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Root morphological response and P uptake of groundnut (*Arachis hypogaea* L.) genotypes for phosphorous efficiency

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Abstract
An experiment was conducted to screen 20 groundnut genotypes for tolerance to phosphorus (P) insufficiency. Significant genotypic variation among genotypes were observed under both P sufficient and deficient treatments. The study revealed that the mean root length and shoot length recorded high in P sufficient soils compared to P deficient soils. The genotypes TCGS 1624, 1616, Greeshma and TCGS 1517 recorded high root length whereas TCGS 1622 recorded lowest root length. The mean root biomass showed no significant differences among P treatments whereas, shoot biomass recorded high in P sufficient soils compared to P deficient soils. Among the genotypes, TCGS 1624, Greeshma, TCGS 1616 and 1621 and 1622 recorded high root biomass in P deficient soils whereas, shoot biomass was found maximum in TCGS 1624, 1616, Greeshma and TCGS 1517. The mean root shoot ratio recorded high in P deficient soils compared to P sufficient soils and among the genotypes, root shoot ratio recorded highest in TCGS 1622, 1624, 1616 and Greeshma whereas shoot P % recorded highest in TCGS 1622, Greeshma, TCGS 1616 and 1624. Pod yields recorded high in TCGS 1624, 1616 and Greeshma in P deficient soils. Hence it can be concluded that, TCGS 1624, Greeshma, 1616 can be identified as P efficient groundnut lines based on their high root mining traits, shoot P % and pod yield.

Keywords: Groundnut genotypes, p efficiency, root traits, shoot biomass

Introduction
Groundnut (*Arachis hypogaea* L.) is mainly used as oil and protein source. In India, it is widely grown in states of Gujarat, Andhra Pradesh, Tamil Nadu, Karnataka and Maharashtra, mainly growing under rainfed (kharif) conditions. Andhra Pradesh stands third place in groundnut production, having an irrigated area of 33 thousand hectares and rainfed area of 15 lakh hectares. But, the productivity is very low under rainfed conditions (552 kg/ha.) compared to irrigated conditions (1167 kg/ha.). Groundnut crop grown on marginal lands under rainfed conditions, are poor in nutrients and in these lands, phosphorus (P) deficiency is one of the important cause for low productivity (Schachtman *et al.*, 1998; Lynch and Brown, 2008) [24, 20], mainly in low input farming systems occupying 5.7 billion hectare (B ha.) of global land. Most of the P applied in the form of fertilizers gets adsorbed by the soil and is not available for utilization by plants. To improve acquisition of mineral elements by the root system, it has been suggested that, development of genotypes with specific set of root traits might increase crop yields on low fertile soils (White *et al.*, 2005 and 2013; Lynch, 2007 and 2011) [27, 26, 22, 21]. Adaptation of a plant under P deficiency have developed specialized physiological and biochemical mechanisms along with morphological modifications such as increased root to shoot ratio, plant architecture, increased root hair elongation and proliferation in order to cope with its high per cent of fixation. P deficiency induces many changes in root morphology and architecture in groundnut. Correcting soil P deficiency with heavy application of P fertilizer can be a solution but it is not possible for poor farmers (Lynch, 1995) [18]. Since P is a relatively immobile soil nutrient (Haynes *et al.* 1991) [10], plants need to cope with heterogeneous P distribution in soils. Hence, root spreading, root architecture and elongation of lateral roots become important factors in acquisition of P (He *et al.* 2003) [11]. Studies on evaluating the groundnut genotypes with respect to root traits in relation to P response are meagre. One of the principal component strategies to improve groundnut production with minimum P application is to develop P use efficient genotypes, which can grow well at lower levels of available soil P or explore fixed P from the soil. In the present study, twenty groundnut genotypes were screened for variability in root traits and P uptake for P deficiency tolerance.

