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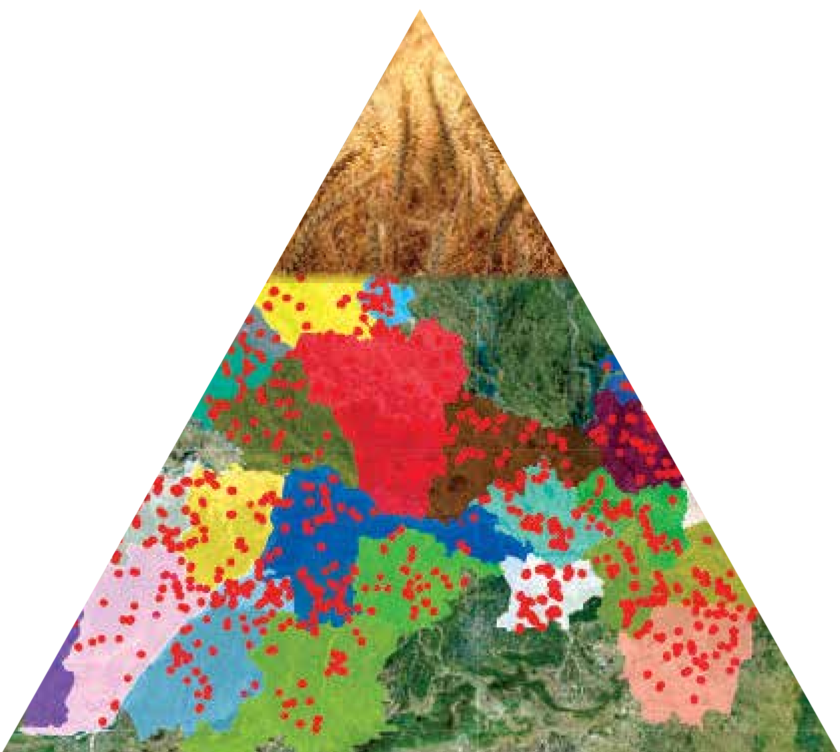
New Frontiers in Agricultural Extension – Volume 1

Editors

A.K. Singh, Peter Craufurd, Andrew McDonald, Ajoy Kumar Singh, Anjani Kumar, Randhir Singh, Balwinder Singh, Sudhansu Singh, Virender Kumar and R.K. Malik



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.

www.csisa.org

Email: cimmyt-csisa@cgiar.org

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New Frontiers in Agricultural Extension

– Volume 1

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Foreword

The green revolution is one of the most outstanding success stories of post-independence India. Success was reflected through development of new crop varieties, which were more efficient in dry matter partitioning to reproductive parts and therefore, had higher harvest indices, with significant gain in the yield potential. However, it was not varieties alone which transformed food production scenarios, but the response of these varieties to external inputs that brought about meaningful advances in food production.

There are regional disparities regarding the gains from the green revolution with productivity levels in the North-West Indo-Gangetic Plains (NWIGP) being higher than in the Eastern Indo-Gangetic plains (EIGPs). In the current scenario, even in NWIGP, the yield growth rate of rice-wheat cropping system (RWCS) has started declining for many reasons. In contrast, the yield growth has been too slow in EIGP. Stagnant yield growth scenarios in the two contrasting ecologies has become an important policy issue, including the reorientation of extension research. Accelerated investment in agricultural research and extension will be crucial to reverse the yield growth trends. Given the fact that investment trends are on the downside, we need to be more aware of adoption patterns of different technologies so that the quality, transparency and the objectivity of investment decisions are based on evidence generated through the participation of farmers. Multi-disciplinary and multi-institutional efforts are needed to change the nature and scope of scaling and the speed of adoption. Research institutes across Indo-Gangetic Plains (IGP) have generated a large number of recommendations, but many of these have not been accepted. Designing a technology for scale consistently needs feedback loops so that we do not get struck with technologies which are not acceptable by farmers. We need to ensure that the entire R4D ecosystem is ready with views from all stakeholders, including researchers, extension agencies, private sector and farmers.

The Extension division of ICAR through a collaborative project funded by Bill & Melinda Gates Foundation (BMGF) entitled “Cereal

System Initiative for South Asia (CSISA)" has brought out this publication based on massive data-generation exercise done by its KVK system across the wheat belt of India. The CSISA-KVK network strengthens the database on crop production practices in farmers' fields to understand adoption patterns of technologies, to generate technology based inventories, improve dissemination and access to new technologies, pinpoint where more resources are needed, encourage services which support the transition, and to strengthen convergence including the role of public, private and non-governmental organizations in extension research.

I compliment the Division of Agriculture Extension and the CSISA team for bringing out this publication which is backed by a unique large dataset to support the type of extension research that the NARES system needs now.

Trilochan Mohapatra
Secretary, Department of Agriculture Research and Education &
Director General, Indian Council of Agricultural Research, New Delhi

Dated : 17th September, 2019
New Delhi

Preface

India's self-sufficiency in food is widely regarded as its greatest achievement since Independence. The green revolution has played a great supporting role in increasing the income of rural households (HHs) where farms are too small and ecologies are too diverse. The top-down scaling out process was fundamental to the accelerated adoption of green revolution technologies in late 1960s and 70s. However, with the current development of an extensive network of KVKs, Indian agriculture has the opportunity to use diagnostic surveys and analytical tools for planning and implementing scaling-up and scaling-out strategies in a bottom-up approach rather than a top-down process. In this book, data based evidence has been utilised for monitoring, evaluation and learning (ME&L) of adoption patterns of technologies. The objective is to achieve accelerated adoption of technologies in different ways, wherein extension also acts as part of priority setting (testing and evaluation at scale plus learning/feedback), and the sum of these components brings the specific technological intervention to focus. This publication on "*New Frontiers in Agricultural Extension*", based on a landscape diagnostic survey of approximately 8,000 fields, is the first in series of three publications from the BMGF-funded KVK-CSISA network project being implemented by Indian Council of Agricultural Research (ICAR). The publication provides evidence on how different technologies are being accepted by farmers and how to improve the delivery system of technologies. The challenge has been to analyse how technologies were modified as they diffused and became more reliable and acceptable by a larger proportion of farmers. The Agricultural Extension Division (ICAR), through its Agricultural Technology Application and Research Institutes (ATARIs), hoped to create an end-to-end feedback mechanism for research and extension, as well as a digital transformation based convergence program, that will define the impact pathways of its KVK system and change the way research and extension systems operate. The innovations include: methods to design spatially representative surveys, digital survey data collection tools that enable rapid data uploading, a web-based portal hosted by ICAR to make data visible and accessible, and data analysis packages in open-source software for analysis. Data have enabled us to increase the reach of KVKs, and once properly analysed such data sets can help KVKs and their parent institutions to serve in a better way and a much larger population of farmers.

The first volume of this document "*New Frontiers in Agricultural Extension*" incorporates the main outcomes of landscape diagnostic survey (LDS) of wheat across 29 districts of Bihar and nine districts of Eastern Uttar Pradesh with 7,648 data points (wheat) and from Odisha with 400 data points (rice). The project has set a target to conduct the LDS in 110 districts across eight ATARIs with more than 40,000 data points.

This volume contains the methodology involved in LDS, data from respondent farmers on the production practices of wheat and rice, and their relationship with existing recommendations. It also contains a priority setting exercise that can be shared with multi-disciplinary research teams in the research institutes including State Agricultural Universities (SAUs) and with Department of Agriculture (DoA) in the concerned state. This publication will help in developing a vibrant and faster cycle of research and extension, by improving the linkage with DoAs for better seasonal planning and linking it with research institutions for setting research priorities and strengthening the monitoring, evaluation and learning (ME&L) in NARES.

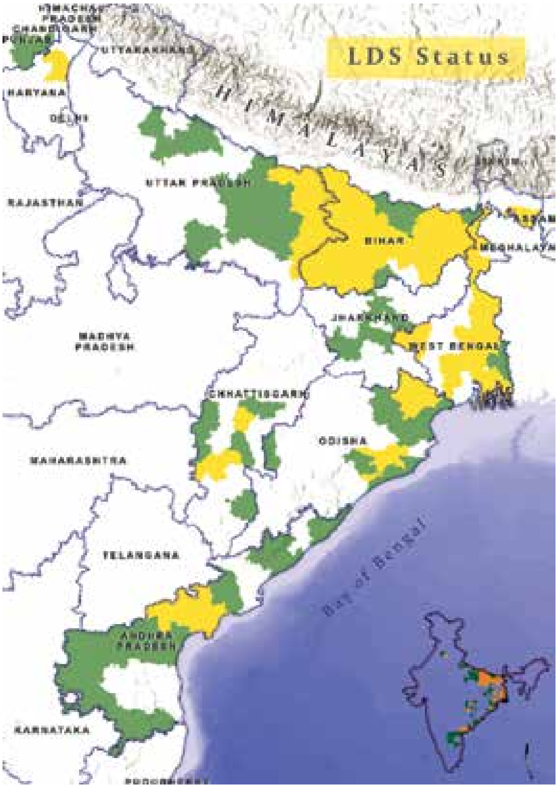
This publication is based on the contributions from Arrindam Samaddar, Anurag Ajay, Ashok Rai, Sachin Sharma, Gokul Paudel and colleagues from Indian Agricultural Statistics Research Institute (IASRI) for methodology, data management and capacity development of KVK and project staff. Cynthia Carmona Reyes, Cynthia Myths, Ajay Kumar Pundir, Shispal Poonia, Anurag Kumar, Madhulika Singh, Shahnawaz Dar, Pankaj Kumar, Prabhat Kumar, Deepak Kumar Singh, Moben Ignatius, Sughanda Munshi, Peramaiyan Panneerselvam, Iftikar Wasim, Bidhan Mohapatra, Nabakishore Parida, Narayan Chandra Banik, Ashok Yadav and 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 rice-wheat cropping system (RWCS) is one of the most important cropping systems in India and covers about 9.5 m ha, with about 90% of this area is concentrated in the Indo-Gangetic Plains (IGP) including Punjab, Haryana, Uttar Pradesh, Bihar and West Bengal. India is heading towards a record wheat production of more than 100 million tonnes during 2018-19, assisted by favourable weather during last few years. However the growth in rice production is slower in the Eastern-Indo Gangetic Plains (EIGP) owing to variable and uncertain monsoon rains. Rice is central to any technical plan of intensifying the RWCS in the EIGP. To respond to slow growth the Government has set a target for doubling the income of farmers by 2022 (Ramesh Chand, 2017). This vision needs strategic planning. To do this, we need to conceptualise and re-design the research and extension interface to generate near-real time evidence, and feedback on what works in farmer's fields.



During the green revolution phase, most projects were implemented with a top-down approach. After the development of second generation problems, farmer participatory processes became more evident. This is because agricultural research and extension was under pressure to deliver impacts. Therefore, we may need more than that. The recommendations generated by Research Institutions and the State Agricultural Universities (SAUs) are not regularly monitored for their acceptability and impact. The lack of monitoring, evaluation and learning discourages dynamism and proper priority setting. Researchers should know what farmers do and want, and set their research priorities accordingly, so that farmers can achieve long term goals of sustained yield growth.

CSISA and the KVK network studied the adoption or use of different technologies across 40 districts of EIGP, two districts of Haryana and three districts of Odisha. This network used mobile-phone or tablet-based Open Data Kit (ODK) software to record observations instead of more traditional time consuming paper based system. In addition to nine training sessions on the methodology, the joint activity of conducting surveys by the KVK staff and CSISA team provided hands-on training to participating KVKs. This has enabled the participating KVK network to conduct a statistically representative Landscape Diagnostic Survey (LDS) to quantitatively assess adoption dynamics and technical performance of technologies at district and regional level. In addition to understanding the use of technology by farmers, the LDS can also be used as part of surveillance program, for example of insects, pests, diseases and weeds problems. In the long run, the LDS database will be made available through an IIASRI portal.

The purpose of LDS is to: (i) undertake monitoring, evaluation and learning (ME&L) about the preferences of farmers and their adoption patterns for recommended technologies; (ii) to provide a feedback to research institutions on what is accepted and what is not accepted and why; and (iii) to suggest better ways of strengthening the convergence of State Departments of Agriculture (DoA) and their State Agricultural Universities (SAUs) through evidence based interventions and policy changes in the scaling process in any given year. This will also help prioritizing services which support transition through subsidies and linking them with other Government schemes. Data generated from LDS, which is transparent and predictable, can be used effectively for real time extension. Overall, it will contribute to improving the dissemination of, and access to, new technologies as the individual KVK can anticipate the changing preferences of farmers and communicate the same to their parent institutions as a feedback mechanism. This phase of the LDS will conclude after completing a survey of approximately 40,000 data points across 110 districts of rice-wheat and rice-rice cropping systems involving eight ATARIs.

The LDS for wheat collected data from 7,855 fields or points including Haryana. These data showed that varietal replacement with timely sown wheat varieties (TSWVs) is 82% in the nine surveyed districts in EUP and 45% in 31 districts of Bihar. Within TSWVs, 10% and 21% HHs from Bihar preferred HD 2967 and PBW 343, respectively. In EUP, the corresponding adoption figures were 49% for HD 2967 and 21% for PBW 343. The adoption of late sown wheat varieties (LSWVs) is now stagnant or declining. In contrast, TSWVs are preferred by 100% of farmers in Haryana. A few years ago early sowing was not practiced, but data now showed that early wheat sowing has been accepted by 18% HHs. The early sown wheat crop is able to survive heat stress during the terminal phase. Data also showed that TSWVs are higher yielding than that of LSWVs at all sowing dates, both early and late. Given that the survey is statistically representative and is an aggregate response across thousands of farmers, TSWVs can be considered as better strategy to manage risk. Perhaps we have reached a tipping point in EUP where adoption of TSWVs will be greater than LSWVs? Based on this evidence, more focus should be put on TSWVs and slowly move away from LSWVs in EIGP.

The average grain yield of timely sown wheat in the LDS was 2.9 t ha^{-1} in Bihar and 3.27 t ha^{-1} EUP, compared to 5.1 t ha^{-1} in Haryana. Average N-use rates are more than the recommended rates at 129-143 kg ha^{-1} in EUP and Bihar, but still lower than the 161 kg ha^{-1} used in Haryana. That suggests there is still room for improvement in the yield growth of wheat, which could come from harnessing the best agronomic management practices such as early sowing, more irrigations, weed management, and no-till systems. We have to leverage and unlock these fundamentals because according to these data sets the issue in EIGP is not lack of varieties or even the soil health. The top 10% of HHs reported wheat grain yield at 6.17 t ha^{-1} in Haryana compared to 4.6 t ha^{-1} in Bihar and 4.71 t ha^{-1} in EUP. Yield gaps below top tenth of HHs were more than 50% but top 10^{th} showed a gap of 24%. Under best management, the yield level of more than 6.17 t ha^{-1} has also been recorded in demonstrations done in EUP and Bihar. This would mean that rather than unfavourable weather conditions, it is better to focus on management which is much better in Haryana. The LDS showed that a grain yield of 5.1 t ha^{-1} can be achieved in the EIGP with early sowing (10 November vs 23 November), 3-4 irrigations vs <2 irrigations, herbicide use vs hand-weeding and line sowing vs broadcasting. Prioritizing the agronomic management is definitely an opportunity and at present it is very relevant for EIGP. Given the better natural resource base in the EIGP, the EIGP should produce wheat yields close to the levels of Haryana and Punjab.

In one year's time, the data collected across 110 districts covering eight Agricultural Technology Application Research Institutes (ATARIs) will be collated. The synchronized data sets will cover rice and two cropping systems, including the major part of RWCS and some part of the rice-rice cropping system (RRCS). Based on the current trends from results of rice, it is evident that except in NW-IGP where varietal turnover is excellent, varietal spectrum in rice in Bihar and Eastern UP is still dominated by old varieties. The evidences however, showed that old varieties like MTU 7029 from long duration group, BPT 5204 from medium duration group, and Sarju 52 from short duration group are yielding same or more than new varieties in the respective groups. How long a variety stays popular with farmers is the best measure for adaptation to unanticipated risks.

The LDS results have provided evidence of a wonderful opportunity to reset the agenda for RWCS in EIGP. The 714 KVKs spread over India provide a great opportunity to conduct research, in the form of monitoring and evaluation of farmer production practices, and help National Agricultural Research and Extension System (NARES) to set priorities at the level of Agricultural Technology Application and Research Institutes (ATARIs). Projects such as CSISA and other ICAR institutes such as *Indian Agricultural Statistics Research Institute* (IASRI) can support and contribute to this vision. IASRI is developing an on-line portal that will manage and visualize the data collected by KVKs in near real-time, allowing front-line staff and decision-makers to quickly understand what farmers are doing in any given location. The evidence on technology adoption and use can help putting a focus on sustainable intensification in the under-performing landscape like EIGP, which is endowed with plenty of natural resources. Choosing a right technology is a matter of judgement; but the judgement should be based on the evidence. The evidence reported here suggested that in EIGP agronomic management needs to be prioritised using multidisciplinary teams as we have in the KVK system.

The processes and systems showcased in this book, using digital data collection and machine learning, and co-developed by CSISA, ICAR and SAUs, are important new initiatives in the research into development continuum. More and near-real time data and data analysis from surveys will enable the KVKs to provide better advice (i.e. what works in their district) as well as focus their own research on key identified constraints. The potential of such evidence based ME&L is substantial and is just the beginning. A broader debate is required.

1. Data collection and its processing methods

1.1 Sampling methodology for crop production practices survey at landscape level in India

A. Samaddar[1], A. Ajay[2], A. Keil[2] and A. Gupta[3]

[1]International Rice Research Institute (IRRI)
[2]International Maize and Wheat Improvement Center (CIMMYT)
[3]Indian Agricultural Statistics Research Institute (IASRI), New Delhi

E-mail: a.samaddar@irri.org

Sampling method is one of the important factors which determines the correctness of survey results. There are many ways of drawing survey samples depending upon the need and situation. If anything goes wrong in selecting samples, survey results get distorted. Cereal System Initiative for South Asia (CSISA) in collaboration with Indian Council of Agriculture Research (ICAR) in India planned to gather information about current crop production practices at large scale. This electronically enabled survey had to be implemented through *Krishi Vigyan Kendra* (KVK) of each district. In 2018, the survey was implemented in 50 districts across five eastern states (Bihar, Uttar Pradesh, Odisha, West Bengal and Chhattisgarh). By 2019, approximately 100 districts have to be covered. 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 have been detailed 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 method – Data are collected in a random sample of 'observation units', typically farm households. Random sampling is required to ensure that the sample is representative of a larger underlying population, e.g. farm households in the district. From each observation unit, the same set of information is elicited using a structured questionnaire. If the observation unit is the farm household, this means that each respondent farmer is asked exactly the same questions. Appropriate statistical methods are used for data analysis. For example, we collect data on wheat 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 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 very 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 relevant aspects during the interviews/discussions, but each such event will differ from the other. For instance, when we discuss a given topic with two groups of farmers separately, the two groups will almost certainly give different kinds of reactions and inputs, leading the discussion in somewhat different directions. It is the task of the researcher 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.

Both quantitative and qualitative methods have their own merits and limitations. None is 'better' than the other; rather, the two approaches complement each other, and which of the two is more appropriate 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 farmers' perceptions are regarding the benefits of these practices and the constraints to their adoption, we need to use the quantitative approach. If we want to delve into great depth or get farmers' views on sensitive or highly complex issues, or we want to investigate particularly contrasting cases/settings, we should pursue the qualitative approach. When, we follow a qualitative approach, we often select the villages where we conduct FGDs or KIIs according to certain criteria, e.g. villages with good market access versus very remote villages;

this means that, in contrast to the quantitative approach, we often use purposive sampling rather than random sampling to select our research villages. Findings from qualitative research cannot be generalized to the population, but they can be used to highlight (contrasting) cases or conditions that require further investigation. Consequently, the sample size (e.g. number of selected villages) in qualitative research is usually very small.

Often, a 'mixed-methods' approach is recommended, combining the strengths of both quantitative and qualitative approaches. Following is an overview of the advantages and disadvantages of the two 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 • More suitable for sensitive or complex issues than 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 the context of field surveys, sampling is a process in which a predetermined number of respondents are 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:

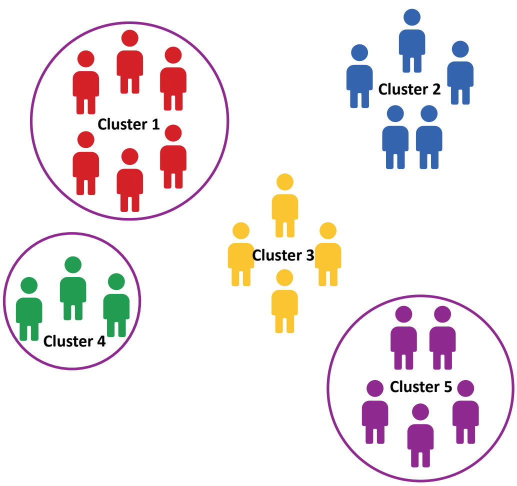
- Probability sampling
- Non-probability sampling

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

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

The ongoing Landscape Diagnostic Survey (LDS) of cereal crops used single stage cluster sampling, a type of probability/random sampling method.

Probability sampling → Cluster sampling Single stage cluster sampling

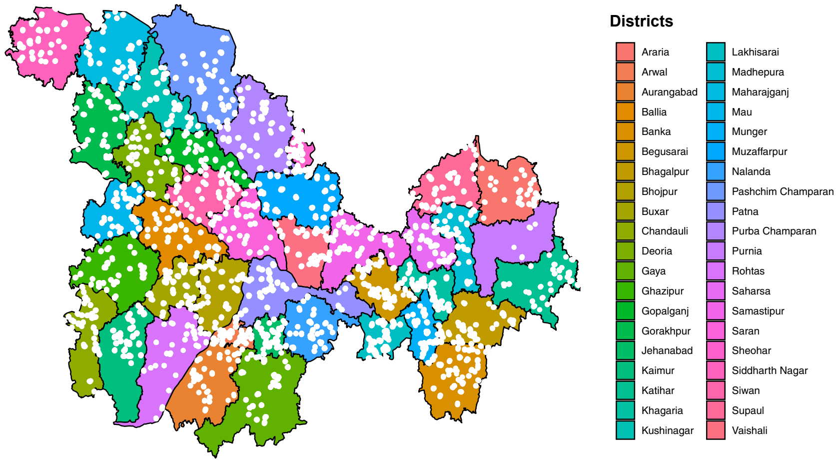


In cluster sampling, entire population is divided into clusters and then the clusters are randomly selected. To apply single stage cluster sampling, samples are drawn randomly from the selected clusters. All the elements of the cluster are used for sampling (Singh, 2018).

Accordingly, LDS 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 then all households of the village

Landscape diagnostic survey (LDS) in Eastern UP and Bihar



Sampling frame: Rural villages with >30 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 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

The larger the sample size, the more precise the 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 we are to detect statistically significant differences between groups (e.g., differences in wheat yields between farmers who sowed before November 15 and those who sowed thereafter). However, the gains in precision decrease quickly at the margin with increasing sample size.

We suggest 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 suggest that sample households be spread across 30 randomly selected villages to capture an adequate degree of across-village variation, e.g. in terms soil conditions, infrastructure, and market access (factors which may influence the outcomes that we are interested in).

Village Selection

Probability proportionate to size 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 a known variable such as number of households. It can also be called unequal probability sampling, because one is 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 the table below:

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 Proportionate 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 contain the number of resident households in each village of a given district.

Household Selection

Once the 30 villages are selected using probability proportional to size 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 the 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, one need to enlist all unique house numbers of the 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. 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 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.

Plot Selection For Crop-Cut

Follow these 10 steps:

- Refer to the selected 7 households in this village
- Select the farmer whom you meet first out of these selected 7
- Ask him for his largest wheat/rice plot – consider this largest plot for crop-cut
- Take farmer's consent for crop-cut
- Crop-cut has to be taken from 2 spots in the selected largest plot
- Size of each of these 2 spots (quadrats) are 2 m × 2 m
- Get on the corner of the plot, move diagonally for almost 5 m and select it as your first spot for taking samples
- Similarly, repeat the procedure from the another corner of this plot and mark second spot
- Finish crop-cut from these two spots and record – total above ground biomass grain weight, and moisture percent
- Use Open Data Kit (ODK) Form – 'Crop Cut Form' to enter these readings along with other basic information asked in this form.

Reference

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1.2 Open data kit for diagnostic crop production survey at landscape level in India

A. Rai[1], A. Ajay[1], S. Sharma[1] and A. Arora[2]

[1]International Maize and Wheat Improvement Center (CIMMYT)
[2]Indian Agricultural Statistics Research Institute (IASRI), New Delhi

E-mail: a.rai@cgiar.org; a.ajay@cgiar.org

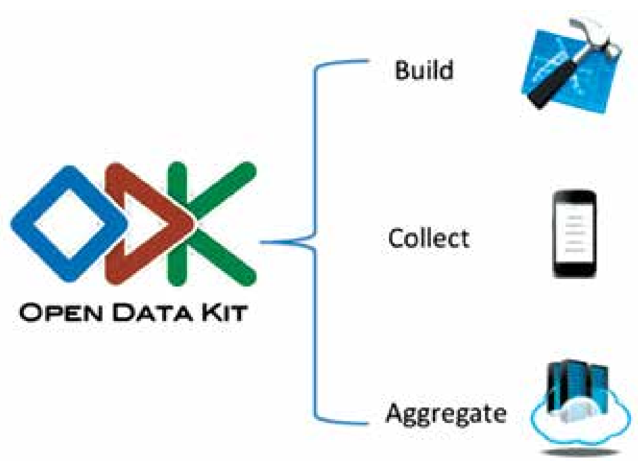
Technologies advancements are bringing great changes in the area of data collection, storage and analysis. Digital data collection (DDC) is a process of collecting data electronically using smart phones, tablets and net-books. This version has significantly improved data quality and reduced resource requirement for field surveys in past few years. Several DDC tools (Kobo, Collect, SurveyCTO, Magpi, Cogo, Insyt, GoSurvey, etc.) have been 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 Agriculture Research (ICAR) in India used Open Data Kit (ODK) for diagnostic survey of crop production practices. In 2018, the survey was implemented in 50 districts across five eastern states (Bihar, Uttar Pradesh, Odisha, West Bengal and Chhattisgarh) through Krishi Vigyan Kendra (KVK) of each district. The survey intended to capture detail information from rice-wheat cropping system so the focus was more on Bihar and east part of Uttar Pradesh along eastern Indo-Gangetic plain. From each district, 210 randomly selected farmers were interviewed in depth for their current crop production practices; approximately 8,000 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 ODK

Developers and researchers at Department of Computer Science and Engineering, University of Washington had founded ODK. ODK began as a Google sponsored sabbatical project in April of 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 large scale survey, data compilation itself require huge resources and task is very much error-prone, whereas, ODK was 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.

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 that can be used with ODK tools.

ODK Collect: It is an Android app that is used in survey-based data gathering. It supports a wide range of question and answer 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:

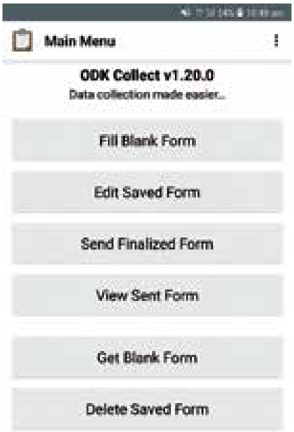
- Host blank XForms used by ODK Collect
- Store and manage XForm submission data
- Visualize collected data using maps and simple graphs
- Export and publish data in a variety of formats

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

- Design the form (questionnaire)
- Download a questionnaire for data collection
- Collect the data, **even if device is offline**
- Submit collected data to ODK Aggregate
- 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 (v1.20.0) 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 are several reasons for preferring ODK in the current landscape diagnostic 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. ODK had been used by CSISA for almost five years for collecting and monitoring data. Considering these factors, it was decided to go with ODK for the current landscape survey. In general, ODK provides other benefits over conventional paper based survey system. The key benefits are as follows:

Cost: There are many elements of cost. Electronic devices of course 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 to analyze and distribute 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 it 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 needs to be re-accessed. Digital data, on the other hand, can be easily and inexpensively stored, copied, and backed up.

Visibility and Tracking: Another important advantage of Digital Data Collection (DDC) 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 is 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 in case of need.

Functionalities

ODK provides wide range of functionalities right at the time of questionnaire designing that improve data quality and restricts users to enter incorrect data. Some of these features are:

Skip patterns: Questions with skip patterns are very common in any form of survey. For example, we may only want to ask a respondent 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 are entirely reliant on the enumerator skills, knowledge of the questionnaire and keenness, leaving plenty of room for error.

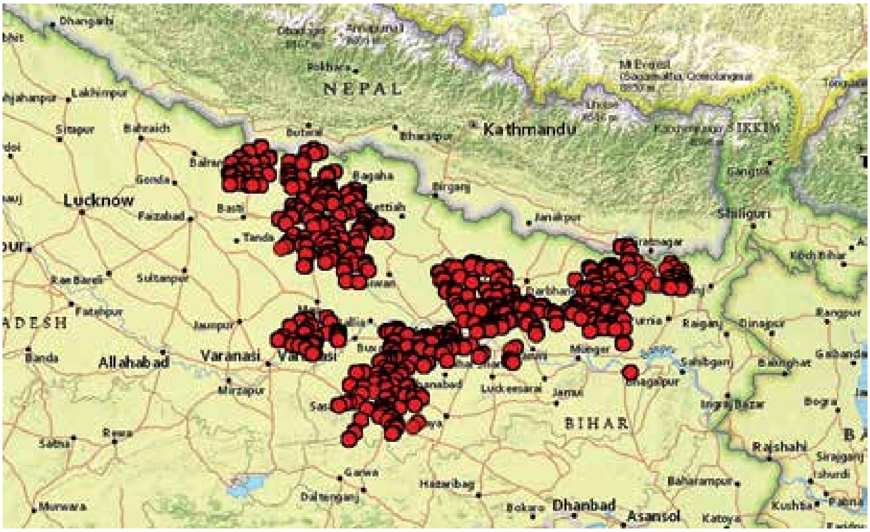
Entry limits: This kind of restriction is usually vital especially for numeric types of questions. For digital surveys, it is possible to restrict entries, by having minimum and maximum values. For example, when taking the second split of urea applied in days after seeding, it cannot be less than the 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 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 don't 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 DDC, 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 is 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 in data we collect through ODK. All the locations (largest plot of respondents) of landscape diagnostic survey henceforth are geo-tagged. It further allows us to layer this data with other parameters such as, soil profile, weather condition, etc. Geo-points of respondents of Bihar and eastern Uttar Pradesh have been furnished below:



Reference

OPEN DATA KIT Documentation. (2017). Retrieved from ODK: https://docs.opendatakit.org/

1.3 Data diagnostic methods for crop production practices survey in India

G. Paudel[1], A. Rai[1], A. Ajay[1] and S. Sharma[1]

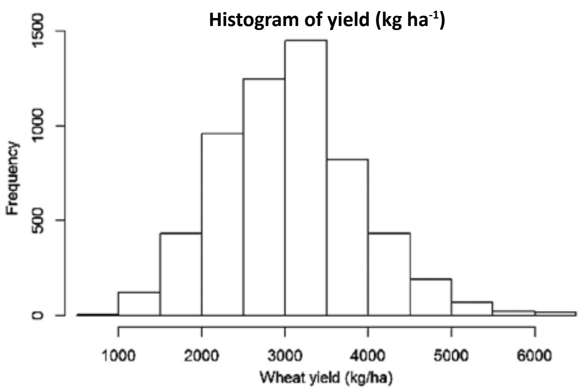
[1]International Maize and Wheat Improvement Center (CIMMYT)

E-mail: g.paudel@cgiar.org, a.rai@cgiar.org

Data analysis is the process of evaluating data using analytical tools to derive useful information for informed decision making. Cereal System Initiative for South Asia (CSISA) in collaboration with Indian Council of Agriculture Research (ICAR), India gathered data through crop production practices survey. By the end of November 2018, data points (5,763) of wheat were available for analysis. The analysis was done using 'R'. The types of analysis applied on this dataset are described here.

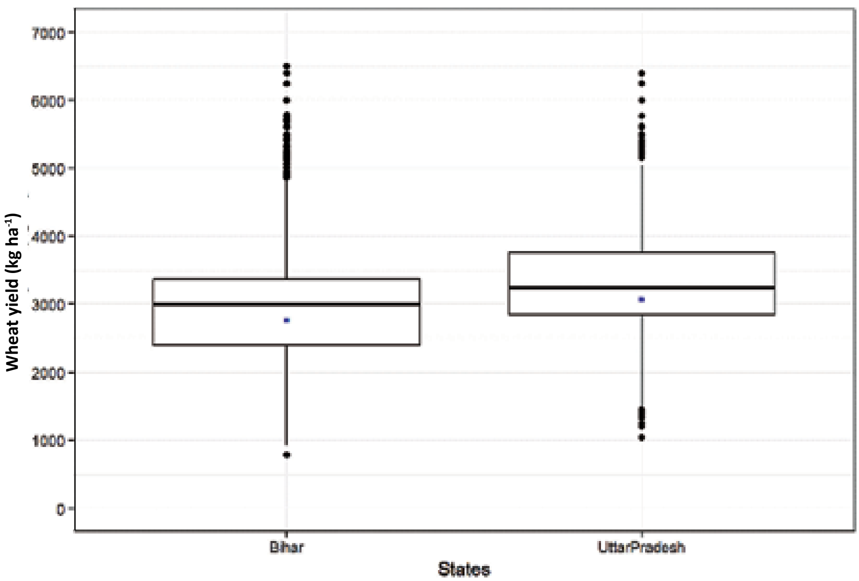
Types of Analysis

Histogram: A histogram, an accurate representation of the distribution of numerical data, is an estimate of the probability distribution of a continuous variable. A histogram relates to only one variable but a bar graph to two variables. To construct a histogram, the first step is to bin (or bucket) the range of values i.e. divide the entire range of values into a series of intervals and then count how many values fall into each interval. Histograms give

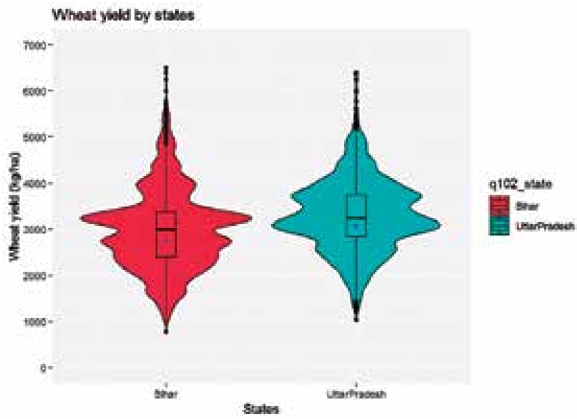


a rough sense of the density of the underlying distribution of data, and often for density estimation. The given histogram is of wheat yield of surveyed farmers.

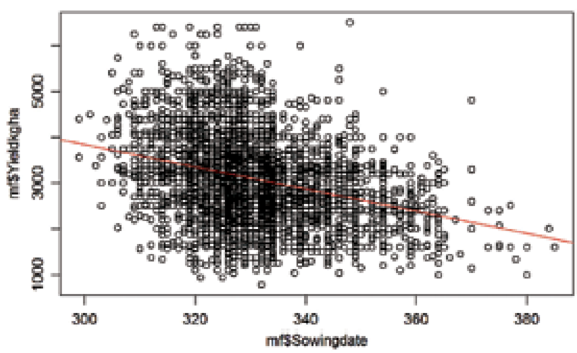
Boxplot: It is a method for graphically depicting groups of numerical data through four quartiles. Box plots may also have lines extending vertically from the boxes (whiskers) indicating variability outside the upper and lower quartiles, hence specifically termed as box-and-whisker plot. Outliers may be plotted as individual points. Box plots are non-parametric: they display variation in samples of a statistical population without making any assumptions of the underlying statistical distribution. Box plots can be drawn either horizontally or vertically. Box plots received their name from the box in the middle. The given boxplot represents wheat yields of two surveyed states.

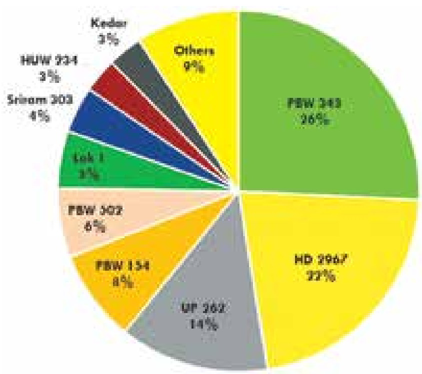


Violin plot: Violin plots are similar to boxplots, except that they also show the probability density of the data at different values, usually smoothed by a kernel density estimator. Typically a violin plot will include all the data in a box plot. So, a violin plot is more informative than a plain boxplot. A boxplot shows summary statistics such as mean/median and interquartile ranges and a violin plot shows the full distribution of the data. The difference is particularly useful when the data distribution is multimodal (more than one peak). In this case a violin plot shows presence of different peaks, their position and relative amplitude. The given violin plot compares wheat yields of two surveyed states.



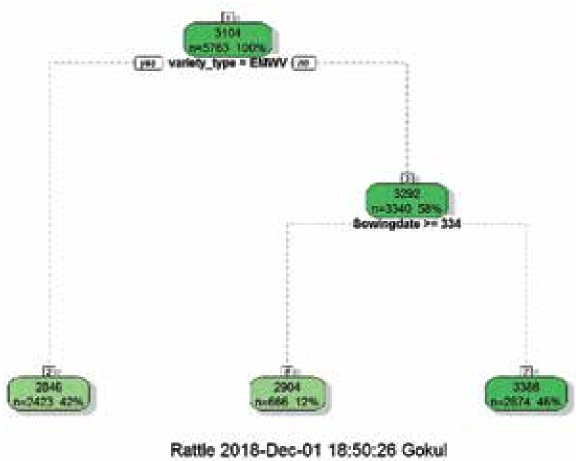
Scatter plot: A scatter plot also called a scatter diagram, is a type of plot using Cartesian coordinates to display values for typically two variables for a set of data. The data are displayed as a collection of points, each having value of one variable determining the position on horizontal axis and the value of other variable determining position on vertical axis. A scatter plot can suggest various kinds of correlations between variables with a certain confidence interval. If the pattern of dots slopes from upper left to lower right, it indicates a negative correlation. A line of best fit (alternatively called 'trendline') can be drawn to study the relationship between variables. The given scatter plot indicates correlation between wheat yield and wheat sowing dates.



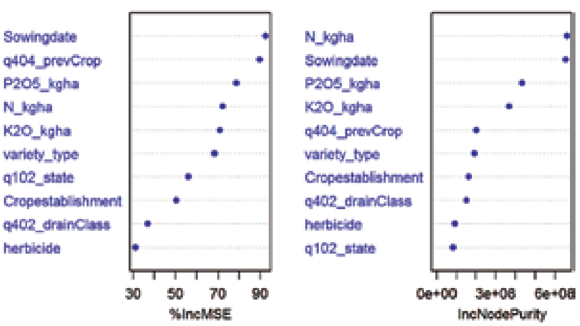


Pie chart: A pie chart (or a circle chart), a circular statistical graphic, is divided into slices to illustrate numerical proportion. In a pie chart, the arc length of each slice (and consequently its central angle and area), is proportional to the quantity it represents. Pie charts are very widely used tool in the business world. It is difficult to compare different sections of a given pie chart, or to compare data across different pie charts. Pie charts can be replaced in most cases by other plots such as the bar chart, box plot or dot plots. The given pie chart shows proportion of farmers using different wheat varieties.

Classification and regression tree (CART): CART is a term used to describe decision tree algorithms that are used for classification and regression learning tasks. A decision tree is a supervised machine learning algorithm. It has a tree-like structure with its root node at the top. Decision tree algorithms are nothing but if-else statements that can be used to predict a result based on data. A classification tree is an algorithm where the target variable is fixed or categorical. A regression tree refers to an algorithm where the algorithm is used to predict its value. The interpretation of results summarized in CART is fairly simple. The given CART predicts wheat yield based on variety type and sowing date.

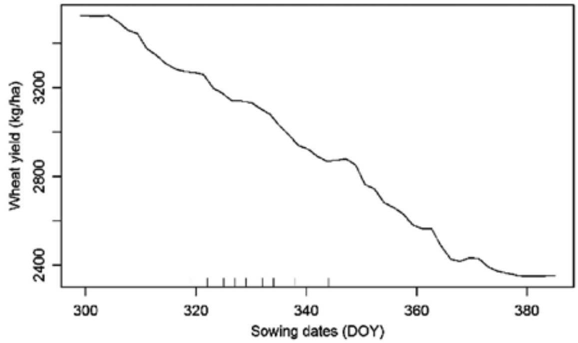


Variable importance plot: Random forests can be used to rank the importance of variables in a regression or classification problem. Variable importance plot provides a list of the most significant variables in descending order. The top variables contribute more to the model than the bottom ones and also have high predictive power. Variable importance is calculated by the sum of the decrease in error when split by



a variable. The relative importance is the variable importance divided by the highest variable importance value. The given plot ranks variables of importance for wheat yield.

Partial dependence plot (PDP): These plots are graphical visualizations of the marginal effect of a given variable on an outcome. Typically, these are restricted to only one or two variables. In linear regression with a single independent variable, a scatter plot of the response variable against the independent variable provides a good indication of the nature of the relationship. If there is more than one independent variable, things become more complicated as this does not take into account the effect of other independent variables in the model.



2. Learnings and priority setting from landscape diagnostic survey database

2.1 Status of wheat varietal spectrum in Eastern Indo-Gangetic Plains: Long duration wheat varieties a win-win emerging scenario

A.K. Singh[1], R.K. Malik[2], Peter Craufurd[2], Balwinder Singh[2], Vartika Singh[3], Andrew McDonald[4], Sudhansu Singh[5], Arrindam Sammadar[5], Ajoy K. Singh[6], Anjani Kumar[1], Ajay Kumar[2], Pankaj Kumar[2], Madhulika Singh[2], Shispal Poonia[2] and Prabhat Kumar[2]

[1]Indian Council of Agricultural Research (ICAR)
[2]International Maize and Wheat Improvement Centre (CIMMYT)
[3]International Food Policy Research Institute (IFPRI)
[4]Cornell University, Ithaca, USA
[5]International Rice Research Institute (IRRI)
[6]Bihar Agricultural University (BAU), Sabour

KEY MESSAGES

- Majority of respondents (100% in Haryana and 54% in Bihar and Eastern UP) prefer timely sown wheat varieties. Grain yield outcome is crucial. Evidences showed that yields of timely sown wheat varieties are the same or better than that of existing popular varieties among late sown wheat varieties.
- Even under late sown conditions, data showed that performance of timely sown wheat varieties (TSWVs) is better than that of late sown wheat varieties (LSWVs). The adoption rate of LSWVs is shrinking even in Easter Indo-Gangetic Plains (EIGP).
- Despite best efforts, the adoption of newly released LSWVs is not reflected in the survey.

Introduction

In 1950-51, the wheat grain yield in India was only 0.66 t ha^{-1}. Beginning of green revolution was in 1967 with the identification of new genotypes like *Kalyan Sona* and *Sonalik*a, which were based on the fundamentals of high harvest index and were semi dwarf and lodging resistant. By 1970s, most farmers realized a breakthrough in breaking the yield barriers. From 1966 till 2018, more than 425 wheat varieties were released in India. During this period two major developments occurred in wheat breeding: discovery of genes responsible for dwarfing and non-lodging habits in 'Norin' wheat varieties; and the development of VEERY lines. In the early 1980s, when the advanced lines derived from the spring x winter cross, their performance was quite the same compared to any previously known high-yielding cultivars. In later tests, these lines were called VEERYs (Villareal *et al*., 1995). The high-yielding cultivars of semi-dwarf wheat have continuously replaced the older tall type varieties at a rate of 2 million ha/year since 1977 (Byerlee and Moya, 1993). Sayre *et al.* (1997) concluded that from 1964 to 1990, yield potential in CIMMYT-derived cultivars increased at a rate of 67 kg ha^{-1} yr^{-1} or 0.88% yr^{-1}. It showed that a yield plateau had not been reached yet. Later on, the performance of wheat lines such as Attilla (PBW 343) which was released in 1996-97, indicated that the yield potential has been further enhanced. However, the gains in the yield growth were seen decreasing (Brown, 1997). Since the release of PBW 343, new varieties like HD 2967 having the same yield potential have been widely adopted. Other factors like degradation of land resources (Pingali and Heisey, 1997) and second generation problems like herbicides resistance (Malik and Singh, 1995), emerging pest and diseases might have also been responsible for this trend. The shift of breeding focus from normal maturing wheat varieties (NMWVs) or timely sown wheat varieties (TSWVs) to early maturing wheat varieties (EMWVs) or late sown wheat varieties (LSWVs) (Mondal *et al*., 2013) especially to beat the terminal heat cannot be expanded because the yield levels are not close to TSWVs. In fact, the progress to develop higher yielding cultivars decreased with every objective added to a breeding program. Ceccarelli (1989) pointed out that the widespread cultivation of some wheat cultivars should not be taken as a demonstration of wide adaptation, since a large fraction of these areas are similar or made similar by use of irrigation and/or fertilizer. Therefore, the term wide adaptation has been used mainly to describe geographical rather than environmental differences. However, such issues have become another point of discussion within India because most successful varieties in EIGP are those which were bred for North-West Plain Zone (NWPZ). The outcomes of this survey hints for a debate within the framework of mega-environments (Rajram *et al.*, 1994). Selected few varieties with a niche for high yields have shown high potential impact across all environments. This study aims to understand the success rate of timely sown wheat varieties (TSWVs) compared to late sown wheat varieties (LSWVs) in improving the wheat yield both in timely and late sown conditions.

Method

The survey of randomly selected farmers with methodology described in Chapter 1 of this document were done immediately after harvesting wheat in 2018; and 7,648 respondents participated in it. The data were collected digitally through Open Data Kit (ODK), an open-source software for collecting and managing data. The households (HHs) were asked the name of the wheat variety sown, date of sowing, source of purchase of seeds, and the total wheat yield realized in the survey season. All the questions corresponded to the largest plot of the household. Since the varietal turnover especially that of late sown varieties is low, the reasons for poor adoption are based on the yield outcomes and the voice of farmers.

Results and Discussion

The collaborative work of National Agriculture Research and Extension System (NARES) of India and International Agriculture Research System (IARS) release number of varieties every year. In the year of release, farmers pay high price for seed but if the yield levels are not as per the promise, the variety goes out of market quickly. The survey based on 7,648 households (HHs) across 31 districts of Bihar and 9 districts of eastern Uttar Pradesh (EUP) suggested that farmers' preference is restricted to few varieties among a pool of more than 62 varieties in Bihar and 23 varieties in EUP. Two broad groups of varieties have been represented in this survey; the early maturing wheat varieties (EMWVs) or late sown wheat varieties (LSWVs) (125-135 days duration) and normal maturing wheat varieties (NMWVs) or timely sown wheat varieties (TSWVs) (135-155 days duration). In our survey, the early maturing wheat varieties (EMWVs) or late sown wheat varieties (LSWVs) group has been used as a check while explaining the results of this survey. This is because historically LSWVs were evolved to reduce the risk of terminal heat and continuous high temperature in wheat growing season in EIGP. The assumption that LSWVs are more suitable to EIGP for counteracting continued high temperature than the NWIGP and also because of early start of terminal heat in the region, does not seem valid in this survey (Tables 1, 2).

Table 1: Frequency (%) and grain yield (t ha^{-1}) of timely sown wheat varieties (TSWVs) with crop cycle of 135-150 days as % age of all varieties within TSWVs (n=4,123) and across TSWVs and late sown wheat varieties (LSWVs) groups (n=7,648)

Variety	No. of respondents	% of households within TSWVs group	% of households across TSWVs and LSWVs groups**	Avg. grain yield (t ha^{-1})
PBW 343	1,616	39%	21%	3.19
HD 2967	1,513	37%	20%	3.46
PBW 502	401	10%	5%	3.17
ShriRam 303	376	9%	5%	3.24
Others*	217	5%	3%	3.23
Overall % households growing TSWVs**			**54%**	

*HD 2733, ShriRam 505, PBW 550, DBW 17, PBW 2076, K 307, WH 711, HD 3086, WH 1105, Dhaulagiri, HD 2781, HD 3059

**Out of 7,648 households 4,123 used TSWVs across all groups and across all dates of sowing

Table 2: Frequency (%) and grain yield (t ha^{-1}) of late sown wheat varieties (LSWVs) with crop cycle of 120-135 days as % of all varieties within LSWVs (n=3,525) and across TSWVs and LSWVs groups (n=7,648)

Variety	No. of respondents	% of households within TSWVs group	% of households across TSWVs and LSWVs groups**	Avg. grain yield (t ha^{-1})
UP 262	885	25%	12%	2.66
Lok 1	621	18%	8%	2.55
PBW 154	588	17%	8%	2.85
Kedar	442	13%	6%	2.57
HUW 234	191	5%	2%	2.50
NL 1	178	5%	2%	2.38
RR 21	164	5%	2%	2.49
Others*	456	13%	6%	2.71
Overall % households growing LSWVs**			**46%**	

*PBW 373, Kundan, Ankur, HI 1563, SUPER 172, HD 2985, GK 7777, C 306, WR 544, Gautam, Baaz, HD 2824, NL 2, Anshu, BL 4341, KW 412, Bansal, Malviya, Aditya, Bhrikuti, BR 26, DBW 14, Diamond, HD 3118, Janaki, Maina, Mico Gold, Pooja, Sabour Nirjal, Suryamukhi, Vijay

**Out of 7,648 households 3,525 used LSWVs across all groups and across all dates of sowing

When we subject this data (varietal turn over) against large number of released varieties in category of others (more than 20), the equilibrium still favors TSWVs. According to data in Table 1, 54% of surveyed households jointly from Bihar and EUP said they adopted TSWVs. The outcome based on very low turnover of LSWVs indicated that we probably overstated the role of these varieties in EIGP. With practically no varietal turnover (Table 2) in this group, gives breeder a chance to rethink over their existing approach to evolve varieties for continued high temperature for whole season to the idea of abrupt rise in temperature during last 10-15 days in the form of terminal heat. Data in Figures 1 and 2 showed that the implications of terminal effects are overlooked and more focused attention is given to continuous (average seasonal temperature) high temperature for evolving heat tolerant varieties. Based on maximum and minimum temperatures data from Air Force Stations of Ambala (Haryana) and Bihta-Patna (Bihar), the yield decline in Bihar in 2004, 2006, 2010 was associated with rise in both maximum and minimum temperature peaks during last 12 days (25 March -5 April) of wheat season. In Haryana also during these years

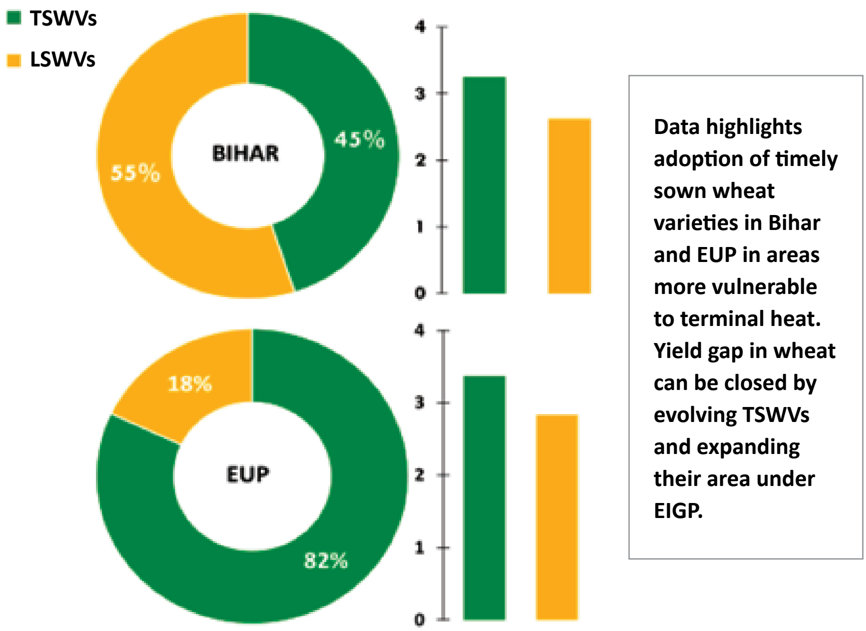
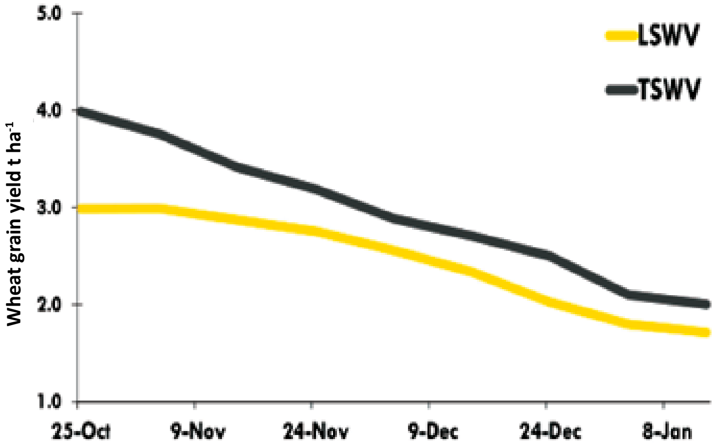


Fig. 1: Compared to late sown wheat varieties (LSWVs), the grain yield of wheat from timely sown wheat varieties (TSWVs) is 24% and 19% higher in Bihar and eastern Uttar Pradesh, respectively



The survey identifies the scope of some promising breeding strategies based on better performance of TSWVs even under late sown conditions. The adoption of some old LSWVs is because of their better grain quality rather than yield performance.

Fig. 2: Compared to late sown wheat varieties (LSWVs), the grain yield of wheat from timely sown wheat varieties (TSWVs) is consistently higher throughout the wheat sowing window in Bihar and eastern Uttar Pradesh

the maximum or minimum temperature rose during these 12 days and affected the yield of wheat. The terminal heat during 10-15 days before maturity occurs twice or thrice probably in every 10 years.

The adoption pattern and preferences of farmers for different varieties with a focus on EIGP show the shaky/risky future of early maturing wheat varieties (EMWVs) or LSWVs.

While looking at the yield levels reported by respondents, the grain yield of TSWVs ranged from 3.17 t ha^{-1} to 3.46 t ha^{-1} (Table 1) against the yield range of 2.38 to 2.71 t ha^{-1} from LSWVs (Table 2). When compared within the TSWVs group, the best yield levels of 3.46 t ha^{-1} from HD 2967 were reported by 37% households (HHs). The segregated data from EUP also showed greater yield trends from TSWVs. That is why the 49% respondents from EUP favored adoption of new variety like HD 2967 (Table 3). The data contain evidences that the consistently high yield levels across different environments were seen to determine the success of any variety, which is contrary to what Ceccarelli (1989) advocated in the past. It is unimaginable to think or clearly understand

Table 3: Frequency (%) and grain yield (t ha^{-1}) of timely sown wheat varieties (TSWVs) with crop cycle of 135-150 days as % of all varieties within TSWVs (n=1,524) and across TSWVs and LSWVs groups (n=1,855) In EUP

Variety	No. of respondents	% of households within TSWVs group	% of households across TSWVs and LSWVs groups**	Avg. grain yield (t ha^{-1})
PBW 343	383	25%	21%	3.22
HD 2967	912	60%	49%	3.45
PBW 502	152	10%	8%	3.26
Shri Ram 303	28	2%	2%	3.58
Others*	49	3%	3%	3.21
Overall % households growing TSWVs**			**82%**	

*HD 2733, PBW 550, DBW 17, PBW 2076, K 307, HD 2781, WH 1105, WH 711
**Out of 1,855 households, 1,524 used TSWVs across all groups and across all dates of sowing

that many new released LSWVs are not finding favor of farmers. Old varieties like UP 262, Lok 1 and PBW 154 released in 1970s have substantial weight of 25%, 18% and 17% within LSWVs group and 12%, 8%, and 8% across combined group of all varieties in 40 districts (Table 2). This becomes more evident in Bihar where 61% respondents reported the cultivations of LSWVs including; UP 262 (27%), Lok 1 (19%) and PBW 154 (15%), within the group of LSWVs (Table 4). Even within TSWVs group, 47% respondents in Bihar adopted PBW 343 released in 1996-97 (Table 5) with yield of 3.2 t ha^{-1} as compared to 3.47 t ha^{-1} of HD 2967. Variety HD 343 is out of seed chain since last almost 10 years. The yield difference might be because of seed availability difference between two varieties. Consistently high yield pressure forces many varieties out of market place. Even very old variety like RR 21 (also known as *Sonalika,* S 308 and HD 1553) is finding favor with 3% farmers in Bihar and 1% in EUP (Tables 4, 6). These results may therefore, be kept as reference point when we weigh the continued low productivity in EIGP. Based on the past experiences (Walker *et al*., 2015; Atkin *et al.*, 2017), absence of any detectable differences in yield, is an odd case where the varietal replacement is not happening. Data also suggested that other factors like *chapatti* making quality and stability may also be at work for the continued adoption of these varieties. Good *chapatti* making quality therefore, seems to have attracted and retained the preference of respondents for these varieties. This, however, opens up

Table 4: Frequency (%) and grain yield (t ha^{-1}) of late sown wheat varieties (LSWVs) with crop cycle of 120-135 days as % of all varieties within LSWVs (n=3,525) and across TSWVs and LSWVs groups (n=5,793) in Bihar

Variety	No. of respondents	% of HHs within LSWVs group	% of HHs across TSWVs and LSWVs groups**	Avg. grain yield (t ha^{-1})
UP 262	859	27%	15%	2.67
LOK 1	621	19%	11%	2.55
PBW 154	470	15%	8%	2.85
Kedar	414	13%	7%	2.57
HUW 234	117	4%	2%	2.32
NL 1	178	6%	3%	2.38
RR 21	154	5%	3%	2.49
Others*	381	12%	7%	2.64
Overall % of households growing LSWVs**			**55%**	

*PBW 373, Kundan, Ankur, HI 1563, SUPER 172, HD 2985, GK 7777, C 306, WR 544, Gautam, Baaz, HD 2824, NL 2, Anshu, BL 4341, KW 412, Bansal, Malviya, Aditya, Bhrikuti, BR 26, DBW 14, Diamond, HD 3118, Janaki, Maina, Mico Gold, Pooja, Sabour Nirjal, Suryamukhi, Vijay

**Out of 5,793 households 3,525 used LSWVs across all groups and across all dates of sowing

Table 5: Frequency (%) and grain yield (t ha^{-1}) of timely sown wheat varieties (TSWVs) with crop cycle of 135-150 days as % of all varieties within TSWVs (n=2,599) and across TSWVs and LSWVs groups (n=5,793) in Bihar

Variety	No. of respondents	% of households within TSWVs group	% of households across TSWVs and LSWVs groups**	Avg. grain yield (t ha^{-1})
PBW 343	1233	47%	21%	3.18
HD 2967	601	23%	10%	3.47
PBW 502	249	10%	4%	3.11
Shri Ram 303	348	13%	6%	3.21
Others*	168	6%	3%	3.24
Overall % households growing TSWVs**			**45%**	

*HD 2733, Shri Ram 505, PBW 550, DBW 17, PBW 2076, K 307, HD 3086, Dhaulagiri, HD 2781, HD 3059

**Out of 5,793 households 2,599 used TSWVs across all groups and across all dates of sowing

Table 6: Frequency (%) and grain yield (t ha^{-1}) of late sown wheat varieties (LSWVs) with crop cycle of 120-135 days as % of all varieties within LSWVs (n=331) and across TSWVs and LSWVs groups (n=1,855) in EUP

Variety	No. of respondents	% of households within LSWVs group	% of households across TSWVs and LSWVs groups**	Avg. grain yield (t ha^{-1})
PBW 154	118	36%	6%	2.86
HUW 234	74	22%	4%	2.77
Kedar	28	8%	2%	2.65
UP 262	26	8%	1%	2.51
RR 21	10	3%	1%	2.41
Others*	75	23%	4%	3.07
Overall % households growing LSWVs**			**18%**	

*Dhanrekha, HD 2824, HD 2985, Kundan, KW 412, Mico Gold, PBW 373
**Out of 1,855 households, 331 used LSWVs across all groups and across all dates of sowing

a question why a specific emphasis is given on evolving LSWVs or early maturing wheat varieties (EMWVs) when their yield levels are 19 to 24% lower (Fig. 1) than TSWVs, even if these are sown late (Fig. 2). The overall average grain yield of TSWVs was 3.29 t ha^{-1} as compared to 2.69 t ha^{-1} for LSWVs with an average date of sowing on 23 November and 2 December, respectively.

Out of 7,648 respondents, 54% grow TSWVs even when the sowings were delayed beyond optimum sowing window; 100 respondents reported the use of TSWVs even under very late sowings. Under very late sown (after 15 December) scenarios, out of a sample size of 7,648, 146 respondents (3%) used TSWVs and 525 HHs (15%) used LSWVs (Tables 7, 8). The average yield level under very late sown scenario was 2.53 t ha^{-1} for TSWVs as compared to 2.15 t ha^{-1} for LSWVs. When sowings are delayed, there is no time available to fit the grain filling period not only for TSWVs but also for LSWVs. Reducing the growth period will further make the variety less productive. Best results will come when we choose right variety and then ensure that it flowers at right time. Since majority of farmers (6,218 out of 7,648) purchased seed from private dealers (Table 9), the seed supply of old varieties which are out of formal seed chain are based on the demand of farmers.

Table 7: Frequency and percentage of TSWVs adopters across 40 districts of Eastern Indo-Gangetic Plains (EUP=9, Bihar=31) and their average grain yield levels (t ha^{-1}) across different sowing schedules

Variety	25 October- 20 November			21 November – 15 December			After 15 December		
	No. of respondents	% HHs	Avg. grain yield (t ha^{-1})	No. of respondents	% HHs	Avg. grain yield (t ha^{-1})	No. of respondents	% HHs	Avg. grain yield (t ha^{-1})
PBW 343	570	14%	3.44	993	24%	3.09	53	1%	2.39
HD 2967	620	15%	3.74	857	21%	3.29	36	1%	2.53
PBW 502	123	3%	3.42	255	6%	3.07	23	1%	2.87
Shri Ram 303	130	3%	3.66	228	6%	3.04	18	0.4%	2.63
Others*	96	2%	3.04	111	3%	2.98	10	0.2%	2.33
Overall	1539	37%	3.59	2444	59%	3.15	140	3%	2.53

Table 8: Frequency and percentage of LSWVs respondents across 40 districts of Eastern Indo-Gangetic Plains (EUP=9, Bihar=31) and their average grain yield levels (t ha^{-1}) across different sowing schedules

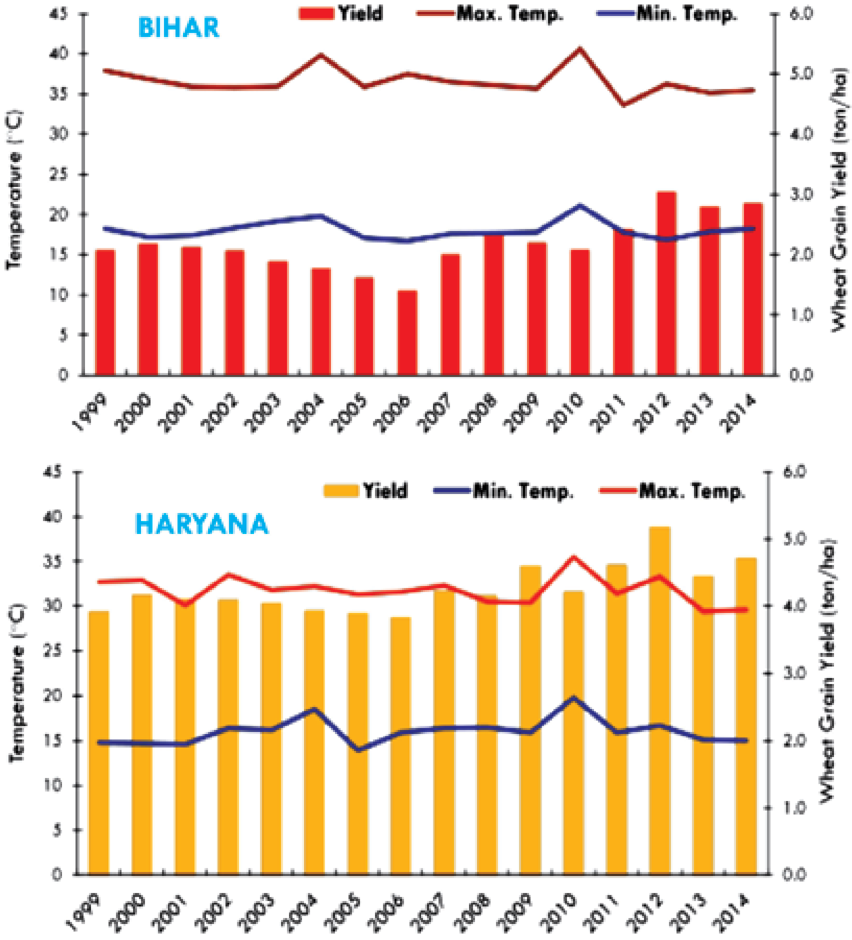
Variety	25 October- 20 November			21 November- 15 December			After 15 December		
	No.of respondents	% of HHs	Avg. grain yield (t ha^{-1})	No. of respondents	% of HHs	Avg. grain yield (t ha^{-1})	No. of respondents	% of HHs	Avg. grain yield (t ha^{-1})
UP 262	187	5%	2.61	610	17%	2.65	88	2%	2.21
Lok 1	87	2%	2.88	410	12%	2.60	124	4%	2.14
PBW 154	118	3%	2.61	423	12%	2.85	47	1%	2.17
Kedar	18	1%	2.98	303	9%	2.75	121	3%	2.06
HUW 234	8	0.2%	3.24	155	4%	2.56	28	1%	1.97
NL 1	64	2%	2.61	112	3%	2.26	2	0.1%	1.85
RR 21	22	1%	2.86	74	2%	2.56	24	1%	2.10
Others*	78	2%	3.06	331	9%	2.61	91	3%	2.22
Overall	582	17%	2.94	2418	69%	2.67	525	15%	2.13

Table 9: Response of surveyed farmers for the source of purchase of wheat seed

Seed source	No. of respondents	No. of respondents (%)
Cooperative	146	2%
Government/ KVK/ SAU	169	2%
Neighbour/ relative	224	3%
Others	3	0%
Private seed Dealer	6,218	81%
Self-saved	888	12%

When data were segregated state wise between EUP and Bihar, 45% respondents in Bihar cultivated TSWVs (Table 5) with a yield range of 3.11 to 3.24 t ha^{-1}. On the contrary, in EUP 82% respondents cultivated TSWVs (Fig. 1; Table 3) with a yield range of 3.21 to 3.58 t ha^{-1}. The corresponding yield levels of LSWVs cultivated by 55% respondents from Bihar were in a range of 2.32 to 2.67 t ha^{-1} (Table 4). These yield levels of 18% respondents who cultivated LSWVs were in a range of 2.41 to 3.07 t ha^{-1} in Eastern UP (Table 6). The adoption of TSWVs is accelerating more quickly in EUP than in Bihar basically because of relatively higher yield levels from TSWVs within EUP. Data showed that most important detriment of varietal adoption is the yield level. Important points for finding value in any variety are given below:

- New varieties should be evaluated at large number of sites across the types of farmers rather than at few sites and with few known farmers before certifying these varieties for farmers use. The decision making has to be driven by bottom-up approach and closely aligned with farmers need for improved yield, quality or both. This will set a new course in the form of transparency.
- Terminal heat during grain filling stage is the single most important variable to yield growth in wheat (Fig. 3). Early maturing wheat varieties are seen as a solution (Mondal *et al.*, 2013) and drew most attention in the past 30 years. However, the results from this survey do not validate this argument. Most important factors for adoption of wheat varieties at farmers fields is all about maximizing yield (Fig. 1) and TSWVs have advantage over LSWVs in terms of yield across the sowing dates. Veery lines as part of selective breeding have been useful for yield enhancement but genetic variation brought for late sowing are not immediately useful because of low yields. It seems that



It is necessary to protect the wheat crop from terminal heat during last 10-15 days of maturity. It would mean that the crop should be sown early so that it is physiologically mature at the time of occurrence of terminal heat.

Note:– *Data on maximum and minimum temperatures from 25-March to 05-April were obtained from Airforce Station Ambala (Haryana) and Bihta (Bihar). The yield data when plotted against average of last 12 days showed that there was a general dip in the yield with increase in maximum or minimum temperature or both. This is a general trend which may also be affected occasionally by factors like poor irrigation management in places like Bihar but not in Haryana where assured irrigation is available.*

Fig. 3: Wheat yield relationship with maximum and minimum temperatures at maturity (between 25-March and 05-April)

studies planned for LSWVs are focusing more on continued high temperature than on the abrupt rise in temperature at the terminal phase of wheat. The risk associated with heat stress at terminal phase (last two weeks) should be factored into future breeding plans.

- The old varieties which were popular since the beginning of green revolution (HD 2009, WL 711, WH 147, HD 2339, PBW 343, PBW 502 and now HD 2967) in a much larger mega -environment in TSWVs group and UP 262, Lok 1, PBW 154, HUW 234 within late sown group within EIGP, have one thing in common. The common trait is high yield and stability at any point of time. Against this background, the adoption rates of so many varieties fell apart within 2-3 years of their release in small pockets. If cross between winter × spring called VEERY lines (PBW 343 and its sister line PBW 502) brought similar transformation with suitability across two mega environments including ME1 of NWIGP (which is highly productive with growing in cool temperatures and suffers terminal heat stress) and the other (Braun *et al.*, 1992) ME 5, comprising eastern Gangetic plain (Tables 5, 7), peninsular India, plains of Nepal and Bangladesh (where continuous high temperature stress is a major concern), it is better to harness this in the long run. These varieties especially TSWVs are good for yield as well as for coping with terminal heat (Fig. 2). Under very late sowings (Tables 7, 8), TSWVs yielded 2.53 t ha^{-1} and LSWVs yielded only 2.13 t ha^{-1}.

- Escaping the terminal heat is at the forefront in the agronomic management in wheat in South Asia. Our results showed that research focus should be on the heat stress in the terminal growth phase of last 10-15 days when the temperature rises abruptly (Fig. 3). Increasing spending on LSWVs or EMWVs and putting special efforts on evolving heat stress tolerant varieties by reducing the growth period is not producing the desired results.

- Old varieties like Lok 1 and UP 262 are still popular with respondents (in EIGP) and not being replaced by new varieties within LSWVs group. What could be the cause of such an imbalance? Data in Tables 1 to 8 conclude that high yield is the best criterion for identifying farmers' favored varieties. To tap into the late sown window, it seems that stability is one criterion but the grain quality has sustained them for so long. For example, RR 21 variety (known by so many names, S 308, Sonalika, HD 1553 etc) which is stress tolerant as well as has high grain quality, is still farmers preference (Table 2). The grain quality includes color and *chapatti* making quality but not necessarily protein or nutrients. The scope of EMWVs is not as good as has been reported (Mondal *et al*., 2013).

The system still seems ambivalent about the long term success of EMWVs or LSWVs. Moreover, if the possibility of rise in temperature is considered, EMWVs will also be vulnerable to terminal heat, if at all, it happens.

Conclusion

Timely sown wheat varieties (TSWVs) or normal maturing wheat varieties perform better or same to that of late sown wheat varieties (LSWVs) or early maturing wheat varieties (EMWVs) under late sown wheat conditions but have yield advantage in timely sowing conditions. What the balance between TSWVs and EMWVs will be in the future, the agenda has to be resolved on priority. With small and marginal farmers in Eastern IGP, even a small missed opportunity will push the variety out of market place. LDS is the right way to select varieties based on what farmers like and what are ground realities.

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2.2 Timely crop establishment of wheat: A self-amplifying strategy for beating the terminal heat in EIGP

R.K. Malik[1], Balwinder Singh[1], Peter Craufurd[1], Andrew McDonald[2], Virender Kumar[3], Arrindam Sammadar[3], Ajoy K. Singh[4], R.K. Sohane[4], Ajay Kumar[1], Pankaj Kumar[1], D.K. Singh[1], Prabhat Kumar[1], Madhulika Singh[1], Amit Srivastava[1], Anurag Ajay[1] and Harshit Rajan[1]

[1]International Maize and Wheat Improvement Centre (CIMMYT)
[2]Cornell University, Ithaca, USA
[3]International Rice Research Institute (IRRI)
[4]Bihar Agricultural University (BAU), Sabour, Bihar

KEY MESSAGE

- Increased focus on early sowing makes sense because it is a foundation to yield growth, a non-cash input with a possible benefit of scale and has geographical reach from NW-IGP to Eastern-IGP.
- The early wheat sowing (EWS) – which was discouraged till 2011 has shown promise to beat the terminal heat in the EIGP.
- Matching varieties and sowing time to achieve flowering time sometime around 15 February can be a good management strategy not only to beat the terminal heat but also to lift the yield potential especially for TSWVs.
- Implementation of policy that promotes early sowing is crucial to increase wheat yields sustainably. Early wheat sowing has positively influenced the grain yield of 18% HHs across EIGP.
- For reducing the turnover time for wheat sowing, the cropping decision in monsoon season is necessary.

Introduction

The most important factor leading to low wheat productivity in eastern India is delayed sowing, leading to terminal heat stress (Harrington et *al.*, 1993; Lobell *et al.*, 2008; Jain *et al.*, 2017). In recent years, data showed that timely or early wheat sowing (EWS) itself has become the surest way to increase and sustain wheat productivity in the region (CSISA Annual Report, 2014, 2015). However, until 2011, the Department of Agriculture (DOA), Bihar used to issue advisories not to sow wheat before 20 November. Changing this recommendation to allow early wheat sowing (EWS) will put wheat yield growth rate on a sustained path of recovery. The effect will be self-amplifying because it will also let farmers adopt timely sown wheat varieties (TSWVs) and improved agronomic management. The study done by Farm Science Centres (also called *Krishi Vigyan Kendras*) has added substantial evidence linking EWS with high wheat productivity in the region. Institutions including Indian Council of Agriculture Research (ICAR), State Agricultural Universities (SAUs) and the state departments of agriculture (DOAs) should converge and work together to develop strategies to create an enabling environment for timely sowing of wheat.

A landscape diagnostic survey (LDS) was conducted in 2018 to document the current wheat sowing trends in farmers' fields and generate evidence on the benefits of early wheat sowing with TSWVs for enhancing wheat productivity in the region.

Method

The survey of 7,648 randomly selected farmers, using the methodology described in Chapters 1, was conducted immediately after harvesting wheat in 2018. Data were collected digitally through Open Data Kit (ODK), an open-source software for collecting and managing data. All important factors that influence wheat yield were included in questions of the survey schedule. Some of the questions were added according to the requirement of different states. The HHs were asked most production practices they follow including the name of the wheat variety sown, date of sowing of the crop and the total wheat yield realized in the survey season. After completing the survey schedule and vetting it through local partners, 30 villages distributed across each district were selected by random method. All the questions corresponded to the largest plot of the household.

Results and Discussion

The low yield growth of wheat in the rice-wheat cropping system (RWCS) of EIGP is a common feature in India. The yield growth in the NWIGP is more than that in EIGP. CSISA-KVK network project team worked with farmers and early wheat sowing was seen as a priority to resolve this issue. Land scape diagnostic (LSD) survey conducted across Bihar, Eastern UP and Haryana (Fig. 1) showed that grain yield of wheat in EUP and Bihar are much below to that in Haryana. The effect of sowing date on wheat yield is clear; late sowing, roughly after 20 to 25 November, reduces yield (Fig. 2). Our survey showed that every 2 weeks delay in wheat sowing translated into a significant decline in wheat yield. Out of total sample size of 7,648, wheat sowing was done before 20 November by 1,232 HHs across 5 districts of Bihar and EUP, and wheat yield ranged from 3.35 t ha^{-1} in Deoria district of UP to 3.71 in Begusarai district of Bihar (data consolidated in Fig. 1) with an average yield of 3.53 t ha^{-1}. When sowings were delayed by 10 days from here, the average wheat yield reported by

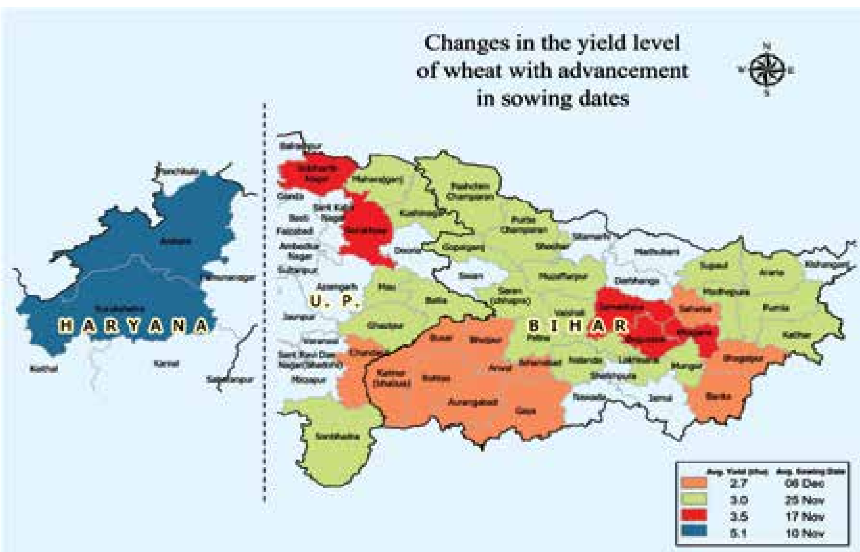
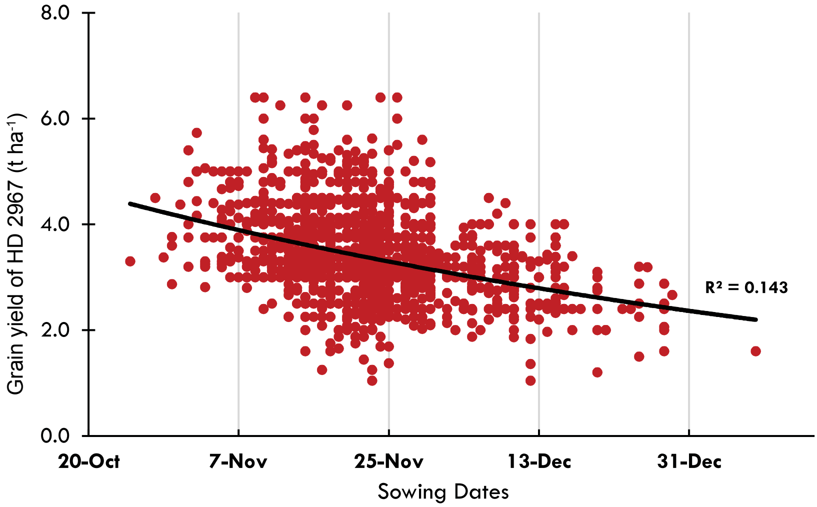


Fig. 1: Effect of average date of sowing on the grain yield of wheat (t ha^{-1}) in Bihar, EUP and Haryana. Only three districts (Begusarai, Khagaria and Samastipur) from Bihar and three districts (Deoria, Gorakhpur and Siddharthnagar) from EUP represented sowing before November 20. The average sowing date in Haryana is 10 November

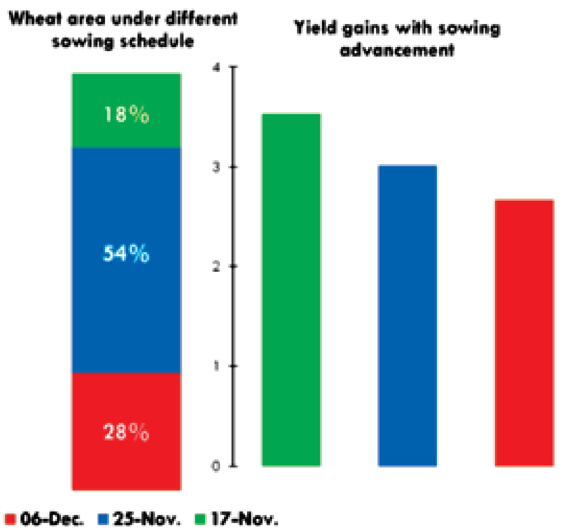


Late sowings and warmer temperature near crop maturity are most associated with low yield of wheat in EIGP. Early sowing is the best strategy to beat the terminal heat. Any effort that helps wheat to reach at physiological maturity at the start of terminal heat will help beating the terminal heat.

Fig. 2: Early sowing is the best option for increasing the productivity of wheat in rice-wheat cropping system of eastern IGP

4,090 HHs across 17 districts was reduced to an average of 3.01 t ha^{-1}. The corresponding average yield from further delay in wheat sowing date by 13 days by 2,326 HHs was 2.68 t ha^{-1} (Data consolidated in Fig. 1).

