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Optimizing Agronomic Practices for Aerobic Rice under Calcareous Soil in Bihar

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Abstract

Three experiments were conducted during 2014-19 at Pusa (Samastipur), Bihar, to develop agronomic practices for aerobic rice with respect to the performance of varieties at different dates of sowing, optimizing seed rate and spacing, and nitrogen requirement and its scheduling under the calcareous soil of North Bihar plains. Sowing during the first week of June resulted in significantly higher yield attributes and grain yield. Among varieties, Abhishek recorded significantly higher grain yield except for the hybrid. Weather variables during different growth phases significantly influenced the yield. The hybrid outyielded all the test varieties. Maximum grain and straw yields were recorded with 20 cm spacing and a 35 kg/ha seed rate. Also, the minimum dry weight of weeds was recorded with this spacing and seed rate. Nitrogen at 140 kg/ha in three or four splits along with brown manuring resulted in significantly higher grain and straw yields. Also, the maximum uptake of NPK and B:C ratio was recorded with this treatment.

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Introduction

The state of Bihar heavily depends on the production of rice for self-sufficiency in food grains for the burgeoning population. Increased demand for rice has to be met from a shrinking resource base. Reduced availability of water and scarcity of labor during the peak rice growing season have been serious issues for sustainable rice production. Innovating into the aerobic system of rice cultivation is one alternative to sustain rice production. This approach is getting worldwide attention as it restricts the wasteful losses of water like evaporation, seepage, percolation, etc. (Bouman *et al.*, 2005). This system is based on the concept of adapting input-responsive varieties to sustain the yield level of 70-80% of flooded rice

(Prasad, 2011).

Time of sowing, plant density per unit area, and scheduling of nitrogen are some of the important factors determining crop productivity. Sowing time greatly influences the temperature and solar radiation, which affect the photosynthetic activities, thereby influencing crop yield. In order to get the best use of prevailing climatic factors, the response of varieties to different dates of sowing needs to be assessed. Nitrogen loss is comparatively higher under aerobic conditions compared to other methods due to alternate wetting and drying, created under this system, which encourages the nitrification-denitrification process resulting in nitrogen loss through N2O and N2. Brown manuring could be helpful to overcome this problem to a great extent as it not only supplies green biomass to the rice crop but also gives a mulching effect. Since nitrogen has a major role in influencing various plant metabolic activities, its proper dose and efficient scheduling are vital for high productivity of aerobic rice (Prasad, 2011).

The information pertaining to the different aspects of aerobic rice cultivation in calcareous soil under the north Bihar plain is lacking. Keeping this in view, three experiments were planned and executed to evaluate (i) the performance of selected varieties to different dates of sowing, (ii) seed rate and spacing, and (iii) levels of nitrogen and their scheduling to optimize the resources with regard to the productivity of aerobic rice.

Material and Methods

Three experiments were conducted during six consecutive wet (*kharif*) seasons from 2014 to 2019 at Dr. Rajendra Prasad Central Agricultural University, Pusa, Samastipur (Bihar). The location is 25.20^0N latitude, 84.40^0E longitude, and 52.3m above mean sea level. Exp. (i) The experiment was laid out during 2014-16 in RBD with 3 replications, comprising 4 varieties *viz.* Arize 6444, Sahbhagidhan, Abhishek, and Rajendra Bhagawti, and 4 dates of sowing,*viz.* 1st June, 15th June, 30th June, and 15th July. Exp. (ii) The second experiment was conducted during 2016-17 for two years in RBD with 3 replications, comprising 4 seed rates of rice, *viz.* 25, 30, 35, and 40 kg/ha, and 3 spacings (cm),*viz.* 20, 25, and 30 cm. Both (exp.1&2) these experiments were fertilized with 120 kg N, 60 kg P_2O_5, and 40 kg K_2O/ha through urea, single superphosphate, and muriate of potash, respectively, along with 25 kg $ZnSO_4$/ha. Phosphorus, potassium, and zinc sulphate were applied basally at the time of sowing, while N was applied in three equal splits at sowing, tillering, and panicle initiation. The rice variety Sahbhagidhan was the test crop. Exp. (iii) The third experiment was conducted for three years during 2017-19 to assess the level and scheduling of nitrogen for aerobic rice in RBD with three replications. The experiment comprised three levels of nitrogen (120, 140, and 160 kg N/ha) and eight schedules of N, *viz.* S_1 ½ Basal (B) + ½ panicle initiation (PI), S_2 + ½ 10 days after sowing (DAS) + ½ PI, S_3- ⅓ B + ⅓ active tillering (AT) + ⅓ PI, S_4-S_3 + brown manuring (BM), S_5-⅓ 10 DAS + ⅓AT + ⅓ PI, S_6 – ¼ B + ¼ AT + ¼ PI + ¼ panicle emergence (PE), S_7-S_6 +BM, S_8- ¼ 10 DAS + ¼ AT + ¼ PI + ¼ PE.

