Original Research Article

Effect of zinc application strategies on growth and yield of soybean in Central India

Abstract

Fertilization of soybean with zinc (Zn) had received considerable attention in recent years due to world-wide spread of its deficiency in soils and also due to malnutrition in infants and children's. Soybean is high nutrient exhausting crop but sensitive to zinc (Zn) deficiency in soil. Application of Zn fertilizers could be a viable option to fulfil this deficiency and also to promote yield and growth parameters. This experiment was conducted at Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur during kharif season of 2019 with fourteen treatments of zinc application strategies [Absolute control (T_1), RDF+ No Zn (T_2), RDF + 5.0 kg Zn ha^{-1}(T_3), RDF + spray of 0.5 % $ZnSO_4$ at 35 DAS (T_4), RDF + spray of 0.5 % $ZnSO_4$ at 35 and 55 DAS (T_5), RDF + 5.0 kg Zn ha^{-1} + spray of 0.5 % $ZnSO_4$ at 35 DAS (T_6), RDF + 5.0 kg Zn ha^{-1} + spray of 0.5 % $ZnSO_4$ at 35 and 55 DAS (T_7), RDF + Zn solubilizer as soil application (T_8), RDF + 5.0 kg Zn ha^{-1}+ Zn solubilizer as soil application (T_9), RDF + Spray of 0.5 % $ZnSO_4$ and 150 PPM salicylic acid at 35 DAS (T_{10}), RDF + spray of 0.5 % $ZnSO_4$ and 150 PPM salicylic acid at 35 and 55 DAS (T_{11}), RDF + 5.0 kg Zn ha^{-1} + spray of 0.5 % $ZnSO_4$ and 150 PPM salicylic acid at 35 DAS(T_{12}), RDF + 5.0 kg Zn ha^{-1} + spray of 0.5 % $ZnSO_4$ and 150 PPM salicylic acid at 35 and 55 DAS (T_{13}) and No RDF + 5.0 kg Zn ha^{-1} (T_{14})] which were replicated three times in randomized block design(RBD). Results showed that growth parameters, yield attributes and yield of soybean were significantly affected by zinc application strategies. It was found that treatment of RDF + 5.0 kg Zn ha^{-1} + spray of 0.5% $ZnSO_4$ + 150 ppm salicylic acid at 35 and 55 DAS (T_{13}) had been found best in terms of growth, yield attributes and yield of soybean.

Key words: Soybean, $ZnSO_4$, zinc solubilizer, salicylic acid, growth, yield, zinc application strategies and RBD

Introduction

Soybean, [*Glycine max* (L.) Merri.], also called soja bean or soya bean, annual legume of the pea family Leguminosae (Fabaceae). The soybean is economically the most important legume in the world, providing vegetable protein. The origins of the soybean plant are obscure, but many botanists believe it was first domesticated in central China. Soybean is an important source of food, protein, and oil, hence more research is required to enhance its yield under different conditions, including stress conditions. Soybean has been considered as “Protein hope of future”. Generally, soybean contains 40-45% protein and 18-20% oil contents (Ibrahim and Kandil, 2007). Countries i.e., USA, Brazil and Argentina are the “Big-3” producers of soybean in the world. In India, soybean is one of the fastest growing crops of Kharif season. The top two soybean growing states in India are Madhya Pradesh and Maharashtra with about 45 and 40 per cent shares, respectively in total production of this crop. In Madhya Pradesh the soybean cultivation spread over 5.01 M ha with total annual production of 4.20 M tones and productivity of 1086 kg ha^{-1} (SOPA, 2017). Zinc (Zn) is one of the most important micronutrients for growth and development of plants as it takes part in completing many vital physiological functions such as protein synthesis, energy production and maintenance of membrane integrity, therefore, optimal supply of Zn is essential (Hansch and Mendel, 2009). However, Zn deficiency in soils of Madhya Pradesh has been reported to the extent of 59.92% and need to be corrected for sustainable productivity and soil health (Shukla *et al*., 2018).

