Green Farming Vol. **7** (3) : 507-511 ; May-June, 2016 **Research Paper**

Screening of pigeonpea genotypes for drought stress at early vegetative phase in Alfisol and Vertisol

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ABSTRACT

The objective of the study is to identify resistant genotypes for water stress condition at early vegetative phase. The results revealed that Alfisol impose moisture stress earlier as compared to Vertisol due to differences in water holding capacity. However, Vertisol restricts root length at deeper zone but allows prolific root growth at superficial soil layer as compared to Alfisol. The longest root length recorded in stressed environment suggested that moisture deficit in soil triggers roots to go further down to extract more soil moisture from deeper soil layers. It was also observe that, increase in moisture stress leads to defoliation, reducing leaf area to restrict transpiration losses and ultimately reducing shoot weight. Among maturity groups, extra-early maturing lines are more vulnerable to moisture stress as compared to medium and long duration lines. In early maturing lines, tendency of fast growth and development rate was observed as compared to medium maturing genotypes which can be consider as a mechanism for drought avoidance. However, the number of primary roots was more dominant in medium-duration genotypes (*i.e.* ICPL 14002) which is an important trait to be consider for imparting drought tolerance.

Key words : *Alfisol, Drought tolerance, Genotype, Irrigation treatments, Maturity duration, Moisture stress, Pigeonpea, Root traits, Terminal drought, Vertisol.*

INTRODUCTION

Pigeonpea [*Cajanus cajan* (L.) Millspaugh], naturally a perennial shrub but is cultivated as an annual crop that possesses a unique ability to grow throughout the dry season, exceeding 6 months, as well as the ability to survive in areas with less than 650 mm of annual rainfall (Mula and Saxena, 2010). The deep and extensive root system of pigeonpea has the capacity to access water stored in the soil throughout the post rainy-season (Nene *et al.,* 1990).

Drought escaping cultivars has been develop at ICRISAT by reducing the maturity duration nevertheless, pigeonpea with earlier maturity period have higher chances of escaping terminal drought, but are sensitive to intermittent drought (Nam *et al.,* 1994). In addition to drought escape, drought tolerant cultivars need to be developed. Although drought tolerance is considered to be related with root systems, little effort has been invested for breeding cultivars of improved root traits because screening for root traits is a costly and labor-intensive process (Upadhyaya *et al.,* 2012).

Not much information on the rooting structure of pigeonpea in relation to drought is available. The stage at which roots extract water illustrate to have significant effects on the crops ability to sustain drought. For example, water extraction during the vegetative stage is negatively and strongly correlated with water extracted at grain filling (Zaman-Allah *et al.,* 2011). The intent of this study is to provide preliminary information for further research on pigeonpea cultivars resistant to drought by observing root responses to water stress at early vegetative phase.

MATERIALS AND METHODS

The experiment was conducted under controlled glasshouse condition at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, Telangana, India during June 10 to August 5, 2014. Materials comprised of 24 pigeonpea cultivars representing three maturity groups (**Table 1**) grown in polyethylene tubes (75 cm x 15 cm) on two types of soil (Vertisol and Alfisol). Soil was prepared based on a composition of 90% soil + 8% FYM + 2% sand, and sterilized at a temperature of 180°C. Prior to sowing, pigeonpea cultivars were hydroprimed for 3-4 hours and treated with

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Table 1. List of pigeonpea genotypes with maturity duration, flowering pattern and days to maturity

GN	Entry name	Maturity duration	Flowering pattern	Days to maturity
1	ICPL 20325	Extra early	NDT	90-100
2	ICPL 11242	Extra early	NDT	90-100
3	ICPL 11300	Extra early	NDT	90-100
4	ICPL 11285	Extra earl	NDT	90-100
5	ICPL 20338	Extra early	DT	85-90
6	ICPL 20340	Extra early	DT	85-90
7	ICPL 11255	Extra early	DT	85-90
8	ICPL 11256	Extra early	DT	85-90
9	ICPL 88039	Early	NDT	120-125
10	ICPL 161	Early	NDT	125-130
11	PRG 176	Early	NDT	140-150
12	ICPL 81-3	Early	NDT	110-120
13	ICPL 87091	Early	DT	110-120
14	MN 1	Early	DT	105-110
15	MN 5	Early	DT	105-11-
16	ICPL 87	Early	DT	110-120
17	ICPL 14001	Medium	NDT	140-160
18	ICPL 14002	Medium	NDT	170-180
19	ICP 7035	Medium	NDT	190-200
20	ICPL 20108	Medium	NDT	170-180
21	ICPH 2671	Medium	NDT	170-180
22	ICPH 2740	Medium	NDT	180-190
23	ICPH 3762	Medium	NDT	170-180
24	ICPH 2751	Medium	ND	170-180

