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RESPONSE OF MAIZE CULTIVARS TO PHOSPHORUS AND ZINC NUTRITION

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Abstract

Phosphorous (P) and Zinc (Zn) fertilization play a key role in the productivity of crops. To study their effects on the maize yield and growth, an experiment was conducted at the University of Agriculture Peshawar, during 2011. Four levels of P (0, 60, 90, 120 kg ha^{-1}) and Zn (0, 5, 10, 15 kg ha^{-1}) each were used for maize cultivars 'Azam' and 'Jalal'. Combinations of variety (V) and P were allotted to main plot and Zn to subplot using randomized block design with split plot arrangements. Maize variety 'Jalal' was significantly responsive in the yield as compared to 'Azam'. Similarly, days to tasseling and silking, leaf area $plant^{-1}$ (LA), leaf area index (LAI), ear weight, thousand grains weight, grain yield (GY) and harvest index (HI) were significantly affected by P and Zn. Early tasseling (48.6), silking (54.4), higher LA (4545 cm^2), LAI (2.9), ear weight (172.9 g), thousand grains weight (267 g), GY (5958 kg ha^{-1}) and HI (37.4%) were exhibited by 120 kg ha^{-1} P treated plots. Plots with 15 kg ha^{-1} Zn showed significantly early tasseling (49.3), silking (55.3), more LA (4347 cm^2), LAI (2.8), ear weight (157.3g), thousand-grains weight (242.9g), GY (5099 kg ha^{-1}) and HI (35.39%). It was concluded from the study that increase in the P and Zn rates improved most of the studied parameter, however in case of yield and yield components, significantly maximum response was given by both cultivars at 90 kg ha^{-1} P and 10 kg ha^{-1} Zn than their lower rates and found non-significant as compared with their upper limits under study.

Keywords: Cultivars, Maize, Phosphorus, Yield, Zinc

Introduction

Maize (*Zea mays* L.) is an important grain crop with great economic value for both livestock (cattle and poultry) and human consumption (Harris *et al.,* 2007). Pakistan's climatic condition as well as its soil is ideal for the production of maize. Plant growth and development needs the availability of essential nutrients in the balance form that lead to the formation of good yield (Randhawa & Arora, 2000).

Phosphorus (P) is an important macro nutrient present in the inorganic as well as organic forms in soil. It stimulates the development of deoxyribonucleic acid (DNA) and ribonucleic acid (RNA), responsible for the heredity transmission. Phosphorus plays a key role in formation of nucleus, cell division and hence, advances the plant growth and development. Absorption of P occurs mainly during vegetative growth stages, and thereafter most of the absorbed P is re-translocated into seeds during reproductive stages (Sharif *et al*., 2014). Hence, it promotes the early growth and formation of roots, which also improves the crop resistance against certain diseases (Havlin *et al*., 2005; Wahid *et al.*, 2015).

Quality and quantity of the crop plants products can be improved through balanced nutrition. In developed countries, the role of micronutrients in the soil fertility is considered as a backbone in the farming system. Micronutrients are indispensable for plants, required in trace amounts (Salwa *et al.,* 2011). The plant's physiological activities and growth is mainly harmonized by these nutrients (Zeidan *et al.,* 2006). The scarcity of these nutrients is prevailing in Pakistan due to the alkalinity, calcareousness of the soil, lack of organic matter, drought, improper irrigation and imbalanced fertilizer application (Narimani *et al.,* 2010).

Zinc (Zn) is one of the most functional micronutrients in biological system (Cakmak, 2008). Zn is a constituent of different enzyme involve in metabolism of carbohydrate, auxin, protein, pollens' formation and maintenance of the biological membranes integrity and infection resistance against certain pathogens (Alloway, 2004; Kobraee *et al.,* 2011). Zn promotes the synthesis of carbonic enzyme, which is responsible for the biosynthesis of chlorophyll and is present in all photosynthetic tissues (Graham *et al*., 2000). Physiological pathways involved in the processing of photosynthetic assimilates are also Zn dependant (Alloway, 2002; Sawan *et al.,* 2008; Yosefi *et al.,* 2011). Because its deficiency decreases the photosynthetic rate (*A*), transpiration rate (*E*) and stomatal conductance (*gs*) significantly (Ilyas *et al*., 2015). Mostly, the unavailability of Zn to crop is because of its immobile behaviour in the soil, and as a result, Zn deficiency reflects in the form of little cell growth and development and hence, reduced shoot growth (Ghasemian *et al*., 2010). It is the third most limiting nutrient in crop production after nitrogen and phosphorus (Zayed, 2011).

