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Pakistan Journal of Biological Sciences, 2 (4): 1518-1526, 1999 **Research Article**

Combining Ability Estimates for Early Maturity and Nonsenescence (Stay-green) Traits in Sorghum (*Sorghum bicolor L.*)

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ıbstract
stimates of general and specific combining ability effects as well as the variances for yield, and stay-green associated omponents were obtained for a set of 12 straight crosses of sorghum (*Sorghum bicolor L*) involving three pure lines from :RISAT and four early local type lines. The F1 and F2 generations were evaluated to determine the combining ability of ıe parents for maturity and stay-green traits. General combining ability estimates were non-significant for all the traits xcept plant height in F1. Specific combining ability estimates were significant for head length, seeds per head, 1000-grain ıeight, threshing percentage, plant height, LAUSL and %GLA 50DAF in F2 generation. The magnitude of GCA was much reater than SCA for majority of the traits in both F1 and F2 generations indicating that additive genetic variance was more nportant than nonadditive genetic variance. Among male parents, Bagdar gave highest GCA for yield per plant, head length ıd 1000-grain weight, whereas Pot.3-9 gave highest GCA for maturity index and threshing percentage. Among the female arents, ICSV 107, as expected for being adapted to the Pothwar tract agro-climatic conditions, gave the best GCA for yield er plant, *head length, seeds per head, 1000-grain weight, threshing percentage and maturity index. ICSV 219* gave the ighest GCA effects for LAUSL, %GLA 50DAF and sugar percentage among the female parents, indicating its superiority stay-green character. Selection for early maturity and high yield in Pothwar area should be practiced among progeny of :SV 107 X Pot.3-9, while selection for the stay-green associated characters be practiced in progeny of ICSV 219 X Pot.3-

ıtroduction
ırly maturing high yielding cultivars coupled with stay-reen characters are the need of the farmers in almost all ırghum growing areas of the country to fit in to the ropping system and to escape natural weather hazards ıch as frost, insects, pests and diseases.

quyen *et al.* (1997) have reported that GCA and SCA fects were highly significant for all the studied traits.They ıund that some parents were having high positive GCA for ain yield and low or negative GCA for culm lenght and ıys to heading which were considered as good combiners. ıadouriva and Saxena (1997) reported that estimates of eneral and specific combining ability effects indicated the esence of both additive and dominance gene action for eld per plant, number of leaves per plant, plant height and ıys to 50 per cent flowering in 7 sorghum bicolor enetypes and their F1s.

llai *et al.* (1995) from their study on combining ability ıalysis for panicle characters in sorghum have reported ıat estimates of variance due to general and specific ımbining ability indicated the presence of non-additive ene action for all the characters except 100-seed weight. anickam and Das (1995) have also reported that non-lditive gene action played a major role in controlling all the rage characters except number of tillers and number of aves per plant.

ˈith all these ideas in mind the present study was ıdertaken to estimate general and specific combining bility of parental lines for earliness and nonsenescence aits; and to determine potential effectiveness of selection ır early maturity, stay-green character to choose the best arents among the selected lines, which can produce ogenies with early maturity and high yield coupled with ay-green character.

Materials and Methods
Estimates of general and specific combining ability effects as well as the variances for yield, and stay-green associated components were obtained for a set of 12 straight crosses made in a factorial mating design among seven pure lines of sorghum (*Sorghum bicolor L*). The parental material consisted of three pure lines from ICRISAT, viz: ICSV 107, ICSV 112, ICSV 219 and four early local type lines viz: Pot.3-9, Red Janpur, Bagdar and DS-75. The F1 and F2 generations were evaluated in the field to determine the combining ability of the parents for maturity and stay-green traits such as yield per plant, head length, seeds per head, 1000-grain weight, threshing percentage, maturity index, plant height, leaves per plant, LAUSL, %GLA 50DAF and sugar percentage. The trials were conducted on F1 and F2 generations in randomized complete block design with three replications at National Agricultural Research Centre Islamabad and Maize & Millet Research Institute Yousafwala during 1993 and 1994, respectively.

The female parents ICSV 107, ICSV 112 and ICSV 219, are late maturing (110 to 120 days) cultivars with high yield potential (3000 to 3500 kg/ha) introduced from ICRISAT. These cultivars are juicy with green mid rib and having stay-green character which persists for 40 to 45 days beyond grain maturity. The male parents namely, Pot.3-9, Red Janpur, Bugdar and DS-75 were selected for having early maturity identified by the National Cooperative Research Programme, NARC Islamabad. All these lines have low yield potential ranging from 1000-2000 kg ha^{-1}. These cultivars are having dry stems with white mid rib and susceptible to foliar diseases. As far as could be ascertained, these lines were not closely related in their origin and thus provided a good deal of genetic diversity. F1 seed of the following 12 hybrids was produced during kharif 1992-93, at the NARC Islamabad.

