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ABSTRACT

The experiment was conducted under glass house with three medium duration pigeonpea hybrids and varieties at Parbhani, Maharashtra during *kharif* 2012 to understand the process of seedling development under regular and limited irrigation conditions. Research revealed that as compared to varieties the hybrids produced longer radicle (17.92 ± 0.53 cm), greater leaf area (166.43 ± 3.14 dm^2), more chlorophyll content (35.49 ± 0.53), high seedling dry weight (4.23 ± 0.11 g), root (1.87 ± 0.05 g) dry weight and greater seedling vigour index (4590.59 ± 180.4) under both regular irrigation and limited irrigation conditions. This indicated that hybrids have potential to survive under drought conditions and produce more dry matter that can be associated with seed yield. The hybrids ICPH 2740, ICPH 3762 and variety Asha were found superior due to high seedling vigour index across the environments.

Key words: *Cajanus cajan, seedling development, hybrids, varieties, environments.*

INTRODUCTION

Pigeonpea (*Cajanus cajan* (L.) Millsp.) is India's one of the important staple foods and second most important pulse crop after chickpea which plays a vital role in daily

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diet due to its richness in protein (20-24%). Pulses in India have been cultivated since time immemorial under rainfed situations which is characterized by poor soil fertility and moisture stress. However, pigeonpea is used in more diverse ways than any other legumes (Nene and Sheila, 1990). Unlike in cereals, yield breakthrough in pulses has not been taken place. Therefore, the productivity has not improved at the desired level. Pigeonpea requires utmost attention in view of large scale shortage to meet domestic requirements. In order to meet domestic obligation, India annually imports about 0.5 to 0.6 million tons of pigeonpea mainly from Myanmar and southern and eastern Africa (Saxena and Nadarajan, 2010).

An understanding of the quantitative and mutual compensatory effects of yield and yield traits of pigeonpea could provide options for formulating selection indices in the improvement of the crop by relying on crops morphological and physiological characteristics (Rodomiro and Langie, 1997). Moreover, seed germination and seedling growth were the most critical phases for successful crop establishment and production (Uniyal *et al*., 1998). According to Brakke and Gardner (1987), the low seedling vigour in pigeonpea was associated with small seed size, however, Bharathi and Saxena (2012) indicated that pigeonpea hybrids utilizes food material reserved in the seed embryo for the development of longer radicle length that helps them to survive in drought conditions along with good vigour. In addition, soil moisture is one of the most important factors which limit the growth and yield of crop (Sinha *et al*., 1988). The objective of this study was to identify the difference between pigeonpea hybrids and varieties in relation to seed germination and seedling vigour under enough and limited moisture conditions.

MATERIALS AND METHODS

Six pigeonpea genotypes were used in this study which includes three hybrids (ICPH 2671, ICPH 2740 and ICPH 3762) and three varieties (BSMR 736, Asha, and BDN 711). Pot experiment was conducted under glasshouse conditions during *kharif* 2012 at Parbhani, Maharashtra, India. These genotypes were planted in pot containing soil, sand and farm yard manure in 1:1:1 proportion. Pots having a diameter of 18 cm and height of 35 cm were used. Each pot was filled with 3.5 kg dry soil media to create uniform bulk density. Seeds were treated with tetramethylthiuramdisulphide @ 2.5 g/kg before sowing.

Genotypes were sown in nine replications with completely randomized design (CRD) in two environments, the regular irrigation and limited irrigation. In regular irrigated conditions, genotypes were irrigated with 500 ml water as per requirement (soil dried upto 3 cm deep). Total eight irrigations provided in regular irrigation conditions. Whereas, in limited irrigation, water was given at the time of sowing and at 15 days after sowing (500 ml). Prior to planting, uniform water was applied to all the treatments to bring them to field capacity. For each genotype 10 pots were sown in each environment and replication. 100 seed weight of genotypes was maintained same for regular and limited irrigation conditions to understand the difference in hybrids and varieties in respect to seedling establishment under both moisture conditions.