tetramethyl thiuram-disulphide fungicide @ 2.5g/kg. A completely randomized design following the factorial experiment with four irrigation treatments (T_0, T_1, T_2, and T_3); two soil types (Vertisol and Alfisol); 24 genotypes (categorized as extra-early, early, and medium duration); with three replications.

Drought tolerance of cultivars were compared using four different irrigation treatments with T_0 (control) - irrigation as required throughout the duration of the experiment (56 days); T_1 - irrigation as required until 21 days after sowing (DAS); T_2 - irrigation as required until 14 DAS; and T_3 - irrigation as required until 14 DAS and at 30 DAS.

Data on plant height (cm) at 14, 21, 28, 35, 42, 49, and 56 DAS were recorded. At 57 DAS, the tubes were soaked overnight in a water pond before roots extraction, using a water spray to wash off the soil. The length and primary basal roots for root length (cm) and number of basal primary roots were recorded. The roots and the shoots were place into separated labeled bags and subjected to oven drying for root dry weight (g) and shoot dry weight (g). Data was analyzed using REML (Restricted Maximum Likelihood) mixed model analysis using SAS software.

RESULTS AND DISCUSSION

Plant height : Soil type, treatment and genotypes differed significantly for this trait. Highest plant height was recorded in Alfisol (66.94 cm) compared to Vertisol (55.74 cm) as revealed in **Table 2**. Very prolific growth was notice in Alfisol and this be

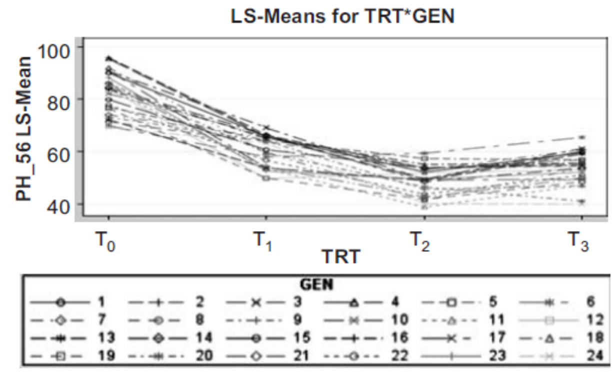


Fig. 1. Effect of irrigation treatment on plant height

due to favorable soil properties, which allows sufficient air diffusion and luxuriant root growth.

The treatment effect revealed that T_0 has the highest plant height (82.24 cm) followed by T_1 (60.35 cm), whereas the lowest plant height was in T_3 (53.63 cm). The decrease in height of T_3 could be due to intermittent application of irrigation.

At genotypic level, the highest plant height was recorded in ICPL 11242 (67.69 cm) followed by ICPL 11300 (67.62 cm) and ICPL 11282 (67.60 cm), and are extra-early category. On the contrary, the lowest plant height was recorded in medium maturing genotypes ICPH 2751 (53.15 cm) and ICP 7035 (54.13 cm). The results indicated that there was highly significant correlation observed between plant height and maturity duration. However, the interaction effect for soil type and treatment was not significant. Extra-early and early maturing lines showed a tendency of quick growth and development rate compared to medium maturing genotypes and this can be considered as a mechanism for drought tolerance. Genotype ICPL 20340 showed interesting results for plant height, it produced highest plant height in stress treatment (T_2) and (T_3) whereas in control treatment (T_0) it recorded lowest plant height as shown in **Fig. 1**.

