Egypt. J. Plant Breed. 14 (2): 173 – 187 (2010)

HETEROSIS, COMBINING ABILITY AND INBREEDING DEPRESSION FOR FORAGE YIELD AND ITS COMPONENTS IN PEARL MILLET

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ABSTRACT

Ten pollen parents of pearl millet were crossed with four male-sterile lines using line x tester mating design. The fourteen parents, 40 F_1's and 40 F_2's were grown to evaluate heterosis and combining ability in F_1 generation as well as inbreeding depression in F_2 generation for forage yield and its related traits. Results showed significant differences among the evaluated genotypes for all studied traits of both cuts. Variable and significant magnitude of heterosis and heterobeltiosis was observed for all studied characters. The highest heterosis was expressed by plant height, number of tillers per plant, fresh and dry yields at both cuts as well as total fresh and dry yields over the two cuts. The highest heterobeltiosis was observed for forage yield in the cross 861A x 87/0591PCNo293 at both cuts. Estimates of variance component for general GCA and specific SCA combining abilities cleared the predominance of variance due to SCA over GCA, indicating non-additive type of gene action involved for the control of plant height, number of leaves/plant, stem diameter, leaf length, leaf width, number of tillers/plant, fresh and dry yields at both cuts as well as total fresh and dry yields over the two cuts. Seventeen of the crosses showed significant and favorable positive SCA effects for forage yield and its related traits. The crosses ICMA98777 x ICMV05111 and 14A x PE00205 expressed significant positive SCA effects for total forage yield. Further 14A x PE00205 and 17A x ICMV05333 exhibited the best combinations for total dry yield. For most studied characters, a large number of hybrids showed a significant positive inbreeding depression.

Key words: *Pearl millet (Pennisetum glaucum), General combining ability, Specific combining ability, Heterosis, heterobeltiosis, Inbreeding depression*

INTRODUCTION

Pearl millet *(Pennisetum glaucum)* breeders have extensively used and exploited combining ability and heterosis to improve forage yield and its components. Soliman (2005) reported significant differences in pearl millet lines, testers and their interaction for plant height, number of leaves, stem diameter and number of tillers/plant. Also genetic diversity among lines and testers were observed for plant height, days to 50% flowering and number of tillers/plant by Karad and Harer (2004) and Kumari *et al* (2003).

The most effective and rapid way to improve biomass yield in pearl millet is likely to be by exploiting heterosis in F_1 hybrids (Hanna and Gupta

1999). In pearl millet, heterosis for biomass yield in hybrids and parental inbreeds is well documented by various breeders. Karad and Harer (2004) in a line x tester crossing programme compare 75 pearl millet hybrids reported positively highly significant heterosis for plant height (101.33%), number of tillers/plant (161.54%) and fodder yield (251.89%). Bidinger *et al* (2003) found that heterosis for stover yield in 49 hybrids (7 lines x 7 testers) of pearl millet varied from -26% to 6%. Presterl and Weltzien (2003) determined the heterotic pattern among 36 diallel pearl millet crosses. They found that mid parent heterosis was generally low ranging from 0.85% for time to 50% flowering to 6.57% for stover yield. Soliman (2005) in 35 hybrids (5 males x 7 testers) of pearl millet reported significant and positive heterosis for plant height (33.88 and 22.65%), number of leaves/plant (7.29 and 11.15%), stem diameter (13.61 and 5.91%), number of tillers/plant (2.99 and 29.65%), fresh weight/plant (70.26 and 127.53%) and dry weight/plant (70.26 and 157.39%) in the first and second cuts, respectively. Also highly significant positive heterosis was observed for total fresh yield (17.75%).

The breeding value of any materials is largely determined by its combining ability for important traits related to productivity (Hallauer and Miranda 1988). Bhanderi *et al* (2007) studied combining ability in 8 x 8 diallel set, for fodder yield and its components in pearl millet. They found that both GCA and SCA variances were highly significant for plant height, number of tillers/plant, days to 50% flowering and fodder yield. Additive genetic variance was predominant for plant height, while, non-additive genetic variance was predominant for days to 50% flowering, number of tillers/plant, and fodder yield. Shanmuganathan and Gopalan (2006) evaluated 55 single cross hybrids derived from 11 x11 diallel cross. They found that both additive and dominance components were significant, with the predominance of non-additive effect for plant height, number of tillers/plant and fodder yield. Yadav *et al* (2000) reported the importance of GCA effects in the genetic control of stover yield, while both GCA and SCA effects were important for time to flowering. Rohitashwa *et al* (2006) studied combining ability in 10 x 10 diallel crosses for dry fodder yield in pearl millet. They found that the variance due GCA and SCA were highly significant indicating the importance of additive and non-additive gene action. The estimates of SCA component were higher in magnitude than that of GCA component, indicating the predominance of non-additive gene action for fodder yield.