The data was recorded after 30 days of sowing on germination (%), radicle length (cm), leaf area (dm^2), chlorophyll content, seedling dry weight (leaf and stem) (g), seed vigour index, plumule length (cm), and root dry weight (g). For recording traits, five plants were selected randomly from each environment and replication. Chlorophyll content in leaves was recorded with SPAD (Special Products Analysis Division) chlorophyll meter on each leaflet of the third leaf from the top.

Leaf area was measured using the automatic leaf area meter and oven dried at 60^{o}C for at least 48 hours to determine the leaf dry weight. For root dry weight, roots were washed off from soil and oven dried at 60^{o}C for 48 hours. The shoot samples were also oven dried at 60^{o}C for 48 hours and dry weight recorded. Seedling dry weight was determined by using stem dry weight and leaf dry weight. The data were subjected to statistical analysis using SAS version 9.2 (2008) to find out the variation present among the genotypes and correlation between the germination characters to regular and limited irrigation conditions.

RESULTS AND DISCUSSION

Germination percentage: All genotypes showed highly significant variation for percent germination in both regular and limited irrigation conditions whereas genotype *x* environment interaction effect was non-significant (Table 1). Hybrids were found non-significant however varieties were highly significant in both regular irrigation and limited irrigation situations. Moreover, hybrids were highly significant with respect to varieties (Table 2). On average (Table 3), hybrids recorded higher mean value (97.75 ± 1.93 %) than varieties (91.93 ± 1.93 %) which are in accordance to the findings of Mercer *et al*. (2006). Findings reveal that germination percentage was positively correlated with seedling vigour index (0.854) and 100 seed weight (0.881) across the environments (Table 4).

Radicle length: For radicle length, all pigeonpea genotypes had highly significant variation in both moisture regimes. Also environmental effect was significant whereas, genotype *x* environment interaction effect was non-significant (Table 1). In present study, Table 2 indicated that hybrids *vs*. varieties exhibited highly significant variation in both regular and limited moisture conditions. Hybrids recorded highly significant differences in regular irrigation and limited irrigation environments however varieties recorded highly significant difference only in limited irrigation situation.

On the basis of mean performance, hybrids exhibited greater mean value (17.92 ± 0.53 cm) than varieties (11.19 ± 0.53 cm) across the environments (Table 3) which expressed the hybrid vigour for this trait. Among all hybrids, ICPH 3762 recorded significantly higher radicle length (18.79 cm) than other cultivars tested which indicates that hybrids utilized reserved food material in the seed embryo for the development of longer radicle which could help them to absorb moisture from deep soil layers and survive in limited moisture condition with good seedling vigour which conforms to the findings of Bharathi and Saxena (2012).

The radicle length exhibited highly significant positive correlation (Table 4) with leaf area (0.985), chlorophyll content (0.929), seedling dry weight (0.987) and root dry weight (0.844), seedling vigour index (0.821) and 100 seed weight (0.892).

Plumule length: Plumule length was significantly influenced by environmental effects. All the genotypes recorded highly significant variation; likewise, genotype *x* environment interaction was highly significant (Table1). Hybrids showed significant differences in both irrigation environments whereas varieties showed highly significant variation in regular irrigated condition. However, hybrids *vs.* varieties showed highly significant differences for plumule length (Table 2). In regular irrigation condition varieties utilized reserved food material in seed embryo for greater plumule development (Bharathi and Saxena, 2012).

On average, varieties recorded higher value (34.92 ± 0.88 cm) as compared to hybrids (29.05 ± 0.88 cm). All varieties were statistically significant for higher plumule length whereas among hybrids, ICPH 3762 was at par compared to other hybrids (Table 3). These results indicated that hybrids had greater plumule and radicle length which showed their potential in maintaining vigour even in inadequate soil moisture condition.

