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Effect of N P K S Zn and B on Yield Attributes and Yield of French Bean in South Eastern Hilly Region of Bangladesh

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ABSTRACT

A field experiment on French bean taking the variety BARI Jhar Shim-2 was conducted with five levels of Nitrogen (0, 40, 80, 120 and 160 kg N ha^{-1}) and four levels of each of phosphorous (0, 40, 80 and 120 kg P_2O_5 ha^{-1}), potassium (0, 30, 60 and 90 kg K_2O ha^{-1}) and sulfur (0, 10, 20 and 30 kg S ha^{-1}), three levels of each of zinc (0, 4 and 8 kg Zn ha^{-1}) and boron (0, 1 and 1.5 kg B ha^{-1}) at the Agricultural Research Station, Raikhali, Rangamati Hill District during Rabi (winter) seasons of 2005-2006 and 2006-2007. The experiment was conducted in Randomized Complete Block Design with three replications. Yield and yield components of French bean were significantly influenced by different fertilizer treatments containing macro and micronutrients separately. Results showed significant effect of fertilizers on plant height, number of branches and leaves per plant, pod length, number of green pods and pod weight per plant and green pod yield during both years. The highest pod yield of 23.14 t ha^{-1} (average of 2005-2006 and 2006-2007) was obtained with 120-120-60-20-4-1 kg of N-P_2O_5-K_2O-S-Zn-B plus 0.5 kg Mo ha^{-1} along with 10 tons cowdung per hectare that was closely followed by 120-80-60-20-4-1 kg of N-P_2O_5-K_2O-S-Zn-B plus 0.5 kg Mo ha^{-1} along with 10 tons cowdung per hectare. The response equations indicated an optimum level of 138.6 kg N, 131.5 kg P_2O_5, 63.4 kg K_2O and 17.4 kg S ha^{-1} for higher green fruit yield of French bean. The economic doses of nutrients came out to be 135.8-123.3-60-17.4 kg of N-P_2O_5-K_2O-S ha^{-1}. Application of 136-123-60-17-4-1 kg N-P_2O_5-K_2O-S-Zn-B plus 0.5 kg Mo ha^{-1} along with 10 tons cowdung per hectare might be considered as profitable dose for growing French bean in South-Eastern hilly region of Bangladesh.

Key words: Legume, French bean, Rabi, Rangamati, *Rhizobium*, AEZ-29, physiological maturation.

INTRODUCTION

French bean (*Phaseolus vulgaris* L.) is an important legume vegetable grown during the rabi season for its tender green pods which form a rich source of protein, calcium and iron. Two French bean varieties (BARI Jhar Shim-1 and BARI Jhar Shim-2) for winter (rabi) season have been developed by Bangladesh Agricultural Research Institute (BARI). French bean (bush type) withdraws 80 kg N, 30 kg P_2O_5 and 100 kg K_2O from the soil for producing 12.0 t ha^{-1} green pods (AVRDC, 1990). The requirement of fertilizer for any crop varies with the cultivars and soil types in

