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National Academy of Agricultural Science (NAAS) Rating : 3. 03

Evaluation of Pigeonpea (*Cajanus cajan* L.) Genotypes under Drought Stress through Growth, Physiological Parameters and Yield

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ABSTRACT: *Eighteen pigeonpea genotypes were evaluated in field with three replications for morpho-physiological traits related to drought tolerance. Plants were maintained in separate sets for irrigated conditions and moisture stress. The parameters such as plant height, root length, root-shoot ratio (RS ratio), leaf area index (LAI), specific leaf weight (SLW), relative leaf water content (RLWC), membrane injury index (MII), seed yield and drought tolerance efficiency (DTE) were recorded at flowering and pod maturation stages. Drought stress reduced the growth and yield of pigeonpea. The drought tolerant genotypes showed significantly higher LAI, SLW, RLWC, DTE and yield compared to drought susceptible genotypes. MII was minimum in tolerant genotypes and maximum in susceptible genotypes. It was concluded that these parameters could be useful and reliable indices for selection in pigeonpea breeding for drought tolerance.*

Key words*: Drought stress, physiological response, yield*

INTRODUCTION

Drought is deleterious for plant growth, yield and mineral nutrition (Garg *et al*. 2004; Samarah *et al*. 2004) and is one of the largest limiting factors in agriculture (Reddy *et al*. 2004). Seed yield is most affected by drought occurring in the flowering and early pod development stages. Genotypic differences in drought resistance are associated with the maintenance of dry mass partitioning into leaves during, and dry mass production following drought periods.

Pigeon pea (*Cajanus cajan* (L.) Millsp.) is the second important pulse crop of India and recognized as a valuable source of protein for the vegetarians in their daily diet. In India, pigeonpea is grown in an area of 4.09 million hectares with a production of 3.27 million tonnes (Anonymous, 2011). It is known that pigeonpea thrives well under drought prone condition. However, there is a great variability for yield performance of different pigeonpea genotypes under drought condition. Attempts to measure the degree of tolerance with a single parameter have limited value because of the multiplicity of the factors and their interactions contributing to drought tolerance under field conditions. The attempts were made to select genotypes tolerant/ resistant to moisture stress condition based on morpho-physiological traits and to make decision for further research. The present investigation was made to evaluate the genotypic differences in drought tolerance and quantify the loss in yield.

MATERIALS AND METHODS

The experiment was conducted at Millet Breeding Station, Tamil Nadu Agricultural University, Coimbatore with eighteen genotypes and three replications. The experimental plot was laid out with a size of 6.0 x 4.0 m^2 in randomized block design. Spacing of 60 cm x 30 cm (ICPL genotypes) and 90 cm x 30 cm (Other genotypes) were adopted. The genotypes such as COPH 2, VRG 11, VRG 17, VRG 54, VRG 61, VRG 62, JKM 144, JKM 185, CO 5, VBN 2, ICPL 4777, ICPL 6997, ICPL 11119, ICPL 11175, ICPL 12755, ICPL 12974, ICPL 11375 and ICPL 11038 were taken up for the study. Recommended package of practices for pigeonpea were followed. Drought stress was imposed to the genotypes by skipping the

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irrigation at onset of flowering and pod development stages. The plants are maintained at irrigated (T_1) and non-irrigated (T_2) conditions in separate plots. The observations on morpho-physiological characters were done at flowering (S_1) and pod maturation (S_2) stages on five selected plants. The yield parameters were assessed at the time of harvest. The samples for dry sample analysis were dried in hot air oven at 80^{o}c for 48 hours.

The drought parameters were calculated by using the following formulae.

1. **Leaf area index** was calculated by employing the formula of Williams (1946).

$$LAI = \frac{Total\, leaf\ area\, of\ a\, plant}{Land\, area\, occupied\, by\, the\, plant}$$

2. **Specific leaf weight** was calculated by using the formula of Pearce *et al.,* (1968) and expressed in mg cm^{-2}.

$$SLW = \frac{Leaf\ dry\ weight}{Leaf\ area}$$

3. **Relative leaf water content (RLWC)** formula given by Kramer (1983).

$$RLWC = \frac{Ew - Dw}{Tw - Dw} \times 100$$

Fw = Fresh weight

Dw = Dry weight

Tw = Turgid weight

4. **Membrane injury index (MII)** formula given by Blum and Ebercon (1981).

