Asian Journal of Chemistry Vol. 8, No. 4 (1996), 589–594

Application of Phosphatic and Zinc Chemical Fertilizers on Yield and Chemical Composition of Soybean in Chromustert Soil

N.K. KHAMPARIA* and K.S. PITRE
Jawahar Lal Nehru Krishi Vishwavidyalaya
Regional Agriculture Research Station
Sagar, India

Field experiments were conducted during Kharif season, to study the influence of increasing rates of phosphorus and zinc containing chemical fertilizers on yield and uptake of these nutrients by soybean at Research Farm of Jawahar Lal Nehru Krishi Vishwavidyalaya Regional Agricultural Research Station and in the farmers' field, of Sagar, India. Results revealed that progressive doses of phosphorus and zinc elements significantly increased the grain and straw yield over control.

INTRODUCTION

Zinc deficiency has become well known as an important and widespread nutritional disorder in various crops. Rathore *et. al.*[1] reported that zinc deficiency might be more extensive in Madhya Pradesh, India at present and is likely to increase with the passage of time due to use of zinc-free fertilizer, high yielding varieties, land reformation and intensification of agriculture. In recent years 75% of zinc deficiency has been reported in soils of Sagar district by Khamparia *et al.*[2] The availability of phosphorus is a serious problem in plant nutrition in black soils. In these soils only 15–20% of phosphorus is available to plants and remaining 85–80% is fixed in the soil. The relationship between phosphorus and zinc in plant nutrition has been studied by several workers, but the interactions between zinc and phosphorus with the supply of zinc and phosphorus to soybean in black soils merit investigation. A field experiment was carried out to investigate the response of soybean to levels of zinc and phosphorus and their interaction in black soil.

EXPERIMENTAL

A field experiment was conducted with soybean variety JS 72-44 in Kharif season, at Research Farm of Jawahar Lal Nehru Krishi Vishwavidyalaya, Regional Agriculture Research Station, Sagar. The fertility status of experimental soil was conducted on entic chromustert clay soil which was medium in organic carbon per cent (0.55%), low in available N (230 kg ha^{-1}), medium in available P (18.8 kg ha^{-1}), high in available K (314 kg ha^{-1}) and low in available Zn (0.4 ppm); pH of soil showed neutral in reaction (7.2 pH) and electrical conductivity was 0.18 dsm^{-1}. Mechanical analysis of soil consisted of 48.9% clay, 22.9% silt and 28.7% sand and textural class name was clayey loam. The phosphorus at the rate of 0 (P_0), 25 (P_{25}), 50 (P_{50}), 75 (P_{75}) and 100 (P_{100}) Kg P_2O_5 ha^{-1} and zinc at the rate of 0, (Zn_0), 2 (Zn_2), 4.0 (Zn_4) and 6.0 (Zn_6) was applied in the form of diammonium phosphate and zinc sulphate. Basal dose of 30 kg nitrogen and 20 kg potassium per hectare was adjusted and supplemented in soil in the form of urea and muriate of potash respectively. Additional sulphur was adjusted with the highest dose uniformly by the application of sodium sulphate. The experiment was laid down in split plot design and all the treatments replicated four times in plot size of 5.0 M × 3.6 M. Soybean was sown @ 100 kg ha^{-1} in lines having row to row distance of 30 cm and plant to plant distance of 5.0 metres. Crop was harvested on maturity and grain and straw yield was recorded plotwise. Representative plant and soil samples were drawn from each plot. Plant and soil samples were processed for post-harvest chemical analysis. Plant samples were digested in triacid mixture and in acid digested aliquot; phosphorus was determined by the method of Koenig *et al.*[3] and zinc was estimated with a Varian Techtron Atomic Absorption Spectrophotometer. Soil samples were analysed for pH (1 : 2 soil-water ratio), electrical conductivity[4], available nitrogen, available phosphorus[5], available potassium by EEL flame photometrically[6] and available zinc by DTPA extraction in atomic absorption spectrophotometer.

