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Variation in Root Traits of Pigeonpea (*Cajanus cajan* (L.) Mill SP.) Genotypes Under Rainfed Conditions

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ABSTRACT: A study was conducted under simulated raised rectangular soil beds in order to know the variation in root traits among the redgram genotypes during *kharif* 2019-20 and 2020-21. Ten redgram genotypes (4 mid early, 4 medium and 2 late duration genotypes) were selected for the present research purpose. Root traits, such as root depth and root biomass, have been identified as the most promising plant traits in legume crops like pigeonpea and chickpea for terminal drought tolerance, as these help in greater extraction of available soil moisture. Conducting research on roots is very labour- expensive and time consuming because extraction of roots from the soil is a very difficult task. So, the present research was conducted separately in raised bed method to evaluate the root traits among mid-early, medium and late duration genotypes of redgram. Root traits were measured at 65 DAS through destructive method and the pooled data revealed that there was significant variation among the three duration genotypes. The highest root length, number of primary and secondary roots, root: shoot ratio was recorded by the medium duration genotype LRG 52, followed by the mid-early duration genotype CO-6. The lowest values of root characteristics were recorded in the late duration genotypes *viz*., ICPL 15062 and ICPL 17103.The remaining mid-early and medium duration genotypes are significantly superior over ICPL 17103 and 15062 and inferior over CO-6 and LRG-52. Hence, it can be concluded that the genotypes LRG-52 and CO-6 are considered as drought tolerant ones by possessing efficient rooting pattern under rainfed conditions.

Keywords: *Cajanus cajan*, root traits, Terminal drought, Raised soil bed.

INTRODUCTION

Pigeon pea is a deep rooted legume crop which is populary known as Arhar and Tur. In India, it is cultivated in an area of 48.24 lakh hectares with 38.8 lakh tonnes production and productivity of 804 kg ha^{-1} (*https://www.indiastat.com*). Major producing countries including India, Pakistan and Iran (FAO, 2003), where the crop is generally planted after the main rainy season and grown on stored soil moisture making terminal drought stress a primary constraint to productivity.

Deep and prolific roots play an immense role for soil water extraction from deeper layers to sustain the crop during critical growth stages. Deeper roots increased the yield of crops by 20 percent (Jordan and Miller, 1980). An increase in the simulated root zone depth has been shown to increase leaf area, growth, photosynthesis, transpiration and yield of crops under drought (Jones and Zur, 1984).

Drought tolerance is closely related to the distribution of root systems in the soil (Sarker *et al*., 2005). Large root system with greater root prolificacy and rooting depth, was shown to influence not only transpiration through soil moisture utilization but also influences shoot biomass production and harvest index (HI) under terminal DS(Drought stress). (Kashiwagi *et al*., 2006; 2013, Zaman-Allah *et al*., 2011; Purushothaman *et al*., 2016a).

Conducting research on root systems in field conditions is very laborious, expensive and time consuming (Subbarao *et al*., 1995). For the selection of drought tolerant genotypes, study on root traits related to below plant parts is essential. Among these traits, root traits (Root length density (RLD), Root dry weight (RDW), root surface area, average root diameter, root volume,) were found to be the major contributors to drought tolerance (avoidance) under rainfed condition

(Krishnamurthy *et al*., 2003; Kashiwagi *et al*., 2006, 2015; Turner *et al*., 2001, Passioura *et al*., 2006; Zhu *et al*., 2010; Uga *et al*., 2013).

In drought prone Southern Zone of Andhra Pradesh, where recurrent droughts in kharif season is ever-present restraint on maximum production of pigeonpea, the genotypes with better root characteristics is a major research priority in order to recommend to the farmers. Hence, this study was taken up to know the variation in root traits of red gram genotypes with different durations under rainfed situation .

MATERIALS AND METHODS

The experiment was conducted in Completely Randomized Block Design (CRD) and replicated twice with ten redgram (4 mid-early, 4 medium and 2 long duration) genotypes under specially raised rectangular soil beds of size i.e., 15m × 2m × 1.5m (L × B × H) structure during *kharif*, 2019 and *kharif*, 2020 at RARS, Tirupati.