1. ICSV 107 X Pothwar 3-9
2. ICSV 107 X Red Janpur
3. ICSV 107 X Bagdar
4. ICSV 107 X DS 75
5. ICSV 112 X Pothwar 3-9
6. ICSV 112 X Red Janpur
7. ICSV 112 X Bagdar
8. ICSV 112 X DS 75
9. ICSV 219 X Pothwar 3-9
10. ICSV 219 X Red Janpur
11. ICSV 219 X Bagdar
12. ICSV 219 X DS 75

In order to ensure that no self pollination occurred in the crossed heads, polythene bag methodology was resorted to, which sterilized the anthers on the plants for use as female parents. The pollinated heads were kept bagged throughout the growing season for protection from birds and insect damage. A few typical plants in each of the lines were self pollinated to obtain selfed seed for the next year planting.

Field trial (F1 Generation): The twelve F1 hybrids alongwith their parents were planted in a randomized complete block design with three replications. Normal cultural practices were followed throughout the season. Fertilizer was applied at the rate of 60-30-0 kg/NPK in the form of nitrophos and urea. Each plot consisted of two rows 5m long 75 cm apart with 25 cm spacing between the hills. Planting was made at the rate of two seeds per hill and when the seedlings reached six leaf stage, these were thinned to a stand of one plant per hill. At both the locations, the crop had a mild attack of shootfly. Furadan 3 G granules were applied at the rate of 16 kg/ha for control of the shootfly. A random sample of twenty plants, regarded statistically adequate, was harvested from each plot and data were recorded for the following characters.

1. Days to 50 per cent flowering
2. Plant height
3. Head length
4. Number of seeds per head
5. 1000-grain weight
6. Yield per plant
7. Threshing percentage
8. Maturity Index
9. Number of leaves per plant
10. Leaf area of upper six leaves (LAUSL)
11. Percent green leaf area 50 days after flowering (%GLA 50DAF)
12. Sugar percentage in stem

Analysis of variance was run on all characters for individual location and combined for the two locations using mean values for each plot at each location as a factorial design in which the pooled sum of squares for males and females estimated general combining ability and male x female interaction sum of squares estimated specific combining ability (Hallauer and Miranda, 1981). General and specific combining ability effects of the parents were estimated according to Simmonds (1979). Analysis of variance for parents and crosses was performed by location and across locations.

Field trial (F2 Generation): Seed from all replications of the F1 trial was bulked for each entry. A random sample from bulked seed of all the entries was taken to plant F2 trial. The F2 entries with the parents were planted in July 199 in randomized complete block design with three replication at NARC Islamabad and MMRI Yousafwala. At both th locations normal cultural practices were followe throughout the season. Fertilizer was applied at the rate o 60-30-0 kg/NPK in the form of nitrophos and urea.
Each plot consisted of four rows 5m long 75 cm apart wit 25 cm spacing between the hills. Planting was made at th rate of two seeds per hill and when the seedlings reache six leaf stage, these were thinned to a stand of one pla per hill. At NARC the crop had been attacked by shootfl Furadan 3 G granules were applied at the rate of 16 kg ha for control of the shootfly. Each trial was harvested 12 days after planting. A sample of 5-10 heads was collecte from each plot in each replication. The data was recorde on the parameters as described for F1 generation. Analys for combining ability was carried out as described for the F generation.

Results and Discussion

F1 Generation: Combining ability of the selected ICRIS and local type parents for early maturity, and stay gre associated characters, was estimated for a set of twe straight crosses in sorghum. The results indicated that the majority of the characters studied, both general a specific combining ability effects contributed significant the GCA effects being more pronounced than the S effects. The results presented in Tables 1 and 2 reveal th there were considerable range of differences for yie maturity and stay-green characters between parents a crosses as well as among crosses. Locations were a significantly different for yield per plant, 1000-grain weig threshing percentage, maturity index, plant height, %G 50DAF and sugar percentage. The SCA mean squares w much smaller than the GCA mean squares for all tr which indicate that additive genetic variances were m important than nonadditive genetic variances. Bhadour and Saxena (1997) have reported that estimates of gen and specific combining ability effects indicated the prese of both additive and dominance gene action for yield plant, number of leaves per plant, plant height and day 50% flowering in sorghum bicolor genetypes and their F Nichaus and Pickette (1966) observed that gen combining ability effects were larger than specific effe Reddy (1963) from his studies on combining ab involving exotic female and Indian males, has also poi towards the greater importance of general combining ab for yield and yield components while Kambal and Web (1965) have observed that both general and spe combining abilities were important in determining yield related characters but comparatively the GCA effects more important and more stable over the years. Rao (1 found that specific combining ability was significan grain yield, yield components, plant height, days to 50 cent flowering, and leaves per plant, indicating importance of nonadditive genetic variance for these t Sprague and Tatum (1942) and Rojas and Sprague (1 have also reported that specific combining ability vari were relatively greater than general combining a ariances. The lines used in the present study were all ighly selected and represented adapted ecotypes of the egions in which these lines were developed and naintained. Therefore one might expect that specific ombining ability should have a more pronounced effect han the general combining ability on the expression of arious characters.

he data presented in this study reveal that for all the components of yield, maturity and stay-green character, the general combining ability effects are relatively more important than the specific combining ability except for head length, seeds per head, 1000-grain weight, threshing percentage, LAUSL, %GLA 50DAF and plant height. This also indicates that contribution of these characters is very little to the overall yield and as such the specific combining ability effects are more pronounced in these characters

able 1: Means squares of combining ability analysis of F1 hybrids over two locations-1993.