RESULTS AND DISCUSSION

The grain and straw yields were significantly (at 5% level) affected by individual treatment at progressive levels of phosphorus and zinc and also their interactions, except P_{100}. The highest values *i.e.*, 30.44 and 46.98 q ha^{-1} were obtained with $P_{50}Zn_6$ dose respectively (Table-1) against control (7.84 and 19.50 q ha^{-1}). The highest yield may be attributed to the optimal nutritional balance and consequently the highest grain : straw ratio (1 : 1.54) was observed at the aforesaid treatment. The per cent grain yield response at level of P and Zn application was calculated 50.79, 105.7, 68.6 and 16.23% and 26.3, 37.28 and 58.65% more over control. The response of phosphorus was limited only up to P_{50}; further increase in dose reduced the grain yield thus showing its toxic effect, but application of the highest level of zinc (6 kg ha^{-1}) gave an additive effect over lower doses and control. Higher yield of oilseeds by zinc application @ 5 kg ha^{-1} was also reported by Singh *et al.*[7] and phosphorus application @ 50 kg ha^{-1} was suggested by Dhillon *et al.*[8] The increase in grain and straw yield was clearly due to the fact that the experiment was conducted in zinc deficient (0.4 ppm) and medium phosphorus (18.8 kg ha^{-1}) status soil with soil addition of zinc and phosphorus. The interaction between P and Zn was found to be positively significant in increasing the yield of the crop.

Phosphorus and Zinc Content: The data in Tables 1 and 2 show that phosphorus concentration in grain and straw was markedly increased with increasing rates of their application. Supply of the highest level of phosphorus intensified the concentration of phosphorus in plant tissue and the highest concentration was noted at P_{100} level.

TABLE-1

EFFECT OF TREATMENTS ON GRAIN AND STRAW YIELD (q ha^{-1}) AND P AND Zn CONTENT (%)

Zinc levels	Phosphorus levels					Mean	$CD_{5\%}$
	P_0	P_{25}	P_{50}	P_{75}	P_{100}		
			Grain yield				
Zn_0	7.84	10.49	19.40	16.05	14.05	13.57	P 1.67
Zn_2	11.88	19.81	23.34	20.00	11.69	17.14	Zn 1.89
Zn_4	11.51	19.91	25.16	20.35	16.85	18.63	P × Zn 4.23
Zn_6	16.57	23.48	30.44	24.19	12.98	21.53	
Mean	11.95	16.02	24.54	20.15	13.89		
			Straw yield				
Zn_0	19.50	26.13	31.00	32.67	23.91	26.64	P 1.95
Zn_2	22.52	32.53	35.72	33.64	21.82	29.25	Zn 1.72
Zn_4	23.23	35.31	42.40	36.56	30.16	33.53	P × Zn 3.84
Zn_6	28.12	36.00	46.98	46.09	24.60	36.36	
Mean	23.34	32.49	39.93	37.72	25.12		
			P content in grain				
Zn_0	0.695	0.735	0.812	0.857	0.880	0.796	P 0.01
Zn_2	0.695	0.727	0.840	0.847	0.075	0.797	Zn, N, S
Zn_4	0.700	0.742	0.812	0.840	0.860	0.791	P × Zn, N, S
Zn_6	0.695	0.732	0.795	0.845	0.852	0.784	
Mean	0.696	0.734	0.815	0.847	0.867		
			P content in straw				
Zn_0	0.090	0.130	0.130	0.175	0.200	0.145	P 0.01
Zn_2	0.075	0.117	0.120	0.160	0.200	0.134	Zn, N, S
Zn_4	0.080	0.110	0.130	0.140	0.120	0.132	P × Zn, N, S
Zn_6	0.085	0.095	0.120	0.150	0.195	0124	
Mean	0.082	0.113	0.125	0.156	0.199		
			Zn content in grain (μg/g)				
Zn_0	76.85	26.71	22.80	24.05	23.75	24.83	P 1.00
Zn_2	37.35	34.35	32.17	28.90	27.50	32.06	Zn 1.33
Zn_4	38.60	35.94	32.50	29.70	26.85	32.72	P × Zn2.97
Zn_6	40.30	35.60	33.90	30.16	28.10	33.61	
Mean	35.77	33.15	30.34	28.20	26.55		

