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Response of french bean (*Phaseolus vulgaris* L.) to phosphorus and sulphur in aluminium stress condition of Nagaland

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ABSTRACT

A greenhouse experiment was conducted at SASRD, Nagaland University, Medziphema during kharif season of 2017-2018 to study the effect of phosphorus and sulphur on growth, yield attributes, yield and nutrient uptake of french bean in aluminium stress condition. The experiment was designed in randomized block design with two levels of aluminium (0 and 67.5 mg kg^{-1} Al), four levels of phosphorus (0, 13.4, 26.8 and 40.2 mg kg^{-1} P_2O_5) and three levels of sulphur (0, 13.4 and 26.8 mg kg^{-1}). Application of aluminium significantly reduced plant height, branches per plant, pods per plant, pod length, seeds per pod, seed and stover yield, protein content, phosphorus and sulphur uptake of french bean. While the test weight and aluminium uptake increased remarkably with application of aluminium. Application of 67.5 mg kg^{-1}aluminium decreased seedand stover yield by 38.7 and 23.9%, respectively over control. Phosphorus application significantly enhanced plant height, branches per plant, per plant, test weight, grain and stover yield, protein content, phosphorus, sulphur and aluminium uptake of french bean and better performance was obtained with application of 26.8 mg kg^{-1} phosphorus. Application of 26.8 mg kg^{-1} phosphorus increased the seed and stover yield by 24.3 and 12.5%, respectively over control. Application of sulphur also significantly enhanced the growth, yield attributes, yields and nutrient uptake of french bean. But branches plant^{-1}, pods plant^{-1} and pod length could not be affected markedly with sulphur application. Application of 13.4 mg S kg^{-1} was found optimum dose and increased the seed yield by 11.2% and stover yield by 3.1% over control. Phosphorus, sulphur and aluminium uptake enhanced remarkably with sulphur application.

Key words: French bean, aluminium, phosphorus, sulphur, yield

INTRODUCTION

French bean (*Phaseolus vulgaris* L.) belongs to family leguminoceae and occupies a premier place among grain legumes in the world including India. French bean is quite nutritious and potential source of protein, carbohydrates and minerals. It is an excellent vegetable crop for pods as well as for seed and is of world- wide significance for direct human consumption and a dietary supplement rich in proteins, vitamins and minerals. French bean is also one of the most important pulse crop in North East India and many parts of the country. In Nagaland, french bean was cultivated on 16750 ha during 2018 with the production of 21350 tonnes of french bean seeds (Anonymous, 2018). Aluminium (Al) toxicity is a major constraint on crop production in acid soils which account for about 40% of the world's arable land. Al is present in all soils, but Al toxicity is manifested only in acid conditions, in which the phytotoxic form Al^{3+} predominates. In plants, the foliar symptoms resemble those of phosphorus (P) deficiency (overall stunting, small, dark green leaves and late maturity, purpling of stems, leaves, and leaf veins, yellowing and death of leaf tips). In some cases, Al toxicity appears as an induced calcium (Ca) deficiency or reduced Ca transport problem (curling or rolling of young leaves and collapse of growing points or petioles). Phosphorous is an essential element for photosynthesis, it is one of the primary structural components of membranes that surround plant cells. It is involved in the synthesis of proteins and vitamins and occurs in important enzymes. It promotes early root formation and growth. Phosphorus when applied to legumes, it enhances the activity of *rhizobia* by increasing nodulation and thereby helps in fixing more atmospheric nitrogen. The phosphorus status of Nagaland soils is medium and some fraction is low. Among secondary nutrients sulphur deficiency is identified as yield limiting factor, particularly in production of pulses and oilseed crops. Sulphur has been found to be an indispensable element for higher pulse production and it is an integral part of proteins, sulpholipids, enzymes etc,

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besides it is involved in various metabolic and enzymatic processes including photosynthesis, respiration and legume-*Rhizobium* symbiotic nitrogen fixation. French bean can absorb sulphur in great quantities and it is necessary to maintain the relation of nitrogen and sulphur in the plant to produce protein**.** Therefore, an attempt was made to study the response of french bean to phosphorus and sulphur under aluminium stress condition of Nagaland.

