cynadon dactylon*	61.7	*Cynadon dactylon*	70.2
Weed 2	*Echinochloa crus-galli*	60.3	*Echinochloa crus-galli*	68.1
Weed 3	*Cyperus rotundus*	50.3	*Echinochloa colona*	57.4
Weed 4	*Echinochloa colona*	44.7	*Cyperus rotundus*	54.6
Weed 5	*Dactyloctenium aegyptium*	29.1	*Dactyloctenium aegyptium*	41.1

and integrated weed management including relevant herbicides. With rainfall of 1,200 mm and bore-well based irrigation, the yield levels are very low (Bhattarai and Narayanamoorthy, 2003). The most dominating weed like *Cynodon* is superior in drought resistance, dehydration avoidance, deep rooting and wear stress tolerance, but have poor shade adaptation (Beard and Sifers, 1997). Therefore, irrigation and *Cynodon dactylon* management should be the focus of attention in this district.

Conclusion

A medium land ecology inhabited by marginal and small landholders HHs (94 %) adopting rice-wheat cropping system (96 %) are the key features of Kushinagar. Arize 6444 Gold and MTU7029 were favoured by farmers. Timely transplanting, access to low cost irrigation and integrated weed management may enhance rice productivity in the district.

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3.58 Use of traditional varieties and delayed transplanting are the two most important reasons for lower paddy yields in Maharajganj district of Uttar Pradesh

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Introduction

The district of Maharajganj falls in North Eastern Plain Zone. The annual rainfall received is between 1,000 and 1,200 mm. Cropping intensity is 142%. Irrigation is through canals and tube-wells. Frequent floods are seen in the district during *kharif*. Mostly it is rice based cropping system. Soil is mostly very fertile alluvial. Rice crop is the foundation for a successful and sustainable cropping system in this district. The uncertain and variable monsoon does not allow farmers to make best use of enough rainfall that supports the rice crop. There are evidences of differentiated adoption pattern of technologies with very high paddy yields that matches in some blocks. There is a need to set priorities based on demand of farmers rather than supply based on top-down approach. The landscape diagnostic survey was conducted to set priorities for research and extension in this district.

Methodology

Villages (30) were randomly selected from the 2011 census data based on probability proportionate to size (PPS) method. The villages and farmers within villages were randomized (Fig. 1) and the sample properly reflects farmers' population in the district. Seven farmers were randomly selected from each village. They were interviewed regarding the prevailing agronomic practices for the rice crop. The

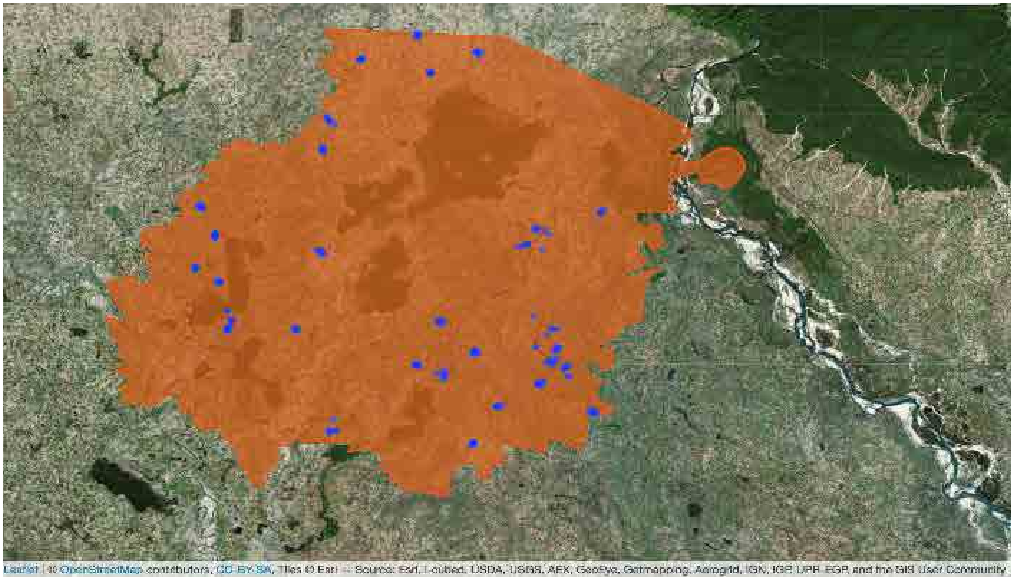


Fig. 1. Village-wise representation of surveyed area in Maharajganj.

randomization process makes it easy to assess the adoption pattern of different technologies in the district.

The questionnaire for landscape diagnostic survey was prepared in a mobile application based digital data collection format of Open Data Kit (ODK), which can transfer real time data to the server or cloud.

Blocks covered : Brijmanganj, Ghuguli, Lakshmipur, Maharajganj, Mithaura, Nautanwa, Nichaul, Paniyara, Partawal and Pharenda.

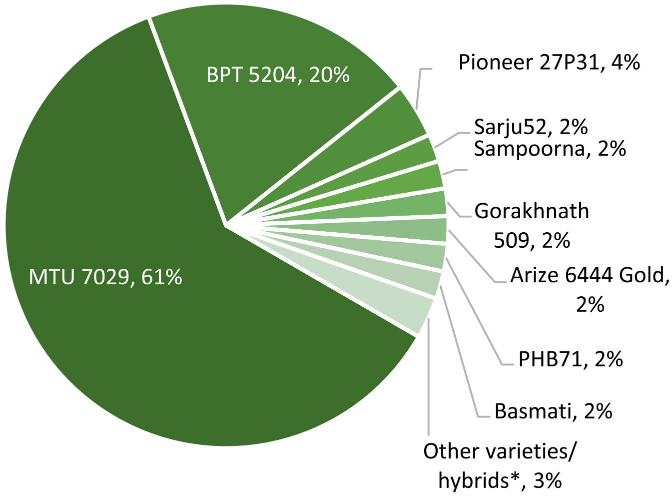
Villages surveyed : Banjarha Sonbarsa, Barwalia, Sahajanwa, Rajdhani, Gopalapur, Biskhop, Sisawa Raja, Laxmipur Deurwa, Natwa, Durgapur, Mahuari, Brahmpur, Dubaulia, Pharenda Khurd, Senduria, Jogiya, Ganeshpur, Mithaura, Ahirauli, Baragadva, sonbarsa, Parsa Khurd, MansoorGanj, Parsa Malik, Basahia bugurg, Khamhaura, Bhagwanpur, Visvanathpur and Pokhar Bindha (Fig. 1).

Results and Discussion

There were 76 % marginal, 18 % small, 4 % medium and 2 % semi-medium farmers based on the surveyed data. Data from drainage class showed that 81 % respondents had medium land, 13.5 % upland, 3 % very low land and 2.5 % lowland. Data based on soil texture revealed that 92 % of plots were with medium soil type, whereas, 7 % with heavy and rest 1 % with light soil type. The dominant cropping system was rice-wheat with 100% respondents.

Data on varietal spectrum showed that 61% farmers cultivated the high yielding variety MTU 7029 followed by 20% BPT 5204 (Fig. 2).

One hybrid (PHB 71) and one variety (MTU 7029 has substantial yield advantage with an average grain yield of 5.7 tha^{-1} and 5.2 tha^{-1} in that order. As expected basmati was the poorest performer with paddy yield of 3.67 tha^{-1} (Fig. 3).



*Other varieties/hybrids- Komal, Moti Gold, Nano, Prasanna, Pioneer 27P63, Poonam, Sabour Sampann

Fig. 2. Varietal spectrum of the surveyed farmers in district Maharajganj.

There was yield decline in varieties with respect to delay in transplanting date after June 15th (Fig. 4). The problem of late transplanting of rice comes on top of perennial problem of uncertain and variable monsoon rains. The additional

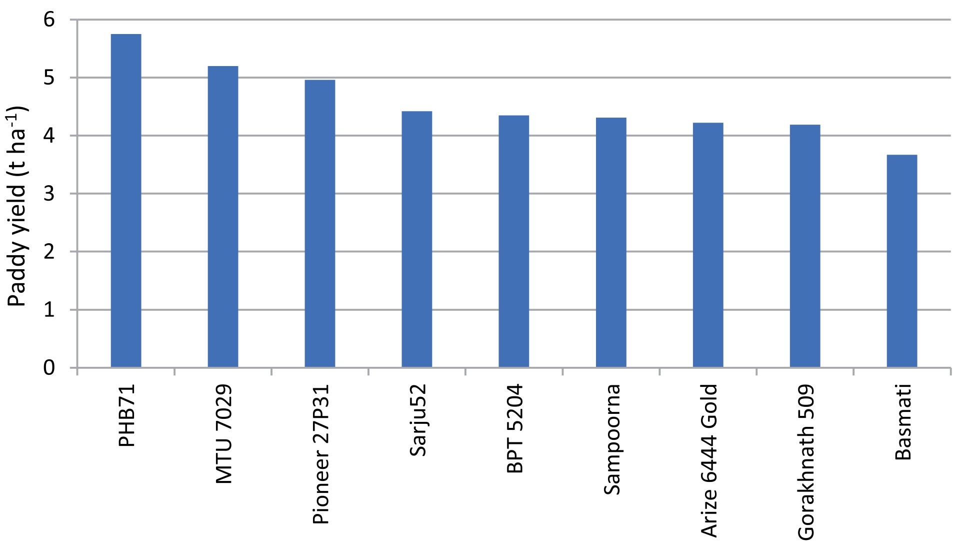


Fig. 3. Varietal performance of the surveyed farmers in district Maharajganj.

