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Comparative assessment of improved management practices for paddy yield in Eastern Indo-Gangetic Plains

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ABSTRACT

Rice is grown around the globe in 113 countries spread over 153 million hectares with estimated total production of 589 million tonnes. Eastern Indo-Gangetic Plains (EIGP) of India contributes major portion in food grain production most particularly in rice but with a low productivity as compared to Western Indo-Gangetic Plains (WIGP) of India. Therefore, field experiment on technological interventions that are fundamental to productivity growth of rice were successfully implemented through farmers' field trials by 10 Krishi Vigyan Kendras (KVKs) across different ecologies in Bihar (8 KVKs), Eastern UP (2 KVKs) during 2016–18. It was found that paddy yield remained same in a range of 5.1 to 5.2 for Long Duration Rice Varieties (LDRVs) and in a range of 5.0 to 5.1 tonnes/ha for Medium Duration Rice Varieties (MDRVs) or hybrids. The grain yield of wheat saw a significant advantage with rice equivalent wheat yields (3.2 tonnes/ha) under CTW and 3.8 tonnes/ha under ZTW. Work done by KVKs (Ara, Buxar and Rohtas) show that creation of rice nursery enterprise (RNEs) can be an alternate way to transplant rice on time. The RNEs created by three KVKs in Bihar, raised nursery on 27.86 acres which was transplanted on 983 acres. When DSR was practiced after pre-sowing irrigation and good field preparation, the paddy yields ranged from 6.2 to 6.4 tonnes/ha in the cluster of 5 KVKs from Agro-Climatic Zone III (Southern East and West), 5.4 to 5.8 tonnes/ha in the cluster of 3 KVKs fromAgro-Climatic Zones I(Northern West) and 5.1 to 5.2 in the eastern UP cluster of 2 KVKs.

Key words: Crop management, Management practices, Paddy, Rice nursery enterprise

Rice (*Oryza sativa* L.), staple crop in India covered about 42 mha during 2015–16 and accounts for about 103.61 million tonnes of the country's total food grain production.It accounts for 29.1% of calories and 22.4% of protein intake daily by Indian population (GRiSP 2013). According to Indian Council of Agricultural Research (ICAR) Vision 2050, the food production density (kcal/km^2/day) requirement in most parts of India will increase from 50,000–100,000 in 2005 to 100,000–500,000 by 2050, and at the same time, it will require a rise in food grain productivity from 25,000 kcal/ha/day to about 46,000 kcal/ha/day (Chaumet *et al.* 2009). India would require about 156 mt of rice to feed its 1523 million population by 2030 (Anonymous 2011), at a yearly increment of 3 mt in the current rice production (Dass *et al.* 2016). Eastern Indo-Gangetic Plains (EIGP) of India covering states like Eastern UP, Bihar, Jharkhand and West Bengal are contributing major portion in food grain production most particularly in rice but with a low productivity (Raj *et al.* 2016a, b) as compared to Western Indo-Gangetic Plains (WIGP) of India. The rice yield potential is 10 t/ha, however, farmers manage to produce only 7-8 t/ha. In the developing countries, where farmers have less access to the inputs and technology, the average yield is 4-5 t/ha.The demand of rice as staple food for about 3 billion people is expected to increase further with increase in population (Directorate of Economics and Statistics, DAC &FW, 2014–15, and Dileep*et al.* 2018). In order to respond to the future food demands, rice production and yields will have to be increased.

MATERIALS AND METHODS

A field experiment on different crop management technologies was conducted through on farm trial at KVKs of Bihar, Eastern Uttar Pradesh under guidance of ICAR-ATARI, Patna and ICAR-ATARI, Kanpur during 2016–18. The experiment has been conducted based on agro-climatic zones in Bihar. In Bihar, Agro-climatic zone I (Northern West), Agro-climatic zone III A (Southern East) and Agro-climatic zone III B (Southern West) was selected for on farm trial. Among the KVKs, three KVKs come under Bihar Agricultural University (Rohtas, Lakhisarai and Madhepura

