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Influence of phosphorus and zinc nutrition on yield and nutrient uptake in wheat (*Triticum aestivum*) and their residual effect on greengram (*Vigna radiata*)

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ABSTRACT

A field experiment was conducted during 2014-16 at farmers' field in Panwari village of Agra district (UP) to study the direct and residual effects of phosphorus and zinc levels on yield, quality and nutrient uptake in wheat (*Triticum aestivum* L.) - greengram (*Vigna radiata* L.) cropping system using treatment combination of phosphorus (0, 30, 60 and 90 kg P_2O_5/ha) and zinc (0, 2, 4 and 6 kg/ha). The results revealed that the application of 60 kg P_2O_5/ha to wheat crop recorded significantly highest plant height (102.7 cm) and test weight (43.9 g). Phosphorus application in preceding wheat crop at 90 kg P_2O_5/ ha was found to be best for growth and yield attributes of greengram. Wheat crop responded significantly up to 60 kg P_2O_5/ ha by producing 5.39 t grain and 7.59 t straw/ ha. The residual effect of P in greengram was significant at 90 kg P_2O_5/ ha and grain and straw yield increments were to the extent of 15.8 and 12.0 %, respectively. Wheat crop responded to zinc application and 4 kg Zn/ ha could be adjudged response level. The residual effect of 6 kg Zn/ ha on succeeding greengram crop produced 12.3 and 7.1% higher grain and straw yield over control. Protein content in wheat and succeeding green gram increased significantly with P and Zn application but P was more effective in improving protein content in both the crops. There was a significant increase in protein yield of wheat and greengram with both the elements. Application of P and zinc showed substantial increase in P and Zn uptake by wheat and succeeding greengram crop over control. Nitrogen uptake by both the crops also improved significantly with these elements. The residual available P and Zn status in post harvest soil improved with the application of respective elements. Thus, application of 60 kg P_2O_5/ha along with 6 kg Zn/ha in wheat were optimum doses for obtaining higher productivity, produce quality and residual P and Zn in soil under wheat-green gram cropping sequence.

Key words: Direct effect, Greengram, Nutrient uptake, Phosphorus, Quality, Residual effect, Wheat, Yield, Zinc

Wheat (*Triticum aestivum* L) is the most important food grain crop among cereals and stands next only to rice in our country. Wheat is a good supplement for nutritional requirement of human body as it contains 9-10% protein and 60-80% carbohydrates. Greengram (*Vigna radiata* (L) Welczeck) is an important legume crop mainly grown in marginal soil and prominent source of vegetable protein. Wheat is an exhaustive crop which requires the major and micronutrients in adequate amounts for higher production. Wheat is quite responsive to phosphorus and zinc, which plays important role in growth and development of this crop. Zinc is essential for promoting certain metabolic reactions. It is necessary for the production of chlorophyll and carbohydrates. Zinc is directly or indirectly required by several enzyme systems, auxin and protein synthesis. Zinc is believed to promote RNA synthesis, which in turn is needed for protein production. At several places, normal yield of crops could not be achieved despite judicious use of NPK fertilizers due to deficiency of zinc. Most of the soils of Agra region have been rated as deficient in available Zn. Moreover it has been reported that P and Zn fertilizers have residual effects on the crops. The inclusion of legume/grain legume is of great importance besides the application of nutrient elements especially P and Zn in required amounts for maintaining crop production at higher level. Significant residual effects of P and Zn applied to winter season crop on succeeding crop have been reported (Singh and Singh 2012, Chaudhary *et al.* 2014). Studies have indicated both synergistic and antagonistic relationship between P and Zn but their relationship depends on their rate of application and crop species. Information on P and Zn management in individual crop is available but system based information

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is lacking. Hence, an experiment was carried out on P and Zn nutrition in wheat-greengram crop sequence in alluvial soil of Agra district of Uttar Pradesh.

