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RESEARCH ARTICLE :

Effect of lime, zinc and boron on yield and nutrient uptake by soybean in lateritic soil

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SUMMARY : A field experiment was conducted at Botany farm, College of Agriculture, Dapoli Konkan (Maharashtra) to study the effect of lime, zinc and boron on soybean yield and uptake of nutrients. The experiment was laidout in randomized block design with three replications and the treatments included two levels of liming *i.e.* ½ L.R. and 1 L.R in combination with soil and foliar application of Zn and B singly or incombination. The soil of the experimental plot was lateritic (Alfisol) and acidic in reaction. It was very high in organic carbon, moderately high in available N, low in available P_2O_5 and very high in available K_2O. The soil was deficient to marginal in Zn and B. The results of the experiment showed significantly increased the grain (25.52 q ha^{-1}) and straw (37.29 q ha^{-1}) yield of soybean due to application of 1 L.R+ Zn +B through soil and foliar spray along with RDF. The uptake of N, P, K, Ca, Mg and S by soybean was also significantly increased by this treatment.

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KEY WORDS :
Lime, Zinc, Boron, Soybean, Yield, Nutrient uptake

BACKGROUND AND OBJECTIVES

The acid soils are characterized by presence of Al, Fe and Mn in soil solution at a toxic level, nutritional imbalance caused due to increase or decrease of the concentration of ions in the soil solution, deficiency of phosphorus, boron, zinc and molybdenum and poor microbiological activity leading to low nitrogen and sulphur availability. Intense leaching due to high rainfall in Konkan region removes major portion of all the bases from the soil giving distinctly acid character. In order to overcome the constraints in the productivity of acid soils, the age old practice is to apply lime judiciously to correct the soil acidity. The use of lime is in no way less important than the application of chemical fertilizers since lime not only furnishes calcium to the plants but also induces greater availability and uptake of other plant nutrients (Mandal *et al.*,1966 and Sarkar *et al.*, 1996).

There is a scope to enhance the yield potential of crops by application of liming material such as lime stone and use of locally available and cost effective industrial wastes such as basic slag, oyster shell, paper mill sludge, pressmud etc. (Panda, 1998).

In Maharashtra, zinc and boron showed their deficiencies to the extent of 38.2 and

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31.7 per cent of analysed soil samples, respectively. Regional variation in the content of DTPA extractable zinc in soils was observed. The DTPA extractable zinc ranged from 0.13 to 3.66 mg kg^{-1} in soils of Konkan. Sixty one per cent of the analysed soils from Konkan region were deficient in boron (Malewar, 2003). Soybean is an environment friendly grain legume and has now become a major source of protein, oil and health promoting phytochemicals for human nutrition and livestock feed around the globe. It is the leading source of edible oil containing about 30 per cent of the world supply. The world soybean production during 2015-16 was about 313.01 million metric tons from 119.94 million hectares with an average productivity 2.61 metric tons/hectares (USDA, 2016). Whereas the area under production of soybean in India during the year 2015-16 was 11.60 million hectares with annual production of about 7.13 million metric tons and an average yield of 0.61 metric tons/ha (USDA, 2016). Soybean cultivation also improves soil health because of its atmospheric nitrogen fixing ability and deep root system. India has a great potential for production and domestic utilization of soybean and its derivatives for health and economic benefits of the people of the country. Although beneficial effects of lime application on various crops in acid soils are well known, the information regarding the effect of B and Zn in presence of lime in legume is not adequate. Considering this situation such studies are very much essential in the context of intensive farming approach. Therefore, in the present study an attempt has been made to consider crops other than the rice for their response to lime.