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KVKs), Buxar comes under ICAR Research Complex for Eastercfn region, One KVK (Bhojpur) comes under Sone Command Area Development Agency (SCAD), three comes under Dr Rajendra Prasad Central Agricultural University (East Champaran, Muzaffarpur and Begusarai KVKs) and two KVKs come under Eastern Uttar Pradesh (ICAR) KVKs (Kushinagar, Deoria).Total 487 trials have been conducted in KVKs of Bihar and Eastern UP in two sets, one included LDRVs followed by conventional till wheat (CTW) and LDRVs fb zero tillage wheat (ZTW) were conducted. The other set included MDRVs or MDRHs fb CTW and MDRVs or MDRHs fb ZTW to intensify RWCS especially when the drought like situation in the early phases of monsoons delays rice transplanting.

RESULTS AND DISCUSSION

Improving rice–wheat cropping system (RWCS) productivity using different crop establishment (CE) methods

Two sets of trials: one included LDRVs followed by conventional till wheat (CTW) and LDRVs fb zero tillage wheat (ZTW) were conducted. The other set included MDRVs or MDRHs fb CTW and MDRVs or MDRHs fb ZTW. The aim was to intensify RWCS especially when the drought like situation in the early phases of monsoons delays rice transplanting. Rice was grown by puddled transplanted method.

Rice equivalent system yields of combination of rice varieties and wheat establishment methods in Agro climatic Zone III (Southern East and Southern West): Data on grain yield of wheat has been presented as rice equivalent yield. Paddy yields (6.8-6.9 t/ha) within LDRVs or MDRVs or MDRHs groups remained almost same. Rice equivalent wheat yields, however, were 3.2 t/ha under CTW and 3.9 t/ha under ZTW. The system productivity was 10.0 t/ha for LDRVs fb CTW and 10.8 t/ha for MDRVs or LDRVs fb ZTW. When LDRVs were replaced by MDRVs or MDRHs, the paddy yields were lower (5.6 – 5.7 t/ha) than LDRVs but rice equivalent wheat yields were 4.0 t/ha for CTW and 5.1 t/ha for ZTW. The system productivity remained almost same with more compensation in the yield of wheat. The study highlights two things. First, LDRVs are potentially high yielder but these varieties will not improve the system productivity if the transplanting is delayed. ZTW will turn into best option for wheat to improve system productivity.

Rice equivalent system yields of combination of rice varieties and wheat establishment methods in Agro climatic Zone I (Northern West): The system yield range in the sites covered by 3 KVKs from Agro-Climatic Zone I remained less than the average of 5 KVKs from Agro-Climatic Zone III. The paddy yield remained same in a range of 5.1-5.2 for LDRVs and in a range of 5.0-5.1 t/ha for MDRVs or hybrids. The grain yield of wheat saw a significant advantage with rice equivalent wheat yields of 3.2 t/ha under CTW and 3.8 t/ha under ZTW. When MDRVs or MDRHs were taken as preceding varieties, such gains in rice equivalent wheat yields were higher at 4.0 t/ha for CTW and 5.5 t/ha for ZTW.

Rice equivalent system yields of combination of rice varieties and wheat establishment methods in eastern UP: Almost similar trends were observed in Eastern UP based KVKs including Kushinagar and Deoria. The only glaring difference was seen in the paddy yields of MDRVs which were slightly lower than other KVKs. This was mainly because in these KVKs BPT 5204 was the main variety under medium duration rice treatment. When we compared the overall trend, the highest system productivity was recorded in the treatment of MDRVs fb. ZTW.

Effects of delayed transplanting on the growth and the yield of rice

The late transplanting of rice has been one of the main reasons for lower rice yield in Eastern Indo-Gangetic Plains (EIGP) especially in Bihar. Under current practice, farmers in Bihar and Eastern UP seed their nursery after the monsoon rains have arrived and that is too late (Table 1).

