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Cluster, correlation and path coefficient analysis of phosphorus use efficiency related traits in pigeonpea

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Abstract

The present investigation was undertaken to study the genetic diversity, correlation and path coefficient analysis for 16 metric traits in 43 pigeonpea genotypes at Department of Plant Breeding and Genetics in the Punjab Agricultural University, Ludhiana during *Kharif* 2013. Pigeonpea genotypes were grown in pots and two phosphorus doses were supplied to soil in the pots; one was recommended dose of phosphorus supplied [Single Super Phosphate@ 250 kg/ha^{-1} nutrient (+P)] and in second, P fertilizer was not added in soil (-P). Within clusters sum of squares were maximum in cluster I. This cluster showed highest average values of root area and perimeter was highest of this cluster than other four clusters under recommended dose of P. Root perimeter was highly positively correlated with root area and a negative correlation was found among leaf P and root length, root P and root length, root P and root dry weight, stem P and root dry weight, stem P and root area, leaf P and root area. Path analysis of leaf P indicated that root dry weight had maximum significant positive direct effect followed by root volume, leaf area on leaf P. Genetic diversity, correlation coefficient and path analysis approaches may be used in selecting traits which contribute for phosphorus use efficiency from large pool of germplasm for breeding purpose.

Keywords: Cluster analysis, pearson correlation coefficient, path analysis, pigeonpea genotypes

Introduction

Pigeon pea (*Cajanus cajan* (L.) Millsp.) is the second most important pulse crop and it has advantages over other legumes, such as tolerant toward drought condition because of its long deep rooting system (Cook *et al.*,2005) [3]. Pigeon pea seed contains 57 – 59% of carbohydrate, 14 – 30% of protein, 1 -9% of fat, 100g of mature raw pigeon peas also provide 76% for pregnant women of the daily requirement of folate and high vitamin A, B complex, and C (Mahalaya *et al.*,2015) [8]. In India, pigeonpea is cultivated in 3.9 million hectare with production of 3.2 million tonnes (INDIASTAT, 2015) [5]. Efforts to enhance the phosphorus (P) efficiency of cropping systems have typically focused on optimizing P-fertilizer application by regulating the rate of fertilizer needed to achieve highest production. Moreover, small amount of P fertilizer confines yields, whereas too large amount is an unnecessary expenditure and can cause damage to environment through leaching (Shapley *et al.*, 1994) [11]. There are a number of possible adaptive mechanisms that the P-efficient plants can utilize for superior root growth on low P soils, including modification in root morphology, root symbiosis, improvement of internal phosphatase activity, secretion of organic acids into the rhizosphere, activation of high-affinity phosphate transporters (Wang *et al.*,2010) [14]. Both internal phosphorus use efficiency (PUE) and external PUE are independent processes, some approaches of improvement in equalizing P uptake be supposed to employed (Veneklaas *et al.*, 2012) [12]. In soil supplied with fertilizers, P availability higher in top layers of soil. Plants with better root traits (more root surface area, hairs, branching and volume) are more capable to acquire P from top soil (Manschadi *et al.*, 2013) [9]. Root hair density and increase in lateral branching are the most useful root traits for phosphorus use efficiency (Clemens *et al.*, 2016) [2]. Plants can also turn on a set of adaptive responses to boost P uptake and P recycling by reprogramming of physiology processes and alter root structure (Jain *et al.*, 2007) [6] to maintain their development rate as feasible (Gutschick and Kay 1995) [4]. Root characters *i.e* root length, fineness, surface area, and root hair density affect the behavior of plant in P deficient soils (Rao *et al.*, 1996) [10]. Keeping in view the investigation of forty three pigeonpea genotypes were undertaken to estimate the correlation and path coefficient for PUE among sixteen characters associated to root and shoot.

