INHERITANCE OF EARLY MATURITY AND NONSENESCENCE IN SOME LOCAL AND EXOTIC CULTIVARS OF SORGHUM (SORGHUM BICOLOR L) MOENCH IN POTHWAR TRACT OF PAKISTAN

BY

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DEPTT. OF BIOLOGICAL SCIENCES
QUAID-I-AZAM UNIVERSITY
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A thesis submitted to the Quaid-i-Azam University
Islamabad, Pakistan

in partial fulfillment of the requirements for the degree

of

DOCTOR OF PHILOSOPHY

DEPTT. OF BIOLOGICAL SCIENCES
QUAID-I-AZAM UNIVERSITY
ISLAMABAD
1996

Approved by

CERTIFICATE

This is to certify that the thesis entitled "INHERITANCE OF EARLY MATURITY AND NONSENESCENCE IN SOME LOCAL AND EXOTIC CULTIVARS OF SORGHUM (SORGHUM BICOLOR L) MOENCH IN POTHWAR TRACT OF PAKISTAN" submitted for the degree of "Doctor of Philosophy" in Biology(Plant Breeding & Genetics) of the Quaid-i-Azam University Islamabad, is a record of the bonafide research work carried out by Mr. Abdul Shakoor, under my supervision and under supervision of co-supervisor Professor Dr. Muhammad Hanif Qazi Member Crop Sciences Pakistan Agricultural Research Council, Islamabad. The title of the thesis has been approved by the Advance Studies and Research Board of the Quaid-i-Azam University. No part of this thesis has been submitted for any other degree. All the assistance and help received during the course of research have been duly acknowledged by him.

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DECLARATION

I, Abdul Shakoor declare that the thesis entitled "INHERITANCE OF EARLY MATURITY AND NONSENESCENCE IN SOME LOCAL AND EXOTIC CULTIVARS OF SORGHUM (SORGHUM BICOLOR L) MOENCH IN POTHWAR TRACT OF PAKISTAN" is a result of bonafide work done by me at the National Agricultural Research Centre (NARC) Islamabad, Maize & Millet Research Institute (MMRI) Yousafwala (Sahiwal) and Quaid-i-Azam University Islamabad, Pakistan. I further certify that the thesis or any part of it has not been published in any manner.

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ABSTRACT

A study on inheritance of early maturity and nonsenescence in sorghum (Sorghum bicolor L) Moench was conducted to determine the mode of inheritance for efficient and effective selection of the desired traits. The study was carried out in two parts: 1) Generation means analysis for early maturity and nonsenecence traits in sorghum and 2) Combining ability estimates for early maturity and nonsenecence traits in sorghum. In the first study two high yielding ICRISAT type cultivars viz: ICSV 107 and ICSV 219 were crossed with an early maturing local type Pot.3-9. A field trial with eight generations namely P1, P2, F1, F2, BC1, BC2, BC1(S) and BC2(S) for each cross was conducted at two locations i.e. National Agricultural Research Centre (NARC) Islamabad and Maize & Millet Research Institute (MMRI) Yousafwala during kharif season 1992.

Analysis of generation means indicated that additive genetic effects were important for yield per plant, head length, seeds per head, 1000-grain weight, threshing percentage, maturity index, leaves per plant, leaf area of upper six leaves (LAUSL), percent green leaves area per plant fifty days after flowering (%GLA 50DAF) and sugar percentage, in both the crosses. Dominance effects were also important for yield per plant, 1000-grain weight, maturity index and %GLA 50DAF in cross 1 and yield per plant, maturity index, leaves per plant, LAUSL, %GLA 50DAF and sugar percentage in cross 2 which indicated that cross 2 (ICSV 219 X Pot.3-9) was more nonsenescent (stay-green). Epistasis was not important for the desired traits in either population. Significant additive effects suggest that effective selection for early maturity, head length, seeds per head, 1000-grain weight and yield, is possible in cross 1 and selection for leaves per plant, LAUSL, %GLA 50DAF and sugar percentage is possible in cross 2. Selection for early maturity would be more effective in later generations. In cross 2, selection for yield could also be practised in early generations.

