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Research Paper

Effect of date of transplanting and nitrogen on productivity and profitability of rice–ratoon (*Oryza sativa*) system under shallow lowland

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ABSTRACT

A field experiment was carried out during the *boro* season of 2014–15 to 2015–16 at the research farm, Gerua, Kamrup, Asom, to identify optimum planting date for main rice (*Oryza sativa* L.) and nitrogen level for ratoon rice under shallow lowland ecosystem. The experiment was laid out in a split-plot design with 3 replications. Three planting dates (5th, 15th and 25th February) were assigned to main plots for main crop and 3 nitrogen levels (0, 20 and 40 kg/ha N) to subplots for ratoon crop. Naveen, a high-yielding variety of rice was taken as test crop. Results revealed that 15th February planting proved significantly more productive and profitable for main rice (6.04 t/ha) as well as ratoon (2.33 t/ha) than those of 5th and 25th February planting. It was mainly owing to higher values obtained for growth and yield attributes like plant height, dry-matter accumulation, tillers/m^2, filled grains/panicle, panicle weight and length for main rice as well as ratoon crop from 15th February planting. Hills/m^2, filled grains/panicle and fertility percentage of ratoon crop were significantly influenced by planting dates. Grain yield of main rice was highly correlated with number of panicles/m^2, spikelets/panicle and filled grains/panicle. However, grain yield of ratoon crop was significantly correlated with hills/m^2, number of panicles/m^2, spikelets/panicle, filled grains/panicle and fertility percentage. Nitrogen levels of 20 and 40 kg/ha resulted in significantly higher hills/m^2, panicles/m^2 and spikelets/panicle which resulted significantly higher grain and straw yields of ratoon rice over the control but remained statistically at par with each other. Thus, 20 kg/ha N application was enough to get good rice ratoon crop and additional income of ₹26,415/ha with benefit: cost ratio 3.36.

Key words: *Boro* rice, Date of transplanting, Nitrogen, Ratooning, Shallow lowlands

Asom occupies a special place in the rainfed rice-production system in the Eastern India by covering more than 10% of the total rice area and contributing 9% to the rice production of India (Pun *et al.,* 2016). In the region, rice is grown under varied ecosystems and hydrologic conditions ranging from waterlogged, flash flood-affected and poorly-drained to well-drained, irrigated and rainfed upland situations. This situation often arises when the established crop is damaged in field due to flash flood during the rainy (*kharif*) season. Low productivity and uncertainty of *kharif* rice diverted farmers to grow *boro* rice (Novemver/December to May/June), as productivity of *boro* rice under shallow lowland is higher (>5.0 t/ha) in north-eastern states which is comparatively higher than that of the national average productivity of rice yield 3.27 t/ha average (Singh *et al.,* 2018). The *boro* rice is commonly known as summer rice, and shallow water level and waterlogging lowlands can be utilized by using *boro* rice cultivation, which remains fallow in winter due to excessive moisture and late-maturing rice. However, the productivity of *boro* rice is not yet up to its potential due to several factors behind the low productivity of *boro* rice but the most important among them are the non-adoption of optimum time of transplanting and poor crop-management practices. The area under *boro* rice is increasing in north-eastern states because of availability of surface as well as groundwater for irrigation during early dry season. *Boro* rice is transplanted in February and harvested in May–June. This provides ample scope to extend growing season up to July by allowing ratoon