Soybean plant absorbs zinc as Zn++ and is a component of synthetic and natural organic complexes. Zinc is directly and indirectly involved in many enzymes’ activities, but it is not known whether it acts as a functional, structural or regulatory co-factor. 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). Particularly, zinc improves photosynthetic activity, chlorophyll synthesis, metabolism of nitrogen and develops resistance to abiotic stresses, while its availability from soil to plant depends on various factors which governs the sorption and desorption of zinc in the soil (Alloway, 2008). Therefore, present study was carried out to quantify the effect of zinc application strategies on growth and yield of soybean.

Materials and methods

The experiment was conducted at the research farm of JNKVV, Jabalpur (23^0 13' N Lat., 79^0 57' E Long. and at an elevation of 393 m amsl.) during *kharif* season of 2019. The soil of the experimental site was a Vertisol belongs to Kheri series of fine Montmorillonite hyperthermic family of *Typic Haplusterts* and popularly known as medium deep black soil. The soil of the experimental field was neutral in reaction (pH 7.18), having EC, organic carbon available-N, available-P, available-K and available-Zn as 0.11 dSm^{-1}, 5.82 g kg^{-1}, 285.4 kg ha^{-1}, 19.7 kg ha^{-1}, 284.1 kg ha^{-1} and 0.525 $mgkg^{-1}$, respectively.

The research experiment was laid out in randomized block design with fourteen treatments of zinc application strategies [Absolute control (T_1), RDF+ No Zn (T_2), RDF + 5.0 kg Zn ha^{-1}(T_3), RDF + spray of 0.5 % $ZnSO_4$ at 35 DAS (T_4), RDF + spray of 0.5 % $ZnSO_4$ at 35 and 55 DAS (T_5), RDF + 5.0 kg Zn ha^{-1} + spray of 0.5 % $ZnSO_4$ at 35 DAS (T_6), RDF + 5.0 kg Zn ha^{-1} + spray of 0.5 % $ZnSO_4$ at 35 and 55 DAS (T_7), RDF + Zn solubilizer as soil application (T_8), RDF + 5.0 kg Zn ha^{-1}+ Zn solubilizer as soil application (T_9), RDF + Spray of 0.5 % $ZnSO_4$ and 150 PPM salicylic acid at 35 DAS (T_{10}), RDF + spray of 0.5 % $ZnSO_4$ and 150 PPM salicylic acid at 35 and 55 DAS (T_{11}), RDF + 5.0 kg Zn ha^{-1} + spray of 0.5 % $ZnSO_4$ and 150 PPM salicylic acid at 35 DAS(T_{12}), RDF + 5.0 kg Zn ha^{-1} + spray of 0.5 % $ZnSO_4$ and 150 PPM salicylic acid at 35 and 55 DAS (T_{13}) and No RDF + 5.0 kg Zn ha^{-1} (T_{14})] which were replicated three times. Recommended doses of nitrogen, phosphorus and potassium (20:80:20 kg/ha) were applied through urea, single super phosphate and muriate of potash. Zinc was applied through zinc sulphate (Heptahydrate) as per the treatments. All the standard recommended agronomic practices, except those in treatments, were followed to grow the soybean crop. Zinc was applied as basal in soil and foliar on crop according to the treatments. Before the foliar application of zinc sulphate it was neutralized by equal amount of calcium oxide.

Soybean (Cv. JS-2029) was sown on 12th July, 2019 and harvested on 24th October, 2019. From each treatment three plants were randomly selected for non-destructive observations. The experimental data were statistically analyzed by applying "Analysis of Variance" technique for randomized block design. The standard error of mean (SEm ±) and critical difference (CD) at 5% significance level were worked out for each parameter of study (Chandel 2002).

