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Direct and residual effects of nitrogen and phosphorus fertilization of Dhaincha (*Sesbania aculeata*) seed crop on succeeding wheat (*Triticum aestivum*) at two levels of N fertilization

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ABSTRACT

A field experiment was carried out for two year (June- April 2009 and 2010) at New Delhi in a sandy loam soil to assess the impact of phosphorus (0, 13.2 and 26.4 kg/ha) and nitrogen (0, 30 kg at sowing, 15 kg each at sowing and flowering and 30 kg at flowering in sub-plots) fertilization on seed production of dhaincha was studied in a split plot design with three replications. The residual effects N and P fertilizers were studied on wheat crop that received 60 and 120 kg/ha N fertilizer. Significantly higher yield of dhaincha, wheat, system and net returns were recorded with 26.4 kg P/ha fertilization of dhaincha. Application of entire N at sowing proved promising for dhaincha seed yield (1.34 t/ha) that however failed to exert any influence on yield of succeeding wheat and the system. Wheat crop responded to 120 kg/ha N fertilization directly. Interaction of N and P fertilization indicated that dhaincha crop receiving N at sowing responded to P fertilization up to 13.2 kg while no N fertilized or N fertilized crop at flowering stage responded to 26.4 kg P application. The interaction effects were found non-significant in wheat and on the system.

Keywords: *Dhaincha, Economics, Nitrogen, Nutrient uptake, Phosphorus, Wheat.*

INTRODUCTION

Green manuring (GM) of dhaincha (Sesbania aculeata (Wills.) Poir.) in rice based cropping systems is an age old practice for maintaining soil fertility. The evolution of the concept brown manuring has not only solved the need for land allocation for GM crop rising separately but also extended its scope to new niches like direct seeded wet land rice (Pathak et al., 2011), upland rice (RWC.,2006) and also to vegetable crops like onion (Prabhakar, 2012). The increasing area under dhaincha manuring calls for planning for supply of quality seed at appropriate time and price. Thus, dhaincha seed crop grown in kharif season could find a place in cropping systems. Among the factors influencing seed production of dhaincha, adequate fertilization especially phosphorus and nitrogen are most important.

Phosphorus, the second most critical plant nutrient over all, assumes primary importance in case of legumes owing to its prominent role in promoting root growth, nodulation and thus biological N fixation (Sinclair and Vadez, 2002). The response

of dhaincha GM crop to P fertilization is well studied. As the seeds are the major sink of P, its requirement by dhaincha seed crop is entirely different from that of its GM crop and the information on P requirements of seed crop of dhaincha are lacking. The low P status of majority of Indian soils (Srinivasarao and Vittal, 2007) and the high and ever increasing prices of P fertilizers in the era of decontrolled fertilizer prices calls for assessing its response and its requirement**.** Though legumes are well known for biological N fixation (BNF) and can not only meet their own N requirements but also contributes to N nutrition of succeeding cereal crops. However, they do require external supply of N through fertilizers during seedling stage (from germination to start of BNF) and also at reproductive stage (after cessation of BNF from nodule, where the N demand exceed the supply from BNF). To overcome the N deficiency induced crop yield losses during the above phases, a starter dose of 10-20 kg N/ha at sowing is recommended (Boroomandan et al., 2009) for all legumes. However, the reported reductions in BNF in dhaincha seed crop with N application at sowing (Uddin, 2008) and improvements in seed yields of dhaincha (Kathiresan and Duraisamy., 2001) due to foliar spray of 2% di-ammonium phosphate and in soybean (Gan et al., 2003) and top dressing of 50 kg N at flowering stage (R1 stage) reveals the importance of time of application of N in legume crops. The reported P and N nutrient interactions on increasing the nodulation and biomass production of Stylosanthes humilis (Gates and Wilson, 1974) Sesbania aculeata and S. rostrata green manure crops (Hiremath and Patel, 1994) as compared to either of these nutrients application calls for assessing the N and P interaction on dhaincha seed crop. The reported economies in nitrogen fertilizer in wheat when grown after grain legumes (Gangaiah, 2012) and of phosphorus applied to field pea on succeeding rice (Singh et al., 2012) calls for assessing the residual effects of N and P fertilizer of dhaincha on succeeding wheat . Hence the present study was made on this new emerging cropping system.