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crop to have second crop with minimum cost of production. Under such circumstances, ratooning of *boro* rice could be an option to produce additional grain and straw yields within short span of 2 months. Rice ratooning is one of the potential-production technologies to enhance rice production mainly in shallow lowland of Eastern and North-Eastern India (Munda *et al.*, 2009). Ratoon crops are usually considered as the bonus to the main crop as less external inputs are required for its successful production. Moreover, the practice of ratooning would not only add to the national food basket, but would also increase the farmers' income and generate more employment in the region and suitably be fitted in to the lag or fallow period between the harvesting of rice and sowing of the succeeding *sali* rice in the areas of rice-rice system of production in India (Munda *et al.,* 2009; Dwibedi *et al.,* 2017). Ratooning of rice has been reported in many countries such as China (Yuan *et al.,* 2019), Japan, United States, Colombia and India, though it is practised only in limited areas. In India, ratooning of rice is practiced in Asom, West Bengal and NEH region (Munda *et al.,* 2009; Dwibedi *et al.,* 2017). Shallow lowland rice cultivation is about 14.4 million ha, which accounts 32.4% of the total area of rice in the country. If rice ratoon crop is managed properly, it could produce more than 50% of grain yield with 50–60% less labour, 32–42% low energy input, short-duration and high-production efficiency relative to main rice crop (Yuan *et al.,* 2019; Singh *et al.,* 2019; Vijaykumar *et al.,* 2020). Nitrogen is the most important input factor in maximizing the ratoon rice productivity. Ratoon rice grain yield increased significantly with application of nitrogen without lodging (Bond and Bolich, 2006). Naveen, a high-yielding rice

