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Influence of Drought Stress on Root Distribution in Mungbean (*Vignaradiata* (L.) Wilczek)

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ABSTRACT: *Drought is generallyassociated with high temperature and shallow rainfall. Terminal drought may be even more critical for bean crops grown during a post-rainy season and are entirely reliant on stored soil moisture. Drought resistance is more important since it is related to yield and is defined as the relative yield of a genotype compared to other genotypes subjected to the same drought stress. To study drought, study was undertaken with ten lines, four testers. These line and testers were crossed in line x tester fashion to get forty hybrids. The lines, testers and the hybrids were evaluated for four root characters namely shoot length, root length, number of roots and root diameter. The experiment was conducted in the Plant Breeding Experimental Farm, Faculty of Agriculture, Annamalai University. The results revealed erratic difference among the lines and testers. Some of the hybrids performed better and showed higher level of resistance than the parental lines*

Keywords: *Mungbean, Drought, Root characters.*

INTRODUCTION

Mungbean (*Vignaradiata*L.) is an important legume crop mainly grown in arid and semi-arid regions of the world, Kumar and Abbo [1]. Turner[2] stressed that in most of the mungbean growing areas, drought is a prominent characteristic which limits yield and can even lead to total crop failure.Seed filling in mungbean is subject to terminal drought, which limits seed yield. Plant performance in mungbean under conditions of drought stress has been extensively studied by Moradia [3]andMahmoodian[4]. Water stress affects various physiological processes associated with growth, development, and economic yield of a crop was reported by Allahmoradi[5]. Water deficit disturbs normal turgor pressure, and the loss of cell turgidity may stop cell enlargement that causes reduced plant growth was observed by Srivalli [6].

Drought or water shortage has been associated with demographic expansion and climatic changes. Their importance and urgency of developing high yielding drought resistant cultivars that use water efficiently, and reduce dependence on irrigation water would help reduce stabilize yield in drought prone environments, while increasing profit margins for commercial producers. Drought at intermittent or terminal stages accompanies with high temperature and shallow rainfall. Terminal drought may be even more critical for bean crops grown during a post-rainy season and are entirely reliant on stored soil moisture. Intermittent drought is the most difficult to simulate experimentally and usually requires extensive field testing over years and locations. The type of genotype functional in each system will be different, although adaptation mechanisms such as earliness, remobilization, partitioning might be useful under both types of drought. Breeders are most interested in selecting for drought resistance not drought tolerance. Drought resistance is more important since it is related to yield and is defined as the relative yield of a genotype compared to other genotypes subjected to the same drought stress. Those genotypes with high yield potential under non-stress and limited yield loss under stress are most desirable and can be identified based on their geometric mean when grown under both stress and non-stress treatmentswas reported by Naveen Choudary [7].

As water resources become limiting for crop production in dry areas, the management of drought becomes increasingly important. Drought or water deficiency can be managed at the plant level through

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drought escape and drought resistance mechanisms was revealed by Levitt [8]. Drought resistance can further be described in terms of dehydration avoidance and dehydration tolerance mechanisms. Roots have a major role in dehydration avoidance as a deep root system is able to obtain more moisture from the deeper soil layers even when the upper soil layer becomes dry. Sponchiado [9] and Pandey [10] hypothesized that the ability of a plant to change its root distribution in the soil is an important mechanism for drought avoidance.

Studies in various crops have shown the importance of a deep root system for extracting moisture under terminal drought stress have been reported by Ludlow and Muchow [11],Saxena and Johansen [12] and Turner [2]. Kashiwagi [13] found substantial variation in root length density among 12 diverse genotypes grown under terminal drought stress. The proportion of the roots at the lower depth is also important in water absorption from deeper soil layers. Roots at the deeper soil layer contribute more to root length or surface area than to root weight was noted by Follett [14].

