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Influence of nitrogen and sulphur fertilization on the growth and yield performance of French bean

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Abstract
The experiment was conducted to study the effect of nitrogen and sulphur on the growth and yield of French bean. The experiment consisted of two factors namely; (i) Nitrogen level *viz.* N_0 (no nitrogen), N_1 (60 kg N/ha), N_2 (90 kg N/ha), N_3 (120 kg N/ha) and N_4 (150 kg N/ha) and (ii) Sulphur level *viz.* S_0 (no Sulphur), S_1 (10 kg S/ha), S_2 (15 kg S/ha) and S_3 (20 kg S/ha). The experiment was laid out in randomized complete block design with three replications. The highest grain yield (1.78 t ha^{-1}) and (1.480 t ha^{-1}) were observed from 120 kg N ha^{-1} (N_3) and 10 kg S ha^{-1} (S_1), respectively. On the other hand, lowest grain yield (1.212 t ha^{-1}) and (1.332 t ha^{-1}) were found from 0 kg N ha^{-1} (N_0) and 20 kg S ha^{-1} (S_3), respectively. Considering the interaction it was found that the yield contributing characters and yield of French bean varieties were increased with the good combination of nitrogen and sulphur doses. The highest grain yield (1.97 t ha^{-1}) was observed from 120 kg N ha^{-1} × 10 kg S ha^{-1} (N_3S_1), whereas lowest grain yield (0.97 t ha^{-1}) was found from 0 kg N ha^{-1} × 15 kg S ha^{-1}. Hence, the nitrogen and sulphur fertilizer management is very important agronomic management practices for higher and efficient production of French bean.

Keywords: French bean, nitrogen, sulphur, grain yield

Introduction
French bean (*Phaseolus vulgaris* L.) is an important vegetable crop belongs to the family Fabaceae. It is known as kidney bean, bush bean or rajma bean. It is planted at hill and plain area in February-March and October-November, respectively. In Bangladesh, the crop is known in different names in different locations e.g. in Sylhet it is known as "Farashi Ori" and "Farash Choi" in Chittagong and in most parts of the country "Jhar Sheem". It is used as tender vegetable, shelled green beans, dry bean and pulses which is highly nutritious. French bean is cultivated popularly in Chittagong, Sylhet, North Bengal, Hill tracts and also many other places of Bangladesh on limited scale during the rabi (winter) season (FAO, 1998) [1]. Now days, it is considered as one of the most important exporting vegetables of Bangladesh to earn foreign currency and is being exported by Horticultural Export Development Foundation (HORTEX), Dhaka, Bangladesh (BARI, 2001) [2] in the extreme super market of European countries.

According to FAO (2012) [3], the production of French bean in Bangladesh was 94,356 ton in 2011. French bean is valued for its protein rich (23%) seeds. It also contains K, Ca, Mg, Fe, P, vitamins A, B, D, starch and no fat. In Bangladesh, its yield is low compared to other French bean producing countries of the world due to lack of high yielding varieties, poor production technology, including optimum date of sowing and spacing, poor fertility and irrigation management (Saini and Negi, 1998) [4] and also lack of marketing facilities, poor knowledge of the people on its use and lack of availability of quality seed.

Among the agronomic management practices, fertilizer management is one of the important factors that contribute to the production and yield of any crop. French bean being a high protein and energy crop and its productivity is often limited by the low availability of essential nutrients or imbalanced nutrition forming one of the important constraints to French bean productivity in Bangladesh.

French bean is highly responsive to fertilizer and has a marked response to nitrogen and Sulphur. French bean lacks biological N fixation because of poor or no nodulation. Hence it needs liberal N fertilization (100-120 kg/ha). It is also an important constituent of chlorophyll and takes part in protein synthesis and vegetative growth. But it is unfortunate that nitrogen content of Bangladesh soil is very low and supplementation of nitrogen fertilizer is essential for better growth and yield of French bean. On the other hand, sulphur is also an important macronutrient which takes part in synthesis of amino acids like cysteine, cystine, methionine

and vitamins (Parvin, 2011) [5]. But Sulphur deficiency has been found to occur in soils of Bangladesh. To overcome these deficiencies, both N and S fertilizers should be applied in soil. In view of above mentioned information the research work was conducted to investigate into the role of nitrogen and sulphur and their interaction on the growth and yield of French bean.

