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Research Paper

Seed production of *dhaincha* (*Sesbania aculeata*) as influenced by nitrogen and phosphorus fertilization

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ABSTRACT

A field experiment was carried out under protective irrigation during *kharif* (June-November) seasons of 2009 and 2010 at New Delhi in a sandy loam soil low in available nitrogen (173 kg/ha) and medium in available phosphorus (13.2 kg/ha) to study the effect of levels of phosphorus (0, 13.2 and 26.4 kg/ha in main plots) 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 [*Sesbania aculeata* (Wills.) Poir.] in a split plot design with three replications. The results indicated significant impacts of nitrogen (N) and phosphorus (P) fertilization on growth, nodulation, biomass and seed production of dhaincha. On an average, application of 13.2 and 26.4 kg P/ha has increased the seed yield of dhaincha by 241 and 113 kg /ha over no P (1,040 kg/ha) and 13.2 kg P application, respectively. Net returns (₹17.47 × 10^3/ha) were highest with application of 26.4 kg P while the agronomic P use efficiency was highest with 13.2 kg P application. Application of 30 kg N at sowing (1,340 kg/ha) or 15 kg each at sowing and flowering (1,320 kg/ha) being at par enhanced the seed yield of dhaincha on average by 221 kg/ha over no N application (1,118 kg/ha). Net returns (₹17.64 × 10^3/ha) and agronomic N use efficiency were highest with 30 kg N application at sowing. Both P (26.4 kg/ha) and N (30 kg/ha at sowing) fertilization have significantly improved nodulation in dhaincha as evident from increased nodule number (108.1 and 106.1) and nodule weight (1.91 and 1.87 g) at 90 days after sowing over control (70.8 and 1.28 g). Interaction of nitrogen and phosphorus fertilization indicated that application of 30 kg N at sowing along with 26.4 kg P resulted in the highest seed yield (1,486 kg/ha) and thus is recommended for seed production of dhaincha.

Key words : Dhaincha, Nitrogen, Nutrient uptake, Phosphorus, Seed yield

Green manuring (GM) is an age old practice of farming for maintaining soil fertility. However, the advent of green revolution has not only increased chemical fertilizer consumption but also marginalized the role of green manures in intensive cropping systems. This is evident from the declining area under GM over time, in 2004-05 it was practiced on 3.57 m ha area (FAI, 2007-08). Of the various crops for *in-situ* GM, Dhaincha is the most important GM crop for rice based cropping systems. Further, dhaincha cultivation is promising even in salt affected, ill drained soils and areas with high rainfall (Parlawar *et al.*, 2003). The major constraint for dhaincha GM is the lack of availability of adequate quality seed at appropriate time and at reasonable price. The seed production is concentrated in Peninsular India and by the time the seed reaches North India, the prices become high, while seed quality is not ensured. The emerging use of protein rich dhaincha seed as a potential ingredient of animal feed (Hossain *et al.*, 2001) also calls for production of more seed.

Of the various factors influencing seed production of dhaincha, adequate phosphorus fertilization is the most important one. Phosphorus fertilization enhances root growth and nodulation in legumes, which helps in biological nitrogen (N) fixation (Sinclair and Vadez, 2002). Seeds are the major sink of P and hence, P need by seed crop of dhaincha is entirely different from that of green manuring crop. With majority soils of India rated low for available P (Devraj *et al.*, 2008; Srinivasarao and Vittal, 2007) responses of dhaincha seed crop to application of P fertilization needs to be worked out**.**

A starter dose of 10-20 kg N/ha at sowing is recommended (Boroomandan *et al.*, 2009) for all legumes. Shortage of N supply during reproductive phase i.e. after cessation of BNF from nodule is also reported in legumes. Thus, not only quantity of N application but also its time of application is important for seed crop of dhaincha as

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evident from the studies of Uddin *et al.* (2008), who observed reductions in BNF of root nodulating *Sesbania aculeata* seed crop with N application at sowing. Thus, top dressing of N as soil or foliar application at reproductive stage may be promising as this stage coincides with peak nodulation and cessation N fixation. Studies on this line by Kathiresan and Duraisamy (2001) clearly indicated that foliar spray of 2% di-ammonium phosphate enhanced the seed yields of dhaincha by 60.8%. However, no studies on time of N application on seed yield of dhaincha have been made.