The experiments received a uniform dose of P_2O_5 (60 kg/ha) and K_2O (40 kg/ha) through single superphosphate and muriate of potash, respectively, at the time of sowing. Nitrogen was applied as per treatment. The crop also received 25 kg $ZnSO_4$/ha at the time of sowing. The rice variety Sahbhagidhan was used in the experiments. In the brown manuring

(BM) treatment, dhaincha (*Sesbania aculeate*) was broadcast sown at 40 kg/ha on the day of rice sowing and killed 20 DAS with the help of 2,4-D ester.

The experimental soil was sandy loam and calcareous with pH (8.1-8.4), low in organic carbon (0.41-0.43), low in available nitrogen (217-226kg/ha), medium in available P (15.5-16.2kg/ha), available K (131-137.8kg/ha), and high in calcium carbonate (CaCO3 23.4-29.8%). The field was prepared through a power tiller followed by leveling. Observations on growth and yield parameters were recorded. Grain and straw yield, along with nutrient uptake, were also recorded. Economics was calculated based on the prevailing market rate of the inputs and the economic produce. The benefit-cost ratio was worked out by dividing net returns by the cost of cultivation. Weed dry weight was recorded at harvest with the help of a quadrate of 0.5 m × 0.5 m placed randomly at 3 places in each plot. It was sundried for 2 days, and subsequently, overdrying till constant weight was recorded. It was subjected to square-root transformation before statistical analysis.

Results and Discussion

Variety and date of sowing

Date of sowing assumes significance as it affects the number of rainy as well as cloudy days, thereby influencing solar radiation and photosynthetic activities, ultimately affecting spikelet sterility of the rice crop.

Rice crop exhibited a significant response to variety and date of sowing in yield-attributing characters. Among the varieties and hybrids, hybrid Arize 6444 recorded maximum values of yield-attributing characters, *viz*., panicles/m^2, grains/panicle, and test weight (g). The hybrid recorded (280/m^2) 7.9, 6.8, and 3.2% higher panicles/m^2 over R. Bhagawati, Sahbhagidhan, and Abhishek, respectively. Among the varieties, Abhishek had the maximum panicles (271), which was 4.8 and 3.7% higher over R.Bhagawati and Sahbhagidhan. Grains/panicle were also significantly higher with the hybrid (96), and it was 25, 18.8, and 7.3% higher over Bhagawati, Sahbhagi, and Abhishek, respectively. Among the varieties, Abhishek (89) had an edge over other varieties in terms of grains/panicle, and it was 19 and 12.4% higher over R.Bhagawati and Sahbhagidhan, respectively. Again, the hybrid (4.63 t/ha) outyielded all other varieties with 15.6, 9.7, and 8.0% higher grain yield over R.Bhagawati (3.91 t/ha), Sahbhagidhan (4.18 t/ha), and Abhishek (4.26 t/ha), respectively. Higher grain yield with Abhishek was to the tune of 8.2 and 1.9% over R.Bhagawati and Sahbhagidhan, respectively. These differences might be due to differences in growth behavior and differential physiological response under aerobic conditions. Variation in yield potential could also be the reason.

The pooled data of three years revealed that yield and yield attributes exhibited marginal differences between 1st and 15th June sowing, but when sowing was delayed by a fortnight, the subsequent delayed sowing recorded significantly minimum values of yield and yield attributes. This indicates that sowing on 1st and 15th June is more conducive for aerobic rice. The early-sown crop on 1st June registered 0.7, 7.5, and 9.3% higher panicles than the 15th June (278), 30th June (259), and 15th July (254), respectively. The corresponding increase in grains/panicle was to the tune of 4.3, 14.0, and 17.2% over

15th, 30th June, and 15th July, respectively. Sowing on 1st June recorded a maximum grain yield (4.63 t/ha), which significantly exceeded all other dates of sowing except 15th June. The per cent increase was 0.44, 9.5, and 16.3 over 15th & 30th June and 15th July, respectively. More sunshine hours and fewer number of rainy/cloudy days were observed during this period. This might have resulted in better interception of solar radiation, facilitating more photosynthesis and thereby higher yield (Chaudhary *et al*., 2011). The first fortnight-sown crop gave a significantly maximum benefit-cost ratio.

