Research Article

Efficacy of Soil Applied Phosphorus and Foliar Zinc Application on Different Growth Stages to Improve Productivity of Maize (*Zea mays*)

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Abstract | Phosphorus (P), foliar zinc (Zn) and its time of application plays an important role in crop productivity. To study its effect on maize, field experiment was conducted at Fodder and Forage Crops Section Harichand- Charsadda, Pakistan. The field experiment was conducted on 7 July 2021. Two levels of P (90 and 120 kg ha^{-1}) and three levels of Zn (0 i.e., water spray only, 2.5 and 5 kg ha^{-1}) were applied at three growth stages, full at vegetative stage (V6), full at reproductive stage (R2) and ½ at V6 and ½ at R2 stage along-with an overall control were used in the experiment. Randomized complete block design was used with three replications. The studied parameters were significantly affected by P, Zn and AT. Ear length (17.8 cm), ear weight (115.8 g), grains ear^{-1} (390) and thousand grains weight (257 g) had significantly affected when 120 kg P ha^{-1} was applied. Similarly, ear length (18.4 cm), ear weight (129.6 g), grains ear^{-1} (407) and thousand grains weight (258.33 g) were significantly affected in plots treated at the rate of 5 kg ha^{-1} with Zn. In case of growth stages, Zn applied half at vegetative and half at reproductive stages significantly enhanced the ear length (18.2 cm), ear weight (127.4 g), grain ear^{-1}(391) and thousand grains weight (255.5 g). It is concluded from the experiment that application of 120 kg P ha^{-1} significantly improved ear length, ear weight, grains per ear and thousand grain weight. In case of foliar application of 5 kg Zn ha^{-1} improved ear length, ear weight, grains per ear and thousand grain weight of cob. Similarly, in case of Zn application stages, ½ at vegetative and ½ reproductive stage will improve productivity of maize crop. Therefore,120 kg P ha^{-1}, 5 kg Zn ha^{-1} along with its application timing ½ at vegetative and ½ reproductive stage is recommended for the agro climatic conditions of Peshawar.

Received | March 03, 2022; **Accepted** | March 23, 2022; **Published** | July 14, 2022
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Citation | Ali, S, S. Shah, M. Amin, A.A. Khan, D. Ahmad, I. Ullah, F. Ahmad, S. Khan and S. Azam. 2022. Efficacy of soil applied phosphorus and foliar zinc application on different growth stages to improve productivity of maize (*Zea mays*). *Sarhad Journal of Agriculture,* 38(3): 912-917.
DOI | https://dx.doi.org/10.17582/journal.sja/2022/38.3.912.917
Keywords | Application time, Maize, Phosphorus, Yield components, Zinc

Introduction

Fertilizers play an important role in crop production and also enhanced quality of crop (Amjadian *et al*., 2021). Balanced fertilizers are very important because it's improved and enhances plant development and also increases yield (Hitha *et al*., 2021). Among the essential nutrients, phosphorus (P) is the second essential nutrient. Phosphorus (P) is important nutrient in the cropping system of agriculture (Roberts and Johnston, 2015; Guignard *et al*., 2017; Khan *et al*., 2018). It plays a role in crop development and in its metabolism (Yadav *et al*., 2017). Phosphorus is the part of nucleic acids, structural proteins and of enzymes (Yao *et al*., 2018). After nitrogen, phosphorus increases yield of crop (Adeyemi *et al*., 2020). Most of the cereal and vegetable crops require phosphorus in large quantity (Ketterings *et al*., 2020). It has two different forms in soil i.e. $H_2PO_4^{-1}$ and HPO_4^{-2} and plant takes it in these two forms. The absorption of $HPO_4^{-2}$is very rapid and faster as compare to $H_2PO_4^{-1}$ (Alamnie and Misganew, 2021). Application of phosphorus give strength to straw of cereal crop and as a result crop lodging decreases. It also increases resistance to many diseases. It plays a crucial role in cell division, nucleus formation, helps in DNA and RNA formation (Kolodiazhnyi*et al.,* 2021). Deficiency of phosphorus limits development and growth of plant (Kewei *et al*., 2014). Phosphorus decreases yield in maize crop when applied in low amount (Cengiz *et al*., 2020).

