Research Article

Response of Maize Growth to Phosphorus, Foliar Zinc and its Application Stage

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Abstract | Phosphorus (P), Zinc (Zn) and its application timing play a very important role in crop productivity. To study its effect on maize, an experiment was conducted at Fodder and Forage Crops Section Harichand, district Charsadda- Pakistan. 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 application stages (AS) i.e., full at vegetative stage V6 (AS_1), full at reproductive stage R2 (AS_2) and ½ at V6 and ½ at R2 stage (AS_3) along with an overall control were used in the experiment. Randomized complete block design was used with three replications. Most of the studied parameters were significantly affected by P, Zn and AT. Least days to tasseling (54) and silking (55), leaf areaplant^{-1} (4180 cm^2), leaf area index (2.8), plant height (255 cm) and days to harvest maturity (89 were significantly affected when120 kg P ha^{-1} was applied. Days to tasseling (53), days to silking (55), leaf areaplant^{-1} (4400 cm^2), leaf area index (3.1), plant height (258.6 cm) and days to harvest maturity (89) were significantly affected in plots treated at the rate of 5 kg ha^{-1} with Zn. In case of application stages (AS), when Zn was applied 1/2 at vegetative and 1/2 at reproductive growth stages significantly enhanced the plant height (260.8 cm). It can be concluded from the study that increases in the rates of P and Zn improved majority of the studied parameters. Similarly, application of Zn, half at vegetative stage (V6) and half at reproductive stage (R2) improved significantly the phenological parameters of maize crop in the agro climatic condition of the study area.

Received | May 10, 2022; **Accepted** | July 08, 2022; **Published** | September 13, 2022
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Citation | Ali, S., S. Shah, M. Amin, A.A. Khan, S. Khan, D. Ahmad, F. Ahmad, M. Khan, S. Azam, S. Ahmad and B. Khan. 2022. Response of maize growth to phosphorus, foliar zinc and its application stage. *Sarhad Journal of Agriculture,* 38(3): 1140-1146.
DOI | https://dx.doi.org/10.17582/journal.sja/2022/38.3.1140.1146
Keywords | Application Time, Maize, Phosphorus, Growth, Zinc

Introduction

Balanced fertilizer is an essential component that plays a significant role in improving the crop production and quality (Amjadian *et al*., 2021). Balanced fertilizer also play an important role plant development and yield formation, the presence of essential nutrients in balanced form is necessary (Hitha *et al*., 2021). Among the essential nutrients, the second essential nutrient is phosphorus (P) after nitrogen. Phosphorus (P) is one of the most limiting nutrients in agricultural cropping systems (Ullah *et al*., 2018; Guignard *et al*., 2017; Khan *et al*., 2018). It is an important macronutrient for optimum growth, metabolism and development of crops (Yadav *et al*., 2017). Worldwide, P is considered a key factor for increasing yield, after nitrogen (Zamin *et al*., 2020; Salimpour *et al*., 2020; Adeyemi *et al*., 2020). It has higher requirements in most cereal and vegetal crops (Ketterings *et al*., 2020). It is present in the in soil in two different forms. It is taken by the plant in the form of $H_2PO_4^{-1}$ and HPO_4^{-2}. HPO_4^{-2} absorption is faster as compared with respect to $H_2PO_4^{-1}$ (Alamnie *et al*., 2021). Lodging is decreases by phosphorus because it gives strength to the straw of cereal crops. Resistance of crop is increased to certain diseases when Pis applied. It plays vital role in nucleus formation, cell division and in the development of plant. Phosphorus also helps in formation of DNA and RNA (Sharma *et al*., 2021; Kolodiazhnyi *et al*., 2021).

Almost all micro-nutrients such as Zn and Fe though are as important as macronutrients (Jake *et al*., 2022). But these micro-nutrients are required to plants in minute quantity. Plants and soils have a very small range of micro-nutrients (Ali *et al*., 2019; Chakraborty *et al*., 2021). They involve in physiological processes and functions of the plant which ultimately improve the phenology of crop (Munish *et al*., 2021).

Similarly, in case of micro-nutrients, Zinc (Zn) is a fundamental micro-nutrient and play key role in all forms of life such as animals, human beings and plants (Natasha *et al*., 2022). Zn is necessary for biosynthesis of chlorophyll (Ali *et al*., 2021; Vazifeh *et al*., 2021). In general, Zn has major role in activating enzyme, proteins synthesis, revival and oxidation reactions and carbohydrates metabolism. 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 *et al*., 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 (Sonal *et al*., 2021). Foliar Zn also significantly enhances size of maize leaf (Ali *et al*., 2021; Raheela *et al*., 2021).