The study of root traits under field conditions is difficult and cumbersome and many researchers have reported the use of controlled environments to study root systems. The objective of our study was to determine the extent of genotypic differences in Mungbean root systems and the effects of soil moisture stress on root distribution at various soil depths.

MATERIALS AND METHODS

A field experiment was conducted at the Plant Breeding Farm, Department of Genetics and Plant Breeding, Faculty of Agriculture, Annamalai University using ten lines (IPM02-14, PUSA9072, IPM02-10, IPM306-1, UPM98-1, B-9, PDM11, IPM306-6, IPM9901-03 and IPM9901-125) and four testers (HUM12, SML47, IPM9901-10 and LGG410) to screen for seedling indices associated with higher productivity under drought. These genotypes were crossed among themselves in line x tester analysis fashionas suggested by Kempthorne [15] resulting forty hybrids using randomized block design (RBD) with three replications. Each genotype was laid out with a spacing of 30 cm between rows and 10 cm between plants.

The irrigation among the genotypes was stopped at the initiation at flowering(water withheld when 50% of the plants in the experiment were at the first flower stage). Need based irrigation was given to prevent permanent wilting. To study of the effect of the drought on seedling traits, polyvinyl chloride (PVC) cylinders (1.20 m x 0.15 m) were used to provide enough space for root growth for a single plant. The base of each cylinder was closed with a perforated netted sheet to allow drainage of excess water. To facilitate root recovery, the cylinders were cut longitudinally along both sides and the joints sealed with duct tape before filling with soil. Cylinders were filled with 1:1 mixture of potting mix and sand to facilitate root harvesting. Three seeds were sown in each cylinder and thinned to one after emergence and seedling establishment. Seeds were treated with need based and recommended doses of fertilizers and protection measures. The cylinders were watered to field capacity two days before sowing. After emergence, plants were maintained near 70% of field capacity until the start of stress treatments, where plants were allowed to grow on progressively depleted soil moisture. The control treatment was kept near 70% of drained upper limit.

Roots were sampled at physiological maturity. Shoots were harvested and dry weights were recorded after drying in a hot air dryer at 45°C for three days. To collect roots, each cylinder was opened longitudinally from one side. The soil core was washed carefully and the root data were recorded.

Four root characters namely shoot length, root length, number of roots and root diameter were measured for both the parental lines and the forty hybrids. The data was subjected to statistical analysis using combining ability analysis (*gca* and *sca*) and heterosis. Analysis of variance was performed for individual as well as combined trials using NPRC Stat.

RESULTS

The analysis of variance showed significant differences among the lines, for majority of the characters. The interaction effect L x T was significant for most of the characters (Table 1).

Table 1
Analysis of variance for seedling characters

		MSS			
Source of variation	*df*	*Root length*	*Shoot length*	*Number of roots*	*Root diameter*
Replication	**2**	105.21	70.43	7.72	1.06
Cross	**39**	46.84**	27.01**	0.45	0.01
Line	**9**	98.60**	20.83**	0.76	0.01
Tester	**3**	22.88**	145.08**	2.90	0.02
L X T	**27**	25.84**	15.95**	0.08	0.03
Error	**78**	6.93	11.48	0.23	0.03

* Significant at 5 per cent level** Significant at 1 per cent level

The combining ability variances for different traits are presented in Table 2. The greater magnitude of SCA variance than GCA variance indicated the role of non-additive genes for all the twenty one characters studied. The estimates of additive and dominance variance revealed that dominance variance (σ^2D) was greater than the additive genetic variance (σ^2 A) for all the characters under study.