The structure was specially constructed with cement bricks and red soil is filled in the cavity and raised the soil bed to 1.8 m level. The soil bed was watered and further filled with soil for better compaction. A spacing of 10 cm from row to row and 5 cm between plants was maintained and the crop was raised in protective root structure which is 6 ft. high from the ground level. Soil properties of the simulated soil bed were as follows. Bulk density: 1.58 mg m^{-3}, Particle density: 2.53 mg m^{-3}, Water holding capacity: 39.4 % and Porosity: 40.4%. The recommended package of practices were adopted during the crop growth period.

At 65 DAS, by removing the cement bricks of the raised bed structure the roots were extracted carefully by removing soil with the help of water. The root traits *i.e*., root length, number of primary and secondary roots, root and shoot dry weight and root: shoot ratio was measured randomly for five tagged plants and calculated by the mean of five plants. After harvesting, the root length was calculated with the help of meter scale and number of primary and secondary roots were counted then the roots and shoots were sundried and then dried for 48hrs at 60°C. Root and shoot dry weights were recorded with the help of weighing balance and expressed as g/plant.

Statistical Analysis. The experimental data was statistically analyzed through OPSTAT statistical package following the one way ANOVA for completely randomized block design on the basis of the model proposed by Panse and Sukhatme (1985). Significance was tested by comparing 'F' value at 5 per cent level of probability.

RESULTS AND DISCUSSION

Roots plays a major role for acquisition of water, minerals and nutrients throughout their crop growth and development. Pooled data revealed that there was significant variation in the root characteristics *i.e*., root length, number of primary roots, number of secondary roots and root: shoot ratio among the ten pigeonpea genotypes. The maximum root length (95.42 cm) was recorded in the mid-early genotype CO-6, which was at par with the medium duration genotype LRG-52 (90.05 cm). The minimum root length was recorded in the late duration genotype ICPL 15062 (57.53 cm) which was at par with ICPL 17103 (63.55 cm)(Table 1). Among the mid-early duration genotypes, CO-6 and among the medium duration genotypes, LRG-52 exhibited superior performance and increased the root length by 66.0 and 57.0 per cent over the late duration genotype ICPL 15062. Lal *et al*. (2003) reported that direct effect of root length on pod yield per plant is positive and high, suggested to include root length as one of the selection criteria along with yield contributing traits to improve yield under rainfed conditions.

LRG-52recorded significantly more number of primary and secondary roots (7.67 and 11.50, respectively) which was at par with thegenotype CO-6 (7.0 and 10.67, respectively) Less number of primary and secondary roots was recorded in the genotype ICPL 17103 (4.67 and 7.67, respectively) which was at par with ICPL 15062(4.83 and 7.33, respectively) (Table 1). The remaining genotypes are found to be statistically inferior over CO-6 and LRG-52 and superior over ICPL 17103 and ICPL 15062. The results are in accordance with the findings of Sakhare *et al*. (2013); Kashiwagi *et al*. (2006).

In the current study, the medium duration genotype LRG-52 increased the number of primary and secondary roots by 64.0 and 50.0 per cent respectively, over the late duration genotype ICPL 17103. And the mid-early duration genotype CO-6 increased the number of primary and secondary roots by 50.0 and 46.0 respectively, over the late duration genotype ICPL 15062. Mula *et al*. (2016) stated that the number of primary roots was more dominant in medium-duration genotype i.e., ICPL 14002 which is an important trait to be considered for imparting drought tolerance under rainfed conditions.

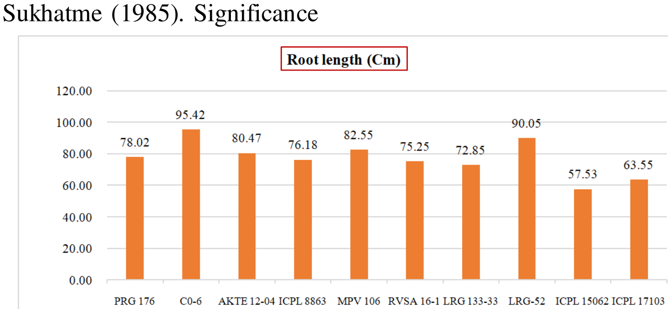

Fig. 1. Variation in pigeonpea genotypes for root length (cm) at 65 DAS under raised soil bed in rainfed condition.

