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Nitrogen scheduling, phosphorus management and green manuring for increasing productivity of lowland rice

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ABSTRACT

Field experiment was conducted during dry and wet seasons of 2005, 2006 and 2007 at Pusa, Bihar to assess the effect of phosphorus management in pre-rice green manure crop dhaincha and rice on the biomass production of Dhaincha and its effect on yield and nutrient uptake of succeeding rice crop and residual fertility build up in soil. Dhaincha biomass production increased with increasing phosphorus level and seed rate, achieving 21.89 t ha^{-1} when entire dose of phosphorus was given to the green manure crop at higher seed rate. The increase in biomass production was 37.2% over no phosphorus to dhaincha. Addition of nitrogen to the soil ranged from 36.7 to 74.4kg N ha^{-1}. Maximum grain and straw yield of rice was recorded when entire dose of phosphorus was added to dhaincha with 75% recommended dose of nitrogen (RDN) to rice crop, however, this remained at par with 50% RDN added to the rice crop. NPK uptake by rice crop also increased significantly due to these treatments. Second experiment was conducted to schedule the nitrogen splitting in summer green manuring-rice system to optimize the efficiency of applied fertilizer N through better synchronization between crop demand and supply. Significantly maximum grain and straw yields , and net return was recorded when N fertilizer was applied in three splits as ¼N at active tillering + ½N at panicle initiation + ¼ N at flowering.

Key words: *rice, green manuring, nitrogen scheduling, phosphorus*

Organic sources of plant nutrient offer the twin benefit of soil health and fertility management while meeting a part of nutrients need of crops (Chettri and Bandhopadhya, 2005). Green manuring is addition of green plant tissue to soil for improving the soil fertility and economizing the agricultural production system. Dhaincha *(Sesbania aculeata)* is considered ideal green manure crop due to its wider adaptability to varying conditions of soil and climate. It can be grown even under adverse conditions of drought, waterlogging, salinity etc. Growing deep rooted green-manure crop like dhaincha and their incorporation facilitates in bringing nutrients to the top layer from deeper layers. Inadequate availability of quality seeds and inconsistent benefits due to poor agronomic management of green manure crop may be some of the reason for its limited adoption by the farmers, although its value for increasing rice production by supplying nutrients and maintaining soil productivity is well established (Thakur *et al*., 1999). Split application of nitrogen in rice is essential to meet the requirements of crop throughout the growing season by synchronizing availability with crop demand (Zaidi *et al*., 2007).

The present experiment was, therefore, conducted to study the effect of phosphorus management and seed rate on biomass production of pre-rice green manure crop Dhaincha and its influence on succeeding rice.The present study was also made to optimize N application under green manuring to exploit yield potential of lowland transplanted rice.

