Proceed. Fourth Pl. Breed. Conf. *Egypt. J. Plant Breed 9(1): 147-159*
March 5, 2005 (Ismailia) *Special Issue (2005)*

HETEROSIS AND COMBINING ABILITY FOR FORAGE YIELD AND ITS COMPONENTS IN PEARL MILLET (*Pennisetum glaucum* L.)

A.M.Soliman

Agronomy Department, Faculty of Agriculture, Cairo University, Giza

ABSTRACT

Seven pollen parents of pear millet were crossed with five male-sterile lines. The twelve parents, 35 F_1's and 35 F_2's were grown to evaluate heterosis and combining ability for forage yield and its components. Significant differences among parents were observed for all characters except tillers plant^{-1} at 1st cut, and for all traits except leaf width at both cuts and tillers plant^{-1} at first cut among crosses. The same was true for the F_2 for all studied traits. Mean performance of F_1's was high for all traits except days to heading at both cuts. Significant positive heterosis was observed for all traits at both cuts except tillers plant^{-1} at 1st cut. Highly significant inbreeding depression was recorded for all traits except days to heading at 2nd cut. Most of hybrids exhibited increased plant height as compared to their mid and superior parent. The highest heterosis, 79.36 and 41.90% over mid and superior parent respective were observed in the cross CMA923333 x IPC90 at first cut. The same cross showed highest heterosis (70.47%) and heterobeltiosis (30.26%) in 2nd cut. Inbreeding depression values for plant height ranged from –4.69 to 28.85% at first cut and from –21.44 to 32.02% at 2nd cut. Hybrids, CMA89111 x POP1 at 1st cut and CMA98777 x IPC45 at both cuts showed highest and significant positive inbreeding depression for this trait. For tillers plant^{-1}, the highest heterosis over mid and superior parent was observed in CMA89111 x IPC293 at first cut; and in CMA89111 x IPC115 at 2nd cut. The inbreeding depression of two crosses was significant positive for tillers plant^{-1} at 2nd cut. From 22 to 33 crosses showed significant positive heterosis for fresh and dry weights at both cuts and for total fresh and dry weights. The number of crosses, which showed significant positive heterobeltiosis, ranged from 12 crosses for fresh and dry weights at 1st cut to 28 crosses for fresh weight at 2nd cut. Eight crosses showed significant positive heterobeltiosis in fresh and dry wt. at both cuts and total fresh and dry wt. The hybrid CMA89111 x IPC293 had shown highest significant heterosis for dry wt. at 2nd cut (460.16%), fresh wt. at 1st cut (287.91%), and dry wt. at 1st cut (273.62%), followed by hybrid CMA92333 x IPC2935 that had shown for total fresh wt. (218.26%) and for fresh wt. at 1st cut (203.39%). The same crosses had shown highest significant heterobeltiosis for fresh and dry wt. at 2nd cut and total fresh yield. The variance due to specific combining ability was larger than general combining ability for all studied traits except fresh yield at 2nd cut. The female line CMA89111 was best combiner for total dry wt., dry wt. at first cut and also it was good combiner for total fresh wt., fresh wt. , and tillers plant^{-1} at both cuts, plant height, leaves plant^{-1} and stem diameter at first cut and dry wt. at *second cut. The male parents, IPC45, IPC90 and IPC115 were the best combiners for total fresh and dry wts., fresh and dry wts. at both cuts, and most other traits. Hybrids CMA92333 x IPC293 and CMA92333 x IPC90 had highest sca effects for total fresh yield and showed high sca effects for fresh yield at first cut.*

Key words: ***Pear millet, Crosses, Heterosis, Combining ability, Inbreeding depression, Forage yield***

INTRODUCTION

Pearl millet is used as forage for livestock in Egypt and any improvement in forage yield would be desirable. In some forage species forage yield can be increased by capitalizing on the heterosis obtained in hybrids (Sleper 1987). Most breeding procedures used in pearl millet are aimed to maximum exploitation of hybrid vigor for both grain and forage yields (Gupta and Gupta1971, Ouendeba *et al*1993, Yadav *et al* 2000, Bidinger *et al* 2003, Presterl and Weltzien 2003, Siles *et al* 2004).

Hybrids from elite pearl millet parents produce more forage than common, open pollinated cultivars (Borton 1968, Harza and Shukla 1998). Karad and Harer (2004) reported significant heterosis in fodder yield up to 251.9 %. The discovery of male sterility in millet made the commercial production of hybrid seed practical and made it necessary to isolate inbred lines that will contribute favorable genes, or combinations of genes, for yield and other agronomic traits to the hybrids. Information about heterotic pattern and combining ability would be helpful in the development of a successful breeding program. The objective of this study were to evaluate heterosis and combining ability for forage production and identify parents that could be used to develop improved hybrids varieties.