$$MII = \frac{C1}{C2}$$

C1 = EC at 45°C for 30 min

C2 = EC at 100°C for 10 min

5. **Drought tolerance efficiency (DTE)** formula given by Fischer and Wood (1981)

$$DTE = \frac{Yield\, under\ stress}{Yield\, under\ no - stress} \times 100$$

RESULTS AND DISCUSSION

Morphological Parameters

Drought is the major constraint to crop growth; production and crops are usually exposed to drought periods of varying duration and intensity (Sadras and Milroy, 1996). Plant height (Table 1) is an important parameter in crop like pigeonpea with indeterminate growth habit. The growth was linear upto flowering stage and it tended to be gradual thereafter. Drought stress imposed at flowering and pod maturation stages drastically reduced the plant height in all the genotypes. A mean reduction of 7.82 and 9.65 per cent was noticed at flowering and pod maturation stages. The plant height increased with increasing irrigation frequency (Arif Ullah *et al.,* 2002). The increased plant height throughout the growth stages can be justified by the fact that, auxin derivatives are involved in cell division and differentiation and also expansion through increasing the plasticity under tissue hydration, thereby enhancing growth and development (Mangal prasad and Rajendra Prasad, 1994).

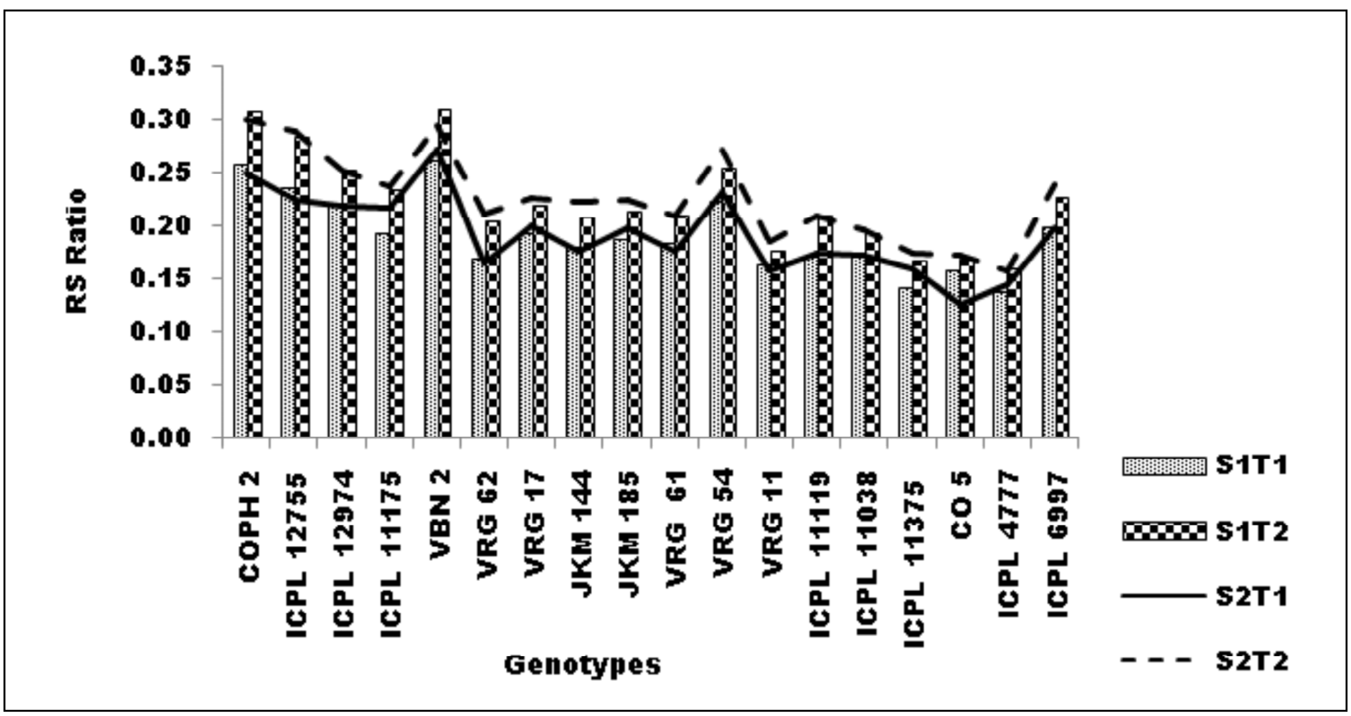
Root length (Table 1) revealed a gradual increase throughout the growth period. Genotypic variation in root penetration and other root traits have been reported in rice (Yu *et al.,* 1995). Moisture stress caused increase in root length at flowering stage (7.41%) and pod maturation stage (5.85%). Among the genotypes, highest root length was noticed at flowering stage in ICPL 12755 (44.8) under non-irrigated conditions and the lowest in Co 5 (27.3). The root length was maximum in VBN 2 (49.1) followed by ICPL 12755 (46.9) and minimum in CO 5 (30.3) at pod maturation stage. Roots with higher penetration ability have an advantage of absorbing water from deeper layers. Extensive and deep root systems were found to be the major attributes to drought tolerance. Kanakadurga *et al*. (2003) opined that there was a positive correlation between drought period and root length in mungbean and urdbean.

