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Effect of Zinc Application Strategies on Growth and Yield of Soybean in Central India

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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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 [(T_1) Absolute control, (T_2) recommended dose of fertilizer+ No Zn, (T_3) RDF + 5.0 kg Zn ha^{-1}, (T_4) RDF + spray of 0.5% $ZnSO_4$ at 35 DAS, (T_5) RDF + spray of 0.5% $ZnSO_4$ at 35 and 55 DAS, (T_6) RDF + 5.0 kg Zn ha^{-1} + spray of 0.5% $ZnSO_4$ at 35 DAS, (T_7) RDF + 5.0 kg Zn ha^{-1} + spray of 0.5% $ZnSO_4$ at 35 and 55 DAS, (T_8) RDF + Zn solubilizer as soil application, (T_9) RDF + 5.0 kg Zn ha^{-1} + Zn solubilizer as soil application, (T_{10}) RDF + Spray of 0.5% $ZnSO_4$ and 150 ppm salicylic acid at 35 DAS, (T_{11}) RDF + spray of 0.5% $ZnSO_4$ and 150 ppm salicylic acid at 35 and 55 DAS, (T_{12}) RDF + 5.0 kg Zn ha^{-1} + spray of 0.5% $ZnSO_4$ and 150 PPM salicylic acid at 35 DAS, (T_{13}) RDF + 5.0 kg Zn ha^{-1} + spray of 0.5% $ZnSO_4$ and 150 ppm salicylic acid at 35 and 55 DAS and (T_{14}) No RDF + 5.0 kg Zn ha^{-1}] which were replicated three times in randomized block design(RBD). Results

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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.

Keywords: Soybean; $ZnSO_4$; zinc solubilizer; salicylic acid; growth; yield; zinc application strategies and RBD.

1. 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 [1]. 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} [2]. 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 [3]. 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 [4].

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 [5]. 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 [6]. In this experimental study some treatments of zinc application are basal and some are applied after sowing at different growth stages for obtaining which strategy of zinc application is best. When all the zinc is applied as basal dose it is fixed with soil minerals and its availability decrease to plants so some quantity of zinc is applied as basal application and some amount is applied after sowing before flowering and after flowering stages of crop growth so chances of obtaining results are increased and also the use efficiency is of nutrients increase.

Soybean seed production is a major constraint due to rapid loss of seed viability during storage and transportation. The seed quality in soybean is influenced by harvesting stages, threshing methods, storage conditions and mechanical damage *etc.* Among harvesting stages, soybean harvested at 90 days after sowing (DAS) at physiological maturity recorded highest germination and moisture, vigour and lower mechanical damage, as compared to other harvesting stages. Delaying harvesting *viz.,*100 DAS and 110 DAS results in increased seed leachates and mechanical damage. Among threshing methods, beating with sticks recorded less mechanical damage and maximum germination, vigour and tractor trampling resulted in higher mechanical damage, and minimum germination and vigour [7]. Therefore, present study was carried out to quantify the effect of zinc application strategies on growth and yield of soybean.

2. 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.

Table 1. Physical and chemical parameters of experimental site

Sr.no.	Parameters	Values
1.	pH	7.18
2.	EC	0.11 dSm^{-1}
3.	Organic Carbon	5.82 g kg^{-1}
4.	Available N	285.4 kg ha^{-1}
5.	Available P	19.7 kg ha^{-1}
6.	Available K	284.1 kg ha^{-1}
7.	Available Zn	0.525 $mgkg^{-1}$

The research experiment was laid out in randomized block design with fourteen treatments of zinc application strategies which were replicated three times. The treatments are applied as soil application (as a basal dose) and foliar spray at different days after sowing.

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 [8].

2.1 Growth Parameters

2.1.1 Nodulation properties

Nodulation studies were done at 30, 45 60 DAS and at harvest by uprooting 3 plants $plot^{-1}$ very carefully taking sufficient care to avoid any losses or damage of nodules. The rhizosphere soil was washed in the running water. After proper washing nodules of plants per plot were counted.

2.1.2 Plant height

Plant height was measured at 30, 45, 60 DAS and at harvest. Three plants from each plot were taken and their heights were measured.

