Research Article

Exploring the Phosphorus Efficient Maize Genotypes on the Base of Growth and Yield Traits

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Abstract | Phosphorus (P) is an imperious nutrient necessary for plants growth and development. Similarly, cultivars also differed significantly in terms of growth, yield and P utilization. Therefore, present study was performed to assess P efficient maize genotypes on the basis of growth and yield. The study was comprised different maize genotypes; CS-2Y10, KSC-SB 9663, FH-949, 30Y87, NT-6621 and DK-6789 and of diverse P levels; control (No P), 40 and 80 kg P ha^{-1}. The maximum root length (RL), shoot length (SL) and root and shoot biomass was noted with 80 kg P ha^{-1} and lowest RL, SL and root and shoot biomass was recorded in control. In case of cultivars FH-949 performed well with maximum RL and SL and root and shoot biomass while NT-6621 performed poorly with minimum RL and SL and root and shoot biomass. Similarly, maximum plant height (199.83 cm), leaves per plant (LPP) (12.15), cob weight (0.209 kg), cob length (17.27 cm), grains/cob (441.06), thousand grain weight (TGW) (279.33 g) and grain yield (GY) (6.49 t ha^{-1}) was noted with application of 80 kg/ha P and lowest plant height (174.39 cm), LPP (10.09), cob weight (0.187 kg), cob length (11.99 cm), grains/cob (300), TGW (181.67 g) and GY (4.31 t ha^{-1}) was recorded in control. Similarly, among cultivars maximum plant height (201.11 cm), LPP (12.86), cob weight (0.217 kg), cob length (17.32 cm), grains/cob (417.67), TGW (263.33 g) and GY (6.17 t ha^{-1}) and minimum plant height (172.11 cm), LPP (10.50), cob length (12.30 cm), grains/cob (347.89), TGW (195.11 g) and GY (4.37 t ha^{-1}) was recorded in NT-6621. In conclusion application of 80 kg/ha P is recommended to significantly increase the growth and productivity of maize crop. Moreover, cultivars FH-949 was emerged as a most efficient uses of P and it can also be used in breeding programs to develop the P efficient cultivars.

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Introduction

Maize is an imperative crop cultivated globally for food and feed purposes (Masood *et al*., 2011) and it is also used in different industries to make various products for human consumption (Menkir *et al*., 2008). It is also an important source of oil and starch which makes him a promising crop (Masood *et al*., 2011; Maqsood *et al*., 2017). In Pakistan maize is cultivated on 8805 thousand hectares and with production of 27.293 million tons (GoP, 2020). Maize is considered to be an exhaustive crop with higher yield potential than other cereals and it significantly use a large amount of nutrients during its life cycle. Amid these nutrients phosphorus (P) is an imperious nutrient needed for plants growth and yield (Masood *et al*., 2011; Taliman *et al*., 2021). However, in P deficient soils a poor developed root system prevents the P absorption which therefore considerably reduced the growth and yield (Nkebiwe *et al*., 2016).

Phosphorus plays a fundamental role in maize growth, development, grain formation and maturation (Szulc *et al*., 2020). Phosphorus also stimulates root development and increased the plant resistance to water deficit conditions (Mollier and Pellerin, 1999). However, P is most limiting nutrient in different cropping systems across the globe (Khan *et al*., 2018) and it has been reported that nearly 67% soils across the globe are P deficient (Dhillon *et al*., 2017). The P use efficacy of cereals is also very low and it varies between 15-30% which is also major reason of lower production of cereals (Dhillon *et al*., 2017). Moreover, P also precipitates with different minerals which is also major reasons of lower P availability (Penn and Camberato, 2019) and crop productivity (Dhillon *et al*., 2017). Additionally, P fixation also creates the problems of global warming, eutrophication which is threatening our ecosystem (Gu *et al*., 2015).