RESOURCES AND METHODS

A field experiment was conducted during *Kharif* season on lateritic soil of Botany farm, College of Agriculture, Dapoli Konkan (Maharashtra) to study the influence of lime zinc and boron on yield and uptake of nutrient by soybean. The soil of the experimental plot was lateritic (Alfisol) and acidic in reaction. The initial soil status was: bulk density 1.45 g cm^{-3}, mean weight diameter 1.52 mm, maximum water holding capacity 57.17 %, pH 5.23, electrical conductivity 0.165 dSm^{-1}, organic carbon 17.7 g kg^{-1}, calcium carbonate 0.42%, exchangeable calcium and magnesium 4.43 and 2.77 $cmol(p^{+})kg^{-1}$, respectively, available N, P_2O_5 and K_2O and S was 467.33, 8.30 484.21 kg ha^{-1} and 9.65 mg kg^{-1}, respectively. The DTPA extractable Zn, Cu, Fe and Mn was 1.26, 1.99, 39.77 and 106.27 ppm, respectively and hot water soluble B was 0.18 ppm. The experiment was laidout in randomized block design with three replications and the treatments included two levels of liming i.e ½ L.R. and 1 L.R in combination with soil and foliar application of Zn and B singly or in combination. Lime requirement was determined using buffer solution (1:2) as described by Shoemaker *et al.* (1961). The liming material was obtained as byproduct of Rashtriya Chemicals and Fertilizers Ltd., Mumbai. Soybean var. MACS-13 was grown with 30 cm X 30 cm distance and harvested at complete maturity. Treatment wise grain and straw yield data have been expressed in (q ha^{-1}). Plant and grain samples were analysed for major and secondary nutrients content by standard methods outlined by Chopra and Kanwar (1978) and AOAC (1980). The experimental data was analysed stastically by adopting Panse and Sukhatme (1967).

OBSERVATIONS AND ANALYSIS

The results obtained from the present study as well as discussions have been summarized under following heads :

Yield of soybean :

The data pertaining to the grain and straw yield of soybean as influenced by various treatments is presented in Table 1. It is observed that the grain and straw yield of soybean were significantly influenced by liming. The lowest value of grain (4.35 q ha^{-1}) and straw yield (10.23 q ha^{-1}) were obtained with absolute control. Recommended dose of NPK fertilizer in combination with lime and micronutrients still produced higher yields as compared to control as well as application of chemical fertilizer. Among the various treatments, treatment T_8 (RDF + 1 L.R.+ Zn @ 20 kg $ZnSO_4$ ha^{-1} + B @ 5 kg Borax ha^{-1} through soil application+ Zn and B as foliar application @ 0.5% $ZnSO_4$ and 0.1 per cent borax, respectively) produced significantly higher yield as compared to all other treatments, which was followed by treatment T_5 (RDF + 1 L.R.+ B @ 5 kg borax ha^{-1} through soil application + 1 spray @ 0.1 per cent borax at flowering time). The magnitude of response by soybean was more in case of boron than zinc. These results suggest mutual synergism between Zn and B. Such synergistic effect of Zn on B on grain and straw yield of soybean was obtained by Malewar, *et al.* (2001). The

treatment T_5 has showed its superiority over T_4, which produced 21.20 q ha^{-1} grain and 31.27 q ha^{-1} straw yield. Shankhe *et al.* (2004) reported that foliar application of boron @ 0.5 per cent borax + soil application of molybdenum @ 1 kg ha^{-1} with RDF resulted in highest kernel and straw yield of groundnut Subramanian *et al.* (2005) attributed application of Zn + S + B + Mo @ 5 kg + 40 kg + 1.5 kg + 0.5 kg, respectively recorded highest grain yield. Murthy *et al.* (2013) reported that application of calcium at 30 kg ha^{1} and boron at 2 kg ha^{1} resulted in high sunflower seed yield in Ca and B deficient red sandy loam soils.

Uptake of nutrients :

Uptake of nitrogen :

The N uptake increased due to application of the recommended dose of NPK and the values raised to 53.47 kg ha^{-1} for grain and 45.47 kg ha^{-1} for straw. Application of lime further increased the N uptake significantly over NPK alone. Among the various treatments, the treatment T_8 recorded significantly highest N uptake of all treatments. Thus, N uptake in grain and straw was increased manyfold by the combined application of RDF, Zn, B with full dose of lime over the control. Liming improves per cent base saturation of soil leading to increase in nitrogen availability and uptake. The above results are in agreement with Patil *et al.* (2001)

Uptake of phosphorus :

