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EVALUATION OF THE PERFORMANCE OF FRENCH BEAN (*Phaseolus vulgaris*) VARIETIES UNDER ALUMINIUM STRESS ENVIRONMENT

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ABSTRACT

A pot experiment was carried out during 2017-19 to evaluate of the performance of french bean (*Phaseolus vulgaris* L.) varieties under aluminium stress condition. Three varieties (Selection-9, Anupam-R and Nagaland local) were screened under three levels of aluminium (0, 0.25 and 0.50 cmol kg^{-1}) in completely randomized design with three replications. Aluminium application significantly reduced growth and yield parameters, root length and root mass of french bean while number of germination days, test weight, Al content in roots and aluminium uptake in grain was significantly increased. Selection-9 variety produced significantly higher growth, yield parameter and root length as compared to other varieties. But higher test weight was recorded in Nagaland local. Significantly higher Al uptake in grains of french bean was recorded in Selection-9 variety. On the basis of seed yield, the order of superiority of varieties was arranged as Selection-9 > Anupam-R > Nagaland local. The results of the present study lead to a conclusion that the growth and yield of french bean were affected by high aluminium levels. Among the varieties, Selection-9 variety may be recommended for cultivation of french bean in Al stress condition of Nagaland as well as other North Eastern states.

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 (Ganie *et al.*, 2014). French bean is becoming popular for its tender pods and shelled beans. Besides, it maintains soil fertility through biological nitrogen fixation in association with symbiotic *Rhizobium* prevalent in their root nodules. 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). In Nagaland region, farmers are generally cultivating local french bean cultivars which vary in colour, shape, size and also in taste. Some of these are high yielder, disease and acid resistant. Dried beans produced in the high hills are considered to be high quality beans and find their way to distant markets and cities. The suitable variety in appropriate soil is the two important factors for higher crop production (Dhanjal *et al.*, 2001). Aluminium toxicity is an important growth-limiting factor for plants in acid soils below pH 5.0 (Foy, 1992). Generally, Al interferes with cell division in root tips and lateral roots, fixes phosphorous in less available forms in soils and on root surfaces, decreases root respiration, interferes with enzyme activity and interfere with the uptake, transport, and also use of several essential nutrients (Ca, Mg, K, P and Fe). Al is present in all soils, but Al toxicity is manifested only in acid conditions, in which the phytotoxic form Al^{3+} predominates. Aluminium is one of the most abundant elements in the earth's crust, and toxic for many plants when the concentration is greater than 2–3 ppm with a soil pH < 5.5. Exchangeable aluminium content in the soils of Nagaland varied from 1.29 to 2.62 cmol kg^{-1} (Chenithung *et al.*, 2014). However, genotype is the most important factor in any crop production programme and is the basic material to which all other technologies are applied (Goutam *et al.*, 2001). Therefore, unless a good genotype of high potential is used; other technologies will also not work. These genotypes are also greatly varied in their performance under different agro-climatic conditions of the country which often creates confusions among the farmers about their choice of variety. So, selection of particular variety for seed production is also prime important for higher seed yield (Das *et al.*, 2014). Hence, it is essential to look forward for the production of quality seed in the state itself to uplift quality production of french bean.Therefore keeping in mind the constraints of soil acidity in Nagaland and other North East states growing french bean the paper deals with evaluation of the performance of french bean varieties under aluminium stress environment.

MATERIALS AND METHODS

A pot experiment was conducted in the greenhouse of the Department of Agricultural Chemistry and Soil Science, School of Agricultural Sciences and Rural Development, Nagaland University, Medziphema, Nagaland with french bean as the test crop. 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 with an average rainfall of 2000-2500 mm.