Result and discussion

Growth parameters

Soybean is a highly exhaustive crop and it respond with fertilizer application. It was clearly evident from the data (table 1) that zinc application significantly increased plant height at different days after sowing (DAS) and at harvest. Plant height at 30, 45, 60 DAS and at harvest were maximum (38.0, 45.1, 54.8 and 54.9 cm), respectively under T_{13} (RDF + 5.0 kg Zn ha^{-1} + spray of 0.5% $ZnSO_4$ + 150 ppm salicylic acid at 35 and 55 DAS) followed by T_{12} (RDF + 5.0 kg Zn ha^{-1} + Spray of 0.5% $ZnSO_4$+ 150 ppm salicylic acid at 35 DAS) treatments. Similar findings in the different experimental plans were also reported by Motalebifard *et al.* (2013), Ramesh *et al*. (2014), Srivastava *et al*. (2015) and Moreira *et al*. (2018).

Table 1: Effect of zinc application strategies on plant height of soybean

Treatments	Plant height (cm)			
	30 DAS	45DAS	60DAS	Harvest
Absolute control	30.0	36.3	40.9	41.1
RDF (No Zn)	32.3	42.0	46.6	46.9
RDF +5.0 kg Zn ha^{-1}	32.5	42.5	48.8	49.0
RDF + Spray of 0.5% $ZnSO_4$ at 35 DAS	33.5	42.8	50.0	50.1
RDF + Spray of 0.5% $ZnSO_4$ at 35 and 55 DAS	34.5	43.4	49.4	50.3
RDF + 5.0 kg Zn ha^{-1} + spray of 0.5% $ZnSO_4$ at 35 DAS	35.3	42.8	50.1	50.3
RDF+5.0 kg Zn ha^{-1} +Spray of $ZnSO_4$ at 35 and 55 DAS	36.4	43.8	50.7	50.9
RDF +Zn Solubilizer (soil application)	34.3	42.8	51.2	51.5
RDF +5.0 kg Zn ha^{-1}+Zn solubilizer (soil application)	36.3	43.1	52.6	52.8
RDF + Spray of 0.5% $ZnSO_4$+150 PPM Salicylic acid at 35 DAS	34.9	43.5	53.2	53.5
RDF +Spray of 0.5% $ZnSO_4$+150 PPM Salicylic acid at 35 and 55 DAS	36.4	43.8	52.6	52.7
RDF +5.0 kg Zn ha^{-1} +Spray of 0.5% $ZnSO_4$+ 150 ppm salicylic acid at 35DAS	36.7	44.8	54.0	54.2
RDF+5.0 kg Zn ha^{-1}+Spray of 0.5% $ZnSO_4$+150 ppm Salicylic acid at 35 and 55 DAS	38.0	45.1	54.8	54.9
No RDF +5.0 kg Zn ha^{-1}	32.2	38.6	42.3	42.4
SEm±	**0.22**	**0.46**	**0.31**	**0.33**
CD (*p=0.05*)	**0.65**	**1.35**	**0.90**	**0.95**

Dry matter accumulation

Data (table 2) clearly indicated that dry matter accumulation in soybean at different days after sowing (DAS) and at harvest was significantly altered by zinc application strategies. Dry matter accumulation at 45, 60 DAS and at harvest was highest under T_{13} (RDF + 5.0 kg Zn ha^{-1} + spray of 0.5% $ZnSO_4$ + 150 ppm salicylic acid at 35 and 55 DAS) followed by T_{12} (RDF +5.0 kg Zn ha^{-1}+spray of 0.5% $ZnSO_4$+ 150 ppm salicylic acid at 35 DAS) treatments, whereas, at 30 DAS it was maximum under T_9 (RDF + 5.0 kg Zn ha^{-1} + Zn solubilizer as soil application) treatment which might be attributed to optimum supply of zinc due to presence of Zn - solubilizer. Findings are in good agreement with those reported by Fageria *et al.* (2001), Jamal *et al*. (2002) and Galavi *et al.* (2011).

