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GROWTH, YIELD AND QUALITY OF FRENCH BEAN (*PHASEOLUS VULGARIS* L.) AS INFLUENCED BY SULPHUR AND BORON APPLICATION ON INCEPTISOLS OF KASHMIR

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ABSTRACT
An experiment was conducted during *Kharif 2011* to study the response of french bean to different levels of sulphur and boron. The treatment combination of $S_{45}B_{1.0}$ recorded significantly higher values for nodulation parameters like number of nodules, their fresh and dry weight, dry matter accumulation at flowering, pod picking and harvesting stages, pod yield, yield attributes like number of pods plant^{-1}, number of seeds pod^{-1} and test weight, seed yield, stover yield and protein content. The percent increase in these parameters over control was observed to be 210.90, 150.11, 164.88, 83.85, 61.55, 35.01, 42.33, 93.13, 30.80, 12.14, 27.13, 40.82 and 28.70, respectively. From the study it was concluded that for realizing higher yield and quality of french bean on inceptisols under temperate conditions of Kashmir valley, the nutrient management may centre around 45 and 1.0 kg ha^{-1} of sulphur and boron respectively, along with the recommended fertilizer dose of N, P, K and FYM.

INTRODUCTION

French bean (*Phaseolus vulgaris* L.) belongs to family leguminosae and occupies a premier place among grain legumes in the world including India, where it is locally called as *Rajmash* (Sharma *et al*., 1994). French bean is quite nutritious and potential source of protein, carbohydrates and minerals. The mineral matter, crude fibre and ether extract are concentrated in seed while crude protein and energy are stored in the cotyledons (Singh and Yadav, 1997). It is an excellent vegetable crop for pods as well as for seed and is of worldwide significance for direct human consumption and a dietary supplement rich in proteins, vitamins and minerals such as calcium, phosphorus, iron and zinc (Broughton *et al*., 2003). French bean is traditionally a crop of temperate region. It is cultivated in hilly tract of Jammu and Kashmir, Himachal Pradesh (Kullu, Barot, Chamba and Shimla valley) and Uttar Pradesh. Globally french bean is cultivated over an area of 29.92 million hectares with an annual production of 23.23 million tons while in India it is cultivated over an area of about 10.80 million hectares with an annual production of 4.87 million tons (Anonymous, 2010). Nutritional study of this important crop was mainly confined to the primary nutrients while as secondary nutrients were least attended and micronutrients forgotten. Among secondary nutrients sulphur deficiency is reported in Inceptisols of Kashmir valley and identified as yield limiting factor, particularly in production of pulses and oilseed crops (Shrivastava *et al.,* 2000). Sulphur has been found to be an indispensable element for higher pulse production and it is an integral part of proteins, sulpholipids, enzymes etc (Das and Misra, 1991), besides it is involved in various metabolic and enzymatic processes including photosynthesis, respiration and legume-rhizobium symbiotic nitrogen fixation (Rao *et al*., 2001). 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). Among micronutrients boron deficiency is found to affect plant growth and reduce yields (Shaaban *et al*., 2004) and is one of the major constraints limiting the production of pulse crops (Mani and Haldar, 1996). Most of the soils (fine as well as coarse textured) are considered to be low in available boron as it has been reported that < 1 mg Kg^{-1} B is not sufficient for optimum plant growth (Reisenaure *et al*., 1973). Boron has been found to play a key role in reproductive processes affecting another development, pollen germination and pollen tube growth (Loomis and Durst, 1992). Boron application has a positive influence on growth, yield and quality of the crop (Sharma *et al*., 2013). Besides, the individual effect of sulphur and boron on pulse production Kaisher *et al*. (2010) while working on mungbean revealed synergistic effect of sulphur and boron with respect to the yield, yield contributing characters as well as quality of the crop. The limited availability of sulphur and boron in our soils calls urgent need for the standardization of optimum fertilizer dose for efficient pulse production. With this back ground present investigation was carried out to find out optimal levels of sulphur and boron for french bean crop on Inceptisols of Kashmir valley.