Variations in weather parameters and rice yield

The variation in maximum temperature, minimum temperature, rainfall, and bright sunshine during sowing to maximum tillering (P1), maximum tillering to reproductive (P2), and the end of reproductive to physiological maturity (P3) stages across the sowing dates is presented in Fig. 1-4. Higher maximum temperature during the initial growing phases of the early-sown crop was found to be beneficial for achieving higher yield, while lower values during the later-sown crop did not benefit the crop. Considering the minimum temperature, its variation during the P3 stage was found to be most significant. A threshold value lower than 25 ^{0}C during the P3 stage negatively influenced the rice yield of later-sown crops. Rainfall was found to vary significantly across different sowing dates with respect to different growing phases. Lower sunshine during the P2 stage affected the rice yield of later-sown rice crops. Transplanting dates and prevailing weather conditions at different growth phases significantly influence rice yield (Sattar and Srivastava, 2021; Bal et al., 2023)

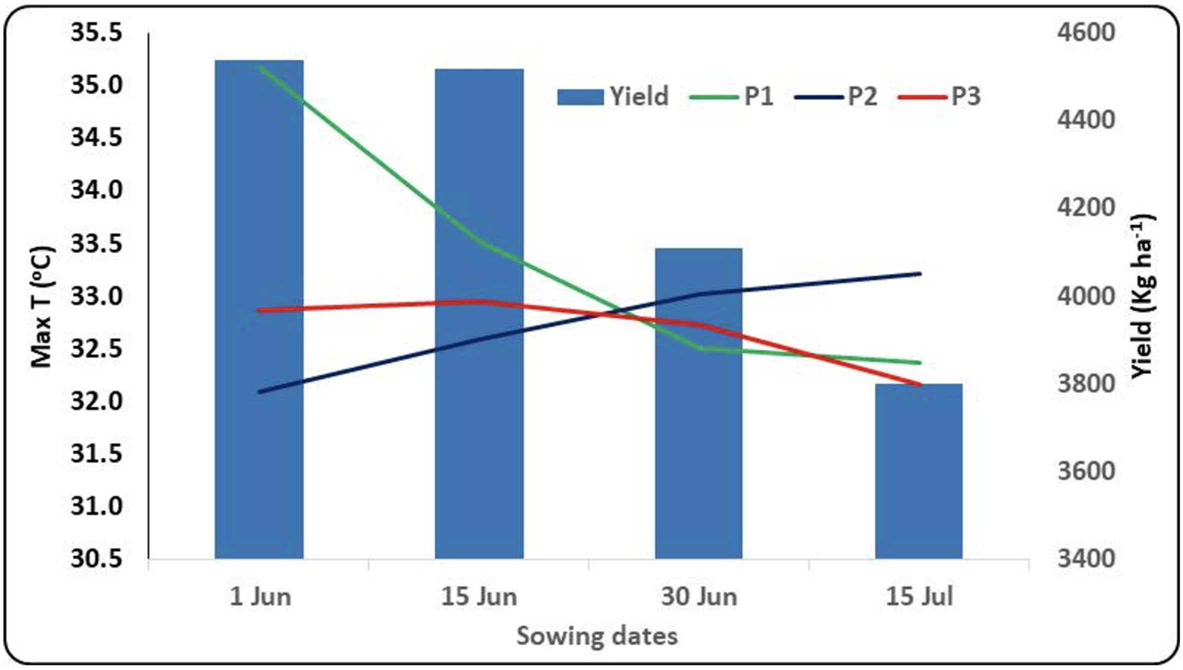

Fig. 1. Variation in maximum temperature (Max T) during different growing phases across the sowing dates of rice