Root length : Root length was observed significantly higher in Alfisol (81.25 cm) as compared to Vertisol (59.95 cm). This reduction in root length is due to soil compactness and structure of Vertisol as compared to Alfisol. The lowest recorded root length was in T_0, (68.80 cm) while T_3 resulted in highest root length (72.72 cm), which is significantly higher than the other treatments (**Table 2**). The reduction in water supply induces dryness in top layer of soil and it moves vertically downwards with time. This shows that increase in root length is a plant mechanism to extract water at deeper soil zone when upper soil zone is depleted with water due to evapotranspiration, which conforms to the findings of Sekia and Araki (2013), there is continuous water extraction from roots due to steady increase in canopy area, which stimulates roots to go down further.

All the genotypes showed non-significant variation on root length (Table 2) however, soil and treatment interaction effect showed significant variation for root length (**Fig. 2**). The highest

Table 2. Effect of different irrigation treatments on 24 genotypes of pigeonpea.

Effect	Soil	Plant height (cm)	Root length (cm)	Primary roots (no)	Shoot weight (g)	Root weight (g)
Soil type	Black	55.74^{a}	59.95^{a}	2.48	3.47^{b}	1.86^{b}
Soil type	Red	66.94^{b}	81.25^{b}	2.34	3.03^{a}	1.49^{a}
Treatment	T_0	82.24^{d}	68.80^{a}	3.90^{c}	5.52^{c}	2.18^{c}
Treatment	T_1	60.33^{c}	70.9^{ab}	2.51^{b}	3.14^{b}	1.58^{b}
Treatment	T_2	49.15^{a}	69.97^{a}	1.64^{a}	2.15^{a}	1.62^{b}
Treatment	T_3	53.63^{b}	72.72^{b}	1.84^{a}	2.17^{a}	1.32^{a}
Genotype	ICPL 20325	66.95^{gh}	69.35	2.81^{cdefg}	3.69	1.45^{abcd}
Genotype	ICPL 11242	67.69^{h}	67.71	2.20^{abcd}	3.25	1.48^{abcd}
Genotype	ICPL 11300	67.62^{h}	69.40	2.12^{abc}	3.05	1.62^{bcdef}
Genotype	ICPL 11285	67.60^{h}	70.92	2.14^{abc}	3.47	1.62^{bcdef}
Genotype	ICPL 20338	63.85^{efgh}	70.29	1.83^{ab}	3.38	1.53^{abcde}
Genotype	ICPL 20340	63.19^{defgh}	71.47	2.06^{abc}	3.21	2.03^{gh}
Genotype	ICPL 11255	63.35^{defgh}	68.17	2.37^{abcde}	3.47	1.64^{bcdef}
Genotype	ICPL 11256	60.88^{bcdef}	67.04	1.76^{a}	3.34	1.44^{abc}
Genotype	ICPL 88039	57.38^{abc}	73.90	2.42^{abcdef}	3.06	1.61^{bcdef}
Genotype	ICPL 161	64.58^{fgh}	73.83	3.31^{fg}	3.25	1.82^{defgh}
Genotype	PRG 176	55.95^{ab}	69.29	2.51^{abcdefg}	2.98	2.11^{h}
Genotype	ICPL 81-3	59.67^{bcdef}	66.81	2.22^{abcd}	3.19	1.80^{cdefgh}
Genotype	ICPL 87091	58.53^{abcde}	75.33	2.84^{cdefg}	3.52	1.87^{efgh}
Genotype	MN 1	63.25^{defgh}	70.42	1.88^{ab}	3.42	1.51^{abcde}
Genotype	MN 5	62.50^{cdefgh}	71.69	1.83^{ab}	3.22	1.87^{efgh}
Genotype	ICPL 87	64.94^{fgh}	77.42	3.18^{efg}	3.58	1.75^{cdefgh}
Genotype	ICPL 14001	60.77^{bcdef}	69.79	2.45^{abcdef}	2.80	1.94^{fgh}
Genotype	ICPL 14002	61.75^{cdefg}	69.71	3.42^{g}	3.09	1.66^{bcdefg}
Genotype	ICP 7035	54.13^{a}	72.65	3.02^{defg}	3.66	1.91^{fgh}
Genotype	ICPL 20108	58.38^{abcde}	69.31	2.48^{abcdef}	2.82	1.34$^{?}$
Genotype	ICPH 2671	58.11^{abcd}	67.54	2.60^{bcdefg}	3.11	1.70^{bcdefg}
Genotype	ICPH 2740	57.33^{abc}	70.04	2.29^{abcde}	3.40	1.52^{abcde}
Genotype	ICPH 3762	60.58^{bcdef}	74.67	2.64^{bcdefg}	3.34	1.93^{fgh}
Genotype	ICPH 2751	53.15^{a}	67.58	1.92^{ab}	2.71	1.17^{a}
Soil x Treatment						
Black x T_0		77.81	61.03^{ab}	4.29^{e}	6.00^{e}	2.78^{e}
Black x T_1		54.08	57.99^{a}	2.50^{c}	3.37^{c}	1.79^{d}
Black x T_2		42.61	58.56^{ab}	1.46^{a}	2.30^{a}	1.67^{cd}
Black x T_3		48.44	62.21^{b}	2.02^{b}	2.20^{a}	1.22^{a}
Red x T_0		86.68	76.56^{c}	3.53^{d}	5.05^{d}	1.58^{bcd}
Red x T_1		66.58	83.82^{d}	2.51^{c}	2.93^{b}	1.38^{ab}
Red x T_2		55.68	81.38^{d}	1.82^{ab}	2.00^{a}	1.58^{bc}
Red x T_3		58.83	83.23^{d}	1.68^{ab}	2.16^{a}	1.449^{b}

