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Review/Overview

Zinc requirement of green gram (*Vigna radiata*)–wheat (*Triticum aestivum*) crop sequence in alluvial soil

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ABSTRACT

A field experiment was conducted during 2008–10 at Bichpuri, Agra on a zinc-deficient soil, to assess the direct and residual effect of different levels of applied Zn on yield of green gram [*Vigna radiata* (L.) Wilczek] and wheat [*Triticum aestivum* (L.) emend. Fiori & Paol.] and uptake of nutrients by the crops and soil fertility under greengram–wheat crop sequence. The experiment was laid out in randomized block design with 5 levels of zinc (0, 2.5, 5.0, 7.5 and 10.0 kg/ha) with 4 replications. An application of 5 kg Zn/ha to greengram recorded significantly highest plant height (53.5 cm), pods/plant (35.8), seeds/pod (12.8) and 1,000-grain weight (32.04 g). Zinc fertilization in preceding greengram crop at 7.5 kg was found to be best for growth and yield attributes of wheat. Green gram crop responded significantly up to 5 kg Zn/ha by producing 1,052 kg grain and 1,816 kg straw/ha. The residual effect in wheat crop was significant at 7.5 kg Zn/ha and grain and straw yield increments were to the extent of 15.3 and 12.4% respectively. The content and yield of protein in both the crops increased significantly with an increase level of zinc. The uptake of Zn by both the crops increased significantly by increasing levels of zinc. A phenomenal increase in N and K uptake, except of P and S, was recorded in greengram and wheat crop due to increasing levels of zinc up to 5 and 7.5 kg/ha respectively. DTPA-extractable Zn was reduced in the control plot harvesting of wheat. At higher levels of Zn, sufficient DTPA-extractable Zn (0.80 mg/kg) remained in the soil after growing 2 crops and further crops could be taken without the application of Zn. The values of efficiency indices decreased with the increase in levels of zinc. Net returns and benefit: cost ratio were the highest with 5 kg Zn/ha in the greengram-–wheat crop sequence.

Key words: Crop management, Alluvial soil, Greengram–wheat crop sequence, Nutrient uptake, Yield, Zinc

Zinc is one of the essential plant micronutrients and its importance for crop productivity is similar to that of major nutrients. Intensive agriculture coupled with continuous use of NPK fertilizers has remarkably increased production but simultaneously brought about problems related to micronutrient deficiencies, particularly that of Zn in soil. Crops require only small amount of Zn for their normal growth but its application rate is high due to very low fertilizer-use efficiency. Therefore, a considerable amount of applied Zn remains in soil, which can be utilized by the subsequent crops. The profitability of Zn application could be higher, if the residual benefits of initial application to subsequent crops are taken in to account. The response of soil-applied Zn could be more correctly assessed on cropping system basis rather than on a single crop basis. Shivay *et al*. (2008) reported significant improvement in net return and benefit: cost ratio of wheat under rice–wheat cropping system due to application of Zn over no-Zn application in rice. They also reported significant improvement in productivity, Zn uptake and Zn-use efficiencies in wheat under rice–wheat cropping system due to Zn application to rice over control. It is expected that the cultivation of greengram in *kharif* in place of pearlmillet may improve soil fertility and consequently the productivity of wheat in mungbean–wheat cropping system. The cultivation of cereals (pearlmillet–wheat) in a year on the same piece of land leads to imbalance in the soil fertility, resulting in decline in yield of both the crops. Inclusion of legumes in crop sequence increases the soil fertility and consequently the productivity of succeeding cereal crop (Singh and Shivay, 2013). Since not much information is available on the zinc requirement of greengram-wheat cropping sequence in alluvial soils of western Uttar Pradesh, present study was initiated on these

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aspects to assess the zinc requirement of greengram-wheat crop sequence grown on alluvial soil which is deficient in zinc.