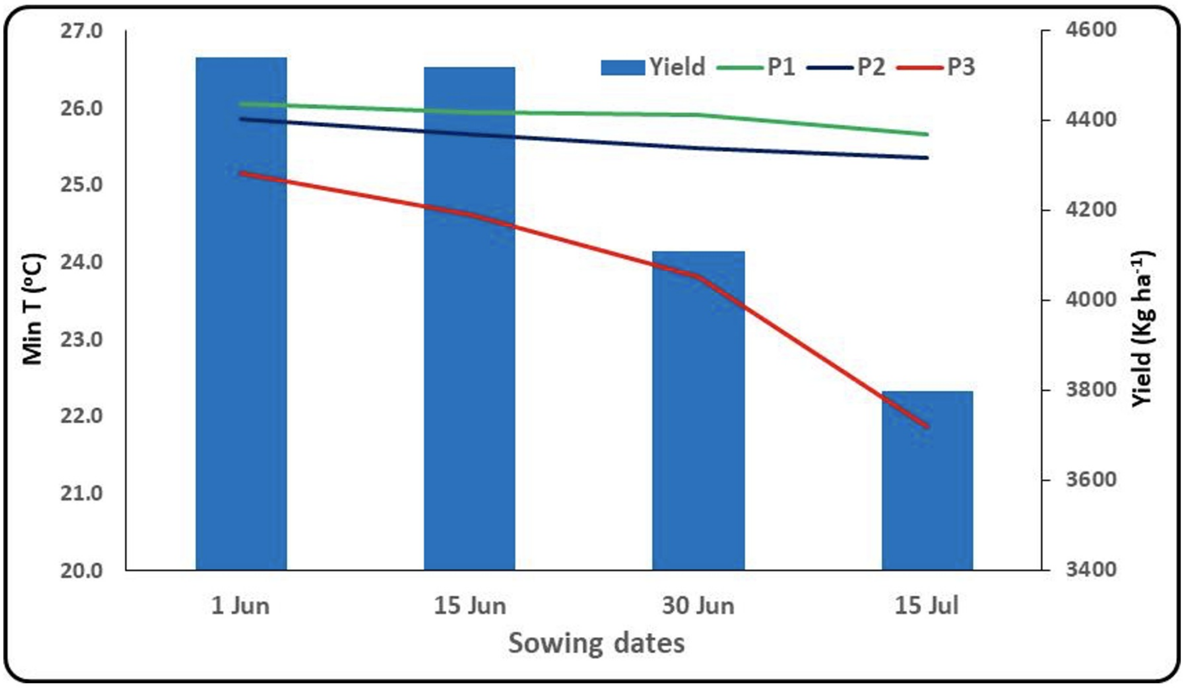

Fig. 2. Variation in minimum temperature (Min T) during different growing phases across the sowing dates of rice

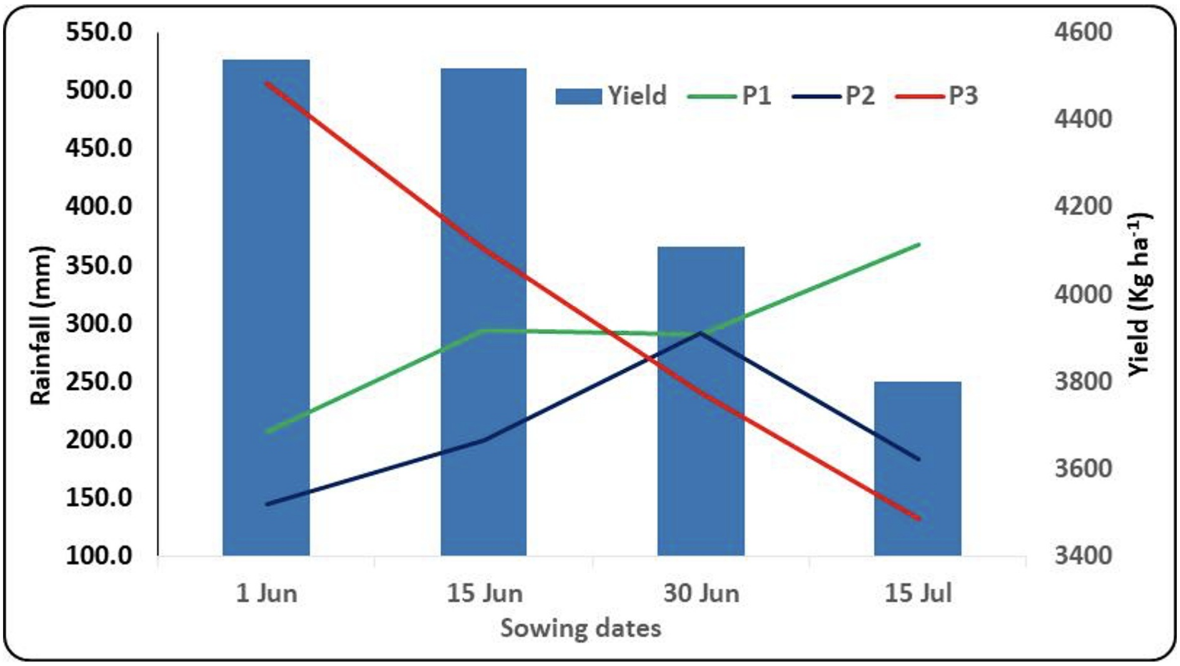

Fig. 3. Variation in rainfall during different growing phases across the sowing dates of rice