MATERIALS AND METHODS

The materials used for this study were five male-sterile (A) lines, viz., CMA89111 (A1), CMA92111 (A2), CMA92333 (A3), CMA96111 (A4) and CMA98777 (A5), five restorer parents i.e. IPC26 (P1), IPC45 (P2), IPC90 (P3), IPC115 (P4), IPC293 (P5), kindly supplied by the International Crops Research Institute for the Semi Arid Tropics (ICRISAT) in India, in addition to two populations one (P6) from Sudan and the other (P7) from Yemen. (A) lines were crossed in 2001 with the seven pollen parents. F_2 seed was produced in 2002 by selfing few plants from each cross.

In 2003, the twelve parents (seven males and five fertile counterparts of the male-sterile female lines), 35 F_1's and 35 F_2's were planted on 25 May at the Experimental and Research Station of the Faculty of Agriculture, Cairo University at Giza in a randomized complete block design (RCBD) with four replications. Plot were single rows for parents and F_1's and two rows for the F_2's. Rows were 4m long and 50cm wide with single-plant hill spaced 25cm apart. Hills were overseeded thin thinned to one plant hill^{-1} after complete emergence. Recommended cultural practices were followed. Pants were cut twice to a stubble height of 15cm shortly after the onset of heading.

Observations were recorded on five guarded plants from each row in each replication for days to heading, number of tillers plant^{-1}, plant height, stem diameter measured at the center of fourth internode, number of leaves stem^{-1}, maximum length and width of the 5th leaf from plant top, fresh and dry weight of fodder for each cut and total fresh and dry fodder weights for both cuts.

Data of plot means were subjected to a regular analysis of variance of RCBD according to Steel and Torrie (1980). The degrees of freedom and sum of squares due to genotypes were further partitioned in to parents, F_1's and F_2's, parents vs. (F_1 + F_2) and F_1 vs. F_2. Also, sum of squares for hybrids was partitioned to general combining ability (gca) of male and female parents, and specific combining ability (sca) resulting from female x male interaction according to the method employed by Beil and Atkins (1967). The gca effects of parents and sca of crosses were calculated as shown in the same reference. F_1 heterosis was calculated for each cross as the difference between the cross performance and the mean of its parents (mid-parent). Heterobeltiosis was, also computed as the difference between cross means and the mean of the higher parent. Inbreeding depression (ID) in the F_2 was computed for each cross as: (mean of F_1 - mean of F_2) x 100 / (mean of F_1). Significance of heterosis and inbreeding depression was tested by appropriate least significant differences.

RESULTS AND DISCUSSION

The analysis of variance revealed highly significant differences for all the traits among the entries evaluated (Table 1). The mean squares due to parents also differed significantly for all characters except tillers plant^{-1} at 1st cut indicating great deal of diversity. Differences among F_1 crosses were highly significant for all traits except leaf width at both cuts and tillers plant^{-1} at first cut (Table 1). The same was true for the F_2 for all studied traits. Highly significant differences were also observed for the comparisons indicating heterosis, viz., parents vs. (F_1 + F_2) for all traits except leaf length at 2nd cut and leaf width at st cut; and for F_1 vs. F_2 for all characters indicating inbreeding effect.

Table 1. Mean squares from ANOVA analysis for 12 parents, their F_1 crosses and F_2's for studied traits.

S.V	df	Days to heading		Plant height		Leaves plant^{-1}		Leaf length		Leaf width	
		I	II	I	II	I	II	I	II	I	II
Genotypes	81	32.59**	15.34**	4816.0**	1292.35**	5.08**	1.61**	524.82**	119.93**	0.904**	0.44**
Parents(P)	11	75.0**	62.48**	11609.11**	3924.9**	13.2**	3.5**	876.7**	929.25**	2.44**	1.23**
Crosses(F_1)	34	32.53**	26.81**	2425.7**	782.89**	2.46**	0.97**	206.63**	85.59**	0.32	0.12
Males (M)	6	58.43**	57.27**	4642.25**	149.72**	3.7	1.4**	384.97**	160.8*	0.43**	0.2*
Females(F)	4	34.2**	23.43*	2263.0**	740.8**	3.2	1.1*	256.3**	73.4	0.55**	0.12
M x F	24	25.78**	19.75**	1898.67**	610.7**	2.03	0.84**	153.77**	68.84	0.26**	0.1
F_2	34	14.17**	11.83**	1528.93**	520.79**	2.57**	1.27**	267.82**	71.2**	0.51**	0.47**
P vs.(F_1+F_2)	1	167.63**	143.08**	73451.44**	13228.73**	37.97**	9.69**	272.7**	8.56	0.34	1.6**
F_1 vs. F_2	1	58.51**	51.78**	54489.2**	3952.5**	57.5**	5.8**	16462.9**	889.29**	17.8**	0.48**
Error	243	7.55	6.89	288.29	141.3	0.99	0.36	44.23	42.33	4.13	0.09

Table 1. Cont.