Materials and Methods

The experiment entitled "response of maize growth to phosphorus, foliar zinc and its application stage" was performed at Fodder section Harichand, district Charsadda- Pakistan. The experiment comprised of three factors.The experiment comprised two levels of phosphorus (90 and 120 kg ha^{-1}) and three levels of zinc (0, 2.5 and 5 kg ha^{-1}) were applied at three growth stages (*i.e.* foliar application at vegetative (V6, collar of 6th leaf visible), reproductive (R2, Kernels are small and watery, silks are browning and dry) and ½ at vegetative (V6) and ½ at reproductive (R2) stage along with one unsprayed check 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 x 4.0 m. Jalal variety was used for sowing. Planting was made on flat beds in rows spaced of 0.70m. Phosphorus was applied in the form of SSP at the time of sowing. For application of Zn, 0.5% solution of $ZnSO_4.7H_2O$ 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. Plots were sprayed as per levels of factor-C. First irrigation was given12 days after sowing and subsequent irrigation was adjusted according to the need of crop. For all the treatments, other agronomic practices were kept uniform. The soil of the research field as tested in the laboratory is 48.1% silt, 37% clay and 9.4% sand, 12.4% $CaCO_3$ and 7.9 pH.

Statistical analysis

The experimental data of both the two years were statistically analysed as per the statistical design. Means of the recorded data were compared at p≤0.05 (LSD test) upon significant F-test (Jan *et al*., 2011).

Results and Discussion

Days to 50% tasseling

Data on days to 50% tasseling shown in Table 1. Mean values of the data showed that more (53 days) was noticed when 90 kg P ha^{-1} was applied while less (52 days) was noticed when 120 kg P ha^{-1}was applied. Normal amount of P bring early tasseling as compared to high level because high amount of phosphorus disturb various physiological processes in plants (Yue *et al*., 2021). Similarly, in case of Zn, more (53 days) were taken when no Zn was applied while minimum (51 days) was observed when 5 kg Zn ha^{-1} was applied. It is because that Zn activates enzyme and also take part in metabolism in plant (Peng *et al*., 2020). In case of Zn application timing, more (53 days) were shown when Zn was applied half at V6 and half at R2 stage while less (52 days) was notice when applied full at V6 stage. Split dose of zinc application at vegetative and reproductive growth stage can easily take by the plants. This might be due to attaining sufficiency level of nutrient absorption (Singh *et al*., 2015).

Table 1: *Days to 50% tasseling of maize as affected by phosphorus, foliarZn and its application stages.*

Phosphorus (kg ha^{-1})	Zn (kg ha^{-1}) Application	Application Stage (AS)		Mean
		100% at V6	50% at V6	
90	0	54	54	54
	2.5	53	53	53
	5.0	52	52	52
120	0	52	53	52
	2.5	51	52	51
	5.0	51	52	51
-	0	53	54	53a
-	2.5	52	53	52ab
-	5.0	51	52	51 b
90	-	53	53	53a
120	-	51	52	52b
Mean		52b	53a	52
Control				54 a
Rest				52b

Days to 50% silking

Data on days to 50% silking shown in Table 2. Mean values of the data showed that more days to 50% silking (55) were noticed when 90 kg P ha^{-1}was applied, while less days (53) was noticed when 120 kg P ha^{-1}was applied. Tasseling and silking were comparatively earlier when P was applied at higher rates. Early silking and tasseling in maize crop is the result of phosphorus because it develop strong root system as a result plant complete its life cycle earlier as possible (Olatunji *et al*., 2020). Similarly, in case of Zn, 55 days to 50% silking was noticed when no Zn was applied, while 54 days were noticed when 5 kg Znha^{-1}was applied. Earlier silking was produced because zinc speeded the rate of photosynthesis due to which early silking occurs in maize crop (Hassan *et al*., 2021). In case of Zn application timing, more days to 50% silking (54) were noticed when Zn was applied half at V6 and half at R2 stage while less (54) were noticed at AT1 stage.

