LINE X TESTER ANALYSIS TO IDENTIFY POTENTIAL SEED PARENTS AMONG NON-RESTORER LINES IN SORGHUM (*Sorghum Bicolor* (L.)MOENCH)

19

THESIS SUBMITTED TO THE
ANDHRA PRADESH AGRICULTURAL UNIVERSITY
IN PARTIAL FULFILMENT OF THE REQUIREMENTS
FOR THE AWARD OF THE DEGREE OF

MASTER OF SCIENCE IN AGRICULTURE

BY

Y. RAVINDRA NATH REDDY B. Sc. (Ag.)

DEPARTMENT OF GENETICS AND PLANT BREEDING
COLLEGE OF AGRICULTURE, RAJENDRANAGAR, HYDERABAD

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CERTIFICATE

This is to certify that the thesis entitled 'Line x Tester analysis to identify potential seed parents among non-restorer lines in Sorghum (*Sorghum bicolor* (L.) Moench) submitted in partial fulfilment of the requirements for the degree of Master of Science in Agriculture of the Andhra Pradesh Agricultural University, Hyderabad, is a record of the bonafide research work carried out by Mr. Y. Ravindra Nath Reddy under my guidance and supervision. The subject of the thesis has been approved by the student's advisory committee.

No part of the thesis has been submitted for any other degree of diploma or has been published. Published part has been fully acknowledged. All the assistance and help received during the course of the investigations have been fully acknowledged by him.

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INTRODUCTION

Successful hybrids of sorghum have been developed and released for commercial cultivation in many countries. A cytoplasmic genetic mechanism of male-sterility is used in the production of these hybrids in which a female designated as A-line is out-crossed to a restorer (R-line) to produce the hybrid seed. The most commercially exploited cytoplasm has come from a milo kafir relationship. The system has abundant restorers, however, the non-restorers are often limited. This has restricted breeders' opportunity of producing a large number of seed parents hence hybrid combinations.

Rao (1962) reported the occurrance of cytoplasmic genetic male-sterility in Indian sorghums and converted M35-1 and IS-3691, into steriles. King et al. (1961) developed new male-sterile lines in sorghum but due to lack of diversity they have not been so useful in hybridization programmes.

In India, nine hybrids have been released, three of which have been particularly successful. Poor nicking has contributed to seed production problems and the availability of adequate quantities of seed. This problem can be overcome by having a sufficient number of male-sterile female parents of suitable grain quality so that easily producible hybrids with high yield and good levels of resistance to major limiting factors could be developed.

ICRISAT's programme on hybrids has placed emphasis on the development of new female parents. Non-restoring random mating populations have been developed and these populations are being improved by recurrent selection methods. A large number of non-restoring lines with good agronomic eliteness have been identified. These lines have to be backcrossed to a cytoplasmic male-sterile line. The process is complicated as several plant to plant crosses are required to recover good male-sterile parents (no partial fertility). Usually, the converted lines (new A-lines) are tested in hybrid combination to study their general combining ability before using them extensively in a hybridization programme. Often, it is realized that only a few lines produce desirable hybrids. Rao et al. (1968) emphasized that a line x tester analysis should be useful to screen the lines for combining ability before converting them to A-lines. In such studies the lines are usually hand-crossed with restorer lines to get hybrids. However, a larger number of non-restorer lines cannot be screened in this way because of the limitation of hand emasculation in producing an adequate quantity of F_1 seed on a sufficient large number of testers.

Therefore, in this study, attempts were made to evaluate non-restorer lines by using cytoplasmic male-steriles as testers. In this way a large number of non-restorer lines can be evaluated. The difficulty in the system is in the evaluation of hybrids (A-line x non-restorer lines) for grain yield as they are male-sterile. In the present study, the hybrids were evaluated by using interlards of fertile hybrids as pollinators for the test hybrids.

The objectives of the present line x tester analysis were as follows:

(I) To evolve a satisfactory system of evaluating non-restorer lines prior to converting them into A-lines.

(II) To identify potential non-restorer lines and recommend them for conversion by backcrossing and

(III) Based on this study to contribute information on gene action and interactions for several traits in sorghum.

REVIEW OF LITERATURE

Sorghum (*Sorghum bicolor* (L.) Moench) is an important food and fodder crop in most of the parts of the world. Increase in yield and stability has been reported in sorghum by resorting to a hybridization programme. The mechanism involved is hybrid vigour or heterosis. Hybrid vigour can be defined such that an F_1 hybrid falls outside the range of the parents with respect to some character or characters (Allard, 1960), usually applied to size, rate of growth or general fitness. Heterosis was noted as early as 1763 by Koelreuter, in tobacco hybrids and it was reported in sorghum by Conner and Karper (1927), for the first time.

Quinby (1963), noted an increased vegetative growth, extreme lateness of maturity, increased size of the endósperm, greater height, greater tillering, heavier seeds, increased number of seed, seed that mature faster, increased threshing percentage, and greater production of grain in sorghum hybrids.

Moll et al., (1962), pointed out that the success of heterosis breeding depends on the amount of genetic diversity present in the material. Heterosis in sorghum was recorded as high as 100 percent.

According to Subramaniam et al., (1962), heterosis in sorghum can be manifested in different degrees for all the characters except internodal number. He also noted an increased vigour for length, width, number of grains and weight of the panicle.

COMBINING ABILITY

Sprague and Tatum (1942) for the first time, put forward the concept of combining ability while working with corn improvement. The term general combining ability (g.c.a.) was used to describe average performance of a line in hybrid combinations and specific combining ability (s.c.a.) as the deviation from performance predicted on the basis of g.c.a.

A systematic study of g.c.a. and s.c.a. of quantitative characters influencing yield and it's components is very helpful in selecting the best parents for hybridization either to exploit heterosis or to isolate desirable homozygotes from segregating populations.

Kramer (1960), was the first to report in sorghum the importance of g.c.a. and s.c.a. in the expression of yield. In the case of g.c.a. the genes with additive effects are more important, while s.c.a. is more dependent on genes with dominance and epistatic effects.

Whitehead (1962) made a comprehensive combining ability study involving 58 varieties of grain sorghum crossed with Martin and CK60A male sterile. He reported that additive gene action was predominant for flowering date, plant height and head length in dwarf varieties, but additive gene action for these traits was found to be less in plants having intermediate height. He also indicated that s.c.a. was important in obtaining good hybrids from poor performing parents and poor hybrids from good performing parents. He also suggested that g.c.a. was more important in producing good hybrids from good parents and poor hybrids from poor parents and he felt that g.c.a. is more important than s.c.a. in developing good hybrids.

Niehaus (1964) reported that g.c.a. and s.c.a. in sorghum are equally important in determining yielding ability but he observed that g.c.a. is predominant.

Niehaus and Pickett (1966) found high g.c.a. effects in the F_1 and F_2 progenies from an 8 line diallel of sorghum, but s.c.a. effects were high only in the F_1. Lower s.c.a. effects in the F_2 indicated that there was considerable non-additive gene action in the F_1 generation, much of which was lost in the F_2 generation. S.c.a. variance was higher than g.c.a. variance only for 100 seed weight in the F_1.

Kambal and Webster (1965) noticed that g.c.a. in sorghum is more important than s.c.a. for yield, seed weight, days to bloom, plant height and weight/bushel. Their suggestion was based on the observation that lines could be effectively evaluated for combining ability when crossed on to three or four females. They further noticed that general effects were considerably more stable than specific effects over years.

Greater stability associated with g.c.a. was also reported by Rojas and Sprague (1952) in corn. They suggested that g.c.a. is more important in unselected material.

Combining ability studies are useful in classifying lines on the basis of their hybrid performance.

Liang and Walter (1968) found significant difference between g.c.a. and locations for yield and time to anthesis in lines of sorghum. They indicated that specific combining ability seems to be more important for grain yield and general and specific combining abilities are important for time to anthesis.

Beil and Atkins (1967) studying the performance of 40 F_1's produced by crossing 8 R-lines to 5 A-lines at 3 locations over 2 years found that variance for g.c.a. for grain yield in sorghum was three times larger than the s.c.a. effects for grain yield, heads per plant and 100 seed weight. The degree of dominance for number of seeds per head was markedly larger than the degree of dominance observed for the other characters.

Kirby and Atkins (1968) in a study of heterotic response for vegetative and mature plant characters in grain sorghum (*Sorghum bicolor* (L.)) indicated that g.c.a. effects were often more significant than were s.c.a. effects. However, s.c.a. components were found to be significant for six of the thirteen characters studied. The mean square for parents vs. hybrids was significant for five characters indicating that non-additive gene effects were important in the expression of these traits.

Malm (1968) in his study of the use of exotic germplasm in grain sorghum indicated that g.c.a. effects were 20.1, 64.1 and 17.5 times greater than the s.c.a. effects. He used the ratio of mean square values as a measure of combining ability for yield, seed size and protein and he found a predominance of additive effects.

Chandra et al. (1969) in their line x tester studies in forage sorghum indicated the occurence of high additive genetic variance for various characters, especially in the female parents. Cross combinations like high x high and high x medium resulted in high general combining ability effects. In general, high x high and high x medium crosses also showed a higher degree of heterosis.

Shankaregowda et al., (1972) in his line x tester experiments with three male sterile lines and eleven pollinators of sorghum at two locations indicated that 2219 A was good for several desirable traits. Heterosis tended towards earliness for days to bloom, which is most desirable for breeding early hybrids.

Singh and Joshi (1966), in their line x tester analysis in linseed found that non-additive effects were of greater importance for the traits that they studied. They suggested that instead of using number of testers in separate crosses, it would be better to use single or double crosses as testers involving lines with high g.c.a. They also suggested that parental performance itself is not necessarily a guarantee of it is usefulness in breeding programme.

Studies on combining ability by Singh et al., (1971) in their line x tester analysis in cotton found that two lines with good combining ability may not always have high s.c.a. This can be attributed to the absence of interaction between favourable alleles contributed by the two parents.

Singh and Gupta (1969), noticed in wheat that the combining ability for yield was influenced by the combining ability of it's components.

Rao et al., (1968) suggested that the line x tester method was found to be an efficient method for screening a large number of stocks for their combining ability. Three yellow endosperm male steriles developed in India and CK60A were used as female parents in crosses with a set of eleven exotic and Indian varieties as male parents. They found that variance due to g.c.a. was greater for the characters that they studied. They emphasized that choice of female parents be based on prior evaluation of combining ability before back crossing to develop the 'A -line in order to avoid disappointment if the new A-line fails to be useful. The newly developed male steriles did not exhibit superiority over combine kafir 60 for yield or g.c.a. They however, resulted in free threshing hybrids with Indian pollinator parents which is not the case with CK60A.

King et al., (1961) developed new male sterile lines in sorghum, but due to lack of diversity they have not been so useful in hybridization programmes - they are primarily kafirs and karif-milos.

Vidyabhushanam (1965) transferred male sterility to a number of derived yellow endosperm kafirs since it was thought that hybrids based on such steriles would have superior grain quality.

Madhavarao, et al., (1970), were interested in the male-sterile M31-2A as it possessed valuable characters for the rabi season such as pearly white grains, resistant to shootfly, tolerance to drought and fodder quality lacking in CSH-1 and CSH-2.

Goud, (1971) organized an experiment using CK60A and M31-2A as females and 20 male parents. He found that CK60A had higher g.c.a. for reduction in the plant height, earlier flowering and head length as compared to M31-2A.

Gupta and Gupta (1971) in studies on pearl millet obtained higher s.c.a. variances for most of the characters considered. g.c.a. effects were important for leaf size, stem thickness and leaf number. This calls for the need to exploit s.c.a. to obtain high yielding combinations.

Studies by Gupta and Singh (1973) on pearl millet indicates that genetic diversity of the parental material contributed to higher variances for g.c.a. than for s.c.a. They also point out that improvement in grain yield could be obtained by improving it's component characters. They observed average to good combining ability for component characters when both parents and crosses have good general and specific combining ability for grain yield.

Studies by Ahluwalia (1962) on pearl millet indicated that combining ability effects were related to the test material involved and the effects could change if there was a change in parents.

Riccelli Mattel (1975) while experimenting on combining ability in sorghum, found significant g.c.a. effects especially for pollen parents and he considered this to be important. Variance due to additive effects was 4 to 18 times greater than variance due to non-additive effects for grain yield and 9 to 14 times greater for fodder yield. He felt that the best guide to hybrid grain yield was parental grain yield.

Subba Rao et al., (1974) while studying combining ability in Sudan grass reported that the differences among the hybrids, male parents and the interaction between females x males were significant for all the characters except days to bloom. Predominatly non-additive gene action was observed for all the characters. They highlighted the importances of non-additive gene effects in a fodder breeding programme.

Nagur and Menon (1974) while studying combining ability in sorghum reported higher mean sum of squares due to females when compared to those due to males or females x males indicating greater diversity among female parents. Both g.c.a. and s.c.a. were found to be important for the expression of days to 50% bloom. S.c.a. was more important for plant height and ear width. G.C.A. was found to be more important for leaf length, leaf width and ear length.

Bains and Nagi (1972) while studying the combining ability of male sterile lines of pearl millet, reported male sterile x inbred interaction ranked the inbreds for the head length and thickness but not for grain yield, tiller number, days to flower and plant height. For head length and thickness, the F_1 performance was in accordance with the _per se_ performance of the inbreds.

Singh & Singh,(1974) in a line x tester analysis in green gram concluded that additive x additive and dominant x dominant types of gene action were predominant. They noticed a high degree of association between g.c.a. effects and the mean performance of lines and testers, but they did not find any association between the _per se_ performance of the crosses and their specific combining ability.

Laoshwan and Atkins (1977) suggested that genetic male sterile lines available from random mating sorghum populations also could be used as broad tester stocks for evaluating performance of lines.

Sangwan, _et al._, (1977) after their study on combining ability on forage sorghum noted that s.c.a. variance was higher than g.c.a. variance for dry matter and green fodder yield, leaf length and width, and leaf and tiller number per plant indicating that non-additive gene action was important for these traits.

Kaw and Menon (1978) while working on soyabean in a line x tester experiment indicated that for none of the 10 traits studied did the genetic variability appear to be predominantly additive, suggesting variance due to s.c.a. is an important measure to gene action.

Correlations

A programme of breeding for high yield is supported by information on the nature and magnitude of variation in the available material, association of characters with yield and among themselves and the extent of environmental influence on these characters.

Reddy and Rao (1971) evaluated various selection schemes and found that selection for flowering and height were more effective than for grain yield in sorghum. Panicle length was negatively correlated with plant height, days tobbloom, 100 grain weight and number of secondary branches. It was suggested that selection based on yield, flowering and plant height was as effective as selection based on all above mentioned characters.

Studies by Atkins *et al* (1968) on the interrelation between dry weight of the panicle, threshing percent, and grain yield in sorghum showed positive highly significant correlations between panicle weight and threshed grain weight but indicated the importance of separation of grain from the panicle when precise evaluation for grain yield *per se* is needed.

Rao et al., (1973) while working with some exotic x Indian crosses of sorghum noted that days to 50% bloom is more important to yield than is plant height.

Liang (1969) determined genotypic and phenotypic correlations among 12 characters in a segregating population of sorghum and found that grain yield was positively and significantly correlated with head weight, kernel number, half bloom date. It was suggested that head weight and half bloom date are considered the best indicators for yield.

Dabholkar (1970) reported in sorghum that number of grains in primary branches was positively and significantly correlated with grains per panicle, and that grain yield per plant, test weight and number of grains per panicle had a maximum contribution to grain yield.

Eckebil and Ross.,(1977) after studying three populations of sorghum point out that grain yield per unit area generally was best correlated with grain yield per head, plant height, threshing percent and 1000 seed weight. Days to bloom and grain protein percent were negatively correlated with yield.

MATERIALS AND METHODS

3.1: Experimental materials:

Five cytoplasmic genetic male sterile lines (A lines) of diverse origin with similar maturity and plant height were crossed with twenty non-restorer lines (B lines). The resulting 100 hybrids were planted along with their parents in the month of June 1980 at ICRISAT centre, Patancheru, Hyderabad,on both Alfisols and Vertisols.

