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Effect of Graded Levels of Phosphorus and Zinc Fertilization on Wheat Yield and Nutrient Concentration in Different Phosphorus Status Soils

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ABSTRACT

A screen house experiment was conducted during *rabi* season of 2018-19 to find out the effect of different levels of P and Zn on wheat yield, concentration of different nutrients in grain and straw in low and high P status soil. Five levels of P (0, 30, 60, 120 and 180 mg P kg^{-1} soil) and four levels of Zn (0, 2.5, 5 and 10 mg Zn kg^{-1} soil) were applied in completely randomized design with three replications. The content of all macro and micronutrients were found higher in high P status sandy loam soil of Saniyana as compared to low P status sandy soil of Sadalpur. In low P status soil, the optimum yield of grain and straw was recorded at 30 mg P kg^{-1} + 10 mg Zn kg^{-1} level which was found at par with other higher doses of P. While in high P status soil application of Zn alone at 10 mg kg^{-1} soil was found sufficient to achieve optimum yield of grain and straw. Application of different levels of P and Zn did not significantly influence the N and K concentration in grain and straw of wheat crop in both soils. The higher mean content of P in grain and straw was recorded at 120 and 60 mg P kg^{-1}, respectively and found at par with higher dose of P. In high P status soil, the higher mean P content of grain and straw was recorded at 180 mg kg^{-1} and 60 mg kg^{-1} soil, respectively. The maximum mean Zn content in grain and straw was recorded at highest level of applied Zn in both soils. Comparatively higher grain protein content was recorded in high P status soil as compared to low P status soil. However application of P and Zn either alone or in combination had no significant influence on protein content of grain in both low P and high P status soil.

Introduction

Wheat (*Triticum aestivum* L.) is the world's most commonly consuming cereal grain crop. It is the cultural base or foundation of nourishment as it provides about 60% of proteins and 55% of the calories in the average human diet. It contains carbohydrate (60-80%), protein (approx.12%), also rich in catalytic elements, mineral salts and vitamins (B, K and E). During 2017-18, the total area, production and productivity of wheat in India were 29.65 million hectares, 99.87 million tonnes and 3368 kg ha^{-1}, respectively (Anonymous, 2021). Haryana is one of the leading wheat producing state of India and produced 10.76 million tonnes of wheat (10.77 % of total wheat production) from an area of 2.44 million hectares (8.22% of total area under wheat cultivation at national level) with productivity of 4412 kg ha^{-1} (2^{nd} highest after Punjab in India) during 2017-18. Yet, there is a wide difference between actual yield realized at farmer's field and potential yield of wheat. This gap can be bridged by maintaining deteriorating soil health through effective and judicious management of both macro and micronutrients in soil from organic and inorganic sources.

Indiscriminate and increased use of high analysis straight fertilizers in intensive cropping system, use of high yielding crop varieties, increase in cropping intensity and net negative nutrient balance leads to deficiency of not only the macronutrients (nitrogen, phosphorus and potassium), but also deficiency of micronutrients (%) in Indian soils like zinc (36.5), iron (12.8), copper (4.2), manganese (7.1) and boron (23.4) (Shukla and Behera, 2017). Phosphorus (P) is the 2^{nd} most deficient macronutrient after nitrogen in Indian soils. In India, the deficiency of P is more pronounced in northern and western part of the country and soils of 91% of Indian districts were found either low or medium in available P (Muralidharudu *et al.*, 2011). Phosphorus plays an important role in synthesis of nucleic acids, transformation of starch and sugars, promotes early root formation and auxin metabolism. In wheat crop, deficiency of P reduces plant growth (vigour), number of tillers and plant leaf area by producing smaller and less number of leaves (Sato *et al.*, 1996).

Zinc (Zn) is one of the most widespread deficient micronutrient. Nearly 36.5% of Indian soils and 15.4% of Haryana soils are deficient in Zn (Shukla and Behera, 2017). Deficiency of Zn reduces the photosynthetic rate, chlorophyll content, activity of carbonic anhydrase and protein biosynthesis (Cakmak, 2008 and Fu *et al.*, 2016). The most characteristics symptoms of Zn deficiency in wheat plant are reduction in plant height, leaf area, number of tillers and development of whitish-brown necrotic spots on middle-aged leaves. Therefore, when the supply of plant-available zinc is insufficient, crops yield reduced and the growth period is prolonged resulting in delayed maturity.

