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Effect of Phosphorous Levels on Growth and Yield of Maize (*Zea mays* L.) Cultivars under Saline Conditions

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ABSTRACT

A field experiment was conducted to study the effect of different levels of phosphorus (0, 25, 50, 75 and 100 kg P_2O_5 ha^{-1}) on two maize cultivars (Hybrid N-6240 and Hybrid 6622) under saline conditions. Plant height, number of cobs per plant, number of grain rows per cob, number of grains per cob, grain weight per cob, 1000-grain weight, stalk and grain yield increased significantly with phosphorus applications. The maize plants fertilized with 75 kg P_2O_5 ha^{-1} performed better in grain weight per cob, number of grains per cob, cob weight and 1000-grain weight over other levels. Maximum plant height and number of cobs per plant were recorded in maize plants fertilized with 100 kg P_2O_5 ha^{-1} whereas maximum number of grain rows per cob was produced in maize plants fertilized with 50 kg P_2O_5 ha^{-1}. The non-significant effect of phosphorus on harvest index was observed. The non-significant effect of phosphorus on harvest index was due to the better ability of heavy plants (producing greater biomass) to produce more economic yield under the saline conditions. Genotypic and genotype × phosphorous effects were non-significant for all the characters studied. The application of phosphorus at the rate of 75 kg P_2O_5 ha^{-1} appeared the best dose for maize crop under the saline conditions.

Key Words: Phosphorous; Maize cultivars; Growth; Yield; Saline conditions

INTRODUCTION

The best soils for maize are well drained deep loams and silt loams. Maize can be grown on soils with a pH from 5.0 to 8.0, but it is moderately sensitive to salinity, and 90% relative yield is obtained at an electrical conductivity of about 1.8 dS m^{-1} (Jones, 1985). Salt-affected soils in Pakistan are 6.28 m ha, out of which 2.3 m ha has been presently declared as wasteland due to high salinity and sodicity (Hanjra *et al*., 2003).

Adequate and balanced supply of essential elements to growing crop plants is one most important way to exploit genetic potential of crop plants. The saline conditions affect the uptake of nutrient by plants and cause the accumulation of toxic ions in the plant tissues (Yeo & Flowers, 1984; Tivy, 1990). In alkaline soils the availability of many plant nutrients becomes generally low. In the pH range 6 to 8 the phosphorus concentration in the soil solution may not decline but rather increase with pH (Welp *et al*., 1981). In Pakistan, the pH of alkaline soils is more than 8 and organic matter content is less than 1. The equilibrium constants of inorganic phosphates are imbalanced by low soil organic matter content and increased pH of alkaline soil.

In general, phosphorus deficiency in crop plants growing in alkaline soils is caused primarily by very low levels of total phosphorus and soil moisture, that is, when the mobility of phosphorus is limited and root growth is restricted (Marschner, 1995). Plant growth behavior is influenced by the application of phosphorus (Hajabbasi & Schumacher, 1994; Gill *et al*., 1995; Kaya *et al*., 2001). Phosphorus application increases the plant height, grain weight per cob, dry matter yields and grain yield (Sharma & Sharma, 1989; Mullar & Weigert, 1991; Singh & Dubey, 1991; Sharma & Gupta, 1998). Higher phosphorous applications reduce the sodium absorption ratio and increase crop production in saline sodic soils (Chaudhry *et al*., 1992). The present study was, therefore, undertaken to determine the growth and yield response of maize cultivars to varying levels of phosphorous under saline conditions.

MATRIALS AND METHODS

Studies pertaining to the effect of varying levels of phosphorus on growth, yield and quality parameters of two maize were conducted under saline conditions, at the Research Area of University College of Agriculture, Bahauddin Zakariya University, Multan, Pakistan. The soil had pH 8.3, EC 7.0 dS m^{-1} and Exchangeable Sodium Percentage 14.8. The concentrations of Nitrogen, Phosphorus and Exchangeable Potassium in the soil were found 0.03%, 9.25 ppm and 116.0 ppm, respectively. The experiment was laid out in randomized complete block design in factorial arrangement with four replications. The factors under study were maize cultivars and different phosphorus levels. The maize cultivars were Hybrid N-6240 and Hybrid 6622. The levels of phosphorus were 0, 25, 50, 75 and 100 kg ha^{-1}.