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agro-ecological zones (Mitra *et al*., 1990). Being a shy nodulator, French bean crop readily responds to large doses of Nitrogen and optimum Nitrogen was as high as 125.6 kg ha^{-1} (Srinivas and Naik, 1990). Ivanove *et al* (1987) reported that the pod yield of French bean was increased with the increase nitrogen levels up to 150 kg ha^{1}. Short growth cycle of this crop is one of the reasons that Nitrogen fixation is not as efficient as other legumes because carbohydrate production by the French bean plant occurs at the same time as the plants and the rhizobium needs a maximum carbohydrate supply and there is a heavy competition for Carbohydrate between the bacteria and French bean (Van Schoonhaven and Voysests, 1991). This crop responds to the application of phosphorous more and production increases with the increasing Phosphorous doses because with Phosphorous fertilizer, the plant develops its roots better and increases penetration with a better root system of deeper penetration and thus absorbs more Phosphorus which the bean plants need up to the physiological maturation phase (Malavolta, 1972) and optimum Phosphorus level was found to be as high as 123 kg ha^{-1}) (Srinivas and Rao, 1984). There are reports that Potassium deficiency symptoms are hard to absorb and the deficiency in bean plant occurs without being noticed by the farmers and hence all fertilizer recommendations always include potassium nutrients (Van Schoonhaven and Voysests, 1991). French bean can absorb sulfur in great quantities and it is necessary to maintain the relation of nitrogen and sulfur in the plant to produce protein (Hendrix, 1967) and application of S between 10-20 kg ha^{-1} can control sulfur deficiency (Van Schoonhaven and Voysests, 1991). It is reported that among the most important food crops, French bean crops are the most responsive to all micronutrient application and they have a higher response to zinc but lower response to boron (Lucas and Knezek, 1972). Boron and sulfur deficiency can be controlled by soil application of 1kg B ha^{-1} and 25 kg $ZnSo_4$ ha^{-1} (6-9 kg ha^{-1}) (Parthosharothi, 1999). A combined nutrition of N, P, K, S and micronutrient is always beneficial for increasing yield of French bean. Despite evidence of benefits of fertilization, very little work has so far been done on the use of N, P, K, S, Zn and B in French bean in Bangladesh. The present investigation was, therefore, undertaken to evaluate the effects of N, P, K, S, Zn and B at different levels on the growth and yield of French bean in the South-Eastern Hilly region of Bangladesh.

MATERIALS AND METHODS

The experiment was conducted at the Agricultural Research Station, Raikhali in the district of Rangamati during the *Rabi* (winter) seasons of 2005-2006 and 2006-2007 using French bean var. BARI French bean-2. The experimental field belongs to AEZ-29. Texturally the soil is sandy clay loam. Particle size was determined by hydrometer method and other characteristics were determined by Agro Services International (ASI) method (Hunter, 1984). The initial soil analysis result is shown in Table 1. There were 19 treatment combinations consisting of five levels of Nitrogen (0, 40, 80, 120 and 160 kg N ha^{-1}) and four levels each of phosphorous (0, 40, 80 and 120 kg P_2O_5 ha^{-1}), potassium (0, 30, 60 and 90 kg K_2O ha^{-1}) and sulfur (0, 10, 20 and 30 kg S ha^{-1}), three levels each of zinc (0, 4 and 8 kg ha^{-1}) and boron (0, 1 and 1.5 kg B ha^{-1}). N, P, K, S, Zn and B were given in the form urea, TSP, MOP, gypsum, zinc oxide and boric acid. The 19 treatmentwise fertilizer combinations are given in Table 2.

Table 1. Some physical and chemical properties of the soil of experimental plots prior to fertilizer application

Year	Texture	pH	OM%	meq 100g^{-1}			µg g^{-1}						
				Ca	Mg	K	NH4-N	P	S	B	Cu	Mn	Zn
2005-2006	Sandy clay loam	5.7	0.98	2.8	1.4	0.16	0.17	19	15	0.2	8	40	2.1
2006-2007	Sandy clay loam	5.5	0.92	2.4	1.5	0.23	0.16	17	14	0.2	8	42	2.1
Critical level	-	-	-	2.0	0.8	0.2	75	14	14	0.2	1	33	2

Table 2. Effect of N P K S Zn and B on growth characters of French bean (var. BARI Jhar Shim-2)