MATERIALS AND METHODS

A field experiment was conducted for 2 consecutive years (2008–10) in randomized block design at farmer field at Panwari village, Agra. The experimental site is characterized by semi-arid climate, with extreme temperature during summer (45^o to 48^oC) and very low temperature during winter (as low as 2^oC). The average rainfall is about 650 mm, most of which is received from June to September. The soil was sandy loam with alkaline pH (8.0), low in soluble salt (0.15 dS/m) and organic carbon content (3.0 g/kg). The soil was low in N (142 kg N/ha), P (8 kg P_2O_5/ ha) and medium in K (125 kg K_2O/ha). The soil was deficient in Zn having initial Zn status of 0.54 ppm. Greengram was sown with 5 levels of Zn, i.e. control, 2.5, 5.0, 7.5 and 10.0 kg Zn/ha applied as zinc sulphate hepta hydrate and four replications during the rainy season (*kharif*) season. The recommended dose for greengram was 20 kg N + 60 kg P_2O_5 + 40 kg K_2O/ha and wheat 150 kg N + 60 kg P_2O_5 + 60 kg K_2O/ha. Full dose of phosphorus and potassium applied as diammonium phosphate and muriate of potash was applied at the time of sowing of greengram. Half dose of N and full dose of P and K were applied at the time of sowing of wheat. Remaining nitrogen was top-dressed in 2 slots–at first and second irrigation. After the harvest of the *kharif* greengram, wheat was grown as residual crop during the winter (*rabi*) season in the same plot without application of zinc. At harvest, grain and straw yield of both the crops were recorded. The grain and straw samples were digested in diacid mixture (3:1 of HNO_3 : $HClO_4$) and analysed for P by molybdovanadate yellow colour method, K by flamephotometer, S by turbidimetric method and zinc by atomic absorption spectrophotometer. Nitrogen content in grain and straw was determined by modified Kjeldahl's method (Jackson, 1973). Post-harvest soil samples collected after two years of experiment were air-dried, ground to pass through 2 mm sieve and analysed for available Zn after extraction with DTPA (Lindsay and Norvell, 1978). Economics and system productivity were calculated the basis of prevailing market prices.

RESULTS AND DISCUSSION

Direct effect on greengram

*Yield attributes and yield***:** Effect of Zn fertilization on plant height, pods/plant, grains/pot and 1,000-grain weight of greengram was significant up to 5 kg Zn/ha over the control. These growth and yield attributes tended to decreased with higher levels of zinc over 5 kg Zn. Application of graded doses of Zn to greengram significantly enhanced the grain and straw yields (Table 1). Highest grain and straw yields were recorded with 5 kg Zn/ ha over rest of the treatments, but was on a par with 7.5 kg Zn/ha. Application of 5 kg Zn/ha increased the grain and straw yields of greengram to the tune of 14.9 and 20.1% over the control respectively. The favourable influence of Zn application on the yield of greengram may be attributed to its role in various enzymic reactions, growth processes, hormone production and protein synthesis and also the translocation of photosynthates to reproductive parts thereby leading to higher yield of the crop. Increase in yield owing to application of Zn is quite obious, as the soil under study was deficient in available Zn (0.54 ppm). Islam *et al.* (2005) and Singh and Singh (2012) reported similar results in mungbean and chickpea respectively.

Protein: The protein in greengram grain increased from 24.4 to 26.6% with 10 kg Zn/ha. This increase in protein content with Zn addition may be attributed to its involvement in N metabolism. The protein yield increased significantly with each increment of zinc dose. The highest protein yield was obtained with 5 kg Zn/ha which was significantly higher than the control and lower levels of Zn. This was mainly owing to higher grain yield and protein percentage in greengram grain. Singh and Singh (2012) also reported such results in chickpea.