Crop was sown in the field by dibbling on July 23, 2003 on well prepared seedbeds with row to row distance 75 cm and plant to plant distance 20 cm using a seed rate of

30 kg ha^{-1}. All of phosphorus according to treatments and half of nitrogen was side dressed at sowing in the form of urea and di-ammonium phosphate, while remaining dose of nitrogen was side dressed at knee height stage. Thinning was done when crop attain a height of about 15 cm to assure uniform plant population in each plot. The objective of thinning was to eliminate the effect of plant population on growth and yield components of maize. All other agronomic and plant protection practices were kept constant during the crop period.

The data on germination count (m^{-2}) were recorded from the total plants germinated per plot divided by the area of a plot. Ten plants were randomly selected from each plot to record data on plant height, total number of cobs, number of grain rows per cob and number of grains per cob and then averaged. When leaves turned yellow, the plants of each plot were harvested and were stacked at the threshing floor for fifteen days for drying. The sun-dried cobs were removed from the plants and shelled to record the grain yield. The stalk yield was taken by subtracting grain yield from total biomass of each plot. Three samples of 1000-grains were taken at random from the grain lot of each plot and then weighed on triple beam balance and then averaged for 1000-grain weight. The harvest index was recorded by taking the ratio between economic yield and biological yield expressed in percent.

RESULTS AND DISCUSSION

Phosphorous application significantly affected plant height, cobs $plant^{-1}$, grain rows cob^{-1}, number of grains cob^{-1}, grain weight cob^{-1}, 1000-grain weight, stalk and grain yield whereas its application did not affected harvest index (Tables 1, 2, 3 & 4). The genotypic and interaction effects on all parameters were non-significant

Plant height of maize cultivars varied from 183.1 to 208.9 cm (Table I). Plant height increased linearly with phosphorous applications. Maximum plant height (208.9 cm) was recorded in maize plants fertilized with 100 kg P_2O_5 ha^{-1} followed by plants fertilized with 75 kg P_2O_5 ha^{-1} with plant height of 207.1 cm. The detrimental effects of salinity on plant height were offset by phosphorus nutrients. The results indicate that maize plants have the potential to increase plant height with phosphorus fertilizer applications under saline conditions. The results also indicated that maize plants in the presence of high soil phosphorus content were least affected by salinity at the later stages of growth. The increasing trend in height of maize plants with an increase in phosphorus application requires further research with higher levels of phosphorus. The results are conformity with those of Amin *et al.* (1989) who reported that plant height of maize plants increased with increasing phosphorus levels.

Different phosphorus levels significantly affected the number of cobs per plant (Table I). The number of pods per plant as influenced by phosphorus levels varied from 1.500 to 1.900 under saline conditions. The individual comparison of treatment means showed that higher phosphorus applications (75 & 100 kg P_2O_5 kg ha^{-1}) produced significantly higher number of cobs (1.90) per plant over all other treatments. The data also revealed that the plants achieving the height more than 200 cm (Table I) produced significantly more number of cobs per plant.

Different levels of phosphorus significantly affected the number of grain rows per cob (Table I). The number of grain rows per cob ranged between 13.00 and 14.75 in maize plants. The maximum number of grain rows per cob (14.88) was produced by phosphorus application at the rate of 50 kg P_2O_5, followed by 75 and 100 kg P_2O_5 with 14.50 and 14.75 number of grain rows per cob, respectively. The control treatment produced the lowest number of grain rows at 13.0 per cob. By comparing the results of Table I, it is evident that number of cobs per plant and number of grain rows per cob were significantly increased up to phosphorus application at rate of 75 and 50 kg P_2O_5, respectively. The results indicated that the two important yield components of grain yield of maize (number of cobs per plant and number of grain rows per cob) cannot be increased by application of further higher doses of phosphorous under saline conditions.