The demands of P for plants must be consider as maize is exhaustive crop and it needs a quick replacement of P in soil solution (Lino *et al*., 2018). Nonetheless, most of the applied P is lost into environmental owing to lower P use efficiency (PUE) (Li *et al*., 2017). Therefore, most efficient P genotypes must be used to improve the P use efficacy and reduced the P losses. The cultivars differed significantly for the P use efficiency (Pandey *et al*., 2002). Moreover, P use efficacy is also influenced by root system size and architecture (Pandey *et al*., 2002), kinetic uptake parameters (Gahoonia *et al*., 1997) and root exudates (Subbarao *et al*., 2003). Phosphorus is unequally distributed in soil and degree of root exploitation of cultivars significantly affects the P uptake (Gahoonia *et al*., 2004). The cultivars with better root systems have more P use efficiency as compared to cultivars with poor root systems (Gahoonia *et al*., 2004). We hypothesized that cultivars would perform differently for growth and yield following addition of different rates of P. Thus, this research was performed to compare the different maize cultivars for P use efficiency on the basis of growth and yield.

Materials and Methods

Experimental site

The present study was carried at student research farm, Department of Agronomy UAF in 2017 to explore maize genotypes for phosphorus efficient traits. The experimental site had hot and humid summer with dry winter conditions (Hassan *et al*., 2019; 2020) and more climatic conditions are presented in Table 1. The soil samples were taken (0-30 cm depth) with help of soil augar to determine the various soil physiochemical properties (Homer and Pratt, 1961). The soil identified as sandy loam with pH 7.82, total nitrogen (0.019%) and available phosphorus and potassium 4.08 and 128 mg kg^{-1}.

Table 1: *Weather conditions during the growth period*.

Months	Maximum temperature (°C)	Minimum temperature (°C)	Relative humidity (%)	Total rainfall (mm)
July	38.5	28.9	70.0	117.2
August	38.1	28.6	68.9	68.9
September	36.7	36.7	67.7	35.6
October	35.0	19.2	68.2	0.0

Experimental details

The study was comprised of different maize genotypes; CS-2Y10, KSC-SB 9663, FH-949, 30Y87, NT-6621 and DK-6789 and diverse phosphorus levels; control (No phosphorus application), 40 kg phosphorus ha^{-1} and 80 kg phosphorus ha^{-1}. The study was performed in RCBD with factorial plot arrangement having three replicates.

Crop husbandry

The soil was ploughed thrice and planked to prepare the final seed bed. Maize hybrids were by using seed rate of 20 kg ha^{-1}. N-K fertilizers were used @ 100:75 kg per ha in the forms of urea and sulphate of potash, while phosphorus was applied according to the treatments. Irrigations were applied according to the crop needs.

Data collection

Five plants were carefully uprooted from each plot and roots were separated from the shoots. The length of roots and shoots were measured and average was taken. Similarly, roots and shoots were weight to determine the fresh weight later on oven dried (70°C) to determine the dry weight. An area of 1 square meter in each plot was selected and plant was counted to determine the plant population. Tens plants were randomly selected and leaves per plant were counted and plant heights were measured to determine the plant height. Similarly, ten cobs from different plants were harvested to determine the cob weight and later on their lengths and diameters were measured and average was taken. Moreover, ten cobs from different plants were taken and grain rows per cob were counted and later cobs were shelled separately and grains of each cob were counted and average was taken. Additionally, sub-sample of 1000 grains was taken to determine the 1000 grain weight. Lastly, all cobs from each plot were harvested, shelled and weighed to determine the grain yield and converted into t ha^{-1}.

Statistical analysis

The data regarding growth and yield characters were analyzed by Fisher's ANOVA and difference amongst treatments was worked out using LSD test at 5% probability (Steel *et al*., 1996).

Results and Discussion

The results indicated different levels of phosphorus (P) application and cultivars had significant impact on the growth traits (Table 2). The maximum root length (RL) and shoot length (SL) was obtained wit P at 80 kg/ha and minimum RL and SL was recorded in control (Table 1). Among cultivars FH-949 performed appreciably well with maximum RL (30.07 cm) and SL (167.27 cm) followed by 30Y87 and NT-6621 performed poorly with minimum RL (19.50 cm) and SL (123.89 cm) (Table 2). This study revealed that genotypes and P application had significant differences for the RL and SL. Cultivar FH-949 was characterized as best cultivar and it had more RL and SL possibly due to its genetic character to produce longer roots (Ahmed and Farooq, 2013). Moreover, P application also significantly improved the RL and SL. The P play a significantly role in ATP production therefore the present increase in RL and SL by P can be attributed to higher energy production (Parewa *et al*., 2010; Habibzadeh, 2015).