MATERIALS AND METHODS

Experimental site characteristics

A field experiment was conducted during for two years (June- April 2009-10 and 2010-11) at the Research farm of Indian Agricultural Research Institute, New Delhi located at 28°35‟N latitude and 77°12‟E longitude at an altitude of about 228.61 m above mean sea level at a new site each year. The experimental sandy loam soil (61.2% sand, 19.6% silt and 19.2% clay estimated by hydrometer method, Bouyoucos, 1962) with 0.39% & 0.37 organic carbon had 170 & 175 kg/ha of available N, 221.7 & 195 kg/ha of available K (1:2.5 soil : water), 7.8 & 7.7 pH (Jackson, 1973) and 13.3 & 13.1 kg/ha of available P (Olsen *et al*., 1956) before sowing dhaincha in 2009 & 2010, respectively.

Weather conditions

The experimental site has a semi-arid and sub-tropical climate with hot dry summers and severe cold winters. The mean maximum and minimum daily temperatures that were highest is at the time of sowing during dhaincha in June / July (~40 and 24°C) gradually decreased to 31 and 15°C at its harvest time in November. The temperature reached their lowest values in January (13.2 and 1.9°C) during wheat season and gradually rose to 35 and 19°C in April. The location has a mean (56 years) annual rain fall of 769 mm (January-December), with nearly 85 per cent of this being received during July to September and the rest during the period of October - May.

Experimental Design and Treatments

The study on dhaincha “local variety” was made using a split plot design while that of wheat “PBW 343” was done using split-split plot design with treatments replicated thrice. In dhaincha, the treatments were formed by combination of three levels of phosphorus (0, 13.2 and 26.4 kg P/ha in main plots) and three schedules of nitrogen fertilization (30 kg/ha) i.e. N application at sowing only, N application at flowering only and two equal split application of N at sowing and flowering) along with an absolute control (no N) treatment as sub-plots. During wheat season, dhaincha treatments were further sub-divided to accommodate two levels of recommended dose of N fertilization (RDN) i.e. 50 and 100% with an RDN of 120 kg/ha.

Crop culture

Land was prepared after a pre-sowing irrigation in mid June (for Dhaincha) and November (for wheat) by running disc twice followed by harrowing and leveling. Dhaincha was sown by placing the seeds in the furrow opened with manual drawn plough (*kera* method) in rows at 60 cm apart on 30 June and 2 July and was harvested on 3 and 5 November in 2009 and 2010, respectively. Wheat was sown in rows 22.5 cm apart using a seed rate of 100 kg/ha through tractor drawn seed drill on 15 November and was harvested in third week of April during both the years. Gap filling was done a week after germination, wherever necessary while thinning was done 15 days after sowing (DAS) to maintain an intra plant spacing of 20 cm in dhaincha. In dhaincha, entire dose of P as single super phosphate (SSP) and N as prilled urea (PU) as per treatment was applied broadcast and incorporated by cultivator. The N applied at flowering stage was placed (no incorporation) near the hill of the plant after an irrigation. In wheat, N as PU was applied as per treatments in two equal splits at sowing and at first irrigation at 21 days later coinciding with crown root initiation (CRI) stage. Wheat crop also received 75% of the recommended dose of P (19.8 kg/ha) as SSP at sowing. Both the crops received 36 kg/ha of potassium (K) as muriate of potash uniformly that was

broadcast and was mixed into the soil by tractor drawn cultivator before sowing. To supplement the rainfall during the crop growth period, dhaincha received four need based irrigations while wheat crop was 6 irrigations at critical growth stages (crown root initiation, tillering, jointing, flowering, milking and dough stage). Weeds were managed through three manual weedings done at 20, 40 and 60 DAS in dhaincha. In wheat, weeds were managed through pre-emergence application of pendimethalin (1 kg a.i/ha in500 liters of water, done immediately after sowing) and two manual weeding at 19 and 40 days after sowing. The crops were harvested at physiological maturity stage.