Uptake of nutrients: Nitrogen uptake by greengram grain and straw increased significantly with increasing levels of Zn and the highest N uptake was observed with 5 kg Zn/ha, i.e. 42.7 and 25.2 kg/ha and lowest in the

Table 1. Direct effect of zinc levels of growth, yield attributes and yield and protein yield of greengram

Zinc(kg/ha)	Plant height (cm)	Pods/plant	Grains/pod	1,000- grain weight (g)	Grain yield (t/ha)	Straw yield (t/ha)	Protein content (%)	Protein yield (kg/ha)
0	97.0	33.4	12.2	28.9	0.92	1.51	24.37	223.2
2.5	98.9	34.6	12.5	30.8	1.00	1.67	24.81	247.1
5.0	100.7	35.8	12.8	32.0	1.05	1.82	25.37	266.9
7.5	100.0	34.9	12.6	31.8	1.00	1.63	26.06	261.4
10.0	98.7	34.0	12.4	31.0	0.98	1.60	26.56	260.3
SEm±	0.45	0.31	0.010	0.36	0.002	0.002	0.014	5.11
CD (P=0.05)	1.27	0.88	0.028	1.02	0.006	0.006	0.040	14.46

control i.e. 35.7 and 20.2 kg/ha (Table 2). Thus, the beneficial effect of Zn on photosynthesis and metabolic processes augments the production of photosynthates and their translocation to different plant parts including grain, which ultimately increased the uptake of N in grain and straw. These results are in accordance with the findings of Dwivedi *et al.* (2001) and Tripathi *et al.* (2011). Phosphorus uptake first increased due to increase in yield but at the higher levels of zinc, it decreased due to reduced P content in the grain and straw. The decrease in P uptake with higher dose of zinc might be due to antagonistic effect between P and Zn. Similar results were reported by Islam *et al*. (2005) for wheat. The uptake of K by greengram grain and straw was significantly increased with increasing levels of Zn up to 5 kg/ha. The magnitude of significant increases in K uptake with 5 kg Zn/ha was 17.7 and 22.1 % in grain and straw respectively, over the control. There was a slight increase in S uptake by greengram grain and straw with the application of Zn up to 2.5 kg/ha over the control. Thereafter, a reduction in S uptake was noted at higher levels of zinc (Tripathi *et al.* 2011). Zinc uptake by greengram increased significantly with increasing levels of Zn application (Table 2). Highest Zn uptake was found with 10 kg Zn/ha and lowest in the control. The increase in Zn uptake by grain and straw with 10 kg Zn/ha was 73.6 and 102.5% over the control respectively. The higher Zn removal due to Zn application could be attributed to the priming effect caused by higher crop growth and consequently higher removal due to balanced fertilization. Singh and Singh (2012) also reported similar results.

Residual effect on wheat

Yield attributes and yield: Among the zinc levels, residual effect of 7.5 kg Zn/ha was significant on plant height, grains/ear and 1,000-grain weight. A further slight increase in these characters was recorded when the level of Zn was raised to 10 kg Zn/ha in preceding greengram crop. Pooniya and Shivay (2011) reported such findings in wheat. In wheat, marked positive residual effect of addition of Zn to preceding greengram was noticed in terms of grain and straw yield (Table 3). Residual effect was more prominent under application of 7.5 kg Zn/ha and grain and straw yield increments were to the extent of 15.3 and 12.4% respectively, over the control. In general, the marked improvement in productivity of wheat with residual Zn could be ascribed to the enhancement of zinc content of soil. These findings are in accordance with those reported by Varshney *et al*. (2008) and Pooniya and Shivay (2011).

Protein: The residual effect of Zn levels had significant beneficial effect on protein percentage in wheat grain over the control. The maximum protein content in grain was recorded under 10 kg Zn/ha applied in preceding greengram crop. The successive increase in Zn levels applied in greengram crop significantly increased the protein yield over lower levels of Zn. Protein yield is the function of protein content and grain yield. Since variation in pro-

Table 2. Direct effect of zinc levels on uptake of N, P, K, S and Zn by greengram (mean of 2 years)

Zinc (kg/ha)	Nitrogen (kg/ha)		Phosphorus(kg/ha)		Potassium(kg/ha)		Sulphur(kg/ha)		Zinc(g/ha)	
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
0	35.7	20.2	2.5	2.7	7.9	31.2	2.3	2.4	22.0	23.7
2.5	39.5	22.6	2.7	2.2	8.7	35.0	2.5	2.5	28.4	31.0
5.0	42.7	25.2	2.6	2.2	9.3	38.1	2.5	2.5	34.7	42.1
7.5	41.8	23.5	2.4	1.6	9.1	34.6	2.3	2.1	36.5	44.1
10.0	41.6	23.8	2.1	1.4	9.0	34.2	2.1	1.9	38.2	48.0
SEm±	0.79	0.94	0.036	0.036	0.20	0.97	0.09	0.08	0.72	1.22
CD (P=0.05)	2.26	2.66	0.102	0.08	0.56	2.76	NS	NS	2.05	3.48

