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Influence of soil applied zinc on productivity of soybean (*Glycine max*) in south-western Rajasthan

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ABSTRACT

A field experiment was conducted to study the influence of soil applied zinc on productivity, nutrient uptake and profitability of soybean (*Glycine max* L.) under Typic Haplustepts soil of sub-humid southern plain and aravalli hills region of Rajasthan during *kharif* 2016 and 2017. The treatments were consisted of five levels of zinc, viz. zero (control), 3 kg Zn/ha, 4 kg Zn/ha, 5 kg Zn/ha and 6 kg Zn/ha with four replications. Results revealed that significantly (P=0.05) maximum number of pods per plant, number of seeds per pod, test weight, seed yield, haulm yield, biological yield, nutrient content and uptake (N, K and Zn) in seed and haulm, net return and B:C ratio were recorded with the application of zinc @ 6 kg/ha along with the recommended dose of fertilizer (NPK) during 2016–17 and in pooled basis. However, the increase was significant up to 5 kg Zn/ha during both the years as well as in pooled analysis which was found statistically at par with 6 kg Zn/ha. Whereas, the application of zinc significantly decreased the phosphorus content in seed and haulm as compared to control and phosphorus uptake by seed and haulm was found to be non-significant with the application of zinc during both the years as well as in pooled analysis. The application of recommended dose of fertilizer along with combined application of Zn @ 5 kg/ha offered the best combination in realizing maximum yield of soybean and maximizing the economics both in absolute terms (net returns) and benefit-cost ratio.

Keywords: Economics, Productivity, Soybean, Uptake, Zinc

Soybean (*Glycine max* L.) is most popular *kharif* legume and oilseed crop of India grown in various agro-climatic conditions. It is also known as vegetarian meat, wonder crop, miracle crop and golden bean due to its rich and cheap source of 40–42% good quality protein, 18-20% oil having about 85% unsaturated fatty acids including 55% polyunsaturated fatty acids (PUFA) and about 0.3% flavones. In India it is cultivated in 11.39 million ha with the production of 13.51 million tonnes having the productivity of 1185 kg/ha (FAI 2019-20). In Rajasthan it is cultivated in 10.60 lakh ha with the production of 66.85 metric tons having the productivity of 1150 kg/ha (FAI 2019-20).

The productivity of soybean in Rajasthan is low due to erratic distribution of monsoonal rains, high energy requiring crop, continuous nutrients mining by high yielding crop, insufficient addition of organic manure, continuously growing of soybean in the same piece of land and low organic carbon status of soil (Wilmot 2009). Most of the soils of Rajasthan are coarse textured with low to medium organic carbon content and deficient in zinc (Singh and Singh 1981). Soybean is sensitive to zinc deficiency that needed for protein and nucleic acid metabolism, chlorophyll formation, growth hormone stimulation, lipids and carbohydrates synthesis enzymatic activity and reproductive processes, and also has effects on growth of stem and root (Kabata-Pendias 1999), zinc is an essential catalytic component of over 300 enzymes, including alkaline phosphatase, alcohol dehydrogenase, Cu-Zn superoxide dismutase, and carbonic anhydrase (Fox and Guerinot 1998), plays major role in cell defenses against reactive oxygen species and as a protective factor against several chemical compositions of oxidation such as membrane lipids, protein, chlorophyll, and enzyme having SH and DNA (Cakmak 2008). Hence, looking to the above facts the present investigation was carried out to study the influence of zinc application on productivity, nutrient uptake and profitability of soybean crop.

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MATERIALS AND METHODS

Experimental site and soil: A field experiment was

conducted during *kharif* 2016 and 2017 at Instructional Farm (Agronomy), Rajasthan College of Agriculture, Udaipur situated at an altitude of 579.5 m above mean sea level and at 24^0 34' N latitude and 73^0 42' E longitude. The region falls under agro-climatic zone-IVa (Sub-humid Southern Plain and Aravalli Hills) of Rajasthan. Soil of the experimental plot was clay loam in texture, alkaline in reaction (8.12), medium in organic matter, low in available N, P and high in available K and low in available zinc.

Experimental design and treatments: The experiment was laid out in randomized block design and replicated four times in the plots (5.0 m × 3.6 m) with five levels of zinc, i.e. control (T_1), 3.0 kg Zn/ha (T_2), 4.0 kg Zn/ha (T_3), 5.0 kg Zn/ha (T_4) and 6.0 kg Zn/ha as soil application (T_5).

Fertilizer application: Nitrogen @ 20 kg/ha was applied in two equal splits, half as basal and the remaining half was top dressed at the time of first irrigation. The basal dose was applied through urea after adjusting the quantity supplied through di-ammonium phosphate (DAP). The phosphorus @ 40 kg/ha (DAP) and different doses of zinc through $ZnSO_4.7H_2O$ were applied as basal and drilled at the depth of 8-10 cm along with basal dose of N prior to sowing.