Treatment code	Treatment combination (kg ha^{-1})						Plant height (cm)		Branches per plant (no.)		Leaves per plant (no.)	
	N	P_2O_5	K_2O	S	Zn	B	2005-2006	2006-2007	2005-2006	2006-2007	2005-2006	2006-2007
T_1	0	0	0	0	0	0	28.73g	30.00g	4.84g	4.13e	9.80h	10.06h
T_2	0	80	60	20	4	1	29.33fg	30.20g	5.50d-g	4.33de	10.69g	11.44g
T_3	40	80	60	20	4	1	30.08efg	30.67g	5.60c-g	4.47cde	11.02fg	12.03fg
T_4	80	80	60	20	4	1	31.55b-e	38.27gef	5.86c-f	5.27b-e	12.82bc	14.09a-d
T_5	120	80	60	20	4	1	33.60a	43.93abc	6.20a-d	6.27ab	13.18b	14.50abc
T_6	160	80	60	20	4	1	33.76a	46.13a	6.30a-d	5.93b	13.01bc	14.41abc
T_7	120	0	60	20	4	1	31.10cde	36.73f	5.35efg	5.67bcd	12.29cd	13.57cde
T_8	120	40	60	20	4	1	30.72def	36.47f	5.80c-f	5.73bc	12.89bc	14.19abc
T_9	120	120	60	20	4	1	33.74a	41.47b-e	6.32abc	5.33b-e	13.93a	15.26a
T_{10}	120	80	0	20	4	1	31.20cde	37.47ef	5.84c-f	6.40ab	12.62ef	12.83ef
T_{11}	120	80	30	20	4	1	32.15a-d	43.93abc	5.88c-f	6.40ab	13.02b	14.38abc
T_{12}	120	80	90	20	4	1	33.46a	43.53abc	6.83ab	5.93b	13.26b	14.73abc
T_{13}	120	80	60	0	4	1	32.70a-d	43.87abc	5.93c-f	5.40b-e	12.58bc	13.90b-e
T_{14}	120	80	60	10	4	1	33.23ab	44.93ab	6.20a-d	6.60ab	13.01bc	14.42abc
T_{15}	120	80	60	30	4	1	32.73abc	40.00c-f	5.13fg	5.87b	11.69de	12.91def
T_{16}	120	80	60	20	0	1	32.80abc	40.17c-f	5.92c-f	6.23ab	12.63bc	13.94b-e
T_{17}	120	80	60	20	8	1	33.33a	40.17c-f	6.18a-d	6.37ab	13.00bc	14.36abc
T_{18}	120	80	60	20	4	0	33.20ab	38.87def	6.70b-e	5.60bcd	12.87bc	14.24abc
T_{19}	120	80	60	20	4	1.5	33.80a	42.27a-d	6.91a	7.33a	13.15b	14.76ab
	CV (%)						2.83	3.61	6.97	7.42	3.07	2.75

Means showing different letters in a column within a year are significantly different at 5% level of probability by DMRT.

A blanket dose of golybdenum (0.5 kg ha^{-1} from sodium-molybdate) and cowdung (10 t ha^{-1}) was used. The total amount of cowdung, TSP, and MP, gypsum, zinc oxide, boric acid, sodium-molybdate and one-half quantity of urea was applied prior to planting seeds and the remaining quantity of urea was applied 25 days after sowing as side dressing.

Seeds of the variety BARI French bean-2 were dibbled being 2 seeds/hill on 26 and 22 December of 2005 and 2006, respectively, maintaining plant spacing of 20 x 10 cm. The unit plot was 3.0 x 1.2 m. After 15 days of sowing when the germination was completed, thinning was done leaving one seedling in each site In addition to pre-sowing irrigation; four additional irrigations were given to the crop. All the recommended cultural and plant protection measures were followed throughout the experimental period. Tender green pods were picked at regular intervals from an area of 3.6 m^2 for recording plot yield of the total five pickings.

The data on plant height at 1^{st} flowering, number of branches per plant, number of trifoliate leaves per plant, pod length, pod width, number of green pods per plant and green pod weight per plant were recorded from randomly selected 10 plants of the inner rows. The plot yield was converted to per hectare yield.

The optimum and economic doses of N, K and S for maximum green pod yield was calculated from simple polynomial regression equation *i.e*. $Y = \alpha + \beta_1 X + \beta_2 X^2$ (Zaman *et al.,* 1982). Here X is the independent variable (fertilizer) and Y is the dependent variable (pod yield). The optimum dose of fertilizer for maximum yield was $X = -\beta_1/2\beta_2$. The data were analyzed through MSTAT Program and the treatment means were separated by DMRT at 5% level of probability for interpretation of the results.