Further, application of N and P together may be promising for dhaincha than application of either of the nutrients. In *Sesbania aculeata* and *S. rostrata* grown for green manure purpose, a significant increase in biomass production, nodulation was reported with combined application of N and P (Hiremath and Patel, 1994). The present study was undertaken to assess the effects of N and P fertilization and time of N application on the seed yield of dhaincha.

MATERIALS AND METHODS

A field experiment was conducted during the rainy seasons (June-November) of 2009 and 2010 at the Indian Agricultural Research Institute, New Delhi. The experimental soil was sandy loam of 7.7 pH on an average (mean of two years) contained 0.38% organic carbon, 13.2 kg/ha of available P, 173 kg/ha of available N and 208 kg/ha of available K at the time of sowing. The experiment was conducted in a split plot design with three levels each of phosphorus (0, 13.2 and 26.4 kg P/ha) in main plots and nitrogen fertilization (no N, 30 kg N at sowing, 30 kg N at flowering and 15 kg N each at sowing and flowering) in sub-plots with 3 replications. After a pre-sowing irrigation, the land was prepared by running disc twice followed by harrowing and levelling. Dhiancha (local variety) was sown on 30 June and 2 July and was harvested on 3 and 5 November in 2009 and 2010, respectively. Seeds were placed in the furrow opened with manual drawn plough (*kera* method) in rows formed at 60 cm apart. 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. The entire dose of P as single super phosphate and N as prilled urea as per treatment were applied as broadcast and incorporated by last planking. The N applied at flowering was placed (no incorporation) near the hill of the plant after an irrigation. The rainfall during the crop growth period was 499.1 mm in 2009 and 521.6 mm in 2010 and to protect the crop from moisture stress four need based irrigations were given. Three manual weedings were done at 20, 40 and 60 DAS during both the years to keep the crop free from weed competition. The crop was harvested at the ground level with the help of a sickle and allowed to sun dry for 3 days. The seeds were then separated by beating with sticks. Chemical analyses of plant and soil samples were done using standard procedures (Prasad, 1998). Nutrient uptake was arrived as product of nutrient concentration and yield. Agronomic use efficiency of nutrient was worked out as ratio of seed yield (kg/ha) in fertilized-seed yield in unfertilized plot/amount of fertilizer applied (kg/ha) and expressed as kg grain/kg nutrient application. Nutrient harvest index was worked as ratio of nutrient uptake by seed to that of total nutrient uptake by the crop. Economics (mean) were calculated using market prices of inputs and outputs. Net Benefit: cost (B:C) ratio was worked as ratio of net returns to that of cost of cultivation.

RESULTS AND DISCUSSION

Growth attributes and nodulation

Each successive increase of 13.2 kg P fertilizer application significantly increased plant height at maturity, branches/plant at harvest, nodule number and nodule weight/plant both at 60 and 90 DAS up to 26.4 kg/ha P application during both the years. However, the increase in number of branches/plant and nodules/plant at 90 DAS during 2010 were significant with application of 26.4 and 13.2 kg P over control (no P) only. Phosphorus by way of promoting root growth might have increased the number of nodules and their weight. Increase in plant height and nodule number of the present investigation is in close agreement with the findings of Khan *et al.* (2001). An increase in nodule weight due to P fertilization in legumes was also reported by Kolawole and Kang (1997).