Data in Fig. 1 compare the grain yield of wheat in different ecologies including Haryana, EUP and Bihar. Data clearly reflected how the effect of time management helped in realizing high yields (5.1 t ha^{-1}) with an average sowing date of November 10 in Haryana and how the yield of wheat reduced if the sowings are delayed in different ecological zones of Bihar and EUP. Such effects are often ignored despite the common belief that the continuous high temperature (Rane *et al.*, 2002; Chatrath *et al.*, 2007) during the wheat growth phase and terminal heat (Lobell *et al.*, 2008) in the last 10-15 days are the most common factors that reduce the wheat yield. The danger of abrupt rise in temperature during the terminal phase is frequently ignored in EIGP. For example the grain yield of wheat in the preceding years (before 2009) was around 2.0 t ha^{-1} in Begusarai district of Bihar when the sowing's were late. However, now the average date of sowing of some districts has advanced to 17 November with an average yield of 3.53 t ha^{-1}. There are indications that the continued high temperature during wheat growth season in eastern India does not necessarily always limits the yield. This has also been reflected in Figure 2 where the grain yield of wheat reduces with each day delayed sowing. This data of 7,648 data points showed that early wheat sowing has to be the top priority intervention, and one that is likely to have more impact than the argument on evolving LSWVs (Rane *et al*., 2002; Chatrath *et al*., 2007; Mondal *et al.*, 2016). The documented evidence that heavy dependence on LSWVs (*refer* Chapter on varieties in this document) has not solved the problem of terminal heat in EIGP. In our dataset (Fig. 3), early wheat sowing was practiced by 18% HHs and late sowing (after 01 Dec) by 28% of HHs. If that 28% and 54% is sown 10 days earlier, then they would potentially have increased their yield by 1.05 mt in 2.97 m ha in the surveyed districts. It showed the potential of bringing wheat sowing area in early window.



Early sowing closed the yield gap by 17% from advancement of average sowing date from 25 Nov. to 17 Nov. and 13% from 06 Dec. to 25 Nov. The wheat area in the districts covered in the survey is 2.97 million ha. Out of this, average sowing (based on % respondents) date is 17 Nov. in 18% area, 25 Nov. in 54% area and 6 Dec. in 28% area. Realistically, we should focus on early sowing to beat the terminal heat in eastern IGP.

Begusarai, Khagaria, Samastipur, Deoria, Gorakhpur and Siddharthnagar

Purnia, Araria, Siwan, Vaishali, Gopalganj, Muzzafarpur, Katihar, Saran, Madhepura, Supaul, Seohar, West Champaran, Nalanda, East Champaran, Lakhisarai, Patna, Munger, Mahrajganj, Balia, Kushinagar, Mau and Gazipur

Bhagalpur, Buxar, Ara, Gaya, Saharsa, Jahanabad, Rohtas, Aurangabad, Kaimur, Banka, Arwal and Chandauli

Fig. 3: Farmers reported grain yield (t ha^{-1}) of timely sown and late sown wheat varieties (2017-18) with advancement in wheat sowing across different districts of Bihar and EUP (n=7648)

The success of early wheat sowing in Bihar came even when a full page advisory on wheat sowing date appeared in the newspapers during 2010 and 2011, where farmers were advised that they should not sow wheat before 20 November. After the field work done by CSISA and KVK network, one advisory came in 2013 where farmers were advised to sow wheat starting from 1 November for higher yield. Now Bihar Agricultural University, Sabour has included this in its recommendations. With the implementation of CSISA project by its NARES partners, an opportunity has been created for advancing wheat sowings in EIGP (CSISA, Annual Report, 2014-15). The support came after getting evidence from the work of CISA-KVK network which showed glaring advantage from early sowings. Such benefits of early sowings may happen due to longer yield formation phase (Hunt *et al.*, 2012), higher water-use efficiency (Gomez-Macpherson and Richards, 1995; Richards *et al.,* 2014) and greater interception of solar radiation (Stapper and Harris, 1989).

Once the EWS becomes an established practice, it will trigger the use of TSWVs which are higher yielder than LSWVs. The trends in the data in this survey showed that it is already happening at farmers' fields and will increase in future because adjusting sowing time is non-monetary input. The link between early sowing and the adoption of TSWVs is also evident from Table 1. Early sowings will increase the adoption rate of TSWVs. Data in Table 1 also showed that TSWVs with high yield potential have performed better than LSWVs. Based on the work done in the past, this data also hinted that even the yield of LSWVs can also be increased by targeting their flowering time so that the effect of terminal heat can be minimized. Optimum flowering time is critical to grain yield as the grain number is determined just prior to or at flowering (Fischer, 1985) and therefore the grain yield is most

Table 1: Performance of Timely and Late Sown Wheat varieties under different sowing schedules across Bihar and EUP (2017-18 LDS Data)

Date schedule	LSWVs		TSWVs	
	Yield (t ha^{-1})	No. HHs	Yield (t ha^{-1})	No. HHs
Till Nov 15	3.13	355	3.70	698
16 Nov - 25 Nov	2.92	1076	3.33	1783
26 Nov - 5 Dec	2.75	1182	3.14	791
06 Dec -15 Dec	2.54	809	2.87	289
After 15 Dec	2.15	549	2.52	116

sensitive to stresses during this period (Giunta *et al*., 1993). Terminal heat stress that occurs at the end phase of the growing season (Reynolds *et al*., 1994) and future warming may further decrease yield. Sowing time can mitigate the effects of temperature, especially which allow the crop to mature prior to experiencing terminal heat stress (Erenstein and Laxmi, 2008). These strategies are particularly important for the eastern IGP where delayed planting of wheat is more common and temperatures are warmer than in the west. EWS is among the best strategies available to cope with extremes at this developmental stage. Further, the combination of management (sowing time) and varieties will be needed to adjust the target of the flowering around optimum time (Anderson *et al*., 1996) in these ecologies. High temperature (>35°C) after anthesis can significantly reduce grain number and quality (Tashiro and Wardlaw, 1990). We must target flowering time (across varieties) to the short period sometime in the middle of February so that enough time is available for grain development. On the contrary, it is theoretically possible when TSWVs are integrated with early sowings, because then more biomass and ground cover developed by wheat will decrease the canopy temperature during terminal period and will help crop stay green for few days. The research done earlier (Jackson *et al*., 1981; Hatfield *et al*., 1987; Reynolds *et al*., 1994) suggested the difference between leaf or crop canopy temperature and air temperature is approximately linearly related to stomatal conductance. The canopy temperature depression (CTD) below air temperature is highly correlated with grain yield. The correlation between temperature depression and biomass remains high. This is reflected in the yield because poor ground cover causes hotter canopy. Even though the ground cover may not be directly correlated with yield but growth during the cooler months can help increasing the biomass.

As might be expected, the link between EWS and TSWVs (Table 1; and Fig. 1) was strongest in Haryana and 5 districts of Bihar and Eastern UP. Therefore, with the case of advancement in wheat sowing, the data on the adoption of TSWVs is worth considering. Data showed that in spite of major focus on the release of LSWVs or EMWVs (Mondal *et al*., 2016), the grain yield of wheat from TSWVs stayed same or more than LSWVS under all sowing dates. It also suggested that the evolution of LSWVs may not compensate the number of grains (Farooq *et al*., 2011) found in the TSWVs. In addition, a heat-tolerant variety will be usually characterized by higher photosynthetic rates reflected in stay-green leaves (Nagarajan *et al*., 2010) which is possible in TSWVs like PBW 343.

It also suggested that the advantage in grain yield is more in eastern UP than that in Bihar. Data also suggested that the scale starts with adding up of management options and TSWVs is one of them. Therefore, matching varieties and sowing time to achieve flowering time sometime around 15 February can be a good management strategy not only to beat the terminal heat but also to lift the yield potential especially for TSWVs.

- The research and extension establishments in EIGP initially had difficulty adjusting to this fundamental change but overtime the system started accepting this fact. Experience of CSISA-KVK network hints at a trend towards advancement in wheat sowing in Bihar and Eastern UP.
- The wheat crop should be programmed to have enough vegetative phase to enter into flowering sometime in the middle of February so that it escapes the terminal heat. This will represent a fundamental change in the way varieties face the terminal heat during last two weeks of its growth cycle rather than for the whole growing season.
- We need to do a lot more to improve the chances of success by focusing on TSWVs. The combination of early sowings and TSWVs will increase wheat yield. Motivation for high yield will be self-serving for farmers to adopt TSWVs. Available trend from this data showed that the pattern towards adoption of TSWVs and EWS is overdue.
- The planting of wheat is closely related to harvest of rice or other monsoon crops. As an example, in some districts like Begusarai, early harvesting of maize or soybean facilitates early planting of wheat; that is why this district has the highest productivity of wheat in Bihar. Late sown wheat seeded with LSWVs has less time to tiller and less time for grain filling and consequently/obviously results in lower yields.
- The average grain yield of wheat of 140 HHs (3% of total HHs) from TSWVs sown after 15 December was 2.53 t ha^{-1} whereas average grain yield 525 HHs (15% of total HHs) from LSWVs in same sowing schedule was 2.13 t ha^{-1}. Data clearly demonstrated that there is no obvious downside of TSWVs when seeded very

late (Table 1). There are no cases in this survey which showed higher yield from LSWVs than that from TSWVs (*refer* Chapter on varieties in this document). Is it not the time to change the breeding strategies?

Conclusion

The work done by CSISA- KVK network for 9 years and the current LDS illustrated that early wheat sowing has yield advantage and also gaining scale. It is much more than what is normally understood. This is only pragmatic approach that will succeed and that would need lot of work in the rice phase for early vacation of fields. Early sowing of wheat in EIGP means longer growing season, more time for photosynthesis, enhanced growth and better response to sudden rise in temperature and capacity to defend the terminal heat. Breeding efforts should therefore focus on crop establishment phase rather than terminal phase.

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2.3 Current tillage and seeding practices: The case for zero tillage

R.K. Malik[1], Balwinder Singh[1], Andrew McDonald[2], Virender Kumar[3], Peter Craufurd[1], Arrindam Sammadar[2], Rajbir Singh[5], P. Adhiguru[5], S.R. Dar[1], S.K. Dubey[5], Ajay Kumar[1], Anurag Kumar[1], Sachin Sharma[1] and Moben Ignatius[1]

[1]International Maize and Wheat Improvement Centre (CIMMYT)
[2]Cornell University, Ithaca, USA
[3]International Rice Research Institute (IRRI)
[4]Bihar Agricultural University (BAU), Sabour, Bihar
[5]Indian Council of Agricultural Research (ICAR)

KEY MESSAGES

- In EIGP, ZT allows early sowings with reduced cost of cultivation and same or more yield than the conventional tillage (CT).
- ZT can help optimising the cropping systems leading to sustainable intensification of cropping system– one of the best way to double the income of farmers.
- The use of rotavator is helping early sowings but we need to fix the immediate problem of yield penalty, increased problem of weed pressure and lodging.
- The long-term impacts of decreased soil quality is another issue that warrants further research.

Introduction

The introduction of zero tillage (ZT) has been a milestone for the improvement of the rice-wheat cropping system (Vincent *et al.*, 2002; Malik *et al.*, 2002). In India, research on ZT for wheat started almost four decades ago (Hobbs *et al.*, 2017). Several State Agricultural Universities

(SAUs) tried zero tillage technology in the 1970s but their efforts failed due to the lack of specialized agricultural machinery in South Asia. The idea of making such drills and attracting private manufacturers became reality from 1983 to 1991 (Harrington and Hobbs, 2009), though the diffusion through innovation and collaboration was a challenge. The reinvention of the entire system (farmers, scientists, private sector and extension agencies) to transform the tillage system from conventional tillage (CT) needed the input from users – the farmers. The rapid adoption and widespread adoption of ZT started from Haryana state (Malik *et al.*, 2002; Laxmi *et al.*, 2007) and ZT is now helping farmers to advance their wheat sowing date, a key factor for higher yield (Ortiz-Monasterio *et al.*, 1994; Jain *et al.*, 2017; Hobbs *et al*., 2017). The evidence provided by Keil *et al.* (2015) showed a gain in wheat yield by 19.4% but the adoption rate is still very low. ZT also supports cropping system intensification. From long-term on-farm trials maintained since 1996-1997, it was found that soil health of ZT plots was superior to CT as studied by Ajeet *et al.* (2015). Data showed that the carbon stock in surface to 0.4 m soil depth increased by 19.0, 34.7 and 38.8% over CT in 15 years in sandy loam, loam and clay loam soil, respectively. Grain yield of wheat and cropping system yields (rice-wheat, pearl millet-wheat and sorghum-wheat) have been higher with ZT in last 20 years in Haryana. The aim of this study was to provide data about the adoption pattern of ZT technology and look at ways to further scale out this technology in Indo-Gangetic Plains (IGP).

Method

The survey of randomly selected farmers (n=7,648) was overtaken with methodology described in Chapters 1-3 and was done immediately after harvesting wheat in 2018. The survey included questions on crop establishment method and seed rates.

Results and Discussion

Although the survey was conducted in all 39 districts (nine in Eastern UP and 30 Bihar) only five districts in Bihar (Buxor, Kaimur, Rohtas, Arah, Begusarai) and four districts in EUP (Gorakhpur, Kushinagar, Maharajganj, Siddharthnagar) were found to be using ZT in wheat (Table 1). In these nine districts, the adoption rate was 10.6% while overall adoption of ZT by surveyed farmers was only 2.4%. This was below expectations. Elsewhere, the broadcast method of wheat sowing was the normal practice of respondent farmers.

Table 1: Effect of method of sowing on the yield of wheat across Bihar and EUP

Crop establishment method	Land preparation method	No. of respondents	Average yield (t ha^{-1})	Std. Dev.
Broadcasting	Cultivator	2279	2.79	0.87
	Cultivator + rotavator	4804	3.07	0.82
	rotavator	125	2.89	0.79
Line sowing	With conventional tillage (cultivator)	272	3.08	1.05
Zero tillage	No tillage	168	3.38	0.82

A rotavator was used by 58% of respondents for crop establishment method of broadcasting (i.e. broadcasting wheat seeds and mixing the seed at a shallow depth by one or two passes of rotavator). The clean field that the rotavator creates impresses farmers. The use of rotavator has spread rapidly, despite its limitations of poorer establishment and lower yields (Paudel *et al.*, 2019). This is in part because of the mindset of farmers, which is based on a very old saying (proverb) 'that intense cultivation is good for high yields' (quoted from Singh, 2012). This proverb has now lost relevance due to the availability of suitable machines, better access to irrigation and herbicides. Meanwhile, a small group of service providers (SPs) and tractor manufacturers see this as a more profitable business (Paudel *et al.*, 2019), and are willing to invest and promote the use of rotavator. In the process rotavator has been promoted without looking at the long-term consequences on soil physical properties and the possible effects on yields.

Comparison of broadcasting and ZT in the nine districts, where ZT was reported is given in Table 2. On an average, the date of sowing was 4 days earlier in case of rotavator users (25 November) compared to ZT users (29 November), an obvious incentive for farmers. However, earlier sowing did not result in higher yields than ZT (Table 1).

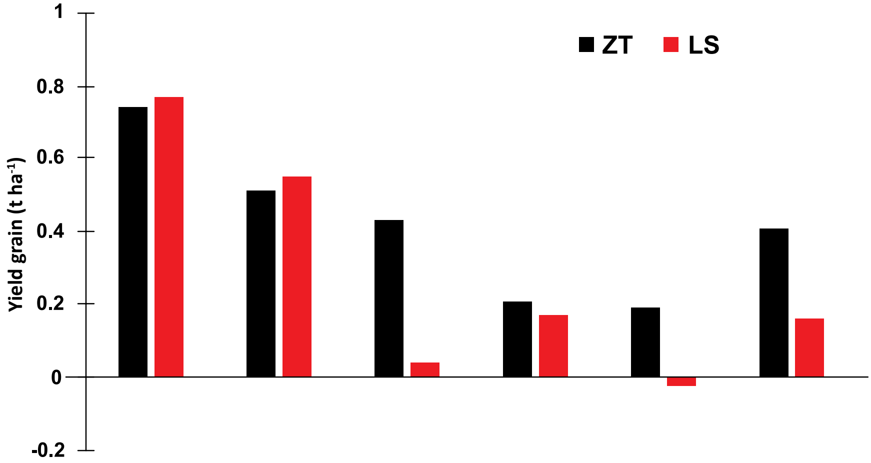
The use of rotavator is not a viable solution because it does not exceed the yield that we may get from ZT or even line sowing (Fig. 1). The past work showed that ZT technology is known to be effective and has the potential for sustained profits (Malik *et al.*, 2002; Hobbs *et al.*, 2017) and significantly higher yield gains (19.4%) in EIGP regions like Bihar (Keil *et al.*, 2015). In another survey done by CSISA project on

Table 2: Effect of crop establishment methods on the grain yield of wheat (t ha^{-1}) across seven districts of Bihar (5) and EUP (4)

State	Districts	Broadcasting			Zero tillage		
		Avg. yield (t ha^{-1})	No. of respondents	Avg. DOS	Avg. yield (t ha^{-1})	No. of respondents	Avg. DOS
Bihar	Arah	2.88	183	4 Dec	3.17	5	9 Dec
	Begusarai	3.67	199	12 Nov	4.31	11	9 Nov
	Buxar	3.00	77	1 Dec	3.24	62	1 Dec
	Kaimur	2.52	157	9 Dec	2.62	32	11 Dec
	Rohtas	2.74	164	9 Dec	2.86	8	7 Dec
Uttar Pradesh	Gorakhpur	3.64	190	18 Nov	3.75	9	19 Nov
	Kushinagar	3.17	175	23 Nov	3.61	20	23 Nov
	Maharajganj	3.31	198	21 Nov	3.43	11	21 Nov
	Siddharthnagar	3.39	188	20 Nov	3.51	5	21 Nov
Overall		3.18	1531	25 Nov	3.26	163	29 Nov

the cost and returns from ZT, it was found that yield of wheat for three years (2011-12 to 2013-14) fell from 4.0 – 4.21 t ha^{-1} range in ZT to 3.1-3.5 t ha^{-1} range in conventional till (CT) fields (Table 2).

The corresponding cases of surveyed farmers showed that the net returns fell from a range of INR 21,117-32,929/ha with ZT farmers to INR 5,799-19,135/ha with CT farmers (Table 3). In the same domain, the sowing time got advanced from 2011-12 to 2013-14 (Table 3). Thus, ZT has the promise to facilitate early sowing and cut cost at the same time. Rotavator also facilitates early sowing but it is less efficient and more costly. There is a trade off. Compared to ZT (Krishna *et al.*, 2017), we will have to look at the lower yield that accompanies (Avtar Singh *et al.*, 2013; Paudel *et al.*, 2019) rotavator use at farmers' fields. In spite of its inferior performance (Tripathi, 2007), and negative effects like sub-soil compaction, creation of hard-pan due to very shallow tillage (Avtar Singh *et al.*, 2013) and reduced pore spaces and poor root growth (Ahmad *et al.*, 2010), the adoption of sowing by using rotavator and broadcasting seeding is happening. Our interaction with farmers have clearly shown that lodging is a serious problem with rotavator. Other problems that farmers told are water stagnation, yellowing of



Sowing Time	Gain with ZT	Gain with LS
Before 10 Nov.	21%	21%
11 – 20 Nov.	15%	17%
21 – 30 Nov.	14%	1%
01 – 10 Dec.	8%	6%
11 – 20 Dec.	8%	-1%
After 21 Dec.	19%	8%
Overall	14%	9%

2.5% households have adopted zero-tillage technology. The relative grain yields of wheat across ecologies and agronomic management are more in zero-tillage and line sowing. This intervention needs more attention both for improving the system productivity and better environmental footprints.

Fig. 1: Yield advantage through zero-tillage (ZT) and line sowing (LS) over broadcasting method establishment across ecologies

wheat leaves after first post sowing irrigation and more population of *Phalaris minor*, the most troublesome weed of wheat and which is showing resistance against herbicides (Malik *et al.*, 2002). There is no yield gain from rotavator based seeding but farmers are mentally satisfied because they see the clean field. Data in Fig. 1 indicated that the magnitude of increase in yield of wheat established by ZT or line sowing is more than broadcast method. When sowings are delayed, the magnitude of yield increase is lower. That is why the benefit from ZT is more when the sowings are done on time or say early. Some of

Table 3: Cost and return (INR) analysis of zero tillage and conventional tillage (broadcasting method) based on survey of adopters and non-adopters of zero tillage

Cost & Return Heads	2011-12		2012-13		2013-14	
	ZT	CT	ZT	CT	ZT	CT
Seed	2,420	2,860	2,975	3,425	3,136	3,948
Crop establishment (machineries)	1,393	4,655	1,737	4,613	2,070	5,032
Fertilizer	3,726	4,956	5,310	5,796	5,640	5,962
Irrigation	4,363	5,237	5,472	6,417	4,704	
Labour (crop establishment & care)	2,730	2,838	2,143	2,318	1,920	2,303
Harvesting + threshing + post harvest	10,990	9,923	6,710	7,300	6,435	5,972
Total cost	25,622	30,470	24,348	29,870	23,905	28,114
Gross return	46,800	36,270	51,400	42,405	56,835	47,250
Net return	21,177	5,799	27,051	12,534	32,929	19,135

the service providers are not using this in their own field but use only on custom hire basis. The state extension agencies want to help but that help comes at the cost of ZT. It took almost 40 years to encourage line sowing in wheat but it took less than 5 years to bring it back to square one by encouraging seed broadcasting rotavator mixing for crop establishment in wheat. The exposure of ZT to the direct competition from rotavator through policy intervention has caused a shift from ZT to rotavator based crop establishment method. It happened in leading states like Haryana but farmers are again coming back to ZT. Due to subsidy, there has been aggressive expansion in the market of rotavators by the manufacturers. In the same process, the increased income from service charges by service providers (SPs) has more to do with business proposition than benefits to farmers. This business perspective, in fact, has masked the weakness of lower yields or long-term consequences on soil physical properties or re-emergence of resistance in weeds like *Phalaris* in some ecologies. This has been happening even if the cost and return analysis favours ZT in these areas (Table 3). ZT will lower costs and increase the yield at the same time. Starting from Haryana the decision of farmers to adopt zero tillage on large scale and in a short possible time was because farmers aspirations for herbicide resistance management were fulfilled with sustained yield growth (Malik *et al.*, 2002; Erenstein *et al.*, 2007; Erenstein and Laxmi, 2008; Coventry *et al.*, 2011).

Moreover, if we look at the business perspective for service providers (SPs), dealers, machine manufactures and even tractor manufacturers, rotavators provide multiple perspective in the value chain of mechanization. In ZT however, the lower costs and higher yield provide much better and sustainable business perspective through service provisions. High seed rate (Fig. 2; Table 3) and cost of crop establishment, fertilizer, irrigation and labour is another worry with broadcasting method. Seed saved should be considered as seed produced. Even otherwise also higher seed rate increases plant density but intra-plant competition results in taller stems of reduced diameter with weak anchorage (Curtis, 2002). Shallow seeding and weak stem makes the crop susceptible to lodging which is a serious problem with rotavator. Very heavy rains in February-March during 2016-17 and 2017-18 caused serious losses in wheat in few pockets. Based on the current survey of two districts in Haryana, the number of rotavator users has reduced. There are few other reasons to worry. With subsidy in place, the adoption is faster even at the cost of low yield (compared to ZT) and in this survey (Table 1), poor root growth, soil compaction,

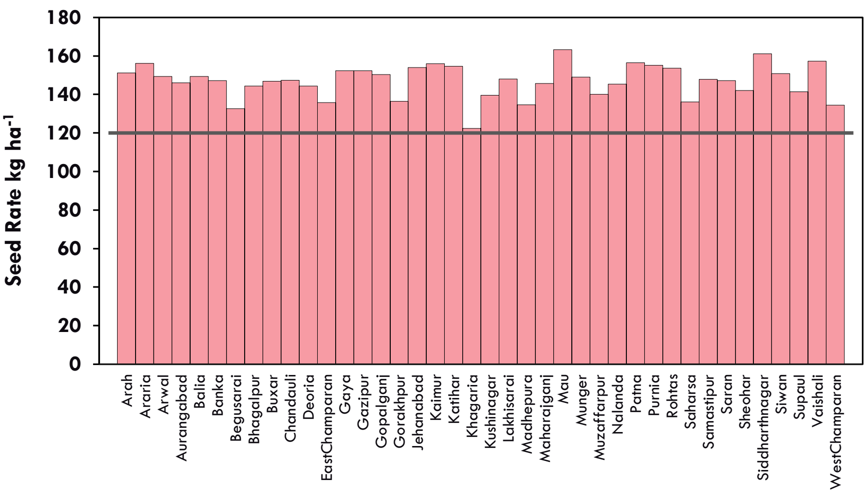


Fig. 2: Seed rate of wheat across EUP and Bihar (n=7,648). The seed rate is mostly based on broadcasting method as only 2.5% of the households used zero-tillage. Seed rate of 120 kg ha^{-1} is slightly above the recommended rates

more weed problem (Karayel and Ozmerzi. 2003; Avtar Singh *et al.*, 2013) and long term soil degradation are associated with rotavator sowing. Rotavator adversely affects the system in several other ways including high seed rate as given in Fig. 2 and staggered maturity and small size of ear heads. This is because the proper placement of seed and fertilizer is not possible with rotavator (Singh *et al.*, 2007). Based on the complexities of decision making and historical perspective of frequent tillage, we propose that Department of Agriculture (DOA) to regulate and launch an awareness program about ZT as a much better option. This is also something which the DOA may need to regulate, while deciding the subsidy. The experience showed that there is a need to dilute the culture of subsidy and instead focus on creating service providers who then serve other farmers so that the technology goes to the smallest farmer. With 20-25% poverty rate in EIGP (Planning Commission, 2014), the diffusion of ZT is slow compared to NWIGP. With this being the core of its strategy, we have created 3,641 SPs for ZT with a growth of more than 25% per year since 2011. Proximity to ZT service provider (< 5 km) is important prerequisite to ZT use especially in districts (other than three given in Table 1) which are still poorly covered. With this approach, the use rate of ZT from 2012-13 to 2015-16 by small, medium and large farmers increased by 55, 35 and 21%, respectively (Keil *et al.*, 2019, unpublished data). Out of 25 cited references, 13 have shown significant yield gains under ZT but none has shown any yield penalty (Krishna *et al.*, 2017).

Recently we have gone through two interventions for sustainable intensification of cropping system; these include ZT and rotavator. Both technologies save time and facilitate timely crop establishment. The ZT improves yield and soil health but rotavator has some yield penalty and the clean field gives a cosmetic look. The comparison of ZT with rotavator may bring some differences with the scientists who are associated with rotavator but our strategic interests in yield and long term soil properties must be explained and researched. For the department of agriculture, it is better to switch the facility of subsidy from rotavator to ZT drills.

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2.4 Mismatch of irrigation explains the poor efficiency of fertilizer and high yielding wheat varieties in EIGP

Balwinder Singh[1], Andrew McDonald[2], Peter Craufurd[1], R.K. Malik[1], Madhulilka Singh[1], Prabhat Kumar[1], Sachin Sharma[1], Anurag Kumar[1], Deepak Kumar[1], Shahnawaz Dar[1] and Pankaj Kumar[1]

[1]International Maize and Wheat Improvement Centre (CIMMYT)
[2]Cornell University, Ithaca, USA

KEY MESSAGES

- In wheat, 80% of farmers use between two and three irrigations; only a tiny minority do not irrigate or use five irrigations.
- Yield increases on average by about 0.5 t ha^{-1} with each additional irrigation.
- The yield of both timely sown wheat varieties (TSWVs) and late sown wheat varieties (LSWVs) responds similarly to irrigation.
- The yield response is higher in upland than lowland ecologies.
- The yield response to irrigation is slightly higher at early (<30 November) than late (>30 November) sowings.
- Irrigation increases the partial factor productivity of nitrogen from 17.3 kg grain per kg N with zero irrigation to 32.9 kg grain per kg N with five irrigations.

Introduction

The assured irrigation in Punjab and Haryana has ensured sustained productivity, with average wheat grain yields of more than 4.5 t ha^{-1}. Most farmers in progressive states have access to a well-developed system of tube-wells and canals, and are also provided with highly subsidized electricity for pumping water for irrigations (Khan and Hanjra, 2008; Scott and Sharma, 2009). In contrast, access to and adoption of irrigation has been far more limited in the Eastern Indo-Gangetic Plains (EIGP), largely because irrigation in the EIGP is based on costly diesel based pumps. Low farm productivity due to small farm sizes (Hirashima, 2001) also impacts the investment decisions on irrigation, especially at critical stages of wheat. This is one of the most important reasons why wheat yields in EIGP, especially in Bihar, are significantly lower than that in Punjab. The adoption of green revolution varieties in these ecologies can be transformative if the access to irrigation is increased. To understand current practice and the promise that irrigation has in harnessing the yield potential of this region, the LDS in Bihar and Eastern UP included questions on irrigation type and frequency.

Method

The survey of 7,648 randomly selected farmers, using the methodology described in Chapters 1-3, was done immediately after harvesting wheat in 2018. The data were collected digitally through Open Data Kit (ODK), an open-source software for collecting and managing data. The households (HHs) were asked the name of the wheat variety sown, date of sowing of the crop, source of irrigation, application of irrigation at different stages, no. of irrigations, decisive factors for irrigating the plot, use of pump for irrigation, energy source for the pump, use of lay flat pipe for irrigation, application of mineral fertilizers, and the total wheat yield realised in the survey season. All the questions corresponded to the largest plot of the household.

Results and Discussion

Number of irrigations

The number of irrigations in the survey ranged from zero to five and yield ranged from 1.5 to 4.7 t ha^{-1}, though only in the case of early sowings were five irrigations used by 14 farmers. Most farmers (80%) used two or three irrigations. Further grain yield of TSWVs sown before 30 November increased from 1.99 t ha^{-1} with zero irrigation to 4.70 t ha^{-1} with five irrigations (Table 1). From Fig. 1, which shows TSWVs and LSWVs yields grouped by planting before and after 30 November, we can see that across both varieties and planting dates, the response to the number

Table 1: Farmers reported grain yield of wheat (t ha^{-1}) as affected by no. of irrigations, sowing schedule and two groups of varieties including timely sown wheat varieties (TSWVs) and late sown wheat varieties (LSWVs)

No. of Irrigations	Till 30th November				After 30th November			
	TSWVs		LSWVs		TSWVs		LSWVs	
	Avg. yield (t ha^{-1})	No. of respondents	Avg. yield (t ha^{-1})	No. of respondents	Avg. yield (t ha^{-1})	No. of respondents	Avg. yield (t ha^{-1})	No. of respondents
0	1.99	2	0.97	4	1.70	3	1.21	18
1	2.95	362	2.37	296	2.12	79	1.87	289
2	3.27	1688	2.74	1004	2.79	350	2.40	770
3	3.53	1108	3.11	516	3.03	255	2.74	494
4	4.31	220	3.77	74	3.23	42	3.18	60
5	4.70	14	NA	NA	NA	NA	NA	NA

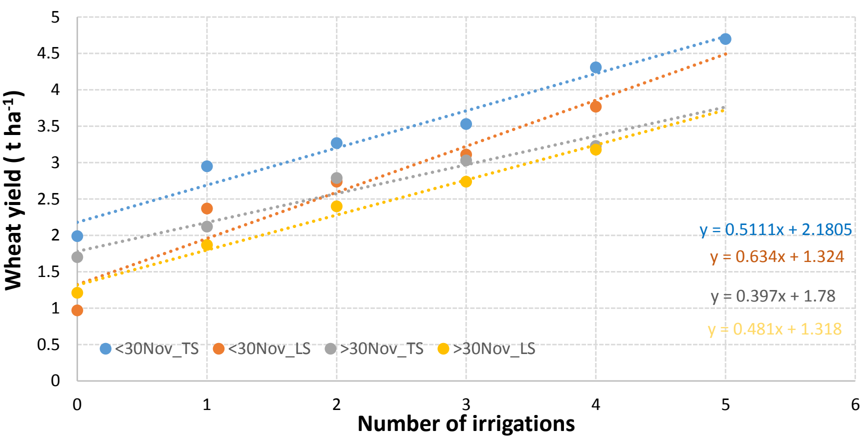

Fig. 1. Relations between grain yield and number of irrigations in TSWVs and LSWVs planted before and after 30 November (modify as needed, include zero irrigation points as well; but do not regress through zero)

of irrigations was similar and linear. At plantings before 30 Nov. for both TSWVs and LSWVs, yield increased by 0.50-0.60 t ha^{-1} for each additional irrigation. So, although LSWVs have a lower yield potential than TSWVs, their response to irrigation was similar. With later plantings, yield also responded positively to irrigation, but at a slightly lower rate (0.40 to 0.48 t ha^{-1} per irrigation). As expected, yields were lower with late sowing. These ecologies generally have continued high day and night temperatures which depress photosynthesis (Acevedo *et al*., 2002) during the day time and have more dark respiration (García *et al*., 2015) during night time, any shortage of irrigation will nearly always reduce crop biomass and yield.

Based on the background of continued high temperature in EIGP, breeders have focused on early maturing varieties (Mondal *et al.*, 2016), (referred as LSWVs in this paper). In Chapters 48 and 49 we have argued that TSWVs are better than LSWVs under all circumstances and clearly the farmers will get better returns from irrigation by planting TSWVs rather than LSWVs. Since lack of irrigation is a major constraint to increasing production in the Eastern Gangetic Plains (EIGP), reducing crop duration could save 10% water (Reinke *et al*., 1994) but the reduced duration will always reduce yield potential and hence water productivity (Williams *et al*., 1999) as has been seen in this survey (Table 1). There is in fact, a need to amplify the potential of TSWVs through irrigation management (Fig. 1).

Timing of irrigation

The effect of both frequency of irrigation and the stage of irrigation on grain yield on TSWVs and LSWVs sown before and after 30 November is shown in Table 2. Only 17% households (HHs) applied three irrigations, including one at flowering or at milk stage. Only 3.2% HHs reported a third irrigation at milking stage. Irrigation at crown root initiation (CRI) stage is practiced by most HHs. Out of these, 29% HHs apply irrigation both at CRI and at flowering stage and 14.5% apply irrigation at CRI and at jointing stage. Comparing irrigation of TSWVs sown before 30 Nov, we can see that yield increases as follows:

- a single irrigation at CRI or tillering = 2.97 t ha^{-1};
- two irrigations at CRI + tillering or jointing = 3.25 t ha^{-1};
- three irrigations at CRI + tillering or jointing + jointing or flowering or milking = 3.53 to 3.66 t ha^{-1};
- four irrigations at CRI + tillering + either two of jointing, flowering or milking = 4.1 to 4.49 t ha^{-1}.

Given that most farmers currently use two irrigations, there is a considerable scope to raise yield with one or two additional irrigations. To further increase the yield from here, the irrigation at flowering or milk stage,

Table 2: Effect of stages of irrigation on the farmer's reported yield (t ha^{-1}) of Timely Sown Wheat Varieties (TSWVs) and Late Sown Wheat Varieties (LSWVs) seeded before and after Nov. 30

Irrigation Stages	Till 30th November				After 30th November			
	TSWVs		LSWVs		TSWVs		LSWVs	
	Avg. yield (t ha^{-1})	No. of respondents	Avg. yield (t ha^{-1})	No. of respondents	Avg. yield (t ha^{-1})	No. of respondents	Avg. yield (t ha^{-1})	No. of respondents
Crown root initiation (CRI)	2.96	348	2.38	277	2.18	73	1.88	260
Tillering	2.98	11	2.24	17	0.94	2	1.85	15
Pre-seeding + CRI	3.36	49	2.93	12	2.77	5	2.46	12
CRI + tillering	3.25	915	2.76	573	2.83	212	2.41	478
CRI + jointing	3.26	559	2.78	284	2.64	85	2.36	184
CRI + flowering	3.42	125	2.58	104	2.95	39	2.46	61
Pre-seeding* + CRI + tillering	3.35	234	3.08	35	3.14	32	2.72	37
Pre-seeding* + CRI + jointing	3.68	22	2.96	10	3.21	6	2.16	10
CRI + tillering + jointing	3.58	248	3.03	117	2.93	97	2.63	186
CRI + tillering + flowering	3.48	278	3.16	219	3.03	59	2.89	145
CRI + tillering + milking	3.29	40	3.02	24	3.23	6	2.87	17
CRI + jointing + flowering	3.66	123	3.17	43	3.26	16	2.85	36
CRI + jointing + milking	3.59	99	3.12	32	2.99	24	2.66	32
Pre-seeding* + CRI + tillering + jointing	3.85	27	3.37	15	2.98	4	3.11	7
CRI + tillering + jointing + flowering	4.12	70	3.93	24	3.12	17	3.05	22
CRI + tillering + flowering + milking	4.49	51	3.73	15	3.37	7	3.18	11

*Pre-seeding irrigation is practiced by only 6% households across eastern UP and Bihar or both, is necessary, especially at sowings before 30 Nov. Our earlier studies in the same ecology also showed that the irrigation variables are important factors in explaining yield variation within the IGP (Jain *et al.*, 2017). To get tangible impact, irrigation at flowering or milk or both can be another way to beat the terminal heat.

In RWCS, it is critical to make use of residual moisture from the rice phase by sowing crop immediately after rice harvest (Erenstein and Laxmi, 2008; Blackwell *et al.*, 2004). This is because the rainfall during the second half of rice growing season is sufficient especially in the low land ecologies. This survey also confirmed this as only 1.7% respondents' use pre-sowing irrigation (Table 2). After saving one irrigation prior to seed bed preparation, one irrigation (70 mm) at crown root initiation (21 DAS) and one last irrigation no later than mid-March for crops sown on time and one irrigation in between these stages preferably at late jointing stage is a must. Farmers can make decisions for fourth post sowing irrigation. This will have a total water use of 210-280 mm. For good harvest, wheat needs 400 mm water which is used as evapotranspiration (ET). In these ecologies, where water table is not so deep, farmers do not see any major yield penalty even if they do not provide irrigation for 100% ET requirement. This becomes even more important because the depth of irrigation is very shallow in these ecologies. Moreover, with diesel based irrigation, farmers cannot bring the soil profile with 100% field capacity. The evapotranspiration in wheat is at its peak at the flowering stage (Ferguson, 1965). Water shortage during the three or four weeks after flowering along with high temperature at the grain developing stages leads to poor grain growth and less yield. With possibility of rainfall equivalent to one irrigation, the total water use will be 240 mm. With diesel based costly irrigation system, depth of irrigation is very low in EIGP and hence, it rarely makes it to 240 mm.

Yield response in different ecologies

The LDS covers a wide range of wheat growing ecologies, including lowland and upland ecologies. The yield levels at different irrigation frequencies are better in upland ecologies than lowland ecologies of Bihar and yield difference ranged from 0.2 to 0.6 t ha^{-1} at same irrigation level under both ecologies (Table 3). By and large, farmers in upland of Samastipur and Vaishalli favour TSWVs and while farmers in lowland Ara, Buxor and Rohtas plant both TSWVs and LSWVs. Planting date in lowland ecologies did not change the preference for variety group (Table 3).

Table 3: Response of different irrigation frequencies on the grain yield of wheat (t ha^{-1}) under timely and late sown conditions of lowland (Arah, Buxar, Rohtas) and upland (Samastipur, Vaishali) ecologies of Bihar

Districts Group	No. of Irrigations	Till 30th November				After 30th November			
		TSWVs		LSWVs		TSWVs		LSWVs	
		Avg. yield (t ha^{-1})	No. of respondents	Avg. yield (t ha^{-1})	No. of respondents	Avg. yield (t ha^{-1})	No. of respondents	Avg. wyield (t ha^{-1})	No. of respondents
Lowland ecologies (Arah, Buxar, Rohtas)	1	3.00	4	2.62	3	2.07	7	1.98	3
	2	3.13	43	2.82	46	2.86	79	2.65	94
	3	3.20	87	2.99	52	2.90	90	2.63	68
	4	3.76	12	3.28	5	2.94	8	2.79	8
Upland ecologies (Samastipur, Vaishali)	1	3.21	20	2.75	1				
	2	3.44	219	3.07	37				
	3	3.50	109	3.67	3				
	4	4.38	6	4.40	1				

Irrigation and nutrient management

As we have shown above, varieties showed a strong yield response to the number of irrigations. We might expect that rates of fertiliser application would also vary with the number of irrigations, and in this section, we examined this question. Table 4 shows the rates of N, P and K application with irrigation frequency. Farmers clearly realised that with none and one irrigation, applying high rates of fertiliser is not warranted, with rates of N for example 60 and 30 kg ha^{-1} respectively below the rate used with two irrigations. However, what is most striking from Table 4 is that farmers really do not change their fertiliser application rate much at all when they irrigate more frequently than twice. This is despite, yield levels increasing from 2.91 kg ha^{-1} to 4.70 kg ha^{-1}. If we examine the partial factor productivity (PFP) of N use with irrigation, i.e. yield per unit N applied, then we see that with no irrigations it is 17.3 kg grain per kg N, which is very low. With one to three irrigations the efficiency increases to about 22 kg grain per kg N, rising to 32.9 kg grain per kg N with five irrigations (Fig. 2). These PFP values would suggest that actually rates of fertiliser application are too

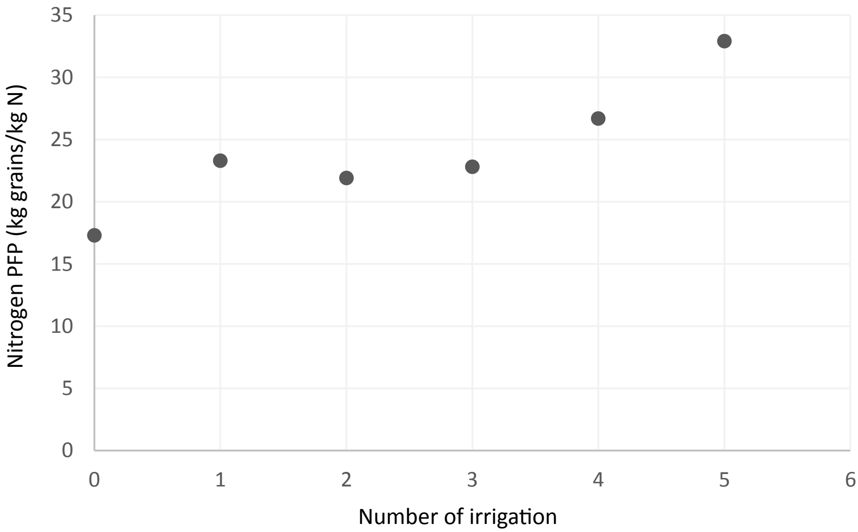

Fig. 2: Nitrogen partial factor productivity under different irrigation levels

high at lower irrigation frequencies. Indeed, if a PFP of 32.9 kg grain per kg N was achieved with five irrigations, for example, then only 88.4 kg N would be needed.

Because of high cost, farmers neglect irrigation management (an average of only 2.3 irrigation) in favour of more spending on the use of fertilizers. Across Bihar and Eastern UP, respondents have focused more on the use of fertilizer without any associated increase in the irrigation frequency (Table 4) Data showed that there is temptation of more fertiliser use, with 50 % farmers using N: P_2O_5:K_2O use at 133:60: 21 kg ha^{-1} at irrigation frequency of 2.0. But it is also evident from the data that the response of fertilizer increases with the increase in irrigation frequency. With slight increase (app 10 kg ha^{-1}) in the dose of nitrogen, the increase in the grain yield of wheat is at 3.22, 3.92 and 4.71 t ha^{-1} at 3, 4 and 5 irrigations, respectively. This is, in fact, the response of irrigation not fertiliser. On the whole, in these ecologies, N rates are relatively high but irrigation levels are sub-optimal. If farmers do not invest in irrigation, the required benefits of high nutrient rates cannot be realised. In fact, irrigation is required to carry nutrients within soil and plant. When sufficient moisture is not available, the absorption of N from the soil is reduced with significant adverse impact on yield. Studies elsewhere suggested that the interaction of irrigation and nitrogen level on the length of ear head is significant (Shirazi *et al*., 2014). The

Table 4: Effect of irrigation frequencies on the fertilizer use pattern and its effect on grain yield of wheat (t ha^{-1}) across all ecologies of EUP and Bihar

No. of irrigations	N (kg ha^{-1})	P_2O_5 (kg ha^{-1})	K_2O (kg ha^{-1})	Avg. yield (t ha^{-1})	n
0	74	42	14	1.28	27
1	104	53	19	2.42	1,026
2	133	60	21	2.91	3,812
3	141	61	17	3.22	2,373
4	147	64	21	3.92	396
5	143	65	24	4.70	14
Overall	**132**	**59**	**20**	**2.99**	**7,648**

efficiency of N fertilizer is low as the average yield levels are around 3.0 t ha^{-1}. Since, most fertilizer N was taken up between tillering and anthesis (Garabet *et al.*, 1998), any water shortage at these stages will reduce the efficiency of both nitrogen and irrigation. There is, therefore, a need to embark on opportunities by keeping a balance between nutrient and irrigation management. Since wheat is rotated with rice, which is again highly fertilized, the irrigation management becomes even more relevant in this scenario. Similarly, due to uncertainties associated with lodging, farmers generally decide not to irrigate at grain filling stage. This is not always true. Lack of irrigation at grain filling will shorten the grain filling duration and reduce the yield. The decrease in the yield by terminating irrigation at milk or dough stages has also been reported by Guttieri *et al.* (2001). Therefore, the irrigation variables are important factors in explaining yield variation within the IGP (Jain *et al.*, 2017). In the eastern IGP, farmers primarily rely on less developed canal networks and use unsubsidized and expensive diesel pumps to draw irrigation (Kishore, 2004). It is therefore, plausible that yields in Bihar could be raised higher than regional optimal levels if policies and technologies are introduced to enhance irrigation access and reduce pumping costs similar to that in Punjab.

Conclusion

The LDS survey is part of an exercise that helps us to understand where the problem is. There is a mismatch between the amounts of fertilizer farmers add and how it is utilized by plant due to lack of timely irrigation. Data illustrated that current fertiliser use pattern cannot sustain its yield advantage without matching irrigation levels. While tracking the irrigation levels and the response of applied fertilizer, it is evident that 50% respondents when applied N: P_2O_5:K_2O at 133:60: 21 kg ha^{-1} increased wheat yield to 2.9 t ha^{-1} compared to 2.4 t ha^{-1} at 104: 53:19 kg ha^{-1} and 1.28 t ha^{-1} at 74:42:14 kg ha^{-1}. These yield levels were at 2, 1 and 0 irrigations, respectively. Beyond two irrigations, the increase in yield was not due to fertilizer use but majorly due to increase in irrigation levels. The tendency for improvement in the efficiency of added fertilizer with increase in the irrigation levels was evident. Access to irrigation is bigger concern than nutrient management for improving the total factor productivity. Irrigation has to be leveraged for better nutrient management. This clarity warrants for policy decisions to improve irrigation infrastructure in EIGP.

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2.5 Good agronomic management is needed to keep momentum on yield growth through nutrient management in Eastern Indo-Gangetic Plains

Balwinder Singh[1], Shispal Poonia[1], Andrew McDonald[2], Peter Craufurd[1], Vartika Singh[3], Ajoy K. Singh[4], S.K. Singh[5], Anurag Kumar[1], Pankaj Kumar[1], Madhulika Singh[1] and R.K. Malik[1]

[1]International Maize and Wheat Improvement Centre (CIMMYT)
[2]Cornell University, Ithaca, USA
[3]International Food Policy Research Institute (IFPRI)
[4]Bihar Agricultural University (BAU), Sabour, Bihar
[5]Indian Council of Agricultural Research (ICAR)

KEY MESSAGES

- Even after adopting more than or recommended rates of nitrogen and phosphorus, farmers are facing the challenge of ensuring high agronomic efficiency.
- The agronomic efficiency (AE) of N is very low due to poor management of factors other than nutrient management.
- There is a perception that soil health is related only to nutrient management, which is not the case. To find solutions for extremely poor AE, we should incentivise farmers to make better choice for best-bet agronomy rather than focusing on manipulations within nutrient management.
- We should not overload farmers with high doses of nitrogen and phosphorus if the wheat sowing is done in the last week of November or first two weeks of December or if farmers are using late sown varieties (LSWVs) instead of timely sown varieties (TSWVs), or if farmers are not using appropriate weed management or if farmers are applying only 2 irrigations.

Introduction

The rice-wheat cropping system (RWCS) is the most common cropping system in the Eastern Indo-Gangetic Plains (EIGP) districts of Bihar and Eastern Uttar Pradesh (EUP). Nutrient management is often seen as the most important variable that affects wheat yield. However, the yield response to added fertilizer is not in line with expected gains in comparison with the North-West IGP. There are certain critical areas in the whole agronomic management cycle to ensure best efficiency from the existing recommendations on nutrient management. One of the goals of landscape diagnostic survey (LDS) in 40 districts of Bihar and Eastern UP was to find out the reasons for low productivity and low nutrient-use efficiency of wheat in RWCS given that fertilizer use is almost similar to that are being followed in higher productivity North-West IGP (Punjab and Haryana). The rest of this chapter describes, first, the use of nitrogen (N), phosphorus (P) and potash (K) in Eastern UP and Bihar and its relation to yield; and second shows how management factors affect the response and especially the efficiency, measure as partial factor productivity of N.

Results

Nitrogen

Results of survey carried in 40 districts of EIGP revealed that farmers are using recommended or more than the recommended rates of nitrogen (N) and phosphorus (P). The use of N is well targeted with almost 99.7% respondents using N at rates ranging from 104 to 152 kg ha^{-1}. The overall N use (based on 5,778 farmers) was 128.9 kg ha^{-1} in different agro-climatic zones of Bihar with an average yield of 2.90 t ha^{-1}. Average N-use was 142.5 kg ha^{-1} from nine districts of Eastern UP (based on as 1,850 farmers) with an average grain yield of 3.28 t ha^{-1} (Fig. 1; Table 1).

Within the nine districts of Eastern UP (Table 1), it was found that wheat yield ranged from 2.86 to 3.65 t ha^{-1}. It was also observed that in Chandouli and Mau districts, wheat yield levels were 2.86 and 3.08 t ha^{-1}, respectively, at 140.6 and 141.5 kg N ha^{-1}. In districts like Mahrajganj, Kushinagar and Siddarthnagar, the use of N was comparatively lower (127.9, 134.1 and 126.6 kg ha^{-1}) but yields attained were higher (3.35, 3.23 and 3.39 t ha^{-1}) than that in Chandouli and Mau districts.

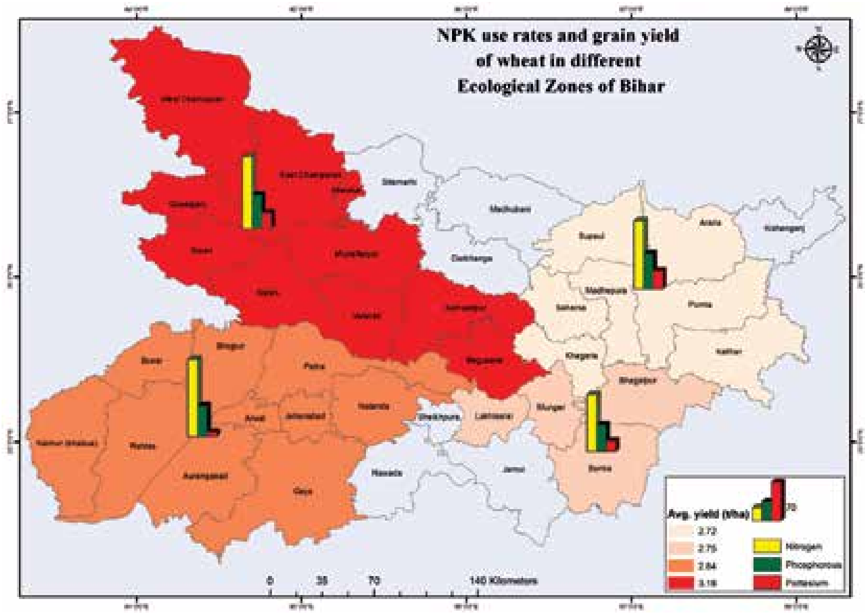


Fig. 1: Grain yield of wheat as influenced by $N:P_2O_5:K_2O$ rates in different zones of Bihar

The higher N response from surveyed farmers in Mahrajganj, Kushinagar and Siddarthnagar districts is because of better agronomic management, including early sowing, more irrigations and better weed management (Hobbs *et al.*, 1998). Similarly, a comparison of yield trends of surveyed farmers of different climatic zones of Bihar revealed that grain yields in Zone IIIA (Southern-East), Zone II (Northern-East), Zone IIIB (Southern-West) and Zone I (Northern-West), respectively, were 2.73 (784), 2.75 (981), 2.78 (1970) and 3.18 (2043) t ha^{-1} (Fig. in parenthesis are number of respondents) at average N application of 104.4, 124.5, 140.1 and 131.7 kg ha^{-1}. Lower wheat yield of 2.78 t ha^{-1} in Zone IIIA (Southern-East) compared to 3.18 t ha^{-1} in Zone I (Northern-West), besides more N application, is due to delayed wheat sowing in Zone IIIA (Southern-East) ecologies and the use of LSWVs which have less yield potential (Table 2) than that of TSWVs. Results are also confirmed that when application of N was done in different splits, the yield levels also increased. The yield in TSWVs was 3.13 (22), 3.14 (833), 3.32 (3067) and 3.65 (191) t ha^{-1} when sole N was applied as basal, basal with 1 split application, basal with 2 split applications and basal with 3 split applications, respectively. The trend was similar in

Table 1: Average grain yield of wheat across management practices as affected by farmers reported variable rates of $N:P_2O_5:K_2O$ kg ha^{-1}

District	Nitrogen		Phosphorus		Potassium	
	Average N (kg ha^{-1})	Yield of N users (t ha^{-1})	Average P_2O_5 (kg ha^{-1})	Yield of P_2O_5 users (t ha^{-1})	Average K_2O (kg ha^{-1})	Yield of K_2O users (t ha^{-1})
Balia	148.15 (216)	3.24 (216)	62.43 (216)	3.24 (216)	24.71 (216)	3.14 (141)
Chandauli	140.64 (208)	2.86 (208)	58.72 (208)	2.85 (204)	03.45 (208)	3.14 (31)
Deoria	151.18 (209)	3.35 (209)	62.20 (209)	3.35 (207)	11.39 (209)	3.35 (105)
Ghazipur	158.69 (210)	3.33 (210)	76.02 (210)	3.33 (210)	09.04 (210)	3.37 (63)
Gorakhpur	151.55 (210)	3.65 (210)	61.93 (210)	3.66 (204)	14.06 (210)	3.67 (107)
Kushinagar	133.42 (195)	3.23 (194)	57.65 (195)	3.24 (188)	20.11 (195)	3.17 (151)
Mahrajganj	126.05 (210)	3.35 (207)	56.77 (210)	3.36 (206)	16.46 (210)	3.40 (128)
Mau	140.79 (204)	3.08 (203)	61.77 (204)	3.08 (202)	12.25 (204)	2.92 (90)
Siddharthnagar	126.59 (193)	3.39 (193)	58.50 (193)	3.40 (174)	15.62 (193)	3.36 (113)
Overall average of EUP districts	142.12 (1855)	3.28 (1850)	61.85 (1855)	3.28 (1811)	14.11 (1855)	3.29 (929)

Table 2: Farmers reported average yield of wheat for timely and late sown wheat varieties as affected by nitrogen application done at different stages of crop growth

No. of Applications	Timely sown wheat varieties (TSWVs)		Late sown wheat varieties (LSWVs)	
	Average yield (t ha^{-1})	Std. Dev.	Average yield (t ha^{-1})	Std. Dev.
No application	1.68 (n=10)*	0.77	1.35 (n=10)	0.22
All N as basal application	3.13 (n=22)	0.86	2.44 (n=26)	0.80
Basal with 1 split application	3.14 (n=833)	0.85	2.47 (n=1,134)	0.78
Basal with 2 split applications	3.32 (n=3,067)	0.81	2.73 (n=2,231)	0.68
Basal with 3 split applications	3.65 (n=191)	0.99	2.75 (n=124)	0.77

*Value in parenthesis represent no. of respondents

LSWVs and corresponding yield levels were 2.44 (26), 2.47 (1,134), 2.73 (2,231) and 2.75 (124) t ha^{-1} for respective N application practices (Table 2). The magnitude of increase in grain yield was less in LSWVs than in TSWVs.

Effect of phosphorus

In EIGP, fertilizer use rates are more skewed towards phosphorus. The overall average of P_2O_5 among P users was 59.4 kg ha^{-1} in different agro-climatic zones of Bihar and 63.4 kg ha^{-1} in Eastern UP districts. If comparison is further segregated zone wise in Bihar, it is concluded that in Zone IIIA (Southern-East), Zone IIIB (Southern-West), Zone I (Northern- West) and Zone II (Northern-East), the average P_2O_5 kg ha^{-1} use was 49.8, 57.1, 62.7 and 65.0, respectively (Fig. 1). In nine districts of Eastern UP, the maximum P_2O_5 kg ha^{-1} used was 76.0, 64.9 and 63.6 in Ghazipur, Siddharthnagar and Gorakhpur, respectively, whereas least use of 57.8, 59.8 and 59.9 prevailed in Mahrajganj, Kushunagar and Chandauli, respectively. The average wheat yield of P_2O_5 users in Bihar was 2.91 t ha^{-1}, whereas Eastern UP districts it was 3.28 t ha^{-1}. Maximum P_2O_5 application of 76.0 kg ha^{-1} was done in district Ghazipur and wheat grain yield was just 3.33 t ha^{-1}, whereas in districts Mahrajganj and Gorakhpur respective P_2O_5 application rates were lower, i.e. 57.9 and 63.7 kg ha^{-1}, and wheat yields were 3.36 and 3.66 t ha^{-1}, respectively, which was much higher than Ghazipur. Higher yield level in some districts at lower P application is because of early sowings (Table 1).

Effect of potash

Potassium users were fewer in both Bihar (66.5%) and Eastern UP (50.0%) (Fig. 3). The average K_2O applied by user HHs across different climatic zones of Bihar was 32.1 kg ha^{-1} with wheat yield 2.98 t ha^{-1}, whereas, in different districts of eastern UP this rate was slightly lower at 28.2 kg ha^{-1} with yield 3.29 t ha^{-1} (Table 1). However, K-use varied substantially with an average of only 7.9 kg ha^{-1} in Zone IIIB compared with 33.4 kg ha^{-1} in Zone II in Bihar. Ballia and Ghazipur were only two districts where K use was more than 30 kg ha^{-1}. Like Bihar, in Eastern UP, yield was not in accordance to rate of K application. Maximum yield 3.67 t ha^{-1} among K users in these ecologies was observed in Gorakhpur with K_2O application @ 27.6 kg ha^{-1}. The least yield 2.92 t ha^{-1} among K users in these ecologies was observed in Mau with K_2O @ 27.8 kg ha^{-1}.

Discussion

The development of high fertilizer-responsive rice and wheat varieties resulted in a dramatic rise in productivity and production in the RWCS (Bijay-Singh *et al.*, 2003). These responses are a function of yield potential of varieties. Even the highest grain yield of 3.04 t ha^{-1} (n=4,995 HHs) in case of farmers who applied more than recommended doses of N (120 kg N ha^{-1}) is too low compared to previous survey done in Haryana (Sher Singh *et al.*, 2010). Out of 7,648 surveyed farmers, only 19% or 1,488 farmers used FYM. This seems better than Punjab and Haryana (Sheoran, 2003). With much better natural resource base and more use of FYM in these two states than Haryana, the yield advantage due to fertilizer use is not as high as it should be.

Grain yield at the same N and P use is highest in maize-wheat cropping system, which is because of early sowing due to early vacation of maize fields (Table 3). The partial factor productivity (PFP) of N in Bihar and EUP were 24.3 and 24.7 kg grain yield per kg N, respectively. To increase PFP, we need good growing conditions that improve crop metabolism and proper source-sink relationship. This is not happening as most factors such as sowing time, irrigation and weed management (Fig. 2) that improve plant growth are sub-optimal in these ecologies. Only 10 HHs reported zero nitrogen use with wheat grain yield of 1.68 t ha^{-1} with TSWVs and 1.35 t ha^{-1} with LSWVs. Although in the absence of enough data on the yield of wheat without nitrogen, it is difficult to access the agronomic efficiency (AE), but approximate trends do indicate negative AE with bottom 30% performer HHs with lowest yields.

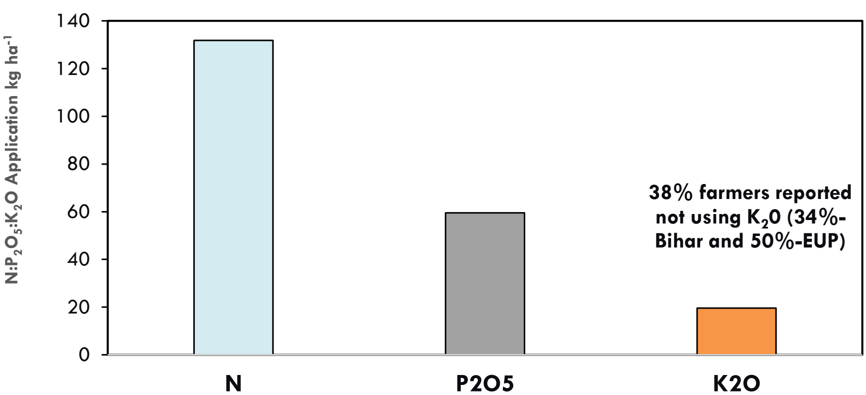
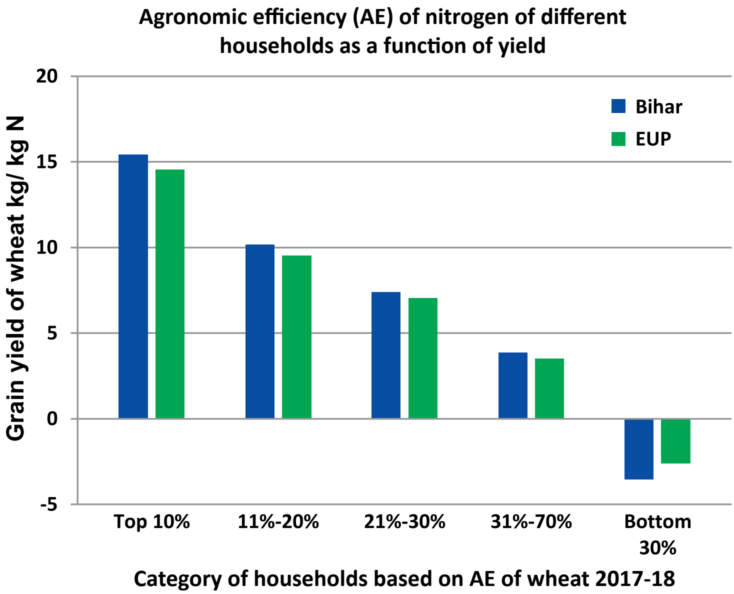


Fig. 2: Average use rates of N, P_2O_5 and K_2O across Eastern UP (9 districts) and Bihar (31) districts across date of sowing, varieties and all other agronomic practices

Table 3: N:P_2O_5:K_2O use (kg ha^{-1}) and wheat yield in different cropping systems of Bihar and Eastern UP

Cropping systems	Avg. N (kg ha^{-1})	Avg. P_2O_5 (kg ha^{-1})	Avg. K_2O (kg ha^{-1})	Avg. yield (t ha^{-1})
Fallow-wheat (n=690)	131.3	65.75	30.9	2.70
Maize-wheat (n=362)	130.7	64.28	25.1	3.52
Rice-wheat (n=6,256)	131.9	58.13	17.7	2.97
Sugarcane-wheat (n=37)	122	57.96	20.9	2.94

Based on N, omission trials conducted by CSISA, the AE of applied N is about 15.0 kg grain yield/kg N with grain yield 2.45 t ha^{-1} at 0N rates. Thus, AE is in negative trend with bottom 30% performer HHs (Fig. 3). This is an anxiety and does not agree with the idea of inappropriate nutrient management (Majumdar *et al*., 2012) and changes within it. This agrees to some extent with Gupta *et al*. (2010), who suggested that the management of yield gaps in wheat in Punjab, Haryana, Eastern UP and Bihar were 17, 14, 47 and 48%, respectively. If we draw a parallel between these ecologies and the ecologies in Punjab and Haryana, current nutrient management has failed to steady the yield growth in EIGP. There is an average yield gap of more than 1.5 t ha^{-1} (4.5 t ha^{-1} in Haryana survey of 2010 and 3.0 t ha^{-1} in the current survey), if the current survey is compared with the survey conducted by Sher Singh *et al*. (2010). Farmers used higher N for wheat (165.74 kg N ha^{-1}) in Haryana compared to 131.9 kg N ha^{-1} in Bihar and Eastern UP (Table 3); use 57.1 kg P_2O_5 ha^{-1} against 57.9 to 76.0 kg P_2O_5 ha^{-1} in Eastern UP and 49.8 to 65.0 kg P_2O_5 ha^{-1} in Bihar, use 5.52 kg K_2O ha^{-1} in Haryana but it is 31.3 kg K_2O ha^{-1} in Bihar and Eastern UP, K use by 9.2% farmers in Haryana against 68% farmers in Bihar and 50% farmers in Eastern UP. The LDS of 2018-19 for Kurukshetra and Ambala districts of Haryana also confirmed these trends with N:P_2O_5:K_2O use rate of 161:56:02 with K used by only 6% of 402 respondents. The organic carbon is more in EIGP than Haryana and thus the current N use in EIGP should be sufficient to give as high yield as in Haryana. A decline in N response in irrigated areas from 13.4 to 3.7 kg grain per kg N between 1970 and 2005 was also reported (Biswas and Sharma, 2008). In high productive zones, the total factor productivity of N, P and K for food grain production has fallen from almost 81 kg grain per kg of N, P, and K in 1966 to 15 kg grain per kg N, P, and K in 2006 (Benbi



Pre-requisites for improving the agronomic efficiency of nitrogen`

Factors affecting agronomic efficiency	State	Categories of households with range of yield performance				
		Top 10%	11%-20%	21%-30%	31%-70%	Bottom 30%
DOS	Bihar	18 Nov	23 Nov	24 Nov	27 Nov	5 Dec
	EUP	18 Nov	20 Nov	23 Nov	24 Nov	30 Nov
Irrigation	Bihar	2.77	2.52	2.33	1.92	1.92
	EUP	2.90	2.44	2.43	2.16	2.16
No weed management (% HHs)	Bihar	5%	7%	27%	28%	47%
	EUP	2%	3%	7%	12%	21%

Fig. 3: Agronomic efficiency of nitrogen in different categories of households based on differential management practices

and Brar, 2009). What could be the scenario in EIGP where productivity is much lesser than that of Haryana and fertilizer use rates are as per recommendation and more. Past studies done by Witt *et al*. (1999) also indicated that the nutrient use efficiency is low in South Asia and it could be still low in the EIGP.

Targeting higher yield from an average yield level of 2.99 t ha^{-1} in EIGP is difficult because use of phosphorus is already on the higher side. It is applied both in rice and wheat, again at more than the recommended rates which is not the case in Haryana. On the contrary, in the past studies, it has been advocated that P application should be made to the wheat crop and the rice crop be allowed to benefit from the residual P left in the soil as P applied in wheat show greater residual effect on rice (Palmer *et al.*,1990). Data in Table 3 suggested that nitrogen and phosphorus use rates were almost same in fallow-wheat cropping system (FWCS), maize-wheat cropping system (MWCS) or rice-wheat cropping system (RWCS) but potash use rates were in the order of 31, 25 and 17 kg ha^{-1}, respectively. These findings revealed that release of native potassium from illitic minerals in these soils could meet the potassium requirements of these crops. Hundal and Pasricha (1993) earlier reported similar findings in IGP.

In EIGP, farmers use P in both rice and wheat but in Haryana only 85% farmers use P in rice but 100% farmers use P in wheat. Crop removal of fertilizer P seldom exceeds 30% of applied P (Bijay-Singh and Yadvinder-Singh, 2004). In addition, Punjab and Haryana farmers use less P than EIGP with much higher yields. Thus, in RWCS farmers who apply P alternatively in rice or wheat must be educated that P applied to wheat shows greater residual effect on the succeeding rice, while P applied to rice has less residual effect on the succeeding wheat (Palmer *et al*., 1990).

K use is less in rice-wheat cropping system, which is common across all ecologies including Haryana in the current survey (data not included). Even new concepts like site specific nutrient management (SSNM) tools including nutrient expert, green seeker and crop manager (Mujumdar *et al.*, 2015) which have been recommended after testing against soil test results would warrant further studies especially the recommendations which support increased K use in some ecologies. This is because K use pattern does not show any relation with wheat yield which are at 3.0 t ha^{-1} with 8 kg ha^{-1} in South-west zone of Bihar or at 3.2 t ha^{-1} with 30 kg K_2O ha^{-1} in the North-west zones of Bihar or even higher at 3.7 t ha^{-1} with only 14 kg K_2O ha^{-1} in Ghazipur district of Eastern UP. These K use rates differences are expected because yield responses are not high enough to convince farmers to use potash as per recommendations. The K application is done by 66%, farmers in Bihar and 50% in Eastern UP (Table 1) against 21% farmers in Haryana where yields are much higher than Bihar or Eastern UP. This survey gave a clear message that nutrient has to be closely aligned with other factors like advance seeding, timely sown wheat varieties, irrigation frequency and weed management. Whatever scrutiny including soil health cards is happening is not in the best interest of farmers, if these factors which help enhancing yields are not focused.

Diagnostic surveys (Yadav *et al.*, 2000) indicated that rice-wheat farmers in the IGP seldom adopt recommended fertilizer doses and K fertilizers are rarely used. Evidence on K use-efficiency is more limited than either N or P. This is partly due to the environmentally benign nature of K where interest in efficiency is driven primarily by agronomic or economic factors. Soils in the IGP generally contain sufficient exchangeable K; total K in alluvial soils of IGP ranges from 1.3 to 2.8% and exchangeable K contents range from about 78 to 273 mg K kg^{-1} soil (Tandon and Sekhon, 1988). The lowest responses to fertilizer K experienced in R-W grown in IGP revealed that the release of native potassium from illitic minerals in these soils could meet the potassium requirements of these crops (Hundal and Pasricha, 1993).

Conclusion

Data clearly showed that focus on nutrient management alone including soil health cards will not work. It is also not only soil test based recommendations but also crop response that matters. Nothing will change on the ground, if other management options like early sowing, timely sown wheat varieties, irrigation, weed management and drill sowing are not considered as pre-requisite in a cropping system perspective for efficient nutrient management in EIGP. Rationality around these agronomic options is the central issue for integrated nutrient management.

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2.6 Lifting the yield potential in wheat

Balwinder Singh[1], Andrew McDonald[2], Peter Craufurd[1], Rajbir Singh[3], S.S. Singh[3], Anjani Kumar[3], Anurag Ajay[1], Shantanu Kumar Dubey[3], Deepak Kumar[1], Ajay Kumar Pundir[1] and R.K. Malik[1]

[1]International Maize and Wheat Improvement Centre (CIMMYT)
[2]Cornell University, Ithaca, USA
[3]Indian Council of Agricultural Research (ICAR)

KEY MESSAGES

- We have to unlock the fundamentals because the evidence showed that the issue is not that of varieties or even the soil health. Focus should be more on harnessing best from varieties and nutrient management by early wheat sowing, better access to irrigation, evolution of timely sown wheat varieties, zero tillage technology and weed management.

Introduction

Uncertainties about wheat productivity in the Eastern- Indo-Gangetic Plains (EIGP) has been the cause of concern for the last 50 years. The weather has been considered sub-optimal but availability of enough natural resources has been the bright spot. Continuous high temperature during the whole growth cycle has been argued to constrain the productivity of wheat. New varieties credited with bringing green revolution were not alone to bring the revolution but their response to modern inputs and Government policies that created irrigation infrastructure and road map that worked quietly without too much of published work. The work done by CSISA during last 10 years showed that wheat has performed well in these so called sub-optimal environments for the growth and development of wheat. The landscape in these ecologies has very high levels of diversity from lowlands to uplands within the same district, block, and a village. Farms sizes are too small and fragmented with no consolidation in places like Bihar. Even with abundant natural resources, availability of best varieties and use of recommended nutrients, this landscape is under-performing in respect of wheat yields.

Method

The survey of randomly selected farmers with methodology described in Chapters 1 of this publication was done immediately after harvesting wheat in 2018. In this survey 7,648 respondents participated. The data were collected digitally through Open Data Kit (ODK), an open-source software for collecting and managing data. The households (HHs) were asked the name of the wheat variety sown, date of sowing of the crop, application of irrigation at different stages, and the wheat yield realised in the survey season. All the questions corresponded to the largest plot of the household. The discussion also includes the crop-cut data which was collected in 20 districts across Bihar 15 and EUP 5. The growth in the number of zero-tillage service providers is also highlighted.

Results and Discussions

Survey data showed that 10% top farmers among the respondents are still getting wheat grain yield (4.6 t ha^{-1}) (Table 1) as high as or close to the average of Punjab and Haryana. The survey based evidence showed that in spite of best varieties and recommended fertilizer used by farmers, the wheat yield has remained stagnant in EIGP, as the average yield is around 3 t ha^{-1} which indicated further scope in improving the wheat yield. The agronomic problems in EIGP are different but managable. First problem delayed in crop establishment either because rice is harvested late or because low land ecologies

Table 1: Wheat yield (t ha^{-1}), wheat sowing date, irrigation and nitrogen application at fields of 10% top performing farmer in survey data

State	No. of respondents	Yield (t ha^{-1})	Std Dev	Average DOS	Average irrigation	Average nitrogen (kg ha^{-1})
Bihar	546	4.64	0.48	18 Nov	2.8	142
Uttar Pradesh	218	4.62	0.54	18 Nov	2.9	149
Overall	764	4.63	0.50	18 Nov	2.8	144

do not allow fields in working condition for wheat sowing well on-time. These features are common in the EIGP with delayed sowing extending till December end to even in January, in the order of Central UP, Eastern UP, Bihar and West Bengal. Data further suggested that many underlying factors that are fundamental to improve the performance of varieties and fertiliser still exist in the system.

This survey suggested that most important factor responsible for low wheat yield in EIGP is late wheat sowing. Early wheat sowing resulted in higher wheat yield in all districts. Adjusted for sowing time, 6 districts where average sowings dates were in a range of 12 November to 20 November showed grain yield in a range of 3.35 to 3.65 t ha^{-1}. Timely wheat sowing is the best sustainability strategy for EIGP and should be kept as key focus topic across these EIGP. This interpretation is supported by 8 years continued demonstration of high yields of more than 5.7 t ha^{-1} from early sowing based better-bet – agronomy in Laser Mahadeva (district Maharajganj) and Kathotia village (district–Siddhartnagar in Eastern UP) of Eastern UP. The grain yield of 7.0 t ha^{-1} was also possible in 2011-12 in these sites. We can create more value by advancing the sowing time sequentially. The argument for sub-optimal climate weather in EIGP is not always true because if we could get more than 7.0 t ha^{-1} wheat yield in so called sub-optimal weather, i.e. as good as the best performance in Punjab and Haryana; where the weather is rated as optimal. There is no limit as how much we can expand the area under early sowing as 18% respondents in this survey of 38 districts with an area on 2.97 million ha have already adopted it. It was almost negligible in the year 2008-09. The expansion is not intended for sowing wheat before 15 November. The aim is to sequentially expand the area from late December sowing to early December sowing and from early December sowing to late November sowing in that order.

Second important factor that ranks in the priority is the strategic direction in the evolution of late sown wheat varieties. TSWVs have slight advantage even under late sown conditions (Table 2) although there is hypothesis that TSWVs do not yield as high as LSWVs under late sown conditions; after 15 December, varieties released only for late sown conditions have ended up in same or poor yield than TSWVs when both are sown late. The focus on the problem of terminal heat is good but the data showed that ideas need rethinking. Overall good performance of TSWVs across EUP and Bihar and across all dates

Table 2: Key impacts of time of sowing on the grain yield of wheat (t ha^{-1}) and response of Timely Sown Wheat Varieties (TSWVs) and Late Sown Wheat Varieties (LSWVs) when seeded late

Sowing time of wheat	Bihar	EUP
Average date of sowing	29 Nov	23 Nov
Average yield across all varieties	2.90	3.27
Before 15 Nov (Bihar-717, EUP-336)	3.49	3.56
Between 16 Nov- 30 Nov (Bihar-3,024, EUP-1,211)	3.02	3.32
Between 01 Dec- 15 Dec (Bihar-1,428, EUP-267)	2.65	2.84
After 15 Dec (Bihar- 624, EUP-41)	2.21	2.37
Average yield of TSWVs (Bihar=475 , EUP=119) sown from 1-15 Dec	2.86	2.98
Average yield of LSWVs (Bihar=953 , EUP=148) sown from 1-15 Dec	2.54	2.73
Average yield of TSWVs (Bihar=129 , EUP=11) sown after 15 Dec	2.52	2.58
Average yield of LSWVs (Bihar=495 , EUP=30) sown after 15 Dec	2.13	2.29

of sowing is driven by high genetic yield potential of these varieties. There has been no substantial progress in implementation of our strategic plan on evolution of wheat varieties in this segment after late 1970s. The varietal turnover of late sown varieties is extremely poor. To accelerate the transformation through varietal changes, focus on LSWVs may be diluted and the investment on TSWVs (Table 3) may be further increased. We may get around the problem if we focus on terminal heat during last two weeks of wheat crop cycle rather than high temperature region for the whole crop cycle. In reality, the adoption of new LSWVs has not happened since late 1970s.

The irrigation management (Table 4) has added interesting dimensions to the outcome of this survey. To overcome the high cost of irrigation, farmers are using sub-optimal irrigation across all ecologies in Bihar and Eastern UP. When we plot the fertiliser use rates against the irrigation frequencies, the performance is much below assumptions. With increase in irrigation frequency from 2 to 3, 4 and 5, the gains in yield from slightly higher doses are much larger. Lack of irrigation at critical stages is an obstacle to harness the potential of nutrient used by farmers. With

Table 3: Response of households (n=7,648) on adoption pattern of Timely Sown Wheat Varieties (TSWVs) and Late Sown Wheat Varieties (LSWVs) across 40 districts (Bihar 31, EUP 9) and the grain yield of wheat (t ha^{-1}) in 2017-18

Adoption pattern of TSWVs and LSWVs	TSWVs	LSWVs
Total no. of varieties grown by the surveyed districts and their households across Bihar and EUP	18	64
Varieties preferred by > 85% households	3	7
Overall % varietal adoption from TSWVs (n=4,134) and LSWVs (n=3,514) groups	54	46
% of varietal adoption from TSWVs (n=2,609) and LSWVs (n=3,184) groups in Bihar	45	55
% of varietal adoption from TSWVs (n=1,525) and LSWVs (n=330) groups in EUP	82	18
Average wheat yield across from TSWVs (n=4,134) and LSWVs (n=3,514) groups	3.29	2.64
Average wheat yield from TSWVs (n=2,609) and LSWVs (n=3,184) groups in Bihar	3.25	2.62
Average wheat yield from TSWVs (n=4,134) and LSWVs (n=3,514) groups in EUP	3.37	2.83
Crop cut yield from TSWVs (n=198) and LSWVs (n=103) groups	3.59	3.02

Table 4: Effect of irrigation on the grain yield of wheat (t ha^{-1}) and use rate (kg ha^{-1}) of N: P_2O_5: K_2O*

Irrigation Stages	No. of HHs	Yield (t ha^{-1})	N (kg ha^{-1})	P_2O_5 (kg ha^{-1})	K_2O (kg ha^{-1})
CRI**	961	2.44	104	53	19
CRI + tillering/jointing	4,029	2.95	133	60	21
CRI + tillering/jointing + flowering	1,158	3.39	141	61	17
CRI + tillering/jointing + flowering + milking	128	4.10	147	64	21

*Pre-seeding irrigation is done by only 1.8 % of the households
**Crown root initiation

limited irrigation at flowering stages or at milking stages, even the best varieties can not endure in the terminal heat phase of growth cycle near their maturity. We can conclude that it is time to start improving the access of farmers to irrigation and make this critical input easily accessible and less costly. This could be seen as third important research and extension issue and also an investment opportunity for creating electricity based tube-wells as an important accessibility issue in EIGP.

Next factor is to be considered is alternate crop establishment like zero tillage seeding. Many projects have planned to further strengthen the case of zero tillage. We can identify key districts especially in low land ecologies where wheat sowings are frequently delayed. Some districts like Buxor, Arah, Rohtas, Kaimur in Bihar and Kushinagar and Deoria in Eastern UP have shown success. Rules for burning the rice stubbles are tightening and *in-situ* residue management is getting required support from the Governments. The transition is underway. We however, can build on the model of using private service providers (PSPs) who purchase the machines and rent them to other farmers rather than custom centers where large chunk of machine remain unutilised. Reducing the turn-around time after rice harvest, cost of crop establishment, emission of CO_2, and cost of first irrigation is important. ZT can become fourth important means and investment opportunity for beating terminal heat and sustainably increase the wheat yields. The subsidy on rotavator, however, is at the dis-advantage to zero tillage, especially when the yields are reducing. Data given in Fig. 1 showed that line sowing is critical to get higher yield and ZT is critical to get both high yield and more profits along with accomplishing timely wheat sowing. The data in Fig. 2 showed that PSPs model could be the best option in these ecologies where the tractor population is extremely low (approximately 7-9 tractors/ 1,000 ha).

