Agronomic of Zinc on Yield

Subjects: Agriculture, Dairy & Animal Science

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Phosphorus (P) and zinc (Zn) are essential plant nutrients and their deficiency in soils and antagonistic effect of P on Zn are the important concerns world-over. Thus, a two-year (2012-13 to 2013-14) experimentation was carried out to assess grain yield, nutrient uptake and quality parameters of wheat by various levels of P and Zn. The results revealed that 50% Recommended Dose of P (RDP) through phospho-enriched compost (PEC) + 50% RDP through fertiliser and soil application of 12.5 kg $ZnSO_4.7H_2O$ ha^{-1} + one foliar spray of 0.5% $ZnSO_4.7H_2O$ recorded significantly higher grain yield (4.81 and 4.61 t ha^{-1}, respectively), straw yield (7.20 and 6.92 t ha^{-1}, respectively) and protein content (11.5% and 11.3%, respectively). The concentrations of Zn in grain (35.6%) and straw (57.3%) was not affected due to organic P application but 100% P through P fertilizer reduced the Zn content in the grains. Both soil and foliar application of Zn was found more promising in increasing Zn and Fe concentration in grains (37.5 and 30.9 mg kg^{-1}, respectively) and straw (60.3 and 398 mg kg^{-1}, respectively). Overall, the treatment combination of 50% RDP through PEC + 50% RDP through fertiliser and soil applied 12.5 kg $ZnSO_4.7H_2O$ ha^{-1} + one spray of 0.5% Zn was beneficial in reducing antagonistic effect of P on Zn and increasing Zn and Fe concentration in wheat grain and, thus, could be used for improving the yield of Zn and Fe enriched wheat grains.

Keywords: Phosphorus ; wheat ; Zinc fortification

1. Yield and Yield Parameters

The application of P_{50}-PEC + P_{50}-F resulted in significantly higher yield attributes, such as spikes m^{-2}, grains $spike^{-1}$, test weight, spike length and spikelets $spike^{-1}$ than P_{100}-F. However, it was at par with P_{100}-PEC and the minimum values of yield parameters were observed in plots without P (Table 2, Figure 1). The increase in grain yield with application of P_{50}-PEC + P_{50}-F over P_{100}-F was 11.3%. This increase was due to improvement in yield components and improved bioavailability of residual soil phosphorus [1]. The differences in grain and straw yields among the different treatments were also associated with differences in grain and shoot P concentrations (Table 3), revealing that P enrichment in grain and straw is more important to improve crop productivity. The application of PEC along with chemical fertiliser provided continuous and ready availability of both macro and micro-nutrients, which, in turn, enhanced the yield of wheat crop. Matar and Brown [2] reported that early and continuous P uptake increases yield potential of crops in both the cropping seasons by stimulating growth and development of plants.

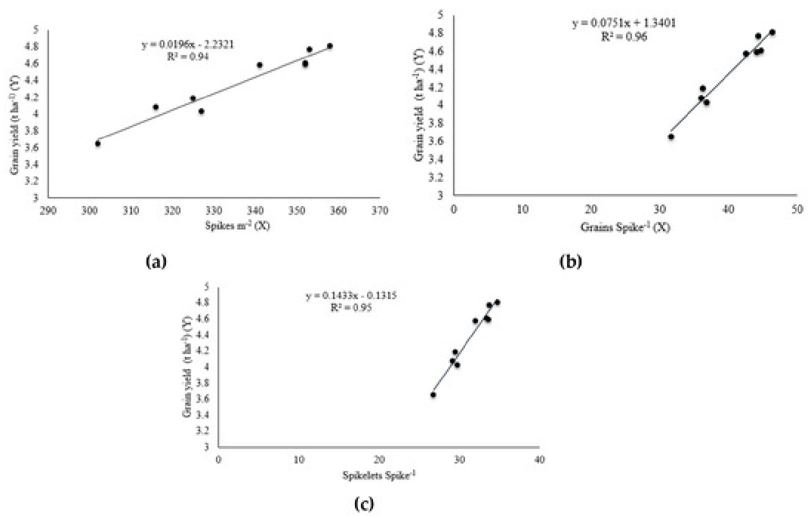

Figure 1. Relationship between grain yield and yield parameters. (**a**) Grains $spike^{-1}$, (**b**) spikelets $spike^{-1}$ and (**c**) spikes m^{-2}.