RESULTS AND DISCUSSION

Plant height

Plant height was significantly influenced by different fertilizer treatments (Table 2). In 2005-2006 the highest plant height at 1^{st} flowering recorded in T_{19} treatment which was superior to T_1, T_2, T_3, T_4, T_7, T_8 and T_{10} treatments but at par with the remaining treatments, while in 2006-2007 maximum plant height was recorded in T_6 treatment which was statistically identical to T_5, T_{11}, T_{12}, T_{13} and T_{19} treatments. The lowest plant height at 1st flowering was obtained from control treatment (T_1). Nitrogen helps in chlorophyll formation, P establishes strong root system, K and B helps in translocation of photosynthates, Zn helps in auxin synthesis. Therefore their integrated actions increased plant height. Application of N irrespective of other fertilizer nutrient significantly influenced plant height at 1st flowering (Table 2). Plant height was significantly increased up to 120 kg N ha^{-1} in both years. Although 160 kg N ha^{-1} increased plant height, there was no significant difference between 120 and 160 kg N ha^{-1}. During both years plant height was significantly increased up to 80 kg P_2O_5 ha^{-1}. Although application of phosphorus at the highest level (120 kg P_2O_5 ha^{-1}) increased plant height, no significant difference was observed between 80 and 120 kg P_2O_5 ha^{-1} in the first year and in the 2nd year, when P was applied @ 120 kg P_2O_5 ha^{-1} decreased plant height significantly. Amount of N beyond optimum level brings about nutrient imbalance and suppressed growth of the plant and excess P level causes reduction in vegetative growth. The similar effect of N and P on plant height was reported by Srinivas and Naik (1990). All the levels of potassium increased plant height but no significant difference was observed among 30, 60 and 90 kg K_2O ha^{-1}. Application of S did not significantly influence plant height in both years while in the 2nd year, S application at higher dose (30 kg ha^{-1}) decreased plant height significantly. There is little effect on plant height due to Zn and B application in both years.

Number of branches

Number of branches per plant was significantly influenced due to fertilizer treatments during both years (Table 2). Maximum branches per plant was recorded in T_{19} treatment, in both years, which was at par with T_5, T_6, T_9, T_{12}, T_{14} and T_{17} in the first year and in the second year with T_5, 7_{10}, T_{11}, T_{14}, T_{16}, T_{17}, and T_{18} treatments. Branches per plant increased significantly with the increase of N up to 120 kg N ha^{-1} in both years (Table 2). Although branches per plant increased up to 160 kg ha^{-1} in 2005-2006, this parameter was decreased at 160 kg N ha^{-1} in 2006-2007; there was no significant difference between 120 and 160 kg N ha^{-1} in any of the years in respect of number of branches per plant. Branches per plant increased up to 80 kg P_2O_5 ha^{-1} in both years with no significant difference between 80 and 120 kg P_2O_5 ha^{-1}. The results of N and P are in agreement with Srinivas and Naik (1990). Dhanjal *et al.* (2001) found significantly higher branches per plant at 120 kg N ha^{-1} Application of 60 kg K_2O, 10 kg S, 4 kg Zn and 1 kg B ha^{-1} significantly influenced number of branches per plant in 2005-2006, but no significant influence was observed in respect of branches per plant due to K, S, Zn and B application in 2006-2007. Potassium and S enhanced the formation of chlorophyll and encouraged vegetative growth while Zn promotes biosynthesis of auxin and B helps in N absorption. Therefore, their combined actions increased number of branches per plant.