Phosphorus and zinc are known to occur in soil in different forms differing in their solubility and thus their availability to plants. The amount of available P and Zn depends upon soil texture, pH, organic matter content and sesquioxides. Application of higher doses of phosphatic fertilizers increases the severity of Zn deficiency in soil (Norvell *et al.*, 1987) and also increased level of P interferes with plant metabolism involving plant uptake and utilization of Zn (Haldar and Mandal, 1981), resulting in metabolic disorders within plant cells. Improper use of P and Zn has become a major constraint to production and productivity of cereals or more specifically of wheat. Hence, judicious use of these two most widespread deficient nutrient elements is the need of hour for sustaining the productivity. Therefore, the present study was carried out to find the optimum level of phosphorus and zinc and their interaction for better wheat growth, yield and higher nutrient content in grain and straw of wheat crop in different P status soils of Haryana.

Materials and Methods

Experimental site

The screen house experiment was conducted at department of soil science, CCS HAU, Hisar during *rabi* season of 2018-19 by using wheat as a test crop. For this experiment two different soils, one was low in available P (from village Sadalpur, Hisar, Haryana) and another was high in available P (from village Saniyana, Fatehabad, Haryana) were brought from farmer's field and these soils were used in pot filling.

Experimental design and materials used

The experiment was laid out in completely randomized design with three replications. Five different levels of phosphorus (0, 30, 60, 120 and 180 mg P kg^{-1} soil) was applied through KH_2PO_4 and four levels of zinc (0, 2.5, 5 and 10 mg Zn kg^{-1}) were applied by using $ZnSO_4.7H_2O$ as source of Zn to both soils. Thus, total 120 pots (each pot having four kg soils) were filled and placed in the screen house. The treatments of P and Zn were applied at the time of sowing along with recommended basal dose of nitrogen (through urea). Ten wheat seeds were sown in each pot during second fortnight of November, after germination thinning of wheat plants was done and four healthy plants were left in each pot. Rest of the agronomic practices kept normal and uniform and the plants were allowed to grow up to maturity and the crop was harvested in first week of April.

Initial soil analysis

The processed samples of both the soils were used for the determination of selected physico-chemical properties of the soil. The analytical methods used for various soil parameters are given in Table 1.

Plant analysis

After harvesting of crop, grain and straw yield from each pot was recorded separately and these samples were further used for determination of N, P, K and Zn content in grain and straw by using following methods as given in Table 2:

Protein content (%)

The protein content (%) in grain was calculated by multiplying the nitrogen content in grain by factor of 6.25.

Protein (%) = N (%) in grain x 6.25

Statistical analysis

The data generated through this experiment was subjected to statistical analysis for significance at 0.05 using OPSTAT software.

Results and Discussion

Initial physico-chemical properties of soils

In general, the content of all macro and micronutrients were found higher in high P status Saniyana soil as compared to low P status Sadalpur soil. The texture of low available P statussoil was sand (92% sand, 4% silt and 4% clay). The pH, EC, OC and CEC of this soil was 7.4, 0.12 dS m^{-1}, 0.15% and 4.46 cmol (p^{+}) Kg^{-1}, respectively. Available N, P and K content of the soil was 28, 8 and 112 kg ha^{-1}, respectively and the DTPA-extractable Zn, Fe, Cu and Mn were found 0.3, 2.11, 1.94 and 2.48 mg kg^{-1}, respectively. On the other side the texture of high available P status Saniyana soil was sandy loam (60% sand, 24% silt and 16% clay). The pH, EC, OC and CEC of the soil was 7.1, 1.0 dS m^{-1}, 0.62% and 9.28 cmol (p^{+}) Kg^{-1}, respectively. The available N, P and K content of the soil was 182, 25 and 430 kg ha^{-1}, respectively and DTPA-extractable Zn, Fe, Cu and Mn were found to be 0.72, 18.74, 3.08 and 10.26 mg kg^{-1}, respectively.