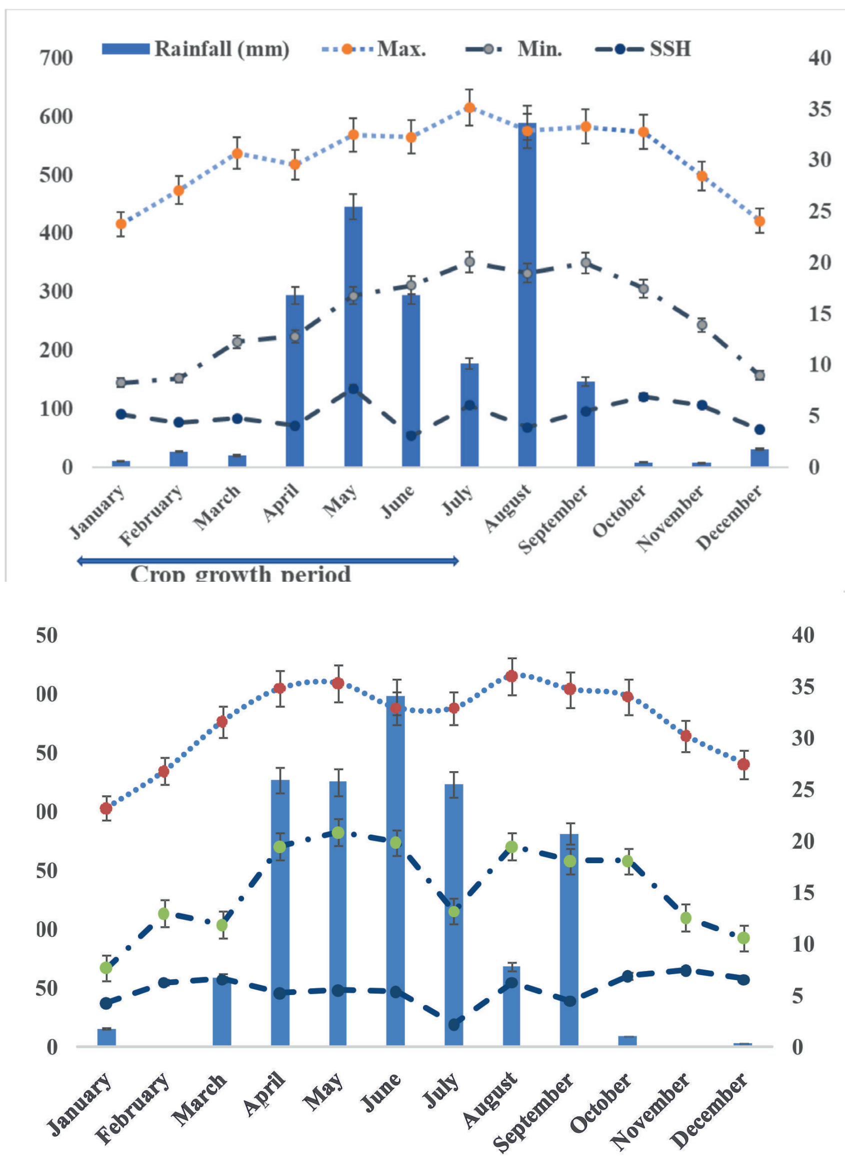

Fig. 1. Weather parameters during crop growth period of main and ratoon rice during 2015 (top) and 2016 (bottom)

variety was identified by the Regional Rainfed Lowland Rice Research Station, ICAR-NRRI, Gerua, Asom which can produce more than 50% grain yield of main rice crop of *Sali* season (Singh *et al.,* 2019). Since not much study had been done on nutrient management in ratoon rice in India, especially on nitrogen application after harvesting of main rice, an experiment was conducted with 'Naveen' variety to assess the productivity and profitability of rice ratooning under different planting dates and nitrogen levels.

MATERIALS AND METHODS

A field experiment was conducted in main *boro* rice followed by its ratoon crop during 2014–15 and 2015–16 at the Regional Rainfed Lowland Rice Research Station, ICAR-National Rice Research Institute, Gerua, Asom (28° 14' 59" N, 91° 33' 44" E, 49 m above mean sea-level). Soil of the experimental site was characterized as slightly acidic (*p*H 6.15), high in organic carbon (1.02%), available nitrogen (245 kg/ha), phosphorus (15.5 kg/ha) and potassium (305 kg/ha). Main crop (711 and 550 mm) and ratoon (561 and 490 mm) received rainfall with varying intensity at time of reproductive phase during both the years, respectively. Average bright sunshine hours were 5.1 and 4.8 hr/day and mean evaporation was 4.1 and 3.5 mm/day during both years respectively (Fig. 1). The experiment was laid out in a split-plot design with 3 replications. The main *boro* rice crop was raised with 3 dates of transplanting (5th, 15th and 25th February) assigned to main plots and 3 nitrogen levels (0, 20 and 40 kg/ha N) in subplots (N levels imposed after harvesting of main rice to get better rice ratoon). 'Naveen', a high-yielding variety of rice was used as test crop. Staggered nurseries were raised and 45 days-old seedlings were transplanted at spacing of 20 cm × 15 cm and uniformly accommodating 34 hills/m^2. Recommended dose of nutrients, i.e. 80: 40: 40 kg/ha of N: P_2O_5: K_2O, was applied to the main crop through urea, diammonium phosphate and muriate of potash respectively. Full dose of P_2O_5, one-third of N and three-fourths of K_2O were applied as basal at the time of transplanting. Remaining N was applied in 2 equal splits at the maximum tillering and panicle-initiation stage, one-fourth of K_2O was applied as top-dressing at panicle initiation. Weeding and irrigation agronomic practices were kept normal and uniform for all date of transplanting of main crop. The main crop was harvested leaving about 15 cm standing stubble height between the last week of May and the first week of June during both the years. Just after harvesting of the main crop, 20 and 40 kg/ha N were applied to ratoon through urea to the allotted treatments of subplots. A unit area (1 m^2) for both main and ratoon crop was selected and harvested to measure yield variables like effective tillers/m^2, panicle length, grains/panicle, grain weight/panicle and 1,000-grain weight. Grain yield was recorded from net plot of 5 m × 4 m after harvesting and threshing and expressed in t/ha at after sun drying at about 14% moisture. Production efficiency was computed by dividing the yield with duration of both main and ratoon crop. Percentage yield recovery from ratoon was also calculated with grain yields of main and ratoon crop for all treatments. The amount of seed required per hectare was calculated and the cost of seed was estimated based on their market price. The minimum support price of paddy (₹13,800 and 14,100/t in 2014–2015 and 2015–2016 respectively) was used to calculate economics and profitability of the treatments during the year of experimentation. Pooled average data of 2 years were analysed statistically using the F-test as per the standard procedure.