Number of leaves

Number of leaves per plant was significantly influenced by the application of fertilizer (Table 2). Significantly highest plant height was recorded in T_9 treatment (both years), which was superior to all other treatments in 1st year and statistically identical to T_4, T_5, T_6, T_8, T_{11}, T_{12}, T_{14}, T_{17}, T_{18}, T_{19} in 2nd year. Number of leaves was significantly increased up to 80 kg N ha^{-1} with no significant difference among 80, 120 and 160 kg N ha^{-1} (Table 2). Application of phosphorus @ 40, 80 and 120 kg P_2O_5 ha^{-1} increased number of leaves per plant compared to control but no significant difference was observed among 40, 80 and 120 kg P_2O_5 ha^{-1}. Number of leaves per plant was increased due to the application of K, S, Zn and B compared to control in both years but there was no significant difference among higher doses each of K, S, Zn and B. Nitrogen and K promotes chlorophyll formation and P helps in nutrient absorption by lateral root development. As a result number of leaves per plant increased.

Pod length and pod width

Maximum pod length was recorded in T_{19} (2005-2006) and in T_9 (2006-2007), which was at par with T_5, T_9 and T_{12} in first year and superior to T_1, T_2, T_3, T_4, T_7 and T_{13} treatments in second year (Table 3). The minimum pod length was obtained from T_1 treatment in both years. Pod length increased with the increase of N up to 120 kg N ha^{-1} beyond which pod length declined in both years (Table 3). Optimum level of N (120 kg ha^{-1}) increases the rate of photosynthesis by chlorophyll formation and thus more ptoassimilates were made and pod length increased. However when N was applied @ 160 kg ha^{-1}, N increased vegetative growth instead of pod development. Singh (2000) got maximum pod length from the application of 125 kg N ha^{-1} which was at par with 100 and 75 N ha^{-1}. Potassium application increased pod length up to its highest level but no significant difference was observed between 80 and 120 kg P_2O_5 ha^{-1} during both years. Pod length was increased significantly up to 60 kg K_2O ha^{-1} in 2005-2006 while no significant influence was observed due to K application in 2006-2007. Phosphorus helped in developing flowers and fruits and K maintains balance between N and P. In first year, maximum pod length was observes at 20 kg S ha^{-1} but at 10 kg S ha^{-1} in 2^{nd} year. Application of Zn and B significantly increased pod length up to 4 kg Zn and 1.0 kg B ha^{-1} in 2005-2006, but no significant influence was noticed due to Zn and B application in 2006-2007. Pod width was significantly influenced in 2005-2006 (Table 3). Maximum pod width was recorded in T_{19} treatment which was at par with T_5, T_9, T_{12} and T_{18} treatment.

Table 3. Effect of N P K S Zn and B on yield attributes and yield of French bean (var. BARI Jhar Shim-2)