Table 2
Combining ability variances and gene action for seedling characters

Variance	*Root length*	*Shoot length*	*Number of roots*	*Root diameter*
GCA	0.18	70.43	0.01	0.01
SCA	2.33	27.22	0.05	0.05
s^2 A (F = 1)	0.37	20.83	0.01	0.01
s^2 D (F = 1)	9.34	145.08	0.20	0.02
s^2 A / s^2 D	0.04	15.95	0.05	0.50
GCA/SCA	0.08	11.48	0.20	0.20

Per se performance

Root length (cm)

The range exhibited by the parents for this trait was from 21.55 (PDM 11) to 31.61 cm (IPM 306-6) and 22.25 (SML 47) to 28.32 cm (IPM 9901-10) among lines and testers, respectively. The grand mean for lines and testers are 27.56 cm and 24.35 cm, respectively. Among the parents studied, the lines IPM 02-14, UPM 98-1, IPM 306-6, IPM 9901903, IPM 9901-125 and the tester IPM 9901-10 had higher values than the general mean (Figure 1).

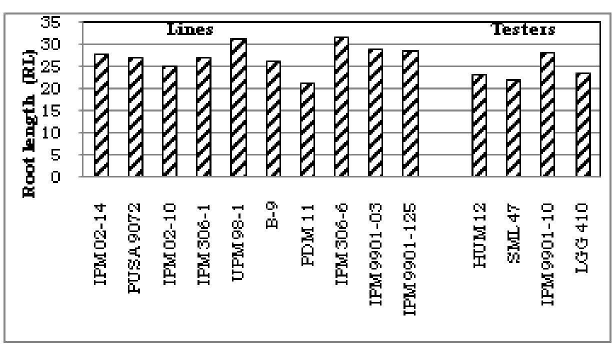

Figure 1.

The value for root length was highest in the hybrid UPM 98-1/IPM 9901-10 (34.56 cm) and lowest in PDM 11/SML 47 (25.65 cm) with a general mean of 30.22 cm. Sixteen hybrids recorded significantly higher values than the grand mean (Figure 5).

Shoot length (cm)

The range exhibited by the parents for this trait was from 25.89 (Pusa 9072) to 34.49 cm (PDM 11). The grand mean for lines and testers were 29.86 cm and 29.07 cm, respectively. Among the parents studied, the lines UPM 98-1, B-9, PDM 11, IPM 9901-03 and the testers IPM 9901-10 and LGG 410 had higher values than their respective general means (Figure 2).

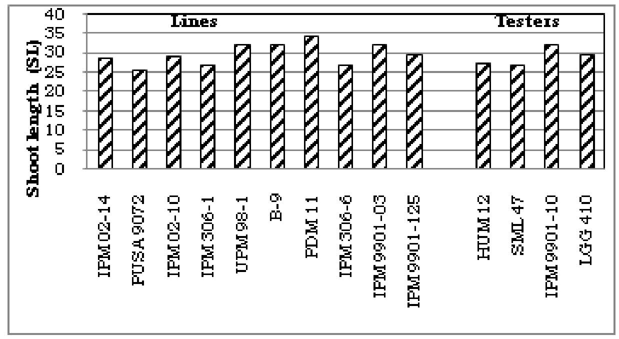

Figure 2.

The range exhibited by the hybrids for this trait was from 35.10 cm (Pusa 9072/HUM 12) to 23.61 cm (Pusa 9072/IPM 9901-10). Twenty hybrids registered significantly higher for shoot length than the general mean (29.09 cm) (Figure 6).

Number of roots

The range exhibited by the parents for this trait was from 4.00 (PDM 11) to 5.33 (UPM 98-1and IPM 306-6) and 36.7 (SML 47) to 5.00 (IPM 9901-10) among lines and testers, respectively. The grand mean for lines and testers are 4.83 and 4.16 respectively. Among the parents studied, the lines IPM 306-1, UPM 98-1, IPM 306-6, IPM 9901-03, IPM 9901-125 and the tester IPM 9901-10 had higher values than their respective general means (Figure 3).