Leaf area: Leaf area exhibited highly significant differences for environments, genotypes and genotype *x* environment interaction effect (Table 1). Likewise, all the genotypes (hybrids as well as varieties) had highly significant differences for leaf area in both environments (Table 2). Moreover, hybrids *vs*. varieties showed highly significant differences in regular and limited irrigation conditions.

The mean performance of genotypes across the environments (Table 3) indicated that hybrids had higher value (166.43 ± 3.14 dm^2) than varieties (89.08 ± 3.14 dm^2). Correlation studies indicated that leaf area recorded positively correlated with chlorophyll content (0.963), seedling dry weight (0.984), root dry weight (0.987) and seedling vigour index (0.897) and 100 seed weight (0.862) across the environments (Table 4). Saxena and Sharma (1981) indicated that leaf area was significantly and positively correlated with 100 seed weight.

Chlorophyll content: Both environment, genotype, and genotype *x* environment interaction effects were found to be highly significant (Table 1) for chlorophyll content. Hybrids showed significant variation in both regular and limited irrigation conditions. However, hybrids exhibited highly significant differences for chlorophyll content compared to varieties (Table 2). On average, hybrids recorded maximum values (35.49 ± 0.53) than varieties (32.14 ± 0.53). Among the hybrids, ICPH 2671 (36.09 ± 0.53) was at par with rest of the hybrids. Chlorophyll content was positively correlated with seedling dry weight (0.903), root dry weight (0.932) and 100 seed weight (0.852).

Seedling dry weight (g): Table 1 revealed that for seedling dry weight, environments, genotypes, and genotype *x* environment interaction effect were highly significant. Hybrids showed highly significant variation in both regular and limited irrigation conditions whereas varieties recorded highly significant differences in regular irrigated condition and significantly different in limited water environment. However, hybrids *vs*. varieties showed highly significant differences in both environments (irrigated and limited irrigation conditions) (Table 2).

On mean performance (Table 3) of genotypes across location it was observed that hybrids (4.23 ± 0.11) recorded higher seedling dry weight in comparison to varieties (2.62 ± 0.11) which is in conformity to the findings of Saxena *et al*. (1996). Out of three hybrids, ICPH 3762 exhibited significant seedling dry weight (4.53 g).

Seedling dry weight was positively correlated with root dry weight (0.989), seedling vigour index (0.835) and 100 seed weight in both the environments (Table 4) which agrees to the findings of Deotale *et al*. (1989). The present study revealed that water is an important factor for producing more biomass and ultimately produced good seed yield which conforms to the findings of Sinha *et al*. (1988).

Root dry weight (g): All the genotypes and environments recorded significant differences for root dry weight. Highly significant variation was observed in hybrids, varieties, and hybrids *vs*. varieties (Table 2). Although, hybrids recorded higher mean values (1.87 ± 0.06) than varieties (0.83 ± 0.06).

Correlation studies indicated that, root dry matter was positively and significantly correlated with seedling vigour index (0.832) and 100 seed weight (0.806) in both environments (Table 4). Moreover, hybrids had more root dry biomass that helps to maintain good vigour even at inadequate soil moisture condition.

Seedling vigour index: All genotypes and both irrigation environments recorded significant differences for seedling vigour index whereas genotype *x* environment interaction effect was found non-significant (Table 1). Likewise, hybrids exhibited highly significant differences for seedling vigour index in both regular irrigation and limited irrigation conditions as compared to varieties but varieties showed significant difference under regular irrigated condition (Table 2).

Hybrids recorded higher mean value for seedling vigour index (4590.59 ± 180.4) than varieties (4249.01 ± 180.4) which conforms to the findings of Saxena *et al*. (1996) (Table 3). Among all genotypes, ICPH 3762 (4712.37) and Asha (4579.03) exhibited significant seedling vigour index across the environments.