Mean temperature ranges from 21ºC to 30ºC during summer and rarely goes below 8ºC during winter due to high atmospheric humidity. The experiment was conducted for two consecutive years (2017-18 and 2018-19) in earthen pots. Each pot was 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 and K content 222.2, 14.7 and 174.6 kg ha^{-1}, respectively, total potential acidity 9.7 cmol(p+)kg^{-1} and exchangeable Al 1.64 cmol(p+)kg^{-1}. The experiment was laid out in complete randomized design (CRD) with three replications. The experiment included three levels of aluminium (0, 0.25 and 0.50 cmol kg^{-1}) and three varieties (Selection-9, Anupam-R and Nagaland local). Aluminium levels were developed by aluminium chloride ($AlCl_3$). Recommended dose of nitrogen, phosphorus and potassium (26 mg kg^{-1} each) was applied through urea, single superphosphate (SSP) and muriate of potash (MOP), respectively. 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. The data on germination, plant height, number of branches, number of pods $plant^{-1}$, pod length, number of seeds pod^{-1}, test weight, grain and stover yield, root length and root mass were recorded. For protein content, seed samples was analyzed for N content by Kjeldahl method. Aluminium content in plant samples was determined in diacid (HNO_3, $HClO_4$) extract by adopting standard procedure. Aluminium content in plant samples was determined using atomic absorption spectrophotometer (Hanlon, 1998). Aluminium uptake was calculated by multiplying grain and stover yield with their respective Al content. The data was analyzed statistically to compare the treatment effects (Panse and Sukhatme, 1961).

RESULTS AND DISCUSSION

Growth parameters

Application of aluminium significantly affected the growth of french bean (Table 1).The germination was significantly delayed with every increased level of aluminium as compared to preceding lower level.The minimum number of days to germination (3.3 days) was recorded in the control while maximum days to germination were recorded at 0.50cmol kg^{-1}aluminium level (4.83 days).However, the effect of different varieties on germination was insignificant. Aluminium toxicity induced increase in accumulation of Cl^- and $Al3^+$ which might have inhibited the germination of seeds (Samad *et al*., 2017). The results of the present investigation are contrary to the findings of Bhamburdekar *et al*. (2011) who reported that seed germination declined with increased Al concentration. Aluminium application significantly decreased plant height of french bean at 30 DAS, 60 DAS and at harvest. Maximum reduction in plant height was recorded with highest level (0.50 cmol kg^{-1}) of Al. Plant height was reduced by 20.4, 14.0 and 17.0% with application of 0.25 cmol kg^{-1} and 33.5, 29.1 and 28.4% with application of 0.50 cmol kg^{-1} Al over control at 30 DAS, 60 DAS and at harvest, respectively. French bean varieties showed significant variation in plant height at all the growth stages. Maximum plant height was recorded in the order of Selection-9> Nagaland local > Anupam-R. At harvest, Selection-9 variety gave 14.1 and 12.3% more plant height over Anupam-R and Nagaland local varieties, respectively. Number of branches decreased significantly with increasing aluminium concentration in soil. The 0.25 and 0.50 cmol kg^{1} Al levels reduced number of branches to the extent of 11.1% and 19.6%, respectively over control. However, varieties did not show any significant variation in number of branches. But selection-9 variety produced higher number of branches in comparison to other varieties. Higher concentration of aluminium in soil might have reduced the absorption of essential nutrients by plant and create unfavourable soil environment in root zone which in resulted stunted plant growth. Furthermore, plant absorbed more aluminium from aluminium rich soil solution 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 also been reported by Farias *et al*. (2011).

Yield attributes

Aluminium application markedly affected the yield attributes of french bean (Table 1). Pods per plant, pod length and number of seeds per pod decreased significantly with aluminium application, while test weight was increased significantly. Irrespective of treatments, number of pod per plant, pod length and number of seeds per pod were ranged from 7.94 to 13.78, 7.40 to 11.79 cm and 3.31 to 4.94, respectively. A critical examination of data showed that 0.50 cmol kg^{-1} Al reduced number of pod per plant, pod length

Table 1: Growth and yield attributes of french bean varieties as affected by aluminium (Pooled)

Treatments	Days to germination	Plant height (cm)			Branches	Pods	Pod	Seeds	Test
		30 DAS	60 DAS	At harvest	plant-1	plant-1	length (cm)	pod-1	weight (g)
Al levels (cmol kg^{-1})									
0	3.33	22.48	30.09	31.51	9.5	13.78	11.79	4.94	26.58
0.25	4	17.57	24.61	25.66	9.22	11.17	9.51	4.02	28.06
0.5	4.83	14.94	21.33	22.54	7.83	7.94	7.4	3.31	31.04
SEm±	0.1	0.13	0.21	0.21	0.23	0.14	0.17	0.13	0.52
CD (p=0.05)	0.28	0.36	0.6	0.6	0.66	0.39	0.49	0.37	1.49
Varieties									
Selection-9	4	20.17	27.29	28.82	9.06	11.72	9.99	4.24	27.58
Anupam-R	4	17.09	23.81	25.25	8.83	11	9.69	4.15	28.38
Nagaland local	4.17	17.73	24.93	25.65	8.67	10.17	9.03	3.88	29.72
SEm±	0.1	0.13	0.21	0.21	0.23	0.14	0.17	0.13	0.52
CD (p=0.05)	NS	0.36	0.6	0.6	NS	0.39	0.49	NS	NS