The objective of the present investigation was to study the general and specific combining abilities of the non-restorer lines which are the advanced generation lines derived from different populations maintained at ICRISAT Centre. There is interest to convert to A lines, by repeated back crossing, those non-restorer lines with superior combining ability.

Techniques of crossing :

1. Seed parents

The following are the five cytoplasmic genetic male sterile lines which were used as female parents.

	Testers	Pedigree
i)	CK 60A	CK 60A
ii)	2219 A	2219 A
iii)	10430 A	10430 A
iv)	10406 A	10406 A
v)	10360 A	10360 A

2. Pollinator parents

The following twenty non-restorer lines served as pollinator parents :

Line No.	Pedigree
Line 1	Diallel BC 2-346-1-7
Line 2	FLB 8952-1-1
Line 3	Rs/B-119-132-2-1-1
Line 4	Us/R 392
Line 5	FLB 187-43-1-1-2
Line 6	Rs/B 97-108-2-2
Line 7	FLB 146-33-3-2
Line 8	FLR 141 x Cs 3541-1-2-1-1-F_8
Line 9	FLR 141 x Cs 3541-2-1-2-2-F_8
Line 10	Rs/R S8 21-8614-1-1
Line 11	Us/R (C_1) S_{11} 398-2-1
Line 12	Indian Synthetic 89-2
Line 13	Indian Synthetic 312-2
Line 14	WAE S7-3-1067-3-5-1
Line 15	FLR 266 x CS 3541-2-1-1
Line 16	FLR 274 x CS 3541-6-1-1
Line 17	FLR 274 x CS 3541-6-1-6
Line 18	Nigerian 7-1499-1
Line 19	RS1 x VGC-S8-21-14-2
Line 20	RS1 x VGC

Techniques for crossing

Five cytoplasmic male steriles (A lines) and the twenty non-restorer lines were planted at Bhavanisagar, in the month of January, 1980. Each A-line plot included 20 rows, 4 meters in length and rows 45 cm apart with plants 15 cm apart in the row. The non-restorers were sown in four row plots on two dates one week apart to insure nick. The non-restorer lines were bagged after the emergence of the head prior to anthesis. The pollen collected from these non-restorer lines was dusted on each of the heads of the five male sterile lines. 10 crosses per A line with each B line were made following this procedure.

Field plot techniques and layout

The resulting 100 F_1s were planted along with parents, which were randomized separately, on 22nd June, 1980, in a randomized replicated design, with three replications each in alfisols and vertisols at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) centre, Patancheru, Hyderabad. The experimental plot consisted of 2 rows, 4m length, 75 cm apart. The planting was done by mechanical planter and later thinned to 35 plants/row giving a plant to plant spacing of 11 cm within a row. Thinning was done 15-20 days after planting. As the F_1s in this study came from crosses between A x non-restorer lines they were male sterile so they needed supply of pollen to set seed. For this purpose two rows of F_1 hybrids were alternated with one row of a pollinator bulk consisting of CSH-1, CSH-5 and CSH-6 hybrids. The pollinator bulk was also sown on all sides of the field to ensure that the pollen supply was adequate.

One irrigation was found necessary in Alfisols as rains were inadequate; this irrigation was given 15 days after sowing. The field was fertilized with 300 kg/ha of 28:28:0 as a basal dose and 100 kgs of urea/ha was given as a top dressing when the plants were 30-35 days old making up a total of 130 kg N, 84 kg P_2O_5 and 0 kg of K_2O/ha.

One spraying of malathion was given to control borer and at a later stage one spray to control earhead pests was also provided.

3.2: Characters studied:

Six random competitive plants were tagged in each replication leaving border plants on either sides. The data in respect of the following characters is presented as a mean over six plants in each replication.

i) Plant height : Measured in centimeters, after the emergence of the panicle, from the ground level to the tip of the head. This measure is presented as the mean of the six tagged plants.

ii) Grain yield per plant : This measure in grams, is the mean of the threshed grain of the six competitive plants after two weeks of sun drying.

iii) Head yield per plant : This measure, in grams, is from the mean of the six tagged plants.

iv) Head length : Expressed as the mean length of the panicle in centimeters from base to the tip of the panicle.

v) 500-grain weight : Five hundred seeds were randomly taken from the grain of the six plants and the weight was recorded in grams for each replication, for each treatment.

The following traits were measured on a plot basis-

i) Days to bloom : The measure was made in days from the day of sowing until 50 percent of the plants in a plot came to flower.

ii) Grain yield/ha : Recorded in grams/plot and expressed in q/ha : All plants in the plot were harvested and bulkthreshed, and the grain weight of the selected six plants was added to obtain the total grain yield for the plot.

iii) Head yield/ha : Expressed in q/ha, includes the heads from the bulk harvest and of the six selected plants.

Using the data described above the following two characters were computed :

i) No.of grains per head: This was calculated by the formula

$$\frac{\text{Grain yield per plant}}{\text{500 grain wt.}} \times 500$$

ii) Threshing percent : This is a ratio of plot grain weight/plot head weight and expressed in percentage. The values obtained were transformed by using the angular transformation technique for statistical analysis.

3.3: Statistical analysis:

a. Combining ability analysis : The analysis of combining ability was based on the method of Kempthorne (1957). The covariance of half-sibs and full-sibs was used to obtain estimates of general and specific combining ability and their variance as follows.

Source	Degrees of freedom	Sum of squares	Mean squares	Expected mean squares
Replications	(r-1)	$\frac{X^2..K}{m.f} - \frac{X^2...}{m.f.r.}$		
Hybrids	(mf-1)	$\frac{X^2_{ij}}{r} - \frac{X^2...}{m.f.r}$		
Males	(m-1)	$\frac{X^2_{i}..}{f.r} - \frac{X^2...}{m.f.r}$	M_1	σ^2+r(COV.(F.S)-2 COV.(H.S) +fr COV. (H.S)
Females	(f-1)	$\frac{X^2_{j}..}{m.r} - \frac{X^2...}{m.f.r}$	M_2	σ^2+r(COV.(F.S)-2 COV.(H.S) +mr COV. (H.S)
Males x Females	(m-1)x(f-1)	$\frac{X^2(ij)}{} - \frac{X^2_{i}...}{f.r} - \frac{X^2.j}{m.r.} - \frac{X^2...}{m.f.r}$	M_3	σ^2+r(COV.)F.S)-2 COV. (H.S)
Error	(r-1)x(m.f-1)	by difference	M_4	σ^2
Total	(m.f.r - 1)	$X^2(ij)K - \frac{X^2...}{m.f.r}$		

r = number of replications

m = number of male parents

f = number of female parents

X = sum of all the (ij) hybrid combinations

$X_{..K}$ = sum of K^{th} replication

$X_{(ij)}$ = sum of ij^{th} hybrid combination over all replications

X_i = sum of i^{th} male parent over all female and replications

X_j = sum of j^{th} female parent over all males and replications

$X_{ij}K$ = ij^{th} observation in K^{th} replication

From the expectations of the Mean Sum of Squares, covariance (COV) of full-sibs (F.S.) and covariance of half-sibs (H.S.) were estimated by using the formulae of Kempthorne (1957) as shown below :

$$\text{Covariance of (H.S.)} = \frac{(M_1 - M_3) + (M_2 - M_3)}{r\,(m + f)}$$

$$\text{Covariance of (F.S.)} = \frac{(M_1 - M_4) + (M_2 - M_4) + (M_3 - M_4)}{3\,r} + \frac{6r\ \text{COV.(H.S)} - r\,(m + f)\ \text{COV. (H.S)}}{3\,r}$$

Estimation of variances : After estimating the COV. of (H.S) and COV.(F.S) using the above equations, variances due to general combining ability (σ^2 g.c.a.) and variances due to specific combining ability (σ^2 s.c.a.) were estimated as

$$\sigma^2 \text{ g.c.a.} = \text{Covariance of (H.S)}$$

$$\sigma^2 \text{ s.c.a.} = \text{Covariance of (F.S)} - 2\ \text{Cov. (H.S)}$$

Estimation of g.c.a. and s.c.a. effects

The additive model used to estimate the g.c.a. and s.c.a. effects of the ijk observations was

$$X_{ij} + \mu + g_i + g_j + s_{ij} + e_{ijk}$$

where

$\hat{\mu}$ = population mean

$\hat{g}_i$ = g.c.a. effect of i^{th} male parent

$\hat{g}_j$ = g.c.a. effect of j^{th} female parent

$\hat{s}_{ij}$ = s.c.a. effect of ij^{th} combination

e_{ijk} = error associated with the observation x_{ijk}

i = number of male parents

j = number of female parents

k = number of replications

The individual effects were estimated as follows :

(I) $\hat{\mu} = \frac{X...K}{m.f.r.}$

Where $X...$ = Total of all hybrid combinations over all replications

(II) $\hat{g}_i = \frac{X_{i}..}{f.r} - \frac{X...}{m.f.r}$

where $X_{i}..$ = Total of i^{th} male parent over all females and replications

(III) $$\hat{g}_j \qquad \frac{X_{j\ldots}}{m.r} \qquad \frac{X\ldots}{m.f.r}$$

Where $X_{j..}$ = Total of j^{th} female parent over all male parents and replications

(IV) $$\hat{s}_{ij} = \frac{X_{(ij)}}{r} - \frac{X_i}{f.r} - \frac{X_j}{m.f} + \frac{X\ldots}{m.f.r}$$

Where

(X_{ij}) = ij^{th} combination total over all replications.

<u>Standard errors for combining ability effects</u> : The S.E's pertaining to g.c.a effects of males and females and s.c.a. effects of different combinations were calculated as shown below :

$$\text{S.E. } (\hat{g}_i) \text{ males} = \sqrt{\frac{\text{Error variance}}{r.f}}$$

$$\text{S.E. } (\hat{g}_j) \text{ females} = \sqrt{\frac{\text{Error variance}}{r.m.}}$$

$$\text{S.E. } (\hat{s}_{ij}) \text{ male x female combination} = \sqrt{\frac{\text{Error varance}}{r}}$$

Where r = number of replications

m = number of males

f = number of females

<u>Correlations</u> : Simple correlation coefficients (r) for hybrids and correlation coefficients between mean performance of hybrids and their g.c.a. effects among different characters were calculated (Panse and Sukhatne, 1957)

$$r = \frac{\text{Cov. X Y}}{\sqrt{\text{Var.X . Var. Y}}}$$

$$\text{Cov. } XY = \Sigma XY - \frac{\Sigma X.\ \Sigma Y}{\ }$$

$$\text{Var. } X = \Sigma X^2 - \frac{(\Sigma X)^2}{n}$$

$$\text{Var. } Y = \Sigma Y^2 - \frac{(\Sigma Y)^2}{\ }$$

Where

r = correlation coefficient

Cov. = covariance

Var. = variance

X & Y = Two indepent variables

RESULTS

The results of the present investigation are presented under the following headings:

4.1: Mean performance of parents.

4.2: Analysis of variance for parents.

4.3: Analysis of variance for hybrids.

4.4: Mean performance of hybrids.

4.5: General and specific combining ability effects.

4.6: Correlations.

4.1: Mean performance of parents:

Means for different characters of the 25 parental lines are shown in Table 1, and the analysis of variance for these characters are presented in Table 2. The mean values of the non-restorer lines were statistically different from one another for all the characters studied. But non significant difference between mean values was noticed for tester parents for days to bloom, threshing percent at both locations. The tester, CK60A, showed significantly different mean value at both, locations for plant height.

The 'B' lines, L_7 (56, 58, days, alfisols; vertisols) L_1 (61, 61 days) and L_4 (60, 62 days) showed statically different lower mean values for days to bloom at both locations. The late maturing 'B' lines were L_{16} (73, 72 days:alfisols, vertisols) L_{10} (71, 72 days) and L_{12} (70, 68 days) were also statistically different from others at both locations. For plant height the dwarf 'B' lines were L_7 (111, 120 cm alfisols, vertisols), L_3 (116, 129 cm) and L_5 (118, 124 cm) at both locations. On the contrary, 'B' lines, L_{16} (195, 200 cm) L_{19} (191, 219 cm) and L_{12} (171, 187 cm) showed, statically different, higher mean values at both locations. Among tester parents, CK60A (126, 139 cm) and 10406A (115, 120 cm) showed statically different, maximum and minimum mean values respectively at both locations. For grain yield and head yield per plant the lines, L_9 (49.0, 65.0 g) grain yield, head yield), L_{12} (39.6, 54.3 g)), L_{13} (35.6, 46.0 g.) and L_6 (31.3, 47.3 g.) on alfisols and L_{16} (46.6, 68.6 g.) L_{17} (40.6, 55.0 g.) and L_{20} (38.0, 55.6 g.) on vertisols showed statically different, higher mean values. However the lines, L_6, L_9 and L_{12} also performed well on vertisols. Among testers, 10430A showed maximum mean yield even though statistically not different from others at both locations. The 'B' lines L_{13} (14.5, 13.2 g.) alfisols, vertisols) L_{18} (12.7, 12.6 g.) and L_{15} (12.4, 12.4 g.) showed superior mean performance for 500 grain weight at both locations. The tester, 10430A showed maximum mean value for the same trait. For number of grains per head, L_{16} (1611, 2085), L_{12} (1860, 1520) and L_{11} (1598,1541) were superior at both locations. But the lines, L_9 (2141, alfisols) and L_{20} (1791, vertisols) were superior either on alfisols or vertisols. The 'B' lines did not differ significantly for threshing percentage. However, L_{19} (83.0%) and L_{15} (81.3%) on alfisols and L_{17} (77 %) L_{11} (75.7%) on vertisols, L_{12} (78.6, 78.3 %, alfisols, vertiosls) and L_{20} (81.6, 75.3%) at both locations showed higher threshing percentage. For grain yield and head yield

TABLE 1 : MEAN PERFORMANCE OF PARENTS.

Source	Days to bloom		Plant height (cm)		Grain yield/plant (g)		Head yield/plant (g)		Head length (cm)	
	Alfisols	Vertisols	Alfisols	Vertisols	Alfisols	Vertisols	Alfisols	Vertisols	Alfisols	Vertisols
Males										
L 1	61	61	151	167	30.0	32.0	35.0	44.6	21	23
L 2	63	60	143	154	24.0	25.6	32.0	36.0	21	22
L 3	69	67	116	129	27.0	31.0	31.3	38.3	21	24.
L 4	60	62	168	176	23.3	20.0	37.0	32.6	25	26
L 5	63	64	118	124	24.3	24.3	35.0	38.0	20	22
L 6	63.	63	155	160	31.3	32.3	47.3	49.6	20	23
L 7	56	58	111	120	25.6	15.6	36.6	26.0	20	20
L 8	67	66	130	151	18.6	23.0	27.0	33.3	19	21
L 9	67	66	168	170	49.0	30.3	65.0	44.7	23	22
L 10	71	72	158	170	23.3	19.6	32.3	29.6	19	21
L 11	65	61	140	153	31.0	29.3	41.6	40.6	19	23
L 12	70	68	171	187	39.6	32.6	54.3	42.0	26	25
L 13	68	70	123	126	35.6	34.3	46.0	49.0	16	19.
L 14	62	65	123	139	24.3	27.0	37.0	44.3	19	24
L 15	67	66	150	186	26.6	36.0	41.3	46.0	22	23
L 16	73	72	195	200	25.3	46.6	36.3	68.6	26	28
L 17	72	67	118	139	25.3	40.6	35.6	55.0	22	24
L 18	63	65	153	155	27.0	21.3	33.6	33.0	28	19
L 19	67	65	191	219	22.6	31.3	30.0	43.0	20	22
L 20	67	66	165	181	27.6	38.0	36.3	55.6	21	24

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(Cont'd)

Source	500 grain weight (g)		No. of grains/head		Threshing %		Grain yield q/ha		Head yield q/ha	
	Alfisols	Vertisols	Alfisols	Vertisols	Alfisols	Vertisols	Alfisols	Vertisols	Alfisols	Vertisols
Males										
L1	12.9	11.7	1171	1386	77	72	41.4	38.2	52.3	52.7
L2	11.7	10.6	1138	1226	76	75	20.6	28.5	27.0	37.5
L3	9.0	11.1	1506	1408	67	73	33.9	25.0	41.8	34.0
L4	10.2	9.1	1148	1113	75	70	21.2	23.6	27.9	32.3
L5	10.7	11.9	1146	1033	74	63	31.1	19.2	41.3	30.0
L6	9.9	11.6	1426	1395	75	69	28.6	23.7	37.8	34.3
L7	11.6	11.7	1118	761	80	70	28.6	18.2	35.6	25.7
L8	10.9	11.7	1196	1010	76	69	29.9	24.4	37.8	34.7
L9	11.5	11.0	2141	1400	77	70	28.7	29.2	36.5	37.5
L10	9.8	7.9	1195	1321	77	68	24.2	18.4	30.7	24.5
L11	9.7	9.4	1598	1541	75	75	31.4	27.0	39.1	35.7
L12	12.0	10.9	1860	1520	78	78	40.0	43.5	50.7	54.9
L13	14.5	13.2	1240	1353	76	70	32.7	19.6	41.1	27.4
L14	10.2	11.1	1200	1215	71	67	23.1	25.3	31.5	37.2
L15	12.4	12.4	1088	1451	81	75	42.3	32.6	53.5	43.6
L16	12.0	11.3	1611	2085	72	68	27.2	17.9	37.4	25.1
L17	10.5	10.6	1203	1950	74	77	22.0	23.9	30.5	30.7
L18	12.7	12.6	1075	863	76	72	26.7	26.2	34.6	34.6
L19	10.8	11.9	1278	1323	83	75	32.6	35.2	39.1	46.1
L20	10.5	10.7	1300	1791	81	75	29.7	19.5	36.2	25.6

Contd...