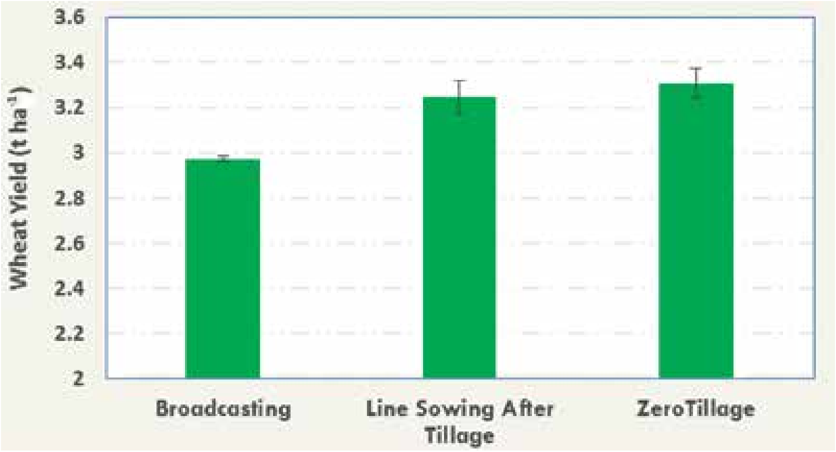


Fig. 1: Farmers reported grain yield of wheat (t ha^{-1}) in association with Zero tillage

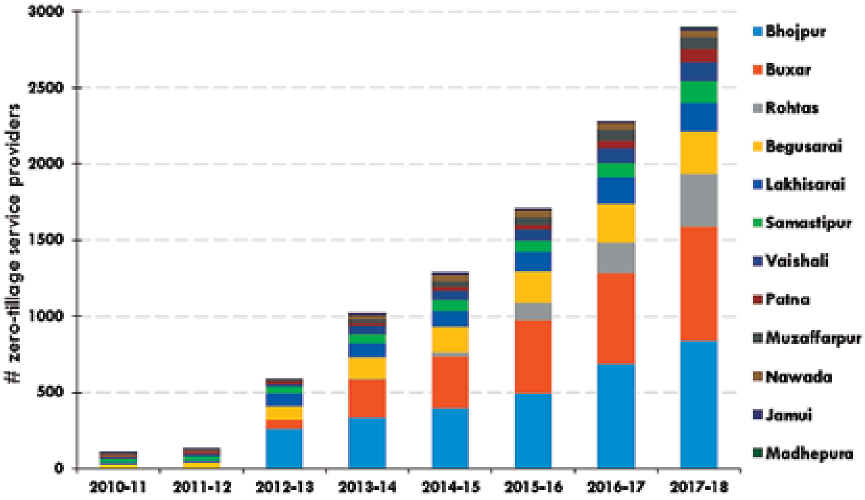


Fig. 2: Yearly growth of zero-tillage service providers in Bihar

Data on weed management options showed that there is a rapid rate of growth in herbicide use in wheat. It is dominated by herbicide mixtures. In districts, where herbicide use is less, the yield levels are also low. The scarce and costly labour and simplification of weed flora in districts of relatively high yield are at the centre of this change. Data generated from the survey also show that high frequency of *Phalaris minor* is associated with high yields and high frequency of *Cynodon dactylon* is associated with low yields. High yields are bringing about a shift in weed flora in favour of annual grasses and shifting the focus from complex flora to simple flora. This is another issue that sets the stage for herbicide use. The value that weed management adds in shielding losses from weeds also increases the efficiency of inputs and helps lifting the yield potential of varieties. Weed management, therefore, is fifth important variable that will lead to improved agronomic management in these ecologies.

Data suggested that both varieties and nutrient application are already at the forefront and farmers are trying to adopt the best out of these recommendations. The use of fertilizers is far ahead of what is needed for an average yield of more than 4.0 t ha^{-1} but their efficiency has to improve through above interventions rather than focusing our energies within one component of nutrient management. However, benefits to farmers will go beyond these two prevailing and focused interventions on late sown varieties and soil health issues.

2.7 Weed flora and weed management practices of smallholder wheat farmers in eastern Uttar Pradesh and Bihar

Virender Kumar[1], Andrew McDonald[2], Sudhansu Singh[1], Peter Craufurd[3], Ajay Kumar[3], Anurag Ajay[3], Sachin Sharma[3], Ajoy K. Singh[4], U.S. Gautam[6], Madhulika Singh[3], Pankaj Kumar[3], Anjani Kumar[5] and R.K. Malik[3]

[1]International Rice Research Institute (IRRI)
[2]Cornell University, Ithaca, USA
[3]International Maize and Wheat Improvement Centre (CIMMYT)
[4]Bihar Agricultural University (BAU), Sabour, Bihar
[5]Indian Council of Agricultural Research (ICAR)
[6]Banda University of Agriculture and Technology (BUAT), Banda, U.P.

KEY MESSAGES

- The most common as well as the most troublesome weed of wheat is *Chenopodium album* in Bihar and *Phalaris minor* in Eastern Uttar Pradesh (EUP).
- The top five troublesome weeds of wheat identified by farmers in both Bihar and EUP are same: *Phalaris minor*, *Chenopodium album*, *Polypogon monspeliensis, Lathyrus aphaca* and *Anagalis arvensis.* However, the ranking of these troublesome weeds varied with the state.
- The spatial distribution of 10 most common and top five most troublesome weeds of wheat in 30 districts of Bihar and nine districts of EUP identified. This will help in developing and deploying appropriate weed management products in specific districts as per weed flora.

- In Bihar, weed flora differed with wheat planting dates – *Avena ludoviciana* is the most common in early planted wheat and *Phalaris minor* in the median to late-planted wheat. Also *Cannabis sativa* was present in early planted wheat and not in later-planted wheat.
- On an average 26% farmers in the surveyed 40 districts of Bihar and EUP are not controlling weeds in their wheat fields with a higher percentage (31%) in Bihar than that in EUP (10%).
- Herbicide-based weed control is much higher in EUP (73% farmers) than that in Bihar (49%).
- Hand weeding based weed control is practiced by 17-20% farmers in both states
- Wheat yield increased in the following order: Herbicide-based (sole herbicide or herbicide + hand weeding) weed control (3.20 t ha^{-1}) > weed control by hand weeding only (2.98 t ha^{-1}) > no weed control (2.54 t ha^{-1}). Herbicide-based weed control was higher yielding than hand weeded fields.
- Herbicide-based weed control resulted in a yield gain of 0.65 t ha^{-1} (26%) compared to farmers who did not control weeds in their fields. In 16 districts of Bihar and three districts of EUP, yield gain from herbicide-based weed control was 30-66%.
- Results suggested that significant opportunity exists to close the wheat yield gap by reducing losses caused by weeds in eastern India.

Introduction

Wheat is the second most important staple cereal after rice in India. India has made tremendous progress in improving wheat productivity over time. Wheat productivity has increased from 0.85 t ha^{-1} in 1961 to 3.22 t ha^{-1} in 2017 (FAO, 2019). This major progress was witnessed in north western Indo-Gangetic Plains (IGP) (e.g., Punjab and Haryana); however, the eastern IGP (Eastern Uttar Pradesh, Bihar, and West Bengal) lags behind in yield gain observed during the same period (FAO 2017; Paulsen *et al*., 2012). For example, the eastern IGP state of Bihar, with the average yield of 2.43 t ha^{-1}, has the lowest wheat yield in the IGP (MOA, 2017).

Large wheat yield gaps exist in the eastern IGP states, ranging from 58% in Uttar Pradesh to 111% in Bihar. In contrast, yield gaps in Punjab and Haryana (northwest IGP) were only 9-12% (Jain *et al*., 2017). This is mainly because of poor adoption of best crop management practices.

The existing wheat yield gap in eastern India can partially be closed by minimizing yield losses caused by weeds. Weeds are one of the major biological constraints to the attainment of optimal yield grain of wheat crop in eastern India. In general, weed management is poor in the eastern IGP causing high yield losses in wheat due to weed competition. In Bihar, based on CSISA on-farm trials, it was observed that yield was increased by 13% with the application of new and effective herbicides compared to the current practice of hand weeding.

The weed flora in the eastern IGP is complex mainly because of poor crop growth/canopy development due to late planting and low input use (Kumar *et al.*, 2013). Hand weeding has traditionally been the most common method of weed control in the eastern IGP. But, in recent times, because of labor scarcity and non-availability of labor at critical times, hand-weeding is frequently delayed leading to high yield losses. Scarce and costly labour is now shaping the weed management in favour of herbicide-based weed control. Herbicide use alone also undermines the sustainability of an effective and economically viable weed management program.

Good agronomic practices (GAP) make sense because these practices manage weed-crop competition in favour of the crop and reduce weed prevalence by not allowing them to enrich their soil seed bank. Agronomic practices also change the weed flora and conceptually we may need integrated weed management for a long term solution. It is therefore important to document farmers' current management practices, their knowledge gaps on weed control, and emerging new weed flora, so that appropriate management solutions can be developed and disseminated.

Spatially representative household survey studies in the major landscapes in which wheat is grown are a useful approach to understand and characterize farmers' weed management practices and how they influence yield. The specific objectives of this survey study were to: (i) to generate the spatial information on the distribution of most common and troublesome weeds of wheat, (ii) to document farmers current weed management practices/knowledge in wheat, (iii) identify key knowledge gap in their current weed management practices, and (iv) assess association of weed flora with crop management practices and landscape positioning.

Materials and Methods

The survey of 7,648 randomly selected farmers (the methodology is described in Chapter 1.1) was conducted in Bihar and eastern Uttar Pradesh (EUP) immediately after the harvesting of wheat in 2018. The survey covered 30 districts of Bihar and nine districts of EUP. The data were collected digitally through Open Data Kit (ODK), open-source software for collecting and managing data (see Chapter 1.2). The survey questionnaire collected the following information: farmers' profile and socio-demographic characteristics, farm characteristics, farmers' current agronomic practices, major weeds invading their wheat farms, and their current weed management practices. To identify the major weeds invading their fields, farmers were shown posters with photos of 28 weed species commonly associated with wheat (https://drive.google.com/open?id=1LdNN87eX6L4arZX_DLhlbv1MAuN6SWXb). The names along with their abbreviations are given in Table 1. From the

Table 1: Wheat weed species which were included in weed poster for weed identification by farmers during survey in 2018

Sr. No.	Weed code	Weed name	Sr. No.	Weed code	Weed name
1	ARGME	*Argemone mexicana*	15	LATAP	*Lathyrus aphaca*
2	AMASP	*Amaranthus spinosus*	16	MALPA	*Malwa parviflora*
3	AMAVI	*Amaranthus viridis*	17	MEDDE	*Medicago denticulate*
4	ANAAR	*Anagalis arvensis*	18	MELIN	*Melilotus indica*
5	AVELU	*Avena ludoviciana*	19	OXACO	*Oxalis corniculata*
6	CANSA	*Cannabis sativa*	20	PARHY	*Parthenium hysterophorus*
7	CHEAL	*Chenopodium album*	21	PHAMI	*Phalaris minor*
8	CIRAR	*Cirsium arvense*	22	POLMON	*Polypogon monspeliensis*
9	CONAR	*Convolvulus arvensis*	23	POAAN	*Poa annua*
10	CORDI	*Coronopus didymus*	24	Solanum	*Solanum spp*
11	CYNDA	*Cynadon dactylon*	25	SPEAR	*Spergula arvensis*
12	EUPHE	*Euphorbia helioscopia*	26	RUMDE	*Rumex dentatus*
13	FUMPA	*Fumaria parviflora*	27	VICSA	*Vicia sativa*
14	GNAPU	*Gnaphalium purpurium*	28	XANST	*Xanthium strumarium*

poster, surveyed farmers were asked to list the major species present in their field ('most common') and to rank top five most troublesome weeds – those that are difficult to control and their infestation level is severe causing major yield losses.

Results and Discussion

1. Spatial distribution of most common and troublesome weeds of wheat

Most common weeds

The 12 most common (the dirty dozen) weeds invading wheat fields in Bihar and EUP are given in Table 2. Out of 12, nine weeds are common in both Bihar and EUP whereas three differ. For example, *Phalaris minor*, *Polypogon monspeliensis, Chenopodium album*, *Anagalis arvensis*, *Lathyrus aphaca*, *Vicia sativa*, *Solanum* spp, *Rumex dentatus*, and

Table 2: The 12 most common (dirty dozen) weeds of wheat invading farmer's fields in (a) Bihar and (b) Eastern Uttar Pradesh

Bihar (N = 5,793)				Eastern Uttar Pradesh (N = 1,855)			
Sr. No.	Weed name	N	%	Sr. No.	Weed name	N	%
1	*Chenopodium album*	4,415	76	1	*Phalaris minor*	1,716	93
2	*Phalaris minor*	4,057	70	2	*Chenopodium album*	1,383	75
3	*Polypogon monspeliensis*	3,654	63	3	*Anagalis arvensis*	1,352	73
4	*Lathyrus aphaca*	3,198	55	4	*Polypogon monspeliensis*	1,204	65
5	*Anagalis arvensis*	3,025	52	5	*Lathyrus aphaca*	933	50
6	*Cynadon dactylon*	2,753	48	6	*Avena ludoviciana*	657	35
7	*Vicia sativa*	2,522	44	7	*Vicia sativa*	648	35
8	*Cannabis sativa*	1,952	34	8	*Solanum spp*	639	34
9	*Rumex dentatus*	1,740	30	9	*Cynadon dactylon*	523	28
10	*Solanum spp*	1,591	27	10	*Rumex dentatus*	448	24
11	*Parthenium hysterophorus*	1,572	27	11	*Fumaria parviflora*	428	23
12	*Coronopus didymus*	1,478	26	12	*Poa annua*	386	21

Cyanadon dactylon are common key weed species invading farmers' wheat fields in both states. However, three species varied – *Avena ludoviciana*, *Fumaria parviflora*, and *Poa annua* were other weed species reported by farmers in EUP, whereas *Cannabis sativa*, *Parthenium hysterophorus, and Coronopus didymus* were reported by farmers in Bihar. Out of these 12 weed species, the top five weeds were same in both states. The difference was that *P. minor* is the most commonly reported by farmers in EUP, whereas *C. album* ranked the most common weed of wheat in Bihar. *P. minor* is the most dominant weed of wheat in northwest Indian states such as Punjab, Haryana and Western Uttar Pradesh where wheat yields are higher (Kumar *et al*., 2013). The dominance of *P. minor* may be associated with agronomic practices that produce higher yields.

The top 10 most important weeds of wheat in each district reported by farmers from 30 districts of Bihar and nine districts of EUP are presented in Tables 3 and 4, respectively. In Bihar, *C. album* was the most cosmopolitan as farmers from all the 30 districts selected this weed as one of the most common weeds in their wheat fields (Table 3). In most of the districts, it ranked among the top 1 to 3. Other widely distributed weed species include *L. aphaca* and *A. arvensis* with presence in 29 districts, and *P. minor, P. monspeliensis*, and *C. dactylon* with presence in 28 districts in Bihar. *L aphaca*, although widely distributed, was only ranked as top three commonly invading weed in Arah, Arwal, Buxar, Kaimur, Nalanda, Patna, and Vaishali districts. *V. sativa* is another widely distributed weed in 19 districts. Similarly, *C. sativa* is also expanding its niche and is now among the top 10 important weeds of wheat in 15 districts of Bihar. Other species were more common in specific districts. For example, *Xanthium strumarium* was among top 10 important weeds in Arwal, Aurangabad, Banka, Bhagalpur, Lakhisarai, Nalanda, and Patna districts. *Poa annua* was featured among the top 10 important weeds in Buxar, Gopalganj, Gaya, and West Champaran. *P*. *hysterophorus*, an invasive weed which generally thrives in the non-cropped area has become a common weed of wheat in districts such as Samstipur, Begusarai, and Khagaria, and is also expanding in other districts such as Ara, Aurangabad, Buxar, Munger, Jahanabad, and Sivan. Other emerging weed problems include *Solanum* spp, *R. dentatus*, *C. didymis*, *C. arvense*, *A. ludoviciana*, *Oxalis corniculata* and *A. mexicana* in selected districts of Bihar.

In EUP, the following weeds species were widely distributed and were among the top 10 most important weeds of wheat in all the nine surveyed

Table 3: Top 10 major weeds invading farmers' wheat fields in 30 districts of Bihar State[1]

Sr. No.	District	N	DOS	Yield	CHEAL	PHAMI	LATAP	ANAAR	POLMO	CYNDA	VICSA	CANSA	Solanum	RUMDE	CORDI	PARHY	CIRAR	XANST	OXACO	AVELU	ARGME	POAAN	MELIN	FUMPA	MEDDE	AMAVI	EUPHE	GNAPU	AMASP	MALPA
					Ranking of top 10 weeds invading wheat fields[2]																									
1	Arah	208	03-Dec	2.89	2	4	1	3	8	7	6	10		5		9														
2	Araria	117	22-Nov	2.32	1		9	3	8	2			4	7	6				5					10						
3	Arwal	181	13-Dec	2.17	1	2	3	7	4	8	6			5	10			9												
4	Aurangabad	194	09-Dec	2.53	2	3	4	8	1	6	5				7	10		9												
5	Banka	176	13-Dec	2.13	1	2	8	5	4	7	3			10				6	9											
6	Begusarai	213	12-Nov	3.71	1	2	4	3		7	9	6				5	10							8						
7	Bhagalpur	207	01-Dec	2.66	1	3	7	4	2	5	8				6			9	10											
8	Buxar	207	01-Dec	3.04	3	1	2	6	4	10	5					7				9		8								
9	E. Champaran	205	30-Nov	2.93	4	2		3	1	7		5	6				8		10		9									
10	Gaya	193	04-Dec	2.99	2	1	4	5	3	6	9									8		7	10							
11	Gopalganj	210	22-Nov	3.27	3	2	6	7	1	5			8								10	4			9					
12	Jehanabad	189	05-Dec	2.90	3	2	6	8	1	4	5			7		10											9			
13	Kaimur	204	10-Dec	2.52	2	3	1	5	6	8	4			7	10					9										
14	Katihar	115	23-Nov	2.63	1	9	5	2		3		7	4		10				6							8				
15	Khagaria	205	17-Nov	3.49	1	4	9	6	10	5		2	8			3					7									
16	Lakhisarai	195	30-Nov	3.33	2	1	4	9	8	5	3			6	7			10												
17	Madhepura	169	25-Nov	2.47	1		8	2	4	3		7	6	10	5				9											

Sr. No.	District	N	DOS	Yield	CHEAL	PHAMI	LATAP	ANAAR	POLMO	CYNDA	VICSA	CANSA	Solanum	RUMDE	CORDI	PARHY	CIRAR	XANST	OXACO	AVELU	ARGME	POAAN	MELIN	FUMPA	MEDDE	AMAVI	EUPHE	GNAPU	AMASP	MALPA
					Ranking of top 10 weeds invading wheat fields[2]																									
18	Munger	210	30-Dec	2.71	1	4	7	2	3	6	5		8			10					9									
19	Muzzafarpur	204	22-Dec	2.96	2	3	9	8	1	7	10	4	6				5													
20	Nalanda	196	28-Dec	3.03	7	3	1	2	4	6	5							8		9						10				
21	Patna	203	30-Nov	3.02	9	1	3	6	4	7				5	8			2							10					
22	Rohtas	196	09-Dec	2.73	1	3	5	7	2	6	8			4														9	10	
23	Saharsa	163	04-Dec	2.67	1	4	9	3	5	2	8	7	6		10															
24	Samastipur	202	20-Nov	3.59	1	8	4	3	6	9	10	2				5							7							
25	Saran	209	25-Nov	3.17	3	2	5	6	1	8		4					10			9			7							
26	Sheodhar	209	26-Nov	3.19	3	2	5	4	1	9		7					8			10										6
27	Siwan	198	22-Nov	2.86	1	4	5	6	3			2				9	8				10			7						
28	Supaul	206	26-Nov	2.50	1	8	5	4	3	2	10	7	9						6											
29	Vaishali	196	22-Nov	3.26	1	2	3		4		6	5	7				8			9	10									
30	W. Champaran	205	27-Nov	2.74	2	1	7	4	3	5		6					8				10	9								
	Present in no. of districts				30	28	29	29	28	28	19	15	11	10	10	9	8	7	7	7	7	4	3	3	2	2	1	1	1	1

[1]Refer Table 1 for weed abbreviations; [2]Ranking number given based on frequency (% farmers reported). Ranking 1 = highest frequency; Raking 10: lowest frequency;

Table 4: Top 10 major weeds invading farmers' wheat fields in 9 districts of Eastern Uttar Pradesh

Sr. No.	District	N	DOS	Yield	Ranking of top 10 weeds invading wheat fields[1]																									
					CHEAL	PHAMI	LATAP	ANAAR	POLMO	CYNDA	VICSA	CANSA	Solanum	RUMDE	CORDI	PARHY	CIRAR	XANST	OXACO	AVELU	ARGME	POAAN	MELIN	FUMPA	MEDDE	AMAVI	EUPHE	GNAPU	AMASP	MALPA
1	Balia	216	22-Nov	3.24	3*	1	2	4	5		6	9								7		10				8				
2	Chandauli	208	07-Dec	2.86	2	1	4	5	7		3		9	6						10	8									
3	Deoria	209	17-Nov	3.35	3	1	7	2	6	8	10	5								4		9								
4	Gazipur	210	27-Nov	3.33	2	1	3	7	4	8	6					9			10	5										
5	Gorakhpur	210	18-Nov	3.65	3	1	7	4	2				5							8	10	9		6						
6	Khushinagar	195	23-Nov	3.22	1	3		2	4	5		7	6				8			10				9						
7	Maharajganj	210	21-Nov	3.32	2	1	7	3	4	9			6		8							10		5						
8	Mau	204	25-Nov	3.07	5	1	3	2	4		6	10		7						9		8								
9	Siddharthnagar	193	20-Nov	3.39	4	1	10	5	2				3							7	9	8		6						
	Present in no. of districts				9	9	8	9	9	4	5	4	5	2	1	1	1	0	1	8	3	6	0	4	0	1	0	0	0	0

*Ranking number given based on frequency (% farmers reported). Ranking 1= highest frequency; Raking 10: lowest frequency districts: *P. minor*, *C. album*, *A. arvensis, P. monspeliensis* (Table 4). Weeds such as *L. aphaca* and *A. ludoviciana* were also common and were among the top 10 important weeds in 8 out of 9 surveyed districts. Other weed species which were among top 10 important weeds were limited to specific districts include *C. dactylon, V. sativa, C. sativa, Solanum spp, P. annua,* and *Fumaria parviflora.*

Weed spectrum can be affected by planting date as the temperature can have strong influence on germination ecology of weed species. Weed flora reported by farmers in Bihar and EUP in their wheat fields planted at different dates are presented in Fig. 1. In Bihar, in early planted wheat (Nov 1-15), *A. ludovician* was the first most common (in 74% farmers' fields), whereas in the later-planted wheat (after Nov 15), *A. ludoviciana* dropped to sixth ranking with presence in 18-22% farmers' field (Fig. 1A). In contrast, *P. minor* ranked fourth most common weed with 51% frequency in early planted wheat (Nov 1-15), whereas under late-planted wheat, it becomes the top most common weed of wheat with the frequency of 72-76%. For *P. minor*, it was observed that it germinates over a temperature range of 10-25°C but optimum at 10-20°C. The reason for lower frequency of *P. minor* in early planted wheat in Bihar could be due to less favourable temperature for *P. minor* germination. However, this trend was not observed in EUP (Fig. 1B). Both *P. minor* and *A. ludoviana* were equally dominant at all planting dates. This differential response in both states could be due to temperature variation at planting time between EUP and Bihar state. Similarly, *C. sativa* was observed more as top 10 important weeds in early planted wheat (10%) in Bihar and EUP and it was not observed in wheat planted after Nov 16.

These results suggested that *P. minor* is more associated with late planting and or with high yields. For example, in Araria and Mahedpur district of Bihar, *P. minor* was not reported as among the top 10 weeds, which could be because of combination of early planting and lower yields in these districts (Table 3). In Samastipur and Begusarai, despite relatively early planting, *P. minor* is eighth and second most common weed in these districts, respectively, mainly because of higher wheat yields. In contrast, in all late planted wheat, irrespective of wheat yield, it was observed among the top 1 to 4 most common weeds. This suggested that with increase in yield potential, *P. minor* problem may increase even in early November planting. Studies have reported further reduction in *P. minor* establishment in late October planted wheat in Haryana (Kumar *et al*., 2013).

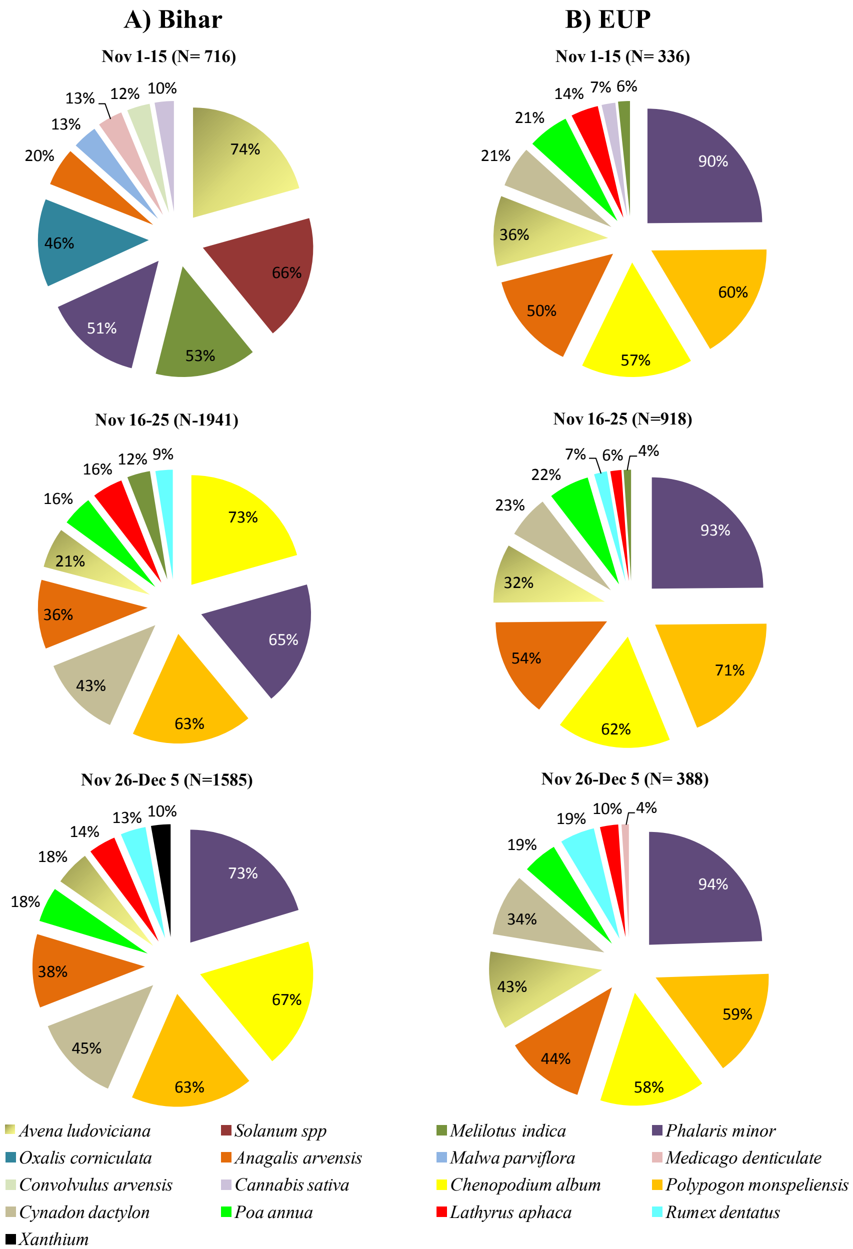


Fig. 1 (A-B): Top 10 major weed flora of wheat under different wheat planting dates in (A) Bihar and (B) EUP. Ranked based on frequency (% of farmers reported)

Top five troublesome weeds

Top five most troublesome weeds of wheat were the same in both Bihar and EUP but their ranking varied with the state (Fig 2). In Bihar, *C. album* was the most troublesome weed followed by *P. minor* whereas, in EUP, *P. minor* was most troublesome followed by *C. album. P. monspeliensis* was the third most troublesome weed of wheat in Bihar whereas; it was the fourth most troublesome weed in EUP. *L. aphaca* and *A. arvensis* were fourth and fifth most troublesome weeds in Bihar, whereas in EUP these were a fifth and third most troublesome weeds of wheat, respectively.

These top five troublesome weeds of wheat varied with district and are presented in Table 5 for Bihar and for EUP in Table 6 also and shown in Fig. 3. In Bihar, *C. album* was reported as one of the most troublesome weeds in most of the districts followed by *P. minor* and *P. monspeliensis* (Table 5; Fig. 3 A-C). In EUP, *P. minor* was reported the number one troublesome weed in 8 out of 9 surveyed districts (Table 6; Fig. 3 A). *C. sativa* has emerged as troublesome weed species in 10 districts of Bihar, whereas, it featured only in Deoria in EUP. Similarly, *C. dactylon* has also emerged as one of the top five troublesome weeds in 8 districts of Bihar, whereas, it was reported by only Khushinagar farmers in EUP.

This information on spatial distribution of troublesome weeds at the district level will help in developing and deploying effective integrated

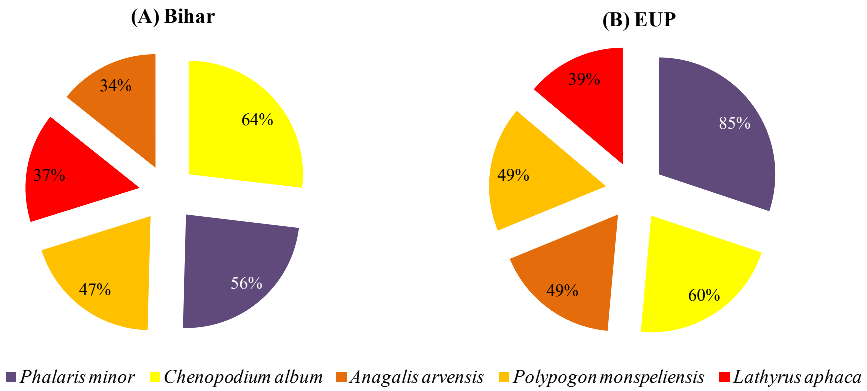


Fig. 2: Top five most troublesome weeds of wheat in (a) Bihar and (b) EUP state. ranking based on frequency (% of farmers reported)

Table 5: Top 5 troublesome weeds of wheat reported by farmers from 30 districts in Bihar[1]

Sr. No.	District	N	DOS	Yield	CHEAL	PHAMI	POLMO	LATAP	ANAAR	CANSA	VICSA	CYNDA	RUMDE	Solanum	PARHY	XANST	POAAN
					Ranking of top 5 troublesome weeds[2]												
1	Arah	208	03-Dec	2.89	2	3		1	5				4				
2	Araria	117	22-Nov	2.32	1				2			3	4	5			
3	Arwal	181	13-Dec	2.17	1	2	3	4					5				
4	Aurangabad	194	09-Dec	2.53	4	2	1	3			5						
5	Banka	176	13-Dec	2.13	1	2	4		5		3						
6	Begusarai	213	12 -Nov	3.71	1	3			5	4					2		
7	Bhagalpur	207	01-Dec	2.66	1	4	3		2			5					
8	Buxar	207	01-Dec	3.04	3	1	5	2							4		
9	E. Champaran	205	30 Nov	2.93	3	1	2		4	5							
10	Gaya	193	04-Dec	2.99	2	1	3	5	4								
11	Gopalganj	210	22-Nov	3.27	3	1	2					5					4
12	Jehanabad	189	5-Dec	2.90	2	3	1	5			4						
13	Kaimur	204	10-Dec	2.52	1	3		2			4		5				
14	Katihar	115	23 Nov	2.63	1			5	2			3		4			
15	Khagaria	205	17 Nov	3.49	2	4	5			1					3		
16	Lakhisarai	195	30 Nov	3.33	3	1		5			2		4				

Sr. No.	District	N	DOS	Yield	CHEAL	PHAMI	POLMO	LATAP	ANAAR	CANSA	VICSA	CYNDA	RUMDE	Solanum	PARHY	XANST	POAAN
					Ranking of top 5 troublesome weeds[2]												
17	Madhepura	169	25-Nov	2.47	1			4	2	5		3					
18	Munger	210	30 Nov	2.71	1	5	4		2		3						
19	Muzzafarpur	204	22-Nov	2.96	1	2	3			4				5			
20	Nalanda	196	28-Nov	3.03		1	4	3	2		5						
21	Patna	203	30-Nov	3.02		1	4	2					5			3	
22	Rohtas	196	09-Dec	2.73	5	1	3				4		2				
23	Saharsa	163	04-Dec	2.67	1	2	4			5		3					
24	Samastipur	202	20-Nov	3.59	1		5	3	4	2							
25	Saran	209	25-Nov	3.17	3	1	2	5		4							
26	Sheodhar	209	26-Nov	3.19	3	2	1	5	4								
27	Siwan	198	22-Nov	2.86	1	2	3	5		4							
28	Supaul	206	26-Nov	2.50	1	4	2	5				3					
29	Vaishali	196	22-Nov	3.26	1	2	3	5		4							
30	W. Champaran	205	27-Nov	2.74	3	1	2		4			5					
Presence in no. of districts					28	26	23	18	14	10	8	8	7	3	3	1	1

[1]Ranking number given based on frequency (% farmers reported). Ranking 1= highest frequency ; Raking 5: fifth highest frequency

Table 6: Top 5 troublesome weeds of wheat reported by farmers from 9 districts in Eastern Uttar Pradesh[1]

Sr. No.	District	N	Yield	DOS	CHEAL	PHAMI	ANAAR	POLMO	LATAP	Solanum	VICSA	CANSA	AVELU	CYNDA
					Ranking of top 5 troublesome weeds[2]									
1	Balia	216	3.24	22-Nov	4	1	5	3	2					
2	Chandauli	208	2.86	07-Dec	2	1	5		3		4			
3	Deoria	209	3.35	17-Nov	3	1	2					5	4	
4	Gazipur	210	3.33	27-Nov	2	1		4	3		5			
5	Gorakhpur	210	3.65	18-Nov	4	1	3	2		5				
6	Khushinagar	195	3.22	23-Nov	1	3	2	5						4
7	Maharajganj	210	3.32	21-Nov	2	1	3	4		5				
8	Mau	204	3.07	25-Nov	4	1	5	3	2					
9	Siddharthnagar	193	3.39	20-Nov	4	1	5	2		3				
# of districts with troublesome weeds					9	9	8	7	4	3	2	1	1	1

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

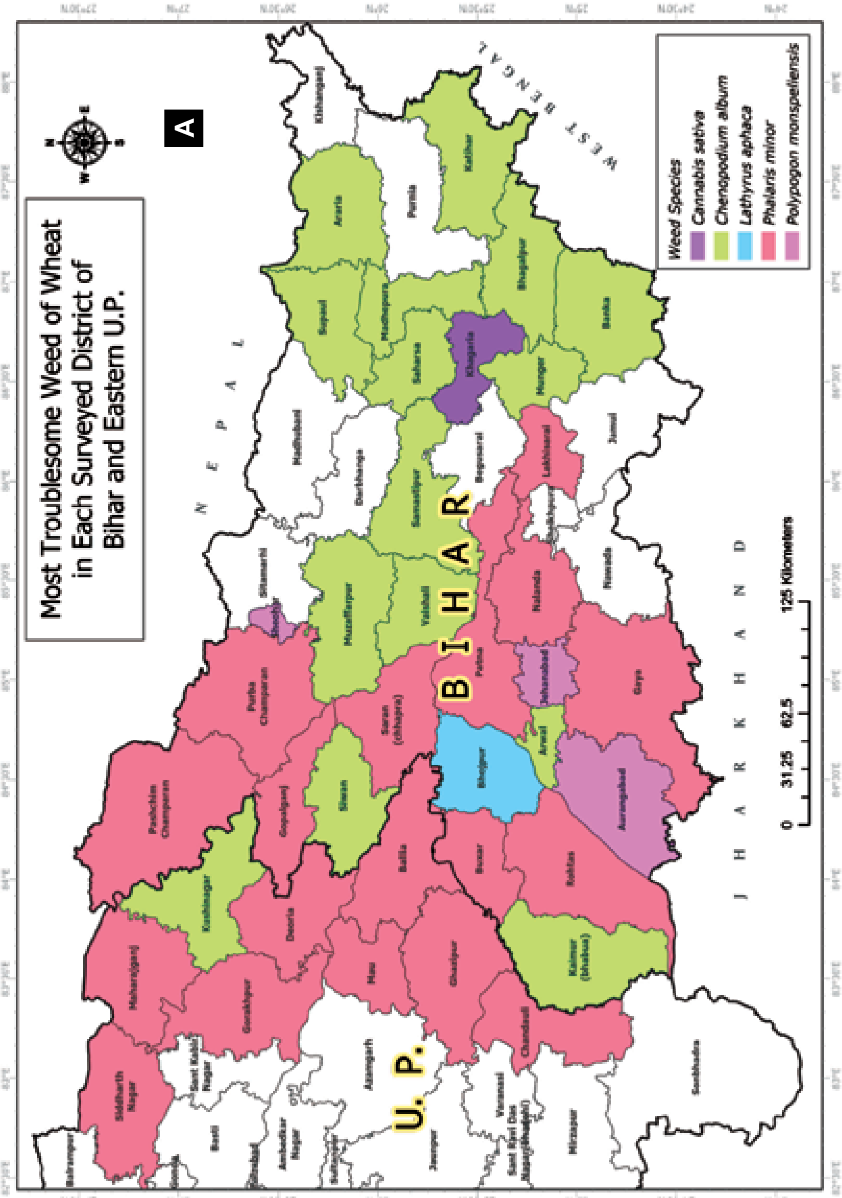
weed management strategies as per weed flora by both public and private sector partners.

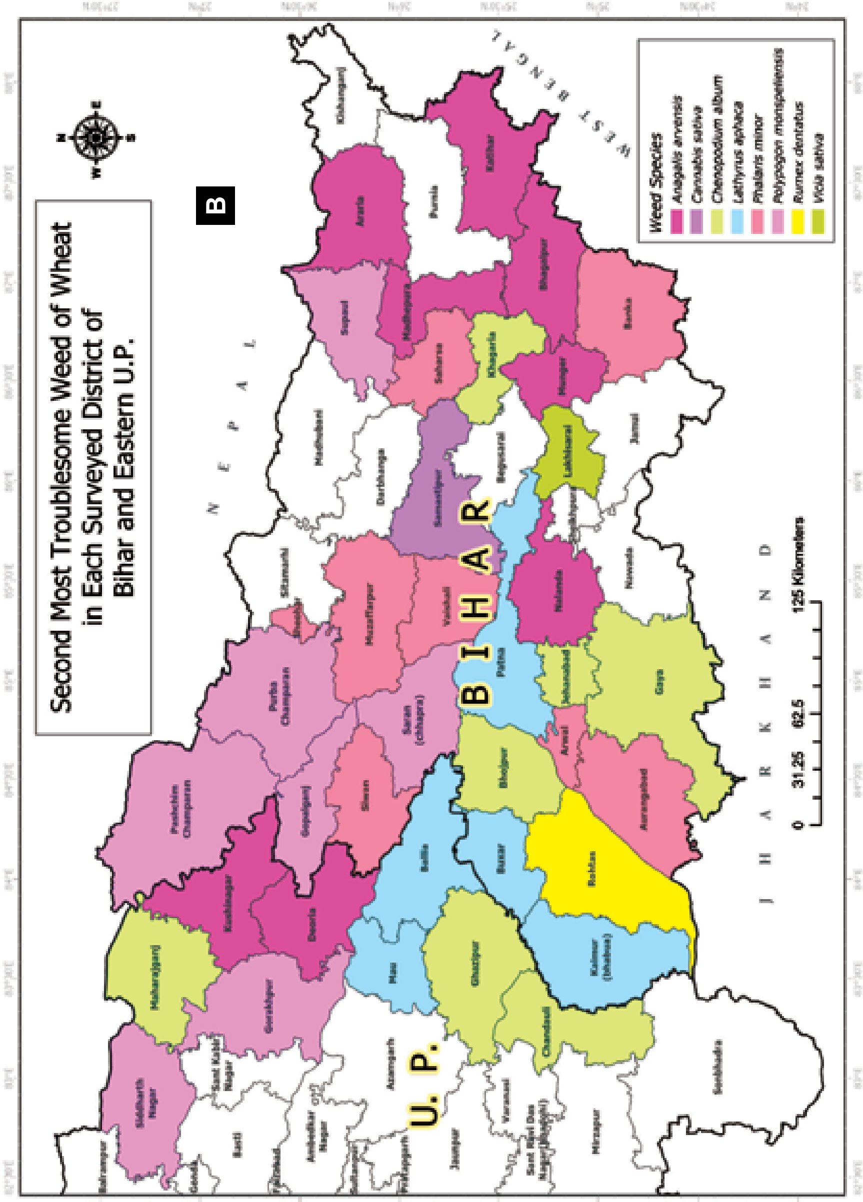
2. Weed management practices and wheat yield

In general, a higher percentage of farmers from EUP (90%) managed weeds in their wheat fields as compared to farmers from Bihar (69%) (Fig. 4). On an average 31% surveyed farmers in Bihar and 10% in EUP did not do any weed management in wheat (Fig. 4). A higher percentage of farmers used herbicides-based weed control in EUP (73%) than in Bihar (49%) state and hand weeding based weed control was deployed by similar percentage of farmers in both states (17-20%)

The type of weed management practices varied a lot with districts (Fig. 5, 6). In districts Arwal, Patna, Munger, and Lakhisarai in Bihar about 50-68% of farmers are still not managing weeds in their wheat fields, whereas in

Purnia, E. Champaran, Banka, Gaya, Buxar, Gopalganj, and Aurangabad, about 40-50% of farmers did not practice any weed management. In another 10 districts, 15-30% of farmers did not control weeds in their wheat




Second Most Troublesome Weed of Wheat in Each Surveyed District of Bihar and Eastern U.P.
B
NEPAL
WEST BENGAL
BIHAR
U. P.
JHARKHAND
Weed Species
Anagallis arvensis
Cannabis sativa
Chenopodium album
Lathyrus aphaca
Phalaris minor
Polygonum monspeliensis
Rumex dentatus
Vicia sativa
0 31.25 62.5 125 Kilometers

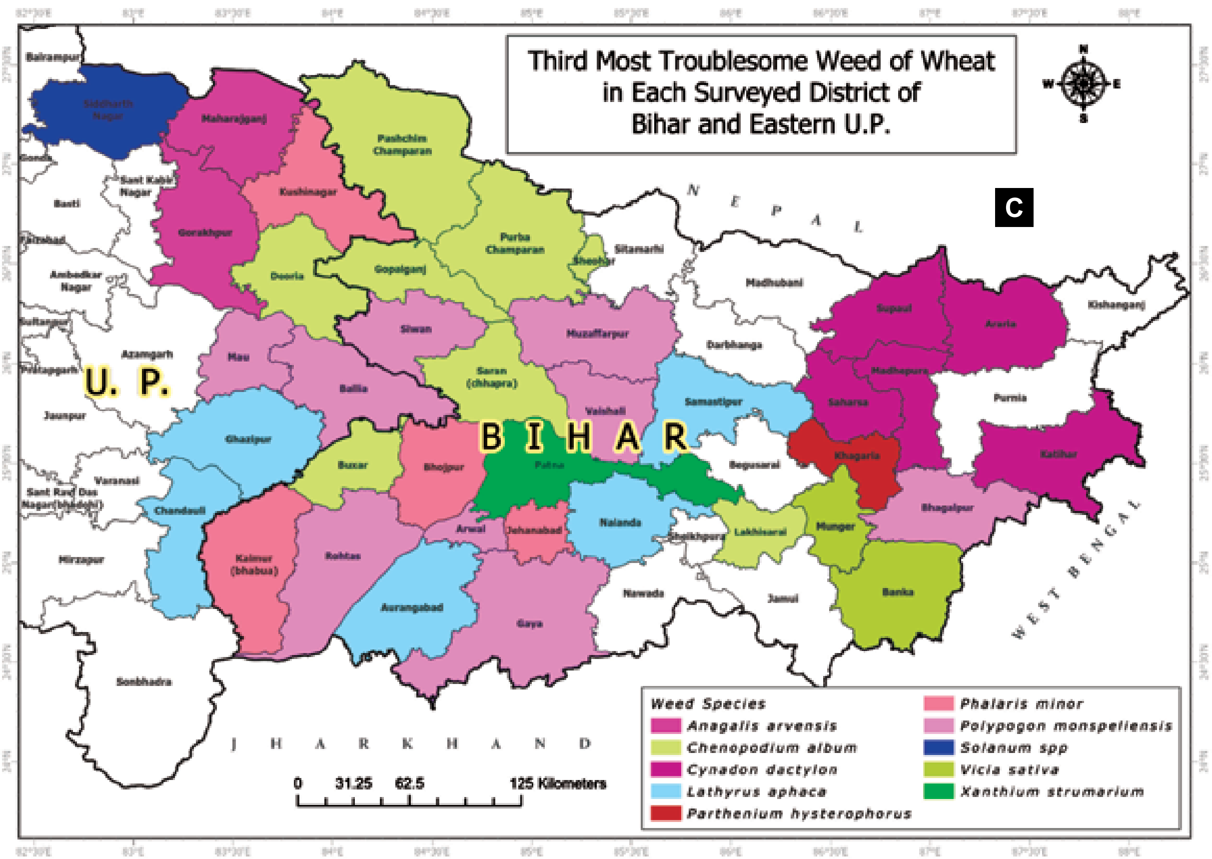


Fig. 3 (A-C): Spatial distribution of first (A), second (B) and third (C) most troublesome weeds of wheat in districts of Bihar and EUP

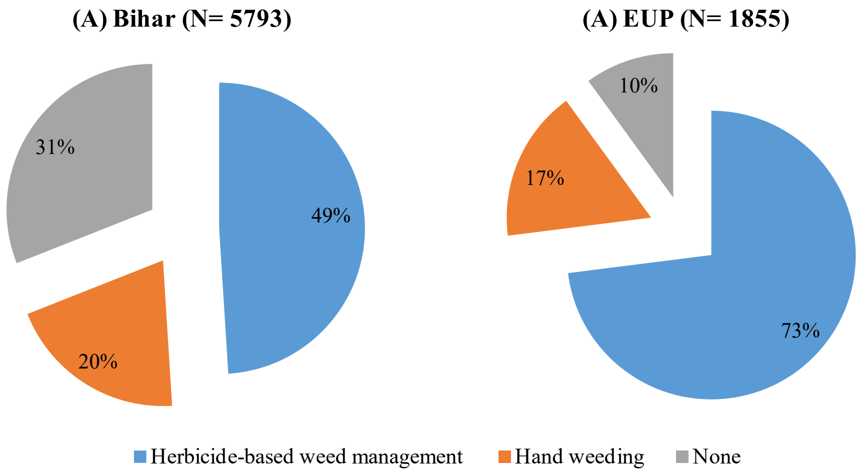


Fig. 4: Types of weed control practices (%) used by farmers for weed control in wheat in (A) Bihar and (B) EUP in 2017-18

fields. Most of the districts where adoption of weed control is low are those where wheat sowing is late (in December or late November).

In EUP, in districts like Sidharathnagar, Maharajganj, and Gorkhpur, only a fraction of farmers (< 4%) did not do control weeds in their fields (Fig. 5). In other districts of EUP such as Deoria, Chandauli, and Mau, about 10-12% farmers and in Balia and Kushinagar, about 18-21% of farmers did not practice any weed control in their wheat fields.

The adoption of herbicide-based weed control also varied by the district (Figs. 5, 6). In Bihar, herbicide based weed control was high (75-85%) in districts such as Muzzafarpur, Nalanda, and Jahanabad, intermediate level (50-70%) in 14 districts such as Samastipur, Vaishali, Supaul, Begusarai, Kaimur, Khagaria, Saran, Gaya etc, low adoption (30 to <50%) in 9 districts and very low adoption (<30%) adoption in districts such as Munger, Banka, Patna, Bhagalpur, and Arwal (Figure 6). In EUP, adoption of herbicide-based weed control was higher in all districts with highest adoption in Sidharthnagar (94%), Maharajganj (88%), and Gorkhpur (88%). In other districts, herbicide-based weed control adoption was 63-72%.

Out of 16 herbicides or their combinations used by farmers, 2, 4-D – the oldest herbicide – is still the most frequently used herbicide with 46 % herbicide users (Table 7). It is followed by a combination of

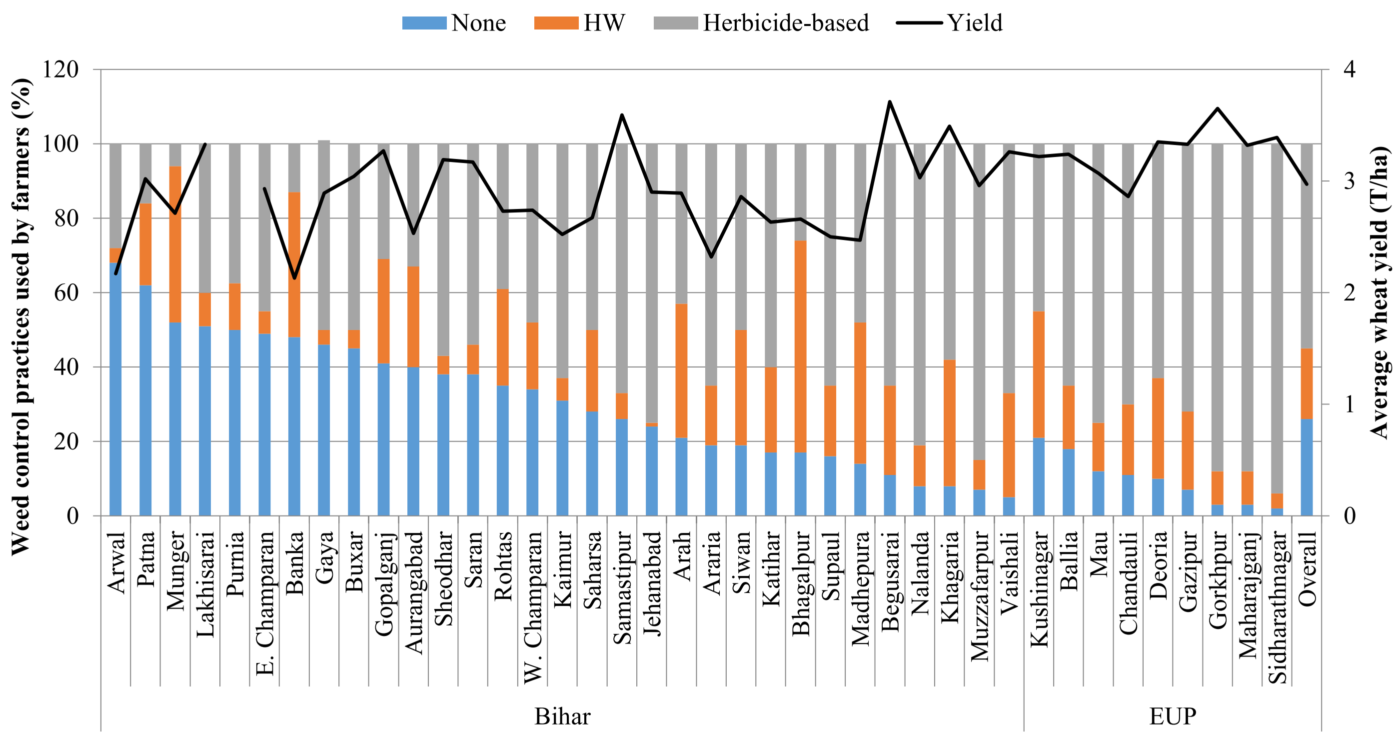


Fig. 5: Types of weed control practices (%) used by farmers for weed control in wheat in different districts of Bihar and EUP with average wheat yield in 2017-18

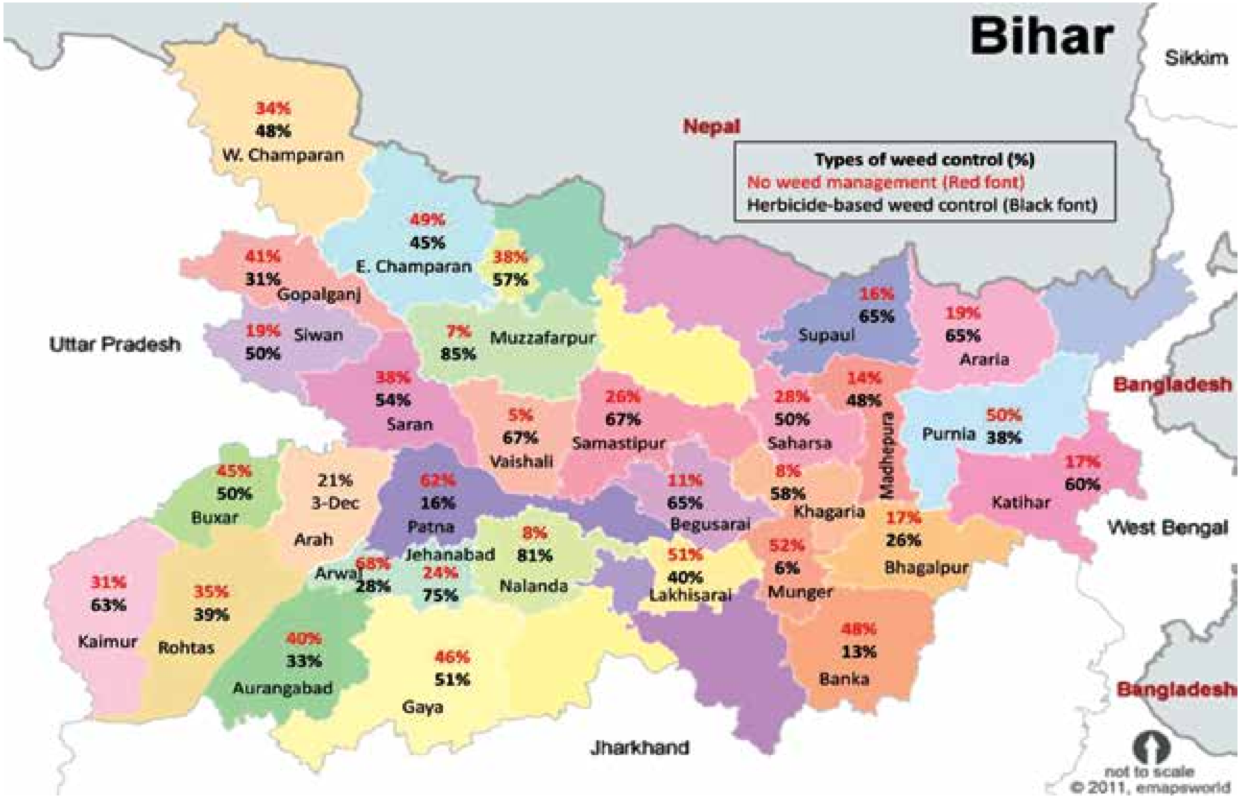


Fig. 6: Percent of wheat field with no weed management (red font) and with herbicide-based weed control (black font) in different districts of Bihar

Table 7: Different herbicides used by wheat farmers for weed control and their impact on wheat yield (n=4,192)

Herbicide	No. HHs	% of respondents	Avg. yield
2,4-D	1,934	46%	3.13
Sulfosulfuron + Metsulfuron	1,207	29%	3.29
Sulfosulfuron	534	13%	3.36
Others* including unknown	301	7%	3.07
Clodinafop	101	2%	3.33
Pendimethalin	52	1%	2.62
Carfentrazone	25	1%	3.70
Metsulfuron	21	0.5%	3.61
Sulfosulfuron + Carfentrazone	17	0.4%	3.66

*Isoproturon, Clodinafop + Metsulfuron, Metsulfuron + Idosulfuron, Carfentrazone + Sulfosulfuron, 2,4-D + Sulfosulfuron

sulfosulfuron+ metsulfuron with 29% of respondents, and sulfosulfuron alone with 13% of farmers. Farmers who used herbicides other than 2, 4-D in general had higher grain yield (Table 7). New herbicides are more effective in controlling complex flora, and new broadleaf herbicides such as carfentrazone and metsulfuron are more effective in controlling a wider range of broadleaf weeds compared to 2,4-D. This could be the reason of lower yield in 2,4-D applied fields compared to other herbicides. Despite this, farmers are still using 2,4-D widely suggesting that there is a need to raise awareness about new, safer and more effective herbicide molecules in Bihar and EUP to manage complex weeds. Nonetheless, many herbicides, including sulfosulfuron, metsulfuron, carfentrazone alone or their mixture, are gaining popularity in Bihar and EUP. In eastern India, considering the more complex weed flora in wheat fields, herbicide mixtures are the best way to combat the problem of complex weed flora. This should help farmers contain the cost of manual weeding. Private companies are now bringing ready-made premix combinations of herbicides such as sulfosulfuron + metsulfuron (e.g., Total), clodinafop + metsulfruon (e.g., Vesta), and sulfosulfuron + carfentrazone (e.g., Broadway). These ready-made herbicide combinations are eliminating the requirement for farmers to tank mix manually and are an effective strategy for controlling complex weed flora in eastern UP and Bihar (CSISA 2015).

Based on the survey results, wheat yield (average of all districts) increased in the following order: Herbicide-based (sole herbicide or herbicide + hand weeding) weed control (3.20 t ha^{-1}) > weed control by hand weeding only (2.98 t ha^{-1}) > no weed control (2.54 t ha^{-1}). Herbicide-based weed control was yielding higher than that in hand weeded fields. This could be because grass weed control cannot be done efficiently using manual labor because of problems associated with the identification of grass weeds from wheat plants. In addition, labor is becoming scarce and expensive and sometimes it is difficult to find labor at a critical time. In addition, in the broadcast method of sowing, it is more difficult to do manual weeding. Line sowing of wheat could facilitate mechanical weeding or reduce labor use in manual weeding as identification of weeds between rows is much easier than a broadcast method.

Results demonstrated that farmers who managed weeds in their wheat fields with herbicide-based weed control practices obtained on an average 0.65 t ha^{-1} (26%) higher wheat yield than farmers who did not control weeds in their wheat fields (Fig. 7). The yield difference between herbicide-based weed control fields and fields without any weed control ranged from 0.13 t ha^{-1} (5%) in Siwan district to 1.38 t ha^{-1} (66%) in Jahanabad district. The possible reasons for large variation in response of herbicide-based weed control compared to no weed control among districts could be due to combination of difference in wheat planting dates (in general higher yield losses in late planted wheat where crop is slow growing and hence less competitive to weeds), types of herbicides used for the control of troublesome weed present (2, 4-D based versus tank mix combinations– yield gain less if weed controlled by 2, 4-D than with tank mix combinations), and sampling size under types of weed control practices (some districts have very low % for the category of no weed control).

The survey result suggested that there is huge scope to improve the wheat yield by avoiding weed competition in those districts where the significant percent of farmers are not managing weeds in their wheat fields and losses due to weeds are high (Figs. 5-7). In districts such as Arwal, Lakhisarai, Banka, Gaya, Gopalganj, Aurangabad, Kaimur, Jahanabad, Arah, Araharia, Katihar, Bhaglpur, and Madhepur, many farmers (16-68% depending on district) are not doing any weed control (Figs. 5, 6) in their wheat field and yield responses to weed control are high (30-66%) (Fig. 7). These districts can be targeted for increasing

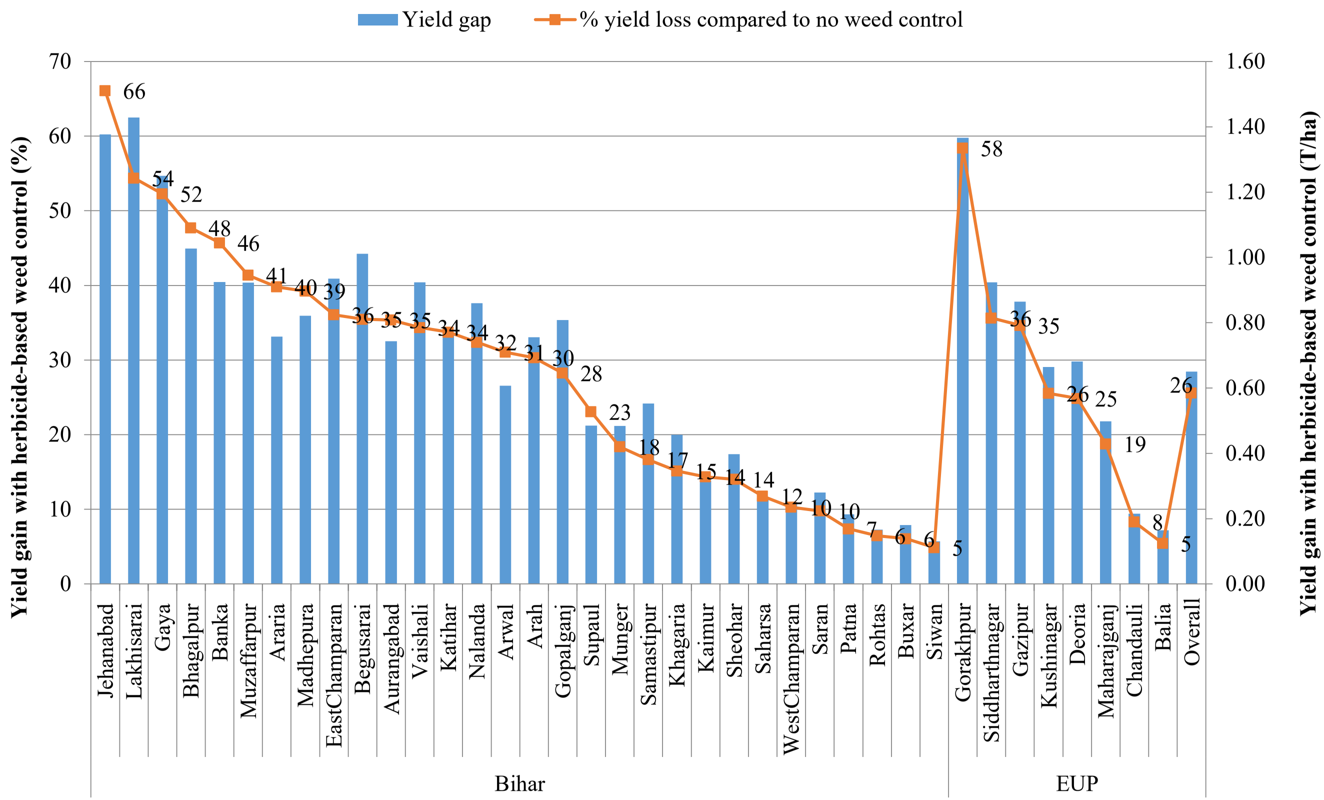


Fig. 7: Gain in yield in t ha^{-1} and in % with herbicide-based weed control compared to no weed control farmers from different districts in Bihar and EUP

awareness among farmers about the importance of weed control and losses caused by them and demonstrating the value of effective weed control for improving their wheat yields.

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3. Evidence based district level adoption patterns of technologies to identify future actions

3.1 Low wheat productivity is still a challenge in Bhojpur district

Pravin K. Dwivedi[1], Deepak K. Singh[2], S.B.K. Shashi[1] and S.P. Poonia[2]

[1]Krishi Vigyan Kendra, Arah
[2]International Maize and Wheat Improvement Centre (CIMMYT)

Introduction

The district of Bhojpur is in the Southern part of Bihar and inhabitats 999 villages covering a total geographical area of 233,700 ha land of which 185,100 ha is cultivable. The district population is 2, 243,144 (2011 census). The predominant soil type in the district is clayey and fine sandy loam (approximately 88%). The Landscape Diagnostic Survey (LDS) aims to seek the market opinion for the success and failure of new technologies. Although the Krishi Vigyan Kendra (KVK) had been developing the technical programs during the Scientific Advisory Committee (SAC) meetings, data from survey coupled with proper analytics will allow KVKs at district level, and Agricultural Technology Application Research Institutes (ATARIs) at regional levels to visualize the technology development or deployment differently and productively.

Methods

Details on methodology are given in Chapter 1

Blocks covered: Agiaon, Ara, Bihiyan, Koilwar, Jagdishpur, Piro, Sahar, Shahpur, Tarari and Udvantnagar.

Village 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).

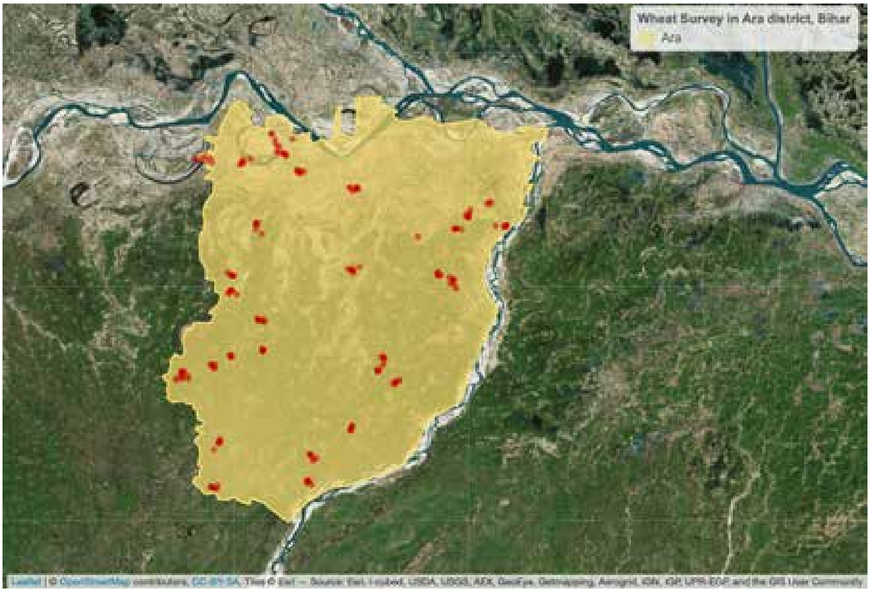

Fig. 1: GPS points of surveyed farms in Bhojpur

Results and Discussion

The rice-wheat cropping system (RWCS) is the major cropping system (Fig. 2). The survey revealed that the grain yield in this district was affected by broad range of factors; majorly early wheat sowing (EWS). The trends indicated that EWS is being accepted by farmers. The work of CSISA-KVK network also confirmed that advancement in wheat sowing is as crucial as the introduction of timely sown wheat varieties (TSWVs). On observing the varietal spectrum of the district, it was seen that there was equal distribution of many varieties (Table 1) in the area including Kedar, UP 262, PBW

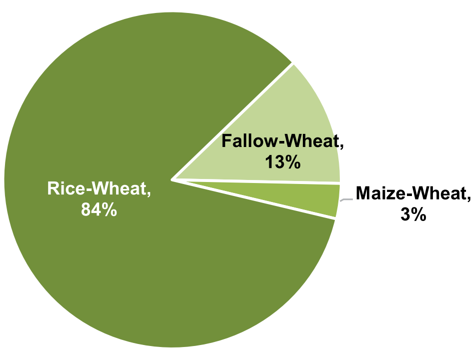

Fig. 2: Major cropping system prevailing in the district as per surveyed farmers

Table 1: Summary of important varieties including timely sown wheat varieties (TSWVs) and late sown wheat varieties (LSWVs) (2017-18) (n=208)

Varieties	Number of respondents	Percentage
TSWVs		
HD 2733	10	5%
HD 2967	12	6%
PBW 343	13	6%
PBW 502	14	7%
ShriRam 303	21	10%
LSWVs		
PBW 154	32	15%
UP 262	35	17%
Kedar	41	20%
LOK 1	14	7%
Others*	16	8%

*Includes PBW 550, WH 1105 from TSWVs group and HUW 234, RR 21 from LSWVs group

154, Shriram 303 etc. The usage of new and high yielding varieties is still very low. The yield performance of TSWVs was 3.11 t ha^{-1} and of late sown wheat varieties (LSWVs) 2.78 t ha^{-1} (Fig. 3). Most farmers (85%) sow their wheat in December and only 18% sow wheat very late (after 15 December). The November sown wheat fields were more productive than the December sown ones (Fig. 4). The more realistic assessment of factors which contribute to lower wheat yield include selection of LSWVs by farmers and lack of positive interaction between nutrient management and irrigation. This is because most farmers use more than 143 kg N ha^{-1} and

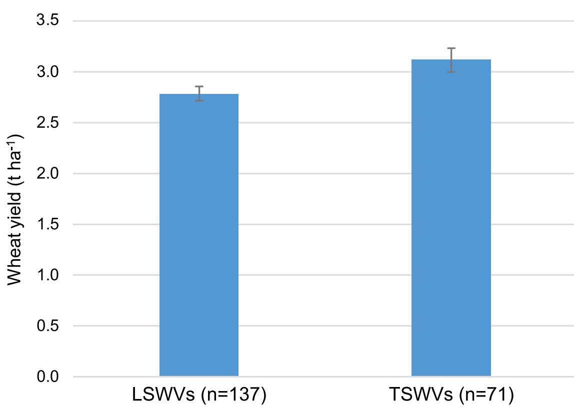

Fig. 3: Average grain yield of timely sown wheat varieties (TSWVs) and late sown wheat varieties (LSWVs) across different agronomic management options

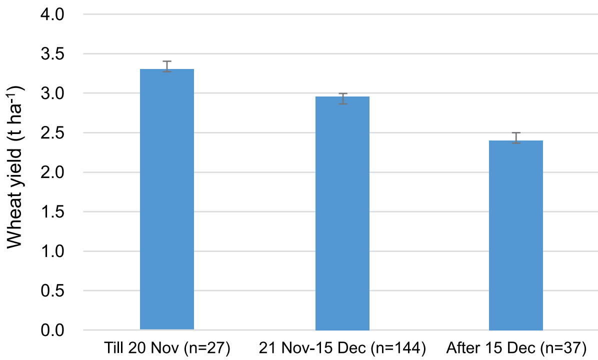

Fig. 4: Average grain yield of wheat as affected by three different sowing schedules across varieties and management practices

64 kg P_2O_5 ha^{-1} with only 2.5 irrigations where maximum response was seen up to 4 irrigations. On an average, 85% farmers do not use potash with an average use rate of 3.9 kg ha^{-1} (Table 2). The district has higher N usage than the recommended dose whereas the phosphorus usage is very near to the state recommendations, Potassium use was quite low as observed in the surveyed sample. Nearly 84% of the surveyed farmers did broadcasting, whereas 12% opted for zero tillage and line sowing whereas 4% opted for surface seeding (Fig. 5). The yield is higher in ZT or line sowing in comparison to broadcasting and surface seeding (Fig. 6).

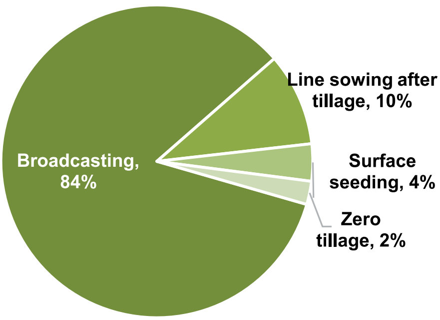

Fig. 5: Crop establishment methods practiced by farmers (n=19)10%

The weed management trend showed that the 21% surveyed population did not have any herbicide usage, whereas 36% opted for hand weeding, 41% used herbicides and 2% used both herbicide

Table 2: The use rates of N: P_2O_5: K_2O (kg ha^{-1}) and irrigation frequencies of surveyed farmers (potash users 15%)

NPK rates and irrigation frequency	Average dose	SD	SE
N	143.08	27.07	1.88
P_2O_5	60.76	16.05	1.12
K_2O	25.53	8.78	1.55
Irrigation Number	2.50	0.66	0.05

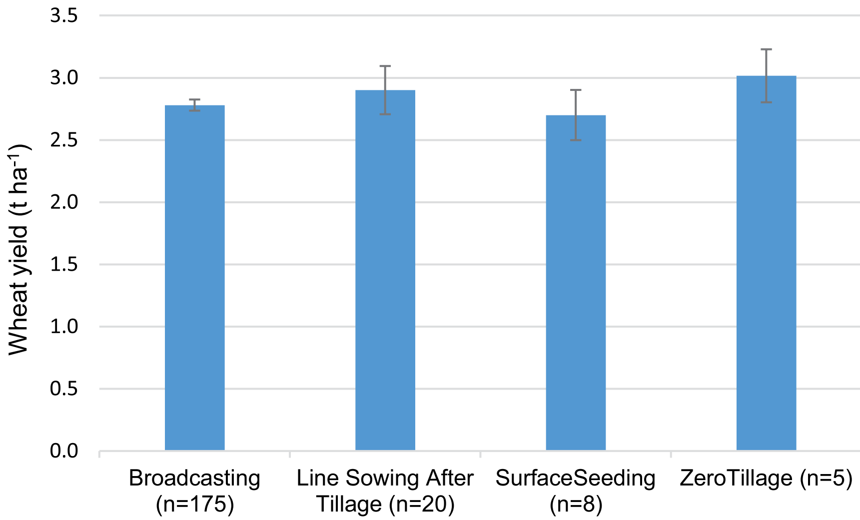

Fig. 6: Farmers reported average grain yield under four different crop establishment methods practiced by farmers

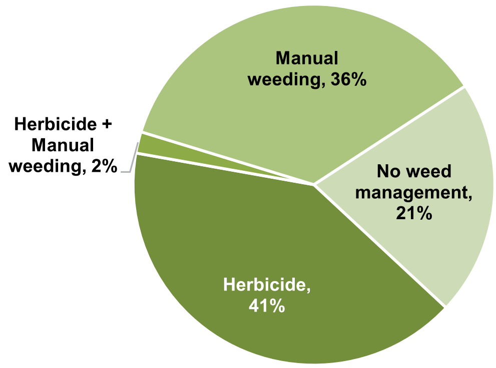

Fig. 7: Farmers reported weed management options practiced in the district (n=208)

as well as manual weeding (Fig. 7). There is a double delay that includes the harvesting time of rice and the sowing time of wheat. Increased use of farm machinery for rice harvesting and ZT for wheat can do this job, which is being adopted in few blocks but not reflected in the data on ZT. The adoption of TSWVs has been as good as in some other districts. Turnover of new varieties is critical (Atkin *et al.*, 2017), which is not happening and the new varieties will not reach the full yield potential until they were paired with irrigation and fertilizer (Gollin *et.al.* 2005). The low yield level at this fertilizer rates (Table 2) showed that the lack of irrigation is not helping to harness the impact of these fertilizer rates. The wheat yield increased with increase in number of irrigation from 1 to 4 (Fig. 8).

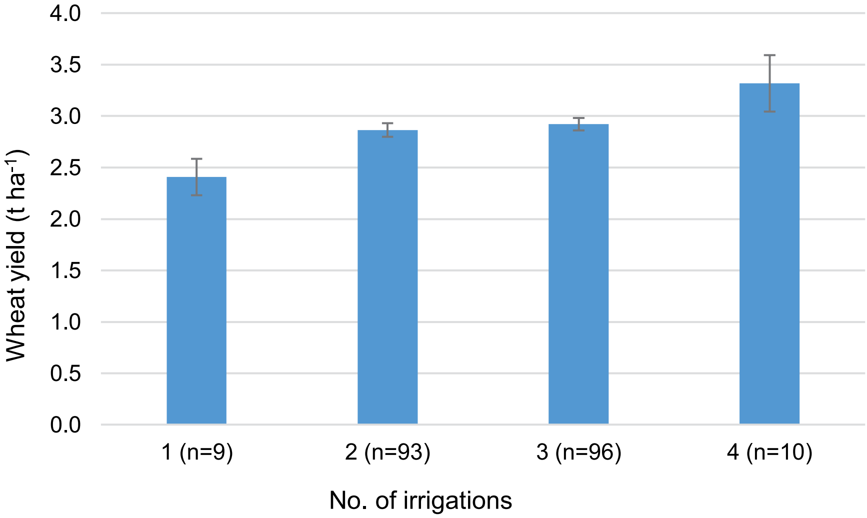

Fig. 8: The average grain yield of wheat under different irrigation frequencies

Conclusion

In a scenario like this, farmers with nutrient management on a higher side, should shift to early sowings with TSWVs. Data calls for an overhaul of agronomic management with focus on zero tillage and irrigation.

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3.2 Delayed sowing and use of late sown wheat varieties (LSWVs) are responsible for low yields in Araria

Arvind K. Sinha[1], Moben Ignatius[2], Sachin Sharma[2] and Pankaj Sinha[1]

[1]Krishi Vigyan Kendra, Araria
[2]International Maize and Wheat Improvement Center (CIMMYT)

Introduction

The district of Araria has 2 subdivisions, 9 blocks, 218 *panchayats* (local Government) and 751 villages. It has a total 268,500 ha geographical area of which 160,300 ha is cultivable. The net irrigated area is 108,780 ha. The total area under rice is 121,285 ha and wheat is 36,223 ha. Total rainfall is 1,608 mm. This district is dominated by sandy to sandy loam soils in 71% area and clay loam to clay in 29 % area. In many cases the wheat is grown in fallow land (Source: Contingency Plan, BAU, Sabour, Bihar). The wheat productivity levels are the lowest in this district. The crop production system remains vulnerable to excess water or floods. This is also a high rainfall zone with fields remaining wet till late in December. The Landscape Diagnostic Survey (LDS) was conducted to understand why the wheat productivity is low and what could be the triggering factor towards improving the wheat yields even in the fallow-wheat cropping system.

Methods

Details on methodology are given in Chapter 1

Block covered: Araria, Bhangama, Forbesganj, Jokhihat, Narpatganj, Palasi, Raniganj and Sikti.

Villages surveyed: Sisauna, Majgama, Dubba, Marichgaon, Balua, Basantpur, Rampur mohanpur, Bochi, Jitwarpur, Sisauna Araria, Girda, Chakai, Chirah, Hardar, Dhangawan, Dhengri, Baradhbatta, Benga, Ghiwaha, Saifganj, Raghunanthpur Uttar, Kupari, Dhanesri, Madhura Uttar, Haripur and Khapdeh (Fig. 1).

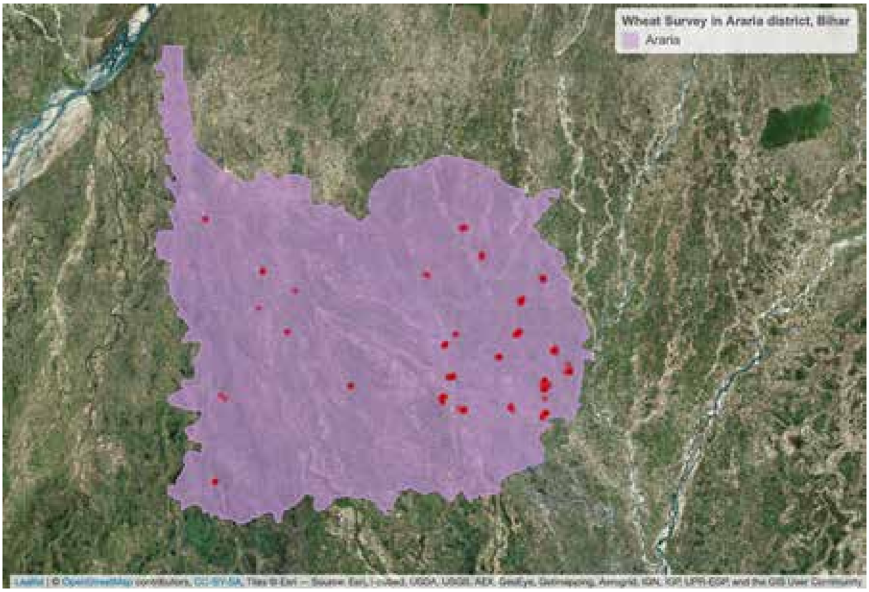

Fig. 1: GPS points of surveyed farms in Araria

Results and Discussion

The district is fallow-wheat dominated with 97% of surveyed farmers (Fig. 2). According to LDS data, this district ranks at the bottom of wheat grain yield at 2.1 t ha^{-1}. Varietal turnover is extremely low with the dominance of Nepal variety NL1 (Table 1). The part of problem has more to do with time management. It is among unique places with floods and drought occurring at the same time. In low land ecologies like this, the crop growth remains slow often incentives with yellowing of leaves. Sowings are delayed

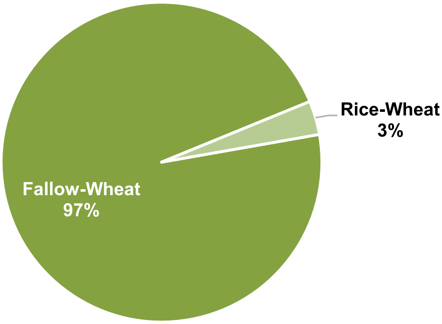

Fig. 2: Major cropping system prevailing in the district as per surveyed farmers

Table 1: Summary of important varieties including timely sown wheat varieties (TSWVs) and late sown wheat varieties (2017-18) (n=117)

Varieties	Number of respondents	Percentage
TSWVs		
PBW 343	4	3
LSWVs		
NL 1	97	83
UP 262	7	6
Ankur	4	3
Other*	5	4

*Includes Shriram 303 from TSWVs group and Kedar and Anshu from LSWVs group

and farmers have no incentive in the form of high yielding varieties to adopt modern technologies. The cooler temperature that follows affects moist soils leading to poor and stunted growth. Most respondents showed preference for local varieties from Nepal rather than improved varieties. Although only 5 respondents adopted TSWVs, yet the 0.3 t ha^{-1} higher yield may convince farmers to adopt these varieties. There is a scope of sowing much earlier than now (Fig. 3). Early sowing with TSWVs and nitrogen management can overcome the adverse effect of moist soils. N: P_2O_5:K_2O use at 124:77:39 kg ha^{-1} (Table 2) is on the higher side especially when fallow-wheat is the dominant cropping system. In addition, there is a consistent silting of canals/channels. This also causes uneven land. Sowing by broadcasting method then further leads to uneven and patchy crop. There is a better synchrony in tiller maturity with zero tillage (ZT) because most seeds are placed at same depth and emerge on the same day. In broadcast method of sowing, the rate and extent of emergence varied significantly (Malik *et al.*, 2014).

