RESEARCH ARTICLE

Differential Phosphorus Acquisition and Phosphorus Efficiency of Maize Genotypes

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ABSTRACT

A field experiment was conducted at Chinnamathampalayam village of Periyanaicanpalayam block of Coimbatore district (11°.21'14" N ; 76°97'78" E) to evaluate the maize genotypes (CMH08 - 156, COH (M) 7, COH (M) 8, CMH08 - 337, COH (M) 9 and CO 6) for yield and phosphorus (P) efficiency indices at varied levels of P application *viz*., (0, 37.5, 56.5 and 75 kg P_2O_5 ha^{-1} (0, 50, 75 and 100 per cent of RDP) in a low P soil. Maize genotype, CMH08- 337 recorded the highest grain yield both under P stress (no P) and P sufficient condition (100% RDP). The highest phosphorus efficiency (PE), phosphorus acquisition efficiency (PAE), and grain yield efficiency index (GYEI) were also recorded by the maize genotype CMH08- 337. Based on GYEI, the genotypes CMH08 -337 and COH (M) 8 with GYEI > 1 were grouped under efficient P users and the remaining genotypes, CMH08 - 156, COH (M) 7, COH (M) 9 and CO 6 were grouped under moderately P users.

Keywords: *Maize, Genotypes, Phosphorus, Acquisition Efficiency, Use Efficiency*

Phosphorus (P) has been termed as the bottleneck of world hunger (Rorty, 1946) and it is indeed a frequently limiting plant nutrient in tropical and subtropical soils. Its availability in soil depends on soil characteristics and contents of mobilizable P fractions.

In India, 42 per cent of the districts are in low P availability, 38 per cent are in medium P category, and 20 per cent districts are high in P availability (Motsara (2002)). This data focuses on the widespread occurrence of P deficiency in India. The extent of P deficiency, anticipated phosphate crisis in the 21st century for agriculture (Cordell *et al*., 2009) coupled with farmer's inability to purchase expensive phosphatic fertilizers and transformation of the added P to plant unavailable forms has threatened agricultural productivity and demands for an effective strategy to deal with the efficient utilization of P and its availability.

Different crop species and cultivars within a species vary widely in their ability to thrive in nutrient deficient environment. Genotypic differences in P utilisation are related to differences in acquisition of P by the roots or utilization in the plant or both. The integration of crop species/cultivars that can make most efficient use of the P supplied by the soil and maintenance of fertilizer applications represents a critical element of the sustainable cropping system.

Classification of crop varieties based on their P acquisition and P uptake will be useful in identifying suitable genotypes for cultivation in different soils and selection of parents for breeding programs to develop P efficient cultivars. With this background, a field experiment was conducted to study the genotypic variation in phosphorus utilization efficiency of maize.

MATERIALS AND METHODS

The field experiment was carried out in a farmer's field at Chinnamathampalayam village of Periyanaicanpalayam block of Coimbatore district (11°.21'14" N; 76°97'78" E). The experiment was laid out in factorial randomized block design with six genotypes of maize, CMH08 - 156, COH (M) 7, COH (M) 8, CMH08 - 337, COH (M) 9 and CO 6 and four levels of phosphorus (0 (P_0), 37.5 (P_{50}), 56.5 (P_{75}) and 75 ($P1_{100}$) kg P_2O_5 ha^{-1} i.e., 0, 50, 75 and 100 per cent of RDP) as single superphosphate. The experiment was replicated three times.

The experimental soil was sandy clay loam in texture, alkaline in reaction, low in $KMnO_4$ nitrogen (176 kg ha^{-1}), low in Olsen – P (9.85 kg ha^{-1}) and medium in $NNNH_4OA_c$ (181 kg ha^{-1}). Nitrogen, potassium fertilization and other management practices were carried as per Crop Production Guide. The crop was grown to maturity and harvested. Post-harvest soil sample collected from each treatment was analysed for available P (Olsen, 1954). Grain and stover yield was recorded at harvest and the representative grain and stover samples after processing was analysed for P content (Piper, 1966).

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With the analytical data obtained, various derived parameters namely; phosphorus uptake, Phosphorus Efficiency (PE), Phosphorus Acquisition Efficiency (PAE) and Grain Yield Efficiency Index (GYEI) were calculated. The formula for the calculation of the parameters listed above is given below.

Phosphorus uptake	:	(P content (%) /100) x Grain or stover yield (kg ha^{-1})
PE	:	Grain yield in control (P_0) /Grain yield in 100 % RDP (P_{100}) x 100
PAE	:	(Total P uptake in P0 / Total P uptake in P_{100}) x 100

Grouping of genotypes

$$GYEI : \frac{\text{Grain yield of the genotype at low P level /Average Grain yield of the genotypes at low P level}}{\text{Grain yield of the genotype at high P level /Average Grain yield of the genotypes at high P level}}$$

Genotypes having GYEI values >1 were classified as efficient (E) P user, genotypes having GYEI values between 0.5 and 1 were classified as moderately efficient P user (ME) and those with GYEI values < 0.5 were classified as inefficient P user (IE) (Fageria *et al*. (1988)).

RESULTS AND DISCUSSION

Significant genotypic variation was observed in maize concerning grain yield at varying levels of P application. Grain yield under control (no P application) ranged from 3912 (CMH08-156) - 6290 kg ha^{-1} (CMH08 -337) (Table 1). A significantly lower yield under control might be due to the reason that P deficiency is associated with restricted growth and development (Havlin *et al.,* 2007).