TABLE . (Contd.)

Source	Days to bloom		Plant height(cm)		Grain yield/plant(g)		Head yield/plant(g)		Head length (cm)	
	Alfisols	Vertisols	Alfisols	Vertisols	Alfisols	Vertisols	Alfisols	Vertisols	Alfisols	Vertisols
Females										
CK60A	62	62	126	139	17.7	18.6	24.6	26.3	21	21
2219A	61	61	108	117	26.0	18.6	35.6	26.3	25	26
10430A	60	61	116	126	29.0	24.6	39.6	35.3	22	22
10406A	58	62	115	120	21.0	20.6	28.3	29.6	22	22
10360A	60	62	118	122	25.6	18.6	34.3	27.1	20	24
S.Em.	0.52	1.16	2.83	4.75	1.75	3.12	1.96	4.39	0.64	0.85
C.D.at 5%	1.50	3.30	8.05	13.52	4.98	8.87	5.58	12.48	1.84	2.42

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TABLE : contd..

Source	500 grain weight (g)		No.of grains per head		Threshing %		Grain yield q/ha		Head yield q/ha	
	Alfisols	Vertisols	Alfisols	Vertisols	Alfisols	Vertisols	Alfisols	Vertisols	Alfisols	Vertisols
Females										
CK60 A	13.0	13.4	686	695	75	71	22.7	18.0	26.3	24.4
2219 A	9.8	12.6	1330	778	77	70	20.2	19.2	26.3	27.08
10430A	13.6	13.3	1070	941	76	71	19.2	13.3	23.9	18.3
10406A	13.0	13.0	810	805	80	70	18.9	12.8	23.8	17.3
10360A	12.8	12.0	1001	791	81	62	18.8	8.7	24.3	13.8
S.Em.	0.46	0.50	157.89	142.72	3.31	3.10	3.71	2.23	4.68	2.55
C.D. at 5%	1.32	1.43	448.85	405.72	9.43	8.82	10.55	6.35	13.30	7.27

per hectare, the 'B' lines, L_{12} (40.0, 50.7 q/ha grain yield, head yield, alfisols) (43.5, 54.9 q/ha vertisols), L_1 (41.4, 52.3, q/ha, alfisols) (38.2, 52.7 q/ha, vertisols) and L_{15} (42.3, 53.5 q/ha, alfisols) (32.6, 43.68, q/ha, vertisols) showed superior mean performance at both locations. Among testers, CK60A on alfisols and 2219A on vertisols showed highest mean values for yield.

4.2: <u>Analysis of variance for parents</u>:

The analysis of variance for parents (Table 2) showed that the characters viz. days to bloom, plant height, grain yield per plant, head yield per plant, head length 500 grain weight and number of grains per head were highly significant for both locations. Threshing percent was not significant at both locations while grain yield per hectare and head yield per hectare for alfisols were also found to be non-significant. An examination of variances due to testers and non-restorer lines indicated that non-restorer lines were exhibiting higher mean sum of squares when compared to testers for the traits days to bloom, plant height, grain yield per plant, head yield per plant, head length, number of grains per head, grain yield per hectare and head yield per hectare for both alfisols and vertisols indicating greater diversity in the non-restorer lines. The mean sum of squares were slightly greater for testers than non-restorer lines for 500 grain weight for alfisols and vertisols and for threshing percent for vertisols.

TABLE 2 : ANALYSIS OF VARIANCE FOR PARENTS

Source	df	Mean squares							
		Days to bloom		Plant height		Grain yield per plant		Head yield per plant	
		Alfisols	Vertisols	Alfisols	Vertisols	Alfisols	Vertisols	Alfisols	Vertisols
Replications	2	5.61	30.33	146.33	844.68	0.95	198.97	27.61	564.36
Parents	24	60.91**	40.41**	1952.03**	2351.15**	129.57**	186.98**	225.34**	339.60**
Males	19	55.37**	42.52**	1044.21**	2131.54**	139.79**	177.26**	239.13**	303.92**
Females	4	22.26**	0.56	130.83**	226.16**	59.98**	20.40	107.60**	43.46
Males vs females	1	320.77**	159.72**	26485.41**	15023.70**	213.75**	1037.98**	434.29**	2202/08**
Error	48	0.83	4.05	24.11	67.86	9.23	29.21	11.57	57.89

*,** significant at 5% and 1% levels of probability,respectively.

TABLE : 2 (cont'd)

Source	df		Mean squares					
			Head length		500 grain Test weight		No. of grains per head	
			Alfisols	Vertisols	Alfisols	Vertisols	Alfisols	Vertisols
Replications	2		15.68**	25.24**	3.18**	4.23 **	320564**	661895**
Parents	24		17.59**	14.14**	6.08**	7.23**	281504**	416780**
Males		19	19.13**	15.77**	5.24**	6.34**	230225**	326735**
Females		4	12.39**	9.73**	6.70**	8.09**	184510	23723
Males vs Females		1	9.13**	0.81	19.56**	20.70**	1643781	** 3699852 **
Error	48		1.26	2.18	0.65	0.78	74794	61111

*, ** Significant at 5% and 1% levels of probability, respectively.

.Contd...

TABLE 2 (Cont'd)

Source	df	Mean squares					
		Threshing %		Grain yield/ha		Head yield/ha	
		Alfisols	Vertisols	Alfisols	Vertisols	Alfisols	Vertisols
Replications	2	46.29	126.45*	99.17	114.52**	142.95	175.65**
Parents	24	37.13	46.14	51.83	69.31**	78.63	109.90**
Males	19	41.10	43.54	35.75	53.00**	59.30	80.36**
Females	4	16.93	49.43	2.23	19.70	1.78	31.92
Males vs. Females	1	42.50	82.38	555.75**	577.64**	753.30**	938.08**
Error	48	33.04	28.90	41.37	14.97	65.74	19.63

*,** Significant at 5% and 1% levels of probability respectively.

4.3: Analysis of variance for hybrids:

An examination of variances for hybrids (Table 3) indicated that hybrids were significantly different for all characters studied for both locations except for number of grains per head on vertisols. Variances due to testers, non-restorer lines, and lines x testers were found to be significant for days to bloom, plant height, grain yield per plant, head yield per plant, head length, 500 grain weight, threshing percent, and grain yield per hectare at both locations (Table 3), except for variance due to testers for grain yield/ha on vertisols, and variance due to interaction for head length on alfisols. The number of grains per head for testers and non-restorers lines were not significantly different on vertisols, but non-significant interaction for this trait was noticed on alfisols. The interaction for head yield per hectare was not significant on alfisols (Table 3).

The variances due to general combining ability and specific combining ability were determined for the ten characters on alfisols and vertisols and are presented in Table 3; the details are presented below.

4.3.1: Days to bloom:

The relative estimates of the variance due to g.c.a. and s.c.a. were 1.99:1 on alfisols and 0.56:1 on vertisols.

4.3.2: Plant height:

The relative estimates of the variances due to g.c.a. and s.c.a. were 1.35:1 on alfisols and 0.98:1 on vertisols.

4.3.3: Grain yield per plant:

The variance due to g.c.a. was found to be 1.00 while that for s.c.a. 1.32 on alfisols while the s.c.a. variance (33.53) was nearly seven times that of g.c.a. (4.84) on vertisols.

4.3.4: Head yield per plant:

The relative estimates of variances due to g.c.a. and s.c.a. were 0.37:1 on alfisols and 0.22:1 on vertisols for this trait.

4.3.5: Head length:

The ratios of g.c.a./s.c.a. were 1.33:1 on alfisols and 1.42:1 on vertisols.

4.3.6: 500 grain weight:

The ratios of g.c.a./s.c.a. were 3:1 and 0.65:1 on alfisols and vertisols respectively.

4.3.7: Number of grains per head:

The ratios of g.c.a./s.c.a. were 0.76:1 on alfisols and 0.08:1 on vertisols.

4.3.8: Threshing percent:

0.01:1 and 0.19:1 were the relative estimates due to g.c.a. and s.c.a. variances on alfisols and vertisols respectively.

(Cont'd)

Source	d.f		MEAN SQUARES					
			Threshing %		Grain Yield/ha		Head yield/ha	
			Alfisols	Vertisols	Alfisols	Vertisols	Alfisols	Vertisols
Replication	2		18.05**	4.55**	6507670**	6557830**	7141840**	6313920**
Hybrids	99		8.06**	9.93**	1084080**	1692460**	1584410**	2343050**
Males		19	14.34**	18.55**	2429890**	3194620**	3564930**	3767820**
Females		4	0.85**	25.16**	3061640**	1624140	4677090**	3488460**
Males x Females		76	6.87**	16.97**	643545*	1320520**	926503	1926570**
Error	198		0.14	0.87	477757	751017	700963	671378
σ^2 g.c.a.			0.019	0.396	56059.2	29036.2	85186.8	45375.3
σ^2 s.c.a.			2.244	2.032	55262.6	189834.0	75179.9	418396.0
g.c.a./s.c.a.			0.01:1	0.19:1	1.01:1	0.15:1	1.13:1	0.11:

(cont'd)

Source	d.f	MEAN SQUARES					
		Head length		500 grain weight		No.of grains/head	
		Alfisols	Vertisols	Alfisols	Vertisols	Alfisols	Vertisols
Replications	2	2.35	20.12**	4.19**	5.41**	688133**	313506
Hybrids	99	8.03**	7.72**	4.00**	4.04**	184594**	515021
Males	19	21.11**	22.84**	12.69**	11.15**	360901**	496592
Females	4	35.75**	37.07**	18.18**	13.73**	535566**	809767
Males x Females	76	3.30	2.39**	1.09*	1.76**	122045	504116*
Error	198	1.78	0.84	0.72	0.45	75269	345654
σ^2 g.c.a.		0.67	0.735	0.382	0.284	1.001	3975.04
σ^2 s.c.a.		0.505	0.517	0.121	0.435	1.325	52820.42
g.c.a./s.c.a.		1.33:1	1.42:1	3.16:1	0.65:1	0.76:1	0.08:1

TABLE 3: ANALYSIS OF VARIANCE FOR HYBRIDS

Source	d.f	Days to Bloom Alfisols	Days to Bloom Vertisols	Plant height Alfisols	Plant height Vertisols	Grain yield per plant Alfisols	Grain yield per plant Vertisols	Head yield per plant Alfisols	Head yield per plant Vertisols
		MEAN SQUARES							
Replications	2	23.76**	19.02**	175.78	0.69	669.75**	1.42	395.44**	73.48**
Hybrids	99	16.62**	15.23**	906.56**	1109.56**	114.71**	142.65**	177.14**	188.31**
Males	19	54.23**	40.87**	3445.32**	4250.03**	195.75**	268.29**	329.89**	337.15**
Females	4	57.37**	49.31**	1969.49**	2405.06**	222.83**	300.64**	350.56**	566.26**
Males x Females	76	5.07**	7.03**	215.93**	256.26**	88.76**	102.93**	129.82**	131.21**
Error	198	3.03	1.61	68.36	5.87	57.06	2.34	83.96	13.93
σ^2 g.c.a.		1.352	1.010	66.440	81.900	1.001	4.843	5.611	8.540
σ^2 s.c.a.		0.680	1.800	49.190	83.460	1.325	33.532	15.285	39.093
g.c.a./s.c.a.		1.99:1	0.56:1	1.35:1	0.98:1	0.76:1	0.14:1	0.37:1	0.22:1

* Significant at 5% level of significance

** Significant at 1% level of significance

σ^2 g.c.a. = Variance of general combining ability

σ^2 s.c.a. = Variance of specific combining ability

g.c.a./s.c.a. = Ratio of g.c.a./s.c.a.

Cont..

4.3.9: Grain yield per hectare:

The relative estimates of variances due to g.c.a. were 1.01:1 on alfisols and 0.15:1 on vertisols.

4.3.10: Head yield per hectare:

The relative estimates of variances due to g.c.a. and s.c.a. were 1.13:1, 0.11:1 on alfisols and vertisols respectively.

4.4: Mean performance of hybrids:

The mean values of the 100 hybrids for different characters under study are reported only on alfisols and are presented in Table 4, as an example for the reason that the average performance of the hybrids produced by non-restorer lines across testers were almost similar for most of the traits at both locations.

The average performance of the hybrids produced by non-restorer lines were significantly different for all characters except grain yield and head yield per plant.

4.4.1: Days to bloom:

The average performance of the hybrids produced by non-restorer lines across five testers ranged from 56.6 days to 64.2 days. Among non-restorers lines, L_7 (55.8 days) was the earliest followed by L_{14} (56.8 days), L_1 (57.2 days), and L_6 (57.4 days) which showed statistically different lower mean values. The genotype, L_{16} produced latest maturing hybrids, averaging 64.2 days. Among tester parents, the earliest hybrids were found with 10406A (57.4 days) and the latest hybrids were found when CK60A was used as the seed parent (60.0 days).

4.4.2: Plant height:

Average plant height of the hybrids across testers ranged from 132 cm to 178 cm. The shortest hybrids were found when L_3 (132 cm) and L_5 (132 cm) were pollinator parents. Dwarf hybrids were also found when L_7 (133 cm), L_{14} (140 cm), L_2 (143 cm) and L_{18} (144 cm) were pollinator parents where as L_9 (178 cm), L_{16} (176 cm) and L_{19} (175 cm) produced tall hybrids. Among tester parents, 2219A (147 cm) and CK60A (163 cm) resulted in dwarf and tall hybrids respectively.

4.4.3: Grain yield per plant:

The average yield per plant of hybrids produced by each non-restorer line across testers ranged from 26.8 g. to 39.6 g. The hybrids of non-restorer line (line-12) when averaged across the five tester parents had highest mean performance (39.6 g). Other good non-restorers were L_1 (39.2 g), L_8 (37.4 g) and L_{19} (36.4 g). The highest mean performance among testers was found with CK60A (34.1 g.)

4.4.4: Head yield per plant:

Average yields for the hybrids of non-restorer lines across testers for this trait ranged from 35.2 g. to 53.6 g. The non-restorer lines,

TABLE 4: MEAN PERFORMANCE OF HYBRIDS ON ALFISOLS.