Drought adaptive mechanism enabling a crop to maintain water uptake would be combination of a more dense (greater root-soil interface/ cm^{-3} of soil) and deeper rooting habit. Root system characteristics have been often related to apparent drought resistance of cereals. **Root – shoot ratio (Fig. 1)** was highest in VBN 2 (0.310) followed by COPH 2 (0.307) and lowest in ICPL 4777 (0.159) at flowering stage. At pod maturation stage, higher RS ratio was noticed in COPH 2 (0.300) and lowest in ICPL 4777 (0.157) under water deficit condition. Moisture deficit at flowering and pod maturation stages increased the root – shoot ratio in all the genotypes at both flowering (5.85%) and pod maturation stages (74%). In general, shoot growth was reduced more than root growth, because more severe water deficit developed in transpiring shoots and probably persisted longer. Thus, root/ shoot ratio was generally increased by water stress.

Table 1
Effect of Moisture Stress on Plant Height (cm) and Root Length (cm) in Pigeonpea at Flowering (S_1) and Pod Maturation (S_2) Stages

Genotypes	*S_1*				*S_2*			
	Plant height		*Root length*		*Plant height*		*Root length*	
	T_1	*T_2*	*T_1*	*T_2*	*T_1*	*T_2*	*T_1*	*T_2*
COPH 2	138.5	132.1	39.7	40.6	144.6	141.2	41.8	42.3
ICPL 12755	171.6	158.5	40.3	44.8	195.3	166.3	43.7	46.9
ICPL 12974	182.5	169.0	40.2	42.7	200.4	179.3	43.6	45.2
ICPL 11175	178.4	160.2	34.2	37.5	191.2	172.1	41.3	41.8
VBN 2	166.6	152.2	43.5	47.2	172.7	167.3	47	49.1
VRG 62	194.2	176.3	38.5	40.1	203.6	187.2	40.1	44.7
VRG 17	177.6	164.2	34.1	35.9	192.4	171.1	38.2	38.6
JKM 144	198.4	177.6	35.8	37	219.3	185.2	38.7	41.1
JKM 185	192.7	183.3	36.2	39.3	199.9	189.9	39.3	42.6
VRG 61	203.2	188.0	37.3	39.2	219.4	198.3	38.6	41.5
VRG 54	172.5	161.9	38.3	41.2	183.9	167.0	42.5	45.4
VRG 11	223.5	211.5	36.5	37.3	238.2	216.3	37.3	39.9
ICPL 11119	196.8	181.2	33.6	37.9	208.9	190.3	36.2	39.5
ICPL 11038	217.3	202.3	37.3	38.9	227.4	210.3	39.1	41
ICPL 11375	201.5	188.2	28.6	31.5	217.7	198.0	34.5	34.4
CO 5	187.0	162.5	23.7	27.3	212.1	176.3	26.8	30.3
ICPL 4777	238.5	221.0	32.9	35.2	255.4	238.1	36.6	37.5
ICPL 6997	190.3	173.3	32.2	35.4	210.4	182.1	34.8	38.2
Mean	190.6	175.7	35.72	38.28	205.1	185.3	38.89	41.11
SEd	3.9	3.7	0.78	0.77	4.2	3.7	0.75	0.77
CD (P:0.05)	8.2	7.8	1.66	1.63	8.9	7.9	1.59	1.63

Figure 1: Effect of Moisture Stress on RS Ratio of Pigeonpea at Flowering and Pod Maturation stages



S_1 – Flowering stage, S_2 – Pod maturation stage
T_1- Control, T_2 – Non - irrigated