Grain and straw yield of wheat crop

The result presented in Table 2 indicated that application of P and Zn dosage rate synergistically affected grain and straw yield of wheat crop. It was recorded that the average grain yield of wheat in low P status soil increased from 6.96 to 7.42 and 6.66 to 7.63 g pot^{-1} over control (4.36 and 5.50 g pot^{-1}) with the application of P and Zn, respectively. Whereas, the average straw yield of wheat increased from 9.53 to 10.01 and 8.98 to 9.88 g pot^{-1} over control (5.52 and 7.65 g/pot with the application of P and Zn, respectively.

Application of 30 mg P kg^{-1}along with 10 mg Zn kg^{-1}was found optimum fertiliser dose for higher grain (7.84 g pot^{-1}) and straw yield (10.11 g pot^{-1}) of wheat crop in low P status soil. Data given in Table 4.3 revealed that in high P status soil, application of graded level of P alone or in combination with different levels of Zn did not have any significant effect on grain and straw yield of wheat crop. Application of Zn alone had significant effect on grain and straw yield of wheat crop.

In case of Zn treatments, the maximum mean grain yield (8.23 g pot^{-1}) and straw (10.70 g pot^{-1}) was obtained at highest dose of Zn *i.e.* 10 mg kg^{-1} level. The results of grain and straw yield at different levels of P and Zn is in agreement with the findings of Jain and Dahama (2006), Arshad *et al.,* (2016) and Mishra *et al.,* (2017).

Table.1 Methods followed for initial soil analysis

Soil properties	**Method used**	**References**
Soil texture	International pipette method	Piper (1966)
pH (1:2)	Glass electrode pH meter	Jackson (1973)
EC (dS m^{-1})	Conductivity bridge meter	Richard (1954)
Organic carbon (%)	Wet digestion method	Walkley and Black(1934)
Cation exchange capacity [(cmol (p^{+}) kg^{-1})]		Hesse(1971)
Available nutrients		
Nitrogen	Kjeldhal method	Subbiah and Asija(1956)
Phosphorus	Olsen method	Olsen *et al*.(1954)
Potassium	Flame photometry method	Jackson(1958)
Zn, Fe, Mn and Cu	DTPA extractable method	Lindsay and Norvell(1978)

Table.2 Methods followed for plant analysis

Nutrient	**Method used**	**References**
Nitrogen	Colorimetric method	Lindner (1944)
Phosphorus	Vanadomolybdo phosphoric acid yellow colour method	Koenig and Johnson (1942)
Potassium	Flame photometer method	Jackson (1958)
Zinc	Atomic absorption spectrophotometer	Model: Varian AA240z

Table.3 Effect of P and Zn on grain and straw yield (g pot^{-1}) of wheat in low P status soil

P levels (mg kg^{-1})	Zn levels (mg kg^{-1})				Mean
	0	**2.5**	**5**	**10**	
Grain					
0	0.50	4.50	6.20	6.70	4.36
30	6.57	6.64	6.80	7.84	6.96
60	6.80	7.37	7.52	7.86	7.39
120	6.80	7.38	7.55	7.86	7.40
180	6.82	7.42	7.56	7.87	7.42
Mean	5.50	6.66	7.04	7.63	
CD (p=0.05)	P-0.47 Zn-0.40 PxZn-0.90				
Straw					
0	0.66	5.93	7.26	8.22	5.52
30	9.26	9.36	9.40	10.11	9.53
60	9.36	9.53	9.99	10.33	9.80
120	9.38	10.02	10.04	10.41	9.96
180	9.57	10.05	10.10	10.31	10.01
Mean	7.65	8.98	9.36	9.88	
CD (p=0.05)	P-0.50 Zn-0.45 PxZn-1.00				

Table.4 Effect of P and Zn on grain and straw yield (g pot^{-1}) of wheat in high P status soil