Nutrient uptake: Uptake of nitrogen, phosphorus and potassium at harvest in seed and haulm were estimated by using the following formula:

$$\text{N, P, K uptake (kg/ha)} = \frac{\text{Content in seed/haulm (\%)} \times \text{Yield (seed/haulm) (kg/ha)}}{100}$$

Uptake of zinc at harvest in seed and haulm was estimated by using the following formula:

$$\text{Zn uptake (g/ha)} = \frac{\text{Content in seed/haulm (ppm)} \times \text{Yield (seed/haulm) (kg/ha)}}{1000}$$

Statistical analysis: The data recorded for different parameters were analyzed with the help of analysis of variance (ANOVA) technique for a randomized block design. The results are presented at 5% level of significance difference (P=0.05).

RESULTS AND DISCUSSION

Yield attributes: Zinc application significantly enhanced the number of pods per plant, seeds per pod and test weight of soybean over the control. The maximum number of pods per plant, number of seeds per pod and test weight were recorded with the application of zinc @ 6 kg/ha during 2016, 2017 and in pooled analysis (Table 1). However, the effect of application of 5 and 6 kg Zn/ha was found statistically at par with respect to yield attributes (number of pods per plant, number of seeds per pod and test weight) during both the years as well as in pooled analysis. The data further revealed that the per cent increase in number of pods per plant, number of seeds per pod and test weight were in order of 66.78, 28.23 and 26.13 in pooled analysis due to application of 6 kg Zn/ha as compared to control, respectively. The increase of yield attributes with increasing levels of Zn might be due to the application of Zn through zinc sulphate had a positive effect on formation of stamens and pollens and can increase the activity of stamens and the flowers fertilized well and resulted more yield attributes produced in the plant (Upadhyay and Singh 2016).

Yield: The application of increasing levels of Zn significantly increased the seed and haulm yield of soybean (Table 1). The maximum seed yield (1415.94 kg/ha), haulm yield (1558.04 kg/ha) and biological yield (2973.98 kg/ha) of soybean was recorded under 6 kg Zn/ha followed by 5 kg Zn/ha, 4 kg Zn/ha and 3 kg Zn/ha as compared to control in pooled basis. However, the increase in the yield was significant up to application of Zn @ 5 kg/ha during both the years as well as in pooled analysis which was found statistically at par with Zn @ 6 kg/ha. The data further revealed that the per cent increase in seed yield, haulm yield and biological yield were in order of 53.69, 68.47 and 60.48 in pooled analysis due to application of 6 kg Zn/ha as compared to control, respectively (Table 1). The increase in yield might be due to increased supply of available zinc in deficient soil and role of Zn in biosynthesis of indole acetic

Table 1 Effect of zinc application on yield attributes, yield and economics of soybean on pooled basis

Treatment	Number of pods per plant	Number of seeds per pod	Test weight (g)	Seed yield (kg/ha)	Haulm yield (kg/ha)	Biological yield (kg/ha)	Net return (₹/ha)	B:C ratio
Control	22.61^{a}	2.48^{a}	94.25^{a}	924.86^{a}	928.26^{a}	1853.12^{a}	16552^{a}	0.91^{a}
3 kg Zn/ha as soil application	32.06^{b}	2.70^{b}	110.69^{b}	1031.72^{b}	1075.98^{b}	2107.69^{b}	20576^{b}	1.12^{b}
4 kg Zn/ha as soil application	34.78^{c}	2.91^{c}	113.21^{bc}	1130.71^{c}	1296.53^{c}	2427.24^{c}	24515^{c}	1.33^{c}
5 kg Zn/ha as soil application	36.96^{d}	3.12^{d}	116.57^{bcd}	1346.21^{d}	1459.52^{d}	2805.73^{d}	32173^{d}	1.74^{d}
6 kg Zn/ha as soil application	37.71^{de}	3.18^{de}	118.88^{bcde}	1415.94^{de}	1558.04^{de}	2973.98^{de}	35185^{de}	1.89^{de}
SEm±	0.40	0.05	2.77	32.55	38.95	55.75	1190	0.06
CD at 5%	1.16	0.15	8.08	95.00	113.69	162.73	3473	0.19

*Means superscripted with same letters are statistically at par at P=0.05

Table 2 Effect of zinc application on nitrogen, phosphorus, potassium and zinc content in seed and haulm of soybean on pooled basis

Treatment	N content (%)		P content (%)		K content (%)		Zn content (mg/kg)	
	Seed	Haulm	Seed	Haulm	Seed	Haulm	Seed	Haulm
Control	6.12[a]	1.51[a]	0.595[a]	0.227[a]	1.14[a]	1.55[a]	94.68[a]	60.32[a]
3 kg Zn/ha as soil application	6.19[b]	1.59[b]	0.561[b]	0.214[b]	1.19[b]	1.60[b]	102.74[b]	64.75[b]
4 kg Zn/ha as soil application	6.27[c]	1.68[c]	0.518[c]	0.205[c]	1.22[c]	1.65[c]	109.28[c]	67.38[c]
5 kg Zn/ha as soil application	6.37[d]	1.79[d]	0.465[d]	0.190[d]	1.31[d]	1.71[d]	114.04[d]	70.66[d]
6 kg Zn/ha as soil application	6.39[de]	1.81[de]	0.462[de]	0.188[de]	1.32[de]	1.72[de]	115.84[de]	71.64[de]
SEm±	0.01	0.01	0.003	0.002	0.007	0.010	1.02	0.61
CD at 5%	0.05	0.03	0.008	0.006	0.022	0.029	2.97	1.79

*Means superscripted with same letters are statistically at par at P=0.05

acid and especially due to its role in initiation of primordial of reproductive parts and partitioning of photosynthates towards them (Wear and Hagler 1968). The results obtained get support from findings of Mahilane and Singh (2018).