MATERIALS AND METHODS

A field experiment was conducted during *kharif* season 2011 at Regional Research Station, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir (SKUAST-K), Wadura (34°. 20¹N and 74°. 24A¹ E, 1585.26 m amsl.) on clay loam soil belonging to taxonomic class *Eutrochrepts*, low in available sulphur (8.92ppm) and boron (0.56ppm), medium in available nitrogen (310.38 Kg ha^{-1}), phosphorus (21.92Kg ha^{-1}) and potassium (55.0Kg ha^{-1}), high in organic carbon(1.30%)and neutral in reaction (pH 7.02). The climate of the experimental site is temperate with mild summers and cold winters, with a wide variation in the mean maximum and minimum temperatures. The experiment was laid out in a factorial RBD with four sulphur levels (0, 15, 30 and 45 kg ha^{-1}) and four boron levels (0, 0.5, 1.0 and 1.5 kg ha^{-1}) and replicated thrice. Fertilizer application was done at the time of sowing in accordance with treatment details. The nutrient sources used were gypsum and boric acid for sulphur and boron respectively. Nitrogen at a dose corresponding to 50% RDF and Phosphorus and Potassium at RDF were applied basally through urea, di-ammonium phosphate and muriate of potash, respectively. Remaining half dose of nitrogen was top dressed when true leaves emerged (25 days after sowing). Sowing was done on 8th June 2011 and all other cultural practices were followed as per the package of practices. Nodulation parameters were recorded at flowering stage. Dry matter accumulation was recorded at flowering, pod picking and harvesting stage of the crop. Fresh weight of total green pods harvested from ten randomly selected plants in three pickings was recorded to work out the average pod yield $plant^{-1}$. Seed was harvested from 16 undisturbed plants (net area = $0.5m^2$) from each plot and expressed in q ha^{-1}. Green pods and seeds taken at pod picking and harvesting stages, respectively were oven dried at 60-65°C to a constant weight, ground and subsequently used for chemical analysis to assess quality components. The N content of ground samples was estimated by alkaline $KMnO_4$ method (Subbiah and Asija method, 1956) and carbohydrate content by phenol-sulphuric acid method (Sadasivum and Manikam, 1992). Crude protein content was calculated by multiplying the nitrogen content with the factor 6.25. Gravimetric method was employed to determine moisture content of pods and seeds. Statistical analysis was done as per the method described by Panse and Sukhatme (1978). The significance of "F" test was tested at 5 percent level of significance as given by Fisher (1970) and the software used for the analysis of data was OPSTAT.

RESULTS AND DISCUSSION

Effect of S and B on

Growth

Data presented in the Table 1 reveals that the nodulation activity increased significantly with the increasing levels of sulphur as compared to control. The highest number (14.44), fresh weight

Table 1: Individual and interaction effect of sulphur and boron application on growth of French bean *(Var. Contendor)*