Pearl millet like other cross-pollinated crops, exhibits depression in vigour during selfing. The phenomenon of inbreeding depression in this crop has been studied by Soliman (2005) who reported that inbreeding depression (or gain) in 35 F'_2 for total fresh yield ranged between -16.54 to 47.49%, while it varied from -27.56 to 65.04% for total dry yield. Agarwal and Shrotria (2005) studied inbreeding depression over 50 crosses in F'$_2$ generation. They found that the inbreeding varied from 23.19% to 47.19% for green fodder yield, while it ranged between 37.0% and 59.38 % for dry fodder yield.

The objectives of this study were to: 1) Estimate heterosis and combining ability of parents and their derived crosses, 2) Determining the most important mode of gene action which controls forage yield and its components, and 3) Recognizing the best lines and top crosses to be recommended for further use.

MATERIALS AND METHODS

The present study was carried out at the Research Station, Faculty of Agriculture, Cairo University, Giza, Egypt during 2006, 2007 and 2008 summer growing seasons. The genetic materials used for this study comprised four male-sterile lines (861A, ICMA98777, 14A and 17A) and ten restorer parents (PE00048, PE00205, E00208, ICMV05111, ICMV05333, ICMV05444, 87/059IPCN045, 87/059IPCN0293, 87/059IPCN0115 and Sudan population). The Sudan population was received from the Sudan, while the other parental genotypes were received from the International Crop Research Institute for the Semi-Arid Tropics (ICRISAT).

Male-sterile lines were crossed with the restorer parents during 2006 season. F_2 seeds were produced in 2007 by selfing F_1 plants. In late June of 2008 season, the fourteen parents (four male-sterile lines and ten testers), 40 F_1's and 40 F_2's in addition to two standard checks (Shandaweel 1 and EL-wady EL-gadid landrace) were planted in a randomized complete block design (RCBD) with three replications. The plot size was a single row for parents and F_1's, while it was two rows for the F_2's. Rows were 3m long with row spacing of 50 cm and plant to plant spacing of 25 cm. Recommended cultural practices were followed to raise agronomically good managed crop. Plants were cut twice to a stubble height of 15 cm shortly at 50% flowering.

Observations were recorded on five guarded plants from each row in each replication for 11 traits viz., days to 50 % flowering, plant height, stem diameter (measured at the center of fourth internode), number of leaves/plant, maximum length and width of the 5th leaf from plant top, number of tillers/plant, fresh and dry fodder weights/plot for each cut as well as total fresh and dry fodder weights over cuts.

Data of plot means were subjected to a regular statistical analysis of RCBD according to Gomez and Gomez (1984). The degree of freedom and sum of squares due to genotypes were partitioned into parents, crosses, and parents vs. crosses. Also, degrees of freedom and sum of square due to crosses were further partitioned into lines, testers and line x tester interaction according to method outlined by Singh and Choudhary (1985).

Heterosis for each F_1 cross was estimated as the deviation of F_1 mean from the mid-parents, and heterobeltiosis was calculated as the deviation of the mean from the better parent and expressed in percentages. Inbreeding depression (ID) in the F_2 generation was estimated for each cross as the deviation of F_1 mean from the F_2 mean. Significance of heterosis and inbreeding depression was tested using appropriate least significant difference. The GCA effects of parents and SCA effects of F_1 crosses were calculated according to the method described by Kempthorne (1957).

RESULTS AND DISCUSSION

Analysis of variance

The analysis of variance (Table 1) showed significant differences among the evaluated genotypes for all studied traits at both cuts. The mean squares due to parents also differed significantly for all studied characters of the two cuts. Significant differences among the top crosses were recorded for all characters in the first and second cuts, indicating sufficient genetic variation in parental lines and crosses for all studied characters. Highly significant differences were also observed for the comparison indicating heterosis Parent vs. crosses for most studied traits except leaf length and number of tillers/plant in the first cut and number of leaves/plant, stem diameter and days to 50 % flowering in the second cut.

Line x tester analysis showed highly significant differences among testers (Table 1) for all studied traits except for plant height and number of leaves/plant in the first cut, and in lines for most evaluated characters with exception of plant height. The line x tester interaction also showed significant variation for plant height, leaf length and leaf width in both cuts as well as stem diameter and days to 50% flowering in the first cut, while it was significant for number of tillers/plant and dry yield/plot in the second cut. The existence of significant differences in lines, testers and their interaction for studied traits revealed the importance of both additive and non-additive gene action for those traits.

Mean performance of all tested entries, heterosis and inbreeding depression

The mean performance of parents, F_1's, and/or F_2's as well as heterosis, heterobeltiosis and inbreeding depression percentages for studied characters are given in Table (2). Mean performance of F_1 showed higher values for all traits except days to heading at both cuts compared with mean performance of their parents. All characters showed decreasing trend in the mean performance from F_1 to F_2 except number of tillers/plant and dry yield/plot at the first cut.

Table 1. Mean squares of line x tester analysis for forage yield and its components of two cuts.