Treatment code	Pod length (cm)		Pod width (cm		Green pods per plant (no.)		Green pod weight per plant (g)		Green pod yield (t ha^{-1})		
	2005-06	2006-07	2005-06	2006-07	2005-06	2006-07	2005-06	2006-07	2005-06	2006-07	Pooled
T_1	11.43h	11.52d	0.69h	0.75	11.40g	11.60g	45.00j	38.48j	11.21k	9.51g	10.36h
T_2	11.53gh	11.42d	0.74f	0.76	12.60g	13.00g	58.27i	45.90j	14.26j	10.47g	12.36h
T_3	11.63fgh	11.90bcd	0.76cde	0.74	16.70f	16.83f	65.93b	65.53i	16.78i	15.48f	16.12g
T_4	12.00d-h	12.55abc	0.77bcd	0.75	20.60cd	20.67b-e	87.20de	83.10gh	19.98e-h	17.72e	18.85ef
T_5	13.07abc	12.53abc	0.78ab	0.77	24.55a	24.77a	95.67b	107.6ab	22.53abc	23.69ab	23.11a
T_6	12.53b-e	12.41abc	0.75def	0.77	21.98bc	22.00abc	89.00cd	103.3bc	21.80c-f	19.12de	20.46b-e
T_7	12.00d-h	11.91bcd	0.75def	0.75	19.67d	19.93c-f	74.20g	63.61i	18.50hi	14.69f	16.59fg
T_8	12.47c-f	11.98a-d	0.75def	0.75	22.69b	22.62abc	83.83ef	102.03bc	19.34gh	18.80f	18.41efg
T_9	13.31ab	12.78a	0.78abc	0.77	25.49a	24.49a	93.97b	111.1a	22.58abc	23.70a	23.14a
T_{10}	11.97d-h	12.46abc	0.72g	0.76	16.82f	16.86f	80.53f	82.40gh	20.91c-g	19.80cde	20.35cde
T_{11}	12.30c-h	11.73ad	0.77bcd	0.76	18.20ef	18.30def	92.73bc	94.78def	22.27bcd	22.45ab	22.62abc
T_{12}	13.33ab	12.40abc	0.78ab	0.77	25.49a	22.79a	96.33b	96.82cde	24.25ab	21.62bc	22.93ab
T_{13}	11.70e-h	11.80bcd	0.71g	0.74	17.40f	17.53def	73.20g	82.03h	18.63hi	17.87e	18.42efg
T_{14}	12.13d-h	12.65ab	0.74ef	0.77	17.53f	17.50ef	84.40def	89.68efg	19.27gh	19.17de	18.56efg
T_{15}	12.03d-h	12.09a-d	0.73g	0.76	17.78f	17.82def	81.67f	86.40gh	19.79fgh	18.27e	19.03ef
T_{16}	12.27c-h	12.01a-d	0.75def	0.77	19.47de	19.60c-f	83.00ef	85.42gh	20.31d-h	19.52de	19.92de
T_{17}	12.40c-g	12.02a-d	0.76cde	0.77	20.87cd	20.81bcd	86.46de	96.71c-f	19.56gh	20.41cd	20.16cde
T_{18}	12.63bcd	12.05a-d	0.77abc	0.75	22.73b	22.53abc	87.27de	97.30cd	21.98cde	23.11ab	22.55abc
T_{19}	13.47a	12.38abc	0.79a	0.77	24.93a	23.80ab	109.10a	89.68efg	24.48a	19.05de	21.77a-d
CV (%)	3.63	4.24	2.65	3.88	4.16	5.29	3.04	2.71	5.77	4.96	5.41

Means showing different letters in a column within a year are significantly different at 5% level of probability by DMRT. Details of treatment combinations were given in Table 2.

Number of green pods

Different levels of N, P, K, S, Zn and B significantly affected the number of green pods per plant in both years (Table 3). The highest number of green pods per plant was recorded in T_5 treatment in both the years. In the first year, the T_5 treatment was superior to all the treatments except T_9, T_{12}, and T_{19} treatments in 2005-2006 and in 2^{nd} year except T_6, T_8, T_9, T_{12}, T_{18} and T_{19} treatments. During both years number of pods per plant increased with increasing N up to 120 kg N ha^{-1} beyond which it declined. In case of P, number of pods per plant was increased up to 120 kg P_2O_5 ha^{-1} in 2005-2006 and up to 80 kg P_2O_5 ha^{-1} in 2006-2007. There was no significant difference observed between 80 and 120 kg P_2O_5 ha^{-1} in the first year and between 40 and 80 kg P_2O_5 ha^{-1} in 2006-2007. The results influenced by N and P are in consonance with Srinivas and Naik (1990), Rana and Singh (1998) and Baboo *et al.* (1998). Singh (2000) obtained significantly maximum pod at 100 kg N ha^{-1} compared to 125 kg N ha^{-1}. Dahatonde and Nalamwar (1996) reported that application of N @ 120 kg ha^{-1} produced maximum number of pods per plant that was statistically similar to 90 kg N ha^{-1}. Number of pods per plant increased up to 90 kg K_2O ha^{-1} with no significant difference between 60 and 90 kg K_2O ha^{-1} in 2005-2006. But in 2006-2007 pods per plant increased up to 60 kg K_2O ha^{-1} and further increase in K level did not increase pods per plant although no significant difference was noticed between 60 and 90 kg K_2O ha^{-1}. Pod per plant were increased up to 20 kg S, 4 kg Zn in both years beyond which number of pods declined. In 2005-2006 pod number increased up to 1.5 kg B ha^{-1} while in 2006-2007 up to 1.0 kg B ha^{-1}.