Micro-nutrients though are as important as macro-nutrients (Jake *et al*., 2022). However, as compared to macronutrients, micronutrients are required in very small amount. Generally, in most cases, both the plants and soils have very small amounts of micro-nutrients (Chakraborty *et al*., 2021). Micro-nutrients play a key role in plant growth and its development, improve crop phenology and also involve in various physiological processes (Hassan *et al*., 2019). Similarly, in case of micro-nutrients, Zinc (Zn) is an important micro-nutrient and plays a key role in plants (Natasha *et al*., 2022). Zn is necessary for biosynthesis of chlorophyll (Ali *et al*., 2021). In general, Zn has major role in activating enzyme, proteins synthesis, revival and oxidation reactions and carbohydrates metabolism (Ali *et al*., 2021). The deficiency of Zn may lead to photosynthesis decline and destruction of RNA, decreased protein synthesis, carbohydrates solution and thus affecting performance and quality of crop (Kadyampakeni and Chinyukwi, 2021). Foliar application of both Zn and Fe also enhances the phenological development and yield component of wheat crop (Ali *et al*., 2021). Application of Zn enhances height of maize crop when applied at split doses. Foliar Zn also significantly enhances size of maize leaf (Raheela *et al*., 2021).

Materials and Methods

Field experiment

The experiment entitled "efficacy of soil applied phosphorus and foliar zinc application on different growth stages to improve productivity of maize (*Zea mays*) was performed at Fodder and Forage crops section Harichand, Charsadda, Khyber Pakthunkhwa; Pakistan. The field experiment was conducted on 7 July 2021. The experiment comprised of the following factors along with their respective levels. Two levels of P (90 and 120 kg ha^{-1}) were applied at the time of sowing and three levels of Zn (0 i.e., water spray only, 2.5 and 5 kg ha^{-1}) were applied at three growth stages i.e., full at vegetative stage (V6), full at reproductive stage (R2) and½ at V6 and ½ at R2 stage along with an overall control were used in the experiment. The experiment was conducted in randomized complete block design with three replications. Treatment combinations of all the three factors along with a control were randomly allotted to the experimental plots in each block. Plot size was 4.9 × 4.0 m. Jalal variety was used for sowing. Planting was made on flat beds in rows spaced 0.70m. For application of Zn, 10% solution of $ZnSO_4.H_2O$ was prepared. Keeping in view the treatments and volume to wet the subplot area completely, the solution was further diluted with water. Control plots were sprayed with equivalent quantity of water. First irrigation was given on 19 July 2021after sowing and subsequent irrigation was adjusted according to the need of crop. For all the treatments, other agronomic practices were kept uniform.

Locality of the experimental site

The experimental field is placed at 34.02^0 N, 71.47^0 E and 331 m above the level of sea. The mean annual rainfall of the location is 360 mm. The mean maximum summer temperature is 40 °C and the mean minimum is 25 °C while in winter minimum mean temperature is 4 °C and mean maximum temperature is 18.34 °C.

Soil sample collection and laboratory analysis

The soil characteristics as evaluated in laboratory and classified the soil as texture silty clay loam having 51.3% silt, 40% clay and 8.7% sand, 14.4% $CaCO_3$, 8.08 pH and having low organic matter of 0.58% g kg^{-1}. Similarly, the mineral contents of soil were i.e. 0.21 ppm zinc, 66.38 ppm iron, 2.86 ppm nickel, 1.07 ppm lead, .085 ppm chromium and 0.937 ppm was copper.

Statistical analysis

The data noticed on different parameters was analyzed statistically according to the procedure relevant to randomized complete block design as described by little and Hills (1978). Least significant difference (LSD) test were used for mean separation when the F test was significant.

Results and Discussion

Ear length (cm)

Data of ear length showed in Table 1. Maximum ear length (17.8 cm) was noticed when 120 kg P $ha^{-1}$was applied while minimum (16.8 cm) was noticed when 90 kg P $ha^{-1}$was applied. The reason for increased of ear length of maize might be that phosphorus could translocate assimilation to ears has accrued and have been resulted in to increased ear length (Juan *et al*., 2021). Similarly, in case of Zn, maximum ear length (18.4 cm) was observed when 5 kg Zn $ha^{-1}$was applied while minimum (16.1 cm) was noticed with water spray only. Ear length and weight increased with higher rate of Zn (Hisham *et al*., 2021). In case of Zn application timing, maximum ear length (18.2 cm) was recorded when Zn was applied all at AT3 stage while minimum (16.5 cm) was noticed when applied all at AT1 stage.