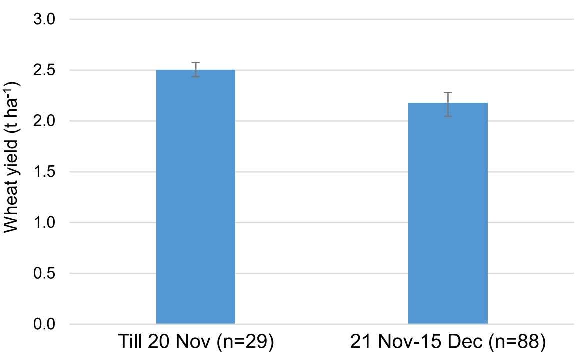

Fig. 3: Average grain yield of wheat by two different sowing schedules across varieties and management practices

Table 2: The use rates of N: P_2O_5: K_20 (kg ha^{-1}) and irrigation frequencies of surveyed farmers (potash users 97%)

NPK rates and irrigation frequency	Average dose	SD	SE
N	124.18	43.34	4.01
P_2O_5	76.71	27.17	2.53
K_2O	39.97	13.86	1.30
Irrigation Number	1.88	0.56	0.05

Another issue is irrigation which is costly. Irrigation frequency is low at 1.9 (Table 2) but its efficiency can be improved by targeting tillering phase and the grain filling stage. There is no-weed management carried out by 20% of farmers (Fig. 4). There is a huge advantage of irrigation, almost a yield difference of 1 t ha^{-1} is seen when 1 irrigation is applied in comparison to 3 irrigations (Fig. 5).

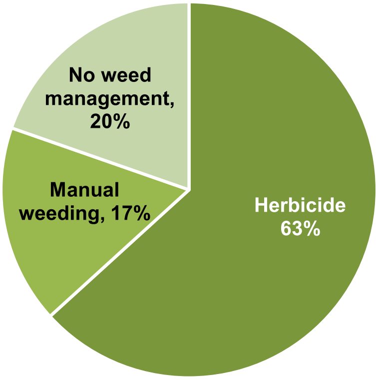

Fig. 4: Farmers reported weed management options practiced in the district (n=117)

In this district, we should focus on advancing wheat sowings, bringing breeding innovations at crop establishment phase rather than at terminal phase, improving varietal turn over and introducing zero-tillage to ensure the security at terminal phase. Wheat breeding and seed

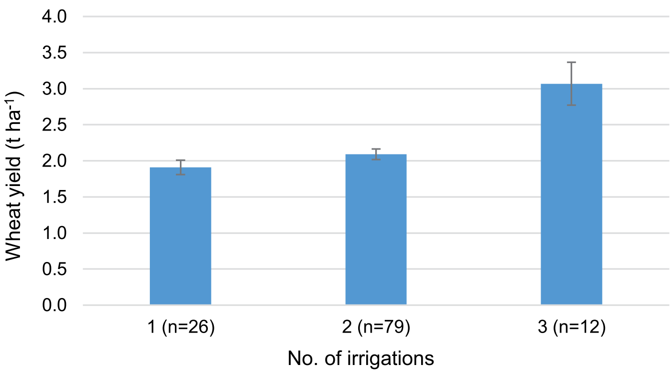

Fig. 5: The average grain yield of wheat under different irrigation frequencies

delivery systems might be the primary cause of slow cultivar turnover in the region (Krishna *et al.,* 2016)

Conclusion

The district has one of the lowest yield growth. The fallow- wheat system needs to be balanced by early sowing, nitrogen and irrigation management and zero tillage based interventions.

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3.3 Early wheat sowing is the surest way to increase wheat yield

Surendra Chaurasia[1], C.N. Choudhary[1], Sachin Sharma[2] and Nishant Prakash[1]

[1]Krishi Vigyan Kendra, Arwal
[2]International Maize and Wheat Improvement Center (CIMMYT)

Introduction

Arwal is a small district of Bihar with 63,400 ha of cultivable land. The texture of soil is clay and sandy loam. The net irrigated area is 26,500 ha. Total rice area is 44,100 ha whereas 15,000 ha is under wheat (Source: Contingency Plan BAU). Delayed sowing and late sown wheat varieties (LSWVs) are the reasons for low yield in Eastern Indian Gangetic Plan (EIGP). We never had a plan to address this issue. We avoided this issue and argued that early wheat sowing is not possible because of late harvesting of rice. There is no way to increase wheat productivity if we continue maintaining the status quo of late sowings. The landscape diagnostic survey (LDS) was planned to understand the current production practices and set priorities for research and extension.

Methods

Details on methodology are given in Chapter 1

Blocks covered: Arwal, Kahar, Karpi, Khutaha, Sonbhadra Banshi 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).

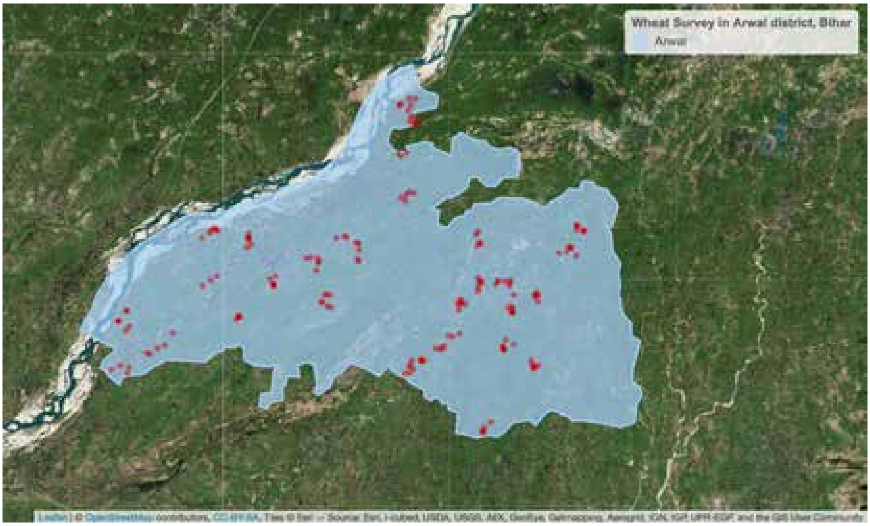

Fig. 1: GPS points of surveyed farms in Arwal

Results and Discussion

The district Arwal is majorly dominated by the rice-wheat cropping system (RWCS). By and large, farmers are less cautious about better-bet agronomy including varieties and time of sowing. Based on LDS, the late sown wheat varieties (LSWVs) including Lok 1, Kedar, UP 262 and PBW 154 constitutes 80% of varieties grown in the district (Table 1). This showed that the replacement rate of all varieties is very low. It may be because of lack of awareness or new varieties are not superior to the existing ones. Data indicated that majority of farmers have not advanced early sowings with only 9% farmers sowing their wheat crop before 20 November and 46% farmers after 15 December. Farmers who shifted towards early sowing of wheat (before 20 November) attained a yield of 3.39 t ha^{-1}. On an average, wheat sown from 21 November -15 December yielded 2.32 t ha^{-1} whereas sowing done after 15 December yielded only 1.8 t ha^{-1} (Fig. 2). Data for varietal spectrum showed that the preference for timely sown wheat varieties (TSWVs) is increasing with 20% respondents. The grain yield of LSWVs reported by respondents was 61% lower than TSWVs. As

Table 1: Summary of important varieties including timely sown wheat varieties (TSWVs) and late sown wheat varieties (2017-18) (n=181)

Varieties	Number of respondents	Percentage (%)
TSWVs		
HD 2967	23	13
PBW 502	7	4
PBW 343	6	3
LSWVs		
Lok 1	43	24
PBW 154	12	7
Kedar	32	18
UP 262	26	14
Other*	32	18

*Includes HUW 234 from LSWVs group

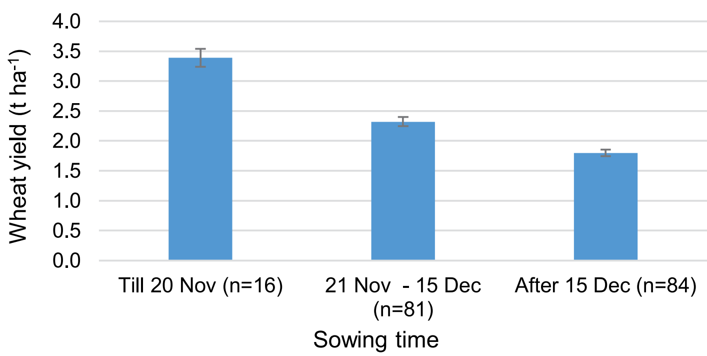

Fig. 2: Average grain yield of wheat as affected by three different sowing schedules across varieties and management practices

part of strategy, the productivity of EIGP should improve if the focus is changed from LSWVs (Joshi *et al*., 2007) to TSWVs. Average yield of TSWVs is 3.14 t ha^{-1} whereas that of LSWVs 1.93 t ha^{-1} (Fig. 3). Much of this reduced performance is due both to late sowing and low yield potential of LSWVs. From the existing data set, it is clear that advancement in wheat sowing and the adoption of TSWVs can help creating conditions for better growth and development that can beat the terminal heat. Timely sowing, determinant is the most important to achieve optimum flowering time. N: P_2O_5:K_2O use at 149:42:7 kg ha^{-1} is within normal rate limits. As such there are no soil health issues. The average number of irrigation was 2.45 (Table 2). No weed management

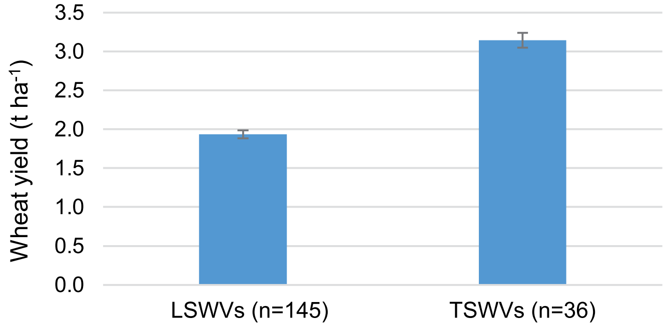

Fig. 3: Average grain yield of timely sown wheat varieties (TSWVs) vs late sown wheat varieties (LSWVs) across different agronomic management options

Table 2: The use rate of N: P_2O_5: K_2O (kg ha^{-1}) and irrigation frequencies of surveyed farmers (potash users 25%)

NPK rates and irrigation frequency	Average dose	SD	SE
N	148.75	38.27	2.84
P_2O_5	42.47	13.25	0.99
K_2O	25.71	21.78	3.21
Irrigation Number	2.45	0.83	0.06

(Fig. 4) was adopted by 68% of the farmers. Despite these factor, data also highlighted the need for including zero tillage (Keil *et al.,* 2015) in combination with weed management (Malik *et al.,* 2014). Direct relation was also observed between yield and irrigation frequency (Fig. 5).

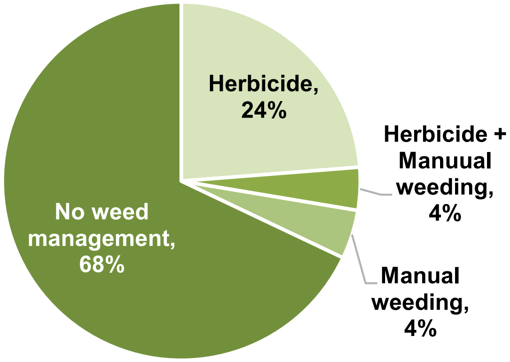

Fig. 4: Farmers reported weed management options practiced in the district (n=181)

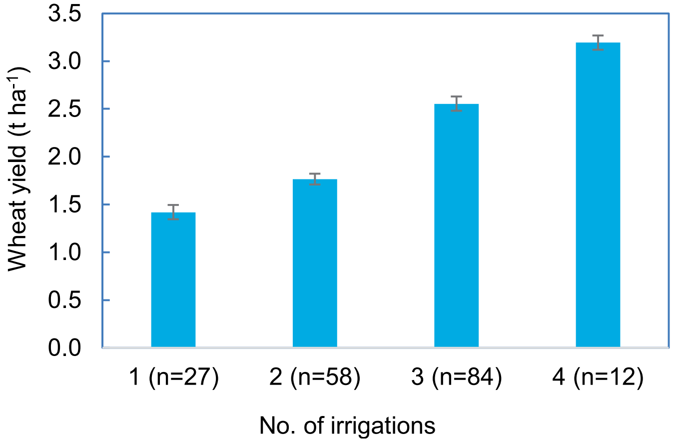

Fig. 5: The average grain yield of wheat under different irrigation frequencies

Conclusion

Planting seeds of TSWVs directly into untilled soil immediately after rice harvest and weed management are strategic issues.

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3.4 Delayed wheat sowing is one of the main reasons for low wheat yields in Aurangabad

Sachin Sharma[1], Nityanand[2], Rajeev K. Singh[2] and Ravi Ranjan Kumar[2]

[1]International Maize and Wheat Improvement Center (CIMMYT)
[2]Krishi Vigyan Kendra, Aurangabad

Introduction

Aurangabad district has 2 subdivisions, 10 blocks, 102 panchayats and 1,884 villages. It covers an area of 3,305 km^2 and a population of 102,244 (2011 census). It has a total 167,958 ha of cultivable land. The net irrigated area is 100,330 ha. The total area under rice is 105,259 ha and total area under wheat is 52,479 ha.

Terminal heat is affecting wheat yields every year in this district. Present landscape diagnostic survey (LDS) is an attempt to understand the factors which can help in seeking new initiatives to beat the terminal heat. This survey also seeks an improvement on the earlier emphasis on evolving early emerging wheat varieties which are potentially low yielders. After working at farmers' fields, we saw a huge opportunity in agronomic management of the cropping system as a whole and are now looking for the single most important variable, which could make large differences in the productivity of wheat in the rice-wheat cropping system.

Methods

Details on methodology are given in Chapter 1

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).

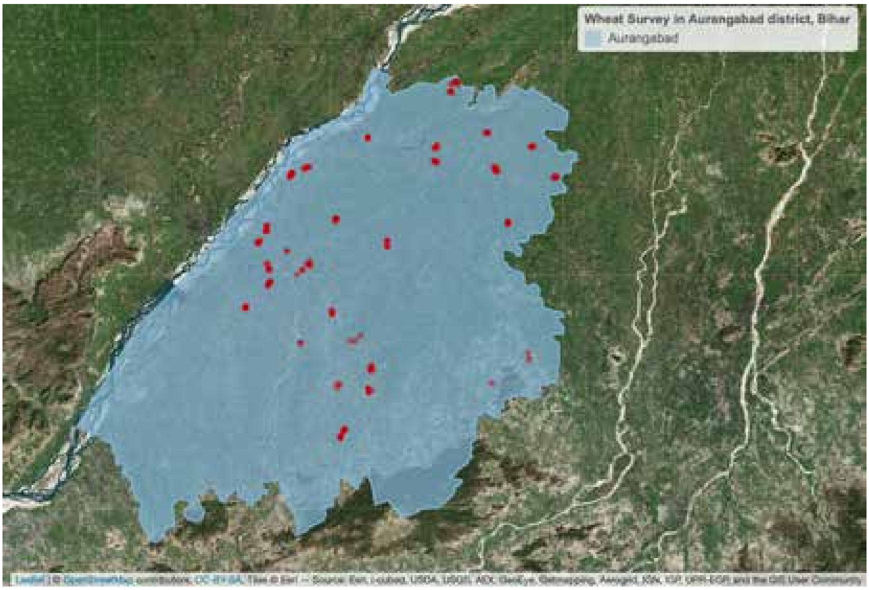

Fig. 1: GPS points of surveyed farms in Aurangabad

Results and Discussion

None of the new varieties released during last 10 years could find favour of farmers in this district. Only 2% farmers accepted the new variety HD 2967. There is no sign of new varieties beating the existing ones in large number. This is because more than 35 years old varieties like Lok 1 (25%), UP 262 (14%), RR21 or Sonalika (9%) and local varieties (22%) are still popular as seen in Table 1. All these and many more in the "others" category are late sown wheat varieties. The preference for LSWVs by more than 90% farmers showed the underlying correlation with late wheat sowings. The average wheat yield at 2.87 t ha^{-1} for timely sown wheat variety (TSWVs) showed some improvement over

Table 1: Summary of important varieties including timely sown wheat varieties (TSWVs) and late sown wheat varieties (LSWVs) (2017-18) (n=194)

Varieties	Number of respondents	Percentage (%)
TSWVs		
HD 2967	3	2
PBW 343	7	4
LSWVs		
HUW 234	8	4
Kedar	15	8
Local**	42	22
LOK 1	49	25
PBW 154	4	2
RR 21	17	9
UP 262	28	14
Ankur	9	5
*Others	12	6

*Includes ShriRam 303 from TSWVs group and Bhikruti, BL 4341, DBW 14, HI 1563, Maina, PBW 373, Suryamukhi from LSWVs group.
**Farmers were not able to recall the name of the varieties.

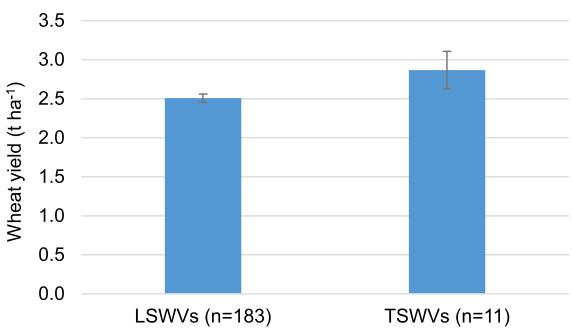

Fig. 2: Average grain yield of timely sown wheat varieties (TSWVs) vs late sown wheat varieties (LSWVs) across varieties and management practices

the grain yield of 2.51 t ha^{-1} for LSWVs, but this is not sufficient (Fig. 2). Having seen the success of TSWVs over LSWVs in many other districts of Eastern UP and Bihar (CSISA report 2014, 2015), we should encourage the evolution and use of TSWVs and also sequentially advancing the wheat sowings. The yield reduction of 0.4 t ha^{-1} was reflected when sowings were done after December 15 (Fig. 3). The survey points to poor weed management with 40% HHs not controlling weeds at all. This is one of the reasons for lower yield. Herbicide use

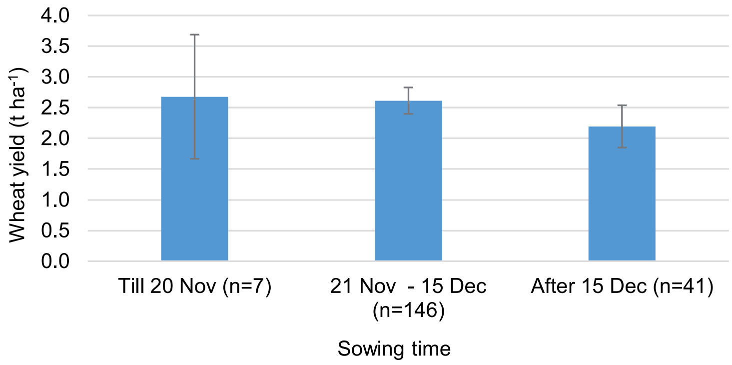

Fig. 3: Average grain yield of wheat as affected by different sowing schedules across varieties and management practices

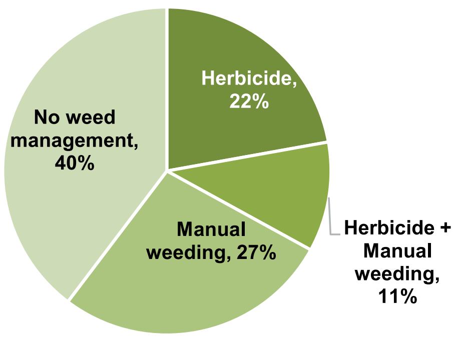

Fig. 4: Farmers reported weed management options practiced in the district (n=194)

rate of 22% is expected at this low yield level but 40% reporting on no weed control would mean heavy yield losses (Fig. 4). The yield levels were 1.37 t ha^{-1} for 0 irrigation and 3.54 for 4 irrigation (Fig. 5).

Without sufficient irrigation these initiatives may not work the way these are intended. Higher temperature during last few weeks of crop growth leads to early maturity, which is further compounded by lack of irrigation. The effect of water stress is mainly

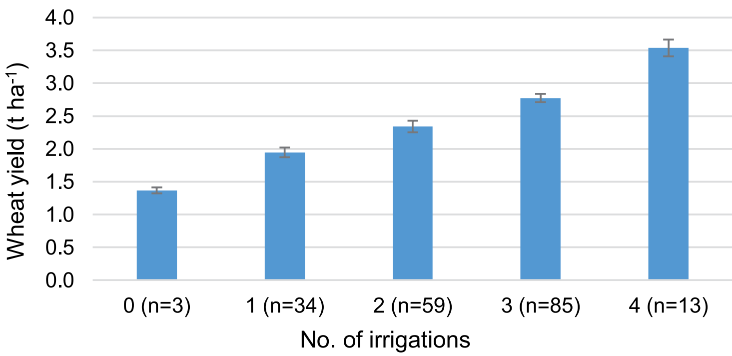

Fig. 5: The average grain yield of wheat under different irrigation frequencies

related to the hastening of last reproductive phase for fear of lodging. Water stress along with high temperature at the grain developing stages resulted in decreasing growth rate of grain and this results in poor yields (Spiertz *et al.*, 2006)

Farmers reported that the N : P_2O_5 : K_2O use was at 131:62:23 kg ha^{-1}. Low K rate is obviously on the expected line as most other districts in this survey also showed that K use in RWCS is much lower than other cropping systems (Table 2). LDS revealed that all agronomic parameters

Table 2: The use rates of N: P_2O_5: K_2O and irrigation frequencies of surveyed farmers (potash users 14%)

NPK rates and irrigation frequency	Average dose (unit kg ha^{-1})	SD	SE
N	130.84	38.13	2.73
P_2O_5	62.41	26.96	1.98
K_2O	22.81	10.58	2.00
Irrigation Number	2.30	1.55	0.13

except fertilizer use are indicative of poor performance of wheat in the district. These obstacles are best resolved when fundamentals of timely sowing with good agronomy are resolved. Cutting cost and boosting profits through zero tillage is another way of ensuring against terminal heat. It will also ensure the intensification of cropping system. The intensification can even be more profitable by combining ZT with short duration hybrids in rice. Such type of consolidation of management efforts are needed to bring the scale of cost saving for small farmers to improve their profits (Malik *et al.*, 2005).

Conclusion

Late sown wheat varieties must be sequentially replaced by timely sown wheat varieties. Rate of fertilizer is not an issue but their efficiency is an issue. The efficiency can be improved by better access to irrigation and deployment of better weed management practices.

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3.5 High potential of yield growth in wheat by exploiting current nutrient and irrigation management

Rajiv K. Singh[1], Deepak K. Singh[2], P.L. Srivastava[1], Shahnawaz R. Dar[3] and Madhulika Singh[2]

[1]Krishi Vigyan Kendra, Ballia
[2]International Maize and Wheat Improvement Centre (CIMMYT)
[3]International Rice Research Institute (IRRI)

Introduction

The district Balia has a total reported area 299,265 ha, out of which 215,498 ha (72%) is net sown area. The average wheat grain yield in Ballia is low. It has humid sub-tropical climate and deep alluvial soils. The dominant rice-wheat cropping system is vulnerable to both uncertain monsoon rains in the rice phase and the terminal heat in the wheat phase. In most cases, the late sowing is prevalent. Even at good resource base, the rice is harvested late, wheat seeding is delayed and consequently the crop is more prone to terminal heat. To help understand the production practices the landscape diagnostic survey (LDS) was undertaken. It will help institutions to respond to unexpected events and to identify technologies, which might help increasing or sustaining the productivity in the context of cropping systems rather than component crops.

Methods

Details on methodology are given in Chapter 1

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, Sohaon1, Sohaon2 Nauka Gaon, Narai (Fig. 1).

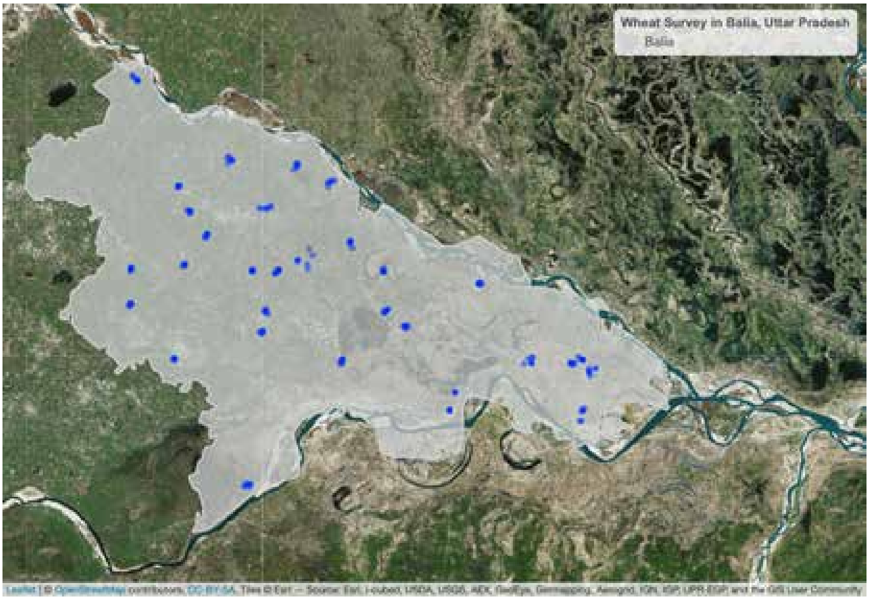

Fig. 1: GPS points of surveyed farms in Balia

Result and Discussion

Of the 216 households (HHs) surveyed, 87% had the rice-wheat cropping system as the most dominating cropping system (Fig. 2). Other cropping system was maize-wheat with 11% farmers. HD 2967 was the most dominant wheat variety grown by 30% respondents (Table 1). On the whole, the survey pointed to a significant change towards timely sown wheat varieties (TSWVs)

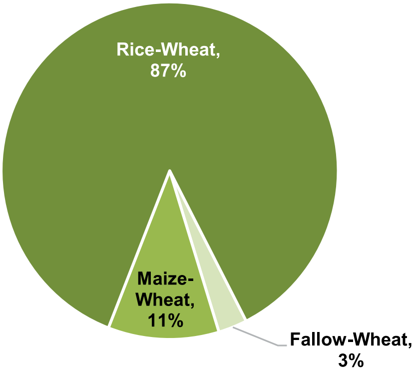

Fig. 2: Major cropping system prevailing in the district as per surveyed farmers

Table 1: Summary of important varieties including timely sown wheat varieties (TSWVs) and late sown wheat varieties (LSWVs) adopted by surveyed farmers (2017-18) (n=216)

Varieties	Number of house holds (HHs)	Percentage of total HHs
TSWVs		
HD 2967	64	30
PBW 502	38	18
ShriRam 303	8	4
PBW343	58	27
LSWVs		
PBW 373	7	3
PBW154	15	7
HUW 234	7	3
Other*	19	9

*Includes HD 2733, PBW 550 from TSWVs group and Kedar, UP 262 from LSWVs group.

with more than 75% farmers. This is well matched by a yield advantage of 0.3 t ha^{-1} when compared with late sown wheat varieties (LSWVs) (Fig. 3). When we differentiate two cases, namely TSWVs and LSWVs, there were 98 cases of early sowing and 170 cases of TSWVs. That means out of 118 cases of sowing done between 21 November and 15 December, 72 respondents used TSWVs. That also showed that choices of respondents were based on high yield potential of TSWVs and that is why the differences in yield narrowed down between two

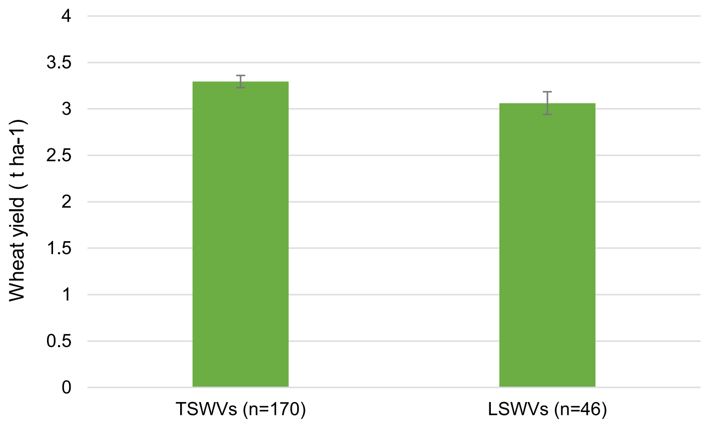

Fig. 3: Average grain yield of timely sown wheat varieties (TSWVs) and late sown wheat varieties (LSWVs) across different agronomic management options

sowing times (Fig. 4). As with the case of advancement in wheat sowing, the data on the adoption of TSWVs is worth considering. In fact, farmer's willingness to grow TSWVs even under late sowings showed the ultimate benefits of these varieties across sowing time. Data showed that in spite of major focus on the release of LSWVs, the grain yield of wheat from TSWVs stayed same or more than LSWVs. TSWVs established niches with more number of grains/ear head. With the implementation of CSISA project by its National Agriculture Research and Extension System (NARES) partners, an opportunity was created for advancing wheat sowings in EIGP (CSISA, Annual Report, 2014 and 2015). Early sowings may benefit due to longer yield formation phase (Hunt *et al.,* 2012) and the evolution of LSWVs cannot compensate the higher number of grains (Wardlaw *et al.,* 1980) in TSWVs. However, the integrated effect of TSWVs, nutrient management and irrigation that helps creating synergies was not visible in the wheat yield. The efficiency of N: P_2O_5:K_2O use rate of 148:62:39 kg ha^{-1} can be improved with the level of irrigation at 2.9 (Table 2). Whether soil

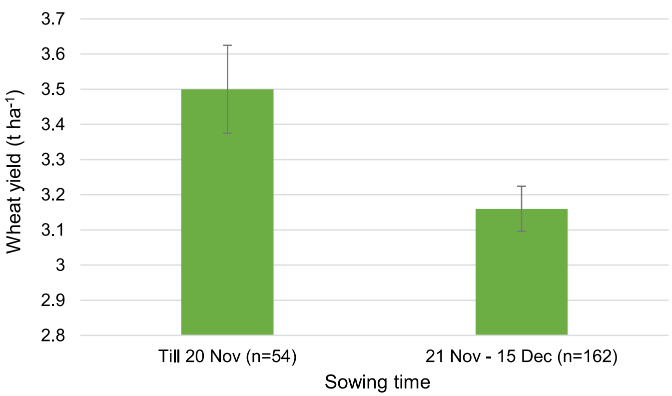

Fig. 4: Average grain yield of wheat as affected by two different sowing schedules across varieties and other management practices

Table 2: The use rates of N: P_2O_5: K_2O (kg ha^{-1}) and irrigation frequencies of surveyed farmers (potash users 67%)

Nutrient and irrigation management	NPK rates and irrigation frequency	SD	SE	n
N	148.15	29.99	2.04	216
P_2O_5	62.43	16.10	1.10	216
K_2O	38.75	16.67	1.39	141
Irrigation number	2.87	0.65	0.04	216

health issues that focus on rescheduling NPK rates only or something more than that, is the question. With this input base, the sowing date can be advanced further by using new technologies like zero tillage. Broadcasting method of wheat sowing is common with 90% of surveyed farmers whereas 10% do line sowing after tillage (Fig. 5). This is where awareness about crop establishment especially ZT is needed. Work done by Malik *et al.* (2005) in the many parts of NW India showed a significant yield advantage from ZT wheat sowing. Weed management is another area which needs attention because only 53% farmers use herbicides and 18% do not control weeds (Fig. 6). The sowing has to be advanced further. Weed management and ZT need attention by both farmers and researchers. The irrigation frequency at 4.0 was the best (Fig. 7) in this survey.

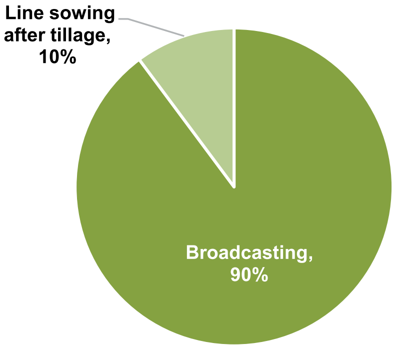

Fig. 5: Crop establishment methods practiced by farmers

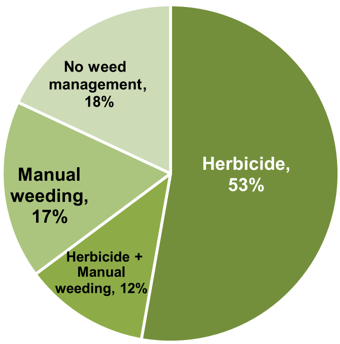

Fig. 6: Farmers reported weed management options practiced in the district (n=216)

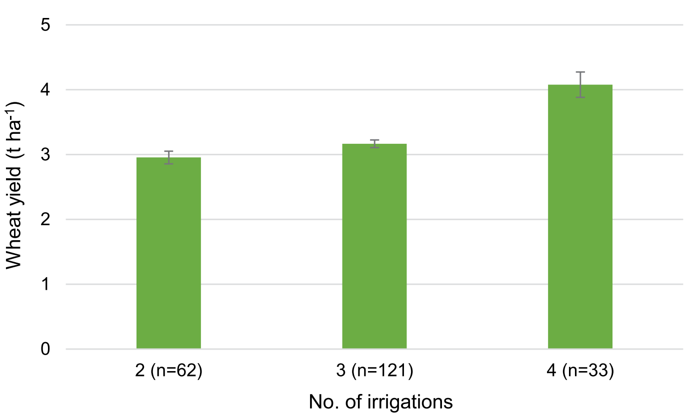

Fig. 7: The average grain yield of wheat under different irrigation frequencies

Conclusion

The nutrient management, irrigation management and TSWVs are not accompanied by early wheat sowing, zero tillage technology and season long weed management. Early sowing represents a fundamental change which will positively change the way other factors interact.

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3.6 Escaping the terminal heat should be at the forefront to affect a change in agronomic management in wheat

Raghubar Sahu[1], Anurag Kumar[2], Sanjay Kumar Mandal[1], Kumari Sharda[1] and Shishpal Poonia[2]

[1]Krishi Vigyan Kendra, Banka
[2]International Maize and Wheat Improvement Center (CIMMYT)

Introduction

The landscape of Banka is complex and it is not always easy to employ best management practices. It is thickly populated with 1,618 inhabited villages with a population of 2,029,339. The soil texture of this district is clay loam to sandy loam having a pH range from 7.12 to 7.8. Mostly the soils of this district are low to medium in nitrogen and high in phosphorus and medium to high in potash; zinc deficiency is widely spread in the district.

Escaping the terminal heat is at the forefront in the agronomic management for wheat. It is time to draw attention to this critical issue and focus only on the heat stress in the terminal phase of last 10 days when the temperature rises abruptly. Late sown wheat varieties (LSWVs) evolved to beat the terminal heat (Mondal *et al.*, 2016) have not been able to resolve this issue. What is needed is agronomic management that helps the crop reach at physiological maturity at the beginning of terminal heat. To understand this, the landscape diagnostic survey (LDS) was conducted in 2018. This is the first systematic survey to understand the adoption pattern of different recommendations and to set new priorities for research and extension in Bihar.

Methods

Details on methodology are given in Chapter 1

Blocks covered: Amarpur, Banka, Barahat, Belhar, 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, Uprama (Fig. 1).

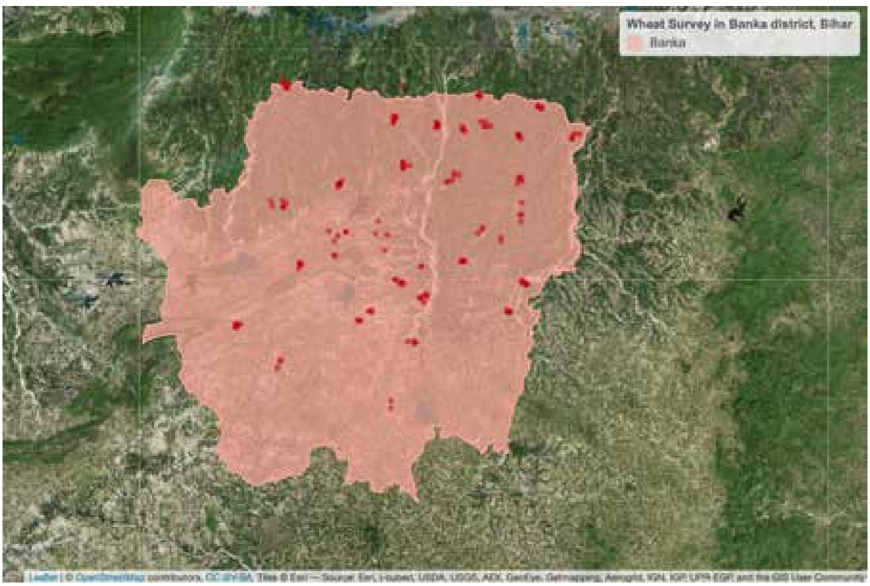

Fig. 1: GPS points of surveyed wheat farms in Banka

Results and Discussion

The rice-wheat is the dominant cropping system in this district. Only 10% farmers have adopted timely sown wheat varieties including HD 2967 and PBW 343. Kedar (43%) and Lok 1 (28%) were the dominating varieties in this district (Table 1). The vulnerability to conditions of water stress due to high cost of irrigation and terminal heat has been repeated

Table 1: Summary of important varieties including timely sown wheat varieties (TSWVs) and late sown wheat varieties (LSWVs) (2017-18) (HHs=176)

Varieties	n	%
TSWVs		
HD 2967	10	6
PBW 343	7	4
LSWVs		
Kedar	76	43
Lok 1	50	28
UP 262	15	9
*Other	18	10

*Includes Sriram 505 from TSWVs group and GK 7777, Sabour nirjal, Sonalika, unknown from the LSWVs group.

number of times in the past. The risk associated with late sowing is still the main reason to drive down the wheat yield. On the other hand, late sown wheat varieties (LSWVs) with low yield potential are not the answer to the perennial problem of terminal heat. With LSWVs, the grain yield at 2.0 t ha^{-1} is a big drag. The grain yield level of 3.4 t ha^{-1} showed that the adoption of TSWVs should increase (Fig. 2). Although very few farmers reported early sowing but the gain of yield of almost 1.0 t ha^{-1} is enough to focus on this variable (Fig. 3). Low temperatures and long pre-flowering period favour greater grain number (Prasad *et al.*, 2008).

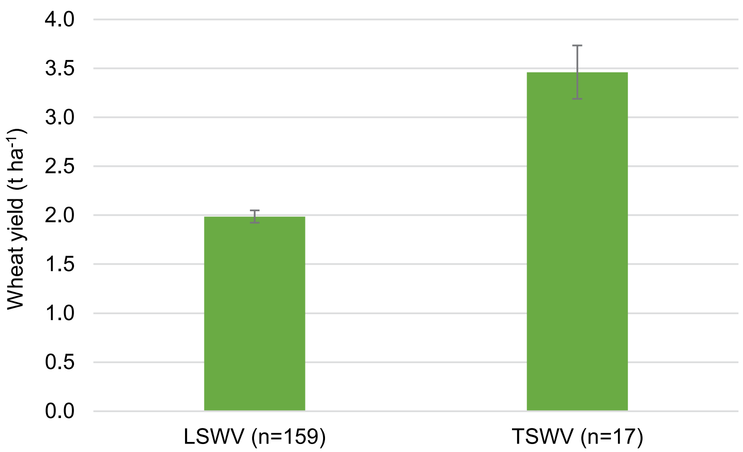

Fig. 2: Average grain yield of Timely Sown Wheat Varieties (TSWVs) and Late Sown Wheat Varieties (LSWVs) across different agronomic management options

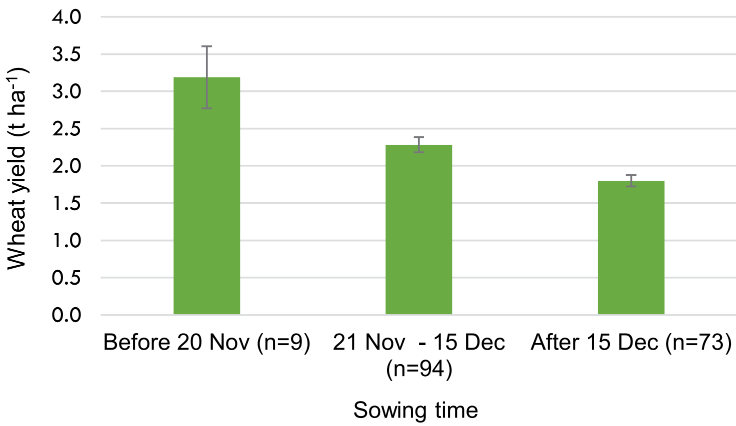

Fig. 3: Average grain yield of wheat as affected by three different sowing schedules across varieties and management practices

Temperature above 31°C may affect flowering and grain setting (Ferris *et al.,* 1998). Early sowing can help crop to reach flowering at lower temperature, which is somewhere in the middle 10 days of February.

Farmers in this district reported a significantly less fertilizer use at 71:41:21 kg ha^{-1} with an average irrigation frequency of 1.72 (Table 2). How access to irrigation is affecting the adoption of improved agronomic practices is visible here.

Figures reported for weed management showed that the progress is slow with 48% farmers not using any weed management option that could shield the losses from weeds (Fig. 4). These trends indicated that it might be possible to improve the productivity, if the access to irrigation is improved. A difference of 3 t ha^{-1} observed between application of 0 irrigation and 4 irrigations explains this very well (Fig. 5). Data clearly indicated that the slow yield growth is set to continue if the management

Table 2: The use rates of N: P_2O_5: K_2O (kg ha^{-1}) and irrigation frequencies of surveyed farmers. (potash users 79%)

NPK rates and irrigation frequency	Average dose	SD	SE
N	70.84	29.43	2.24
P_2O_5	40.94	13.01	0.99
K_2O	25.51	9.00	0.76
Irrigation number	1.72	0.90	0.07

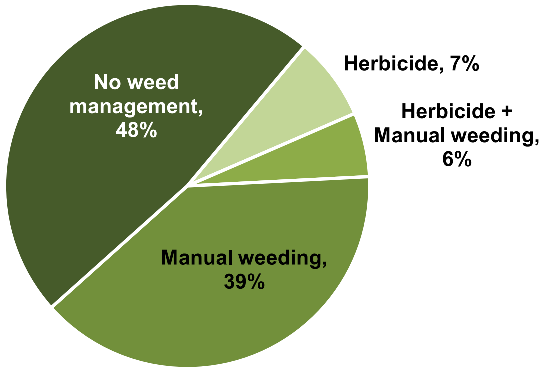

Fig. 4: Summary of weed management options of surveyed farmers – differentiated by three methods and no weed control (HHs=176)

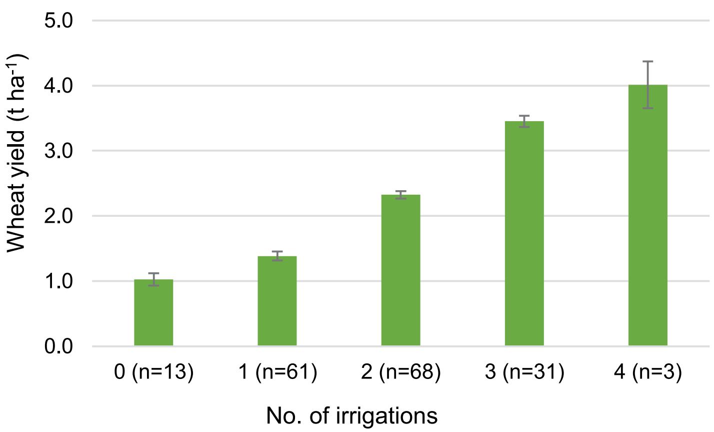

Fig. 5: The average grain yield of wheat under different irrigation frequencies

issues are not reoriented towards, irrigation, early sowings and TSWVs. Due to late sowings, the increased temperatures in the end of March makes the plant to mature early. Similar arguments of premature plant senescence and shortened period of photosynthetic activity (Al-Khatib and Paulsen 1984) were reported earlier also. Water stress during grain filling has a detrimental effect on panicle weight and subsequently grain yield due to shortening of the grain filling duration (Lalonde *et al.*, 1997).

Conclusion

Lack of access to irrigation is not encouraging farmers to adopt new technologies. In the meantime, wheat should be sown early and

TSWVs need to be promoted. Once these two interventions are in place, farmers will also be encouraged to use proper weed management.

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3.7 Early wheat sowing and timely sown wheat varieties: The game changer

Raju Kumar Srivastava[1], Anurag Kumar[2], Sidhnath Singh[1] and Shishpal Poonia[2]

[1]Krishi Vigyan Kendra, Begusarai
[2]International Maize and Wheat Improvement Center (CIMMYT)

Introduction

The soil types of Begusarai are sandy loam to loam. It has 18 blocks, 231 gram panchayats and 1,140 inhabited villages; mostly small farmers, having a population of 2,970,541 with 117,000 ha net sown area, of which area under rice is 18,149 ha and area under wheat is 60,600 ha. Net irrigated area is 74,225 ha. Less area under rice is one of the reasons why CSISA-KVK network attempted early sowings of wheat in this district since 2013. The evidence based data collection will be effectively used to spot what has worked and then seek strategic direction that will help sustainably improving wheat productivity in this district and beyond.

Methods

Details on methodology are given in Chapter 1

Blocks covered: Bachhawada, Barauni, Begusarai, Bhagwanpur, Birpur, Cheriyabariyarpur, chhaurahi, Dandari, Garpura, Khodawanpur, Mansurchak, Matihani, Sahebpurkamal, Teghra

Villages surveyed: Fafot, Lakhanpatti, Bariarpur, Rajaura, Bharra, Shaunkh, Parra, Amraur Kiratpur, Ninga, Nonpur, Hajipur, Matihani, Bakhadda, Iniar, Sonapur, Bahdarpur, Govindpur, Rudauli, Samsa, Pipradewas, Teyai, Katataharia, Chauki, Saligrami, Gopalpur, Ludhiyahi, Sonbarsa, Ajni, Deona, Govindpur, Matihani, Mohanpur (Fig. 1).

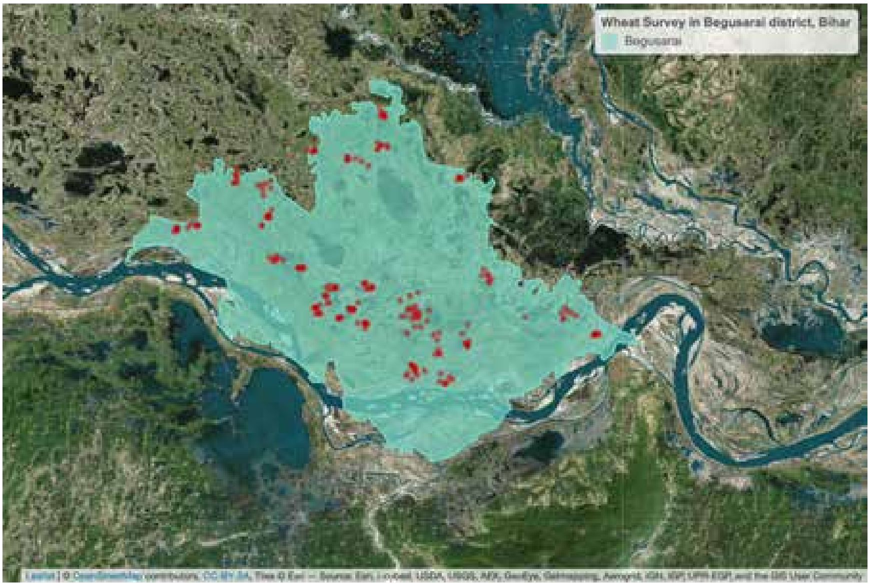

Fig. 1: GPS points of surveyed Wheat farms in Begusarai

Results and Discussion

Begusarai is dominated by soybean-wheat (45%) and maize-wheat (25%) (Fig. 2) cropping systems. During 2012-13, the resistance to change was overwhelmed by farmers by shaking off the old legacy of late wheat sowings. Begusarai is at the top of all districts surveyed so far with 90% farmers sowing their wheat crop before November 20th. This was justified with an average yield of 3.74 t ha^{-1} (Fig. 3). The grain yield of wheat seems to influence the decision of farmers on adoption of varieties with 89% of them growing timely sown wheat varieties (TSWVs) but within that PBW 343 is still popular with 53% farmers (Table 1). The grain yield from these varieties is 1.22 t ha^{-1} more than the late sown wheat varieties (LSWVs) (Fig. 4). Perhaps the real issue for

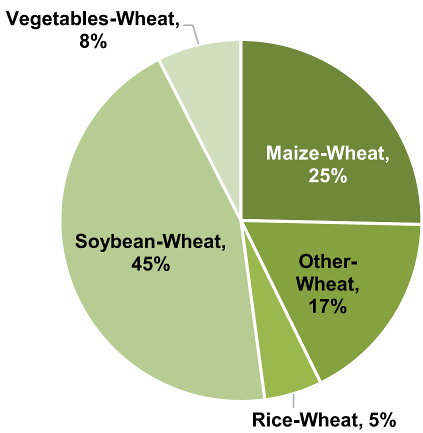

Fig. 2: Diversified cropping system of Begusarai (Households surveyed -213)

Table 1: Wheat varieties sown by surveyed farmers - summarised for the whole district based on time of maturity and still dominated by PBW 343 (HHs=213)

Varieties	Number of households	Percentage of HHs (%)
TSWVs		
HD 2733	4	2
HD 2967	39	18
PBW 343	112	53
PBW 502	8	4
PBW 550	9	4
ShriRam 303	17	8
LSWVs		
UP 262	19	9
Other*	5	2

*Includes Dhaulagiri from TSWVs group and Kundan, PBW 154 and PBW 373 from LSWVs group.

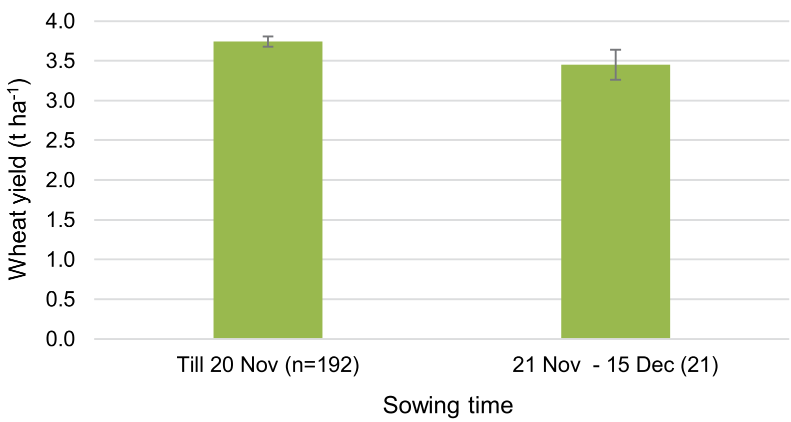

Fig. 3: Average grain yield reported by farmers from wheat sown at different time and emerging trends of early wheat sowings

improving and sustaining the improvement in yield growth is to focus on breeding TSWVs and seed early. Therefore, the earliness suggested as a good approach for wheat breeding in the Eastern Gangetic Plains (EIGP) that suffers from high temperature stress during grain filling (Joshi *et al*., 2007) is not finding favour from farmers. The evolution of LSWVs can not compensate the number of grains (Farooq *et al*., 2011) found in the TSWVs.

Irrigation frequency is still low (2.13) but the use of phosphorus (73 kg ha^{-1}; Table 2) seems on the higher side. Here the dominance of maize based system seems to be influencing the decision of farmers to apply more phosphorus. With highest yield in Bihar, farmers typically think of using better bet agronomy and therefore 89% households (HHs) opted for good weed management practices and the rest did not control weeds (Fig. 5). Irrigation management can also enhance productivity because yield difference comes around 2.42 t ha^{-1} between 1 irrigation and 4 irrigations applied in wheat (Fig. 6). Better access to irrigation can help farmers to further increase the wheat productivity in the area. Data have also given a framework

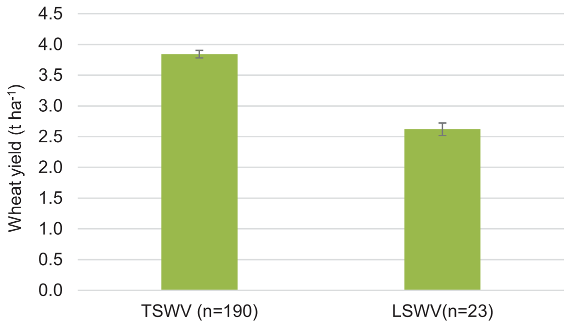

Fig. 4: Performance of timely sown wheat varieties (TSWVs) and late sown wheat varieties (LSWVs) based on the grain yield of wheat reported by farmers

Table 2: The use rates of N: P_2O_5: K_2O (kg ha^{-1}) and irrigation frequencies of surveyed farmers (potash users 92%)

NPK and irrigation management	NPK use rates and irrigation levels	SD	SE
N	136.00	30.07	2.07
P_2O_5	73.01	16.44	1.13
K_2O	37.08	6.59	0.47
Irrigation number	2.13	0.50	0.03

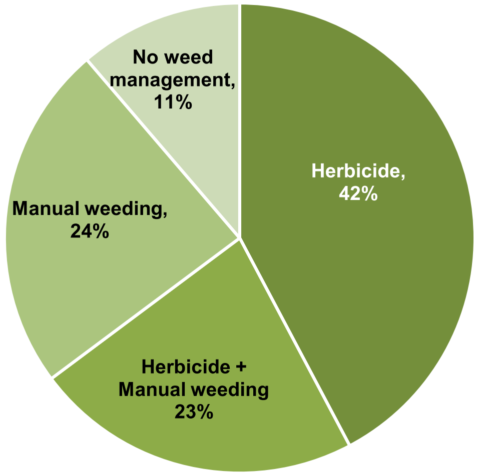

Fig. 5: Different weed management practices adopted by surveyed farmers (HHs=213)

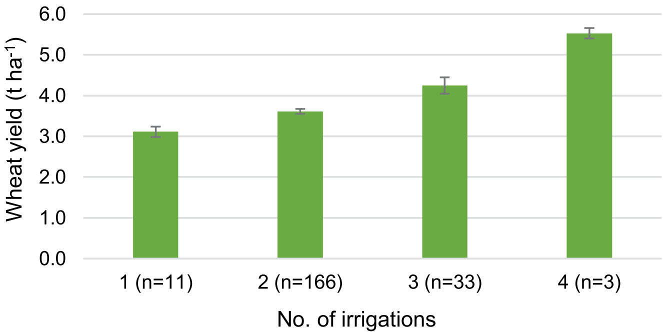

Fig. 6: Irrigation frequency vs yield levels

for increased focus on irrigation and weed management in addition to further advancement of wheat sowing through tillage options.

Conclusion

Intense heat near maturity affects wheat yield. Policy makers need to watch the yield trends in this district. Highest yield is basically because of early sowing and TSWVs. Farmers who plant late are subjecting their wheat for terminal heat effects. Weather is not sub-optimal but definitely agronomic management is. Trends in this district could be large part of policy interventions that we need for improving wheat productivity.

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3.8 Alteration in the agronomic management in favour of timely sown wheat varieties can help improve the efficiency of inputs and timely sowings

Ajay Kumar Maurya[1], Anurag Kumar[2], Pankaj Kumar[1], Krishnakant Dubey[1], Vinod Kumar[1] and Shishpal Poonia[2]

[1]Krishi Vigyan Kendra, Bhagalpur
[2]International Maize and Wheat Improvement Center (CIMMYT)

Introduction

Wheat yield growth in Bhagalpur district of Bihar has been seriously affected by delayed sowing. As the environment of uncertainty in sowing prevails throughout the district, it weighs heavily on the selection of varieties in favour of late sown wheat varieties (LSWVs), which are low yielders. In ecologies like Eastern Indo-Gangetic Plains (EIGP), the possibility of continuous high temperature (Ortiz *et al.*, 2008) has been the basis for evolving LSWVs. However, the major issue is abrupt rise of temperature at the terminal phase of wheat and not the continuously high temperature. We must offer a way round the constraint of late sowings. It makes sense to understand whether early sowing is more important or LSWVs. To understand the internal processes of adoption patterns of technologies by farmers, the production practice survey was conducted. The district of Bhagalpur falls in the Agro-climatic Zone IIIA (southern-east). The major soil type is fine sandy loam followed by clayey loam. The net sown area is 153,600 ha with a cropping intensity of 125 per cent.

Methods

Details on methodology are given in Chapter 1

Blocks covered: Bihpur, Colgong, Gopalpur, Goradih, Jagdishpur, Narayanpur, Nathnagar, Pirpainti, Rangra chawk, Shahkund, Sonhaula, 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, Taradiha (Fig. 1).

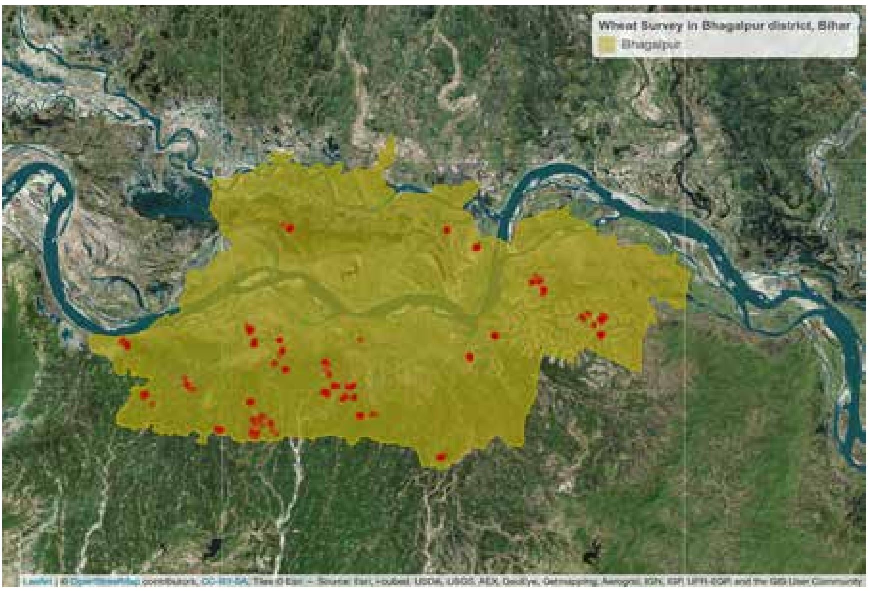

Fig. 1: GPS points of surveyed farms in Bhagalpur

Results and Discussion

Data suggested that 69% farmers practice rice-wheat cropping system (RWCS) followed by 14% maize-wheat cropping system (Fig. 2). Out of five timely sown wheat varieties (TSWVs), farmers' preference was seen in the order of PBW 343 (19%), PBW 502 (6%), Sri Ram (6%), HD 2733 (1%) and HD 2967 (1%) (Table 1). Among LSWVs, Lok 1 was favourite of 45% respondents. Data illustrated that early wheat sowing could be a way

Table 1: Summary of important varieties including timely sown wheat varieties (TSWVs) and late sown wheat varieties (LSWVs) (2017-18) (n=207)

Varieties	Number of respondents	Percentage
TSWVs		
DBW 17	2	1
HD 2733	2	0.97
HD 2967	2	0.97
PBW 343	39	19.32
PBW 502	13	5.8
ShriRam 303	13	5.8
LSWVs		
Kedar	3	1.45
Lok 1	91	45.41
UP 262	15	6.76
Other	27	13.53

*Includes Janki, Kundan, and unknown from LSWVs group

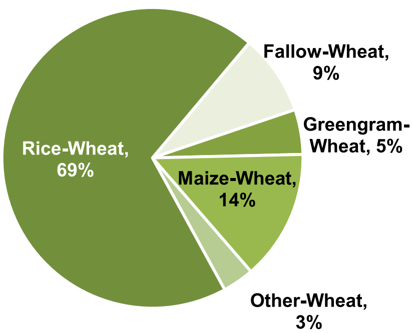

Fig. 2: Major cropping system prevailing in the district as per surveyed farmers

to increase the wheat productivity with grain yield of 2.80, 2.65 and 2.42 t ha^{-1} when the sowings were done before 20 November, between 21 November and 15 December and after 15 December, respectively (Fig. 3). Data also found the evidence for an incentive from early sowings in the form of adoption of TSWVs. At adoption rate of 32%, the average grain yield of these varieties combined together was 0.51 t ha^{-1} more than LSWVs (Fig. 4). Average N: P_2O_5:K_2O use was 112:50:32 kg ha^{-1} (Table 2). The question is not whether we should increase or decrease NPK rates by small changes which is happening in most cases. Rather, we should better switch our emphasis towards improving the efficiency of NPK (Table 2). More than 57% HHs adopt manual weeding and the herbicide use was only 14% (Fig. 5). Data suggested that factors other than nutrient management are affecting the yield growth of wheat. Farmers stand to gain if the sowing time is sequentially advanced and TSWVs are brought in as part of management

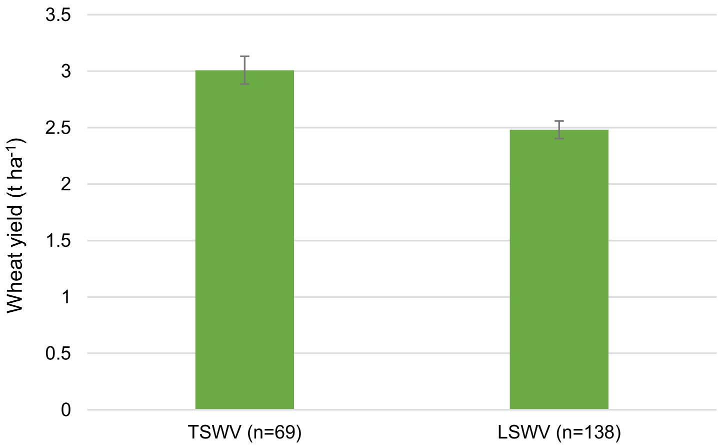

Fig. 3: Average grain yield of timely sown wheat varieties (TSWVs) and late sown wheat varieties (LSWVs) across different agronomic management options

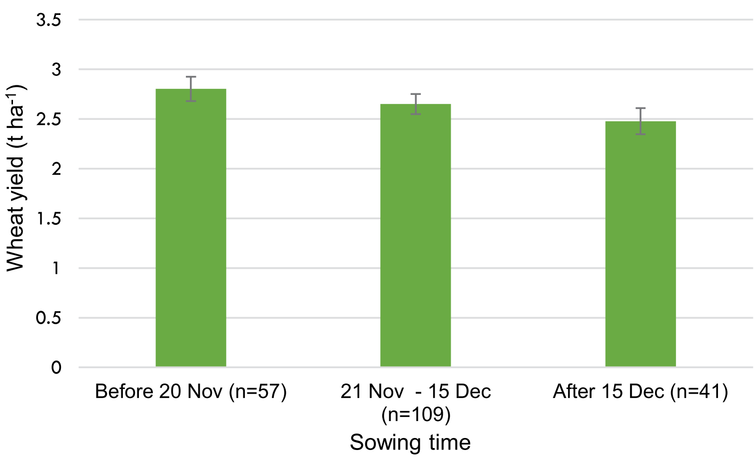

Fig. 4: Average grain yield of wheat as affected by three different sowing schedules across varieties and management practices

Table 2: The use rates of N: P_2O_5: K_2O (kg ha^{-1}) and irrigation frequencies of surveyed farmers (potash users 74%)

n=207	Mean	SD	SE
N	112.43	36.20	2.52
P_2O_5	50.17	18.80	1.31
K_2O	32.29	17.02	1.37
Irrigation number	2.22	0.88	0.06

options. With the increase in yield, weed flora will get simpler allowing farmers to start using herbicides. Similarly, improvement in irrigation management both by increasing its frequency (Fig. 6) and ensuring it at grain filling stage will help. Immediate priority will be early sowing, TSWVs and increased irrigation frequency. Zero tillage can help advancing wheat sowings. Altered agronomic management option is the best way forward (Easterling *et al.*, 2003).

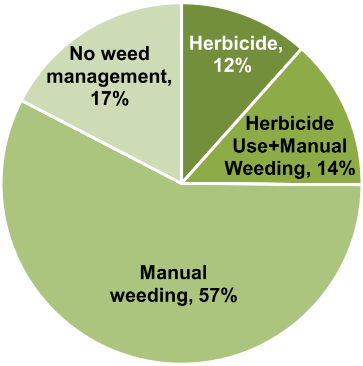

Fig. 5: Farmers reported weed management options practiced in the district (n=207)

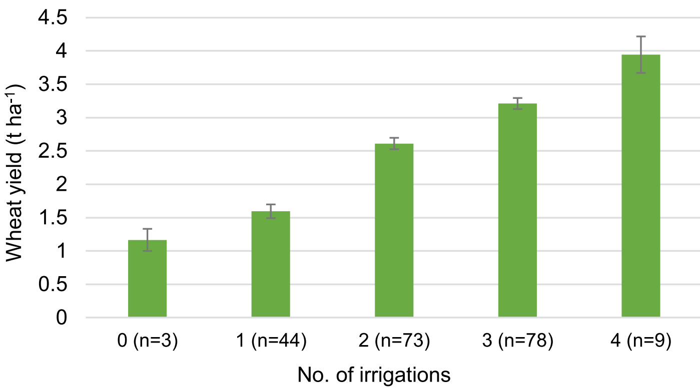

Fig. 6: Irrigation frequency vs yield levels

Conclusion

The feedback from farmers illustrated that low key approach by researchers and extension agencies in favour of timely sown wheat varieties (TSWVs) is not helping in improving the efficiency of inputs and early sowings.

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3.9 Wheat yield growth can improve through agronomic management

Mandhata Singh[1], Deepak K. Singh[2], V. Dwivedi[1], Deokaran[1], J.S. Mishra[3], B.P. Bhat[3] and S.P. Poonia[2]

[1]Krishi Vigyan Kendra, Buxar
[2]International Maize and Wheat Improvement Centre (CIMMYT)
[3]ICAR Research Complex for Eastern Region, Patna

Introduction

The agriculture scenario of Buxar district is better than most districts in Bihar but wheat yields are still low compared to districts like Begusarai. With a population of 1.4 million spread over 1,134 villages, the net geographical area is 493,700 and net sown area 235,800 ha. The total area under rice is 177,500 ha and wheat is 81,500 ha. The major soil type is sandy loam and clay loam. Agriculture is the mainstay of economy here, keeping 59% of the population gainfully employed. The landscape diagnostic survey (LDS) conducted in 2018 was aimed at creating a platform to seek farmers' opinion and provide them with the correct feedback.

Methods

Details on methodology are given in Chapter 1

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).

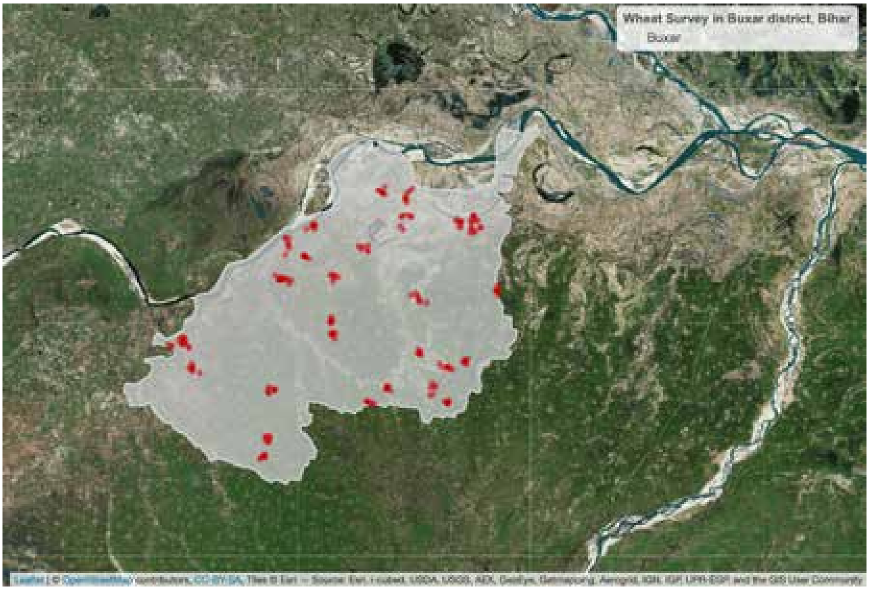

Fig. 1: GPS points of surveyed farms in Buxar

Results and Discussion

Data showed the dominance of rice-wheat cropping system (Fig. 2). Farmers of the district have larger plots than most other district in Bihar. Two new varieties including HD 2967 (34%) and Shri Ram 303 (28%) are preferred by farmers. Among late sown wheat varieties (LSWVs), like PBW 154 released in 1970s is still a favourite variety with 23% farmers reporting its adoption (Table 1).

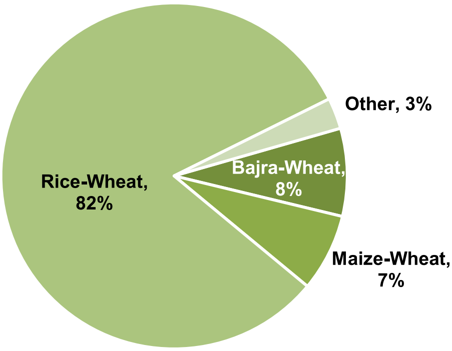

Fig. 2: Major cropping system prevailing in the district as per surveyed farmers

Timely sown wheat varieties (TSWVs) provided grain yield of wheat at 3.12 t ha^{-1} compared 2.86 t ha^{-1} from LSWVs (Fig 3). Data on the yield is further justified by the reduction in demand for these LSWVs varieties. The data showed that 69% farmers grow TSWVs compared to 31% who preferred LSWVs. Wheat sown till November 20, between 21 November

Table 1: Summary of important varieties including timely sown wheat varieties (TSWVs) and late sown wheat varieties (LSWVs) (2017-18) (n=208)

Varieties	Number of respondents	Percentage (%)
TSWVs		
HD 2967	71	34
ShriRam 303	58	28
PBW 502	12	6
LSWVs		
Kedar	12	6
PBW 154	47	23
Other*	7	3

*Includes PBW 343 from TSWVs group and Lok 1, PBW 373 and UP 262 from LSWVs group.

and 15 December or after 15 December provided an average yield of 3.31, 3.05 and 2.6 t ha^{-1}, respectively (Fig. 4). Substantially lower yields from late sowings done after 15 December showed that early sowings when combined with a TSWVs will leave farmers with more profits. This could be a new optimization (Herndl *et al.*, 2008; Stone *et al.*, 1995) because this combination can help manipulating flowering time in the

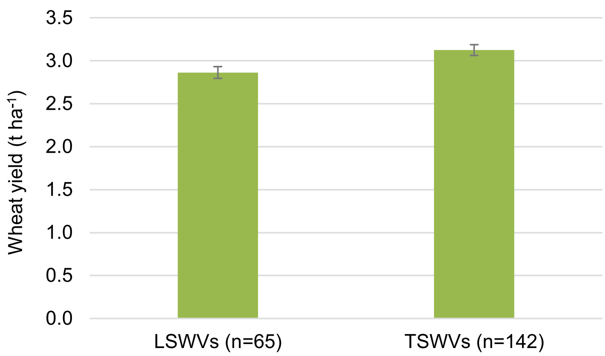

Fig. 3: Average grain yield of timely sown wheat varieties (TSWVs) and late sown wheat varieties (LSWVs) across different agronomic management options

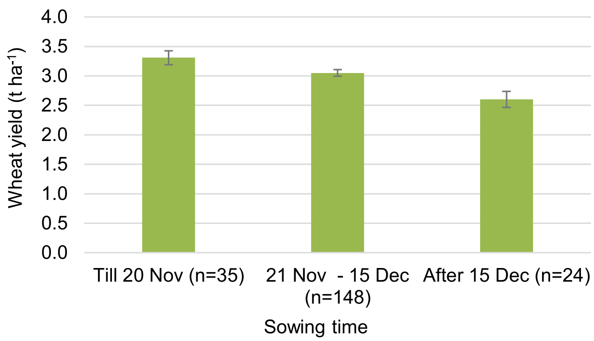

Fig. 4: Average grain yield of wheat as affected by three different sowing schedules across varieties and management practices

first half of February. This is enough to beat the terminal heat. The part of the default line is that the combination of late sowing and LSWVs is not offering any advantage to farmers. The overall nitrogen, phosphorus and potash 38 usage in the district was 149.5 kg ha^{-1}, 67.55 kg ha^{-1}, of Potash 7.76 kg ha^{-1}, respectively and the overall average irrigation was 2.58 (Table 2).

Table 2: The use rates of N: P_2O_5: K_2O (kg ha^{-1}) and irrigation frequencies of surveyed farmers (potash users 20%)

NPK rates and irrigation frequency	Average dose (kg ha^{-1})	SD	SE
N	149.50	30.29	2.11
P_2O_5	67.55	18.85	1.31
K_2O	38.22	13.47	2.08
Irrigation number	2.58	0.59	0.04

The part of the problem also lies in poor weed management with 45% farmers not employing any weed management method. There is a need to persuade farmers to adopt weed management in wheat (Fig. 5). The district also tops in the adoption of zero tillage (ZT), 30% surveyed farmers adopted this technology. We have already seen yield gains of 19.4% from zero tillage based early sowing (Keil *et al.,* 2015). The data from the surveyed farmers also showed that the yield response towards broadcasting was 2.99 t ha^{-1}, line sowing was 2.91 t ha^{-1} and zero tillage was 3.24 t ha^{-1} (Fig. 6). There was a gradual increase in yield from 2.72 to 4 t ha^{-1}, respectively, with increase in the number of irrigations from 1 to 4 (Fig. 7). The fewer number of irrigation frequency at 2.6 is low because if we miss irrigation at grain filling, the effect of terminal heat will be more severe. To further improve the yield levels in this district, the better responses of nutrients need to be harnessed from proper irrigation management and weed management.

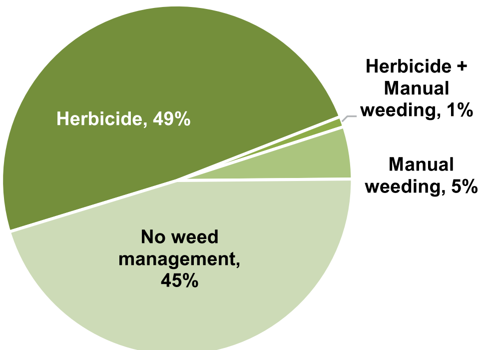

Fig. 5: Farmers reported weed management options practiced in the district (n=208)

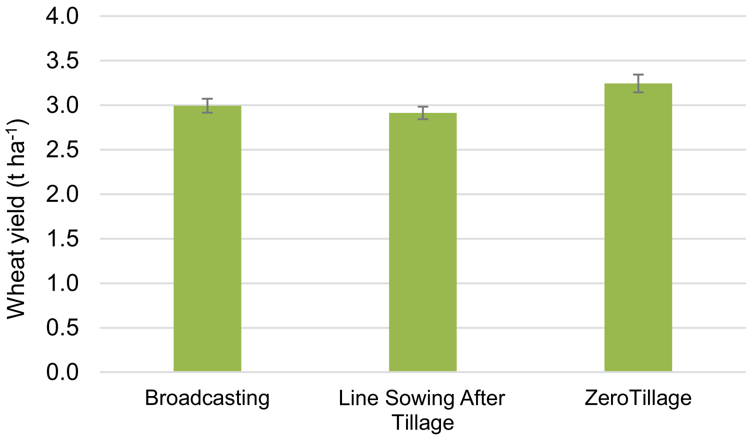

Fig. 6: Farmers reported average grain yield under four different crop establishment methods practiced by farmers

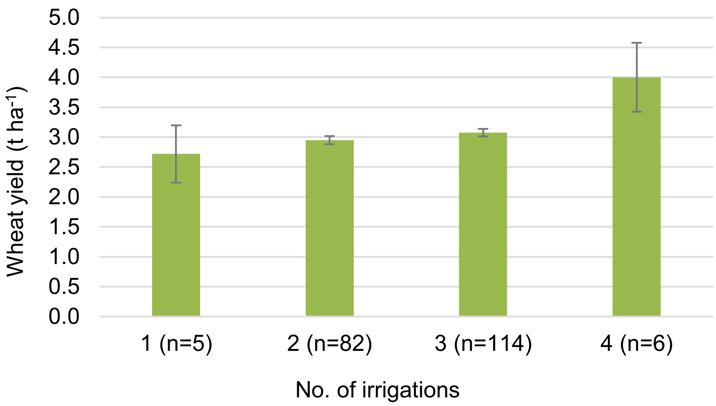

Fig. 7: The average grain yield of wheat under different irrigation frequencies

Conclusion

The tracking of adoption patterns showed that there is a shift towards TSWVs but it is not matched by early sowings, proper weed and irrigation management. The goal is not only to harness the yield potential but also to raise the yield potential of these varieties.

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3.10 Linking varieties with time of sowing for increasing wheat yields in Chanduali

R.P.S. Raghuvanshi[1], Deepak K. Singh[2], S.K. Pandey[1] and Ajay Kumar[2]

[1]Krishi Vigyan Kendra, Chandauli
[2]International Maize and Wheat Improvement Centre (CIMMYT)

Introduction

The district of Chandauli comes under the Eastern Plain Zone of Uttar Pradesh. It has a population of 1,952,756 spread over 5 tehsil, 9 blocks and 1,651 villages. The total cultivable area is 135,590 ha. Rice is grown in 114,060 ha and wheat in 101,970 ha. The major soil type is loam and clay loam. Wheat productivity is low as majority of wheat sowing is delayed beyond November. Farmers are small and resource poor with subsistence level of farming. Efforts made in the past have not produced desired results and wheat yields have remained stagnated. Based on the past data (Joshi *et al.,* 2003, Singh 2016), the success rate of zero tillage is high with a yield gain of 12.9% and variety HUW 234 is the most popular variety. The area under ZT has decreased substantially now. The adoption rate of new technologies is lesser than expectations. How we are expected to know adoption pattern of technologies without collecting the response from farmers? Data from diagnostic surveys will help anticipating the best investment option by the department of agriculture (DoA) and a feed back to researchers about the changes in strategies. That will also allow KVK to understand a shift in farmer's behaviour.

Methods

Details on methodology are given in Chapter 1

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, Wakhra (Fig. 1).