Green pod weight

A significant difference in green pod weight per plant was obtained with different rates of N P K S Zn and B during both years (Table 3). The highest green pod weight per plant recorded in T_{19} treatment which was significantly different from other treatments in 2005-2006. But in 2006-2007, maximum green pod weight per plant was obtained from T_9 treatment closely followed by T_5 treatment. The minimum green pod weight per plant was obtained from control treatment (T_1) in both years. Green pod weight per plant increased significantly with the increase of N up to 120 kg N ha^{-1} beyond which green pod weight decreased in both years (Table 3). The results are in agreement with Srinivas and Naik (1990). Singh (2000) reported that pod weight per plant was maximum at 125 kg N ha^{-1} with no significant difference at 100 kg N ha^{-1}. Similar response was also observed in case of P application only in 2005-2006 but in 2006-2007 green pod weight was increased up to 120 kg P_2O_5 ha^{-1} with no significant difference between 80 and 120 kg P_2O_5 ha^{-1}. Srinivas and Naik (1990) observed no significant difference between 40 and 80 kg P_2O_5 ha^{-1} and reported 143.33 kg P_2O_5 ha^{-1} as optimum dose for French bean production in Bengalore. Application of K increased green pod weight per plant up to its higher level (90 kg K_2O ha^{-1}) in 2005-06 but in 2006-07, green pod weight per plant was significantly declined at 90 kg K_2O ha^{-1} compared to 60 kg K_2O ha^{-1}. In both years, green pod weight per plant increased significantly up to 20 kg S ha^{-1} but further increase in S level did not increase pod weight per plant. Green pod weight per plant was significantly highest at 4 kg Zn ha^{-1} in both years. In case of B application, pod weight per plant increased significantly up to 1.5 kg B ha^{-1} in 2005-2006 but in 2006-2007 pod weight increased up to 1.0 kg B ha^{-1} beyond which it declined.

Green pod yield

Significant increase in green pod yield was observed with different fertilizer treatment in both years as well as in pooled data (Table 3). In 2005-2006, the highest green pod yield ha^{-1} recorded with T_{19} treatment, which was at par with T_5, T_9 and T_{12} treatment but in 2006-2007, maximum pod yield was obtained from T_5 treatment closely followed by T_9, T_{11} and T_{18} treatments. Pooled analysis showed that the highest yield was obtained from T_9 treatment which was at par with T_5, T_{11}, T_{12}, T_{18} and T_{19} treatments. The lowest pod yield per hectare was recorded in control treatment (T_1) in both years and pooled data. In pooled data, green pod yield increased significantly with increasing N rate up to 120 kg N ha^{-1} beyond which yield decreased (Table 3; Figure 1.A). Application of N at 120 kg N ha^{-1} produced significantly maximum pod size (pod length x pod width), number of green pods per plant and green pod weight per plant than that of 160 kg N ha^{-1} which resulted the highest pod yield from the treatment. Pod yield increased by 30.42, 52.50, 86.97 and 65.33% over control due to application of 40, 80, 120 and 160 kg N ha^{-1}, respectively (Table 4). Highest yield might be due to the fact that N is an integral part of chlorophyll and play a vital role in photosynthesis and carbohydrate production. Singh (2000) and Srinivas and Naik (1990) obtained the highest yield of pod at 125 and 120 kg N ha^{-1}, respectively. BARI (2004) reported that application of N @ 150 kg N ha^{-1} produced significantly higher pod yield of BARI Jhar Shim-1 that was at par with 200 kg N ha^{-1}. Projapoti et al. (2004) also recorded higher pod yield of French bean from 120 kg N ha^{-1}. Pooled yield reveled that pod yield increased gradually with the increase of P up to 120 kg P_2O_5 ha^{-1} with no significant difference between two higher doses (80 and 120 kg P_2O_5 ha^{-1}). Phosphorus application @ 120 kg P_2O_5 ha^{-1} performed better than that of 80 kg P_2O_5 ha^{-1} in respect of all yield contributing characters and thus gave the highest pod yield. P application @ 40, 80, 120 kg P_2O_5 ha^{-1} increased pod yield of French bean by 14.95, 23.11 and 23.14%, respectively, over control. The pod yield of French bean increased by 80 kg P_2O_5 ha^{-1} application was very close to that of 120 kg P_2O_5 ha^{-1} over control. Srinivas and Naik (1990) reported that significantly highest pod yield was recorded at 80 kg P_2O_5 ha^{-1}. BARI (2004) got pod yield in response of the variety, BARI Jhar Shim-1 up to 60 kg P (137.4 kg P_2O_5 ha^{-1}) with no significant difference with application of 40 kg P (91.6 kg P_2O_5 ha^{-1}). Pod yield increased up to 60 kg K_2O ha^{-1} and further increase in K decreased pod yield (Figure 1. C). Sulfur, Zn and B also showed similar effect of K. Application of S, Zn and B @ 20, 4 and 1 kg ha^{-1}, respectively increased pod yield by 25.83, 16.01 and 2.48% over control (Table 4) and further increase in levels of each S, Zn and B decreases pod yield (Table 4).

