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Research Paper

Studies on impact of phosphoenriched compost, chemical fertilizer and method of zinc application on yield, uptake and quality of maize (*Zea mays*)

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ABSTRACT

A field experiment was conducted during the rainy (*kharif*) seasons of 2012 and 2013 at New Delhi to examine the effect of phosphorus (P) sources and zinc (Zn) application on yield, uptake and quality of maize (*Zea mays* L.). Application of P_{50}-phosphoenriched compost (PEC) + P_{50}-fertilizer (F) recorded higher yield attributes, grain yield (4.3 t/ha) and protein (9.2%) with amino acids content in grain. The P_{50}- PEC + P_{50}- F recorded higher P, Zn and Fe uptake in grain, stover and total (grain + stover) than the control. The application of 12.5 kg/ha of $ZnSO_4$ + 1 foliar spray of $ZnSO_4$ @ 0.5% recorded the highest values of yield attributes and grain yield (4.2 t/ha) of maize. The P and Zn uptake in grain and stover were found highest in soil + foliar-applied plots. The higher Fe uptake in grain was found with 2 foliar sprays of Zn. The higher crude protein (9%) and amino acids were found in 25 kg/ha of $ZnSO_4$ and it was on a par with soil + foliar application of Zn. Overall, combined application of PEC and chemical fertilizer with soil + foliar application of Zn proved promising in for higher yield with increased tissue uptake of nutrients and for higher protein and amino acids content in grain.

***Key words* :** Amino Acids, Nutrient Uptake, Phosphorus, Phosphoenriched Compost, Protein, Zinc

Maize crop regarded as a queen of cereals occupies a pride place among rainy season (*kharif*) crops in India and contributes around 24% of total cereal production (Singh *et al*., 2011). It is the principal crop of *kharif* season in northern hills of the country but plains of northern states like Uttar Pradesh, Rajasthan, Madhya Pradesh and Bihar also have sizeable acreage under this crop. Maize, a crop with high yield and market potential, fits well into rice–wheat systems by replacing rice (Srinivasan *et al.*, 2004).

Phosphorus (P) is a limiting factor to plant growth and productivity and its uptake in plants is often constrained by the very low solubility of P in the soil. In agricultural systems, phosphorus in the harvested crops is removed from the system, resulting in P deprived soils if no P is supplemented as fertilizer (Mallarino, 2008). Plants that are deficient in phosphorus experience restricted growth and development due to inadequate energy. Phosphorus is essential in DNA and RNA, the genetic code needed to produce protein, seed and genetic transfer, promotes root proliferation that increases root volume and improves soil nutrient exploration and improves fruit, forage, vegetable and grain quality of crops (IPNI, 2011).

The regions with Zn-deficient soils are also the regions where Zn deficiency in human beings is widespread, for example in India, Pakistan, China, Iran and Turkey (Hotz and Brown, 2004). Low solubility of Zn in soils rather than low total amount of Zn is the major reason for the widespread occurrence of Zn-deficiency problem in crop plants. Phosphorus is the most important element which interferes on zinc uptake by plants. Numerous studies have been done about the interaction of zinc and phosphorus and all confirms that zinc and phosphorus imbalance in the plant, as a result excessive accumulation of phosphorus, causing zinc imposed deficiency (Salimpour *et al*., 2010).

There is increasing evidence showing that foliar or combined soil + foliar application of zinc fertilizers under field conditions are highly effective and very practical way to maximize uptake and accumulation of zinc in plants . Agronomic biofortification strategy appears to be essential in keeping sufficient amount of available zinc in soil solution and maintaining adequate zinc transport to the seeds during reproductive growth stage. Finally, agronomic

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biofortification is required for optimizing and ensuring the success of genetic biofortification of cereal grains with zinc. In case of greater bioavailability of the grain zinc derived from foliar applications than from soil, agronomic biofortification would be a very attractive and useful strategy in solving zinc deficiency (Cakmak, 2008). Keeping the above facts in view an experiment was conducted to investigate the effect of various sources and combinations of P sources, dose and methods of Zn application in maize on productivity and quality.