Table 2: Effect of zinc application strategies on dry matter accumulation in soybean

Treatments	Dry matter accumulation (t ha^{-1})			
	30DAS	**45DAS**	**60DAS**	**Harvest**
Absolute control	1.27	1.89	2.25	3.67
RDF (No Zn)	1.57	2.03	2.81	4.10
RDF +5.0 kg Zn ha^{-1}	1.69	2.31	2.92	4.31
RDF+Spray of 0.5% $ZnSO_4$ at 35 DAS	1.46	2.13	2.85	4.14
RDF+Spray of 0.5% $ZnSO_4$ at 35 and 55 DAS	1.52	2.14	2.83	4.26
RDF+5.0 kg Zn ha^{-1} + spray of 0.5% $ZnSO_4$ at 35 DAS	1.56	2.33	2.99	4.44
RDF+5.0 kg Zn ha^{-1} +Spray of $ZnSO_4$ at 35 and 55 DAS	1.55	2.35	2.97	4.43
RDF +Zn Solubilizer (soil application)	1.68	2.12	2.86	4.28
RDF +5.0 kg Zn ha^{-1}+Zn solubilizer (soil application)	1.89	2.30	2.92	4.36
RDF + Spray of 0.5% $ZnSO_4$+150 PPM Salicylic acid at 35 DAS	1.83	2.08	2.87	4.19
RDF +Spray of 0.5% $ZnSO_4$+150 PPM Salicylic acid at 35 and 55 DAS	1.64	2.37	2.88	4.32
RDF +5.0 kg Zn ha^{-1} +Spray of 0.5% $ZnSO_4$+ 150 ppm salicylic acid at 35DAS	1.70	2.39	2.91	4.58
RDF+5.0 kg Zn ha^{-1}+Spray of 0.5% $ZnSO_4$+150 ppm Salicylic acid at 35 and 55 DAS	1.64	2.96	3.78	5.09
No RDF +5.0 kg Zn ha^{-1}	1.31	2.06	2.61	3.85
SEm±	**0.07**	**0.09**	**0.13**	**0.14**

CD (*p=0.05*)	**0.20**	**0.27**	**0.38**	**0.42**

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Root nodulation

Root nodulation properties in leguminous crops has key role in nutrients supply. Data (table 3) revealed that zinc application strategies significantly influenced the nodulation properties at different days after sowing. Highest mean number of nodules (20.1, 36.1 and 33.6) were obtained under T_{13} (RDF+5.0 kg Zn ha^{-1}+spray of 0.5% $ZnSO_4$+150 ppm salicylic acid at 35 and 55 DAS) treatment, respectively at 30,45 and 60 DAS of the crop. The similar findings were also reported by Sarkar et al (1990), Kobraee et al. (2011) and Seyed (2016).

Table 3: Effect of zinc application strategies on nodulation in soybean

Treatments	Number of nodules $plant^{-1}$		
	30 DAS	**45 DAS**	**60 DAS**
Absolute control	16.4	26.9	22.6
RDF (No Zn)	17.4	34.0	31.2
RDF +5.0 kg Zn ha^{-1}	16.3	33.2	31.0
RDF+Spray of 0.5% $ZnSO_4$ at 35 DAS	17.4	33.4	31.1
RDF+Spray of 0.5% $ZnSO_4$ at 35 and 55 DAS	17.4	32.8	31.3
RDF+5.0 kg Zn ha^{-1} + spray of 0.5% $ZnSO_4$ at 35 DAS	17.8	32.6	31.7
RDF+5.0 kg Zn ha^{-1} +Spray of $ZnSO_4$ at 35 and55 DAS	19.1	34.4	32.4
RDF +Zn Solubilizer (soil application)	18.3	33.3	31.1
RDF +5.0 kg Zn ha^{-1}+Zn solubilizer (soil application)	18.8	32.9	31.4
RDF + Spray of 0.5% $ZnSO_4$+150 PPM Salicylic acid at 35 DAS	18.4	34.3	32.1
RDF +Spray of 0.5% $ZnSO_4$+150 PPM Salicylic acid at 35 and 55 DAS	18.4	33.1	31.3
RDF +5.0 kg Zn ha^{-1} +Spray of 0.5% $ZnSO_4$+ 150 ppm salicylic acid at 35DAS	19.1	34.2	31.8
RDF+5.0 kg Zn ha^{-1}+Spray of 0.5% $ZnSO_4$+150 ppm Salicylic acid at 35 and 55 DAS	20.1	36.1	33.6
No RDF +5.0 kg Zn ha^{-1}	16.8	29.6	24.4
SEm±	**0.56**	**0.48**	**0.44**