Table 4. Single effect of N, P, K, S, Zn and B on green pod yield (pooled) of French bean

Nutrient (kg ha^{-1})	Average green pod yield (t ha^{-1})	Yield increase over control (%)	Nutrient (kg ha^{-1})	Average green pod yield (t ha^{-1})	Yield increase over control (%)
Nitrogen (kg N ha^{-1})			Sulfur (kg S ha^{-1})		
0	12.36	-	0	18.41	-
40	16.12	30.42	10	19.22	4.40
80	18.83	52.50	20	23.11	25.53
120	23.11	86.97	30	19.03	3.37
160	20.46	65.33	-	-	-
Phosphorus (kg P_2O_5 ha^{-1})			Zinc (kg Zn ha^{-1})		
0	16.59	-	0	19.92	-
40	19.07	14.95	4	23.11	16.01
80	23.11	23.11	8	20.16	1.20
120	23.14	23.14	-	-	
Potassium (kg K_2O ha^{-1})			Boron (kg B ha^{-1})		
0	20.35	-	0	22.55	-
30	22.62	11.40	1	23.11	2.48
60	23.11	13.56	1.5	21.76	(-) 3.50
90	12.93	12.68	-	-	-

Response equations

Regression analyses were done to quantify the relationship of applied N, P, K and S with pod yield. Applied N, P, K and S showed a quadratic relationship with pod yield (Figure 1). Pod yield response of French bean to applied N, P, K and S can be described by the equations $Y = 11.929 + 0.1386 N – 0.0005 N^2$, $Y = 16.312 + 0.1052P – 0.0004 P^2$, $Y = 20.406 + 0.0887K – 0.0007K^2$ and $Y=17.858 + 0.4242 S – 0.0122S^2$, respectively (Figure 1). The co-efficient of determinations (R^2 = 0.9238 for N, 0.9501 for P, 0.9876 for K) were significant at 1% level of probability but R^2 for S (0.5555) was significant at 5% level of probability. From the response equations the optimum levels of N, P, K and S were estimated as 138.6, 131.5, 63.36 and 17.4 kg ha^{-1}, respectively. The optimum Zn and B levels were found to be 4 and 1 kg B, respectively. The economic doses of N, K, P and S came to be as 135.8, 123.3, 60.14 and 17.37 kg ha^{-1}, respectively.

From the above results and discussion it could be suggested that application of 136-123-60-17-4-1 kg of N-P_2O_5-K_2O-S-Zn-B ha^{-1} plus 0.5 kg ha^{-1} Mo along with 10 t ha^{-1} cowdung could be the profitable dose for maximizing pod yield of French bean for the variety, BARI Jhar Shim-2 in the South-Eastern Hilly region of Bangladesh (AEZ-29).

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