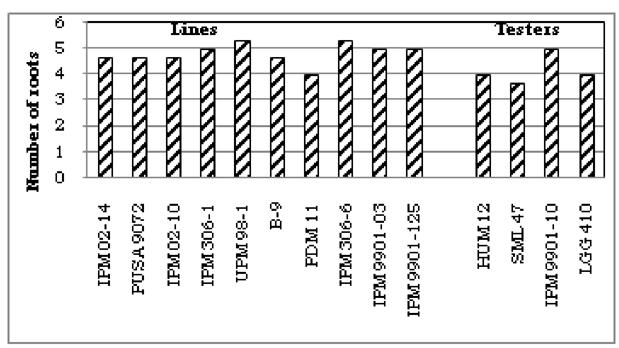

Figure 3.

Among the hybrids, the mean values for this trait ranged from 4.00 (PDM 11/SML 47 and PDM 11/LGG 410) to 5.79 (IPM 9901-03/HUM 12). Among the 40 hybrids studied, fifteen hybrids recorded significantly higher values than the general mean (4.79) (Figure 7).

Root diameter

The range exhibited by the parents for this trait was from 0.44 (IPM 9901-125) to 0.77 (UPM 98-1 and 0.40 (SML 47) to 045 cm (IPM 9901-125) among lines and testers, respectively. The grand mean for lines and testers are 0.59 and 0.42 respectively. Among the parents studied, the lines IPM 02-14, UPM 98-1, B-9, PDM 11 and the testers IPM 901-10 and LGG 410 had higher values than the general mean (Figure 4).

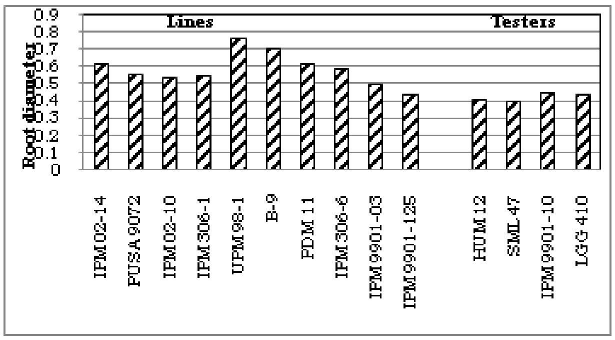

Figure 4.

The mean values for this trait ranged from 0.50 cm (IPM 9901-125/HUM 12) to 0.83 cm (IPM 306-6/IPM 9901-10). Among the forty hybrids studied, fourteen hybrids recorded significantly higher values than the general mean (0.63 cm) (Figure 8).

General combining ability (gca)

Root length

The *gca* effects of the lines varied from -3.50 (PDM 11) to 2.20 (UPM 98-1) and the *gca* effects of the testers ranged from -1.22 (SML 47) to 1.99 (IPM 9901-10). The line *viz.*, UPM 98-1 and the tester IPM 9901-10 recorded significant positive *gca* effects. Significant negative *gca* effects was recorded by the line PDM 11 and the tester SML 47 (Table 3).

Shoot length

The *gca* effects of the lines varied from -1.97 (IPM 9901-125) to 2.01 (IPM 306-6) and the *gca* effects of the testers ranged from -1.70 (LGG 410) to 3.09 (HUM 12). The line *viz.*, IPM 306-6 and the tester HUM 12 recorded significant positive *gca* effects. Significant negative *gca* effects was recorded by the line IPM 9901-125 and the testers IPM 9901-10 and LGG 410 (Table 3).

Number of roots

The *gca* effects of the lines varied from -0.53 (PDM 11) to 0.39 (UPM 98-1) and the *gca* effects of the testers ranged from -0.21 (SML 47) to 0.46 (IPM 9901-10). The line *viz.*, UPM 98-1 and the tester IPM 9901-10 recorded significant positive *gca* effects. Significant negative *gca* effects was recorded by the lines IPM 02-10, PDM 11 and HUM 12, SML 47 in the testers (Table 3).

Root diameter

The *gca* effects of the lines varied from -0.05 (IPM 306-1 and IPM 9901-125) to 0.06 (UPM 98-1) and the *gca* effects of the testers ranged from -0.03 (HUM 12) to 0.03 (LGG 410). The lines *viz.*, UPM 98-1recorded significant positive *gca* effects. None of the testers showed significant *gca* for this trait (Table 3).