The number of grains per cob ranged from 290.0 and 434.0 by phosphorous applications under saline conditions (Table II). Among various phosphorus fertilizer treatments, plants fertilized with 75 kg P_2O_5 ha^{-1} resulted in increased number of grains per cob (434.0) over control, followed by 50 kg P_2O_5 ha^{-1} and 100 kg P_2O_5 ha^{-1} treatments. Similar trend to increase number of grains per cob by phosphorous applications was observed as in number of cobs per plant (Table I). Higher phosphorus applications (75 and 100 kg P_2O_5 ha^{-1}) failed to add any significant increments to number of grains per cob under saline environment. The results are in accordance with those of Sharma and Sharma (1989) who reported that phosphorous fertilizer applications significantly affected the grains per cob.

Different phosphorus levels significantly affected grain weight per cob of maize plants (Table II). All fertilizer treatments increased significantly grain weight per cob than that of control treatment. However, phosphorus application at 75 kg P_2O_5 ha^{-1} with constant rates of 150 kg ha^{-1} nitrogen resulted in higher grain weight (113.50) per cob over other treatments. The results indicated that grain weight per cob of maize plants increased by phosphorus application up to the level of 25 kg P_2O_5 ha^{-1}. Further increments of phosphorus (above 25 kg P_2O_5 ha^{-1}) did not affect significantly the grain weight per cob under saline conditions. The results are contradictory to the findings of Amin *et al.* (1989) who reported significant increase in grain weight per cob by increasing phosphorus applications above 25 kg P_2O_5 ha^{-1}. The contradiction between the results might be due to differences in soil conditions of two experimental sites. Sharma and Sharma (1989) reported that phosphorous application increased grain weight cob^{-1}.

The data showed significant effect of different rates of phosphorus application on 1000-grain weight of maize plants (Table II). The 1000-grain weight varied from 241.5 to 289.3 g. Maximum 1000-grain weight of 293.00 g was obtained by applying 75 kg P_2O_5 ha^{-1} at constant rates of 150 kg nitrogen ha^{-1} over control, while minimum 1000-grain weight (240.00 g) was recorded in plants which were not fertilized with phosphorous. Phosphorous application at 75 kg P_2O_5 ha^{-1} also resulted maximum grain weight per cob (133.00 g) compared with other treatments (Table II). The results are in line with those of Sharma and Sharma (1989) who reported that phosphorus applications had significant effect on 1000-grain weight.

It is clear from the data that phosphorus levels significantly affected the stalk yield (Table III). The stalk yield increased linearly with increasing level of phosphorus application only up to 75 kg P_2O_5 ha^{-1} in salt affected soil. Thereafter, the stalk yield was statistically non-significant by higher phosphorus application (100 kg P_2O_5 ha^{-1}). The results are in agreement with those obtained by Mullar and Weigert (1991) who reported that dry matter yields were increased with phosphorus applications.

Grain yield was increased significantly with different levels of phosphorous applications in maize plants (Table III). Maximum grain yield (5.18 t ha^{-1}) was obtained by applying 75 kg phosphorus ha^{-1} while minimum grain yield (2.730 t ha^{-1}) was obtained from the control treatment. Maintaining equal number of plants per unit area by the practice of thinning eliminated the effect of plant population. The fluctuations in number of cobs per plant, grain number per cob and grain weight influenced the maize grain yield. The phosphorus treatments showing higher grain yield also showed increased number of cobs per plant, grain number per cob and grain weight cob^{-1} (Tables I & II). Most of the important yield components of maize plants

Table I. Plant height at maturity, number of cobs $plant^{-1}$ and number of grain rows cob^{-1} as influenced by phosphorous levels under saline conditions

P_2O_5 kg ha^{-1}	Plant height (cm)			Cobs $plant^{-1}$			Grain rows cob^{-1}		
	Hybrid N-6240	Hybrid 6622	Mean	Hybrid N-6240	Hybrid 6622	Mean	Hybrid N-6240	Hybrid 6622	Mean
0	183.50	182.75	183.10d	1.50	1.50	1.50c	13.00	13.00	13.00c
25	188.25	189.50	188.90c	1.60	1.68	1.64b	13.75	14.00	13.88b
50	195.75	197.75	196.80b	1.68	1.70	1.69b	14.75	15.00	14.88a
75	206.00	208.25	207.10a	1.85	1.90	1.88a	14.25	14.75	14.5
100	207.75	210.00	208.90a	1.90	1.90	1.90a	14.50	15.00	14.75
Mean	196.25	197.65		1.71	1.74		14.05	14.35	
LSD (0.05)	NS		5.14	NS		0.12	NS		0.86