MATERIALS AND METHODS

A greenhouse experiment was conducted at School of Agricultural Sciences and Rural Development, Nagaland University, Medziphema, Nagaland with french bean (var. Selection 9) as the test crop during kharif season of 2017 and 2018. The greenhouse is located at 25°45'45"N latitude and 93°51'45"E longitude at an elevation of 310 m above mean sea level. The average rainfall varies between 2000 and 2500 mm. The experiment was conducted in earthen pots of 30 cm diameter, filled with 10 kg of soil. The experimental soil was sandy clay loam with pH 5.44,organic carbon 17.2 g kg^{-1}, available N, P, K and S status 222, 14.7, 174 and 20.2 kg ha^{-1}, respectively, total potential acidity 9.7 cmol(p^+) kg^{-1} and exchangeable Al 1.64 cmol(p^+) kg^{-1}. Two levels of aluminium (0and 67.5 mg kg^{-1}), four levels of phosphorus (0, 13.4, 26.8 and 40.2 mg kg^{-1} P_2O_5) and three levels of sulphur (0, 13.4 and 26.8 mg kg^{-1}) were tested in factorial randomized block design with three replications. Aluminium levels were developed by aluminium chloride ($AlCl_3$). Phosphorus and sulphur were supplied through di-ammonium phosphate and elemental sulphur, respectively. Recommended dose of nitrogen (26.8 mg kg^{-1}) was applied through urea after adjusting the amount of nitrogen being supplied through DAP and potassium (26.8 mg $kg^{-1}K_2O$) was supplied through muriate of potash. Full dose of phosphorus, potassium and sulphur was applied one day before sowing while nitrogen was supplied in two equal splits *viz.* half at sowing time and rest half after 30 days of sowing. Aluminium chloride was applied three days before sowing. Three seeds in each pot were sown on 3rd October, 2017 and 1st October, 2018 at a depth of 5 cm at optimum soil moisture level to ensure proper germination. Thinning was done ten days after germination and only one healthy plant in each pot was allowed to grow. Weeding was done at regular interval to check the weed growth in the pots and crop was irrigated as and when required. Data on plant height, number of branches $plant^{-1}$, number of pods $plant^{-1}$, pods length, number of seeds pod^{-1}, test weight and grain and stover yield were recorded. For N content, seed samples were analyzed by Kjeldahl method. Phosphorus and sulphur in grain and stover samples were determined in diacid (HNO_3, $HClO_4$) extract by advocating standard procedure (Jackson, 1973). Aluminium content was determined using atomic absorption spectrophotometer. The data were analyzed statistically to compare the treatment effects (Panse and Sukhatme, 1961).

RESULTS AND DISCUSSION

Growth parameters

Aluminium application significantly decreased plant height at all the growth stages. Plant height was reduced by 20.4, 14.0 and 17.0% with application of 67.5 mg kg^{-1} aluminium over control at 30 DAS, 60 DAS and at harvest, respectively (Table 1). Number of branches decreased significantly with aluminium application at all growth stages. At harvest, application of 67.5 mg Al kg^{-1} reduced branches to the extent of 11.1% over control. The decreased growth of plants due to Al might be because of its higher concentration in soil solution which reduced the absorption of essential plant nutrients and create unfavourable soil environment in root zone resulted stunted plant growth. Further, plant absorbed more aluminium which might have reduced the metabolic activities and cell division, ultimately decreased the plant growth in term of plant height and number of branches. Similar results have been reported by Riberio *et al.* (2013).Significant effect of phosphorus and sulphur application was observed on plant height at all growth stages. Maximum plant height was recorded with application of 40.2 mg kg^{-1} phosphorus which was at par with 26.8 mg kg^{-1} phosphorus at 60 DAS and at harvest, while at 30 DAS, significantly higher plant height was recorded with 26.8 mg 5 kg^{-1} phosphorus, The maximum plant height was obtained with 26.8 mg S kg^{-1}application but this level was at par with 13.4 mg Skg^{-1}at 60 DAS. Application of

26.8 mg kg^{-1} phosphorus enhanced plant height by 16.3% over control at harvest, while 26.8 mg kg^{-1} S increased plant height by 13.5% over control. Number of branches $plant^{-1}$ enhanced significantly with phosphorus application at 30 DAS and at harvest, while sulphur application did not show any significant effect. Maximum branches were recorded with application of 40.2 mg kg^{-1} phosphorus but effect was at par with 26.8 mg kg^{-1} phosphorus. This might be due to involvement of phosphorus in energy transformation within plant system and cell division. Similar results have also been reported by Nyekha *et al.* (2015).