Narrowsense heritability estimates from variance components ranged from low to high in both populations. Low heritability for yield suggested that selection in cross 1 should be practised in later generations. Low correlation between yield and early maturity in both crosses indicated that selection for early and favourable recombinants could be possible from these crosses.

Estimates of general and specific combining ability effects as well as the variances for yield, and stay-green associated components were obtained for a set of 12 straight crosses made in a factorial mating design among seven pure lines of sorghum. The parental material consisted of three pure lines from ICRISAT, viz: ICSV 107, ICSV 112, ICSV 219 and four early local type lines viz: Pot.3-9, Red Janpur, Bagdar and DS-75.

All these lines had been maintained for more than six years. The F1 and F2 generations were evaluated in the field to determine the combining ability of the parents for maturity and stay-green traits such as yield per plant, head length, seeds per head, 1000-grain weight, threshing percentage, maturity index, plant height, leaves per plant, LAUSL, %GLA 50DAF and sugar percentage. The trials were conducted on F1 and F2 generations in randomized complete block design with three replications at the two locations during 1993 and 1994, respectively.

General combining ability estimates were non-significant for all the traits except plant height in F1. Specific combining ability estimates were significant for head length, seeds per head, 1000-grain weight, threshing percentage, plant height, LAUSL and %GLA 50DAF in F2 generation. The magnitude of GCA was much greater than SCA for majority of the traits in both F1 and F2 generations indicating that additive genetic variance was more important than nonadditive genetic variance. Among male parents, Bagdar gave highest GCA for yield per plant, head length and 1000-grain weight, whereas Pot.3-9 gave highest GCA for maturity index and threshing percentage. Among the female parents, ICSV 107, as expected for being adapted to the Pothwar tract agro-climatic conditions, gave the best GCA for yield per plant, head length, seeds per head, 1000-grain weight, threshing percentage and maturity index. ICSV 219 gave the highest GCA effects for LAUSL, %GLA 50DAF and sugar percentage among the female parents, indicating its superiority in stay-green character.

There was a highly significant positive correlation of maturity with plant height and %GLA 50DAF and significantly negative correlation with yield per plant and head length. Selection for early maturity and high yield in Pothwar area should be practised among progeny of ICSV 107 X Pot. 3-9, while selection for the stay-green associated characters be practised in progeny of ICSV 219 X Pot.3-9. F3 progenies will be planted and evaluated at NARC to identify the best crosses under local agro-climatic conditions.

ACKNOWLEDGEMENTS

I wish to express my sincere appreciation to my supervisor, Dr.Afsari S.Qureshi and Co-supervisor, Dr.Muhammad Hanif Qazi, for their inspiration, guidance, encouragement, assistance and constructive criticism throughout this study.

I am very much thankful to the Government of Pakistan, the Pakistan Agricultural Research Council and to the Quaid-i-Azam University for granting me permission to undertake the present research project of national importance for my Ph.D. research. Special thanks go to Dr. Zafar Altaf, the Chairman Pakistan Agricultural Research Council, Islamabad and to Dr. Abdul Hafiz Chairman Deptt. of Biological Sciences Quaid-i-Azam University for their interest in this project.

I acknowledge and express my sincere thanks to the National Agricultural Research Centre Islamabad and the Maize and Millet Research Institute Yousafwala for their assistance and cooperation during this study. The encouragement and moral support extended by my colleagues, is highly appreciated.

I wish to record my special thanks to Dr.Naazar Ali and Dr. Salim Akhtar of the National Agricultural Research Centre Islamabad for their help in statistical analysis on the SAS Prog. Their valuable suggestions in presentation of the data are also appreciated. A special thank goes to Mr.Sultan Muhammad LDC/Typist for typing many drafts on computer and laser printing of this thesis. The help in field work extended by the field staff of Sorghum & Millet Research Programme NARC and that of MMRI, Yousafwala is gratefully acknowledged.