Effects of delayed transplanting of rice on the yield (t/ha) of different varieties/hybrids of Rice (^) in Agro climatic Zone III (Southern East and Southern West): The yield penalty with each successive delay of 10 days was 1.6, 1.7, 5.8 and 4.8% when compared with earliest transplanting date of 16 June. In the present case, the last

Table1 Effects of delayed transplanting of rice on the yield (t/ha) of different varieties/hybrids of Rice (^)

Variety	Transplanting date	Yield (t/ha)		
		Average of 5 KVKs (#) under Agro-Climatic Zone III	Average of 3 KVKs (#) under Agro-Climatic Zone I	Average of 2 KVKs(#) EUP
Long duration varieties	16 Jun-25 Jun	7.22	6.13	5.86
	26 Jun-05 Jul	7.1	5.68	5.62
	06 jul-15 Jul	6.98	5.29	5.33
	16 Jul-25 Jul	6.61	4.68	4.97
	26 Jul-05 Aug	6.29	4.09	NA
Medium duration varieties / Hybrids	16 Jun-25 Jun	6.09	6.13	5.13
	26 Jun-05 Jul	6.05	5.46	4.71
	06 jul-15 Jul	5.74	4.93	4.32
	16 Jul-25 Jul	5.58	4.54	4.12
	26 Jul-05 Aug	5.17	4.22	NA
Short duration varieties / Hybrids	16 Jun-25 Jun	5.34	4.71	4.59
	26 Jun-05 Jul	5.46	4.12	4.32
	06 jul-15 Jul	5.31	3.81	3.98
	16 Jul-25 Jul	4.41	4.22	3.55
	26 Jul-05 Aug	4.68	3.85	NA

^ Long Duration Varieties-159 (Agro-Climatic Zone III), 95 (Agro-Climatic Zone I), 40 (EUP), Medium Duration Varieties/Hybrids-165 (Agro-Climatic Zone III), 109 (Agro-Climatic Zone I), 40 (EUP) and Short Duration Varieties/Hybrids-73 (Agro-Climatic Zone III), 71 (Agro-Climatic Zone I), 40 (EUP)

DOT was 26thJuly. The corresponding yield penalty in case of MDRVs or hybrids with starting DOT of 26thJune and end DOT was 6thAugust were 0.7, 5.1, 2.8 and 7.3%. In case of SHRVs or hybrids with start date being 6th July, and end date being 16th August, the yield decline did not follow any regular trend. The irregular trends were majorly because of hybrids which out yielded SDRVs. Data shows that farmers can hold the transplanting operation in case of short duration group but not in case of LDRVs or MDRVs.

Effects of delayed transplanting of rice on the yield (t/ha) of different varieties/hybrids of Rice (^) in Agro climatic Zone I (Northern West): Consolidated data in the domain of 3 KVKs including Muzaffarpur, East Champaran and Begusarai did show that losses in the yield of paddy of LDRVs add up in each successive 10 days delay in the time. The corresponding losses were in the order of 7.3, 6.9, 11.5 and 12.6% with highest yield being 6.13 t/ha when the transplanting was done on 16th June. In case of medium duration varieties or hybrids, the yield decline varied from 7-10% across different varieties with no trend in response to each delay in transplanting. Data from the group that represented DRVs to hybrids also showed decline in each successive delay except from 6-16 July.

Effects of delayed transplanting of rice on the yield (t/ha) of different varieties/hybrids of Rice (^) in eastern UP: In Eastern UP, only 4 dates of transplanting were considered. Maximum paddy yield from LDRVs, MDRVs, SDRVs were 5.86, 5.33 and 4.59 t/ha when the representative transplanting dates of 16thJune, 26th June and 6th July, respectively for each group. When compared with 16 June, the order of yield penalty of LDRVs were 4.1, 5.2 and 6.8% within each 10 days' delay up to 16th July. The total yield loss in one-month delay was 15.2%. In case of MDRVs, when the transplanting was delayed from 16th June-26 July, the average loss in paddy yield was 19.7%.

Developing entrepreneurship on rice nursery marketing:

In Bihar and EUP farmers are not ready for transplanting rice at the time of on-set of monsoon. KVKs were asked what they thought about the new process of creating rice nursery enterprise and how sure they were for scalability of that model where KVKs sell nursery instead of seed and how Rice Nursery Enterprise (RNE) can help scaling the process compared to the concept of community nursery. Three KVKs (Rohtas, Buxar and Ara) in the Agro-Climatic Zone III have raised nursery at their own farm to encourage farmers to adopt this process in the next season. Farmers who purchased nursery from these RNEs could transplant rice before July 20. When timely transplanted is combined with young and healthy seeding supplied by RNEs, it improved the paddy yield in all clusters (Fig 1).