Nutrient content and uptake: The application of increasing levels of Zn significantly increased the nutrient content and uptake by seed and haulm of soybean (Table 2 and 3). The maximum nutrient content and uptake (N 6.39% and 90.58 kg/ha in seed and 1.81% and 28.27 kg/ha in haulm, K 1.32% and 18.74 kg/ha in seed and 1.72% and 26.86 kg/ha in haulm and Zn 115.84 mg/kg and 164.14 g/ha in seed and 71.64 mg/kg and 111.64 g/ha in haulm) of soybean was recorded under Zn @ 6 kg/ha followed by Zn @ 5 kg/ha, Zn @ 4 kg/ha and Zn @ 3 kg/ha as compared to control in pooled basis (Table 2 and 3). However, the increase in the nutrient content and uptake was significant up to application by Zn @ 5 kg/ha during both the years as well as in pooled analysis which was found statistically at par with Zn @ 6 kg/ha (Table 2 and 3). Whereas, the application of zinc significantly decreased the phosphorus content in seed and haulm as compared to control during 2016, 2017 and in pooled analysis (Table 2). The phosphorus uptake by seed and haulm was found to be non-significant with the application of zinc during both the years as well as in pooled analysis (Table 3). It might be due to the synergistic interaction between zinc and nitrogen, potassium many zinc dependent enzymes are involved in carbohydrate metabolism in general and leaves in particular, impartment of K in stomata regulation, phloem export of assimilation from the source, i.e. the leaves into the sink organs, maintained water balance in the soil-plant atmosphere continuum (Shivay *et al.* 2015). Whereas, phosphorus content in seed and haulm of soybean decreased with increasing level of zinc. It might be due to the antagonistic effect of zinc on phosphorus absorption (Dewal and Pareek 2004). The increase in zinc content and uptake at harvest might be due to the presence of increased amount of zinc in soil solution by the application of zinc that might have facilitated the absorption of zinc through phloem (Ranpariya and Polara 2018). Similarly, Nogiya *et al*. (2019) observed that rice

Table 3 Effect of zinc application on nitrogen, phosphorus, potassium and zinc uptake by seed and haulm of soybean on pooled basis

Treatment	N uptake (kg/ha)		P uptake (kg/ha)		K uptake (kg/ha)		Zn uptake (g/ha)	
	Seed	Haulm	Seed	Haulm	Seed	Haulm	Seed	Haulm
Control	56.60[a]	13.98[a]	5.50	2.11	10.60[a]	14.46[a]	87.54[a]	55.89[a]
3 kg Zn/ha as soil application	63.90[b]	17.09[b]	5.78	2.30	12.35[b]	17.25[b]	105.94[b]	69.69[b]
4 kg Zn/ha as soil application	70.98[c]	21.81[c]	5.86	2.67	13.86[c]	21.41[c]	123.57[c]	87.36[c]
5 kg Zn/ha as soil application	85.84[d]	26.20[d]	6.26	2.78	17.66[d]	24.97[d]	153.60[d]	103.15[d]
6 kg Zn/ha as soil application	90.58[de]	28.27[de]	6.54	2.94	18.74[de]	26.86[de]	164.14[de]	111.64[de]
SEm±	1.97	0.75	0.17	0.08	0.43	0.66	3.89	2.94
CD at 5%	5.76	2.19	NS	NS	1.26	1.91	11.36	8.59

*Means superscripted with same letters are statistically at par at P=0.05

grain yield was higher under iron treated soil as compared control in the both genotypes.

Economics: The increasing levels of Zn application, significantly increased the net return and B:C ratio of soybean (Table 1). The significantly maximum net return (₹ 35185/ha) and B:C ratio (1.89) was recorded under 6 kg Zn/ha followed by 5 kg Zn/ha, 4 kg Zn/ha and 3 kg Zn/ha as compared to control in pooled basis. However, the increase was significant up to the application of Zn @ 5 kg/ha during both the years as well as in pooled analysis which was found statistically at par with the application of Zn @ 6 kg/ha. The increasing levels of zinc up to 5 kg/ha to soybean crop significantly increased the net return, and it is clear from the treatments that there was significant increase in seed and haulm yield which ultimately resulted in more net return. The increase in net return and B:C ratio due to application of zinc were also reported by Jat *et al.* (2018).

On the basis of experimental finding, it can be concluded that the application of zinc @ 5 kg/ha along with the recommended dose of fertilizer results in significantly higher yield and economics (net return and benefit-cost ratio) of soybean under Typic Haplustepts soil of Sub-Humid Southern Plain and Aravalli Hills Region of Rajasthan.

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