Table 2 : Yield, protein content, root growth and Al uptake of french bean varieties as affected by aluminium (Pooled)

Treatments	Seed yield (g pot^{-1})	Stover yield (g pot^{-1})	Root length (cm)	Root mass (g)	Protein content (%)	Al content in root(%)	Al uptake (mg pot^{-1}) Grain	Stover
Al levels (cmol kg^{-1})								
0	18.33	33.44	13.92	6.83	21.58	0.61	3.66	24.8
0.25	13.02	22.86	11.56	5.72	20.59	1.12	6.14	23.22
0.5	8.58	16.02	7.24	3.79	18.99	1.52	5.85	23.46
SEm ±	0.17	0.16	0.15	0.11	0.22	0.07	0.06	0.15
CD (p=0.05)	0.48	0.47	0.42	0.32	0.62	0.22	0.18	0.44
Varieties								
Selection-9	14.66	25.84	11.28	5.61	20.74	1.08	5.79	25.71
Anupam-R	13.41	24.19	10.09	5.48	20.35	1.07	5.25	23.92
Nagaland local	11.86	22.3	11.36	5.25	20.07	1.07	4.61	21.84
SEm ±	0.17	0.16	0.15	0.11	0.22	0.07	0.06	0.15
CD (p=0.05)	0.48	0.47	0.42	NS	NS	NS	0.18	0.44

and number of seeds per pod to the extent of 42.4, 37.5 and 33.0%, respectively over control. However, 0.25 cmol kg^{-1} Al reduced number of pod per plant, pod length and number of seeds per pod by 18.9, 19.3 and 18.6%, respectively over control. This may be due to poorly developed root system that limits nutrient and water uptake leading to decrease in yield attributes. Similar results were recorded by Kenechukwu (2007) in cowpea. Test weight was increased significantly with Al application and highest value was recorded at 0.50 cmol kg^{-1} Al level. It may be because the 100 seed weight showed direct positive relation with seed size; the pods under treatment 0.50 cmol kg^{-1} Al have shorter pod length with lower number of seeds per pod which in turn produced bolder seeds as compared to the more number of seeds per pod with smaller seed size produced under control. These results are in accordance with those of Coimbra *et al*. (1998) in case of french bean. Different varieties showed positive impact on yield attributes. Maximum pods per plant and pod length (11.72 and 9.99 cm) were recorded from Selection-9 followed by Anupam-R (11.0 and 9.69 cm) and Nagaland local (10.2 and 9.0 cm) whereas seeds per pod were not affected significantly with three varieties. Selection-9 variety produced 6.1 and 13.2% higher pods per plant and 3.0 and 9.6% higher pod length as compared to Anupam-R and Nagaland local, respectively. On the basis of pods per plant and pod length, superiority of varieties may be arranged as Selection-9 > Anupam-R > Nagaland local. The variation among the three varieties may be due to their inherited traits and to some extent by environmental factors. Similar results were also reported by Pandey *et al*. (2012) and Kumar *et al*. (2014).