S.V	Df	Stem diameter .		Tillers plant^{-1}		Fresh yield		Dry yield		Total yield	
		I	II	I	II	I	II	I	II	fresh	dry
Genotypes	81	11.79**	2.70**	1.71**	5.66**	214888.6**	43974.2**	47335.5**	8448.2**	392476.4**	83620.43**
Parents(P)	11	40.03**	8.11**	1.62	7.01**	412476.83**	24674.05**	28734.67**	2418.63**	614441.67**	45690.77**
Crosses(F_1)	34	5.25**	1.29**	0.62	3.41**	157066.05**	22869.1**	45876.19**	8023.05**	243255.43**	82809.8**
Males (M)	6	8.87**	1.96*	0.9	4.87	263427.68**	33466.07	76424.14**	11791.75**	410357.53**	133767.19**
Females(F)	4	5.98	1.45	0.7	3.3	172870.6**	23847.65	48416.55**	8946.3*	245335.79**	88584.48**
M x F	24	4.23*	1.09	0.52	3.06	127841.53**	20056.76	37815.81**	6926.99**	201133.13*	69108.01**
F_2	34	6.86**	1.84**	0.6**	1.8**	83431.06**	13212.67**	11007.4**	4217.57**	121747.7**	18379.95**
P vs.(F_1+F_2)	1	29.86**	0.23	5.06**	9.72**	22826643.1**	598773.68**	224483.27**	159269.27**	6165869.2**	753816.99**
F_1 vs. F_2	1	72.52**	22.69**	62.23**	197.06**	1769987.6**	1464942.9**	1359567.8**	82251.48**	6455750.9**	2076387.7**
Error	243	2.99	0.70	0.6	1.92	48698.96	6768.79	6384.1	1858.6	71912.4	10325.82

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

Over all performance, heterosis and inbreeding depression

The mean performance of parents, F_1's ,F_2's and the percent of heterosis and inbreeding depression for the studied traits are given in Table 2. Mean performance of F_1's had 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. Significant positive heterosis was observed for all traits at both cuts except tillers plant^{-1} at 1st cut. However, significant negative heterosis was obtained for days to heading at 1st and 2nd cuts. Highly significant inbreeding depression was recorded for all traits except days to heading at 2nd cut.

Table 2. Mean performance of parents, F_1's ,F_2's and the percent of heterosis and inbreeding depression (I.D.)for the studied traits.

Trait	Cut	Parents Mean	F_1's Mean	F_2s Mean	Heterosis %	I.D. %
Days to heading	I	75.71	74.14	73.23	-2.07**	1.23**
	II	68.45	67.05	66.50	-2.05**	0.67
Plant height cm	I	165.9	222.10	194.20	33.88**	12.56**
	II	95.88	117.60	110.10	22.65**	6.38**
Leaves plant^{-1}	I	11.11	11.92	8.41	7.29**	29.45**
	II	6.65	6.28	5.99	11.15**	4.62**
Leaf length cm	I	67.42	77.66	62.32	15.1**	19.75**
	II	40.65	42.88	39.32	5.49*	8.30**
Leaf width cm	I	3.70	4.05	3.55	9.46	12.35*
	II	2.31	2.55	2.47	10.39**	3.14*
Stem diameter. mm	I	9.77	11.10	10.10	13.61**	9.01**
	II	6.09	6.45	5.88	5.91*	8.84**
Tillers plant^{-1}	I	4.02	4.14	3.20	2.99	22.71**
	II	4.25	5.51	3.83	29.65**	30.49**
Fresh wt. g. plant^{-1}	I	600.84	947.47	788.44	57.69**	16.78**
	II	151.53	344.77	[illegible]	127.53**	41.82**
Dry wt. g. plant^{-1}	I	204.46	348.11	208.79	70.26**	40.02**
	II	50.84	129.93	95.68	157.39**	26.36**
Total wt. g. plant^{-1}	Fresh	752.39	1292.24	988.50	71.75**	23.50**
	Dry	245.92	476.71	304.45	3.85**	36.14**

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

Heterosis in specific crosses

The range for mid-parent heterosis, heterosis relative to the higher parent (heterobeltiosis), inbreeding depression and number of hybrids showing significant heterosis in desirable direction are presented in Table 3. Large estimates of heterosis was expressed for dry and fresh weight plant^{-1} at 2nd cut, total dry weight, dry and fresh weight at 1st cut, total fresh weight, tillers plant^{-1} at 2nd cut, plant height at 1st cut, stem diameter at 1st cut, and plant height at 2nd cut. The lowest estimates of heterosis were recorded for days to heading, leaves plant^{-1} at both cuts, leaf length and width at first and second cuts.