root length was observed in Alfisol with T_1 (83.82 cm) but not significantly different with T_2 and T_3 while the lowest root length observed was in Vertisol with T_1 (57.99 cm). The highest root length recorded in stressed environment suggested that moisture deficit in soil triggers roots to go further down to extract more soil moisture from deeper soil layers.

Number of primary roots : The parameter was not influence by soil type but significant variation observed in different treatments. Table 2 showed that the highest primary roots were observed in T_0 (3.90) followed by T_1 (2.51) and lowest numbers was recorded in T_2 and T_3 which indicated that moisture stress significantly influences the production of primary roots.

Genotypes significantly differed in number of primary root and highest number was observed in ICPL 14002 (3.42) followed by ICPL 161 (3.31), ICPL 87 (3.18) and ICP 7035 (3.02) as shown in Table 2. The lowest recorded primary roots was observed in determinate extra-early and early genotypes like, ICPL 11256 (1.76), MN 5 (1.83), ICPL 20338 (1.83) and MN 1 (1.88). This suggests that extra-early and early maturing lines are more vulnerable to moisture stress as compared to medium duration lines.

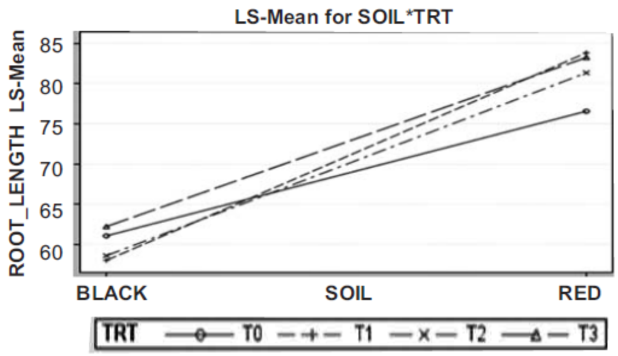


Fig. 2. Interaction effect of irrigation treatment and soil type on root length parameter

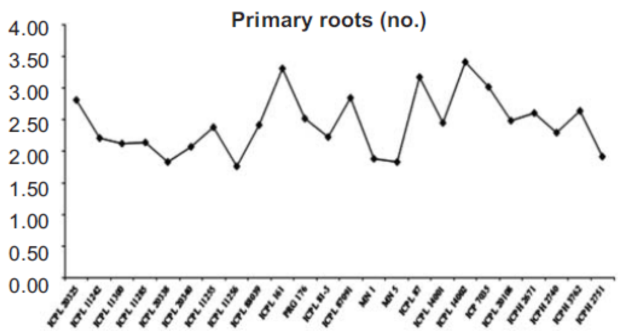


Fig. 3. Genotypic variation for number of primary roots

Number of primary roots is an important trait to consider for drought resistance, which is in confirmation with the highest primary roots in ICPL 14002 genotype, which is widely adapted to drought prone areas.