The maximum root fresh weight (RFW) (33.47 g) and root dry weight (RDW) (9.20 g) was recorded with application of P applied at 80 kg/ha and lowest RFW (18.23 g) and RDW (4.98 g) was recorded in control (Table 2). In case of cultivars maximum RFW (34.87 g) and RDW (9.51 g) was recorded in FH-949 after 30Y87 and lowest RFW (19.40 g) and RDW (6.20 g) was recorded in NT-6621 (Table 2). The cultivars had differential response for the root and shoot biomass. The cultivars FH-949 produced maximum root and shoot biomass owing to longer roots and shoots. Likewise, P application also improved the root and shoot biomass to improvement in root and shoot growth due to better energy production and photosynthetic efficiency (Fernandes and Rogerio, 2012; Shrestha *et al*., 2016).

The P application and maize cultivars also significantly affected the shoot fresh weight (SFW) and shoot dry weight (SDW) (Table 2). The maximum SFW (316.78 g) and SDW (50.75 g) was recorded with maximum level of P application and lowest SFW (220.42 g) and SDW (37.87 g) was recorded without application of P (Table 2). Amid cultivars again FH-949 performed appreciably well with maximum SFW (316.17 g) and SDW (53.16 g) that remained same with 30Y87 and lowest SFW and SDW was recorded in NT-6621 (Table 2). The cultivar FH-949 had maximum root length which improved the water and nutrient uptake therefore it produced the longer shoots with maximum weight. Moreover, P application also improved the root growth which ensures the good water as well as nutrient uptake consequently improved the above ground biomass production (Fernandes and Rogerio, 2012; Razaq *et al*., 2017).

The diverse P levels and genotypes non-significantly influenced the plant population (Table 3). Taller plants (199.83 cm) with maximum LPP (12.15) were noted with 80 kg/ha P and shortest plants (174.39 cm) with maximum LPP (10.09) was recorded in control (Table 2). In case of cultivars taller plants (201.11 cm) with more LPP (12.86) was recorded in FH-949 and shorter plants (172.11 cm) with minimum

Links Researchers

Table 2: *Effect of different phosphorus rates on growth attributes of maize cultivars*.