Figure 1 revealed that the performance of genotypes varies as per environments. However, on the basis of regular and limited irrigation data (Figure 2), ICPH 2740, ICPH 3762 and Asha were recorded with higher seedling vigor index across the environments with least from BDN 711. Seedling vigour index was positively correlated (Table 4) with germination percentage (0.909), radicle length (0.821), leaf area (0.897), seedling dry weight (0.835) and root dry weight (0.832). The present study indicated that hybrids can encounter the early drought condition due to hybrid vigour.

Narayanan *et al.* (1981) reported that the seed food reserves rather than size of the shoot and root length were important factors in determining seedling size.

100 seed weight: All Genotypes recorded highly significant differences for 100 seed weight (Table 1). Hybrids recorded non-significant differences whereas varieties exhibited significant differences in limited irrigation condition. Hybrids recorded higher mean values (11.4 ± 1.2) as compared to varieties (10.1 ± 1.2). In correlation study (Table 4), 100 seed weight recorded significant positive correlation with germination percentage (0.881), radicle length (0892), leaf area 90.862), chlorophyll content (0.852), seedling dry weight (0.844), root dry weight (0.806) and seedling vigour index (0.855). These results indicated that seed size significantly influenced the growth of seedling.

CONCLUSION

The present study revealed that hybrids had greater radicle length, biomass and seedling vigour index than varieties in both irrigation environments. Hybrids performed superior almost in all characters related to seedling vigour than varieties even in limited soil moisture conditions due to longer radicle length. ICPH 3762 recorded significant higher radicle length (18.79 cm), plumule length (30.06 cm), seedling dry weight (4.53 g), and root dry weight (1.99 g). Also ICPH 2740, ICPH 3762 and Asha were observed for high seedling vigour index in regular as well as limited irrigation conditions.

Pigeonpea yield can be increased by improving uniform germination, good plant stand and vigour which conform to the study of Chauhan *et al*. (1995) that hybrid had higher crop growth rates and early vigour than the inbred cultivars which is associated with seed yield of pigeonpea. They also reported that the differences in plant vigour between hybrids and varieties began to appear during early seedling stage and became more pronounced with time making them suitable for economic situations. These investigation results suggested that breeders can increase pigeonpea yield by selecting hybrid seed with bigger seed size, radicle length and seedling vigour index.

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Table 1: Analysis of variance (ANOVA) for early seedling vigour characters across the environments

Source	DF	Germination (%)	Radicle length (cm)	Plumule Length (cm)	Leaf area (dm^2)	Chlorophyll content	Seedling dry weight (g)	Root dry weight (g)	Seedling vigour index (I)	100 Seed weight (g)
Environment	1	3.71	1559.92**	480.66**	2506.64**	352.45**	192.54**	26.01**	33077050.07**	12.34
Genotypes	5	558**	402.35**	120.45**	1541.06**	65.57**	15.58**	6.05**	2423568.28**	238.08**
Genotype x environment	5	2.13	1.61	9.95**	12.35**	9.72**	0.39**	0.05**	145421.8	24.96
Error	80	8.46	2.1	5.12	50.75	0.64	0.03	0.01	33727.65	13.64

Note: * Significant at 5%, ** Significant at 1%

Table 2: Statistical significance of hybrids and varieties in individual environment for germination characters

Source	DF		Germination (%)		Radicle length (cm)		Plumule length (cm)		Leaf area (dm^2)	
	RI	LI	RI	LI	RI	LI	RI	LI	RI	LI
Genotypes	5	5	273.80**	287.00**	116.97**	137.08**	168.41**	56.03**	15317.25**	19145.44**
Hybrids	2	2	15.26	30.48	12.35**	4.71**	15.32*	12.17*	204.30**	38.44**
Varieties	2	2	417.15**	481.44**	2.96	3.38**	15.82**	12.79	3366.30**	1374.19**
Hybrids *vs* Varieties	1	1	504.17**	411.13**	554.24**	669.22**	779.76**	230.23**	69445.04**	92901.93**
Error	48	48	7.75	9.86	1.85	0.25	1.46	3.66	40.92	9.83