Application of N fertilizer at sowing (entire or 50% of recommended) significantly increased the plant height, nodule number and nodule weight over control and entire N application at flowering stage of crop. These attributes have attained highest values with entire N application at sowing which in turn was at par with 50% N application at sowing and flowering. Application of entire N at flowering though enhanced the plant height significantly over control, it failed to improve number of branches/plant, nodule number and nodule weight. Significant increases in number of branches/plant were obtained when entire N was applied at sowing over control only. The N applied at sowing (either 30 or 15 kg) enabled the crop to derive N from soil during the period of exhaust of seed N reserves to that of meeting N needs by plant from BNF from nodules. Further, nitrogen being a constituent of phosphonucleotide might have favoured increase in cell division and thus increased the cell mass formation that was manifested as increased plant height and also in formation of more branches. The increase in plant height due to N application at flowering corroborate the findings of Kathiresan and Duraisamy (2001) who reported increase in plant height with 2% DAP spray over control. Low N status of the soil coupled with non-treatment of dhaincha seeds with *Rhizobium* culture might be the reasons for N response of dhaincha as measured in terms of growth and nodulation. However, the current investigation findings are in contrast to those of Kumar Rao *et al.* (1981) with pigeonpea, who observed 74% decline in nodule mass/plant at 30 DAS with N fertilization at sowing and these differences however disappeared by 60 DAS.

Yield attributes, yield and economics

The yield attributes, yield and harvest index pooled data (Table 2) reveals significant impacts of P and N fertilization. Application of 13.2 kg P fertilizer has significantly increased pods/plant, seeds/pod and test weight of dhaincha over no P application. Though increasing the P fertilization to 26.4 kg/ha has enhanced the above yield attributes to their highest values, the increases were not statistically significant. Application of 13.2 kg P has increased the pods/plant, seeds/pod and test weight of dhaincha by 2.9, 3.5 and 0.41 g, respectively over control. The corresponding increase with 26.4 kg P application over 13.2 kg P was 2.3, 0.9 and 0.42 g, respectively. 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. The increase in seed yield of dhaincha with 13.2 and 26.4 kg P application over control and 13.2 kg P application was 23.1 (240 kg/ha) and 8.8% (113 kg/ha), respectively. The increased plant height and number branches /plant (Table 1) along with higher seed yields (Table 2) with application of 13.2 kg P/ha led to significant increase in biological yield of dhaincha over control, though 26.4 kg P/ha recorded the highest biological yields. Harvest index followed the trend of biological yield. The greater increases in seed yield in comparison to biological yield have led to increases in harvest index with P fertilization. Higher seed and biological yield of *Sesbania aculeata* with P fertilization of the present study are in close agreement with the findings of Parlawar *et al.* (2005) and Yaragoppa *et al.* (2003).

N fertilization and its time of application have significant influence on pods/plant, seed yield and biological yield only (Table 2). Application of entire N (30 kg) at sowing being on par with 15 kg N application at sowing and flowering has significantly increased number of pods/plant of dhiancha over no N application or entire N (30 kg) application at flowering. N application at sowing (entire or 50% N) has enhanced pod number of dhaincha by 5.8 over control and 5.2 over entire N application at flowering. The increase in branches/plant with N fertilization (30 at sowing and 15 each at sowing and flowering) has enabled the plant to bear more number of pods/plant. N supply as per needs of crop right from sowing has enabled the plant to produce more source (biomass) that were effectively translocated into the sink i.e. pods. On the contrary, application of 30 kg N at flowering though enhanced plant height, branches and biomass; the same were not translocated into reproductive structures and thus failed to enhance pods/plant markedly. 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 and marginally higher values of seeds/pod and test weight with 30 kg N at sowing or 15 kg N each at sowing and flowering together have led to 221 and 202 kg/ha of more seed yield than unfertilized control.

Table 1. Effect of phosphorus and nitrogen fertilization on growth attributes and nodulation of *dhiancha*