Leaf area index (Table 2) is the principle factor influencing net photosynthesis which in turn is related to dry matter production and yield (Hansen, 1972). A drastic reduction in LAI was recorded during stress at flowering and pod maturation stages. Considering the genotypes, a maximum LAI of 2.32 was found in ICPL 12755 and ICPL 12974 and the lowest in ICPL 6997 (1.28) during flowering stage. Similar results were observed by Lopez *et al.* (1997). The reduction in LAI was primarily due to leaf abscission as individual leaf growth was over after flowering. The leaf area index declined during reproductive development and pod maturation stage as the leaf number was reduced by water stress. Genotypic differences in drought resistance were reflected in the ability to maintain LAI particularly under water stress. The reduction in LAI due to water stress during reproductive development was greater than that during flowering for all genotypes. Similar reduction in leaf area was registered by Parameshwarappa and Salimath (2008) and Hirich *et al.* (2011) in chick pea. The decreased leaf area may be due to decreased growth and expansion of leaves (Hall, 2004). The plants with high LAI were placed in a better position enabling them to harvest maximum solar radiation.

Specific leaf weight (Table 2), the parameter indicating leaf thickness is highly correlated with the development of reproductive organ namely flower and ultimately yield (Arnon, 1975). SLW showed an increasing trend upto flowering stage and thereafter, it declined. Highest SLW was observed in COPH 2 and the lowest in CO 5. Moisture deficit increased SLW by 38.0 per cent and 0.98 per cent at flowering and pod maturation stages respectively. Increase in SLW is usually accounted by smaller and thicker cells and dark green leaves, all related with stress evading mechanism in plants. Similar results were observed by Decosta and Shanmugathasan (1999).

Physiological Characters

Relative leaf water content (RLWC, Table 3) is one of the measures to identify tissue water status. The plant water status increased progressively at vegetative stage and declined gradually as the crop growth advanced. Among the genotypes, highest RLWC was maintained in COPH 2 (81.7) and least in ICPL 6997 (66.9) at flowering stage and a similar trend was observed at pod maturation stage under non-irrigated conditions. The pigeonpea genotypes showed reductions in RLWC when drought stress was imposed at flowering stage (6.9%) and pod

Table 2
Effect of Moisture Stress on LAI and SLW (mg cm^{-2}) in Pigeonpea at Flowering (S_1) and Pod Maturation (S_2) Stages

Genotypes	*S_1*				*S_2*			
	LAI		*SLW*		*LAI*		*SLW*	
	T_1	*T_2*	*T_1*	*T_2*	*T_1*	*T_2*	*T_1*	*T_2*
COPH 2	2.38	1.93	7.43	7.52	1.68	1.48	6.12	6.93
ICPL 12755	2.69	2.32	7.28	7.45	1.91	1.59	5.92	6.23
ICPL 12974	2.77	2.32	7.11	7.33	2.03	1.58	5.56	6.82
ICPL 11175	2.80	2.29	7.42	7.23	2.47	2.06	5.24	6.42
VBN 2	2.14	1.84	6.86	7.12	1.82	1.54	5.43	5.68
VRG 62	2.60	2.21	6.67	6.68	1.82	1.37	5.66	6.04
VRG 17	2.04	1.64	6.30	6.65	1.75	1.57	5.25	5.84
JKM 144	2.20	1.86	6.65	6.95	1.60	1.19	6.02	6.23
JKM 185	2.23	1.86	6.47	6.72	1.77	1.51	5.38	5.54
VRG 61	2.51	1.78	6.42	6.76	1.50	1.18	5.34	5.50
VRG 54	2.16	1.76	6.35	6.61	1.49	1.13	5.87	6.12
VRG 11	1.19	1.01	4.71	5.34	0.93	0.71	4.41	4.72
ICPL 11119	1.98	1.65	6.23	6.52	1.49	1.16	5.37	5.98
ICPL 11038	1.85	1.54	6.32	6.56	1.06	0.70	5.82	5.91
ICPL 11375	1.91	1.49	6.24	6.42	1.58	1.21	5.53	5.75
CO 5	1.79	1.36	5.92	6.30	1.20	0.86	5.10	5.52
ICPL 4777	1.59	1.31	6.11	6.21	1.19	0.79	5.73	5.84
ICPL 6997	1.57	1.28	5.60	5.84	1.10	0.92	4.81	5.27
Mean	2.13	1.74	6.44	6.68	1.57	1.25	5.47	5.91
SEd	0.08	0.07	0.12	0.09	0.07	0.06	0.07	0.15
CD (P:0.05)	0.16	0.14	0.24	0.20	0.14	0.13	0.15	0.19

Table 3
Effect of Moisture Stress on RLWC and MII in Pigeonpea at Flowering (S_1) and Pod Maturation (S_2) Stages