Table 3: Range of heterosis, heterobeltiosis, inbreeding depression (I.D.) and number of crosses showing significant heterosis in desirable direction in pear millet.

Trait	Cut	Heterosis		Heterobeltiosis		I.D.	
		Range	no.	range	no.	range	no.
Days to Heading	I	-9.21 to 7.88	5	-12.61 to 4.30	0	-7.29 to 11.20	3
	II	-11.05 to 9.16	6	-13.14 to 6.87	1	-9.13 to 13.40	6
Plant Height cm.	I	4.23 to 79.36	33	-20.71 to 14.90	15	-4.69 to 28.85	20
	II	-6.81 to 70.47	27	-22.43 to 30.26	6	-21.44 to 32.02	7
Leaves Plant^{-1}	I	-15.42 to 32.99	18	-19.14 to 26.11	4	15.37 to 51.44	35
	II	-8.14 to 32.58	18	-16.67 to 25.00	3	-26.93 to 30.36	6
Leaf Length cm	I	-5.93 to 43.10	24	-19.21 to 25.54	5	3.07 to 41.03	30
	II	-24.37 to 38.04	5	-29.63 to 19.21	0	-22.93 to 36.24	4
Leaf width cm.	I	-5.66 to 48.33	0	-19.34 to 29.93	0	-1.86 to 33.14	0
	II	-15.25 to 34.69	20	-20.63 to 14.61	0	-27.71 to 31.07	8
Stem Dia. Mm.	I	-12.24 to 77.03	13	-29.11 to 41.31	3	-13.62 to 41.00	7
	II	-12.21 to 33.67	10	-20.97 to 6.56	0	-12.64 to 33.58	9
Tillers Plant^{-1}	I	-23.17 to 43.31	4	-33.50 to 37.88	2	-11.23 to 47.65	14
	II	-53.67 to 95.65	14	-60.40 to 80.00	4	-4.00 to 65.83	14
Fresh wt. g. plant^{-1}	I	-19.09 to 203.98	22	-47.76 to118.30	12	-38.03 to 47.12	8
	II	17.98 to 287.91	33	-13.46 to 231.46	28	10.23 to 67.65	21
Dry wt. g. plant^{-1}	I	-29.49 to 234.81	23	-46.10 to 175.70	12	-40.94 to 68.97	19
	II	24.98 to 460.16	24	-3.95 to 388.09	17	-33.65 to 66.39	8
Total wt. g. plant^{-1}	Fresh	-5.69 to 218.26	26	-32.84 to 135.47	15	-16.54 to 47.79	14
	Dry	-6.25 to 273.62	26	-30.36 to 197.02	18	-27.56 to 65.04	18

Most of hybrids exhibited increased plant height as compared to their mid and superior parent, with 33 and 15 hybrids at 1st cut; 27 and 6 hybrids at 2nd cut showing significant positive heterosis and heterobeltiosis, respectively. The highest heterosis, 79.36 and 41.90% over mid and superior parent, respectively, were observed in the cross A3 x P3 at first cut. The same cross showed highest heterosis (70.47%) and heterobeltiosis (30.26%) in 2nd cut. Positive heterosis over mid and better parent for plant height was also shown by Lal and Singh (1968), Ouendeba *et al* (1993) and Karad and Harer (2004). Inbreeding depression values for plant height ranged from –4.69 to 28.85% at first cut and from –21.44 to 32.02% at 2nd cut. Among the crosses, 20 at 1st cut and six at 2nd cut showed significant positive inbreeding depression for plant height. Hybrids, A1 x P6 at 1st cut and A5 x P2 at both cuts showed highest and significant positive inbreeding depression for this trait. The highly significant reduction in plant height in the F_2 is due to the presence of large dominance gene effects in the expression of this character (Lal and Singh 1968).

For tillers plant^{-1}, four crosses at 1st cut and 14 crosses at 2nd cut showed significant positive heterosis; and two crosses at 1st cut and four crosses at 2nd cut exhibited significant positive heterobeltiosis. The highest heterosis over mid and superior parent was observed in A1 x P5 i.e. 43.31

and 37.88% at first cut; and in A1 x P4 i.e. 95.65 and 80.00% at 2nd cut, respectively. The inbreeding depression of two crosses was significant positive at 2nd cut. Lal and Singh (1968) observed similar results.

All crosses showed positive heterosis for fresh and dry weight at 2nd cut (Table 3). The majority of crosses exhibited positive heterosis for fresh and dry weight at 1st cut, and for total fresh and dry yields. Among the crosses, from 22 to 33 crosses showed significant positive heterosis for fresh and dry weights at both cuts and for total fresh and dry weights. The number of crosses, which showed significant positive heterobeltiosis, ranged from 12 crosses for fresh and dry weights at 1st cut to 28 crosses for fresh weight at 2nd cut (Table 3). Eight crosses showed significant positive heterobeltiosis in fresh and dry wt. at both cuts and total fresh and dry wt. (data not shown).