ource	df	Yield per plant (g)	Length of head (cm)	Seeds per head	1000-grain Weight (g)	Threshing %	Maturity Index
ocations	1	103.16**	4.38	170520.75**	174.14**	47.93*	862.00**
ep(Loc	4	5.26	2.23	32824.95	5.23	16.37	9.28
ntries	18	231.86**	125.59**	1115835.90**	129.35**	116.00**	613.89**
lale vs Female	1	48.21**	234.25*	464752.61*	715.10**	365.16*	2186.90**
arent vs Cross	1	67.81**	98.91**	3577082.33**	24.71*	1225.16	829.66
mong Males	3	29.82	54.31	140387.33	171.95	65.40	556.77
mong Females	2	3.69	0.82	24186.50	9.11	25.16	148.1
mong Cross	11	11.90*	19.39**	236834.74**	122.40**	136.32**	150.82**
lales	3	4.60	24.95	291255.51	6.22	64.08	107.04
emales	2	32.62	26.84	349838.24	405.08	303.77	466.46
lale X Female	6	3.97	13.81*	162192.74**	19.79*	76.68**	7.60
oc X Entry	18	5.35	6.04*	19350.48	7.63	33.25**	32.98**
oc x Parent	6	5.83	5.09	18385.82	29.45	283.33	94.74
oc X Cross	11	6.18	7.96	22474.86	8.75	40.11**	50.32**
oc X Male	3	10.28	14.29*	13943.90	6.68	47.84**	88.24**
oc X Female	2	4.29	11.17	34842.93	3.11	50.47	4.18
X M X F	6	4.77	3.73	22623.15	11.67	32.79**	46.76**
X P vs C	1	15.54*	7.58	360946.67	21.04*	147.04	271.98*
rror	72	5.11	3.57	24280.49	6.82	10.73	10.95

Significant at 5% level ** Significant at 1% level.

able 2: Means squares of combining ability analysis of F1 hybrids over two locations-1993.

ource	df	Plant Height(cm)	Leaves per Plant	L A U S L (cm^2)	%GLA 50DAF	Sugar %
ocations	1	1259.53**	1.92	78496.22	243.38**	11.17**
ep(Loc)	4	27.91	1.80	43910.59	4.42	0.51
ntries	18	9192.44**	9.30**	520180.50	940.11**	49.35**
lale vs Female	1	3120.62*	17.23*	194390.41**	352.60**	17.66**
arent vs cross	1	3722.25	8.50	206870.37	361.58	13.52
mong Males	3	11767.16**	10.22	734462.49	102.55	0.88
mong Females	2	53.68*	0.61	29355.72	156.47	2.12
mong Cross	11	8439.01**	1.84*	232864.74**	135.08**	8.38**
lales	3	983.65**	0.21	374637.18	300.99	8.46
emales	2	25998.31**	4.79	243801.13	248.15	23.24
lale X Female	6	2144.48**	0.90	180139.07**	23.25**	0.92
oc X Entry	18	255.77**	2.08**	17002.0aw17**	75.96**	2.75**
oc X Parent	6	817.21	9.13	212356.66	198.39	5.41
oc X Cross	11	374.72**	2.87**	214118.71**	109.42**	3.07*
oc X Male	3	485.47**	0.33	554682.57**	43.12**	2.28*
oc X Female	2	634.82**	8.21**	173423.01*	379.45**	8.40**
X M X F	6	232.65**	2.35*	57402.01	52.56	1.69
X P vs C	1	979.43	13.72	136219.33	149.19	4.77
rror	72	55.91	0.77	51672.39	6.42	0.79

*Significant at 5% level. ** Significant at 1% level.

han others. These results are in agreement with those eported by Kambal and Webster (1965) and Nichaus and ickette (1966). In the present study, the pure lines and the rosses involving ICSV 107 and ICSV 219 produced longer eads, heavier and more number of seeds per head, more number of leaves and more LAUSL, %GLA 50DAF and sugar percentage in comparison with rest of the pure lines studied. Number of seeds per head, 1000-grain weight, head length and threshing percentage showed relatively higher association with yield and LAUSL, %GLA 50DAF

Table 3: Means of F1 hybrids and Parents for maturity and stay-green traits over two locations-1993.