Shoot weight : Shoot weight was significantly higher in Vertisol as compared to Alfisol and regularly irrigated treatment (T_0) resulted in significantly higher shoot weight (5.52 g) followed by T_1 (3.15 g) while T_3 (2.17 g) and T_2 (2.15 g) produced the lowest shoot weight (Table 2).

Non-significant variation was observed in all genotypes however, the genotype ICPL 20325 recorded highest shoot weight (3.69 g) followed by ICP 7035 (3.66 g) while the lowest was ICPH 2751 (2.71 g) as shown in Table 2.

In soil type and treatment interaction, highest shoot weight recorded was in Vertisol with T_0 (6.00 g) followed by Alfisol in T_0 (5.05 g) (Table 2). This indicates that shoot weight was significantly affected with moisture stress. Increase in moisture stress tends the plant leaves to defoliate, reduces leaf area to restrict transpiration losses, and ultimately reduces shoot weight (**Fig. 3**) which is in conformity to the findings of Kashiwagi *et al.* (2005).

Root weight : Soil type affected root weight in significant manner due to different physiochemical properties of black and red soil. Maximum root weight was observed in Vertisol (1.86 g) as compared to Alfisol (1.49 g) but is contrary to the character of

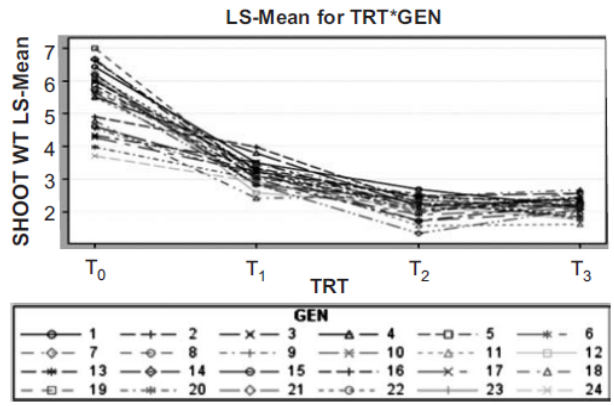


Fig. 4. Interaction effect of irrigation treatments and genotypes for shoot weight

root length, where maximum length was recorded in Alfisol (Table 2). This suggests that, vertisol restricts root length at deeper zone but allows prolific root growth at superficial soil layer as compared to Alfisol. The control (T_0) recorded significantly higher root weight (2.18 g) than all other treatments however, T_1 and T_2 showed non-significant difference while T_3 (1.33 g) was the lowest. There was a significant variation observed at genotypic level and highest root weight was observed in PRG 176 (2.11 g) followed by ICPL 20340 (2.03 g) while ICPH 2751 (1.17 g) was the lowest (Table 2).

Soil type and treatment interaction recorded significant variation for root weight. Vertisol recorded highest root weight in all the treatments except treatment T_3 where higher values were recorded in Alfisol. This might be due to intermittent application of irrigation at 30 DAS, which triggered root growth (**Fig. 5a**).

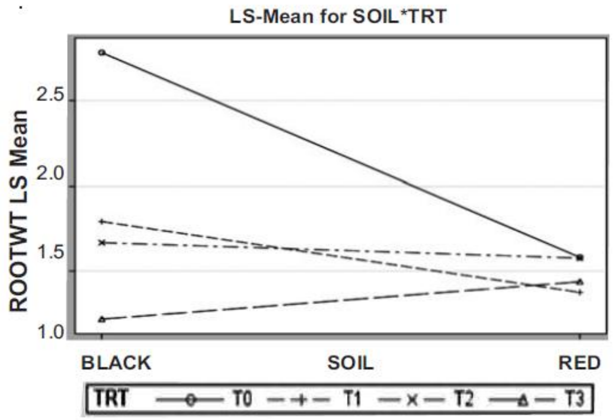
Soil type and genotype interaction was significant for root weight wherein PRG 176 genotype recorded the highest root mass in Vertisol and ICPL 11255 genotype in Alfisol while ICPL 20325 and ICPL 11242 showed very little variation and stable for both soil type (**Fig. 5b**).

While, in treatment x genotype interaction all the extreme values were recorded in T_0 treatment recording maximum root weight in genotype MN 5 and minimum in ICPH 2751 (**Fig. 5c**).