Materials and Methods

Forty three genotypes (AL1584, AL1778, AL1812, AL1816, AL1817, AL1836, AL1838, AL1839, AL1842, AL1843, AL1847, AL1849, AL1853, AL1873, AL1881, AL1931, AL1932, AL1933, AL1941, AL15, AL1593, AL1747, AL1756, AL1758, AL201, IC245504, IC245506, IC245507, ICPL 20329, ICPL 20330, ICPL 20340, ICPL 88039, Manak, MN1, MN5, P2001, P2002, P992, Pant A 402, Paras, PAU881, UPAS120 and VLA11) were assessed in pots with eight replications in factorial complete randomized design. Seeds of genotypes were obtained from International Crops Research Institute for the Semi-Arid Tropics, Hyderabad, Chaudhary Charan Singh Haryana Agricultural University, Hisar, Punjab Agricultural University, Ludhiana. Two phosphorus doses were supplied to soil in the pots; one was recommended dose of phosphorus supplied [Single Super Phosphate@ 250 kg/ha^{-1} nutrient (+P)] and in second, P fertilizer was not added in soil (-P). The present investigation was carried out at the experimental area and laboratories of the Pulses section, Department of Plant Breeding and Genetics in the Punjab Agricultural University, Ludhiana during *Kharif* 2013. Observations were recorded for sixteen characters *viz.*, root length, root volume (cm^3), root dry weight (g), root area (mm^2,) root perimeter (mm^2), number of root tips, shoot length (cm), shoot dry weight (g), number of leaves, leaves dry weight (g), leaf area (cm^2), photosynthesis rate, stem p , root p and leaf p at 60 days after sowing. Genotypes were classified on the basis of their root traits was done using the ward cluster method. Pigeonpea genotypes were divided into different clusters under both P treatments by using Manitab17 software.

Result and Discussion

Growth and root characteristics based clustering

Forty three pigeonpea genotypes based on root acid phosphatase activity, photosynthetic rate, root and shoot morphological traits were categorized into five groups using ward cluster squared Euclidean distance method.

First cluster genotypes

Genotypes AL1584, AL1843, AL1873, AL1593, AL1758, IC245507, MN1, P992, Paras and UPAS120 were classified in the first cluster out of 43 genotypes (Table 1). The minimum inter-cluster distance (D = 2.334) was found between cluster I and II under no added P condition.

AL 1584, AL 1778, AL 1812, AL 1816, AL 1817. AL 1836, AL 1839, AL 1842, AL 1843, AL 1853, AL 1873, AL 1881, AL 1932, AL 1933, AL 1941, AL 1593, AL 1756, AL 1758, IC 245504, Pant A 402 and VLA11 (Table 2). Least inter-cluster distance (D = 4.202) between cluster I and II was observed (Table 3). Within clusters sum of squares were maximum in cluster I. This cluster showed highest average values of root area and perimeter was highest of this cluster than other four clusters under recommended dose of P.

Second cluster genotypes

AL 1778, AL 1747, AL 1756, IC 245504, ICPL 20329, P 2001, P2002, Pant A 402 and VLA11 genotypes were categorized in the second cluster. Highest and two successively lower inter-cluster distance values were 5.584, 5.257 and 3.973 for cluster V and II, IV and II, III and II, respectively under no added P condition.

Genotypes AL1838, AL 1847, AL 1849, AL 1931, AL15, AL 201, ICPL 20329, Manak, MN1, P 2001, P992, Paras, PAU 881 and UPAS120 belonged to this cluster under recommended dose of P. Inter-cluster distance 7.565, 7.413 and 5.481 was found between cluster V and II, III and II, IV and II respectively.

Table 1: Distribution of pigeonpea genotypes to different clusters on the basis of ward cluster method (P not added)

Clusters	Number of genotypes	Genotypes
I	10	AL1584, AL 1843, AL 1873, AL 1593, AL 1758, IC245507, MN1 P992, Paras, UPAS120
II	9	AL 1778, AL 1747, AL 1756, IC 245504, ICPL 20329, P 2001, P2002, Pant A 402, VLA11
III	10	AL 1816, AL 1839, AL 1842, AL 1881, AL 1932, AL 1933 AL 1941, AL 15, IC245506 , PAU 881
IV	10	AL 1812, AL 1817, AL 1836, AL 1838, AL 1847, AL 1849, AL 1853, AL 1931, AL 201, Manak,
V	4	ICPL 20330, ICPL 20340, ICPL 88039, MN5

Table 2: Distribution of pigeonpea genotypes to different clusters on the basis of ward cluster method (recommended P dose)

Clusters	Number of genotypes	Genotypes
I	21	AL 1584, AL 1778, AL 1812, AL 1816, AL 1817. AL 1836, AL 1839 AL 1842, AL 1843, AL 1853, AL 1873, AL 1881, AL 1932, AL 1933 AL 1941, AL 1593, AL 1756, AL 1758, IC 245504, Pant A 402, VLA11
II	14	AL 1838, AL 1847, AL 1849, AL 1931, AL 15, AL 201, ICPL 20329 Manak, MN1, P 2001, P992, Paras, PAU 881, UPAS120
III	3	AL 1747, IC245506, IC245507
IV	4	ICPL 20330, ICPL 20340, ICPL 88039, MN5
V	1	P2002

Third cluster genotypes

Ten genotypes namely AL 1812, AL 1816, AL 1839, AL 1842, AL 1881, AL 1932, AL 1933, AL 1941, AL 15 and IC245506 were included in this cluster. Highest average mean value of stem P content was observed under no added P condition.