Parents.	Yield per plant (g)	Length of head (cm)	Seeds per head	1000-grain Weight(g)	Threshing %	Maturity Index
ICSV 107 X Pot.3-9	37.56a	32.13a	1858a	34.332bc	79.56a	142.17b
ICSV 107 X R/Janpur	33.75bcd	31.10abc	1752a	28.848defc	78.86ab	139.00bcd
ICSV 107 X Bagdar	36.79ab	31.18abc	1687abc	40.498a	72.91cdefg	132.17fg
ICSV 107 X DS-75	35.66abcd	29.32cd	1817a	29.958cd	73.19cdef	129.67gh
ICSV 112 X Pot.3-9	34.52abcd	30.18abc	1575abc	33.153bc	74.31cdef	137.33cde
ICSV 112 X R/Janpur	33.85abcd	26.07e	1488c	29.592def	74.92bcde	134.50ef
ICSV 112 X Bagdar	36.93a	29.20cd	1542bc	40.360a	68.72ghij	126.67h
ICSV 112 X DS-75	34.56abcd	30.48abc	1819a	29.162defg	76.72abc	127.67h
ICSV 219 X Pot.3-9	34.18abcd	29.07cd	1726ab	35.393b	79.27a	138.67bcd
ICSV 219 X R/Janpur	32.80d	27.28de	1740ab	26.606efg	79.24a	135.17def
ICSV 219 X Bagdar	36.46abc	31.90ab	1129d	36.183b	66.73j	129.17gh
ICSV 219 X DS-75	36.19abc	29.52bcd	1656abc	31.365cd	66.91j	130.33gh
ICSV 107	33.78bcd	30.75abc	1541de	28.964defg	67.54ij	118.00c
ICSV 112	35.08abcd	30.90abc	1157d	26.819efg	71.48efghi	108.33j
ICSV 219	33.67cd	30.20abc	1143d	26.840efg	70.46fghij	111.17j
Pot. 3-9	18.38f	21.40f	589f	34.208bc	76.29abcd	149.83a
Red Janpur	18.49f	17.08g	541f	25.766g	70.48fghij	140.00bc
Bagdar	21.83e	17.35g	632f	36.239b	72.17defgh	129.83gh
DS-75	22.67e	23.15f	887e	26.381fg	68.38hij	129.67gh

Means with the same letters are not significantly different according to Waller-Duncan multiple range test (K ratio = 100

Table 4: Means of F1 hybrids and Parents for maturity and stay-green traits

Source	df	Plant Height(cm)	Leaves per Plant	L A U S L (cm^2)	%GLA 50DAF	Sugar%
ICSV 107 X Pot.	3-9	273.73a	12.98d	3327.8abcd	73.31cd	7.78cd
ICSV 107 X R/Janpur		210.97e	14.38abc	3032.7def	73.56cd	6.05ef
ICSV 107 X Bagdar		252.67b	14.55ab	3481.0a	75.90cd	6.75d
ICSV 107 X DS-75		181.29f	14.37abc	3379.2ab	73.05cd	5.32f
ICSV 112 X Pot.	3-9	272.38a	13.23cd	2873.2fg	77.17b	8.80c
ICSV 112 X R/Janpur		228.16d	14.18abc	2943.2efg	69.31efg	6.12e
ICSV 112 X Bagdar		207.65e	13.82abcd	3190.0abcde	66.86fg	8.20c
ICSV 112 X DS-75		159.05i	14.42abc	3312.0abcd	68.95efg	6.00e
ICSV 219 X Pot.	3-9	248.25bc	13.62abcd	4551.5abc	82.67a	8.75c
ICSV 219 X R/Janpur		243.43bc	13.62abcd	3021.7def	66.44g	6.53e
ICSV 219 X Bagdar		210.97e	14.72a	3141.5def	71.09de	8.18c
ICSV 219 X DS-75		176.60fg	14.33abc	3064.5cdef	68.43efg	7.06d
ICSV 107		173.06fgh	14.06abcd	3138.7bcdef	75.07bc	12.93
ICSV 112		167.16hi	13.42bcd	3065.2cdef	69.94ef	11.75b
ICSV 219		170.95gh	13.79abcd	3205.0abcde	80.15a	12.75
Pot. 3-9		227.21d	10.19f	2344.3h	40.19i	3.42
Red Janpur		244.05bc	11.53e	2429.0h	41.53c	3.43
Bagdar		239.60c	13.32cd	3117.8bcdef	48.23h	4.20
DS-75		249.54j	11.18ef	2728.7g	47.55h	3.45

Means with the same letters are not significantly different according to Waller-Duncan multiple range test (K ratio = 10

while sugar percentage, showed positive and significant association with nonsenescence. On the whole however, both general and specific combining abilities contributed significantly to the total genetic variability for all the characters. The GCA resulted primarily from differences in the additive gene effects and the differences in SCA were due to differences in non-additive gene effects. The data presented herein, show that additive gene effects were more important in the expression of yield and characters related to nonsenescence. For certain characters i.e head length, seeds per head, 1000-grain weight, LAUSL, %GLA 50DAF and plant height, the non-additive effects w rather more pronounced than additive gene effects. T fact would seem to suggest that testing of parental lines GCA should also involve appraisal of individual cr combinations for SCA and heterotic effects.

An overall assessment of the data in tables 3 and 4 indi that the cross ICSV 107 X Pot. 3-9 was found to be best cross, as it exhibited superiority over the other cro for plant height, yield per plant, seeds per head, h length, threshing percentage and maturity. The cross I 219 X Pot.3-9 was the best one for having significant able 5: Estimates of specific combining ability effects for yield, maturity and stay-green traits in F1 hybrids over two locations-1993.