Methods and Materials

Experimental site

The research work was conducted at the Agronomy Field Laboratory, Department of Agronomy, Bangladesh Agricultural University, Mymensingh which is located at 24.75°N latitude, 90.50°E longitude and an average altitude of 18 m above the sea level and belongs to the Old Brahmaputra Floodplain (AEZ-9) soil (Islam *et al*., 2011) [6]. The experimental field was a medium high land with well drained clay loam textured soil having a pH value of 6.8. During the experimental period the maximum, minimum and average temperature ranges from 29.96 ^{0}C - 32.06 ^{0}C, 19.73 ^{0}C - 25.86 ^{0}C and 24.85 ^{0}C - 28.96 ^{0}C, respectively. While the average relative humidity, total sunshine and total rainfall ranged from 73.74-85.50%, 116.7-233.0 hours month^{-1} and 32.6-413.7mm, respectively.

Treatments and experimental design

Two sets of treatments included in the experiment viz. Factor A- nitrogen level (5); N_0 (no nitrogen), N_1 (60 kg N/ha), N_2 (90 kg N/ha), N_3 (120 kg N/ha) and N_4 (150 kg N/ha) and Factor B: sulphur level (4): S_0 (no Sulphur), S_1 (10 kg S/ha), S_2 (15 kg S/ha) and S_3 (20 kg S/ha). The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. The total number of plot was 60 (5×4×3). Each plot size was 5 m^2 (2m×2.5m).

Crop husbandry

BARI Jharsheem2 was used as experimental crop which was developed by Bangladesh Agricultural Research Institute (BARI) as a variety of French bean. Seeds were sown in the month of October with a standard dose of biofertilizer (Uddin *et al*. 2018) [7]. Seeds were sown maintaining a spacing of 25 cm × 15 cm. The blocks and unit plots were separated by 1 m and 0.75 m spacing, respectively. Firstly, the land was ploughed with a power tiller and kept open to sunlight. Afterwards the experimental plot was prepared by several ploughing and cross ploughing followed by laddering to break the clods and to level the soil. Urea and gypsum were used as source of nitrogen and sulphur. The whole amount of TSP (165 kg ha^{-1}) and Urea and Gypsum (as per treatment) and MoP 50 kg ha^{-1} as basal dose (BARC, 2012) [8] were applied during final land preparation. Before seed sowing, Carbendazem @ 5g kg^{-1} seed were treated with the seed uniformly for controlling soil borne diseases. Two seeds were sown per hole at a depth of 5.0 cm. Weeding was done manually in the plots from time to time to keep the plots free from weeds and facilitated better soil aeration. One healthy seedling per hill was kept and excess seedling was uprooted after 15 days of emergence of seedlings. Irrigation was applied in the experimental plots in two times by watering cane to keep the soil moisture in field capacity. Ovide (Malathion 57E) and Sevin 85SP (1-naphthyl methylcarbamate) were sprayed at the rate of 2 mL litre^{-1} at an interval of 7days in two times to protect the plants from insects and pests. Mature dry pods were harvested by hand picking and weighed to estimate the yield of dry seeds. The crop bundles were sun dried for five days by placing them on the open threshing floor. Seeds were separated from the plants by beating the bundles with bamboo sticks. The collected seeds were dried in the sun for reducing the moisture content at a constant level.

Data collection

Data was collected at different growth stages and finally at harvest stage. Data was recorded for yield contributing parameters such as plant height at harvest (cm), number of pods plant^{-1}, length of pod (cm), number of seeds pod^{-1}, number of seeds plant^{-1}, weight of seeds plant^{-1}, grain yield (t ha^{-1}), straw yield (t ha^{-1}), weight of 1000 seeds, harvest index (%). Harvest index was calculated with following formula:

$$\text{Harvest Index (\%)} = \frac{\text{Seed yield}}{\text{Seed yield} + \text{Stover yield}} \times 100$$

Statistical analyses

The collected data were compiled and analyzed statistically using the analysis of variance technique using SAS PROC GLM (SAS Version 9.1; SAS Institute, Cary, NC) and the difference among treatment means were adjudged by Duncan's Multiple Range Test (Gomez and Gomez, 1984) [9].