P levels (mg kg^{-1})	Zn levels (mg kg^{-1})				Mean
	0	**2.5**	**5**	**10**	
Grain					
0	5.40	6.36	7.26	8.20	6.81
30	6.10	6.40	7.26	8.22	6.99
60	6.12	6.62	7.30	8.23	7.07
120	6.13	6.68	7.31	8.24	7.09
180	6.14	6.70	7.31	8.24	7.10
Mean	5.98	6.55	7.29	8.23	
CD (p=0.05)	P- NS Zn-0.53 PxZn- NS				
Straw					
0	6.85	8.20	9.07	10.16	8.57
30	7.55	8.09	9.39	10.87	8.98
60	8.35	8.61	9.49	11.53	9.50
120	7.70	8.33	9.42	10.45	8.98
180	7.77	8.51	9.42	10.50	9.05
Mean	7.64	8.35	9.36	10.70	
CD (p=0.05)	P-NS Zn-0.68 PxZn-NS				

Table.5 Effect of P and Zn on the phosphorus content (%) in wheat grain and straw in low P status soil

P levels (mg kg^{-1})	Zn levels (mg kg^{-1})				Mean
	0	2.5	5	10	
Grain					
0	0.22	0.26	0.26	0.28	0.25
30	0.26	0.26	0.28	0.28	0.27
60	0.27	0.27	0.31	0.29	0.29
120	0.29	0.30	0.31	0.30	0.30
180	0.34	0.32	0.31	0.31	0.32
Mean	0.28	0.28	0.29	0.29	
CD (p=0.05)	P-0.02	Zn-NS	PxZn-NS		
Straw					
0	0.019	0.023	0.022	0.023	0.022
30	0.022	0.024	0.023	0.023	0.023
60	0.024	0.027	0.028	0.025	0.026
120	0.026	0.027	0.027	0.026	0.027
180	0.03	0.028	0.026	0.026	0.028
Mean	0.024	0.026	0.025	0.025	
CD (p=0.05)	P-0.002	Zn-NS	PxZn-NS		

Table.6 Effect of P and Zn on the phosphorus content (%) in wheat grain and straw in high P status soil

P levels (mg kg^{-1})	Zn levels (mg kg^{-1})				Mean
	0	2.5	5	10	
Grain					
0	0.25	0.29	0.29	0.31	0.29
30	0.29	0.29	0.31	0.31	0.30
60	0.30	0.32	0.34	0.33	0.32
120	0.33	0.35	0.35	0.34	0.34
180	0.40	0.36	0.35	0.35	0.37
Mean	0.31	0.32	0.33	0.33	
CD (p=0.05)	P-0.02	Zn-NS	PxZn-NS		
Straw					
0	0.023	0.027	0.026	0.027	0.026
30	0.026	0.028	0.027	0.027	0.027
60	0.028	0.031	0.032	0.029	0.030
120	0.030	0.031	0.031	0.030	0.030
180	0.034	0.032	0.030	0.030	0.032
Mean	0.028	0.030	0.029	0.029	
CD (p=0.05)	P-0.002	Zn-NS	PxZn-NS		

Table.7 Effect of P and Zn on the zinc content (mg kg^{-1}) in wheat grain and straw in low P status soil

P levels (mg kg^{-1})	Zn levels (mg kg^{-1})				Mean
	0	**2.5**	**5**	**10**	
Grain					
0	20.40	21.78	22.31	25.07	22.39
30	19.56	21.42	22.28	23.59	21.71
60	19.59	20.24	22.87	23.21	21.48
120	19.18	20.74	22.31	24.81	21.76
180	19.05	20.00	22.95	24.11	21.53
Mean	19.56	20.84	22.54	24.16	
CD (p=0.05)	P-NS Zn-1.31 PxZn-NS				
Straw					
0	9.98	11.97	12.19	14.09	12.06
30	9.67	11.69	12.05	12.62	11.51
60	9.78	11.11	12.08	12.51	11.37
120	9.70	11.01	12.00	12.33	11.26
180	9.73	11.18	11.95	12.24	11.28
Mean	9.77	11.39	12.06	12.76	
CD (p=0.05)	P-NS Zn-0.53 PxZn-NS				

Table.8 Effect of P and Zn on the zinc content (mg kg^{-1}) in wheat grain and straw in high P status soil