Finally my special words of thanks to my parents, wife, daughters, son, sisters and brothers whose heartfelt blessings have always been the major significance in my this achievement. Their encouragement, patience, support and understanding made this study possible.

ABBREVIATIONS

Abbreviations used throughout the text are as follows:

Agril.	=	Agricultural
A	=	Additive
AA	=	Additive X Additive
AD	=	Additive X Dominance
BC1	=	Backcross 1 (F1 X P1)
BC2	=	Backcross 2 (F1 X P2)
BC1(S)	=	Backcross 1 selfed
BC2(S)	=	Backcross 2 selfed
D	=	Dominance
DD	=	Dominance X Dominance
F1	=	First filial generation (P1 X P2)
F2	=	Second filial generation
F3	=	Third filial generation
GLA% 50DAF	=	Percent Green Leaves Area per plant 50 Days After Flowering.
Ha	=	Hectare
GCA	=	General Combining Ability
ICRISAT	=	International Crops Research Institute for the Semi-Arid Tropics, Hyderabad, India.
ICSV	=	ICRISAT Sorghum Variety
LAUSL	=	Leaf Area of Upper Six Leaves per plant.
MMRI	=	Maize & Millet Research Institute
M	=	Intercept
NARC	=	National Agricultural Research Centre
NWFP	=	North West Frontier Province
P1	=	Parent 1
P2	=	Parent 2
Pot.	=	Pothwar Tract of Pakistan
SCA	=	Specific Combining Ability

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COMBINING ABILITY ESTIMATES FOR EARLY MATURITY AND NONSENESCENCE (STAY-GREEN) TRAITS IN SORGHUM

INTRODUCTION

Sorghum (Sorghum bicolor L) Moench is an important food, feed and fodder crop worldwide and is grown throughout the tropical and temperate regions. It remains the staple crop for millions of people in the semi-arid regions of the world. Its unique ability to withstand periods of drought and other adverse edaphic and climatic factors have led to its widespread cultivation, utilization and consumption in Africa and Asia. Sorghum is grown in some of the harshest environments and most fragile lands in the world, resulting in low and unstable grain production. As population pressure increases in these areas, the need to boost production in environmentally sound ways becomes increasingly urgent (Jhon 1992).

Production of sorghum in the world is generally restricted to the areas between latitude of 34^0 N and 35^0 S. India, China and Africa are the largest producers of sorghum. About 65 percent of the total is produced in the dry rainfed areas of the semiarid tropics where the yields range from 600-800 kg/ha. These yields are very low compared to those of 2500 kg/ha obtained in the developed countries.

The area under sorghum production in Pakistan during the year 1993-94 was 369,000 hectares. About 55 percent of this area was in Punjab, 25 percent in Sindh, 14 percent in Balochistan and 6 percent in NWFP. The major portion of the total area which is rainfed, fluctuates from one year to another depending on the amount and distribution of rains.

With rapid increase in population (3.2%) of Pakistan, sorghum as a food grain crop can support wheat, rice and other food grain crops. Almost 70 percent of sorghum grain is used as food in the sorghum growing areas of Pakistan. Sorghum is also used as green fodder crop for feeding livestock before grain formation.

A recent new demand dimension has been opened up by its use in poultry feed production. Presently more than one million tone of wheat is being used in the poultry feeds, which could otherwise be used for the human beings in the long run in view of the increased population which would be only possible if production of sorghum crop is enhanced substantially.

The major production constraints are pests, diseases, non-availability of improved varieties and unreliable rainfall patterns of the semi-arid tropics. Much research has been done to develop high yielding and disease-resistant cultivars of sorghum, but these cultivars do not perform well under abnormal weather conditions in many sorghum growing areas. Early maturing cultivars may escape some of these natural weather hazards. Some developing counties like Pakistan need early maturing cultivars for a double cropping system with other crops.

Maturity is an important and complex consideration in sorghum breeding. Fortunately the wide variability in length of pre and post flowering period provides an important base for selection. To avoid yield reduction due to earliness and yet fit a time frame, we need to develop genotypes which utilize the time period most efficiently without sacrificing yield potentials.