Results and Discussion

A. Effect of nitrogen on the yield contributing characters and yield of French bean

The nitrogen had significant influence on plant height, number of pods plant^{-1}number of seeds pod^{-1}, and number of seeds plant^{-1}, stover, grain and biological yield at harvest. The maximum plant height (39.95 cm) from 150 kg N ha^{-1} (N_4), number of pods plant^{-1} (7.485), and number of seeds pod^{-1} (5.841) which was statistically similar with 60 kg N ha^{-1} (N_1), number of seeds plant^{-1} (26.55), grain yield (1.780 t ha^{-1}), stover yield (2.313 t ha^{-1})and biological yield (4.095 t ha^{-1}) from 120 kg N ha^{-1} (N_3) were observed. The minimum plant height (34.20 cm), number of pods plant^{-1} (5.233), number of seeds plant^{-1} (23.23), grain yield (1.212 t ha^{-1}), stover yield (1.625 t ha^{-1}), and biological yield (2.837 t ha^{-1}) were found from 0 kg N ha^{-1} (N_0) (Table 1). The minimum number of seeds pod^{-1} (5.549) found from 90 kg N ha^{-1} (N_2), which was statistically similar with no nitrogen application (N_0). Harvest index was significantly variation due to different nitrogen on the yield of French bean. The highest harvest index (43.65 %) was found from 150 kg N ha^{-1} (N_4), which was statistically similar all other treatments except N_1 (60 kg N ha^{-1}) (Table 1). Similar trend was followed in maximum number of pods plant^{-1} (9.45) with the application of nitrogen level up to 150 kg N ha^{-1}(Kakon at el., 2016) [10]. Kakon *et al*., 2016 [10] reported from experiments conducted during *rabi* (winter) seasons of 2010-11 and 2011-12 at the Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur that plant height increased with the increase in nitrogen level up to 150 kg N ha^{-1}. Shumi *et al.* (2018) [11] also confirmed the result of plant height in his experiment. Number of pods plant^{-1} increased due to sufficient supply of N for better growth of plant which might have led to higher photosynthesis and the development of higher number of pod bearing branches (Kumar *et al*., 2004; Reddy *et al*., 2010) [12, 13]. The results are corroborated with the finding of Shukla *et al*., (2006) [14] their finding revealed that number of pods per plant had appositive contribution to seed yield. There was insignificant variation in length of dry pod and weight of 1000 seeds at harvest though the highest length of dry pod (11.58

cm) was obtained from 150 kg N ha^{-1} (N_4) and minimum length of dry pod (11.31cm) was obtained from 120 kg N ha^{-1} (N_3). There was about statistically similar weight of 1000 seeds for all dose of phosphorus (Table 1). Similar results reported by Coimbra *et al.* (1998) [15] in French bean varieties. Similar varietal effect on seed yield was found by Sharma *et al*. (2013) [16] who showed the highest seed yield in Contender (V_3) than other two varieties Arka Komal (V_1) and Swaran Priya (V_2) in India.

Jitendra *et al*., 2018 [17] also observed from en experiment that seeds obtained from treatment of nitrogen (120 kg ha^{-1} recommended dose) application with relatively bolder seeds with more number of seeds per pod, and higher bearing capacity per plant generally gives higher seed yield. Singh *et al*. 2018 [18] proved that nitrogen at the rate of 120 kg/ha was superior to 90, 60 and 30 kg/ha in respect of all growth and yield attributes which recorded highest grain yield in the field experiment at Agronomy Research Plot of Allahabad Agricultural Institute, Allahabad. Srinivas and Naik (1988) [19] recommended the optimum fertilizer levels of 125.0 N ha^{-1} from the field trial for French bean. Pod yield increased proportionately to N levels up to 160 kg/ha. Production increase in response to N fertilization increased weight and number of pods/plant and harvest index. Sharma *et al.* (1996) [20] found that increasing level of N significantly increased seed yield, number and weight of pods/plant and number of seeds/pod up to 120 kg N/ha. Application of N in three equal splits gave higher seed yield and yield attributes of the crop.