Line	Days to bloom						Plant height (cm)					
	Tester						Tester					
	CK60A	2219A	10430A	10406A	10360A	Mean	CK60A	2219A	10430A	10406A	10360A	Mean
L 1	57	59	58	55	57	57.2	170	150	155	150	160	157
L 2	59	59	58	58	59	58.6	135	140	140	150	150	143
L 3	57	58	57	58	59	57.8	140	125	125	135	135	132
L 4	58	57	56	56	56	56.6	175	170	165	155	175	168
L 5	59	58	58	58	60	58.6	140	130	130	125	135	132
L 6	58	58	57	55	59	57.4	180	135	165	165	160	161
L 7	55	55	57	55	57	55.8	140	120	145	140	120	133
L 8	60	61	60	59	61	60.2	150	140	165	150	165	154
L 9	61	59	58	58	61	59.4	180	170	180	180	180	178
L 10	58	58	58	57	60	58.2	170	155	165	160	150	160
L 11	66	62	56	56	60	60.0	190	115	140	135	135	151
L 12	61	60	61	60	61	60.6	180	155	165	165	170	167
L 13	61	62	59	57	61	60.0	175	155	165	165	170	166
L 14	60	56	56	56	56	56.8	145	135	145	140	135	140
L 15	59	59	61	57	61	59.4	180	155	160	165	165	165
L 16	66	62	64	63	66	64.2	185	175	170	180	170	176
L 17	62	60	62	61	62	61.6	135	145	150	155	140	145
L 18	60	58	58	58	58	58.4	145	145	140	145	145	144
L 19	61	68	57	56	59	58.2	185	165	175	175	175	175
L 20	62	55	59	56	60	59.2	175	165	175	165	170	170
Mean	60.0	58.9	58.5	57.4	59.7		163	147	156	155	155	

Contd...

S.E. $\pm$ 0.10
C.D. at 5% 2.78

S.E. $\pm$ 0.47
C.D. at 5% 13.22

Contd.

Line	Grain yield per plant (gm)						Head yield per plant (gm)					
	Tester						Tester					
	CK60A	2219A	10430A	10406A	10360A	Mean	CK60A	2219A	10430A	10406A	10360A	Mean
L 1	52	39	40	34	31	39.2	68	50	50	45	48	52.2
L 2	27	32	18	29	28	26.8	35	42	25	39	35	35.2
L 3	31	40	27	31	26	31.0	41	52	36	44	36	41.8
L 4	36	35	26	34	32	32.6	46	46	35	34	43	40.8
L 5	33	37	32	36	28	33.2	48	48	43	49	36	44.8
L 6	36	31	27	34	30	31.6	47	43	35	47	37	41.8
L 7	31	33	33	25	34	31.2	42	45	44	35	46	42.4
L 8	44	36	34	34	38	37.4	57	54	44	47	52	50.8
L 9	32	26	44	34	32	33.6	44	41	56	47	40	45.6
L 10	37	33	48	28	23	33.8	48	44	61	36	30	43.8
L 11	35	25	30	32	28	30.0	46	32	39	41	44	40.8
L 12	35	51	40	34	38	39.6	47	68	57	46	50	53.6
L 13	32	30	25	30	26	28.6	44	40	37	42	36	39.8
L 14	32	29	24	31	26	28.4	43	44	31	47	35	40.8
L 15	37	38	27	42	20	30.8	47	39	36	56	37	43.0
L 16	30	31	39	25	23	29.6	39	44	51	34	30	39.6
L 17	30	26	36	30	27	29.8	39	37	45	39	36	39.2
L 18	30	20	27	34	30	28.2	39	43	36	45	45	41.6
L 19	37	40	43	29	33	36.4	50	51	47	43	42	48.6
L 20	26	42	28	32	30	31.6	34	56	36	41	37	40.8
Mean	34.1	32.4	31.9	31.9	29.1		45.2	45.9	42.9	42.8	39.7	

S.E. + 0.43 4.36

C.D. at 5% = 12.08

S.E. ± 0.53

C.D. at 5% = 14.65

Contd...

Contd..

Line	Head length (cm)						[illegible] weight (gm)					
	Tester						Testers					
	CK60A	2219A	10430A	10406A	10360A	Mean	CK60A	2219A	10430A	10406A	10360A	Mean
L 1	24	24	22	23	23	23.2	15.0	13.2	14.1	13.6	12.9	13.7
L 2	23	25	20	23	23	22.8	11.5	10.4	11.6	12.7	11.8	11.6
L 3	24	27	24	23	24	24.4	12.2	10.5	11.9	11.8	10.6	11.4
L 4	24	27	24	23	26	24.8	13.7	13.6	13.6	13.6	13.5	13.6
L 5	24	25	22	24	23	23.6	12.8	11.7	12.7	13.2	12.7	12.6
L 6	25	24	22	24	22	23.4	12.8	11.8	13.4	13.9	13.0	12.9
L 7	22	25	22	21	23	22.6	12.7	12.4	13.3	13.2	13.3	12.9
L 8	25	26	23	24	24	24.4	12.6	10.7	12.9	11.6	12.6	12.1
L 9	21	22	22	22	22	21.8	14.1	11.5	12.8	14.5	12.5	13.1
L 10	22	23	23	21	20	21.8	11.9	12.2	14.0	13.3	12.3	12.5
L 11	24	21	21	23	21	22.0	14.1	10.8	12.3	11.9	12.1	12.2
L 12	24	28	26	25	25	25.6	13.7	12.5	13.3	13.5	13.6	13.3
L 13	21	21	21	20	20	20.6	15.7	13.5	17.9	15.6	15.5	15.6
L 14	22	24	21	23	22	22.4	13.0	11.8	12.0	12.8	12.1	12.3
L 15	23	23	21	24	21	22.4	14.7	12.2	14.1	14.1	13.6	13.7
L 16	23	24	24	23	23	23.4	13.6	12.8	14.4	13.2	13.9	13.6
L 17	23	23	25	23	22	23.2	12.0	12.6	12.9	12.1	12.3	12.4
L 18	21	25	21	22	21	22.0	14.0	12.3	14.0	13.8	13.4	13.5
L 19	22	24	24	22	22	22.8	12.8	12.2	13.0	13.3	12.6	12.8
L 20	21	25	21	23	22	22.4	13.0	12.2	13.3	13.4	12.7	12.9
Mean	22.9	24.3	22.4	22.8	22.4		13.3	12.0	13.4	13.2	12.8	

Contd..

S.E. ± 0.07

C.D. at 5% = 2.13

S.E. ± 0.04

C.D. at 5% = 1.35

Contd.

Line	No. of grains per head						Threshing %					
	Tester						Tester					
	CK60A	2219A	10430A	10406A	10360A	Mean	CK60A	2219A	10430A	10406A	10360A	Mean
L 1	1745	1475	1435	1260	1210	1425	78	81	80	81	78	79.6
L 2	1185	1520	804	1130	1205	1169	80	81	82	82	83	81.6
L 3	1290	1900	1125	1340	1215	1374	80	81	81	78	81	80.2
L 4	1305	1275	965	915	1200	1132	82	80	82	83	78	81.2
L 5	1300	1575	1255	1365	1085	1316	80	80	76	80	81	79.4
L 6	1435	1320	1015	1225	1145	1228	81	80	83	67	82	78.6
L 7	1230	1340	1250	965	1290	1215	80	86	64	76	81	77.4
L 8	1730	1670	1310	1480	1480	1534	79	79	81	78	77	78.8
L 9	1125	1170	1725	1190	1290	1300	80	78	81	84	80	80.6
L 10	1565	1360	1690	1045	935	1319	82	81	82	82	78	80.8
L 11	1245	1170	1225	1340	1165	1229	79	75	81	79	79	78.6
L 12	1295	2040	1525	1240	1410	1502	82	80	79	79	82	80.4
L 13	1030	1095	715	980	860	936	76	79	73	71	81	76.0
L 14	1225	1250	1025	1215	1060	1155	77	77	76	75	78	76.6
L 15	1270	1140	965	1455	750	1116	82	81	69	77	77	77.2
L 16	1100	1205	1345	950	840	1089	80	80	78	83	81	80.4
L 17	1275	1050	1400	1230	1105	1212	78	79	81	82	76	79.2
L 18	1060	825	955	1235	1120	1039	80	70	92	80	80	82.0
L 19	1480	1580	1680	1120	1320	1436	83	80	80	81	83	81.4
L 20	990	1760	1040	1190	1190	1234	81	81	83	76	79	80.0
Mean	1294	1386	1222	1194	1144		80.0	79.8	79.2	78.7	79.1	

Contd..

S.E. ± 15.83

C.D. at 5% = 438.83

S.E. ± 0.02

C.D. at 5% = 0.57

Contd.

Line	Grain yield q/ha Tester CK60A	2219A	10430A	10406A	10360A	Mean	Head yield q/ha Tester CK60A	2219A	10430A	10406A	10360A	Mean
L 1	46.70	44.30	40.95	40.15	42.40	42.90	59.20	54.40	50.90	49.30	54.20	53.60
L 2	34.00	38.95	23.90	29.30	31.80	31.60	42.10	47.70	29.00	35.55	38.05	38.50
L 3	38.25	38.50	36.50	34.70	34.50	36.50	47.40	47.20	45.00	44.05	42.45	45.20
L 4	39.75	41.00	32.65	25.55	38.25	35.44	48.10	50.85	39.30	30.80	48.55	43.50
L 5	38.35	38.65	29.95	35.10	29.20	34.25	47.35	48.20	39.05	43.00	36.05	42.73
L 6	36.30	43.55	32.55	30.60	29.60	34.52	44.55	54.10	39.10	45.95	35.75	43.90
L 7	33.20	38.35	30.50	29.05	28.20	31.86	41.00	44.30	47.90	37.90	34.40	41.10
L 8	45.65	44.80	43.20	38.50	36.15	41.66	57.10	56.60	53.30	48.75	46.40	52.43
L 9	33.70	32.45	40.85	40.55	34.75	36.46	41.50	41.10	50.45	47.70	43.30	44.80
L 10	39.85	48.85	41.45	37.75	23.65	38.31	48.00	60.11	50.85	45.70	29.80	46.90
L 11	40.40	22.85	34.05	34.65	27.90	32.00	50.70	29.95	41.95	43.65	34.75	40.20
L 12	43.85	45.50	47.95	38.90	41.10	43.46	53.00	56.65	59.95	49.00	50.05	53.73
L 13	32.05	31.00	23.85	31.80	30.40	29.82	41.80	38.80	32.30	45.05	37.40	39.10
L 14	27.45	37.70	31.05	31.85	30.15	31.64	35.20	48.80	40.35	41.65	38.20	40.85
L 15	47.50	35.40	25.50	40.10	34.15	36.53	57.75	43.65	37.00	51.40	43.70	46.70
L 16	35.15	38.20	25.30	35.75	26.00	32.08	43.90	48.45	32.45	42.90	31.90	39.90
L 17	38.10	36.20	42.25	40.90	33.90	38.27	48.45	45.75	51.60	49.55	43.90	47.85
L 18	28.00	34.95	26.70	33.00	32.90	31.11	34.65	44.40	29.90	40.75	40.90	38.12
L 19	37.60	37.55	43.15	39.90	34.80	38.60	45.15	46.35	53.45	48.70	41.70	47.10
L 20	29.05	38.65	31.15	32.70	37.45	33.80	35.40	47.45	37.45	43.35	38.30	40.40
Mean	37.24	38.37	34.16	35.04	32.86		46.11	47.74	43.06	44.23	40.50	

S.E. $\pm$ 0.39

C.D. at 5% = 11.05

S.E. $\pm$ 0.45

C.D. at 5% = 13.39

superior in producing good hybrids for grain yield per plant were also superior for this trait i.e. L_{12} (53.6 g.), L_1 (52.2 g.), L_8 (50.8 g.) and L_{19} (48.6 g.), resulted in hybrids with higher head yields per plant. Interestingly, the tester, 2219A resulted in hybrids with average performance (45.9 g.).

4.4.5: Head length:

The mean performance of the hybrids produced by non-restorer lines across testers ranged from 20.6 cm to 25.6 cm. Among non-restorer lines, L_{12} (25.6 cm) resulted in hybrids with the longest heads. The 'B' lines, L_4 (24.8 cm), L_8 (24.4 cm) and L_3 (24.4 cm) also resulted in hybrids with good head length. Among tester parents, 2219A and 10360A were found in hybrids with maximum (24.3 cm) and minimum (22.4 cm) mean values, respectively.

4.4.6: 500-grains weight:

An examination of Table 4 reveals that the hybrids of the twenty non-restorer lines averaged over five testers differed significantly in their mean value for 500 grain weight. Among the 'B' lines, L_{13} resulted in hybrids with the highest mean performance (15.6 g.) and lines, L_1 (13.7 g), L_{15} (13.7 g.), L_4 (13.6 g.), L_{16} (13.6 g.) and L_{12} (13.3 g.) were found to be superior. Among testershybrids on 10430-showed highest mean performance.

4.4.7: Number of grains per head:

The range varied from 936 to 1534 in number. Among 'B' lines, L_8 (1534), L_{12} (1502) and L_1 (1425) resulted in hybrids with relatively higher values. Among tester parents, 2219A (1386) contributed to hybrids with the maximum mean value.

4.4.8: Threshing percent:

The range was from 76.0 percent to 81.6 percent. Genotypes, L_{19} (81.4 percent), L_{16} (80.4 percent) and L_{12} (80.4 percent) were superior among 'B' lines, and the tester CK60A (80.0 percent) resulted in hybrids with maximum mean values.

4.4.9: Grain yield per hectare:

Average yield per hectare of non-restorer lines across testers ranged from 31.11/ha to 43.46 q/ha. The 'B' lines, L_{12} (43.46 q/ha), L_1 (42.90 q/ha) and L_8 (41.66 q/ha) contributed to superior hybrids for this trait. The results are generally in agreement with grain yield/plant. The tester 2219A contributed as seed parent in the highest yielding hybrids.

4.4.10: Head yield per hectare:

Average head yield per hectare of non-restorer lines across testers ranged from 38.12 q/ha to 53.73 q/ha. The mean performance of non-restorer lines were similar to those for grain yield per hactare. Genotypes, L_{12} (53.73 q/ha), L_1 (53.6 q/ha) and L_8 (52.4 q/ha) among 'B' lines and 2219A (47.74) among testers resulted in hybrids with superior mean performance, 4.5: General and specific combining ability effects:

The g.c.a. effects estimated for the different characters among non-restorer lines and male sterile lines testers are presented in the Table 5a. The parents showing superior g.c.a. effects based on their rank were also given in Table 5b. The estimates for s.c.a. are given in Tables 6 and 7 for alfisols and vertisols, respectively.

4.5.1: Days to bloom:

Significant g.c.a. effects were noticed among testers and 'B' lines. The estimates of effects ranged from -3.1 (L_7) to 5.23 (L_{16}) on alfisols and -2.31 (L_{14}) to 4.35 (L_{16}) on vertisols. 'B' lines, L_{14} (-2.10, -2.31 alfisols, vertisols), L_4 (-2.23, -1.84) and L_6 (-1.56, -1.84) recorded highly negative g.c.a. effects on the contrary L_{16} (5.23, 4.35), L_{17} (2.56, 2.68) and L_{12} (1.83, 1.22) exhibited higher positive g.c.a. effects at both locations. Among tester parents 10406A yielded early hybrids (-1.41, -1.41) and CK60A was a good combiner to produce late maturing hybrids (1.03; 1.10).