Materials and Methods

The groundnut genotypes for the study were procured from Department of Plant Breeding and Genetics, Regional Agricultural Research Station, Tirupati. A pot culture experiment was conducted in *kharif*, 2016 at Regional Agricultural Research Station, Tirupati. The experiment was carried out in a completely randomized design (CRD) with 20 genotypes sown in two P treatments i.e., P sufficient (78.6 kg/ha of soil available P_2O_5) and P deficient (23.5 kg/ha of soil available P_2O_5) soils and each treatment replicated thrice. The genotypes were grown in plastic pots filled with P sufficient and P deficient soils and four groundnut seeds were laid in each pot. At 60 DAS, SPAD Chlorophyll Meter Reading (SCMR) and shoot (stem and leaf) P content were recorded. SCMR was measured using Minolta SPAD 502m (Tokyo, Japan) for the third fully expanded leaf from the top of the main stem. The shoot samples were dried at 65°C for 72 hrs in a hot air oven, ground, weighed, digested and P concentration was estimated according to Tandon (1993). At harvest, observations were recorded for root parameters *viz.*, primary root length (PRL), shoot length (SL), root dry weight (RDW) and shoot dry weight (SDW) and pod yields were recorded after drying of individual plants and expressed in g/plant. The statistical significance of variance was assessed by Two Way Analysis of Variance (ANOVA) and critical difference values at 5% level of significance were calculated to compare mean values by GENSTAT software.

Results and Discussion

The relative growth rate of roots and shoots may be related to genotypic differences in phosphorus use efficiency. The result of present study to screen P efficient lines based on shoot and root morphology reveals that, SCMR showed no significant differences among the P treatments (P sufficient and P deficient soils). Among the genotypes, TCGS 1517 recorded highest SCMR followed by TCGS 1624 and 1621. The mean shoot length recorded low in P deficient soils compared to P sufficient soils. Shoot length recorded highest in TCGS 1613 and lowest in TCGS 1622 and 1514. The mean shoot biomass recorded low in P sufficient soils compared to P deficient soils. Among the genotypes, TCGS 1624 recorded highest shoot biomass followed by Greeshma, TCGS 1616 and 1621. Shoot P % and pod yields recorded low in P deficient soils compared to P sufficient soils and highest shoot P % was recorded in TCGS 1622, Greeshma, TCGS 1616 and 1624 (Table 1). Though the mean root length recorded low in P deficient soils compared to P sufficient soils, but among the genotypes, 8 genotypes recorded high root length in P deficient soils and the remaining 10 genotypes recorded high root length in P sufficient soils. Highest root length recorded in TCGS 1624 followed by TCGS 1616, Greeshma and TCGS 1517. Although, the root dry weight showed no significant differences among the P treatments, except TCGS 1603, 1609, 1511, 1517 and 1528, all other genotypes recorded high root dry weight in P deficient soils compared to P sufficient soils. Highest root biomass recorded in TCGS 1624 followed by Greeshma and TCGS 1616, 1621 and 1622. Root shoot ratio recorded high in P deficient soils compared to P-sufficient soils and maximum root shoot ratio recorded in TCGS 1622 followed by TCGS 1624, 1616 and Greeshma. The nutritional status of the plant can be characterised by the P concentration in the dry matter. Pod yields recorded low in P deficient soils compared to P sufficient soils. In P sufficient soils, pod yields recorded maximum in TCGS 1624, 1616, 1621 and Greeshma whereas in P deficient soils, TCGS 1624, 1616 and Greeshma recorded high pod yields (Table 2).

To withstand P stress condition, plants acquire adaptations at physiological, biochemical and molecular levels. One of the adaptations under reduced P supply is changes in root morphology and these changes include, increased root shoot ratio, lateral root number, root length and biomass (Gahoonia and Neilson, 2004) [3] to enhance P acquisition. In the present study, among the genotypes, TCGS 1624 recorded highest shoot and root biomass followed by Greeshma, TCGS 1616 and 1621. In the responsive genotypes, root growth is enormous to adapt with P stress condition, thus providing greater contact area, for better acquisition of less mobile element like P (Otani *et al.* 1996) [23].

Table 1: Effect of SCMR, shoot biomass and shoot P % of groundnut genotypes grown in P sufficient (P S) and P deficient (P D) soils