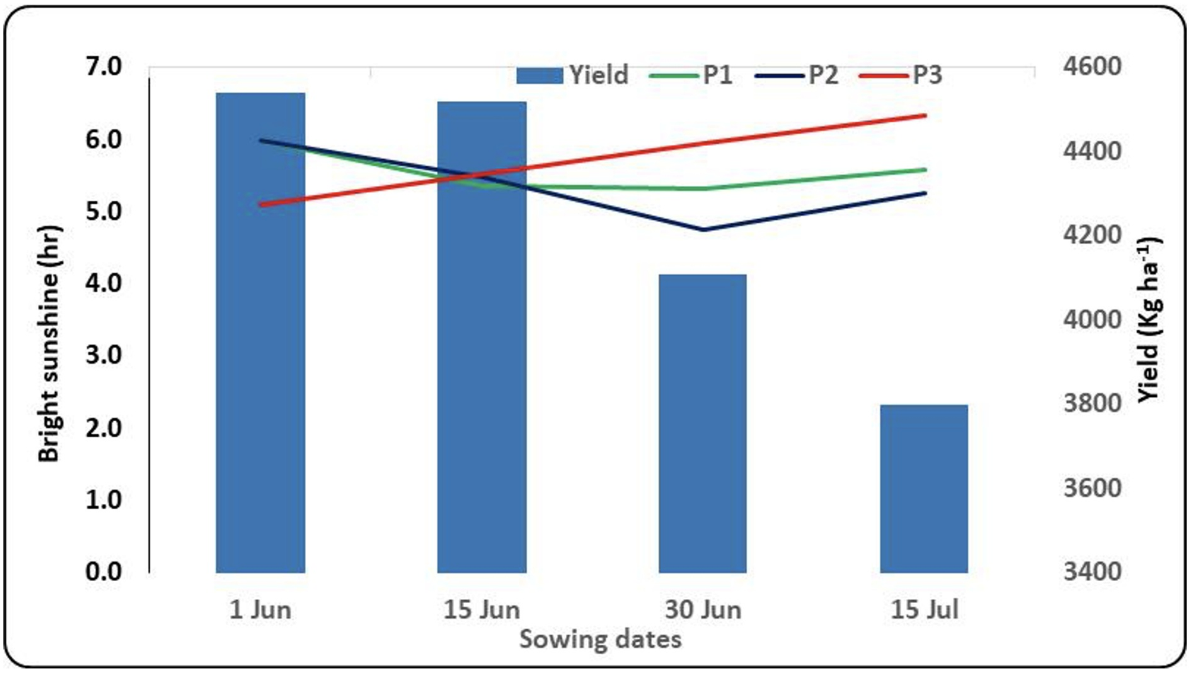

Fig. 4. Variation in bright sunshine (BSS) during different growing phases across the sowing dates of rice

Seed rate and spacing

The relationship of grain yield with various yield attributes is crucial to understand the mechanism involved in yield with respect to plant density, ultimately identifying suitable seed rate and spacing for achieving higher productivity of aerobic rice.

The two years pooled data revealed that yield parameters of rice, *viz.*, panicles/m^2, grains/panicle, test weight (g), were influenced by seed rate (Table 2). Seed rate at 35 kg/ha produced significantly higher panicles/m^2 than 25 and 30 kg/ha but remained on par with 40 kg/ha. There was a 26.5% and 6.8% increase in panicles/m^2 under 35 kg/ha over 25 and 30 kg/ha, respectively. The improvement in panicles may be ascribed to the more no. of plants/m^2 with the increasing rate.