Means not sharing a letter common in column differ significantly with each other at 0.05 level of probability
NS = Non-significant

Table II. Number of grains cob^{-1}, grain weight $cob^{-1}$and 1000-grain weight as influenced by phosphorous levels under saline conditions

P_2O_5 kg ha^{-1}	Number of grains cob^{-1}			Grain weight cob^{-1}			1000-grain weight (g)		
	Hybrid N-6240	Hybrid 6622	Mean	Hybrid N-6240	Hybrid 6622	Mean	Hybrid N-6240	Hybrid 6622	Mean
0	287.50	292.50	290.00c	67.00	69.00	68.00b	243.00	240.00	241.50c
25	365.50	361.50	363.50b	100.00	103.00	101.50a	270.75	273.50	272.10b
50	428.50	429.50	429.00a	108.00	108.00	108.00a	282.50	287.00	284.80ab
75	432.25	435.75	434.00a	112.00	113.00	112.50a	289.50	293.00	291.30a
100	430.00	432.50	431.30a	109.00	110.00	109.50a	288.00	290.50	289.30a
Mean	388.75	390.35		99.20	100.60		274.75	276.80	
LSD (0.05)	NS		37.27	NS		11.73	NS		14.66

Means not sharing a letter common in column differ significantly with each other at 0.05 level of probability
NS = Non-significant

Table III. Stalk yield, grain yield and harvest index as influenced by phosphorous levels under saline conditions

P_2O_5 kg ha^{-1}	Stalk yield (t ha^{-1})			Grain yield (t ha^{-1})			Harvest index (%)		
	Hybrid N-6240	Hybrid 6622	Mean	Hybrid N-6240	Hybrid 6622	Mean	Hybrid N-6240	Hybrid 6622	Mean
0	6.45	6.00	6.23d	2.82	2.73	2.78d	30.77	31.72	31.25
25	8.57	8.15	8.36c	4.20	4.02	4.11c	32.94	32.98	32.96
50	9.87	10.41	10.14b	4.66	4.87	4.77b	31.96	31.90	31.93
75	11.37	12.02	11.69a	5.11	5.26	5.18a	30.99	30.46	30.72
100	11.10	11.58	11.34a	5.00	5.19	5.09ab	31.00	30.94	30.97
Mean	9.47	9.63		4.36	4.41		31.53	31.60	
LSD (0.05)	NS		1.02	NS		0.40	NS		NS

Means not sharing a letter common in column differ significantly with each other at 0.05 level of probability; NS = Non-significant improved at 75 kg P_2O_5 ha^{-1} and hence the maximum grain yield was obtained with this rare of application. The leaf area duration during the reproductive stage and the fraction of the total duration devoted to grain filling may affect total grain yield. Phosphorus deficiency limits seed/grain yield by decreasing leaf area duration (Marschner, 1995). Although the leaf area duration was not measured yet higher yields in phosphorus fertilized plants can be attributed to increased leaf area duration. The increased leaf area duration, because of phosphorus application, enhanced the yield potential of almost all the important yield contributing traits of maize plants. Earlier workers (Singh & Dubey, 1991; Millarino & Blackmer, 1992; Alam *et al*., 1995; Sharma & Gupta, 1998) reported increased maize grain yield by phosphorus applications.

The effect of phosphorous application on harvest index of maize plants was found non-significant (Table III). The plots showing higher economic yield must show higher values of harvest index. But in this trial the values of harvest index did not coincide with economic yield. The data on total biomass are presented in this section but it was calculated for the determination of harvest index. It was calculated by adding economic yield to stalk yield. The divider of harvest index (total biomass) increased with the same rate, as increased economic yield with phosphorus applications. Dry matter yield of maize increases with increasing phosphorous rate (Zia *et al*., 1988). The non-significant results indicated that total biomass production and economic yield of maize under stress conditions were directly related with each other. The maize plants fertilized phosphorus produced more biological yield as well as grain yield.