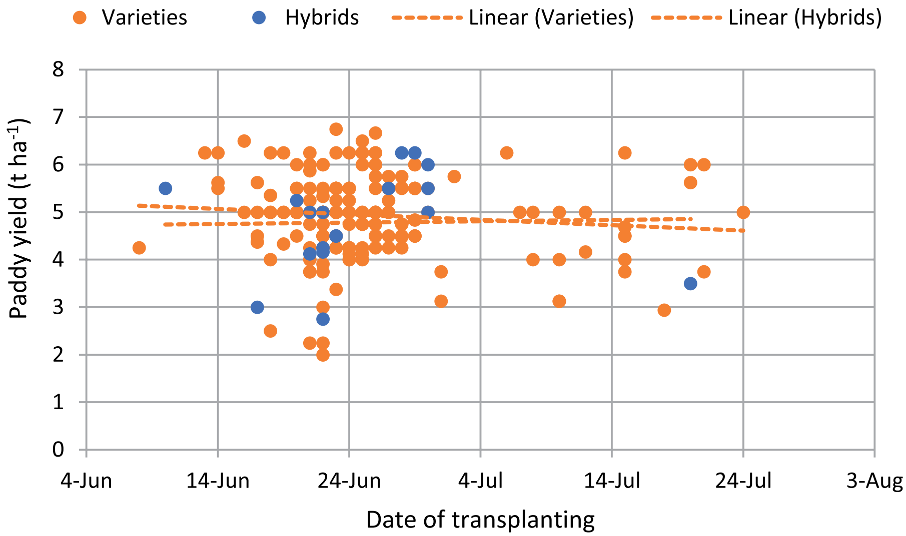


Fig. 4. Effect of dates of transplanting on paddy yield in district Maharajganj.

combination of timely transplanting and use of hybrids will manage the growth cycle well. How much compensation is possible may depend on factor like introduction of hybrids of shorter or medium duration (Liu *et al.*, 2017).

The grain yield, NPK and irrigation application for both hybrid and improved varieties were at par (Table 1). There was no evidence for frequent debates that hybrids need more fertiliser use than varieties.

Table 1. Nutrients and irrigation application pattern in improved varieties and hybrids in Maharajganj

Particulars	Hybrid	Improved varieties
Average yield (tha^{-1})	4.8	4.9
Average nitrogen application (kgha^{-1})	130.2	149.9
Average phosphorus application (kgha^{-1})	58.6	58.7
Average potash application (kgha^{-1})	30.0	22.9
Average irrigations applied	3.0	2.9
Total households	18	178
% households applying nitrogen	100	100
% households applying phosphorus	78	89
% households applying potash	17	26
% of households applying irrigation	100	100

The two most common weeds were *Echinochloa crus-galli* with 91% and *Echinochloa colona* with 84.5% household responding for them. The most troublesome weeds were *Echinochloa crus-galli* and *Echinochloa colona* as per response of 86.5% and 62.5% HHS, respectively (Table 2). In conventional tilled paddy field, puddling in 10- 15 cm standing water is effective to control *Echinochloa* sp. and other hygrophytic weed species (Shibayama, 2001). Such weed spectrum can be effectively managed by the use of herbicides available in the market.

Table 2. Five most common and troublesome weeds and yield of paddy in Maharajganj district

Rank	Common weeds	% HHS	Troublesome weeds	% HHs
Weed 1	*Echinochloa crus-galli*	91.0	*Echinochloa crus-galli*	86.5
Weed 2	*Echinochloa colona*	84.5	*Echinochloa colona*	62.5
Weed 3	*Cyperus rotundus*	68.0	*Cyperus rotundus*	37.0
Weed 4	*Scirpus juncoides*	60.5	*Scirpus juncoides*	36.5
Weed 5	*Fimbristylis* spp.	48.5	*Fimbristylis* spp.	32.0

Conclusion

As per our survey, Maharajganj district is dominated by marginal and small farmers and comprise mostly medium lands. MTU 7029 is grown by most farmers (61%) but hybrids have ample scope in the district with an edge in yield. Delayed planting more particularly in varieties and weed infestation are the other two reasons for lower yield, which need immediate attention of the extension agencies to educate the growers properly.

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3.59 Promotion of hybrids, timely transplanting of rice varieties and precise agronomic management are needed to raise rice productivity in Mau district of Uttar Pradesh

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Introduction

The district Mau falls in Eastern Plain Agro-climatic zone receiving an average annual rainfall of 800 mm. The soil type is alluvial with varying percentage of silt and clay and the cropping intensity is 138 %. A large area in the district has saline/ alkaline soil under water logged condition and *diara*. The district suffers major constraints of flood and water logging in many areas. Almost 78 % of the area is irrigated but still the crop productivity is low. There is a need to devote good amount of time in evaluating and identifying most important factors to bridge the yield gaps, check the effect of leading technologies on yield of crops and cropping system and putting more efforts of the emerging research and extension agenda. The landscape diagnostic survey (LDS) was conducted to understand this.

Methodology

Villages (30) were randomly selected from the 2011 census data based on probability proportionate to size (PPS) method. The villages and the farmers within villages were randomized (Fig. 1) and the sample properly reflects farmers'

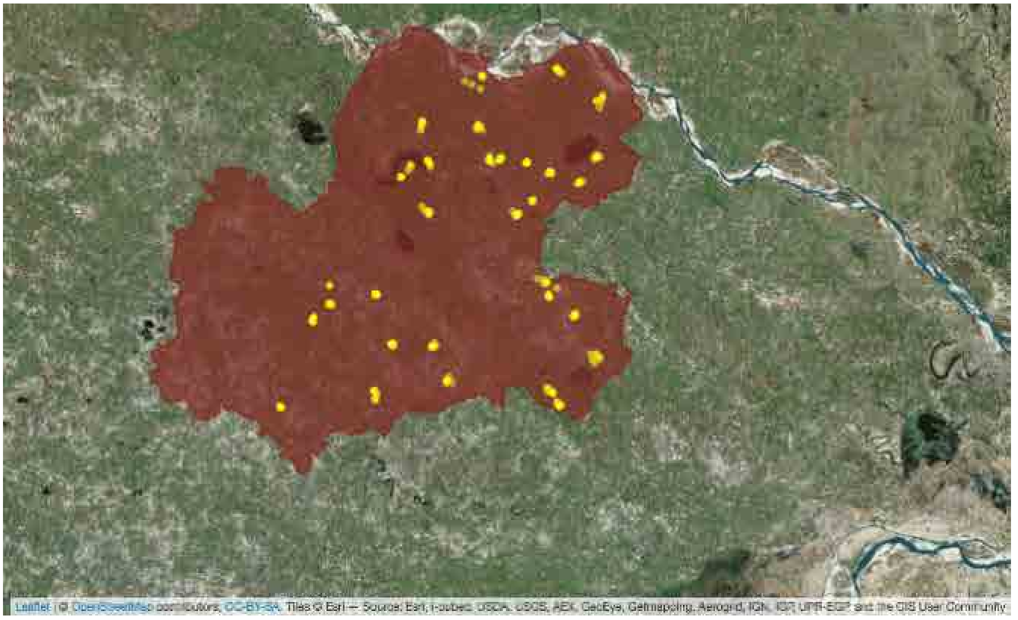


Fig. 1. Village wise representation of surveyed area in Mau.

population in the district. Seven farmers were randomly selected from each village. They were interviewed regarding the prevailing agronomic practices for the rice crop. The randomization process makes it easy to assess the adoption pattern of different technologies in the district.

The questionnaire for the landscape diagnostic survey was prepared in a mobile application based digital data collection format of Open Data Kit (ODK), which is capable of transferring real time data to the server or cloud.

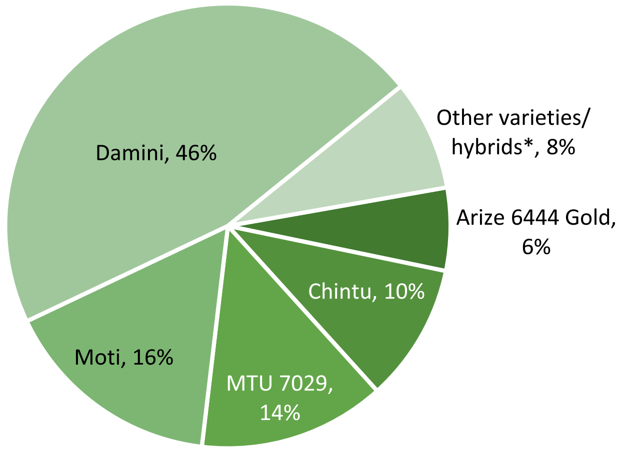
Block covered : Badraon, Dohri Ghat, Muhammadabad Gohna, Ghosi, Ranipur, Fatehpur Madraon, Pardaha, and Ratanpura blocks.

Villages surveyed : Abdupur Chirai kot, Amila, Bandi Kala, Belbhadrapur, Belchaura, Dharauli, Dharampur Bishanpur, Itaura, Jaitpur, Karhan, Karisath, Khaira Nasir, Khurahat, Kunda Sharif, Lakhnaur, Makhna, Mau Kuber, Mirpur, Mishrauli Molanpur, Nadaur, Pakri Bujurg, Pyarepur, Pindhari, Rasulpur Gnamudinpur, Ratanpura, Ratohi, Sultanpur, Tajopur and Taradih (Fig. 1).

Results and Discussion

The data on landholding size revealed that 70% farmers were marginal, 18% small, 8% semi-medium and 2% each in large and medium category. The data on drainage class showed that 89% of surveyed farmers cultivated rice on medium land, 6.5% on upland and 4.5% on lowland. The soil texture data showed that 78.5% soils were medium, 14.5% light and 7% heavy. The major dominant cropping system is rice-wheat with 92.5% HHs.