MATERIALS AND METHODS

A field experiment was conducted for two consecutive years (2014-15 and 2015 -16) at farmers' field at Panwari village, Agra (U P). The experimental site is characterized by semi-arid climate with extreme temperature during summer (45^0 to 48^0 C) and very low temperature during winter (as low as 2^0 C). The soil was sandy loam in texture with alkaline pH (8.0), low in organic carbon (3.0 g/kg). The soil was low in available N (155 kg/ha), P (8 kg/ha), medium in K (125 kg/ha and deficient in DTPA-Zn (0.54 mg/kg). The treatments comprising four levels each of phosphorus (0, 30, 60 and 90 kg P_2O_5/ha) and zinc (0, 2, 4 and 6 kg/ha) were evaluated in factorial randomized block design with three replications. Wheat (HD 2329) was grown during the *rabi* seasons of 2014-15 and 2015-16. Basal application of 150 kg N and 40 kg K_2O/ha was made through urea and muriate of potash, respectively. Phosphorus and zinc were applied as single superphosphate and zinc sulphate, respectively. Full quantity of P, K and Zn was applied at sowing time. Half of N was applied at sowing time and another half was applied in two splits, one-half at first irrigation and the other at tillering stage. After the harvest of wheat, greengram (K-851) was grown as residual crop during *kharif* season in the same plot without application of P and zinc. The recommended dose for greengram was 20 kg N and 40 kg K_2O/ha. Full doses of N and K were applied at the time of sowing of greengram. Plant height and test weight of wheat and plant height, pods/plant, seeds/pods and test weight of greengram were recorded at maturity. At harvest grain and straw yields of both the crops were recorded. The grain and straw samples were digested in di-acid mixture (3:1 of HNO_3:$HClO_4$) and analysed for P by molybdovanadate yellow colour method and zinc by atomic absorption spectro-photometer. Nitrogen content in grain and straw was determined by modified Kjeldahl's method (Jackson 1973). The uptake of nutrients was computed from their concentrations in grain and straw and respective yields of both the crops. Post harvest soil samples collected after two years of experiment were air-dried, ground to pass through 2 mm sieve and analysed for available P (Olsen *et al.* 1954) and Zn (Lindsay and Norvell 1978). The mean data on various parameters obtained from consecutive two years were statistically analyzed as per procedure given by Gomez and Gomez (1984). Least significant difference (LSD) values at P = 0.05 were used to determine the significance of difference between treatment means.

RESULTS AND DISCUSSION

Direct effect on wheat

Yield attributes and yield: Among the phosphorus levels, the effect of 60 kg P_2O_5/ ha was significant on plant height and test weight of wheat over rest of the P levels. The increase in these parameters may be attributed to increased availability of P which has positive effect of growth of the plant. These results are in close conformity with the findings of Mishra *et al.* (2017). Significant highest grain yield (5.39 t/ha) of wheat was recorded under application of phosphorus @ 60 kg/ha after that it was reduced at 90 kg P_2O_5/ha. The increments in wheat grain yield under 30, 60 and 90 kg P_2O_5/ha were 13.1, 36.1 and 32.8% over control, respectively. The corresponding increases in straw yield were 12.3, 36.0 and 29.5 per cent. The higher level of P (90 kg P_2O_5/ha) was statistically at par with 60 kg P_2O_5/ ha in increasing the yield. The positive response to P in this soil may be attributed to low P status of soil. Similar results were reported by Singh *et al.* (2017).

Effect of zinc fertilization on plant height and test weight of wheat was significant up to 4 kg Zn/ha over control. These growth and yield attributes tended to decrease with higher level of zinc over 4 kg Zn/ ha. The favourable influence of Zn application on growth may be due to its role in various enzymatic reactions, growth processes and protein synthesis leading to higher growth of crop (Mishra *et al.* 2017). A significant response of applied Zn to wheat was observed and 4 kg Zn/ha may be adjudged the response level (Table 1). With the application of 4 kg Zn/ha an increase of 19.8 % was recorded in wheat grain yield over the control. The corresponding increase in straw yield was 14.1%. The response to zinc application may be attributed to the DTPA extractable Zn status of the soil (0.54 mg/ kg) which was below the critical level. Mishra *et al.* (2017) also reported the significant response of applied Zn to wheat in alluvial soils.