Out of 100 crosses, five cross combination on alfisols and twenty three on vertisols showed significant s.c.a. effects. The estimates of s.c.a. effects ranged from -3.68 (10430A x L_{11}) (low x high) to 4.63 (CK60A x L_{11}) (high x high) in alfisols and -4.28 (10430A x L_7) (low x low) to 3.48 (10406A x L_{16}) (low x high) on vertisols. The cross combination

TABLE 5 : (Cont'd)

Males	500 grain weight		No of grains/head		Threshing %		Grain Yield/ha		Head Yield/ha	
	Alfisols	Vertisols	Alfisols	Vertisols	Alfisols	Vertisols	Alfisols	Vertisols	Alfisols	Vertisols
L_1	0.76**	0.41*	177.22*	90.97	0.65**	0.32	734.83**	439.42*	927.00*	458.01*
L_2	-1.38**	-1.59**	- 79.46	-168.42	0.84**	0.98**	-397.24	-141.68	-584.90*	-253.76
L_3	-1.55**	-1.61**	126.50	- 12.09	-0.57**	-0.44	94.49	-279.57	90.24	-381.54
L_4	0.63**	0.24	-116.32	526.51**	1.35**	-2.07**	-11.37	-423.24	- 80.74	-539.87*
L_5	-0.32	-0.19	68.32	-125.62	-0.65**	-0.69**	-129.58	- 51.46	-160.20	- 70.54
L_6	0.01	-0.20	- 20.46	-109.35	0.32*	0.14	-102.46	141.20	- 44.02	100.01
L_7	0.01	0.40*	- 33.44	-111.62	-0.11	-0.25	-368.95	-485.57	-322.88	-635.54**
L_8	0.83**	-0.88**	286.13*	166.31	0.55**	0.77**	609.83**	655.86**	810.05**	715.67**
L_9	0.11	0.55**	52.04	141.57	-0.22	-0.07	89.58	- 53.24	47.45	-133.21
L_{10}	-0.21	-0.09**	69.86	192.64	0.34*	1.46**	284.78	280.53	255.78	145.56
L_{11}	-0.72**	-0.71**	-18.12	- 29.62	-0.26	-0.38	-358.04	-649.24**	-412.30	-630.65**
L_{12}	0.33	0.44*	253.56*	- 58.69	0.33*	-0.48	791.68**	850.31**	939.50**	776.67**
L_{13}	2.68**	2.02**	-312.06*	-130.95	-1.73**	-0.70**	-573.50**	377.75	-525.77*	533.56*
L_{14}	-0.60*	-0.14	-92.85	-195.42	-2.14**	-2.24**	-390.69*	-617.13*	-349.58	-426.65
L_{15}	0.77**	1.34**	-132.09	-75.29	-0.02	1.54**	98.06	780.53**	237.77	1072.23**
L_{16}	0.61*	0.70**	-158.68*	106.51	-0.33*	0.40	-327.25	12.86	-441.51	-96.43
L_{17}	-0.59*	-0.27	- 36.41	-262.70	-0.50**	0.38	270.98	-255.80	352.62	151.90
L_{18}	0.54*	0.15	-209.45*	- 55.22	0.13	-1.44**	-444.57*	-676.57**	-621.06**	-627.65**
L_{19}	-0.20	-0.41*	188.66*	187.84	1.54**	1.60**	303.35	27.86	275.77	-211.54
L_{20}	-0.07	-0.14	- 12.93	- 77.35	1.84**	1.20**	-173.90	67.20	-393.41	53.78
S.E.(gi) ±	0.220	0.174	70.830	151.800	0.096	0.241	178.46	223.75	216.17	211.56

TABLE 5a: GENERAL COMBINING ABILITY EFFECTS

Males	Days to Bloom		Plant Height		Grain Yield per plant		Head Yield per plant		Head Length	
	Alfisols	Vertisols	Alfisols	Vertisols	Alfisols	Vertisols	Alfisols	Vertisols	Alfisols	Vertisols
L_1	-1.7**	-0.91*	1.81	5.44**	7.09*	4.38**	8.71**	4.56**	0.47	-0.15
L_2	-0.30	-1.58*	-12.38**	-15.08**	-5.23*	-7.49**	-8.03**	-9.96**	-0.24	-0.11
L_3	-0.90	-0.51	-23.38**	-24.62**	-1.13	-3.92**	-1.61	-5.18**	1.66**	2.19**
L_4	-2.23**	-1.84**	12.61**	11.24**	-1.38	-2.08**	-2.45	-0.54	1.74**	2.64**
L_5	-0.30	0.08*	-24.78**	-29.02**	1.06	-3.15**	1.26	-3.91**	0.44	0.07
L_6	-1.56**	-1.84**	5.68*	- 0.22	-0.47	-2.56**	-1.28	-1.97*	0.37	0.37
L_7	-3.1**	-0.71*	-22.48**	-20.35**	-0.77	-1.06*	-0.92	-0.78	-0.46	-1.01**
L_8	1.30**	1.28**	- 1.31	-1.28	4.95*	2.85**	7.64**	4.09**	1.16**	0.26
L_9	0.36	0.02	21.88**	22.78**	1.65	6.51**	1.66	8.09**	-0.89*	0.24
L_{10}	-0.76	-0.31	3.88	0.78	1.56	5.21**	0.56	3.20**	-1.35**	-0.81**
L_{11}	1.10**	1.55**	-11.98**	-11.35**	-2.06	-1.75**	-2.99	-2.23*	-0.96*	-0.13
L_{12}	1.83**	1.22**	9.94**	9.51**	7.63*	0.36	10.43**	1.27	2.81**	1.95**
L_{13}	1.10*	0.88*	11.38**	13.31**	-3.31	3.05**	-3.66	3.13**	-2.22**	-2.37**
L_{14}	-2.10**	-2.31**	-13.85**	-13.48**	-3.52	-4.45**	-2.65	-3.70**	-0.48	-0.42
L_{15}	0.56	-0.71*	10.21**	16.31**	-1.27	2.54**	-0.19	2.54*	-0.50	-0.47
L_{16}	5.23**	4.35**	19.61**	25.91**	-2.52	5.97**	-3.51	7.57**	0.53	1.21**
L17	2.56**	2.68**	- 9.55**	-15.42**	-2.26	-7.12**	-3.96	-7.40**	-0.08	-0.51**
L_{18}	-0.50	-1.44**	-11.18**	-12.15**	-3.92*	-0.32	-1.80	0.03	-0.91*	-1.54**
L_{19}	-0.76	-0.31	19.14**	17.31**	4.52*	4.61**	5.24*	3.57**	-0.30	-0.46
L_{20}	0.16	0.42	14.74**	20.31**	-0.58	-1.58**	-2.42	-2.37*	-0.78*	-0.94**
S.E. (gi) ±	0.449	0.327	2.134	0.626	1.950	0.395	2.365	0.963	0.345	0.237

Females	Days to Bloom		Plant Height		Grain Yield per plant		Head Yield per plant		Head Length	
	Alfisols	Vertisols	Alfisols	Vertisols	Alfisols	Vertisols	Alfisols	Vertisols	Alfisols	Vertisols
CK60A	1.03**	1.10**	8.06**	8.61**	2.11	3.57**	1.95	4.07**	-0.05	0.03
2219A	-0.10	-0.30	-8.11**	-8.58**	1.07	-0.13	2.54	1.89*	1.32**	1.34**
10430A	-0.31	0.08	0.58	-2.10**	0.38	-1.99**	-0.44	-2.20*	-0.51*	-0.50**
10406A	-1.41**	-1.41**	-0.28	-0.67	-0.63	0.32	-0.49	-0.20	-0.18	-0.49*
10360A	0.80*	0.25	-0.25	2.74**	-2.94*	-1.77**	-3.55*	-3.56**	-0.57*	-0.31
SE (gj)±	0.224	0.164	1.067	0.313	0.975	0.197	1.180	0.481	0.172	0.118

Contd..

(Cont'd)

Females	500 grain weight		No of grains/head		Threshing %		Grain Yield/ha		Head Yield/ha	
	Alfisols	Vertisols	Alfisols	Vertisols	Alfisols	Vertisols	Alfisols	Vertisols	Alfisols	Vertisols
CK60A	0.33*	0.18	45.95	85.62	0.04	0.17	168.56	100.64	178.88	162.37
2219A	-0.91**	-0.81**	138.09*	50.99	0.08	-1.08**	286.79*	26.97	340.90*	35.48
10430A	0.40*	0.38*	- 25.48	-148.62	-0.20	-0.03	-35.20	-170.18	-126.90	-295.71*
10406A	0.28	0.27*	- 53.80	111.07	0.01	0.57**	- 50.73	205.06	- 8.94	286.31*
10360A	-0.11	-0.03	-104.77*	-101.07	0.07	0.37*	-269.42*	-162.49	-383.94*	-188.46
S.E. (gj)±	0.110	0.080	35.418	75.900	0.048	0.120	89.230	111.870	108.080	105.780

TABLE 5b : PARENTS SHOWING SUPERIOR ESTIMATES OF g.c.a. EFFECTS

	NON-RESTORER LINE						TESTER	
	Alfisols			Vertisols			Alfisols	Vertisols
	Rank			Rank				
	1	2	3	1	2	3		
Days to bloom	L7 (-3.1)	L4 (-2.23)	L16 (5.23)	L14 (-2.31)	L4 (-1.84)	L16 (4.35)	10406A (-1.41)	10406A (-1.41)
Plant height	L5 (-24.78)	L7 (-22.48)	L16 (19.61)	L5 (-29.02)	L3 (-24.62)	L16 (25.91)	2219A (-8.11)	2219A (-8.58)
Grain yield per plant	L12 (7.63)	L1 (7.09)	L8 (4.95)	L9 (6.51)	L16 (5.97)	L10 (5.21)	CK60A (2.11)	CK60A (3.57)
Head yield per plant	L12 (10.43)	L1 (8.71)	L8 (7.64)	L9 (8.09)	L12 (7.57)	L1 (4.56)	2219A (2.54)	CK60(A) (4.07)
Head length	L12 (2.81)	L4 (1.74)	L3 (1.66)	L12 (1.95)	L16 (1.21)	L1 (0.41)	2219A (1.32)	2219A (1.34)
500 grain weight	L13 (2.68)	L8 (0.83)	L1 (0.76)	L13 (2.02)	L15 (1.34)	L16 (0.70)	10430A (0.40)	10430A (0.38)
No of grains per head	L8 (286.13)	L12 (253.56)	L1 (171.22)	L 4 (26.51)	L10 (192.64)	L8 (166.31)	2219A (138.10)	10406A (111.07)
Threshing %	L20 (1.84)	L19 (1.54)	L4 (1.35)	L19 (1.60)	L15 (1.54)	L10 (1.46)	2219A (0.08)	10406A (0.57)
Grain yield/ha	L12 (791.68)	L1 (734.83)	L8 (609.83)	L12 (850.31)	L5 (780.53)	L8 (655.86)	2219A (286.80)	10406A (205.06)
Head yield/ha	L12 (939.50)	L1 (927.00)	L8 (810.05)	L15 (1072.23)	L12 (776.67)	L8 (715.67)	2219A (340.90)	10406A (286.31)

viz., 10406A x L_{11} (low x high) gave the higher negative s.c.a. effect (-2.58) while 2219A x L_{11} (low x high) (2.13), (10430A x L_{15} (low x low) (2.18), showed significant positive s.c.a. effects on alfisols. The cross combinations, 10360A x L_2 (low x low) (-2.58), CK60A x L_6 (high x low) (-2.50), 10406A x L_{10} (low x low) (-2.18) showed significantly negative s.c.a. effects and on the contrary, crosses, viz., 2219A x L_6 (low x low) (3.29), CK60A x L_{14} (high x low) (2.96) gave positive s.c.a. effects on vertisols.

4.5.2: Plant height:

The estimates of g.c.a. effects for testers and 'B' lines ranged from -24.78 (L_5) to 21.88 (L_9) on alfisols and -29.02 (L_5) to 25.91 (L_{16}) on vertisols. Highly significant negative g.c.a. estimates were exhibited by L_5 -24.78, -29.02 alfisols, vertisols), L_3 (-23.38, -24.62), L_7 (-22.48, -20.35) and L_{14} (-13.85 to -13.48) at both locations. 'B' lines, L_9 (21.88, 22.78), L_{16} (19.61, 25.91) and L_{19} (19.14, 17.31) showed highly significant positive g.c.a. effects. Two tester parents viz., 2219A (-8.11, -8.58), CK60A (8.06, 8.61) were recorded highly negative and positive g.c.a. effects respectively at both locations.

Significant s.c.a. effects were noticed for thirteen cross combinations on alfisols and for sixty eight on vertisols. The s.c.a. effects ranged from -19.22 (2219A x L_6) (low x high) to 37.26 (CK60A x L_{11}) (high x low) on alfisols and on vertisols when the range was -25.08 to 33.85 for the same crosses. The combinations viz., 2219A x L_{11} (high x high) (-18.55), on alfisols, CK60A x L_{17} (high x low) (-17.49) and CK60A x L_2 (high x low) (-14.66) at both locations showed negatively significant s.c.a. effects. Highly significant positive s.c.a. effects were noticed for the combinations, viz., CK60A x L_6 (high x high) (13.26), 10360A x L_8 (low x low) (12.58), on alfisols and 10430A x L_7 (low x low) (13.23) showed high s.c.a. effect at both locations. The other combinations with higher s.c.a. were 10360A x L_6 (high x low) (19.25), 10406A x L_{17} (low x low) (11.53) on vertisols.

4.5.3: Grain yield per plant:

Significant g.c.a. effects were noticed among testers and 'B' lines for this character. The g.c.a. effects ranged from -5.23 to 7.63 on alfisols and from -7.49 to 6.51 on vertisols. 'B' lines, L_{12} (7.63) on alfisols and L_9 (6.51) on vertisols exhibited highest positive g.c.a. effects. Significant positive g.c.a. effects were recorded for L_1 (7.09, 4.38 alfisols, vertisols), L_{19} (4.52, 4.61) and L_8 (4.95, 2.85) at both locations. Tester parent, CK60A showed highest g.c.a. effect at both locations.

By observation of Tables 6 & 7 it was noted that of 100 crosses, six cross combinations on alfisols and thirty six on vertisols showed significantly positive s.c.a. effects. Out of these crosses, the highest s.c.a. effect 18.53 was noticed in the combination 10430A x L_{10} (low combiner x high combiner) on alfisols and, 14.69 in the combination

CK60A x L_{10} (high x high) on vertisols. Positively significant s.c.a. effects were also recorded for the combinations viz., 10406A x L_{15} (low x low) (11.29), CK60A x L_1 (high x high) (11.04) 10430A x L_9 (low x low) (10.11) and 2219A x L_{20} (low x low) (9.78) on alfisols. And on vertisols the superior combinations were 10430A x L_8 (low x high) (12.90), CK60A x L_{11} (high x high) (12.31), 10430A x L_{14} (low x low) (9.78) and 10360A x L_7 (high x low) (7.03).

4.5.4: Head yield per plant:

The estimates of g.c.a. effects are in accordance with grain yield per plant. The parents ranged from -8.03 (L_2) to 10.43 (L_{12}) on alfisols and -9.96 (L_2) to 8.09 (L_9) on vertisols. Among 'B' lines, L_1 (8.71 to 4.56), L_{19} (5.24, 3.57), and L_8 (7.64, 4.09) showed significant positive g.c.a. effects at both locations.

Tester parent 10360A (-3.55, -3.56) recorded significant negative g.c.a. at both locations while CK60A (4.07) showed significant positive g.c.a. effect on vertisols only.

Out of 100 crosses only six on alfisols and twenty six on vertisols showed significant positive s.c.a. effects. The results are in accordance with grain yield per plant except that only 28 crosses were found to be significant on vertisols. The s.c.a. effects ranged from -11.30 (2219A x L_{11}) (high x low) to 17.24 (10430A x L_{10}) (low x low) on alfisols and -11.34 to 14.09 (L_{10} x CK60A) low x high (CK60A x L_7) (high x low) on

TABLE 6: SPECIFIC COMBINING ABILITY EFFECTS OF HYBRIDS ON ALFISOLS.