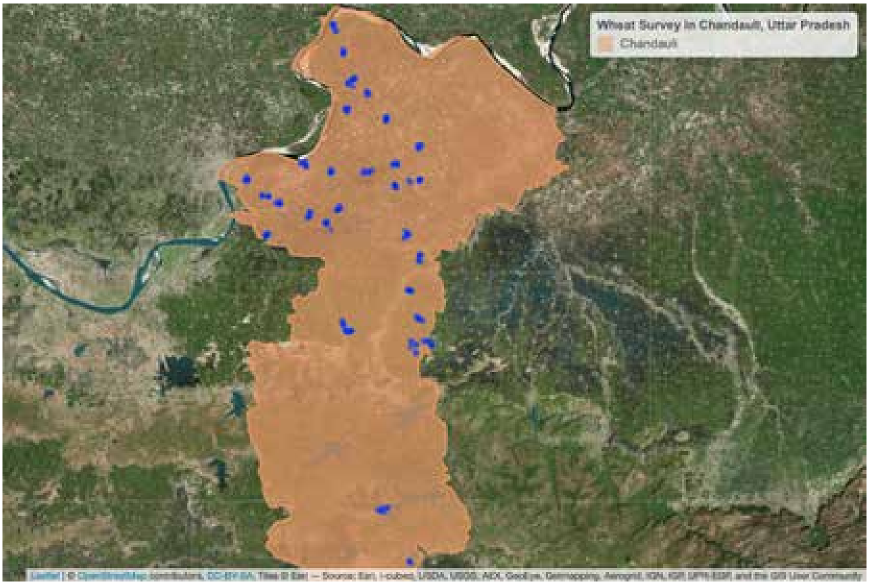

Fig. 1: GPS points of Surveyed farms in Chandauli

Results and Discussion

The cropping system of the district showed the dominance of rice-wheat (Fig. 2). Wheat cultivars represented two major categories (Table 1), timely sown wheat varieties (TSWVs) also referred as normal maturing wheat (NMWVs) varieties including HD 2967 (16%) and PBW 343 (4%), and

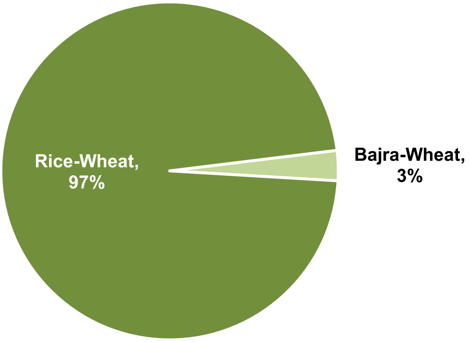

Fig. 2: Major cropping system prevailing in the district as per surveyed farmers

Table 1: Summary of important varieties including timely sown wheat varieties (TSWVs) and late sown wheat varieties (LSWVs) (2017-18) (n=208)

Varieties	Number of respondents	Percentage (%)
TSWVs		
HD 2967	34	16
PBW 343	8	4
LSWVs		
HUW 234	52	25
Kedar	23	11
PBW 154	36	17
UP 262	19	9
PBW 373	20	10
Other*	16	8

*Includes HD 2733, PBW 502, PBW 550, K 307 from TSWVs group

the late sown wheat varieties (LSWVs), which are also called as early maturing wheat (EMWVs) varieties including HUW 234 (25%), PBW 154 (17%), PBW 373 (10%) and UP 262 (9%). This district is still not catching up in respect of new varieties as HUW 234 was the most popular even in 2003 (Joshi *et al.*, 2003). Set of LSWVs are more common than TSWVs. The average yield of TSWVs was 3.2 t ha^{-1} and that of LSWVs 2.8 t ha^{-1} (Fig. 3). On the whole, the lower average yield in this district could be because of dominance of LSWVs. Farmers reported grain yield of wheat from sowings done before 20 November, between 21 November and 15 December and after 15 December were in the order of 3.2, 2.9 and 2.5 t ha^{-1}, respectively (Fig. 4). There is a need to tailor this developmental cycle to beat the effect of terminal heat in wheat. An increase in the night temperature, which is common here, will accelerate grain

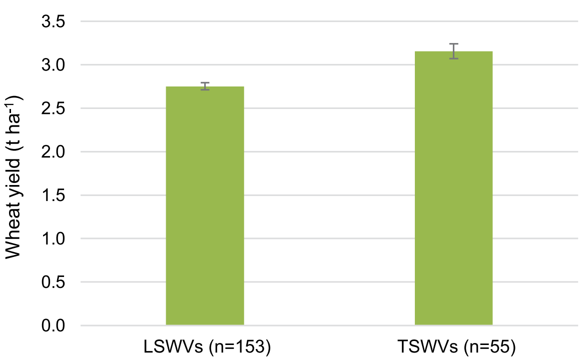

Fig. 3: Average grain yield of timely sown wheat varieties (TSWVs) and late sown wheat varieties (LSWVs) across different agronomic management options

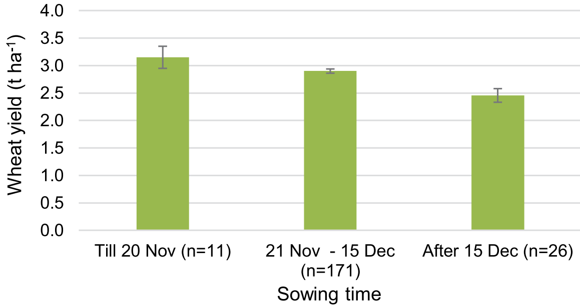

Fig. 4: Effect of different sowing schedules on the famers reported wheat yield in the study area (2017-18)

filling and decrease grain weight. Under late sowings especially in TSWVs an increase in grain number m^{-2} could be accompanied by a decrease in grain weight due to a lack of enough assimilates available to filled grains (Kato and Osawa, 2013). Therefore an increased sink size mediated by early sowing or TSWVs is a better option. Therefore, the combination of early sowing and TSWVs is necessary for this district. Similarly, if zero tillage was popular in 2003 with significant yield gains why then there is dis-adoption of this technology in this district is a question mark. The DoA should constantly streamline its operations by creating awareness and also by introducing an area expansion model through private service providers. This is critical to improve yield growth of wheat.

The proportion of farmers practicing late sowing in this district is more than other districts. Farmers reported the N: P_2O_5:K_2O use at 141:59:3 kg ha^{-1}. Low K rate is on the expected line as most other districts in this survey also show that K use in RWCS is much lower than other cropping systems. There is a strong mismatch between N and P use rates and the yield levels in this district. This has happened even under relatively better irrigation frequency (2.6) in this district (Table 2). Most farmers apply one or other weed management options but this is another area where farmers are not able to shield the losses in yield. Eighty nine surveyed farmers opted for weed management techniques of which 69% used herbicides and 19% used manual weeding (Fig. 5). The data of crop establishment revealed that maximum cases fell

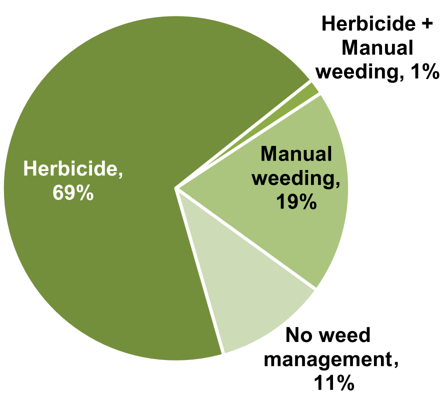

Fig. 5: Weed management options employed by farmers in the study area of Chandauli district (n=208)

Table 2: The use rates of N: P_2O_5: K_2O (kg ha^{-1}) and irrigation frequencies of surveyed farmers (potash users 15%)

N: P_2O_5: K_2O (kg ha^{-1}) and Irrigation Frequency (sample size 208)	Mean use rates	SD	SE
N	140.64	32.79	2.27
P_2O_5	58.71	18.58	1.30
K_2O	23.16	11.51	2.07
Irrigation number	2.55	0.66	0.05

under broadcasting method of sowing. (Singh, 2016), Once popular ZT is now not finding a place in this survey. There is a gradual increase in yield with increase in number of irrigations at 2, 3 and 4 irrigation levels (Fig. 6).

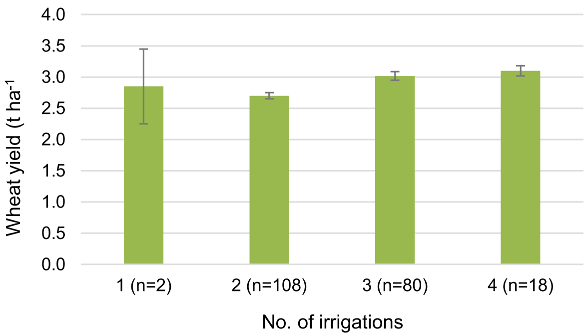

Fig. 6: Effect of number of irrigations on the wheat yield of surveyed farmers. The sample size of 2 is too small to make comparison of one irrigation with 2 or 3 irrigations

Conclusion

When we pay attention to yield gaps, unusually more number of respondents (74%) use late sown wheat varieties and only 5% respondents sow their crop on time. Zero tillage rather than rotavator is the better option to handle early sowing.

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3.11 Early wheat sowing: An escape mechanism to beat the terminal heat

Rajneesh Srivastava[1], Anuradha Ranjan Kumari[1], Ajay Kumar[2], Kamlesh Meena[1] and Vipin Kumar[3]

[1]Krishi Vigyan Kendra, Deoria
[2]International Maize and Wheat Improvement Centre (CIMMYT)
[3]International Rice Research Institute (IRRI)

Introduction

The district of Deoria has 16 blocks, 1,189 gram panchayats and 2,162 villages. It has 254,000 ha land of which 190,254 ha is cultivable. The net irrigated area is 153,206 ha. The total area under rice is 129,408 ha and total area under wheat is 140,328 ha and the soil type is alluvial. The soil type is alluvial. The scaling of any technology is possible only if it delivers high yields, more profit margins and environmental safety. The question is how the research and extension be organized so that above three purposes can be fulfilled. The monitoring and evaluation should reflect the way the technologies are performing and how much is the return on investment. The landscape diagnostic survey (LDS) presented here should be used as bench mark for seasonal planning at any point of time. It also represents the case for studying causes of stagnant yield of wheat. This will also help isolating production components which are fundamental to yield growth in rice-wheat cropping system (RWCS) in Deoria. It will also help KVKs to come closer to farmers in the district as a whole rather than few villages they adopt.

Methods

Details on methodology are given in Chapter 1

Blocks covered: Baitalpur, Bankata, Barhaj, Bhagalpur, Baluhani, Bhatani, Bhatparrani, Deoria, Desai Deoria, Lar, Gauri Bazar, Patherdeva, 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, Boliya Pandey (Fig. 1).

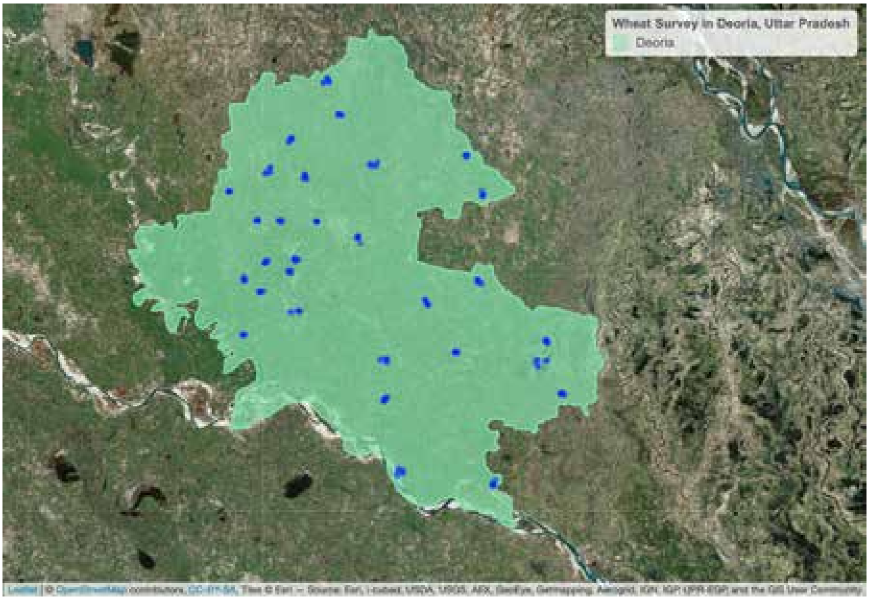

Fig. 1: GPS points of surveyed wheat farms in Deoria

Results and Discussion

Data showed that 63% surveyed farmers have RWCS and 23% have fallow–wheat cropping (FWCS) system (Fig. 2). This district seems more progressive with 74% farmers reported the adoption of HD 2967, a relatively new variety (Table 1). When combined with PBW 343 (11%) and PBW 502 (4%), the wheat cultivation is dominated by

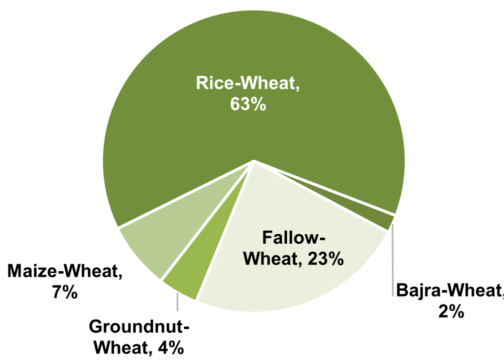

Fig. 2: Major cropping system prevailing in the district as per surveyed farmers

Table 1: Summary of important varieties including timely sown wheat varieties (TSWVs) and late sown wheat varieties (LSWVs) (2017-18) (n=208)

Varieties	Number of respondents	Percentage (%)
TSWVs		
HD 2733	4	2
HD 2967	154	74
PBW 502	8	4
ShriRam 303	5	2
PBW 343	23	11
LSWVs		
HD 2985	3	1
PBW 154	12	6

TSWVs. The focus on TSWVs seems to be reliable way of sustainably improving wheat yields as the grain yield of this group which matures in 135-150 days is more than LSWVs. Therefore, the earliness suggested as a good approach for wheat breeding in the eastern Gangetic plains that suffers from high temperature stress during grain filling (Joshi *et al*., 2007) is not finding favour in this district because these varieties have less yield. These varieties have high potential and that can be better realised if matching space of 150 days is given to these varieties. That means we need a practical solution by advancing the wheat sowing. In most cases, early wheat sowing was reported to have been adopted by 66% farmers with a grain yield of 3.4 t ha^{-1} (Fig. 3). There was a yield difference of 0.5 t ha^{-1} between wheat sown till Nov 20th and from Nov 21st to Dec 15th (Fig. 4). Data based agronomic management system emerging from this survey perhaps pointed to a change in sowing schedule in the first three weeks of November. Best solution is to integrate early sowing and zero tillage that facilitate early sowing. Data showed that ZT still has high

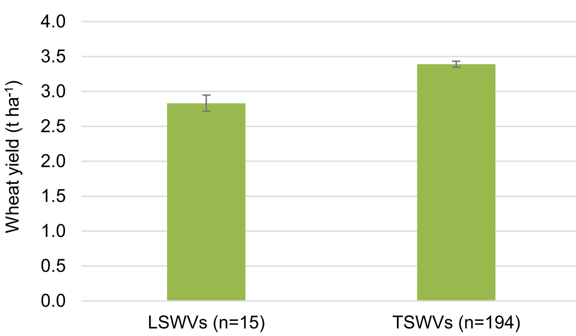

Fig. 3: Average grain yield of timely sown wheat varieties (TSWVs) and late sown wheat varieties (LSWVs) across different agronomic management options

barriers and that is where DOA should focus. Flowering time is critical to grain yield as the grain number is determined just prior to or at flowering (Fischer, 1985). To do that the combination of sowing time, zero tillage to facilitate early sowing and varieties will be needed to adjust the optimum flowering time (Anderson *et al.*, 1996, Malik *et al.*, 2014). The use of 151 kg of N per hectare could be justified but yield levels are still low at this dose. This is partially explained by low frequency of irrigation at 2.0 which is too low for early sown wheat (Table 2). Eleven (11) percent farmers did not control weeds (Fig. 5). Yield of 5.25 t ha^{-1} was achieved by those farmers who applied 5 irrigations. Significantly higher yields from the combination of early sowing and TSWVs can be achieved by increasing the frequency of irrigation from current level of 2 (Fig. 6).

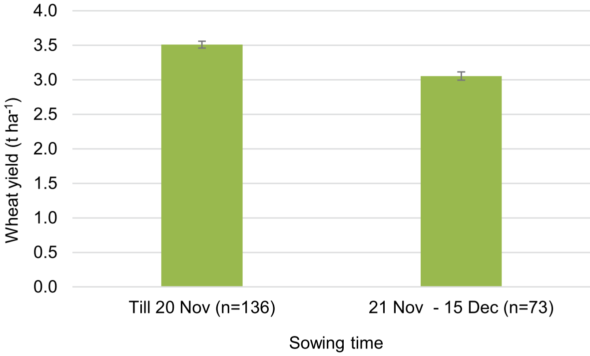

Fig. 4: Average grain yield of wheat as affected by three different sowing schedules across varieties and management practices

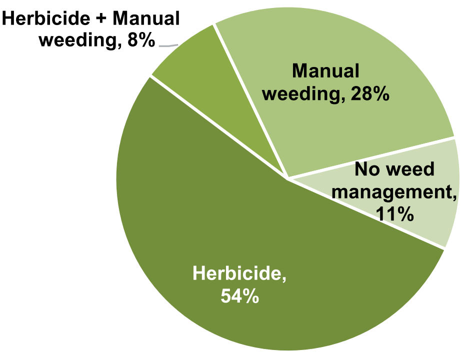

Fig. 5: Farmers reported weed management options practiced in the district (n=209)

Table 2: The use rates of N: P_2O_5: K_2O (kg ha^{-1}) and irrigation frequencies of surveyed farmers (potash users 50%)

NPK rates and irrigation frequency	Average dose (kg ha^{-1})	SD	SE
N	151.18	33.52	2.32
P_2O_5	62.19	16.99	1.18
K_2O	22.67	10.37	1.01
Irrigation number	2.45	0.69	0.05

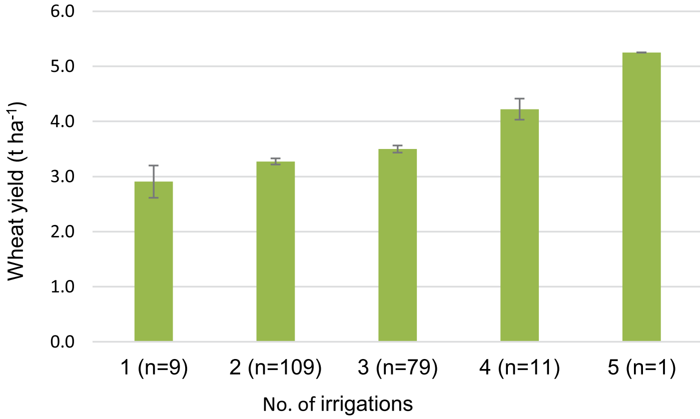

Fig. 6: The average grain yield of wheat under different irrigation frequencies

Conclusion

The most important factor which matters the most is terminal heat. Early wheat sowing has helped escaping the terminal heat effects but the issues around irrigation frequency, zero tillage, and proper weed management need to be resolved and properly addressed.

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3.12 Early wheat sowing, appropriate irrigation and weed management: A need for higher yield growth in East Champaran district of Bihar

Arvind Kumar Singh[1], Prabhat Kumar[2], Rambabu Sharma[1] and Ajay Kumar[2]

[1]Krishi Vigyan Kendra, Piprakothi
[2]International Maize and Wheat Improvement Centre (CIMMYT)

Introduction

The soils of district East Champaran are fine sandy loamy to saline calcareous. It has 27 blocks, 405 gram *panchayats* and 1,344 revenue villages. The district has 396,800 ha land, of which 266,200 ha is cultivable. It has a population of 5.1 million (2011 census). The cropping intensity is 174%. The net irrigated area is 66.12%. The total area under rice remains 177,000 ha and total area under wheat is 121,000 ha. The survey intends to create a system that seeks the opinion of farmers, maintains checks and balances on what works and what does not work, and also to provide feedback to institutions on technologies that do not work at the ground level with the farmers.

Methods

Details on methodology are given in Chapter 1

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).

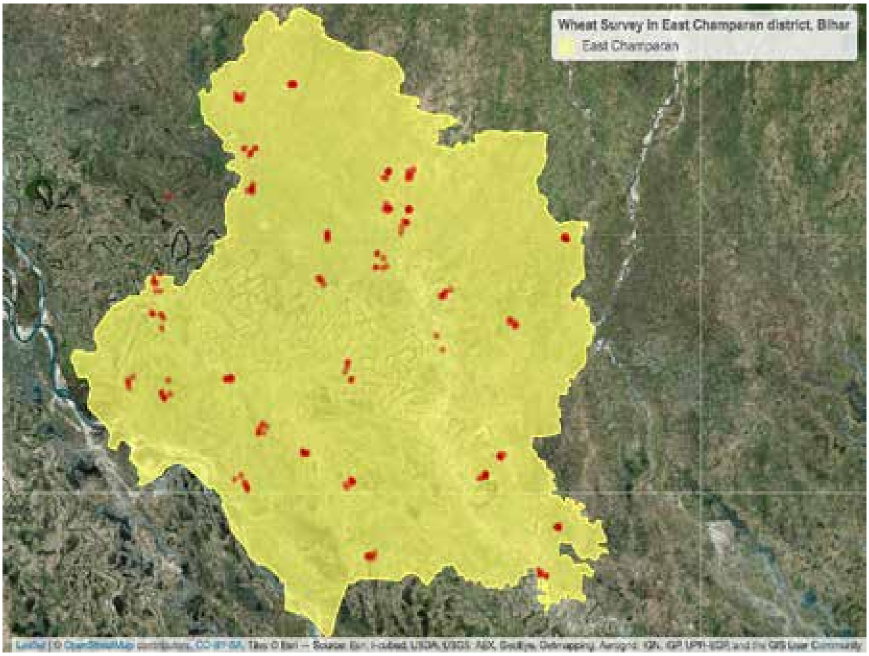

Fig. 1: GPS points of surveyed farms in East Champaran

Results and Discussion

In this district rice-wheat cropping system is dominant (Fig. 2). The varietal balance between timely sown wheat variety (TSWVs) and late sown wheat variety (LSWVs) is almost 50:50 (Table 1), with replacement rate of 7.8% (very slow), growing HD 2967 released in 2011. It may be because new varieties are not better than old varieties. Average yield of TSWVs is 3.15 t ha^{-1} whereas that of LSWVs

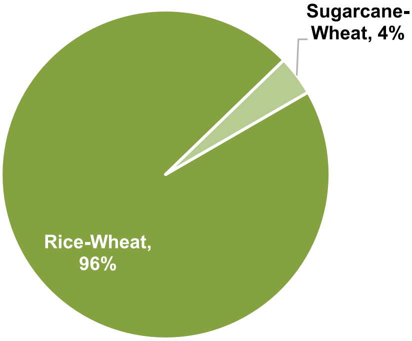

Fig. 2: Major cropping system prevailing in the district as per surveyed farmers

is 2.96 t ha^{-1} (Fig. 3). Farmers are shifting towards early sowing with 20% farmers sowing their wheat crop before November 20 with a yield of 3.51 t ha^{-1}. Wheat sown from 21 November to 15 December yielded 2.87 t ha^{-1} whereas sowing done after 15 December resulted into 2.34 t ha^{-1} (Fig. 4). N: P_2O_5:K_2O use rate informed by respondents is at 118:59:22 kg ha^{-1}, which is within the normal rate limits (Table 2). As such there are no soil health issues. The average number of irrigation was 1.66 and the yield increase with the increasing in frequency of irrigation (Fig. 5). That means with trend towards

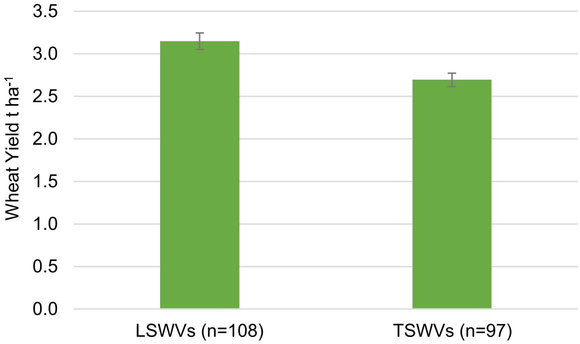

Fig. 3: Average grain yield of timely sown wheat varieties (TSWVs) and late sown wheat varieties (LSWVs) across different agronomic management options

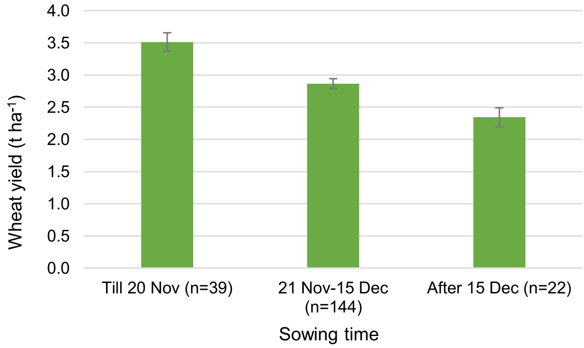

Fig. 4: Average grain yield of wheat as affected by three different sowing schedules across varieties and management practices

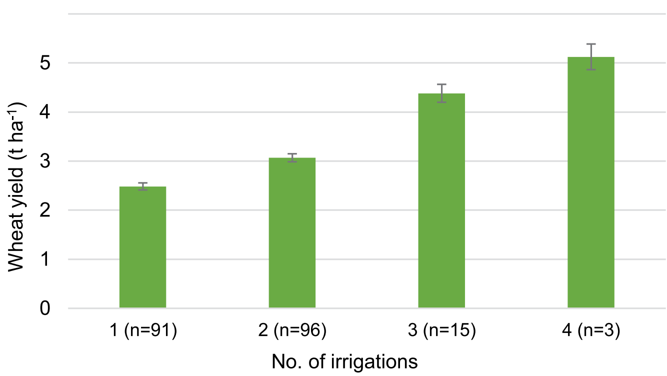

Fig. 5: The average grain yield of wheat under different irrigation frequencies

Table 1: Summary of important varieties including timely sown wheat varieties (TSWVs) and late sown wheat varieties (LSWVs) (2017-18) (n=205)

Varieties	Number of respondents	Percentage (%)
TSWVs		
HD 2967	16	7.80
PBW 343	73	35.61
PBW 502	10	4.88
ShriRam 303	9	4.39
LSWVs		
LOK 1	4	1.95
PBW 154	24	11.71
UP 262	64	31.22
Other*	5	2.44

*Includes Kedar, Kundan, PBW 373, RR 21 from LSWVs group.

Table 2: The use rates of N: P_2O_5: K_2O (kg ha^{-1}) and irrigation frequencies of surveyed farmers (potash users 93%)

NPK rates and irrigation frequency	Average dose (kg ha^{-1})	SD	SE
N	118.59	40.25	2.82
P_2O_5	58.66	16.41	1.15
K_2O	24.28	9.87	0.72
Irrigation number	1.65	0.68	0.047

early sowing and with fertiliser use rates being normal, the irrigation frequency is very low. Here irrigation matters more than nutrient management. Most of the farmers are still engaged in broadcast method of wheat sowing with only 2% farmers reported use of zero tillage based wheat sowing (Fig. 6). Broadcast method of sowing could affect yield because

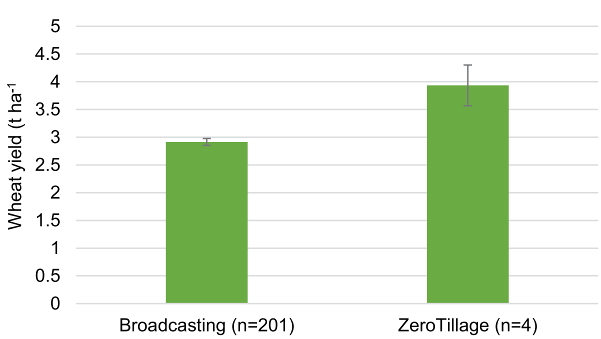

Fig. 6: Crop establishment methods practiced by farmers

of uneven population, uneven emergence and uneven maturity. With 49% respondents not following any weed management (Fig. 7). The crop management system is not fully integrated. Data have brought forward the focus on early wheat sowing that may help flower initiation well before the rise in temperature. Optimum flowering time is critical to get high grain yield (Fischer, 1985). The combination of management (sowing time) and varieties will be needed to adjust the optimum flowering time (Kirkegaard and Hunt, 2010). The district requires to work more towards accepting new technologies comprising weed management, irrigation and crop establishment.

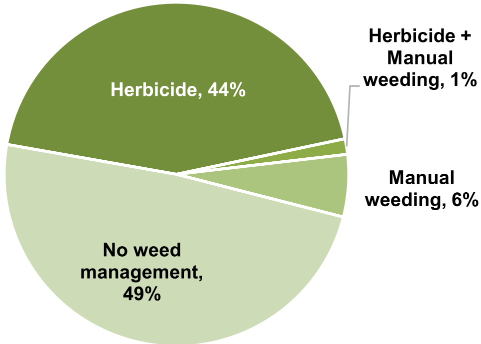

Fig. 7: Farmers reported weed management options practiced in the district (n=205)

Conclusion

Early sowing risks losing advantage with irrigation frequency at 1.66 and almost 50% farmers not adopting weed management. The system should not depend only on varieties for yield growth in wheat, but should also incorporate best bet management practices.

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3.13 Timely sown wheat varieties are associated with high yields in Gaya district

S.B. Singh[1], Madhulika Singh[2], Devendra Mandal[1] and Shahnawaz R. Dar[3]

[1]Krishi Vigyan Kendra, Gaya
[2]International Maize and Wheat Improvement Centre (CIMMYT)
[3]International Rice Research Institute (IRRI)

Introduction

The district of Gaya falls in agro-climatic zone III B. The total geographical area in the district is 493,700 ha and net cultivable land is 235,800 ha, out of which net irrigated area is 100,300 ha. The major area falls in black soil type followed by sandy soil. The district has been divided in to 24 blocks with 2,889 villages. Like other districts, it has the potential to significantly increase the cropping system productivity by building a fundamentally strong framework of time management from seeding to harvesting of crops in rotation. There is, however, a need to understand the technology-linked options for clearly defined decision making in research and extension. The landscape diagnostic survey (LDS) reflects how the farmers are adopting different production practices in Gaya district.

Methods

Details on methodology are given in Chapter 1

Blocks covered: Atri, Barachatti, Belaganj, BodhGaya, Mohanpur, Neem ChakBathani, 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).

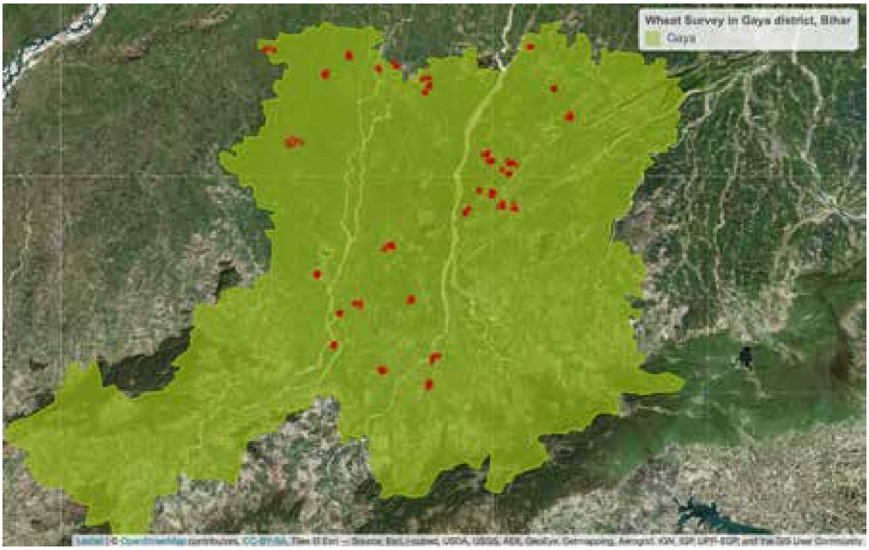

Fig. 1: GPS points of surveyed farms in Gaya

Results and Discussion

The survey showed that the district has rice-wheat as the most prominent cropping system. Still most farmers use late sown wheat varieties (LSWVs) including Kedar (11%), UP 262 (8%), HI 1563 (6%) and many others. However, according to this survey, farmers are getting the new ideas and have adopted timely sown wheat varieties (TSWVs) including PBW 343 (11%), HD 2967 (7%) and also Super 172 (4%) (Table 1). Data revealed that the grain yield of wheat of approximately 25% respondents of TSWVs was 3.7 t ha^{-1} compared to an average of 2.8 t ha^{-1} from LSWVs (Fig. 2). Data clearly indicated that those respondents who practiced wheat sowing from 1-15 November got an average grain yield of

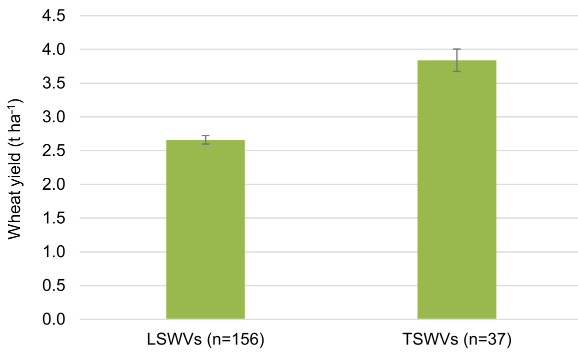

Fig. 2: Farmers reported grain yield levels of timely sown wheat varieties (TSWVs) and late sown wheat varieties (LSWVs) across different agronomic management options

Table 1: Summary of important varieties including timely sown wheat varieties (TSWVs) and late sown wheat varieties (LSWVs) (2017-18) (n=193)

Varieties	Number of respondents	Percentage (%)
TSWVs		
PBW 343	21	11
HD 2967	14	7
C 306	5	3
LSWVs		
Super 172	7	4
Lok 1	6	3
HUW 234	4	2
Ankur	5	3
HI 1563	11	6
UP 262	16	8
Sonalika	18	9
Kedar	22	11
PBW 154	29	15
Other*	35	18

*Includes HD 2824, PBW 550, ShriRam 303 from TSWVs group and Baaz, BL 4341, Diamond, Gautam, PBW 373 and RR 21 from LSWVs group.

4.2 t ha^{-1}. The average yield of majority farmers who practiced wheat sowing from 16 November-15 December was 2.8 t ha^{-1} 33% lower than above group. The yield was still lower at 2.4 t ha^{-1} for those who did sowing after 15 December (Fig. 3). Past discussion on advancing wheat sowing across whole spectrum of this district hinted that it may not be that easy but in some ways it is not that difficult too because advancement can be made by 10-15 days by all farmers' from

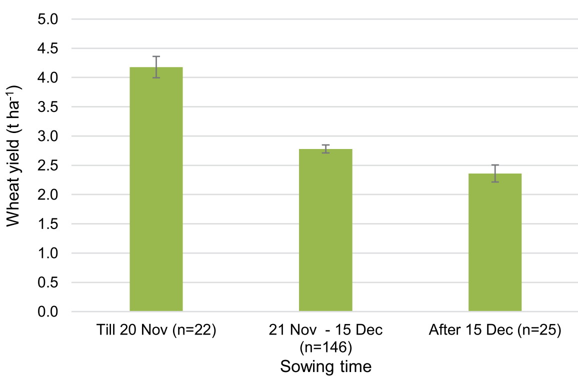

Fig. 3: Influence of time of sowing on the grain yield of wheat as reported by surveyed farmers

date they are sowing now starting from 1 November. Results are not ambiguous and department of agriculture (DoA) can do it easily. As in other districts in UP, the N: P_2O_5:K_2O use rate at 121:47:8 kg ha^{-1}, does not have any direct linkage with the farmers reported yield. The irrigation frequency of 2.6 seems low at this fertilizer rate (Table 2). Data exhibited a poor show of weed management with 46% farmers did not control weeds at all in their fields (Fig. 4).With increase in number of irrigation frequency, there was a gradual increase in yield i.e. with 1 irrigation the yields were only 1.86 t ha^{-1} whereas with 4 irrigations frequency, the yields were 3.63 t ha^{-1}(Fig. 5).

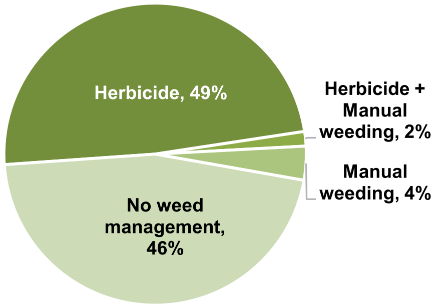

Fig. 4: Weed management methods employed by farmers the district (n=193)

Table 2: Average N: P_2O_5:K_2O use rates and number of irrigations applied by farmers frequency (Potash users 23%)

NPK rates and irrigation frequency	Average use rates (kg ha^{-1})	SD	SE
N	121.42	44.11	3.18
P_2O_5	47.02	18.13	1.31
K_2O	33.35	14.91	2.25
Irrigation number	2.61	0.92	0.07

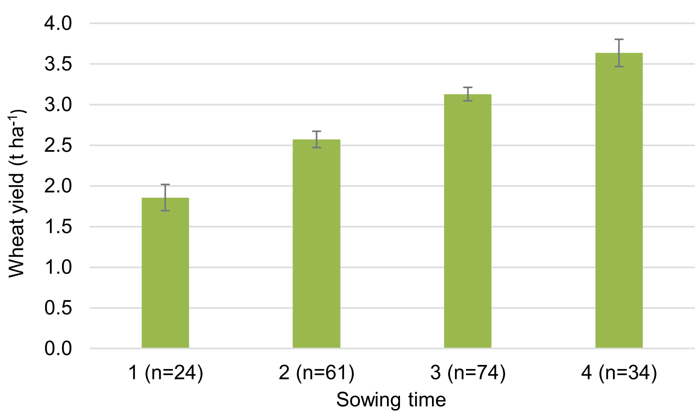

Fig. 5: Effect of irrigation frequency on the grain yield of wheat

The answer to the problem of low wheat yield is to facilitate early wheat sowing and the adoption of TSWVS to beat the terminal heat. Both an increase in biomass as well as an increase in harvest index (Beche *et al.,* 2014) is must to harness the yield potential of these varieties. This is happening in North-West IGP but not in EIGP. Time from seed to harvest is short and this issue should be resolved. After having adopted these two interventions, farmers will be encouraged to adopt weed management which is very crucial (Malik *et al.*, 2014) for improving the efficiency of applied inputs.

Conclusion

Early sowing has helped increase the yield. It should be encouraged further. But weed management is lagging behind. These two factors must be weighed appropriately for increasing wheat yield in Gaya district.

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3.14 Landscape diagnostic survey (LDS) shows wheat yield growth through agronomic management of timely sown wheat varieties

Omkar Singh[1], Deepak K. Singh[2], Dinesh Singh[1], D.K. Singh[1] and Ajay Kumar[2]

[1]Krishi Vigyan Kendra, Ghazipur
[2]International Maize and Wheat Improvement Centre (CIMMYT)

Introduction

The district of Ghazipur has a total of 254,711 ha as cultivable land. It has a population of 36, 20,000 (2011 census) spread over 3,385 inhabited villages. The net irrigated area is 218,402 ha whereas the area under rice is 82,300 ha and that of wheat is 80,500 ha. The major soil type in the district is clayey and fine sandy loam. The conventional practice involves late harvesting of rice followed by late seeding of wheat. This brings into the idea of reducing the time between rice harvesting and wheat sowings. Because we need solutions from rice for wheat. The agronomic management can help managing the time. The landscale diagnostic survey (LDS) is for looking management practices (Ingram *et al*., 2008) that help realizing high yield of wheat. The outcomes then can be used for setting priorities both for research and extension.

Methods

Details on methodology are given in Chapter 1

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).

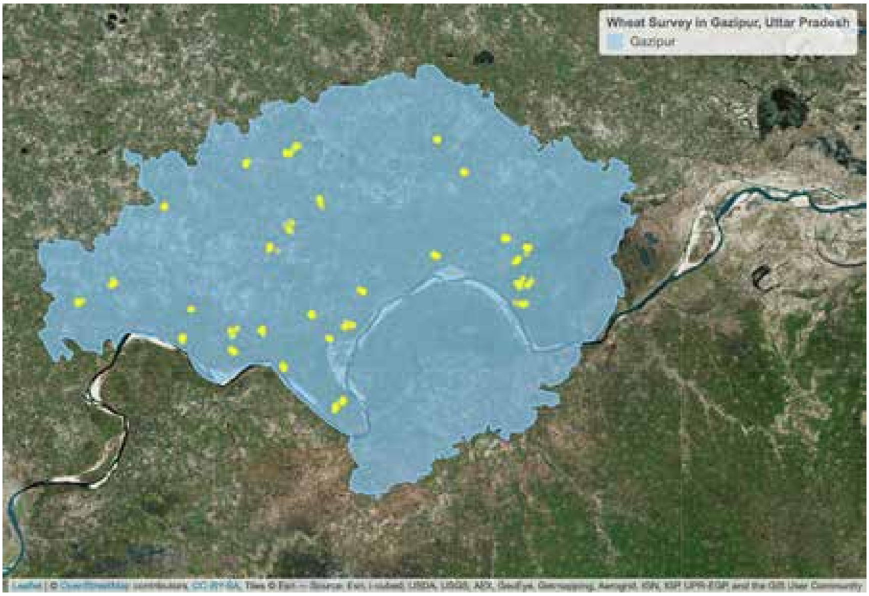

Fig. 1: GPS points of surveyed farms in Ghazipur

Results and Discussion

With 90% farmers reporting rice-wheat as the main cropping system (Fig. 2), data indicated a strong need to push for reforms around technologies that help better management of time. The adoption of timely sown wheat varieties (TSWVs) which mature in 135-150 days represented by HD 2967 (38%), PBW 502 (27%) and PBW 343 (16%) has helped increasing the grain yield of wheat, the main criteria for adoption of any technology

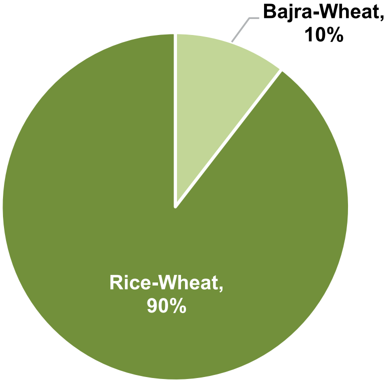

Fig. 2: Dominant cropping systems of Gazipur farmers

(Table 1). That, in effect, is evidenced by the data reported by farmers with 0.4 t ha^{-1} more yield (Fig. 3) than late sown wheat varieties (LSWVs). The less magnitude of yield difference between two different times of sowings (Fig. 4) was because of more number of farmers taking up TSWVs even under the sowing schedule from 21 November to 15 December. Although only 3 farmers reported sowing after 15 December but yield difference of 1.0 t ha^{-1} compared to early

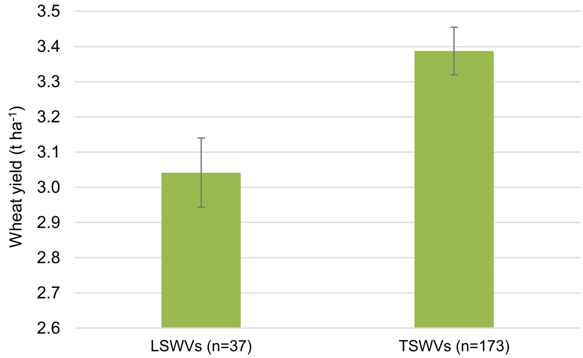

Fig. 3: The farmers reported average yield of timely sown wheat varieties (TSWVs) and late sown wheat varieties (LSWVs) across different agronomic management options

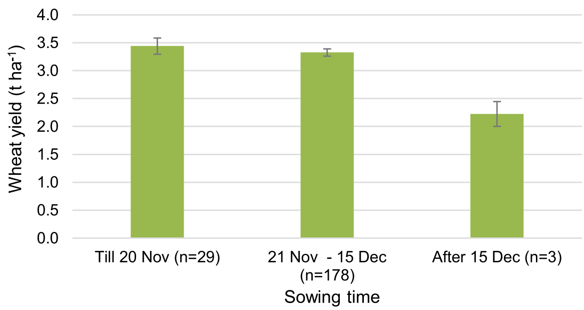

Fig. 4: Influence of sowing time on the grain yield of wheat in Gazipur district of Eastern UP

Table 1: Summary of important varieties including timely sown wheat varieties (TSWVs) and late sown wheat varieties (LSWVs) (2017-18) (n=210)

Varieties	Number of respondents	Percentage (%)
TSWVs		
HD 2967	79	38
PBW 343	34	16
PBW 502	56	27
LSWVs		
PBW 154	21	10
HUW 234	12	6
Other*	8	4

*Includes PBW 550, ShriRam 303 from TSWVs group and Kedar from LSWVs group.

sowing showed that the risk associated with late sowings is high. The average number of irrigation reported by farmers is 2.68. Better yield of TSWVs could also be because of relatively good irrigation management in this district. This warrants more focus on increasing the number of irrigations. Farmers reported the N: P_2O_5:K_2O use at 159:76:9 kg ha^{-1} (Table 2). Low K rate is on the expected line similar to other districts dominated by RWCS where usage of K is lesser than any other cropping system. There is a mismatch between use rates of N and P and the yield levels of this district. This along with irrigation management has emerged as an important area that would need focused attention towards achieving high yields. Weed management is being done by 93% of the total surveyed farmers (Fig. 5). Whereas, 100% crop establishment was done by broadcasting method. This mismatch understandably signals the case for promoting line sowing especially zero tillage so that the cropping system is suitably intensified (Malik *et al.,* 2014). With glaring advantage that early sowing has offered, ZT can help facilitating early sowing.

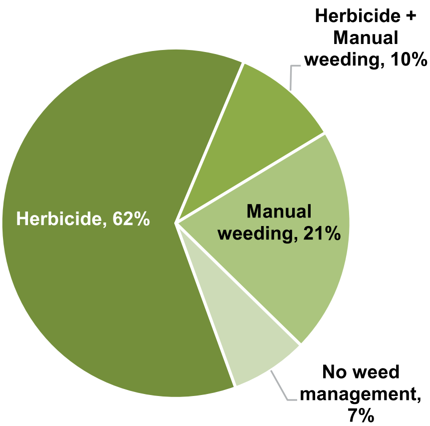

Fig. 5: Current weed management practices of surveyed farmers (n=210)

Data showed the scope of smooth transition from LSWVs to TSWVs in the times to come. Farmers have taken advantage of TSWVs even when the wheat sowings were done after 20 November. If we continue evolving LSWVs with no major yield gain as shown in the data, it will lead to further

Table 2: The use rates of N: P_2O_5: K_2O (kg ha^{-1}) and irrigation frequencies of surveyed farmers (Potash users 30%)

NPK rates and irrigation frequency	Average use rates (kg ha^{-1})	SD	SE
N	158.69	30.98	2.14
P_2O_5	76.02	15.20	1.05
K_2O	30.15	12.03	1.52
Irrigation number	2.68	0.62	0.04

uncertainty with continued adoption of very old varieties. This scenario will lead to continued stagnant growth in wheat yield. There is a positive correlation between number of irrigation applied and crop yield i.e. with 2 irrigations the yield is 3.06 and that with 4 irrigations 4.43 t ha^{-1} (Fig. 6).

Farmers reported yield during survey indicated that with the current practices in respect of varieties and nutrient management, the yield levels are low. There are few other areas like early sowing, irrigation management, crop establishment methods and weed management, which require more attention in the district to attain better yields.

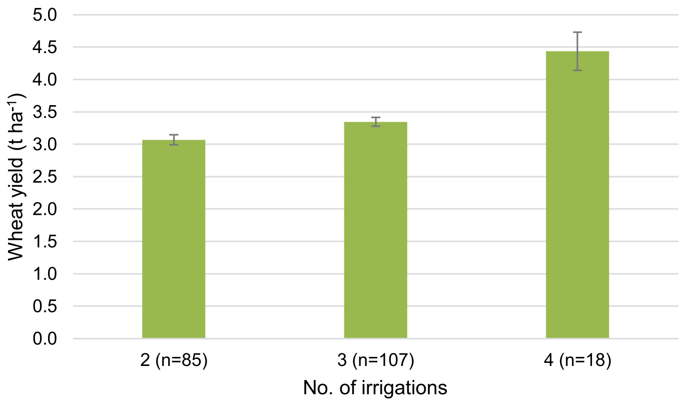

Fig. 6: The average grain yield of wheat under different irrigation frequencies

Conclusion

Farmers in this district are embracing TSWVs. Research establishments need to accept the technical niche of TSWVs for high yields. The use rates of nitrogen and phosphorus is very high for relatively low yields. Irrigation and zero tillage should be focused to improve the efficiencies of inputs including seeds.

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3.15 Effect of timely seeding is weakened by poor irrigation and weed management in Gopalganj

Ramakrishna Roy[1], Prabhat Kumar[2], Mohd. Sajid Hussain[1] and Moben Ignatius[2]

[1]Krishi Vigyan Kendra, Sipaya
[2]International Maize and Wheat Improvement Centre (CIMMYT)

Introduction

The district, Gopalganj has 14 blocks, 234 gram panchayats and 1,566 villages. The district has 203,700 ha land of which 163,100 ha is cultivable. Its population is 2.56 million (2011 census). The cropping intensity is 150%. The soil type is fine sandy loamy to saline calcareous. The net irrigated area is 71%. The total area under rice is 87,200 ha and wheat is 91,200 ha. Faced with stagnant growth, the Department of Agriculture (DoA) and the State Agricultural Universities (SAUs) are attempting to understand how wheat productivity restrained and which technological and policy interventions can help. However, these efforts are too little, if the strategic direction is not put in place after seeking farmers' opinion and understanding the current practices preferred by farmers. The upward trend in wheat productivity realized in last few years also indicated the possibility of introducing agronomic management reforms in this district. The land scape diagnostic survey is an attempt to understand how unconventional tools like time of sowing can be integrated with whole range of agronomic management to bridge the yield gaps in this district.

Methods

Details on methodology are given in Chapter 1

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, Bakhari (Fig. 1).

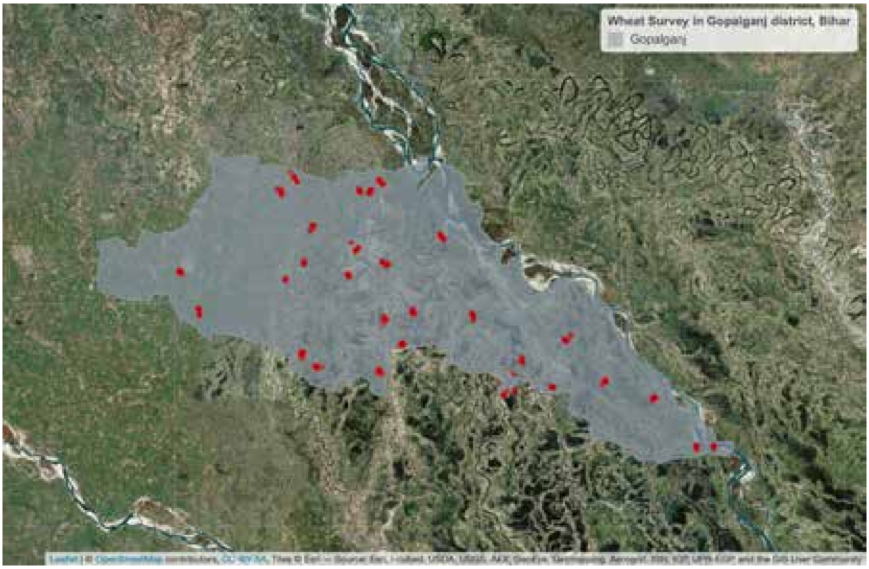

Fig. 1: GPS points of surveyed farms in Gopalganj

Results and Discussion

The major cropping system dominant in the district is rice-wheat with 97% of the surveyed farmers (Fig. 2). In this districts farmers are growing very old late sown wheat varieties (LSWVs) which are in the order of PBW 154 (40%), UP 262 (34%), Lok 1 (4%) and others in same category (2%). Timely sown wheat varieties (TSWVs) like PBW 343 and HD 2967 were grown by 12-13% of

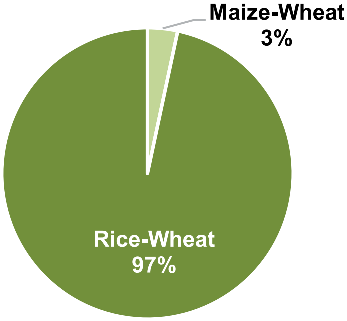

Fig. 2: Major cropping system prevailing in the district as per surveyed farmers

surveyed farmers (Table 1). Although 42% farmers have adopted early wheat sowings but they still rely on LSWVs which are potentially lower yielder (Fig. 3). Data illustrated that this is mismatch and the advantage of early sowing can not be secured if it is not combined with

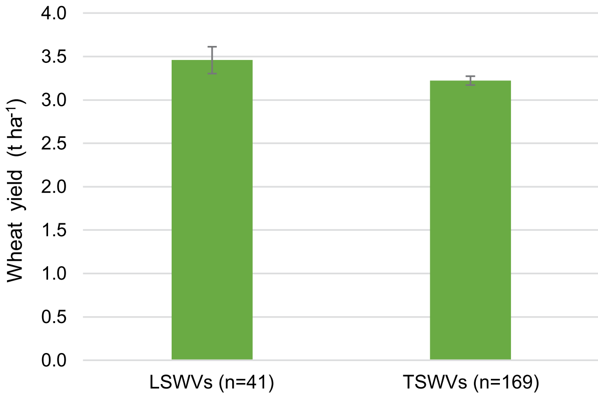

Fig. 3: Average grain yield of timely sown wheat varieties (TSWVs) and late sown wheat varieties (LSWVs) across different agronomic management options

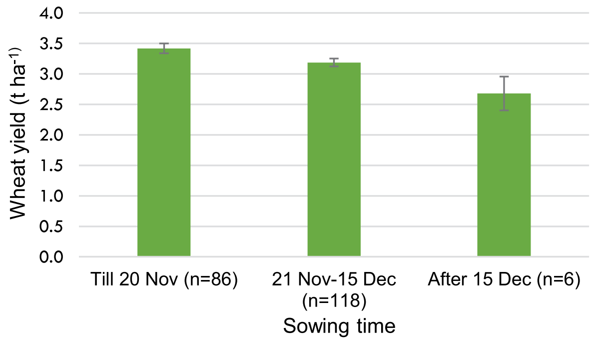

Fig. 4: Average grain yield of wheat as affected by three different sowing schedules across varieties and management practices

TSWVs. That means the trends towards early sowing is a significant development but the use of TSWVs is also central to consolidate the gains from advancement in sowings (Fig. 4). Late-sown conditions which

Table 1: Trends in adoption of important wheat varieties including timely sown wheat varieties (TSWVs) and late sown wheat varieties (LSWVs) (2017-18) (n=210)

Varieties	Number of respondents	Percentage (%)
TSWVs		
HD 2967	14	7
PBW 343	12	6
ShriRam 303	14	7
LSWVs		
LOK 1	9	4
PBW 154	84	40
UP 262	72	34
Other*	5	2

*Includes C 306, PBW 502 from TSWVs group and Kundan, RR 21 from LSWVs group.

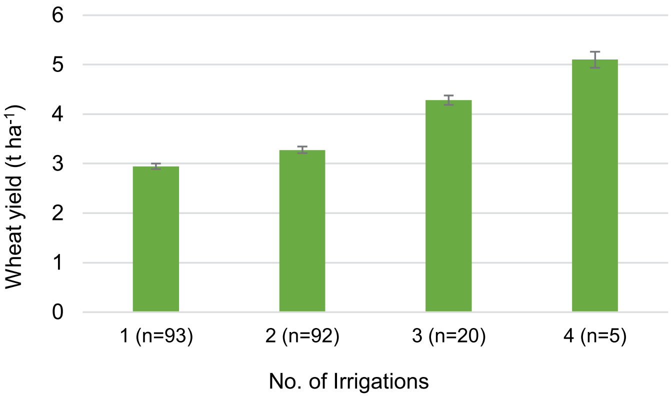

Fig. 5: Irrigation frequency and scope of yield growth

exposes the crop to heat stress adversely effect photo-synthesis (Pushpalatha *et al.*, 2008), number of grains (Rawson and Bagga, 1979) and the grain yield. Since grain yield is dependent more on number of grains than on the test weight, the combination of TSWVs which have more grains/ear head and early sowings will help increasing the wheat yield in the area. Farmers reported the N: P_2O_5:K_2O use at 124:55:32 kg ha^{-1} but irrigation frequency is very low at 1.7 as seen in Table 2. Water stress during grain filling has a detrimental effect on panicle weight and subsequently grain yield through a shortening of the grain filling duration (Lalonde *et al.*, 1997). This was also supported by the data in Fig. 5. Data showed that timely sowing with 4 irrigations provided best yield at 5.1 t ha^{-1}. We need to overhaul the weed management strategy because 41% of the surveyed farmers said that they do not do weed management (Fig. 6).

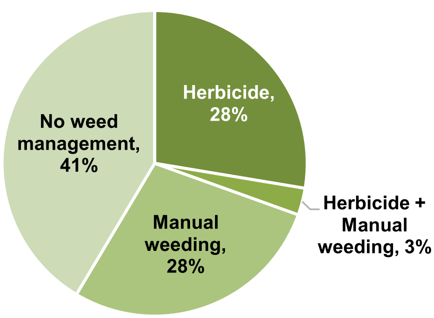

Fig. 6: Weed management shields yield losses and its current status reported by surveyed farmers in the district (n=210)

Conclusion

There is ample scope to significantly increase share of TSWVs against the present trend in favour of LSWVs. The impact of timely

Table 2: The use rates of N: P_2O_5: K_2O (kg ha^{-1}) and irrigation frequencies of surveyed farmers (Potash users 94%)

NPK rates and irrigation frequency	Average use rates	SD	SE
N	123.79	41.53	2.87
P_2O_5	55.39	13.05	0.90
K_2O	31.70	12.47	0.89
Average irrigation	1.7	0.74	0.05

seeding and recommended nutrient management cannot be realized due to poor irrigation management, poor weed control and the use of LSWVs with low yield potential.

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3.16 It is time to push for agronomic management based on early wheat sowing

S.K. Tomar[1], Ajay Kumar[2], Vipin Kumar[3], S.P. Singh[1], S.K. Singh[2], A.P. Rao[4], S.K. Dubey[5], A. Singh[5] and U.S. Gautam[5]

[1]Krishi Vigyan Kendra, Gorakhpur
[2]International Maize and Wheat Improvement Centre (CIMMYT)
[3]International Rice Research Institute (IRRI)
[4]Narendra Dev University of Agriculture and Technology
[5]ICAR- Agricultural Technology Application and Research Institute

Introduction

Wheat crop in majority of cases is part of the double cropping system, which is generally followed by rice. Till 2009, wheat was planted after 15 November as the optimum planting date recommended was after this period. Early maturing (Mondal *et al.*, 2016) wheat varieties were more suitable and recommended for these ecologies. High temperature during March leads to early heading and still shorter crop duration. Thus, there are two questions that came to our mind. Are we looking for solutions for continuous high temperature during wheat season? Or we are aiming for terminal heat stress based solutions? Planting wheat early will allow it to reach at physiological maturity when terminal heat stress starts affecting the crop thus, preventing the decline in wheat yields. The current survey aims at collecting data on current production practices which can be analysed and used for setting priorities.

Methods

Details on methodology are given in Chapter 1

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, Uska Jogi 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).

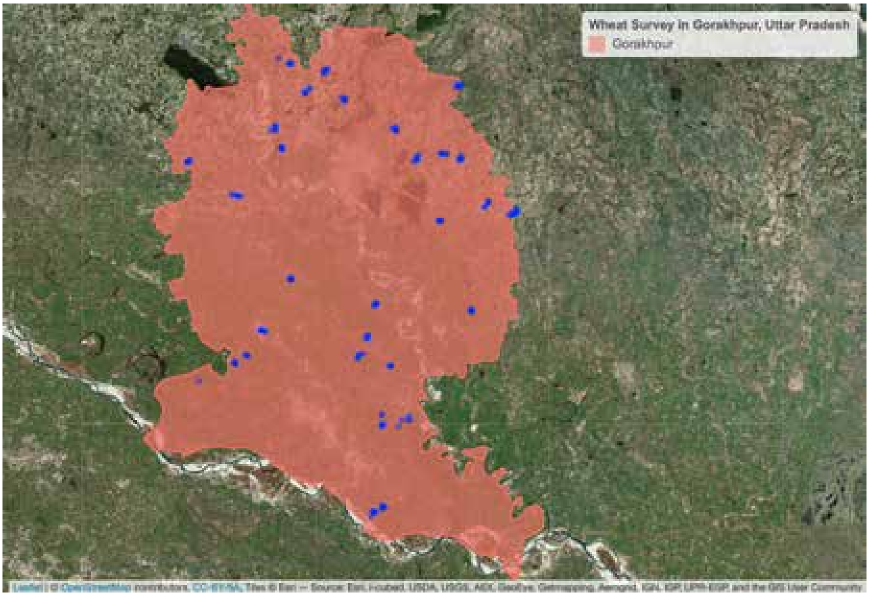

Fig. 1: GPS points of surveyed farms in Gorakhpur

Results and Discussion

Data from surveyed households (HHs) showed that 89% area is covered with rice-wheat cropping system (RWCS) and rest with fallow-wheat cropping system (FWCS) as seen in Fig. 2. Data also illustrated that the new initiative by CSISA-KVK network on early wheat sowings has almost replaced late sown wheat varieties (LSWVs) with timely sown wheat varieties (TSWVs) by almost 90% HHs. Within TSWVs, 63 and 27% used HD 2967 and PBW 343, respectively (Table 1). Data further indicated that 65% of surveyed HHs adopted sowing before 20 November. If we consider 91% HHs who adopted TSWVs and 61% farmers who adopted early sowings, it could be fundamental change improving and sustaining the yield growth of wheat. (Table 1, Fig. 3). The yield gap between two sowings (before 20 November and after 20 November) schedules narrowed down significantly because of replacement of most of LSWVs with TSWVs (Fig. 4). This is also reflected in the average grain

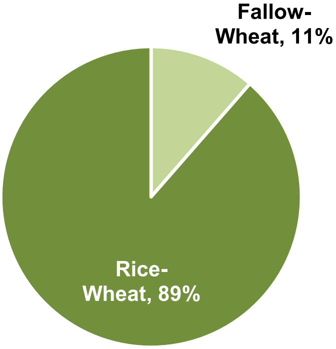

Fig. 2: Major cropping system prevailing in the district as per surveyed farmers

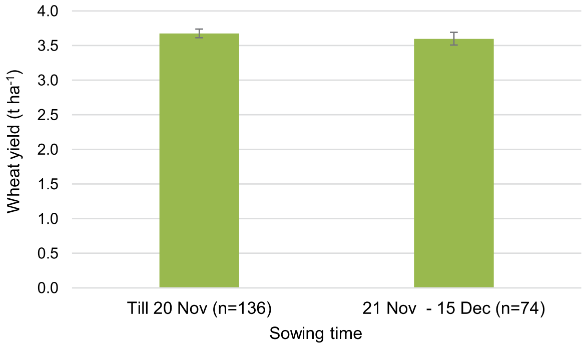

Fig. 3: Effect of time of sowing on grain yield of wheat according to different sowing schedules across varieties and management practices

yield at 3.7 t ha^{-1} from TSWVs against 3.2 t ha^{-1} from LSWVs. In Gorakhpur district N: P_2O_5:K_2O use is at 152:62:28 kg ha^{-1} (Table 2). The use of potash is low and of phosphorus matches the recommendation but still appears on higher side because farmers also use P in rice (Table 1). Most farmers use weed management with 77% adopting herbicides as the favoured method against only 9% adopting manual weeding. The trend towards scarce and costly labour reflected significant

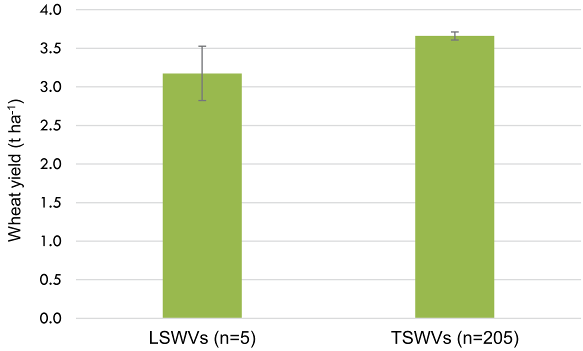

Fig. 4: Grain yield of wheat can be increased by replacing late sown wheat varieties (LSWVs) with timely sown wheat varieties (TSWVs) across all sowing schedules and agronomic management options

Table 1: Summary of important varieties including timely sown wheat varieties (TSWVs) and late sown wheat varieties (LSWVs) (2017-18) (n=210)

Varieties	Number of respondents	Percentage (%)
TSWVs		
DBW 17	4	2
HD 2967	132	63
PBW 343	56	27
LSWVs		
PBW 154	5	2
PBW 502	8	4
Other*	5	2

*Includes ShriRam 303 and WH 1105 from TSWVs group.

weed management (Fig. 5). The adoption of broadcast method of sowing by 90% farmers with an average yield of 3.75 t ha^{-1} and zero tillage method of crop establishment by only 4% farmers with an average yield of 3.75 t ha^{-1} should be viewed as an integral part of line of action by the department of agriculture (Fig. 6, 7). There was an increase in yield with increase in the number of irrigations applied (Fig. 8) and for that reason the average number of irrigation of 2.52 used by the farmers is low. Significant development has been the advancement in wheat sowings leading to an increase in the spectrum of varieties in favour of TSWVs. The combination of both brought increased wheat yield. Therefore, the focus should

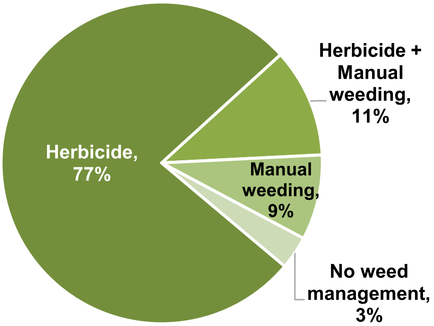

Fig. 5: Current weed management practices followed by surveyed farmers (n=210)

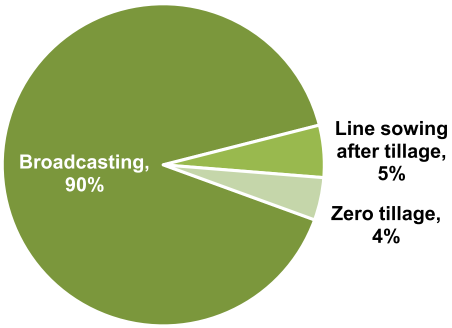

Fig. 6: Crop establishment methods adopted by the surveyed farmers in Gorakhpur district of UP (2017-18)

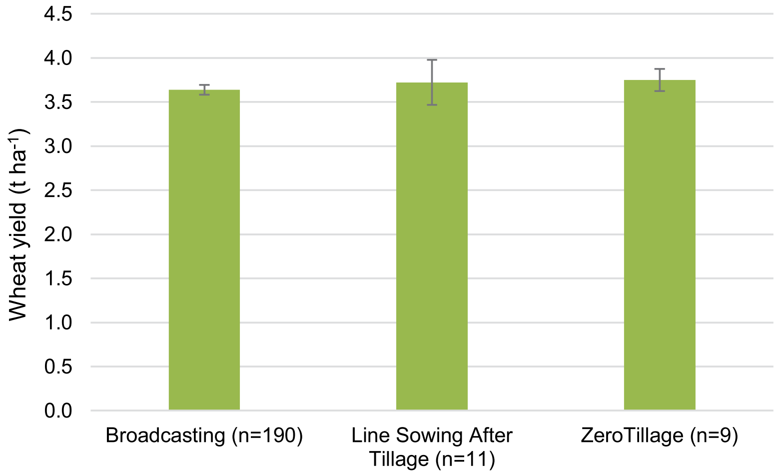

Fig. 7: Effect of crop establishment methods on the grain yield of surveyed farmers (2017-18) Yield Comparison

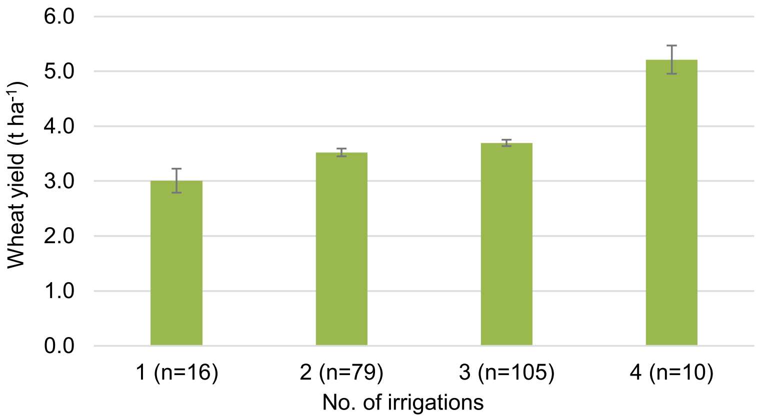

Fig. 8: Influence of irrigation frequency on the grain yield of wheat

Table 2: The use rates of N: P_2O_5: K_2O (kg ha^{-1}) and irrigation frequencies of surveyed farmers (Potash users 51%)

NPK rates and irrigation frequency	Average use rates	SD	SE
N	151.5	35.1	2.4
P_2O_5	61.9	21.3	1.5
K_2O	27.59	12.16	1.18
Average irrigation	2.52	0.71	0.05

change from LSWVs to TSWVs. The adoption of ZT is low. Based on these findings (Keil *et al.,* 2015) the deployment of a capital-intensive technologies such as ZT by private-sector service providers can lead to relatively socially inclusive outcomes as farmers' awareness and trust in the technology increases and the service economy matures.

Conclusion

Ongoing change in production practices like early wheat sowing with TSWVs is a testimony to the success of this strategy. It should be supported by technologies like zero tillage and enhanced level of irrigation.

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3.17 Early wheat sowing will improve the efficacy of other management options that beat the terminal heat

Shobha Rani[1], Madhulika Singh[2], Ajit K. Paswaan[1] and Shahnawaz R. Dar[3]

[1]Krishi Vigyan Kendra, Jehanabad
[2]International Maize and Wheat Improvement Centre (CIMMYT)
[3]International Rice Research Institute (IRRI)

Introduction

The district of Jehanabad is spread in an area of 95,900 ha with a population of 1,124,176. The total cultivable land is 49,900 ha with 33,000 ha of net irrigated land. The intensification of rice-wheat cropping system (RWCS) is the key to increasing the income of farmers. Late transplanting of rice and consequently the late seeding of wheat is part of the bigger problem. Given the late sowing scenarios and also the continued focus on late sown wheat varieties (LSWVs), the improvement in the productivity growth is unlikely to come in wheat. There are certain fixations in the minds of researchers and extension agencies that very high yields of wheat is not possible because weather is not favourable in the Eastern Indo Gangetic Plain (EIGP) compared to as in North West Indo Gangetic Plain (NWIGP). This may not be true. The landscape diagnostic survey (LDS) was taken up to understand the underlying position and then set priorities for improving the wheat productivity in the district. The whole idea is how to make research and development in a bottom-up approach rather than in a top-up manner.

Methods

Details on methodology are given in Chapter 1

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).

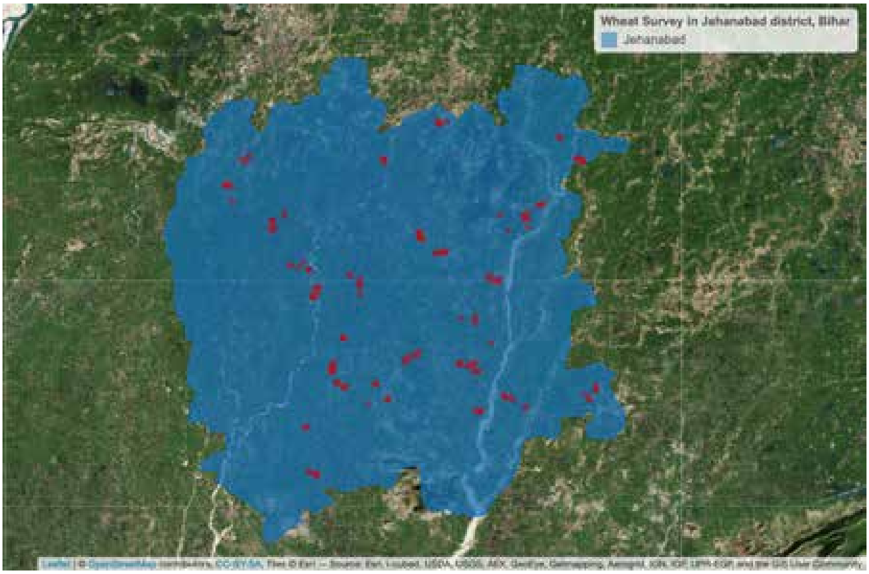

Fig. 1: GPS points of surveyed farms in Jehanabad

Results and Discussion

The success of rice-wheat cropping system (RWCS), which is the main stay of farmers' income seems to be based on the innovations starting from crop establishment phase of both rice and wheat. In the traditional model, late sown wheat varieties (LSWVs) were more popular than timely sown wheat varieties (TSWVs). Based on the data collected from farmers, only two varieties; HD 2967(14%) in TSWVs group and Kedar (33%) in LSWVs group (Table 1) have been replaced. Matching the growth and development of wheat within the short time available due to late sowings is tough. That is why there is more prevalence of LSWVs. In the present study, TSWVs seeded before 20 November could fit well

Table 1: Spectrum of timely sown wheat varieties (TSWVs) and late sown wheat varieties (LSWVs) (2017-18) (n=196)

Varieties	Number of respondents	Percentage (%)
TSWVs		
HD 2967	26	14
PBW 343	21	11
Kedar	63	33
Kundan	21	11
LOK 1	7	4
HUW 234	3	2
PBW 154	4	2
LSWVs		
PBW 502	17	9
Sonalika	11	6
UP 262	7	4
Other*	9	5

*Includes Aditya, Ankur, PBW 2985, PBW 373 and Prabhat from LSWVs group.

in the extended time-frame for matching their flowering time that beat the terminal heat. This helped attain the grain yield at 3.83 t ha^{-1} (Fig. 2). LSWVs are released solely for late sowing. The need for LSWVs was argued on the ground of relatively high temperature in the first two weeks of November is not true (CSISA Project Annual Report 2014, 2015). The

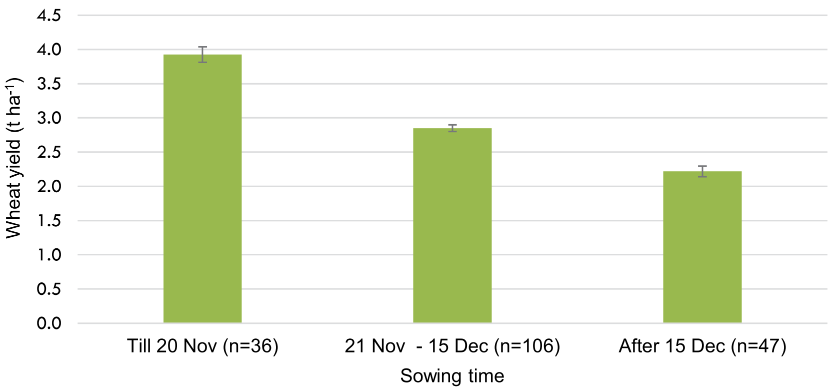

Fig. 2: Farmers reported wheat yield as affected by three different sowing schedules across varieties and management practices

gap of almost 1.0 t ha^{-1} when sowings are delayed beyond 20 November seen in this survey proves this fact. Similarly, the TSWVs showed more yield than LSWVs by a margin of approximately 1 t ha^{-1} (Fig. 3). The use of N: P_2O_5:K_2O use rate at 135:51:36 kg ha^{-1} did not match the yield of wheat (Table 2). One-fourth farmers did not undertake any weed

Fig. 3: Farmers reported gains in wheat yield from timely sown wheat varieties (TSWVs) and late sown wheat varieties (LSWVs) across different agronomic management options

management (Fig. 4). In addition to late sowing, the lower efficiency of applied nutrient may also be the consequence of poor-weed management. There was a gradual increase in yield with the increase in number of irrigations. With only 1 irrigation the reported yield level was 1.73 t ha^{-1} compared to 4.44 t ha^{-1} with 5 irrigations (Fig. 5).

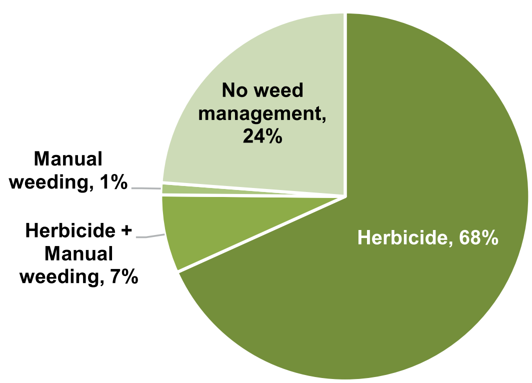

Fig. 4: Farmers reported trend towards herbicide use in Jehnabad district of Bihar. No weed control is big drag on yield (n=189)

Grain growth rates of wheat between 20 and 45 days after anthesis exceed crop growth rates (Rawson and Evans, 1971. That would mean that when the seeding is done between 1 and 20 November, the carbon for grain growth could be easily met from photosynthesis. When sowing is

Table 2: The use rates of N: P_2O_5: K_2O (kg ha^{-1}) and irrigation frequencies of surveyed farmers (Potash users 74%)

NPK rates and irrigation frequency	Average dose	SD	SE
N	134.51	29.05	2.11
P_2O_5	51.31	19.74	1.45
K_2O	36.25	12.64	1.07
Irrigation number	2.93	0.89	0.06

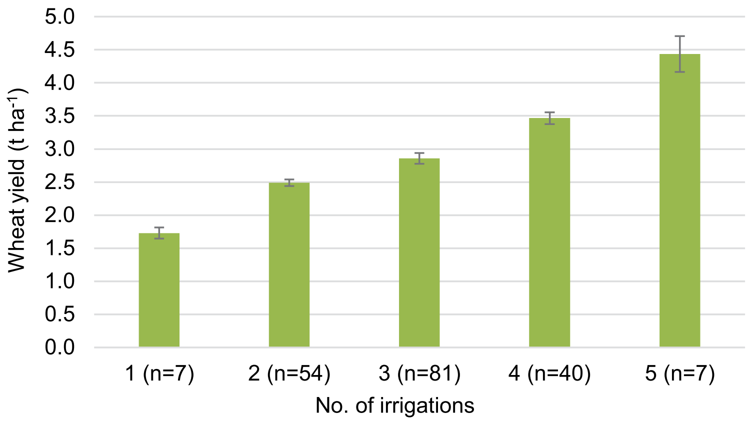

Fig. 5: Farmers reported gains in wheat productivity as influenced by the frequency of irrigation

done late, the reduced growth rate in the terminal phases of crop will not be able to support the grain growth. Moreover, total dry-matter production must increase for any gain in wheat yield. This does not seem possible when the sowings are delayed. Even if the loss in grain weight between anthesis and maturity in TSWVs is greater than that in LSWVs, it will be compensated by more number of grains in TSWVs. Therefore, the combination of early sowing and TSWVs will result in more yield. Wheat yields do not match the N:P_2O_5:K_2O use rate at 135:51:36 because average irrigation frequency is low. Balanced use of irrigation and fertilizer application gives the full potential of varieties (Kanwar 1969).

Conclusion

To achieve a sustained gain in wheat productivity, timely sowing, TSWVs and weed management need to be practiced as priorities in that order.

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3.18 Improve access to timely sown wheat varieties (TSWVs) and early sowings for yield growth of wheat

Amit Kumar Singh[1], S.N. Rai[1], Rishikesh[1], Pradeep Sagwal[2] and Shahnawaz R. Dar[2]

[1]Krishi Vigyan Kendra, Kaimur
[2]International Rice Research Institute (IRRI)

Introduction

District Kaimur spreads in a geographical area of 340,400 ha out of which 176,700 ha is cultivable. The area under rice and wheat is 81,700 and 68,400 ha, respectively. Almost 45.6% area has clay loam soil whereas 30.8 and 23.5% area is under sandy loam and red laterite soil, respectively. The research system in Bihar has brought number of late sown wheat varieties (LSWVs) that mature in 125-135 days and timely sown wheat varieties that mature in 135-150 days. The share of TSWVs grown by farmers is increasing but breeding efforts for these ecologies are still more on LSWVs compared to TSWVs. Terminal heat is a perennial problem, we may need to adjust sowing dates so that potentially high yield group reaches peak flowering stage sometime in the mid-February. Similarly, the research direction needs to be towards new agronomic management options. In order to get these options localised, the diagnostic survey was conducted to seek guidance towards new directions so that wheat yields can be increased sustainably.

Methods

Details on methodology are given in Chapter 1

Blocks covered: Bhabua, Bhagwanpur, Ramgarh, Nuaon, Kudra, Mohania, Durgawati, Chainpur, 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).

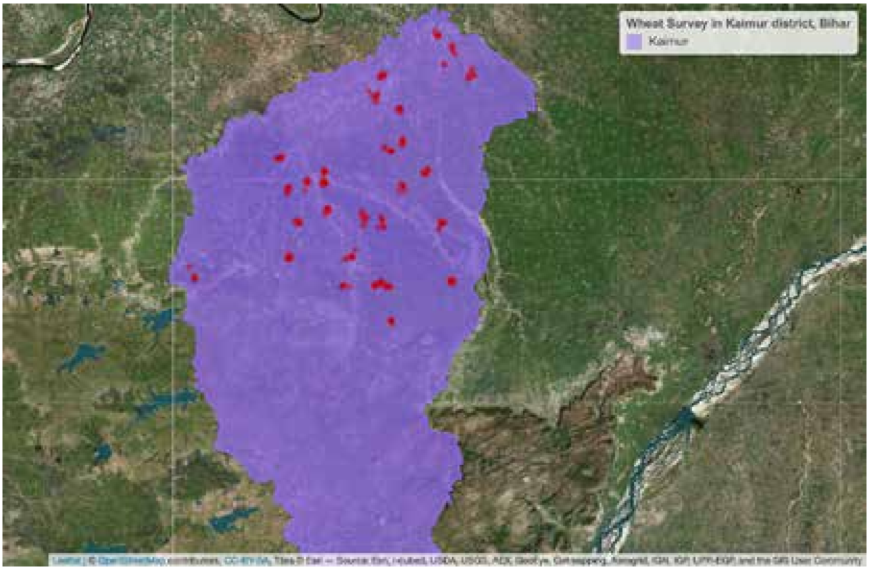

Fig. 1: GPS points of surveyed farms in Kaimur

Results and Discussion

Based on the landscape diagnostic survey (LDS) conducted in 2017-18, the respondents' favourite varieties among LSWVs were HUW 234, Kedar and PBW 154 with adoption rate of 19,21 and 3%, respectively. There has been an increasing trend towards TSWVs with HD 2967 and Shri Ram 303 (a variety from private sector) occupying 25% and 15% space, respectively (Table 1). On the whole, 45% farmers favoured TSWVs- a trend towards new varieties in this group. The primary driver of this trend is the grain yield which is 2.91 t ha^{-1} for TSWVs compared to 2.15 t ha^{-1} for LSWVs (Fig. 2). When looked into the major cause of yield stagnation in this district, late sowing beyond 15 December reduced the yield by more than 0.4 to 0.8 t ha^{-1} (Fig. 3). Gain in wheat

Table 1: Summary of important varieties including timely sown wheat varieties (TSWVs) and late sown wheat varieties (LSWVs) (2017-18) (n=208)

Varieties	Number of respondents	Percentage (%)
TSWVs		
HD 2967	50	25
PBW 502	6	3
PBW 343	11	5
Shri Ram 303	31	15
LSWVs		
PBW 154	6	3
HUW 234	39	19
Kedar	43	21
Other*	18	9

*Includes HD 2733, PBW 550 and SriRam 505 from TSWVs group and Lok 1, PBW 373 and UP 262 from LSWVs group.