2.1.3 Plant dry biomass

Plants dry biomass is taken at 30, 45 and 60 DAS and at harvest the root portion of three plants were cut off and plants were dried in a hot air oven at 60^{0}C for 5-6 days till constant weight is attained to record the dried shoot and root biomass. After taking the dry weight of plants it is calculated accordingly in relation to per hectare plant population. After recording the weight, the dried plant samples were ground in grinder for further analytical work.

Table 2. Treatment details of experimental site

Sr.no.	Treatments
T_1	Absolute control
T_2	RDF+ No Zn (Recommended dose of fertilizer)
T_3	RDF + 5.0 kg Zn ha^{-1}
T_4	RDF + spray of 0.5 % $ZnSO_4$ at 35 DAS
T_5	RDF + spray of 0.5 % $ZnSO_4$ at 35 and 55 DAS
T_6	RDF + 5.0 kg Zn ha^{-1} + spray of 0.5 % $ZnSO_4$ at 35 DAS
T_7	RDF + 5.0 kg Zn ha^{-1} + spray of 0.5 % $ZnSO_4$ at 35 and 55 DAS
T_8	RDF + Zn solubilizer as soil application
T_9	RDF + 5.0 kg Zn ha^{-1}+ Zn solubilizer as soil application
T_{10}	RDF + Spray of 0.5 % $ZnSO_4$ and 150 PPM salicylic acid at 35 DAS
T_{11}	RDF + spray of 0.5 % $ZnSO_4$ and 150 PPM salicylic acid at 35 and 55 DAS
T_{12}	RDF + 5.0 kg Zn ha^{-1} + spray of 0.5 % $ZnSO_4$ and 150 PPM salicylic acid at 35 DAS
T_{13}	RDF + 5.0 kg Zn ha^{-1} + spray of 0.5 % $ZnSO_4$ and 150 PPM salicylic acid at 35 and 55 DAS
T_{14}	No RDF + 5.0 kg Zn ha^{-1}

3. RESULTS AND DISCUSSION

3.1 Growth Parameters

Soybean is a highly exhaustive crop and it respond with fertilizer application. It was clearly evident from the data (Table 3) 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 significantly highest (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. At 45 DAS data shows that T_{13} is significantly higher which is significantly at par with treatment T_7, T_{11} and T_{12}. At 60 DAS data also shows that T_{13} is significantly highest which is at par with T_{12} treatment. At harvest data shows that T_{13} is significantly highest which is at par with T_{12}. Similar findings in the different experiments were also reported by Motalebifard et al. [9], Ramesh et al. [10], Srivastava et al. [11], Moreira et al. [12] and Radhika and Meena [13] which revealed that levels of zinc significantly affect the plant height with maximum under optimum level of zinc application. It might be due to adequate supply of zinc which accelerated the activity of enzymes and auxins metabolism in plants resulted in higher plant height.

3.2 Dry Matter Accumulation

Data (Table 4) 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 significantly highest under treatment T_9 (RDF + 5.0 kg Zn ha^{-1} + Zn solubilizer as soil application) which is significantly at par with T_{10} and T_{12}. It is might be attributed to optimum supply of zinc due to presence of Zn - solubilizer. Findings are in good agreement with

Table 3. Effect of zinc application strategies on plant height of soybean

Sr. no	Treatments	Plant height			
		30 DAS	**45 DAS**	**60 DAS**	**At harvest**
T_1	Absolute control	30.0	36.3	40.9	41.1
T_2	RDF (No Zn)	32.3	42.0	46.6	46.9
T_3	RDF +5.0 kg Zn ha^{-1}	32.5	42.5	48.8	49.0
T_4	RDF + Spray of 0.5% $ZnSO_4$ at 35 DAS	33.5	42.8	50.0	50.1
T_5	RDF + Spray of 0.5% $ZnSO_4$ at 35 and 55 DAS	34.5	43.4	49.4	50.3
T_6	RDF + 5.0 kg Zn ha^{-1} + spray of 0.5% $ZnSO_4$ at 35 DAS	35.3	42.8	50.1	50.3
T_7	RDF+5.0 kg Zn ha^{-1} +Spray of $ZnSO_4$ at 35 and 55 DAS	36.4	43.8	50.7	50.9
T_8	RDF +Zn Solubilizer (soil application)	34.3	42.8	51.2	51.5
T_9	RDF +5.0 kg Zn ha^{-1}+Zn solubilizer (soil application)	36.3	43.1	52.6	52.8
T_{10}	RDF + Spray of 0.5% $ZnSO_4$+150 PPM Salicylic acid at 35 DAS	34.9	43.5	53.2	53.5
T_{11}	RDF +Spray of 0.5% $ZnSO_4$+150 PPM Salicylic acid at 35 and 55 DAS	36.4	43.8	52.6	52.7
T_{12}	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
T_{13}	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
T_{14}	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**

