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Interactive effect of phosphorus and zinc on nutrient uptake and nutrient use efficiency of soybean

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ABSTRACT: *A field experiment was conducted at Research Farm, Department of Soil Science and Agricultural Chemistry, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola during the kharif 2014 to study the Interactive effect of phosphorus and zinc on yield, quality and nutrient use efficiency of soybean. The experiment was laid out in Randomized Block Design (RBD) with seven treatments randomized in three replications. The levels of phosphorus were 100, 125, 150% RDP with and without zinc @ 5 kg ha*$^{-1}$*. The source of phosphorus was SSP and zinc was applied through* $ZnSO_4$*. The treatments comprised of unfertilized control. Application of 100% RDP i.e. 30:75:30 NPK kg ha*$^{-1}$ *with 5 kg zinc ha*$^{-1}$ *were recorded higher soybean yield, uptake of nutrients as well as maximum nutrient use efficiency (NUE) and nutrient recovery by soybean.*

Key words: *Interactive, phosphorus, zinc, uptake, nutrient use efficiency, soybean*

The plants require essential nutrients *viz.*, primary, secondary and micro nutrients. Micronutrients have assumed a greater importance in a modern agriculture. Among the micronutrients, zinc deserves special attention. Recently, zinc has gained key position in intensive cropping system with the use of organic manures resulting in the depletion of zinc from soils of majority of agriculturally productive areas of Maharashtra. However, soil has not received due to attention because of the presumption that these soils have adequate reserves of micronutrients. Though, large group of soil contain sufficient amount of total zinc (10-300 mg kg^{-1}) but, its availability in soil is very less (Swaine, 1995).

Phosphorus is the important element that interferes on zinc uptake, as zinc uptake by plants reduces by increasing phosphorus in soil. High levels of phosphorus may decrease the availability of zinc or the onset of zinc deficiency associated with phosphorus fertilization may be due to plant physiological factors. Some forms of phosphatic fertilizers, such as superphosphate, contain significant amounts of zinc as impurities and also have an acidifying effect on soils. When these are replaced with "high analysis" forms of phosphatic fertilizers, such as monoammonium phosphate (MAP) and diammonium phosphate (DAP) the incidence of zinc deficiency has often been found to increase. Zinc is active element in biochemical processes and has a chemical and biological interaction with some other elements.

Zinc is needed modicum but critical concentrations and if the amount available is not adequate, plants and animals will suffer from physiological stress brought about by the dysfunction of several enzyme systems and other metabolic functions in which zinc plays a part (Alloway, 2008). In general zinc have main role in synthesis of proteins, enzyme activating, oxidation and revival reactions and metabolism of carbohydrates. By utilizing of fertilizers contain zinc and other micronutrients, performance on quality of crops is increasing and with shortage of this elements due to decline in plant photosynthesis and destroy RNA, amount of solution carbohydrates and synthesis of protein decreased and then performance and quality of crop will be decreased. (Mousavi S.R. *et el.*, 2007) reported that utilization of zinc from resource zinc sulphate increased efficiency and quality of potato crop. Phosphorus is the important element that interferes on zinc uptake, as zinc uptake by plants reduces by increasing phosphorus in soil.

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MATERIAL AND METHODS

The present study effect of various doses of P with Zn and it's interactive effect on yield, quality and nutrient use efficiency of soybean investigation was conducted during the *Kharif* 2014 on Research Farm, Department of Soil Science and Agricultural Chemistry, Dr. PDKV, Akola.

Akola is situated in the subtropical region at $22^0 42'$ North latitude and $77^0\ 02'$ East longitude and at an altitude of 307.42 m (Agromet observatory) above mean sea level. The climate of Akola is semi-arid and characterized by three distinct seasons' viz., hot and dry summer from March to May, warm and rainy monsoon from June to October and mild cold winter from November to February. Average annual precipitation is 812.4 mm (Average of 30 years). The normal mean monthly maximum temperature is 42.5^0C during the hottest May. While the normal mean monthly minimum temperature is 10.6^0C in the coldest December. The experiment consist of seven treatments each replicated thrice in a randomized block design (RBD) having individual plot size 3.6×4.5 m. experimental soil alkaline in nature , EC 0.38 dSm^{-1} organic carbon status was moderate. Available status of nutrients in soil before sowing N, P, S and micronutrient Zn were moderately deficient and potassium availability was good. The treatment combination were T_1- (Control), T_2- 100% RDP, T_3- 125% RDP, T_4- 150% RDP, T_5- 100% RDP + 5 kg Zn ha^{-1}, T_6- 125% RDP + 5 kg Zn ha^{-1} and T_7- 150% RDP + 5 kg Zn ha^{-1}. (Recommended dose of fertilizer for soybean N:P:K 30:75:30 kg ha^{-1}) N and K dose was same in all plots except control (T_1). N, P_2O_5, Zn applied through urea, SSP, MOP and zinc sulphate respectively.