Rana *et al.* (1998) [21] conducted a field trial to study the effect of N (0, 40, 80 and 120 kg N/ha) with Phosphorus in French bean and observed that dry matter production (seed and straw) increased significantly up to 120 kg N/ha. Tewari and Singh (2000) [22] conducted a study to determine the optimum and economical dose of nitrogen (0, 40, 80, 120 or 160 kg/ha) and phosphorus (0, 20, 40 or 60 kg/ha) for better growth and seed yield of French bean and found that application of 120 kg N/ha produced significantly higher number of pods per plant, weight of seeds per plant, number of seeds per pod and seed yield. The differences in the plant growth characters may be due to the genetic variability within the genotype itself or may be due to the environmental effects. The results are corroborated with the finding of Shukla *et al*., (2006) [14] their finding revealed that number of pods per plant had appositive contribution to seed yield. Prajapati *et al.* (2003) [23] reported that application of 120 kg N/ha enhanced significantly higher growth and yield attributing parameters as well as seed yield of French bean. French bean is the main source of plant protein, of which nitrogen is the main constituent necessary for growth and chlorophyll synthesis and is a part of the chlorophyll. Nitrogen is essential constituent of amino acid and helps in protein synthesis, fruit formation. As compared to other leguminous crops, nodule formation in roots of French bean is very less or even absent in the plain land. Therefore it is high nutrient demanding crop and due to this the crop responds sharply to high doses of nitrogen (Ghosal *et al.*, 2000) [24]. It improves the quality of fruit, vegetable and grain crops.

B. Effect of sulphur on the yield contributing characters and yield of French bean

The sulphur had significant influence on plant height, number of pods $plant^{-1}$ and length of dry pod, number of seeds pod^{-1}, grain yield, stover yield, biological yield and harvest index of French bean. The maximum plant height (37.81 cm), number of pods $plant^{-1}$ (6.714), length of dry pod (11.62 cm), number of seeds pod^{-1} (6.531), grain yield (1.480 t ha^{-1}), stover yield (1.976 t ha^{-1}), biological yield (3.457t ha^{-1}) from 10 kg S ha^{-1} (S_1) and harvest index (44.95 %) from 15 kg S ha^{-1} (S_2) were observed. Gokila *et al.* (2017) [25] also ensured the findings of similar trend of plant height in his trial On the other hand, the minimum plant height (34.45 cm) from 0 kg S ha^{-1}(S_0) treatment which was statistically similar with 20 kg S ha^{-1} (S_3), number of seeds pod^{-1} (5.606) found from 0 kg S ha^{-1}(S_0) that was statistically similar with 15 kg S ha^{-1} (S_2), number of pods $plant^{-1}$ (5.693), grain yield (1.332 t ha^{-1}), biological yield (3.184 t ha^{-1}), harvest index (41.88 %) from 20 kg S ha^{-1} (S_3), length of dry pod (11.24cm) from 15 kg S ha^{-1} (S_2) and stover yield (1.756. t ha^{-1}) from 15 kg S ha^{-1} (S_2) were obtained (Table 2). Islam (2015) [26] also recorded highest yield from 10 kg S ha^{-1} treatment. There was significant variation in number of seeds $plant^{-1}$at harvest due to different dose of Sulphur. There was about statistically similar number of seeds $plant^{-1}$for all dose of sulphur except the highest (26.52) was found from 10 kg S ha^{-1} (S_1) (Table 2). There was no significant variation in weight of 1000 seeds at harvest due to different dose of sulphur. There was about statistically similar weight of 1000 seeds for all dose of Sulphur (Table 2). Similar results reported by Coimbra *et al.* (1998) [15] in French bean varieties.

Islam (2015) [26] observed that the highest number of pods per plant, number of seeds per pod, thousand seed weight, seed yield (1.494 tha^{-1}) from the application10 kg S ha^{-1}. Various yield contribution characters like number of pods $plant^{-1}$, number of seeds pod^{-1} and 1000 seed weight increased significantly as the dose of sulphur was increased by Ganie *et al*., (2014) [27]. Sulphur is an integral part of proteins, sulpholipids, enzymes etc. and has been found to be an indispensable element for higher pulse production (Das and Misra, 1991) [28], besides it is involved in various metabolic and enzymatic processes including photosynthesis, respiration and legume rhizobium symbiotic nitrogen fixation (Rao *et al*., 2001) [29]. Sulphur response has been observed for several legume crops including French bean and its application to sulphur deficient soils have been found to increase the crop yield and improve the quality of crop produce (Kumar *et al*., 2009) [30].