MATERIALS AND METHODS

The field experiment was conducted during the rainy season of 2012 and 2013 at the Indian Agricultural Research Institute, New Delhi, (28.4^{o}N, 77.1^{o}E and 228.6 above mean sea-level). The maximum and minimum temperatures recorded in 2012 were 34.8^o C and 19.2^{o}C and in 2013 were 36.2^{o}C and 21.7^{o}C respectively. The crop received 612 and 957 mm rain in 15 and 37 rainy days during 2012 and 2013 respectively. The pH of soil was 7.9 with sandy clay loam texture, the soil is low in available N (168.3 kg/ha), medium in available P (11.9 kg/ha) and available K (241.5 kg/ha) along with 0.68 mg DTPA-extractable available Zn per kg of soil. The experiment was conducted in a split-plot design with 3 replications. The main plots comprised 5 levels of phosphorus, viz. control, recommended dose of fertilizer (RDF), 100% P through phospho-enriched compost (P_{100}-PEC), 50% P through PEC+ 50% P through fertilizer (P_{50}-PEC+ P_{50}-F) and 75% P through PEC + vesicular arbuscular mycorhiza (VAM) + phosphorus solubilising bacteria (PSB) (P_{75}-PEC + VAM + PSB). Subplot consisted of 4 levels of Zn application, viz. control, 25 kg/ha soil application (25 kg/ha-soil), 2 foliar spray @ 0.5% at tasseling and silking stage (0.5%–2 FS), 12.5 kg soil + 1 foliar spray @ 0.5% at silking stage (12.5 kg soil + 0.5% 1 FS). Sowing of maize 'PEHM 2' was done in rows at 60 cm with 30 cm plant-to-plant spacing. All other recommended practices were followed during crop growing season. The recommended doses of fertilizers 120, 60 and 40 kg N, P_2O_5 and K_2O/ha were applied to maize. The phospho-enriched compost (PEC) applied at the time of sowing as per treatment. The PEC contains about 0.8% N, 1.2% available P_2O_5 and 0.6% of available K_2O. The N and K doses were adjusted by substracting nutrient supply by PEC and remaining N, P and K were compensated in the form of urea, diammonium phosphate and muriate of potash respectively.

Yield attributes of maize were recorded from the representative samples taken from each plot. The grain and stover yields were recorded by weight of produce in plot wise. The concentrations of P, Zn and Fe in plant samples were estimated by vanadomolybdophosphoric acid yellow colour method, di-acid digestion method and DTPA-extractable methods. Similarly, the P, Zn and Fe uptake by maize was determined by multiplying dry-matter accumulation with their respective concentrations in grain and stover of maize. Grain protein content was also measured using Kejeldahl-N (AOAC, 1975). The amino acid composition such as tryptophan content, lysine and methionine content was determined by the method of Spies and Chamber (1949), Felker *et al*. (1978) and Horn *et al*. (1940) respectively. The data recorded for different parameters were analysed with the help of analysis of variance (ANOVA) technique for a splitplot design using MSTAT-C software. The results are presented at 5 % level of significance (P=0.05).

RESULTS AND DISCUSSION

Yield and yield attributes

Significantly higher cob weight, grains/cob, rows/cob, cob length, 1,000-seed weight, shelling percentage, cob girth, grain and stover yield were recorded with P_{50}-PEC+ P_{50}-F during (Table 1). It was mainly owing to balanced and continuous supply of macro and micro nutrients from PEC throughout the growing period and ready availability of P through chemical fertilizers (Table 1). This is because of positive increase associated with integrated phosphorus management on the yield components and improved bioavailability of residual soil phosphorus. Garg and Bahl (2008) also reported similar results.

Among different Zn levels, the 25 kg/ha-soil has recorded significantly higher cob length, cob weight/plant, 1,000-seed weight, rows/cob, grains/cob, shelling percentage cob girth, grain and stover yield and it was at par with 12.5 kg soil + 0.5% 1 FS. The increase in yield parameters might be owing to involvement of zinc in various enzymatic processes which helps in catalyzing reaction for growth finally leading to development of superior yield-attributing characters. The results confirm the findings of Jakhar *et al*. (2006). The increase in yield could be attributed to the proper supply of Zn up to harvesting stages in soil + foliar applied plots and which might have led to increased photosynthetic activity for longer period and their beneficial effect on metabolism of plants thereby finally increased dry-matter accumulation. These results are in accordance with Hussain and Yasin (2004).