Line	Days to bloom					Plant height				
	Tester					Tester				
	CK 60A	2219 A	10430 A	10406 A	10360 A	CK 60A	2219 A	10430 A	10406 A	10360 A
L 1	-1.23	1.56	1.45	-0.45	-1.33	4.13	-1.02	-1.38	-5.18	3.45
L 2	-0.96	0.50	0.05	0.48	-0.06	-14.66**	7.17	-4.84	5.01	7.31
L 3	-1.70	0.43	-0.35	1.41	0.20	2.00	-0.82	-6.51	3.01	2.31
L 4	0.63	0.43	-0.01	0.75	-1.80	-2.33	11.17*	-1.51	-12.31**	4.98
L 5	-0.96	-0.50	-0.28	1.15	0.60	-0.59	6.24	-3.44	-5.58	3.38
L 6	-0.70	0.43	-0.01	-0.58	0.86	13.26**	-19.22**	2.75	2.61	0.58
L 7	-1.50	-0.70	1.18	0.95	0.06	-2.89	-4.05	10.58*	6.95	-10.58*
L 8	-1.56	0.56	0.45	0.21	0.33	-14.06**	-5.05	8.08	-1.54	12.58**
L 9	0.70	-0.50	-0.61	-0.18	0.60	-6.26	-0.75	2.55	2.08	2.38
L 10	-0.83	-0.36	-0.15	-0.05	1.40	0.73	2.91	5.88	-0.24	-9.28
L 11	4.63**	2.43**	-3.68**	-2.58*	-0.80	37.26**	-18.55**	-2.58	-6.71	-9.41*
L 12	-1.10	-0.30	0.91	1.01	-0.53	5.33	-3.49	-3.18	-2.31	3.65
L 13	0.30	1.76	-0.68	-1.58	0.20	2.56	-4.25	-0.61	-1.74	4.05
L 14	1.83	-0.70	-0.48	0.61	-1.26	-3.53	3.64	5.28	0.81	-6.21
L 15	-1.16	-0.70	2.18*	-1.38	1.06	8.06	-1.09	-8.11	1.08	0.05
L 16	0.50	-1.70	0.51	-0.05	0.73	0.66	6.17	-6.18	4.35	-5.01
L 17	-0.16	-1.70	0.51	0.61	0.73	-17.49**	8.67	3.65	10.18*	-5.01
L 18	0.23	-0.63	-0.08	1.35	-0.86	-8.53	7.97	-2.71	3.48	-0.21
L 19	1.50	-0.03	-0.81	-0.38	-0.26	1.46	-0.02	0.28	-0.51	-1.21
L 20	1.56	-0.3	-0.08	-1.31	0.13	-5.13	4.37	2.01	-3.44	2.18

S.E. $(\hat{Sij})$ ± 1.00 S.E. $(\hat{Sij})$ ± 4.77

* Significant at 5% level of significance

** Significant at 1% level of significance

Contd.

Line	Grain yield per plant					Head yield per plant				
	Tester					Tester				
	CK 60A	2219 A	10430 A	10406 A	10360 A	CK 60A	2219 A	10430 A	10406 A	10360
L 1	11.04*	-1.65	0.48	-4.34	-5.53	13.80*	-5.01	-1.80	-6.36	-0.61
L 2	-1.88	3.73	-8.69*	2.62	4.21	-1.76	4.46	-10.20*	3.96	3.52
L 3	-1.89	7.89	-4.61	1.03	-2.41	-2.70	8.05	-5.26	2.39	-2.48
L 4	2.90	2.86	-4.59	-5.68	4.51	3.53	2.69	-5.48	-6.11	5.26
L 5	-1.76	2.49	-1.60	3.59	-2.72	1.07	0.59	-1.25	4.91	-5.48
L 6	2.49	-1.73	-4.73	2.95	1.01	3.40	-1.08	-6.70	5.67	-1.25
L 7	-2.28	0.52	1.34	-5.36	5.78	-2.62	0.03	2.31	-6.60	6.87
L 8	4.45	-2.11	-3.48	-2.64	3.79	4.21	0.22	-6.00	-3.37	4.94
L 9	-4.08	-8.45	10.11*	1.26	1.15	-3.31	-7.80	11.56*	0.47	-0.93
L 10	0.94	-1.73	13.53*	-5.34	-7.40	2.46	-2.40	17.24**	-7.21	-10.08*
L 11	2.96	-6.01	-0.50	2.45	1.10	3.58	-11.30**	-1.30	1.60	7.40
L 12	-6.47	10.24*	0.46	-5.41	1.18	-8.23	11.81*	4.16	-7.44	-0.30
L 13	1.24	-0.37	-3.73	2.24	0.62	2.59	-2.11	-2.38	2.85	-0.94
L 14	1.43	-0.10	-4.51	3.21	-0.02	0.58	0.45	-5.29	6.54	-2.29
L 15	4.51	-4.08	-4.07	11.29*	-7.64	1.79	-6.81	-6.64	13.87*	-2.21
L 16	-1.97	0.25	8.82*	-3.75	-3.35	-2.43	2.17	11.57*	-5.06	-6.24
L 17	-1.72	-4.55	5.76	0.57	-0.01	-1.90	-4.93	6.03	0.19	0.61
L 18	-0.70	-8.98*	-1.96	6.60	4.99	-4.53	-1.34	-5.14	4.43	6.58
L 19	-1.48	2.02	6.38	-6.33	-0.59	-0.79	-0.24	9.12	-5.36	-2.71
L 20	-7.72	9.78*	-4.38	1.00	1.32	-8.75	12.56*	-4.53	0.59	0.12

S.E. ($\hat{S}ij$) $\pm$ 4.361 S.E. ($\hat{S}ij$) $\pm$ 5.290

* Significant at 5% level of significance

** Significant at 1% level of significance

Contd.

Line	Head length					500 grain weight				
	Tester					Tester				
	CK 60A	2219 A	10430 A	10406 A	10360 A	CK 60A	2219 A	10430 A	10406 A	10360 A
L 1	0.84	-0.81	-0.58	-0.08	0.63	0.93	0.34	-0.09	-0.41	-0.76
L 2	0.01	1.07	-2.53**	0.47	0.97	-0.46	-0.28	-0.39	0.83	0.31
L 3	-0.29	1.60*	0.28	-1.10	-0.49	0.42	0.03	0.12	0.10	-0.68
L 4	-1.09	0.58	0.03	-1.28	1.76*	-0.21	0.91	-0.41	-0.30	0.02
L 5	0.53	0.05	-0.77	0.45	-0.26	-0.15	0.01	-0.31	0.27	0.18
L 6	1.65*	-1.09	-1.20	1.23	-0.59	-0.47	-0.29	-0.01	0.65	0.13
L 7	-0.71	1.12	0.41	-1.86*	1.04	-0.58	0.34	-0.10	-0.06	0.42
L 8	0.37	0.33	-0.38	-0.27	0.05	0.13	-0.49	0.41	-0.83	0.79
L 9	-0.68	-0.94	0.72	0.50	0.39	0.70	-0.68	-0.64	1.12*	-0.50
L 10	0.39	-0.08	1.58*	-1.08	-0.80	-1.17*	0.38	0.87	0.23	-0.32
L 11	2.28**	-2.31**	-0.30	0.53	-0.19	1.54**	-0.57	-0.35	-0.59	-0.02
L 12	-1.38	1.18	0.96	-0.25	-0.52	0.08	0.12	-0.45	-0.13	0.38
L 13	0.09	-1.16	1.11	0.00	-0.04	-0.25	-1.19*	1.85**	-0.33	-0.06
L 14	0.01	0.31	-0.85	0.76	-0.23	0.32	0.39	-0.77	0.20	-0.14
L 15	0.65	-0.83	-1.05	1.78*	-0.54	0.62	-0.61	-0.05	0.07	-0.02
L 16	-0.16	-0.42	1.24	-0.52	-0.13	-0.31	0.13	0.40	-0.64	0.42
L 17	00.15	-0.81	1.36	0.14	-0.52	-0.67	1.14	0.13	-0.59	-0.01
L 18	-0.88	1.35	-0.52	0.58	-0.52	0.17	-0.25	0.06	-0.02	0.03
L 19	-0.49	-0.36	1.41	-0.47	-0.08	-0.34	0.38	-0.21	0.24	-0.07
L 20	-1.00	1.23	-0.93	0.46	0.24	-0.27	0.17	-0.03	0.21	-0.08

S.E. $(\hat{S}ij)$ $\pm$ 0.770 S.E. $(\hat{S}ij)$ $\pm$ 0.489

* Significant at 5% level of significance

** Significant at 1% level of significance

Contd.

Line	No.of grains per head					Threshing %				
	Tester					Tester				
	CK 60A	2219 A	10430 A	10406 A	10360 A	CK 60A	2219 A	10430 A	10406 A	10360 A
L 1	272.85	-90.18	17.86	-110.58	-109.95	-1.57**	1.97**	0.61**	1.16**	-2.16**
L 2	-31.03	213.27	-338.68	16.81	139.62	-0.93**	-1.02**	0.55**	0.29	1.11**
L 3	-128.22	389.10*	-224.53	19.87	-56.22	0.53*	0.27	0.87**	-2.42**	0.73**
L 4	129.56	6.77	-142.37	-164.75	170.78	-0.53*	-0.76**	1.63**	2.06**	-2.42**
L 5	-63.99	121.45	-34,30	104.98	-128.14	0.23	-0.59**	-2.24**	2.05**	0.53*
L 6	161.36	-45.86	-188.41	49.43	23.47	-0.29	-0.43*	0.59**	-0.94**	1.07**
L 7	-32.35	-13.34	62.60	-195.48	178.58	2.18**	3.53**	-3.27**	-4.65**	0.22
L 8	149.11	-4.25	-197.45	0.77	51.81	-0.29	-0.59**	-0.15	-0.58**	1.64**
L 9	-219.00	-268.33	451.87**	-57.31	92.78	0.18	-1.01**	-0.11	2.26**	-1.34**
L10	201.35	-97.51	394.97*	-217.93	-289.87	1.09**	-0.13	0.70**	1.41**	-3.05**
L11	-30.98	-195.31	20.53	165.66	40.10	-1.96**	0.63**	1.25**	-0.77**	0.83**
L12	-255.17	401.22*	51.79	-208.26	10.41	1.68**	-0.62**	0.14	-1.75**	0.54*
L13	47.87	19.85	-196.52	97.33	31.46	-1.18**	0.38	-1.93**	0.74**	1.98**
L14	26.12	-41.75	-104.59	113.53	6.69	0.15	-0.59**	0.15	0.63**	-0.34
L15	109.24	-113.55	-124.68	392.05*	-263.05**	2.44**	0.18	0.81**	-2.96**	-0.48*
L16	-37.45	-23.19	281.19	-78.88	-141.65	-0.06	0.32	-2.34**	1.28**	0.81**
L17	15.46	-302.37*	211.65	74.89	0.35	-1.95**	-1.20	1.47**	1.85**	-0.19
L18	-22.93	-351.27*	-61.53	249.59	186.15	0.30	-0.23	-0.35	0.00	0.25
L19	- 3.50	6.26	270.41	-263.31	-9.85	0.96**	-0.71**	0.40	-0.72**	0.16
L20	-288.28	389.00*	-169.80	11.57	57.51	-1.02**	0.65**	1.13**	-0.93**	0.16

S.E. $(\hat{S}ij)$ $\pm$ 158.398 S.E. $(\hat{S}ij)$ $\pm$ 0.208

* Significant at 5% level of significance

** Significant at 1% level of significance

Contd.

Line	Grain yield/ha Tester CK 60A	2219 A	10430 A	10406 A	10360 A	Head yield/ha Tester CK 60A	2219 A	10430 A	10406 A	10360 A
L 1	211.58	-149.56	-60.88	-222.71	221.58	382.47	-259.11	-143.01	-422.54	442.19
L 2	71.64	449.19	-632.18	-180.35	291.70	182.30	580.10	-820.39	-283.28	341.27
L 3	7.01	-84.88	132.88	-127.53	72.52	39.75	-142.16	104.24	-107.07	105.23
L 4	262.17	270.94	-144.08	-938.60*	549.56	278.58	391.76	-293.74	-1263.00*	886.39*
L 5	240.39	151.63	-294.89	137.43	-234.57	284.52	204.10	-242.00	36.20	-282.83
L 6	7.22	615.75	-60.80	-339.16	-223.01	-114.38	677.31	-349.87	215.49	-428.55
L 7	-32.71	361.19	-3.23	-230.06	-95.18	-189.40	-21.73	805.54	-310.46	-283.93
L 8	229.93	24.48	289.76	-263.22	-280.96	290.02	77.36	211.28	-358.72	-219.94
L 9	-451.56	-685.00	576.91	460.37	99.27	-510.18	-711.28	689.75	299.29	232.42
L 10	-25.12	758.26	489.93	-15.72	-1207.34**	-66.23	981.70*	521.67	-111.45	-1325.68**
L 11	676.56	-1200.13**	344.99	319.32	-140.75	872.03	-1366.41**	302.06	352.14	-159.83
L 12	-131.68	-82.07	585.21	-403.75	32.29	-252.67	-47.19	750.31	-465.35	14.90
L 13	56.68	-171.40	-462.22	247.32	329.62	93.82	-370.53	-549.22	606.94	218.98
L 14	-590.13	318.58	78.47	71.62	121.45	-745.08	458.52	77.81	88.84	119.89
L 15	927.15	-398.59	-966.68*	409.01	29.09	926.44*	-646.38	-845.67	479.93	85.67
L 16	119.56	404.84	-563.83	396.26	-356.83	219.16	511.78	-620.14	306.04	-416.85
L 17	-187.38	-494.36	535.00	315.67	-168.91	-118.92	-552.64	503.36	179.23	-11.03
L 18	-481.09	99.11	-307.31	242.69	446.59	-524.64	284.43	-696.30	272.76	663.74
L 19	-266.19	-387.55	592.78	180.94	-119.96	-371.90	-414.27	762.85	178.97	-155.65
L 20	-644.04	199.57	-129.83	59.83	633.81	-675.71	364.65	-168.52	306.01	173.56

S.E. $(\hat{S}ij)$ $\pm$ 399.370 S.E. $(\hat{S}ij)$ $\pm$ 483.370

* Significant at 5% level of significance

** Significant at 1% level of significance

TABLE 7 : SPECIFIC COMBINING ABILITY EFFECTS OF HYBRIDS ON VERTISOLS.

Line	Days to bloom Tester					Plant height Tester				
	CK 60A	2219 A	10430 A	10406 A	10360 A	CK 60A	2219 A	10430 A	10406 A	10360 A
L 1	0.56	-0.30	-0.75	0.08	0.41	-2.61	5.58**	2.43	-5.66**	0.25
L 2	2.56**	-0.30	0.91	-0.58	-2.58**	-13.74**	6.78**	0.30	4.20**	2.45
L 3	1.49*	-1.03	-0.82	1.01	-0.65	-3.54*	2.32	0.17	1.73	-0.68
L 4	-1.17	0.28	1.51	0.34	-0.98	6.25**	-2.88*	-4.03**	-0.79	1.45
L 5	0.23	-0.97	1.58*	-1.25	0.41	-1.48	5.72**	-5.76**	1.13	0.38
L 6	-2.50**	3.29**	-1.48*	2.01**	-1.32	-4.28**	-25.08**	8.77*	1.33	19.25**
L 7	1.03	-4.70*	-4.28**	1.88*	1.54*	-9.51**	-9.28**	13.23**	14.80**	-8.94**
L 8	-0.63	0.16	0.71	-1.45*	1.21	8.45**	-11.68**	-2.49	-6.26**	11.98**
L 9	-0.37	0.09	-0.02	0.48	-0.18	1.05	10.58**	-7.56**	-2.33	-1.74
L 10	0.29	0.43	2.31**	-2.18**	-0.85	4.72**	5.25**	-11.23**	-1.66	2.92*
L 11	1.43*	1.23	0.78	-1.38	-2.05	33.85**	-4.28**	-3.43**	-12.53**	-13.61**
L 12	0.09	-1.43*	1.11	0.94	-0.72	4.98**	-13.48**	-0.96	5.27**	4.18**
L 13	-0.23	-0.43	-0.55	1.28	-0.05	4.45**	-3.01	3.83**	-5.93**	0.65
L 14	2.96**	0.43	-1.68*	-0.85	-0.85	-0.68	4.18**	-7.63**	3.27**	0.85
L 15	-1.30	-0.17	1.71*	-1.12	0.88	-0.48	0.38	-5.09**	4.47**	0.72
L 16	-1.37	-0.90	-1.02	3.48**	-0.18	1.92	5.45**	2.30	-2.79*	-6.88**
L 17	-1.03	1.09	-1.02	-1.52	2.48**	-15.41**	5.12**	11.63**	11.53**	-12.88**
L 18	-0.57	0.56	1.44*	-1.05	-0.38	-14.01**	11.52**	4.37**	-7.06**	5.18**
L 19	-0.37	-0.57	-0.35	-0.52	1.81	5.85**	0.05	-2.76	-6.53**	3.38*
L 20	-1.10	-1.30	-0.08	0.41	2.08	-5.48**	6.72**	3.90**	3.80**	-8.94**

S.E. $(\hat{S}_{ij})$ = $\pm$ 0.733 S.E. $(\hat{S}_{ij})$ = $\pm$ 1.399

* Significant at 5% level of significance

** Significant at 1% level of significance

Contd.