Treatment	Flowering Stage No. of Nodules/Plant	Fresh weight of nodules (mg/Plant)	Dry weight of nodules (mg/Plant	Dry matter accumulation (q ha^{-1})	Pod Picking Stage Dry matter accumulation (q ha^{-1})	Harvesting Stage Dry matter accumulation (q ha^{-1})
S_0	9.42	86.33	15.68	11.36	17.09	44.87
S_{15}	11.27	93.75	17.13	11.70	19.68	48.05
S_{30}	14.12	117.06	21.40	14.47	22.07	50.57
S_{45}	14.44	119.88	21.48	14.77	22.39	50.89
C.D $_{(p \leq 0.05)}$	0.95	9.87	0.20	0.65	0.52	0.42
B_0	7.41	67.58	12.25	10.26	17.25	43.82
$B_{0.5}$	12.02	100.50	17.96	12.14	17.81	47.33
$B_{1.0}$	14.76	123.52	22.71	14.90	23.07	51.55
$B_{1.5}$	15.07	125.42	22.78	14.99	23.10	51.68
C.D $_{(p \leq 0.05)}$	0.95	9.87	0.20	0.65	0.52	0.42
$S_o B_0$	5.50	56.01	9.37	9.29	16.10	39.93
$S_o B_{0.5}$	7.13	71.66	12.63	10.22	16.18	44.27
$S_o B_{1.0}$	12.26	107.00	20.29	12.73	17.89	47.41
$S_o B_{1.5}$	12.80	110.66	20.42	13.19	18.17	47.88
$S_{15}B_0$	6.90	60.66	10.70	9.67	16.36	42.20
$S_{15} B_{0.5}$	11.20	91.66	15.65	10.55	16.63	46.69
$S_{15} B_{1.0}$	13.26	110.33	21.02	13.03	22.68	51.45
$S_{15} B_{1.5}$	13.73	112.34	21.16	13.53	23.05	51.86
$S_{30} B_0$	8.26	75.66	14.44	10.90	18.15	46.47
$S_{30} B_{0.5}$	14.86	117.00	21.70	13.81	19.03	49.08
$S_{30} B_{1.0}$	16.95	138.92	24.77	16.75	25.70	53.44
$S_{30} B_{1.5}$	16.40	136.66	24.70	16.41	25.40	53.27
$S_{45} B_0$	8.96	78.00	14.48	11.17	18.38	46.67
$S_{45} B_{0.5}$	14.90	121.66	21.87	13.98	19.40	49.28
$S_{45} B_{1.0}$	17.10	140.09	24.82	17.08	26.01	53.91
$S_{45} B_{1.5}$	16.80	139.75	24.75	16.83	25.77	53.71
C.D $_{(p \leq 0.05)}$	1.90	19.75	0.40	1.30	1.04	0.84

(119.88 mg) and dry weight (21.48mg) of nodules plant^{-1} was recorded at 45 kg S ha^{-1}. However the nodulation activity at 45 kg S ha^{-1} was statistically on a par with 30 kg S ha^{-1}. The increase in nodulation activity with increasing levels of sulphur could be attributed to concomitant increase in ferridoxin content which is responsible for nodulation activity. Ferridoxins are rich in sulphur and contain Fe-S clusters which play vital role in N_2 fixation (Ali *et al.,* 2004). Similarly, increase in boron application resulted in a significant increase in nodulation activity. The maximum number (15.07), fresh weight (125.42 mg) and dry weight (22.78) of nodules plant^{-1} was recorded at 1.5 kg B ha^{-1}. These values nevertheless were statistically not different from 1 kg B ha^{-1}. The significant increase in nodulation activity with boron application could be attributed to increased activity of nitrogenase enzyme and nitrogen fixing bacteria as boron plays an essential role during bacterial differentiation by stabilizing the conjugate components of the inner face of peribacteroid membrane (Bolanos *et al*., 1996). Moreover, in nodules boron apparently plays a structural role in maintaining the integrity of cell wall and membranes (Bolanos *et al*., 1994) which in turn might have resulted in an increased nodulation activity. Boron and sulphur interaction showed positive and synergistic effect on nodulation activity at lower levels of boron application and the highest number (17.10), fresh weight (140.09 mg) and dry weight (24.82 mg) of nodules was recorded with 45 kg S ha^{-1} in combination with 1.0 kg B ha^{-1}. Highest level of boron (1.5 kg ha^{-1}) resulted in antagonistic effect on nodulation activity with 30 and 45 kg S ha^{-1}. The results obtained are in agreement with the findings of Hamdaoui *et al.,* 2003 and Yakuba *et al.,* 2010).

Dry matter accumulation was markedly influenced by sulphur and boron fertilization (Table 1). Discernible gradual improvement at flowering, pod picking and harvesting stage was observed in this important character due to sulphur up to 45 kg ha^{-1}. Highest dry matter accumulation was recorded at flowering (14.77 q ha^{-1}), Pod picking (22.39 q ha^{-1}) as well as harvesting stage (50.89 q ha^{-1}) with 45 Kg S ha^{-1}. This increase could be attributed to low status of sulphur in the studied soil and its subsequent role in increase in chlorophyll contents and photosynthetic rate that paved the way for increased dry matter production (Juszczuk and Ostaszewska, 2011). It was also found that dry matter accumulation recorded significant improvement at flowering (14.99 q ha^{-1}), pod picking (23.10 q ha^{-1}) and harvesting (51.68 q ha^{-1}) up to 1.5 kg B ha^{-1}. The significant increase in dry matter accumulation may be attributed to low status of boron in the studied soil. Boron and sulphur interaction showed positive and synergistic effect on dry matter accumulation at lower levels of boron and the maximum dry matter accumulation at flowering (17.08 q ha^{-1}), pod picking (26.01q ha^{-1}) and harvesting (53.91) was recorded with 45 Kg S ha^{-1}in combination with 1.0 kg B ha^{-1}. Highest level of boron (1.5 kg ha^{-1}) showed antagonistic effect on dry matter accumulation with 30 and 45 kg S ha^{-1}. The results obtained are in tune with the findings of Khanna and Gupta 2005.