Table 2. Influence of integrated P management and Zn application on yield, yield attributes and protein percent in wheat grain (average of 2 years).

Treatments	Spikes m^{-2}	Grains $Spike^{-1}$	Test Weight (g)	Spike Length (cm)	Spikelets $Spike^{-1}$	Grain Yield (t ha^{-1})	Straw Yield (t ha^{-1})	Protein (%)
Phosphorus levels								
Without P	302 ^{d}	31.6 ^{d}	35.9 ^{c}	9.4 ^{d}	26.8 ^{d}	3.65 ^{d}	5.90 ^{d}	9.5 ^{d}
P_{100}-F	327 ^{c}	36.8 ^{c}	36.1 ^{c}	10.3 ^{c}	29.7 ^{c}	4.03 ^{c}	6.19 ^{c}	10.0 ^{c}
P_{100}-PEC	353 ^{a}	44.3 ^{b}	40.4 ^{a}	11.7 ^{a}	33.7 ^{a}	4.77 ^{a}	7.09 ^{a}	11.3 ^{ab}
P_{50}-PEC + P_{50}-F	358 ^{a}	46.4 ^{a}	40.6 ^{a}	11.8 ^{a}	34.7 ^{a}	4.81 ^{a}	7.20 ^{a}	11.5 ^{a}
P_{75}-PEC + VAM + PSB	341 ^{b}	42.5 ^{b}	39.2 ^{b}	11.1 ^{b}	32.0 ^{b}	4.58 ^{b}	6.68 ^{b}	11.2 ^{b}
Application of $ZnSO_4.7H_2O$								
Without Zn	316 ^{c}	36.1 ^{b}	36.6 ^{b}	10.1 ^{b}	29.1 ^{b}	4.08 ^{c}	6.16 ^{c}	10.1 ^{b}
25 kg-Soil	352 ^{a}	44.7 ^{a}	40.2 ^{a}	11.5 ^{a}	33.4 ^{a}	4.61 ^{a}	7.01 ^{a}	11.3 ^{a}
Two foliar **	325 ^{b}	36.3 ^{b}	36.3 ^{b}	10.1 ^{b}	29.5 ^{b}	4.19 ^{b}	6.36 ^{b}	10.2 ^{b}
Soil + Foliar *	352 ^{a}	44.1 ^{a}	40.7 ^{a}	11.6 ^{a}	33.6 ^{a}	4.59 ^{a}	6.92 ^{a}	11.2 ^{a}

Table 3. Influence of integrated P management and Zn application on P concentration and uptake by wheat (average of 2 years).

Treatments	Grain P Concentration (%)	Straw P Concentration (%)	Grain P (kg ha^{-1})	Straw P (kg ha^{-1})	Total P (kg ha^{-1})
Phosphorus levels					
Without P	0.28 ^{c}	0.13 ^{b}	10.4 ^{c}	7.6 ^{c}	17.9 ^{d}
P_{100}-F	0.3 ^{b}	0.13 ^{b}	13.5 ^{b}	8.2 ^{c}	21.7 ^{c}
P_{100}-PEC	0.38 ^{a}	0.15 ^{a}	18.1 ^{a}	10.5 ^{b}	28.6 ^{a}
P_{50}-PEC + P_{50}-F	0.37 ^{a}	0.15 ^{a}	18.0 ^{a}	11.0 ^{a}	29.0 ^{a}
P_{75}-PEC + VAM + PSB	0.38 ^{a}	0.15 ^{a}	17.3 ^{a}	10.2 ^{b}	27.4 ^{b}
Application of $ZnSO_4.7H_2O$					
Without Zn	0.34 ^{b}	0.15 ^{a}	13.9 ^{c}	9.1 ^{b}	23.0 ^{d}
25 kg-Soil	0.33 ^{b}	0.13 ^{c}	15.6 ^{b}	9.1 ^{b}	24.7 ^{c}
Two foliar **	0.36 ^{a}	0.15 ^{a}	15.4 ^{b}	9.8 ^{a}	25.2 ^{b}
Soil + Foliar *	0.36 ^{a}	0.14 ^{b}	16.9 ^{a}	10.0 ^{a}	26.9 ^{a}