CONCLUSIONS

It is concluded that maize plants fertilized with 75 kg P_2O_5 ha^{-1} improved grain weight per cob, number of grains per cob, cob weight and 1000-grain weight over other levels hence grain yield. Further higher phosphorous rate (100 kg P_2O_5 ha^{-1}) increased plant height and number of cobs $plant^{-1}$ but did not show any effect on grain yield. So, phosphorus application at 75 kg P_2O_5 ha^{-1} appeared the best dose for maize crop under the saline conditions of the experimental site.

REFERENCES

Alam, S.M., A. Latif and Z. Iqbal, 1995. Response of maizeto zink and phosphorous application. *Pakistan J. Agric. Res. Ind. Res.*, 38: 371–4

Amin, R., M.S. Zia, K.C. Berger and K. Aqil, 1989. Effect of fertilizer rate and phosphorus placement methods on corn production. *Sarhad J. Agric*., 5: 221–7

Chaudhry, M.R., C.B. Ahmed and Ihsanullah, 1992. Phosphorus response by paddy and wheat in a saline sodic soil. *In*: *Symposium on the Role of Phosphorous in Crop Production*, pp. 425–38. National Fertilizer Development center, Islamabab, Pakistan.

Gill, M.P.S., N.S. Dhillon and G. Dev, 1995. Phosphorous requirement of pearl millet and sorghum fodder as affected by native fertility of arid brown soil. *Indian J. Agric. Res*., 29: 83–8

Hajabbasi, M.A. and T.E. Schumacher, 1994. Phosphorus effect on root growth and development in two maize genotypes. *Plant and Soil*, 158: 39–46

Hanjra, S.H., M. Abdullah, M.A. Kahlown and N.H. Khilji, 2003. Production of halophyte shrubs on degraded arid lands in Pakistan. *Pakistan J. Soil Sci*., 22: 90–6

Jones, C.A., 1985. *C4 Grasses and Cereals: Growth, Development and Stress Response*. Wiley, New York, USA.

Kaya, C., D. Higgs and H. Kimak, 2001. The effect of high salinity (NaCl) and supplementary phosphorous and potassium on physiology and nutrition development of spinach. *Bulg. J. Plant Physiol*., 27: 47–59

Marschner, H., 1995. *Mineral Nutrition of Plants* (2nd Ed.), pp. 184–96. Academic Press Ltd., London.

Millarino, A.P. and A.M. Blackmer, 1992. Comparison of methods of determining critical concentrations of soil test phosphorous for corn. *Agron. J.*, 84: 850–6

Muller, S. and I. Weigert, 1991. Uptake and utilization of phosphorous and potassium by CCM maize in relation to different PK application. *Agron. J. Crop Sci*., 167: 128–34

Sharma, M.P. and J.P. Gupta, 1998. Effect of organic materials on grain yield and soil properties in maize–wheat cropping system. *Indian J. Agric. Sci.*, 68: 715–7

Sharma, J.P. and U.C. Sharma, 1989. Effect of nitrogen and phosphorous on the yield and severity of turcicum blight of maize in Nagaland. *Indian Phytopathol.*, 44: 383–5 (Maize Absts., 9(3): 1768; 1993).

Singh, V.K. and O.P. Dubey, 1991, Response of maize to the application of nitrogen and phosphorus. *Current Res*., 20: 153–4

Tivy, J., 1990. *Agricultural Ecology*, pp. 212–4. Longman Scientific and Technical, New York, USA.

Welp, G., U. Herms and G. Brummer, 1981. Finfluss von Bodenreaktion, Redox–bedingungen und organischer Substanz auf die Phosphatgehalte der Bodenlosung. Z. Pflanzenernahr. *Bodenk*, 146: 38–52

Yeo, A.R. and T.J. Flowers, 1984. Mechanism of salinity resistance in rice and their role as physiological criteria in plant breeding. *In*: Staples, R.C. and G.H. Toenniessen, *Salinity Tolerance in Plants, Strategies for Crop Improvement*. (9th Eds.), pp. 151–170. John Wiley and Sons. New York, USA

Zia, M.S., A. Rohul, F. Qayum and M. Aslam, 1988. Plant tissue concentration and uptake of phosphorous by maize as affected by levels of fertilization. *Pakistan J. Agric. Res*., 9: 335–8

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