C. Interaction effect of nitrogen and sulphur on the yield contributing characters and yield of French bean

The interaction between nitrogen and sulphur was found to be significant effect on the studied yield contributing characters and yield of French bean. The highest plant height (48.20 cm), number of pods $plant^{-1}$ (8.07), length of dry pod (15.16 cm), number of seeds pod^{-1} (6.69) from the treatment combination of 120 kg N ha^{-1} × 10 kg S ha^{-1} (N_3S_1) which is statistically similar with (6.65) obtained from 120 kg N ha^{-1} × 20 kg S ha^{-1} (N_3S_3), number of seeds $plant^{-1}$ (28.47), grain yield (1.97 t ha^{-1}), stover yield (2.53 t ha^{-1}) and biological yield (4.5t ha^{-1}) from combination of 120 kg N ha^{-1} × 10 kg S ha^{-1} (N_3S_1) were observed. The highest harvest index (48.53 %) was found from combination of 60 kg N ha^{-1} × 15 kg S ha^{-1} (N_1S_2) (Table 3). Again, the lowest plant height (27.07 cm) from combination 0 kg N ha^{-1} × 0 kg S ha^{-1} (N_0S_0), number of pods $plant^{-1}$ (4.33), number of seeds $plant^{-1}$ (19.33), grain yield (0.97 t ha^{-1}), stover yield (1.37 t ha^{-1}), biological yield (2.34 t ha^{-1}) from combination of 0 kg N ha^{-1} × 15 kg S ha^{-1} (N_0S_2), length of pod (10.89cm) from combination of 90 kg N ha^{-1} × 10 kg S ha^{-1} (N_2S_1), number of seeds pod^{-1} (5.12) from combination of 0 kg N ha^{-1} × 10 kg S ha^{-1} (N_0S_1) and harvest index (37.85 %) from combination of 60 kg N ha^{-1} × 20 kg S

ha^{-1} (N_1S_3) were obtained (Table 3). The interaction effect between nitrogen and sulphur was not significant on the weight of seeds plant^{-1} at harvest. There was about statistically similar weight of 1000-seeds for all combination of nitrogen and sulphur (Table 3). Singh *et al.* (2018) [18] and Parvin (2011) [5] partially confirmed the results in case of plant height and number of pods plant^{-1} of French bean. Tewari and Singh (2000) [22] and Gokila *et al.* (2017) [25] assured the conclusion number of seeds pod^{-1} in their experiment. Shumi *et al.* (2018) [11] conducted an experiment in Ethiopia during 2016-17 to investigate the effect of blended NPS rates on growth, yield and yield components of common bean varieties and the result showed that significantly the highest number of primary branches per plant (2.77) and number of total pods (18.52) from 250 kg NPS ha^{-1}, number of total nodules (80.47) and effective nodules per plant (35.54) from 200 kg NPS ha^{-1}, grain yield (3260 kg ha^{-1}) from 250 kg NPS ha^{-1} were recorded. They concluded that combined application of 200 kg ha^{-1} of blended NPS with variety Ibado proved to be superior with respect to economic advantage. Singh *et al.* (2018) [18] conducted an experiment in India to investigate the effect of different levels of nitrogen, phosphorus and sulphur on growth and yield of Rajmash and nitrogen 120 kg ha^{-1} proved significantly superior to 90, 60 and 30 kg ha^{-1} in respect of all growth and yield attributes which recorded highest grain yield 13.59 q ha^{-1}. Sulphur application proved beneficial in bringing about significant improvement in yield attributes. 30 kg S ha^{-1} produced highest grain yield 11.47 q ha^{-1}. Sharma *et al.* (2013) [16] conducted a field experiment in India to study on French bean (*phaseolus vulgaris* l.) varieties under different n, p, k and s levels for growth, yield and economics. Among fertilizer levels (100:80:80:50 kg ha^{-1} NPKS) resulted in highest growth parameters, yield parameters and yield of pods.

It was found that French bean responded to 120 kg N ha^{-1} and 10 kg S ha^{-1} for obtaining the highest yield. Since, sulphur content was below the critical level in the soil of experimental field for the French bean plant growth, the additional sulphur supply with nitrogen in the soil therefore boosted yield in the plant. 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) [31] and application of Sulphur between 10-20 kg ha^{-1} can control sulfur deficiency (Van Schoonhaven and Voysests, 1991) [32]. Sulfur deficiency can be controlled by soil application of 25 kg ZnSo4 ha^{-1} (6-9 kg S ha^{-1}) (Parthasharathy, 1993) [33]. A combined application of nitrogen and sulphur is always beneficial for increasing yield of French bean.