CD (*p= 0.05*)	**1.63**	**1.39**	**1.28**

Yield attributes and yield

Results revealed that zinc application strategies significantly increased yield attributes and yield of soybean. Highest pods plant^{-1}, seed and stover yields were obtained with RDF + 5.0 kg Zn ha^{-1} + spray of 0.5% $ZnSO_4$ + 150 ppm salicylic acid at 35 and 55 DAS treatment followed by RDF +5.0 kg Zn ha^{-1} + Spray of 0.5% $ZnSO_4$+ 150 ppm salicylic acid at 35 DAS treatment, while lowest values for these parameters were obtained under absolute control. Similar findings were also reported by Wasmatkar *et al.* (2002), Bairagi *et al.* (2007), Jadhav *et al*. (2009), Mueller *et al.* (2011), Prasad *et al*. (2012) and Alam et al. (2016) from different experiments.

Treatment	Pods plants^{-1}	Yield (t ha^{-1})	
		Seed	Stover
Absolute control	22.4	1.14	2.39
RDF (No Zn)	28.3	1.27	2.75
RDF +5.0 kg Zn ha^{-1}	29.7	1.34	2.89
RDF +Spray of 0.5% $ZnSO_4$ at 35 DAS	28.6	1.28	2.78
RDF +Spray of 0.5% $ZnSO_4$ at 35 and 55 DAS	28.8	1.32	2.85
RDF+5.0 kg Zn ha^{-1} + spray of 0.5% $ZnSO_4$ at 35 DAS	29.9	1.38	2.94
RDF+5.0 kg Zn ha^{-1} +Spray of $ZnSO_4$ at 35 and55 DAS	30	1.37	2.97
RDF +Zn Solubilizer (soil application)	28.9	1.33	2.92
RDF +5.0 kg Zn ha^{-1}+Zn solubilizer (soil application)	29.9	1.35	2.99
RDF + Spray of 0.5% $ZnSO_4$+150 PPM Salicylic acid at 35 DAS	28.7	1.30	2.81
RDF +Spray of 0.5% $ZnSO_4$+150 PPM Salicylic acid at 35 and 55 DAS	28.9	1.34	2.89
RDF +5.0 kg Zn ha^{-1} +Spray of 0.5% $ZnSO_4$+ 150 ppm salicylic acid at 35DAS	30	1.42	3.07
RDF+5.0 kg Zn ha^{-1}+Spray of 0.5% $ZnSO_4$+150 ppm Salicylic acid at 35 and 55 DAS	30.2	1.58	3.41
No RDF +5.0 kg Zn ha^{-1}	23.3	1.19	2.55
SEm±	**0.923**	**0.04**	**0.10**
CD (*p=0.05*)	**2.684**	**0.13**	**0.30**

Conclusion

The results of the present investigation clearly concluded that among the different strategies of zinc application in soybean, use of RDF + 5.0 kg Zn ha^{-1} + spray of 0.5% $ZnSO_4$ + 150 ppm salicylic acid at 35 and 55 DAS treatment was found best in terms of growth, yield attributes and yield of soybean and also the zinc application strategies increase growth and its attributes, yield attributes and yield of soybean.

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