The varietal spectrum reported the use of Damini by 46%, Moti 16%, MTU 7029 14%, Chintu 10%, Arize 6444 Gold by 6% and rest 6% by other varieties or hybrids (Fig. 2).



*Other varieties/hybrids- MTU 1010, Pusa 1121, Radhika, Sankar, Sonam, Super Moti, Basmati, Moti Gold, Sarju52

Fig. 2. Varietal spectrum of the surveyed farmers in district Mau.

One of the most popular high yielding long duration rice genotype (MTU 7029 -inbred) with a paddy yield of 4.7 tha^{-1} was much better placed when compared with medium duration hybrid (Arize 6444-hybrid) with an average yield of 4.0 tha^{-1}. Yield of other varieties had lower yield–almost 1 tha^{-1} (Fig. 3). Some of the varieties released after MTU 7029 showed 11 to 14% yield advantage over this variety (Mallick *et al.*, 2015) but did not perform as promised.

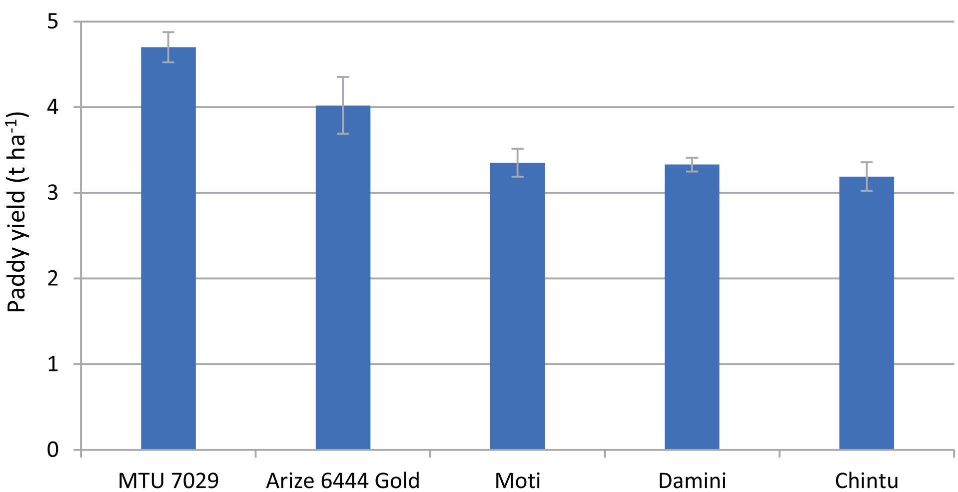


Fig. 3. Varietal performance of the surveyed farmers in district Mau.

The yield of hybrids showed increasing trend when transplanting was delayed from June to mid-July in the district whereas varieties showed a negative trend with delayed transplanting dates (Fig. 4). However, overall picture showed that yield of varieties/hybrids reduced with delay in transplanting after 15 July (Fig. 5). The transplantation of high yielding varieties of rice at the appropriate time is the most important factor for obtaining high yield of rice (Bashir *et al.*, 2010). In a way, late

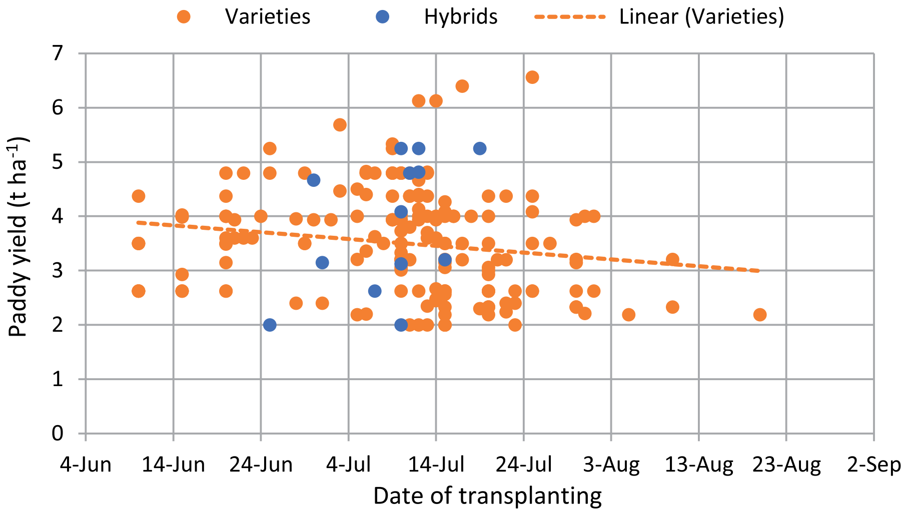


Fig. 4. Effect of dates of transplanting on paddy yield in district Mau.

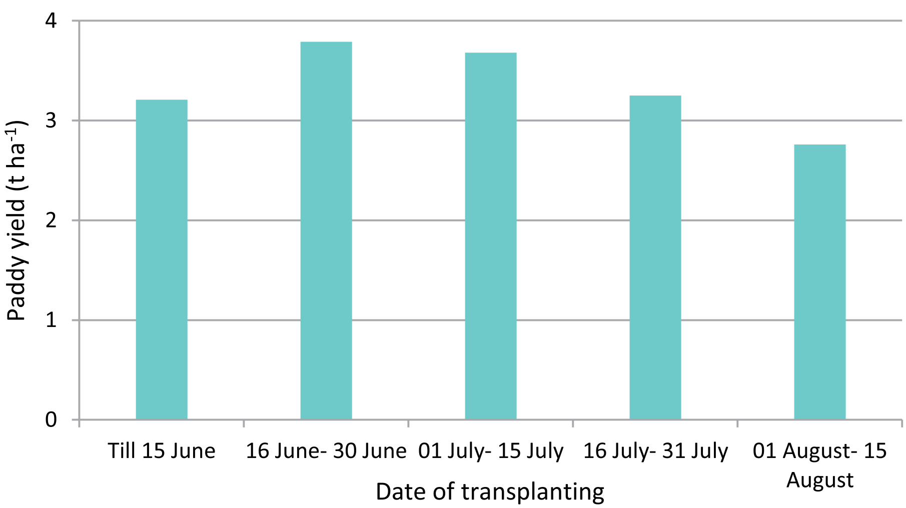


Fig. 5. Effect of dates of transplanting on paddy yield in varieties/hybrids in district Mau.

crop establishment is the key vulnerability for rice and also for wheat in rotation. This is the major factor that undermines the growth and development of both crops in rotation.

The grain yield, NPK and irrigation application for both hybrid and improved varieties were at par (Table 1).

Table 1. Nutrients and irrigation application pattern in improved varieties and hybrids in Mau

Particulars	Hybrids	Improved varieties
Average yield (tha^{-1})	3.8	3.5
Average nitrogen application ($kgha^{-1}$)	135.7	129.4
Average phosphorus application ($kgha^{-1}$)	52.7	55.5
Average potash application ($kgha^{-1}$)	28.5	29.3
Average irrigations applied	4.9	4.6
Total households	13	183
% households applying nitrogen	100	99
% households applying phosphorus	100	91
% households applying potash	46	37
% of households applying irrigation	100	100

The major biotic constraint that limits the rice yield across the globe is weeds (De Datta and Baltazar, 1996). The two most common weeds were *Echinochloa colona* with 90.0 % and *Echinochloa crus-galli* with 78.6 % HHs responding for them (Table 2). *Echinochloa colona* and *Cyperus rotundus* with 82.1 and 65.2 % were the most troublesome weeds.

Table 2. Five most common and troublesome weeds and yield of paddy in Mau district

Rank	Common weeds	% HHS	Troublesome weeds	% HHs
Weed 1	*Echinochloa colona*	90.0	*Echinochloa colona*	82.1
Weed 2	*Echinochloa crus-galli*	78.6	*Cyperus rotundus*	65.2
Weed 3	*Cyperus rotundus*	74.6	*Echinochloa crus-galli*	38.8
Weed 4	*Cyperus iria*	73.1	*Fimbristylis* spp	35.8
Weed 5	*Scirpus juncoides*	57.7	*Cyperus iria*	33.8

Conclusion

Mau is dominated by marginal and small landholding farmers and soil types are mostly medium textured. Rice-wheat is the major cropping system and yield levels of rice are majorly low due to adoption of traditional varieties and delayed transplanting. Hybrids have better scope in the district. Timely sowing along with precise nutrient and weed management should also be emphasized to attain higher yields.

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3.60 Current rice production practices in Siddharthnagar district of Uttar Pradesh– An overview

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Introduction

Agro-climatically Siddharthnagar district of Uttar Pradesh falls under Middle Gangetic Plain Region and North east plain zone. With more than 2500 villages divided in 5 subdivisions and 14 blocks, the Siddharthnagar district covers an area of 2752 km^2 with a population of 25,53,526 (2011 census). It has a total 2,06,768 ha of cultivable land. The total area under rice is 1,70,364 ha and total area under wheat is 1,45,109 ha. Soil is mostly clay and sandy loam type. Annual rainfall received is between 1041-1400 mm. Cropping intensity of district is 173 %.

The landscape diagnostic survey (LDS) was planned to support the research and extension system for setting priorities by highlighting issues which need more attention than others.

Methodology

In total 30 villages were randomly selected from the 2011 census data based on probability proportionate to size (PPS) method. The villages and the farmers within villages were randomized (Fig. 1) and the sample properly reflects the farmer's population in the district. Seven farmers were randomly selected from each village. They were interviewed regarding the prevailing agronomic practices for the rice crop. The randomization process makes it easy to assess the adoption pattern of different technologies in the district.