Table 1: Variation in pigeonpea genotypes for root length (cm), Number of primary and secondary roots at 65 DAS under raised soil bed in rainfed condition.

Genotypes	Root length (cm)			No. of primary roots			No. of secondary roots		
	2019	2020	pooled	2019	2020	pooled	2019	2020	pooled
Mid -early Duration									
PRG 176	75.38	80.67	78.02	5.67	5.33	5.50	9.33	9.00	9.17
C0-6	94.67	96.17	95.42	7.67	6.33	7.00	10.33	11.00	10.67
AKTE 12-04	81.93	79.00	80.47	5.67	5.00	5.33	8.33	10.00	9.17
ICPL 8863	79.53	72.83	76.18	6.33	5.33	5.83	8.00	8.67	8.33
Medium Duration									
MPV 106	82.60	82.50	82.55	6.67	4.67	5.67	9.00	9.33	9.17
RVSA 16-1	77.97	72.53	75.25	6.00	5.00	5.50	8.00	9.00	8.50
LRG 133-33	74.83	70.87	72.85	6.33	5.00	5.67	8.33	8.67	8.50
LRG-52	89.43	90.67	90.05	8.33	7.00	7.67	11.00	12.00	11.50
Late Duration									
ICPL 15062	59.07	56.00	57.53	5.67	4.00	4.83	7.67	7.00	7.33
ICPL 17103	62.90	64.20	63.55	5.33	4.00	4.67	7.33	8.00	7.67
CD(p=0.05)	11.55	12.29	7.82	1.80	1.74	1.49	2.03	1.88	2.07
SEm±	3.89	4.14	2.63	0.61	0.59	0.50	0.68	0.63	0.70
CV(%)	8.65	9.36	5.90	6.47	9.68	5.10	3.55	1.82	3.42

Maximum root dry weight (4.86 g plant^{-1}) was recorded in the genotype LRG-52 which was at par with CO-6 (4.29 g plant^{-1}) and the minimum root dry weight was recorded in the late duration genotype ICPL 17103 (1.88 g plant^{-1}) which was at par with ICPL 15062 (1.91 g plant^{-1}) (Table 2).

CO-6 recorded more shoot dry weight (12.22 g plant^{-1}) which was at par with the genotype LRG-52 (11.80 g plant^{-1}). Lesser shoot dry weight was recorded in the late duration genotype ICPL 15062 (7.09 g plant^{-1}) which was at par with ICPL 17103 (7.60 g plant^{-1}). The remaining genotypes are significantly superior over ICPL 17103 and ICPL 15062 and inferior over CO-6 and LRG-52. Water stress lowers the cell turgor and causes slower cell expansion, consequently growth and development of a plant decreased that leads to a lower root and shoot dry weights. The results of the present study is similar to the findings of Suresh *et al*. (2016); Amira and Qados (2014). Higher root: shoot ratio was recorded in the genotype LRG 52 (0.41) and the lesser root: shoot ratio was recorded in ICPL 8863 (0.23). LRG-52 increased the root: shoot ratio by 78.0 percent over ICPL 8863 (Fig. 2). High root/shoot ratio was found to increase water uptake and have a positive effect on yield under stress. Similar results of increased root: shoot ratio were recorded by Uddin *et al*. (2013).