Chemical analysis, economics, and wheat equivalent yields

Chemical analyses of plant and soil samples were done using standard procedures (Prasad, 1998). The nutrient (N and P) concentration of economic produce and stalks of dhaincha and wheat (grain and straw) was determined and uptake was obtained as product of concentration and yield. In calculation of economics, minimum support price of wheat was taken (Rs.10, 000, 10,800 / ton of wheat grain in 2009 and 2010) while for dhaincha a assumed seed price of Rs.20,000 /ton in both the years was taken as this crop is not covered under minimum support price of government. The dhaincha stalks and wheat straw were assigned a price of Rs 500 and 1,500/ton. A fertilizer price (Rs/kg) of 11, 55 and 6 is used for N, P and K. The dhaincha crop yields were converted to wheat equivalent yield (WEY) by obtaining the product of yield of dhaincha and its seed price, which is divided by price of wheat. The WEY of dhaincha thus obtained was added to that of wheat yield and system WEY was arrived.

Statistical analysis

The analysis of variance (ANOVA) was done in split-plot design for dhaincha and split-split plot for wheat for various soil and plant observations recorded. The significance of treatment differences was tested by F (Variance ratio) test. Critical difference (CD) at 5 per cent level of significance (P=0.05) was worked out for comparison and statistical interpretation of treatments as per Gomez and Gomez (1988). Pooled analysis was also carried out when two year results were similar.

RESULTS AND DISCUSSION

Dhaincha

Phosphorus and nitrogen fertilization had a significant influence on growth attributes, nodulation (Table 1) yield attributes and yield (Table 2) of dhaincha. The interaction effects of N x P was also found to have significant influence on seed yield of dhaincha (Table 3).

Each successive increase of 13.2 kg phosphorus fertilization from 0 to 26.4 kg has significantly increased plant height, nodule number and nodule weight, while the increase in number of branches /plant was significant up to 13.2 kg P application only (Table 1). Similar increases in plant height and nodulation of seven legume crops including *S.aculeata* grown for green manure purpose with P fertilization were reported (Pramanik, 2009).

Among the yield attributes of dhaincha, pods/plant, seeds/pod (during both the years) and test weight (during 2010 only) increased significantly with P fertilization up to 13.2 kg only however, 26.4 kg P fertilization recorded the highest values (Table 2). On mean basis, application of 13.2 kg P has increased the pods/plant and seeds/pod of dhaincha by 10.3, and 15.0% over control. The corresponding increase with 26.4 kg P application over 13.2 kg P was 5.5, and 3.36 %. Test weight increased at a constant rate of 2.24% with each increase of 13.2 kg P fertilization up to 26.4 kg P dose over their preceding dose. The increase in branches/plant with P fertilization has led to production of more number of pods/plant.

The seed yields increased significantly with each successive increase of 13.2 kg P fertilization from 0 to 26.4 kg/ha. On an average, the seed yield of dhaincha increased by 23.1 and 8.8% with 13.2 and 26.4 kg P fertilization over 0 and 13.2 kg P application (Table 2). The increased seed yield with phosphorus fertilization was due to cumulative effects of improved yield attributes. The increased plant height, number branches /plant (Table 1) along with higher seed yields (Table 2) with application of 26.4 kg P /ha led to significant increase in biological yields of dhaincha over control during both the years. The biological yield of dhaincha with 13.2 kg P fertilization was at par with 0 and 26.4 kg P application during both the years. In general, dhaincha has low harvest index (0.086) that was significantly improved (17.1%) with 13.2 kg /ha P fertilization over control only, however, their values were highest with 26.4 kg P fertilization. The higher increases in seed yield as compared to biological yield have led to increases in harvest index with P fertilization. Higher seed and biological yield of *S.aculeata* with P fertilization of the present study are in close agreement with the findings of Parlawar. 2005 and Yaragoppa.2003.