Genotypes	S_1				S_2			
	RLWC		*MII*		*RLWC*		*MII*	
	T_1	T_2	T_1	T_2	T_1	T_2	T_1	T_2
COPH 2	88.4	81.7	22.85	27.19	84.8	74.0	25.60	35.32
ICPL 12755	88.5	78.9	25.29	30.49	85.0	72.2	28.33	39.09
ICPL 12974	86.2	77.8	26.31	30.45	82.7	71.2	29.46	40.66
ICPL 11175	84.9	76.3	27.68	31.74	81.5	70.0	31.00	42.78
VBN 2	86.3	77.3	26.76	30.88	82.8	70.8	29.97	41.36
VRG 62	84.3	76.9	27.13	31.22	80.9	70.5	30.38	41.93
VRG 17	85.3	77.1	26.95	31.05	81.8	70.7	30.18	41.65
JKM 144	83.4	73.1	30.53	33.43	80.0	67.4	34.19	47.18
JKM 185	84.9	74.1	29.61	34.56	81.4	68.3	33.16	45.77
VRG 61	85.9	73.7	29.97	32.91	82.5	67.9	33.57	46.33
VRG 54	84.9	72.7	30.89	38.77	81.5	67.1	34.60	47.75
VRG 11	83.9	74.6	29.15	35.13	80.5	68.7	32.64	45.05
ICPL 11119	85.3	70.4	32.88	35.65	81.8	65.3	36.82	50.81
ICPL 11038	88.9	77.1	26.95	34.05	85.3	60.7	30.18	41.65
ICPL 11375	83.5	73.6	30.06	36.99	80.2	67.8	33.67	46.47
CO 5	83.4	69.9	33.37	37.11	80.0	64.9	37.37	51.57
ICPL 4777	84.9	69.5	33.73	39.45	81.5	64.6	37.78	52.13
ICPL 6997	83.6	66.9	35.98	39.58	80.2	62.5	40.30	55.61
Mean	85.4	74.5	29.20	33.92	81.9	68.0	32.73	45.17
SEd	0.2	0.5	0.57	0.60	0.2	0.5	0.64	0.88
CD (P:0.05)	0.5	1.1	1.19	1.12	0.5	1.0	1.34	1.85

maturation stage (10.8%). Similar reductions in RLWC were also observed in pigeonpea (Deshmukh and Mate, 2013), chickpea (Nayyar and Chander, 2004; Talebi *et al*., 2013) and in French beans (Upreti *et al.,* 1998). Reduction in RLWC could be attributed to the hardship in maintaining the internal water balance on account of continuous evaporation loss even in moisture stress conditions. High RWC may result from osmoregulation by osmoprotectants, as carotenoids or sugars are often accumulated in plants subjected to drought stress (Gunes *et al*. 2008).