Soil application + foliar spray of Zn resulted in significantly larger yield attributes, such as spikes m^{-2}, test weight, spike length and spikelets $spike^{-1}$, and was at par with 25 kg-Soil application of Zn (Table 2 and Figure 1). However, the grains $spike^{-1}$ were significantly superior with 25 kg-Soil application of Zn and at par with soil + foliar spray of Zn. Significantly lower values of all yield attributes were observed from plots without Zn. The grain and straw yields of wheat were highest with 25 kg-Soil application of Zn; the second highest yields were produced by the crop receiving soil + foliar spray of Zn. The 25 kg-Soil application of Zn resulted in 16.7% yield enhancement over plots without Zn. The increase in yield parameters and yield could be attributed to the proper supply of Zn up to the harvesting stage in soil + foliar applied plots and enhancement of various enzymatic activities leading to increased photosynthetic activity and dry matter accumulation, which in turn led to higher yield attributes and yield [3][4][5][6]. Alloway [7] described that Zn improves photosynthesis, transformation of carbohydrates and seed development. Thus, increased Zn content and uptake resulted in bolder grains, finally improving test weight. These results are supported by the findings of Nawaz et al. [8], who reported that Zn application improved the wheat yield over control. Imran and Rehim [9] also revealed that soil + foliar application would be more beneficial for improving plant growth and yield over soil application alone.

2. Phosphorus Concentration and Uptake

The P concentration in grain as well as in straw was highest with P_{100}-PEC followed by P_{50}-PEC + P_{50}-F and P_{75}-PEC + VAM + PSB (Table 3). The P uptake in grain was found highest with P_{100}-PEC and the uptake of P in straw and total P uptake were highest with P_{50}-PEC + P_{50}-F. The percent increase in wheat grain P concentration due to P_{100}-PEC over without P was 39.2%. This might be due to better availability and consistent supply of P from PEC and chemical fertiliser up to harvest and also increased microbial activity in soil helping to increase the P uptake and leading to increased concentration in grain and straw [10][11]. The near perfect linear relationship of grain yield with grain P concentration showed that differences in yield were associated with differences in grain P concentration and their corresponding uptake (Figure 2). These results firmly revealed that P uptake is of greater significance in enhancing crop productivity. Zaki and Radwan [12] reported that application of P fertilizer and PSB enhanced P and micronutrients availability and concentration in plants. Shivay et al. [13] reported that minute quantity of fertilizer P is bioavailable for plant uptake. The bioavailable P in the soil was found to be higher whenever an organic source of P was applied externally. The increased P levels proportionately increased the bioavailable P in the soil, which caused the increased P concentration and uptake in wheat parts.

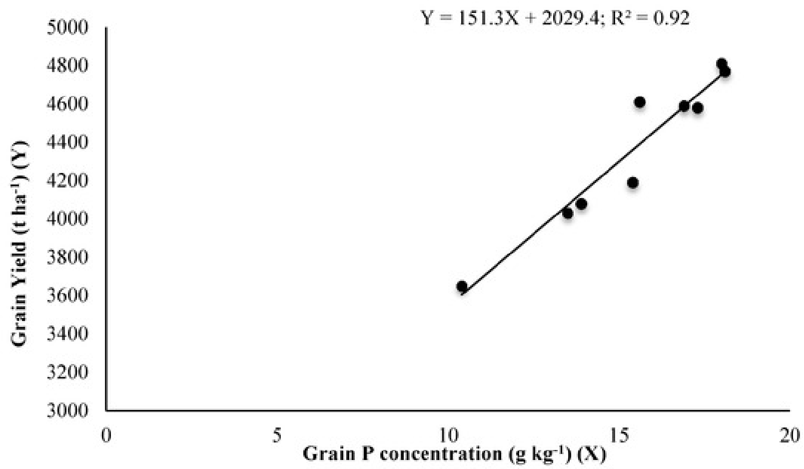

Figure 2. Response of grain P uptake to grain yield of wheat (grain P uptake with grain yield of wheat under different P and Zn levels were taken for this response calculation).