Table 1. Effect of planting date on duration of main and rice ratoon (mean of 2 years)

Date of planting	Main rice		Rice ratoon		Duration of rice-ratoon system (days)
	Days to 50% flowering	Days to maturity	Days to 50% flowering	Days to maturity	
5th February	119	152	31	60	212
15th February	117	148	32	59	207
25th February	114	144	31	57	201

Table 2. Growth and yield attributes of main rice as influenced by planting date (mean of 2 years)

Date of planting	Plant height (cm)	Tillers/hill	Panicles/ m^2	Spikelets/ panicle	Filled grains/ panicle	Fertility (%)	Panicle length (cm)	Panicle weight (g)	Test weight (g)
5th February	106.7	8.3	224.7	134.1	108.0	80.6	24.0	3.19	21.0
15th February	109.1	8.9	252.1	150.8	124.2	82.3	24.3	3.44	21.5
25th February	116.7	9.2	268.4	140.9	112.7	80.0	25.0	3.25	22.0
SEm±	1.13	0.23	7.14	1.35	1.12	0.53	0.31	0.07	0.22
CD (P=0.05)	3.31	0.68	20.87	3.93	3.27	1.55	NS	0.20	0.65

The LSD values at $P \leq 0.05$ were used to determine the significance of difference between treatment means.

RESULTS AND DISCUSSION

Duration of rice–ratoon system

Days to 50% flowering and maturity duration of rice decreased with delay in date of transplanting (Table 1). Transplanting on 5th February required the maximum days to 50% flowering and maturity period followed by 15th and 25th February transplanting. This might be due to gradual increase in the air temperature with delay in transplanting. However, date of transplanting did not influence the days to 50% flowering and maturity period on subsequent ratoon crop as air temperature remained high for all dates of transplanting. The maximum duration of rice-ratoon system was recorded with 5th February transplanting which was 12 days more over 25th February transplanting. The variation in maturity period was mainly due to low air temperature in the first fortnight of February. Singh *et al.,* (2014) also reported that, rice transplanted in cool month of January resulted longer duration for flowering and maturity.

Growth and yield attributes of main rice crop

Growth and yield attributes were significantly influenced by date of transplanting except panicle length (Table 2). The higher values for spikelets/panicle, filled grains/panicle, fertility percentage and panicle weight were obtained with 15th February transplanting and found significant over 5th and 25th February date of transplanting. However, the minimum values of growth and yield parameters were obtained with 5th Feb. transplanting. This might be due to low temperature during early phase of crop and later transplanting dates coinciding with favourable weather conditions. However, plant height, number of tillers/hill, panicles/m^2, panicle length and 1,000-grain weight were significantly higher with 25th February transplanting over 5th Feb. transplanting but remained statistically at par with 15th February date of transplanting except for plant height.

The higher number of spikelets/panicle, filled grains/panicle and heavier panicles resulted significantly higher grain and straw yield with 15th February transplanting as compared to 5th February transplanting (Table 3). Transplanting on 15th February resulted 13.3 and 3.5% higher grain yield over 5th and 25th February transplanting respectively. However, the grain and straw yields remained statistically at par between 15th and 25th February date of transplanting. This is mainly due to gradual rise in the air temperature and optimum temperature throughout the plant growth and maturity. Harvest index remained unaffected

Table 3. Yield and production efficiency of main rice crop as influenced by planting date (mean of 2 years)

Date of planting	Grain yield (t/ha)	Straw yield (t/ha)	Harvest index	Production efficiency (kg/day/ha)
5th February	5.33	5.66	0.48	35.07
15th February	6.04	6.54	0.48	41.09
25th February	5.85	6.38	0.48	41.20
SEm±	0.03	0.10	0.003	
CD (P=0.05)	0.35	0.29	NS	