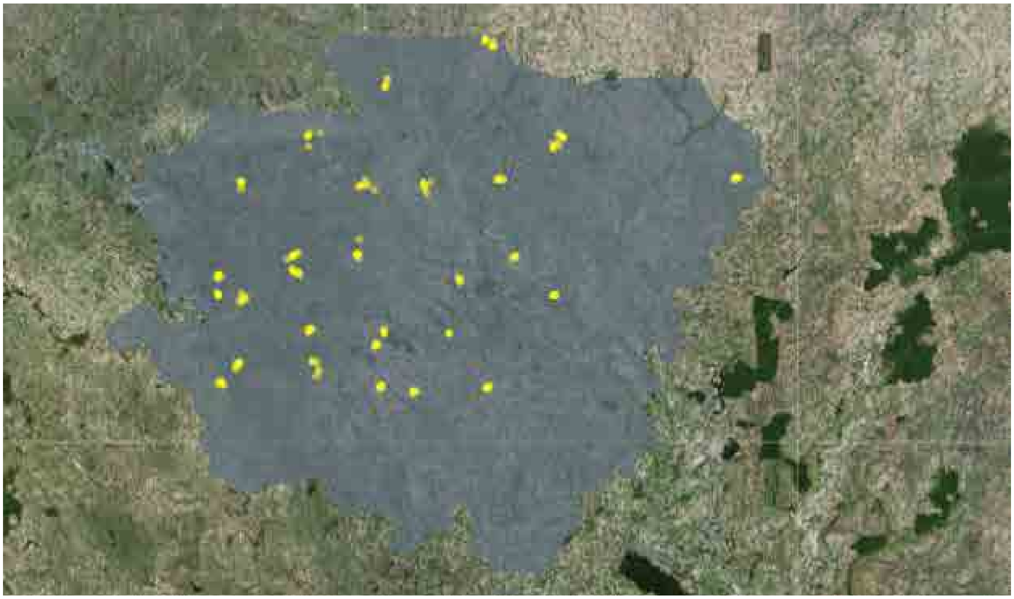


Fig. 1. Village-wise representation of surveyed area in Siddharthnagar.

The questionnaire for the landscape diagnostic survey was prepared in a mobile application based digital data collection format of Open Data Kit (ODK) which can transfer real time data to the server or cloud.

Blocks covered : Bansi, Barhni, Bazaar, Bhanwapur, Dumriyaganj, Itwa, Jongiakas, Khuniaon, Mithwal, Shoratgarh and Uska Bazar.

Villages surveyed : Navel, Khurpahwa, Girdarpur, Bharatbhari, Jhahraon, Pipra, Ramwapur, Rehra, Mudila, Kehunia, Solapur Majhari, Allahapur, Jigna, Mehdani, Dhowha, Madarahana, Rangrejpur, Parsha Hateem, Badhay, Malda, Gorya, Puraina, Bhalukoni Japti, Khajuriya Sakari, Kotiya, Sihorawha, Masjidiya, Kanhekusum and Keotaliya (Fig. 1).

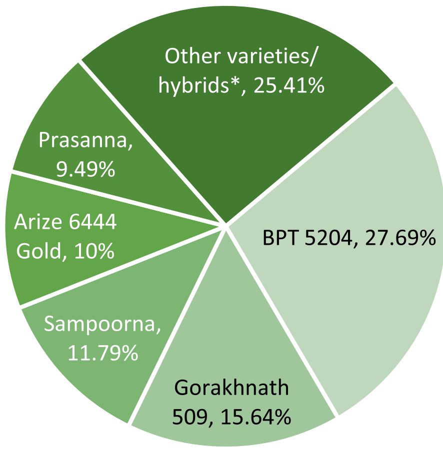
Results and Discussion

Based on the surveyed data, there were 57 % marginal, 26 % small, 4 % medium, 13 % semi-medium and 0.26 % large farmers. Almost 95 % respondents had medium land, 3 % lowland, 2 % upland and only 0.3 % had very lowland. This district is dominated by rice-wheat cropping system (RWCS) with 89 % farmers and some pockets of rice-fallow system with 10.8 % farmers. Data based on soil texture reveals that 98.2 % of plots were with medium soil type whereas 1.3 % with light and rest 0.5 % with heavy soil type. Around 27.7 % farmers cultivated BPT5204 followed by

15.6 % Gorakhnath 509. Amongst hybrids, Arize6444 and Prasanna were grown by 10 % and 9.5 %, respectively. Around 11.8 % farmers also cultivated Sampoorna followed by other varieties/hybrids (Fig. 2) which were: Arize6633, Basmati, Dhanya775, Godawari, LK-Dhanyarekha, Sabour Sampann, Sabour Samriddhi, US382, Kaveri, Mahyco-Maheen, PHB71, Poonam, Shushk Samrat, Sonam, Pioneer27P31, MTU7029, Pioneer 27P635.

Highest paddy yield was reported in Arize 6444 at 4.82 tha^{-1} and the lowest was reported from Gorakhnath-509 at 4.25 tha^{-1} (Fig. 3).

There was yield decline in case of varieties with respect to delay in transplanting date after 15th July (Fig. 4).



*Other varieties/hybrids- Arize 6633, Dhnaya 775, Godawari, JK Dhanyareka, Radhika, Sabour Sampann, Sabour Samriddhi, Sankar, US 382, Kaveri, Mahyco Maheen, PHB71, Poonam, Shushk Samrat, Sonam, Pioneer 27P31, MTU7029, Pioneer 27P63

Fig. 2. Varietal spectrum of the surveyed farmers in district Siddharthnagar.

Total households who grew improved rice varieties and hybrids, respectively harvested an average paddy yield of 4.39 and 4.65 t ha^{-1} , respectively with almost similar amount of N (134 & 132 $kgha^{-1}$), P_2O_5 (52 & 51 $kgha^{-1}$) and K_2O though sub-optimal in varieties only (28 $kgha^{-1}$) and similar level of irrigation (2.5 & 2.4) applications (Table 1). N, P_2O_5

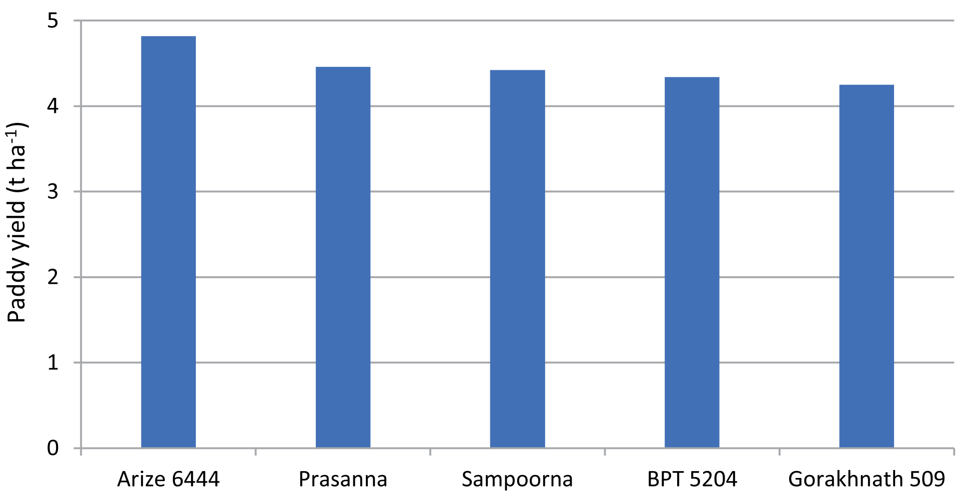


Fig. 3. Varietal performance of the surveyed farmers in district Siddharthnagar.

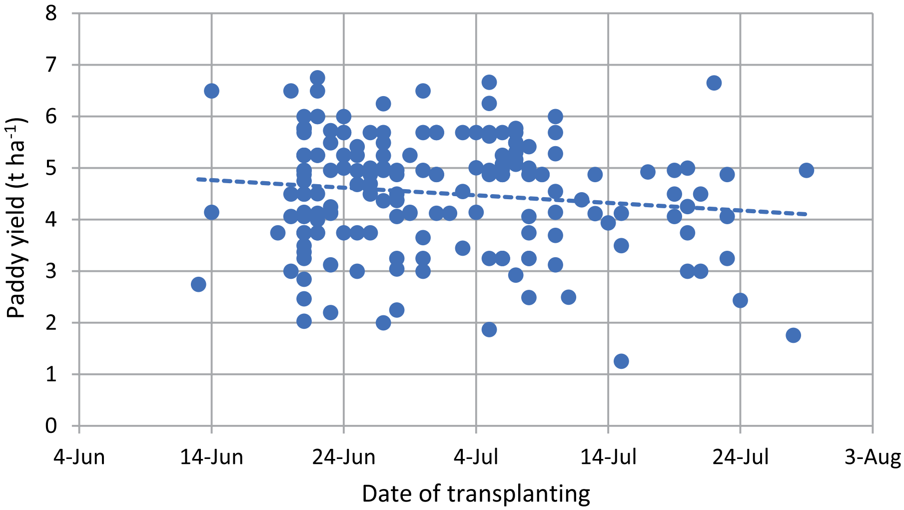


Fig. 4. Effect of dates of transplanting on paddy yield in district Siddharthnagar.

and K_2O were applied by 100, 88.29 and 27.09% HHs in rice varieties, respectively and the corresponding figures in hybrids were 100, 92.22 and 24.44%.

Among five topmost troublesome weeds infesting rice crop in Siddharthnagar (Table 2), 76.7% HHs indicated *Echinochloa crusgalli* as the most serious weed (rank 1) closely followed by *Echinochloa colona* ranking 2 (64.8% HHs*).* The simple weed flora (Zhang et al., 2017) is dominated by these two annual weeds on account of more moisture and more use of nitrogen. With slight push from supplementary irrigation paddy yield can be significantly increased in this district.