Yield attributes

Number of pods per plant, pod length and seeds per pod decreased significantly with aluminium application while test weight was increased markedly (Table 1). This may be due to poorly developed root system which limits nutrient and water uptake leading to decrease in yield attributes. Similar results were recorded in cowpea by Kenechukwu (2007). Test weight was recorded highest with application of 67.5 mg Al kg^{-1} as compared to control, Pots treated with 67.5 mg Al kg^{-1}produced shorter pod length with lower number of seeds per pod resulted bolder seed formation. Phosphorus and sulphur application showed positive impact on yield attributes and maximum pods per plant (13.64), pod length (12.07 cm) and test weight (29.22 g) were recorded from 26.8 mg kg^{-1} phosphorus, while maximum seeds per pod (5.29) was recorded with application of 40.2 mg kg^{-1} phosphorus. Application of 26.8 mg kg^{-1} phosphorus improved number of pods per plant, pod length, number of seeds per pod and test weight by 7.4, 15.5, 9.0 and 5.3% over control, respectively. This may be attributed to the important role of phosphorus in flowering and fruiting including seed development. These results are in conformity with the findings of Zohmingliana *et al.* (2018). Number of seeds per pod and test weight enhanced significantly with sulphur application. Maximum seeds per pod and test weight was recorded with 13.4 and 26.8 mg S kg^{-1}, respectively, but difference between these two levels was non significant for both parameters. Sulphur is mainly responsible for enhancing the reproductive growth and the proportion of the reproductive tissues like inflorescences and pods. Similar results werereported bySingh *et al.* (2017).

Table 1: Effect of aluminium, phosphorus, sulphur levels on growth and yield attributes of french bean (Pooled)

Treatments	Plant height (cm)			No. of branches			No. pods $plant^{-1}$	Pod length (cm)	No. seeds pod^{-1}	Test weight (g)
	30 DAS	60 DAS	At harvest	30 DAS	60 DAS	At harvest				
Aluminium (mg kg^{-1})										
0	23.7	33.7	36.0	4.37	7.81	8.38	15.5	13.0	5.6	27.2
67.5	18.9	28.7	29.9	3.64	6.46	7.45	10.8	9.9	4.5	29.5
SEm±	0.2	0.43	0.47	0.11	0.16	0.12	0.13	0.12	0.08	0.23
CD (p=0.05)	0.57	1.23	1.34	0.32	0.46	0.35	0.37	0.35	0.23	0.66
Phosphorus (mg kg^{-1})										
0	19.9	28.5	29.49	3.25	6.67	7.42	12.7	10.4	4.7	27.7
13.4	21.2	30.0	32.18	3.98	7.06	7.87	13.5	11.6	5.1	28.1
26.8	23.0	32.5	34.30	4.39	7.39	8.17	13.6	12.0	5.2	29.2
40.2	21.5	33.6	35.96	4.39	7.42	8.20	13.0	11.7	5.2	28.5
SEm±	0.28	0.61	0.66	0.15	0.23	0.17	0.19	0.17	0.11	0.32
CD (p=0.05)	0.8	1.74	1.88	0.43	NS	0.49	0.54	0.49	0.26	0.32
Sulphur (mg kg^{-1})										
0	21.1	29.6	30.8	3.84	7.07	7.84	13.0	11.2	4.9	27.8
13.4	21.6	31.3	33.1	4.07	7.23	7.94	13.5	11.5	5.2	28.4
26.8	21.4	32.6	35.0	4.11	7.11	7.96	13.1	11.6	5.1	28.9
SEm±	0.25	0.53	0.58	0.13	0.20	0.15	0.16	0.15	0.1	0.2
CD (p=0.05)	NS	1.51	1.65	NS	NS	NS	NS	NS	0.29	0.80

Yield and protein content

Grain and stover yield and protein content of french bean were affected badly by aluminium application (Table 2). Application of 67.5 mg Al kg^{-1} decreased significantly grain and stover yield and protein content to the extent of 38.7 and 24.0% over control. Low translocated content of phosphorus to the plant shoots reduces the photosynthetic rate, which caused a lower accumulation of carbohydrates resulted low yield. Application of 67.5 mg Al kg^{-1} decreased the protein content by 6.9% over control. (Riberio *et al.*2013). Phosphorus and sulphur application had significant beneficial effect on seed and stover yield and protein content of french bean. Maximum seed yield and protein content was recorded at 26.8 mg kg^{-1} phosphorus beyond this level a reduction was noticed in these parameters. While maximum stover yield was observed under 40.2 mg kg^{-1} phosphorus but it was at par to 26.8 mg kg^{-1}phosphorus. Application of 26.8 mg kg^{-1} phosphorus increased seed and stover yield and protein content by 24.4, 11.4 and 4.5%, respectively over control. Maximum seed and stover yield and protein content was recorded 13.4 mg S kg^{-1}. However, effect of 26.4 mg S $kg^{-1}$was at par to 13.4 mg kg^{-1} sulphurin case of stover yield. Application of 13.4 mg S kg^{-1}enhanced seed and stover yield and protein content to the extent of 11.2, 3.5 and 2.4%, respectively over control. The increase in above ground dry biomass yield with phosphorus and sulphur might be attributed to the enhanced availability of these nutrients for better overall vegetative growth of the plants. Phosphorus application improved the root growth resulted plant absorbed more nutrients from soil for effective dry matter production and translocation of photosynthetes from leaves to reproductive parts for better development of seeds (Gadi *et al.* 2018 and Zohmingliana *et al.* 2018).