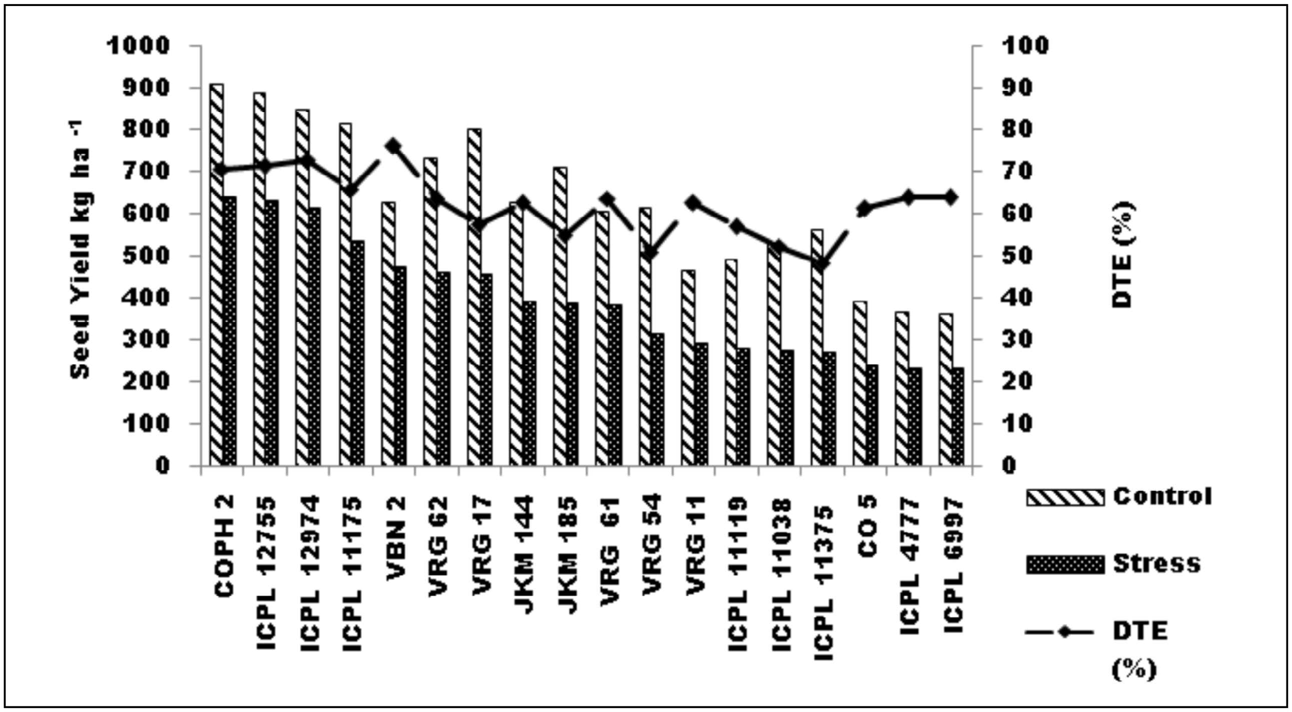
Membrane injury index (Table 3) is an indicator of drought tolerance (Prem Chandra *et al*., 1990). The MII increased throughout the crop growth stages till harvest. Among the genotypes, the highest MII was recorded in ICPL 6997 (39.58, 55.61) and the lowest in COPH 2 (27.19, 35.32) at both flowering and pod maturation stages under water deficit conditions. Membrane injury index increased when drought stress was imposed at flowering (16.3%) and pod maturation stages (38.0%) respectively. Under drought stress, membranes are one of the first cellular structures to undergo damage and deterioration (Poliyath and Fletcher (1995), leading to perturbation of critical ion gradients (Li and Wolyn, 1995). Lower membrane injury index was noticed in the drought tolerant genotypes, in our study and similar results were obtained by Parameshwarappa and Salimath, 2008.

Yield and Drought Tolerance Efficiency (DTE) (Fig. 2)

Seed yield is the product of many growth processes ocuring through the development of the plant. Highest seed yield was observed in COPH 2 and lowest in ICPL 6997. Drought stress reduced the yield to an extent of 58.1 per cent. Similar results have been observed in pigeon pea (Deshmukh and Mate, 2013) and chickpea (Arif Ullah, 2002; Talebi *et al*., 2013). Seed weight decreases in stress conditions and it was emphasized that drought stress at reproductive growth stages disrupted photosynthesis and remobilization in plants, which can caused reduction in the number and weight of grains (Kobraei *et al*., 2011). The yield loss caused due to water stress may be due to increased rate flower and pod abortion and detrimental effects of drought avoidance on CO_2 assimilation (Randhawa *et al*., 2014).

DTE is an index to identify the tolerance level of any genotype under stress conditions in terms of

Figure 2: Effect of Moisture Stress on Seed Yield (kg ha^{-1}) and DTE (%) of



yield. From the genotypes studied under limited water conditions, it was revealed that VBN 2 (75.9) recorded the highest DTE followed by ICPL 12974 (72.6) and ICPL 12755 (71.2) and ICPL 11375 (48.4) recorded the lowest DTE. Similar results were obtained by Baroowa *et al*. (2012) in black gram and green gram and Deshmukh and Mate (2013) in pigenpea.

CONCLUSION

Identification of a drought tolerant variety of pigeonpea is a difficult job for several reasons. Several attributes are related to drought tolerance. It is highly impossible to have a genotype possessing all these characters responsible for drought tolerance. For the selection of such genotypes, the studies on morpho-physiological characters related to plant parts are essential. From the present study varying tolerance limits in these genotypes for water deficit during important phenophases were revealed. Based on the findings on the morpho-physiological changes in the genotypes COPH 2, ICPL 12755, ICPL 12974, ICPL 11175, VBN 2 and VRG 62 are grouped as drought tolerant; VRG 17, JKM 144, JKM 185, VRG 61, VRG 54 and VRG 11 as moderately drought tolerant genotypes and ICPL 1119, ICPL 11038, ICPL 11375, Co 5, ICPL 4777 and ICPL 6997 as drought susceptible genotypes.

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