Table 1. Nutrients and irrigation application pattern in varieties and hybrids in Siddharthnagar.

Particulars	Improved varieties	Hybrids
Average yield (t ha^{-1})	4.4	4.6
Average nitrogen application (kgha^{-1})	134	132
Average phosphorus application (kgha^{-1})	52	51
Average potash application (kgha^{-1})	28	28
Average No. of irrigations applied	2.5	2.4
% households applying nitrogen	100	100
% households applying phosphorus	88.3	92.2
% households applying potash	27.1	24.4
% of households applying irrigation	99.3	97.8

Table 2: Top five troublesome and common weeds in Siddharthnagar

Rank	Troublesome weeds	% HHs	Common weeds	% HHs
Weed 1	*Echinochloa crus-galli*	76.7	*Echinochloa crus-galli*	88.2
Weed 2	*Echinochloa colona*	64.8	*Echinochloa colona*	72.1
Weed 3	*Ischaemum rugosum*	38.5	*Ischaemum rugosum*	53.8
Weed 4	*Cyperus rotundus*	28.5	*Cyperus rotundus*	50.5
Weed 5	*Scirpus juncoides*	27.4	*Scirpus juncoides*	40.7

Ischaemum rugosum (rank 3; 38.5% HHs), *Cyperus rotundus* (rank 4; 28.5% HHs) and *Scirpus juncoides* (rank 5; 27.4%HHs). Among top five common weeds of transplanted rice crop were, *Echinochloa crusgalli, Echinochloa colona, Ischaemum rugosum, Cyperus rotundus*, *Scirpus juncoides*, as reported by 88.2, 72.1, 53.8, 50.5and 40.7% HHs, respectively.

Conclusion

Sidharathnagar district represents medium land (90%) and RWCS is predominantly followed by 89% farmers. BPT 5204 is the dominant variety because of its quality. Hybrids are coming up and may be able to replace so called research varieties. Weed flora is simple and can be effectively controlled by herbicides.

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3.61 Comparing fallow-rice system with cropped-rice system in Purulia, West Bengal

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Introduction

Purulia district which belongs to the red and lateritic zone of West Bengal, is one of the country's 250 most backward and one of the 11 most backward districts of West Bengal (GoI, 2009). Purulia lies between 22.60 degrees and 23.50 degrees north latitudes and 85.75 degrees and 86.65 degrees east longitudes. The geographical area of the district is 625.65 thousand ha and total cultivated area is 437.8 thousand ha and cropping intensity is 118 % (GoWB, 2018-19). Cultivation practice of the district is predominantly mono-cropped and rice is the primary crop. Apart from agriculture, sericulture is one of the important source of livelihoods for the people of Purulia district which produces about 90 % of total lac production in the state. The red and lateritic zone has a hot tropical dry sub-humid climate with average annual rainfall ranging from 1100 mm to 1400 mm. It holds the current national record of India's highest temperature, 51.1 °C (124.0 °F). Growing season terminates early here and the soils have low water holding capacity (50 mm) (Asis *et al*., 2015).

Methodology

Thirty villages *viz*. Malthod, Ghongha, Tartari, Dumdumi, Arsha, Jhujka, Amagara, Hatnadih, Charra, Pukurkata, Sirisgora, Sorgora, Digardhi, Bagbinda, Dhanara, Jabla, Bharatdih, Tukya, Salanchi, Nutandi, Kotaldi, Jamra, Jorrow, Bhabanipur, Cheliyama, Alaldi, Pachhandapur, Shalaya, Rampur, Gar Panchkot were randomly selected based on the probability proportionate to size from the Census 2011 data. From this 30

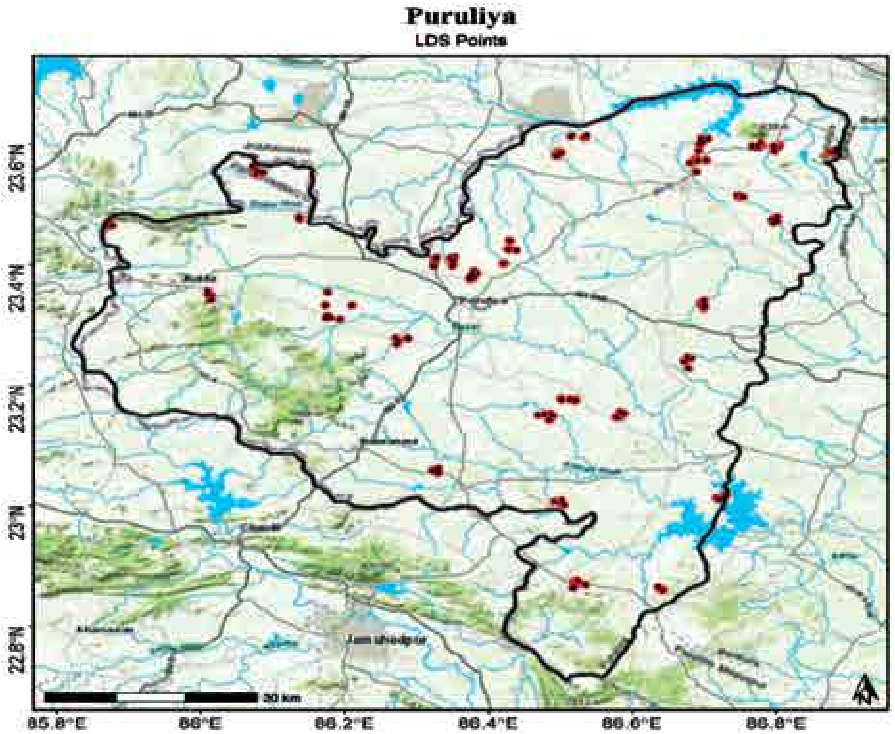


Fig. 1. Geotagged points of surveyed households in Purulia district.

randomly selected villages, 7 households were randomly selected from each village based on the election commission's electorate roll. The data were collected through open data kit (ODK) app installed in smart phone.

Each farmer interviewed for the survey was geotagged for finding the distribution of surveyed farmers in the district. Total 213 farmers' households were surveyed on rice in *kharif* 2018. Geotagged locations of respondents are furnished in Fig. 1.

Results and Discussion

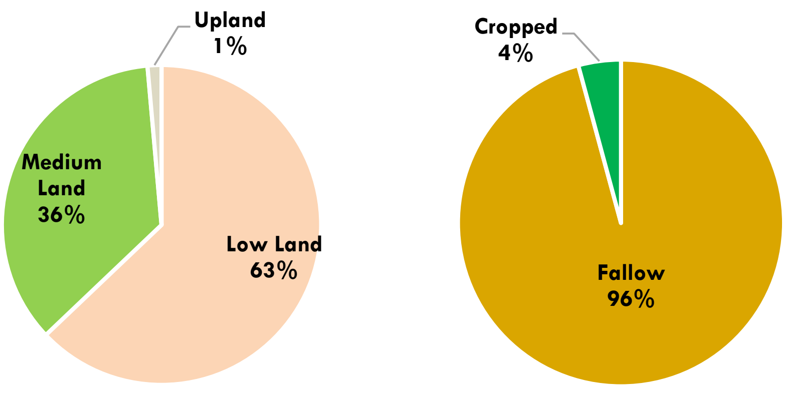
The district has the maximum number of farmers' population of schedule tribe (17%) and schedule caste (15%) who are considered to be the most underdeveloped classes in the state and country (Table 1). This resource poor farmers mostly practice subsistence farming under adverse and risky environmental conditions like soil erosion, erratic and scanty rainfall, drought, flood and cyclones.

The topography in the district is undulating and not suitable because steep slopes do not allow water to percolate into the soil and results in fast surface runoff. Due to

Table 1: Population of schedule tribe (ST) and schedule caste (SC) in Purulia

Farmer's category	Count of farmers	% of farmers
General	123	58
OBC	21	10
SC	33	15
ST	36	17
Grand Total	**213**	**100**

unsuitable topography, soil erosion, erratic and scanty rainfall, the rivers Kanshabati, Damodar and Dwarakeshwar flowing through the district provide little irrigation facilities. The district is mostly mono-cropped and predominant cropping system is rice-fallow (96 %). Rice is being grown mostly in low and medium land topographies (99 %) in the district (Fig. 2).



Land topography of surveyed farmers   Intensity of Rice-Fallow System

Fig. 2. Land topography and rice-fallow system in Purulia.

The yield of paddy in cropped-rice system (4.36 t ha^{-1}) is significantly higher than that of fallow-rice system (2.58 t ha^{-1}) and notably mean date of rice transplanting in cropped-rice system is 17^{th} July i.e. about 8 days earlier than fallow-rice system (25^{th} July) in the district (Fig. 3).

The study revealed that early transplanting favours higher paddy yield in the district. Rice transplanting between 18^{th} June to 9^{th} July recorded increasing trend in paddy yield (>3 t ha^{-1}) and from second week of July to second week of August recorded paddy yield between 2-3 t ha^{-1} but transplanting after that caused decrease in paddy yield (Fig. 4).