S. V	df	Plant height		No. of leaves/plant		Stem diameter		Leaf length		Leaf width	
		Cut 1	Cut 2	Cut 1	Cut 2	Cut 1	Cut 2	Cut 1	Cut 2	Cut 1	Cut 2
Genotypes	53	2978.14**	1280.9**	6.47**	2.26**	8.15**	2.55**	552.16**	77.21**	0.904**	0.27**
Parents	13	5421.51**	2562.4**	11.37**	3.28**	17.14**	3.97**	1104.9**	81.18**	1.267**	0.51**
Crosses	39	731.75**	658.1**	4.08*	1.98**	4.86**	2.11**	379.06**	71.85**	0.622**	0.19**
Par. vs. crosses	1	58823.6**	8914.1**	36.20**	0.003	19.39**	0.92	117.58	234.50**	7.190**	0.26*
Lines	3	142.06	529.7	16.73**	0.83	9.18**	3.43**	1030.4**	164.81**	3.042**	0.19*
Testers	9	407.12	1212.7**	2.64	3.01**	8.76**	4.45**	644.60**	132.78**	0.490**	0.33**
Lines x Testers	27	905.48**	487.5**	3.15	1.77	3.08**	1.19	218.18**	41.21**	0.398**	0.14**
Error	106	403.36	245.18	2.54	1.16	1.504	0.89	48.48	20.956	0.143	0.07
		No. of tillers/plant		Days to 50 % flowering		Fresh yield/plot		Dry yield/plot		Total yield	
Genotypes	53	12.32**	11.86**	243.19**	37.35**	94.76**	6.68**	3.25**	1.822**	132.4**	6.48**
Parents	13	17.67**	10.61**	464.13**	112.2**	185.44**	8.92**	3.32**	2.085**	268.99**	8.61**
Crosses	39	10.69**	11.95**	157.43**	13.11*	61.65**	5.55*	2.63**	1.529**	80.97**	4.17**
Par. vs. crosses	1	5.96	24.87**	715.38**	10.12	207.23**	21.61**	26.76**	9.861**	362.67**	68.88**
Lines	3	23.86**	22.82**	594.93**	32.76**	79.90*	4.49	1.08	1.432*	100.97*	2.94
Testers	9	26.50**	9.04*	300.36**	22.50**	135.47**	10.73**	5.79**	1.969**	187.42**	9.33**
Lines x Testers	27	3.99	11.70**	61.18**	7.80	35.010	3.97	1.758	1.393**	43.27	2.59
Error	106	3.30	3.98	6.427	8.276	26.881	3.545	1.253	0.459	33.25	1.91

Table 2. Mean performance of parents, F_1's, F_2's and heterosis, heterobeltiosis and inbreeding depression percentages for studied characters.

Traits	Cut	Parent's mean	F_1's mean	F_2's mean	Heterosis %	Hetero-beltiosis %	Inbreeding depression %
Plant height (cm)	1st	190	236.83	208.03	38.35**	15.31	12.16
	2nd	147.7	164.72	144.39	20.3	3.67	12.34
No. of leaves/plant	1st	13.24	14.37	13.31	12.14**	0.37	7.38**
	2nd	9.9	9.89	9.46	0.53	-4.32**	4.35**
Stem diameter ml	1st	12.89	13.68	12.94	12.00**	-0.91	5.41**
	2nd	11.56	11.73	11.13	3.73**	-1.87*	5.12**
Leaf length (cm)	1st	75.29	77.23	69.89	8.12	-2.97	9.50*
	2nd	52.25	55	51.64	7.50*	1.72	6.11*
Leaf width cm	1st	4.3	4.78	4.39	14.47**	3.70**	8.16**
	2nd	4.38	4.47	4.25	3.34**	-1.47**	4.92**
No. of tillers/plant	1st	7.19	7.61	7.68	15.27**	-3.55*	-0.92
	2nd	6.5	7.39	6.96	21.8**	5.75**	5.82**
Days to heading	1st	75.1	70.15	68.5	-3.94	-12.00*	2.35
	2nd	39.43	38.86	37.96	3.71	-6.54**	2.32
Fresh yield plot^{-1} Kg	1st	15.51	17.87	16.49	35.00**	8.72*	7.72*
	2nd	9.79	10.63	10.17	13.59**	3.94**	4.33
Dry yield plot^{-1} kg	1st	3.2	4.12	4.15	41.12**	20.2**	-0.73
	2nd	3.2	3.78	3.76	27. 73**	8.94**	0.53
Total yield plot^{-1} kg (over two cuts)	Fresh	25.3	28.72	27.48	26.79**	7.6	4.32
	Dry	6.4	7.91	8.13	34.19**	14.76**	-2.78*

*,** significant at 0.05 and 0.01 respectively.

Significant positive heterosis was observed for all traits except plant height at second cut. Significant heterobeltiosis was recorded for all characters except plant height and leaf length at both cuts and number of leaves/plant and stem diameter at first cut. Significant positive heterobeltiosis was recorded for fresh and dry yield/plot at both cuts, total yield/plot at second cut as well as leaf width and number of tillers/plot at first cut

Variable and significant magnitude of heterosis and heterobeltiosis were exhibited by different cross combinations for all studied characters, especially for fresh and dry yields/plot in both cuts as well as total fresh and dry yields over the two cuts indicated sufficient divergence in parental material for these traits. The high magnitudes of heterosis were expressed by fresh and dry yields/plot at both cuts, total fresh and dry yields over the two cuts as well as number of tillers per plant at both cuts and plant height in the first cut. The low magnitude of heterosis was recorded for days to 50% flowering at both cuts.