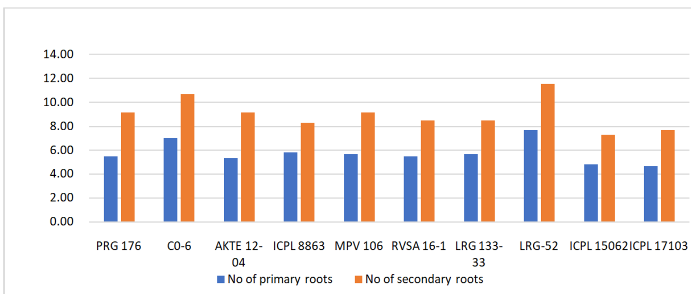

Fig. 2. Variation in pigeonpea genotypes for Number of primary and secondary roots at 65 DAS under raised soil bed in rainfed condition.

Table 2: Variation in pigeonpea genotypes for root dry weight, stem dry weight and root:shoot ratio at 65 DAS under raised soil bed in rainfed condition.

Genotypes	Root Dry weight (g plant^{-1})			Shoot dry weight (g plant^{-1})			Root to Shoot ratio		
	2019	2020	pooled	2019	2020	pooled	2019	2020	pooled
Mid -early Duration									
PRG 176	2.92	3.02	2.97	8.29	9.01	8.65	0.36	0.34	0.35
C0-6	4.14	4.44	4.29	11.22	13.22	12.22	0.37	0.34	0.36
AKTE 12-04	3.06	3.29	3.18	9.56	9.56	9.56	0.32	0.35	0.33
ICPL 8863	2.03	2.26	2.15	9.46	9.46	9.46	0.22	0.24	0.23
Medium Duration									
MPV 106	3.19	3.36	3.27	9.53	9.61	9.57	0.40	0.36	0.34
RVSA 16-1	3.12	3.15	3.13	8.72	8.72	8.72	0.36	0.36	0.36
LRG 133-33	3.39	3.54	3.47	9.65	9.65	9.65	0.36	0.37	0.37
LRG-52	4.86	4.86	4.86	11.43	12.16	11.80	0.43	0.40	0.41
Late Duration									
ICPL 15062	1.85	1.97	1.91	7.00	7.17	7.09	0.26	0.27	0.27
ICPL 17103	1.78	1.98	1.88	7.27	7.93	7.60	0.25	0.25	0.25
CD(p=0.05)	0.64	0.87	0.65	1.28	1.93	1.42	0.09	0.07	0.09
SEm±	0.21	0.29	0.22	0.43	0.65	0.48	0.03	0.04	0.03
CV(%)	2.25	6.00	2.25	8.21	4.67	8.83	5.58	8.63	5.46

Greater root depth and extent of soil water extraction could increase the amount of water available at critical growth stages. Increased root depth, density, increased conductance and better root to shoot dry weight ratio would help the crop in sustaining its growth during rainfed period (Sharp and Davies, 1989; Ingram *et al*., 1994).

In the current study, the mid-early duration genotype CO-6, and the medium duration genotype LRG-52, possessed higher root length, number of primary and secondary roots, root to shoot ratio over the late duration genotypes ICPL 15062 and ICPL 17103. By possessing efficient rooting pattern they are considered as drought tolerant ones. Consequently, there is a need to identify pigeonpea genotypes possessing early maturity and deep rooting genotypes. Finally, there is a need to investigate the physiological basis of superior performance of pigeonpea hybrids under drought stress conditions.

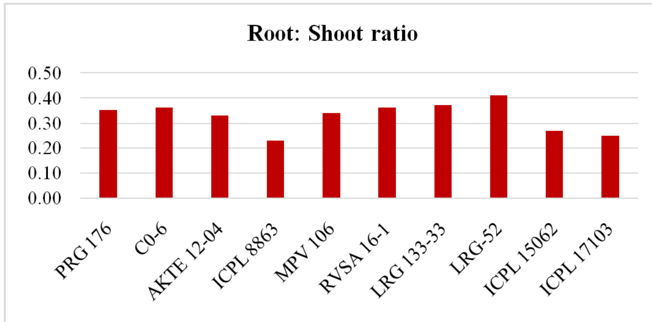

Fig. 3. Variation in pigeonpea genotypes for root: shoot ratio at 65 DAS under raised soil bed in rainfed condition.

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Conflict of Interest. None.

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