TABLE-2
EFFECT OF TREATMENTS ON P AND Zn CONTENT AND UPTAKE IN GRAIN AND STRAW

Zinc levels	Phosphorus levels					Mean	$CD_{5\%}$
	P_0	P_{25}	P_{50}	P_{75}	P_{100}		
			Zn content in straw (μg/g)				
Zn_0	10.41	9.45	8.70	7.48	6.45	8.50	P 1.0
Zn_2	17.50	14.57	13.10	12.50	9.43	13.42	Zn 2.8
Zn_4	16.88	15.63	14.37	12.92	10.63	14.09	Zn × Zn NS
Zn_6	15.40	16.00	15.07	14.37	9.77	14.12	
Mean	15.05	13.91	12.81	11.82	9.07		
			P uptake in grain (kg ha^{-1})				
Zn_0	5.45	7.71	15.75	13.75	12.36	10.80	P 1.92
Zn_2	8.26	13.67	19.61	16.94	10.23	13.66	Zn 1.64
Zn_4	8.06	14.33	20.43	17.09	14.49	14.75	P × Zn NS
Zn_6	11.52	17.19	24.20	20.44	11.06	16.88	
Mean	8.32	13.23	20.04	17.07	12.04		
			P uptake in straw (kg ha^{-1})				
Zn_0	1.76	3.66	4.03	5.72	4.78	3.86	P 4.28
Zn_2	1.69	3.81	4.29	5.38	4.36	3.92	Zn 0.10
Zn_4	1.86	3.88	5.51	5.12	5.78	4.43	P × Zn 0.23
Zn_6	2.39	3.42	5.64	6.90	4.80	4.69	
Mean	1.91	3.67	4.88	5.80	5.00		
			Zn uptake in grain (g ha^{-1})				
Zn_0	24.05	28.02	44.33	28.60	33.37	33.69	P 7.48
Zn_2	44.37	64.61	75.08	57.80	32.15	54.95	Zn 6.75
Zn_4	44.43	68.74	85.29	61.38	47.35	62.61	P × Zn 15.79
Zn_6	66.78	83.59	103.19	72.95	36.47	72.36	
Mean	42.74	59.74	74.61	56.82	36.88		
			Zn uptake in straw (g ha^{-1})				
Zn_0	20.30	24.69	26.67	24.44	45.42	22.64	P 5.08
Zn_2	39.38	47.40	46.79	42.05	20.58	39.25	Zn 10.29
Zn_4	39.21	55.19	60.93	47.24	32.06	47.74	P × Zn NS
Zn_6	43.30	57.60	70.80	66.12	24.03	51.34	
Mean	35.13	45.19	50.00	43.99	32.78		

The P application synergistically and linearly increased the P content, while Zn application reduced it antagonistically, but when they were applied together at the interaction level of $P_{50}Zn_6$ they gave balance P content in grain and straw. Higher interactions showed zinc induced P deficiency. The response of Zn application from 0 to 6 kg ha^{-1} decreased the P content in grain and straw. Sharp decreased in P content in plant tissue and vegetative response of zinc was due to the experimental soil profile being rich in calcium carbonate content (2.0%). The phosphorus concentration in soybean decreased thereafter with the advent of time as phosphorus concentration was found to be higher in grain than straw. This might be due to dilution and translocation rate of phosphorus from the shoot to the grain. Addition of phosphorus doses started decreasing the Zn concentration in plant tissue from initial level and showing the adverse effect of P on Zn content. This explains the antagonistic relationship in P × Zn interaction regarding zinc content, whereas P limited growth and additional P depressed zinc concentration and induced zinc deficiency in plant by promoting growth, thus diluting the available zinc supply[9]. Similarly the concentration of zinc in soybean increased significantly with zinc application up to 6 kg ha^{-1} in presence of phosphorus. The P content in grain was relatively higher than zinc content as compared with straw at maturity stage. This might be due to the active role of phosphorus in seed formation. Higher concentration of zinc (40.30 µg/g) was found in grain as compared to straw (16.0 µg/g). The increased zinc concentration in plant with zinc application might have arisen due to greater dissolution of P from the binding sites due to competition for growing on soils. They are (i) dilution of Zn in plant tissue by promotion of plant growth by P fertilizer, (ii) inhibition of Zn absorption by the cations added with P fertilizer, (iii) P enhancement of Zn absorption by oxides and hydroxides of Fe and Al in the soils resulting in decreased absorption of Zn by plant roots[10]. Singh *et al.*[11] reported that P and Zn when used alone increased their uptake but antagonized when supplied in combination.