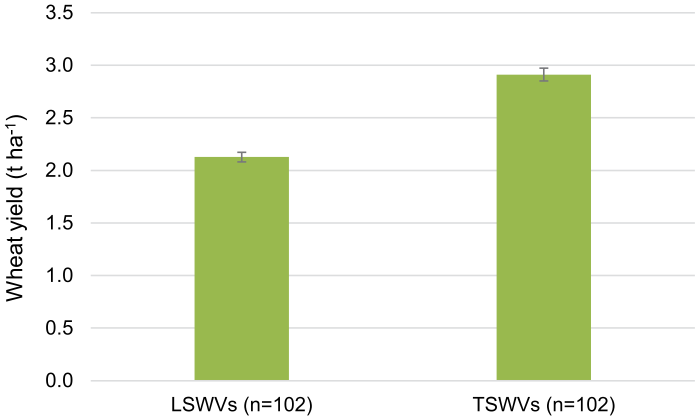

Fig. 2: Farmers reported yield of timely sown wheat varieties (TSWVs) and late sown wheat varieties (LSWVs) across different agronomic management options in Kaimur district

yield from early sowing (before 20 November) is lower compared to that of other districts. This is because of very small sample size of only 3 farmers. Moreover, 50% TSWVs in the system also increased the yield even under sowing schedule of 21 November to 15 December. We need to address the advancement in wheat sowings sequentially from current sowing dates to at least 10-15 days early starting from 1 November. We

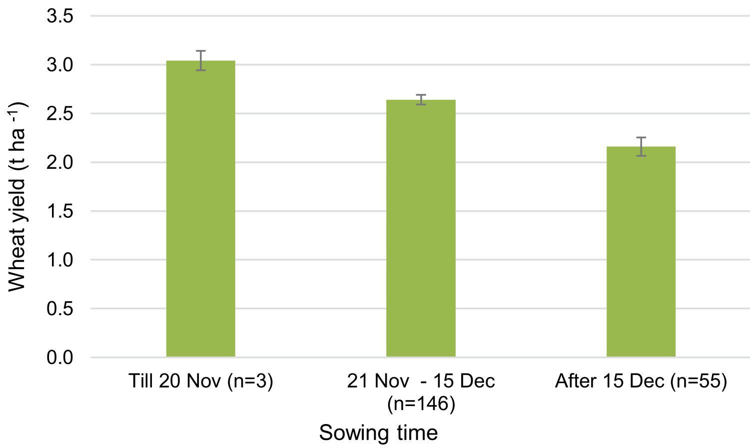

Fig. 3: Effect of late sowings on the farmers reported grain yield of wheat across varieties and management practices

expect the State Agricultural Universities (SAUs) will step in to bring TSWVs in the system and extension agencies to promote early sowings to beat the terminal heat. This step is expected to bring changes in yield growth in the near future for this district. Delayed sowings stands at the center of continuing low yields due to high temperatures and resultant hastened crop maturity (Dhillon and Ortiz-Monasterio 1993). Earlier studies under very different climate conditions also showed that that potential grain yield is more limited by sink size than by post-anthesis assimilate supply (Rahman *et al.*, 1977). High temperatures during grain filling may reduce the grain growth period by shortening the duration of photosynthetic tissue. To focus on the core issue of early sowing, the appropriate framework of zero tillage adoption is available with 16% households (HHs) adopting this technology (Fig. 4).

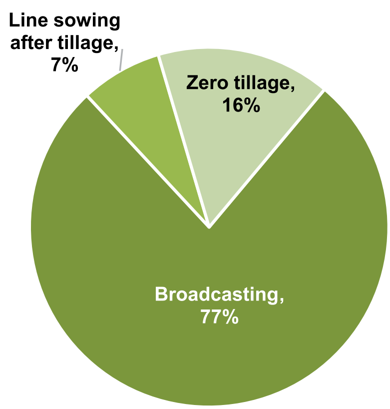

Fig. 4: Crop establishment methods practiced by farmers

Farmers used the $N:P_2O_5:K_2O$ at 133:59:23 kg ha^{-1}. The average frequency of irrigation is low at 2.26 (Table 2). P use is more than the potential use especially when the irrigation frequency is so low.

Table 2: The use rates of N: P_2O_5: K_2O (kg ha^{-1}) and irrigation frequencies of surveyed farmers (Potash users 18%)

NPK rates and irrigation frequency	Average use dose	SD	SE
N	133.18	45.32	3.17
P_2O_5	58.73	23.89	1.70
K_2O	22.83	13.34	2.19
Irrigation number	2.26	0.57	0.04

Enhanced biomass due to early sowing and higher grain number of TSWVs for yield progress and also the efficient use of nutrient, which is very low in this survey, can be sustained if appropriate weed management is in place. No weed management by 31% respondents is not a good sign for yield growth (Fig. 5). There was a gradual increase in grain yield with increase in irrigation frequency (Fig. 6). It is wrong to assume that growth period of wheat is short in this district.

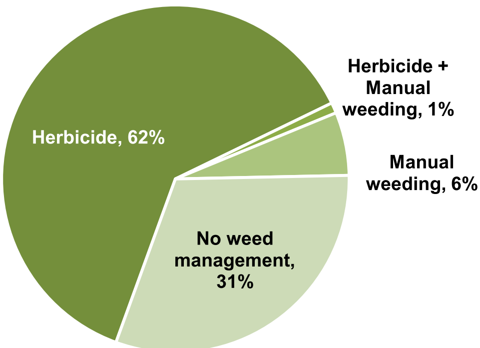

Fig. 5: Current status of weed management. The trend towards herbicide use as shown by farmers response (n=204)

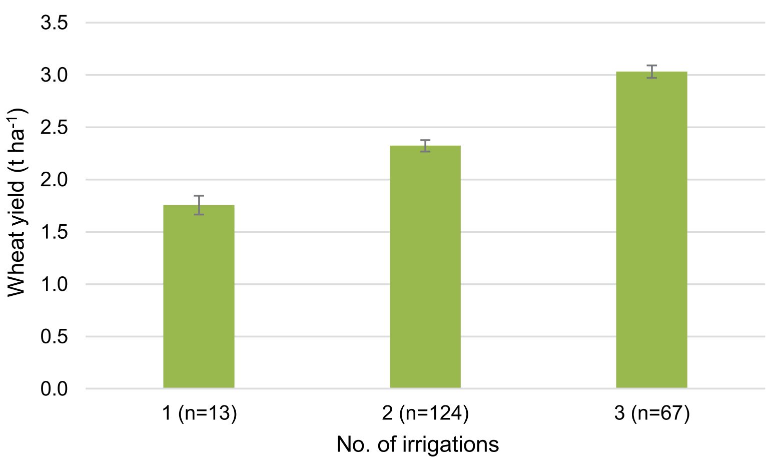

Fig. 6: Yield gains under different irrigation frequencies

It is essential to understand this factor and change the direction of research from LSWVs to TSWVs.

Conclusion

Advancing wheat sowing, changes in the varietal spectrum from LSWVs to TSWVs, appropriate weed management and increased irrigation frequency can shift the balance in favour of high wheat yield.

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3.19 Ensure high wheat yields through early sowing, timely sown wheat varieties and improved irrigation management

Jitendra Kumar[1], Anurag Kumar[2], Ranjeet Pratap Pandit[1], Brajendu Kumar[1] and Shishpal Poonia[2]

[1]Krishi Vigyan Kendra, Khagaria
[2]International Maize and Wheat Improvement Center

Introduction

Khagaria district has total cultivable land of 104,000 ha with 86,100 ha net sown area of which 68,300 ha is irrigated. The major soil type is fine loamy soil and loamy to fine loamy soil. The district represents maize-wheat cropping system (MWCS) as the main cropping system. Even in *rabi* maize is predominant crop of this district, the wheat yield in this district is increasing but not at the same pace as in Begusarai- the adjoining district. Only late sown wheat varieties (LSWVs) has been sown for decades but only few varieties have been successful especially those with better quality but not for high yields. Idea is to fit a suitable variety in a short growing cycle due to late sowings so that LSWVs flower mature almost at the same time as timely sown wheat varieties (TSWVs) sown on time. Now, the early wheat sowing in some districts can be treated as a breakthrough in achieving high yield. Timely sown wheat varieties (TSWVs) are becoming popular. However the sustainability of TSWVs will now depend on the associated agronomic management including irrigation and weed management. The purpose of present survey undertaken during 2017-18 was to understand what kind of research is needed to affect changes based on this survey, and which interventions need to be promoted by the extension agencies in the district.

Methods

Details on methodology are given in Chapter 1

Blocks covered: Alauli, Beldaur, Chautham, Gogri, Khagaria, Mansi, Parbatta.

Villages surveyed: Alauli, Amni, Araiya, Banni, Belasimri, Bhadas, Bhagwanchak, Bharsauk, Chanpur, Goriami, Hathwan, Hiyatpur, Jhiktiya, Katghara, Kavela, Khutia Mansi, Kothia, Lagma, Marar, Pasraha, Rahimpur, Rampur, Rasaunk, Ratan, Rohiyama, Samspur, Sanhauli, Sapaha, Sherchakala, Samsuddinpur, Shashpur, Shekhpura, Shergarh, Tehai, Terasi, Tetrabad, Basudevpur, Waisa (Fig. 1).

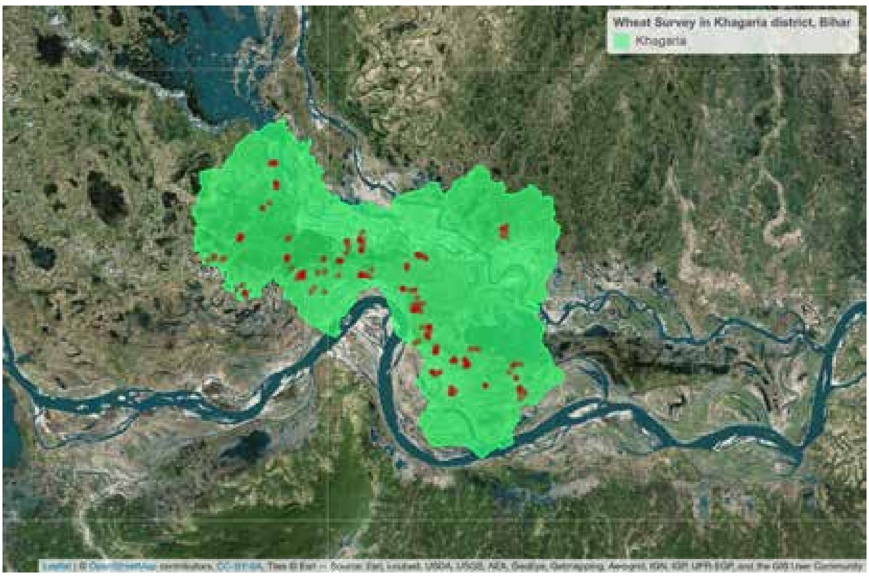

Fig. 1: GPS points of surveyed farms in Khagaria

Results and Discussion

The adoption trends showed that the district is moving away from LSWVs represented by UP 262 (4%) and others (19%). Farmers of this district have adopted TSWVs (Table 1) including HD 2967 (28%), PBW 343 (25%) and Sri Ram 303 (23%) maize-wheat (47%) followed by rice-wheat (26%) are two prominent cropping systems in the district (Fig. 2). This may be due to spill over effect of adjacent Begusarai district where TSWVs have replaced LSWVs. TSWVs are more attractive to wider

Table 1: Summary of important varieties including timely sown wheat varieties (TSWVs) and late sown wheat varieties (LSWVs) (2017-18) (n=205)

Varieties	Number of respondents	Percentage (%)
TSWVs		
HD 2967	57	28
PBW 343	52	25
ShriRam 303	48	23
LSWVs		
UP 262	9	4
Other*	20	19

*Includes PBW 550, PBW 502, HD 3086, HD 3059, HD 2824, HD 2733, Dhaulagiri from TSWVs group and Gautam, HD 2985, HD 3118, Kundan, PBW 2086, RR21, WR 544 and unknown from LSWVs group.

range of households because the average yield of these varieties is 0.4 t ha^{-1} higher than that of LSWVS (3.59 t ha^{-1}) (Fig. 3). Higher yield of these varieties can also be attributed to advancement in wheat sowing by 65% households (Fig. 4).

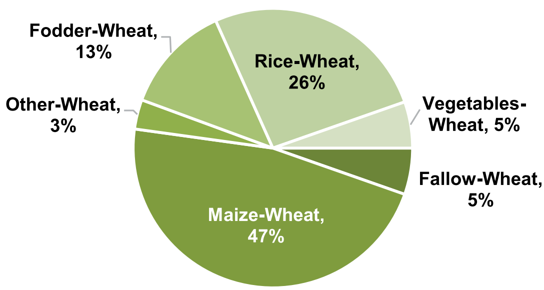

Fig. 2: Diversified cropping system of Khagaria district of Bihar. Results are based on the response from 205 farmers across the district

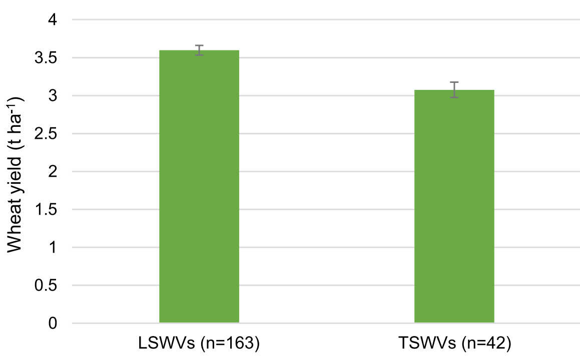

Fig. 3: Data on preference of farmers for timely sown wheat varieties (TSWVs) in place of late sown wheat varieties (LSWVs)

The other challenge in this district is that even after best nutrient use scenario of $N:P_2O_5:K_2O$ use rate at 121:60:30 kg ha^{-1}, the yield levels are a bit lesser than the expectations from this level (Table 2). Farmers are counting on good weed management

Table 2: The use rates of N: P_2O_5: K_2O (kg ha^{-1}) and irrigation frequencies of surveyed farmers (potash users 93%)

NPK rates and irrigation frequency	Average use rates (kg ha^{-1})	SD	SE
N	121.01	34.54	2.41
P_2O_5	60.75	14.97	1.04
K_2O	32.83	7.52	0.54
Irrigation number	2.71	0.75	0.05

options as more than 60% have adopted herbicides or herbicide plus manual weeding (Fig. 5). As per the Fig. 6, the grain yield of wheat is directly proportional to number of irrigations. This is not happening in this district.

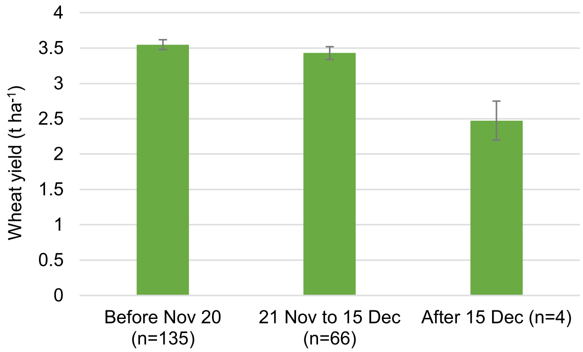

Fig. 4: Effect of sowing time on the grain yield of wheat reported by surveyed farmers across varieties and management practices

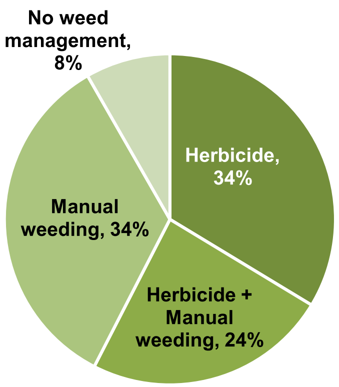

Fig. 5: Farmers reported weed management practices adopted in the district (n=205)

The survey indicated that relatively better yields than many other district except Begusarai can be attributed to the combination of early sowing and TSWVs. New strategy should be centred on these two options. Yield and the efficiency of inputs like fertilizer may suffer from lesser than required level of irrigation. With early wheat sowings and TSWVs farmers may count two most important variables including more grain number m^{-2} (Abbate *et al.*, 1998) and larger sink size in response to either higher pre-anthesis growth (Shearman *et al.*, 2005). Technologies like zero tillage must be promoted to facilitate early sowings and reduce the cost of cultivation.

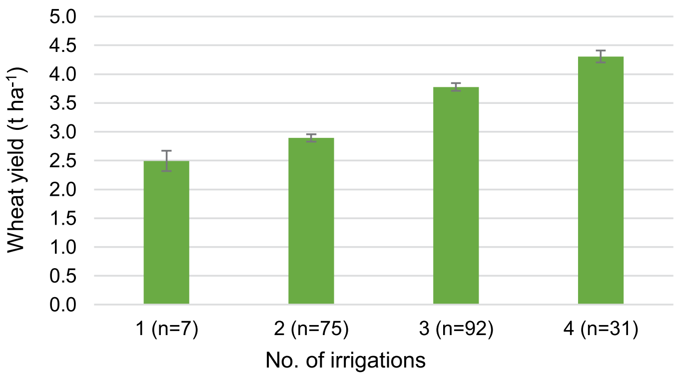

Fig. 6: Effect of irrigation on the farmers reported yield of wheat

Conclusion

Access to irrigation and new crop establishment methods like zero tillage can create synergies with early wheat sowings and timely sown wheat varieties.

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3.20 Production practice survey reflect the focus on timely sown wheat varieties (TSWVs) rather than late sown wheat varieties (LSWVs)

A.K. Dubey[1], Ajay Kumar[2], Vipin Kumar[3], Ashok Rai[1], T.N. Rai[1], Ajay Rai[1], S.K. Dubey[4], A. Singh[4] and U.S. Gautam[4]

[1]Krishi Vigyan Kendra, Kushinagar

[2]International Maize and Wheat Improvement Centre (CIMMYT)

[3]International Rice Research Institute (IRRI)

[4]ICAR-Agricultural Technology Application and Research Institute, Kanpur

Introduction

When KVK Kushinagar and CSISA team started working together at farmers' field in 2009, the average grain yield of wheat was 2.4 t ha^{-1}. In 2018, the picture is quite different. The landscape diagnostic survey (LDS) was conducted to understand how the production practices have shifted during last 10 years and what could be the issue that need increased research thrust and which technologies can be pushed for increased adoption to sustainably intensify the rice-wheat based cropping system in Kushinagar district of Eastern Uttar Pradesh. The area of the district is 2873.50 sq. km. The district is divided into 14 blocks with 1,571 villages. The district falls under the middle Gangetic (North-East) plains having alluvial soil. The net area sown is 233,166 ha with 167,000 ha area under irrigation.

Methods

Details on methodology are given in Chapter 1

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).

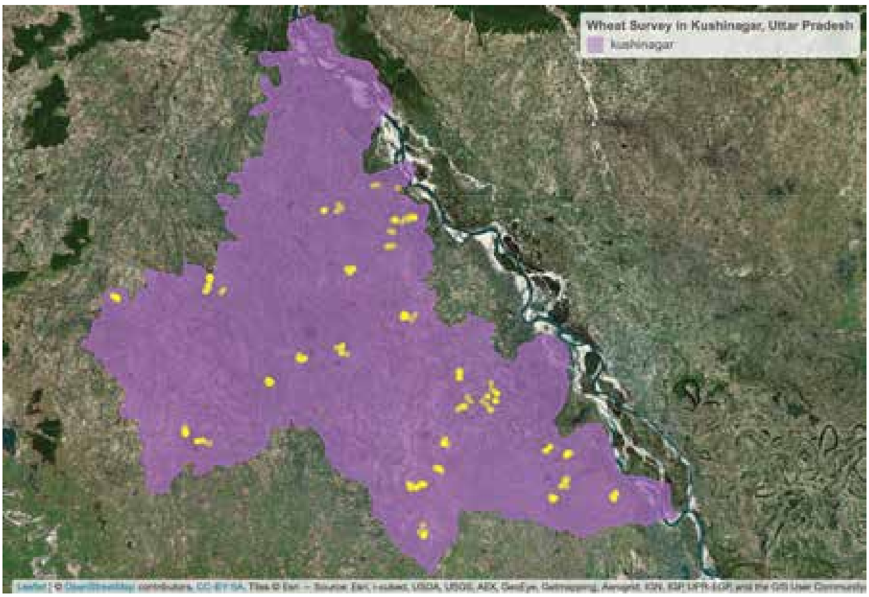

Fig. 1: GPS points of surveyed farms in Kushinagar district

Results and Discussion

To understand the future course of action of varietal spectrum, data on current varieties grown by farmers was captured. Data showed that the timely sown wheat varieties (TSWVs) are tending to get more attention of farmers. The use of TSWVs variety (HD 2967) is favourite of 59% respondents. Two other varieties in this group viz. PBW 343 (20%) and PBW 502 (5%) are still preferred by farmers (Table 1). The use of late sown wheat varieties (LSWVs) accounted for only 18% of total varietal spectrum. The district is dominated (73%) by rice-wheat cropping system (RWCS) with diversification towards maize-wheat and sugarcane-wheat cropping systems in a range of 10-11% of surveyed farmers (Fig. 2). Farmers have started to lower their use of late sowing with only 18% farmers sowing wheat after 15 December and 27% farmers sowing wheat before 20 November. In 2009, early sowing before 15 November was a rare event. Now farmers have starting shifting towards early sowing with higher yield (Fig. 3). Farmers reported relatively more yield when the sowings were done between 16 November and 15 December probably because even in this sowing schedule farmers adopted TSWVs rather than LSWVs. High average yield of 3.4 t ha^{-1} from TSWVs compared to 2.9 t ha^{-1} from LSWVs reported by HHs helps to explain why TSWVs are important in these ecologies (Fig. 4). Average N: P_2O_5: K_2O use was 133:58:20 kg ha^{-1}, which is more than

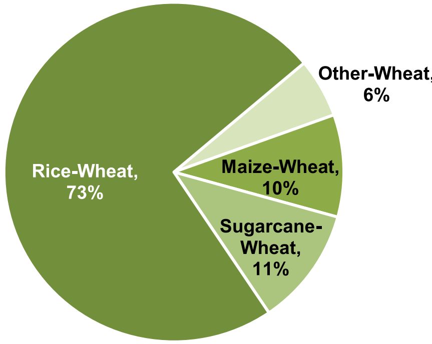

Fig. 2: Prevailing cropping systems in Kushinagar district of Eastern UP. Data is based on 195 respondents across whole district

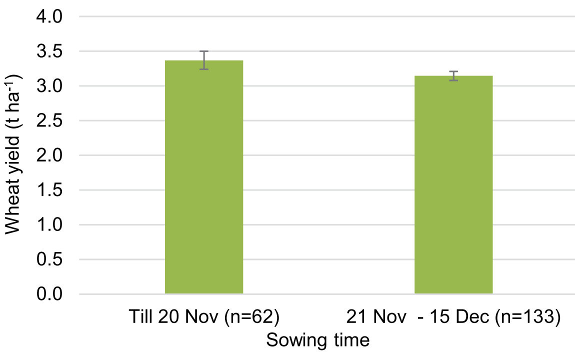

Fig. 3: Average grain yield of wheat as affected by three different sowing schedules across varieties and management practices as reported by surveyed farmers

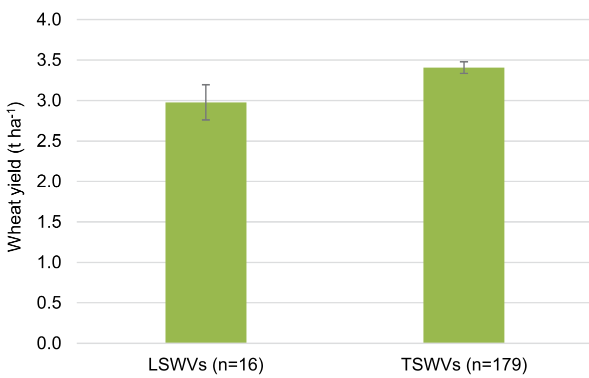

Fig. 4: Average grain yield as influenced by timely sown wheat varieties (TSWVs) and late sown wheat varieties (LSWVs) across different agronomic management options

Table 1: Summary of important varieties including timely sown wheat varieties (TSWVs) and late sown wheat varieties (LSWVs) sown by surveyed farmers (2017-18) (n=195)

Varieties	Number of respondents	Percentage (%)
TSWVs		
HD 2733	3	2
HD 2967	116	59
ShriRam 303	4	2
PBW 343	39	20
PBW 502	10	5
LSWVs		
PBW 154	7	4
Other*	16	8

*Includes DBW 17, HD 2781, HD 2985, PBW 2076, PBW 550 from TSWVs group and Kedar and UP 262 from LSWVs group.

the recommendations in Eastern UP (Table 2). Weed management is done by 79% farmers where 42% are using herbicides and 34% HHs doing manual weeding (Fig. 5). According to the surveyed farmers 90% of them followed broadcasting as crop establishment method whereas the rest 10% used zero tillage (Fig. 6). However, when the yield levels are considered, the grain yield from zero tillage was 4.11 t ha^{-1} (Fig. 7). While from broadcasting method it was 3.3 t ha. The grain yield increased with corresponding increase in the frequency of irrigation (Fig. 8). This

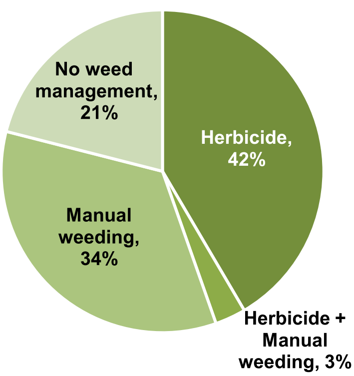

Fig. 5: Farmers reported weed management options practiced in the district (n=195)

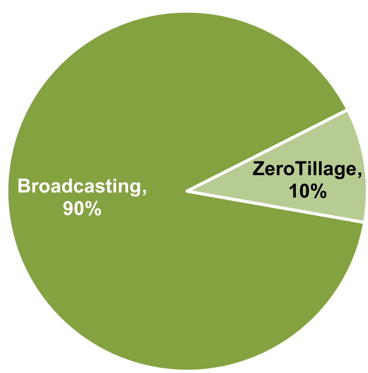

Fig. 6: Crop establishment methods practiced by farmers

Table 2: The use rates of N: P_2O_5: K_2O (kg ha^{-1}) and irrigation frequencies of surveyed farmers (Potash users 77%)

NPK rates and irrigation frequency	Average use rates (kg ha^{-1})	SD	SE
N	133.41	33.53	2.41
P_2O_5	57.65	17.725	1.29
K_2O	25.97	11.15	0.91
Irrigation number	2.08	0.86	0.06

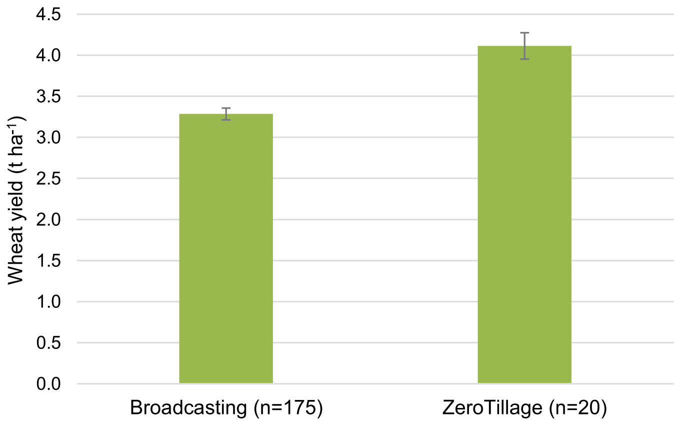

Fig. 7: Farmers reported average grain yield under four different crop establishment methods practiced by farmers in Kushinagar district

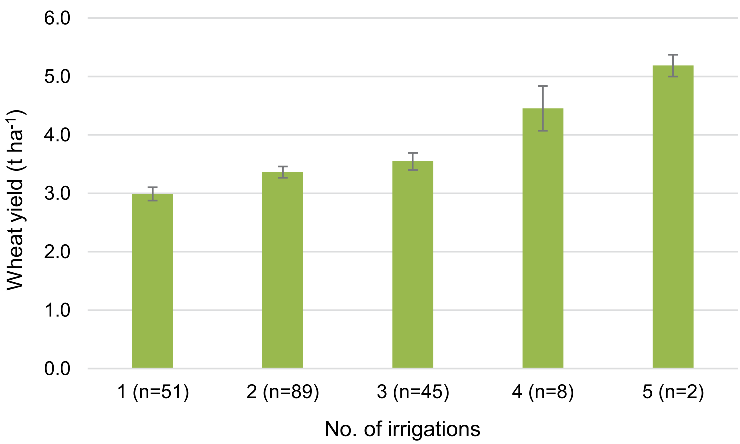

Fig. 8: Changes in farmers reported average response to number of irrigation. Majority farmers stay between 1 and 3 irrigations

is not followed by farmers because it is costly. The data from the survey showed that the yield of TSWVs sown on time need to be improved by using better weed management options and by increasing the frequency of irrigation. In spite of a possible rise of 0.32°C and 0.28°C per decade (Rao *et al.*, 2014) in the minimum and maximum temperatures over wheat growing areas in India, there has been a large scale reluctance to irrigate wheat at grain filling stage of wheat. The potential kernel weight especially in timely sown wheat may be limited at post-anthesis due to assimilate supply constraint. Based on earlier work by Rawson and Evans (1971) it is possible that during terminal heat phase even if the loss in weight from the vegetative organs between anthesis and maturity was greater in the high yielding varieties, the margin between demand for carbon by grains of TSWVs and LSWVs will be minimum.

Conclusion

With increasing trends towards early sowings, the choice of timely sown varieties is getting even more important. The changed scenario has to be supported by proper weed management and better access to irrigation.

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3.21 Poor weed management and low irrigation: Obstacles in increasing yield levels

Uday Prakash Narayan[1], Anurag Kumar[2], Shambhu Rai[1] and Shishpal Poonia[2]

[1]Krishi Vigyan Kendra, Lakhisarai
[2]International Maize and Wheat Improvement Center (CIMMYT)

Introduction

The soil types of Lakhisarai are sandy loam to loam. It has 7 blocks, 80 gram *panchayats* and 460 villages. It has 128,100 ha land of which 77,200 ha is net sown. It has a total population of 1,000,912 (2011 census). The net irrigated area is 42,100 ha. The total area under rice is 24,453 ha and wheat is 29,400 ha. Knowing where we are and how we have progressed so far makes sense. KVK-CSISA network turned to farmers to gauge the real issues and understand why some technologies are not accepted and why some technologies have large acceptance.

Methods

Details on methodology are given in Chapter 1

Blocks covered: Barhaiya, Chanan, Halsi, Lakhisarai, Pipariya, Ramgarh Chawk, 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, Walipur (Fig. 1).

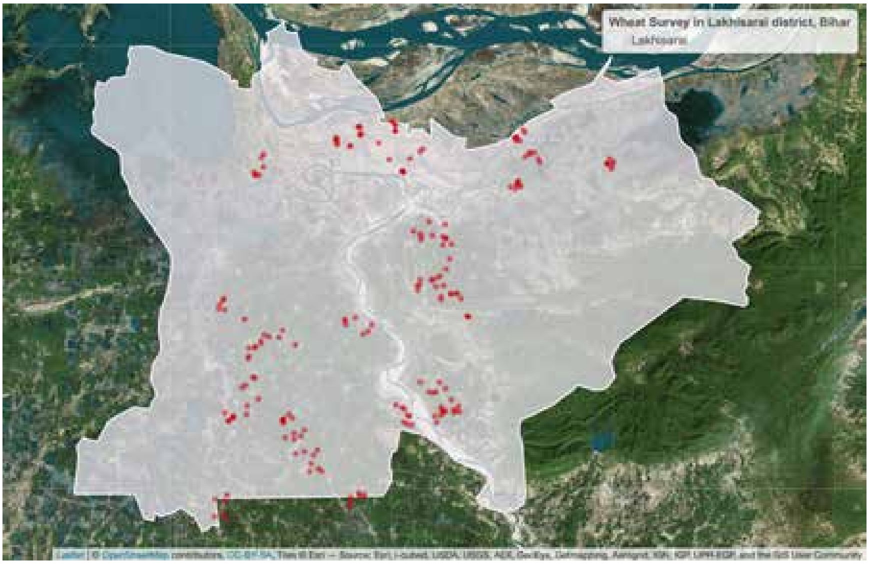

Fig. 1: GPS points of surveyed Wheat farms in Lakhisarai

Results and Discussion

Data from diagnostic survey showed that the average share of rice-wheat, maize-wheat and fallow wheat cropping systems in Lakhisarai is 65, 27, and 8% (Fig. 2), respectively. The share of old varieties like PBW 343 and Lok 1 is 23 and 34% (Table 1), respectively. That means the varietal turnover is low, which is not a good sign of varietal progress in the district. Timely sown wheat varieties (TSWVs) can give their potentially high yield benefits, if sown before 20 November which has started happening with 33% farmers reported early sowing before 20 November. Late sown wheat varieties (LSWVs) have lower yield (2.64 t ha^{-1}) than TSWVs (4.14 t ha^{-1}) (Fig. 3). When seeded early, the yield could even be higher. Data showed that when sowing was done before 20 November, the average yield (Fig. 4) across varieties was 4.23 t ha^{-1}

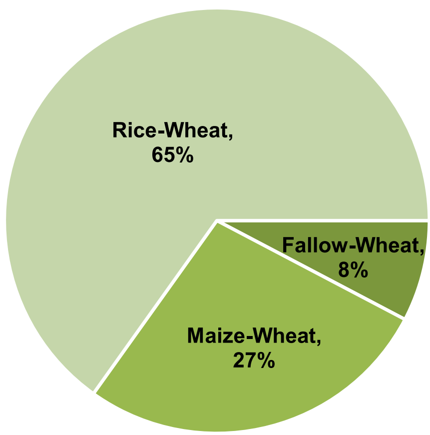

Fig. 2: Major cropping system prevailing in the district as per surveyed farmers

Table 1: Summary of important varieties including timely sown wheat varieties (TSWVs) and late sown wheat varieties (LSWVs) (2017-18) (n=195)

Varieties	Number of respondents	Percentage (%)
TSWVs		
HD 2733	8	4.10
HD 2967	28	14.36
PBW 343	44	22.56
PBW 502	8	4.10
LSWVs		
Lok 1	67	34.36
PBW 154	7	3.59
Kedar	20	10.26
Other*	13	6.67

*Includes Shri Ram 303 from TSWVs group and HD 2985, RR 21, HI 1563, PBW 373 from LSWVs group.

compared to when the sowing was done between 21 November and 15 December (3.03 t ha^{-1}) or after 15 December (2.58 t ha^{-1}), N: P_2O_5:K_2O use at 121:61:30 kg ha^{-1} (Table 2) is close to other districts. Slightly higher dose of K compared to other rice-wheat cropping system (RWCS) dominated districts is as per trends from districts where maize-wheat or sugarcane wheat are part of the system.

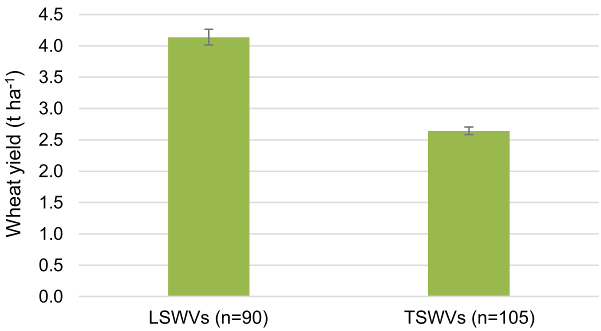

Fig. 3: Average grain yield of timely sown wheat varieties (TSWVs) and late sown wheat varieties (LSWVs) across different agronomic management options

With still average low yields in the district, even at the recommended fertilizer rates showed that the use efficiency is very low. To improve the fertilizer use efficiency, the number of irrigations should increase. At present the irrigation frequency of 2 is very low (Table 2). High weed population represented by complex weed flora collectively can cause losses in the yield because 51% farmers still do not practice any weed management (Fig.

5). The vulnerability of crop to losses by weeds has to reduce to improve the yield performance in the district. When input cost is rising and yield is not increasing profits margins are low and less persistent. Data showed that focused attention on factors other than varieties (Krishna *et al.,* 2016) and nutrient management will make the cropping systems more efficient and productive. Zero tillage and line sowing have been found to yield more compared to broadcast (Fig. 6). Therefore, zero tillage and weed management practices which are still not followed by

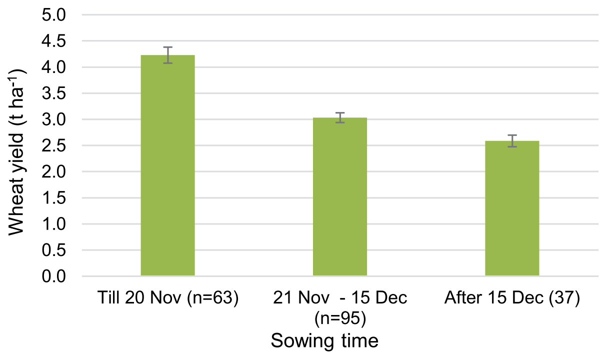

Fig. 4: Average grain yield of wheat as affected by three different sowing schedules across varieties and management practices

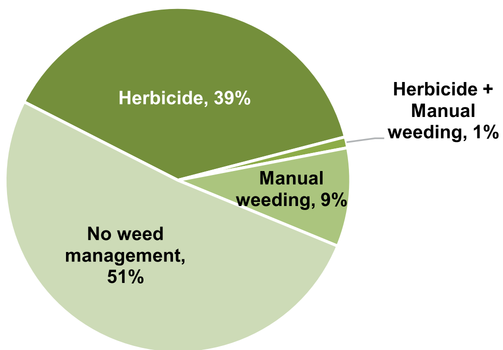

Fig. 5: Farmers reported weed management options practiced in the district (n=195)

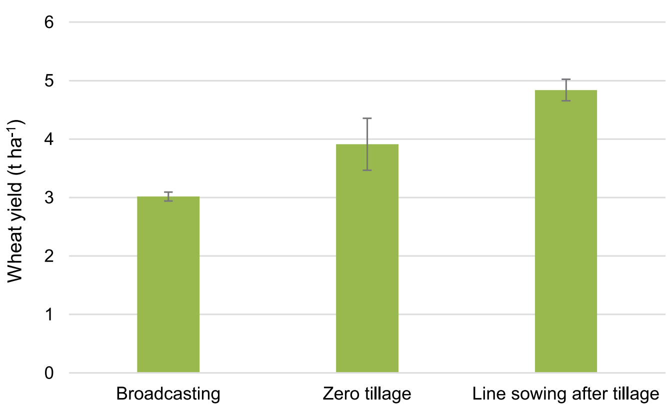

Fig. 6: Farmers reported average grain yield under three different crop establishment methods practiced by farmers

Table 2: The use rates of N: P_2O_5: K_2O (kg ha^{-1}) and irrigation frequencies of surveyed farmers (Potash users 54%)

NPK rates and irrigation frequency	Average use rates (kg ha^{-1})	SD	SE
N	120.82	32.45	2.32
P_2O_5	61.96	17.73	1.27
K_2O	29.52	11.64	1.13
Irrigation number	2.12	0.82	0.06

farmers should be prioritised (Malik *et al.,* 2002). Irrigation frequency need to be improved as it has improved the yield (Fig. 7).

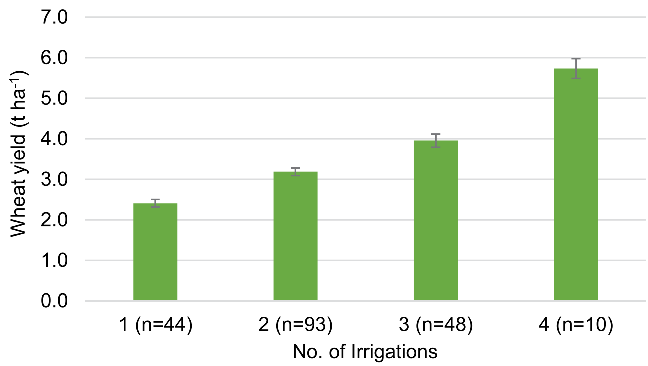

Fig. 7: The average grain yield of wheat under different irrigation frequencies

Conclusion

The trend towards adoption of timely sown wheat varieties and early sowings is a positive development but its efficiency can improve significantly, if factors other than varieties and nutrient management (early sowing, weed management, irrigation and zero tillage) are given priorities.

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3.22 Madhepura still in the early phases of good agronomy

M.K. Roy[1], Moben Ignatius[2] and R.P. Sharma[1]

[1]Krishi Vigyan Kendra, Madhepura

[2]International Maize and Wheat Improvement Centre (CIMMYT)

Introduction

Madhepura one of the Bihar state's most backward districts, is a part of Kosi division with a population of 1,994,618 (1,116 inhabitants per square kilometre, 93% rural). It has 13 blocks, 170 gram panchayats and 449 inhabited villages. It has total 193,004 ha as cultivable land. The net irrigated area is 137,048 ha. The total area under rice is 70,854 ha and wheat is 9,610 ha. The average rain fall in this district is 1,300 mm. It is one of the flood prone districts of Bihar. The soils are of poorly drained type. They are mostly moderately acidic to neutral. The areas close to the Kosi channels possess soil types of sandy loam, loamy sand and sand character, whereas, the areas away from the river channels consist of silty sand to sandy silt in nature.

With small wheat area, the researchers and extensionists keep focusing on short growing cycle of wheat, which may not be the case especially in the fallow-wheat areas of this district. The survey looked at factors which are most crucial to improve the wheat productivity in Madhepura.

Methods

Details on methodology are given in Chapter 1

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, Garthan (Fig. 1).

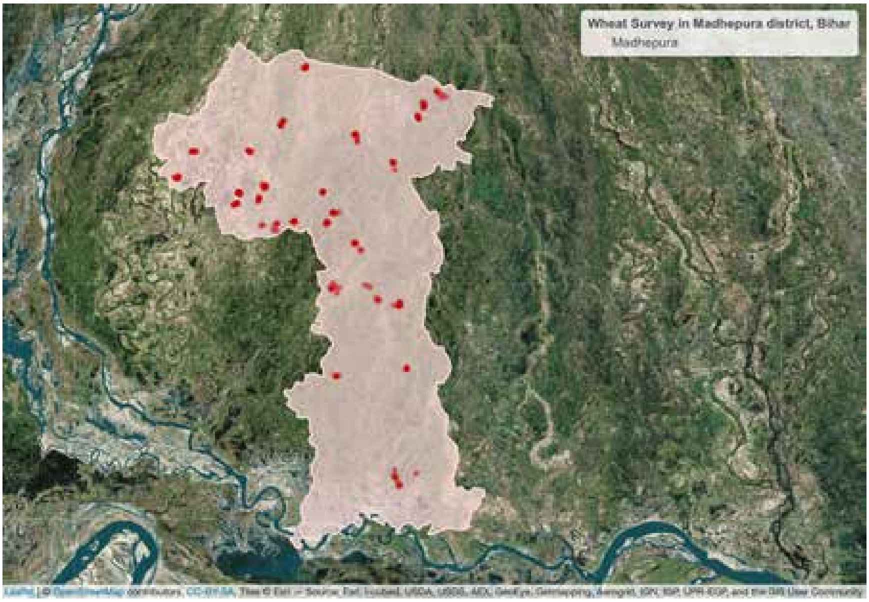

Fig. 1: GPS points of surveyed farms in Madhepura

Results and Discussion

The core in the assessment of technologies through LDS is the prevalence of fallow -wheat cropping system, which is dominant cropping system with 69% farmers (Fig. 2). The vulnerability to risks associated with Kosi river based accumulation of excess water is the reason for the prevalence of this cropping system. The varietal spectrum is different with 46% farmers growing UP 262 and 7% farmers adopting Nepal variety (NL 1). The adoption of timely sown wheat varieties (TSWVs) like PBW 343 is 18%. New entrant like Shri Ram 303 has also been reported by 18% respondents (Table 1). The grain yield of TSWVs was 2.65 and of LSWVs 2.38 t ha^{-1} (Fig. 3). Since it is a fallow-wheat dominated area, early wheat sowing

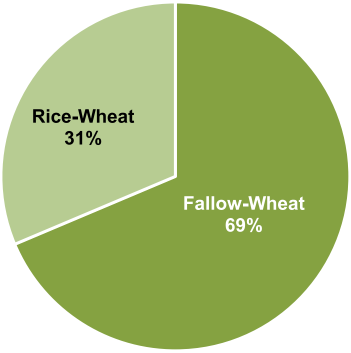

Fig. 2: Major cropping system prevailing in the district as per surveyed farmers

Table 1: Summary of important varieties including timely sown wheat varieties (TSWVs) and late sown wheat varieties (LSWVs) (2017-18) (n=169)

Varieties	Number of respondents	Percentage (%)
TSWVs		
PBW 343	31	18
ShriRam 303	30	18
LSWVs		
Ankur	5	3
Kedar	8	5
NL 1	12	7
PBW 154	2	1
UP 262	77	46
Other*	4	2

*Includes PBW 502 from TSWVs group and Lok 1 from LSWVs group.

which is still 26% can be an important intervention. However, the yield difference till November 20th and post 15 December was only 0.3 t ha^{-1} (Fig. 4). Since the number of grains/ear head is the main driver for post-anthesis growth through its effects on sink strength and photosynthetic ability at the post-anthesis stage (Acreche and Slafer, 2009), it is better to take a call on the combination of LSWVs and TSWVs. But still this combination is not as big a driver of change as in other districts.

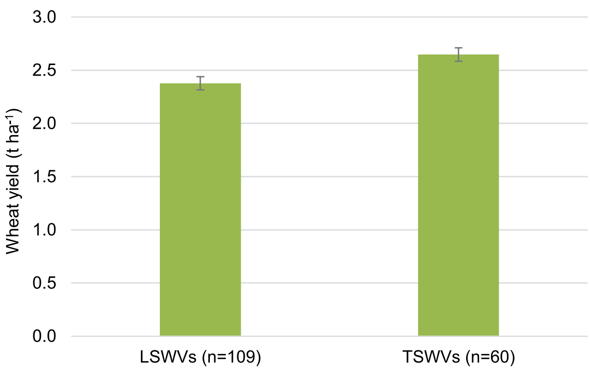

Fig. 3: Average grain yield of timely sown wheat varieties (TSWVs) and late sown wheat varieties (LSWVs) across different agronomic management options

It is more indicative of factors associated with acid soils and poor efficiency of applied nutrients especially phosphorus which is used at relatively high rates. We need to pair timely sowing with fertilizer, irrigation with fertilizer application and weed management with

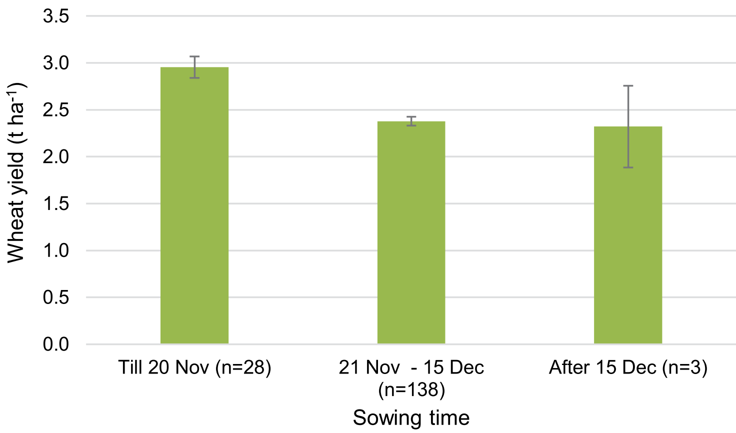

Fig. 4: Average grain yield of wheat as affected by three different sowing schedules across varieties and management practices

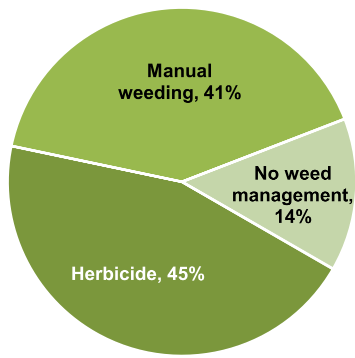

Fig. 5: Farmers reported weed management options practiced in the district (n=169)

fertilizer application, so that wheat plants are able to efficiently utilize the added nutrients rather than unutilized or wasting them for purposes other than crop. Although P is less impact generating nutrient for increasing the growth and the yield of wheat, but its use by farmers is still more than the optimum recommended in Bihar and Eastern Uttar Pradesh. The effects of water and fertilizer on crop growth are not isolated, but instead interact with each other, and show a coupling effect (Ma *et al.,* 2017). Incremental changes in fertilizer use may not have large impact. Similarly, the area is highly flood prone and may have other soil related issues. Weed flora is likely to be complex and herbicide alone may not help. No weed management is practiced by 14% farmers but still the herbicide use is 45% (Fig. 5). With irrigation frequency of 2.5, the low yields would need focused attention on irrigation at grain filling (Table 2). For LSWVs where yield levels are low, the grain quality influences the decision of farmers. The grain yield was found to increase with increase in irrigation frequency (Fig. 6). The current survey showed that earlier LSWVs dominated but now it is changing. The late wheat sowing has to combine with TSWVs. Similarly zero tillage and weed management options should be explored.

Table 2: The use rates of N: P_2O_5: K_2O (kg ha^{-1}) and irrigation frequencies of surveyed farmers (Potash users 99%)

NPK rates and irrigation frequency	Average dose (kg ha^{-1})	SD	SE
N	119.98	32.24	2.48
P_2O_5	62.57	14.13	1.09
K_2O	31.63	12.41	0.96
Irrigation number	2.46	0.65	0.05

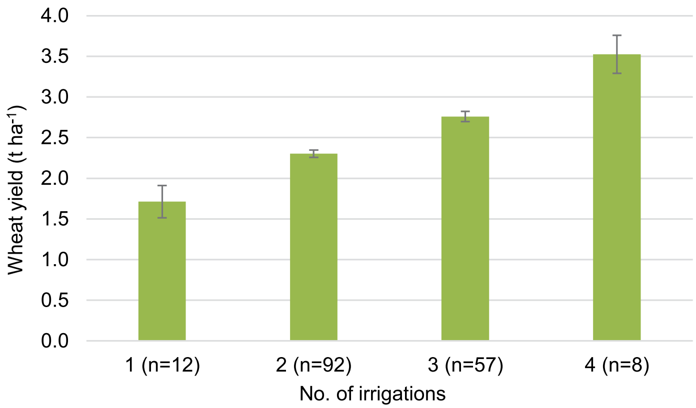

Fig. 6: The average grain yield of wheat under different irrigation frequencies

Conclusion

To improve wheat yields data reflects the case for long-term shift towards agronomic management including early sowing, irrigation and weed management.

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3.23 Maharajganj : A promising district for improving wheat productivity in the region

D.P. Singh[1], Ajay Kumar[2], T. Tiwari[1], V. Chandra[1], V.B. Singh[1], A.P. Rao[3], S.K. Dubey[4], A. Singh[4] and U.S. Gautam[4]

[1]Krishi Vigyan Kendra, Maharajganj
[2]International Maize and Wheat Improvement Centre (CIMMYT)
[3]Narendra Dev University of Agriculture and Technology, Faizabad
[4]ICAR-Agricultural Technology Application and Research Institute

Introduction

Maharajganj district has 12 blocks, 947 gram *panchayats* and 1,262 inhibited villages. It has 202,200 ha of cultivable land with total population of 2,588,000 (2011 census). The soil type is alluvial loam. The net irrigated area is 163,699 ha. The wheat productivity growth in Maharajganj district is constrained by late sowing and terminal heat stress during maturity time. The success so far, albeit with a small footprint in two villages has already proved that grain yield as high as 7.3 t ha^{-1} is possible with best management practices in Pharenda block of this district. Now the question is how to bridge the gap between attainable yield and the actual average yield of 3.2 t ha^{-1}. To place the management option in context, the landscape diagnostic survey (LDS) can help understand which factors that are likely to bring maximum benefit. Once the priorities are short listed on the basis of the LDS analysis, we may expect high return on capital that we invest in yearly research and extension especially by the Department of Agriculture (DoA) on its subsidy schemes. The survey intends to create a system that seeks the opinion of farmers on setting priorities for factors that help in bridging the yield gap. It would provide feedback to institutions on technologies that have not been largely accepted by farmers.

Methods

Details on methodology are given in Chapter 1

Blocks covered: Brijmanganj, Ghuguli, Lakshmipur, Maharajganj, Mithaura, Nautanwa, Nichaul, Paniyara, Partawal, 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, Pokhar Bindha (Fig. 1).

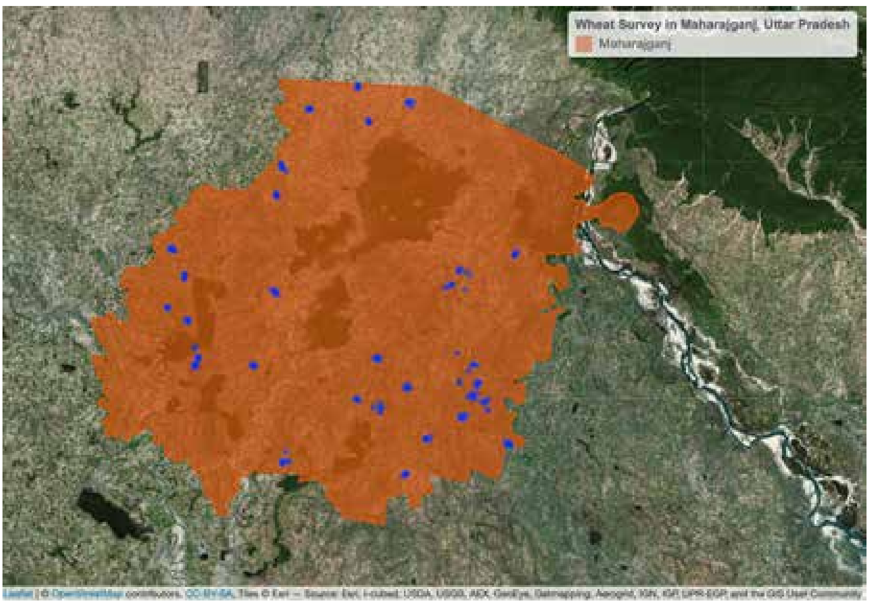

Fig. 1: Village wise representation of surveyed area in Maharajganj

Results and Discussion

Most surveyed farmers (98%) had rice-wheat cropping system (Fig. 2). The adoption of varieties was in the order of HD 2967 (70%), PBW 343 (21%), and PBW 502 (4%) (Table 1). It means that the varietal spectrum is dominated by timely sown wheat varieties (TSWVs). The average market share of TSWVs has gone up because of their high yield potential. The early sowing is practiced by 36% farmers. If the large

Table 1: Summary of important varieties including timely sown wheat varieties (TSWVs) and late sown wheat varieties (LSWVs) (2017-18 (n=210)

Varieties	Number of respondents	Percentage (%)
TSWVs		
HD 2967	146	70
PBW 343	44	21
PBW 502	9	4
WH 711	4	2
Other*	7	3

*Includes PBW 550, K 307, HD 2733, DB W17 from TSWVs group and PBW 154 from LSWVs group.

scale adoption of TSWVs is an accomplishment in this district (Fig. 3), the focus should now shift towards early sowing of the area still under late sowing. This is further authenticated by the fact that the yield difference between first two sowing schedules and sowings done after December 15 are in the range of 1.3-1.4 t ha^{-1}. Because of high yield potential, the

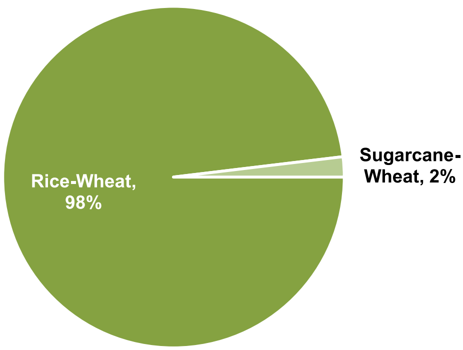

Fig. 2: Major cropping system prevailing in the district as per surveyed farmers

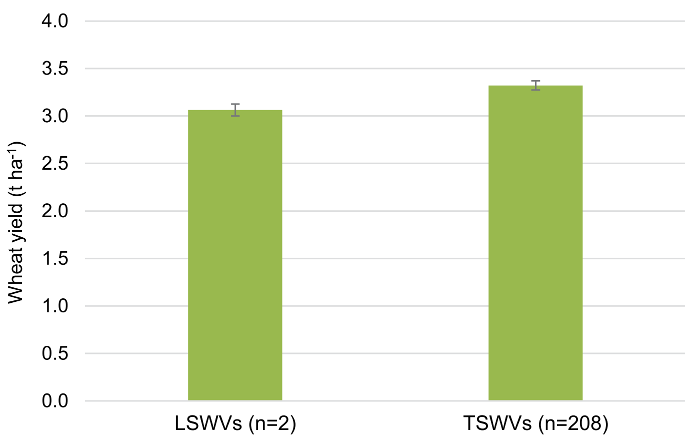

Fig. 3: Average grain yield of timely sown wheat varieties (TSWVs) and late sown wheat varieties (LSWVs) across different agronomic management options

TSWVs might have compensated the loss from late sowing. That would also mean that TSWVs are performing better under all sowing schedules. Therefore, there is a strong case for promoting early wheat sowing and TSWVs (Figs. 3, 4). All these yield levels in this district are at N: P_2O_5:K_2O use rate of 126:57:17 kg ha^{-1} and that also at an irrigation frequency of 2.0 (Table 2). That would mean the yield levels could still go up significantly with better bet agronomic management of RWCS especially the irrigation frequency. Herbicide use rate by farmers is 85% which indicated that the awareness level of farmers in this district for weed management is high (Fig. 5). Data found that 95% surveyed farmers are using broadcasting method for crop establishment whereas 5% are using zero tillage (Fig. 6). In another data set, the increase in yield with corresponding increased irrigation frequency was also observed (Fig. 7). That might be because irrigation at flowering or at milk stage or both has helped sustain the better growth in the pre-flowering stages of crop. The scope of early wheat sowing through the use ZT technology is much greater in Maharajganj. With better management options especially for early sowing and irrigation

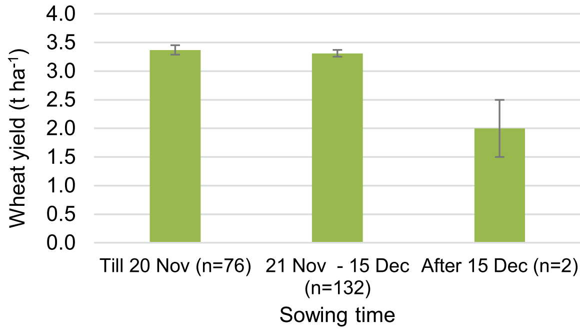

Fig. 4: Average grain yield of wheat as affected by three different sowing schedules across varieties and management practices

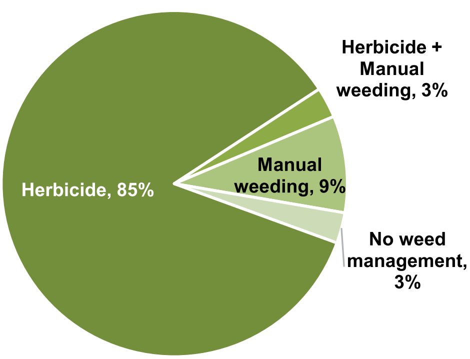

Fig. 5: Farmers reported weed management options practiced in the district (n=210)

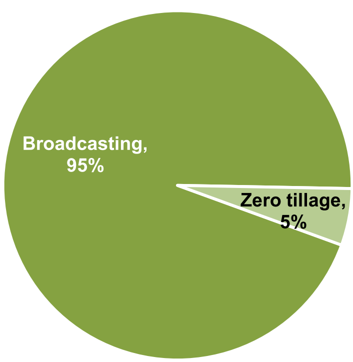

Fig. 6: Crop establishment methods practiced by farmers

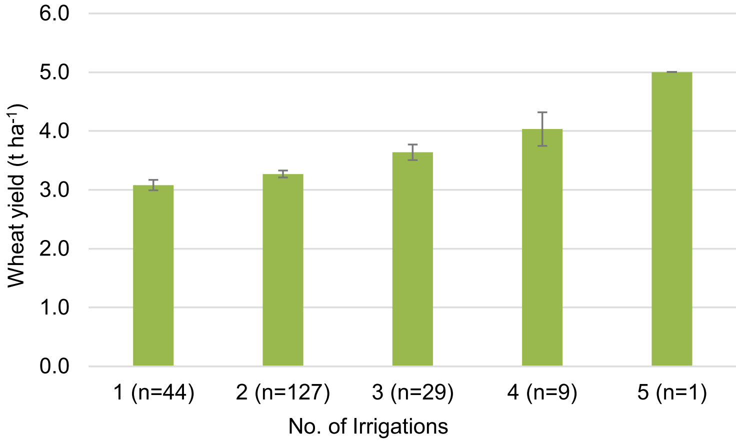

Fig. 7: The average grain yield of wheat under different irrigation frequencies

Table 2: The use rates of N: P_2O_5: K_2O (kg ha^{-1}) and irrigation frequencies of surveyed farmers (Potash users 61%)

NPK rates and irrigation frequency	Average dose (kg ha^{-1})	SD	SE
N	126.05	30.42	2.10
P_2O_5	56.77	12.76	0.88
K_2O	27.01	10.09	0.63
Irrigation number	2.03	0.75	0.05

management, the yield levels could be as high as the best in the country. Earlier work suggested that we should direct wheat breeding efforts towards production of higher yielding (Reynolds *et al.*, 2012) varieties. An opportunity has been created for advancing wheat sowings in EIGP (CSISA, Annual Report 2014, 2015). Good yields from TSWVs even under late sowings showed that continued high temperature may not be a serious issue but the high temperature at terminal phase is an issue. That would need focused attention for breeding effort at the establishment phase so that the flowering time of varieties fits well in the first two weeks of February. The other end of spectrum will be irrigation and weed management.

Conclusion

The district may have long term advantage if the progress on the

TSWVs and early sowing captured so far is well supported by better access to irrigation, weed management and crop establishment by ZT methods. Soil health does not seem to be an high priority issue.

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3.24 Agronomic management options to improve wheat productivity in Mau district of Eastern UP

V.P. Singh[1], Deepak K. Singh[2], V.K. Singh[1], Madhulika Singh[2], Shahnawaz R. Dar[3], S.N.S. Chauhan[2] and Saurabh Verma[2]

[1]Krishi Vigyan Kendra, Mau
[2]International Maize and Wheat Improvement Centre (CIMMYT)
[3]International Rice Research Institute (IRRI)

Introduction

The district Mau has 4 tehsils, 684 gram panchayats and 1,691 villages. The total geographical area of the district is 171,620 ha land, of which 125,290 ha is cultivable and supports a population of 2,205,170 (2011 census). The major soil type in the district is loam and clay loam. KVKs remain closely engaged with Department of Agriculture (DOA) at district level to improve the productivity of wheat. The convergence however, can be further improved if concerted efforts are made to monitor the adoption patterns of different technologies so that the desired changes based on bottom-up approach can be made in the recommendations. In recent years CSISA-KVK network in the adjoining districts has emphasised the accelerated adoption of early wheat sowing which helped to bring in the adoption of timely sown wheat varieties (TSWVs) and other agronomic management options with desired results in the yield growth of wheat. The Landscape Diagnostic Survey (LDS) is an attempt to understand the existing production practices and provide a feedback to National Agriculture Research and Extension System (NARES) to speed up dissemination of new technologies and provide a road map for future research agenda.

Methods

Details on methodology are given in Chapter 1

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)

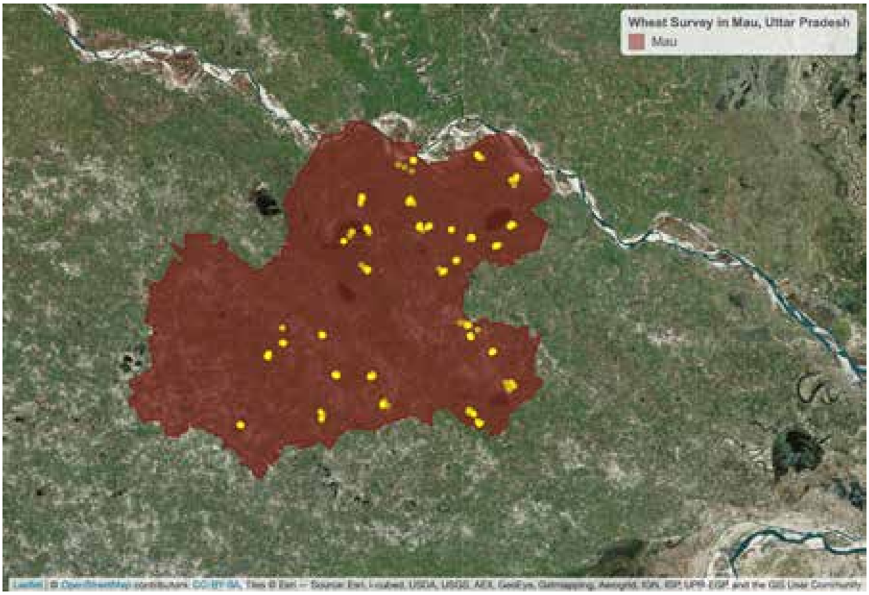

Fig. 1: Village wise representation of surveyed area in Mau

Results and Discussion

The data from the surveyed farmers showed that rice-wheat cropping system is prevalent with all respondents. Farmers were relatively more positive about the adoption of TSWVs. These varieties, in particular, were accepted across all sowing dates with 38% under earlier sowing dates and rest under situations where the sowings were done after 20 November. The adoption of TSWVs under late sowings, in fact, made up for potential yield losses (due to delayed sowings). The average grain yield of wheat from TSWVs was 20% more than late sown wheat varieties (LSWVs) (Fig. 2). TSWVs represented 71% of the whole varietal spectrum with the dominance of PBW 343 (34%) and HD 2967 (29%) (Table 1). Twenty percent of the surveyed farmers sowed their wheat crop before November 20 which does not match with the dominance of TSWVs (71%), generally recommended for timely sowing. The grain yield of wheat sowing done before November 20 was 0.2 t ha^{-1} more than the sowings done from 21 November to 15 December whereas the difference between the post- December 15 and pre-15 December sowing was of approximately 1.0 t ha^{-1} (Fig. 3). That would mean the

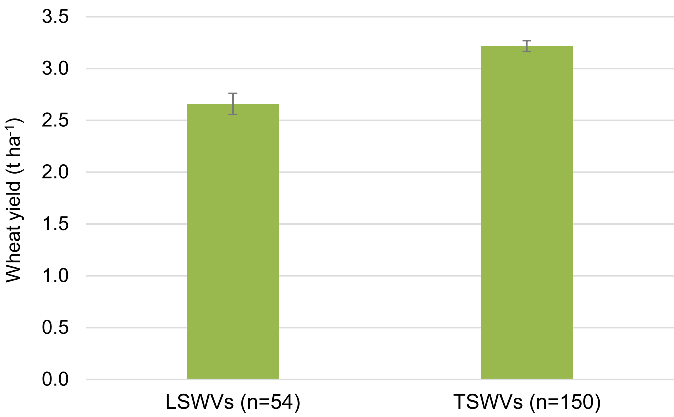

Fig. 2: Average grain yield of timely sown wheat varieties (TSWVs) and late sown wheat varieties (LSWVs) across different agronomic management options

Table 1: Summary of important varieties including timely sown wheat varieties (TSWVs) and late sown wheat varieties (LSWVs) (2017-18) (n=208) (n=204)

Varieties	Number of respondents	Percentage (%)
TSWVs		
HD 2967	60	29
PBW 343	69	34
PBW 502	16	8
LSWVs		
PBW 154	18	9
PBW 373	12	6
Other*	29	14

*Includes DBW 17, Shri Ram 303 from TSWVs group and from HUW 234, Kedar, and UP 262 LSWVs group.

performance of TSWVs was better than that of LSWVs even under late sowings. Within three major stages in wheat including-- vegetative period up to floral initiation, a reproductive period from floral initiation to anthesis, and a final grain-filling period, the positive interaction between breeding and agronomy is needed (Fischer *et al.*, 2014). The duration of grain filling period is affected more by terminal heat which is a problem of last 10-15 days of wheat growth cycle. Since overall ear head weight is dependent on the number of grains and its size (Amin *et al.*, 1995), TSWVs may score better over LSWVs in beating the terminal heat owing to more number grains per ear head.

Farmers reported N: P_2O_5:K_2O use rate at 141:62:28 kg ha^{-1} (Table 2) is on higher side for nitrogen. If district average is considered the response of applied nutrients is lesser than the expected response. The use of phosphorus was on the higher side but of K on the lower side. Similar

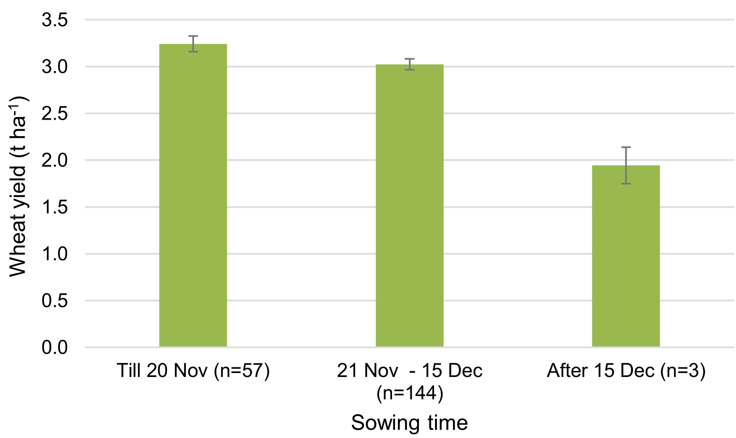

Fig. 3: Average grain yield of wheat as affected by three different sowing schedules across varieties and management practices

Table 2: The use rates of N: P_2O_5: K_2O (kg ha^{-1}) and irrigation frequencies of surveyed farmers (Potash users 44%)

NPK rates and irrigation frequency	Average dose (kg ha^{-1})	SD	SE
N	140.79	33.77	2.37
P_2O_5	61.77	18.08	1.28
K_2O	27.77	7.88	0.83
Irrigation number	2.38	0.54	0.04

pattern was observed in other districts. If we look around vulnerabilities associated with terminal heat, both TSWVs and nutrient management are in place. On the whole the yield levels do not match the N level. That means the factors other than varieties and fertilizer-use are at play in this district. Eighty eight per cent (88%) farmers use some or other kind of weed management with 68% using herbicides (Fig. 4). The crop establishment is done mostly by broadcasting method which is highly inefficient. Similarly, the irrigation at critical stages especially at grain filling is neglected in the irrigation frequency of 2.4. There is mismatch between varietal spectrum and fertiliser use rates and the grain yield of wheat.

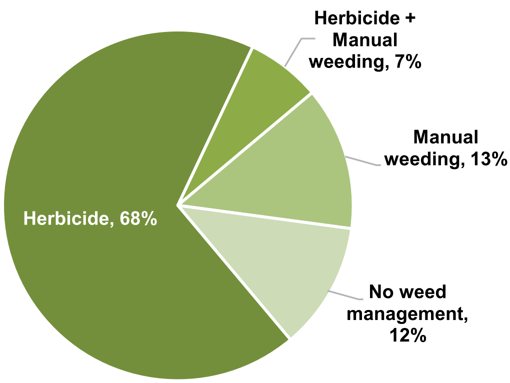

Fig. 4: Farmers reported weed management options practiced in the district (n=204)

Conclusion

We need to ensure timely crop establishment by zero tillage (which is not happening), timely weed management and irrigation management, these will then add to potential of TSWVs and efficient nutrient management. Soil health and varieties may not be serious issues at this point of time.

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3.25 Early wheat sowing, timely sown wheat varieties (TSWVs) and irrigation at grain filling stage can result in better-than-expected yield in Munger district of Bihar

Vinod Kumar[1], Anurag Kumar[2], Mukesh Kumar[1] and Shishpal Poonia[2]

[1]Krishi Vigyan Kendra, Munger
[2]International Maize and Wheat Improvement Center (CIMMYT)

Introduction

The total inhabited villages in Munger are 903, cultivable area is 60,300 ha (out of geographical area of 155,700 ha). Major soil type is heavy followed by clay. KVK Munger and CSISA team conducted landscape diagnostic survey (LDS) from 30 randomly selected villages in September-October 2018, to understand the existing adoption pattern of agronomic practices in wheat and then set priorities for research and extension by State Agricultural University (SAU) and the Department of Agriculture (DoA), Bihar. The objective is to convert the data based evidence into new recommendations.

Methods

Details on methodology are given in Chapter 1

Blocks covered: Asarganj, Dharhara, Jamalpur, Kharagpur, Munger, Sangrampur, Tarapur, Titiha Bambor.

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, Teghra Jagirdari (Fig. 1).

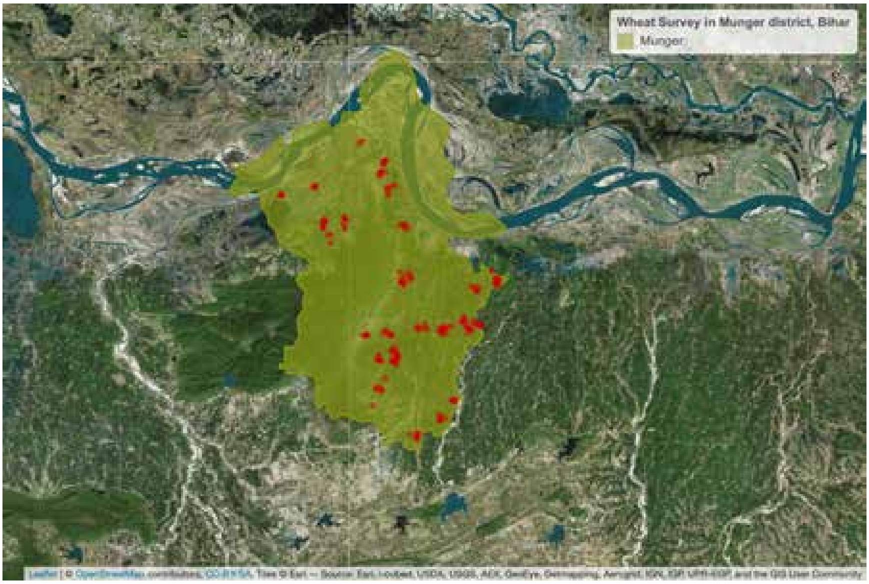

Fig. 1: GPS points of surveyed wheat farms in Munger

Results and Discussion

In Munger district, 88% households (HHs) reported Rice-Wheat Cropping System (RWCS) and 8% reported Maize-Wheat Cropping System (MWCS) as the main production systems, (Fig. 2). Among varieties, farmers showed greater preference for late sown wheat varieties (LSWVs) including Lok 1 (58%), followed by Kedar (10%) (Table 1). Compared to LSWVs, timely sown wheat varieties (TSWVs) including HD 2967, PBW 343 and Sri Ram 303 as a group (22%) out performed with an

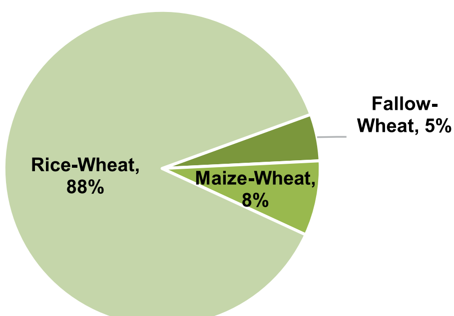

Fig. 2: Major cropping system prevailing in the district as per surveyed farmers

Table 1: Summary of important varieties including timely sown wheat varieties (TSWVs) and late sown wheat varieties (LSWVs) (2017-18) (n=210)

Varieties	Number of respondents	Percentage (%)
TSWVs		
HD 2967	2	1
PBW 343	12	6
Shri Ram 303	31	15
LSWVs		
UP 262	17	8
Kedar	21	10
LOK 1	121	58
Others*	6	3

*Includes HD 2733 from TSWVs group and RR 21, Local from LSWVs group.

average wheat grain yield gain of 0.5 t ha^{-1} (Fig. 3). Out of 210 HHs, 19% sowed their wheat crop before 20 November while 8% sowed their crop after 15 December. When compared with sowing done before 15 December, the wheat grain yield was 28% higher when the sowings were done after 15 December (Fig. 4). Average N: P_2O_5:K_2O use was 107:43:23 kg ha^{-1} (Table 2), which is lesser than (especially N) many other districts in Bihar. Most farmers

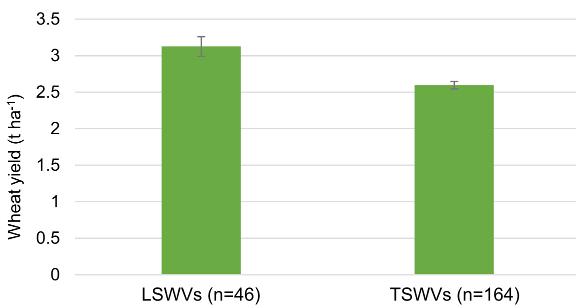

Fig. 3: Farmers reported grain yield of timely sown wheat varieties (TSWVs) and late sown wheat varieties (LSWVs) across different agronomic management options

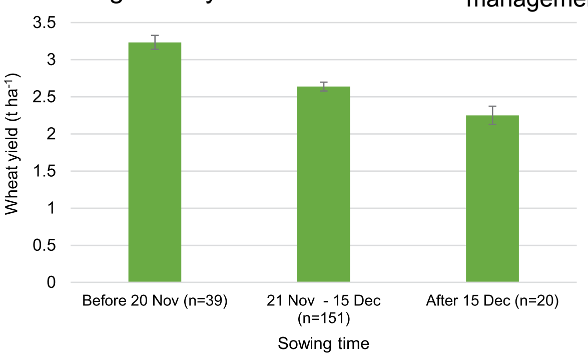

Fig. 4: Change in grain yield pattern of wheat as affected by three different sowing schedules across varieties and management practices

(52% HHs) do not use any weed management (Fig. 5) whereas 42% adopted manual weeding, Only 5% HHs applied herbicides. Proper irrigation management enhanced productivity level from 1.6 t ha^{-1} with no irrigation to 5.04 t ha^{-1} with 4 irrigations (Fig. 6). There is a large scale reluctance to adopt TSWVs in Munger. The evidence for the success of early wheat sowing and TSWVs showed that farmers can harvest better-than-expected yield in this district, if they adopt early sowings and TSWVs.

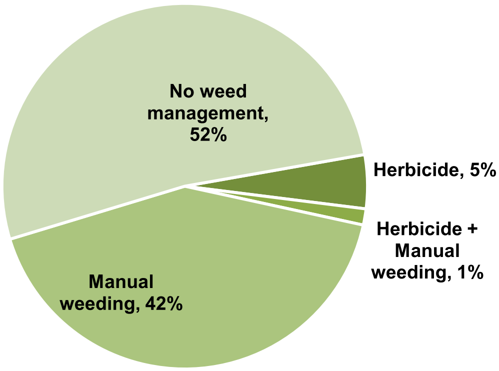

Fig. 5: Weed management practices including 52% without any weed management (n=210)

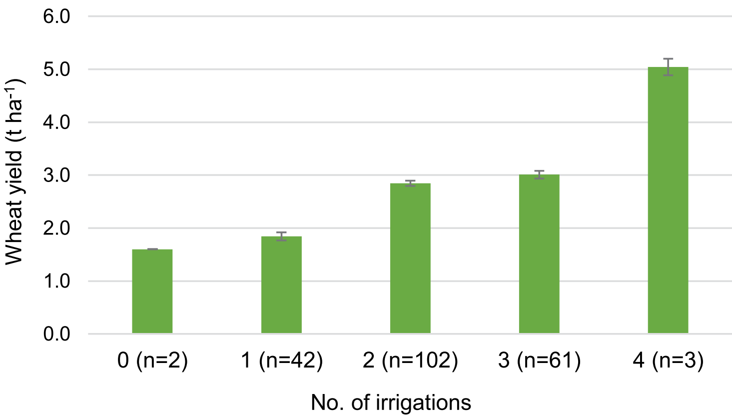

Fig. 6: Wheat grain yield as affected by number of irrigations given by respondents

Table 2: The use rates of N: P_2O_5: K_2O (kg ha^{-1}) and irrigation frequencies of surveyed farmers (Potash users 78%)

NPK rates and irrigation frequency	Average use rates	SD	SE
N	107.33	31.16	2.15
P_2O_5	43.60	16.31	1.12
K_2O	23.21	7.51	0.59
Irrigation number	2.1	0.76	0.05

Higher temperature during last few days lead to early maturity which is further compounded by lack of irrigation. Bagga and Rawson (1977) showed that water stress during grain filling is detrimental to grain yield especially under terminal heat stress conditions; frequently seen in these ecologies (Jain *et al.*, 2017).