Highest magnitude of heterosis over mid and superior parent observed in fresh and dry wt. at both cuts and total fresh and dry wt. The hybrid A1 x P5 had shown highest significant heterosis for dry wt. at 2nd cut (460.16%), for fresh wt. at 1st cut (287.91%), for dry wt. at 1st cut (273.62%), followed by hybrid A3 x P5 218.26% for total fresh wt. and 203.39% for fresh wt. at 1st cut. The same crosses had shown highest significant heterobeltiosis for fresh and dry wt. at 2nd cut and total fresh yield.

It was noticed that the hybrids having significant heterosis for forage yield also had significant heterosis for one or more characters i.e. plant height and tillers plant^{-1}. This indicated that the heterosis for forage yield seems to be influenced by heterosis for one or more important components of the yield. Similar results were reported by Ahluwalia and Patnaik (1963) and Karad and Harer (2004). High heterosis in F_1 was sometimes accompanied by high inbreeding depression in F_2. Most F_1 crosses showed positive heterosis for forage yield coupled with positive inbreeding depression in the F_2 indicating a major role for non-additive gene effects in heterosis. Lal and Singh (1968) found similar results.

Combining ability

Estimates of variance components for general and specific combining ability for all traits from analysis of variance are given in Table 4. An estimate of the relative importance of the additive and non-additive effects of genes can be obtained from the ratio of the components of variance for general to those of specific effects. The variance due to specific combining ability was larger than general combining ability for all studied traits except fresh yield at 2nd cut indicating that non-additive gene effects were involved in the inheritance of these traits. These results agreed with the

Table 4. Estimates of components of combining ability of F_1 crosses for studied traits.

S.V	Days to heading		Plant height		Leaves plant^{-1}		Leaf length		Leaf width	
	I	II	I	II	I	II	I	II	I	II
$^{2}_{f}$	0.3	0.13	13.01	4.65	0.04	0.01	3.66	0.16	0.01	0.001
$^{2}_{m}$	1.63	1.88	137.18	44.45	0.08	0.03	11.56	4.60	0.01	0.01
$^{2}_{fxm}$(sca)	4.07	3.05	426.4	108.77	0.01	0.11	30.67	0.69	0.04	0.01
$^{2}_{gca}$	0.1	0.1	7.72	2.52	0.01	0.002	0.77	0.25	0.001	0.00
$^{2}_{sca/gca}$	41.15	29.48	55.21	43.10	1.97	59.32	39.85	2.82	41.77	17.06

Table 4. Cont.

S.V	Stem dia.		Tillers plant^{-1}		Fresh yield		Dry yield		Total yield	
	I	II	I	II	I	II	I	II	fresh	Dry
$^{2}_{f}$	0.06	0.01	0.01	0.01	1608.18	135.39	378.6	72.12	1578.67	695.59
$^{2}_{m}$	0.23	0.04	0.02	0.09	6779.31	670.47	1930.42	243.24	10461.22	3232.96
$^{2}_{fxm}$(sca)	0.42	0.06	0.02	0.09	16409.28	6.03	7497.44	1009.57	20670.8	13388.38
$^{2}_{gca}$	0.02	0.003	0.001	0.005	428.29	41.22	118.13	16.06	617.31	200.80
$^{2}_{sca/gca}$	27.63	20.90	12.08	17.17	38.31	0.15	63.47	82.85	33.49	66.67

findings of Borton (1959) for forage yield; Murty *et al* (1967) for tillers plant^{-1}; Gupta and Gupta (1971) for green fodder yield, plant height, leaves plant^{-1}, and stem thickness; Upadhyay and Murty (1971) for days to 50% flowering and plant height; Ouendeba *et al* (1996) for dry forage yield; Ali *et al.* (2001) for forage yield.

However, fresh yield at 2nd cut recorded higher ratio of gca/sca variances meaning that additive gene effects were of considerable magnitude for this trait. Lynch *et al.* (1995) for forage yield reported similar results.

General combining ability effects

Table 5 shows the range of gca and sca effects, the two best general combiners, and two best specific combinations for different traits. The female line A1 was found to be best combiner for total dry wt., dry wt. at first cut and also it was good combiner for total fresh wt., fresh wt., and tillers plant^{-1} at both cuts, plant height, leaves plant^{-1} and stem diameter at first cut and dry wt. at second cut. The female A5 had a significant positive effect on total dry wt., dry wt. and leaf length at second cut, and it had highly significant positive effect for plant height and leaves plant^{-1} at second cut.