The P concentration in grain and straw was highest with two foliar sprays of Zn followed by soil + foliar spray of Zn. However, the highest P uptake was noticed with soil + foliar spray of Zn. The increase in grain P concentration with two foliar sprays of Zn over 25 kg-Soil application of Zn was 9%. This trend could likely be due the antagonistic effect of excessive Zn on P-absorption and further translocation from roots to other parts of the plants. However, the Zn application by foliar spray increased P-absorption from the soil by plants [14]. Soil Zn application increased the N and P concentration but at higher dose reduced the P concentration [15].

3. Zinc Concentration and Uptake

There were significant differences among treatments for Zn concentration and uptake in wheat (Table 4). The Zn concentration and uptake in wheat were significantly higher with P_{50}-PEC+ P_{50}-F followed by P_{100}-PEC; the lowest Zn concentration in grain and straw was noticed with P_{100}-F. The increase in grain Zn concentration with P_{50}-PEC + P_{50}-F over P_{100}-F was 13.3%. The increased Zn concentration with integrated P management resulted from the reduction in antagonistic effect of P on Zn when organic P was applied [16]. The decreased Zn concentration in grain and straw seen in P_{100}-F plots might be due to dilution effect [17][18]. Ryan et al. [19] described that higher application of P fertilizers induces Zn deficiency in plants due to dilution effect. The Zn concentration in grain and straw was highest with two foliar sprays of Zn and it was at par with soil + foliar spray of Zn. The Zn uptake in grain, straw and total uptake of Zn were highest with soil + foliar spray of Zn. The increase in grain Zn concentration with two foliar sprays of Zn over 25 kg-Soil application of Zn was 10.4%. The results revealed that soil and foliar application of Zn are efficient in improving the Zn concentration in grains as nutrients are absorbed quickly through leaves as compared to uptake from the plant roots [9][20]. Similar results were obtained by Ghasal et al. [21]; they reported that soil + foliar application of Zn increased Zn uptake by 4–7% over soil application alone. Habib [22] found that the concentration of Zn in wheat increased by three times by foliar application of Zn at the reproductive stage of the crop. Ghasal et al. [23] reported that Zn concentration in grain increases significantly with an increase in Zn level in soil.

Table 4. Influence of integrated P management and Zn application on Zn concentration and uptake by wheat (pooled data of two years).

Treatments	Grain Zn Concentration (%)	Straw Zn Concentration (%)	Grain Zn (mg^{-1} kg)	Straw Zn (mg^{-1} kg)	Total Zn (mg kg^{-1})
		Phosphorus levels			
Without P	34.9 ^{b}	56.5 ^{a}	127.7 ^{c}	335 ^{c}	463 ^{d}
P_{100}-F	31.5 ^{c}	50.6 ^{c}	127.0 ^{c}	313 ^{d}	440 ^{d}
P_{100}-PEC	35.6 ^{a}	57.2 ^{a}	170.5 ^{a}	407 ^{a}	578 ^{a}
P_{50}-PEC + P_{50}-F	35.6 ^{a}	57.3 ^{a}	171.9 ^{a}	414 ^{a}	586 ^{a}
P_{75}-PEC + VAM + PSB	34.6 ^{b}	55.5 ^{b}	158.9 ^{b}	371 ^{b}	530 ^{b}
		Application of $ZnSO_4.7H_2O$			
Without Zn	28.7 ^{c}	46.2 ^{c}	117.8 ^{c}	285 ^{c}	403 ^{c}
25 kg-Soil	34.2 ^{b}	54.8 ^{b}	158.2 ^{b}	385 ^{b}	544 ^{b}
Two foliar **	37.2 ^{a}	60.3 ^{a}	156.3 ^{b}	384 ^{b}	540 ^{b}
Soil + Foliar*	37.5 ^{a}	60.3 ^{a}	172.6 ^{a}	419 ^{a}	591 ^{a}