Yield and yield attributing characters

An important test to judge the performance or efficiency of a treatment is yield. In the present study, it was found that yield

Table 2: Individual and interaction effect of sulphur and boron application on quality of French bean (Var. *Contendor*).

Treatment	Green Pods Crude Protein content (%)	Carbohydrate content (%)	Moisture content (%)	Seeds Crude Protein content (%)	Carbohydrate content (%)	Moisture content (%)
S_0	1.65 (1.628)	4.77 (2.403)	91.78 (9.632)	18.16 (4.379)	59.12	11.90 (3.591)
S_{15}	1.68 (1.637)	5.11 (2.473)	91.71 (9.629)	20.03 (4.583)	59.71	11.83 (3.582)
S_{30}	1.75 (1.657)	5.45 (2.539)	91.47 (9.616)	21.05 (4.681)	63.12	11.59 (3.548)
S_{45}	1.77 (1.665)	5.11 (2.474)	91.30 (9.607)	21.08 (4.692)	61.29	11.42 (3.524)
$C.D_{(p \le 0.05)}$	0.0096	0.0073	NS	0.024	0.15	NS
B_0	1.67 (1.635)	4.85 (2.419)	91.67 (9.627)	18.95 (4.457)	59.98	11.79 (3.576)
$B_{0.5}$	1.70 (1.643)	5.10 (2.471)	91.60 (9.623)	19.77 (4.548)	61.13	11.72 (3.567)
$B_{1.0}$	1.73 (1.654)	5.28 (2.298)	91.52 (9.619)	20.78 (4.645)	61.13	11.64 (3.555)
$B_{1.5}$	1.75 (1.657)	5.20 (2.491)	91.46 (9.616)	20.81 (4.653)	61.00	11.58 (3.546)
$C.D_{(p \le 0.05)}$	0.0096	0.0073	NS	0.024	0.15	NS
$S_o B_0$	1.61 (1.616)	4.27 (2.296)	91.85 (9.636)	17.00 (4.240)	58.00	11.97 (3.601)
$S_o B_{0.5}$	1.64 (1.627)	4.77 (2.403)	91.80 (9.633)	17.63 (4.314)	59.52	11.92 (3.595)
$S_o B_{1.0}$	1.68 (1.637)	5.00 (2.450)	91.76 (9.631)	18.94 (4.463)	58.06	11.88 (3.589)
$S_o B_{1.5}$	1.68 (1.637)	5.03 (2.456)	91.69 (9.628)	19.06 (4.475)	60.92	11.81 (3.579)
$S_{15}B_0$	1.63 (1.622)	5.07 (2.465)	91.90 (9.639)	19.31 (4.505)	59.78	12.02 (3.608)
$S_{15} B_{0.5}$	1.65 (1.628)	5.03 (2.456)	91.73 (9.630)	19.75 (4.547)	59.27	11.85 (3.585)
$S_{15} B_{1.0}$	1.68 (1.637)	5.14 (2.479)	91.61 (9.623)	20.44 (4.623	59.95	11.73 (3.568)
$S_{15} B_{1.5}$	1.75 (1.657)	5.21 (2.492)	91.60 (9.623)	20.63 (4.656)	59.84	11.71 (3.566)
$S_{30} B_0$	1.73 (1.654)	5.00 (2.450)	91.53 (9.619)	19.75 (4.547)	61.60	11.65 (3.556)
$S_{30} B_{0.5}$	1.74 (1.655)	5.42 (2.534)	91.48 (9.617)	20.81 (4.653)	62.94	11.60 (3.550)
$S_{30} B_{1.0}$	1.78 (1.667)	5.78 (2.604)	91.49 (9.617)	21.88 (4.768)	64.57	11.61 (3.551)
$S_{30} B_{1.5}$	1.78 (1.667)	5.60 (2.569)	91.38 (9.611)	21.75 (4.754)	63.38	11.50 (3.535)
$S_{45} B_0$	1.74 (1.655)	5.07 (2.464)	91.41 (9.613)	19.75 (4.537)	60.56	11.53 (3.539)
$S_{45} B_{0.5}$	1.75 (1.657)	5.20 (2.491)	91.39 (9.612)	20.88 (4.676)	62.79	11.51 (3.537)
$S_{45} B_{1.0}$	1.79 (1.669)	5.20 (2.491)	91.22 (9.603)	21.88 (4.782)	61.94	11.34 (3.513)
$S_{45} B_{1.5}$	1.78 (1.667)	4.99 (2.448)	91.17 (9.601)	21.81 (4.774)	59.85	11.28 (3.505)
$C.D_{(p \le 0.05)}$	0.0192	0.015	NS	0.048	0.30	NS