The crop was harvested at maturity and yield data, uptake of nutrient and calculate nutrient use efficiency of soybean. Grain and straw samples of soybean were collected at harvest and digested. Nitrogen was determined by Kjeldahl's method using digestion mixture consisting of $CuSO_4$, K_2SO_4, Selenium powder and H_2SO_4. Half-a-gram plant sample was digested in a block digestion unit. After complete digestion the samples were distilled. Using micro-Kjeldahl unit and the liberated ammonia was trapped in boric acid containing mixed indicator and titrated against 0.01 N H_2SO_4 (Jackson, 1973) and for P, K and Zn analyzing one gram plant sample was first pre-digested with 5 ml of nitric acid and then digested with triacid mixture consisting of nitric acid, perchloric acid and sulphuric acid, (10:4:1).

RESULT AND DISCUSSION

Content of nutrients in soybean: The data regarding the content of nutrients by soybean was influenced by various treatments are given in Table 3.

Nitrogen content: The highest nitrogen content in soybean grain (6.46%) and straw (0.89%) was recorded with application of phosphorus @ 125% RDP + 5 kg Zn ha^{-1} (T6) over remaining treatments but found statistically at par with 100% RDP + 5 kg Zn ha^{-1} (T5) and 150% RDP + 5 kg Zn ha^{-1} (T7), where as the lowest nitrogen content in grain (6.22%) and straw (0.78%) was recorded in control (T1). The results were in agreement with the findings reported by (Balkrishnan *et al*. 1985).

Phosphorus content: The highest phosphorus content in soybean grain (0.44%) and straw (0.24%) was recorded with application of phosphorus @ 150% RDP (T4) over remaining treatments but found statistically at par with 125% RDP (T3) and 150% RDP + 5 kg Zn ha^{-1} (T7), where as the lowest phosphorus content in grain (0.37%) and straw (0.19%) was recorded in control (T1) Similar result stated with (Zhimini *et al*. 1999[a]).

Potassium content: The highest potassium content in soybean grain (1.65%) and straw (0.72%) was recorded with application of phosphorus @ 125% RDP + 5 kg Zn ha^{-1} (T6) over remaining treatments but found statistically at par with 100% RDP + 5 kg Zn ha^{-1} (T5) and 150% RDP + 5 kg Zn ha^{-1} (T7), where as the lowest potassium content in soybean grain (1.54%) and straw (0.64%) was recorded in control (T1). Increase in K content in grain and straw might be increase due to application of phosphorus with zinc. Similar result stated with (Wasmatkar *et al*. 2002).

Zinc content: The highest zinc content in soybean grain (28.99 ppm) and straw (18.26 ppm) was recorded with application of phosphorus @ 100% RDP + 5 kg Zn ha^{-1} (T5) over remaining treatments but found statistically at par with 125% RDP + 5 kg Zn ha^{-1} (T6), where as the lowest zinc content in soybean grain (17.42 ppm) and straw (13.98 ppm) was recorded with application of 150% RDP (T4).

Total uptake of nutrients by soybean: The data regarding the uptake of nutrients by soybean was influenced by various treatments given in Table 3.

Uptake of nitrogen: The uptake of nitrogen by soybean was significantly influenced by application of phosphorus with and without zinc over control. The highest uptake of nitrogen (62.10 kg ha^{-1}) was recorded in the treatment application of 125% RDP + 5 kg Zn ha^{-1} (T6) over other treatments, but statistically found at par with application of 100% RDP + 5 kg Zn

ha^{-1} (T5). Uptake of nitrogen by soybean was increased with application of P with Zn could be attributed to synergistic effect between N and Zn. This might be partially attributed to the favourable effect of zinc application to form vegetative plant material which in terns increases in N uptake by soybean. It is also inferred that plant are not able to survive without adequate or sufficient zinc because it is essential for synthesis of DNA and RNA and to mobilizing carbohydrates, lipids and protein production. They attributed an increase in weight of air born organ to increase in N uptake was reported by (Abbas *et al.* 2009).

Uptake of phosphorus: The uptake of phosphorus by soybean was significantly influenced by application of phosphorus with and without zinc over control. The highest uptake of phosphorus (5.94 kg ha^{-1}) was recorded with application of 125% RDP + 5 kg Zn ha^{-1} over other treatments, but statistically found at par with treatment T3, T4, T5 and T7. Lowest phosphorus uptake (3.24 kg ha^{-1}) was recorded in control (T1). The increase in concentration of P in grain with application of phosphorus in increasing level but was decreased with application of zinc could be attributed to antagonistic effect between P and Zn. was noticed by Alam et al. (2000).