The experience so far indicates this model can be sustainable for anyone doing custom service and also ensures the timely availability of quality rice seedlings to the user farmers. This could prove to be the right step in facilitating timely transplanting of rice and optimizing the cropping system as a whole.

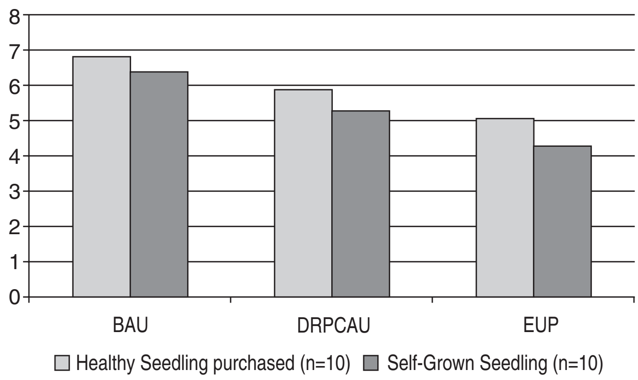

Fig 1 Difference in paddy yield due to type of nursery

With success in the domains of 4 KVKs (Three in Agro Climatic Zone III) and Deoria in Eastern UP, the overall income from NREs could be matched by data given in Table 2. NREs who did the marketing of nursery could, on an average, transplant one-acre nursery into 50 acres. Based on the existing ratio of 1:10 five times more area can be transplanted from one-acre nursery. In the same context the seed rate for one-acre nursery from participating NREs from Rohtas district was 176 KGs, thus a major saving in seed rate. During the current year, work done by KVKs (Ara, Buxar and Rohtas) shows that creation of rice nursery enterprise (RNEs) can be an alternate way to transplant rice on time. The RNEs created by three KVKs in Bihar raised nursery on 27.86 acres which was transplanted on 983 acres. Here the ratio of nursery to transplanted acres is 1:35 against existing practice of 1:12, thus saved not only seed but facilitated timely transplanting of rice.

Impact of age of rice nursery on the growth and yield of transplanted rice

Data presented from trial of NRE based trial and from CE methods does indicate the importance of transplanting young seedlings. A simple trial of 5 treatments representing 15-20, 21-25, 26-30, 31-35 and more than 35 days old seedling was conducted across 10 KVKs. Transplanting of youngest seedlings of 15-20 days old seeding was most productive with maximum paddy yield at all locations. As an example from 5 KVKs in the Agro-Climatic Zone III, the paddy yields were in the order of 7.0, 6.7, 6.4, 5.9 and 5.4 t/ha as the seedling age for transplanting increased from 15-20 days old to more than 35 days old seedlings. Same trend was followed in all other KVK trials.

Performance of conventional till DSR with and without pre-sowing irrigation

In this study the dry seeding followed by pre-sowing irrigation seed bed preparation have been compared with PTR. As part of best option, sites where direct seeding of rice was practiced after pre-sowing irrigation and good field preparation, the paddy yields ranged from 6.2-6.4 t/ha in the cluster of 5 KVKs from Agro-Climatic Zone III, 5.4-5.8 t/ha in the cluster of 3 KVKs consisting of Agro-Climatic Zone I and 5.1-5.2 in the eastern UP cluster of 2 KVKs.

Table 2 Economic analysis per acre (4000 m^2) rice nursery area (This analysis is based on cost and return analysis from RNE)

Particular	Cost (₹)	Cost (USD*)
Seed	7040	96.5
Seed Treatment	336	4.6
Tillage	3200	43.9
Irrigation	3840	52.7
Fertilizer	1760	24.1
Labour	1600	21.9
Land Rental Value	1600	21.9
Plan Protection	384	5.3
Herbicides	448	6.1
Other	2816	38.6
Total Cost	23024	315.7
Gross Return	40000	548.5
Net Profit	16976	232.8
B:C	1.74	1.74