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

Trait	Cut	Gca				Sca	
		Female		Male		Range of effects	Best combinations
		Range of effects	Best combiners	Range of effects	Best combiners		
Days to heading	I	-1.25 to 1.50	A2*, A3	-1.99 to 3.66	P4**, P2**	-3.35 to 3.21	A3XP5*, A2XP2
	II	-1.14 to 0.95	A3 , A5	-2.14 to 1.80	P2*, P7*	-3.01 to 2.69	A1XP2, A4XP3
Plant height cm.	I	-9.64 to 9.14	A5**,A1	-42.34 t 22.21	P3**, P4**	-28.84 to 32.71	A3XP4**, A5XP1
	II	-6.99 to 3.90	A3, A5	-23.95 to 9.40	P2**, P7*	-13.26 to 15.64	A4XP4*, A5XP1*
Leaves plant^{-1}	I	-0.58 to 0.38	A5, A3	-0.85 to 0.61	P4, P5	-1.26 to 1.31	A3XP5, A3XP7
	II	-0.17 to 0.29	A5*, A2	-0.46 to 0.27	P5*, P3	-0.71 to 0.90	A1XP7**,A1XP5
Leaf length cm.	I	-6.16 to 3.76	A4**, A1	-11.71 to 4.89	P7**, P2**	-6.10 to 4.70	A3XP5, A5XP3
	II	-1.12 to 0.89	A5, A3	-5.06 to 3.57	P7*, P2*	-7.85 to 4.79	A5XP4, A1XP5
Leaf width. cm.	I	-0.18 to 0.28	A3**, A4*	-0.27 to 0.13	P1, P7	-0.33 to 0.37	A5XP2*, A3XP4*
	II	-0.05 to 0.06	A3, A4	-0.18 to 0.15	P2*, P4	-0.21 to 0.23	A1XP5, A2XP6
Stem dia. mm.	I	-0.53 to 0.76	A3*, A4	-1.71 to 0.52	P4, P2	-1.48 to 1.85	A5XP2*, A2XP5
	II	-0.31 to 0.19	A2, A4	-0.38 to 0.47	P4*, P5	-0.88 to 1.02	A4XP4*, A2XP5
Tillers plant^{-1}	I	-0.25 to 0.20	A1, A2	-0.27 to 0.20	P1, P5	-0.63 to 0.48	A4XP4, A1XP7
	II	-0.21 to 0.28	A1, A2	-0.42 to 0.48	P3, P6	-1.65 to 2.10	A1XP7*, A5XP6*
Fresh wt. g. plant^{-1}	I	-87.74 to111.78	A3*, A1	-242.82 to 139.04	P3*, P5*	-271.62 to 273.40	A3XP5*, A3XP3
	II	-35.05 to 28.04	A5, A4	-73.34 to 36.34	P7, P3	-78.49 to 155.16	A5XP6* ,A4XP4
Dry wt. g. plant^{-1}	I	-41.40 to 52.05	A1**, A5	-131.26 to 92.50	P3**, P2**	-133.62 to 183.34	A1XP5**,A1XP7**
	II	-01.25 to 01.50	A5*, A1	-43.31 to 22.10	P2, P3	-56.42 to 74.12	A1XP5**,A5XP6**
Total wt. g. plant^{-1}	Fresh	-77.76 to105.43	A3, A1	-316.15 to 173.20	P3*, P2	-334.03 to 355.32	A3XP5*, A3XP3
	Dry	-48.05 to 60.38	A1**, A5*	-173.24 to 106.29	P3**, P2*	-172.56 to 258.49	A1XP5**,AXP7**

*,** had significant positive effects at 0.05 and 0.01, respectively.

Among the male parents, P2, P3 and P4 were the best combiners for total fresh and dry wts., fresh and dry wts. at both cuts and most of other traits. P6 and P7 were moderate combiners for most of yield components. P1 was low combiner for majority of the traits. It is 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.

Based on ranking of all crosses for total fresh yield, which is controlled by non-additive gene action (Table 3), reached it maximum sca effects in hybrids A3 x P5 and A3 x P3. These hybrids had highest per se performance (1874.1 and 1884.4 g plant^{-1}) for total fresh yield. Further, these crosses also showed high sca effects for fresh yield at 1st cut. Theses crosses involved combinations high x high (A3 xP3) and high x low (A3 x P5) general combiners. The performance of cross combinations is, therefore, 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 combining ability, my be recommended to increase fresh and dry yield. Hybrids A3 x P4 and A5 x P1 (at 1st cut), A5 x P1 (at both cuts) and A4 x P4 (at 2nd cut) showed maximum positive sca effects for plant height. For tillers plant^{-1}, A4 x P4 and A1 x P7 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

Ahluwalia, M. and M.C.Patnaik (1963). A study of heterosis in pearl millet. Indian J.Genet. Plant Breed. 23(1): 34-39.

Ali, A.M., C.T.Hash, A.S.Tbrahim and A.G.B.Raj (2001). Population diallel of elite medium-and long-duration pearl millet composites: 1. Populations and their F_1 crosses. Crop Sci.41: 705 711.