Conclusion

There is a need to shift the focus away from LSWVs and towards TSWVs. Benefits from adoption of TSWVs can be harnessed by shielding losses from weeds as 52% of respondents farmers do not follow any weed management practice. Yield potential of TSWVs can be further enhanced by increasing number of irrigators.

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3.26 Wheat yield growth pick-up is happening in Muzzaffarpur

Hemchandra Chaudhary[1], Pankaj Kumar[2], Anupma Kumari[1] and Shahnawaz Rassol Dar[3]

[1]KVK, Saraiya, Muzaffarpur
[2]International Maize and Wheat Improvement Center (CIMMYT)
[3]International Rice Research Institute

Introduction

Muzaffarpur falls in the Agro-climatic zone I (Northern-west). Soils are sandy loam and clay and the pH range falls between 6.5 and 8.4. The district receives an average total rainfall between 1,040 and 1,440 mm. Maximum and minimum temperatures varies from a maximum of 36.6 to 7°C. Cropping intensity is 138%. The major cropping patterns are rice-wheat, rice-maize, maize-wheat etc. It has 16 blocks, 387 gram panchayats and 1,827 villages. The net irrigated area is 81,000 ha. The total area under rice is 85,896 ha and wheat is 43,138 ha. Present landscape diagnostic survey (LDS) intends towards creating a system that seeks the opinion of farmers and analyse the adoption patterns and potential benefits of different technologies at district level. It will also provide feedback to institutions on technologies that have not been largely accepted by farmers. In Muzaffarpur, early sowing was tried and tested with the KVKs at farmers' field from 2012-13. This change majorly solves the problem of terminal heat and reflects a change which will lay foundation for a sustained yield growth of wheat. This also allows the adoption of timely sown wheat variety (TSWVs) which are potentially high yielders.

Methods

Details on methodology are given in Chapter 1

Blocks covered: Saheganj, Motipur, Bandra, Salrav, Puroo, Saraiya, Kudhani, Kanti, Morwan, Minapur, Mushahri, Bochahan, Aurai, Katra, Gaighat, Muraul.

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, Sukhwara (Fig. 1).

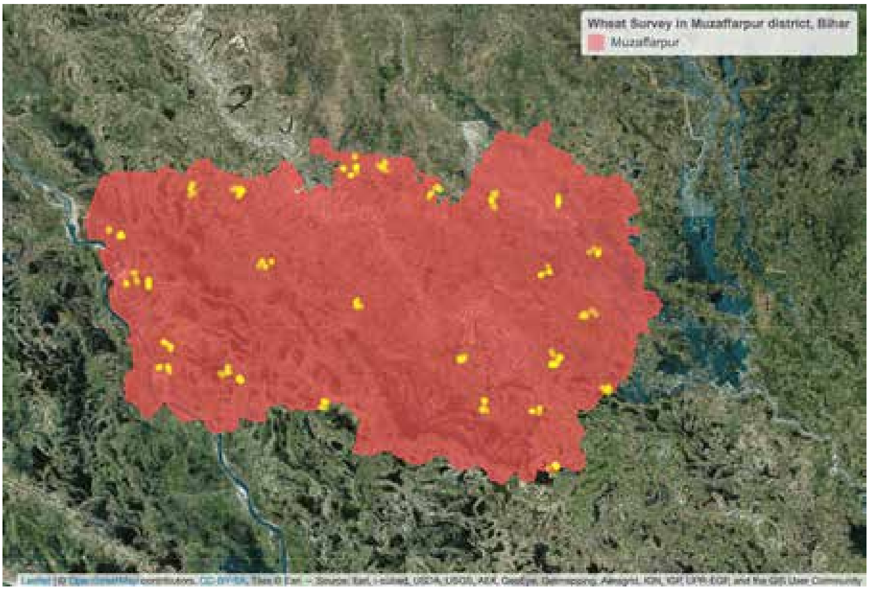

Fig. 1: GPS points of surveyed wheat farms in Muzaffarpur

Results and Discussion

The district showed a 100% domination by rice-wheat cropping system (RWCS) of the surveyed farmers. The trend towards adoption of early wheat sowing is growing. The trend also highlighted changes in the varietal spectrum in favour of TSWVs. The adoption of varieties was in the order of PBW 343 (45%), HD 2967 (15%), HD 2733 (14%), and PBW 502 (13%) (Table 1). This is also reflected in the grain yield advantage of 0.69 t ha^{-1} from TSWVs compared to late sown wheat varieties (LSWVs). The adoption LSWVS is decreasing with only 11% adoption and are not well placed to lead the varietal spectrum (Fig. 2). The early

Table 1: Summary of important varieties including timely sown wheat varieties (TSWVs) and late sown wheat varieties (LSWVs) (2017-18) (n=204)

Varieties	Number of respondents	Percentage (%)
TSWVs		
HD 2733	29	14
HD 2967	31	15
PBW 343	92	45
PBW 502	26	13
ShriRam 303	3	2
LSWVs		
UP 262	19	9
Kundan	4	2

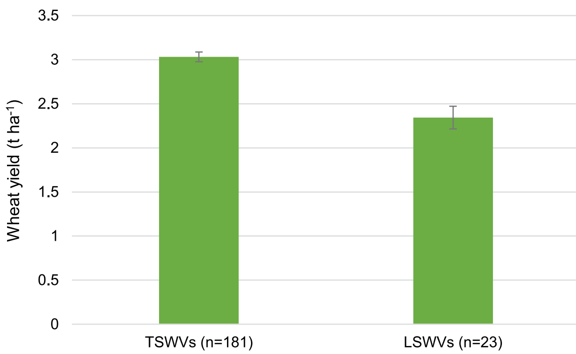

Fig. 2: Average grain yield of timely sown wheat varieties (TSWVs) and late sown wheat varieties (LSWVs) across different agronomic management options

wheat sowing done before 20 November showed a yield advantage of 0.28 t ha^{-1} when compared with the sowing done from 21 November to 15 December (Fig. 3). This is a significant milestone when compared with the past recommendation of "not to sow wheat" before 20 November. N: P_2O_5:K_2O use at 146:64:33 is relatively high when we consider the average wheat yield in the district (Table 2). Weed management (Fig. 4) is better than many other

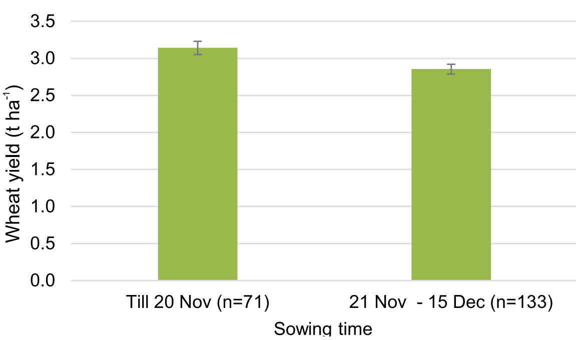

Fig. 3: Average grain yield of wheat as affected by three different sowing schedules across varieties and management practices

Table 2: The use rates of N: P_2O_5: K_2O (kg ha^{-1}) and irrigation frequencies of surveyed farmers (potash users 85%)

NPK rates and irrigation frequency	Average use rates	SD	SE
N	146.38	26.31	1.84
P_2O_5	63.71	13.70	0.96
K_2O	33.72	7.21	0.55
Irrigation number	2.04	0.38	0.03

districts with herbicide use at 84% compared to no weed control at 7%. The irrigation frequency at 2.0 is an issue which need immediate attention as the efficiency of high fertilizer use is low. Lack of irrigation at proper time will not generate synergies with nutrient management, which is happening as evidenced by data in this survey. The highest yield achieved by farmers who applied 4 irrigations was 3.92 t ha^{-1} whereas farmers who applied 1 irrigation got a yield of 2.68 t ha^{-1} (Fig. 5).

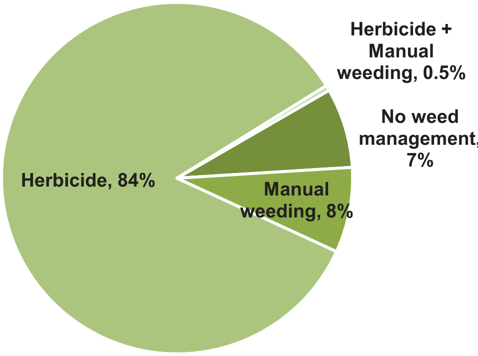

Fig. 4: Farmers reported weed management options practiced in the district (n=204)

When we first presented to the farmers the case of early wheat sowing in 2011, most farmers resisted because Department of

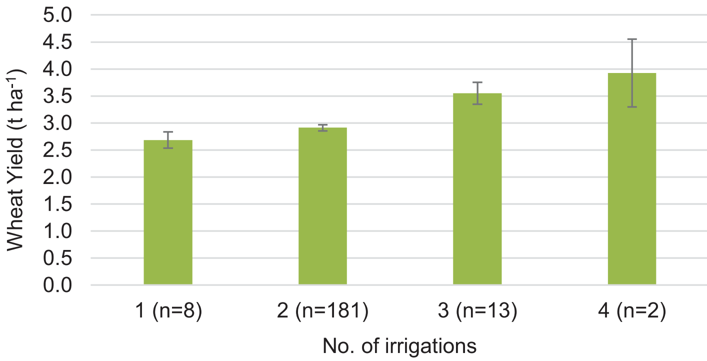

Fig. 5: The average grain yield of wheat under different irrigation frequencies

Agriculture (DoA) had issued advisories not to sow wheat before November 20 as it will reduce yield. The crop needs enough vegetative growth and tillering to support the longer yield formation phase (Hunt *et al.,* 2012). The early sowing when combined with varieties can help in manipulating flowering time to increase wheat grain yield (Herndl *et al.,* 2008), that help escaping the terminal heat. The present LDS clearly indicates pathway to improved wheat growth with early wheat sowing and TSWVs.

Conclusion

There is still a lack of access to irrigation. The district has high potential for growth, if agronomic management is thoroughly integrated with crop establishment methods like zero tillage which is still not happening.

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3.27 Agronomic management options: A critical need for achieving higher yield growth of wheat

Jyoti Sinha[1], Madhulika Singh[2], U.N. Umesh[1], Vibha Rani[1] and B.K. Singh[3]

[1]Krishi Vigyan Kendra, Nalanda
[2]International Maize and Wheat Improvement Centre (CIMMYT)
[3]Krishi Vigyan Kendra, Lakhisarai

Introduction

District Nalanda falls in the Agro-climatic zone IV i.e. the middle Gangetic Plain. The district is divided into 3 sub-divisions with a geographical area of 234,900 ha and cultivable area of 191,100 ha with a population of 2,368,327. The net irrigated area remains 93,400 ha. The total rice area is 130,000 ha whereas wheat area is 93,000 ha. The major soil type of the district is clay (38%), fine sandy loam (26%) and the rest is sandy and coarse sandy loam. The district comprises 20 blocks and 1,011 revenue villages.

The landscape diagnostic survey (LDS) was undertaken to seek the market opinion for the success and failure of new technologies. Although we had been developing the technical programs of each KVK during the State Advisory Committee (SAC) meetings, data from survey coupled with proper analytics will allow KVKs at district level and ATARIs at regional levels to visualize the technology development or deployment differently and productively.

Methods

Details on methodology are given in Chapter 1

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, Mustafapur1, Mustafapur2, Narari, Ghustawan, Pachauri, Shahpur, Shivnagar, Surajpur, Takiakalan, Jagdishpur Tiari, Jiar, Khakhra, Khorampur, Lodhipur, Muragawan, Pyarepur, Utra and Uttarnawan (Fig. 1).

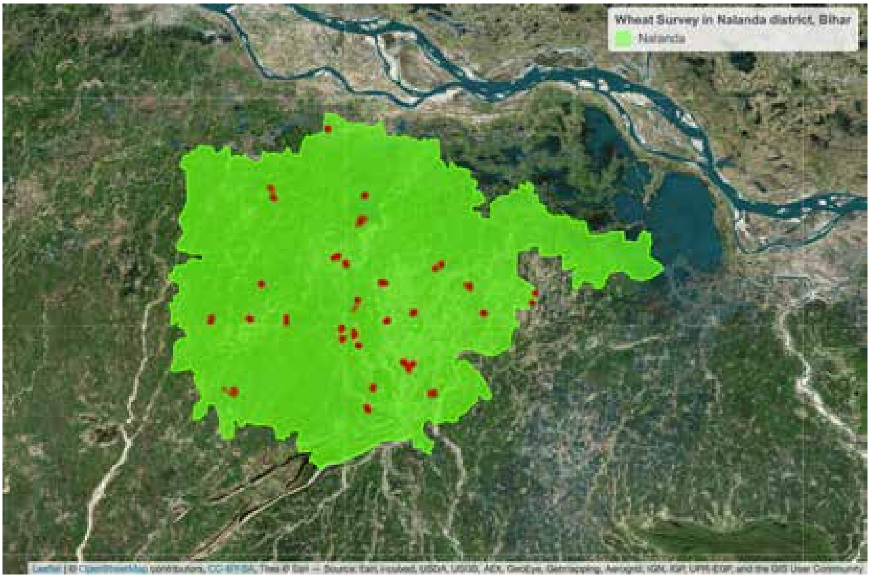

Fig. 1: GPS points of surveyed wheat farms in Nalanda

Results and Discussion

The cropping system for Nalanda district was found to be 100% rice- wheat dominated. Data from LSD survey revealed that the average share of two very old varieties like Lok 1 and UP 262 was still 61% (Table 1). Both these varieties are of 120-135 days maturity range and have been categorised as late sown wheat varieties (LSWVs). Worries around very high turnaround time for LSWVs should prompt breeders to recast the breeding strategies in favour of TSWVs even under late sown conditions. Date of sowing presented in Fig. 2 indicated that only 16% farmers seeded wheat from 1-20 November, and typically has the history of late sowings. The grain yield of wheat was higher from 10% farmers who had grown timely sown wheat varieties (TSWVs). Lower yield of

Table 1: Summary of important varieties including timely sown wheat varieties (TSWVs) and late sown wheat varieties (LSWVs) (2017-18) (n=196)

Varieties	Number of respondents	Percentage (%)
TWSWs		
HD 2967		3
PBW 343		8
ShriRam 303		1
LSWVs		
PBW 154		1
UP 262		15
Kedar		22
Lok 1		46
PBW 373		3
RR 21		3

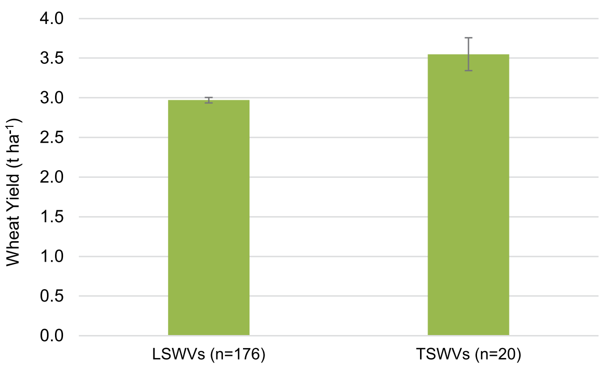

Fig. 2: The average grain yield of timely sown wheat varieties (TSWVs) and late sown wheat varieties (LSWVs) across different agronomic management options

LSWVs (2.97 t ha^{-1} compared with TSWVs (3.55 t ha^{-1}), reflects the need for replacement of LSWVs with TSWVs (Fig. 3). Most sowings were late with only 15% farmers' reported early sowings and realised the grain yield level of 3.58 t ha^{-1} (Fig. 3). It is possible that TSWVs and early wheat sowings affected crop duration for grain filling, which helped in realising higher yield. It is essential to develop high-yielding TSWVs despite the short growing season. Early wheat sowing can help early accumulation of carbon in the grain before rise in the temperature during the end of March. The relevance of grain growth has been emphasised in wheat under heat stress conditions (Spiertz *et al.,* 2006). All genotypes should maximize their yield by flowering during the best environmental condition (Dhillon and Ortiz-Monasterio, 1993) which lies somewhere between 10 and 20th February in Bihar conditions. Out of the total surveyed farmers, 80% farmer used herbicides whereas 8% did not practice any weed management (Fig. 4). The gain in yield will be limited by assimilated supply, which will be impacted by weed competition if weeds are not controlled on time. On observing the overall data for crop establishment, 100% farmers surveyed for district Nalanda practiced broadcasting for crop establishment. Data from Bihar showed that zero tillage technology is the best suited for Bihar and must be promoted (CSISA Annual report, 2014, 2015). The surveyed farmers who applied only one irrigation attained a yield of 2.5 t ha^{-1} whereas those who applied 4 irrigations achieved a yield of 4.73 t ha^{-1} (Fig. 5). The total

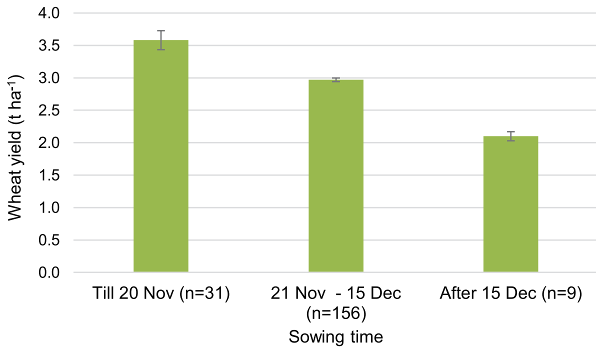

Fig. 3: Grain yield of wheat as affected by different sowing schedules, across varieties and management practices

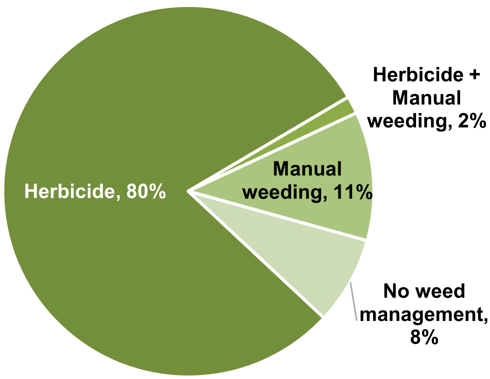

Fig. 4: Farmers reported weed management options followed by respondent farmers (n=196)

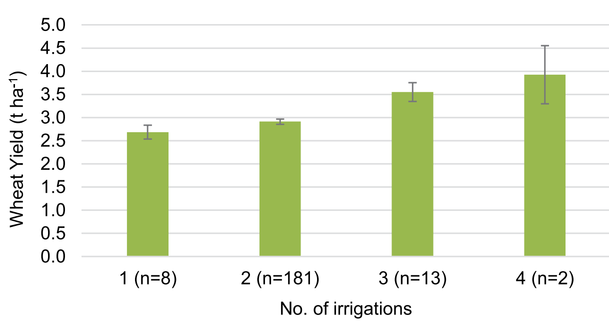

Fig. 5: Number of irrigations followed by farmers and their effect of the grain yield of wheat

fertilizer usage with the surveyed farmers was found to be more than optimum for N and P whereas the K usage was a bit on the lower side. With N: P_2O_5:K_2O use at 155:43:33 kg ha^{-1}, the yield levels are low. The irrigation frequency of 2.43 does not show any synergy with these fertiliser rates (Table 2).

Table 2: The use rates of N: P_2O_5: K_2O (kg ha^{-1}) and irrigation frequencies of surveyed farmers (Potash users 44%)

NPK rates and irrigation frequency	Average use rates (kg ha^{-1})	SD	SE
N	154.76	28.73	2.05
P_2O_5	43.33	18.47	1.34
K_2O	33.50	18.62	2.00
Irrigation number	2.43	0.56	0.04

Conclusion

There is a better scope of advancing the wheat sowings and use of TSWVs as a combined approach. Proper weed management with improved herbicide application technologies will keep future to improve grain yield of weed. Late sown wheat varieties (LSWVs) do not seem to have any advantage of beating the terminal heat as their yield levels are still lower than TSWVs.

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3.28 Wheat productivity needs better agronomic management including improved varietal turnover

B.D. Singh[1], Madhulika Singh[2], Mrinal Verma[1], Shahnawaz R. Dar[3] and S.P. Poonia[2]

[1]Krishi Vigyan Kendra, Patna
[2]International Maize and Wheat Improvement Centre (CIMMYT)
[3]International Rice Research Institute (IRRI)

Introduction

Patna district is situated in the south Bihar alluvial plains. The soil type is clay to clay loam, sandy loam and medium to heavy soils and divided proportionately throughout the district. The district has 23 blocks, 344 Panchayats and 1,433 villages. The total geographical area is 317,200 ha of which 228,500 ha is cultivable. The district population is 6,691,442 (2011 census). Despite stagnant yield growth of wheat, there has been not many new policy interventions except some focus on adoption of zero tillage in wheat. Importance of early wheat sowings was never acknowledged until 2013. On the contrary, for fear of yield loss, the wheat sowing before 20 November was discouraged through advisories from DoA circulated (till 2011) through news papers. We need to respond with changes in the agronomic management options that help improving the yield growth of wheat and wheat based cropping systems. All these possible changes need to happen by keeping in mind the variable monsoon in the rice phase and terminal heat in the wheat phase. To achieve these goals, the landscape diagnostic survey was conducted to understand the current production practices and plan for impact pathways.

Methods

Details on methodology are given in Chapter 1

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).

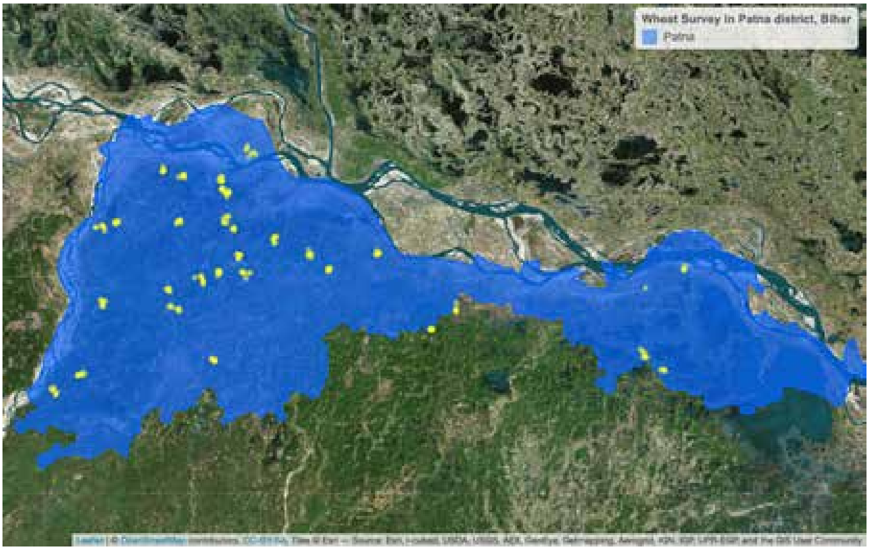

Fig. 1: GPS points of surveyed farms in Patna

Results and Discussion

The dominating cropping system in the district is rice-wheat by 96% respondents (Fig. 2). Data from landscape diagnostic survey (LDS) indicated that there is still a pervasiveness of very old varieties including UP 262, Lok 1, and PBW 154 with 50, 27 and 2% farmers (Table 1). Most other varieties are also from the group of late sown wheat

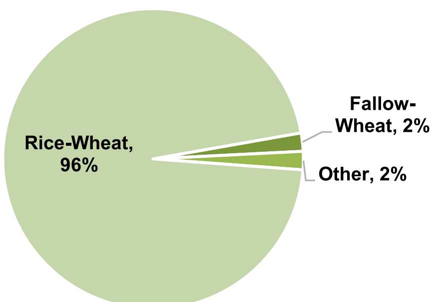

Fig. 2: Major cropping system prevailing in the district as per surveyed farmers

Table 1: Summary of important varieties including timely sown wheat varieties (TSWVs) and late sown wheat varieties (LSWVs) (2017-18) (n=203)

Varieties	Number of respondents	Percentage (%)
TSWVs		
HD 2967	5	2
PBW 343	6	3
LSWVs		
PBW 154	5	2
UP 262	101	50
Kedar	4	2
Lok 1	54	27
Others*	28	14

*Includes include DBW 17, PBW 502, PBW 550 from TSWVs group and RR 21, HI 1563, Kundan from LSWVs group.

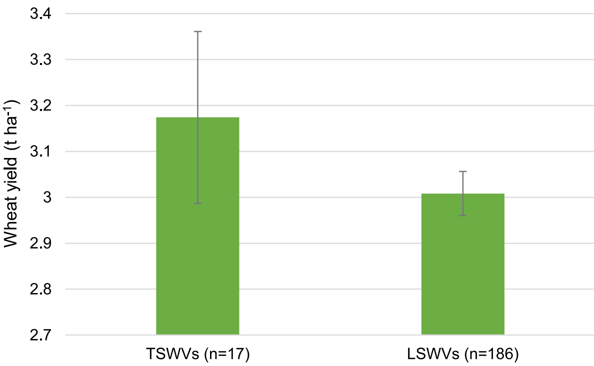

Fig. 3: Average grain yield of timely sown wheat varieties (TSWVs) and late sown wheat varieties (LSWVs) across different agronomic management options

varieties (LSWVs). Only 8% farmers have adopted timely sown wheat varieties (TSWVs) (Fig. 3). The positive impact of early wheat sowing is visible with grain yield of 3.2, 3.0 and 2.7 t ha^{-1} when the sowings were done before November 20, between 21 November to 15 December and after December 15 respectively (Fig. 4). With 37% surveyed farmers reporting early sowing, the lesser than expected yield reported by these respondents might be connected to the adoption of LSWVs, which are potentially low yielders. Instead of looking at maturity class (120-135 days for LSWVs or 135 -150 days for TSWVs), we should better target the flowering time of these varieties. Here early wheat sowing is more valuable to manage the flowering time than the varieties. Within varieties, number of grains is more important asset than the test weight. Earlier studies showed a significant interaction between

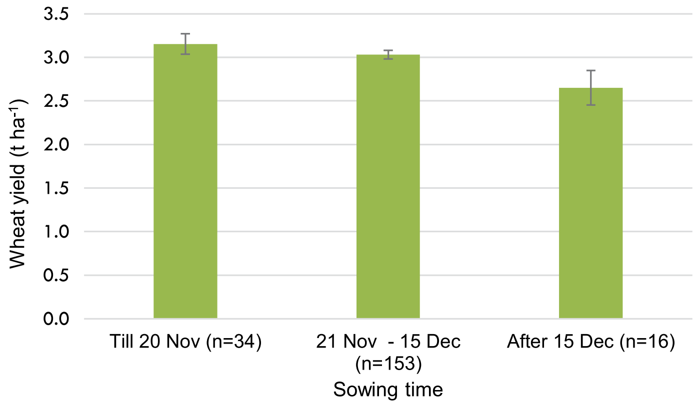

Fig. 4: Time of sowing and its influence on the average grain yield of wheat across varieties and management practices

cultivars and the time of sowing (Ortiz-Monasterio *et al.,* 1994). Spike dry matter at anthesis is an important parameter for fruiting efficiency (Fischer, 2016), which decreases from early sowing to late sowings. Fertilizer use is within limits with $N:P_2O_5:K_2O$ use at 126:54:18 kg ha^{-1}. There is negligible use of K in the district. Even with this range of N and P, the yield levels were low (Table 2). Most farmers (62%) do not control weeds and herbicide use is only 15% (Fig. 5). Among the surveyed farmers 96% followed broadcasting, 3% followed line sowing after tillage and 1% followed zero tillage (Fig. 6). A

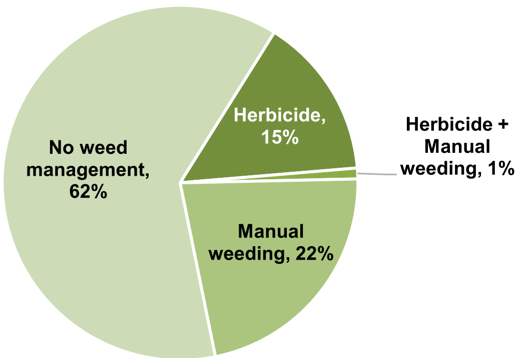

Fig. 5: Weed management practices adopted by farmers with majority showing no adoption of weed management in the district (n=203)

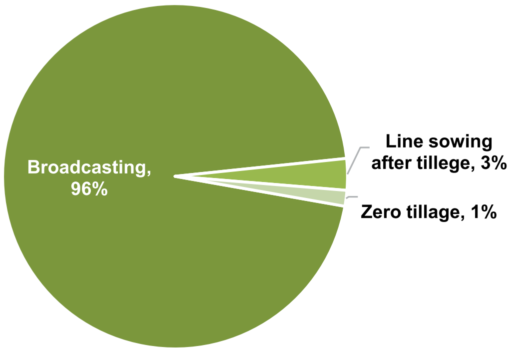

Fig. 6: Different crop establishment methods adopted by respondents

Table 2: The use rates of N: P_2O_5: K_2O (kg ha^{-1}) and irrigation frequencies of surveyed farmers (Potash users 3%)

NPK rates and irrigation frequency	Average use rates (kg ha^{-1})	SD	SE
N	125.62	33.18	2.32
P_2O_5	53.66	18.76	1.31
K_2O	17.87	18.94	7.73
Irrigation number	2.81	0.65	0.05

review of work done on zero tillage (Malik *et al.*, 2014) showed that this is the best technology for facilitating early sowing. It should be promoted. There was an increase in yield observed with increase in number of irrigation applied (Fig. 7).

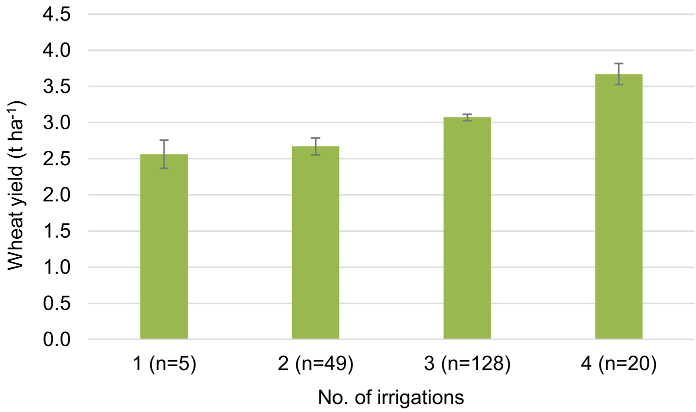

Fig. 7: Effect of number of irrigation given by farmers on the average grain yield of wheat

Conclusion

This district should take up the case for adoption of TSWVs, early wheat sowing, ZT and weed management.

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3.29 Low yield growth needs agronomic management options in Rohtas

Ram Pal[1], Deepak K. Singh[2], Sachin Sharma[2], Reeta Singh[1], Pradeep Sagwal[3] and S.P. Poonia[2]

[1]Krishi Vigyan Kendra, Rohtas
[2]International Maize and Wheat Improvement Centre (CIMMYT)
[3]International Rice Research Institute (IRRI)

Introduction

Rohtas is the rice bowl of Bihar. In this district, the soil conditions and weather are good. Rice is the major crop but wheat productivity is low. The delayed rice transplanting along with long duration rice varieties constrains timely wheat seeding. The delayed wheat sowing exposes the crop to terminal heat near crop maturity which reduces wheat yield and is expected to get worse in the coming decades (Lobell *et al*., 2011) Our work in CSISA –KVK network showed that wheat sowing is delayed due to late rice establishment, the prevalence of long duration rice varieties, and the long turnover period for vacation of fields between rice harvest and wheat sowing. The land scape diagnostic survey (LDS) was conducted to identify technologies which might help increasing the wheat productivity without sacrificing rice yields, which is the proud feature of this district. The surveyed data for wheat was only considered for this chapter.

Methods

Details on methodology are given in Chapter 1

Blocks covered: Rohtas, Sanjhauli, Dawath, Kargahar, Karakat, Bikramganj, Sasaram, Nauhatta, Kochas, Dinara, Nasriganj, Chenari, Nokha, Tilouthu and Sheosagar.

Village 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, Sonhar (Fig. 1)

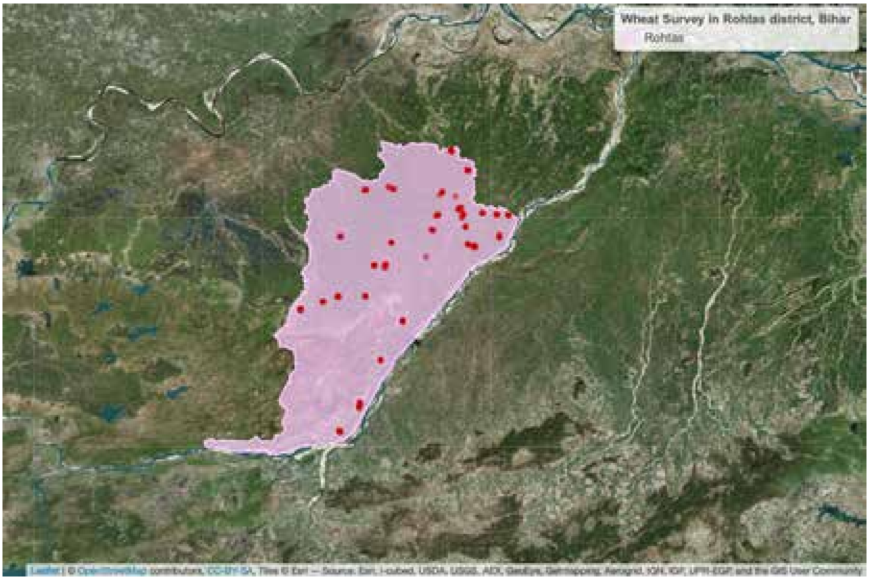

Fig. 1: GPS points of surveyed farms in Rohtas

Results and Discussion

The district represents fertile plains with 100% dominance of rice-wheat cropping system (RWCS) with surveyed farmers. Adoption of timely sown wheat varieties (TSWVs) by 60% surveyed farmers is the first good step towards increasing the wheat yields (Fig. 2). The data on date of sowing suggested that

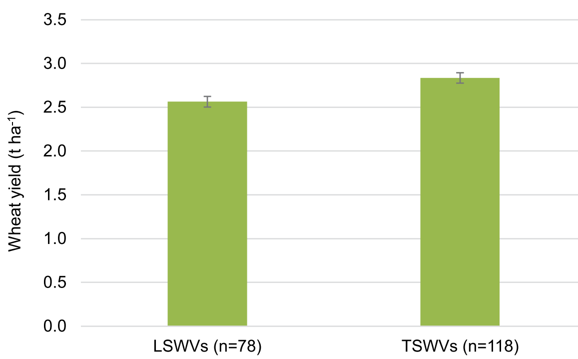

Fig. 2: Average grain yield of timely sown wheat varieties (TSWVs) and late sown wheat varieties (LSWVs) across different agronomic management options

there is huge scope for attaining significantly higher yield if 60% TSWVs could be matched with early sowings. In the current data set ,only 3.6% wheat was sown before 20 November, which attained the grain yield of wheat at 3.4 t ha^{-1}, 19.4 % farmers of surveyed farmers did their sowing after 15 December and got a yield loss of almost 1.0 t ha^{-1}. Sowing done in the intervening period also had a yield loss of 0.7 t ha^{-1} (Fig. 3). TSWVs might have been the factor for better yield growth during late establishment dates. In this scenario, still more focus should be given on early sowing (Dhillon and Ortiz-Monasterio, 1993) and the varietal spectrum, which at present is evenly distributed between timely sown wheat varieties (TSWVs) and late sown wheat varieties (LSWVs) should have been tilted towards TSWVs (Table 1). However, the turnover of the new wheat varieties is very low. In a district like this, there is precision in rice transplanting but in wheat more than 80% farmers still adopt broadcasting method of wheat. While early sowing and TSWVs did have an effect on yield but here late sowing is a cropping system problem where decision on wheat are linked to crop management done in the rice phase. Canal irrigation is limited and unreliable. We therefore need to consider this and the source of irrigation is an important entry point. Our experience showed that zero tillage did have an effect in advancement of wheat sowing by utilizing the residual moisture (Keil *et. al.* 2015). The adoption of ZT is with 4% respondents whereas line sowing after tillage is practiced by 12% farmers (Fig. 4). The less adoption of

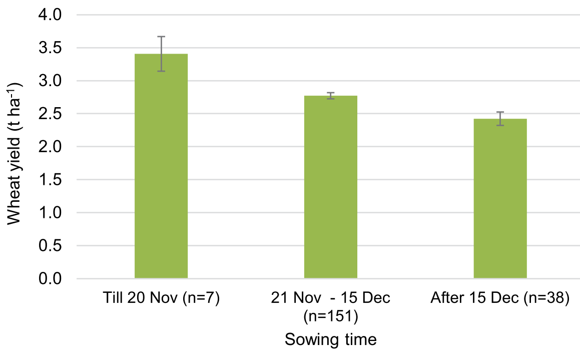

Fig. 3: Average grain yield of wheat as affected by three different sowing schedules across varieties and management practices

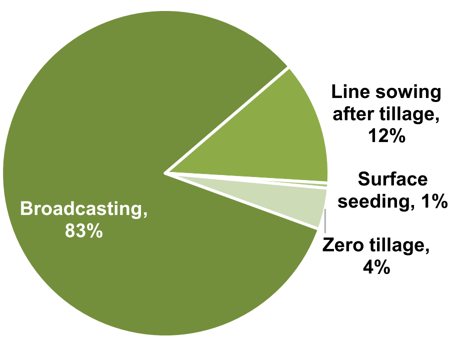

Fig. 4: Crop establishment methods practiced by farmers

Table 1: Summary of important varieties including timely sown wheat varieties (TSWVs) and late sown wheat varieties (LSWVs) (2017-18) (n=196)

Varieties	Number of respondents	Percentage (%)
TWSWs		
HD 2733	5	2.5
HD 2967	52	26
PBW 343	21	11
PBW 502	18	9
ShriRam 303	12	6
PBW 2076	6	3
LSWVs		
PBW 154	13	7
UP 262	7	4
HUW 234	33	17
RR 21	12	6
Lok 1	5	2.5
Others*	12	6

*Includes K 307, PBW 550, Super 172 from TSWVs group and Baaz, HD 2985, Kedar, KW 412, Local from LSWVs group.

ZT in this survey is because of randomization process which might have not covered blocks saturated with ZT. This is the status evenafter the district is having the maximum number of ZT machines. The survey results showed that the adoption of ZT is not distributed evenly across Rohtas. This is a solid case for creating more awareness about the usefulness of this technology. Weeds are a serious problem but 35 % farmers do not practice any method to control weeds (Fig. 5). Fertilizer usage is within limits with N: P_2O_5:K_2O use at 137: 72: 5 kg ha^{-1} whereas the irrigation frequency was 2.73 (Table 2). However, at such low yield levels, the use of P is on

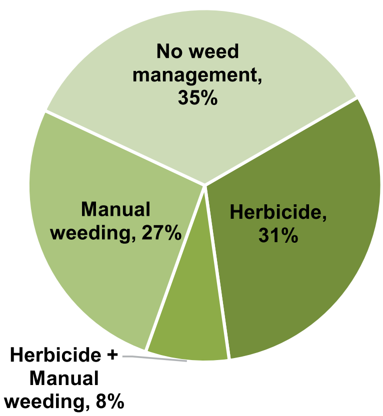

Fig. 5: Farmers reported weed management options practiced in the district (n=196)

Table 2: The use rates of N: P_2O_5: K_2O (kg ha^{-1}) and irrigation frequencies of surveyed farmers (Potash users 18%)

NPK rates and irrigation frequency	Average use rates (kg ha^{-1})	SD	SE
N	137.30	34.72	2.48
P_2O_5	72.21	22.09	1.59
K_2O	28.24	9.96	1.68
Irrigation number	2.73	0.62	0.04

the higher side. The increase in number of irrigation showed increase in grain yield as well (Fig. 6). There is a strong case for creating synergies between nutrient management and irrigation. Best varieties and the recommended nutrients are the pillars of RWCS productivity growth. Both have been accepted by farmers where N and P are used in more than recommendation but K is less than recommendation. Rohtas being endowed with best natural resources needs focused attention on other management practices in combination with these two factors.

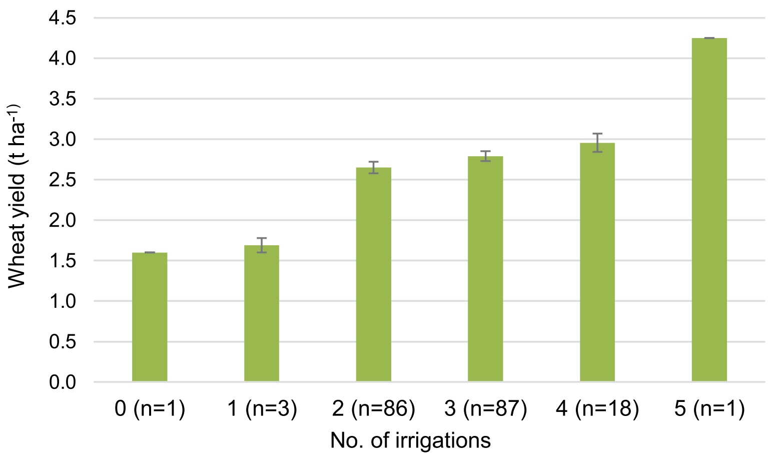

Fig. 6: The average grain yield of wheat under different irrigation frequencies

Conclusion

When early sowing and TSWVs are encouraged wheat productivity will gain significantly. That would need focused attention on rice so those fields are vacated on time.

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3.30 Irrigation management: An alternative to beat the terminal heat stress in wheat

Vimlesh Kumar Pandey[1], Moben Ignatius[2], Anand Chaudhary[1] and Sachin Sharma[2]

[1]Krishi Vigyan Kendra, Saharsa
[2]International Maize and Wheat Improvement Centre (CIMMYT)

Introduction

The district of Saharsa spreads over 164,559 ha of which 107,143 ha is cultivable and 55,318 ha is irrigated. The total area under rice crop is 27,940 and wheat crop is 49,690 ha. The major soil type is loam to silt loam and loam to loamy clay.

The trends in the current production practices of wheat along with trend in input use have been captured and discussed in the light of survey findings. The sustained improvement in wheat productivity has been compromised by several factors and some of these factors should be prioritized for research in the State Agricultural Universities (SAUs) and for extension activities by the state. The landscape diagnostic survey (LDS) was conducted to guide the multidisciplinary teams both from research and extension streams in Bihar.

Methods

Details on methodology are given in Chapter 1

Blocks covered: Ban Matiahari, Kharahara, Mahishi, Nauhatta, Salkhua, Satarkatiya, Saubazar, Simri Bakhtiyarpur, 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, Tariyawan (Fig. 1).

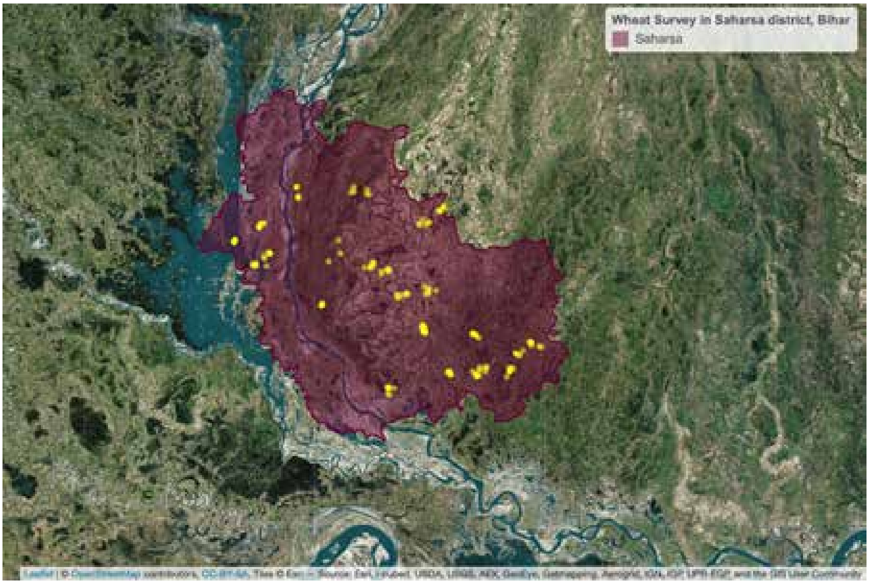

Fig. 1: GPS points of surveyed farms in Saharsa

Results and Discussion

The survey highlights the production trends in rice-wheat (51%) and fallow-wheat (47%) cropping system (Fig. 2). Almost equal proportion farmers sowed wheat crop before 20 November or after 15 December (Fig. 3). More than 75% farmers sow their crop after 21st November. Varietal turnover is very poor with 51% farmers growing PBW 343 and others older varieties (more than 25 years) like UP 262, HUW 234 and PBW 154 (Table 1). It means that none of the varieties released after 1996 are finding place with the farmers. Absence of detectable yield advantage was the main reason for non-adoption (Walker *et al.*, 2015) of varieties. These results are contrary to that reported by Mondal *et al.*, (2016) Timely sown wheat varieties (TSWVs) are performing better than late sown wheat varieties (LSWVs) even under late sowings

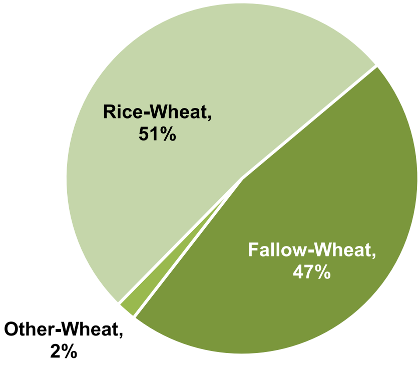

Fig. 2: Major cropping system prevailing in the district as per surveyed farmers, Other includes Green Gram, Green Manure and Jowar

(Fig. 4). N: P_2O_5: K_2O use at 127:65:34 (Table 2) is relatively high at such yield levels of around 2.5 t ha^{-1} and with fallow-wheat dominant cropping system. Almost 60% farmers gave two irrigations leading to low yield of around 2.6 t ha^{-1} (Fig. 5). Real ability

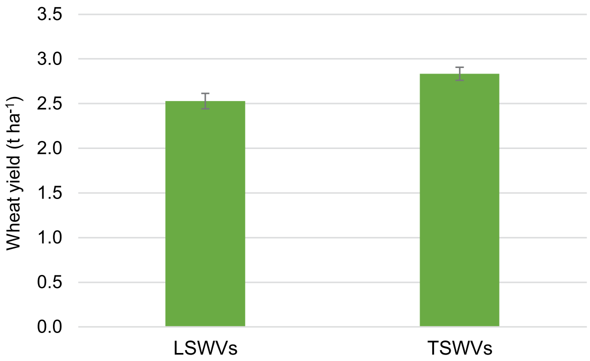

Fig. 3: Average grain yield of timely sown wheat varieties (TSWVs) and late sown wheat varieties (LSWVs) across different agronomic management options

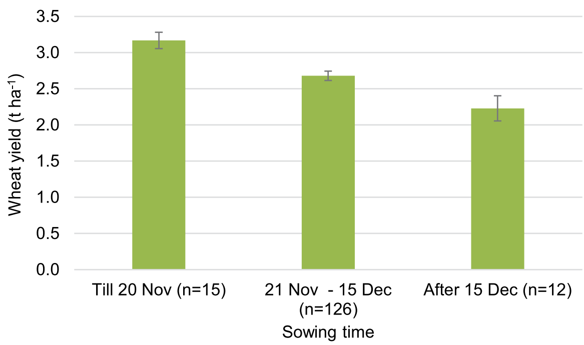

Fig. 4: Average grain yield of wheat as affected by three different sowing schedules across varieties and management practices

to track the farmers need is not in the choice of varieties or use of fertilizer but it is other management options. Timely sown wheat varieties (TSWVs) constitute around 50% adoption rate but varietal turnover is still low. Weed management

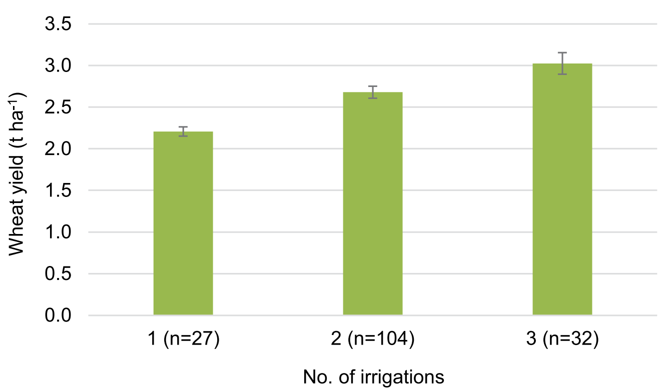

Fig. 5: The average grain yield of wheat under different irrigation frequencies

Table 1: Summary of important varieties including timely sown wheat varieties (TSWVs) and late sown wheat varieties (LSWVs) (2017-18) (n=163)

Varieties	Number of respondents	Percentage (%)
TWSWs		
HD 2967	2	1
PBW 343	83	51
PBW 502	3	2
ShriRam 303		1
LSWVs		
PBW 154	4	3
UP 262		28
HUW 234	15	9
Lok 1	2	1
Local	3	1.5
Others*		4

*Includes, Radha 4, RR 21 from LSWVs group.

is another important intervention to improve grain yield of wheat as still 28% farmers did not use any weed management (Fig. 6). Mechanization especially zero tillage can be a useful technology for facilitating the early sowing. Once adopted early wheat sowing can have spillover effects on adopting better agronomic management and increase in number of irrigation.

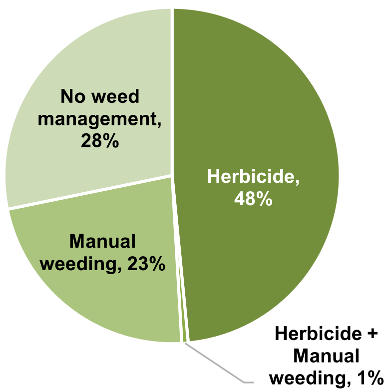

Fig. 6: Farmers reported weed management options practiced in the district (n=163)

Table 2: The use rates of N: P_2O_5: K_2O (kg ha^{-1}) and irrigation frequencies of surveyed farmers (Potash users 96%)

NPK rates and irrigation frequency	Average use rates (kg ha^{-1})	SD	SE
N	127.02	31.14	2.45
P_2O_5	64.97	14.52	1.14
K_2O	35.17	14.14	1.13
Irrigation number	2.04	0.65	0.05

Conclusion

Switchover from the late sowings to early sowing will trigger the adoption of TSWVs accompanied with more number of irrigations and proper weed management.

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3.31 Irrigation management: An alternative to beat the terminal heat in wheat

R.K. Tiwari[1], Pankaj Kumar[2] and Sanjay Kumar[1]

[1]Krishi Vigyan Kendra, Samastipur

[2]International Maize and Wheat Improvement Center (CIMMYT)

Introduction

District Samastipur falls in the Agro-climatic zone I, Northern west, Bihar. The soil types of Samastipur are sandy loam. The current area under cultivation is 184,061 ha with rice-wheat, rice-maize (*rabi*) and maize-wheat as the dominant cropping systems. Diversification is popular in upland areas with cash crops like vegetables and tobacco, spices etc. The farm sizes are too small with 1,248 villages. The net irrigated area is 66,080 ha. The total area under rice is 88,666 ha and wheat is 49,357 ha. The landscape diagnostic survey (LDS) intends to know how farmers are responding to changes in the technologies, and why the productivity is still low even after its close proximity to the State Agricultural University and BISA Farm of CIMMYT. Early sowing was realized to have a high acceptance in the district attributed to better awareness and communication between the extension persons and farmers.

Methods

Details on methodology are given in Chapter 1

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, Wirshinghpur (Fig. 1).

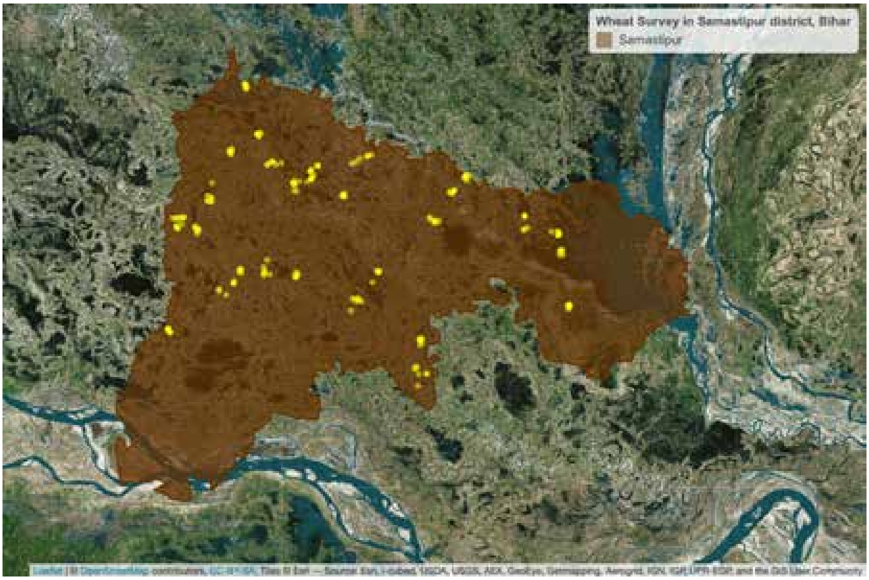

Fig. 1: GPS points of surveyed wheat farms in Samastipur district

Results and Discussion

Samastipur has a diversified cropping system but rice-wheat cropping system still dominates. Almost 87% surveyed farmers in the district use PBW 343, HD 2967 and HD 2733 varieties, which are improved timely sown varieties (Table 1) of which HD 2967 and HD 2733 are comparatively new in terms of date of release. Timely sown wheat varieties (TSWVs) have been accepted by more than 92.6% farmers which gave a yield benefit of 0.3 t ha^{-1} in comparison to late sown wheat varieties (LSWVs) (Fig. 2). There is a significant

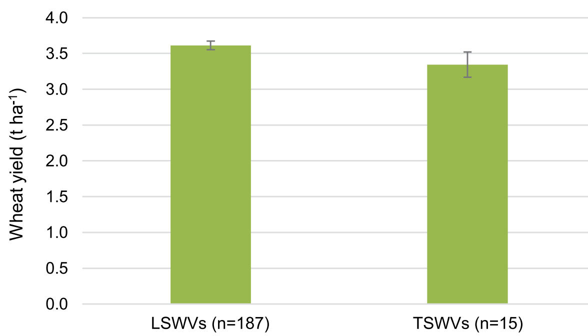

Fig. 2: Average grain yield of timely sown wheat varieties (TSWVs) and late sown wheat varieties (LSWVs) across different agronomic management options

Table 1: Summary of important varieties including timely sown wheat varieties (TSWVs) and late sown wheat varieties (LSWVs) (2017-18) (n=202)

Varieties	Number of respondents	Percentage (%)
TWSWs		
HD 2733	30	15
HD 2967	37	18
PBW 343	108	54
Shri Ram 303	9	4
LSWVs		
UP 262	12	6
Others*	6	3

*Includes, K 307, PBW 502, Super 172 from TSWVs group and HD 2985, RR 21 from LSWVs group.

change from legacy of late sowings to early sowings with 40% farmers adopting wheat sowing before November 20. Now farmers understand that early sowing was right option to adopt. The average yield levels in the first scenario is 3.8 t ha^{-1} compared to 3.5 t ha^{-1} in the second scenario where the sowngs were delayed (Fig. 3). N: P_2O_5:K_2O use at 142:79:44 kg ha^{-1} is on the higher side (Table 2). It is tempting to see that K use was significantly more in

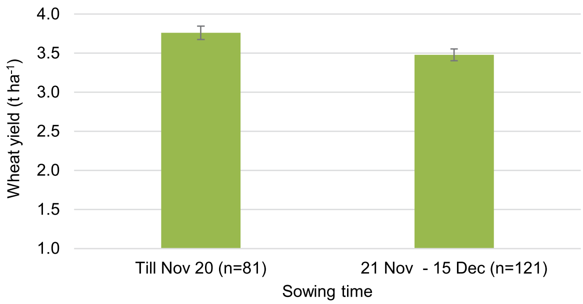

Fig. 3: Average grain yield of wheat as affected by three different sowing schedules across varieties and management practices

Table 2: Use rates of N: P_2O_5: K_2O (kg ha^{-1}) and irrigation frequencies of surveyed farmers (Potash users 94%)

NPK rates and irrigation frequency	Average use rates (kg ha^{-1})	SD	SE
N	142.07	31.84	2.24
P_2O_5	78.50	18.45	1.29
K_2O	43.80	15.39	1.12
Irrigation number	2.24	0.66	0.05

this district compared to other districts. This may be due to more diversified cropping system with potato, tobacco and maize coming in between rice-wheat cropping system, The efficiency of these inputs seems low because the irrigation frequency is low at 2.2 (Table 2). Data showed that 26% farmers do not control weeds (Fig. 4). As the adoption of early wheat sowing and TSWVs takes hold, new management options like timely irrigation and weed management will evolve. The yield gains from irrigation showed (Fig. 5) that farmers will support a better irrigation management. Shifting away from late sowings will further improve wheat productivity (Ortiz-Monasterio *et al.,* 1994) and additional irrigation will add value (Jain *et al.,* 2017) in sustainably improving the wheat productivity in the district.

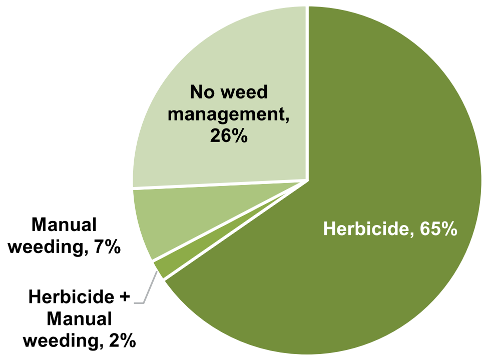

Fig. 4: Farmers reported weed management options practiced in the district (n=202)

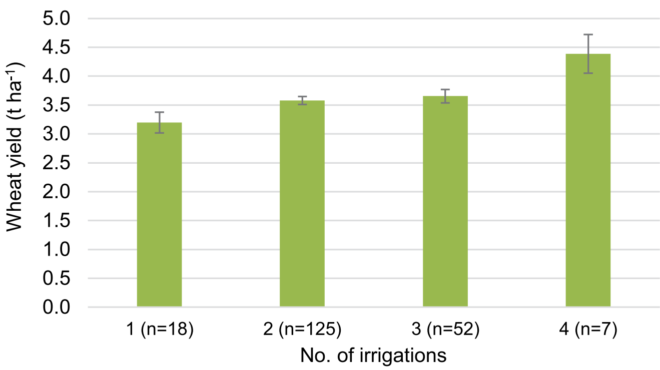

Fig. 5: The average grain yield of wheat under different irrigation frequencies

Conclusion

With early sowings the yield levels crossing 3.75 t ha^{-1} the irrigation and weed management have become more critical. With prevalence of rice hybrids in this district, the sowings can be advanced further with big gains in wheat productivity. The early wheat sowing have been set in motion now and in future the average date of sowing should be brought around 10th November.

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3.32 Survey makes the case for timely sown wheat varieties (TSWVs) and appropriate weed management

Devendra Kumar[1], Prabhat Kumar[2], Surendra Prasad[1] and Sachin Sharma[2]

[1]Krishi Vigyan Kendra, Manjhi
[2]International Maize and Wheat Improvement Centre (CIMMYT)

Introduction

The district Saran has a total geographic land of 2,64,100 ha of which 1,99,930 ha is cultivable. It has a population of 3.94 million (2011 census). Wheat, rice and maize are the major crops being produced here. Major soil type of the district is alluvial saline soil to alluvial soil to heavy clay soil. The total area under rice is 71,800 ha and wheat is 108,000 ha. The cropping intensity is 174.7%. The net irrigated area is 52%. By and large, both research and extension agencies are fixated towards weather conditions for relatively poor wheat yield in the region. The question is how to encourage these agencies to work on early wheat sowings and convince farmers to take up this case for sustained growth in wheat yields. The point is that we have to prepare the wheat crop for eventualities like terminal heat and that will need evidence. To convince policy makers and to seek new direction landscape diagnostic survey was conducted. The objectives were almost same as was done in the past surveys in rice-wheat cropping system (Harrington *et al.* 1993).

Methods

Details on methodology are given in Chapter 1

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, Kharauni (Fig. 1).

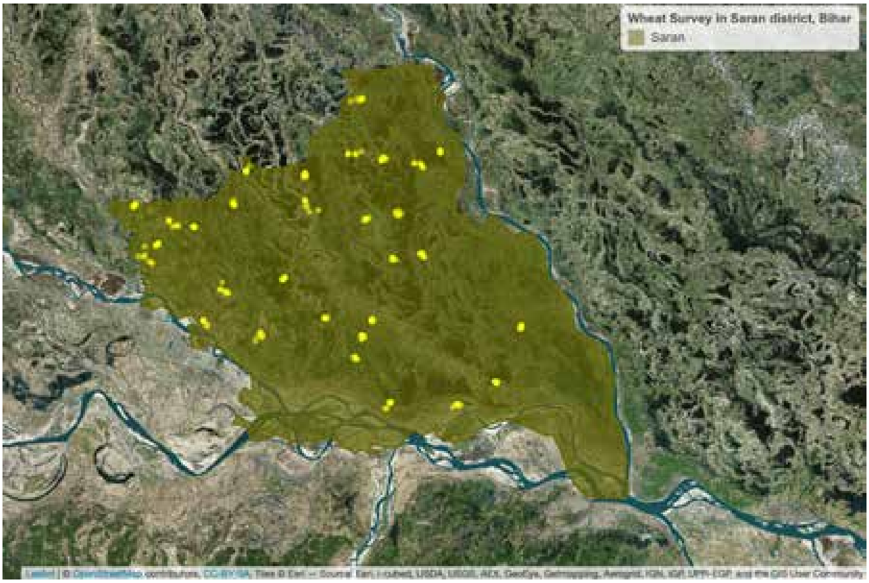

Fig. 1: GPS points of surveyed farms in Saran

Results and Discussion

The cropping system is dominated by rice-wheat (95%) with some 5% farmers reporting maize-wheat and fallow-wheat cropping system including some other crops (Fig. 2). Data when classified according to maturity groups, late sown wheat varieties (LSWVs) maturing in 120-135 days with the dominance of PBW 154 (49%) and UP 262 (19%) were more prevalent in this district. Twenty five percent farmers were seen to turn into timely sown wheat

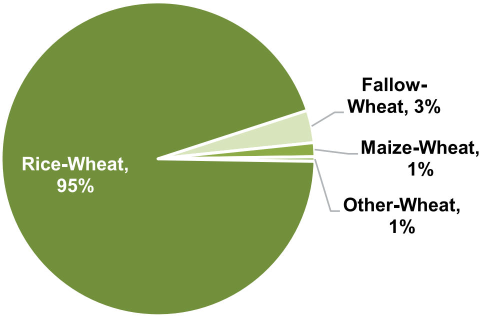

Fig. 2: Major cropping system prevailing in the district as per surveyed farmers

varieties (TSWVs) which mature in 135-150 days. Among TSWVs, PBW 343 is still popular with 18% farmers (Table 1). The survey data showed that on an average the grain yield of 3.7 t ha^{-1} for TSWVs compared to 2.96 t ha^{-1} for LSWVs was reported by farmers (Fig. 3). A heat-tolerant variety is usually characterized by higher photosynthetic rates reflected in stay-green leaves (Nagarajan *et al.*, 2010), which is possible in TSWVs like PBW 343.

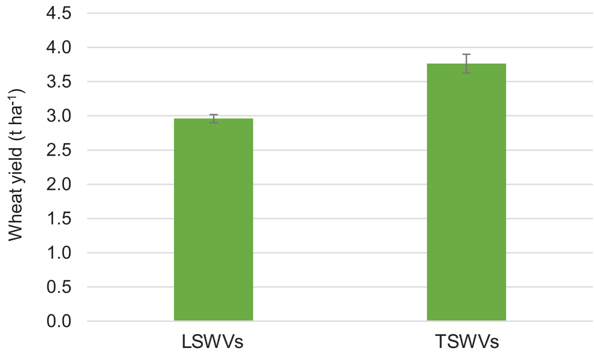

Fig. 3: Average grain yield of timely sown wheat varieties (TSWVs) and late sown wheat varieties (LSWVs) across different agronomic management options

Advancement in wheat sowing is happening with 26% farmers with an average yield of 3.3 t ha^{-1} when the sowings were done before 20 November (Fig. 4). This has not been appropriately matched by the adoption of TSWVs. The number of farmers planting wheat early will

Table 1: Summary of important varieties including timely sown wheat varieties (TSWVs) and late sown wheat varieties (LSWVs) (2017-18) (n=209)

Varieties	Number of respondents	Percentage (%)
TWSWs		
HD 2967	11	5
PBW 343	38	18
PBW 502	3	2
ShriRam 303	2	1
LSWVs		
PBW 154	102	49
UP 262	39	19
Kedar	4	2
WR 544	5	2
RR 21	5	2

*Includes, K 307, PBW 502, Super 172 from TSWVs group and HD 2985, RR 21 from LSWVs group.

rise rapidly if it is combined with high irrigation frequency, which is moderate at 1.89. N: P_2O_5:K_2O use at 120:57:32 kg ha^{-1} is appropriate but the efficiency is still low. The use of K is more than many other districts dominated by RWCS (Table 2). Extra irrigations resulted in yield as high as 5 t ha^{-1}. Three irrigations also provide good yield which is approximately 4.5 t ha^{-1}. Nearly 62% farmers applied 2 irrigations with an average yield of 3.2 t ha^{-1} (Fig. 5). Herbicide use is increasing (50%)

Table 2: The use rates of N: P_2O_5: K_2O (kg ha^{-1}) and irrigation frequencies of surveyed farmers (Potash users 83%)

NPK rates and irrigation frequency	Average use rates (kg ha^{-1})	SD	SE
N	120.49	32.77	2.27
P_2O_5	56.85	13.54	0.94
K_2O	32.59	11.32	0.86
Irrigation number	1.89	0.69	0.05

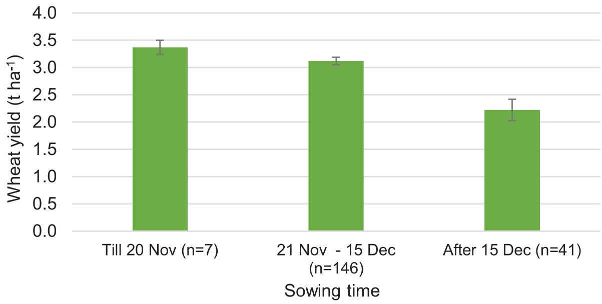

Fig. 4: Average grain yield of wheat as affected by three different sowing schedules across varieties and management practices

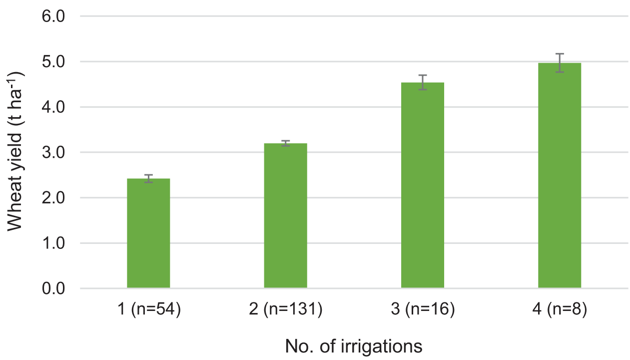

Fig. 5: The average grain yield of wheat under different irrigation frequencies

but 38% farmers still do not care for weed management which is a big gap (Fig. 6). With irrigation being very costly due to rise in diesel cost, the efficiency of inputs like fertilizer will be invariably low because interaction of irrigation and fertiliser application is well established. We need to understand the distinct role that irrigation plays in improving the efficiency of fertilizer and in realizing potential benefits of early sowing especially in beating the terminal heat. Line sowing had an yield advantage her broadcasting (Fig. 7).

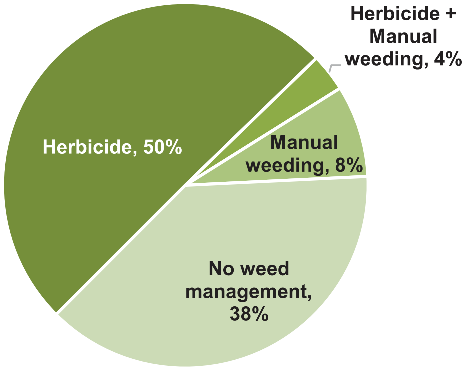

Fig. 6: Farmers reported weed management options practiced in the district (n=209)

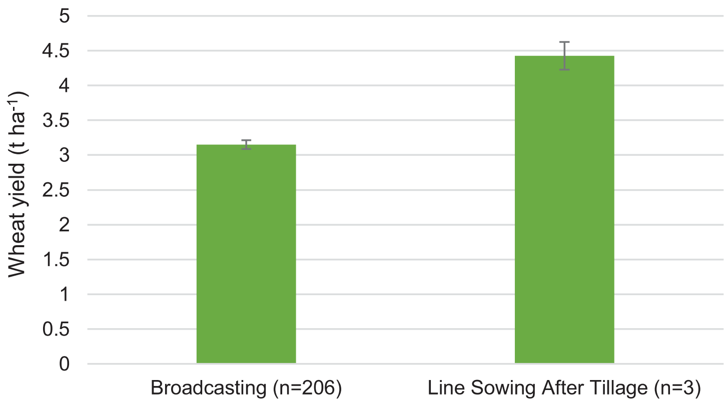

Fig. 7: Farmers reported average grain yield under two different crop establishment methods practiced by farmers

Conclusion

The adoption of new TSWVs, appropriate weed management and irrigation management should be synchronised. Soil health does not seem to be a big issue as farmers are using appropriate amount of fertilizers. The efficiency of nutrient should improve with better management option rather than changes in few kilograms of one or other fertilizer.

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3.33 Improved crop management can enhance productivity of Sheohar

Ram Niwas Singh[1], Prabhat Kumar[2], Rajendra Prasad[1] and Manoj Kumar[1]

[1]Krishi Vigyan Kendra, Sheohar
[2]International Maize and Wheat Improvement Centre (CIMMYT)

Introduction

The Sheohar is the smallest district of Bihar with a population of 0.65 million. The district latitude is 26.33' N and longitude is 85.17' E. The soil type is fine sandy loamy to saline calcareous. It has 5 blocks, 206 villages and 30,600 ha cultivable land holding. The cropping intensity is 145%. The net irrigated area is 45%. The total area under rice remains 20,000 ha and wheat is 17,000 ha. Other crops include sugarcane, maize, pulses and oilseed. Although agronomic management of wheat is centred on and around rice, yet fundamentals still can be managed with a target to increase cropping system productivity. The most favoured research focus is on evolving late sown wheat varieties. The cost of delayed sowing of wheat is hurting the interest of farmers. Researcher and extension agencies want data regarding what is happening at farmer's field. The aim of this survey was to understand the expectations of farmers and build these expectations in research and extension.

Methods

Details on methodology are given in Chapter 1

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, 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, Sankarpur Bindhi (Fig. 1).

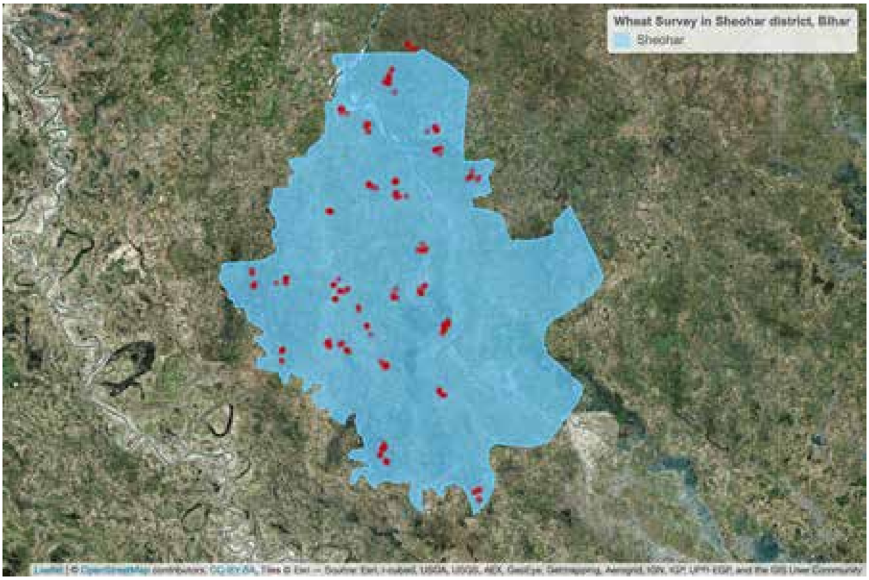

Fig. 1: GPS points of surveyed farms in Sheohar

Results and Discussion

The cropping system is dominated by rice-wheat (99%) with some 1% farmers reporting fallow-wheat cropping system (Fig. 2). Data when classified according to maturity groups, most farmers are growing PBW 343 (66%), PBW 502 (8%) and HD 2967 (7%), which are timely sown wheat varieties (TSWVs) and mature in 135 to 150 days. The adoption rate of late sown wheat varieties (LSWVs) is only 10% for PBW 373 and 7% for UP 262 (Table 1). The average grain yield of TSWVs was reported as 3.23 t ha^{-1}

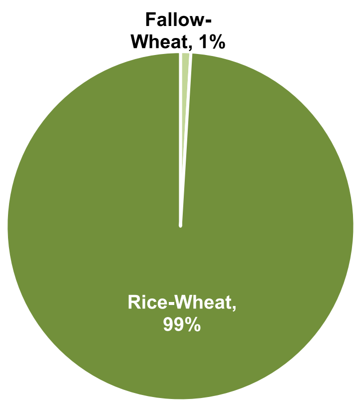

Fig. 2: Major cropping system prevailing in the district as per surveyed farmers

Table 1: Summary of important varieties including timely sown wheat varieties (TSWVs) and late sown wheat varieties (LSWVs) (2017-18) (n=209)

Varieties	Number of respondents	Percentage (%)
TWSWs		
HD 2967	14	7
PBW 343	138	66
PBW 502	16	8
LSWVs		
PBW 154	5	2
UP 262	14	7
PBW 373	21	10

compared to 3.05 t ha^{-1} for LSWVs (Fig. 3). Advancement in sowing is happening with 23% farmers with an average yield of 3.32 t ha^{-1} when the sowings were done before 20 November. Sowing done in between 21st Nov-Dec 15 is recorded by 75% farmers with an average yield of 3.16 t ha^{-1} (Fig. 4). The number of farmers planting early wheat will rise rapidly if it is combined with high irrigation frequency which is as low as 1.96 with the surveyed farmers. Since irrigation cost is high, it becomes

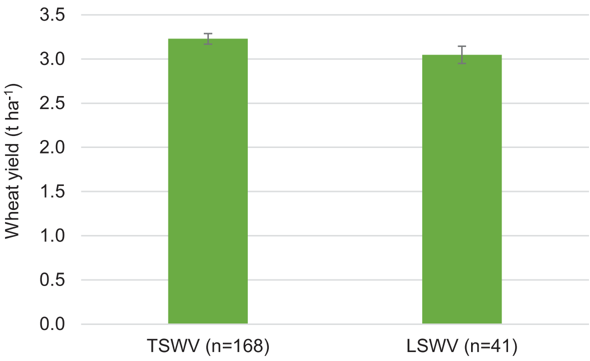

Fig. 3: Average grain yield of timely sown wheat varieties (TSWVs) and late sown wheat varieties (LSWVs) across different agronomic management options

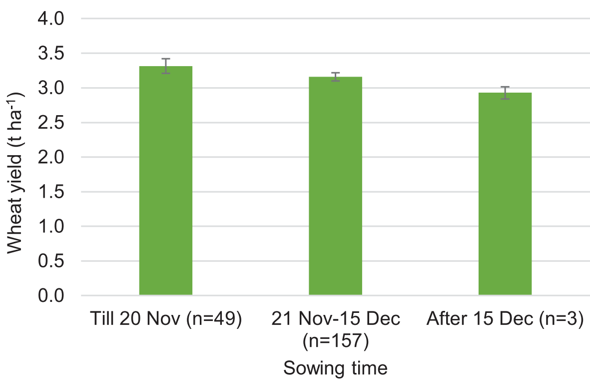

Fig. 4: Average grain yield of wheat as affected by three different sowing schedules across varieties and management practices

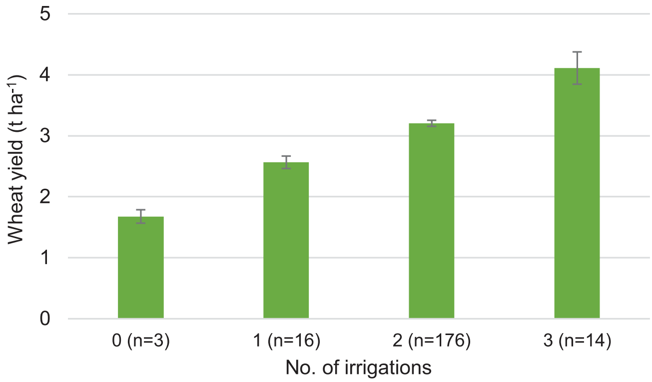

Fig. 5: The average grain yield of wheat under different irrigation frequencies

unattractive if late wheat sowing is combined with LSWVs which are potentially low yielder than TSWVs. Increase in the number of irrigation with maximum 5 has typically given higher yields across all districts. In this district 84% farmers applied 2 irrigations and their average yield is 3.2 t ha^{-1}. On the contrary 7% who provided one additional irrigation i.e. 3 irrigations got 28% extra yield at 4.1 t ha^{-1} (Fig. 5). N: P_2O_5:K_2O use at 138: 54: 30 kg ha^{-1} is reasonably appropriate but the efficiency is still low. The use of N is more than surrounding districts which is dominated by RWCS (Table 2). The issue of timely weed management is rarely raised in the planning meetings and this is a reason why 38% still do not adopt any weed management method (Fig. 6). The untapped potential of irrigation (Sairam *et al.,* 1992), weed management and zero tillage (Malik *et al.*2002) technology (especially for advancing wheat sowing), the other management options, should be exploited for

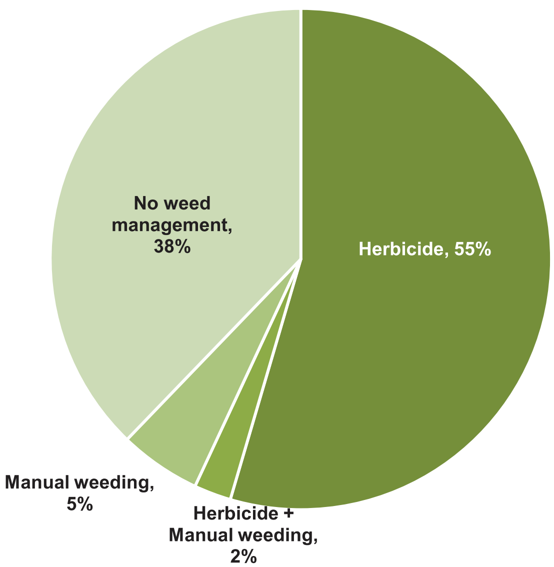

Fig. 6: Farmers reported weed management options practiced in the district (n=209)

Table 2: The use rates of N: P_2O_5: K_2O (kg ha^{-1}) and irrigation frequencies of surveyed farmers (Potash users 96%)

NPK rates and irrigation frequency	Average use rates (kg ha^{-1})	SD	SE
N	138.61	25.52	1.76
P_2O_5	53.84	12.62	0.87
K_2O	29.90	5.50	0.39
Irrigation number	1.96	0.45	0.031

realising the full potential of wheat in this ecology. These interventions identified through this survey especially on weed management and irrigation especially at flowering and grain filling need to be tested at farmers, fields and then approved as specific recommendation for use by farmers.

Conclusion

The advancement in wheat sowing will help in realizing the high yield potential of TSWVs which have been accepted by farmers. To further cope with this change irrigation, weed management and zero tillage need to get focused attention.