S. No.	Genotype	SCMR		Shoot length (cm)		Shoot dry weight (g)		Shoot P (%)	
		P S	P D	P S	P D	P S	P D	P S	P D
1	TCGS 1602	43.1	35.7	23.7	18.0	4.36	4.19	0.38	0.31
2	TCGS 1603	38.5	38.5	21.8	15.5	6.83	4.63	0.42	0.34
3	TCGS 1609	35.8	35.9	17.5	22.1	3.19	3.01	0.41	0.28
4	TCGS 1611	41.4	39.6	19.4	18.3	5.02	4.77	0.42	0.28
5	TCGS 1613	40.5	38.0	25.6	22.4	8.58	6.08	0.42	0.26
6	TCGS 1616	42.6	41.8	16.7	14.6	7.61	7.05	0.53	0.43
7	TCGS 1621	46.4	44.5	21.4	20.0	7.29	6.94	0.49	0.26
8	TCGS 1622	40.7	40.9	17.8	13.2	5.71	4.66	0.48	0.45
9	TCGS 1623	43.2	41.2	20.8	15.3	7.63	6.50	0.40	0.27
10	TCGS 1624	47.5	45.3	16.2	15.8	9.27	8.43	0.51	0.41
11	TCGS 1511	40.8	40.1	22.5	16.2	10.02	6.77	0.41	0.31
12	TCGS 1514	44.8	43.5	19.3	13.2	8.94	6.58	0.45	0.26
13	TCGS 1517	52.1	48.1	19.9	20.0	8.09	7.01	0.38	0.36
14	TCGS 1522	42.9	40.7	21.4	18.4	7.00	5.48	0.43	0.35
15	TCGS 1528	43.5	42.2	18.0	15.5	7.52	5.60	0.47	0.27
16	Dharani	43.9	41.5	19.6	17.5	8.54	6.22	0.52	0.34
17	K 6	39.2	40.6	22.9	17.5	6.46	6.02	0.46	0.29
18	Narayani	40.6	42.6	19.1	16.4	5.89	5.67	0.56	0.47
19	TAG 24	39.3	41.3	22.7	17.3	5.24	4.84	0.63	0.48
20	Greeshma	39.3	40.9	23.7	17.3	8.67	7.20	0.54	0.44
	Mean	42.3	41.1	20.5	17.2	7.09	5.88	0.47	0.34
		SEm	CD (5 %)	SEm	CD (5 %)	SEm	CD (5 %)	SEm	CD (5 %)
	P treatments	0.26	NS	0.26	0.73	0.14	0.40	0.004	0.012
	Genotypes	0.83	2.34	0.82	2.31	0.43	1.26	0.014	0.039
	Interaction	1.18	3.31	1.16	3.26	0.62	1.78	0.019	0.055

Table 2: Effect of root traits and pod yield of groundnut genotypes grown in P sufficient (P S) and P deficient (P D) soils

S. No.	Genotype	Root length (cm)		Root dry weight (g)		Root shoot ratio		Pod yield (g/plant)	
		P S	P D	P S	P D	P S	P D	P S	P D
1	TCGS 1602	30.5	19.8	0.38	0.48	0.091	0.110	11.0	8.2
2	TCGS 1603	26.5	27.8	0.98	0.49	0.143	0.106	9.3	7.2
3	TCGS 1609	27.0	17.5	0.75	0.47	0.235	0.156	10.2	7.4
4	TCGS 1611	20.0	21.1	0.46	0.64	0.092	0.134	4.3	3.1
5	TCGS 1613	25.3	27.2	0.73	0.71	0.085	0.117	12.2	9.7
6	TCGS 1616	25.9	32.5	1.14	1.24	0.150	0.176	16.8	13.6
7	TCGS 1621	22.7	27.8	1.45	1.06	0.199	0.153	16.5	8.9
8	TCGS 1622	25.4	17.0	0.91	1.09	0.159	0.234	11.6	7.4
9	TCGS 1623	29.7	28.9	0.87	0.95	0.114	0.146	12.0	7.1
10	TCGS 1624	33.7	33.5	1.19	1.27	0.128	0.151	20.3	15.4
11	TCGS 1511	25.6	23.7	0.94	0.82	0.094	0.121	11.1	8.8
12	TCGS 1514	24.3	24.3	1.03	1.08	0.115	0.164	15.1	9.4
13	TCGS 1517	20.2	28.7	0.97	0.95	0.120	0.136	11.5	9.1
14	TCGS 1522	36.5	17.8	0.74	0.84	0.106	0.153	11.1	5.7
15	TCGS 1528	22.4	23.7	1.13	0.66	0.150	0.118	10.1	6.4
16	Dharani	32.2	17.7	0.67	0.97	0.078	0.156	13.2	10.1
17	K 6	28.5	25.0	0.84	0.93	0.130	0.154	13.1	9.6
18	Narayani	31.0	18.3	0.71	0.91	0.121	0.160	12.7	9.8
19	TAG 24	20.8	19.9	0.50	0.79	0.095	0.163	11.8	8.1
20	Greeshma	30.0	30.6	0.85	1.26	0.098	0.175	16.3	14.5
	Mean	26.9	24.1	0.86	0.88	0.125	0.149	12.5	9.0
		SEm	CD (5 %)	SEm	CD (5 %)	SEm	CD (5 %)	SEm	CD (5 %)
	P treatments	0.32	0.91	0.03	NS	0.005	0.012	0.28	0.85
	Genotypes	1.02	2.88	0.09	0.24	0.010	0.031	0.51	1.46
	Interaction	1.45	4.07	0.12	0.34	0.021	0.057	1.21	3.06