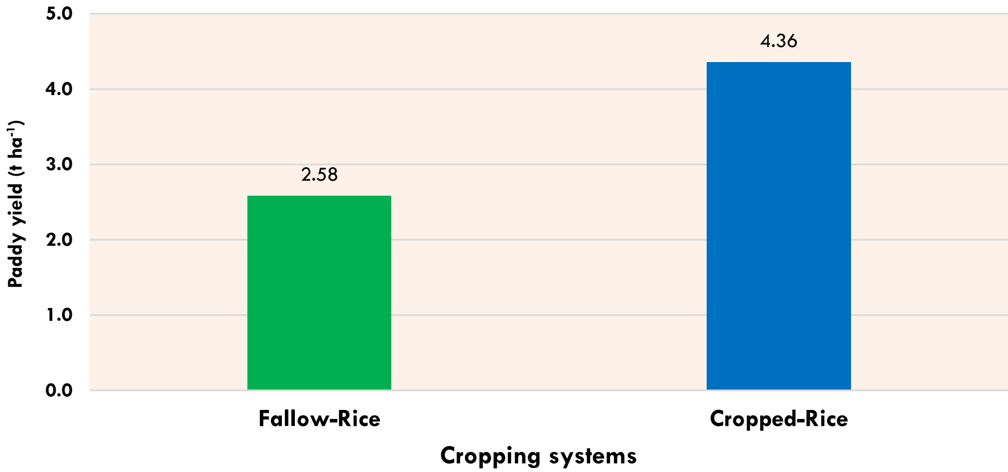


Fig. 3. *Kharif* paddy yield (t ha^{-1}) in two cropping systems.

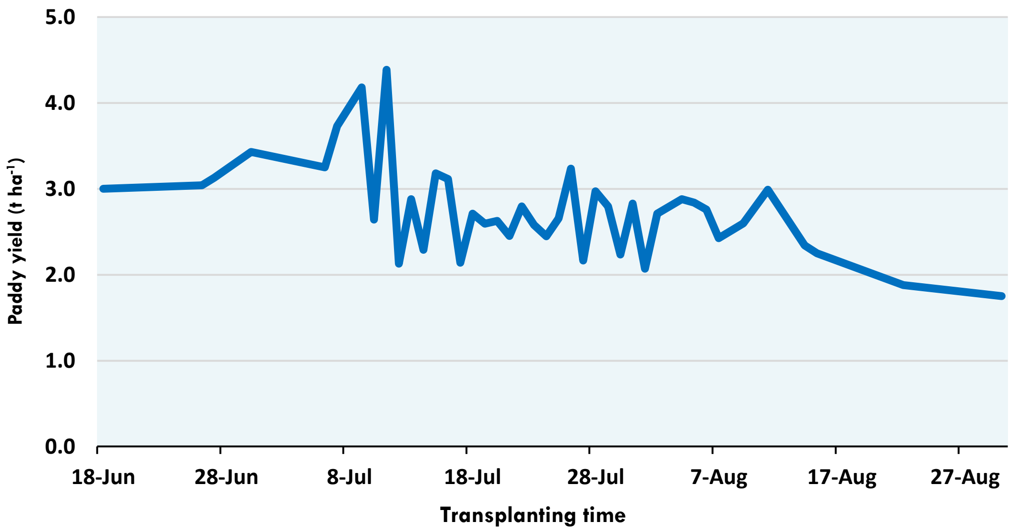


Fig. 4. Paddy yield (t ha^{-1}) alongwith transplanting time.

MTU 7029 (Swarna), Lalat, MTU 1001, Super Shyamali and Sourav are the five top most rice varieties cultivated by the farmers in Purulia district with mean transplanting date between 19th July to 1st August. More than 50% HHs prefer to grow MTU 7029 (Swarna) rice variety (Table 2). In fallow-rice system increasing trend was found in paddy yield with increased number of hand weeding and maximum paddy yield (3.11 t ha^{-1}) recorded where 3 hand weeding operations were done. In cropped-rice system, there was no significant yield difference between 1 or 2 hand weeding operations in rice fields (Fig. 5).

Table 2. Top-5 rice varieties and their mean transplanting dates in Purulia

Top-5 varieties	Mean transplanting dates	Number of HHs	% of HHs
MTU 7029	22-Jul	109	51
Lalat	01-Aug	52	25
MTU 1001	22-Jul	18	8
Super Shyamali	20-Jul	10	5
Sourav	19-Jul	5	2

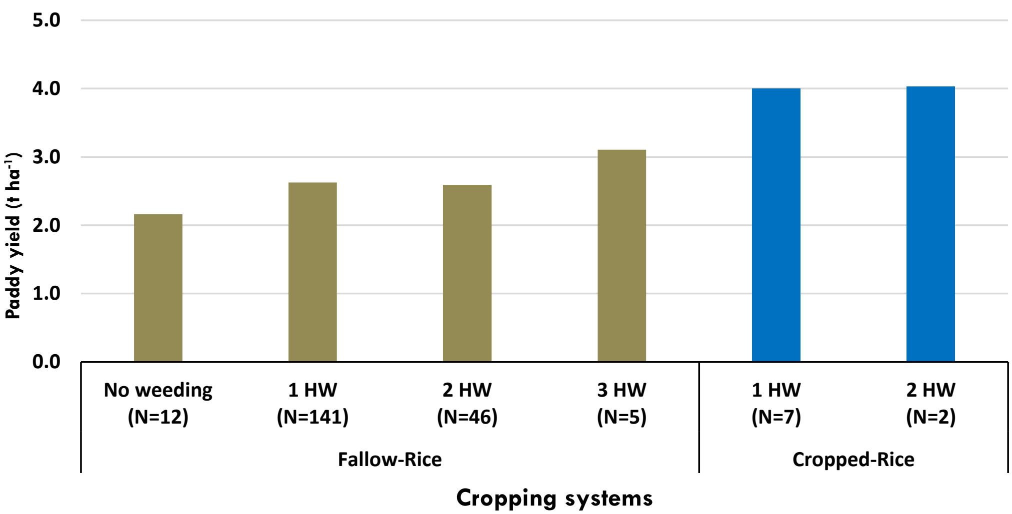


Fig. 5. Intensity of hand weeding (HW) and paddy yield (t ha^{-1}) in two systems.

Conclusion

Rice-Fallow cropping system accounts for 96 % of rice cultivated area in Purulia and characterized by 1.78 t ha^{-1} lesser average yield compared to *rabi* cropped areas. Almost, half of the farmers found to be growing MTU 7029 and transplanting during second fortnight of July. Intensification of cropping system (*rabi* fallow areas) needs to be addressed for augmenting farmers' wellbeing in the district.

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3.62 Various cropping systems and related *kharif* paddy yields in Murshidabad, West Bengal

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Introduction

The Murshidabad district comes under two agro-climatic zones *viz.* old alluvial zone and new alluvial zone of West Bengal. It lies between 23º43'N to 24º52'N latitude and 87º49'E to 88º44'E longitude. The geographical area of the district is 532.5 thousand ha and total cultivated area is 402.4 thousand ha and cropping intensity is 235 % (GoWB, 2018-19). It has a tropical wet and dry climate having average annual rainfall of about 1600 mm. *Kharif* and winter paddy are predominantly cultivated here. The district is drained by the Bhagirathi and Jalangi rivers and their tributaries. Floods are common during the monsoon season. The soils are rich fertile clayey-loam, loam and loamy-sand types. Crop diversification is very high in this district which is visible during the post green revolution period. A wide spatio-temporal variation of crop diversity exists among different blocks of Murshidabad district (Pal, 2008).

Methodology

Twenty villages *viz*. Airmari, Masurdanga, Joykrishnapur, Bhagirathpur, Padmanabhpur, Adwaitanagar, Garaimari, Kupila, Haroa, Kadoa, Godhanpara, Dhulauri, Rajdharpur, Gurah, Kutubpur, Moktarpur, Purushottampur, Dhanigram, Siata, Narasinghapur were randomly selected from Murshidabad district using probability proportionate to size method using census 2011 data. Selection of 7 households from each of these 20 villages were done randomly using respective voter

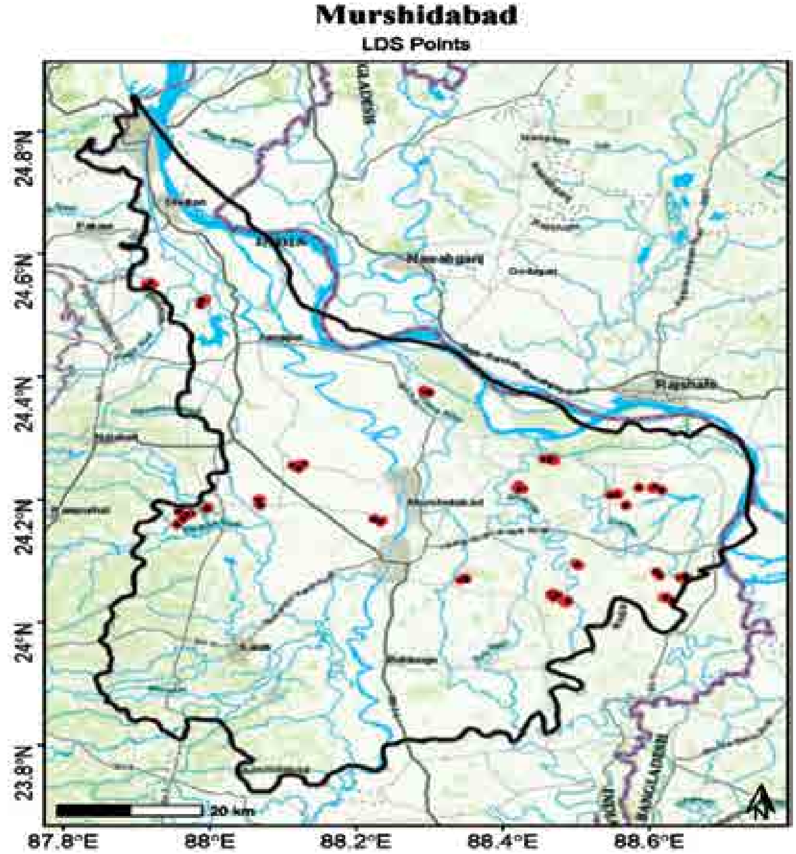

Fig. 1. Geotagged points of surveyed households in Murshidabad district.

lists of the villages. Accordingly, 136 farmers were surveyed in *kharif* 2018 using digital questionnaire on ODK. Geotagged locations of respondents are furnished in Fig. 1.