The overall performance of yield and yield attributes were better during the second year than the first year because the most important weather parameters, i.e. number of rainy days were 37 and total quantity of rainfall received was 957 mm which helped in better crop growth that ultimately reflected in the yield of crop.

Table 1. Influence of integrated phosphorous management and zinc application on yield and yield attributes of maize (pooled data of 2 years)

Treatment	Cob length (cm)	Cob weight (g)	Test weight (g)	Rows/ cob	Grains/ cob	Shelling (%)	Cob girth (cm)	Grain yield (t/ha)	Stover yield (t/ha)
Phosphorus level									
Control	9.8	88	213	11	329	70.6	11.7	3.6	5.5
RDF (NPK)	12.1	95	212	12	337	69.4	11.6	3.8	6.1
P_{100}-PEC	13.3	101	224	13	356	72.7	13.5	4.1	6.4
P_{50}-PEC+ P_{50}-F	14.9	106	237	14	371	78.1	14.4	4.3	6.9
P_{75}-PEC + VAM + PSB	13.0	101	218	12	356	73.3	13.1	4.1	6.6
SEm±	0.3	1	2	0.4	1	1.0	0.4	0.04	0.1
CD (P=0.05)	0.9	3	6	1.2	4	3.1	1.4	0.13	0.2
Application of $ZnSO_4.7H_2O$									
Control	11.1	90	210	11	341	69.7	11.4	3.7	5.8
25 kg-Soil	13.8	105	233	14	362	75.6	13.8	4.2	6.6
0.5%- 2 FS**	11.9	93	214	12	343	69.1	12.4	3.8	6.1
12.5 kg Soil+0.5 % 1 FS*	13.7	105	227	14	354	76.9	13.8	4.2	6.6
SEm±	0.5	1	3	0.5	3	1.3	0.5	0.1	0.1
CD (P=0.05)	1.4	4	9	1.5	9	3.7	1.5	0.2	0.3

RDF, Recommended dose of fertilizer; PEC, phospho-enriched compost; VAM, vesicular arbuscular mycorhiza; PSB, phosphorus-solubilizing bacteria; FS, foliar spray

**Two foliar sprays at tasseling and silking stage; *1 foliar spray at silking stage

Phosphorus, zinc and iron uptake in maize

The significantly higher P uptake in grain, stover and total (grain + stover) by maize was recorded with P_{50}-PEC+ P_{50}-F and it was significantly superior to the control and RDP through chemical fertilizers (Table 2). This might be owing to better availability and consistent supply of P from PEC and chemical fertilizer up to harvest and increased microbial activity in soil may helped increase the P uptake and led to increased concentration in grain and stover. These results confirm the findings of Xu *et al*. (2008) and Beri *et al*. (2002), who reported that the addition of triple superphosphate in combination with organic fertilizer resulted in highly positive effect on phosphorus uptake. Significantly higher P uptake in grain, stover and total (grain + stover) was recorded with 12.5 kg soil + 0.5% 1 FS over the control. Soil zinc application increases the nitrogen and phosphorus concentration but at higher level of zinc application reduces the concentration of phosphorus in plants. Foliar application of $ZnSO_4$ increased phosphorus absorption by plants (Bukvic *et al.*, 2003).

Table 2. Influence of integrated phosphorous management and zinc application on phosphorus (P) uptake by maize (pooled data of 2 years)

Treatment	Grain P (kg/ha)	Stover P (kg/ha)	Total P (kg/ha)
Phosphorus level			
Control	9.6	10.6	20.2
RDF (NPK)	11.7	13.4	25.2
P_{100}-PEC	14.0	16.5	30.5
P_{50}-PEC+ P_{50}-F	15.0	17.0	32.0
P_{75}-PEC+VAM+PSB	13.7	15.7	29.3
SEm±	0.3	0.4	0.6
CD (P=0.05)	1.1	1.3	2.1
Application of $ZnSO_4.7H_2O$			
Control	12.2	13.7	25.8
25 kg-Soil	12.6	14.0	26.6
0.5%- 2 FS**	12.7	15.3	28.0
12.5 kg Soil+0.5 % 1 FS*	13.8	15.5	29.3
SEm±	0.4	0.5	0.8
CD (P=0.05)	1.1	1.4	2.3