Nitrogen fertilization at sowing alone being on par with its equal split application at sowing and flowering produced significantly taller plants with more number of branches, nodule number and nodule weight than no N fertilized and flowering stage N fertilized dhaincha. Similar significant increases in pods/plant among yield attributes with N fertilization was observed. Nitrogen application at sowing (entire or 50% N) has enhanced pod number of dhaincha on an average by 15.3% over control and by 13.3% over N application at flowering only. Better N supply at seedling stage with N fertilization at

sowing (100 or 50%) has favoured the production of taller plants with more branches/plant that has enabled the plant to bear more number of pods/plant. Though seeds/pod and test weight of dhaincha were not influenced by N fertilization, their values were highest with N application at sowing (entire or 50% of recommended). The significant increases in number of pods/plant coupled with the higher number of seeds/pod and test weight of dhaincha with N application at sowing alone and 50% N each at sowing and flowering together has increased dhaincha seed yields on an average by 19.6 (0.22 t/ha) and 17.9 % (0.20 t/ha) over unfertilized control. A significant increase in seed yield of dhaincha due to N application at flowering alone over control was seen during second year only. The increases in seed yield of soybean due to N fertilization at sowing (Wang ShuQi Han *et al.,* 2009; Boroomandan *et al.,* 2009) supports the current investigation findings. The increased plant height and number branches /plant (Table 1) along with higher seed yields (Table 2) with application of N at sowing alone or 50% N each at sowing and flowering has led to marked improvement in biological yields over control. The biological yield on an average increased by 17.3 and 13.3% with N fertilization at sowing only and 50%N each at sowing and flowering stages. Nitrogen fertilization failed to exert any marked influence on dhaincha harvest index.

Table 1. Effect of phosphorus and nitrogen fertilization on growth attributes and nodulation of *dhaincha* (Pooled data of two years)

Treatment	Pods /plant		Seeds /pod		Test weight (g)		Seed yield (t/ha)		Biological yield (t/ha)		Harvest index*
	2009	2010	2009	2010	2009	2010	2009	2010	2009	2010	
P level (kg/ha)											
0	38.8	36.8	23.6	22.9	18.36	18.31	1.06	1.02	13.32	14.03	0.076
13.2	41.6	41.8	26.6	26.9	18.61	18.88	1.30	1.26	14.12	14.79	0.089
26.4	44.0	44.0	27.9	27.4	19.14	19.20	1.37	1.42	14.76	15.20	0.093
SEm±	0.63	0.59	0.69	0.80	0.19	0.17	0.012	0.027	0.29	0.28	0.002
CD (P=0.05)	2.50	2.34	2.69	3.11	NS	0.51	0.036	0.08	1.13	1.08	0.006
N level (kg/ha) and time of application											
0	39.1	37.6	24.8	23.7	18.34	18.39	1.17	1.06	12.84	13.55	0.085
30 at Sowing (S)	43.5	45.0	27.0	27.3	18.83	18.98	1.30	1.38	15.03	15.94	0.087
30 at Flowering (F)	39.9	38.2	25.7	25.5	18.60	18.62	1.18	1.16	13.58	14.13	0.084
15 each at S & F	43.4	45.1	26.5	26.3	19.05	18.93	1.31	1.33	14.80	15.09	0.088
SEm±	0.88	0.75	0.83	1.02	0.18	0.16	0.007	0.028	0.49	0.44	0.003
CD (P=0.05)	2.60	2.22	NS	NS	NS	NS	0.028	0.11	1.47	1.34	NS

Table 2. Effects of nitrogen and phosphorus fertilization on yield attributes, yield and economics of dhaincha