Grains/panicle and test weight (g) remained statistically unaffected. However, maximum grains/panicle were obtained with 25kg seed rate (81) and it was 4.9, 6.2, and 7.4% higher over 30, 35, and 40 kg/ha seed rate, respectively. More number of panicles at the higher seed rate might have created a competition for growth resources, leading to a lower number of grains/panicle. Weed dry weight (g) was significantly reduced with the successive increase in seed rate from 25 to 40 kg/ha. Higher plant population resulting from the higher seed rate might have caused smothering of weeds, resulting in the reduced dry weight of weeds at harvest (Mahajan *et al.*, 2010). All these factors led to significantly maximum grain yield with 35 kg/ha, except 40 kg/ha.

The pooled data revealed that the row spacing at 20 cm recorded a significantly higher number of panicles/m^2, and it was 6.9 and 12.3% higher over 25 and 30 cm spacing, respectively. Contrary to this, higher values of grains/panicle were with the spacing of 30 cm. However, grains/panicle did not differ significantly at each spacing. Grains/panicle with 30 cm spacing was 3.8% higher over 25 and 20 cm. The maximum grain yield was recorded with 20 cm spacing, and it was significantly higher than the grain yield of 25 and 30 cm spacing. The increase in yield with 20 cm was to the tune of 5.6 and 14.6% over 25 and 30 cm, respectively. Higher yield with narrow spacing might be ascribed to the higher panicles/m^2 and minimum weed pressure. Increasing spacing from 20 to 30 cm significantly enhanced the weed dry weight from 14.48 to 18.07 g/m^2. The per cent increase in weed dry weight was 18.4 and 34.3 under 20 cm over 25 and 30 cm spacing, respectively.

Nitrogen level & scheduling

Pooled data of three years (Table 3) revealed that application of 140 kg/N/ha produced significantly higher values of yield parameters, *viz*., panicles/m^2, grains/panicle, and 1000-grain wt. The per cent increase in panicles/m^2 was to the tune of 8.1 and 6.7 with 140 kg over 120 and 160 kg N/ha, respectively, whereas grains/panicle and test weight remained unaffected. The efficient translocation of photosynthate from source to sink is manifested in terms of grains/panicle. However, the maximum no. of grains/panicle was recorded with 140 kg N/ha, and it was 2.6 and 5.3% higher over 120 and 160 kg N/ha, respectively. Grain yield of rice is generally regarded as the product of the number of panicles/m^2, grains/panicle, and 1000-grain weight. Significantly higher grain yield (3.83 t/ha) was with 140 kg N/ha, which was 6.1 and 5.2% higher over 120 and 160 kg N/ha, respectively. Increased application of N might have enhanced the availability of nutrients to the plants, resulting in higher yield attributes and yield (Chaoudhary *et al*., 2014; Gill and Walia, 2014). Almost all the methods of N-scheduling differed significantly amongst themselves for panicle, grain, and straw yield (Table 3), except 3-splitting (S_3) and 4-splitting (S_6). Pooled data on panicles/m^2 revealed that when splitting of N coincided with active tillering (AT), panicle initiation (PI), and panicle emergence (PE) along with basal, it gave significantly higher numbers of panicles over other methods of N-scheduling. Scheduling of N thrice in equal amounts at B, AT, and PI gave 4.5 and 7.1% higher values over splitting twice at B and PI, and 10 DAS and PI, respectively. This value increased to 7.3 and 9.9% when compared with 4-splitting. In all the methods of splitting, basal application of N proved better over delayed application at 10 DAS. The increase was more evident with brown manuring (BM). The maximum number of panicles was noticed when splitting of N at B, AT & PI and B, AT, PI & PE was carried out along with BM. The per cent increase in panicle number was to the tune of 7.3 in brown manured crop with 3-splitting over without (BM). In 4-splitting, the difference between with and without BM was 6.8%. This may be due to the continuous availability of N to the rice crop. Moreover, BM supplies a sizeable amount of N besides other nutrients. It is also involved by way of solubilizing unavailable macro-micro nutrients. Grains/panicle and test weight remained statistically unaffected due to different treatments; however, increased values of these parameters were observed with 3 and 4 splitting of N along with BM. Maximum grain yield of 4.17 t/ha was observed with 4-splitting along BM, which remained at par with 3-splitting with BM while significantly superior over 2-splitting of N and the without brown manured crop.

Four splittings of N along with BM registered 9.1 and 18.5 % higher yield over without BM (4-splits) and 2 splittings at B & PI, respectively, whereas 3 splittings with BM had an advantage of 9.0 and 14.6 % over without BM and 2 splittings at B & PI. Maximum B: C ratio was recorded with 4 splittings along with BM (S_7), which maintained statistical superiority over the rest of the treatments except 3 splittings with BM (S_4). 3 or 4 splittings with BM were also significantly superior to 3 or 4 splittings without BM.