RDF, Recommended dose of fertilizer; PEC, phospho-enriched compost; VAM, vesicular arbuscular mycorhiza; PSB, phosphorus-solubilizing bacteria; FS, foliar spray

**Two foliar sprays at tasseling and silking stage; *1 foliar spray at silking stage

The Zn uptake in grain, stover and total by maize was significantly higher in P_{50}-PEC+ P_{50}-F over all other treatments (Table 3). The result clearly indicates that decreased Zn uptake in grain and stover was seen wherever the P was supplied through chemical fertilizer alone, which may occurs due to dilution effect (Ryan *et al.*, 2008). The higher Zn uptake in PEC and in combined chemical fertilizers and PEC plots might be due to reduced antagonistic effect of P to Zn when organic P was applied. These results support the work of Nayak and Gupta (1995). Significantly higher Zn uptake in grain was obtained with 12.5 kg soil + 0.5% 1 FS and it was found at par with 0.5%- 2 FS. Significantly superior stover and total uptake of Zn was observed with 12.5 kg soil + 0.5% 1 FS. Thus, foliar application is very fast method for providing required amount of Zn in plants because it absorbed quickly through leaves as compared to uptake from soil through plant roots (Maralian, 2009). Zakaria *et al*. (1997) reported zinc uptake by cotton increased by application of biological phosphorus fertilizers and zinc foliar application.

The highest Fe uptake in grain, stover and total of maize was recorded with P_{50}-PEC+ P_{50}-F over all other treatments (Table 3). However, for Fe uptake in grain it was at par with P_{100}-PEC. It proves that, there was an antagonistic effect of P on Fe concentration in grain and stover in maize. The sole application of RDP through fertilizer P reduced Fe concentration significantly and recorded lower total uptake of Fe. The higher uptake of Fe in P plots over the control plot is because of higher dry-matter production by P application. Significantly higher Fe uptake in grain by maize was obtained with 0.5%- 2 FS and it was at par with 12.5 kg soil + 0.5% 1 FS. The significantly higher stover uptake of Fe and total (grain+straw) was observed with 12.5 kg soil + 0.5% 1 FS. Hence, soil application of Zn have considerable antagonistic effect on Fe uptake in grain and stover. It may get accumulated in the roots or zinc might reduce the Fe translocation from root to shoot or may reduce the uptake form soil itself (Haldar and Mandal, 1981; Abbas *et al*., 2009).

Protein and amino acids

The P fertilization significantly affected the protein content, protein yield, lysine, methionine and tryptophan content (Table 4). The significantly higher protein content, protein yield, lysine, methionine and tryptophan content were seen with P_{50}-PEC+ P_{50}-F and significantly lower values were noticed in the control. This might be due to the effect of increased P concentration in soil, which in turn led to higher root activity and it may increased the absorption and assimilation of 'N' by plants (Harper and Paulsen, 1969) and encouraged the translocation of 'N' from vegetation to grain which might indirectly affect protein concentration. The results are in agreement with the findings of Mosolov and Volleidt (1962).

Among zinc levels, 25 kg $ZnSO_4$/ha-soil has recorded significantly higher protein, protein yield, lysine, methionine and tryptophan content, but it was at par with 12.5 kg soil + 0.5 % 1 FS and the lower protein, protein yield, lysine methionine and tryptophan was found in the control plots. It is well known that zinc is actively involved in protein synthesis of plants, as Zn is an important structural component of the protein synthesis machinery and is involved in the form of zinc mottifs in protein synthesis of plant. Jhaw (1991) reported similar results.

The amino acid composition of the whole maize flour such as lysine, tryptophan and methionine content were significantly affected by P and Zn application during both the years (Table 4). The increase in the amount of amino acids owing to P and Zn may be ascribed to the fact that both these minerals play a vital role in protein synthesis during the grain-filling stages in the maize crop and indirectly enhance the availability of nitrogen to the plants.