Treatment	Plant height (cm)	Branches/ plant	Nodules/plant		Nodule weight (g/plant)	
			60 DAS	90 DAS	60 DAS	90 DAS
P level (kg/ha)						
0	257.9	12.8	38.9	70.8	0.14	1.28
13.2	277.6	14.6	57.2	92.4	0.20	1.58
26.4	296.0	15.4	70.9	108.1	0.23	1.91
SEm±	2.00	0.50	1.8	4.0	0.0055	0.04
CD (P=0.05)	7.80	1.90	6.9	15.7	0.022	0.18
N level (kg/ha) and time of application						
0	254.8	13.2	48.5	71.9	0.14	1.25
30 at Sowing (S)	294.2	15.1	64.8	106.1	0.24	1.87
30 at Flowering(F)	269.4	14.1	50.9	84.8	0.16	1.44
15 each at S & F	290.4	14.6	58.3	98.9	0.22	1.81
SEm±	2.60	0.50	2.9	5.5	0.012	0.063

The interaction effect of phosphorus and nitrogen fertilization (Table 3) on dhaincha indicates that when no nitrogen was applied or applied at flowering stage only, seed yield increased significantly with P fertilization up to 26.4 kg/ha. In contrast, dhaincha crop receiving N at sowing (100 or 50%), seed yield increased significantly up to 13.2 kg P only. This result indicates that by scheduling N fertilizer of dhaincha at sowing, 13.2 kg P fertilizer can be economized. Application of N at sowing alone along with 26.4 kg P has resulted in the production of highest seed yield closely followed by equal split application of N at sowing and flowering during both the years.

Table 3. Interaction effect of nitrogen and phosphorus fertilization on seed yield of *Dhaincha*

P dose (kg/ha)	N dose (30 kg/ha) & time of application							
	2009				2010			
	0	At S	At F	At S & F	0	At S	At F	At S & F
0	0.96	1.15	0.96	1.18	0.86	1.15	0.95	1.10
13.2	1.23	1.35	1.25	1.35	1.09	1.42	1.15	1.39
26.4	1.32	1.41	1.33	1.40	1.24	1.56	1.38	1.50
SEm±	0.021				0.050			
CD (P=0.05)	0.062				0.150			

S: Sowing; F: Flowering

Wheat

The yield attributes and yield data of wheat as influenced by residual effects of N and P fertilization dhaincha seed crop and direct N fertilization are presented in Table 4. The data shows significant impacts of P fertilization of Dhaincha and N fertilization of wheat on all yield attributes (except test weight) and grain and straw yield of wheat during both the years. Residual effects of N fertilization of dhaincha and interaction effects of N x P (dhaincha) x N fertilization (wheat) were found non significant.

Wheat crop grown after dhaincha receiving 26.4 kg P produced significantly higher number of ear heads and grains/ ear head than that after no P fertilized dhaincha during both the years. The yield attributes of wheat after13.2 kg P applied dhaincha were at par with no P and 26.4 kg P application. On an average, application of 26.4 kg P to dhaincha has increased the number of ear heads/m^2 and grains/ ear head of wheat by 28.6 and 2.1 over no P application. The above increases in ear heads/m^2 and grains/ ear head of together led to a mean wheat grain yield increase of 0.38 t/ha in 26.4 kg P applied plots over no P fertilized plots of dhaincha. Straw yield of wheat followed the trend of grain yield. Similar residual effects of P fertilization of chhollia (chickpea harvested for green seeds) on baby corn (Gangaiah and Ahlawat, 2008) and filed pea on rice (Singh *et al*., 2012) were reported.

System productivity

The system productivity expressed as wheat equivalent yield (WEY) as influenced by residual effects of N and P fertilization dhaincha is presented in Table 4. The data reveals significant influence of P fertilization on WEY of system. Each successive increase of 13.2 kg P fertilization of dhaincha up to 26.4 kg/ha has significantly improved WEY. The WEY of system increased by 12.6 and 8.8% with application of 13.2 and 26.4 kg P fertilizer over 0 and 13.2 kg P fertilization.