Sorghum growers of the Pothwar tract of Pakistan are also interested in high yielding and early maturing cultivars to reduce the risks involved with abnormal growing conditions particularly at the end of the season. In Pothwar tract, rains come usually in last week of June or 1st week of July. The last soaking rain usually comes in the last week of September. There is usually adequate moisture for 70 to 80 days. Under such conditions 110 to 120-day varieties have no chance of being adapted. There is a need for varieties which mature in 80 to 85 days, and fit in cropping sequences that permit crop intensification and better utilization of the available land and water resources. Productivity should be viewed as yield per unit area per unit time rather than yield per unit area only.

Plant breeding has contributed substantially to solving the problems by increasing agricultural productivity and efficiency of production. The development of early maturing cultivars with high yield potential is one of the priority objectives of a breeding programme in almost all the sorghum growing countries including Pakistan. Several methods have been suggested by scientists for determination of maturity in sorghum with respect to length of its growing period. The indices used for determination of maturity in sorghum are: days to 50% flowering, days to 30% grain moisture, time to 100% milk line and days to physiological maturity. Plett (1992) has reported time to 50% silking as the most consistent measure of maturity. In the present study the number of days from planting to relative maturity (formation of black layer) and the colour of aleurone layer has been taken as the maturity index.

In local sorghum cultivars, lack of stay-green character is one of the factors affecting its acceptance by the farmers because they use sorghum as green fodder to feed their livestock particularly at the end of the crop season when there is general scarcity of green fodder. Cultivars lacking stay-green character loose the chlorophyll content as these attain maturity. The local types which are a source of early maturity, generally have no stay-green character. In contrast ICRISAT types are late in maturity but have stay-green character. A small degree of stay-green character in maize has been reported by Bhatti (1964) who has emphasized the importance of this character in maize breeding. Duncan et al (1976) studied the characteristics and inheritance of nonsenescence in crosses of US and ICRISAT type sorghums. He reported that this characteristic is under the control of only one major factor or chromosome segment.

In view of the importance of sorghum stover for animal feeding in Pakistan, breeding of dual-purpose (grain-cum-fodder) varieties should be considered a priority area in the breeding programme. Thus, besides grain yield and quality, forage yield as well as quality in terms of leafiness, stem juiciness and sweetness, ability to tiller, production of fine stems and stay-green character should be among the criteria for selection.

As sorghum is commonly cultivated both for grain as well as for fodder purposes, the stay-green character in sorghum has, therefore, a great economic importance from the point of view of its utility for green fodder supply. By virtue of this character, it is commonly cultivated both for grain as well as for fodder purposes. The nonsenescence or stay-green trait in sorghum is thought to provide a measure of resistance to lodging, charcoal rot and terminal drought. It is therefore, a potential means of improving grain and fodder yields, as well as the agronomic value of sorghum genotypes in terminal stress environments as reported by Duncan (1984).

According to the Economic Survey of Pakistan (1994), there are about 115.7 million head of livestock (all kinds) in Pakistan, for which we have to set apart 1/6 to 1/8 of the crop area for raising fodder crops. Inspite of keeping apart so much area, there is still general shortage of green fodder especially at the time when the sorghum crop is harvested for grain purpose, since at this period the kharif season fodder crops are finished up and rabbi season fodder crops are not ready for providing green fodder. The stay-green varieties of sorghum could help a lot in patching-up the gap of fodder supply to a great extent, by incorporating this character into sorghum hybrids. But before this useful character can be bred into sorghum hybrids, information on inheritance of this character is an essential prerequisite.

A number of local type lines with 80 to 90 days maturity have been developed but these lines have low fodder and grain yields. High yielding cultivars are of ICRISAT type having stay-green character but are late in maturity. The early maturing cultivars are usually local type with very little or no stay-green character and low yields.