At 45 days after sowing, significant contribution of root traits viz., root length, volume, number of lateral roots and root surface area were reported towards better uptake of total P in blackgram (*Vigna mungo*) (Jakkeral, 2009) [12]. Increase in root-shoot ratio which is reported as significant change for adaptation to P deficiency in plants (Vandamme *et al.*, 2016, Hammond and White, 2011) [5] is due to increase in carbohydrates accumulation in roots. In the present study, root shoot ratio recorded high in P deficient soils compared to P-sufficient soils and maximum root shoot ratio recorded in TCGS 1622 followed by TCGS 1624, 1616 and Greeshma. Genotypes with extensive root systems coupled with a large shoot system would be P efficient, contributing to yield stability during reduced P supply. Groundnut genotypes vary genetically with respect to their translocation, uptake, accumulation and use of phosphorus. This was earlier reported by Krishna (1997) [13] where in traits like root length, rate of P uptake by root, stem, leaf and pod and dry matter produced per unit of P absorbed (P efficiency ratio) were determined. An increase in root biomass in response to P stress might enhance P acquisition from the soil. Phosphorus efficient genotypes have usually highly branched root systems with numerous basal roots, while the inefficient plants had smaller, less branched roots (Hammond *et al.*, 2009) [6]. In the present study, shoot P % recorded low in P deficient soils compared to P sufficient soils and highest shoot P % was recorded in TCGS 1622, Greeshma, TCGS 1616 and 1624.This is especially true for low soil P availability because P acquisition is strongly dependent on soil exploration and root architecture (Lynch and Beem, 1993) [17]. Therefore, genotypes having greater ability to tolerate P stress condition would be able to acquire P efficiently from low P soil. High P uptake genotypes retained more P in shoot in P deficient and sufficient condition, revealed better mobilization of P in to shoot from roots (Krishnappa *et al.*, 2011) [14]. Better uptake of P from soil with increased dry matter production and yield per unit of P absorbed are important aspects of utilization efficiency (Gourley *et al.* 1993) [4] Higher P content in groundnut genotypes has been found to be improved with increased root length and root weight (Fohse *et al.* 1991) [2]. Variation in root traits when grown in sufficient and deficient P conditions which contributed to variable acquisition and utilization of P in groundnut genotypes (Kumar *et al.* 2015) [15]. Responsive genotypes were found superior in both acquisition and utilization of P in P stress condition due to enhanced root production and shoot expansion, respectively.

Development of groundnut genotypes with highly developed root system and thus capable of using a higher proportion of P present in soils could be an attractive and cost effective approach to increase groundnut yields in P deficient soils. In the present study, TCGS 1622 showed high root shoot ratio recording low pod yields. Increased root C costs under P stress (because of a higher root/shoot ratio) may be an important component of reduced plant productivity (Lynch *et al.*, 1991; Lynch and Beebe, 1995) [16, 18].

Phosphorus use efficient genotype showed higher relative root growth because of the additional P taken up by roots, allow further biomass accumulation which leads to more production. Phosphorus use efficient groundnut genotypes developed various adaptive strategies such as increased root length, root and shoot biomass and P content to enhance the P acquisition and utilization efficiency under P deficient soil condition (Amit Kumar *et al.*, 2009) [1]. In conclusion, genotypes differed for root traits and TCGS 1624, Greeshma and TCGS 1616 were identified as the most responsive genotypes for reduced P supply. The selected P efficient genotypes can be evaluated in field for agronomic performance at different P levels. Genetic basis of superiority in P deficient condition could be determined. Genes responsible for P deficiency tolerance can be transferred to agronomically superior genotypes.

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