TABLE-3
APPLIED RESEARCH HIGHLIGHT TESTED ON FARMERS' FIELDS OF SAGAR DISTRICT, (INDIA) IN DIFFERENT YEARS (1986–89) ON GRAIN YIELD (q/ha) OF SOYBEAN

Blocks of Sagar district	Zn content (ppm)	Applied research significant treament (kg/ha)				
		P_0	P_{50}	$P_{50}Zn_6$	Zn_6	Average
Sagar	0.36	21.10	22.20	24.00	21.50	22.20
Rahatgarh	0.38	8.00	12.40	14.00	9.20	10.90
Rehli	0.62	10.16	10.88	11.84	13.26	11.54
Khurai	0.28	6.00	8.60	9.00	6.20	7.45
Banda	0.68	16.92	18.64	18.92	17.96	18.11
Average	0.46	12.44	14.54	15.55	13.62	
$CD_{5\%}$		1.63				

Farmers' Field Trials

The applied research highlights were also tested in zinc deficient soil of farmers' fields of five blocks *i.e.*, Sagar, Rahatgarh, Rehli, Khurai and Banda of Sagar district as adaptive trials in different years from 1986 to 1989 with soybean as a test crop. The results revealed that addition of zinc and phosphorus significantly increased the grain yield of soybean. The highest grain production *i.e.*, 24.00 q ha^{-1} was obtained in Sagar block with the combined, application of 50 kg P_2O_5 ha^{-1} and 6 kg Zn ha^{-1} ($P_{50}Zn_6$). Therefore, on the basis of the above study an important message must be conveyed to the farmers of Sagar and Damoh districts that optimum production of soybean can be obtained by the application of nitrogen 20 kg, phosphorus 50 kg, potassium 20 kg and zinc 6 kg per hectare for proper nutrient balance in soil.

REFERENCES

1. G.S. Rathore, R.S. Khamparia, G.P. Gupta, S.K. Dubey, B.C. Sharma and V.S. Tomar, Twenty-five years of micronutrient research in soils and crops of Madhya Pradesh, *Tech. Bull. Deptt. of Soil Sci. and Agric. Chem.*, Jawahar Lal Nehru Krishi Vishwavidyalaya, Jabalpur (1995).
2. R.S. Khamparia, B.C. Sharma, and G.S. Rathore, *J. Indian Soc. Soil Sci.*, **42**, 88 (1994).
3. A. Koenig and C.R. Jonson, *Indust. and Engg. Chem. Anal. Ed.*, **14**, 155 (1942).
4. C.S. Piper, Soil and Plant Analysis, Thomas Murphy and Co., London (1957).
5. S.R. Olsen, C.V. Cole, R.S. Watanabe, and L.A. Dean, Estimation of available phosphorus in soil, USDA Cir. No. 939, 1–9 (1954).
6. C.A. Black, Methods of Soil Analysis, Amer. Soc. Agron. Inc., Madison, Wisconsin, U.S.A. (1965).
7. A.B. Singh, R. Sakal, R.B. Sinha and N.S. Bhogal, *J. Indian Soc. Soil Sci.*, **42**, 413 (1994).
8. K.S. Dhillon and S.K. Dhillon, *J. Indian Soc. Soil Sci.*, **39**, 104 (1991).
9. I.U. Ahmad, S.M.S. Faiz, B. Faiz, M.A. Sayeed and Abdul Sattar, *J. Indian Soc. Soil Sci.*, **40**, 782 (1992).
10. D.A. Stanton and R. du T. Burger, *Agrochemophysica*, **2**, 63 (1970).
11. M. Singh and S.C. Singh, *Soil Sci.*, **129**, 282 (1980).

(*Received*: 21 July 1995; *Accepted:* 4 March 1996) AJC-1100