Table 1. Grain yield of maize as influenced by genotypes and phosphorus levels

Genotypes / P levels	Grain yield (kg ha^{-1}) P_0	P_{50}	P_{75}	P_{100}	Mean
CMH08 - 156	3912	4783	5929	6427	5263
COH (M) 7	4012	4298	4778	5229	4579
COH(M) 8	4952	5312	5675	6689	5657
CMH08 - 337	6290	6583	6945	7152	6743
COH (M) 9	4381	4627	5198	5806	5003
CO 6	4190	4646	5467	6376	5170
Mean	4623	5042	5665	6280	5402

Source	Grain yield	
	SEd	CD (0.05)
Genotype (G)	223	449
Phosphorus (P)	182	366
G x P	446	898

An adequate supply of P has been associated with increased root growth which in turn resulted in better uptake of nutrients and water. Many studies have shown that application of phosphatic fertilizers has a great impact on crop yields because P deficiency also limits the response of plants to other nutrients (Alam *et al.,* 2002; Ahmad *et al.,* 2003).

All the genotypes responded to P application and wide variation was observed between the genotypes in terms of yield response. Grain yield reduction of 12 per cent was observed from P_{100} to P_0 in the maize genotype CMH08 -337 whereas the grain yield reduction was 39 per cent in CMH08 -156.

Table 2. Phosphorus uptake by maize as influenced by genotypes and phosphorus levels

Genotypes / P levels	Phosphorus uptake (kg ha^{-1}) P_0	P_{50}	P_{75}	P_{100}	Mean
CMH08 – 156	9.62	18.24	24.86	29.81	20.63
COH (M) 7	12.39	19.42	23.20	24.42	19.86
COH(M) 8	13.31	20.01	22.25	28.56	21.03
CMH08 337	17.82	25.76	27.94	30.40	25.48
COH (M) 9	12.65	19.75	23.74	26.83	20.73
CO 6	12.36	19.50	23.44	27.60	20.60
Mean	13.03	20.45	24.24	27.94	21.39

Source	Phosphorus uptake	
	SEd	CD (0.05)
Genotype (G)	1.55	3.11
Phosphorus (P)	1.26	2.54
G x P	3.09	6.23

Genotypes, phosphorus levels and their interaction exerted a significant effect on phosphorus uptake of maize. Total P uptake under control ranged from 9.62 kg ha^{-1} (CMH08 -156) to 17.81 kg ha^{-1} (CMH08 -337) and in P_{100} ranged from 24.42 kg ha^{-1} for COH(M) 7 to 30.40 (CMH08 -337 and COH(M) 9) (Table 2). Phosphorus uptake is governed by both dry matter accumulation and P concentration in plants. Improved growth and higher accumulation of P with increasing P levels lead to increased P uptake. The increase in P uptake with the higher application of P could have been resulted from the enhanced supply of P to the plants as reported by Arora and Nayyar (1983), Yadav *et al.* (2002), Singh and Singh (2004) Laxminarayana (2007) and Kaleeswari *et al.* (2012)

Table 3. Phosphorus Efficiency (PE), Phosphorus Acquisition Efficiency (PAE) and Grain Yield Efficiency Index (GYEI) as influenced by genotypes and phosphorus levels

Genotypes	PE (%)	PAE (%)	GYEI
CMH08 - 156	61	32.3	0.87
COH (M) 7	77	50.7	0.72
COH(M) 8	74	46.6	1.14
CMH08 337	88	58.6	1.55
COH (M) 9	75	47.2	0.88
CO 6	66	44.8	0.92
Mean	74	46.6	1.00

Phosphorus efficiency defined as the ability of the plant to grow and yield well under P deficient conditions showed a variation among the maize genotypes studied. Phosphorus efficiency (grain) of the genotypes ranged from 61 (CMH08 -156) to 88 (CMH08-337) per cent. Phosphorus efficiency declined in the order of CMH08 337 < COH (M) 7

< COH (M) 9 < COH (M) 8 < CO 6 < CMH08 – 156 (Table 3).

The low mobility of P in soil makes P acquisition by the plant very dependent on soil exploration by time and space (Marschner, 1995). The plant attributes that lead to enhanced P acquisition efficiency are related to the extent to which roots are able to intercept more soil available P or to mobilize P from poorly soluble sources. The efficiency of P acquisition, depends markedly on root architecture, root morphology, high affinity transporters, and rhizosphere alteration (Lambers *et al*., 2006) and this in turn on plant genotype, soil chemical and physical properties. Phosphorus acquisition efficiency (PAE) showed a wider variation from 32.3 (CMH08 -156) to 58.6 (CMH08 - 337) (Table 3) and PAE showed a significant positive correlation with grain yield (0.736**).

Grain yield efficiency index ranged from 0.72 (CO(H)M 7) to 1.55 (CMH08 - 337) (Table 3). Based on GYEI the genotypes were grouped as detailed below.

Table 4. Grouping of genotypes based on grain yield efficiency index

Category	Genotypes
Efficient P user	CMH08 - 337, COH(M)8
Moderately efficient P user	CMH08 -156, CO 6 , COH(M)7, COH(M)9

CONCLUSION

Maize genotypes studied differed significantly in yield, P uptake and in various P efficiency indices in the low P soil at varying levels of applied P. Maize genotype CMH08-337 recorded higher grain yield both under P deficient (P_0) and P sufficient (P_{100}) condition. The maize genotypes, CMH08 – 337 and COH(M) 8 are efficient P users and can be grown under P deficient conditions.

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