Yield and root characteristics

Grain and stover yield, root length and root biomass of french bean were badly affected by aluminium application (Table 2). It was recorded that each increasing level of Al decreased significantly grain and stover yield in comparison to preceding lower level of Al. Irrespective of treatments, the seed and stover yield varied from 8.58 to 18.33 g pot^{-1} and 16.02 to 33.44 g pot^{-1}, respectively. The 0.25 cmol kg^{-1} aluminium level reduced seed and stover yield to the extent of 29.0 and 31.6%, respectively over control, while 0.50 cmol kg^{-1} Al reduced seed and stover yield by 53.2 and 52.1%, respectively. The reduction recorded in the yield attributes such as pods per plant, pod length and number of seeds per pod induced by aluminium may also be the consequence of the observed reduction in the seed yield. These results are in accordance with the findings of Kenechukwu (2007) and Dong *et al*. (2018). A critical analysis of the data revealed that different varieties had significant beneficial effect on seed and stover yield of french bean. Among the different varieties, the highest seed yield was recorded in Selection-9 (14.66 g pot^{-1}) followed by Anupam-R (13.4 g pot^{-1}) and Nagaland local (11.86 g pot^{-1}). Selection-9 variety produced 9.3 and 23.6% higher grain yield, respectively as compared to Anupam-R and Nagaland local. However, Anupam-R gave 13.1% higher yield in comparison to Nagaland local. The variation in grain yield may be due to genetic inheritance. These results are in agreement with those of Das *et al*. (2014). Selection-9 produced highest stover yield (25.84 g pot^{-1}) followed by Anupam-R (24.19 g pot^{-1}) and Nagaland local (22.30 g pot^{-1}). It was observed that Selection-9 produced 6.8 and 15.8% higher stover yield over Anupam-R and Nagaland local, respectively. The observation recorded in the growth related parameters such as the plant height, number of branches per plant and pods per plant may be the possible consequence of the variation in the stover yield of different varieties. The root length and root mass was drastically reduced by increased levels of aluminium. Each increasing level of Al resulted significant reduction in root length and root mass of french bean in comparison to preceding lower level of Al. Highest level of Al (0.50 cmol kg^{-1}) reduced the root length and root mass by 47.9 and 44.5%, respectively over control. This may because root exposure to aluminium were associated with the collapse of the conducting tissue of the stele and disintegration of the outer cells of the root leading to shorter and under developed roots. Furthermore higher concentration of aluminium reduced the root length which might have caused the reduction of root mass. Similar results have been reported by Thangavel (2002). Among the three varieties the highest root length was observed in Selection-9 (11.28 cm) followed by Nagaland local (11.36 cm). The shortest root length was recorded in Anupam-R (10.09 cm) while the root mass was not effect significantly. Selection-9 was at par to Nagaland local with regard to root length. The variation in length of roots of french bean varieties observed in the present study may be due to their inherited traits and to some extent by environmental factors. Das *et al*. (2014) also reported similar results.

Protein content, root Al content and Al uptake

Protein content in seed of french bean reduced significantly with increasing concentration of Al in soil (Table 2). Application of 0.25 and 0.50 cmol kg^{-1} Al decreased the protein content by 4.6 and 13.6%, respectively over control but the varieties did not show significant effect on protein content in seeds of french bean. Increased aluminium concentration in growth medium might have decreased the nitrogen content which resulted reduction in protein content. These results are in agreement with those of Riberio *et al*. (2013). Al content in roots was enhanced significantly with application of aluminium. Irrespective of treatments, the Al content in roots varied from 0.61 to 1.52%. Maximum Al content in roots was recorded at 0.50 cmol kg^{-1} Al level. The 0.25 and 0.50 cmol kg^{-1} Al levels increased Al content in roots by 83.6 and 149.2% over control, respectively. However, 0.50 cmol kg^{-1} Al enhanced Al content by 35.7% over 0.25 cmol kg^{-1}, which indicated a decreasing trend of Al absorption by roots with increasing Al concentration in growth medium. These results are in accordance with those of Thangavel (2002). French bean varieties did not affect Al content in roots significantly. Application of aluminium increased Al uptake in grain significantly over control, while in case of Al uptake in stover, effect was insignificant. Maximum Al uptake in grain was recorded at 0.25 cmol kg^{-1} level of aluminium and beyond this level, Al uptake was reduced significantly. Al uptake in grain was increased by 67.7% and 59.8% over control, respectively with application of 0.25 and 0.50 cmol kg^{-1} Al. Increase in Al uptake was obvious as the soil Al concentration was increased which resulted in absorption of more aluminium by plant. Different varieties of french bean showed significant difference in Al uptake by grain. The highest Al uptake by grains (5.79 mg pot^{-1}) was recorded in Selection-9 whereas the lowest uptake (4.61 mg pot^{-1}) was recorded in Nagaland-local. Al uptake in grain of Selection-9 was 10.3% and 25.6% higher and in stover was 6.9% and 15.05% higher respectively in comparison to Anupam-R and Nagaland local. Al application increased the aluminium content in grain while reduced the seed yield which resulted in significant increase in aluminium uptake of grains. The maximum seed yield at higher Al concentration was recorded from Selection-9 hence higher the Al uptake in the seeds.

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