The National Cooperative Research Programme on Sorghum has a major sorghum breeding programme, and development of early maturing cultivars with stay-green character is one of their main objectives which is the need of the farmers in almost all sorghum growing areas of the country and to fit it into the cropping system and to escape natural weather hazards such as frost and diseases. Local genotypes, having been adapted to the local prevailing environmental conditions, are the major source of early maturity, but their yield potential is very low compared to ICRISAT types. Selection among segregates from crosses of local and ICRISAT genotypes could lead to the development of high yielding and early maturing cultivars of sorghum.

Although some high-yielding exotic varieties have been identified, and some have even been released, they have not yet spread among farmers, because of intrinsic shortcomings such as poor grain quality, short stature resulting in low fodder yield, late maturity, poor germination, emergence and establishment under moisture-stress conditions.

For incorporation of the desired characteristics in a cultivar, knowledge of the mode of inheritance of the characters, heritability and combining ability of the lines is the basic requirement in selection of the parents.

Plant breeders need to understand the type of gene action controlling the desired traits, the extent of genetic variability available among the parents and selection of parents to use in a hybridization programme to get the desired progenies. In addition, knowledge of heritability is also very important to determine selection procedure to be used and the generation in which selection could be practised effectively. A significant relationship between the combining ability for yield, maturity and stay-green character and that of any of its components can help formulate criteria for selecting pure lines during the inbreeding generations for ultimate use in production of early maturing, high-yielding lines coupled with stay-green character.

With these ideas in mind the present study was undertaken to choose the best parents among the selected lines, which can produce progenies with early maturity and high yield coupled with stay-green character. Accordingly the objectives of the study are:

a) To estimate mean and variance components (additive, dominance and epistasis) for early maturity and nonsenescence traits;

b) To estimate narrow sense heritability of earliness and stay-green character;

c) To estimate general and specific combining ability of the selected parental lines for earliness and nonsenescence traits; and

d) To determine potential effectiveness of selection for early maturity, stay-green character and their correlations.

REVIEW OF LITERATURE

The genus Sorghum belongs to the tribe Andropogoneae of the family Gramineae and includes both wild species and species cultivated for their grain, fodder, commercial and other purposes. All the cultivated sorghums have a haploid chromosome number of n=10 and cross readily with each other. All the cultivated forms are grouped under a single species Sorghum bicolor L. Moench. It is a semi arid tropical crop, which is drought resistant and grows most successful in warm and dry climates (Tahir 1980).

In Pakistan, it is grown in most districts located at latitude 34^0N but is particularly important in D.G. Khan, Rahim Yar Khan, Rawalpindi, Attock, and Jhelum in Punjab; Sukkur, Khairpur, Dadu, Nawabshah, and Sanghar in Sindh; Nasirabad, Lasbella and Sibbi in Balochistan; and D.I.Khan in NWFP. Depending upon the varieties and environment, it takes 80 to 120 days to mature. There are differences in maturity, photoperiodic reaction and degree of drought tolerance.

INHERITANCE OF MATURITY:

Literature presented on different aspects of sorghum maturation and related studies, has indicated that high yields are achieved by hybrids and varieties which can utilize maximum length of growing seasons. More simply stated, the longer the crop takes for growth and development in the field, the higher it produces. The time of ripening, however, is critical in regions where frost is a threat or in the areas where the system of farming is reduced to rotation of sorghum and winter cereals. Hence, a point may be reached where increasing yields by longer or later maturing hybrids is not practical. Grain yield is of primary interest, in addition to the total duration, the contribution of photosynthesis to yield must be considered in terms of the durati.n of vegetative and reproductive periods.

The definition of maturity as a trait cited in literature has not been consistent and none of the definitions, is equally acceptable to plant breeders, physiologists, agronomists or even to the farmers. Three measurements of maturity which have been used frequently in classifying sorghum varieties and hybrids are: 50% anthesis date, physiological maturity (formation of black layer at the placenta of kernel) and grain moisture at harvest. 50% anthesis date and grain miosture are the most common measures because they are easy to obtain. Physiological maturity has gained more importance in recent years, because this is the time when maximum dry matter accumulation is completed in the kernel.