Beil, G.M. and R.E. Atkins (1967). Estimates of general and specific combining ability in F_1 hybrids for grain sorghum yield and its components in grain sorghum. *Sorghum bicolor* pres. Crop Sci., 7:225-228.

Bidinger, F.R., O.P.Yadav, M.M.Sharma, E.J.V.Oosterom and Y.P.Yadav (2003). Exploitation of heterosis for simultaneous improvement in both grain and stover yield of arid zone pearl millet (*Pennisetum glaucum* (L.)R.Br.). Field Crops Research. 83: 13-26.

Burton, G.W (1959). Breeding methods for pearl millet (*Pennisetum glaucum*) indicated by genetic variance component studies. Agron. J. 51: 479-481.

Burton, G.W (1968). Heterosis and heterozygosis in pearl millet forage production. Crop Sci., 8:229-230.

Gupta, S.P. and V.P.Gupta (1971). Combining ability for green fodder characters in pearl millet. Indian J.Genet. Plant Breed. 31(1): 36-42.

Hazra, C.R. and G.P.Shukla (1998). Recent research advancement in forage pearl millet improvement programme. Forage Res., 24 (3): 147-151.

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

Lal, S. and D. Singh (1968). Heterosis and inbreeding depression in components of grain and fodder yield in pearl millet. Indian J. Genet. Plant Breed. 28: 190-195.

Lynch, P.J., E.W.Rattunde, and K.J.Frey (1995). Inheritance of vegetative growth index and related traits in pearl millet. Crop Sci. 35: 394-396.

Murty, B.R., J. L.Tiwari and G.Harinarayana (1967). Line x tester analysis of combining ability and heterosis for yield factors in *Pennisetum typhoides* (Burm.) S.&H. Indian J.Genet. Plant Breed. 27(2): 238-245.

Ouendeba,B., G.Ejeta, W.E.Nyquist W.W.Hanna, and A.Kumar (1993). Heterosis and combining ability among African pearl millet landraces. Crop Sci. 33: 735-739.

Ouendeba,B., W.W.Hanna, G.Ejeta, W.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.Weltziem (2003). Exploitation of heterosis in pearl millet for population breeding in arid environments. Crop Sci. 43: 767-776.

Siles, M.M., W.K. Russell, D.D. Baltensperger, L.A. Nelson, B. Johnson, L. D. V. Vleck, S.G. Jensen and G. Hein (2004). Heterosis for grain yield and other agronomic traits in foxtail millet. Crop Sci. 44: 1960-1965.

Sleper, D.A (1987). Forage grasses. P. 161-208. In W.R.Fehr (ed.) Principles of cultivar development. Vol. 2. Crop species. Macmillan Publishing Co., New York.

Steel, R.G.D. and J.H.Torrie (1980). Principles and Procedures of Statistics. Abiometerical approach, 2nd ed., Iowa State. Univ. press, Ames, Iowa, U.S.A.

Upadhyay, M.K. and B.R. Murty (1971). Genetic diversity and combining ability in pearl millet. Indian J.Genet. Plant Breed. 31(1): 63-72.

Yadav, O.P., E.W.Rattunde, F.R.Bidinger and V.Mahalakshmi (2000). Heterosis inlandrace-based topcross hybrids of pearl millet across arid environments. Euphytica . 112:285-295.

قوة الـــهجين والقدرة على التآلف لـــمحصول العلف ومكوناته في الدخن الحولي

أحـــمد منجـــد سليمـــــان

قسم الـــمحاصيل – كلية الزراعة – جامعة القاهرة – الجيزة .

أجريت هذه الدراسة لتقدير التباين في قوة الهجين و أهمية القدرة العامة والخاصة على التـــآلف في تحديد الفروق بين هجن الجيل الأول الناتجة من التهجين بين خمسة سلالات عقيمة ذاتيا مع سبعة أبـــاء معيدة للخصوبة و تأثير التربية الداخلية في الجيل الثاني لهذه الهجن . لذلك تم تقييم الأباء وهجـــن الجيـــل الأول والثاني في تجربة مصممة بنظام القطاعات كاملة العشوائية خلال موسم ٢٠٠٣ في محطة التجـــارب الزراعية بكلية الزراعة جامعة القاهرة. وتم حش النباتات مرتين مع قياس الصفات التالية في كل حشة: عدد الأيام حتى التزهير، طول النبات، عدد الأوراق / النبات، طول وعرض الورقة، قطر الساق، عدد الأفـــرع / النبات، المحصول الأخضر والجاف / النبات و المحصول الأخضر والجاف للحشيتين معا.