P levels (mg kg^{-1})	Zn levels (mg kg^{-1})				Mean
	0	**2.5**	**5**	**10**	
Grain					
0	23.78	25.16	26.12	28.88	25.99
30	23.07	24.93	26.39	27.70	25.52
60	23.40	24.05	26.68	27.02	25.29
120	22.99	24.55	26.12	28.62	25.57
180	22.86	23.81	26.76	27.92	25.34
Mean	23.22	24.50	26.41	28.03	
CD (p=0.05)	P- NS Zn- 1.74 PxZn- NS				
Straw					
0	11.23	13.22	13.44	15.34	13.31
30	10.92	12.94	13.30	13.87	12.76
60	11.03	12.36	13.33	13.76	12.62
120	10.95	12.26	13.25	13.58	12.51
180	10.98	12.43	13.20	13.49	12.53
Mean	11.02	12.64	13.30	14.01	
CD (p=0.05)	P- NS Zn- 0.77 PxZn- NS				

Table.9 Effect of P and Zn on the protein content (%) of wheat grain in low and high P status soil

P levels (mg kg^{-1})	Zn levels (mg kg^{-1})				Mean
	0	2.5	5	10	
Low P status soil					
0	6.81	7.14	6.93	6.88	6.94
30	6.94	7.15	6.88	7.03	7.00
60	6.85	6.50	6.87	7.72	6.98
120	7.48	6.46	7.02	7.47	7.11
180	7.21	6.91	7.49	7.18	7.20
Mean	7.06	6.83	7.04	7.26	
CD (p=0.05)	P-NS Zn-NSPxZn-NS				
High P status soil					
0	9.31	9.73	10.00	9.69	9.68
30	10.59	10.34	9.53	10.63	10.27
60	10.16	9.99	9.96	10.34	10.11
120	10.26	10.73	9.96	10.74	10.42
180	10.20	10.29	10.09	8.92	9.88
Mean	10.11	10.22	9.91	10.06	
CD (p=0.05)	P-NS Zn-NS PxZn-NS				

Plant analysis

N, P, K and Zn concentration in grain and straw of wheat crop

The N and K content in grain and straw of wheat crop was found slightly higher in high P status soil as compared to low P status soil. Whereas application of different levels of P and Zn had non-significant effect on N and K concentration of grain and straw obtained from both soils.

Application of Zn either alone or in combination with different levels of P did not have any significant effect on P content in grain and straw of both types of soils. Increasing level of P in low P status soil from 0 to 180 mg kg^{-1} significantly increased the mean P content from 0.25 to 0.32 % in grain and from 0.022 to 0.028% in straw. The maximum mean content of P in grain (0.32%) was recorded at highest level of P *i.e.* 180 mg kg^{-1} which was found statistically at par to 120 mg P kg^{-1} level. Similarly in straw also, maximum mean content (0.028%) was recorded at highest level of P which was proved statistically par with 60 and 120 mg P kg^{-1} level.

In high P status soil, the mean P content of grain and straw increased significantly from 0.29 to 0.37% and 0.026 to 0.032%, respectively with the increasing level of P from 0 to 180 mg kg^{-1}. The maximum mean P content in grain (0.37%) and straw (0.032%) was also recorded at highest dose of P *i.e.* 180 mg P kg^{-1}.

It is evident from zinc concentration data (Table 7 & 8) that application of different level of P either alone or in combination with Zn did not have any significant effect on Zn content of grain and straw. In low P status soil, increasing level of Zn form 0 to 10 mg kg^{-1} increased the average Zn content from

19.56 to 24.16 mg kg^{-1} in grain and from 9.77 to 12.76 mg kg^{-1} in straw. The maximum mean content of Zn in grain (24.16 mg kg^{-1}) and straw (12.76 mg kg^{-1}) was recorded in treatment receiving highest dose of Zn.

Similarly, in high P status soil, the mean Zn content in grain and straw also increased from 23.22 to 28.03 mg kg^{-1} and 11.02 to 14.01 mg kg^{-1} with increasing level of Zn from 0 to 10 mg kg^{-1}(Table 8). The maximum mean content of Zn in grain (28.03 mg kg^{-1}) and straw (14.01 mg kg^{-1}) was recorded at highest level of Zn and found at par with Zn applied at 5 mg kg^{-1} soil.

Protein content (%)

The application of P and Zn either alone or in combination had no significant influence on protein content of grain and straw in both low P and high P status soils (Table 9). However, comparatively high content of protein was recorded in grain than straw in both types of soil. Similar findings were also reported by Zhu *et al.,* (2012).

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