Source	DF		Chlorophyll content		Seedling dry weight (g)		Root dry weight (g)		Seedling vigour index (I)		100 Seed weight (g)	
	RI	LI	RI	LI	RI	LI	RI	LI	RI	LI	RI	LI
Genotypes	5	5	62.23**	13.05**	8.17**	7.80**	3.54**	2.55**	1193219.47**	1375770.62**	72.34**	41.85**
Hybrids	2	2	5.24*	2.35*	0.84**	1.08**	0.20**	0.18**	273692.09**	104048.79**	3.65	1.25
Varieties	2	2	2.62	2.67**	3.10**	0.16*	0.10**	0.11**	2454206.58*	1722948.7	4.35	2.43*
Hybrids *vs.* Varieties	1	1	295.40**	55.21**	32.98**	36.51**	17.11**	12.14**	510300.01**	3224858.03**	176.9**	89.46**
Error	48	48	0.79	0.53	0.05	0.03	0.01	0.01	49598.89	65299.59	1.02	0.89

Note: * Significant at 5%, ** Significant at 1% And RI-Regular irrigation, LI- Limited irrigation

Table 3. Mean performance of hybrids and varieties for seedling related traits in across the environments

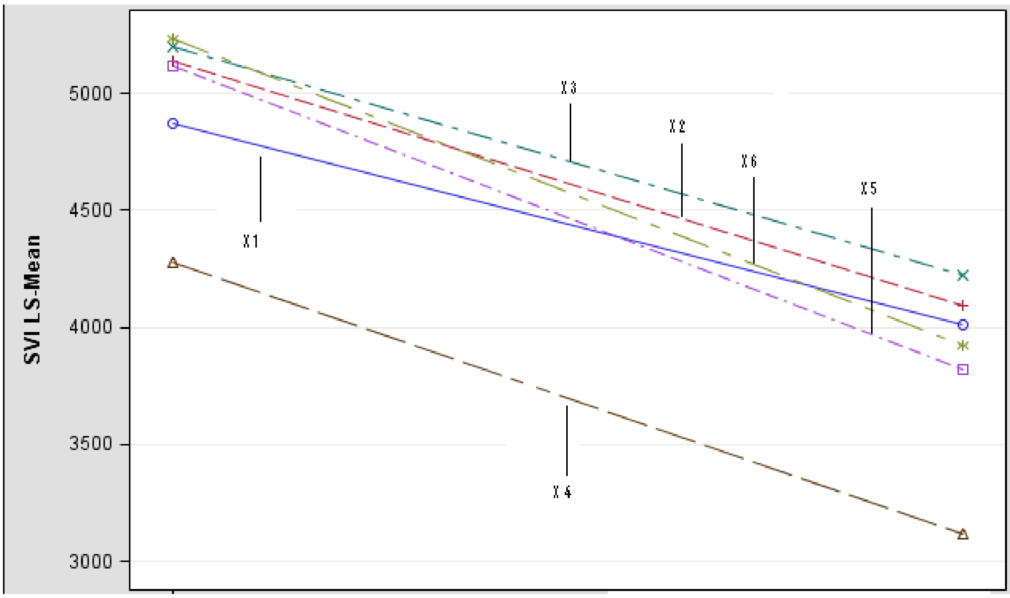
Genotypes	Germination (%)	Radicle length (cm)	Plumule length (cm)	Leaf area (dm^2)	Chlorophyll content	Seedling dry weight (g)	Root dry weight (g)	Seedling vigour index (I)	100 Seed weight (g)
Hybrids									
ICPH 2671	99.44	16.93	27.73	162.59	36.09	3.88	1.71	4441.91	11.3
ICPH 2740	97.39	18.04	29.35	167.58	35.53	4.28	1.91	4617.51	11.6
ICPH 3762	96.39	18.79	30.06	169.11	34.82	4.53	1.99	4712.37	11.1
Mean (hybrids)	97.75	17.92	29.05	166.43	35.49	4.23	1.87	4590.59	11.4
Varieties									
BDN 711	83.78	10.53	33.53	70.85	31.56	2.22	0.72	3698.54	9.2
BSMR 736	95.89	11.41	35.22	97.06	32.21	2.77	0.86	4469.46	10.1
Asha	96.11	11.66	35.98	99.36	32.62	2.89	0.93	4579.03	11.0
Mean (varieties)	91.93	11.19	34.92	89.08	32.14	2.62	0.83	4249.01	10.1
LSD	1.93	0.53	0.88	3.14	0.53	0.11	0.06	180.4	1.2
SE(±)	0.69	0.19	0.31	1.11	0.19	0.04	0.02	43.29	0.21
CV	3.07	5.45	4.11	3.69	2.36	4.84	6.23	4.16	4.22