Significant inbreeding depression was obtained for number of leaves/plant, stem diameter, leaf length and leaf width at both cuts in addition to fresh yield/plot at first cut and number of tiller/plant at second cut.

The range of mid-parent heterosis, heterosis relative to the high parent (heterobeltiosis), inbreeding depression and number of hybrids showing significant heterosis in desirable direction for forage yield and its contributing characters are presented in Table (3).

Heterosis over the better parent (heterobeltiosis) for plant height ranged from -15.84 to 66.44 % and -16.27 to 26.27 % at the first and second cuts, respectively. In the first cut, 9 crosses showed significant heterobeltiosis for plant height. The maximum significant heterobeltiosis was recorded in the cross ICMA98777 x PE00048 (66.44 %) followed by 14 A x PE00048 (54.87 %) and 14 A x PE00208 (51.59 %), while in the second cut, only one cross 861A x 87/059IPCNo293 showed significant heterobeltiosis (26.27 %) (data not presented). For number of tillers/plant, heterobeltiosis ranged from -38.84 to 72.86 % and -49.86 to 108.5 % in the first and second cuts, respectively. In the first cut, 10 crosses exhibited significant heterobeltiosis, the maximum positive heterobeltiosis was observed in the cross 861A x 87/059IPCNo45 (72.86 %) followed by 861A x Sudan population (58.58 %) and 14 A x 87/059IPCNo293 (51.16 %). In the second cut, 17 crosses recorded significant heterosis the highest significant heterobeltiosis was expressed by the cross 14 A x 87/059IPCNo45 (66.64 %) followed by 861A x PE00205 (60.67 %) and ICMA98777 x PE00048 (58.77 %).

Most of crosses exhibited increased fresh and dry yields/plot at both cuts, as well as total fresh and dry yields over cuts as compared to their mid parents and superior parent. For fresh yield/plot, 34 and 20 hybrids at first cut; 28 and 20 hybrids at second cut showing significant positive heterosis and heterobeltiosis, respectively. The highest magnitudes of heterobeltiosis (132.1 and 32.80 %) were observed in the cross 861A x 87/059IPCNo293 at the first and second cuts, respectively (data not shown). For dry yield/plot, 36 and 26 hybrids at first cut; 35 and 25 hybrids at second cut expressed significant positive heterosis and heterobeltiosis, respectively. The highest

Table 3. Range of heterosis, heterobeltiosis, inbreeding effects (I.E.) and number of crosses showing significant heterosis in desirable direction for studied traits.

Traits	cut	Heterosis %		Heterobeltiosis %		I.E. %	
		Range	No	Range	No.	Range	No
Plant height	1st	2.11 to 176.4	22	- 15.84 to 66.44	9	- 9.93 to 40.06	0
	2nd	- 6.81 to 50.73	19	- 16.27 to 26.27	1	- 23.65 to 33.61	11
No. of leaves/plant	1st	- 4.44 to 48.41	26	- 13.38 to 35.43	12	- 16.07 to 44.19	25
	2nd	- 22.02 to 23.16	18	- 30.33 to 22.32	7	- 20.95 to 18.10	27
Stem diameter	1st	- 6.51 to 44.86	30	- 19.21 to 16.24	12	- 13.46 to 32.81	23
	2nd	- 7.13 to 16.53	23	- 14.80 to 26.20	12	- 10.87 to 30.49	21
Leaf length	1st	- 24.5 to 43.15	18	- 35.52 to 29.33	10	- 15.66 to 63.38	16
	2nd	- 16.10 to 27.22	21	- 28.35 to 26.75	12	- 20.77 to 23.30	22
Leaf width	1st	- 14.32 to 51.13	33	- 15.62 to 36.92	24	- 12.12 to 40.9	31
	2nd	- 11.25 to 17.62	26	- 22.29 to 16.28	18	- 15.00 to 25.81	31
No. of tillers/plant	1st	- 26.62 to 84.51	25	- 38.84 to 72.86	10	- 121.1 to 38.0	23
	2nd	- 40.32 to 117.4	27	- 49.86 to 108.5	17	- 116.7 to 49.30	25
Days to 50% heading	1st	- 20.8 to 15.54	2	- 31.80 to 12.30	1	- 28.11 to 20.35	18
	2nd	- 11.29 to 21.21	19	- 21.38 to 9.52	5	- 8.41 to 15.46	9
Fresh yield plot^{-1} kg	1st	- 15.2 to 148.2	34	- 38.12 to 132.1	20	- 59.65 to 44.15	23
	2nd	- 14.24 to 50.22	28	- 28.25 to 32.80	20	- 52.37 to 27.48	26
Dry yield plot^{-1} kg	1st	- 9.77 to 103.9	36	- 36.00 to 102.3	26	- 141.9 to 52.72	19
	2nd	- 13.85 to 96.19	35	- 34.00 to 67.03	25	- 60.06 to 36.12	21
Total yield plot^{-1} kg (over two cuts)	Fresh	- 12.86 to 104.07	32	- 36.75 to 90.03	21	- 68.25 to 32.87	19
	Dry	- 0.05 to 76.34	39	- 31.84 to 64.86	28	- 70.83 to 33.02	20

magnitude of heterobeltiosis in the first cut was recorded by the cross 17 A x ICMV05333 (102.3 %) followed by 861 A x ICMV05444 (83.63 %), 14 A x 87/059IPCNo45 (78.51 %) and ICMA98777 x ICMV05444 (76.04 %), while in the second, the highest magnitudes were expressed in the crosses ICMA98777 x ICMV05333 (67.03 %), 1x9 (57.72 %) and 14 A x 87/059IPCNo293 (50.85 %).