MATERIALS AND METHODS

Two field experiments were conducted on rice at Rajendra Agricultural University, Pusa (Bihar) on a silty loam soil with pH 8.6, organic carbon 0.48%, $CaCO_3$ 30.4% and available nitrogen, phosphorus and potassium 242.6, 26.2 and 129.2 kg ha^{-1}, respectively. The first experiment was carried out during dry and wet seasons of 2005, 2006 and 2007 The experiment was laid out in split-plot design with three replications. There were 18 treatment combinations consisting of 6 combination of P management in rice and preceeding Dhaincha with Dhaincha at two levels of seed rate in the main plot and 3 levels of nitrogen to rice crop in sub-plots. The main plot treatments were whole P to Dhaincha and no P to rice with Dhaincha at seed rate of 20 kg ha^{-1}; whole P to Dhaincha with Dhaincha at seed rate of 30 kg ha^{-1}; ½ P to Dhaincha + ½ P to rice with Dhaincha at 20 kg ha^{-1} seed rate; ½ P to dhaincha + ½ P to rice with Dhaincha at seed rate of 30 kg ha^{-1}; No P to Dhaincha and whole P to rice with Dhaincha at seed rate of 20 kg ha^{-1} and No P to Dhaincha and whole P to rice with Dhaincha at seed rate of 30 kg ha^{-1}. The sub-plot treatments were control, 50% of RDN (recommended dose of nitrogen) and 75% of RDN to rice crop during wet season. The recommended doses of fertilizer for rice was 80-40-20 kg NPK ha^{-1}. Dhaincha was sown by broadcasting at two seed rate (20 and 30 kg ha^{-1}) as per treatment with basal dose of 20 kg N ha^{-1}. Phosphorus was added to Dhaincha as per treatment. Dhaincha was sown during last week of May for maintaining suitable age during both the years and incorporated *in-situ* at 50 days after sowing (DAS). 25 days old seedling of rice var. Rajshree was transplanted 5 days after incorporation of Dhaincha in same layout with 3 levels of nitrogen (0, 50 and 75% RDN). Rice crop was transplanted at a spacing of 20 x 15 cm. 75% of recommended dose of potassium, was added as basal. Remaining potassium was added at PI stage. Nitrogen was applied in 3-equal splits, *viz*., one third each at basal active tillering and panicle initiation stage. The second experiment was laid out in RBD with 6-treatments and 5 replications and conducted during 2006 and 2007 to determine the proper stage of N application in the field enriched with pre-rice green manuring to enhance the rice yield. The nitrogen treatments included were 1/3N each at basal (B)+ active tillering (AT) + panicle initiation (PI)., 1/3N each at 7 days after transplanting (DAT) + PI + flowering (FL), 1/3N each at AT + PI +FL, ¼N 7DAT + ¼ AT + ¼ N PI +1/4N FL., ¼ AT +½PI +¼ FL, ½ PI + ½ FL. Twenty five days old seedling of rice var. Rajshree was transplanted 5 days after *in situ* incorporation of Dhaincha at 50 DAS which was grown as pre- rice crop with seed rate at 30kg ha^{-1}, basal dose of N @ 20kg ha^{-1} and phosphorus @ 40kg ha^{-1}. No P was added to the succeeding rice crop. Nitrogen scheduling was done at 75% RDN (60kg ha^{-1}). Potassium was added as 75% basal and 25% at PI. Yield components and the grain and straw yields were recoded at harvest and the data were statistically analysed. Plant NPK uptake and soil available NPK at harvest were estimated.

RESULT AND DISCUSSION

As pre-rice legume, Dhaincha produced 10.78-21.89 t ha^{-1} biomass which contributed 36.7-74.4 kg N ha^{-1} to the soil at different levels of phosphorus and seed rate (Table 1). Dhaincha biomass production increased with increasing phosporus level and seed rate, achieving 21.89 t ha^{-1} biomass when entire dose of P was given to the green manure crop with higher seed rate.Addition of nitrogen due to Dhaincha biomass production ranged from 36.7 to 74.4 kg N ha^{-1}. The increase in biomass production due to P application might be due to increased root biomass, which in turn improved the nutrient-uptake pattern leading to better metabolism and assimilation of photosynthates resulting into greater biomass production and finally more addition of N to the succeeding rice crop.

There was significant effect of combination of phosphorus management and seed rate of preceding Dhaincha green manure crop on growth and yield

Table 1. Effect of treatments on biomass production and nitrogen addition by Dhaincha (pooled data of 3-years)

Treatment	Biomass (t ha^{-1})	N-addition (kg ha^{-1})
Whole P to Dhaincha with seed rate at 20kg ha^{-1}	16.23	55.2
Whole P to Dhaincha with seed rate at 30kg ha^{-1}	21.89	74.4
Half P to Dhaincha with seed rate at 20kg ha^{-1} + Half P to rice	14.36	48.8
Half P to Dhaincha with seed rate at 30kg ha^{-1} + Half P to rice	18.94	64.4
Whole P to rice and Dhaincha with seed rate at 20kg ha^{-1}	10.78	36.7
Whole P to rice and Dhaincha with seed rate at 30kg ha^{-1}	13.74	46.7

attributes of succeeding transplanted rice. Significantly higher growth and yield contributing characters of rice: *viz.*, panicles m^{-2}, grains panicle^{-1} 1000-grain weight, leaf and shoot dry weight, and root dry weight were recorded when entire dose of recommended P was added to preceding Dhaincha compared with the treatment when entire P was added to the succeeding rice crop directly. Significantly more number of panicle m^{-2} along with more grains panicle^{-1} were observed in the treatment receiving full dose of P to Dhaincha with higher seed rate (30 kg ha^{-1}) compared with the control when entire P was added directly to the rice crop. Leaf and shoot dry weight and root dry weight per metre square behaved similar to panicles m^{-2}, and grains panicle^{-1}, indicating that supplementing the inorganic P with organic source which enhanced the chemical status due to N-fixation and solubilization effect of Dhaincha on P, and other nutrients, helping to improve the nutritional environment of rhizospheric as well as plant system and ultimately metabolic and photosynthetic activity, resulting in better development of yield attributes (Pattanayak *et al*., 2007)