Table 3. Residual effect of zinc levels on yield attributes and yield protein yield of succeeding wheat (mean of 2 years)

Zinc(Kg/ha)	Plant height (cm)	Tillers/ running m	Grains/ear	1,000- grain weight (g)	Yield (t/ha)		Protein (%)	Protein yield(kg/ha)
					Grain	Straw		
0	97.0	103.8	43.2	43.7	4.26	6.52	13.6	580.3
2.5	98.9	105.0	43.4	44.0	4.45	6.68	13.8	611.9
5.0	100.7	106.3	43.6	44.4	4.68	7.04	13.9	652.2
7.5	104.8	108.4	44.0	44.7	4.92	7.33	14.1	691.1
10.0	101.7	108.7	44.0	44.9	4.97	7.47	14.1	701.9
SEm±	0.36	0.56	0.02	0.014	0.07	0.09	0.01	10.05
CD (P=0.05)	1.02	1.60	0.05	0.039	0.20	0.26	0.03	28.44

tein content has genetic and biochemical limitations, the protein yield is more influenced by grain yield and thus followed almost trend similar to grain yield. Khare and Dixit (2011) also reported similar results.

Uptake of nutrients: The uptake of nutrients (N and K) by wheat grain and straw was significantly affected by the residual effect of zinc application in greengram. On an average, the uptake of N and K by grain and straw increased with 10 kg Zn/ha applied in preceding crop by 20.8 and 26.7, 22.9 and 18.4% respectively, over the control. The uptake of P by wheat grain and straw increased with the application of 5 kg Zn/ha in preceding greengram crop over the control, followed by a reduction in P uptake at higher residual levels of Zn. The response of wheat crop to applied Zn in preceding greengram crop may be attributed to an enhanced availability of Zn in soil at a level below where the optimum requirement of crop is fulfilled. This showed that enhancement in Zn levels not only increased the yields but also increased the nutrient concentration and ultimately their uptake. Owing to the antagonistic relationship of Zn and P, reduction in P uptake was recorded with the application of Zn. Pooniya and Shivay (2011) and Khare and Dixit (2011) reported increase in uptake by N, P and K with increasing levels of Zn applied in greengram crop. The residual effect of the Zn levels was further noticed on Zn uptake by wheat grain and straw. The data revealed that there was a significant residual effect of the levels of Zn to produce higher Zn uptake by wheat than the control. This may be attributed to increase in Zn content and yield of crop with Zn application. Our results confirm the findings of Jat *et al.* (2013).

Efficiency indices

Zinc fertilization had a significant effect on agronomic efficiency of applied zinc for both the crops. The maximum values of zinc-use efficiency for greengram and wheat were at 2.5 kg Zn/ha and 7.5 kg Zn/ha respectively. Agronomic efficiency decreased as the level of Zn fertilization increased (Table 5) for Zn, agronomic efficiency in greengram and wheat declined from 66.4 to 8.9 and 87.2 to 71.0 when the level of K was increased from 2.5 to 10 kg Zn/ha, respectively. Similar results were reported by Jat *et al.* (2013). Recovery efficiency of Zn in greengram and wheat was the highest with application of 2.5 and 7.5 kg Zn/ha, respectively and lowest at 10 kg Zn/ha.