Line	Grain yield per plant					Head yield per plant				
	Tester					Tester				
	CK 60A	2219 A	10430 A	10406 A	10360 A	CK 60A	2219 A	10430 A	10406 A	10360A
L 1	-6.47**	4.05**	-4.34**	6.71**	0.05	-8.44**	6.48**	-6.94**	8.05**	0.85
L 2	0.66	1.68	-0.07	0.09	-2.36**	2.17	2.74	-1.07	-2.34	-1.49
L 3	-6.73**	-4.47**	-0.28	6.10**	5.39**	-4.28*	-6.00**	-2.57	7.89**	4.96*
L 4	-5.74**	-0.19	5.58**	1.60	-1.24	-7.03**	-0.73	4.27*	3.17	0.31
L 5	4.00**	5.96**	-1.50	-7.89**	-0.57	3.61	7.94**	-0.66	-10.90**	0.00
L 6	-5.15**	-2.49**	4.66**	-3.19**	6.18**	-5.58**	-2.57	4.99*	-2.25	5.42*
L 7	-10.20**	0.11	-1.92**	4.98**	7.03**	-11.34**	-0.80	-2.04	7.42**	6.77**
L 8	7.22**	-5.60**	12.90**	-11.87**	-2.65**	8.95**	-10.65**	11.98**	-7.57**	-2.70
L 9	4.99**	4.95**	-10.22**	-3.27**	3.55**	4.22	6.29**	-9.69**	-1.65	0.82
L 10	14.69**	3.97**	-8.29**	-5.22**	-5.04**	14.09**	6.82**	-9.48**	-6.04**	-5.39*
L 11	12.31**	-2.93*	-1.93**	-0.28	-7.17**	14.16**	0.28	-3.00	-3.16	-8.28**
L 12	2.40**	4.42**	-3.95**	0.81	-3.68**	6.44**	5.61*	0.01	-6.71**	-5.36*
L 13	-1.43	-9.17**	6.54**	0.45	3.62**	-5.19*	-10.83**	6.34**	0.97	8.71**
L 14	-2.06*	-7.37**	9.78**	-0.06	-0.28	-1.69	-6.42**	9.23**	-0.80	-0.31
L 15	-6.52**	5.05**	-3.72**	1.97*	3.21**	-8.98**	2.61	-4.45*	3.46	7.36**
L 16	-0.34	2.10*	1.94*	3.21**	-6.92**	-2.07	1.16	6.71**	4.36*	-10.16**
L 17	4.33**	-4.94**	-2.49**	0.19	2.91**	1.89	-4.54*	-1.44	0.44	3.65
L 18	-6.33**	0.62	-3.89**	4.01**	5.59**	-5.91*	1.42	-3.27	3.35	4.41*
L 19	-0.18	1.01	1.97*	-0.26	-2.53**	2.43	1.68	0.37	-0.46	-4.02
L 20	0.58	3.21**	-0.62	1.90*	-5.08**	2.57	-0.52	0.72	2.78	-5.56*

S.E. ($\hat{S}ij$) $\pm$ S.E. ($\hat{S}ij$) $\pm$ 2.154

* Significant at 5% level of significance

** Significant at 1% level of significance

Contd.

Line	Head length					500 grain weight				
	Tester					Tester				
	CK 60A	2219 A	10430 A	10406 A	10360 A	CK 60A	2219 A	10430 A	10406 A	10360
L 1	-0.68	0.22	-1.14*	0.78	0.82	0.57	-0.34	-0.46	-0.38	0.62
L 2	0.93	0.06	0.36	-0.92	-0.44	0.28	-0.37	-0.01	0.55	-0.45
L 3	-1.37*	0.64	-1.11	0.59	1.24*	-0.52	0.30	1.00*	-0.05	-0.73
L 4	-2.43**	-0.02	1.38*	0.93	0.13	-0.86*	0.47	0.33	0.07	-0.01
L 5	0.02	0.65	0.28	-0.11	-0.85	0.19	-0.79*	0.83*	-0.55	0.33
L 6	0.23	-0.42	-0.40	0.30	0.28	0.67	-0.54	-0.31	0.20	-0.01
L 7	-1.05*	1.13*	0.87	-1.13*	0.18	-0.82*	-0.21	-0.32	1.43**	-0.06
L 8	0.66	-0.65	1.28*	-0.47	-0.82	0.29	0.02	0.05	-0.62	0.25
L 9	0.18	0.45	-0.55	-0.61	0.53	-0.07	0.38	-1.53**	0.31	0.90*
L 10	2.07**	0.49	-0.04	-1.05	-1.46**	-1.01*	0.42	0.95*	-0.14	-0.21
L 11	1.56**	0.53	-1.44**	-0.68	0.02	1.96**	-1.87**	-0.16	-0.44	0.51
L 12	0.13	0.63	0.95	-0.72	-1.01*	0.68*	-0.68	0.49	0.15	-0.65
L 13	-0.31	-1.56**	0.78	0.99	0.09	-0.85*	-0.90*	0.90*	-0.12	-0.73
L 14	0.41	-0.17	-0.76	0.21	0.31	0.40	0.33	-0.01	-0.29	-0.44
L 15	-0.26	0.26	-0.64	0.65	-0.01	-0.83*	1.16**	-0.48	0.05	0.09
L 16	-0.17	-0.32	0.69	0.62	-0.82	-0.11	0.70	-0.90*	0.75	-0.43
L 17	0.27	-1.03	-0.17	0.58	0.34	-1.62**	1.79**	0.10	-1.46**	1.19**
L 18	-0.96	0.50	-0.09	-0.15	0.71	0.53	-0.17	-0.17	-0.14	-0.03
L 19	0.61	-0.58	0.37	-0.57	0.15	-0.21	0.35	-0.08	0.19	-0.24
L 20	0.15	-0.83	-0.61	0.73	0.55	-0.36	-0.06	-0.20	0.50	0.12

S.E. $(\hat{S}ij)$ $\pm$ 0.530 S.E. $(\hat{S}ij)$ $\pm$ 0.389

* Significant at 5% level of significance

** Significant at 1% level of significance

Contd.

Line	No.of grains per head					Threshing %				
	Tester					Tester				
	CK 60A	2219 A	10430 A	10406 A	10360 A	CK 60A	2219 A	10430 A	10406 A	10360 A
L 1	-271.96	233.67	-84.37	149.59	-26.92	0.05	-0.14	0.20	-0.28	0.14
L 2	39.44	152.40	23.35	-181.67	-33.52	-1.93**	1.16**	-0.21	-0.48	1.37*
L 3	-192.56	-201.26	-91.97	130.99	354.80	-0.73	1.54**	-0.32	-0.34	-0.16
L 4	-767.16	-699.52*	-455.57	2594.72**	-672.46*	5.02**	0.78	-2.94**	-2.07**	-0.79
L 5	150.30	363.27	-94.77	-392.14	-26.66	-0.38	0.41	0.28	1.84**	-2.17**
L 6	-224.96	-11.99	239.62	-272.41	269.74	-3.33**	-2.63**	-0.38	4.02**	2.31**
L 7	-280.02	45.27	22.55	-86.14	298.34	-0.48	-1.91**	1.51**	0.72	0.12
L 8	285.70	-177.66	526.29	-538.41	-95.92	-1.25*	0.33	0.35	0.28	0.27
L 9	219.44	182.07	-191.97	-283.67	74.14	-0.77	0.83	0.84	0.97	-1.40*
L 10	747.04*	122.34	-377.37	-334.41	-157.59	0.29	-1.03	1.56**	0.42	-1.1*
L 11	254.64	159.94	-32.77	-92.81	-288.99	0.78	-1.57**	0.79	0.68	-0.70
L 12	32.70	281.00	-146.04	-119.74	-47.92	0.18	-1.44**	-1.18	2.11**	0.34
L 13	-86.69	-215.06	138.89	-82.81	245.67	1.60**	-0.03	0.18	-2.79**	1.05*
L 14	-79.56	-296.59	404.02	-94.34	66.47	0.26	-0.57	-0.65	1.00	-0.07
L 15	-122.36	82.94	-41.77	-63.14	144.34	-0.84	0.93	0.36	-1.35*	0.87
L 16	22.84	32.14	205.42	-94.27	-166.12	0.28	0.94	0.67	-1.75**	-0.15
L 17	378.04	-331.66	-79.37	1.92	31.07	0.67	-0.43	-0.44	-1.04	1.02
L 18	-243.42	65.54	-98.17	35.12	240.94	1.96**	0.60	-1.66**	-1.15**	0.26
L 19	51.50	46.47	107.09	-167.61	-37.46	-0.80	0.02	1.08*	-0.93	0.59
L 20	87.04	166.67	26.95	-108.74	-171.92	-0.67	2.44**	0.02	0.04	-1.64**

S.E. $(\hat{S}ij) \pm$ 339.437 S.E. $(\hat{S}ij) \pm$ 0.539

* Significant at 5% level of significance

** Significant at 1% level of significance

Contd.

Line	Grain yield/ha					Head yield/ha				
	Tester					Tester				
	CK 60A	2219 A	10430 A	10406 A	10360 A	CK 60A	2219 A	10430 A	10406 A	10360 A
L 1	-430.64	329.13	85.74	38.82	-23.06	-547.59	494.85	82.77	65.68	-95.65
L 2	-1030.64*	661.35	341.65	249.38	-221.95	-1200.26*	813.29	505.60	276.90	-395.53
L 3	-671.64	369.24	-206.36	247.27	261.49	-366.59	419.40	-147.17	316.35	280.01
L 4	2229.80**	-719.86	-372.14	-825.17	-312.81	2371.41**	-698.37	-229.40	-1039.21*	-404.42
L 5	58.57	965.02*	-436.70	-474.17	-112.72	38.73	1283.41*	-457.62	-702.42	-162.09
L 6	-1145.20**	-656.53	452.30	442.05	907.78	-1370.15**	-717.15	875.15	240.35	971.79*
L 7	-610.64	-284.20	507.41	927.71	-540.28	-801.26	-287.15	677.93	1139.79*	-729.31
L 8	372.35	-55.08	-354.58	139.05	-101.72	458.07	67.18	-398.84	99.12	-225.53
L 9	33.68	134.57	-308.81	205.38	-64.83	140.29	180.51	-349.95	103.57	-74.42
L 10	127.12	91.35	-222.03	477.16	-473.61	100.40	188.40	-315.95	478.68	-451.53
L 11	1057.47*	-1142.02*	308.85	167.49	-391.61	317.73	-918.70*	856.93	55.46	-311.42
L 12	-27.64	-42.86	-538.47	301.82	307.16	-345.70	-327.70	-523.73	642.01	555.12
L 13	687.13	-11.97	-418.70	-867.28	610.82	238.51	-173.48	-348.95	-839.31	1123.24*
L 14	-988.53*	-583.20	260.07	542.05	769.60	-1636.82**	-167.15	445.15	815.90	542.90
L 15	246.57	-874.75	164.63	885.49	-421.95	-276.26	-374.92	-194.84	563.68	282.35
L 16	428.68	735.13	5.63	-1517.39**	347.93	1160.74*	805.40	-588.95	-1449.87**	72.68
L 17	416.80	-96.20	-0.70	135.16	-455.06	1247.47**	-328.48	-1101.73*	1302.91**	-1120.09*
L 18	-428.53	675.13	75.63	-677.39	355.16	236.40	89.96	91.15	-917.53*	500.01
L 19	-378.53	-472.64	100.07	259.27	491.82	438.07	-1227.82*	511.71	179.12	98.90
L 20	53.80	978.57*	556.3	-656.72	-931.95	298.85	878.51	610.82	-1331.21**	-456.98

S.E. $(\hat{S}ij)$ $\pm$ 500.338 S.E. $(\hat{S}ij)$ $\pm$ 437.067

* Significant at 5% level of significance

** Significant at 1% level of significance

vertisols. Positively significant s.c.a. effects were also exhibited by cross combinations viz., 10406A x L_{15} (low x low) (13.07), CK60A x L_1, (high x high) (13.80), 2219A x 120 (high x low) (12.56) on alfisols and CK60A x L_{10} (high x high) (14.09), 10430A x L_8 (low x high) (11.98) and 10430A x L_{14} (low x low) (9.23) on vertisols.

4.5.6: Head length:

The estimates for g.c.a. ranged from -2.22 (L_{13}) to 2.81 (L_{12}) on alfisols and -2.37 (L_{13}) to 2.64 (L_4) on vertisols. Among 'B' lines, L_{12} (2.81, 1.95), L_4 (1.74, 2.64) and L_3 (1.66, 2.19) exhibited highly significant positive g.c.a. effects. The tester parent, 2219A (1.32, 1.34) exhibited highly significant positive g.c.a. effect at both locations.

Significant positive s.c.a. effects were noticed for six crosses on alfisols and vertisols. The range observed was from -2.53 (10430A x L_2) (low x low) to 2.28 (CK60A x L_{11}) (low x low) on alfisols and -2.43 (CK60A x L_4) (low x high) to 2.07 (CK60A x L_{10}) (low x low) on vertisols. Some crosses showing positive significant s.c.a. effects were 10406A x L_{15} (low x low) (1.78), 10360A x L_4 (low x high) (1.76), and CK60A x L_6 (low x low) (1.65) on alfisols and CK60A x L_{11} (low x low) (1.56), 10430A x L_4 (low x high) (1.38) and 10430A x L_8 (low x low) (1.28) on vertisols.

4.5.6: 500-grain weight:

The 'B' lines were found to be significantly different for their combining ability effects. The g.c.a. ranged from -1.55 (L_3) to 2.68 (L_{13})

on alfisols and -1.61 (L_3) to 2.02 (L_{13}) on vertisols. 'B' lines, L_1 (0.76, 0.41), L_{15} (0.77, 1.34) and L_{16} (0.61, 0.70) showed significant positive g.c.a. effects at both locati ns. Among testers, 10430A was a superior combiner (0.40, 0.38) at both locations.

Significantly positive s.c.a. effects were noticed for three and ten crosses on alfisols and vertisols respectively. The cross combinations ranged from -1.19 (2219A x L_{13}) (low x high) to 1.85 (10430A x L_{13})(high x high) on alfisols and -1.87 (2219A x L_{11}) (low x low) to 1.96 (CK60A x L_{11}) (low x low) on vertisols. The cross combinat viz., CK60A x L_{11} (high x high) (1.54) and 10604A x L_9 (low x low) (1.12) on alfisols and 2219A x L_{17} (low x low) (1.79) and 10406A x L_7 (high x high) (1.62) on vertisols showed superior s.c.a. effects.

4.5.7: <u>Number of grains per head</u>:

An examination of g.c.a. effects for this character indicated that 'B' lines differed significantly for their combining ability effects. Among 'B' lines L_{12} (253.56) and L_1 (177.22) on alfisols and L_4 (526.51) on vertisols and showed highly superior combining ability whereas L_8 (286.13, 166.31) showed superior performance at both locations. Tester, 2219A gave significant positive g.c.a. effect (138.09) among five testers on alfisols.

Only five crosses on alfisols and two crosses on vertisols had significant positive s.c.a. effects for this trait. The range was from

-351.27 (2219A x L_{18}) (high x low) to 451.87 (10430A x L_9) (low x low) on alfisols and -767.16 (CK60A x L_4) (low x high) to 2594.72 (10406A x L_4) (high x high) on vertisols. Crosses viz., 10406A x L_{15} (low x low) (392.05), 2219A x L_{20} (high x low) (389.00) on alfisols and CK60A x L_{10} (low x low) (747.04) on vertisols exhibited positively significant s.c.a. effects.

4.5.8: Threshing percent:

Significantly different estimates of g.c.a. effects were recorded for testers on vertisols and for 'B' lines at both locations. L_{19} (1.54, 1.60) was found to be combining well at both locations for this trait. The 'B' lines, L_{20} (1.84), L_4 (1.35) on alfisols and L_{15} (1.54), L_{10} (1.46) on vertisols were among those found to be superior combiners. Among tester parents, 10406A exhibited highly significant positive g.c.a. effect on vertisols.