Phosphorus rates	RL (cm)	SL (cm)	RFW (g)	RDW (g)	SFW (g)	SDW (g)
0 (P1)	17.36C	121.80C	18.23C	4.98B	220.42C	37.87C
40 kg/ha (P2)	25.06B	142.50B	30.21B	8.67A	275.61B	42.46B
80 kg/ha (P3)	30.54A	169.17A	33.47A	9.20A	316.78A	50.75A
LSD≤0.05P	0.81	6.67	1.63	0.54	12.32	3.31
Cultivars						
CS-2Y10	21.13E	132.89CD	22.10D	6.88DE	247.33CD	41.67B
KSC-SB 9663	24.41C	146.33B	29.46BC	7.67BC	275.19B	43.57B
FH-949	30.07A	167.27A	34.87A	9.51A	316.17A	53.16A
30Y87	27.82B	158.00A	30.76B	8.34B	299.00A	49.09A
NT-6621	19.50F	123.89D	19.40E	6.20E	233.00D	32.39C
DK-6789	22.98D	138.56BC	27.24C	7.10CD	252.93C	42.29B
LSD≤0.05P	0.15	9.58	2.32	0.77	17.42	4.69
Interaction						
CS-2Y10×P1	14.03	112.33	14.67j	4.47	203.67h	35.47
KSC-SB 9663×P1	17.40	124.33	18.93hi	5.20	221.90gh	37.33
FH-949×P1	22.97	138.80	25.03fg	6.60	243.83fg	45.27
30Y87×P1	21.03	131.33	20.33hi	5.47	235.00fg	43.57
NT-6621×P1	13.41	106.33	13.83j	5.83	197.33h	29.23
DK-6789×P1	15.33	117.67	16.60ij	4.33	220.80gh	36.33
CS-2Y10×P2	22.33	127.67	24.63fg	7.93	253.67f	39.97
KSC-SB 9663×P2	24.73	146.33	33.40cd	8.47	288.33cd	41.67
FH-949×P2	30.53	165.33	37.03bc	10.73	318.00c	52.30
30Y87×P2	28.47	161.0	33.87cd	9.23	306.33cd	46.83
NT-6621×P2	20.70	121.33	21.67gh	6.40	244.00fg	33.97
DK-6789×P2	23.57	133.33	30.67de	8.23	237.33fg	40.23
CS-2Y10×P3	27.03	158.67	27.0ef	8.23	284.67de	49.57
KSC-SB 9663×P3	31.10	168.33	36.03bc	9.33	315.33c	51.90
FH-949×P3	36.70	197.67	42.53a	11.20	386.67a	61.90
30Y87×P3	33.97	181.67	38.07b	10.33	355.67b	56.87
NT-6621×P3	24.40	144.0	22.70gh	6.37	257.67ef	33.97
DK-6789×P3	30.03	164.67	34.47bcd	8.73	300.67cd	50.30
LSD≤0.05P	NS	NS	4.01	NS	30.18	NS

RL: *root length;* **SL:** *shoot length;* **RFW:** *root fresh weight;* **RDW:** *root dry weight;* **SFW:** *shoot fresh weight;* **SDW:** *shoot dry weight. Means with different letter different at 0.05 P level.*

LPP (10.50) was recorded in NT-6621 (Table 3). The variations amid the tested difference among for the plant height could be due to variations in their genetic make for the plant height (Hussain *et al*., 2010). The improvement in plant height with phosphorus application can be due to better root growth which resulted in better uptake of nutrients and water and thereby improved the plant height (Hussain *et al*., 2004). Cultivars also had significant differences for the LPP similarly P application also induced significant increase in LPP. The difference amongst cultivars for the leaves count/plant can be ascribed to their genetic ability to produce the leaves (Kusaksiz, 2010). The phosphorus application also increased the LPP which can be attributed to the better root growth which results in better nutrient uptake and resultantly produced the more assimilates for plant growth and thereby increased the production of leaves (Masood *et al*., 2011).

The P application and cultivars had significant impact on the cob weight (CW), cob length (CL) and cob

Table 3: *Effect of different phosphorus rates on yield attributes of maize cultivars.*