System productivity and profitability

System productivity of the cropping system in terms of greengram grain-equivalent yield (GEY) was influenced significantly under different levels of zinc (Table 6). In levels of applied zinc to greengram, significantly highest GEY (2.5 t/ha) was obtained with 5 kg Zn/ha which was 9.2% higher than the control (no zinc). The use of zinc in greengram increased the productivity of greengram and also enhanced productivity of succeeding wheat thereby improved system productivity was noticed under these levels of zinc. The pooled data showed that application of 5 kg Zn/ha resulted in significantly higher greengram yields

Table 4. Residual effect of zinc levels in uptake of N, P, K, S and Zn by succeeding wheat (mean of 2 years)

Zinc(kg/ha)	Nitrogen (kg/ha)		Phosphorus (kg/ha)		Potassium (kg/ha)		Sulphur (kg/ha)		Zinc(g/ha)	
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
0	92.9	37.1	9.8	9.1	26.8	134.9	9.4	9.8	142.7	129.0
2.5	97.9	39.4	10.2	8.7	28.5	139.5	9.3	10.0	160.2	156.8
5.0	104.4	42.2	10.3	9.1	30.4	148.6	9.3	9.8	184.9	190.1
7.5	110.6	45.4	9.8	8.0	31.9	155.3	8.8	9.5	209.9	223.5
10.0	112.3	47.0	9.4	7.5	32.8	159.7	8.4	8.2	221.2	256.8
SEm±	1.28	0.99	0.05	0.04	0.61	1.78	0.25	0.48	1.58	2.98
CD (P=0.05)	3.65	2.84	0.17	0.14	1.73	5.09	0.72	1.37	4.51	8.49

Table 5. Effect of zinc levels on zinc efficiency and available Zn after harvest of succeeding wheat (mean of 2 years)

Zinc (kg/ha)	AE Zn (kg grain increased/ kg Zn)		RE Zn (%)		Available Zn(mg/ kg)
	Greengram	Wheat	Greengram	Wheat	
0	-	-	-	-	0.49
2.5	66.4	75.6	0.26	0.70	0.58
5.0	61.0	84.2	0.25	0.84	0.64
7.5	16.4	87.2	0.19	0.89	0.72
10.0	8.9	71.0	0.16	0.78	0.80
SEm±					0.02
CD (P=0.05)	-	-	-	-	0.05

Table 6. Effect of zinc levels on greengram grain equivalent yield (GEY), net returns (×10³/₹ha) and benefit: cost ratio of greengram, wheat and cropping system

Zinc level(kg/ha)	GEY (t/ha)	Greengram		Wheat		Cropping system	
		Net returns	Benefit: cost ratio	Net returns	Benefit: cost ratio	Net returns	Benefit: cost ratio
0	2.06	33.3	3.55	40.5	2.22	73.8	2.88
2.5	2.20	34.7	3.57	42.7	2.30	77.4	2.93
5.0	2.25	39.1	3.87	45.6	2.43	84.8	3.15
7.5	2.26	36.3	3.47	48.5	2.55	84.7	3.01
10.0	2.25	35.0	3.22	49.1	2.54	84.1	2.88
SEm±	0.014						
CD (P=0.05)	0.040						

and also proved economically beneficial with highest net returns and benefit: cost ration. This could be attributed to higher yields with this treatment. The residual effect of 7.5 kg Zn/ha in succeeding wheat also resulted in significantly higher net returns and benefit: cost ratio. This could be ascribed to the fact that substantial fraction of zinc applied in greengram was utilized by succeeding wheat which consequently reflected in net return accrued from wheat (Singh and Shivay, 2013). Considering the whole cropping system, the net return and benefit: cost ratio were maximum with 5 kg Zn/ha.

DTPA-extractable Zn after harvest of crops are presented in Table 5. It increased with increasing levels of Zn after harvest of the crops (Table 5). The Zn content in control plot decreased after taking the crops over initial value, indicating an exhaustion of Zn by the crops. DTPA-Zn remained much higher than the original level at higher levels of Zn, thus, indicating that further crops could be taken without the application of Zn.

From the present investigation, it may b inferred that application of 5 kg Zn/ha in greengram resulted in higher yields and uptake of nutrients by greengram with a residual effect that could produce wheat grain and straw yield which was at par with the effect of highest Zn application (10 kg Zn/ ha). Therefore, it is concluded that application of 7.5 kg Zn/ha appears to be the best dose for obtaining high productivity and utilization of nutrients in greengram–wheat cropping sequence under agro-climatic conditions of Agra region.

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