From the perusal of data showed more or less similar trend to that of nitrogen uptake by grain and straw of soybean. The absolute control revealed the minimum uptake of phosphorus *i.e.* 1.58 kg ha^{-1} for grain and 0.86 kg ha^{-1} for straw. Lime application further increased P uptake significantly over NPK alone and absolute control. Zinc and Boron application and individually with full dose of lime and RDF recorded significant increase in P uptake by grains as well as straw. Combined application of nutrients (T_8) *i.e.* RDF + 1 L.R.+ Zn @ 20 kg $ZnSO_4$ ha^{-1} + B @ 5 kg Borax ha^{-1} through soil application + Zn and B as foliar application @ 0.5 per cent $ZnSO_4$ and 0.1 per cent Borax, respectively was found significantly superior to all other treatments. The total removal of P by the soybean crop (grain + straw) was 2.44 kg P ha^{-1} with absolute control, and the highest 27.54 kg P ha^{-1} with application of 1 L.R.+ RDF + Zn @ 20 kg $ZnSO_4$ ha^{-1} + B @ 5 kg Borax ha^{-1} through soil application + Zn and B as foliar application @ 0.5 per cent $ZnSO_4$ and 0.1 per cent Borax, respectively. This may be due to the phosphorus supplied by P-fertilizers in itself and increase in available P as a result of increase in pH of acid lateritic soil resulting into increase in availability of native as well as applied phosphorus. Above results are supported by the findings of Bishnoi *et al.* (1988).

Uptake of potassium :

The treatment T_8, registered significantly higher K

Table 1 : Effect of application of lime, zinc and boron on grain and straw yield of soybean

Tr. No.	Treatments details	Grain yield (q ha^{-1})	Straw yield (q ha^{-1})
T_1	Control (No fertilizer and no lime)	4.35	10.23
T_2	RDF (Recommended Dose of Fertilizer)	9.18	17.83
T_3	RDF + 1L.R (lime requirement)	15.65	23.96
T_4	RDF + 1L.R. + Zn @ 20 kg $ZnSO_4$ ha^{-1} through soil + 1 spray @ 0.5% $ZnSO_4$ at flowering time	16.03	24.14
T_5	RDF + 1L.R. B @ 5 kg Borax ha^{-1} through soil application + 1 spray @ 0.1% Borax at flowering time	21.20	31.27
T_6	RDF + 1/2 L.R. + Zn @ 20 kg $ZnSO_4$ ha^{-1} through soil + 1 spray @ 0.5% $ZnSO_4$ at flowering time	15.36	23.35
T_7	RDF + 1/2 L.R. B @ 5 kg Borax ha^{-1} as soil application @ 0.1% borax at flowering time	21.05	30.99
T_8	RDF + 1 L.R.+ Zn @ 20 kg $ZnSO_4$ ha^{-1} + B @ 5 kg Borax ha^{-1} through soil application+ Zn and B as foliar application @ 0.5% $ZnSO_4$ and 0.1 % borax, respectively)	25.52	37.29
T_9	RDF + 1/2 L.R.+ Zn @ 20 kg $ZnSO_4$ ha^{-1} + B @ 5 kg Borax ha^{-1} through soil application+ Zn and B as foliar application @ 0.5% $ZnSO_4$ and 0.1% borax, respectively)	20.95	30.63
	S.E.±	0.74	1.01
	C.D.(P=0.05)	2.21	3.02

uptake *i.e.* 43.54 kg ha^{-1} and 34.19 kg ha^{-1} by grain and straw of soybean, respectively. It was followed by treatment T_5 and T_9. The treatment NPK at recommended doses (T_2) was significantly superior over control (T_1) both in K uptake by grain and straw. The uptake of potassium by grain and straw was enhanced by the application of B as seen from treatment T_5, T_9 and T_7. The present findings are in conformity with Bishnoi *et al.* (1988) who reported similar results and attributed increased K uptake to the release of K from non-exchangeable sources and also to the reduction of K fixation in the soil due to liming.

Uptake of secondary nutrients :

Calcium uptake :

From the perusal of data on calcium uptake by soybean, it is inferred that application of lime with Zn, B and RDF resulted into significant and incremental increase in calcium uptake by soybean grain and straw. Minimum calcium uptake of 1.67 kg ha^{-1} and 4.61 kg ha^{-1} for grain and straw, respectively was recorded in the treatment receiving no fertilizer and no lime. Maximum calcium uptake of 17.65 kg ha^{-1} and 27.35 kg ha^{-1} for grain and straw was observed in the treatment T_8, followed by treatments T_5. It is evident from above data that the treatment RDF + lime and B application has proved superior in increasing the uptake of Ca by soybean crop in acid lateritic soil. The present investigation revealed that the calcium, boron and zinc reserve in the acid lateritic soils of Konkan might be inadequate to meet the higher calcium demand of soybean. Hence, significant response to liming, boron and zinc application was obtained in the present investigation. Liming of acidic soil must have inactivated exchangeable Al from moderately acidic soils used for growing soybean crop resulting into adsorption of more calcium on exchangeable complex and its subsequent release to soybean crop. The above data is supported by the findings of Patil *et al.* (2001)