*Values in parenthesis is transformed data

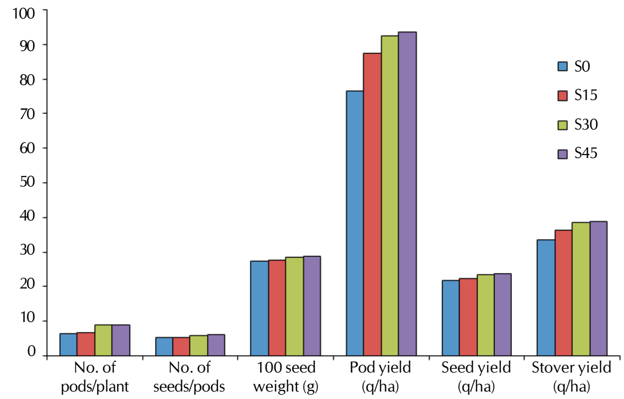

Figure 1: Individual effect of sulphur fertilization on yield and yield attributing characters of French bean

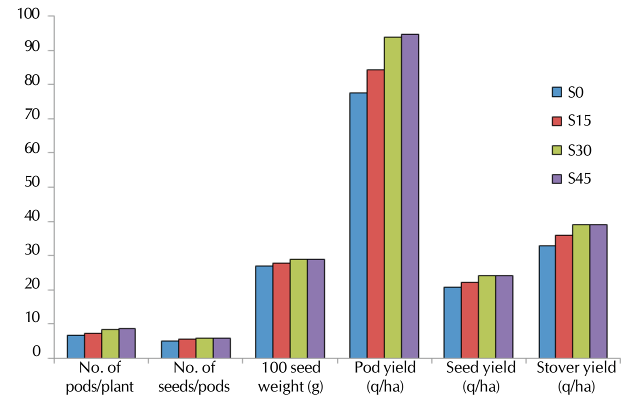

Figure 2: Individual effect of boron fertilization on yield and yield attributing characters of French bean