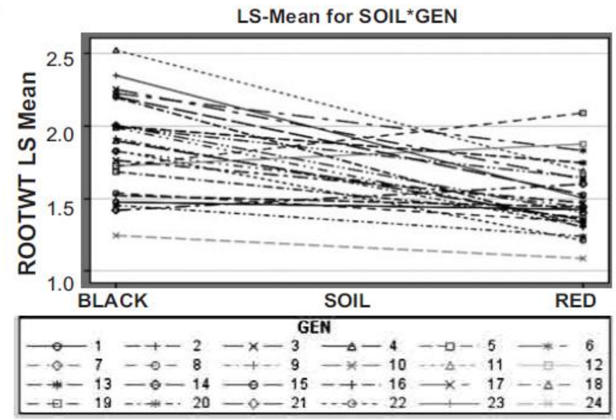
For soil x treatment x genotype interaction, the highest and lowest root mass was noted in Vertisol in T_0 with genotype MN 5 and ICPH 2740 in T_3, respectively (**Fig. 5d**). Moreover, in extreme stressed condition, Vertisol x T_2 x ICPL 88039 and ICPH 3762 interaction recorded highest root mass. Likewise, in Alfisol in interaction with ICP 7035 in T_2 and ICPL 81-3 in T_3 recorded higher root mass.

CONCLUSION

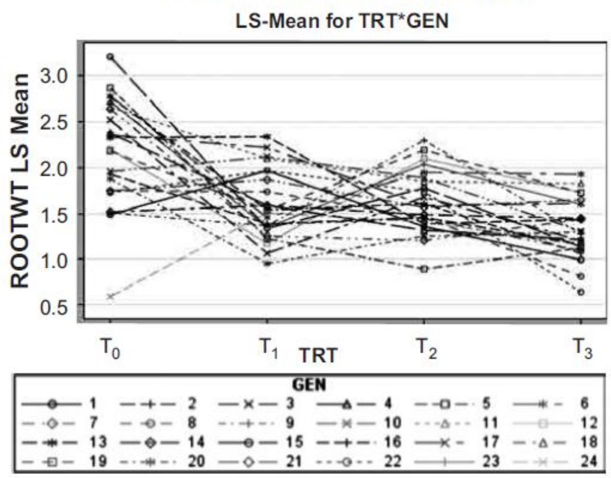
The results indicate that there is highly significant correlation between plant height and maturity duration. However, the interaction for soil type and treatment effect was not significant. Genotypes significantly differed in number of primary root with highest number in medium duration than in extra early duration



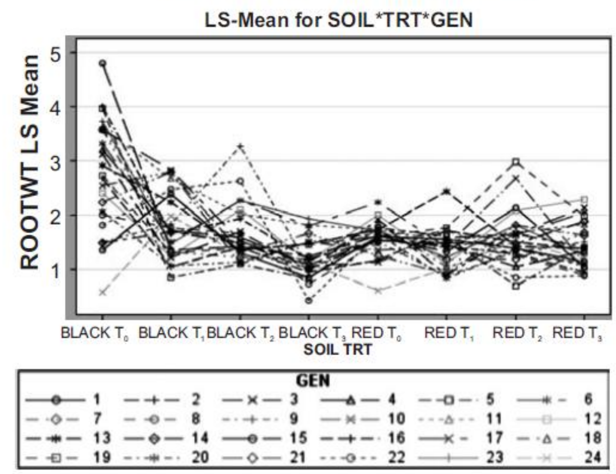
a. Soil type and treatment interaction



b. Soil type and genotype interaction



c. Treatment and genotype interaction



d. Soil x treatment x genotype interaction

Fig. 5 Variation from different interaction effects on root weight.

lines. Soil and treatment interaction effect showed significant variation for root length. The highest root length recorded in stressed environment suggested that moisture deficit in soil triggers roots to go further down to extract more soil moisture at deep soil layers. It is clear that Alfisol impose moisture stress quickly as compared to Vertisol due to differences in water holding capacity. The reduction in water supply induces dryness in top layer of soil, which moves vertically downwards with time. While, on shoot and root weight, soil effect and soil x treatment effect was found significantly higher in Vertisol whereas no significant variation was observed among all the genotypes for shoot weight but significant variation was observed in root weight.

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