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3.34 Timely seeding is underway but irrigation management and zero-tillage need attention

M.K. Pandey[1], Ajay Kumar[2], D.P. Singh[1], S.N. Singh[1], S.K. Mishra[1] and Pardeep Sharma[1]

[1]Krishi Vigyan Kendra, Siddharthnagar
[2]International Maize and Wheat Improvement Center (CIMMYT)

Introduction

With more than 2,500 villages divided in 5 subdivisions and 14 blocks, the district of Siddharthnagar covers an area of 2,752 km^2 with a population of 2,553,526 (2011 census). It has a total 206,768 ha of cultivable land. The total area under rice is 170,364 ha and wheat is 145,109 ha. The yield growth of rice-wheat cropping system (RWCS) which accounts for 90% of agriculture growth in Siddarthnagar district has remained flat for last few decades. Wheat sowings are frequently delayed on account of late rice harvesting. The series of new developments including adoption of hybrid rice and early wheat sowings has prompted CSISA-KVK network to undertake landscape diagnostic survey (LSD) in the district. The experience of KVK showed that this district is ready for a sustained yield growth of wheat provided agronomic management is appropriately integrated. The LDS was planned to support the research and extension system for setting priorities by highlighting issues which need more attention than others.

Methods

Details on methodology are given in Chapter 1

Blocks covered: Bansi, Barhni Bazaar, Bhanwapur, Dumariyaganj, Itwa, Jogiyakhas, Khuniaon, Mithwal, Shohratgarh, Uska Bazaar.

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).

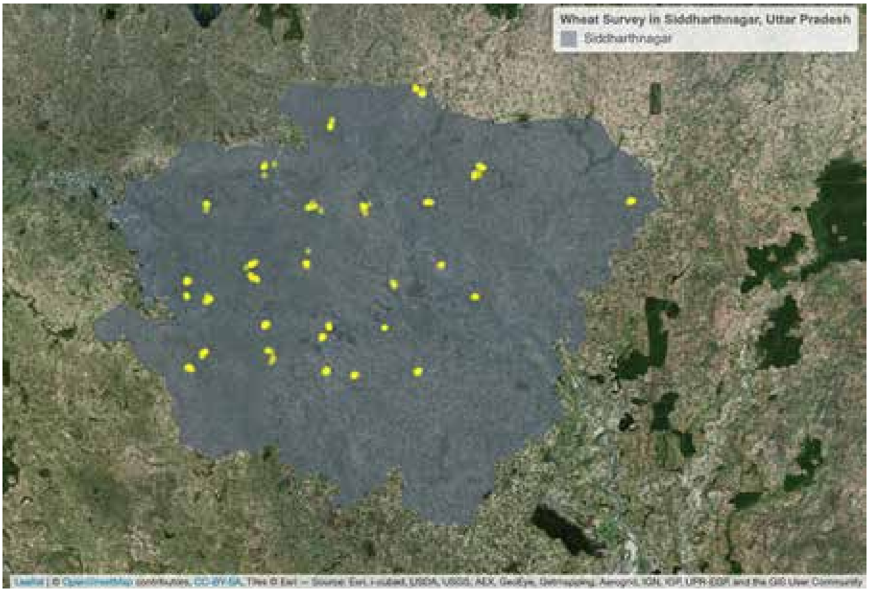

Fig. 1: GPS points of surveyed wheat farms in Siddharthnagar

Results and Discussion

This district is dominated by rice-wheat cropping system (RWCS) with 91% farmers with some pockets of fallow-wheat system (Fig. 2). The LDS reflects large scale adoption of timely sown wheat varieties (TSWVs) in the order of HD 2967 (66%), PBW 343 (27%) and HD 2733 (3%) as depicted in Table 1. As a group, the average yield of TSWVs reported by farmers is 3.4 t ha^{-1} and that of late sown wheat varieties (LSWVs) is 2.84 t ha^{-1} (Fig. 3).

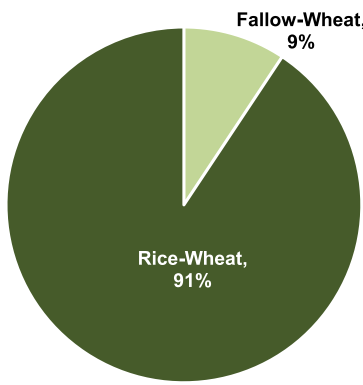

Fig. 2: Major cropping system prevailing in the district as per surveyed farmers

Table 1: Summary of important varieties including timely sown wheat varieties (TSWVs) and late sown wheat varieties (LSWVs) (2017-18) (n=193)

Varieties	Number of respondents	Percentage (%)
TWSWs		
HD 2733	5	3
HD 2967	127	66
PBW 343	52	27
LSWVs		
Others*	9	5

*Includes DBW 17, HD 2985, WH 1105, PBW 502 and SriRam 303 from TSWVs group and PBW 154 from LSWVs group.

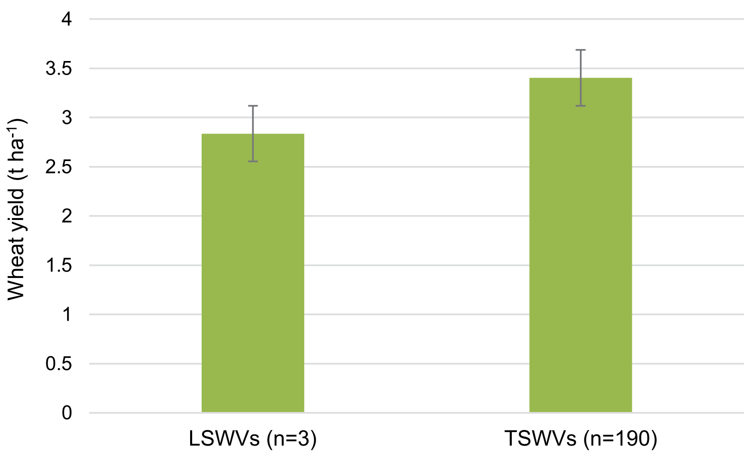

Fig. 3: Average grain yield of timely sown wheat varieties (TSWVs) and late sown wheat varieties (LSWVs) across different agronomic management options

This is a major shift from the existing focus on evolving LSWVs to beat the terminal heat especially when sowings are delayed. On the whole, there is no delayed sowing beyond 15 December. Forty two (42%) farmers with early sowing done before 20 November reported a yield of 3.69 t ha^{-1} compared to 3.17 t ha^{-1} where the wheat sowings were done between 21 November and 15 December (Fig. 4). Adoption of LSWVs by 3 out of 193 respondents is evident enough to persuade breeders to focus more on TSWVs even for late sowings (Fig. 3). That would also mean that evolving TSWVs even for late sowing situation does not risk any loss in wheat yield. Although genetic advantages conferred by breeders did not have same magnitude of productivity growth as was

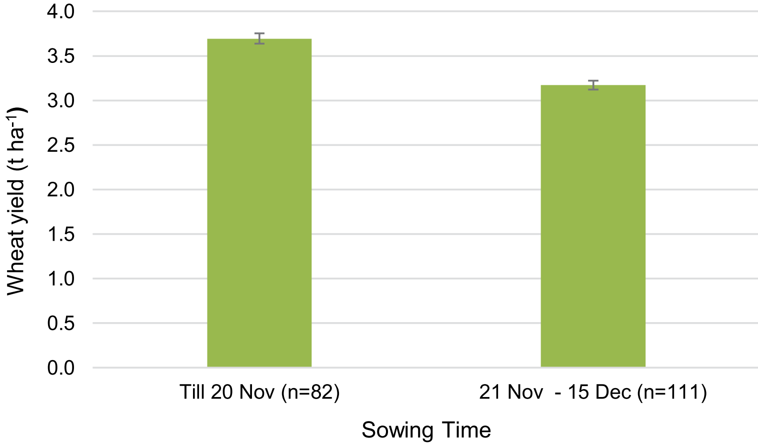

Fig. 4: Average grain yield of wheat as affected by three different sowing schedules across varieties and management practices

seen in green revolution phase (Krishna *et al.*, 2016), the advantages from LSWVs released during last 25 years (Mondal *et al.,* 2016) are even less. Data also showed that N: P_2O_5:K_2O use rate of 127:59:27 kg ha^{-1} which is same as in the adjoining Maharjaganj district (Table 2). The irrigation frequency is very low at 1.74 which again indicated that, if this factor is given focused attention, the grain yield can improve significantly (Table 2). There was a yield difference of above 2.5 t ha^{-1} between 0 and 5 irrigations applied in wheat (Fig. 5). Number of irrigation applied is directly proportional to yield. Farmers are well aware

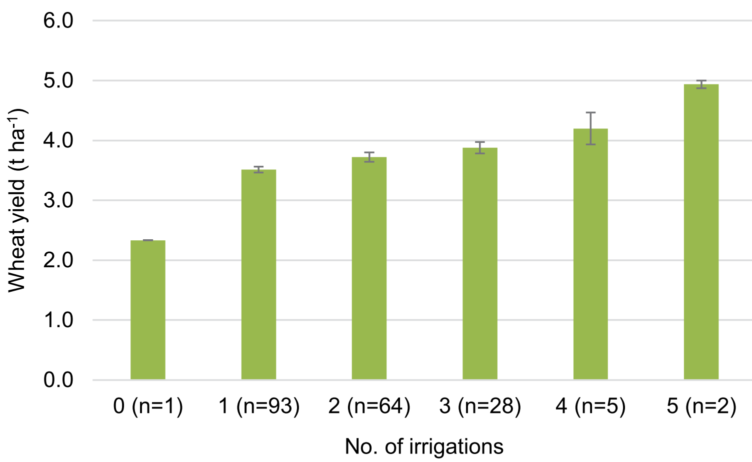

Fig. 5: The average grain yield of wheat under different irrigation frequencies

Table 2: The use rates of N: P_2O_5: K_2O (kg ha^{-1}) and irrigation frequencies of surveyed farmers (Potash users 59%)

NPK rates and irrigation frequency	Average use rates (kg ha^{-1})	SD	SE
N	126.59	36.55	2.63
P_2O_5	58.50	25.24	1.91
K_2O	26.68	10.95	1.03
Irrigation number	1.74	0.88	0.06

of weed management option with more than 79% using herbicide (Fig. 6). Wheat establishment is done by broadcasting method by 97% of the surveyed farmers (Fig. 7) whereas zero till is practiced by only 3% of farmers. Agronomic management will help harnessing more from the

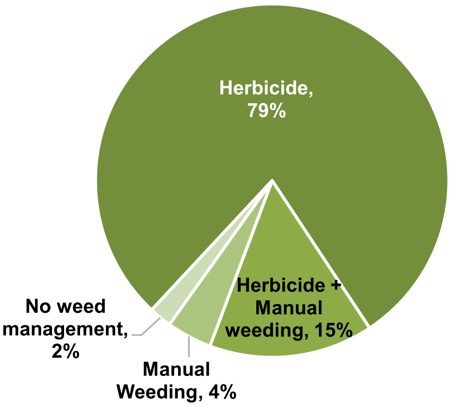

Fig. 6: Farmers reported weed management options practiced in the district (n=193)

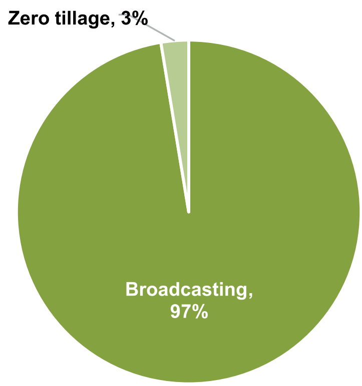

Fig. 7: Crop establishment methods practiced by farmers

combination of TSWVs and early wheat sowing (Evenson and Gollin, 2003).

Conclusion

Data reflected a use change with advancement in sowing and use of TSWVs. The nutrient efficiency and positive impacts on above two factors can be realized with a focused attention on irrigation management and zero tillage option which has not picked up in this district. Zero tillage is one option which can reduce cost that farmers can invest on one extra irrigation.

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3.35 Better access to irrigation can help increasing wheat productivity in Siwan

Raj Kumar Mandal[1], Pankaj Kumar[2], Sunil Kumar Mandal[1] and Prabhat Kumar[2]

[1]KVK, Siwan

[2]International Maize and Wheat Improvement Center (CIMMYT)

Introduction

The soil type in district of Siwan is majorly black followed by sandy loam. The district has a total of 222,000 ha land of which 172,000 ha is cultivable. The net irrigated area is 122,700 ha. The total wheat area is 104,100 ha and rice area is 80,100 ha. The wheat productivity in Siwan district is lower than many other districts of Bihar. This would mean that interventions required here may need to be structured differently. There is no documented evidence to show why yields are low and what can be done to improve it in the rice-wheat cropping system (RWCS) that commonly exists in Bihar. The landscape diagnostic survey (LDS) was conducted to understand how farmers are using the recommendations made by the system and how those recommendations are affecting the yield of wheat.

Methods

Details on methodology are given in Chapter 1

Blocks covered: Siwan, Basantpur, BhagwanpurHat, Barharia, Andar, Darauli, Goriakothi, Raghunathpur, Siwan, Pachrukhi, Guthani, Maharajganj and LakriNabiganj.

Villages surveyed: Raniganj, Bherwaniya, Karahi, Murwar, Lakri, Sani bagahi, Haraipur, Haripur, Bagahi, Baghani, Fajilpur Deoriya, Sareya

Srikant, Done, Rajpur, Tara, Sirsiya, Babhnauli, Pachnerua, Amarpur, Gopalpur, Khujwa, Piparpati, Gopalpur, Piparpatti, Akopur, Sarari, Pratappur, Bania, Alapur, Lakri, Shikatiya, Vabhanauli, Barhoga jaddu, Kasdevara bangara, Ukhai Bichla Tola and Akopur (Fig. 1).

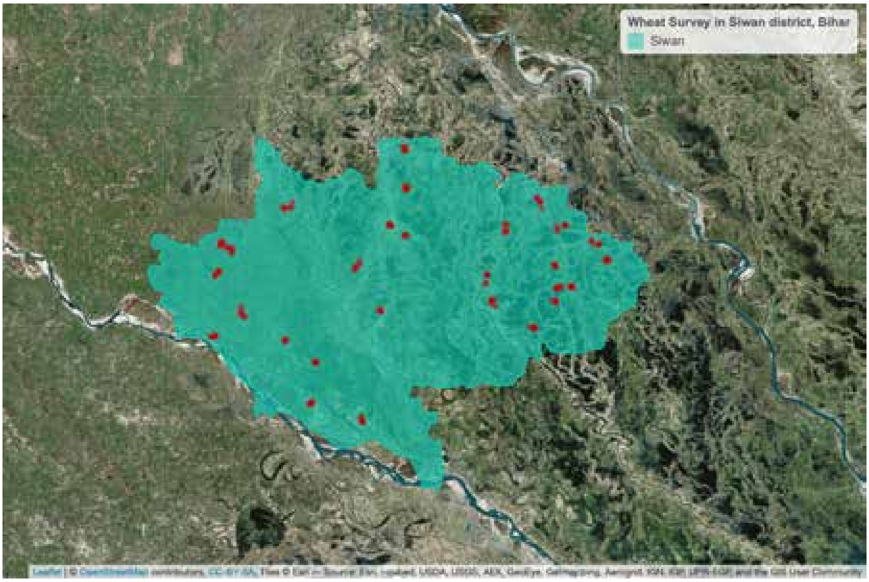

Fig. 1: GPS points of surveyed farms in Siwan

Results and Discussion

According to the surveyed farmers, the rice-wheat cropping system has the major dominance with 83% farmers, followed by 12% maize-wheat and 5% fallow-wheat system (Fig. 2). When asked about their preferred varieties, the timely sown varieties i.e. HD 2967, PBW 343 and PBW 502 were preferred by 17, 11 and 11%, respondents, respectively. The late sown varieties including PBW 154 and UP 262 are grown by 40 and 13%, respondents, respectively (Table 1). The average

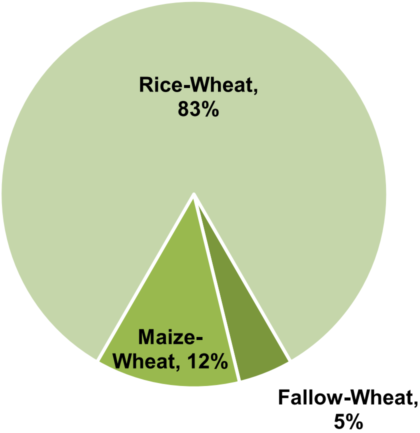

Fig. 2: Major cropping system prevailing in the district as per surveyed farmers

Table 1: Summary of important varieties including timely sown wheat varieties (TSWVs) and late sown wheat varieties (LSWVs) (2017-18) (n=198)

Varieties	Number of respondents	Percentage (%)
TWSWs		
HD 2967	33	16.67
PBW 502	21	10.61
PBW 343	22	11.11
LSWVs		
UP 262	26	13.13
PBW 154	80	40.40
Other*	16	8.08

*Includes PBW 550, HD 2733, SriRam 303 from TSWVs group and Kedar, Lok 1 and NL 1 from LSWVs group.

grain yield of timely sown varietal was 3.06 t ha^{-1} whereas late sown varieties gave a yield of 2.73 t ha^{-1} (Fig. 3). Forty two per cent (42%) responded that before 20 November provided 0.13 t ha^{-1} higher yield than the sowing done after 20 November but before December (Fig. 4). The N: P: K use by the surveyed farmers remained 133:66:28 and the average irrigation rate was 2.19 (Table 2). Lack of timely irrigation is one of the constraints for yield gap between two sowing schedules.

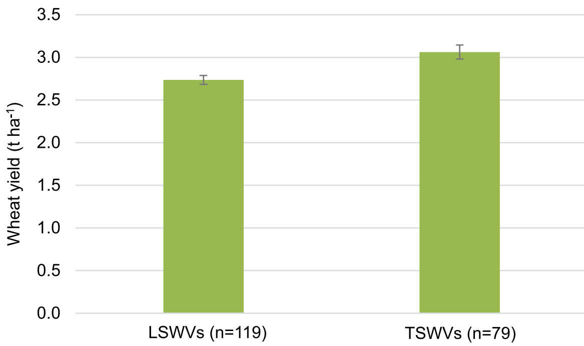

Fig. 3: Average grain yield of timely sown wheat varieties (TSWVs) and late sown wheat varieties (LSWVs) across different agronomic management options

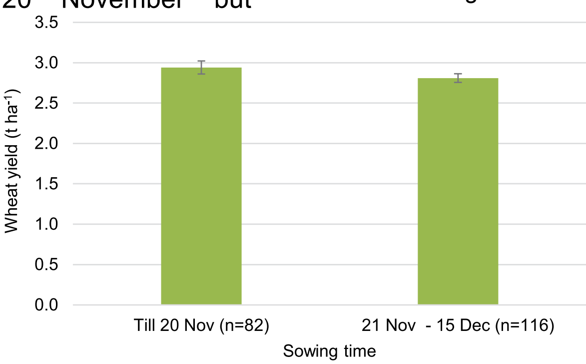

Fig. 4: Average grain yield of wheat as affected by three different sowing schedules across varieties and management practices

Table 2: The use rates of N: P_2O_5: K_2O (kg ha^{-1}) and irrigation frequencies of surveyed farmers (Potash users 85%)

NPK rates and irrigation frequency	Average use rates (kg ha^{-1})	SD	SE
N	133.16	35.12	2.50
P_2O_5	65.74	11.70	0.83
K_2O	28.31	11.49	0.89
Irrigation number	2.19	0.73	0.05

Nitrogen and phosphorus has been fully adopted by farmers. The use of K is lesser than the recommendation and it is still less in RWCS compared to other cropping systems. Farmers' rational for low K use depends on the yield response they get from the added nutrients. That is not happening. There were 48% respondents who are using herbicides whereas 19% did not use any weed management (Fig. 5). High cost of irrigation is causing yield losses because farmers escape irrigations at critical stages. Increased frequency of irrigation showed good results in this survey (Fig. 6). Irrigation management

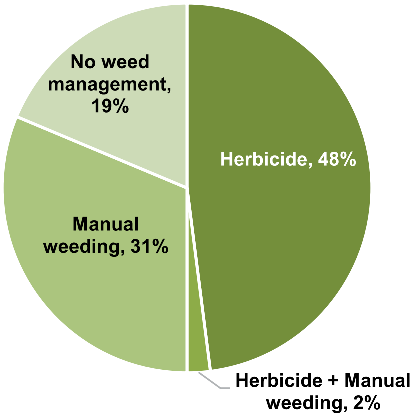

Fig. 5: Farmers reported weed management options practiced in the district (n=198)

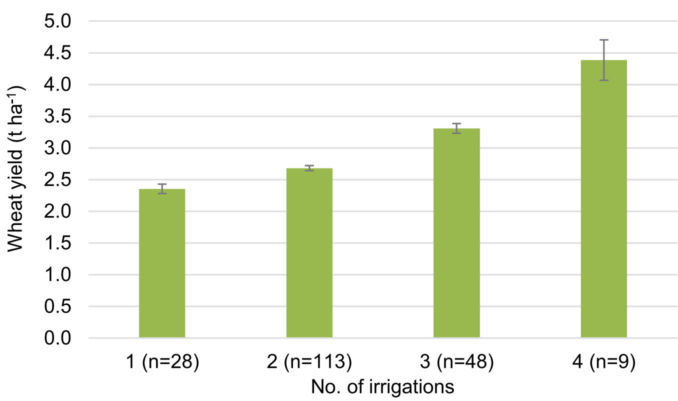

Fig. 6: The average grain yield of wheat under different irrigation frequencies

has showed good response with an average yield of 4.4 t ha^{-1}. In addition, weed management and crop establishment with zero tillage can be powerful factors that affect the performance of nutrients applied externally or internally in the soil. To harness them, we must understand their interactions with nutrients, varieties and sowing dates. The yield variability here seems to be heavily controlled by irrigation potential. We will require considerable changes in the irrigation potential as the fertilizer use is as per the recommendations (Tilman *et al.,* 2011). The importance of irrigation at grain filling stage was also highlighted by Jain *et al.,* (2017).

Conclusion

Bringing more resources to provide better access to irrigation is important in realising good yields in wheat. The efficiency of irrigation will further increase with improved weed management.

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Tilman, D., Balzer, C., Hill, J. and Befort, B.L. (2011).Global food demand and the sustainable intensification of agriculture. *Proc. Natl Acad. Sci.* USA. 108: 20260–20264.

3.36 Benefits of high fertilizer use will depend on irrigation, weed management and focus on timely sown wheat varieties

Bipul Kumar Mandal[1], Moben Ignatius[2], Sachin Sharma[1] and Manoj Kumar[1]

[1]Krishi Vigyan Kendra, Supaul
[2]International Maize and Wheat Improvement Center (CIMMYT)

Introduction

The soil type of Supaul is sandy clay loam. It has 11 blocks, 181 gram panchayats and 556 villages. It has a total of 259,049 ha cultivable land which supports a population of 2,229,146. The total area under rice is 112,077 ha and wheat is 51,184 ha. Farmers' concerns are related with low wheat productivity. The current cropping system dominated by rice-wheat and fallow wheat cropping systems showed some ecological issues related with water stagnation in the rainy season. The landscape diagnostic survey (LDS) was conducted to create a system that seeks the opinion of farmers, maintains checks and balances on what works and what does not work, and also to provide feedback to institutions on technologies that have not been largely accepted by farmers.

Methods

Details on methodology are given in Chapter 1

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, Khokhaha (Fig. 1).

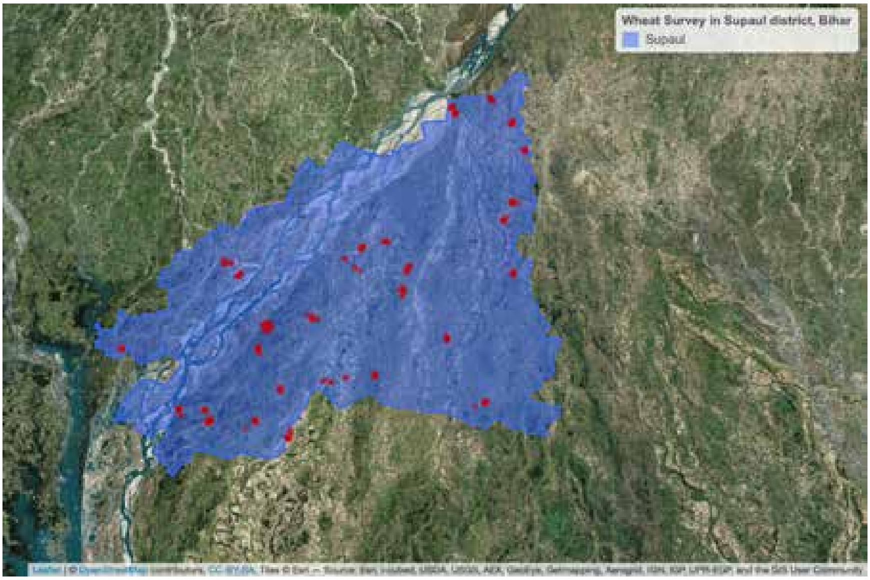

Fig. 1: GPS points of surveyed farms in Supaul

Results and Discussion

The grain yield in Supaul district was found affected by broad range of ecological factors. On an average, 71% farmers are dominated by rice-wheat cropping system (Fig. 2) whereas the rest 29% fell in fallow-wheat system as per the surveyed farmers. The varietal spectrum is dominated by NL 1 variety from Nepal with 31% reporting its adoption. The adoption of timely sown wheat varieties (TSWVs) like PBW 343 and PBW 502 including new varieties like ShriRam 303 and HD 2967

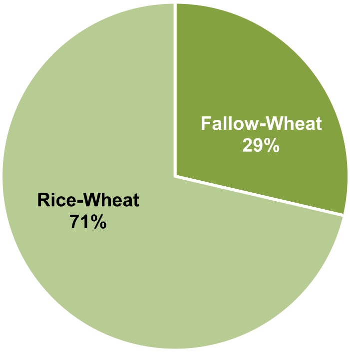

Fig. 2: Major cropping system prevailing in the district as per surveyed farmers

was also reported by 52% respondents (Table 1). Since 111 farmers were found to grow TSWVs and quite a large number from them have sown their wheat crop between 21 November and 15 December, the insufficiency in terms of yield could be due to low yield potential of NL 1 from within this sowing schedule. The farmer reported yield of LSWVs was 2.28 t ha^{-1} followed by TSWVs was 2.59 t ha^{-1} (Fig. 3). There was

Table 1: Summary of important varieties including timely sown wheat varieties (TSWVs) and late sown wheat varieties (LSWVs) (2017-18) (n=206)

Varieties	Number of respondents	Percentage (%)
TWSWs		
HD 2967	3	1.5
PBW 343	41	19.5
PBW 502	40	19
SriRam 303	24	12
LSWVs		
Gautam	3	1.5
UP 262	13	6.5
HI 1563	2	1
NL 1	63	30
NL 2	3	1.5
HUW 234	6	3
Other	8	4

*Includes DBW 17, HD 2781, HD 3086 from TSWVs group and Vijay, RR 21 from LSWVs group.

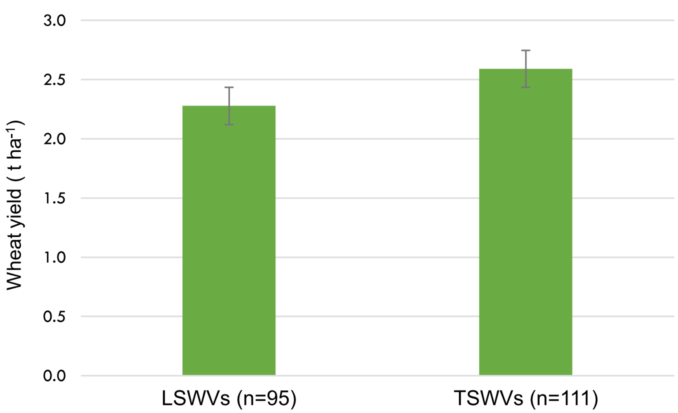

Fig. 3: Average grain yield of timely sown wheat varieties (TSWVs) and late sown wheat varieties (LSWVs) across different agronomic management options

a gradual decrease in yield with delay in sowing (Fig. 4). The NPK rate used by the surveyed farmer was 121:57:25 with an irrigation frequency of 2.47 (Table 2). With irrigation frequency being more than many other district (Fig. 5) but still lower yields, the adoption of low yielding varieties

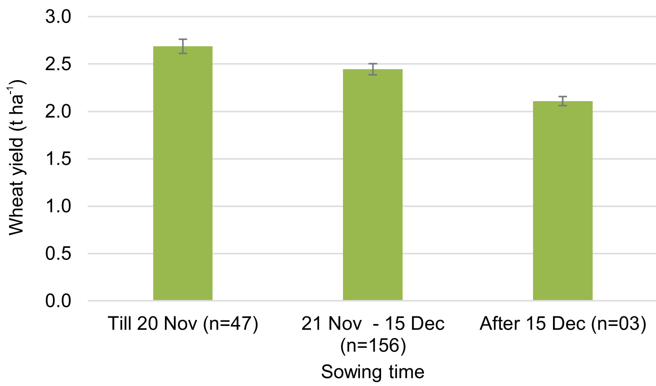

Fig. 4: Average grain yield of wheat as affected by three different sowing schedules across varieties and management practices

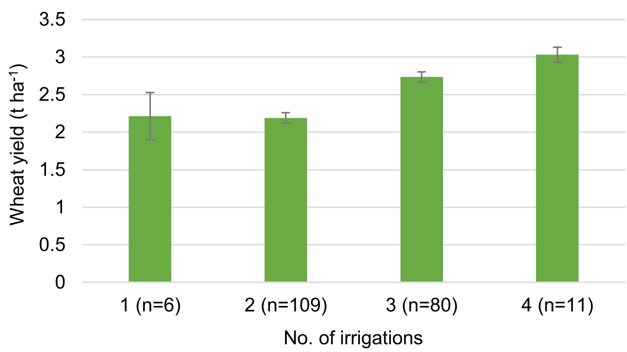

Fig. 5: The average grain yield of wheat under different irrigation frequencies.

Table 2: The use rates of N: P_2O_5: K_2O (kg ha^{-1}) and irrigation frequencies of surveyed farmers (Potash users 98%)

NPK rates and irrigation frequency	Average use rates (kg ha^{-1})	SD	SE
N	118.16	34.51	2.40
P_2O_5	57.44	18.10	1.26
K_2O	25.42	11.92	0.84
Irrigation number	2.47	0.64	0.04

could be a cause of concern. There is a need to tailor the wheat development cycle which determines the number of grains and their test weight. It will totally depend on the time to initiation of flowering. Local varieties like NL 1 may be able to beat the terminal heat but the number of grains per spike may not match the potential of TSWVs as found in this survey. The cap on flower initiation will depend on the time of sowing. Low temperatures (from early sowings) and long pre-flowering period favour greater grain number (Prasad *et al*., 2008) which may not be possible with local varieties like NL1. There were 16% of surveyed farmers who did not adopt any weed management (Fig. 6).

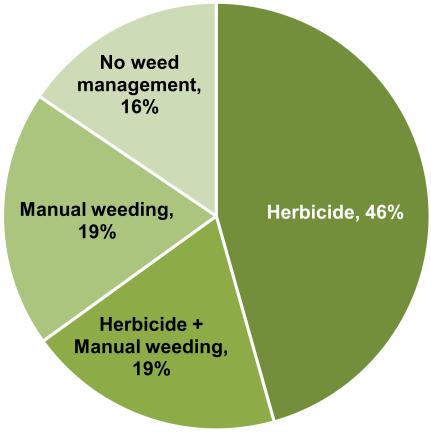

Fig. 6: Farmers reported weed management options practiced in the district (n=205)

We need to seek yield growth opportunities and make sure to concentrate on zero tillage technology (Keil *et al.,* 2015) which has not yet been accepted by farmers. In wheat what has mattered most is the terminal heat. Early wheat sowing has helped in escaping this. But the issue of crop establishment and proper weed management need to be resolved.

Conclusion

We should cap the flowering time of wheat sometime in the mid-February and integrate it with irrigation and weed management.

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3.37 Better time management for improving wheat productivity in district of Vaishali

Devender Kumar[1], Pankaj Kumar[2], Madhulika Singh[2] and Shahnawaaz Rasool Dar[3]

[1]Krishi Vigyan Kendra, Vaishali
[2]International Maize and Wheat Improvement Center (CIMMYT)
[3]International Rice Research Institute (IRRI)

Introduction

District Vaishali falls in the Agro-climatic zone I of Bihar. The soils are sandy loam and loam with intensive cultivation of cereal based systems with 150,200 ha net sown area, out of which the net irrigated area is 39,800 ha. The total area under rice is 85,896 ha and wheat is 43,138 ha. The irrigation is given through diesel pump based bore wells. It has 16 blocks, 387 gram *panchayats* and 1,827 villages. The organic matter content of soil is 0.2-1.0%. The available N is in between 150-350, P 5-50 and K 100-300 kg ha^{-1}. The landscape diagnostic survey (LDS) was conducted to understand the causes and effects of different technologies on yield realization of wheat. The survey sought the adoption pattern of different technologies and their contribution towards grain yield. This will help to set priorities to overcome the problem of stagnant growth in wheat.

Methods

Details on methodology are given in Chapter 1

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).

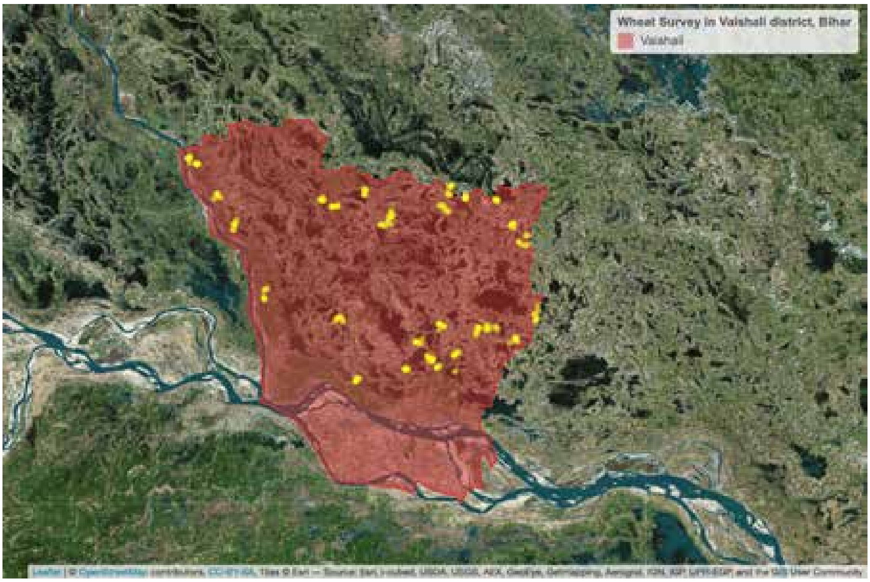

Fig. 1: GPS points of surveyed farms in Vaishali district

Results and Discussion

According to the surveyed farmers the district remains dominated with rice-wheat cropping system (RWCS) with 95% HHs. The rest 5% remains fallow –wheat cropping system (Fig. 2). The LDS data showed that approximately 80% farmers reported the adoption of PBW 343 and PBW 502. New varieties like HD 2967 have occupied only 5% space (Table 1). Combined together, the turnaround time for new varieties is very low. During last 25 years, we have reached

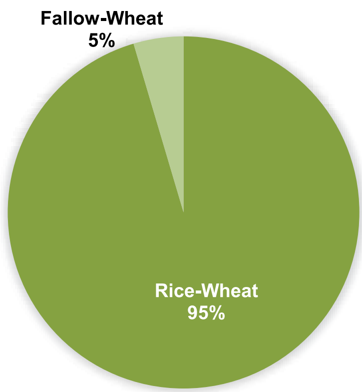

Fig. 2: Major cropping system prevailing in the district as per surveyed farmers

Table 1: Summary of important varieties including timely sown wheat varieties (TSWVs) and late sown wheat varieties (LSWVs) (2017-18) (n=196)

Varieties	Number of respondents	Percentage (%)
TWSWs		
HD 2733	3	1.53%
HD 2967	9	4.59%
PBW 343	146	74.49%
PBW 502	11	5.61%
LSWVs		
UP 262	23	11.73%
Kundan	1	0.51%
PBW 154	3	1.53%

a point at which new varieties are not out yielding the existing ones. Within two broad groups, timely sown wheat varieties (TSWVs) provided 0.28 t ha^{-1} more yield than late sown wheat varieties (LSWVs) as seen in Fig. 3. An imbalance in strength of new varieties compared to existing varieties and the likely success of TSWVs against LSWVs need resolution especially in the arena of terminal heat tolerance under late sown conditions. The grain yield of wheat under early wheat sowing was 3.7 t ha^{-1} against 3.01 t ha^{-1} under late sowing. The gain of 0.5 t ha^{-1} just by advancing the wheat sowing is enough to set priority in favour of early wheat sowing (Fig. 4). On an average, the N: P_2O_5:K_2O use at 147:71:36 kg ha^{-1} is on the higher side especially for phosphorus (Table 2). It becomes more important if we account phosphorus use in rice. Most farmers (95%) use one or the other method of weed management (Fig. 5). High grain yield recorded due to early sowing, could be due to high grain weight per ear head which is a function of higher grain

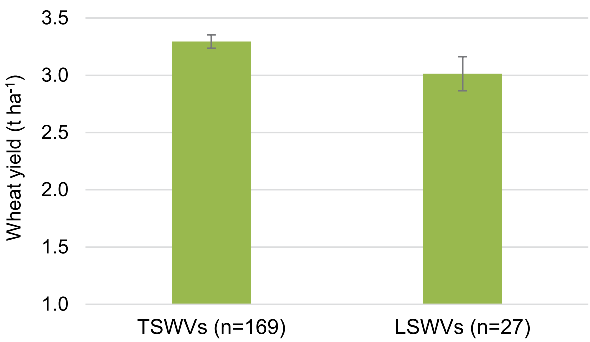

Fig. 3: Average grain yield of timely sown wheat varieties (TSWVs) and late sown wheat varieties (LSWVs) across different agronomic management options

Table 2: The use rates of N: P_2O_5: K_2O (kg ha^{-1}) and irrigation frequencies of surveyed farmers (Potash users 91%)

NPK rates and irrigation frequency	Average use rates (kg ha^{-1})	SD	SE
N	146.77	23.80	1.70
P_2O_5	70.86	18.09	1.30
K_2O	35.67	9.43	0.70
Irrigation number	2.26	0.51	0.04

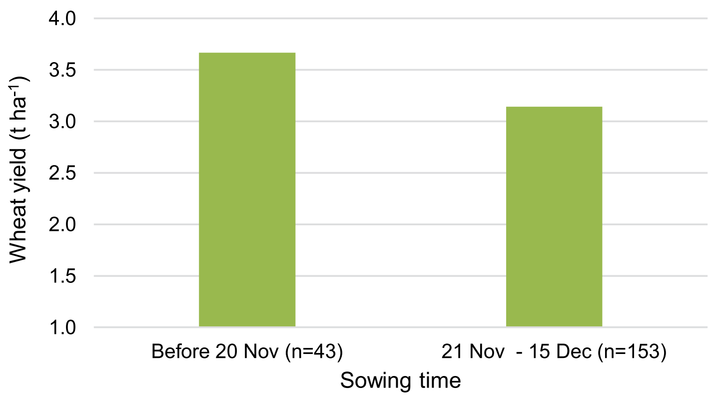

Fig. 4: Average grain yield of wheat as affected by three different sowing schedules across varieties and management practices

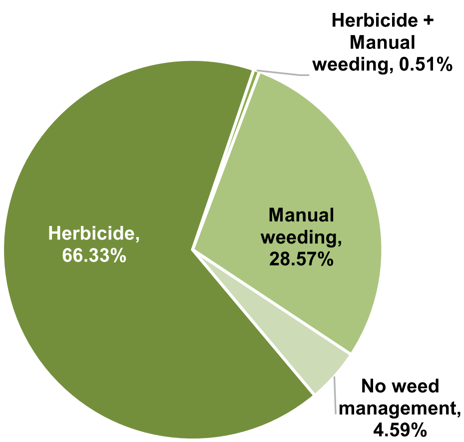

Fig. 5: Farmers reported weed management options practiced in the district (n=196)

number and their test weight. The irrigation frequency at 2.26 is very low (Fig. 6). The district average can be significantly increased, if water stress during 3-4 weeks after flowering could be avoided. The combined effect of water stress and terminal heat of 3-4 weeks after flowering is the most serious constraint in this district. Such types of responses have also been reflected in the previous work at other places (Sairam *et al*., 1992; Amin *et al*., 1995).

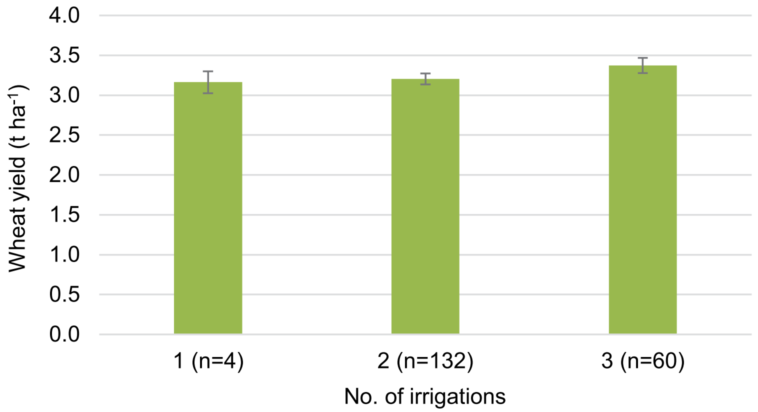

Fig. 6: The average grain yield of wheat under different irrigation frequencies

Conclusion

The changes in the sowing time towards the first two weeks of November and new associated agronomic options will change the prospects for wheat in favour of high yields.

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3.38 Low wheat productivity still a constraint in West Champaran

Riyaz Ahmad[1], Prabhat Kumar[2], Thakur Prasad Mahato[1] and Ajay Kumar[2]

[1]Krishi Vigyan Kendra, Madhopur

[2]International Maize and Wheat Improvement Centre (CIMMYT)

Introduction

The soil type in the district of West Champaran is sandy loam to clay loam to saline soil. It has 18 blocks, 315 gram *panchayats* and 1,507 revenue villages. The district has 271,000 ha cultivable land with a population of 3.91 million (2011 census). The cropping intensity is 145%. The net irrigated area is 76.38%. The total area under rice is 90,000 ha whereas under wheat is 95,000 ha. The KVK and CSISA team surveyed the farmers and tried to find out the reasons behind the adoption of different production practices in their farms possible intervention to raise the productivity.

Methods

Details on methodology are given in Chapter 1

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).

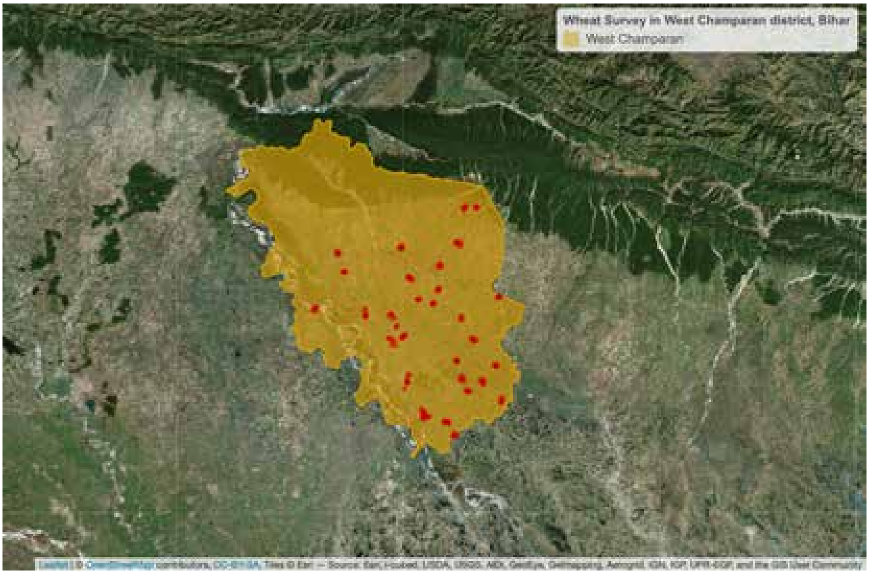

Fig. 1: GPS points of surveyed wheat forms across West Champaran

Results and Discussion

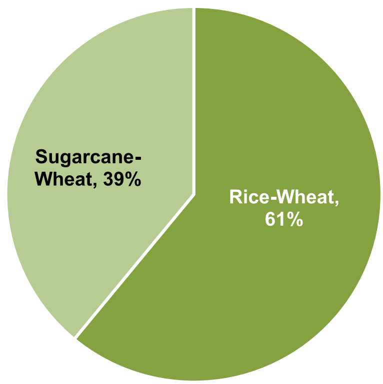

Fig. 2: Major cropping system prevailing in the district as per surveyed farmers

The LDS indicated that in addition to rice-wheat cropping system (RWCS) which is prevalent with 61% farmers, the sugarcane-wheat cropping system (SWCS) is also important with 39% farmers (Fig 2). More than 50% farmers use LSWVs with maximum adoption rate of 49% for UP 262. Even among TSWVs, adoption of PBW 343 is still popular with 27% farmers. On the whole, 42% farmers use TSWVs (Table 1). However, the yield levels of TSWVs are almost same to that of LSWVs (Fig. 3). Late sowing beyond 15 December reduces the yield by more than 0.8 t ha^{-1}. This is where the yield growth will come in this district (Fig. 4). Farmers reported the $N:P_2O_5:K_2O$ use at 107:45:25 kg ha^{-1} (Table 2) (Fig. 5). The average frequency of irrigation is low at 1.62 but 1 irrigation and 3 irrigations reflected significant yield grain compared to no irrigation (Fig. 6). Relatively high K rate compared to other RWCS dominated districts is

Table 1: Summary of important varieties including timely sown wheat varieties (TSWVs) and late sown wheat varieties (LSWVs) (2017-18) (n=205)

Varieties	Number of respondents	Percentage (%)
TWSWs		
HD 2967	16	7.80
PBW 343	54	26.34
ShriRam 303	15	7.32
LSWVs		
HUW 234	6	2.93
RR 21	5	2.44
UP 262	101	49.27
Other*	8	3.90

*Includes PBW502 from TSWVs group and Baaz, Kundan, Lok 1, PBW 154 from LSWVs group.

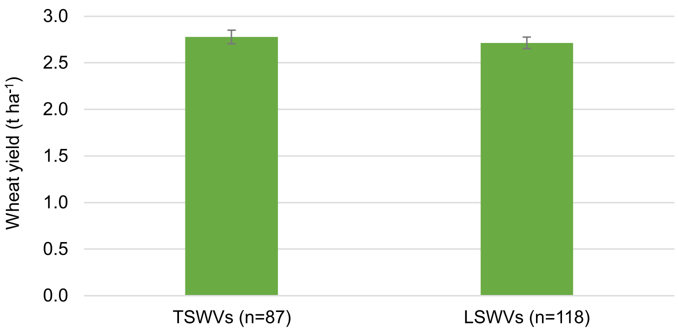

Fig. 3: Average grain yield of timely sown wheat varieties (TSWVs) and late sown wheat varieties (LSWVs) across different agronomic management options

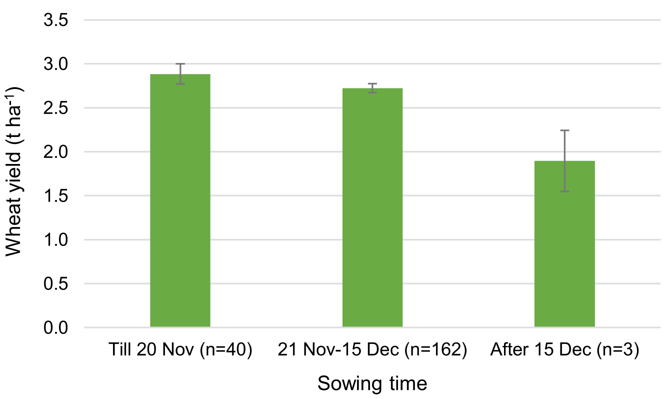

Fig. 4: Average grain yield of wheat as affected by three different sowing schedules across varieties and management practices

Table 2: The use rates of N: P_2O_5: K_2O (kg ha^{-1}) and irrigation frequencies of surveyed farmers (Potash users 91%)

NPK rates and irrigation frequency	Average use rates (kg ha^{-1})	SD	SE
N	107.27	32.96	2.32
P_2O_5	44.69	13.17	0.92
K_2O	24.81	9.19	0.67
Irrigation number	1.62	0.58	0.04

because of SWCS. P use is more than the potential use especially when the irrigation frequency is so low. Weeds are an important issue but 34% respondents do not use any control method. Crop available trend from this data showed that the pattern towards adoption of TSWVs and early wheat sowing is overdue. If the possibility of rise in temperature is considered, LSWVs will be even more vulnerable because their flowering time will not coincide with optimum temperature conditions and then lack of irrigation

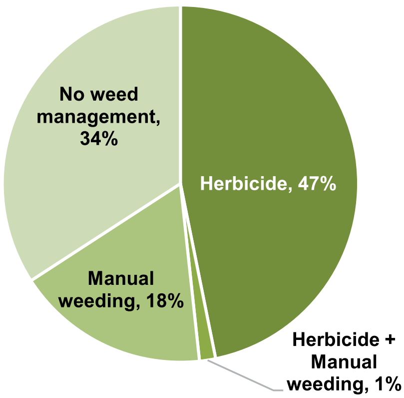

Fig. 5: Farmers reported weed management options practiced in the district (n=205)

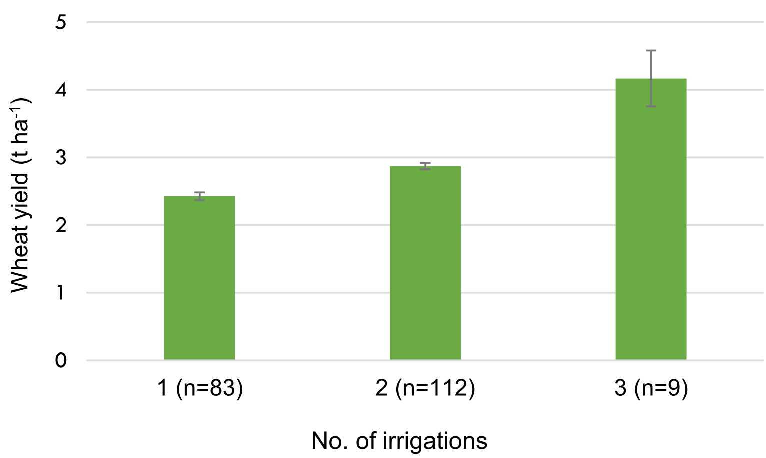

Fig. 6: The average grain yield of wheat under different irrigation frequencies

puts even more stress. High temperature (>35°C) after anthesis can significantly reduce grain number and quality (Tashiro and Wardlaw, 1990). All other agronomic management options like weed management will come into play only if these fundamentals are resolved. These results showed a poor yield growth and that is why many technologies were not accepted.

Conclusion

The sowing date has to be sequentially advanced to improve the yield growth. The poor record of yield growth is also due to lack of irrigation especially last irrigation and very poor weed management.

Reference

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3.39 Tracking seasonal variation in weed spectrum and yield of rice in Cooch Behar, West Bengal

B. Roy[1], N.C. Banik[2], S. Sarkar[1] and A. Ajay[3]

[1]Krishi Vigyan Kendra (KVK), Cooch Behar
[2]International Rice Research Institute (IRRI)
[3]International Maize and Wheat Improvement Centre (CIMMYT)

E-mail: coochbeharkvk@gmail.com; cobkvk@yahoo.co.in

Introduction

In West Bengal, rice is grown in three seasons viz. Aus (late winter), Aman (summer) and Boro (winter). Though, the main season for rice cultivation is Aman, rice productivity is highest in Boro season. This survey was conducted jointly by KVK, Cooch Behar and Cereal Systems Initiative for South Asia (CSISA) to get better insights about production practices of rice-rice cropping system in Cooch Behar. The purpose of the survey was to gather widespread data sets from the district on all parameters of rice production system but more specifically on weed spectrum and current weed control measures being applied by farmers. This survey would generate weed information at landscape level for better targeting.

Method

Thirty villages were randomly selected based on the probability proportionate to size from the Census 2011 data. From these 30 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), an Android based Digital

Data Collection App. Each farmer was interviewed on rice production practices for Aman as well as Boro seasons and their locations were geo-tagged (Fig. 1).

Fig. 1: Distribution of respondents in Cooch Behar, West Bengal

Results and Discussion

Yield variation: The study revealed that rice production practices vary across seasons and so the yield. Rice yields of Aman season (3.70 t ha^{-1}) and Boro season (5.33 t ha^{-1}) were found to be significantly different (Fig. 2). This could be majorly due to seasonal variation in weather conditions and specific sets of practices being applied by farmers as per seasons.

Weed spectrum: Weed control in rice production is one of the most important components as its severity negatively effects grain yield

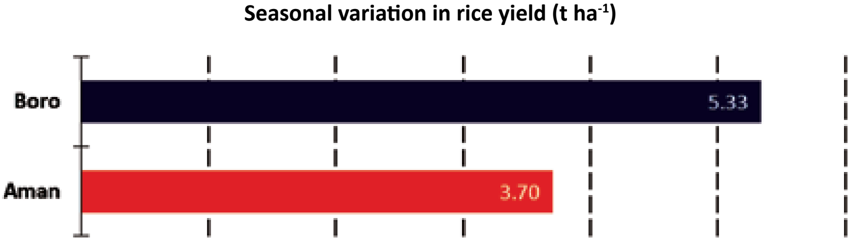

Fig. 2: Yield variation by season in Cooch Behar, West Bengal

(Veeraputhiran and Balasubramanian, 2013). If not managed on-time, weeds can incur yield loss upto 50%. Mukherjee *et al.,* (2008) reported similar observation from an experiment at Research Farm of Uttar Banga Krishi Viswavidyalaya, Cooch Behar that the sedges *Cyperus flavidus, Cyperus difformis, Fimbristylis miliacea, Scirpus juncoides* and grass *Cynodon dactylon* were aggressive and continuously emerged throughout the crop growth in wet seeded rice. So, it becomes important to rightly identify common seasonal weed flora to plan its control at landscape level. The study revealed that *Cynadon dactylon*, *Marsilea minuta, Cyperus irria, Cyperus difformis and Fimbristylis spp* were the top five weeds infesting rice crop in Cooch Behar. Their ranking by farmers based on severity of damage suggested that

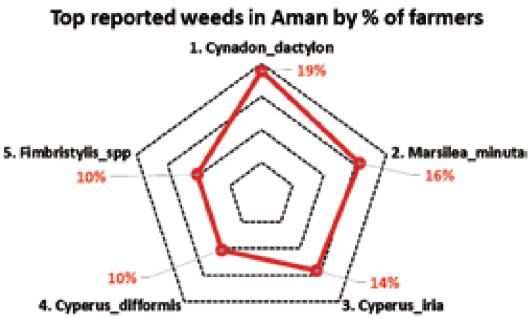

Fig. 3: Top five weeds of Aman in Cooch Behar, West Bengal

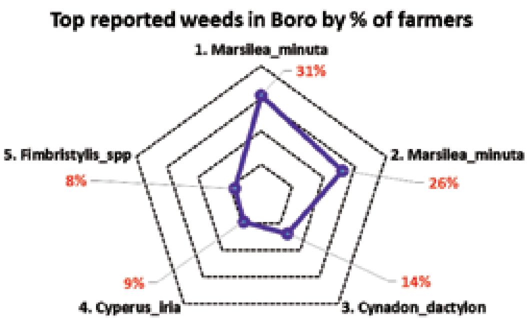

Fig. 4: Top five weeds of Boro in Cooch Behar, West Bengal

infestation intensity of weed species differs by season. Results of the survey suggested that *Cynadon dactylon* was the most problematic weed in Aman whereas *Marsilea minuta* is the most problematic weed in Boro season. Top five problematic weeds of Aman as per rank are given in Fig. 3. Similarly, top five problematic weeds of Boro as per rank are given in Fig. 4.

The study revealed that 68% farmers apply herbicide in rice but among them 97% use pre-emergence (Pretilachlor or Butachlor) herbicides & rest 3% only use post-emergence (2,4 – D or pyrazosulfuron) herbicides.

Conclusion

The study revealed that productivity of Aman rice (3.70 t ha^{-1}) is significantly lower than Boro rice (5.33 t ha^{-1}). *Cynadon dactylon*, *Marsilea minuta*, *Cyperus irria*, *Cyperus difformis* and *Fimbristylis* spp are the top five weeds which effect rice crop both in Aman & Boro seasons in terms of occurrence and severity of damage. It was found that farmers mostly apply pre-herbicides, only 3% farmers use post-emergence herbicide to control weeds in rice.

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3.40 Current rice production practices and relationship of seedling age with crop yield in Cuttack, Odisha

D.R. Sarangi[1], B.K. Mohapatra[2], A. Ajay[3] and R.K. Mohanta[1]

[1]Krishi Vigyan Kendra (KVK), Cuttack
[2]International Rice Research Institute (IRRI)
[3]International Maize and Wheat Improvement Centre (CIMMYT)

E-mail: kvkcuttack@gmail.com; dillipsarangi99@gmail.com

Introduction

It is pertinent to understand farmers' current crop production practices and their effects on crop yield for appropriate technology targeting. This survey was conducted jointly by KVK-Cuttack and Cereal Systems Initiative for South Asia (CSISA) to get better insights of existing rice production practices in Cuttack. As far as rice production is concerned, crop establishment method is important variable in determining yield (Hobbs, 2001) and (Saharawat *et al.*, 2010). Also, the suitable varietal selection based on yield potential and agro-ecology forms the basis of higher yield achievement. Another important component for getting higher yield in transplanted rice is the seedling age. Previous research suggest that 30 days old seedling is appropriate for transplanting (Brar *et al*., 2012). This study tracks the current rice establishment methods and varietal use pattern in Cuttack. Efforts were also made to establish the linkage between seedling age and rice yield.

Method

Thirty villages were randomly selected from Cuttack district using 'probability proportionate to size' method using census 2011 data.

Selection of 7 households from each of these 30 villages was done randomly using respective voter lists of the villages. Accordingly, 210 farmers were surveyed in 2018 using digital questionnaire on ODK. Geo-tagged locations of respondents are furnished in Fig. 1.

Fig. 1: Sample distribution in Cuttack, Odisha

Results and Discussion

Crop establishment: Result highlighted that during *kharif* 2017, 69% farmers established their rice crop through manual transplanting while rest 31% went with manual direct seeded rice (DSR). Further bifurcation suggested that random transplanting was the most commonly applied method (59%) along with some farmers who also followed line transplanting (10%). Among DSR, *beushening* was reported to be the most common practice (21%) whereas simple broadcasting was followed by 10% farmers (Fig. 2). Only one case of DSR was found where farmer had used seed-cum-fertilizer drill. There is immense possibility to test mechanized methods of crop establishment viz. mechanical paddy transplanter and seed-cum-fertilizer drill.

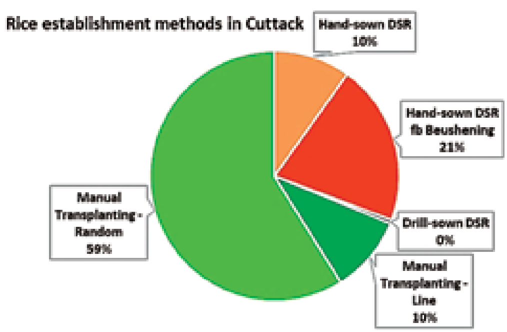

Fig. 2: Crop establishment methods in Cuttack, Odisha

Varieties: Rice varietal spectrum was found to be very diverse in Cuttack where farmers are currently using nearly 20 different varieties. Amongst them, Pooja variety has got the highest preference. 34% farmers reported using Pooja (Fig. 3). This variety was released by National Rice Research Institute (NRRI) in 1990. It is of 150 days duration and has got good yield potential (5.0 t ha^{-1}). Another two common rice varieties in Cuttack are Kalachampa and Pradhan Dhan. Both have got equal share in terms of farmers' acceptance (11%).

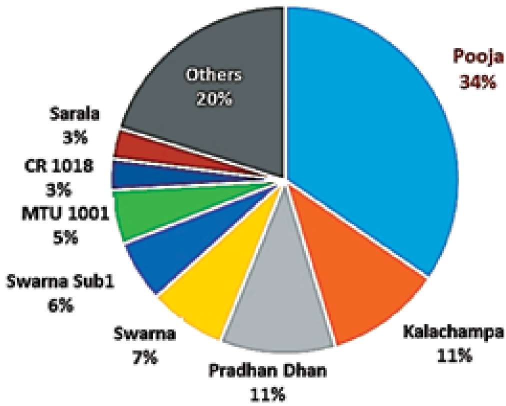

Fig. 3: Transplanted rice varietal spectrum of Cuttack, Odisha

Seedling age: It was found that farmers use rice seedlings of 15 days old up to 65 days old. But, the largest percentage of farmers (57% under transplanting group) reported using seedling of 25-34 days old. The same age group of seedling was found to be the most productive (4.08 t ha^{-1}). Deviation to either side by 10 days didn't effected the yield at greater extent (Fig. 4). This could be due to the fact that the

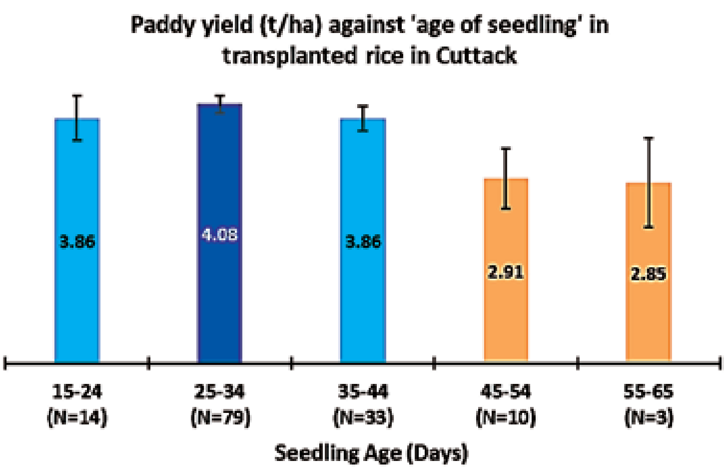

Fig. 4: Effect of seedling age on rice yield in Cuttack

most common rice varieties in Cuttack are of quite long duration. Kalachampa is of 150-170 days and Pradhan Dhan/CR Dhan 409 is of 160-165 days duration. But if, seedlings became older than 45 days, the yield reduction was found to be significantly drastic.

Conclusion

Data was collected electronically through Open Data Kit (ODK) to minimize error and to save time. Study revealed that there is almost no mechanization for rice establishment in Cuttack. Manual random transplanting (59%) and hand-sown DSR followed by beushening (21%) are the two major rice establishment methods. Rice variety, Pooja (34%) is the most favoured variety in Cuttack. In transplanting cases, farmers who used rice seedlings of 25-34 days achieved the average yield of 4.08 t ha^{-1}, which was higher than all other groups.

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3.41 Performance of different crop establishment methods in low land ecologies of Odisha

D.R. Sarangi[1], N.C. Banik[2], A. Das[1], V. Kumar[2], P. Panneerselvam[2], T.R. Sahoo[1] and M. Chourasia[1]

[1]Krishi Vigyan Kendra (KVK), Cuttack & Bhadrak
[2]International Rice Research Institute (IRRI)

E-mail: kvkcuttack@gmail.com; dillipsarangi99@gmail.com

Introduction

Shortage of labour in present day agriculture has driven the shift of interest on direct-seeded rice (DSR) from puddled transplanted rice (PTR) in India as well as in many other countries in south-east Asia (Pandey and Velasco, 1999). On the other hand in traditional broadcasted rice (beushening) yields are reduced because of poor weed control, reduced plant stand, lodging and low fertilizer use-efficiency etc. Seed-drill sown DSR can be a good alternative in this scenario. To test the performance of common rice establishment methods, KVK (Cuttack and Bhadrak) and Cereal Systems Initiative for South Asia (CSISA) collaboratively conducted this trial in two districts of Odisha.

Method

Treatment	Interventions
T1	Manual broadcasting followed by *beushening*
T2	Direct seeded rice (drill sown in dry soil condition)
T3	Manual random transplanting

The trial was conducted on farmers' fields in a participatory mode during *kharif* 2017. Sites were selected in the working domain of KVKs in

Cuttack and Bhadrak districts. Five replications for each treatment were undertaken. Plot sizes selected were in the range of 300 m^2 to 800 m^2. Rice variety selected for the trial was Swarna Sub-1 and planting sowing was done manually in broadcasting and random transplanting and DSR was done through seed-cum-fertilizer drill.

Results and Discussion

The results suggested that drill sown DSR has dual advantage of yield gain and cost saving. In this trial, DSR (T2) produced yield advantage of 0.78 t ha^{-1} compared to T1 i.e., traditional broadcasted rice (*beushening*). Also, T2 produced yield advantage of 0.6 t ha^{-1} compared to traditional manual random transplanting (T3), as given in Fig. 1. In these two coastal districts, there is abundant pre-monsoon rain. Rice established early in dry condition gets into advantageous situation by developing good crop stand by the time heavy monsoon starts. Seed-cum-fertilizer drill used for planting maintains plant spacing and facilitates proper placement of basal fertilizers. So, this method also creates favourable growth environment for rice. It can be interpreted that better yield in case of drill sown DSR was due to timely and proper crop establishment. In cost terms, it was calculated that DSR costed less by INR 10,000 per ha compared to *beushening* and INR by 5,000 per ha compared to manual random transplanting. This is another big advantage in present days labour scarce scenario.

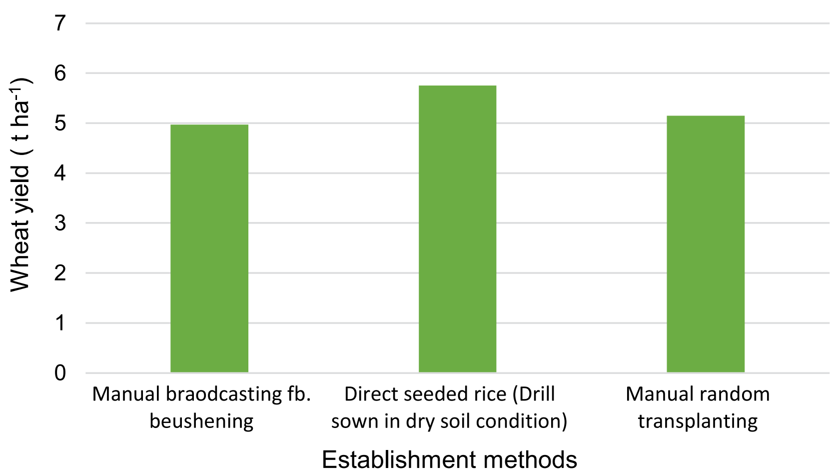

Fig. 1: Average rice yields in three crop establishment treatments in low land ecologies of Odisha

Conclusion

In low land ecologies of Odisha, direct seeding of rice (DSR) can be an alternative method that enable farmers to establish rice early, consequently harvest early, reduce the labor and irrigation water requirements for crop establishment and thus paves way for early sowing of succeeding crop. Adaptive research trial was conducted by KVKs, Cuttack and Bhadrak designed to compare the performance of different establishment method in rice. Trial results suggest that DSR produces yield advantage of 0.78 t ha^{-1} compared to beushening and 0.6 t ha^{-1} compared to manual random transplanting with reduction in cost of cultivation.

Reference

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3.42 Effect of rice establishment methods on grain yield of rice and fertilizers' use rate in Khordha, Odisha

N. Ananth[1], B.K. Mohapatra[2], A. Ajay[3] and S. Singh[1]

[1]Krishi Vigyan Kendra (KVK), Khordha
[2]International Rice Research Institute (IRRI)
[3]International Maize and Wheat Improvement Centre (CIMMYT)

E-mail: ananthkvk100@gmail.com

Introduction

The survey was conducted jointly by KVK-Khordha and Cereal Systems Initiative for South Asia (CSISA) to generate data-based evidences on current crop establishment methods and fertilizer usage. Crop establishment method particularly in case of rice is an important component in determining yield (Saharawat *et al*., 2010). Rice established through transplanting provides better environment for growth of seedlings by providing proper plant spacing, reduced early weed competition, etc. Fertilizer rates especially appropriate dose of nitrogen ensures better rice yield if applied in right combination with P_2O_5 and K_2O (Adhikari *et al*., 1999). It seems that rice yield in Khordha can be enhanced through optimizing the use of nitrogen fertilizer as the current level is very low across all methods of establishment.

Methods

Details on methodology are given in Chapter 1

Thirty villages were randomly selected from Khordha district using 'probability proportionate to size' method using census 2011 data. Selection of 7 households from each of these 30 villages was done randomly using respective voter lists of the villages. Accordingly, 210 farmers were surveyed in 2018 using digital questionnaire on ODK. Geo-tagged locations of respondents are furnished in Fig. 1.

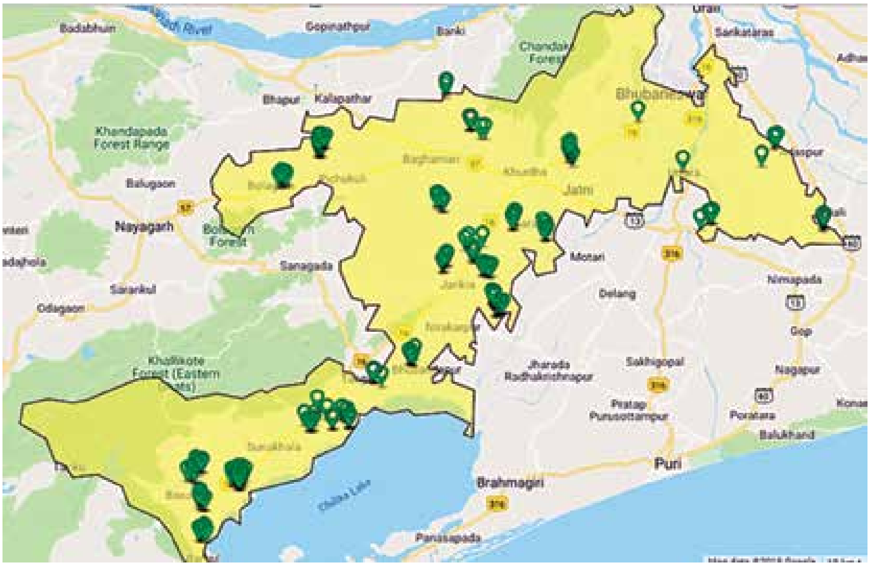

Fig. 1: Sample distribution in Khordha, Odisha

Results and Discussion

Crop establishment: We found that 58% farmers in the district are practicing transplanting whereas rest 42% farmers do broadcasting for rice establishment during *kharif* 2017. Within transplanting, majority of farmers do random transplanting while a small portion opts for transplanting in line. Beushening, an age old practice, is still reported by 16% farmers (Fig. 2). In terms of yield, transplanting farmers got better yield compared with farmers doing broadcasting. There is a need to understand the reasons for large scale adoption of broadcasting inspite of the fact that this method does not provide good yield.

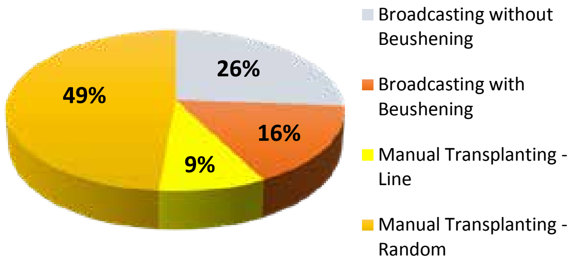

Fig. 2: Rice establishment methods in Khordha, Odisha

Fertilizers use: Average usage rate of N:P:K was found to be 52:36:35 kg ha^{-1} against state recommendation of 80:40:40 kg ha^{-1}. It specifically highlighted the lower use of nitrogen fertilizer across all the four methods (Fig. 3). Another finding of this study was that the first top dressing was skipped by 40% farmers. That could be one of the reasons for lower dose of nitrogen and even for lower yields.

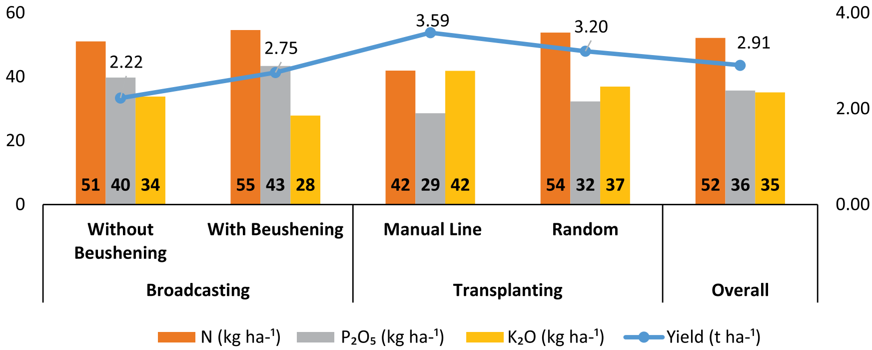

Fig. 3: Nutrient application rates in Khordha, Odisha

It was further identified that application of P_2O_5 was comparatively higher in broadcasting whereas application of K_2O was higher in transplanting. Yield under line transplanting was reported to be better (3.59 t ha^{-1}) even under low nitrogen rate. That signals that this method of transplanting has got some advantages. Random transplanting was also found to be somewhat better compared with broadcasting methods. Either methods of broadcasting was found to be not suitable as the yield levels were quite low (< 3.0 t ha^{-1}). Looking at this, interaction at almost similar level of fertilizers, transplanting clearly seems to be providing better outputs. It can also be foreseen that if farmers enhance nitrogen dose in transplanting, the yield level may further improve.

Conclusion

Study found that nitrogen application rate is much lower in the district compared to state recommendation. Among four different methods of rice establishment, farmers reported using lower amount of N (55 kg ha^{-1}) and P_2O_5 (43 kg ha^{-1}) in beushening and higher amount of K_2O (42 kg ha^{-1}) in manual line transplanting method of establishment. Manual line transplanting was found to be the best yielder (3.59 t ha^{-1}). Both the methods of broadcasting were low yielders still 42% farmers in the district are opting these methods of crop establishment.

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3.43 Maize yield optimization through adequate plant population and balanced fertilization in plateau ecology of Odisha, India

S. Pattnaik[1], N. Parida[2], W. Iftikar[2] and A. Ajay[2]

[1]Krishi Vigyan Kendra (KVK), Mayurbhanj-1
[2]International Maize and Wheat Improvement Center (CIMMYT)

E-mail: kvkmayurbhanj1.ouat@gmail.com

Introduction

Plateau ecology of Odisha is dominated by nutrient deficit red soils. Farmers mostly plant maize behind country plough that leads to sub-optimal plant population. Fertilizer recommendation (120:60:60) is also very generic. Therefore, the present investigation was planned to optimise plant population and nutrient management for hybrid maize. It is evident from the previous research that appropriate plant population play an important role in achieving better maize yield (Abuzar *et al.*, 2011). This experiment was conducted jointly by KVK (Mayurbhanj-1) and Cereal Systems Initiative for South Asia (CSISA) to carve-out desired plant population and nutrient doses for plateau ecology of Odisha.

Method

Main Plot	Sub-plot
S1 (Spacing 60 cm × 30 cm)	F1 ($N:P_2O_5: K_2O$ = 120:60:60)
	F2 ($N:P_2O_5: K_2O$ = 150:60:60)
	F3 ($N:P_2O_5: K_2O$ = 150:75:60)

Main Plot	Sub-plot
S2 (Spacing 60 cm × 20 cm)	F1 ($N:P_2O_5: K_2O$ = 120:60:60)
	F2 ($N:P_2O_5: K_2O$ = 150:60:60)
	F3 ($N:P_2O_5: K_2O$ = 150:75:60)

The trial was conducted on farmers' field in a participatory mode during *kharif* 2017. Sites were selected jointly with State Department of Agriculture in major maize growing clusters of Mayurbhanj district. Five replications for each treatment were taken. Plot size selected were in the range of 500 m^2 to 1,000 m^2. Variety (P 3401) selected for the trial was of long maturity class and planting was done manually in line.

Results and Discussion

Results suggested that maize yields in this ecology can be improved through increasing the plant population as well as increasing the doses of fertilizers. Maize yield improved by increasing the amount of nitrogen alone but the magnitude of this increase was even higher through increased doses of both nitrogen and phosphorus. At same level of fertilizer dose, average yield gain in S2 was 1.3 t ha^{-1} more than S1. By increasing only nitrogen dose (F2) in S1 and S2, maize yield improved by 1.06 t ha^{-1} on an average. By increasing both nitrogen and phosphorus dose (F3) in S1 and S2, maize yield improved by 2.23 t ha^{-1} on an average (Fig. 1). Following table suggested that the best fertilizer

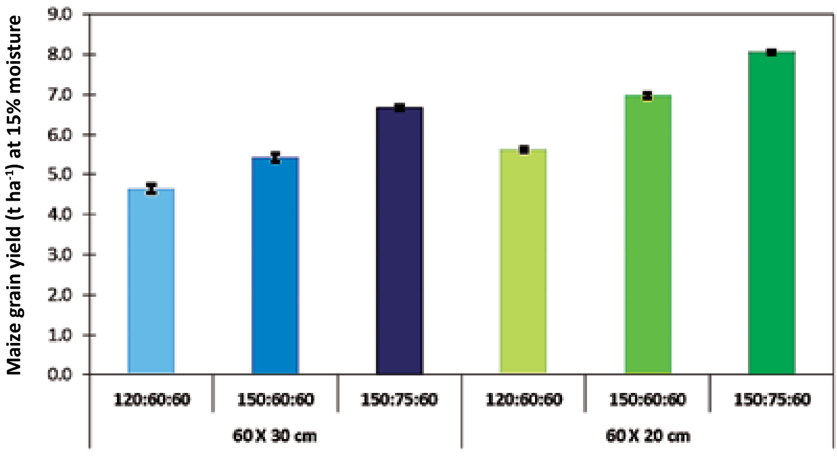

Fig. 1: Yield gains in *kharif* maize with adequate nutrient & plant population in Odisha plateau (N=30)

combination is 150:75:60 of N:P:K with a spacing of 60 cm × 20 cm. This would allow farmers in Plateau ecology to augment their maize yield by 3.41 t ha^{-1}.

Intervention	Yield gain (t ha^{-1})
Farmer practice (120:60:60 with 60 cm × 30 cm)	–
N:P:K dose of 120:60:60 at 60 cm × 20 cm spacing	0.99
N:P:K dose of 150:60:60 at 60 cm × 20 cm spacing	2.33
N:P:K dose of 150:75:60 at 60 cm × 20 cm spacing	3.41

Conclusion

Inadequate plant population and inappropriate fertilizer application are major limiting factors of *kharif* maize productivity in plateau region of Odisha. Adaptive research trial was conducted by KVK, Mayurbhanj-1 designed under two sets of plant spacing in combination with three sets of fertilizer doses each. Trial results suggested that hybrid maize yield in this region can be improved to 8.05 t ha^{-1} from existing 4.64 t ha^{-1} by optimizing plant population and balanced application of nitrogen and phosphorus.

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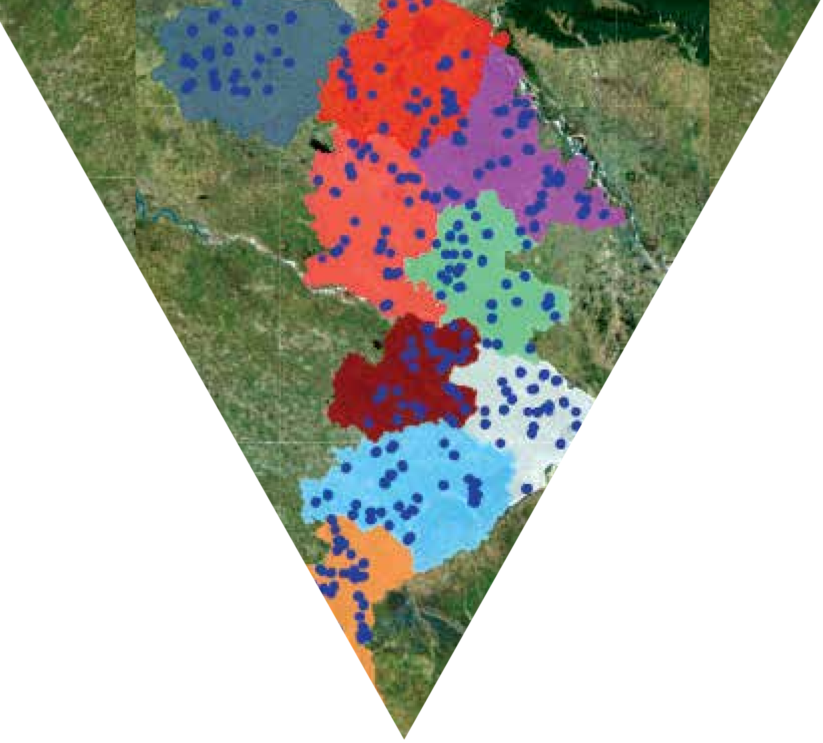

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