Results and Discussion

Most of the land in the district is arable, and used as agricultural land. Analysis of distribution of land types indicates that medium land constitute major share (64%) in the district followed by lowland (28%) and upland (8%) (Fig. 2). The cropping pattern of the district is having high diversification in many blocks where

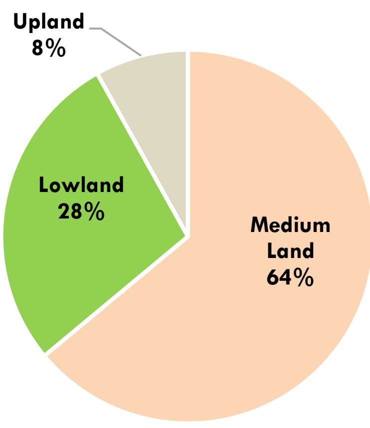

Fig. 2. Distribution of land types.

irrigation and other favourable facilities entertains multiple cropping systems. Modernization in agriculture along with proper irrigation facilities have helped the farmers of the district to go for diversified crops like jute (35 %), oilseeds (8 %), pulses (4 %), vegetables (4 %) and maize (2 %) as previous crop just before *kharif* rice (Fig. 3).

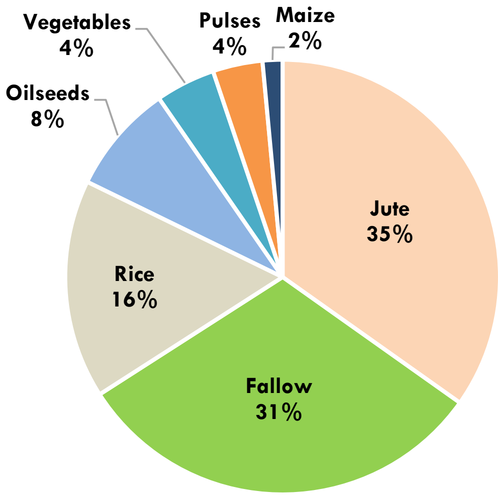

Fig. 3. Coverage of previous *rabi* crops.

Although 16 % of the farmers in the district stick to rice as second crop and 31 % of the farmers grow only *kharif* rice as monocrop. Ananya (2012) reported that in Murshidabad the highest number of crops diversified is six while the lowest is monocrop. Farmers of few blocks hardly ever attempt for diversification in even better conditions. Diversification enhances nitrogen in the soil to replenish the soil fertility which increases the sustainability of arable land. It generates more employment as the agricultural workers remain busy in sowing, weeding, harvesting and marketing of crops throughout the year.

The present study revealed that average number of irrigation provided to rice crop in diversified cropping systems in the district ranges between 12-19 (Table 1). It was found that number of irrigation had impact on rice yield. Number of irrigations from 11-20 resulted into significantly higher paddy yield (> 4.7 t ha^{-1}) compared to in less than 10 number of irrigations where paddy yield recorded was 4.2 t ha^{-1} (Fig. 4).

Table 1. Average number of irrigation across different cropping systems.

Cropping systems	Average number of irrigation
Jute-Rice	19
Fallow-Rice	12
Rice-Rice	16
Oilseeds-Rice	12
Vegetables-Rice	14
Pulses-Rice	14
Maize-Rice	15
Overall	15

The study revealed that paddy yield varied due to the previous crop in sequence. Where *kharif* rice was taken just after jute, it fetched higher paddy yield (4.89 t ha^{-1}) compared to after fallow (paddy yield 3.91 t ha^{-1}) and after boro rice (paddy yield 3.79 t/h) (Fig. 5).

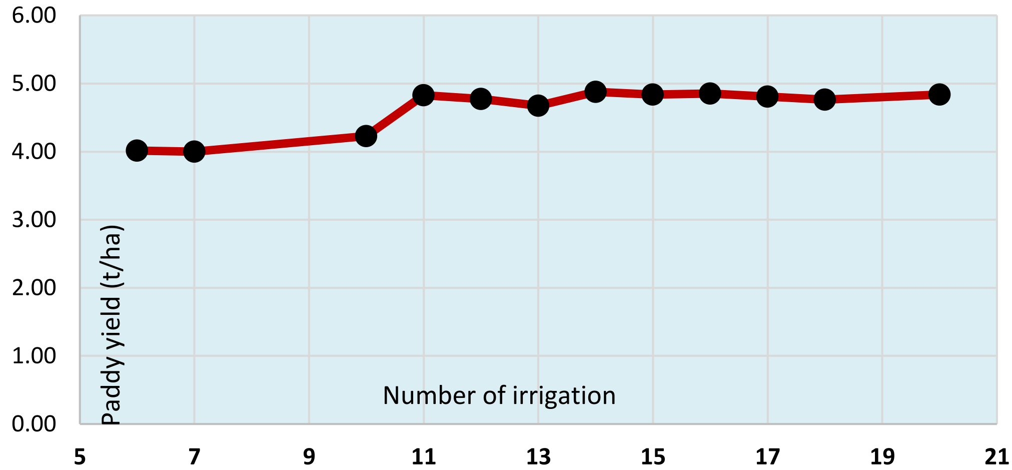

Fig. 4. Effect of number of irrigation on paddy yield (t ha^{-1}).

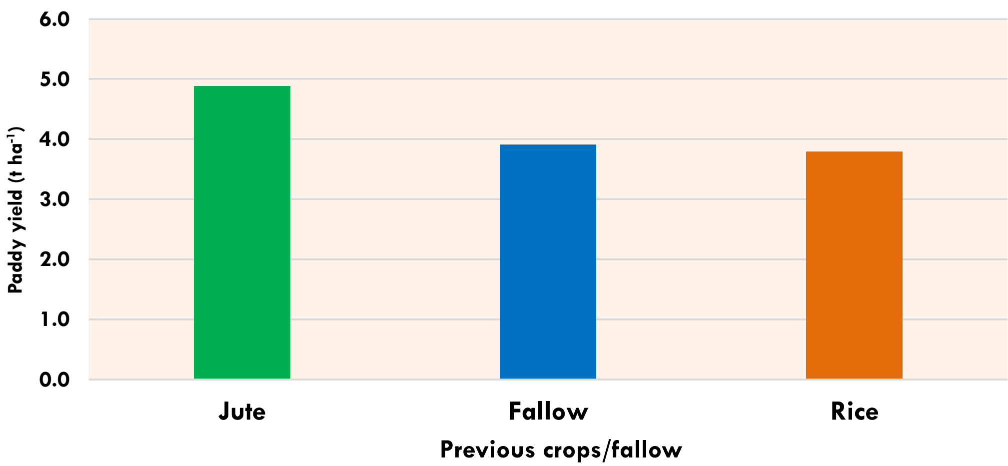

Fig. 5. Previous major *rabi* crops and corresponding *kharif* paddy yield (t ha^{-1}).

It was also found that *kharif* paddy recorded highest yield in all types of soil when jute was previous crop but in heavy soil *kharif* paddy yield was higher (4.15 t ha^{-1}) in fallow system than rice as previous crop (3.53 t ha^{-1}) whereas in light and medium soil conditions, fallow system and rice as previous crop did not cause any significant yield difference in *kharif* paddy (Fig. 6).

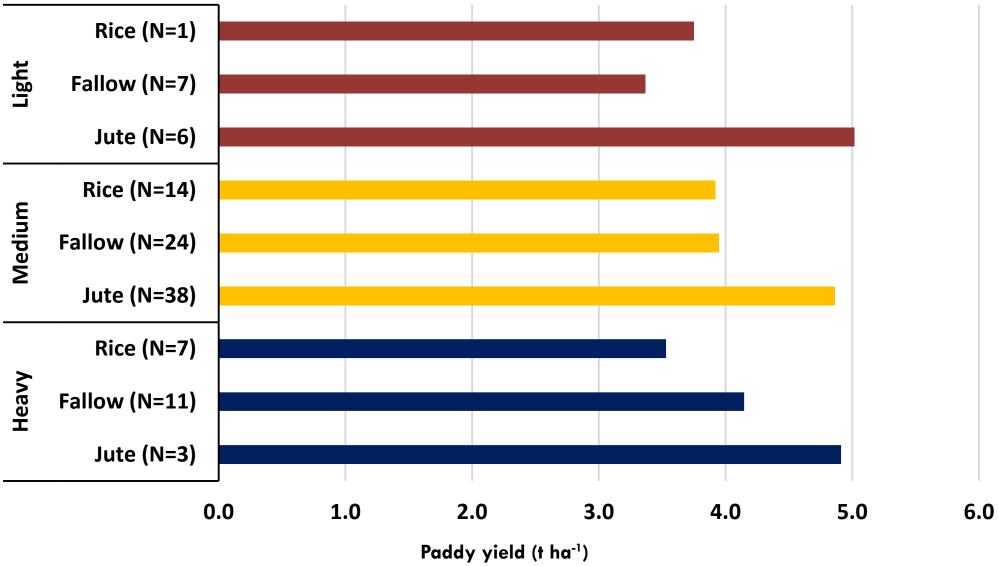

Fig. 6. Yield of *kharif* paddy (t ha^{-1}) segregated by major previous crop and soil types.