arents.	Yield per plant (g)	Length of head (cm)	Seeds per head	1000-grain Weight (g)	Threshing %	Maturity Index
SV 107 X Pot.3-9	+1.33	-0.10	-86.75	-0.386	0.00	+1.55
SV 107 X R/Janpur	-0.22	+1.81	+41.59	+0.080	-0.66	+0.57
SV 107 X Bagdar	-0.44	-0.09	+113.25	+0.927	+1.61	+0.62
SV 107 X DS-75	-0.33	-1.59	+68.08	-0.623	-0.93	-1.76
SV 112 X Pot.3-9	-0.35	+0.07	-16.25	-1.284	-2.79	-0.08
SV 112 X R/Janpur	+0.60	-1.27	-180.91	+1.095	-2.14	+0.28
SV 112 X Bagdar	+0.42	-0.11	+115.75	+1.336	-0.12	-0.67
SV 112 X DS-75	-0.69	+1.52	+81.42	-1.148	+5.06	+0.45
SV 219 X Pot.3-9	-0.63	-0.72	+102.00	+1.670	+2.80	-0.54
SV 219 X R/Janpur	-0.39	-0.52	+139.34	-1.177	+2.81	-0.85
SV 219 X Bagdar	+0.01	+1.17	-229.00	-2.265	-1.48	+0.03
SV 219 X DS-75	+1.00	+0.10	-13.33	+1.769	-4.12	+0.31

ble 6: Estimates of specific combining ability effects for yield, maturity and stay-green traits in F1 hybrids over two locations-1993.

rents	Plant Height(cm)	Leaves per Plant	L A U S L (cm^2)	%GLA 50DAF	Sugar%
SV 107 X Pot.3-9	+ 0.36	-2.53	-118.77	-2.00	-0.01
SV 107 X R/Janpur	-23.78	+0.86	+160.13	-0.92	+0.47
SV 107 X Bagdar	+22.08	-1.90	+ 8.33	+2.22	-0.31
SV 107 X DS-75	- 1.75	-0.77	- 49.77	+2.70	-0.16
SV 112 X Pot.3-9	+13.89	-0.33	-514.07	+1.11	+2.83
SV 112 X R/Janpur	+ 5.59	+2.61	+140.93	+1.20	-0.26
SV 112 X Bagdar	-11.16	-0.68	+116.13	-2.76	+0.34
SV 112 X DS-75	- 8.31	+1.23	+257.03	+0.47	-0.28
SV 219 X Pot.3-9	-14.25	-0.40	+632.73	+0.88	+2.43
SV 219 X R/Janpur	+18.20	+1.59	-301.07	-0.28	-0.20
SV 219 X Bagdar	-10.50	-0.24	-124.37	+0.55	-0.03
SV 219 X DS-75	+ 6.58	+ 0.68	-207.27	-1.16	+0.43

ble 7: Means squares of combining ability analysis of F2 hybrids over two locations-1994.

urce	df	Yield per plant (g)	Length of head (cm)	Seeds per head	1000-grain Weight (g)	Threshing %	Maturity Index
cations	1	2.19	196.05**	79210.74	243.00**	13.11	150.53**
p (Loc)	4	3.94	4.17	75535.72	1.19	16.43	6.24
tries	18	186.73**	76.91**	495913.34**	121.50**	50.68**	488.40
le vs Female	1	1937.19	239.67	1110.04	68.42	33.26	2566.84
rents vs Cross	1	54.69	1.14	41878.72	58.60	59.61	1534.88
nong Males	3	23.69*	2.92	19059.72	10.27	11.26	147.38**
nong Females	2	4.38	27.59	37113.00*	265.57**	43.30**	395.15**
nong Cross	11	7.58	20.41**	83784.30	96.09**	64.70**	106.45**
les	2	7.06	43.70**	77782.05	30.52	8.40	17.51
males	3	12.44	28.63**	109724.17	300.30**	82.84**	316.50**
le X Female	6	5.33	8.53	72815.11	15.85*	76.40**	31.06**
c X Entry	18	6.45	10.23	52569.58	9.10	10.24	12.46*
c X Cross	11	9.52	10.71	81654.95	11.13	13.13	7.89
c X Male	3	9.04	9.31	14139.00	23.89	7.16	5.11
c X Female	2	3.02	22.44*	23957.55	4.18	15.35	1.84
M X F	6	11.93	7.49	134645.39	7.07	15.37	11.29
P vs C	1	9.05	1.67	21168.12	51.85	7.08	3.09
ror	72	8.43	6.72	60565.61	10.12	9.11	5.88

ignificant at 5% level. ** Significant at 1% level.

re area of upper six leaves per plant, %GLA 50 DAF and ar percentage.

alysis of variance, presented in Table 1 reveals that variation due to locations for maturity index, 1000-grain weight, seeds per head, %GLA 50DAF, sugar percentage, and plant height was significant, but not so for head length,

Table 8: Means squares of combining ability analysis of F2 hybrids over two locations-1994.