In soil solution and plants, phosphorus binds with Zn by forming insoluble Zn-phosphate complexes, which inhibits the Zn uptake via roots and its movement in the plants. It has been reported that although higher phosphorus application to soil increases the plants P uptake but decreases the uptake of Zn that causes Zn deficiency (Robson & Pitman, 1983; Zhao *et al*., 2007; Mousavi *et al*., 2011). In maize, higher P and lower Zn concentrations as a result of P toxicity and Zn deficiency reduces the shoot growth. This suggests that heavy P fertilization can cause not only the toxicity of phosphorus but also induces the deficiency of Zn. Therefore, application rate of P in combination with Zn must be chosen carefully. The present study was conducted to determine the effect of phosphorus in combination with Zn on the growth and yield of different maize cultivars.

Materials and Methods

The experiment on the response of maize cultivars to phosphorus and zinc nutrition was carried out at The University of Agriculture Peshawar, Pakistan during summer, 2011. The experiment consisted of the following factors:

	Factor B: Phosphorus (P)	Factor C: Zinc (Zn)	
V1. Azam	P1. Control	Zn1.	Control
V2. Jalal	P2. 60 kg ha^{-1}	Zn2.	5 kg ha^{-1}
	P3. 90 kg ha^{-1}	Zn3.	10 kg ha^{-1}
	P4. 120 kg ha^{-1}	Zn4.	15 kg ha^{-1}

The experiment was conducted in RCB design with split plot arrangements having three replications. Treatment combinations of factor-A and B were randomly allotted to the main plot and factor-C to the subplot. Plot size was 5.25 x 3 m^2. Row to row spacing was 0.75m. SSP/TSP and $ZnSO_4$ were used as sources of P and Zn, respectively. Sulfur supplied at a variable rate as a result of Zn treatments application from $ZnSO_4$, it was uniformed in all plots through using ammonium sulfate as a source of sulfur-cum-nitrogen. Afterwards, remaining nitrogen was supplied from urea.

Data were collected on days to tasseling and silking, leaf area (LA) plant^{-1}, leaf area index (LAI), ear weight, thousand-grains weight, grain yield (GY) and harvest index (HI) during the course of study.

Data on days to tasseling was recorded when more than 80% plants produced tassels in each plot. The difference from date of sowing was calculated and recorded as days to tasseling, and likewise the days to silking. LA plant^{-1} was taken on five plants, selected at random from the central rows at tasseling stage in each plot. The average leaf length and width of all the leaves collected from the selected plants were calculated. Their product was multiplied with the correction factor (0.75) and then divided by 5 (number of plants) to get the value of LA plant^{-1} (Francis *et al*., 1969). LAI was calculated by the given formula;

LAI =leaf area plant^{-1}(cm^2) x plants m^{-2} /10000

Ear weight was taken on five randomly selected ears, weighed and averaged and likewise the thousand-grain weight. GY was recorded on three central rows in each plot. Sun dried ears were threshed and weighed to get the GY for the selected area, which was then converted into kg ha^{-1}. HI was calculated using the given formula:

Harvest index (%) = (Grain yield / Biological yield) x 100

Statistical analysis of data was done by following the ANOVA procedure for RCBD with split plot arrangements. Upon significant F-test, least significant differences (LSD) test at $p \leq 0.05$ was used for comparison of means (Jan *et al*., 2009).

Results and Discussion

Days to tasseling and silking: Data presented in Table 1 showed that P and Zn significantly affected the number of day taken to tasseling and silking. More days to tasseling (51.4) and silking (57.7) were recorded in control plots, while less days to tasseling (48.6) and silking (54.4) were noted in the plots with 120kg P ha^{-1}. Comparatively early tasseling and silking were observed with successively increased level of Zn. Cultivars effect on the days to tasseling and silking was found statistically non-significant. Interaction of P, Zn and V was significant for both the parameters, while all the other interactions were found non-significant except P and Zn interaction for silking. This might be due to the fact that proper and adequate supply of nutrients accomplishes all physiological processes in plants and hence took more days for tasseling and silking. Higher P rates improved the plant growth and development as also reported by Singaram & Kothandaraman (1994). Likewise, least days to tasseling were recorded in maize cultivars with the higher Zn application (Akbar *et al*., 2002; Rasheed *et al*., 2004).