Genotypes AL 1747, IC245506 and IC245507 were classified in third cluster under recommended dose of P. Mean values of root length, root volume, root dry weight, number of root tips, shoot length, shoot dry weight, number of leaves, leaf dry weight, leaf area were more of this cluster.

Fourth cluster genotypes

Cluster IV was formed by AL 1817, AL 1836, AL 1838, AL 1847, AL 1849, AL 1853, AL 1931, AL 201, Manak and PAU 881. Inter-cluster distance values revealed that the maximum inter cluster distance (D= 10.298) was found between cluster V and cluster IV under no added P condition. ICPL 20330, ICPL 20340, ICPL 88039, MN5 were belonged to this cluster under recommended dose of P. This cluster showed highest average values of photosynthetic rate, root acid phosphatase activity, stem P content, root P content and leaf P content. The maximum inter-distance (D= 7.767) found between cluster V and IV (Table 3).

Table 3: Distance values between cluster centroids of pigeonpea genotypes under P not added and recommended P dose conditions

Cluster	-P					+P				
	I	II	III	IV	V	I	II	III	IV	V
I	0					0				
II	2.334	0				4.202	0			
III	3.047	3.973	0			4.593	7.413	0		
IV	3.534	5.257	2.414	0		4.489	5.481	5.223	0	
V	7.218	5.584	8.930	10.298	0	6.846	7.565	7.655	7.767	0

Fifth cluster genotypes

Genotypes ICPL 20330, ICPL 20340, ICPL 88039 and MN5 were classified in this cluster. Mean values of root length, root volume, root dry weight, root area, root perimeter, number of root tips, shoot length, shoot dry weight, number of leaves, leaf dry weight, leaf area, photosynthetic rate, root acid phosphatase activity root P content and leaf P content were more in cluster V under no added P condition. The P2002 was only one genotype belonged to this cluster under recommended dose of P condition.

Pearson correlation coefficient and Path analysis

Correlation coefficient analysis analyze quantitative relationship among root-shoot traits and leaf P. Root perimeter was highly positively correlated with root area (r = 0.934) followed by leaf area and leaf dry weight (r = 0.872), shoot dry weight and shoot length (r = 0.733), root dry weight and root volume (r = 0.695), leaf dry weight and root dry weight (r = 0.684) while leaf P had no correlation with root volume, shoot dry weight, stem P, photosynthetic rate, number of root tips, acid phosphatase activity and root dry weight. A negative correlation was found among leaf P and root length (r = -0.091), root P and root length (r = -0.087), root P and root dry weight, stem P and root dry weight, stem P and root area, leaf P and root area. Number of root tips were negatively correlated with photosynthetic rate, acid phosphatase activity, stem P and root P under +P condition (Table 4). Root area of *Arabidopsis* increased with increase in fine root length in response to P deficient condition (Bates and Lynch, 2001) [1].

Value of coefficient varied from -0.034 (number of root tips and stem P) to (root perimeter and root area) under - P condition (Table 4). Leaf P was positively correlated with leaf dry weight (r = 0.626) followed by root P (r = 0.622), photosynthetic rate (r = 0.618), root dry weight (r = 0.577). There was negative correlation found between stem P and root area (r = -0.038), root perimeter (r = -0.037), number of root tips (r = -0.034), leaf area (r = -0.097), acid phosphatase activity (r = -0.154). Root area with root perimeter (r = 0.980) followed by leaf dry weight and leaf area (r = 0.869), root volume and root dry weight (r = 0.859) were highly positively correlated. It was observed that stem P and root P, root length, root volume, root dry weight, shoot dry weight, number of leaves, root length and acid phosphatase activity had no correlation. A positive significant correlation was observed between total P uptake and root dry weight (Vesterager *et al*., 2006) [13]. Genotypes with maximum P acquisition efficiency represented more root area, volume, dry weight (Zhang *et al*., 2009) [15] and released organic acids to mobilize P under P deficiency (Wang *et al*., 2010). Shoot P content, root dry weight was positively correlated with total dry weight of pigeonpea genotypes in response to low P soil (Krishnappa *et al*., 2014) [7].