Source	df	Plant Height(cm)	Leaves per Plant	L A U S L (cm^2)	%GLA 50DAF	Sugar%
Locations	1	6826.99**	0.03	3994.87	540.16**	12.07**
Rep(Loc)	4	68.18**	1.28	7102.24	23.89	2.26*
Entries	18	7739.61**	6.01**	448640.56**	1141.97**	40.83**
Male vs Females	1	4137.67	15.33	205183.39	417.42	11.49
Parents vs Cross	1	4337.84	7.16	197114.65	449.08	11.11
Among Males	3	45.65	0.42	34900.22	238.15**	2.24
Among Females	2	10688.35**	8.22**	702981.66**	269.79**	1.42*
Among Cross	11	5235.28**	2.80*	263277.62**	109.43**	4.68**
Males	3	13150.25**	9.15**	717465.05**	334.00**	12.90**
Females	2	615.61	1.21	67489.55	32.35	0.72
Male X Female	6	2817.69**	0.16	101446.59**	22.83	1.89*
Loc X Entry	18	1089.21**	1.23	14540.78	83.21**	1.11
Loc X Cross	11	1593.72**	1.69	17008.86	115.83	0.55
Loc X Male	3	1342.03**	2.11	20015.16	274.09**	0.28
Loc X Female	2	1509.99**	0.17	26853.55	19.26	0.26
L X M X F	6	1747.48**	1.98	12224.15	68.88**	0.78
L X P vs C	1	511.57	9.01	90145.44	111.77	3.07
Error	72	155.32	1.05	17467.55	10.28	0.89

* Significant at 5% level. ** Significant at 1% level.

Table 9: Means of F2 hybrids and Parents for maturity and stay-green traits over two locations-1994.

Parents.	Yield per plant (g)	Length of head (cm)	Seeds per head	1000-grain Weight (g)	Threshing %	Maturity Index
ICSV 107 X Pot.3-9	33.92ab	30.38ab	1525.0a	28.736defg	76.79abc	141.50b
ICSV 107 X R/Janpur	32.80ab	26.98abcd	1537.0a	24.046gh	74.52bcde	129.83efg
ICSV 107 X Badgar	36.10a	29.33ab	1401.0abcd	36.720ab	72.18def	129.50efg
ICSV 107 X DS-75	32.75ab	26.86abcd	1311.0abcd	28.675defg	72.55def	130.67def
ICSV 112 X Pot.3-9	33.55ab	27.27abcd	1294.0abcd	31.572cde	73.82cde	136.33c
ICSV 112 X R/Janpur	32.18b	24.48d	1374.0abcd	29.074def	74.23bcde	134.33cd
ICSV 112 X Bagdar	33.08ab	28.72abc	1244.0abcd	37.325a	74.48bcde	127.17fg
ICSV 112 X DS-75	32.63ab	26.42bcd	1463.0abc	29.117def	78.15ab	130.33efg
ICSV 219 X Pot.3-9	35.13ab	25.08cd	1377.0abcd	32.414bcd	78.28ab	135.50c
ICSV 219 X R/Janpur	3aw75.0ab	24.37d	1372.0abcd	26.479fgh	80.16a	131.17de
ICSV 219 X Bagdar	33.32ab	26.52bcd	1142.0cd	34.155abc	60.87f	126.67g
ICSV 219 X DS-75	33.50ab	26.92abcd	1495.0ab	28.366defg	70.92ef	131.33de
ICSV 107	31.92b	30.72a	1091.0cd	25.342fgh	74.30bcde	118.17h
ICSV 112	31.90b	29.73ab	1203.0abcd	24.956fgh	72.18def	108.33j
ICSV 219	35.35ab	29.37ab	1161.0bcd	27.390efgh	71.74def	112.17i
Pot. 3-9	19.55c	20.88ef	698.0f	34.047abc	77.62abc	145.67a
Red Janpur	21.08c	18.82f	638.0f	24.544fgh	75.14bcd	136.83c
Bagdar	19.83c	19.32f	717.0f	36.488ab	72.24def	129.00efg
DS-75	20.98c	23.55de	826.0ef	23.276h	71.92def	128.33efg

Means with the same letters are not significantly different according to Waller-Duncan multiple range test (K ratio = 10

threshing percentage, LAUSL and leaves per plant. While the cross x loc interaction was found to be significant for majority of the characters, studied.

Thus it appears that yield and its components were influenced by environmental fluctuations. Shinde and Jagadeshwar (1986) have reported that both additive and nonadditive gene effects were estimated to be important for the inheritance of grain yield and yield components but nonadditive effects were predominant for most of the characters. Genotype X environment interaction was significant for all the characters. Pillai *et al.* (1995) have also reported that estimats of variance due to general and specific combining ability indicated the presence of non-additive gene action for all the characters except 100-seed weight.

It is evident from Table 1 that the mean squares for b
general and specific combining abilities were significan
all cases. This suggests that the genetic variability am
crosses for yield and its various components
significantly associated with both general and spe
combining ability. The interactions of both general
specific combining abilities with locations were hi
significant for majority of the characters except for yield
plant and seeds per head, suggesting thereby a differe
influence of environmental fluctuations on the comb
ability of the lines for the characters studied.