Uptake of potassium: The uptake of potassium by soybean was significantly influenced by application of phosphorus with and without zinc over control. The highest uptake of potassium (21.83 kg ha^{-1}) was recorded in the treatment application of 125% RDP + 5 kg Zn ha^{-1} over remaining treatments, but statistically found at par with application of 100% RDP + 5 kg Zn ha^{-1} (T5) similar result stated with (Upadhyay *et al.* 1994).

Uptake of zinc: The uptake of Zn by soybean was significantly influenced by application of phosphorus with zinc. Significantly highest uptake of zinc (452.17 g ha^{-1}) was recorded with application of 100% RDP + 5 kg Zn ha^{-1} (T5) over remaining treatment but found statistically at par with application of 125% RDP + 5 kg Zn ha^{-1} (T6). where as lowest uptake of zinc was found in control (T1). The present finding supported result of (Zhimini *et al.* 1999[b]), addition of Zn and P increased the translocation of P and Zn to the soybean leaves.

Soil chemical properties: Data pertaining to available nitrogen, phosphorus, potassium and zinc in soil after harvest of soybean as influenced by various treatments was given in Table 4

Available nitrogen: Available nitrogen in soil after harvest of soybean was found significantly higher with application of phosphorus with and without zinc over control. Available nitrogen increases in soil with increasing the phosphorus level with zinc but decrease with the application of 150% RDP. The significantly higher available nitrogen (236.56 kg ha^{-1}) in soil after harvest of soybean was recorded in treatment 125% RDP + 5 kg Zn ha^{-1} (T6) over remaining treatments, but it was statistically at par with application of 125% RDP (T3) and 100% RDP + 5 kg Zn ha^{-1} (T5). This may be due to the beneficial effect of phosphorus with and without zinc in improving soil properties and enhancing the availability of nitrogen in soil has been reported by (Latha *et al.* 2002).

Available phosphorus: Available phosphorus in soil after harvest of soybean was significantly increases by application of phosphorus with and without zinc over control. The highest available phosphorus (17.14 kg ha^{-1}) was recorded in the treatment 150% RDP + 5 kg Zn ha^{-1} (T7) over remaining treatments but found statistically at par with treatments T3, T4, T5 and T6. These results were more or less similar to those quoted by Sharma *et al.* (2013) reported that the conjunctive use of inorganic fertilizers and organic manure along with bio fertilizers and micronutrients gave highest available N, P, K, S and Zn in soil as compared to other treatment combinations.

Available potassium: Available potassium in soil after harvest of soybean was found to be significant with application of phosphorus with zinc. Available potassium increased in soil with increasing the phosphorus level with and without zinc but decreased with application of 150% RDP. The highest available potassium (393.68 kg ha^{-1}) was recorded in treatment 125% RDP + 5 kg Zn ha^{-1} (T6) over remaining treatments but statistically it was at par with application of 100% RDP + 5 kg Zn ha^{-1} (T5) Similar result reported by (Kumar and Yadav 1993), they reported the increase in available potassium in soil with increasing the dose of zinc.

Available zinc: Available zinc in soil after harvest of soybean was found more availability of zinc with application of phosphorus with zinc. Zinc availability decreases with application of each successive phosphorus level but it was increased with application of Zinc. The highest value of available zinc (0.62 mg kg^{-1}) was recorded in the treatment soil application of 100% RDP + 5 kg Zn ha^{-1} (T5). However, it was at par with application of. 125% and 150% RDP + 5 kg Zn ha^{-1} respectively. Available zinc in soil increased might be due to soil application of zinc but numerical decrease with application of high level of

Table 1
Content of nutrients by soybean as influenced by various treatments

Treatments	*Nutrient Content (%)*							
	N		*P*		*K*		*Zinc (ppm)*	
	Grain	*Straw*	*Grain*	*Straw*	*Grain*	*Straw*	*Grain*	*Straw*
T_1-Control	6.22	0.78	0.37	0.19	1.54	0.64	20.11	16.29
T_2-100% RDP	6.29	0.81	0.40	0.21	1.56	0.69	18.86	15.02
T_3-125% RDP	6.31	0.84	0.41	0.22	1.58	0.68	18.22	14.45
T_4-150% RDP	6.30	0.82	0.44	0.24	1.57	0.66	17.42	13.98
T_5-100% RDP + 5 kg Zn ha^{-1}	6.45	0.87	0.39	0.20	1.63	0.71	28.99	18.26
T_6-125% RDP + 5 kg Zn ha^{-1}	6.46	0.89	0.40	0.22	1.65	0.72	27.55	17.52
T_7-150% RDP + 5 kg Zn ha^{-1}	6.43	0.85	0.43	0.23	1.62	0.68	25.08	16.74
SE (m±)	0.017	0.008	0.011	0.006	0.012	0.007	0.549	0.361
CD at 5 %	0.06	0.03	0.03	0.02	0.04	0.02	1.69	1.08