Table 2: *Days to 50% silking of maize as affected by phosphorus, foliarZn and its application stages.*

Phosphorus (kg ha^{-1})	Zn (kg ha^{-1}) Application	Application Stage (AS)		Mean
		V6	50% at V6	
90	0	55	55	55
	2.5	55	55	55
	5.0	54	54	54
120	0	54	54	54
	2.5	53	55	54
	5.0	53	53	53
-	0	55	55	55 a
-	2.5	54	55	54 a
-	5.0	53	54	54 b
90	-	55	55	55 a
120	-	53	54	53 b
Mean		54b	54 a	54
Control				56 a
Rest				54 b

Leaf areaplant^{-1} (cm^2)

Data on Leaf area plant^{-1} (cm^2) shown in Table 3. Mean values of the data showed that more (4180) leaf areaplant^{-1}was noticed when 120 kg P ha^{-1}was applied while less (4102) was noticed when 90 kg P ha^{-1}was applied. Phosphorus is a vital component of ATP, the "energy unit" of plants. ATP forms during photosynthesis, has phosphorus in its structure, and processes from the beginning of seedling growth through to the formation of grain and maturity. Thus, phosphorus is essential for the general health and vigor of all plants. (Pankaj *et al*., 2021). Similarly, in case of Zn more (4400) leaf areaplant^{-1}was recorded when 5 kg Zn ha^{-1}was applied while less (4103) was noticed when no Zn was applied. This might be that zinc increases chlorophyll content in leaf due to which leaf area enhances (Kandoliya *et al*., 2018).

Leaf areaindex

Data on leaf area index shown in Table 4. Mean values of the Leaf area index showed that maximum leaf area index (2.83) was noted in rest plots while the minimum was observed in control plots (2.03). Incase of P, more (2.77) leaf area index was noticed when 120 kg P ha^{-1} was applied while less (2.63) was noticed when 90 kg P ha^{-1}was applied (Kandoliya *et al*., 2018). Similar in case of Zn maximum (3.09) leaf area index was noticed when 5 kg Zn ha^{-1} was applied while minimum (2.60) was noticed when no Zn was applied.

Table 3: *Leaf areaplant^{-1} (cm^2) of maize as affected by phosphorus, foliarZn and its application stages.*

Phosphorus (kg ha^{-1})	Zn (kg ha^{-1}) application	Application Stage (AS)			Mean
		V6	R2	50% at V6 + 50% at R2	
90	0	4010	4008	3943	3987
	2.5	3988	4106	4097	4064
	5.0	4375	4165	4227	4256
120	0	4197	4172	4289	4220
	2.5	4346	4364	4302	4337
	5.0	4532	4560	4542	4544
-	0	4104	4090	4116	4103 c
-	2.5	4167	4235	4200	4200 b
-	5.0	4453	4363	4384	4400 a
90	-	4124	4093	4089	4102 b
120	-	4187	4148	4204	4180 a
Mean		4241	4229	4233	
Control					3844 b
Rest					4235 a

Table 4: *Leaf area index of maize as affected by phosphorus, foliarZn and its application stages.*

Phosphorus (kg ha^{-1})	Zn (kg ha^{-1}) Application	Application Stage (AS)			Mean
		V6	R2	50% at V6 + 50% at R2	
90	0	2.1	2.4	2.6	2.4
	2.5	2.5	2.2	2.9	2.5
	5.0	2.5	3.2	2.9	2.9
120	0	3.2	2.4	2.7	2.8
	2.5	3.0	3.2	2.6	3.0
	5.0	3.5	3.2	2.9	3.2
-	0	2.6	2.4	2.7	2.6 b
-	2.5	2.8	2.7	2.8	2.7 b
-	5.0	3.0	3.2	2.9	3.0 a
90	-	2.4	2.6	2.8	2.6 b
120	-	2.7	2.6	2.8	2.7 a
Mean		2.8	2.8	2.8	
Control					2.0 b
Rest					2.8 a

Plant height (cm)

Data on plant height (cm) shown in Table 5. Mean values of plant height showed that maximum P (255.7) plant height was noticed when 120 kg P ha^{-1} was applied while minimum (247.3) was noticed when 90 kg P ha^{-1} was applied. Plant height increased with the higher rate of P. It might be due to higher rate of phosphorus, have increased root development and thus helped with plant obtained more phosphorus which resulted in higher plants (Ejaz *et al*., 2020). Similar in case of Zn, maximum (258.6) was noticed when 5 kg Zn ha^{-1} was applied while minimum (243.5) was observed in unfertilized plots. Plant height increased with increasing rate of Zn. It might be due to reason that internodes length increased with Zn application (Majid *et al*., 2018). In case of Zn application timing, maximum plant height (260.8) was noticed when Zn was applied half at V6 and half at R2 stage while minimum (245.7) was noticed when applied full at AT1 stage.