Table 3
General combining ability effect of parents and hybrids for seedling characters

Parents	*Root length*	*Shoot length*	*Number of roots*	*Root diameter*
LINES				
IPM 02-14	0.16	-0.10	0.06	0.02
PUSA 9072	-0.07	1.53	-0.03	-0.03
IPM 02-10	-1.37	-1.57	-0.28*	-0.03
IPM 306-1	-0.17	0.01	-0.03	-0.05
UPM 98-1	2.20*	0.54	0.39**	0.06*
B-9	-0.62	-1.20	-0.03	0.04
PDM 11	-3.50**	-0.28	-0.53**	0.01
IPM 306-6	1.31	2.01*	0.14	0.00
IPM 9901-03	1.54	1.04	0.14	0.02
IPM 9901-125	0.52	-1.97*	0.14	-0.05
SE (*gca* for lines)	0.85	0.97	0.13	0.02
TESTERS				
HUM 12	-0.70	3.09**	-0.18*	-0.03
SML 47	-1.22*	0.03	-0.21*	-0.01
IPM 9901-10	1.99**	-1.43*	0.46**	0.02
LGG 410	-0.07	-1.70**	-0.08	0.03
SE (*gca* for testers)	**0.54**	**0.61**	**0.09**	**0.01**

* Significant at 5 per cent level** Significant at 1 per cent level

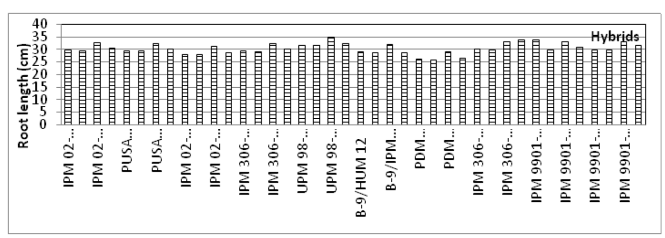

Figure 5.

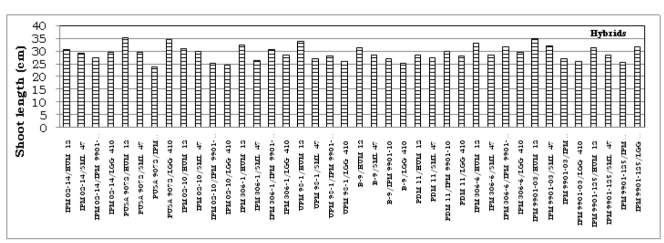

Figure 6.

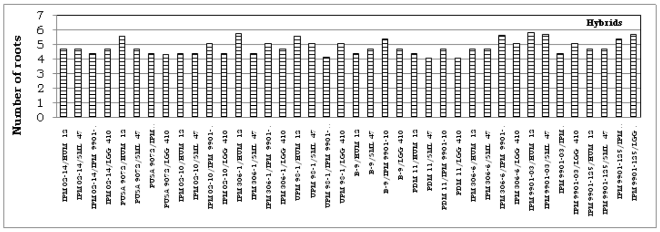

Figure 7.

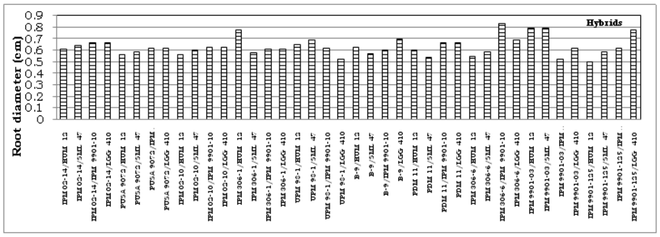

Figure 8.