Among the crosses, 32 and 21 crosses for total fresh yield; 39 and 28 crosses for total dry yield showed significant positive heterosis and heterobeltiosis, respectively. The highest heterosis over the better parent was observed in the cross 861A x 87/059IPCNo293 (90.03 %) for total fresh fodder yield and in the cross 17 A x ICMV05333 (64.86 %) for total dry yield. Significant positive heterosis over mid and better parent for plant height, number of tillers/plant, fresh yield and dry yield was also reported by Desai *et al* (2000), Karad and Harer (2004), Agrawal and Shrotria (2005) and Soliman (2005). It was noticed that the hybrids expressing significant heterosis for fresh yield also had significant heterosis for one or more characters i.e. plant height, stem diameter, number of leaves/plant and number of tillers/plant. This indicated that the heterosis for fresh yield seems to be influenced by heterosis for one or more important components of the yield. Similar conclusion was reported by Karad and Harer (2004) and Soliman (2005).

For most studied characters, a large number of hybrids showed significant positive inbreeding effects (Table 3). The significant reduction in forage yield and its component characters in the F_2 are due to the presence of larger non-additive gene effects in the expression of those characters. It may be seen from the present study in general that the hybrid combinations, that showed higher estimates of heterosis, found to show substantial inbreeding depression. Shull (1914) reported that high positive inbreeding depression is the reflection of higher heterosis, especially in cross-pollinated crops. In the present study, most of heterotic hybrids for number of leaves/plant, leaf width, number of tillers/plant, fresh and dry yields/plot as well as total fresh and dry yields exhibited significant inbreeding depression in F_2. The magnitude of inbreeding effects varied for total fresh and dry yields from -68.25 to 32.87 % and -70.83 to 33.02 % respectively. Similar results were also reported by Sheoran *et al* (2000), Agrawal and Shrotria (2005) and Soliman (2005).

Negative and significant estimates of inbreeding effects have been observed for number of tillers/plant and dry yields/plot in first cut as well as total dry yields. Inbreeding gain may be attributed to the occurrence of transgressive segregants in the F_2 population. The formation of new gene combination as a result of segregation may lead to increase expression of the trait in the F_2 population. For those crosses, showing negative and significant inbreeding gain, there is a scope for selection of desirable plants in the F_2 population for improvement of these traits in such crosses.

Analysis of combining ability

Estimates of variance components for general (σ^2 gca) and specific (σ^2 sca) combining abilities are presented in Table (4). The relative importance of additive and non-additive gene effects can be obtained from the ratio of variance components for general to those of specific effects. Results in Table (4) cleared the predominance of variance due to sca over gca, indicating non-additive type of gene action involved for the control of all studied traits except for days to 50% flowering in the second cut.

Table 4. Estimates of variance components of combining ability of F_1 crosses for forage yield and its components in pearl millet.

Genetic parameter	Plant height		No. of leaves/plant		Stem diameter		Leaf length		Leaf width	
	Cut 1	Cut 2	Cut 1	Cut 2	Cut 1	Cut 2	Cut 1	Cut 2	Cut 1	Cut 2
σ^2 gca	0.01	3.02	0.02	0.001	0.03	0.01	3.07	0.57	0.01	0.01
σ^2 sca	167.37	80.78	0.20	0.20	0.53	0.10	56.57	6.75	0.09	0.03
σ^2sca/σ^2gca	16737.00	26.75	10.00	200.00	17.67	10.00	18.43	11.84	9.00	3.00
	No. of tillers/plant		Days to 50% flowering		Fresh yield/plot		Dry yield/plot		Total fresh yield	Total dry yield
σ^2 gca	0.12	0.01	1.83	0.10	0.47	0.02	0.01	0.01	0.66	0.02
σ^2 sca	0.23	2.58	18.25	0.00	2.71	0.13	0.17	0.31	3.34	0.23
σ^2sca/σ^2gca	1.92	258.00	9.97	0.00	5.77	6.50	17.00	31.00	5.06	11.50

σ^2 gca= general combining ability variance, σ^2 sca= specific combining ability variance.