Protein yield: Protein content in wheat grain and straw increased significantly with application of phosphorus over control (Table 1). The maximum percentage of protein in grain (13.2%) and straw (3.9%) was recorded at 90 kg P_2O_5/ha. There was a consistent and significant increase in protein yield of wheat grain with increasing levels of P and maximum value (706.0 kg/ ha) was recorded with 60 kg P_2O_5/ha. Similar results were reported by Kumar and Singh (2019). The protein in wheat grain increased from 12.3 to 13.1 % with 6 kg Zn/ha. The corresponding range of protein content in wheat straw was 3.5 to 3.8%. 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 Zn dose, the highest protein yields was obtained with 4 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 content in wheat grain. Singh and Pandey (2018) also reported similar results.

Uptake of nutrients: Nitrogen uptake by wheat grain and straw increased significantly with phosphorus application over control. The maximum uptake of nitrogen in grain (112.6 kg/ha) and straw (46.3 kg/ha) was associated with 60 kg P_2O_5/ha. There was a significant increase in N uptake in wheat grain and straw with increasing levels of Zn and the highest values were observed with 4 kg Zn/ha, i.e. 109.2 and 43.5 kg/ha and lowest in the control (86.7

Table 1 Effect of phosphorus and zinc on yield and quality of wheat grain and straw (mean of two years)

Treatment	Plant height (cm)	Test weight (g)	Yield (t/ha)		Protein content (%)		Protein yield (kg/ha)
			Grain	Straw	Grain	Straw	
Phosphorus (kg P_2O_5/ha)							
0	97.0	42.7	3.96	5.58	12.1	3.4	479.0
30	99.2	43.0	4.48	6.27	12.6	3.6	564.4
60	102.7	43.9	5.39	7.59	13.1	3.8	706.0
90	102.0	43.7	5.20	7.23	13.2	3.9	686.4
LSD (P = 0.05)	1.05	0.03	0.35	0.49	0.03	0.02	27.8
Zinc (kg/ha)							
0	98.5	43.0	4.38	6.22	12.3	3.5	538.7
2	100.0	43.4	4.75	6.65	12.6	3.6	598.5
4	101.5	43.6	5.25	7.10	13.0	3.8	682.5
6	101.0	43.7	4.97	6.70	13.1	3.8	650.7
LSD (P = 0.05)	1.05	0.03	0.35	0.49	0.03	0.02	27.8

and 34.8 kg/ha). Thus, the beneficial effect of Zn on photosynthesis and metabolic processes augments the production of photosynthates and their translocation to different plants including grain, which ultimately increased the uptake of N in grain and straw. Phosphorus uptake of 9.4, 12.9 and 13.5 kg P/ha in grain and 6.9, 9.8 and 10.8 kg P/ha in straw were recorded under 30, 60 and 90 kg P_2O_5/ha, respectively (Table 2), which were significantly higher over control values (7.5 and 5.0 kg P/ha). Zinc application resulted in significant increase P uptake up to 4 kg Zn/ha followed by a reduction at higher level of Zn (6 kg Zn/ha). The decrease in P uptake with higher dose of Zn might be due to antagonistic effect between P and Zn (Chaudhary *et al.* 2014).

Phosphorus application also resulted in significant increase in Zn uptake by wheat crop up to 60 kg P_2O_5/ha over control (Table 2). However, at higher level of P application (90 kg P_2O_5/ha), there was a reduction in Zn uptake by the crop. This may be attributed to the fact that higher level of P interfered with Zn translocation showing reduction in its concentration and consequently uptake (Singh and Pandey 2018). Zinc application @ 2, 4 and 6 kg/ha resulted in significant zinc uptake of 142.5, 168.0 and 171.4 g Zn/ha in grain and 160.9, 187.4 and 187.6 g Zn/ha in straw over the control (124.8 and 137.5 g Zn/ha). Higher Zn removal due to its application could be attributed to the priming effect caused by higher crop growth and consequently higher removal due to balanced fertilization. Mishra *et al.* (2017) also reported similar results.