Uptake of Magnesium :

The uptake of magnesium as influenced by lime, zinc and boron application revealed that magnesium uptake by soybean was significantly affected. Application of RDF + 1 L.R.+ Zn @ 20 kg $ZnSO_4$ ha^{-1} + B @ 5 kg Borax ha^{-1} through soil application + Zn and B as foliar application @ 0.5 per cent $ZnSO_4$ and 0.1 per cent Borax, respectively to acid lateritic soil significantly increased magnesium uptake (10.31 kg ha^{-1}) by grain and (15.56 kg ha^{-1}) straw. Addition of lime to acid lateritic soils helps calcium along with magnesium to form the dominant ionic species on the exchange complex which inturn favour the plant to greater uptake of magnesium as compared to non-treated soils. Above results corroborate the findings of Jacob and Venugopal (1994) who noticed that magnesium uptake by soybean increased by 39 and 99 per cent due to application of $CaCO_3$ @ 1.5 and 3 times of exchangeable Al, respectively over no lime in acid soil of Kerala.

Uptake of Sulphur :

It is observed from the data that sulphur uptake by grain and straw was minimum with treatment absolute control. It was 0.86 kg ha^{-1} for grain and 1.09 kg ha^{-1} for

Table 2 : Effect of application of Lime, Zinc and Boron on uptake of nutrients by grain and straw of soybean

Tr. No.	N (kg ha^{-1})		P_2O_5 (kg ha^{-1})		K_2O (kg ha^{-1})		Ca (kg ha^{-1})		Mg (kg ha^{-1})		S (kg ha^{-1})	
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
T_1	23.71	23.84	1.58	0.86	3.60	4.84	1.67	4.61	0.55	1.49	0.86	1.09
T_2	53.47	45.47	3.90	1.95	9.97	10.43	3.98	9.06	1.74	3.52	3.64	5.32
T_3	93.08	62.78	7.17	3.44	19.94	17.00	7.61	13.06	3.39	5.57	5.68	6.19
T_4	101.94	70.36	8.79	4.90	25.13	19.30	9.90	16.24	4.91	8.42	7.49	9.05
T_5	138.82	97.20	13.38	7.62	34.91	26.21	13.81	21.98	7.37	11.77	5.96	6.77
T_6	93.31	62.92	6.99	2.78	21.02	14.11	8.34	13.59	3.88	6.15	5.75	6.63
T_7	129.48	85.54	10.67	4.76	30.11	19.91	12.42	19.57	5.89	9.72	5.72	5.66
T_8	171.41	121.93	17.46	10.08	43.54	34.19	17.65	27.35	10.31	15.56	11.20	12.58
T_9	129.76	87.46	11.30	5.01	30.80	22.46	11.67	18.45	5.52	8.58	7.73	8.36
S.E.±	4.58	3.59	0.56	0.27	1.21	1.04	0.54	0.60	0.34	0.41	0.34	0.38
C.D. (P=0.05)	13.73	10.76	1.66	0.82	3.64	3.12	1.63	1.79	1.01	1.24	1.03	1.13

straw. The application of NPK at recommended doses, however, increased the uptake of sulphur significantly in grains. Liming also enhanced the uptake of sulphur significantly. The treatment T_8 *i.e.* RDF + 1 L.R.+ Zn @ 20 kg $ZnSO_4$ ha^{-1} + B @ 5 kg Borax ha^{-1} through soil application + Zn and B as foliar application @ 0.5 per cent $ZnSO_4$ and 0.1 per cent Borax, respectively increased sulphur uptake by grain and straw significantly over all other treatments. This may be due to the fact that liming neutralizes soil acidity which enhances the mineralization of organic matter and also contributes to the sulphur pool Which resulted in increased uptake of sulphur by soybean plant. These findings are inline with that of Patil *et al.* (2001).

Conclusion :

Thus, application of RDF + 1 L.R.+ Zn @ 20 kg $ZnSO_4$ ha^{-1} + B @ 5 kg Borax ha^{-1} through soil + Zn and B as foliar application @ 0.5 per cent $ZnSO_4$ and 0.1 per cent Borax, respectively found tobe beneficial for maximizing the yield and increasing the uptake of NPK, Ca, Mg and S by soybean was also significantly increased by this treatment.

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