Table 4: Pearson correlation coefficient among different variables and leaf P at 60 DAS of pigeonpea under -P (above the diagonal) and +P (below the diagonal**)**

	RL	RV	RDW	RA	RP	NRT	SL	SDW	NL	LDW	LA	PR	APase	Stem P	Root P	Leaf P
RL	1	0.614**	0.522**	0.515**	0.438**	0.463**	0.585**	0.219**	0.487**	0.428**	0.361*	0.510**	0.284	0.103	0.537**	0.501**
RV	0.635**	1	0.859**	0.754**	0.736**	0.715**	0.621**	0.571**	0.799**	0.739**	0.662**	0.681**	0.563**	0.083	0.655**	0.526**
RDW	0.570**	0.695**	1	0.797**	0.803**	0.714**	0.564**	0.636**	0.697**	0.797**	0.715**	0.698**	0.605**	0.092	0.563**	0.577**
RA	0.609**	0.570**	0.596**	1	0.980**	0.751**	0.605**	0.540**	0.582**	0.723**	0.716**	0.647**	0.425**	-0.038	0.512**	0.408**
RP	0.667**	0.538**	0.547**	0.934**	1	0.751**	0.588**	0.571**	0.595**	0.703**	0.693**	0.630**	0.426**	-0.037	0.478**	0.364*
NRT	0.366*	0.351*	0.472**	0.434**	0.497**	1	0.745**	0.621**	0.765**	0.716**	0.665**	0.567**	0.559**	-0.034	0.485**	0.359*
SL	0.658**	0.537**	0.503**	0.644**	0.626**	0.358*	1	0.685**	0.743**	0.661**	0.576**	0.467**	0.421**	0.062	0.430**	0.412**
SDW	0.552**	0.614**	0.711**	0.632**	0.646**	0.543**	0.773**	1	0.743**	0.750**	0.588**	0.477**	0.475**	0.085	0.360*	0.436**
NL	0.165	0.311*	0.027	0.058	0.050	0.282	0.073	0.193	1	0.811**	0.699**	0.588**	0.489**	0.133	0.620**	0.557**
LDW	0.380*	0.646**	0.684**	0.289	0.317*	0.371*	0.346*	0.596**	0.246	1	0.869**	0.695**	0.613**	0.031	0.603**	0.626**
LA	0.247	0.581**	0.584**	0.212	0.247	0.361	0.170	0.487**	0.246	0.872**	1	0.652**	0.460**	-0.097	0.532**	0.416**
PR	0.196	0.022	0.034	0.117	0.077	-0.037	0.053	0.012	0.004	0.037	0.207	1	0.374*	0.112	0.648**	0.618**
APase	0.057	0.418**	0.248	0.108	0.055	-0.083	-0.125	0.053	0.048	0.400**	0.403**	0.213	1	-0.154	0.433**	0.397**
Stem P	-0.325	-0.258	-0.149	-0.292	-0.319	-0.315	-0.457**	-0.360	-0.130	-0.141	-0.146	-0.062	0.307	1	0.090	0.372*
ROOT P	-0.087	0.169	-0.102	0.028	-0.045	-0.109	-0.025	-0.158	-0.045	0.047	0.191	0.250	0.286	0.044	1	0.622**
Leaf P	-0.091	0.034	0.226	-0.171	-0.164	0.080	-0.079	0.042	-0.005	0.333*	0.431**	0.061	0.175	0.049	0.292	1

RL-Root length, RV- Root volume, RDW- Root dry weight, RA- Root area, RP-Root perimeter, NRT-Number of root tips, SL-Shoot length, SDW-Shoot dry weight, NL-Number of leaves, LDW- Leaf dry weight, LA- Leaf area, PR- Photosynthetic rate, APase- acid phosphatase, P-Phosphorus * Correlation significant at 0.05 level ** Correlation significant at 0.01 level