Residual effect on greengram

The residual effect of P levels had maximum and significant beneficial effect on plant height, pods/plant, grains/pod and test weight of green gram over control when 90 kg P_2O_5/ha applied in preceding wheat crop. Significant effect of applied P on the succeeding greengram crop was recorded (Table 3). Successive increase in P levels up to 90 kg P_2O_5/ha increased the grain and straw yield of

Table 2 Effect of phosphorus and zinc on nutrient uptake in grain and straw of wheat (mean of two years)

Treatment	N (kg/ha)		P (kg/ha)		Zn (g/ha)	
	Grain	Straw	Grain	Straw	Grain	Straw
Phosphorus (kg P_2O_5/ha)						
0	77.2	30.7	4.5	5.0	121.1	136.7
30	90.4	36.4	9.4	6.9	144.2	163.0
60	112.6	46.3	12.9	9.8	169.7	193.5
90	110.2	45.5	13.5	10.8	159.1	178.6
LSD (P = 0.05)	5.73	0.54	0.67	0.54	8.34	5.40
Zinc (kg/ha)						
0	86.7	34.8	10.1	7.5	124.8	137.5
2	96.0	38.6	11.8	9.3	142.5	160.9
4	109.2	43.5	11.5	8.5	168.0	187.4
6	104.4	41.5	9.9	6.7	171.4	187.6
LSD (P = 0.05)	5.73	0.54	0.67	0.54	8.34	5.40

Table 3 Residual Effect of P and Zn on yield and quality of green gram (mean of two years)

Treatment	Plant height (cm)	Pods/ plant	Grain/ pod	Test weight (g)	Yield (t/ha)		Protein in grain (%)	Protein yield (kg/ha)
					Grain	Straw		
Phosphorus (kg P_2O_5/ha)								
0	56.5	32.0	11.2	27.0	0.95	1.50	24.12	229.1
30	57.6	32.8	11.8	28.1	1.03	1.60	24.56	253.0
60	59.2	33.8	12.4	29.4	1.09	1.66	25.06	273.1
90	59.4	34.6	12.6	30.0	1.10	1.68	25.37	279.0
LSD (P = 0.05)	1.74	0.56	0.51	0.89	0.04	0.05	0.04	5.70
Zinc (kg/ha)								
0	57.0	32.6	11.5	27.5	0.97	1.55	24.37	236.4
2	57.8	33.0	11.8	28.0	1.03	1.61	24.55	252.9
4	58.6	33.6	12.3	29.1	1.08	1.65	24.87	267.8
6	59.0	34.0	12.4	30.0	1.09	1.66	25.25	275.2
CD (P = 0.05)	1.74	0.56	0.51	0.89	0.04	0.05	0.04	5.70

greengram by 15.8 and 12.0 %, respectively over control. The increase in green gram yield may be attributed to the buildup of phosphorus in the experimental soil which results in better root development, plant growth and subsequently the greengram yield (Singh *et al.* 2014).

Effect of residual Zn on plant height, pods/plant, grains/pod and test weight of greengram was significant up to 4 kg Zn/ha. The increase in these parameters owing to zinc application is quite obvious as the soil under study was deficient in available zinc. Singh *et al.* (2014) also reported similar results. In greengram, marked positive residual effect of addition of Zn in preceding wheat crop was more prominent under application of 6 kg Zn/ha and grain and straw yield increments were to the extent of 12.3 and 7.1%, respectively over the control. In general, the marked improvement in productivity of greengram with residual could be ascribed to the enhancement of zinc content of the soil. These findings are in accordance with those reported by Chaudhary *et al.* (2014).

The maximum protein content in grain (25.4%) was recorded with higher residual dose of P (90 kg P_2O_5/ha) and minimum under control (Table 3). This might be due to increased N content with concomitant application of P in grain leading to higher protein. The increase in N content in legumes may be due to more fixation of molecular di-nitrogen by symbiotic bacteria. Similar results have been reported by Singh *et al.* (2014). This increase in protein yield with P addition may be attributed to increased grain yield and protein content in grain (Singh and Singh 2015). The maximum protein content in grain was recorded under 6 kg Zn/ ha applied in preceding wheat crop. Protein yield is the function of protein content and grain yield since variation in protein content has genetic and biochemical limitations, the protein yield is more influenced by grain yield and thus followed almost trend similar to grain yield. Singh and Singh (2015) also reported similar results.