and yield attributing characters recorded significant and consistent increase with increase in doses of sulphur and boron (Fig. 1-3). Various yield attributing characters like number of pods plant^{-1}, number of seeds pod^{-1} and 100 seed weight increased significantly as the dose of sulphur was increased. This is probably due to its role in synthesis of sulphur containing amino acids, proteins and enhanced photosynthetic activity of plant with increased chlorophyll synthesis (Juszczukand Ostaszewska, 2011). Similarly, application of sulphur increased pod, seed and stover yield significantly up to 45 kg ha^{-1}, however, these results were at par with 30 kg ha^{-1} (Fig. 1). The improvement in yield due to increase in sulphur levels might be due to its important role in energy transformation, activation of enzymes and carbohydrate metabolism (Davidian and Kopriva, 2010; Juszczuk and Ostaszewska, 2011). Boron application showed significant increase in yield attributes of the crop and the highest values were recorded with 1.5 kg B ha^{-1} which was however statistically on a par with 1.0 kg B ha^{-1} (Fig. 2). The significant increase in yield attributes may be associated partly to the low status of boron in the soil under study and partly to the greater requirement of the nutrient by the crop. Likewise the increment in pod, seed and stover yield with boron application up to 1.5 kg ha^{-1} may be due to its role in regulation of carbohydrate metabolism and its transport within the plant besides the synthesis of amino acids and proteins and fruit and seed setting (Debnath and Ghosh, 2011). The interaction between sulphur and boron revealed a synergistic influence on yield attributing characters and yield which were observed to be highest at 45 kg S ha^{-1} in combination with 1.0 kg B ha^{-1} (Fig. 3). Highest level of boron (1.5 kg ha^{-1}) showed antagonistic effect on yield attributing characters as well as pod, seed and stover yield with 30 and 45 kg S ha^{-1}. The results obtained agree with the findings of Kumar and Singh (2009).

Quality

The results showed that the crude protein content of pods and seeds increased significantly with increasing doses of both sulphur as well as boron (Table 2). With respect to sulphur, the crude protein content in pods and seeds increased significantly up to the dose corresponding to 45 kg ha^{-1}. These values however didn't vary significantly from 30 kg ha^{-1}. It may be ascribed to the fact that it is a constituent of cysteine, methionine and a variety of other metabolites like glutathione, phyto-chelatins, ferredoxin, thioredoxin as well as formation of clusters with iron which plays a role in crucial processes in the plant cell, such as biosynthesis, assembly and activity regulation of proteins (Davidian and Kopriva, 2010). Similarly Patel *et al*. (2013) reported 11.30 percent increase in the protein content of coriander with the application of 30 Kg S ha^{-1}. The highest crude protein content in both pods as well as seeds was recorded at1.5 kg B ha^{-1} which was statistically at par with 1.0 kg B ha^{-1}. This significant rise in crude protein content is probably due to the vital role that boron plays in protein and nucleic acid metabolism (Debnath and Ghosh, 2011). Synergistic interaction between boron and sulphur with respect to crude protein content was noticed. The influence was highest with 45 kg S ha^{-1} and 1.0 kg B ha^{-1} combination. Highest level of boron (1.5 kg ha^{-1}) however displayed an antagonistic effect on crude protein content with 30 and 45 kg S ha^{-1}. Current study corroborates the findings of Nadian *et al*. (2010) and Deshbhratar *et al*. (2010).

Like crude protein, the carbohydrate content also was markedly augmented with the higher doses of two nutrients (Table 2). Carbohydrate content in pods and seeds increased significantly with both sulphur and boron up to 30 kg ha^{-1} and1.0 kg ha^{-1} respectively. The interaction between sulphur and boron revealed a synergistic influence on carbohydrate content in pods and seeds which was highest with 45 kg S ha^{-1}and 1.0 kg B ha^{-1}combination. Highest level of boron (1.5 kg ha^{-1}) showed antagonistic effect on carbohydrate content with 30 and 45 kg S ha^{-1} combination. In our opinion the increase in carbohydrate content is probably because sulphur regulates the metabolic and enzymatic processes including respiration, photosynthesis, carbohydrate metabolism, transport of sugars, stomatal regulation and hormone synthesis and translocation. Moreover increase in carbohydrate content with the increase in boron application could be due to favourable influence of boron on various metabolic processes like photosynthesis, respiration, enzyme activity (Ganie *et al*., 2013) which augments the production of metabolites and their translocation to different parts including seed which ultimately increases the concentration of nutrients in seed and stover.