Increase of N application, significantly and progressively increased the panicles m^{-2}, grains panicle^{-1}, dry matter (leaf and shoot) accumulation including root dry weight. This may be ascribed to the stimulatory effect of N on tillering, and continuous and adequate availability of N during the formation of spikilet thereby preventing its degeneration (Gardner *et al*.1988). Green manuring improved the general soil environment, physico-chemical and biological conditions favourable for growth and yield.

Grain yield was significantly higher in all the treatment where P was added to the pre-rice Dhaincha either full or half of recommended dose over the treatment when entire recommended dose of P was added to the rice alone.The treatment, however, exhibited statistical parity with the treatment getting half of recommended P. Rice staw followed similar pattern as the grain. Maximum grain yield was observed with 75% RDN, being statistically at par with 50% RDN. Both these treatment were significantly superior over control, registering 31.20 and 27.37% increase over control by 75 and 50% RDN, respectively. Lodging tendency was observed in the pre-maturity stage of the rice in the treatment involving 75% RDN, suggesting excess of available N in this treatment. The absence of the yield difference between the application of 75% and 50% RDN to rice indicated that 50% RDN is sufficient along with green manuring. The results on grain yield thus confirmed the trend observed earlier in the yield contributing characters, emphasing importance of green manuring in economizing the chemical fertilizer, particularly nitrogen. Preceding crop Dhaincha add appreciable amount of N, P, K, Ca, Mg, S and micronutrients to the soil (Mankotia, 2007).

The NPK uptake differed significantly due to different treatments. Uptake by grain and straw individually as well as total uptake involving rice were significantly higher in the treatment, whole P to Dhaincha with seed rate of 30 kg ha^{-1}. Maximum uptake of NPK was observed with 75% RDN which was significantly superior over 50% RDN and control. Higher uptake may be ascribed to increased dry matter production and partly due to increase in its concentration (Eagle *et al*., 2001). Increased uptake may also be accounted to the better root growth leading to more absorption from larger soil volume, besides improved soil physical condition (Table 2).

There was marginal improvement in the available NPK in post harvest soil. The maximum value was recorded with the treatment receiving entire P to preceding Dhaincha and 75% RDN to rice. Improvement in chemical status of soil may be attributed to fixation of N, solubilization of reserve soil P as well as added P, release of exchangeable K by the action of organic acids, higher left over crop residues due to favorable crop and development etc (Tripathi *et al*. 2009). The highest net returns were observed with the treatment having superimposition of 75% RDN over dhaincha green manuring and it was closely followed by 50% RDN.

Green manuring with Dhaincha produced about 24.53 t ha^{-1} biomass, contributing about 83kg N ha^{-1} to the soil. The crop was grown as per the stander practice developed during the first year of experimentation (seed rate @ 30kg ha^{-1} and whole P to Dhaincha).

Split application of N affected panicles m^{-2} and grains panicle^{-1} of rice to a significant level. Nitrogen (N) application as 25% at AT + 50% PI + 25% FL gave maximum number of panicle m^{-2}(320) and grains panicle^{-1}(111). This treatment was statistically at par with 75% of RDN to rice crop during wet season and

Table 2. Yield attributes, yield and net return of rice as influenced by different treatments (pooled data of 3-years)