Table 4: Correlation among germination characters across the environments

Traits	Germination (%)	Radicle length (cm)	Plumule length (cm)	Leaf area (dm^2)	Chlorophyll content	Seedling dry weight (g)	Root dry weight (g)	Seedling vigour index (I)
Radicle length	0.613							
Plumule length	-0.401	-0.872**						
Leaf area	0.731	0.985**	-0.857*					
Chlorophyll content	0.717	0.929**	-0.914**	0.963**				
Seedling dry weight	0.693	0.987**	-0.788	0.984**	0.903**			
Root dry weight	0.622	0.844*	-0.865*	0.987**	0.932**	0.989**		
Seedling vigour index	0.909**	0.821*	-0.240	0.897**	0.583	0.835*	0.832*	
100 Seed weight	0.881*	0.892**	-0.575	0.862**	0.852*	0.844*	0.806*	0.855*

Note: * Significant at 5%, ** Significant at 1%

Figure 1: Mean performance of genotypes for seedling vigour index in regular and limited irrigation condition



Regular Irrigation **Limited Irrigation**

Legends:

X1 – ICPH 2671

X2 – ICPH 2740

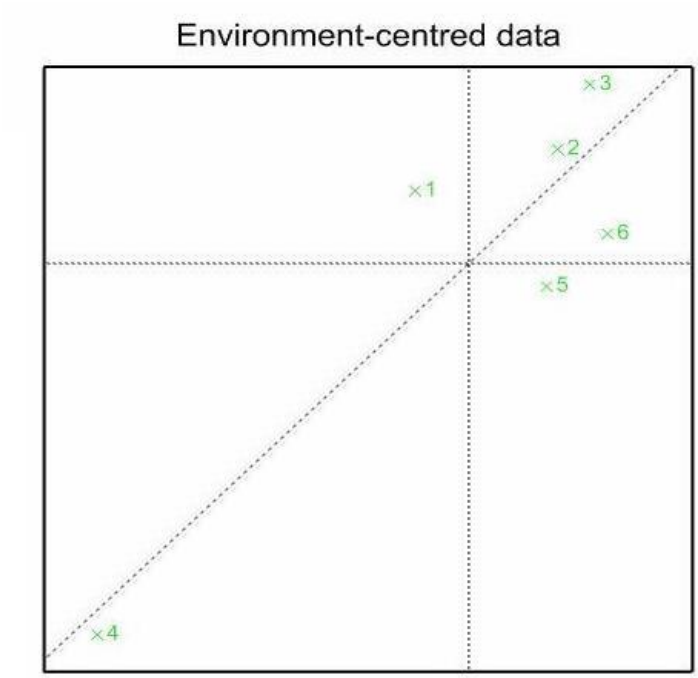
X3 – ICPH 3762

X4 – BDN 711

X5 – BSMR 736

X6 - Asha

Figure 2 : Performance of genotypes across the environments for seedling vigour index



Limited Irrigation

Regular Irrigation

Legends:

X1 – ICPH 2671

X2 – ICPH 2740

X3 – ICPH 3762

X4 – BDN 711

X5 – BSMR 736

X6 - Asha