*USD= 72.92 ₹

#Transplanted area per nursery= 50 acres, Sale price INR 800/ Acre Seed quality for sowing one-acre nursery is 176 kg

The corresponding yield levels in the treatment where dry DSR was done were in the order of 5.9, 5.2 and 4.9 t/ha. Puddled transplanted rice (PTR) performed better than dry DSR at Bihar sites and it was same as dry DSR in Eastern UP. Benefits were significant as the dust mulchis loose dry layer of surface soil maintained where soil capillaries are broken by cultivation under the assumption that it will prevent evaporation of soil moisture. The evidence through all KVKs under reference clearly shows that it is advisable to establish paddy through DSR in *vattar* (pre-sowing irrigation and good field preparation leading to soil mulch) condition before onset of monsoon preferably during last week of May to first week of June. On the whole, paddy yield in DSR can be maximized by drill sowing in *vattar* condition followed by irrigation between 2nd to 3rd weeks of sowing.

Comparative performance of rice establishment methods in different ecologies

Direct seeding of rice (DSR) is the upcoming technology due to shortage of labour for manual transplanting. Machine transplanting of non-puddled rice (MTNPR) to replace manual transplanting (PTR) is another means to save.

Comparative study through 10 KVKs was done to get to the reasons for less adoption of DSR and MTNPR. DSR was seeded after pre-sowing irrigation-considered as a safe bet as was seen in the data on dust mulch based DSR. Seed to seed cycle was maintained almost same in all three treatments. The crop establishment (CE) was done in range of 5-20 June in DSR, 26 May-29 June for PTR, 5-26 June in MTNPR. Data showed that DSR provided same yield to PTR in Agro-Climatic Zone III, 9% less yield in Agro-Climatic Zone I based KVKs and 3% more yield than PTR in 2 KVKs from Eastern UP. On the contrary, data indicated that PTR based paddy yield reduced by a margin of 11% in 5 KVKs from Agro-Climatic Zone III, 9% from Agro-Climatic Zone I based on 3 KVKs and 16% in 2 KVKs from Eastern UP when compared with MTNPR. The yield level of paddy in MTNPR remained more than 6.0 t/ha across all three ecologies. In most cases the varietal spectrum was same with most sites had hybrids in Bihar and varieties (BPT 5204) in EUP. In MTNPR, the age of seedling was less than PTR. Both DSR and MTNPR had less cost of cultivation basically because of saving in labour cost.

Weed management in direct seeded rice (DSR) dominated Cyperus rotundus based mixed weed flora

Four treatments included were; tank mix application of bispyribac+ pyrazosulfuron at 20+20 g ai/ha applied 15-25 DAS followed by one manual weeding at 40-45 DAS, tank mix application of bispyribac+ pyrazosulfuron at 20+20 g ai/ha applied alone at 15-25 DAS, bispyribac alone at 20 g/ha applied 15-25 DAS followed by one manual weeding 40-45 DAS and 2 manual weedings done at 20-25 DAS and at 40-45 DAS.

Tank mix application of bispyribac+ pyrazosulfuron at 20+20 g ai/ha applied 15-25 DAS followed by one manual weeding at 40-45 DAS was seen as the most cost effective weed control measure in DSR. This treatment provided maximum yield (6.55 t/ha) in BAU cluster and also in DRPCAU cluster (5.95 t/ha). In EUP, the maximum yield was recorded with the treatment of 2 manual weeding and it was closely followed by tank mix application of bispyribac+ pyrazosulfuron at 20+20 g ai/ha applied 15-25 DAS followed by one manual weeding at 40-45 DAS.

The paddy yield remained same in a range of 5.1-5.2 for LDRVs and in a range of 5.0-5.1 tonnes/ha for MDRVs or hybrids. The grain yield of wheat saw a significant advantage with rice equivalent wheat yields i.e. 3.2 tonnes/ha under CTW and 3.8 tonnes/ha under ZTW. Delayed transplanting is further compounded by non-availability of rice nursery. Work done by KVKs (Ara, Buxar and Rohtas) showed that creation of rice nursery enterprise (RNEs) can be an alternate way to transplant rice on time. Data for one more year will be needed to secure the backing of concerned SAUs for including this in their package.

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