Treatment	Plant height (cm)		Branches/plant at harvest		Number of nodules/plant				Nodule weight (g)			
					at 60 DAS		at 90 DAS		at 60 DAS		at 90 DAS	
	2009	2010	2009	2010	2009	2010	2009	2010	2009	2010	2009	2010
P level (kg/ha)												
0	264.2	251.6	13.0	12.6	40.4	37.4	71.6	70.0	0.15	0.13	1.27	1.29
13.2	282.1	273.1	14.7	14.5	54.8	59.6	93.1	91.7	0.19	0.21	1.59	1.57
26.4	298.0	294.0	15.3	15.5	74.2	67.6	110.8	105.4	0.23	0.23	1.89	1.93
SEm±	2.30	2.10	0.40	0.63	1.61	1.92	4.25	4.13	0.005	0.007	0.05	0.045
CD (P=0.05)	9.00	8.50	1.60	2.39	6.33	7.64	16.69	16.21	0.02	0.028	0.22	0.21
N level (kg/ha) and time of application												
0	261.1	248.5	13.5	12.9	48.8	48.2	73.9	70.0	0.14	0.14	1.25	1.25
30 at Sowing (S)	298.0	290.4	15.0	15.2	68.3	61.3	107.1	105.1	0.24	0.24	1.90	1.84
30 at Flowering (F)	272.1	266.7	14.2	14.0	49.0	52.8	86.0	83.6	0.15	0.17	1.35	1.53
15 each at S & F	294.7	286.1	14.9	14.3	59.6	57.0	100.3	97.5	0.23	0.21	1.87	1.75
SEm±	2.60	2.39	0.46	0.64	3.58	3.80	6.99	6.75	0.01	0.013	0.091	0.08
CD (P=0.05)	7.72	7.10	1.36	1.92	10.63	11.28	20.77	20.05	0.03	0.039	0.265	0.24

Though the seed yield increased by 52 kg with 30 kg N application at flowering, that could not qualify for statistical significance over unfertilized control. An increase in seed yield of soybean due to N fertilization (Wang ShuQi Han *et al.*, 2009) at sowing i.e. as a starter dose (Boroomandan *et al.*, 2009) also 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 30 kg N at sowing or 15 kg each at sowing and flowering has led to marked improvement in biological yields *i.e.* 2.29 and 1.75 t/ha, respectively over control. The harvest index remained unaffected by N fertilization.

Interaction effects of phosphorus and nitrogen fertilization on seed yield of dhaincha (pooled) was found significant (Table 3). The data reveals that when N was not applied or applied at flowering, dhaincha seed yield increased significantly with P fertilization up to 26.4 kg/ha. In contrast, when N was applied at sowing (entire or 50% of recommended), dhaincha seed yield responded up to 13.2 kg P application only. Application of 30 kg N at sowing along with 26.4 kg P has resulted in the production of highest seed yield closely followed by 15 kg N application at sowing and flowering. Improved plant weights of *Sesbania sesban* as a result of combined N and P fertilization in Ethiopian vertisols was reported by Akyeampong and Tekalign Mamo (1988) which supports the current investigation results.

Economics data of two years (Table 2) indicate that application of 26.4 kg P/ha gave highest net returns, however net BC ratio was highest (1.74) with 13.2 kg P fertilization. Application of 30 kg N at sowing gave both highest net returns as well as net BC ratio. This was closely followed by 15 kg N application each at sowing and flowering.

Nutrient uptake and use efficiency

Nutrient uptake and use efficiency of dhaincha were significantly influenced by phosphorus and nitrogen fertilization (Table 4). Application of 13.2 kg P fertilizer has enhanced total and seed uptake of N and P over no P fertilization. Further increase in P dose failed to enhance the uptake of both the nutrients significantly, however, 26.4 kg P fertilization recorded the highest uptake values. The nutrient uptake /ton of seed production got reduced with increase in P dose. On an average, 143.8 and 18.26; 133.4 and 17.02 and 131.3 & 16.71 kg/ha of N and P were removed for production of a ton of dhaincha seed with application of 0, 13.2 and 26.4 kg P, respectively. Further, the amount of nutrient retained in seed out of total uptake (nutrient harvest index) increased with increased P fertilization up to 26.4 kg for both N and P nutrients. On an average 40.9 and 18.1% of total N and P nutrients taken up by dhaincha crop were translocated in to the seeds. The

Table 3. Interaction effect of nitrogen and phosphorus fertilization on seed yield (t/ha) of *dhiancha* (pooled data of two years)

P dose (kg/ha)	N dose (kg/ha) and time of application			
	Control	30 at sowing (S)	30 at Flowering (F)	15 each at S & F
0	0.91	1.15	0.96	1.14
13.2	1.16	1.38	1.20	1.37
26.4	1.28	1.49	1.35	1.45
SEm±	0.04			
CD (P=0.05)	0.11			