Specific combining ability (sca)

Among the hybrids, the *sca* effects for root length varied between -1.06 (IPM 9901-03/LGG 410) and 2.62 (IPM 9901-03/HUM 12). None of the hybrids recorded positive significant *sca* effect (Figure 9). For shoot length, the *sca* effects for this varied between -5.57 (Pusa

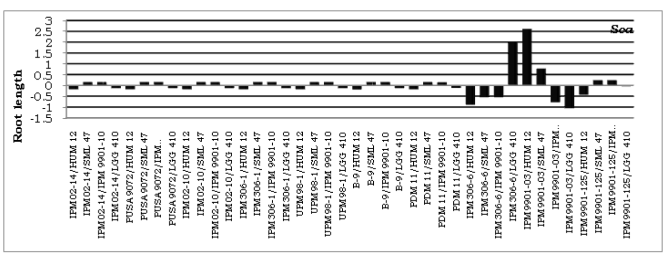

Figure 9.

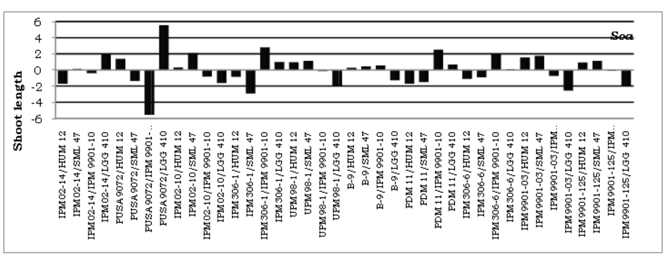

Figure 10.

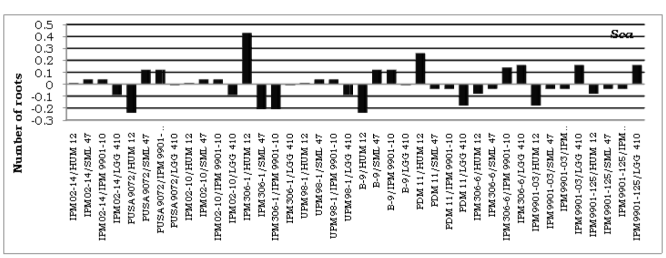

Figure 11.

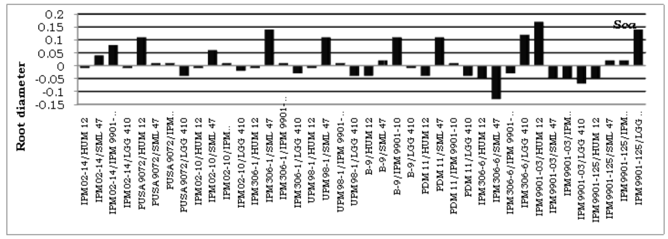

Figure 12.

9072/IPM 9901-10) and 5.55 (Pusa 9072/LGG 410). The hybrid Pusa 9072/LGG 410 showed positive significant *sca* effect (Figure 10).For number of roots, the *sca* effects for this trait varied between -0.24 (Pusa 9072/HUM 12 and B-9/HUM 12) and 0.43 (IPM 306-1/HUM 12). Ten hybrids *viz*., Pusa 9078/SML 47, Pusa 9072/ IPM 9901-10, IPM 306-1/HUM 12, B-9/SML 47, B-9/ IPM 9901-10, PDM 11/HUM 12, IPM 306-6/ IPM 9901-10, IPM 306-6/LGG 410, IPM 9901-03/LGG 410 and IPM 9901-125/LGG 410 showed positive significant *sca* effects (Figure 11). For the character root diameter, the *sca* effects for this trait varied between -0.07 (IPM 9901-03/LGG 410) and 0.17 (IPM 9901-03/ HUM 12). The hybrids namely Pusa 9072/HUM 12, IPM 306-6/SML 47, UPM 98-1/SML 47, B-9/IPM 9901-10, PDM 11/SML 47, IPM 306-6/LGG 410, IPM 9901-03/HUM 12and IPM 9901-125/LGG 410 showed positive significant *sca* effects (Figure 12).