Table 2: Effect of aluminium, phosphorus and sulphur levels on seed and stover yield, protein content and Al, P and S uptake (mg pot^{-1}) (Pooled)

Treatments	Seed yield (g pot^{-1})	Stover yield (g pot^{-1})	Protein content (%)	P uptake		S uptake		Al uptake	
				Grain	Stover	Grain	Stover	Grain	Stover
Aluminium ((mg kg^{-1})									
0	23.92	32.89	21.6	112.2	79.0	78.1	44.2	4.7	20.9
67.5	14.65	25.00	20.1	62.0	34.7	36.6	25.1	6.9	25.3
SEm±	0.29	0.19	0.12	1.64	0.60	1.33	0.81	0.10	0.16
CD(p=0.05)	0.83	0.54	0.35	4.66	1.71	3.78	2.30	0.28	0.66
Phosphorus (mg kg^{-1})									
0	16.91	26.80	20.3	72.7	46.7	46.4	25.6	5.1	22.9
13.4	19.50	28.40	20.9	87.0	53.5	56.5	33.0	5.8	24.3
26.8	21.03	30.17	21.2	95.8	62.0	65.2	38.1	6.2	26.0
40.2	19.71	30.40	21.0	92.9	65.2	61.4	41.7	5.9	26.1
SEm±	0.41	0.27	0.17	2.31	0.85	1.88	1.14	0.14	0.23
CD(p=0.05)	1.17	0.77	0.49	6.56	2.42	5.34	3.24	0.40	0.65
Sulphur (mg kg^{-1})									
0	18.08	28.27	20.5	79.7	54.2	50.2	28.9	5.8	24.2
13.4	20.11	29.17	21.0	91.4	58.0	59.9	35.3	6.0	25.0
26.8	19.68	29.19	21.0	90.2	58.4	62.0	39.7	5.8	25.2
SEm±	0.36	0.23	0.15	2.01	0.73	1.63	0.99	0.12	0.20
CD(p=0.05)	1.03	0.66	0.43	5.71	2.08	4.63	2.81	0.35	0.56

Nutrient uptake

Aluminium application significantly reduced phosphorus and sulphur uptake in grain and stover (Table 2). Application of 67.5 mg Al kg^{-1} decrease P uptake in grain and stover by 44.8 and 56.0%, respectively over control, while S uptake in grain and stover was reduced by 53.1 and 43.2%, respectively. Application of aluminium increased Al uptake significantly over control and maximum Al uptake was recorded with 67.5 mg Al kg^{-1}. Increase in aluminium uptake was obvious due to increased concentration of aluminium in the soil.

Phosphorus and sulphur uptake in grain and stover improved significantly with phosphorus and sulphur application. Highest P uptake in grain was obtained at 26.8 mg kg^{-1} phosphorus and 13.4 mg S kg^{-1}, while maximum P uptake in stover was recorded with 40.2 mg kg^{-1} phosphorus and 26.8 mg S kg^{-1}. Phosphorus uptake in grain and stover enhanced by 31.6 and 39.8%, respectively over control with 26.8 and 40.2 mg kg^{-1} phosphorus. Highest sulphur uptake in grain (65.27 and 62.08 mg pot^{-1}) was obtained from application of 26.8 mg kg^{-1} phosphorus and 26.8 mg S kg^{-1}and in stover (41.78 and 39.75 mg pot^{-1}) with 40.2 mg kg^{-1} phosphorus and 26.8 mg S kg^{-1}. Application of 26.8 mg S kg^{-1}increased sulphur uptake in grain and stover by 23.5 and 37.4%, respectively over control. Phosphorus and sulphur application enhanced Al uptake significantly over control and highest Al uptake was recorded with application of 26.8 mg kg^{-1} phosphorus and 13.4 mg S kg^{-1}. As nutrient uptake is the product of nutrient content and yield, with the increase in these attributes, the nutrient uptake was also increased. Similar results were reported by Kumar *et al.* (2015) and Prajapati *et al.* (2020).

The results of the present study lead to a conclusion that the growth, yield attributes and yield of french bean were affected adversaly with aluminum. Application of 26.8 mg kg^{-1} phosphorus produced higher plant height, branches plant^{-1}, pods plant^{-1}, pod length, seeds per pod, test weight, seed and stover yield, protein content and nutrient uptake of french bean. Application of 13.4 m S kg^{-1}gave highest seed yield and protein content. Phosphorus and sulphur application enhanced Al, P and S uptake, while aluminium application increased Al uptake and reduced P and S uptake in grain and stover. Hence, 26.8 mg kg^{-1} phosphorus and 13.4 mg S kg^{-1}are recommended for better yield of french bean in aluminium stress soil condition of Nagaland.

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