those reported by Fageria et al. [14], Jamal et al. [15], Galavi et al. [16] and Musa and Yusuf [17]. It may be due to increased chlorophyll content, leaf area index, relative growth rate, optimal nutrient availability, nutrient metabolism and growth promoting behaviour of zinc and salicylic acid. Zinc is applied with and without salicylic acid and salicylic acid play a crucial role in the regulation of physiological and biochemical behaviour during the lifespan of plant. Salicylic acid also plays a key role in abiotic and biotic stress condition of plants. Zinc is directly involved in the formation of tryptophan which is the precursor of auxin and auxin is directly affect meristematic growth of the plants.

3.3 Root Nodulation

Root nodulation properties in leguminous crops has key role in nutrients supply. Data (Table 5) 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 data at 30DAS shows that root nodulation in T_{13} is significantly at par with T_9 and T_{12}. Data at harvest is also shows that noduation is significantly highest in treatment T_{13} which significantly at par with T_7 and T_{12} treatments. The similar findings were also reported by Sarkar et al. [18], Kobraee et al. [19], Seyed [20] and Osman *et al*. [21] states that zinc application increased nutrient availability and affect nodule properties.

3.4 Yield Attributes and Yield

Results revealed that zinc application strategies significantly increased yield attributes and yield of soybean. Significantly highest pods plant^{-1} was obtained with T_{13} treatment which is significantly at par with all the treatments except T_1 (absolute control) and T_{14} (No RDF +5.0 kg Zn ha^{-1}).

Table 4. Effect of zinc application strategies on dry matter accumulation in soybean

Sr. no	Treatments	Dry matter accumulation (t ha^{-1})			
		30 DAS	**45 DAS**	**60 DAS**	**At harvest**
T_1	Absolute control	1.27	1.89	2.25	3.67
T_2	RDF (No Zn)	1.57	2.03	2.81	4.10
T_3	RDF +5.0 kg Zn ha^{-1}	1.69	2.31	2.92	4.31
T_4	RDF + Spray of 0.5% $ZnSO_4$ at 35 DAS	1.46	2.13	2.85	4.14
T_5	RDF + Spray of 0.5% $ZnSO_4$ at 35 and 55 DAS	1.52	2.14	2.83	4.26
T_6	RDF + 5.0 kg Zn ha^{-1} + spray of 0.5% $ZnSO_4$ at 35 DAS	1.56	2.33	2.99	4.44
T_7	RDF+5.0 kg Zn ha^{-1} +Spray of $ZnSO_4$ at 35 and 55 DAS	1.55	2.35	2.97	4.43
T_8	RDF +Zn Solubilizer (soil application)	1.68	2.12	2.86	4.28
T_9	RDF +5.0 kg Zn ha^{-1}+Zn solubilizer (soil application)	1.89	2.30	2.92	4.36
T_{10}	RDF + Spray of 0.5% $ZnSO_4$+150 PPM Salicylic acid at 35 DAS	1.83	2.08	2.87	4.19
T_{11}	RDF +Spray of 0.5% $ZnSO_4$+150 PPM Salicylic acid at 35 and 55 DAS	1.64	2.37	2.88	4.32
T_{12}	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
T_{13}	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
T_{14}	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**