Table 4. Growth characteristics of rice ratoon as influenced by planting date and nitrogen (mean of 2 years)

Treatment	Plant height (cm)	Tillers/hill	Leaf-area index		Dry-matter accumulation (g/hill)	
			30 DAH	45 DAH	30 DAH	45 DAH
Date of planting						
5th February	96.0	7.5	2.15	1.90	59.0	65.0
15th February	98.4	8.3	2.18	1.97	66.9	73.0
25th February	102.9	7.9	2.11	1.89	62.6	68.4
SEm±	0.2	0.1	0.02	0.02	0.7	0.7
CD (P≤0.05)	2.6	NS	NS	NS	NS	7.8
Nitrogen						
Control	98.8	7.7	1.98	1.75	57.0	64.4
20 kg/ha	99.4	7.9	2.22	1.99	64.4	70.4
40 kg/ha	99.1	8.2	2.24	2.03	67.1	71.6
SEm±	0.3	0.1	0.02	0.01	0.9	0.6
CD (P≤0.05)	NS	NS	0.17	0.09	8.0	5.6

DAH, Days after harvesting of main crop

with the date of transplanting. The higher values for production efficiency were recorded with 15th and 25th February transplanting than 5th February transplanting, which showed the ideal conditions during later dates of transplanting. These findings are in agreement with the reports of Ukaoma *et al*. (2015) for panicle weight and number of grains/panicle and of Krishna Naik *et al*. (2005) and Akhtar *et al.* (2011) for number of grains/panicle and maturity.

Growth characteristics of ratoon rice

The growth of ratoon rice was greatly influenced by the date of transplanting and nitrogen levels (Table 4). Transplanting on 15th February resulted in the maximum tillers/hills, leaf-area index (LAI) and dry-matter accumulation and remained statistically non-significant with the other date of transplanting except dry-matter accumulation at 45 days after harvesting of main rice crop. However, significantly taller plants were recorded with 25th February transplanting over 5th and 15th transplanting. The growth parameters of subsequent ratoon crop were significantly influenced by transplanting date and harvesting time (Yazdpour *et al.,* 2012; Dwibedi *et al.,* 2017). Nitrogen application of 20 and 40 kg/ha in the form of urea to main rice crop just after harvesting resulted significantly increased the LAI and dry-matter accumulation over the control but remained statistically at par with each other. This might be due to the better utilization of nitrogenous fertilizer. Ali *et al.* (2011) also reported increased growth characteristics of ratoon rice with nitrogen application.

Yield attributes of rice ratoon

Number of hills/m^2, filled grains/panicle and spikelets fertility were significantly influenced by date of transplanting (Table 5). However, other yield attributes such as panicles/m^2, spikelets/panicle, chaffy grains/panicle, panicle length and weight and 1,000-grain weight remained

Table 5. Yield attributes of ratoon rice as influenced by planting date and nitrogen (mean of 2 years)

Treatment	Hills/ m^2	Panicles/ m^2	Spikelets/ panicle	Filled grains/ panicle	Chaffy grains/ panicle	Fertility (%)	Panicle length (cm)	Panicle weight (g)	1000-grain weight (g)
Date of planting									
5th February	28.1	215.9	88.3	67.5	20.8	77.5	21.7	2.06	19.44
15th February	29.4	229.5	97.1	79.3	17.8	81.9	21.7	2.34	19.67
25th February	30.3	223.9	91.1	68.1	23.0	74.1	22.7	2.28	19.42
SEm±	0.2	1.6	0.9	0.4	0.5	0.3	0.1	0.04	0.03
CD (P=0.05)	1.3	NS	NS	5.0	NS	3.5	NS	NS	NS
Nitrogen									
Control	27.7	208.0	84.0	63.3	20.7	75.6	22.2	2.15	19.23
20 kg/ha	30.0	231.4	94.2	75.3	18.9	79.3	21.8	2.17	19.65
40 kg/ha	30.1	229.9	98.3	76.3	22.0	78.7	22.1	2.37	19.65
SEm±	0.2	1.0	0.9	0.5	0.8	0.5	0.1	0.04	0.05
CD (P=0.05)	0.6	9.3	8.0	5.0	NS	NS	NS	NS	NS