Heterosis

Root length

Maximum, positive and significant relative heterosis was recorded by IPM 9901-03/HUM 12 (28.92). Thirty six hybrids recorded significant and positive values. None of the hybrids showed significant and positive values for heterobeltiosis. Standard heterosis was positive significant and maximum in UPM 98-1/IPM 9901-10 (55.36). Among the forty hybrids, none of the hybrids showed significant and positive values for all the three types of heterosis (Figure 13).

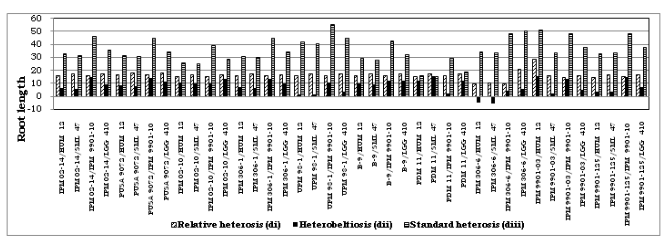

Figure 13.

Shoot length

Among the forty hybrids, one hybrid recorded positive and significant values for relative heterosis

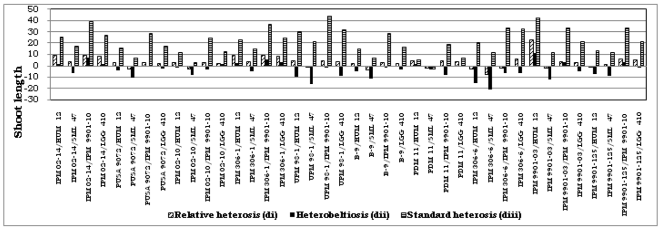

Figure 14.

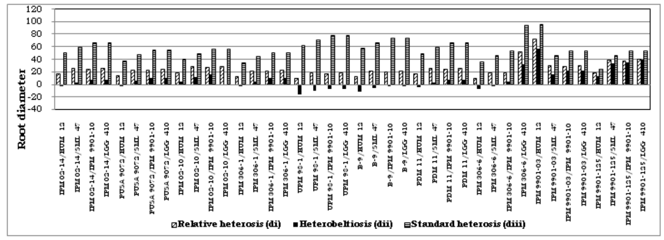

Figure 16.

and it was maximum in IPM 9901-03/HUM 12 (22.82). Heterobeltiosis was negative significant in three hybrids. Standard heterosis was positive and significant in twenty one hybrids None of the hybrids recorded significant and positive values for all the three types of heterosis (Figure 14).

Number of roots

None of the hybrids showed significant and positive values for relative heterosis and the maximum value was recorded by Pusa 9072/SML 47, IPM 02-14/SML 47 and B-9/SML 47 (12.00). The maximum significant and positive value for heterobeltiosis was recorded by none of the hybrids. Standard heterosis was positive and significant in seventeen hybrids. The highest standard heterosis was recorded by UPM 98-1/IPM 9901-10 (41.67). Among the forty hybrids, none of the hybrids recorded positive and significant values for all the three types of heterosis (Figure 15).

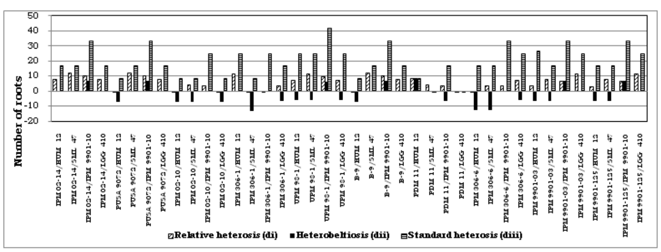

Figure 15.

Root diameter

Among the forty hybrids twenty five hybrids recorded significant and positive values for relative heterosis and the maximum value was recorded by IPM 9901-03/HUM 12 (72.39). The maximum significant and positive value for heterobeltiosis was recorded by IPM 9901-03/HUM 12 (57.28). Standard heterosis was positive and significant in thirty eight hybrids. The highest standard heterosis was recorded by UPM 98-1/IPM 9901-10 (78.86). Among the forty hybrids, five hybrids recorded positive and significant values for all the three types of heterosis (Figure 16).