4. Iron Concentration and Uptake

There was a significant increase in Fe concentration and uptake due to the application of P_{50}-PEC + P_{50}-F followed by P_{100}-PEC over without P and P_{100}-F (Table 5). The increase in wheat grain Fe concentration over P_{100}-F was 13.4%. The lowest Fe concentration and uptake were noticed in plots without P. As the P also exhibited a negative effect on absorption and translocation of Fe, the application of P_{100}-F recorded lower Fe concentration over all other treatments. The application of PEC might have improved the chelation of Fe compounds and helped in absorption of Fe from soil. Two foliar sprays of Zn and soil + foliar spray of Zn improved Fe concentration and uptakes in grain and straw of wheat significantly compared to without Zn treatment. However, soil + foliar spray of Zn resulted in the highest grain, straw and total uptake of Fe because of higher dry matter production. This study indicated that soil application of Zn reduced the Fe absorption from soil. These results are in agreement with the findings of Abbas et al. [24]. Haldar and Mandal [25] reported that Fe may get accumulated in the roots, and higher root Zn might reduce the Fe translocation from root to shoot or may reduce the uptake from soil itself.

Table 5. Influence of integrated P management and Zn application on Fe concentration and uptake by wheat (pooled data of two years).

Treatments	Grain Fe concentration (%)	Straw Fe concentration (%)	Grain Fe (mg^{-1} kg)	Straw Fe (mg^{-1} kg)	Total Fe (g kg^{-1})
		Phosphorus levels			
Without P	27.5 ^{c}	389 ^{abc}	100 ^{c}	2296 ^{c}	2.40 ^{c}
P_{100}-F	26.2 ^{d}	380 ^{d}	106 ^{c}	2355 ^{c}	2.46 ^{c}
P_{100}-PEC	29.3 ^{b}	385 ^{c}	140 ^{a}	2733 ^{a}	2.87 ^{a}
P_{50}-PEC + P_{50}-F	29.7 ^{a}	392 ^{a}	143 ^{a}	2819 ^{a}	2.96 ^{a}
P_{75}-PEC + VAM + PSB	28.6 ^{b}	386 ^{b}	131 ^{b}	2580 ^{b}	2.71 ^{b}
		Application of $ZnSO_4.7H_2O$			
Without Zn	26.1 ^{c}	386 ^{c}	106 ^{d}	2374 ^{d}	2.5 ^{c}

Treatments	Grain Fe concentration (%)	Straw Fe concentration (%)	Grain Fe (mg^{-1} kg)	Straw Fe (mg^{-1} kg)	Total Fe (g kg^{-1})
25 kg-Soil	26.6 ^{c}	371 ^{d}	124 ^{c}	2603 ^{b}	2.7 ^{b}
Two foliar **	30.9 ^{a}	398 ^{a}	130 ^{b}	2533 ^{c}	2.7 ^{b}
Soil + Foliar *	29.4 ^{b}	392 ^{b}	136 ^{a}	2717 ^{a}	2.9 ^{a}

5. Protein and Amino Acids Content

The treatment P_{50}-PEC + P_{50}-F resulted in significantly higher crude protein, lysine, methionine and tryptophan contents compared to all other treatments (Table 1 and Figure 2). The increase in crude protein percentage in grain with the application of P_{50}-PEC + P_{50}-F was 15% over control. This might be due to the increased phosphorus concentration in soil by addition of organic matter and release of native P by more microbial activity. P has been found to enhance higher root growth, N uptake and metabolism, thereby the protein concentration in grain increased considerably. P has been necessary for both nitrate reductase activity and nitrate uptake and may influence the enzyme directly or indirectly, thereby leading to higher protein synthesis. P deficiency led to reduction in nitrate reductase activity, thereby reducing protein synthesis. So, optimum N and P supplementation through organic or inorganic sources of nutrient is a prerequisite to improve protein synthesis. Zinc application also exerted significant influence on crude protein and amino acid contents in grain. Incorporating 25 kg of Zn into soil resulted in significant improvement in crude protein, lysine, methionine and tryptophan contents in grain over control treatment; the respective increase was 11.8% (Figure 3). However, this treatment did not differ significantly from soil + foliar spray of Zn for any of these grain quality parameters. The results indicated that Zn plays an important role in increasing protein and amino acid content in grains. Zn is a stimulant factor which increases the production of indoleacetic acid; thereby it leads to an increase in amino acid and protein content. Zn has a role in improving β-carotene content of wheat and thereby improving protein and other quality parameters in wheat [26]. Soil and foliar application of Zn improved dry matter accumulation and higher N uptake which in turn resulted in higher crude protein content in grains [27]. Zinc deficiency is related to N metabolism; whenever the Zn levels in plants are lowered, the proteins concentration decreases considerably. Zn deficiency leads to impairment of both synthesis and structural integrity of RNA and ribosomes, further lead to higher RNase activity. So, adequate Zn supplementation is required for protein synthesis [28]. Gao et al. [29] reported a positive correlation between Zn content in wheat grain and grain protein content. Ozturk et al. [30] revealed that highest Zn uptake and protein synthesis occurs at same stage of seed formation.