Table 6. Productivity, efficiency and economics of rice ratoon as influenced by planting date and nitrogen (mean of 2 years)

Treatment	Main rice yield (t/ha)	Ratoon yield (t/ha)	Straw yield (t/ha)	Harvest index	Gross return (×10^3₹/ha)	Net return (×10^3₹/ha)	Benefit cost ratio	Production efficiency (kg/day/ha)	Yield recovery in ratoon (%)
Date of planting									
5th February	5.33	2.11	2.79	0.43	32.0	24.2	3.07	35.46	39.59
15th February	6.04	2.33	3.10	0.43	35.4	27.5	3.50	39.83	38.58
25th February	5.85	1.99	3.08	0.39	30.6	22.8	2.90	35.22	34.02
SEm±	0.03	0.01	0.01	0.00					
CD (P=0.05)	0.35	0.19	0.14	0.02					
Nitrogen									
Control	5.71	1.87	2.62	0.42	28.5	21.0	2.80	32.24	32.75
20 kg/ha	5.78	2.25	3.11	0.42	34.3	26.4	3.36	38.79	38.93
40 kg/ha	5.74	2.31	3.24	0.42	35.2	27.1	3.34	39.83	40.24
SEm±	0.03	0.02	0.02	0.00					
CD (P=0.05)	NS	0.19	0.21	NS					

unaffected by the date of transplanting. The mortality of hills was higher under 5th February date of transplanting which resulted lowest hills/m^2. However, the maximum hill/m^2 were recorded with 25th February transplanting followed by 15th February transplanting. The significantly higher values were recorded for filled grains/panicle and fertility percentage with 15th February as compared to 5th and 25th February date of transplanting. Yazdpour *et al.* (2012) Dwibedi *et al.* (2017) also reported effect of date of transplanting on yield attributes of ratoon rice.

Nitrogen application just after harvesting of main rice crop increased the recovery hills/m^2, panicles/m^2, spikelets/panicle and filled grains/panicle. It was observed that, nitrogen application increased the regeneration of hills around 90% which remained the lowest with the control (around 80%). Nitrogen application also increased the panicles/m^2, spikelets/panicle and filled grains/panicle significantly over the control. However, both levels of nitrogen (20 and 40 kg of RDN/ha) remained statistically at par with each other. The other yield attributes such as chaffy grains/panicle, fertility percentage, panicle length and weight and 1,000-grain weight remained unaffected with nitrogen application. Results are closely related with the findings of Ali *et al.* (2011).

Productivity, efficiency and economics of rice ratoon

Transplanting on 15th February resulted in significantly higher grain yield over both early (5th February) and late transplanting (25th February) (Table 6). This is mainly owing to significantly higher filled grains/panicle and higher fertility percentage during 15th February transplanting over both the date of transplanting. Straw yield was significantly higher with 15th and 25th February as compared to 5th February. Harvest index was higher at 5th and 15th February transplanting than at 25th February transplanting. It is mainly due to higher grain yield in both the date of transplanting. The maximum yield recovery for ratoon rice was under 5th February. transplanting followed by 15th and 25th February. However, 5th and 15th February transplanting have almost similar yield recovery. The lowest grain yield in main rice due to poor growth and yield attributes with 5th February resulted in the highest recovery of yield in rice ratoon as compared to other date of transplanting.