Leaf area (cm^2) and leaf area index (LAI): Leaf area (LA) and LAI was significantly affected by P, Zn and interactions of P x Zn and P x Zn x V, where as cultivars and other interactions effect were insignificant (Table 1). More LA (4545 and 4337) and higher LAI (2.9 and 2.8) were found in plots applied with upper level of P (120 kg ha^{-1}) and Zn (15kg ha^{-1}), respectively. Less LA (3567) and LAI (2.3) was noted in control treatments. Maize cv. Jalal produced higher LA (4214) and LAI (2.7) as compared with cv. Azam. In case of P and Zn interaction, plots with P at the rate 120 kg ha^{-1} under 15 kg ha^{-1} Zn produced the higher LA (4263) and LAI (2.8) and for P x Zn x V interaction, higher LA (4811) and LAI (3.0) was recorded in maize cv. Jalal, treated with 90 kg P ha^{-1} and 10 kg Zn ha^{-1}. Application of P and Zn together to the field might improve the enzymes and ATP production concurrently efficient photosynthetic rate (Ilyas *et al*., 2015). Hence, more LA and more LAI were recorded, as also reported by Rasheed *et al*., (2004), Harris *et al.,* (2007).

Ear weight (g): Analysis of variance reflected that P, Zn, V and interactions of P x Zn and P x Zn x V had significantly affected the ear weight (Table 1). Mean value revealed that heavier ears (172.9) were observed in 120 kg P ha^{-1} treated plots, while the lighter (123.8) were noted in control plots. Likewise, Zn at the rate of 15 kg ha^{-1} produced the heavier ears (157.3), while the lighter (146.9) in control plots. In case of P x Zn interaction, plots treated with 120 kg P ha^{-1} produced heavier ears (176.4) under 10 kg Zn ha^{-1}, while lighter ears (118.1) were observed in case of their control. In varieties, Jalal attained the heaviest ear weight (154.8) and lightest ear weight (151.8) was recorded in Azam. Regarding interaction of P, Zn and V, Jalal developed the heavier ears (177.7) at 120 kg P ha^{-1} and 15 kg Zn ha^{-1}, while the lighter ears (115.5) were recorded in Azam at no P and Zn application. Number of grains ear^{-1} increased with the increase in P level (Okalabo & Probert, 1992). This increased number of grains ear^{-1} of maize with increasing level of Zn rate hence increased the ear weight that had also been reported by Harris *et al*., (2007). The varietal genetic makeups significantly differ in grains number and ear weights. Our results are in conformity with Akmal *et al*., (2010) who reported that maize cultivars had significant affect on ear weight with different levels of P and Zn.

Thousand-grains weight (g): Analysis of variance of the data showed that all the three factors as well as their interactions with one another affected the thousand-grains weight (Table 1). The data showed that higher thousand-grains weight (267) was observed in 120 kg ha^{-1} P treated plots, while lower (195.2) was noted in control plots. In case of Zn, plots with 10 kg Zn ha^{-1} produced the heavier grains (243.2) as compared with the lighter grains (228.3) noted in the control plots. Thousand-grains weight of Jalal was higher (240.2) than the Azam (235.3). Interaction of P and Zn elucidated that plots with 120 kg P ha^{-1} and 10 kg Zn ha^{-1} developed the heavier grains (270), while the lighter grains (187.5) were noticed under their control conditions. In case of P x Zn x V interaction, Jalal showed higher thousand-grains weight (373) when treated with 120 kg ha^{-1} P and 10 kg ha^{-1} Zn, while lower (183.3) at no P and Zn application. The heaviest grains at higher P level might be the result of higher P translocation in to the fruiting site, also reported by Sahoo & Panda (2001). Plots with 15 kg Zn ha^{-1} were found with highest thousand-grains weight as compared with lowest in Zn control plots. Thousand-grains weight increased with increased Zn levels and the same phenomenon was also reported by Harris *et al*., (2007).

Table 1. Days to tasseling and silking, leaf area (cm^2)and leaf area index (LAI), ear weight (g), thousand-grains weight (g), grain yield (kg ha^{-1}) and harvest index (%) in maize varieties as affected by phosphorous (P) and zinc (Zn) levels.