Based on the overall results, it indicates that the
additive variances are not statistically significant the
still important. These results are in agreement with S
Rao *et al.* (1976) who reported that variance due to g

able 10: Means of F2 hybrids and Parents for maturity and stay-green traits over two locations-1994.

arents	Plant Height(cm)	Leaves per Plant	L A U S L (cm^2)	%GLA 50DAF	Sugar%
CSV 107 X Pot.3-9	237.47bc	12.95bcd	2865.00ef	77.39bcdef	6.96def
CSV 107 X R/Janpur	200.78de	12.50d	2833.50f	72.74defg	6.72def
CSV 107 X Bagdar	257.10ab	14.08ab	3446.50a	81.02abc	7.38cde
CSV 107 X DS-75	218.23cd	13.10bcd	3331.83a	71.70efg	5.43ghi
CSV 112 X Pot.3-9	238.13bc	12.93bcd	2854.00ef	74.35cdefg	8.37c
CSV 112 X R/Janpur	232.53bc	12.38de	2918.50def	70.63g	5.86fghi
CSV 112 X Bagdar	231.40bc	13.88abc	3119.50b	78.04bcde	7.43cde
CSV 112 X DS-75	179.98ef	12.85bcd	3319.50a	73.19defg	6.15efgh
CSV 219 X Pot.3-9	240.38bc	12.25de	2964.67bcdef	80.03abc	7.35cde
CSV 219 X R/Janpur	244.12abc	12.05def	2901.50ef	69.27g	5.95fghi
CSV 219 X Bagdar	263.66a	13.95abc	3099.83bc	82.22ab	7.82cd
CSV 219 X DS-75	168.72f	12.63de	3091.50bc	73.04defg	6.43efg
CSV 107	170.51f	14.58a	3068.50bcd	76.28bcdefg	13.38a
CSV 112	167.77f	14.20ab	2941.50cdef	73.56defg	11.95b
CSV 219	164.98f	14.05ab	3078.17bcd	85.58a	12.38ab
ot. 3-9	232.90bc	11.12ef	2362.50g	38.84i	5.28ghij
ed Janpur	249.48ab	10.96f	2369.67g	40.23i	4.90hij
agdar	233.87bc	13.35ab	2884.00ef	52.43h	4.70ij
S-75	155.72f	16.67cd	3018.50bcde	49.38h	4.11j

leans with the same letters are not significantly different according to Waller-Duncan multiple range test (K ratio = 100).

able 11: Estimates of specific combining ability effects for yield, maturity and stay-green traits in F2 hybrids over two locations-1994.

arents.	Yield per plant (g)	Length of head (cm)	Seeds per head	1000-grain Weight (g)	Threshing %	Maturity Index
CSV 107 X Pot.3-9	-0.69	+1.35	+60.46	+2.340	+2.02	+2.87
CSV 107 X R/Janpur	-0.19	+0.25	+43.92	-2.642	-2.86	-2.80
CSV 107 X Bagdar	+1.52	-0.30	+73.12	+0.499	-0.74	+0.87
CSV 107 X DS-75	-0.62	-1.30	-177.51	-0.199	+1.60	-0.96
CSV 112 X Pot.3-9	-0.03	-0.09	-70.32	-2.302	-3.54	-1.46
CSV 112 X R/Janpur	+0.22	-0.58	-19.46	+1.908	+0.53	+2.54
CSV 112 X Bagdar	-0.47	+0.76	+15.84	+0.626	+2.88	-0.62
CSV 112 X DS-75	+0.29	-0.09	+73.91	-0.235	+2.52	-0.46
CSV 219 X Pot.3-9	+0.73	-1.28	+ 7.86	-0.040	+1.53	-1.42
CSV 219 X R/Janpur	-0.03	+0.31	-24.48	+0.733	+4.71	-1.47
CSV 219 X Bagdar	-1.05	-0.46	-88.98	-1.124	-2.12	-0.25
CSV 219 X DS-75	+0.34	+1.41	+103.59	+0.434	-4.10	+1.41

able 12: Estimates of specific combining ability effects for yield, maturity and stay-green traits in F2 hybrids over two locations-1994.

arents	Plant Height(cm)	Leaves per Plant	L A U S L (cm^2)	%GLA 50DAF	Sugar%
CSV 107 X Pot.3-9	-3.55	-0.46	-186.78	-0.28	-0.40
CSV 107 X R/Janpur	-27.85	+0.17	-74.89	-0.47	+0.76
CSV 107 X Bagdar	+ 4.02	+0.08	+200.67	+3.11	+0.04
CSV 107 X DS-75	+26.79	+0.21	+ 61.00	-1.35	-0.37
ICSV 112 X Pot.3-9	+5.00	-0.33	-131.20	+0.53	-0.07
ICSV 112 X R/Janpur	+12.25	+0.20	+76.69	+0.27	-0.22
ICSV 112 X Bagdar	-13.79	+0.03	- 59.75	-4.79	+0.03
ICSV 112 X DS-75	-3.47	+0.11	+114.25	+3.99	+0.29
ICSV 219 X Pot.3-9	-1.46	+0.78	+317.97	-0.26	+0.49
ICSV 219 X R/Janpur	+15.13	-0.36	-1.81	+1.21	-0.53
ICSV 219 X Bagdar	+9.76	-0.11	-140.92	+1.69	-0.04
ICSV 219 X DS-75	-23.44	-0.32	-175.25	-2.63	+0.11

and specific combining ability effects, was significant for all characters and they found that additive gene effects were predominant for days to flowering, while nonadditive gene effects were of most importance for plant height, head weight and 1000-grain weight.