Uptake of nutrients

Different levels of N and its scheduling significantly influenced the uptake of nutrients in grain and straw. Increasing levels of nitrogen up to 140 kg N/ha showed an increasing trend of enhanced uptake of NPK in grain and straw. With regards to scheduling of N, significantly higher uptake of NPK was noticed when the supply of N coincided with B, AT, PI, and PE. This increase was still more evident when it was supplemented with brown manuring. This may be attributed to the enhanced availability of nitrogen in the soil, which not only increased the yield but also increased the nutrient concentration and subsequently uptake. Owing to the synergistic relationship of N with P and K, there was enhanced uptake of these nutrients also. BM, besides supplementing the nutrient needs of the crop, also has an effect on other fixed soil nutrients with its solubilizing ability. Besides, higher grain and straw yield could be the reason for enhanced nutrient uptake (Maity and Mukherjee, 2011).

Post-harvest soil

The nitrogen levels and its scheduling significantly improved the NPK and organic carbon status in the post-harvest soil. Improvement was more noticeable with BM. This may be attributed to the higher levels of N and its scheduling (3 and 4 times) along with the nature of the green biomass of *sesbania* in the solubilization of fixed nutrients in the soil and their subsequent release and mineralization of the added biomass (Chaoudhary *et al*., 2014).

Thus, it can be concluded that sowing the recommended variety during the first fortnight of June with a 35 kg seed rate at 20 cm spacing is suitable for aerobic rice. Weed dry weight was also lower with this. Nitrogen at 140 kg/ha in three or four splittings with BM ensures higher yield without endangering soil health.

Tables

Table 1. Yield attributes, yield and economics of rice as affected by varieties and date of sowing (Pooled data over 3 years)

Treatment	Panicles/m^2	Grains/panicle	Grain yield (t/ha)	Straw yield (t/ha)	B: C ratio
(A) Varieties					
V_1-Arize 6444	280	96	4.63	5.79	1.75
V_2-Sahbhagidhan	261	78	4.18	5.43	1.53
V_3-Abhishek	271	89	4.26	5.58	1.63
V_4-Rajendra Bhagawati	258	72	3.91	5.32	1.55
SEm±	6.04	2.06	0.11	0.13	0.03
CD(p=0.05)	17.61	6.13	0.31	0.37	0.10
Date of sowing					
D_1-1st June	280	93	4.54	5.43	1.74
D_2-15th June	278	89	4.52	5.47	1.73
D_3-30th June	259	80	4.11	5.58	1.57
D_4-15th July	254	77	3.80	5.67	1.45
SEm±	6.04	2.06	0.11	0.13	0.03
CD(p=0.05)	17.61	6.13	0.31	0.37	0.10

Table 2. Yield attributes, yield and economics of rice as influenced by seed rate and spacing (Pooled data over 2 years)

Treatment	Panicles/m^2	Grains/panicle	Test weight (g)	Grain yield (t/ha)	Straw yield (t/ha)	B: C ratio	Weed dry weight (g/m^2) at harvest	Nutrient uptake by weeds (kg/ha)		
								N	P	K
(A) Seed rate (kg/ha)										
S_1-25.0	205	81	24.0	2.90	3.57	1.14	18.35	1.56	0.26	2.31
S_2-30.0	260	77	24.09	3.56	4.34	1.40	16.48	1.37	0.23	2.06
S_3-35.0	279	76	24.16	3.78	4.61	1.51	15.50	1.29	0.22	1.94
S_4-40.0	287	75	24.21	3.85	4.66	1.53	14.89	122	0.21	1.86
SEm±	6.17	1.97	0.35	0.07	0.09	0.036	0.31	0.04	0.02	0.05
CD(p=0.05)	18.41	NS	NS	0.22	0.26	0.11	0.93	0.12	0.06	0.14
Spacing (cm)										
R_1-20	276	75	24.0	3.78	4.48	1.47	14.48	1.10	0.20	1.81
R_2-25	257	78	24.10	3.57	4.27	1.39	16.41	1.36	0.23	2.05
R_3-30	242	78	24.25	3.23	4.16	1.34	18.07	1.52	0.25	2.26
SEm±	5.72	1.76	0.32	0.06	0.07	0.034	0.3	0.04	0.02	0.04
CD(p=0.05)	16.33	NS	NS	0.18	0.19	0.09	0.81	0.11	0.05	0.11