Ear weight (g)

Data concerning ear weight are accessible in Table 2. Maximum ear weight (115.8 g) was noticed when 120 kg P $ha^{-1}$was applied while minimum (109.4 g) was observed when 90 kg P $ha^{-1}$was applied. Ear weight of maize crop increased with higher rate of phosphorus because phosphorus increases the amount of endosperm in grain (Perkins *et al*., 2021). Similar in case of Zn, maximum ear weight (129.6 g) was noticed when 5 kg Zn $ha^{-1}$was applied while minimum (113.4 g) was noticed with water spray only. Increase of ear weight is due to the heavier grain weight, because zinc provided adequate amount of carbohydrates to source. Therefore, ear weight increases with the application of Zn (Liu *et al*., 2020). In case of Zn application timing, maximum ear weight (127.4g) was shown when all Zn was applied at AT3 stage while minimum (111.4 g) was noticed with all at AT2 stage. In such away in case of P x AT interaction, the maximum ear weight (124.1 g) was noticed in plots when 120 kg P ha^{-1} and Zn applied half at V6 and half at R2 stage while minimum (97.9 g) was noticed in plot that received 90 kg P ha^{-1} and all Zn at AT2 stage.

Table 1: *Ear length (cm) of maize as affected by phosphorus, foliar Zn and its application timing.*

Phosphorus ($kg\ ha^{-1}$)	Zn ($kg\ ha^{-1}$) application	Growth stages			Mean
		V6	R2	50% at V6 + 50% at R2	
90	0	13.3	17.0	16.7	15.7
	2.5	16.3	17.1	17.2	16.9
	5.0	17.5	17.3	18.8	17.9
120	0	15.8	16.7	17.2	16.6
	2.5	17.0	17.4	19.0	17.8
	5.0	19.0	17.3	20.3	18.9
-	0	14.6	16.9	16.9	16.1 c
-	2.5	16.7	17.2	18.1	17.3 b
-	5.0	18.2	17.3	19.6	18.4 a
90	-	15.7	17.1	17.6	16.8 b
120	-	17.3	17.1	18.8	17.8 a
Mean		16.5 b	17.1 b	18.2 a	
Control					13.0 b
Rest					17.3 a

Table 2: *Ear weight (g) of maize as affected by phosphorus, foliar Zn and its application timing.*

Phosphorus ($kg\ ha^{-1}$)	Zn ($kg\ ha^{-1}$) Application	Growth stages			Mean
		V6	R2	50% at V6 + 50% at R2	
90	0	93.0	101.0	117.3	103.8
	2.5	110.3	96.7	110.3	105.8
	5.0	141.3	96.0	118.3	118.6
120	0	107.3	118.0	143.7	123.0
	2.5	111.3	129.0	143.3	127.9
	5.0	138.0	141.7	142.0	140.6
-	0	100.2	109.5	130.5	113.4 b
-	2.5	110.8	112.8	126.8	116.8 b
-	5.0	139.7	118.8	130.2	129.6 a
90	-	114.9	97.9	115.3	109.4 b
120	-	119.7	103.6	124.1	115.8 a
Mean		117.0 ab	111.4 b	127.4 a	
Control					94.3 b
Rest					119.9 a

V6: Vegetative stage leaf 6th; R2: reproductive stage.

Grains ear^{-1}

Data concerning grains ear^{-1} are obtainable in Table 3. In case of P, maximum grains ear^{-1} (390) was shown when 120 kg P ha^{-1}was applied while minimum (369) grains ear^{-1} was noticed when 90 kg P ha^{-1}was applied. Phosphorus is responsible for the growth of root which directly affects the overall plant performance (Bing *et al*., 2022). It has also reported that grains per ear also increase with phosphorus fertilization (El-Sobky *et al*., 2021). Similarly, in case of Zn, maximum grains ear^{-1} (407) was noticed when 5 kg Zn ha^{-1} was applied while minimum (353) was shown with water spray only. This is because that Zn is essential for pollen grain development and pollen viability; as a result, number of grains increases in ear (Sonal *et al*., 2022). In case of Zn application timing, maximum (391) was noticed when Zn was applied half at V6 and half at R2 stage while minimum (372) was noticed when all applied at AT2 stage.