Table 1: Effect of level of nitrogen on yield and yield contributing characters of French bean

Level of nitrogen	Plant height (cm)	No. of pods plant^{-1}	Length of pod (cm)	No. of seeds pod^{-1}	No. of seeds plant^{-1}	1000 grain weight (g)	Grain yield (t ha^{-1})	Stover yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
N_0	34.20 c	5.233 e	11.39	5.585 b	23.23 c	173.5	1.212 d	1.625 e	2.837 e	42.74 ab
N_1	34.95 c	5.517 d	11.48	5.813 a	23.49 c	174.8	1.290 c	1.803 c	3.092 c	42.00 b
N_2	34.53 c	6.100 c	11.37	5.549 b	22.97 c	174.6	1.273 c	1.713 d	2.985 d	42.56 ab
N_3	37.93 b	7.485 a	11.31	5.841 a	26.55 a	172.2	1.780 a	2.313 a	4.095 a	43.54 a
N_4	39.95 a	6.601 b	11.58	5.727 ab	24.78 b	173.8	1.472 b	1.900 b	3.371 b	43.65 a
‾ Sx	0.485	0.071	0.079	0.070	0.227	1.72	0.018	0.030	0.029	0.371
Level of significance	**	**	NS	**	**	NS	**	**	**	**
CV (%)	4.63	3.96	2.38	4.25	3.26	3.43	4.49	5.53	3.11	3.00

Table 2: Effect of level of sulphur on yield and yield contributing characters of French bean

Level of sulphur	Plant height (cm)	No. of pods plant^{-1}	Length of pod (cm)	No. of seeds pod^{-1}	No. of seeds plant^{-1}	1000 grain weight (g)	Grain yield (t ha^{-1})	Stover yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
S_0	34.45 c	6.428 b	11.45 ab	5.606 c	24.17 b	175.1	1.379 c	1.896 b	3.275 b	41.93 b
S_1	37.81 a	6.714 a	11.62 a	6.531 a	26.52 a	174.7	1.480 a	1.976 a	3.457 a	42.84 b
S_2	36.31 b	6.454 b	11.24 c	5.686 c	24.01 b	171.8	1.430 b	1.756 c	3.188 c	44.95 a
S_3	36.68 ab	5.693 c	11.39 bc	5.989 b	24.11 b	173.5	1.332 d	1.854 b	3.184 c	41.88 b
‾ Sx	0.434	0.063	0.070	0.063	0.203	1.53	0.016	0.027	0.026	0.332
Level of significance	**	**	**	**	*	NS	**	**	**	**
CV (%)	4.63	3.96	2.38	4.25	3.26	3.43	4.49	5.53	3.11	3.00

In a column, figures with same letter (s) or without letter do not differ significantly whereas figures with dissimilar letter differ significantly (as per DMRT), * =Significant at 5% level of probability, ** =Significant at 1% level of probability, NS = Not significant, N_0 = No nitrogen, N_1 = 60 kg N ha^{-1}, N_2 = 90 kg N ha^{-1}, N_3 = 120 kg N ha^{-1}, N_4 = 150 kg N ha^{-1}, S_0= No sulphur, S_1 = 10 kg S ha^{-1}, S_2 = 15 kg S ha^{-1}, S_3 = 20 kg S ha^{-1}.

Table 3: Interaction effects of level of nitrogen and level of sulphur on yield and yield contributing characters of French bean