The importance of specific combining ability variance (non-additive type of gene action) stresses the need for exploiting it production of hybrids to obtain high yielding combinations. These findings are in accordance with those reported by (Basavaraju *et al*, 1980 and Kumari *et al*, 2003) for number of tillers, (Ouendeba *et al*, 1996 , Ali *et al*, 2001 and Rohitashwa *et al*, 2006) for forage yield, (Soliman, 2005) for plant height, number of leaves/plant, leaf size, stem diameter, number of tillers/plant and dry yield

General combining ability effects

Table (5) shows the range of gca and sca effects, the best general combiners, and the best specific combinations for different traits. The female line L1 was found to be best combiner for number of leaves/plant, stem diameter, leaf length, days to 50% flowering and fresh yield/plot at both cuts as well as total fresh yield/plot over tow cuts, number of tillers/plant and plant height at second cut. The female L4 was found to be the best combiner for stem diameter, leaf width and number of tillers/plant at both cuts as well as total dry yield/plot over tow cuts, plant height, leaf length and dry yield/plot at first cut and days to 50% flowering at second cut.

Table 5. Range of gca and sca effects, the best general combining parents and the two combinations showing highest sca for different traits.

Traits	Cut	GCA				SCA	
		Female		Male			
		Range of effects	Best combiners	Range of effects	Best combiners	Range of effects	Best combinations
Plant height	1st	-2.37 to 2.69	L3 , L4	-9.16 to 8.81	T3, T10	-28.38 to 28.34	L2xT2* , L2xT1*
	2nd	-3.89 to 5.86	L1*	-13.16 to 14.57	T3**, T4**	-19.84 to 16.96	L1xT6* , L4xT5*
No. of leaves/plant	1st	-0.879 to 0.95	L1**	-0.69 to 0.85	T1, T4	-1.82 to 1.92	L3xT10* , L3xT3
	2nd	0.13 to 0.24	L1	-0.60 to 1.19	T5**, T4	-1.35 to 1.56	L1xT6* , L4xT5*
Stem diameter	1st	-0.70 to 0.48	L1*, L4*	-1.46 to 1.45	T1**, T8**	-1.45 to 2.04	L1xT8** , L3xT10*
	2nd	-0.38 to 0.39	L1*, L4	-0.91 to 0.82	T3**, T4**	-1.28 to 1.26	L2xT1* , L4xT1
Leave length	1st	-4.54 to 8.46	L1**	-7.75 to 16.65	T1**, T3**	-15.33 to 16.22	L2xT4** , L1xT8**
	2nd	-2.88 to 2.43	L1, L4*	-6.28 to 4.10	T4**, T2**	-8.13 to 6.72	L2xT4* , L4xT5**
Leave width	1st	-0.19 to 0.48	L4**	-0.297 to 0.26	T1*, T8*	-0.51 to 0.92	L1xT8** , L1xT3
	2nd	-0.10 to 0.1	L4**	-0.31 to 0.26	T3**, T2**	-0.43 to 0.34	L1xT3* , L2xT10*
No. of tillers/plant	1st	-0.95 to 1.16	L1**, L4	-2.07 to 2.84	T1**, T6**	-1.73 to 2.41	L1xT7* , L1xT6*
	2nd	-0.65 to 1.22	L3**, L4	-1.44 to 1.68	T1*, T9*	-3.38 to 4.42	L2xT1* , L4xT7*
Days to heading	1st	-3.13 to 6.4	L1**	-5.55 to 9.87	T1**, T2**	-7.57 to 7.13	L4xT6** , L2xT4**
	2nd	-1.03 to 1.28	L1**, L4	-1.94 to 2.23	T3**, T1*	-2.56 to 3.64	L1xT5* , L2xT4
Fresh yield plot^{-1}	1st	-1.01 to 2.43	L1**	-4.12 to 6.0	T1**, T2**	-4.81 to 8.41	L1xT8** , L2xT4*
	2nd	-0.56 to 0.29	L 1, L3	-1.21 to 1.43	T8**, T2*	-1.91 to 2.23	L2xT1* , L4xT3
Dry yield plot^{-1}	1st	-0.25 to 0.199	L4	-0.82 to 1.63	T2**, T1	-1.18 to 1.79	L4xT5** , L2xT4
	2nd	-0.32 to 0.18	L3	-0.78 to 0.62	T8**, T3*	-1.04 to 1.31	L3xT8** , L2xT5**
Total yield	Fresh	-1.57 to 2.65	L1**	-5.27 to 6.82	T2**, T1**	-5.55 to 9.37	L1xT8** , L2xT4*
	Dry	-0.34 to 0.28	L4, L3	-1.60 to 1.84	T2**, T8	-1.20 to 1.75	L4xT5* , L3xT2*

***,** significant at 0.05 and 0.01 respectively.**

Lines: L1= 861A, L2=ICMA98777, L3=14A, L4=17A

Testers: T1=PE00048, T2=PE00205, T3=PE00208, T4=ICMV05111, T5=ICMV05333, T6=ICMV05444, T7=87/059IPCN045, T8=87/059IPCN0293, T9=Sudan population, T10=87/059IPCN0115

Among the male parents, T2 was the best combiner for total fresh and dry yield/plot over two cuts, fresh yield/plot at both cuts and dry yield/plot at first cut as well as most of other traits. T1 showed significant positive effects on most of studied traits. T9 was low combiner for majority of the traits. It was evident that general combining ability for yield is, in general, related with the general combining ability for most of the yield components.