Nitrogen application significantly increased the grain and straw yields over the control. This is mainly owing to regeneration of more hills/m^2, filled grains/panicle and higher fertility percentage under both the levels of nitrogen. However, both levels of nitrogen remained statistically at par for grain and straw yields. The harvest index remained unaffected with nitrogen application. The grain yield recovery in ratoon rice increased with increasing doses of nitrogen. However, both levels of N application recorded almost similar yield recovery, whereas the control recorded 6–7% less.

Rice ratoon crop is an additional crop to the main rice crop. Among the date of transplanting, 15th February resulted the higher profitability with the maximum net return and B:C ratio followed by 5th and 25th February transplanting. The production efficiency was the maximum with 15th February transplanting which indicated the higher conversion rate of photosynthates from source to sink as compared to 5th and 25th February transplanting. The production efficiency of main crop was marginally higher than ratoon rice with 15th February transplanting. Under shallow lowland conditions, the ratooning of rice

Table 7. Correlation coefficients of agronomic traits of main rice crop

Agronomic traits	Plant height (cm)	Tillers/ hill	Panicles/ m^2	Spikelets/ panicle	Filled grains/ panicle	Chaffy grains	Fertility (%)	Panicle length (cm)	Panicle weight (g)	Test weight (g)	Harvest index	Straw yield (t/ha)
Plant height (cm)												
Tillers/hill	0.384*											
Panicles/m^2	0.445*	0.395*										
Spikelets/panicle	0.008	0.229	0.188									
Filled grains/ panicle	–0.053	0.319	0.170	0.945**								
Chaffy grains/ panicle	0.181	–0.229	0.078	0.305	–0.023							
Fertility (%)	–0.162	0.382*	0.0197	0.257	0.558**	–0.403*						
Panicle length (cm)	0.394*	–0.099	0.151	0.119	–0.072	0.445*	–0.506**					
Panicle weight (g)	–0.005	–0.133	0.117	0.461*	0.401*	–0.064	–0.008	0.127				
1000-grains weight (g)	0.478*	0.394*	0.381*	0.292	0.193	0.108	–0.143	0.193	0.005			
Harvest index	–0.282	0.120	–0.052	–0.003	0.097	–0.296	0.314	–0.186	–0.432*	–0.135		
Straw yield (t/ha)	0.303	0.309	0.518**	0.612**	0.571**	0.142	0.133	0.273	0.449*	0.324	–0.201	
Grain yield (t/ha)	0.170	0.319	0.525**	0.645**	0.652**	–0.285	0.287	0.134	0.373	0.288	0.104	0.932**

* Means significant at 5% level; ** Means significant at 1% level

Table 8. Correlation coefficients of agronomic traits of ratoon rice

Agronomic traits	Hills/m^2	Plant height (cm)	Tillers/ hill	Panicles/ m^2	Spikelets/ panicle	Filled grains/ panicle	Chaffy grains/ panicle	Fertility (%)	Panicle length (cm)	Panicle weight (g)	1000-grains weight (g)	Harvest index	Straw yield (t/ha)
Hills/m^2													
Plant height (cm)	0.506**												
Tillers/hill	0.198	0.032											
Panicles/m^2	0.564**	0.180	0.468*										
Spikelets/panicle	0.546**	0.095	0.382*	0.745**									
Filled grains/ panicle	0.543**	–0.044	0.370	0.668**	0.791**								
Chaffy grains/ panicle	0.110	0.215	0.092	0.256	0.493**	–0.143							
Fertility (%)	0.066	–0.390*	0.114	0.093	–0.012	0.578**	–0.839**						
Panicle length (cm)	0.139	0.543**	0.126	0.079	0.250	0.007	0.393*	–0.454*					
Panicle weight (g)	0.371	0.110	0.187	0.188	0.216	0.345	–0.140	0.258	0.198				
1000-grains weight (g)	0.321	0.105	0.135	0.184	0.202	0.459*	–0.326	0.436*	–0.003	0.078			
Harvest index	–0.395*	–0.590**	–0.096	0.081	0.122	0.199	–0.086	0.274	–0.256	–0.128	0.094		
Straw yield (t/ha)	0.785**	0.395*	0.339	0.537**	0.539**	0.631**	–0.024	0.252	–0.043	0.122	0.586**	–0.320	
Grain yield (t/ha)	0.383*	–0.102	0.209	0.553**	0.585**	0.727**	–0.087	0.441*	–0.239	0.002	0.599**	0.528**	0.634**