Table 2. Effects of nitrogen and phosphorus fertilization on yield attributes, yield and economics of dhiancha (pooled data of two seasons)

Treatment	Pods/ plant	Seeds/ pod	Test weight (g)	Seed yield (t/ha)	Biological yield (t/ha)	Harvest index	Cost of cultivation (× 10^3 ₹/ha)	Net returns (× 10^3 ₹/ha)	Net B:C ratio
P level (kg/ha)									
0	37.8	23.3	18.34	1.04	13.68	0.076	8.71	13.20	1.51
13.2	41.7	26.8	18.75	1.28	14.46	0.089	9.48	16.51	1.74
26.4	44.0	27.7	19.17	1.39	14.98	0.093	10.22	17.47	1.71
SEm±	0.52	0.64	0.16	0.018	0.25	0.002	8.71	13.20	1.51
CD (P=0.05)	2.07	2.60	0.63	0.072	1.00	0.006	9.48	16.51	1.74
N level (kg/ha) and time of application									
0	38.4	24.3	18.37	1.12	13.20	0.085	9.17	13.65	1.49
30 at Sowing (S)	44.3	27.2	18.91	1.34	15.49	0.087	9.54	17.64	1.85
30 at Flowering(F)	39.1	25.6	18.61	1.17	13.86	0.084	9.56	14.34	1.50
15 each at S & F	44.3	26.4	18.99	1.32	14.95	0.088	9.61	17.01	1.77
SEm±	0.45	0.50	0.14	0.014	0.37	0.003			
CD (P=0.05)	1.37	1.50	0.42	0.043	1.12	NS			

Sale price: 20/kg seed; 500/tonne of biomass

Table 4. Effect of nitrogen and phosphorus fertilization on nutrient uptake and nutrient use efficiency of *Dhiancha* (pooled data)

Treatment	N uptake by seed (kg/ha)	Total (seed + stover) N uptake (kg/ha)	NHI	AUE-N	P uptake by seed (kg/ha)	Total (seed + stover) P uptake (kg/ha)	PHI	AUE-P
P level (kg/ha)								
0	56.7	149.6	0.379		3.14	18.99	0.166	-
13.2	71.3	170.8	0.418		4.06	21.79	0.186	17.9
26.4	78.6	182.9	0.430		4.47	23.28	0.192	13.3
SEm±	2.1	3.1			0.16			
CD (P=0.05)	8.4	12.3			0.63			
N level (kg/ha) and time of application								
0	61.3	150.0	0.409	-	3.45	18.96	0.182	
30 at S	75.3	183.4	0.411	7.4	4.26	23.49	0.181	
30 at F	64.9	160.4	0.405	1.8	3.64	20.24	0.180	
15 each at S & F	73.9	177.3	0.417	6.8	4.22	22.76	0.185	
SEm±	3.0	5.4			0.25			
CD (P=0.05)	8.9	16.1			0.74			

N/PHI: Nitrogen/phosphorus Harvest index; AUE: Agronomic use efficiency (kg grain/ kg nutrient applied)

agronomic use efficiency of P was highest with 13.2 kg P and decreased with further increase in P dose. The decrease in agronomic use efficiency of P with increase in P dose was due to small increases in yield as compared to increases in P application.

Application of 30 kg N at sowing being at par with 15 kg N application at sowing and flowering has significantly increased N (total uptake and seed uptake) and P (total uptake) uptake of dhiancha over control. Agronomic use efficiency of N was highest when entire N was applied at sowing and least with application at flowering time. Nitrogen applied at sowing by way of meeting initial N needs of legume crop has promoted nodulation, growth, yield attributes and yield and thus enhanced its use efficiency. On the contrary, N applied at flowering failed to meet the crop needs and thus low yield enhancements resulted in lesser use efficiency.

From the two year investigation, it was concluded that 30 kg nitrogen application at sowing along with 26.4 kg phosphorus is recommended for higher seed production and also for realization of highest economic benefits from dhaincha crop.

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