Table 4. Residual effects of N and P fertilization of dhaincha and direct effects of N fertilization of wheat on yield attributes, grain and straw yield (t/ha) of wheat and system productivity

Treatment	Ear heads/m^2		Grains/ear head		Test weight (g)		Grain yield (t/ha)		Straw yield (t/ha)		WEY
	2009	2010	2009	2010	2009	2010	2009	2010	2009	2010	of system (t/ha)*
P level (kg/ha)to dhaincha											
0	313.0	319.7	43.6	45.4	33.1	33.4	4.03	4.13	6.05	6.20	6.16
13.2	324.2	336.1	45.3	47.2	33.7	33.8	4.26	4.50	6.19	6.59	6.94
26.4	341.2	348.7	46.7	48.5	34.1	34.0	4.69	4.83	6.70	7.00	7.55
SEm±	2.83	3.78	0.40	0.46	0.25	0.21	0.056	0.098	0.074	0.11	0.145
CD (P=0.05)	12.73	17.01	1.71	2.07	NS	NS	0.25	0.44	0.33	0.49	0.60
N level (kg/ha) and time of application to dhaincha											
0	318.0	333.0	44.5	46.5	33.4	33.7	4.21	4.43	6.21	6.49	6.55
30 at sowing (S)	334.0	335.4	46.1	47.0	33.5	33.8	4.45	4.50	6.40	6.64	7.16
30 at flowering (F)	320.8	337.0	44.3	47.5	33.8	33.8	4.26	4.54	6.30	6.76	6.74
15 at each at S & F	331.8	334.0	45.9	47.1	33.7	33.7	4.37	4.48	6.36	6.50	7.07
SEm±	3.40	4.53	0.48	0.55	0.30	0.25	0.067	0.118	0.088	0.132	0.169
CD (P=0.05)	10.1	13.41	NS	NS	NS	NS	NS	NS	NS	NS	NS
Nitrogen (kg/ha) to wheat											
60	312.2	320.0	43.5	45.3	33.2	33.3	4.03	4.14	6.09	6.33	
120	340.1	349.7	46.9	48.7	34.1	34.2	4.61	4.84	6.52	6.86	
SEm±	1.98	2.64	0.28	0.32	0.175	0.16	0.039	0.069	0.051	0.077	
CD (P=0.05)	12.1	16.11	1.71	1.98	NS	NS	0.22	0.42	0.29	0.47	

WEY: Wheat Equivalent Yield

*Only grain yield of crops considered

Application of recommended dose of N (RDN) to wheat produced markedly higher number of ear heads and grains/ ear head than 50 RDN fertilized crop during both the years. On an average, wheat crop receiving RDN produced 28.8 and 3.4 higher number of ear heads/m^2 and grains/ ear head than 50% RDN receiving wheat. These increases in ear heads/m^2 and grains/ ear head of wheat together led to a mean grain yield increase of 0.64 t/ha in RDN applied plots over 50%RDN fertilized

crop. Straw yield of wheat followed the trend of grain yield. Similar yields responses of wheat to N fertilization was reported by Ramanjeet Singh 2009.

Economics

The economics of the investigation (Table 5) reveals that net returns of dhaincha, wheat and the system increased with each successive increase of 13.2 kg P fertilization of Dhaincha up to 26.4 kg/ha. Among N fertilizer treatments, 30 kg N application to dhaincha at sowing recorded the highest net returns from component crops as well as the cropping system. This was closely followed by 15 kg N application each at sowing and flowering. Direct application of RDN to wheat led to Rs. 5994 higher net income over 50%RD N application. The greater income in gross income with increased crop yields with N and P fertilization of dhaincha as compared to cost of cultivation has led to the higher net returns.