Specific combining ability effects

The evaluation of hybrids becomes necessary to consider whether a hybrid my be used as a commercial hybrid or further utilized in breeding programme. The specific combining ability is one of the best criteria to evaluate the hybrids. It included both dominance and epistatic effects, which can be related to heterosis.

Data obtained in Table (5) showed that the maximum sca effect for total fresh yield/plot was shown by hybrids L1 x T8 and L3 x T2. These hybrids had highest per-se performance (40.97 kg/plot and 41.15 kg/plot) for total fresh yield/plot. These involved combinations of high x low (L1 x T8) and low x high (L3 x T2) general combiners. The performance of cross combinations is largely in agreement with the combining ability of the parents involved.

Since the total fresh and dry yield along with most other component traits were found to be controlled mainly by non-additive gene action, exploitation of heterosis by crossing two parents with good general combiner my be recommended to increase fresh and dry yield. Hybrids L2 x T2 (at 1st cut), L4 x T5 and L1 x T6 (at 2nd cut) showed maximum positive sca effects for plant height. For number of tillers/plant, L1 x T6 and L1 x T7 (at 1st cut) appeared to be the most superior combinations with regard to sca effect. The previous hybrids could be of value in the future breeding program for improvement of the forage yield and its components.

REFERENCES

Agrawal, M. and P. K. Shrotria (2005). Heterosis and inbreeding depression in forage sorghum (Sorghum bicolor (L) Moench). Indian J. Genet., 65 (1): 12- 14.

Ali, A. M, C. T. Hash, A. S. Tbrahim and A. G. B. Rai (2001). Population diallel of elite medium – and long –duration pearl millet composites: I. populations and their F_1 crosses. Crop Sci. 1: 705-711.

Basavaraju,R., K. M. Safeeulla and B. R. Murty (1980). The rate of gene effects and heterosis for resistance to downy mildew in pearl millet. Indian J. Genet. 40: 112-116.

Bhanderi, S. H., C. J. Dangaria and K. K. Dhedhi (2007). Diallel analysis for yield and yield components in pearl millet. Asian J. Bio Sci. 2 (1/2): 162-166.

Bidinger, F. R., O. P. Yadav, M. M. Sharma, E. J. Van Oosteram and Y. P. Yadava (2003) Exploitation of heterosis for simultaneous improvement in both grain and stover yields of arid zone pear millet (*Pennisetum glaucum* L). Field Crops Res. 83:13-26.

Desai S. A., R. Singh and P. K. Shrotria (2000). Variability and heterosis for forage yield and its component in interspecific hybridization of forage sorghum. Karnataka J. Agric. Sci. 13: 315- 320.

Gomez, K. A. and A. A. Gomez (1984). Statistical Procedures for Agricultural Research. 2nd Ed., Jone Wiley and Sons Inc., New York, pp: 95-109.

Hallauer, A. R. and J.B. Miranda (1988). Quantitative Genetics in Maize Breeding 2nd Ed., Iowa State univ. press, Ames, Iowa.

Hanna, W. W., S. K. Gupta (1999). Breeding for forage. In: Khairwal, I.S., Rai, K.N., Andrews, D.J., Harinarayana, G. (Ed.), Pearl Millet Breeding. Oxford/IBH, New Delhi, India, pp. 303-316.

Karad, S. R. and P. N. Harer (2004). Heterosis in pearl millet (*Pennisetum glaucum* L.). Mysore J. Agric. Sci. 38 (1):19-24.

Kempthorne, O. (1957). An Introduction to Genetic Statistics. John Wiley and Sons., Inc., New York.

Kumari, B. M., G. Nallathambi and P. Nagarajan (2003). Combining ability analysis for yield and its components in pearl millet (*Pennisetum glaucum* (L) R. Br.). Madras Agric. J. 90 (1-3): 25-28.

Nawar, A. A., M. K. Gomana and M. S. Reddy (1979). Heterosis and combining ability in maize. Egyptian J. Genet. and Cytol. 9: 255-267.

Ouendeba, B., W. W. Hanna, G. E. Nyquist and J. B. Santini (1996). Forage yield and digestibility of African pearl millet landraces in diallel with missing cross. Crop Sci. 36: 1517-1520.

Presterl, T. and E. Weltzien (2003). Exploiting heterosis in pearl millet for population breeding in arid environments. Crop Sci. 43:767-776.

Rathore, V. S., D.i. Singhania and M.I. Jakhar (2004). Combining ability of diverse restorers of pearl millet (*Pennisetum glaucum* (L.) R. Br.) for grain yield and its components. Indian J. Genet. 64 (3): 239-240.

Rohitashwa, R. V. Singh and O. P. Khedar (2006). Genetic variability for dry fodder yield in pearl millet (*Pennisetum glaucum* (L) R. Br). Crop Res. Hisar 31(2): 250-252.

Shanmuganathan, M. and A. Gopalan (2006). Genetic component analysis in pearl millet for dual purpose. International J. Agric. Sci. 2 (2): 519-521.