أظهرت النتائج وجود فروق عالية المعنوية بين هجن الجيل الأول لجميع الصفات المدروسة مـــاعدا عرض الورق في الحشتين وعدد الأفرع / النبات في الحشة الأولى. كان متوسط سلوك الجيل الأول أعلى مـــن متوسط سلوك الجيل الثاني في كل الصفات في الحشتين ماعدا صفة عدد الأيام حتى التزهير في كلى الحشتين.

اتضح من النتائج وجود قوة هجين معنوية لكل الصفات المدروسة في الحشتين ماعدا صفة عـــدد الأفرع / النبات في الحشة الأولى كما لوحظ وجود تأثير عالي المعنوية للتربية الداخلية في الجيل الثاني لكـــل الصفات ماعدا صفة عدد الأيام حتى التزهير في الحشة الثانية. أظهرت معظم الهجن زيادة في طول النبـــات مقارنة مع متوسط الأباء وكذلك مع الأب الأفضل. أظهر الهجين CMA92333 x IPC90 أعلى نسبة قـــوة هجين (٧٩, ٤٦ %) مقارنة مع متوسط الأبوين ، (٤١, ٩٠ %) مقارنة مع الأب الأفضل وذلك في الحشة الأولى . كما أظهر نفس الهجين أعلى نسبة قوة هجين (٤٧و٠٧ %) مقارنة مع متوسط الأبوين ، (٣٠.٢٦ %) مقارنة مع الأب الأفضل وذلك في الحشة الثانية وذلك بالنسبة لصفة ارتفاع النبات. تراوحت قيم معـــامل

التربية الداخلية لصفة ارتفاع النبات من (-٤.٦٩ %) إلى (٢٨.٨٥ %) في الحشة الأولى ، ومن (-٢١.٤٤ %) إلى (٢٢.٠٢ %) في الحشة الثانية. وقد أظهر الهجين CMA89111 x P0P1 في الحشة الأولى والهجين CMA98777 x IPC45 في كلا الحشتين أعلى قيمة معنوية للتربية الداخلية لهذه الصفة. بالنسبة لصفة التفريع، أظهر الهجين CMA89111 x IPC293 في الحشة الأولى والهجين CMA89111 x IPC115 في الحشة الثانية أعلى قيمة لقوة الهجين. وكان تأثير التربية الداخلية في هذين الهجينين موجب ومعنوي في الحشة الثانية.

تراوح عدد الهجن التي أظهرت قوة هجين معنوية من ٢٢ إلى ٣٣ هجين في صفات المحصول الأخضر والجاف فى الحشتين والمحصول الكلى الأخضر والجاف. وقد أظهر ثماني هجن قوة هجين معنوية مقارنة بأفضل آبائها وذلك بالنسبة لمحصول العلف الأخضر والجاف في الحشتين والمحصول الكلى الأخضر والجاف. أظهر الهجين CMA89111 x IPC293 أعلى قيمة لقوة الهجين للمحصول الجاف في الحشة الثانية (٤٦٠.١٦ %) و للمحصول الأخضر في الحشة الأولى (٢٨٧.٩١ %) وللمحصول الجاف في الحشة الأولى (٢٧٦.٦٢ %). وتلى ذلك الهجين CMA92333 x IPC29 الذي أظهر قوة هجين عالية للمحصول الأخضر الكلى (٢١٨.٢٦ %) و للمحصول الأخضر في الحشة الأولى (٢٠٣.٣٩ %) وقد أظهر نفس الهجين أعلى قوة هجين مقارنة بأفضل الأباء بالنسبة لصفات المحصول الأخضر والجاف في الحشة الثانية وكذلك المحصول الأخضر الكلى.

وجد أن التباين الراجع إلى القدرة الخاصة للتآلف كان أعلى من التباين الراجع إلى القدرة العامة للتآلف وذلك لكل الصفات ماعدا صفة المحصول الأخضر في الحشة الثانية. كانت السلالة العقيمة CMA89111 هي أفضل قرين بالنسبة للمحصول الجاف الكلى والمحصول الجاف في الحشة الأولى ، كما كانت هذه السلالة قرين جيد بالنسبة للمحصول الأخضر الكلى والمحصول الأخضر والتفريع في كلى الحشتين وارتفاع النبات وعدد أوراق النبات وقطر الساق في الحشة الأولى والمحصول الجاف في الحشة الثانية. وكانت الآباء IPC45 ، IPC90 و IPC115 هي الأفضل بالنسبة للقدرة العامة للتآلف وذلك بالنسبة للمحصول الكلى الأخضر والجاف ، والمحصول الأخضر والجاف في كلى الحشتين ومعظم الصفات الأخرى. أظهر الهجينان CMA92333 x IPC293 و CMA92333 x IPC90 أعلى تأثير للقدرة الخاصة للتآلف بالنسبة للمحصول الكلى الأخضر كما أظهر تأثير عالي للقدرة الخاصة للتآلف في صفة المحصول الأخضر في الحشة الأولى.