Interaction (Level of N x Level of S)	Plant height (cm)	No. of pods plant^{-1}	Length of pod (cm)	No. of seeds pod^{-1}	No. of seeds plant^{-1}	1000 grain weight (g)	Grain yield (t ha^{-1})	Stover yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
N_0 x S_0	27.07 k	4.47kl	11.17def	5.70 b	22.73gh	173.3	1.14 ij	1.52 fgh	2.66 jk	42.68 efgh
N_0 x S_1	37.87 def	6.00ef	11.60cd	5.12 c	25.40cde	172.7	1.37 efg	2.05 d	3.42 ef	40.05 ijk
N_0 x S_2	33.67 ghi	4.33l	11.38cdef	5.79 b	19.33j	172.7	0.97 k	1.37 h	2.34 l	41.53fghij
N_0 x S_3	38.20 de	6.13ef	11.40cdef	5.73 b	25.47cde	175.3	1.37 efg	1.56 efgh	2.93 gh	46.70 abc
N_1 x S_0	35.93 efgh	5.47gh	11.77bc	5.43 bc	23.13fgh	177.0	1.16 ij	1.70 ef	2.86 hi	40.58 hij
N_1 x S_1	34.73fgh	5.80fg	11.45cde	5.69 b	24.27ef	174.3	1.40 def	2.01 d	3.40 f	41.04 ghij
N_1 x S_2	31.60 ij	5.80fg	11.34cdef	5.80 b	24.47def	174.0	1.32 fg	1.68 efg	2.73 ij	48.53 a
N_1 x S_3	37.53 def	5.00ij	11.34cdef	6.33ab	22.07hi	173.7	1.28 hg	2.10 cd	3.38 f	37.85 k
N_2 x S_0	33.20 hij	6.33de	12.32b	5.66 b	22.07hi	174.7	1.11 ij	1.70 ef	2.81 hij	39.50 jk

N_2 x S_1	35.67 efgh	5.80fg	10.89f	5.43 bc	24.07efg	177.7	1.30 fg	1.56 efgh	2.86 hi	45.54 bcd
N_2 x S_2	37.60 def	7.47bc	11.02ef	5.57 bc	24.53def	172.7	1.62 c	2.13 cd	3.75 d	43.14 efg
N_2 x S_3	31.67ij	4.80jk	11.25cdef	5.53 bc	21.20i	173.3	1.06jk	1.46 gh	2.52 k	42.05 fghi
N_3 x S_0	30.53 j	6.06d	11.54cde	5.60 b	27.07ab	176.0	1.74b	2.41b	4.15b	41.96 fghi
N_3 x S_1	48.20 a	8.07a	15.16a	6.69 a	28.47a	174.7	1.97a	2.51a	4.5a	43.77 def
N_3 x S_2	41.67 bc	6.07d	11.07def	5.52 bc	26.73abc	165.3	1.78b	2.27bc	4.05bc	43.97 def
N_3 x S_3	36.73 defg	7.20c	11.45cde	6.65a	27.53ab	172.7	1.76b	2.40b	4.16b	42.34 fghi
N_4 x S_0	45.53 ab	7.80ab	11.31cdef	5.64 b	25.87bcd	174.3	1.75b	2.15 cd	3.90 cd	44.92 cde
N_4 x S_1	38.00 de	6.67d	12.16b	5.82 b	24.00efg	174.3	1.49 d	2.09 cd	3.58 e	41.68fghij
N_4 x S_2	37.00 def	6.60d	11.36cdef	5.75 b	25.00de	174.3	1.46 de	1.61 efg	3.07 g	47.57 ab
N_4 x S_3	39.27cd	5.33hi	11.49cde	5.70 b	24.27ef	172.3	1.19 h	1.75 e	2.93 gh	40.45 hij
N_0 x S_0	0.971	0.141	0.157	0.140	0.455	3.44	0.037	0.061	0.058	0.742
Level of sig.	**	**	**	**	**	NS	**	**	**	**
CV (%)	4.63	3.96	2.38	4.23	3.26	3.43	4.49	5.53	3.11	3.00

In a column, figures with same letter (s) or without letter do not differ significantly whereas figures with dissimilar letter differ significantly (as per DMRT), ** =Significant at 1% level of probability, NS = Not significant, N_0 = No nitrogen, N_1 = 60 kg N ha^{-1}, N_2 = 90 kg N ha^{-1}, N_3 = 120 kg N ha^{-1}, N_4 = 150 kg N ha^{-1} and S_0= No sulphur, S_1 = 10 kg S ha^{-1}, S_2 = 15 kg S ha^{-1}, S_3 = 20 kg S ha^{-1}.

Conclusion

From the experiment it is concluded that BARI Jhar Sheem-2 can be planted with 120 kg nitrogen ha^{-1} and 10 kg sulphur ha^{-1} for obtaining higher and good quality grain yield production of French bean. However, the research should be conducted in different Agro-ecological zone of Bangladesh to draw a valid conclusion.

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