Phosphorus rates	PP (m^{-2})	PH (cm)	LPP	CW (kg)	CL (cm)	CD (cm)
0 (P1)	4.95	174.39C	10.09B	0.187B	11.99C	2.47C
40 kg/ha (P2)	5.0	192.67B	12.09A	0.203A	14.46B	3.37B
80 kg/ha (P3)	5.11	199.83A	12.15A	0.209A	17.27A	4.10A
LSD≤0.05P	NS	6.54	0.53	0.014	0.63	0.123
Cultivars						
CS-2Y10	5.0	181.67C	10.76CD	0.186C	13.16DE	3.12CD
KSC-SB 9663	5.11	194.89AB	11.50BC	0.198B	14.90C	3.29C
FH-949	5.0	201.11A	12.86A	0.210A	17.32A	3.69A
30Y87	5.11	194.44AB	12.03B	0.217A	15.93B	3.49B
NT-6621	5.0	172.11D	10.50D	0.190BC	12.30E	3.04D
DK-6789	4.88	189.56BC	11.03CD	0.195BC	13.83D	3.25D
LSD≤0.05P	NS	9.25	0.75	0.0115	0.90	0.174
Interaction						
CS-2Y10×P1	4.66	172.33	9.53	0.163	10.43	2.25
KSC-SB 9663×P1	5.33	178.67	10.20	0.187	11.67	2.38
FH-949×P1	5.0	184.0	11.40	0.201	15.43	2.93
30Y87×P1	4.67	177.67	10.47	0.201	13.47	2.67
NT-6621×P1	5.33	162.0	9.20	0.185	10.17	2.19
DK-6789×P1	4.66	171.67	9.77	0.183	10.77	2.38
CS-2Y10×P2	5.0	184.67	11.27	0.194	13.43	3.17
KSC-SB 9663×P2	5.0	198.0	12.17	0.198	15.13	3.37
FH-949×P2	5.0	210.0	13.93	0.211	16.93	3.75
30Y87×P2	5.33	195.67	12.50	0.223	15.67	3.54
NT-6621×P2	4.66	175.67	10.03	0.190	11.60	3.11
DK-6789×P2	5.0	192.0	11.67	0.199	14.00	3.27
CS-2Y10×P3	5.33	188.0	11.47	0.201	15.60	3.93
KSC-SB 9663×P3	5.0	208.0	12.13	0.207	17.90	4.11
FH-949×P3	5.0	209.33	13.23	0.218	19.60	4.40
30Y87×P3	5.33	210.0	13.13	0.228	18.67	4.27
NT-6621×P3	5.0	178.67	11.27	0.195	15.13	3.82
DK-6789×P3	5.0	205.0	11.66	0.203	16.73	4.09
LSD≤0.05P	NS	NS	NS	NS	NS	NS

PP: *Plant population;* **PH:** *Plant height;* **CW:** *Cob weight;* **Cl:** *cob length;* **CD:** *Cob diameter. Means with different letter different at 0.05 P level.*

diameter (CD) (Table 2). The maximum CW (0.209 kg), CL (17.27 cm) and CD (4.10 cm) was noted with P application of 80 kg/ha followed by 40 kg/ha and lowest CW (0.187 kg), CL (11.99 cm) and CD (2.47 cm) was recorded in control (Table 2). Among cultivars maximum CW (0.217 kg), CL (17.32 cm) and CD (3.69 cm) FH-949 followed closely with 30Y87 and minimum CW (0.190 kg), CL (12.30 cm) and CD (3.04 cm) was recorded in NT-6621 (Table 2). The results indicated that phosphorus application significantly improved the CW, CL and CD. The increase in CW with P application can be ascribed to improvement in seed weight, grains row per cob which consequently improved the cob weight (Masood *et al*., 2011). Similarly, cultivar FH-949 produced cobs with more weight owing to bold and longer cobs which is consistent with finding of Alias *et al*. (2010). Moreover, P addition also increased the longer cobs with more diameter which can be ascribed to improvement in root growth and nutrient uptake which resulted in production of longer cobs with more diameter (Khan *et al*., 1999; Hussain *et al*., 2010).

Table 4: *Effect of different phosphorus rates on yield attributes of maize cultivars.*

Phosphorus rates	GRPC	GPC	TGW (g)	GY (t ha^{-1})
0 (P1)	8.67C	300.00C	181.67C	4.31C
40 kg/ha (P2)	9.78B	408.00B	223.22B	5.40B
80 kg/ha (P3)	13.44A	441.06A	279.33A	6.49A
LSD≤0.05P	0.98	7.40	11.41	0.28
Cultivars				
CS-2Y10	9.78CD	361.44E	207.56D	4.70D
KSC-SB 9663	10.67BC	390.87C	233.33C	5.64B
FH-949	12.67A	417.67A	263.33A	6.39A
30Y87	11.33B	403.89B	246.56B	6.17A
NT-6621	9.56D	347.89F	195.11E	4.37D
DK-6789	9.78CD	376.44D	222.56C	5.15C
LSD≤0.05P	0.69	10.46	8.09	0.40
Interaction				
CS-2Y10×P1	9.33	283.00i	161.67	3.97k
KSC-SB 9663×P1	9.33	302.67h	179.33	4.40hijk
FH-949×P1	10.67	325.33g	217.33	4.72ghij
30Y87×P1	8.67	321.33g	196.00	4.81ghij
NT-6621×P1	7.33	279.33i	160.00	3.77k
DK-6789×P1	6.67	288.33hi	175.67	4.21jk
CS-2Y10×P2	8.00	387.00f	205.33	4.82ghij
KSC-SB 9663×P2	9.33	414.33e	236.00	5.53ef
FH-949×P2	12.00	440.33cd	252.00	6.50cd
30Y87×P2	10.67	423.67de	240.00	6.09de
NT-6621×P2	8.67	377.00f	190.33	4.39ijk
DK-6789×P2	10	405.67e	215.67	5.09fgh
CS-2Y10×P3	12.00	414.33e	255.67	5.30fg
KSC-SB 9663×P3	13.33	455.33bc	284.67	6.99bc
FH-949×P3	15.33	487.44a	320.67	7.97a
30Y87×P3	14.67	466.67b	303.67	7.62ab
NT-6621×P3	12.67	387.33f	235.00	4.94fghi
DK-6789×P3	12.67	435.33d	276.33	6.14de
LSD≤0.05P	NS	8.31	NS	0.69