Table 5. Effect of nitrogen and phosphorus fertilization on nutrient uptake of *Dhaincha* and wheat (pooled data)

Treatment	Nutrient uptake (kg/ha)						Nutrient addition through fertilizers (kg/ha) to system	
	Dhaincha		Wheat		System			
	N	P	N	P	N	P	N	P
P level (kg/ha) to dhaincha								
0	149.6	18.99	93.0	8.14	242.6	27.13	112.5	19.8
13.2	170.8	21.79	99.0	8.85	269.8	30.64	112.5	33.0
26.4	182.9	23.28	107.0	9.71	289.9	32.99	112.5	46.2
SEm±	3.1	0.53	1.7	0.12				
CD (P=0.05)	12.3	2.09	6.3	0.50				
N level (kg/ha) and time of application to dhaincha								
0	150.0	18.96	98.5	8.73	248.5	27.69	90.0	33.0
30 at S	183.4	23.49	101.6	9.04	285.0	32.53	120.0	33.0
30 at F	160.4	20.24	99.2	8.89	259.6	29.13	120.0	33.0
15 each at S & F	177.3	22.76	99.7	8.94	277.0	31.70	120.0	33.0
SEm±	5.4	0.75	2.04	0.14				
CD (P=0.05)	16.1	2.16	NS	NS				
N dose (kg/ha) to wheat								
60			93.1	8.25				
120			105.6	9.54				
SEm±			1.19	0.08				
CD (P=0.05)			6.72	0.45				

Nutrient uptake and nutrient balance

Nutrient uptake (pooled) dhaincha and wheat was significantly influenced by P and N fertilization of dhaincha and N fertilization of wheat (Table 6). In general, the N and P uptake of dhaincha is 1.68 and 2.40 times that of wheat increased significantly with N fertilization at sowing (entire or 50%) and P fertilization up to 13.2 kg/ha. The N uptake of Dhaincha is 7.46 times that of its mean application (22.5 kg) which most probably has come from biological N fixation (with a small contribution coming from soil reserves) while that of wheat is nearly equal to its application (110% of its application). Dhaincha crop removed ~19 kg of P in unfertilized control plot that increased by 2.8 and 1.5 kg with application of 13.2 and 26.4 kg P fertilization. Wheat crop received 19.8 kg P /ha uniformly recorded lowest uptake in unfertilized dhaincha plots (8.14 kg/ha) that increased significantly with P fertilization of dhaincha. Dhaincha P fertilization @ 13.2 and 26.4 kg P/ha has increased P uptake of wheat by 0.71 and 0.86 kg over 0 and 13.2 kg P application. Phosphorus fertilization of dhaincha @ 26.4 kg significantly increased N uptake of wheat over no P application. Nitrogen fertilization of dhaincha failed to alter N and P uptake of wheat crop. Direct N application to wheat has increased N and P uptake significantly and was highest with RDN. Soil fertility status after harvest of each crop (Table 7) was significantly influenced by P fertilization only. Soil was depleted of P content in no P fertilized plots of dhaincha (1.2-1.3 kg/ha) while there was a positive balance of 0.5-0.8 kg/ha in 26.4 kg P fertilized dhaincha. Addition of 19.8 kg/ha of P to wheat made the soil to recoup from the depletion in control plot. In total, 26.4-19.8 kg P fertilized dhaincha-wheat system maintained the soil P while 0-19.8 fertilization dhaincha-wheat recorded a significant depletion over its initial status. The organic carbon (OC) and N content of soil were not markedly altered by different fertilization treatments; there is positive balance of OC and N after dhaincha and the positive balances of OC continued even after wheat while that of N disappeared. The dhaincha crop at maturity shredded all the foliage at maturity and this along with flower shredding contributed to lot of organic material (>1 ton) carbon addition to top soil hence, high OC values were recorded. The improved n content of soil after dhaincha was ascribed to BNF and its mineralization.