The term "physiological maturity" was first used by Shaw and Loomis (1950). In their opinion, moisture percentage as a basis for prediction of maturity was found to be unreliable. They reported that large differences in moisture percentage at the time of physiological maturity existed among hybrids in any one year and for any one hybird in different years. Chase and Sherret (1964) concluded that higher yields were possible in early hybrids which flower late and loose moisture rapidly after physiological maturity, and that they would compare favourably with those that flower early and dry slowly later in the season.

According to Kiesselbach and Walker (1952) the development of tissue that will eventually turn into the black layer or the closing layer, starts soon after fertilization of kernel. This tissue grows completely across the placento-chalazal region of the kernel by approximately 20 days after pollination and remains active until about two weeks before maturity, when visual black layer development begins. This black closing layer develops in a region of cell layers thick which are formed between the basal endosperm of the kernel and the vascular area of the pedicel early in the seed development. As maturity is approached, cells shrink and become compressed into a dense layer which appers black to the naked eye. At approximately the same time, the basal conducting cells of the endosperm get disorganized and are crushed tangentially ceasing the translocation function.

Many investigators (Daynard and Duncan, 1969; Rench and Shaw, 1971; and Johnson and Tanner, 1972b) have agreed that the black layer formation indicates the attainment of maximum dry matter accumulation in the kernel. It was suggested earlier by Dessureaux et al (1948) that inbred lines and hybrids of corn of contrasting maturity vary in rate of moisture depletion and dry matter accumulation. Not only the time of flowering but the time at which physiological maturity is completed, should be considered for an adequate measure of maturity. However, Shaw and Thom (1951b) reported a constant period of 51 days from silking to maturity, and that, because of consistency, time of maturity could be predicted at silking time.

Daynard (1970) and Poneleit et al (1971) reported wide genetic variation for black layer maturity and grain filling duration. Genotypes differed in growing degree days(GDD) requirements for black spot maturity and grain filling period (Poneleit et al., 1972). GDD requirement for black spot formation and filling period varied from 2406 to 3254 and 992 to 1478, respetively. Similar results were obtained by Carter and Poneleit (1973) where GDD requirements varied from 1337 to 1808 and from 512 to 821 for black layer maturity and kernel filling period, respectively. Rench and Shaw (1972) obtained large significant differences in filling period length. The total variation, 45-70 days was due to maturity, planting and environment. Planting date accounted for 0 to 8 days variation in filling period and environment caused differences of 10-20 days. Cross (1975) found significant differences among hybrids and years for grain filling period, rate of grain filling, yield and thermal units to silking. Significant interaction between hybrids and years was reported for moisture content at harvest.

In earlier work, Hopper (1925) found a range of 57 to 89 days from planting to flowering in 16 varieties of different maturity groups. These differences were due to environmental conditions, date of planting and varietal inheritance. Varieties with shorter period develop smaller areas of assimilating leaves and consequently should be less productive (Shaw and Thom, 1951a).

Sorghum is known to be a short day species. The time of floral initiation controls the number of leaves, the duration of growth and the ultimate size of the plants. The inheritance of duration of growth in sorghum has been studied in detail by Quinby (1967). While working on maturity genes in sorghum, he reported that number of leaves on a sorghum plant depended on the time of floral initiation. The delayed floral initiation was associated with the development of more leaves. Four loci namely Ma1, Ma2, Ma3 and Ma4 have been identified. There are many alleles at each locus. He reported two dominant and eleven recessive alleles at the Ma1 locus; twelve dominant and two recessive alleles at the Ma2 locus, nine dominant and seven recessive alleles at the Ma3 locus; and eleven dominant and one recessive allele at the Ma4 locus. Combinations of dominants and recessives at the four loci in flowering periods ranged from 40 to over 100 days. The maturity period of a sorghum variety is determined by interaction between genotype, temperature and photoperiod. The multiple alleles at each locus differ in response to temperature and cause differences in time of flowering. Tropical varieties are always dominant at the first maturity locus and are usually dominant at the other three loci. Temperate varieties, with very few exceptions, are recessive at the first maturity locus. In another study comparing two genotypes of sorghum, Quinby (1967) observed that 'SM90' and '90M' differed only at locus 1; SM90 was recessive Ma_1 and 90_m was dominant Ma_1. Dominance at locus 1 increased duration of flowering by 53 days, leaf number by 92 percent, plant height by 77 percent, and doubled the dry weight of plant.