Table 3. Influence of integrated phosphorous management and zinc application on zinc (Zn) and iron (Fe) uptake by maize (pooled data of 2 years)

Treatment	Grain Zn (g/ha)	Stover Zn (g/ha)	Total Zn (g/ha)	Grain Fe (g/ha)	Stover Fe (g/ha)	Total Fe (g/ha)
Phosphorus level						
Control	80	547	627	50	838	888
RDF (NPK)	78	601	679	46	917	963
P_{100}-PEC	93	647	740	56	979	1035
P_{50}-PEC+ P_{50}-F	100	687	787	60	1051	1110
P_{75}-PEC+VAM+PSB	93	646	740	55	998	1052
SEm±	2	7	7	1	11	11
CD (P=0.05)	5	22	23	4	34	36
Application of $ZnSO_4.7H_2O$						
Control	67	550	617	50	889	939
25 kg-Soil	91	657	747	43	975	1018
0.5%- 2 FS**	97	632	729	61	954	1015
12.5 kg Soil+0.5 % 1 FS*	101	664	764	58	1008	1066
SEm±	2	9	10	2	13	14
CD (P=0.05)	7	27	28	6	38	39

RDF, Recommended dose of fertilizer; PEC, phospho-enriched compost; VAM, vesicular arbuscular mycorhiza; PSB, phosphorus-solubilizing bacteria; FS, foliar spray

**Two foliar sprays at tasseling and silking stage; *1 foliar spray at silking stage

Table 4. Influence of integrated phosphorous management and zinc application crude protein and amino acid content in maize grain (pooled data of 2 years)

Treatment	Crude protein (%)	Crude protein yield (kg/ha)	Lysine (%)	Methionine (%)	Tryptophan (%)
Phosphorus level					
Control	8.2	292	2.14	1.73	2.11
RDF (NPK)	8.6	327	2.25	1.83	2.21
P_{100}-PEC	8.7	356	2.42	2.06	2.53
P_{50}-PEC+ P_{50}-F	9.2	399	2.51	2.14	2.57
P_{75}-PEC+VAM+PSB	8.8	360	2.38	1.93	2.35
SEm±	0.1	6	0.02	0.01	0.01
CD (P=0.05)	0.3	18	0.05	0.03	0.04
Application of $ZnSO_4.7H_2O$					
Control	8.3	305	2.19	1.82	2.05
25 kg-Soil	9.0	379	2.45	2.03	2.52
0.5%- 2 FS**	8.5	323	2.28	1.89	2.37
12.5 kg Soil+0.5 % 1 FS*	9.0	379	2.43	2.01	2.48
SEm±	0.1	6	0.03	0.02	0.02
CD (P=0.05)	0.2	17	0.08	0.06	0.07

**Two foliar sprays at tasseling and silking stage; *1 foliar spray at silking stage
RDF, Recommended dose of fertilizer; PEC, phospho-enriched compost; VAM, vesicular arbuscular mycorhiza; PSB, phosphorus-solubilizing bacteria; FS, foliar spray
**Two foliar sprays at tasseling and silking stage; *1 foliar spray at silking stage

Table 5. Pearson's correlation matrix between yield and yield components of maize in 2012–13 (pooled data of 2 years)

Parameter	Grain yield (t/ha)	Cob length (cm)	Cob weight (g)	Grains/ cob	Cob girth (cm)
Grain yield (t/ha)	1				
Cob length (cm)	0.973**	1			
Cob weight (g)	0.996**	0.989**	1		
Grains/cob	0.993**	0.958*	0.985**	1	
Cob girth (cm)	0.950*	0.885*	0.927*	0.976**	1

**Correlation is significant at the 0.01 level (2-tailed)

Thus increased efficiency of the protein synthesis is manifested in the increase in its structural components, which include the amino acids such as lysine, tryptophan and methionine (Mishra, 2012).

Correlation

All the yield attributes were found significant with grain yield of maize. The attributes like cob length, cob weight and cob girth were found highly significant with grain yield (Table 5). The direct and residual effect of P, Zn and better weather condition during the second year might had led to higher correlation between yield and yield parameters.

It can be concluded that integrated application of phospho-enriched compost and chemical fertilizers and soil application of $ZnSO_4$ @ 12.5 kg/ha with 1 foliar application of $ZnSO_4$ at silking stage were found as the best treatments for improving yield and quality of maize.

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