* Means significant at 5% level; ** Means significant at 1% level

can provide a reasonable amount of produce with residual fertility. However, proper N management may lead to higher productivity and profitability. It had been observed that without N application one can earn up to 21,020/ha as an additional income but this income could be increased up to 26,500/ha with just additional investment of 500/ha on N management. Both extra application of 20 and 40 kg/ha N resulted 26,415/ha and 27,119/ha with B: C ratio 3.36 and 3.34 respectively. However, control crop gave the lowest net return of 21,020/ha with B: C ratio 2.80. Application of nitrogen just after harvesting of main rice increased the production efficiency over the control, which is mainly owing to higher leaf-area index and dry-matter accumulation leading to higher rate of conversion of photosynthate from source to sink. These results confirm the findings of Munda *et al.* (2009) and Dwibedi *et al.* (2017).

Correlation studies

Correlation studies revealed that grain and straw yields of main rice were highly correlated with number of panicles /m^2 (r = 0.53 and 0.52), spikelets/panicle (r = 0.65 and 0.61) and filled grains/panicle (r = 0.65 and 0.57) respectively. However, other parameters like plant height, tillers/hill, test weight, panicle length and 1000-grains weight were positively correlated with grain and straw yields (Table 7). Number of panicles/m^2 were significantly correlated with plant height and tillers/hill which indicated that healthy plant bears more panicles than the weaker ones. Filled grains/panicle were highly correlated with spikelets/panicle, whereas, chaffy grains/panicle were positively correlated with plant height, panicles/m^2 and spikelets/panicle. However, tillers/hill and filled grains/panicle were negatively correlated with chaffy grains/panicle. Fertility percentage was positively correlated with tillers/hill, panicles/m^2, spikelets/panicle and filled grains/panicle, whereas, negatively correlated with plant height and chaffy grains/panicle. Panicle length was significantly correlated with plant height and chaffy grains/panicle, whereas panicle weight was significantly correlated with spikelets/panicle and filled grains/panicle. Test weight was positively correlated with all parameters except fertility percentage. Dwibedi *et al.* (2017) also reported that, grain and straw yields of main rice were highly correlated with panicles/m^2, test weight and panicle weight.

Grain yield of ratoon crop was significantly correlated with hills/m^2 (r = 0.38), panicles/m^2 (r = 0.55), spikelets/panicle (r = 0.59), filled grains/panicle (r = 0.73), fertility percentage (r = 0.44), test weight (r = 0.60), harvest index (r = 0.53) and straw yield (r = 0.63) (Table 8). However, it was negatively correlated with plant height (r = –0.10), chaffy grains/panicle (r = –0.09) and panicle length (r = –0.24). Straw yield was significantly correlated with hills/m^2, plant height, panicles/m^2, spikelets/panicle, filled grains/panicle and test weight (Table 8). Spikelets/panicle were significantly correlated with hills/m^2, tillers/m^2 and panicles/m^2. Days to maturity, plant height and panicles/m^2 in ratoon had significant positive influence on grain and straw yields (Dwibedi *et al.,* 2017).

Based on the study, it can be concluded that rice ratoon in shallow lowlands is a productive and beneficial option to the rice farmers. Transplanting of *boro* rice on 15th February is the optimum time to harvest optimum main as well as ratoon rice crop yields. The application of 20 kg N/ha is sufficient to obtain higher productivity and profitability from rice ratoon under shallow lowlands of eastern India.

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