Table 2
Uptake of nutrients by soybean as influenced by various treatments

Treatments	*Uptake of nutrients(kg ha^{-1})*			*Uptake of Zn (g ha^{-1})*
	N	*P*	*K*	
T_1-Control	33.91	3.24	12.27	222.31
T_2-100% RDP	53.88	5.22	18.89	303.82
T_3-125% RDP	55.30	5.50	19.25	288.84
T_4-150% RDP	52.09	5.60	17.87	262.95
T_5-100% RDP + 5 kg Zn ha^{-1}	60.49	5.51	21.57	452.17
T_6-125% RDP + 5 kg Zn ha^{-1}	62.10	5.94	21.83	420.68
T_7-150% RDP + 5 kg Zn ha^{-1}	57.50	5.85	20.05	366.84
SE (m±)	0.542	0.145	0.35	10.91
CD at 5%	1.66	0.45	1.03	33.26

Table 3
Available nutrients in soil after harvest of soybean as influenced by various treatments.

Treatments	*Available nutrients(kg ha^{-1})*			*DTPA-Zn(mg kg^{-1})*
	N	*P*	*K*	
T_1-Control	215.33	13.82	376.65	0.58
T_2-100% RDP	233.49	15.57	386.51	0.60
T_3-125% RDP	234.64	16.77	388.61	0.59
T_4-150% RDP	232.18	17.05	385.12	0.58
T_5-100% RDP + 5 kg Zn ha^{-1}	235.63	16.13	392.41	0.62
T_6-125% RDP + 5 kg Zn ha^{-1}	236.56	16.81	393.68	0.61
T_7-150% RDP + 5 kg Zn ha^{-1}	234.51	17.14	390.17	0.60
SE (m±)	0.658	0.343	1.105	0.008
CD at 5 %	2.03	1.06	3.41	0.02

Table 4
Nutrient use efficiency and nutrient recovery by soybean.

Treatments	*Nutrient Use Efficiency(kg kg^{-1})*			*Nutrient Recovery (%)*		
	N	*P*	*K*	*N*	*P*	*K*
T_1-Control	–	–	–	–	–	–
T_2-100% RDP	7.97	3.19	7.97	66.60	2.64	21.97
T_3-125% RDP	8.40	2.69	8.40	71.33	2.41	23.17
T_4-150% RDP	7.17	1.91	7.17	60.63	2.10	18.57
T_5-100% RDP + 5 kg Zn ha^{-1}	9.87	3.95	9.87	88.63	3.03	30.90
T_6-125% RDP + 5 kg Zn ha^{-1}	10.3	3.30	10.3	94.00	2.88	31.77
T_7-150% RDP + 5 kg Zn ha^{-1}	8.81	2.35	8.81	78.67	2.32	25.83

phosphorus. Similar result was observed by those of (Rathod et al. 2012).

Nutrient use efficiency and nutrient recovery by soybean: The data pertaining to nutrient use efficiency (kg kg^{-1}) and nutrient recovery (%) by soybean as influenced by various treatments are given in Table 5.

The maximum nutrient use efficiency and nutrient recovery of nitrogen and potassium by soybean were recorded with the application of 125% RDP + 5 kg Zn ha^{-1} (T6), but maximum phosphorus use efficiency and nutrient recovery was recorded with the application of 100% RDP + 5 kg Zn ha^{-1} (T5). N and K also recorded higher in treatment 100% RDP + 5 kg Zn ha^{-1} (T5) over other treatments except 125% RDP + 5 kg Zn ha^{-1} (T6). Higher nutrient use efficiency of nitrogen (9.87 kg ha^{-1}), phosphorus (3.95 kg ha^{-1}) and potassium (9.87 kg ha^{-1}) as well as recovery of nitrogen (88.63 %), phosphorus (3.03 %) and potassium (30.90 %) was recorded with soil application of 100% RDP + 5 kg Zn ha^{-1} (T5) followed by application of 125% RDP + 5 kg Zn ha^{-1} (T6). The NUE and NR of N, P and K by soybean were recorded higher by application of phosphorus with zinc (Morshedi *et al.* 2011).

CONCLUSION

From the present investigation the following conclusion is drawn:- Application of 100% RDP i.e. 30:75:30 NPK kg ha^{-1} with 5 kg zinc ha^{-1} were recorded higher soybean yield, uptake of nutrients as well as maximum nutrient use efficiency (NUE) and nutrient recovery by soybean.. High levels of available phosphorus in soil or high dose of phosphorus application may induce zinc deficiency in the soil characterized by low concentration of available zinc, so apply recommended dose of phosphorus or phosphorus along with zinc.

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