Among the 100 crosses only thirty eight on alfisols and fifteen on vertisols were found to be positively significant. The s.c.a. ranged from -3.27 (10430A x L_7) (low x low) to 3.53 (2219A x L_7) (low x low) on alfisols and from -2.94 (10430A x L_4) (low x low) to 5.02 (CK60A x L_4) (low x low) on vertisols. The other combinations showing significantly positive s.c.a. effects were CK60A x L_{15} (low x low) (2.44), 10406A x L_9 (low x low)(2.26) on alfisols and 10406A x L_6 (high x low) (4.02), 2219A x L_{20} (low x high) (2.44), 10360A x L_6 (medium x low) (2.31) on vertisols.

4.5.9: Grain yield per hectare:

The estimates of g.c.a. effects on alfisols were in agreement with that of grain yield per plant on alfisols. L_{12} (850.31) L_{15} (780.53) and L_8 (655.86) on vertisols were found to be significantly superior in their combining ability for grain yield per hectare. Among testers, 2219A (286.8) exhibited highest g.c.a. on alfisols.

Only one cross combination, CK60A x L_{15} (low x low) (927.15), on alfisols and two crosses viz., CK60A x L_4 (low x low) (2229.80), 2219A x L_{20} (low x low) (978.57) on vertisols showed positively significant s.c.a. effects. The crosses viz., 10360A x L_{10} (low x low) (-1207.34) on alfisols and 10460A x L_{16} (-1517.39) on vertisols showed negatively significant s.c.a. effects.

4.5.10: Head yield per hectare:

The results are in agreement with grain yield per hectare. The 'B' lines L_1,(927.00, 458.01) (alfisols, vertisols), L_8 (810.05),(715.67) and L_{12} (939.50, 776.67) showed significant, positive g.c.a. effects at both locations.

Three cross combinations viz., 2219A x L_{10} (high x low) (981.70), CK60A x L_{15} (low x low) (926.44) and 10360A x L_4 (low x low) (886.39) on alfisols and two crosses viz., CK60A x L_4 (low x low) (2371.41), 10406A x L_{17} (high x low) on vertisols showed positively significant s.c.a. effects.

4.6: Correlations:

The correlation coefficients were computed among eight different characters from 100 crosses at both locations. The correlations were also worked out between *per se* performance of non-restorer lines and their g.c.a. effects at both locations.

4.6.1: Correlations among eight characters of hybrids:

The correlation coefficients among eight characters on alfisols and vertisols are presented in tables 8 and 9 respectively.

A close observation of Tables88 and 9 revealed that grain yield per plant was best correlated with plant height (r = 0.222, 0.495), (alfisols, vertisols) head yield per plant (r = 0.916, 0.895) 500-grain weight (r = 0.206, 0.284) and number of grains per head (r = 0.925, 0.355). Head yield per plant was correlated significantly with head length (r = 0.631, 0.286) and with number of grains per head (r = 0.858, 0.316) at both locations. Grain yield per plant was strongly and positively correlated with head length (r = 0.574) and threshing percent (r = 0.244), plant height with test height (r = 0.435), head length with number of grains per head (r = 0.634) on alfisols only. Positively significant correlations were also exhibited by plant height with head yield per plant (r = 0.477) and threshing percent (r = 0.289), head yield per plant with 500-grain weight (r = 0.272) on vertisols only. Interestingly negatively significant correlation was noticed between head length and threshing percent on the same location.

TABLE 8 : CORRELATION COEFFICIENTS AMONG DIFFERENT CHARACTERS OF HYBRIDS ON ALFISOLS

	Days to bloom	Plant height	Grain yield per plant	Head yield per plant	Head length	500 grain weight	Threshing %	No. of grain per head
Days to bloom	1	0.190	-0.175	-0,189	-0.061	0.020	-0.001	-0.090
Plant height		1	0,222*	0.200	0.040	0.435**	0.106	0.069
Grain yield per plant			1	0.916**	0.574**	0.206*	0.244**	0.925**
Head yield per plant				1	0,631**	0,167	-0,045	0,858**
Head length					1	0,138	0.058	0.634**
500 grain weight						1	-0.052	0.162
Threshsing %							1	0.104
No. of grains per head								1

** significant at 5% and 1% levels of probability respectively.

TABLE 9 : CORRELATION COEFFICEENTS AMONG DIFFERENT CHARACTERS OF HYBRDIS ON VERTISOLS

	Days to bloom	Plant height	Grain yield per plant	Head yield per plant	Head length	500 grain weight	Threshing %	No. of grains per head
Days to bloom	1	0.145	0.153	0.195	0.140	0.189	0.018	-0.063
Plant height		1	0.495**	0.477**	-0.019	0.408**	0.289**	0.144
Grain yield per plant			1	0.895**	0.170	0.284**	0.086	0.355**
Head yield per plant				1	0.286**	0.272**	-0.040	0.316**
Head length					1	-0.192	-0.266**	0.173
500 grain weight						1	0.041	-0.097
Threshing %							1	-0.062
No. of grains per head								

- significant at 5% and 1% levels of probability respectively

TABLE 10 : CORRELATION CO-EFFICIENT BETWEEN MEAN PEROFRMANCE OF THE NON-RESTORER LINES ('B' lines) AND THEIR g.c.a. EFFECTS

	Characters	'r' values	
		Alfisols	Vertisols
1	Days to bloom	0.802**	0.462**
2	Plant height	0.800**	0.668**
3	Grain yield per plant	0.181	0.052
4	Head yield per plant	0.120	0.121
5	Head length	0.738**	0.728**
6	500 grain weight	0.743**	0.217
7	Threshing %	0.559**	0.242
8	No. of grains per head	0.269	-0.115

4.6.2: Correlations between mean performance of non-restorer lines and their estimates of g.c.a. among different characters.

Highly significant positive correlations were observed (Table 10) between *per se* performance of 'B' lines and their g.c.a. effects for the traits viz., days to bloom (0.802, 0.462) (alfisols, vertisols) plant height (0.800, 0.668) and head length (0.738, 0.728) at both locations.

Significant positive correlations were observed for the traits, 500-grain weight (0.743) and threshing percent (0.559) only on alfisols. But for grain yield per plant (0.181, 0.052) (alfisols, vertisols), head yield per plant (0.120, 0.121) and number of grains per head (0.269), (-0.115) the correlations were not significant at both locations.

D I S C U S S I O N

Concentrated efforts towards the development of sorghum hybrids in India started twenty years ago. The first sorghum hybrids, CSH-1, and CSH-2 released for commercial cultivation in the early 60s in India were based on the introduced male sterile combine kafir 60A. Since then several higher yielding hybrids have been released. Some released hybrids have not been commercially successful. A serious limitation in developing superior hybrids is a limited choice of seed parents. Therefore, development of superior seed parents is important to the development of superior hybrids.

The random mating populations of non-restorers developed at ICRISAT offer ideal source material for deriving non-restorer lines. Large numbers of non-restorers from these populations have been already identified at ICRISAT and more will appear as selection proceeds further. Some non-restoring lines have been identified from conventional pedigree breeding as well as from restorer populations.

The conversion of 'B' lines into 'A' lines (male sterile lines) is a laboureous process of backcrossing and is time consuming. There is a chance that after converting a large number of non-restorers to A-B lines only a few 'A' lines are found to produce hybrids with better yield potential than that of the released hybrids.

The present study was initiated with the objective to identify among non-restoring lines those lines that have the greatest potential as seed parents in hybrids - only these would then be converted to A-B lines.

Twenty non-restorer lines having desirable plant and grain attributes were crossed with five cytoplasmic genetic male sterile lines (testers) of diverse origin but with similar maturity and plant height. (Table 1). Since these hybrids were developed from crosses between A x B lines, the F_1's were male sterile. In order to evaluate these hybrids a pollinator bulk was interplanted. Good seed set was observed on these sterile hybrids which is reflected by acceptable grain yield per plant at both locations indicating that these hybrids could be evaluated successfully.

The ANOVA of parents showed higher mean squares for non-restorer lines than for the testers for most traits indicating greater diversity in the non-restorer lines. These observations confirm earlier notions that a study of this kind on these lines would be useful in identifying potential female parents.

The interesting non-restorers from this study selected either on the basis of high *per se* performance for grain yield or on high g.c.a. effects are given in Table 11 along with days to bloom, plant height and important yield contributing factors associated with grain yields. It was observed that lines 1, 8, and 12 have the best potential to produce high

Table 11: PERFORMANCE OF SELECTED LINES AND THEIR HYBRIDS FOR GRAIN YIELD, DAYS TO BLOOM, AND PLANT HEIGHT.

	Grain yield		Days to bloom		Plant height		Major yield contributing factor
	Line	Hybrid	Line	Hybrid	Line	Hybrid	
L1	V.high	V.high	Early	Early	Inter-mediate	Tall	Kernel weight
L3	Inter-mediate	Low	Medium	Medium	Dwarf	V.Dwarf	-
L6	Inter-mediate	Low	Early	Early	Inter-mediate	Inter-mediate	-
L8	V.low	V.high	Inter-mediate	Late	Inter-mediate	Inter-mediate	-
L9	Inter-mediate	Inter-mediate	Inter-mediate	Inter-mediate	Inter-mediate	Tall	Grain no.
L10	V.low	Inter-mediate	Inter-mediate	Inter-mediate	Inter-mediate	Inter-mediate	-
L11	Inter-mediate	V.low	Inter-mediate	Late	Inter-mediate	Dwarf	Grain no. & threshing %
L12	V.high	V.high	Late	Late	Tall	Tall	Grain no.head length and threshing
L15	High	Inter-mediate	Inter-mediate	Inter-mediate	Tall	Tall	Kernel wt. & Threshing
L19	High	Inter-mediate	Inter-mediate	Inter-mediate	Tall	Tall	Threshing %

yielding hybrids followed by L_{15}, L_{19}, L_9 and L_{10}. Among the best 3 lines, L_1 produced early and tall hybrids, L_8 late and medium height hybrids whereas L_{12} produced late and tall hybrids. A close look at Table 11 indicated that high yielding hybrids can be produced by late as well as early lines of tall and intermediate height. Similarly high yielding hybrids may can vary in hight and maturity.

The observations on the per se performance of the lines and their hybrids for three measured characters namely, maturity, plant height and yield revealed that dwarf lines produce only dearf hybrids, tall lines on the other hand produced tall hybrids whereas intermediate lines may produce either tall, intermediate or dwarf hybrids. The same relationship also exists for maturity. However, for grain yield all kinds of variations were noted i.e. high yielding lines produced high and intermediate hybrids; very low yielding lines produced low as well as very high yielding hybrids and intermediate types produced all types, from very low to high yielding hybrids.

The above observations were further supported by the correlation values (r values) between per se performance of the lines and their g.c.a. effects. It was observed that except for grain yield, head yield and number of grains per head the correlation values for other characters were significant and positive emphasizing that the per se performance of the line is not a good measure of hybrids produced by them for grain yield and grain number per head. Similar results were reported by Kaw and Menon (1978) in soybean. Similarly Singh and Joshi (1966) while working with linseed felt that the parental performance itself is not necessarily a guarantee of it's usefulness in a breeding programme especially for yield. Whereas the hybrids performance for characters namely maturity, height, head length and to a good extent for kernel weight and threshing percent can be predicted on the basis of performance of their parents.

Inter-relationship among several characters of hybrids showed positive significant correlations between grain yield and head yield, 500 grain weight and number of grains per head, indicating that 500-grain weight and number of grains per head are the important yield components. Similar results were reported by Atkins et al., (1968), Liang et al., and Dabhotkar et al., (1970). It was also noticed that grain yield was positively and significantly correlated with plant height but no significant correlation was found between grain yield and days to bloom. Contradictory results were reported by Rao et al., (1973). This adds support to the observation that high yielding hybrids in the present study were intermediate to tall.

The study of specific combining ability effects also confirmed the above observations. The lines 1, 8 and 12, in particular, showed significant s.c.a. effects in a desirable direction in certain combinations for maturity, plant height and yield.

From the analysis of variance table for hybrid (Table 3) it was noted that mean squares due to the males x females were lower than either due to males or females indicating that hybrids were more uniform than the parents. Similar observations were made by Rao et. al., (1968) in their studies.

On the basis of observations on variance ratios of g.c.a./s.c.a. it was noted that grain yield, head yield, no.of grains per head and threshing percent are largely controlled by a non-additive type of gene action. Variance effects for head length are largely additive whereas both types of gene action appear equally important for days to bloom, plant height, and kernel weight. There appears to be a great deal of controversy in the literature on the nature of gene action for different characters in sorghum. However, Karper and Quinby (1954), Kambal (1963) Niehaus (1964) and Nagur and Menon (1974) found that both dominant and epistatic effects appeared to be involved in governing days to bloom and plant height. Contradictory results were reported by Whitehead (1962) Niehaus and Pickett (1966), Rao et al (1968), Goud (1971), Shankaregowda et.al., (1972) for days to bloom and plant height. For yield, additive type of gene action was reported by Kambal and Webster (1965) Niehaus and Pickett (1966), Beil and Atkins (1967) Rao et al (1968), Kirby and Atkins (1968), Malm (1968) and Riccelli Mattel (1975). However, similar results to those presented in this study for yield were reported by Liang and Walter (1968). He also suggested that the magnitude of heritability and genetic parameters for a character would vary from location to location and year to year in the same crop. Kramer (19[illegible]) reported that g.c.a. and s.c.a. in sorghum are equally important in determining yielding ability. Rojas and Spraque (1952) pointed out that s.c.a. variance was more important than variance due to g.c.a. in corn when lines under test had been subjected to previous selection. It appears therefore, that results depend upon the set of material one is working with. The present set of lines were taken after selection for many generations. This may be the reason for the prepondence of s.c.a. effects for most traits, in this study. However, it appears from this study, as one would expect, that there is a poor correlation between per se performance of lines and hybrids for characters with non-additive type of gene action as compared to those having high additive effects.

On the basis of the above study, it was concluded that by growing male-sterile hybrids along with interplanted pollinators, that the evaluation of hybrids for grain yield and other characters can successfully be made. Thus, a large number of non-restorer lines can be evaluated for their combining ability by taking cytoplasmic lines (A-lines) as testers before back crossing is taken upto develop A-B lines. From this study L_1, L_8 and L_{12} appear to be the most suitable lines for converting into A-B pairs.

SUMMARY AND CONCLUSIONS

(1) A Line x Tester experiment, using 20-non-restorer lines as pollen parents and 5 cytoplasmic genetic male-sterile lines as seed parents (testers) was undertaken for the present investigation.

(2) The resulting 100 male-sterile hybrids and 25 parents from the above Line x Tester design were planted in the kharif season of 1980 on alfisols and vertisols at ICRISAT, Patancheru, India, as two separate experiments along with pollinator bulk to provide the pollen for F_1 hybrids. Observations were recorded on, days to bloom, plant height, grain yield and head yield per plant, head length, 500 grain weight, plot grain yield and head yield.

(3) The seed set on hybrids and male-sterile lines was normal and their evaluation for grain yield was satisfactory.

(4) On the basis of overall performance for different characters, L_1, L_8 and L_{12} were found to be good non-restorer lines followed by L_{15} and L_{19} These lines were recommended for conversion to A-B lines by the substitution backcross programme for use as female parents in developing hybrids.

(5) Association between *per se* performance of the parents and the g.c.a. for different characters indicated that *per se* performance is a good indicator

for hybrid performance for simply inherited traits like days to bloom, plant height and head length but not for grain yield. The variety, L_8, exhibited poor _per se_ performance but produced very good hybrids.

Inter-relationship among different characters of hybrids indicated that 500 grain weight and number of grains per head were the best correlated yield components with grain yield. Significant positive correlation was also noticed between grain yield and plant height.

(6) From the results on two soil types it was observed that g.c.a. effects were more consistent over the two environments than were s.c.a. effects.

Based on the ratio of g.c.a. and s.c.a. variances it was noted that the non-additive type of gene action was more important for the expression of yield, number of grains per head and threshing percent. On the contrary, additive type of gene action was found to be important for head length. Both additive and non-additive types appear important for plant height, days to bloom and 500 grain weight.

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