An overall consideration of general combining ability effects for the various characters would indicate that among the female lines, ICSV 107 with the greatest relative combining ability effects for yield had also exhibited the highest combining ability for 1000-grain weight and fairly high combining ability for number of seeds per head, plant height and maturity, however it exhibited a relatively low combining ability for threshing percentage. The next high yielding line ICSV 219 showed highest general combining ability effects for leaves per plant, LAUSL, %GLA 50DAF and Sugar percentage.

On the other hand the line ICSV 112 which had the lowest combining ability for yield, had lowest combining ability for number of seeds per head, head length, threshing percentage, maturity index, LAUSL, and %GLA 50DAF and high combining ability for 1000-grain weight. This would suggest that high and low general combining ability for yield could be attributed mainly to high or low general combining ability for 1000-grain weight.

An over all assessment of the specific combining ability effects for the characters presented in Tables 5 and 6 indicate that the highest specific effects for yield in the cross combination ICSV 107 X Pot.3-9 was accompanied by the high specific effects for number of seeds per head, 1000-grain weight and threshing percentage. The other cross combinations which also exhibited high specific effects for yield, had the highest specific effects for the number of seeds per head, 1000-grain weight and threshing percentage. The cross combinations which exhibited the lowest negative specific effects for yield, had the lowest specific effects for 1000-grain weight, seeds per head, head length and threshing percentage. This again indicates that specific combining ability for yield can largely be attributed to either number of seeds per head, 1000-grain weight and threshing percentage, or due to all these together.

Based on the over all results described above it indicates that the nonadditive variances are not statistically significant, they are still important. These results are in agreement with the findings of Deshmukh (1983), who reported that additive gene action was dominant for plant height, days to 50 per cent flowering, panicle length, panicle girth, grain yield and 1000- grain weight. He added that characters like number of leaves, days to 50 per cent flowering, GCA and SCA variances were equal in magnitude, indicating that additive as well as nonadditive gene action was equally important in expression of these characters. For leaf area and panicle weight, the variances due to SCA were higher, indicating the importance of nonadditive gene action. However the results presented here-in indicate that the parents ICSV 107 and Pot. 3-9 are the best general combiners for yield per plant, head length, seeds per head, threshing percentage and maturity index. Selection for early maturity and high yield should be practiced among the progenies of ICSV 107 X Pot. 3-9. Similarly ICSV 219 and Pot. 3-9 are the best general combiners for the stay-green associated characters viz. plant height, number of leaves per plant, LAUSL, %GLA 50DAF and sugar percentage. Hence selection for the stay-green character should be practiced among the progenies of ICSV 219 X Pot. 3-9.

F2 Generation: SCA mean squares were significant for 1000-grain weight, threshing percentage, maturity index, plant height, LAUSL and sugar percentage. Results in tables 7 and 8 reveal that estimates of GCA were larger in magnitude than SCA indicating that additive genetic variance (GCA) was more important than nonadditive genetic variance (SCA). Similar results were found for the F1 generation. These results support the findings of Niehaus and Pickett (1966) who observed that general combining ability effects were larger than specific effects for seeds per head, while specific effects were larger fo the seed weight.

Interaction of crosses x location was found significant fo maturity and %GLA 50DAF. Estimates of GCA effect indicated that the male parent Pot.3-9 which has th highest GCA effects in F1 for yield per plant, number o seeds per head, 1000-grain weight and maturity inde remained the best general combiner in F2 generation f 1000-grain weight, seeds per head and maturity ind (Tables 9 and 10).

The over all specific combining ability effects for t crosses studied (Tables 11 and 12), showed that cro combinations ICSV 107 X Pot.3-9 exhibited the highe specific combining ability effects for head length, seeds p head, 1000-grain weight, threshing percentage a maturity index while it exhibited poor combining abi effects for plant height, leaves per plant, LAUSL, %G 50DAF and sugar percentage, whereas the cr combinations ICSV 219 X Pot.3-9 exhibited the maxim specific effects for leaves per plant, LAUSL and su percentage. GCA estimates were highly significant for traits except seeds per head and yield per plant in generation.

The major objective of this study was to choose the b parents among the selected lines which can prod progenies with high yield, early maturity coupled stay-green character, the significance level for mat index was used 10%. In F2 generation SCA was signifi for 1000-grain weight, threshing percentage, mat index, plant height, LAUSL and sugar percentage.

The magnitude of GCA was much greater for all the in both generations indicating that additive genetic ef were more important than non-additive genetic eff These results suggested that effective selection for maturity and high yield is possible in early genera 1000-grain weight, threshing percentage, maturity plant height, LAUSL and sugar percentage exh significant nonadditive genetic variance in the F2, b additive variance was many times greater in magn High and significant GCA effects suggested that amo selected parental lines Pot.3-9 and ICSV 107 were th parents for early maturity while ICSV 219 was th parent for the stay-green character.

Therefore, selection for early maturity and high yield should be practiced among the progenies of ICSV 107 X Pot. 3-9 and selection for stay-green character with high yield be practiced among the progenies of ICSV 219 X Pot.3-9 under the agro-climatic conditions in Pothwar region of Pakistan. The ICRISAT cultivar ICSV 112 did not prove to be good combiner for early maturity, which may be due to its lack of adaptation.

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