Moisture content showed a decline with the increase in the

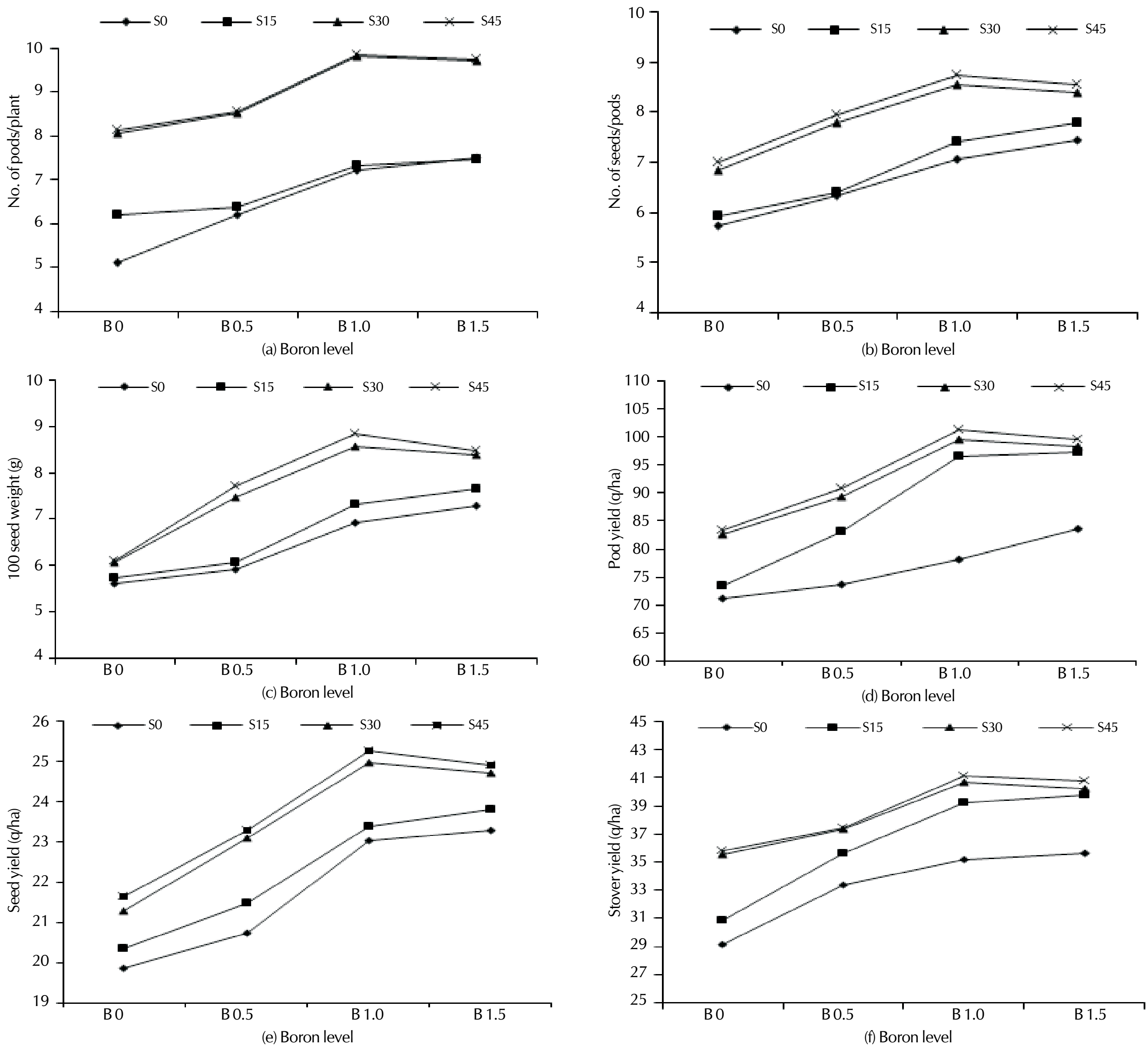

Figure 3: Interaction effect of S and B fertilization on yield and yield attributing characters of French bean

application rate of both sulphur as well as boron however this decrease wasn't statistically worth considering.

CONCLUSION

From the study it is concluded that for realizing economically higher yield and quality of french bean on inceptisols under temperate conditions of Kashmir valley, the nutrient management may centre around 45 kg S and 1.0 kg B ha^{-1}, along with recommended dose of nitrogen (30 kg ha^{-1}), phosphorus (60 kg ha^{-1}), potassium (60 kg ha^{-1}) and farm yard manure (20 ton ha^{-1}).

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