Table 5: *Plant height (cm) of maize as affected by phosphorus, foliarZn and its application stages.*

Phosphorus (kg ha^{-1})	Zn (kg ha^{-1}) application	Application Stage (AS)			Mean
		V6	R2	50% at V6 + 50% at R2	
90	0	233.7	236.3	254.3	241.4
	2.5	246.7	242.7	257.0	248.8
	5.0	258.7	241.0	255.3	251.7
120	0	238.0	242.0	256.7	245.6
	2.5	240.7	259.3	268.3	256.1
	5.0	256.7	266.7	273.3	265.6
-	0	235.8	239.2	255.5	243.5 c
-	2.5	243.7	251.0	262.7	252.4 b
-	5.0	257.7	253.8	264.3	258.6 a
90	-	246.3	240.0	255.6	247.3 b
120	-	245.1	256.0	266.1	255.7 a
Mean		245.7 b	248.0 b	260.8 a	
Control					213.0
Rest					251.5 a

Days to harvest maturity

Data on days to harvest maturity shown in Table 6. More days to harvest maturity (91) was noticed when 90 kg P ha^{-1} was applied while minimum (89) was noticed when 120 kg P ha^{-1} was applied. Days to harvest maturity decrease with increasing rate of P. The possible reason may be due to the development of maize phenology, also might be due to the higher rate of P that increased the development of root and thus the root obtained more P to complete the life cycle earlier as soon as possible. These results are in line with (Ali *et al*., 2019) who reported a significant effect of P on days to maturity of maize. Similarly in case of Zn, maximum (92) days to harvest maturity was noted in unfertilized plots while minimum (88) was shown when 5 kg Zn ha^{-1}was applied. Zinc application bring early maturity because zinc accelerate various physiological processes in plant (Nabat *et al*., 2022). In case of Zn application timing, maximum (91) days to harvest maturity was noticed when Zn was applied at AT2 stage while minimum (89) was recorded at AT1 stage.

Table 6: *Days to harvest maturity of maize as affected by phosphorus, foliar Znand its application stages.*

Phosphorus (kg ha^{-1})	Zn (kg ha^{-1}) application	Application Stage (AS)			Mean
		V6	R2	50% at V6 + 50% at R2	
90	0	93	93	92	92
	2.5	91	91	91	91
	5.0	89	90	90	90
120	0	90	92	92	91
	2.5	88	92	87	89
	5.0	87	87	87	87
-	0	91	92	92	92 a
-	2.5	89	91	89	90 b
-	5.0	88	89	89	88 b
90	-	91	91	91	91 a
120	-	88	90	89	89 b
Mean		89 b	91 a	90 b	
Control					94.33
Rest					90.50

Conclusions and Recommendations

Hence it is concluded from the experiment that application of 120 kg P ha^{-1}significantly improved leaf area per plant, leaf area index and plant height. While 90 kg P ha^{-1}enhanced 50% days to tasseling, 50% days to silking and harvest maturity. In case of foliar application of zinc, 5 kg Zn ha^{-1} improved leaf area per plant, leaf area index and plant height. Similarly in case of application stages of zinc, when applied ½ at vegetative enhanced 50% days to silking, ½ at vegetative & ½ reproductive stage improved plant height and 100% spray of zinc at reproductive (R2) stage improved the productivity of maize crop. Therefore, phosphorus and zinc with its various application stages is recommended for the agro climatic conditions of Harichand, district Charsadda- Pakistan.

Novelty Statement

In the current study, phosphorus and zinc effect and its application timing was determined on maize crop production.

Author's Contribution

Sajid Ali: Did research, data collection, analysis and wrote draft of the manuscript.
Shahen Shah, Muhammad Amin, Asad Ali Khan and Sajjad Khan: Helped in analysis and technical guidelines.
Dawood Ahmad and Faiq Ahmad: Helped in data collection.
Maaz Khan, Sikandar Azam, Siddique Ahmad and Bismillah Khan: Helped in format setting.

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

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