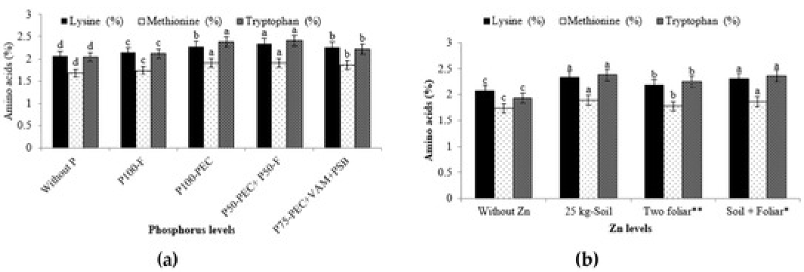

Figure 3. Influence of different sources and doses of P (**a**) and Zn (**b**) on amino acid content in wheat grains.

A correlation matrix (Table 6) showed significant correlations ($P < 0.05$) of all the different yield attributes and nutrient uptake parameters, with grain yields of wheat. This indicated that yield parameter, nutrient concentration and their uptake have significant contribution towards yield enhancement in wheat.

Table 6. Correlation matrix between grain yield, yield attributes and nutrients uptake of wheat.

	GY	S	GS	TW	SL	SS	Grain P	Grain Zn	Grain Fe
GY	1.000								
S	0.971 **	1.000							
GS	0.980 **	0.988 **	1.000						
TW	0.931 **	0.938 **	0.960 **	1.000					
SL	0.973 **	0.990 **	0.993 **	0.968 **	1.000				
SS	0.978 **	0.994 **	0.995 **	0.956 **	0.996 **	1.000			

	GY	S	GS	TW	SL	SS	Grain P	Grain Zn	Grain Fe
Grain P	**0.963 ****	**0.904 ****	**0.902 ****	**0.828 ****	**0.897 ****	**0.906 ****	**1.000**		
Grain Zn	**0.869 ****	**0.869 ****	**0.841 ****	**0.858 ****	**0.846 ****	**0.856 ****	**0.854 ****	**1.000**	
Grain Fe	**0.911 ****	**0.869 ****	**0.849 ****	**0.823 ****	**0.848 ****	**0.867 ****	**0.941 ****	**0.962 ****	**1.000**

6. Conclusions

The results obtained from the experiment provide us major findings on the influence of integrated P management and Zn on yield and quality parameters of wheat. Application of 50% of recommended P through chemical fertilizer and 50% of recommended P through PEC with soil + foliar application of Zn increased yield, nutrient concentration and uptake over control treatments. Increased yield, nutrient concentration and quality of wheat might have been caused by reduced antagonistic effect of P on Zn and Fe with the application of phospho-enriched compost (PEC) and increased bioavailability of Zn to plants. The results of this study indicate that application of 50% of recommended P through chemical fertilizer and 50% of recommended P through PEC with soil application of 12.5 kg ha^{-1} of $ZnSO_4$ as basal dose + one foliar spray of $ZnSO_4$ at 0.5% during one week after anthesis stage is more promising for higher productivity and quality of wheat.

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