Conclusion

Murshidabad is dominated by medium and lowlands and the cropping system is comparatively more diversified one dominated by Jute (35 %) as previous crop to *kharif* rice. Jute as previous crop in sequence results into higher *kharif* paddy yields than that of rice-fallow or rice-rice systems and improved irrigation supply will further help to improve paddy yield.

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3.63 Effect of plot size on paddy yield in South 24 Parganas district of West Bengal

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Introduction

South 24 Parganas district comes under the coastal saline agro-climatic zone of West Bengal. The district is located between 22º30'45" to 20º29' North latitude and between 89º4'56" to 88º3'45'' East longitudes bounded by the river Hooghly in the West. The geographical area of the district is 953.37 thousand ha and total cultivated area is 371.876 thousand ha and cropping intensity is 168 % (GoWB, 2018-19). Soils are mostly heavy clay containing higher salts of sodium, magnesium, potassium with organic matter at different stages of decomposition and mostly neutral. Average annual rainfall ranges between 1600-1800 mm. Monsoon variability is one of the major issues in establishing *kharif* rice. Productivity constraints attributed to prolonged water logging during and after the wet (*kharif*) season, soil salinity and the scarcity of low saline irrigation water as the dry (*rabi*) season progresses (Mandal *et al.* 2020). Frequent inundation of low lying areas results in stagnation of water for certain times of the year (DHDR, 2009).

Methodology

Thirty villages *viz*. Dakshin Ghola, Miyargheree, Arenda, Binarait, Ghunimeghi, Dakshin Rajapur, Chaulkhola, Baratala, Bethuabati Rajarampur, Sarisha, Bagi, Bijayrampur, Dharmatala, Kumirmari, Gobindapur, Karanjali, Lakshmipur, Kundakhali, Ganeshpur, Harishankarpur, Ramchandrapur, Nabagram, Purba Gabberiya, Uttar Damodarpur, Uttar Rameshwarpur, Manoharpur, Uttar Rajarampur, Khanri, Naluya, Kalikapur were selected using probability proportionate to size (PPS) method applying on census-2011 data and 7 households were drawn randomly from each selected village. Open Data Kit (ODK) tool was used for farmer's survey. KVK, South 24 Parganas and CSISA jointly surveyed 210 randomly selected farmers in 2019 for *kharif* 2018 rice and previous season crop to understand current crop production practices being followed by them. Geotagged locations of respondents are furnished in Fig. 1.

Fig. 1. Geotagged points of surveyed households in South 24 Parganas district.

Results and Discussion

The distribution of operational land holdings is extremely fragmented in the South 24 Parganas district. The operational largest plot of the 86% of the farmers in the district is less than one acre and that of 12% of the farmers is 1-2 acres. Only 2% of farmer's largest plot ranges between 2-4 acres (Table 1). In various social caste categories, 38% of the farmers in general category and 40% of the farmers in schedule caste category are having plot size less than one acre (Fig. 2).

Table 1: Operational largest plot size in South 24 Parganas

Largest plot size (Acre)	Count of farmers	% of farmers
0-1	180	86
1-2	25	12
2-3	3	1
3-4	2	1
Grand Total	**210**	**100**

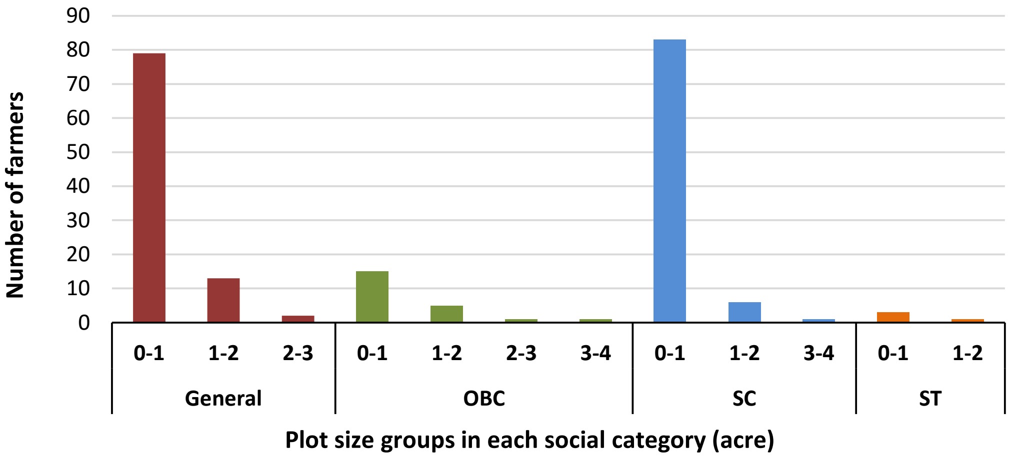

Fig. 2. Distribution of plot size among farmers' social category.

The South 24 Parganas district witnessed many historical movement of share-croppers. In the post-independence period major peasant movements started in West Bengal had originated from the district of South 24 Parganas. The present study revealed that about 30% of the farmers who are doing rice cultivation in the district are landless and they are cultivating the crop under tenancy system (Fig. 3).

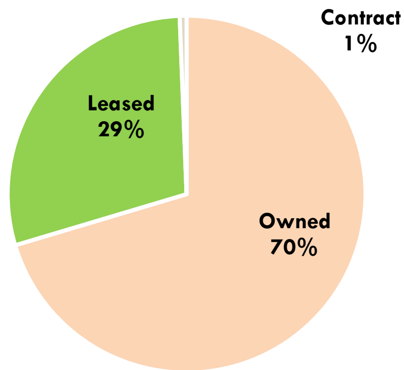

Fig. 3. Rice plot ownership types.

Chand *et al.* (2011) opined that the lower size of land holdings in India have been using higher doses of inputs, making more intensive use of land and adopting new technology on a much larger scale compared to farms in the larger size categories. These patterns of negative association between farm size and productivity enhancing variables have not diluted over time with the advancement of technology or modernisation of agriculture. Cropping intensity, which is important for the growth in agriculture in India was found to be the highest in marginal holdings and it declined with an increase in farm size. The present study revealed that up to 2-3 acres plot size, paddy yield recorded increasing trend but where plot size were 3-4 acres there were decline in paddy yield (Fig. 4).

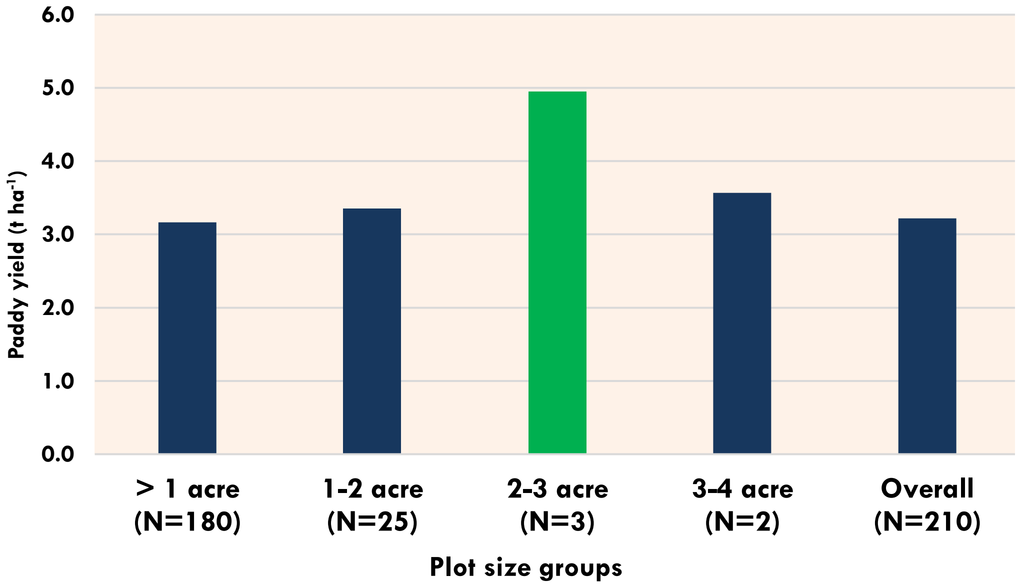

Fig. 4. Paddy yield (t ha^{-1}) as per plot size.

The district represents mostly mono-cropped cultivation in *kharif* rice based cropping system and yield rate of rice has always been lower than that in the State mainly because of the factors such as inundation of saline water in low lying areas, flood, scarcity of saline free irrigation water, drought and water logging for a significant time in a year. The study recorded major varieties are grown such as Dudheshwar, Sabita Patnai, Super Shyamali, MTU 1001 and MTU 7029 (Swarna) had mean paddy yield ranged from 2.73-3.81 t ha^{-1}. Among these varieties, Dudheshwar was adopted by 24% and Sabita Patnai was adopted by 16% farmers in the district. The mean transplanting date of these rice varieties were in the last week of July (Table 2).

Table 2. Major rice varieties with mean transplanting date and yield in South 24 Parganas.

Major varieties	Mean yield (t ha^{-1})	Mean transplanting date	User's per cent
Dudheshwar	2.73	31-Jul	24
Sabita Patnai	2.84	25-Jul	16
Super Shyamali	3.32	24-Jul	9
MTU 1001	3.71	24-Jul	4
MTU 7029	3.81	23-Jul	4

Conclusion

Average plot size of paddy in South 24 Parganas is extremely small with 98% farmers cultivating paddy on less than 2 acres plot size. Nevertheless, majority of farmers (86%) operates on less than 1 acre plot size. Survey resulted indicated that paddy yield in the districts gets better where plot size ranges between 2-3 acres. It signals towards potential of community based rice farming in South 24 Parganas to optimize yield. The most common rice variety reported by farmers in the district was 'Dudheswar' which has low yield potential. This is also an potential area (varietal replacement) for targeting.

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Implementing Partners

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