Table 6. Economics of dhaincha seed crop - wheat system as influenced by phosphorus and nitrogen fertilization of dhaincha and N fertilization of wheat (mean data)

Treatment	Cost of cultivation (Rs/ha)			Gross returns (Rs/ha)			Net returns (Rs/ha)		
	Dhaincha	Wheat	System	Dhaincha	Wheat	System	Dhaincha	Wheat	System
P level (kg/ha) to dhaincha									
0	8,711	25,425	34,136	21,910	51,612	73,522	13,199	26,187	39,386
13.2	9,479	25,724	35,203	25,788	55,144	80,932	16,509	29,420	45,929
26.4	10,215	26,102	36,317	27,829	59,786	87,615	17,474	33,684	51,158
N level (kg/ha) and time of application to dhaincha									
0	9,170	25,254	34,424	22,816	54,648	77,464	13,646	29,394	43,040
30 at sowing (S)	9,535	26,160	35,695	27,173	56,475	83,648	17,638	30,315	47,953
30 at flowering (F)	9,560	25,720	35,280	23,900	55,330	79,230	14,340	29,610	43,950
15 at each at S & F	9,608	25,866	35,474	26,620	55,644	82,264	17,012	29,778	46,790
N dose (kg/ha) to wheat									
60		25,000			51,675			26,675	
120		26,500			59,169			32,669	

MSP of wheat grain (Rs/ton): 10,000 & 10,800 during 2008-09 & 2009-10 and wheat straw 1,500 during both years
Price of Dhaincha seed (Rs/ton) and stalks: 20,000 and 500 during both the years

Table 7. Effects of N and P fertilization of dhaincha and N fertilization of wheat on soil fertility status

Treatment	After dhaincha						After wheat					
	OC (%)		Available N (kg/ha)		Available P (kg/ha)		OC (%)		Available N (kg/ha)		Available P (kg/ha)	
	2009	2010	2009	2010	2009	2010	2009	2010	2009	2010	2009	2010
P dose to *Dhaincha* (kg/ha)												
0	0.426	0.405	179.0	182.3	12.0	11.9	0.3962	0.3765	172.1	178.3	12.5	12.6
13.2	0.433	0.413	181.5	185.0	13.1	13.1	0.4025	0.3841	173.2	178.0	13.0	12.9
26.4	0.444	0.420	183.1	187.0	13.8	13.9	0.4045	0.3914	172.5	176.8	13.2	13.3
SEm±	0.006	0.008	0.86	0.79	0.09	0.07	0.0047	0.0051	2.2	2.4	0.15	0.13
CD (P=0.05)	NS	NS	NS	NS	0.36	0.28	NS	NS	NS	NS	0.62	0.54
N dose (kg/ha) & time of application to *Dhaincha*												
0	0.427	0.408	179.9	181.4	13.1	13.1	0.3967	0.379	168.3	173.9	12.5	12.7
RDN at sowing (S)	0.440	0.418	182.3	186.9	12.9	12.7	0.4039	0.389	172.3	176.9	13.0	12.9
RDN at flowering (F)	0.429	0.410	180.4	183.5	12.9	12.8	0.4016	0.381	170.2	175.0	13.2	13.3
50% RDN each at S & F	0.441	0.416	182.2	187.3	12.9	12.9	0.4021	0.387	172.5	176.4	12.8	12.7
SEm±	0.008	0.011	0.88	1.05	0.27	0.09	0.0056	0.0061	2.6	2.9	0.18	0.156
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
N (kg/ha) to wheat												
60	0.105	0.126	0.072				0.4005	0.379	171.5	175.3	13.0	13.0
120	0.44	0.48	NS				0.4016	0.389	173.1	177.2	12.8	12.9
SEm±							0.0032	0.0035	1.5	1.7	0.102	0.089
CD (P=0.05)							NS	NS	NS	NS	NS	NS
Initial status	0.39	0.37	170	175	13.3	13.1						

Conclusions

This study showed that application of 26.4 kg P along with 30 kg N at sowing is recommended for higher seed production of dhaincha. Significant residual effects of 26.4 kg phosphorus applied to dhaincha were seen on succeeding wheat and the same is effective in maintaining soil P status in Dhaincha-wheat system. Wheat crop responded to 120 kg/ha N fertilization directly. Interaction of N and P fertilization indicated that dhaincha crop receiving N at sowing responded to P fertilization up to 13.2 kg while no N fertilized or N fertilized crop at flowering stage responded to 26.4 kg P application.

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