The uptake of N by grain and straw of greengram increased significantly with residual P levels applied in preceding wheat crop (Table 4). The magnitude of increase in P uptake by grain and straw with 60 kg P_2O_5 / ha was 19.0 and 17.6 % over control, respectively. Similar results were reported by Singh *et al.* (2014) in mungbean. The uptake of N by greengram grain and straw was significantly affected by the residual effect of zinc application in wheat, on an average, N uptake by grain and straw increased with 6 kg Zn/ ha applied in preceding crop by 16.4 and 13.0 %, respectively over the control. The maximum values of P uptake by grain (15.8 kg/ha) and straw (5.7 kg/ha) were recorded with residual effect of 90 kg P_2O_5/ha (Table 4). The response of greengram crop to applied P in preceding wheat crop may be attributed to an enhanced availability of P in soil at a level below which the optimum requirement of the crop is fulfilled (Singh *et al.* 2014). The uptake of P by grain and straw of greengram increased with the application of 4 kg Zn/ ha in preceding wheat crop over the control, followed by a reduction in P uptake at higher residual level of Zn. Owing to the antagonistic relationship of Zn and P, reduction in P uptake was recorded with the application of zinc.

Available nutrients in soil

Application of P in wheat crop improved the available P status of the soil after the harvest of crop in wheat-green gram sequence (Table 4). The available P content in post harvest soil ranged from 7.5 to 15.8 kg/ha with 90 kg P_2O_5/ha application. Available P remained much higher than the initial value (8 kg/ ha) at higher level of P. This is due to the fact that the uptake of P by wheat and green gram crop was much lower compared to the amount of P applied. The status of available P in control was 7.5 kg/ ha as against the initial value of 8.0 kg/ha. Similar results were reported by Singh *et al.* (2014). Available P content of post harvest soil increased markedly with the application of Zn. The maximum value of available P (12.8 kg/ha) was recorded with 4 kg Zn/ha followed by a reduction at higher level of zinc. The minimum value of available Zn status in post harvest soil was recorded in control, which may be

Table 4 Residual Effect of P and Zn levels on uptake of nutrients by succeeding wheat crop and available P and Zn in soil (mean of 2 years)

Treatment	N (kg/ha)		P (kg/ha)		Zn (g/ha)		After harvest of green gram crop	
	Grain	Straw	Grain	Straw	Grain	Straw	Available P (kg/ha)	DTPA-Zn (mg/kg)
Phosphorus (kg P_2O_5/ha)								
0	36.7	13.0	4.3	2.1	29.4	36.9	7.5	0.55
30	40.5	14.2	4.8	2.4	33.1	41.3	10.0	0.57
60	43.7	15.3	5.4	2.8	35.6	44.8	13.2	0.58
90	44.7	15.8	5.7	2.7	35.4	44.3	15.8	0.58
LSD (P = 0.05)	2.04	1.01	0.48	0.29	1.39	1.10	1.70	0.03
Zinc (kg/ha)								
0	37.8	13.8	4.9	2.5	30.5	38.7	10.4	0.49
2	40.5	14.5	5.1	2.6	33.0	41.5	10.8	0.55
4	43.0	15.0	5.3	2.8	35.1	43.6	12.8	0.60
6	44.0	15.6	5.1	2.5	34.5	44.1	12.5	0.64
LSD (P = 0.05)	2.04	1.01	0.48	0.29	1.39	1.10	1.70	0.03

ascribed to greater utilization of Zn by the crops. Phosphorus application improved the zinc content in soil as compared to control. The lowest value of available Zn (0.55 mg/kg) was recorded in control. On the other hand, the maximum value of DTPA-Zn in post harvest soil was recorded with 60 kg P_2O_5/ ha. DTPA extractable-Zn increased with increasing levels of Zn after harvest of the crops. DTPA-Zn remained much higher than the original level at higher level of Zn (Chaudhary *et al.* 2014), thus, indicating that further crops could be taken without the application of Zn.

It was concluded from the experiment that application of 60 kg P_2O_5/ha and 6 kg Zn/ha in wheat were optimum doses for obtaining higher productivity, produce quality and residual P and Zn in soil under wheat-greengram cropping sequence of Agra region.

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