Treatment	Panicles m^{-2}	Panicle length (cm)	Grains $panicle^{-1}$	1000-grain weight	Leaf dry weight ($g\ m^{-2}$)	Shoot dry weight ($g\ m^{-2}$)	Root dry weight ($g\ m^{-2}$)	Grain yield ($t\ ha^{-1}$)	Straw yield ($t\ ha^{-1}$)	Net return (₹ ha^{-1})
P-management & seed rate of Dhaincha										
Whole P to Dhaincha with seed rate at 20kg ha^{-1}	288	27.30	89	21.85	289	1117	182	4.62	7.03	26541
Whole P to Dhaincha with seed rate at 30kg ha^{-1}	297	27.6	96	22.09	309	1213	199	5.26	7.83	31697
Half P to Dhaincha with seed rate at 20kg ha^{-1} + Half P to rice	286	27.26	88	21.85	283	1060	178	4.50	6.79	25457
Half P to Dhaincha with seed rate at 30kg ha^{-1} + Half P to rice	292	27.37	94	21.98	295	1188	189	4.94	7.42	29089
Whole P to rice and Dhaincha with seed rate at 20kg ha^{-1}	283	27.10	86	21.66	275	989	164	4.10	6.19	22097
Whole P to rice and Dhaincha with seed rate at 30kg ha^{-1}	286	27.26	89	21.76	283	1032	174	4.46	6.73	25013
CD ($P<0.05$)	9	NS	4	0.1	11	23	9	0.42	0.52	2941
Nitrogen levels (kg ha^{-1})										
Control	260	26.55	79	21.61	265	978	158	3.64	5.53	18662
50% RDN	295	27.62	91	21.87	283	1103	182	5.01	7.57	29707
75% RDN	311	27.81	98	22.14	319	1219	203	5.29	7.88	31578
CD ($P<0.05$	6	NS	2	0.05	6	13	5	0.33	0.40	2287

50% of RDN (recommended dose of nitrogen) which in turn did not differ statistically from control, ¼N 7DAT + ¼ AT + ¼ N PI +¼ FL and ½ PI + ½ FL. Nitrogen is most effectively utilized for growth and yield formation when it is congruent with crop requirement (Cassman *et al.* 1998). Increased value of yield attributes under these treatments due to delayed N application might be due to better synchronization between crop N demand and supply at critical physiological stages crucial for better assimilation and translocation of photosynthates towards grain (Avasthe, 2009).

Scheduling fertilizer N coinciding with the late growth stages of rice crop recorded significantly higher grain yield over other N scheduling practices, this could be due to sustained supply of N at crucial growth stages (Singh *et al*, 2007). Three splitting of N at AT (25%)+PI (50%)+FL (25%) resulted in significantly higher yield over other treatment except in the treatment involving 1/3 each at AT, PI and FL. N scheduling at 25% at AT + 50% PI + 25% FL gave 12.1, 9.4, 7.51 and 6.4 per cent higher grain yield over control, ¼N 7DAT + ¼ AT + ¼ N PI +¼ FL, 50% of RDN (recommended dose of nitrogen) and ½ PI + ½ FL , respectively. Treatments where major share of N were applied during the early growth stages, produced lower grain yield. This may be attributed to the failure to synchronize the N supply as per demand of the crop at all the major stages of crop growth crucial for higher yields. Delayed application of N might be helpful in keeping the plant greener for long and thereby facilitating the higher production and translocation of photosynthates towards economic parts (Dar *et al*., 2000).

Higher rice yield may also be attributed to the improved soil condition and addition of essential nutrients due to pre-rice green manuring with Dhaincha that could meet the initial N requirement of rice crop. Since rice roots are functional only 7-10 DAT after recovery from the transplanting shock, excess of N application during early growth stages might lead to various loses resulting in declining response to applied fertilizer N (Table 4). Due to quick release nature of Dhaincha, it is not in synchrony with rice N demand (Becker and Ladha, 1997).

The N uptake with the split application of fertilizer N at ¼ at AT+1/2 at PI+ ¼ at FL treatment was significantly higher (4.96 to 14.79%), however it was comparable with ½ PI +½ FL and 1/3 each at AT, PI and FL. De Datta (1981) opined that maximum use

Table 3. Nutrient uptake and nutrient status of soil as influenced by treatment (pooled data of 3-years)