Table 5. Effect of zinc application strategies on nodulation in soybean

Sr. no	Treatments	Number of nodules plant^{-1}			
		30 DAS	45 DAS	60 DAS	At harvest
T_1	Absolute control	16.4	26.9	22.6	16.4
T_2	RDF (No Zn)	17.4	34.0	31.2	17.4
T_3	RDF +5.0 kg Zn ha^{-1}	16.3	33.2	31.0	16.3
T_4	RDF + Spray of 0.5% $ZnSO_4$ at 35 DAS	17.4	33.4	31.1	17.4
T_5	RDF + Spray of 0.5% $ZnSO_4$ at 35 and 55 DAS	17.4	32.8	31.3	17.4
T_6	RDF + 5.0 kg Zn ha^{-1} + spray of 0.5% $ZnSO_4$ at 35 DAS	17.8	32.6	31.7	17.8
T_7	RDF+5.0 kg Zn ha^{-1} +Spray of $ZnSO_4$ at 35 and 55 DAS	19.1	34.4	32.4	19.1
T_8	RDF +Zn Solubilizer (soil application)	18.3	33.3	31.1	18.3
T_9	RDF +5.0 kg Zn ha^{-1}+Zn solubilizer (soil application)	18.8	32.9	31.4	18.8
T_{10}	RDF + Spray of 0.5% $ZnSO_4$+150 PPM Salicylic acid at 35 DAS	18.4	34.3	32.1	18.4
T_{11}	RDF +Spray of 0.5% $ZnSO_4$+150 PPM Salicylic acid at 35 and 55 DAS	18.4	33.1	31.3	18.4
T_{12}	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	19.1
T_{13}	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	20.1
T_{14}	No RDF +5.0 kg Zn ha^{-1}	16.8	29.6	24.4	16.8
	SEm±	**0.56**	**0.48**	**0.44**	**0.56**
	CD (*p=0.05*)	**1.63**	**1.39**	**1.28**	**1.63**

Table 6. Seed and Stover yield under different treatments

Sr. no	Treatments	Pods plants^{-1}	Yield (t ha^{-1})	
			Seed	Stover
T_1	Absolute control	22.4	1.14	2.39
T_2	RDF (No Zn)	28.3	1.27	2.75
T_3	RDF +5.0 kg Zn ha^{-1}	29.7	1.34	2.89
T_4	RDF + Spray of 0.5% $ZnSO_4$ at 35 DAS	28.6	1.28	2.78
T_5	RDF + Spray of 0.5% $ZnSO_4$ at 35 and 55 DAS	28.8	1.32	2.85
T_6	RDF + 5.0 kg Zn ha^{-1} + spray of 0.5% $ZnSO_4$ at 35 DAS	29.9	1.38	2.94
T_7	RDF+5.0 kg Zn ha^{-1} +Spray of $ZnSO_4$ at 35 and 55 DAS	30	1.37	2.97
T_8	RDF +Zn Solubilizer (soil application)	28.9	1.33	2.92
T_9	RDF +5.0 kg Zn ha^{-1}+Zn solubilizer (soil application)	29.9	1.35	2.99
T_{10}	RDF + Spray of 0.5% $ZnSO_4$+150 PPM Salicylic acid at 35 DAS	28.7	1.30	2.81
T_{11}	RDF +Spray of 0.5% $ZnSO_4$+150 PPM Salicylic acid at 35 and 55 DAS	28.9	1.34	2.89
T_{12}	RDF +5.0 kg Zn ha^{-1} +Spray of 0.5% $ZnSO_4$+ 150 ppm salicylic acid at 35DAS	30	1.42	3.07
T_{13}	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
T_{14}	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**

The highest significant seed and stover yield was obtained under treatment 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 followed by T_{12} (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 T_1 (absolute control) treatment. Similar findings were also reported by Wasmatkar et al. [22], Bairagi et al. [23], Jadhav et al. [24], Mueller et al. [25] Prasad et al. [26], Alam et al. [27], Jat et al., [28] and Vaghar et al. [29] from different experiments and also stated that levels of Zn application significantly improved the translocation of photosynthates towards storage organs (pods and seeds) and thus enhanced the yield.

4. 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 significantly highest in terms of growth parameters, yield attributes and yield of soybean and also the zinc application responds very well and increase growth and its attributes, yield attributes and yield of soybean.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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