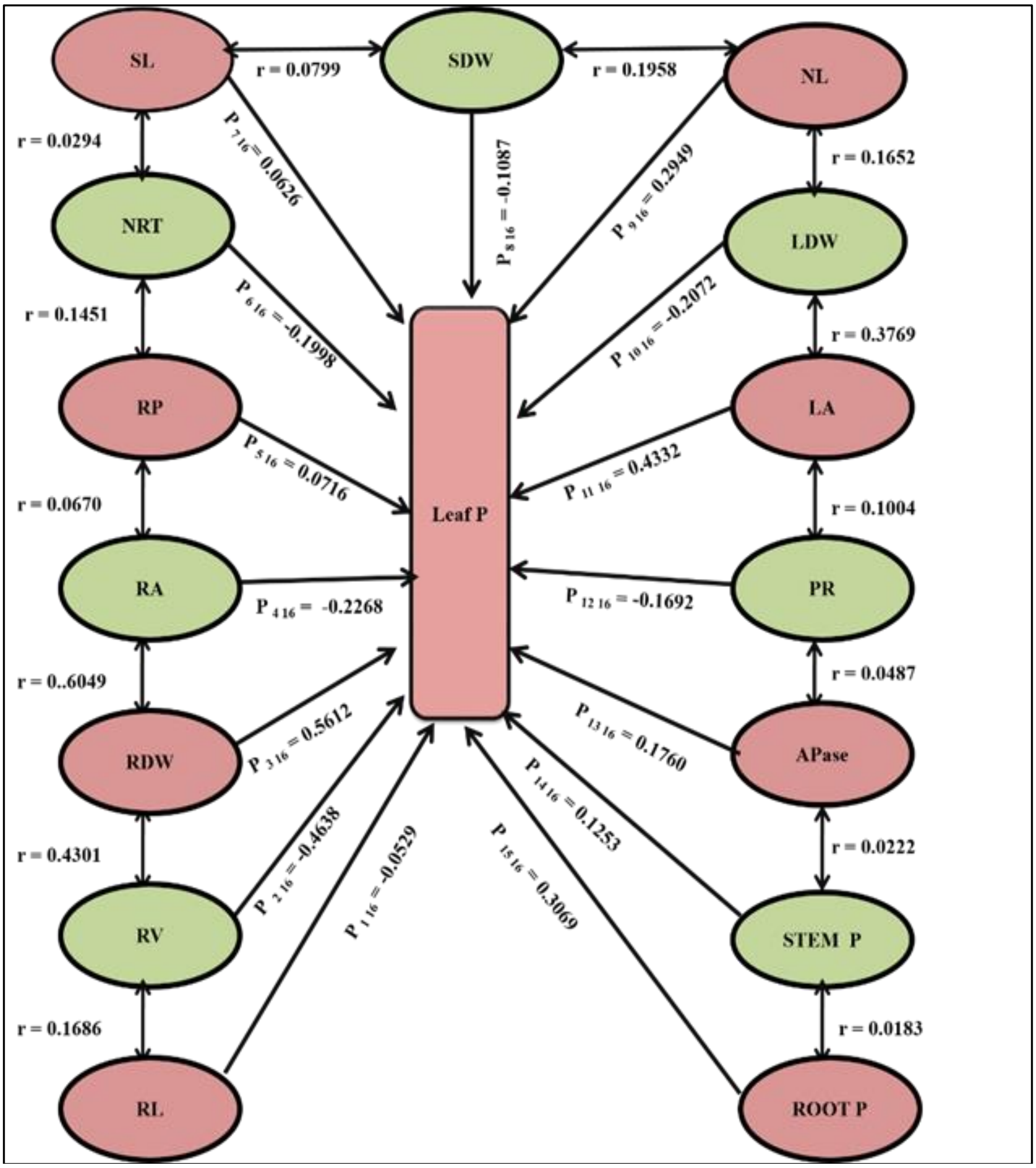

Fig 1: Path coefficient showing direct effects of root length (RL), root volume (RV), root dry weight (RDW), root area (RA), root perimeter (RP), number of root tips (NRT), shoot length (SL), shoot dry weight (SDW), number of leaves (NL), leaf dry weight (LDW), leaf area (LA), photosynthetic rate (PR), acid phosphatase (APase) activity, stem and root phosphorus (P) on leaf P The single headed arrows indicate direct path correlation coefficient. (Data pooled for both P treatments)

Path analysis of leaf P showed that root dry weight had maximum significant positive direct effect ($P_{3\ 16}$ = 0.5612) followed by root volume ($P_{2\ 16}$ = 0.4638), leaf area ($P_{11\ 16}$ = 0.4332) on leaf P (Fig 1.). The direct effect of shoot length found to be minimum ($P_{7\ 16}$ = 0.0626). Root length ($P_{1\ 16}$ = -0.0529), root volume ($P_{2\ 16}$ = - 0.4638), root area ($P_{4\ 16}$ = -0.2268), number of root tips ($P_{6\ 16}$ = - 0.1998), shoot dry weight ($P_{8\ 16}$ = 0.5612), photosynthetic rate ($P_{12\ 16}$ = - 0.1692) had negative effect on leaf P.

Conclusion

Thus from the present study, it can be concluded that root perimeter was highly positively correlated with root area under +P condition. Stem P and root P, root length, root volume, root dry weight, shoot dry weight, number of leaves, root length and acid phosphatase activity had no correlation under –P condition. Path analysis of leaf P revealed that root dry weight had maximum significant positive direct effect followed by root volume, leaf area on phosphorus use efficiency.

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