Table 3. Yield attributes, yield and economics of rice as affected by nitrogen levels and scheduling (Pooled data over 3 years)

Treatment	Panicles/m^2	Grains/panicle	Test weight (g)	Grain yield (t/ha)	Straw yield (t/ha)	B: C ratio
Nitrogen scheduling						
S_1	254	72	23.67	3.40	4.15	1.35
S_2	247	73	23.70	3.31	4.04	1.31
S_3	266	74	23.73	3.62	4.38	1.44
S_4	287	76	24.37	3.98	4.78	1.58
S_5	262	74	23.84	3.53	4.27	1.40
S_6	274	74	23.89	3.79	4.66	1.50
S_7	294	76	24.33	4.17	4.96	1.66
S_8	270	74	24.01	3.71	4.45	1.47
SEm±	6.22	1.73	0.36	0.072	0.11	0.04
CD(p=0.05)	18.16	NS	NS	0.21	0.32	0.12
Nitrogen levels (kg/ha)						
N_1	261	74	23.86	3.61	4.30	1.43
N_2	284	76	23.93	3.83	4.60	1.52
N_3	265	72	24.03	3.63	4.43	1.44
SEm±	5.78	1.69	0.32	0.062	0.094	0.037
CD(p=0.05)	15.17	NS	NS	0.18	0.27	0.11

Table 4. Nutrient uptake and soil properties as effected by nitrogen levels and scheduling(Pooled data over 3 years)

Treatment	Nutrient uptake (kg/ha)									Post-harvest soil			Organic carbon (%)
	N			P			K			N	P	K	
	Grain	Straw	Total	Grain	Straw	Total	Grain	Straw	Total				
Nitrogen scheduling													
S_1- ½ Basal (B) + ½ panicle initiation (PI)	41.14	15.36	56.50	5.78	1.95	7.73	7.14	57.69	64.83	228	16.6	139	0.44
S_2-½ 10 days after sowing (DAS) + ½ PI	40.05	14.95	55.0	5.63	1.90	7.53	6.95	56.16	63.11	227	16.2	139	0.44
S_3- ⅓ B + ⅓active tillering (AT) + ⅓ PI	44.16	16.64	60.80	6.15	2.06	8.21	7.60	60.68	68.48	233	16.8	141	0.46
S_4- S_3 + brown manuring (BM)	49.35	18.64	67.99	7.56	2.34	9.9	9.15	66.92	76.07	246	17.5	147	0.50
S_5- ⅓10 DAS + ⅓ AT + ⅓ PI	42.71	15.80	58.51	6.0	2.01	8.01	7.41	59.35	66.76	234	17.1	140	0.46
S_6- ¼ B + ¼ AT + ¼ PI + ¼ panicle emergence (PE)	45.86	17.24	63.10	6.44	2.19	8.63	7.96	64.77	72.73	235	17.0	143	0.48
S_7- S_6 +BM	52.13	19.84	71.97	8.34	2.48	10.82	11.28	69.94	81.22	251	17.7	149	0.51
S_8- ¼ B + ¼ AT +¼ PI + ¼ PE	44.89	16.47	61.36	6.31	2.09	8.4	7.79	61.86	69.65	237	17.2	143	0.48
SEm±	0.93	0.43	2.02	0.14	0.11	0.18	0.31	0.98	1.99	6.18	0.32	3.18	0.01
CD(p=0.05)	2.76	1.27	6.13	0.42	0.31	0.53	0.91	2.98	5.93	17.61	0.96	9.21	0.03
Nitrogen levels (kg/ha)													
N_1-120	44.07	16.34	60.41	6.40	2.06	8.46	7.99	60.21	68.20	229	16.70	141	0.45
N_2-140	46.73	17.45	64.18	6.77	2.20	8.97	8.45	64.38	72.83	234	17.31	143	0.46
N_3-160	44.31	16.82	61.13	6.43	2.12	8.55	8.03	62.02	70.05	243	17.73	143	0.48
SEm±	0.90	0.42	1.97	0.13	0.08	0.18	0.29	0.97	1.81	5.49	0.32	3.23	0.007
CD(p=0.05)	2.59	NS	NS	NS	0.24	0.51	NS	2.83	NS	15.11	0.94	9.07	0.02
	Initial Value									221	15.8	135	0.43

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