DISCUSSION

The *gca* effect is a value derived from the general mean of hybrid involving all parents. The *gca* effect of parents may be positive or negative. It was also pointed out that the *gca* values were relative and dependent upon the mean of the chosen material. It is better to choose parents possessing significant *gca* effects or merely based on mean performance. This assumption is based on the principle that *gca* effect reflects additive gene action. Sometimes, the immediate hybrid may not perform well despite both the parents possessing high *gca* effects for a trait, due to interaction of the parental *gca* effects which may cause distortions on expectations. The reverse trend may also happen with low performing parents showing high hybrid values than expected. This interaction is measured by the *sca* effects of the hybrids. It is to be remembered that interaction effects are not fixable. The point for consideration here is to identify the hybrids which could be forwarded further for selection in the segregating generation and hybrids suitable for heterosis breeding.

A perusal of the *gca* effects of the parents in the present study indicated that line IPM 02-14 possessed favourable*gca* effects for important traits. Hence, it is necessary to consider both *per se* performance and *gca* effects for the improvement of any character. In the present investigation, IPM 9901-03,B-9,IPM 02-10, IPM 9901-125, LGG 410 and IPM 9901-10 were rated as best parents, since they possessed high mean and *gca* values. Therefore, it could be concluded that crosses involving IPM 9901-03, B-9, IPM 02-10, IPM 9901-125, LGG 410 and IPM 9901-10 would result in the identification of superior segregants with favourable genes for the seed yield per plant and its component characters.

From the perusal of *sca* effects of the hybrids, it was evident that all types (significantly positive or negative or non- significant) of *sca* effects could be obtained in hybrids with different types (high x high, high x low, low x high and low x low) of parental *gca* combinations.

High *sca* effect was produced by high x low or low x high combinations of parental *gca* effects in PUSA 9072/IPM 9901-10, and PUSA 9072/LGG 410 for shoot length; IPM 306-6/SML 47, IPM 306-6/LGG 410, IPM 9901-03/HUM 12, and IPM 9901-125/LGG 410 for number of roots; PUSA 9072/HUM 12, IPM 306-1/SML 47, UPM 98-1/SML 47, B-9/IPM 9901-10, PDM 11/SML 47, IPM 306-6/SML 47, IPM 306-6/LGG 410, and IPM 9901-03/HUM 12 for root diameter.

Hybridization aims to combine the favourable genes present in different parents into a single genotype. The hybrids thus obtained are utilized in two ways namely (i) Directly using the F_1 to exploit hybrid vigour and (ii) Forwarding to further generations and selecting superior individuals. The utilization of hybrids in any of the two ways will depend upon the genetic constitution of the parents as well as the hybrids.

Among the forty hybrids, IPM 306-6/SML 47, IPM 9901-03/IPM 9901-10, IPM 9901-03/HUM 12, IPM 9901-125/HUM 12 and IPM 9901-125/LGG 410 were rated as best hybrids based on overall general mean performance.

There were instances in which involvement of both poor combiners produced superior specific combining hybrids as evidenced from the combinations of IPM 306-6/LGG 410, and IPM 9901-125/LGG 410 for number of roots, PUSA 9072/HUM 12, IPM 306-1/SML 47, B-9/IPM 9901-10, PDM 11/SML 47, IPM 306-6/SML 47, IPM 306-6/LGG 410 and IPM 9901-03/HUM 12 for root diameter.

Based on the combined effect of per se performance, specific combining ability and standard heterosis, the hybrids namely IPM 9901-03/HUM 12 and IPM 9901-125/LGG 410 (number of roots); IPM 9901-03/HUM 12 (root diameter) and were considered the best for root characters under drought condition.

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