Treatment	Uptake (Kg ha^{-1})						Total uptake (kg ha^{-1})			Nutrient status of soil			
	Nitrogen		Phosphorus		Potash		N	P	K	Organic	N	P	K
	Grain	Straw	Grain	Straw	Grain	Straw				(%)	(kg ha^{-1})	(kg ha^{-1})	(kg ha^{-1})
P-management and seed rate of Dhaincha													
Whole P to Dhaincha with seed rate at 20kg ha^{-1}	67.58	33.07	12.50	5.42	18.98	124.54	100.65	17.92	143.52	0.50	251	26.7	141
Whole P to Dhaincha with seed rate at 30kg ha^{-1}	78.92	38.41	15.26	6.19	22.10	140.32	117.33	21.45	162.42	0.52	251	26.9	143
Half P to Dhaincha with seed rate at 20kg ha^{-1}+Half P to rice	65.71	31.27	12.15	5.17	18.45	120.31	96.98	17.32	138.76	0.51	248	27.7	140
Half P to Dhaincha with seed rate at 30kg ha^{-1}+Half P to rice	73.73	35.63	13.36	5.79	20.78	132.11	109.36	19.15	152.89	0.52	249	27.7	141
Whole P to rice and Dhaincha with seed rate at 20kg ha^{-1}	58.63	27.86	10.25	4.71	15.99	108.34	86.49	14.96	124.33	0.51	245	28.6	136
Whole P to rice and Dhaincha with seed rate at 30kg ha^{-1}	64.67	30.98	11.60	5.12	18.29	119.21	95.65	16.72	137.50	0.52	246	27.9	137
CD ($P<0.05$)	5.18	2.76	1.16	0.54	3.11	9.7	5.97	0.73	8.60	0.01	8	0.81	3
Nitrogen levels (Kg ha^{-1})													
Control	51.53	24.47	9.16	4.16	14.43	96.75	76.0	13.32	111.18	0.50	243	26.4	136
50% RDN	73.67	35.40	13.76	5.83	20.91	133.89	109.07	19.59	154.80	0.51	248	27.3	139
75% RDN	79.39	39.0	15.32	6.31	22.56	141.83	118.39	21.63	164.39	0.53	254	29.1	144
CD ($P<0.05$)	3.12	1.43	0.69	0.31	1.87	6.13	3.73	0.46	5.34	0.01	5	0.51	2
Initial value	-	-	-	-	-	-	-	-	-	0.48	242	26.2	129

RDN - *recommended dose of nitrogen*

Table 4. Effect of Nitrogen scheduling on yield, N uptake and net return (₹ ha^{-1}) of transplanted rice

Treatment	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Panicle m^{-2}	Grains panicle^{-1}	N-uptake		Total N uptake (kg ha^{-1})	Net return (₹. ha^{-1})
					Grain	Straw		
1/3 each at B, AT & PI	5.18	7.81	313	98	75.72	35.93	111.65	31140
1/3 each at 7 DAT, PI & FL	5.40	8.12	314	102	79.48	38.20	117.68	32987
1/3 each at AT, PI & FL	5.54	8.27	317	105	82.04	39.72	121.76	34113
¼ 7DAT, ¼ AT, ¼ PI & ¼ FL	5.31	8.01	313	101	78.10	37.66	115.76	32207
¼ AT, ½ PI & ¼ FL	5.81	8.65	320	111	86.61	41.55	128.16	36368
½ PI, ½ FL	5.46	8.19	312	104	81.93	40.17	122.1	33445
CD ($P<0.05$)	0.34	0.41	7	4	-	-	6.34	2361

AT - active tillering, PI - panicle initiation, FL- flowering of applied fertilizer N can be achieved with its synchrony to crop N demand. Thus organic (green manuring) and inorganic sources of N to rice are not only complimentary but also synergistics as green manuring with dhaincha offers twin benefits- addition of nutrients and enhancement in the effect of added mineral fertilizers (Manivannan and Sriramachandrasekharan, 2009). The highest net return (₹ 36368/-) was recorded for three split N application as ¼ N at AT+½ N at PI+ ¼ N at FL amongst the various N application schedules, maintaining statistical parity with 1/3 N each at AT+PI+FL.

On the basis of these two experiments, that there is no need of applying phosphorus to the main crop of rice if the same dose is applied in the preceding green manure crop of Dhaincha, This enchances the growth of green manure crop, thereby giving more quantity of biomass leading to soil enrichment with several essential plant nutrients. This may lead to the saving of substantial amount of N fertilizer. Fertilizer N should be applied in three splits as ¼ N at AT + ½ N at PI +¼ N at FL combined with green manuring for achieving maximum grain yield and net return under existing agro-climatic condition of north Bihar plains.

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