	Days to tasseling	Days to silking	Leaf area (cm^2)	LAI	Ear wt. (g)	Thousand grains wt. (g)	Grain yield (kg ha^{-1})	Harvest index (%)
P (kg ha^{-1}) 0	51.4 a	57.7 a	3567.5 c	2.3 c	123.8 d	195.2 d	2863 c	27.0 c
60	50.4 b	56.2 b	4016.8 b	2.5 bc	150.0 c	233.1 c	4515 b	32.9 b
90	49.0 c	55.0 bc	4503.7 a	2.8 ab	166.4 b	255.8 b	5689 a	36.9 a
120	48.6 c	54.4 c	4545.2 a	2.9 a	172.9 a	267.0 a	5958 a	37.4 a
LSD value	0.93	1.26	379.16	0.31	4.06	6.92	248	2.33
Zn (kg ha^{-1}) 0	50.4 a	56.0 b	4022.5 c	2.5 b	146.9 c	228.3 c	4293 d	30.5 c
5	50.0 ab	56.3 a	4053.9 c	2.6 b	152.7 b	236.7 b	4699 c	33.6 b
10	49.6 bc	55.7 c	4208.9 b	2.6 b	156.3 a	243.2 a	4933 b	34.9 a
15	49.3 c	55.3 d	4347.9 a	2.8 a	157.3 a	242.9 a	5099 a	35.3 a
LSD value	0.40	0.23	116.00	0.41	1.68	2.98	98.00	1.07
Maize CV Azam	49.5	55.6	4102.5	2.6	151.8	235.3 b	4627b	33
Jalal	50.1	56	4214.1	2.7	154.8	240.2 a	4885a	34.2
LSD value	Ns	ns	*	*	2.87	4.89	245	*
P x V	ns	ns	ns	ns	ns	ns	ns	ns
Zn x V	ns	ns	ns	ns	ns	ns	ns	ns
P x Zn	ns	*	*	*	*	*	*	*
P x Zn x V	*	*	*	*	*	*	*	*

Means of the same category followed by different letters(s) reveals significant differences among mean values ($p<0.05$) using LSD test
* = Significant at 5% level of probability , ns = Non significant

Grain yield (kg ha^{-1}): Phosphorus, Zn and V as source of variation significantly affected the grain yield (Table 1). Mean value of the data elucidated that plots with 120 kg P ha^{-1} developed higher grain yield (5958), while lower grain yield (2863) was noted in the control plots. Plots treated with Zn @ 15 kg ha^{-1} produced higher grain yield (5099), while lower (4293) was observed at no Zn addition. Similarly, maize cv. Jalal attained more grain yield (4885) than cv. Azam (4627). Statistically significant interaction was observed between P and Zn. The highest grain yield (6285) was recorded with 90 kg P ha^{-1} and 15 kg Zn ha^{-1}, while the lowest grain yield (2410) was noted in control treatment. As interaction of P, Zn and V was also significant, in which Jalal attained the higher grain yield (6534) at 90 kg ha^{-1} P and 15 kg Zn ha^{-1}, while the lower grain yield (2397) was recorded in control plot of Jalal. Similar to our findings, Amanullah *et al*., (2009) also reported an increase in the maize grain yield with increasing level of phosphorus. Likewise, Abunyewaa & Quareshie (2004) found increase in the grain yield at higher level of Zn. Their findings showed that higher fertilizer levels increases the grain yield due to more vegetative growth period, more leaf area duration and LAI. These accounts for more radiation interception, photosynthetic efficiency, growth rate and hence more grains and weight ear^{-1}. While Khan *et al*., (2013) and Marwat *et al.,* (2007) reported that application of Zn and macro-nutrients increased the yield related parameters of maize.

Harvest index (%): ANOVA revealed significant differences in the harvest index as influenced by different P, Zn and V (Table 1). The data reflected that maximum of harvest index (37.4) was observed in 120 kg P ha^{-1} plots, while minimum harvest index (27.0) was noted in the control plots. Zn plots treated @ 15 kg ha^{-1} showed highest harvest index (35.3) and the lowest (30.5) in control plots.

Interaction between P and Zn was also significant. Plots that received 90 kg P ha^{-1} and 15 kg Zn ha^{-1} developed harvest index of 41.2, while the lowest (23.4) was observed in their control plots. As P x Zn x V interaction was also significant, where the highest harvest index (42.9) was recorded for Jalal at 90 kg ha^{-1} P and 15 kg ha^{-1} Zn, while lowest harvest index (22.9) was recorded for Jalal with no P and Zn application. This might be the result of efficient uptake in response to balance P and Zn nutrition that might improved the photo assimilation and their translocation to the grains, which led to higher HI as also reported by Amanullah *et al*., (2009)

Conclusion and Recommendation

It was concluded from the results of this field trial that maize cv. Jalal performed well than cv. Azam in terms of yield and yield components. Among the studied P and Zn levels, improved yield contributing traits were observed at 90 kg P ha^{-1} and 15 kg Zn ha^{-1}. Therefore, maize cv. Jalal supplied with the stated levels of P and Zn can be grown successfully for improved crop productivity in agro-climate condition of Peshawar.

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