GRPC: *Grain rows per cob;* **GPC:** *Grains per cob;* **TGW:** *Thousand grain weight;* **GY:** *Grain yield. Means with different letter different at 0.05 P level.*

The results indicated that diverse P levels and cultivars had substantiated impacts on the grain rows/cob (GRPC), grains per cob (GPC), thousand grain weight (TGW) and grain yield (Table 4). The maximum GRPC (13.44), GPC (441.06), TGW (279.33) and grain yield (6.49 t ha^{-1}) was obtained with 80 kg/ha P and lowest GRPC (8.67), GPC (300), TGW (181.67) and grain yield (4.31 t ha^{-1}). In case of cultivars FH-949 performed well with maximum GRPC (12.67), GPC (417.67), TGW (263.33) and grain yield (6.39 t ha^{-1}) followed closely with 30Y87 and minimum GRPC (9.56), GPC (347.89), TGW (195.11) and grain yield (4.37 t ha^{-1}) (Table 4). The cultivars had substantiated difference for the GRPC, GPC and seed weight. The cultivar FH-949 produced cobs with more GRPC, GPC and seed weight this difference can be attributed to genetic characteristics and ability of this cultivar to efficiency use the nutrient and applied inputs (Younas *et al*., 2002). The application of P also induced marked increase in GPRC, GPC and 1000 grain weight (Table 4). The increase in GRPC, GPC and seed weight with P application can be attributed to a considerable increase in photosynthetic activities, and translocation of food material to developing grains which insured the production of better GRPC, GPC and seed weight (Ahmad *et al*., 2007; Khan *et al*., 2014). The cultivar FH-949 produced the maximum yield owing to higher cob length, seed weight, grains/cob and grain rows/cob which is same with findings of Saleem *et al*. (2003) they also noted variations amid cultivars for the grain production. The increase in grain production by P might be due to improvement in yield contributing traits such as grain rows, seed per row, cob diameter and seed weight (Hussain *et al*., 2006; Onasanya *et al*., 2009).

Conclusions and Recommendations

Different phosphorus levels cultivars had significant impact on the growth and production traits. However, application of 80 kg/ha phosphorus remained the top performer in improving the growth and grain production of maize crop. Moreover, in case of cultivars FH-949 performed appreciably well in terms of growth and productivity. Therefore, it is suggested that FH-949 was characterized as most efficient user of phosphorus.

Novelty Statement

This is firsthand information about different maize cultivars for phosphorus use efficiency on the basis of growth and yield.

Author's Contribution

Tahir Abbas Khan: Conducted the experiment.
Imran Ashraf: Conceived and planned the experiment and wrote the original draft.
Athar Mahmood: Reviewed and edited.
Muhammad Ilyas: Reviewed and edited.

Sardar Alam Cheema: Reviewed and edited.
Muhammad Mahmood Iqbal: Reviewed and edited.
Muhammad Umair Hassan: Wrote the original draft.

Conflict of interest

The authors have declared no conflict of interest.

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