Sheoran R. K., O. P. Govila and B. Singh (2000). Genetic architecture of yield and yield contributing traits in pearl millet. Annals Agric. Res. 21: 443-445.

***Shull*, G. H. (1914).** Duplicate genes for capsule form in bursa Bursa nastosis. Zeitsch. Induktiv Abstamm–u. Vererbunglehana. 12: 97-149.

Singh, R. K. and B. D. Chaudhary (1985). Biometrical Methods in Quantitative Genetic Analysis. Kalyani publishers, New Delhi, 205-214.

Soliman, A. M. (2005). Heterosis and combining ability for forage yield and its components in pearl millet (*Pennisetum glaucum* L.). Egypt. J. Plant Breed. 9 (1): 147-159.

Yadav, O. P., E. Weltizine, V. Mahalakshmi and F. R. Bidinger (2000). Combining ability of pearl millet landraces originating from arid areas of Rajasthan. Indian J. Genet. 60(1): 45-53.

قوة الهجين والقدرة على التآلف والتربية الداخلية لمحصول العلف ومكوناته فى الدخن

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أجريت هذه الدراسه بهدف تقدير وتقييم قوة الهجين والقدره العامه والخاصه على التآلف لتحديد أهم هجن الجيل الأول الناتجه من التهجين بين أربع سلالات عقيمه الذكرمن الدخن مع عشر كشافات معيده للخصوبه ، وبيان تأثير التربيه الداخليه فى الجيل الثانى لهذه الهجن لذلك تم تقييم الأباء (السلالات والكشافات) والهجن الناتجه منها فى الجيل الأول والثانى فى تجربه بنظام القطاعات كاملة العشوائيه خلال موسم ٢٠٠٨ فى محطة التجارب الزراعيه بكلية الزراعه جامعة القاهره . وتم حش النباتات حشتين ، وفى كل حشه تم تسجيل القياسات موضع الدراسه لصفات عدد الأيام حتى ٥٠ % تزهير ، طول النبات ، عدد الاوراق / النبات ، طول وعرض الورقه ، قطر الساق ، عدد الافرع / النبات ، المحصول الأخضر والجاف / القطعه والمحصول الأخضر والجاف للحشتين معا.

وقد أظهرت نتائج تحليل التباين وجود فروق معنويه بين المصادر الوراثيه لجميع الصفات موضع الدراسه ، وفروق معنويه عاليه بين الأباء والهجن الناتجه منها لمعظم الصفات دلاله على قوة الهجين وقد أكد ذلك الإرتفاع المعنوى لمتوسطات نباتات الجيل الأول مقارنه بأبائها لجميع الصفات ما عدا عدد الأيام حتى ٥٠ % تزهير.

وكانت أكبر قيمه لقوة الهجين بالنسبه لمتوسط الأبوين لصفات طول النبات ، عدد الأفرع / النبات فى الحشه الأولى ، المحصول الأخضر والجاف فى الحشه الأولى والثانيه كما سجلت الهجن أعلى قوة هجين معنويه مقارنه بمتوسط الأب الأعلى لصفات المحصول الأخضر والجاف للحشتين معا.

وكان الهجين 861 A x 87/059IPCNo293 هو الأعلى فى قوة الهجين بالنسبه للأب الأعلى لصفة المحصول الأخضرفى الحشه الأولى والثانيه. وقد كان تأثير التربيه الداخليه على الهجن معنوى موجب لصفات عدد الأوراق / النبات ,قطر الساق ,طول وعرض الورقه فى الحشتين والمحصول الجاف / القطعه فى الحشه

الثانية . والمحصول الاخضر / القطعه فى الحشه الاولى . وأوضحت النتائج أن الهجن التى سجلت قيم عالية المعنويه لقوة الهجين بالنسبه لتلك الصفات سجلت ايضا قيم عالية المعنويه لتأثير التربيه الداخليه لنفس الصفات.

وقد أظهرت نتائج تحليل القدره على التآلف ان التباين الراجع إلى القدره الخاصه على التآلف أعلى من التباين الراجع للقدره العامه لجميع الصفات موضع الدراسه ماعدا عدد الايام حتى ٥٠% تزهير.

وقد تم تحديد افضل السلالات والكشافات ذات القدره العامه على التآلف , وكذا أفضل الهجن ذات القدره الخاصه على التآلف لجميع الصفات موضع الدراسه من خلال حساب تأثيرات القدره العامه والخاصه على التآلف . حيث إتضح أن السلالاتين A 861 ,17A وكذا الكشافين PE00205 , PE00048 هى الأباء الأفضل فى القدره العامه على التآلف لغالبية الصفات تحت الدراسه.

كما اظهرت النتائج ايضا ان افضل الهجن التى سجلت أعلى تأثير معنوى للقدره الخاصه على التآلف مصحوبه بقوة هجين عالية المعنويه بالنسبه للصفات الأكثر أهميه هى 861 A x 87/059IPCNo293 , ICMA98777 x ICMV05111 لصفة المحصول الاخضر للحشتين معا.

وكذلك الهجنين 14A x PE00205 , 17A x ICMV05333 لصفة المحصول الجاف للحشتين معا.