Table 3: *Grains ear^{-1} of maize as affected by phosphorus, foliar Zn and its application timing.*

Phosphorus (kg ha^{-1})	Zn (kg ha^{-1}) application	Growth stages			Mean
		V6	R2	50% at V6 + 50% at R2	
90	0	313.3	343.0	386.7	347.7
	2.5	356.7	351.3	390.0	366.0
	5.0	416.7	381.3	382.7	393.6
120	0	360.0	356.7	359.7	358.8
	2.5	386.7	388.7	400.7	392.0
	5.0	414.7	416.7	430.3	420.6
-	0	336.7	349.8	373.2	353.2 c
-	2.5	371.7	370.0	395.3	379.0 b
-	5.0	415.7	399.0	406.5	407.1 a
90	-	362.2	358.6	386.4	369.1 b
120	-	387.1	387.3	396.9	390.4 a
Mean		374.7 b	372.9 b	391.7 a	
Control					341.0 b
Rest					379.8 a

V6: Vegetative stage leaf 6th; R2: reproductive stage.

Thousand grains weight (g)

Data regarding thousand grains weight are obtainable in Table 4. Statistical analysis of the data show that maximum thousand grains weight (257 g) was seen at 120 kg Pha^{-1}and minimum (233.7 g) thousand grains weight were seen at 90 kg p ha^{-1} application. Heaviest grain weight with higher P level probably may be due to higher P translocation in to the fruiting area which results in highest grain weight. Increasing in P levels increased grain weight (Hamza *et al*., 2022). Similarly, in case of Zn, highest (258.3 g) thousands grain weight was noticed when 5 kg Zn ha^{-1}was applied while minimum (220.5 g) was noticed with water spray only. When the supply of carbohydrates to grain is high then the filling of grain will be high and as a result weight of kernels will be more (Wenxin *et al*., 2017). In case of Zn using timing, maximum thousands grain weight (255.5 g) was shown when Zn was applied half at V6 and half at R2 stage while minimum (228.6 g) was noticed when applied all at V6 stage.

Table 4: *Thousand grains weight (g) of maize as affected by phosphorus, foliar Zn and its application timing.*

Phosphorus (kg ha^{-1})	Zn (kg ha^{-1}) application	Growth stages			Mean
		V6	R2	50% at V6 + 50% at R2	
90	0	195	208	203	202
	2.5	200	220	253	224
	5.0	240	233	260	244
120	0	206	250	260	238
	2.5	250	266	263	260
	5.0	280	243	293	272
-	0	200	229	231	220 b
-	2.5	225	243	258	242 a
-	5.0	260	238	276	258 a
90	-	211	220	238	223 b
120	-	245	253	272	257 a
Mean		228 b	236 b	255 a	
Control					206 b
Rest					240 a

V6: Vegetative stage leaf 6th; R2: reproductive stage.

Conclusions and Recommendations

It is concluded from the experiment that application of 120 kg P ha^{-1} significantly improved ear length, ear weight, grains per ear and thousand grain weight. Similarly, foliar application of 5 kg Zn ha^{-1} improved ear length, ear weight, grains per ear and thousand grain weight of cob. In case of application timing of zinc, when applied ½ at vegetative and ½ reproductive stage will improve productivity of maize crop. Therefore,120 kg P ha^{-1}, 5 kg Zn ha^{-1} along with its application timing ½ at vegetative and ½ reproductive stage is recommended for the agro climatic conditions of Peshawar.

Novelty Statement

This study conducted to find out the impact of phosphorus, Zinc and its application stages to improve maize yield.

Author's Contribution

Sajid Ali: Carried out research and drafted the manuscript.
Shahen Shah: Provided technical guidelines
Muhammad Amin: Helped in data analysis
Asad Ali Khan: Helped in editing and draft improvement
Dawood Ahmad and Ikram Ullah: Helped results and discussion interpretation
Faiq Ahmad and Sajjad Khan: Helped in data collection
Sikandar Azam: Helped in format setting

Conflict of interest
The authors have declared no conflict of interest.

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