In a study of inheritance of leaf-number in sorghum carried out by Semenova (1989) using F1-F2 hybrids involving 10 varieties; 6 out of 10 F2 hybrids showed, transgressive segregation for the leaves per plant. This study also established that Yantar' Rannil 161 and Brod-skaya 2, carry an allele of Ma1, while V3 Sarat being recessive at all 4 loci, is useful as a tester in genetical studies and in breeding for reduced leaf-number and earliness. Height and maturity of genotypes are recognized by breeders to be determining factors for the ecological adjustment of a variety to a particular region and finally in expression of yield. Most genetic studies reveal a close association between genes for maturity and height. Yang (1949) suggested that only a few genes control silking time or plant height and that they are approximately similar in effect for the two traits. A similar conclusion was reached by Rao and Goud (1977) indicating that gene action for plant height and maturity in sorghum is essentially the same. They found additive gene action predominated for the above traits. Anderson (1959) reported a good correlation between plant height and number of days to flower in maize. Late maturing hybrids were taller and had more internodes, as compared to early maturing varieties (Singh, 1970)

Interrelationships between yield, plant height and maturity have been examined by Rao (1970). Cross and Zuber (1973) reported a high correlation between number of days from planting to flowering and plant height, but the relationship was low or insignificant when considered over a wide range of environmental conditions. Dalton (1967) has reported a positive regression between yield and maturity. In an analysis of a 5X5 diallel conducted by Vasudeva and Goud (1977) for six characters, additive genetic effects were found predominant for height and days to flowering. Significant specific combining ability effects were observed in some crosses. All characters showed partial dominance except panicle length, which showed over dominance. Heritability estimates were high for height, days to flowering, number of internodes and peduncle length. Two gene pairs controlled each character except panicle length, which was controlled by three.

Shinde and Joshi (1985) used nonepistatic, epistatic digenic and epistatic trigenic interaction models to obtain least square estimates of various gene effects for plant height and days to flowering in 12 generations from 3 intervarietal crosses. They found that tallness was dominant and epistatic interactions were seven to ten times greater than additive and dominance gene effects. Lateness was associated with Indian varieties and earliness with their derivatives. Epistatic interactions indicated that at least two genes controlled days to flowering, with a third gene having no interaction effect.

Dhillon and Singh (1976) in a study on genetic inverstigation of grain yield and maturity in maize pointed out the importance of over dominance and presence of complementary epistasis in the inheritance of days to silk and grain moisture in a diallel set of twenty maize populaitons. Sreekantavadhya and Mahadevappa (1969) observed non-additive and dominant gene action influenced genetic control of days to silk. Similar results were obtained by Griesbrecht (1960) in his study of inheritance of time of silking and pollen shedding in maize. Earliness appeared to be due mainly to dominant genes (Jones, 1954).

Genetic variance, genotypes environment interaction and the number of gene groups involved in controlling six yield related traits were estimated by Patel et al (1988) in a diallel cross involving eight elite lines. The results suggested that days to 50% flowering and 100-grain weight were influenced by partially dominant gene effects and could be improved by breeding. Genotype effects were more important than environmental effects for all the characters. Plant height and panicle length were estimated to be controlled by at least three groups of dominant genes, while grain yield and number of grains per plant were controlled by two groups; and days to 50% flowering and 100-grain weight by one group.

Geeta and Rana (1987) from a study on genetic changes over six generations in a pedigree breeding programme in sorghum, found that yield was highest in the F1 followed by successive depressions in the F2 and F3 despite selection of the highest yielding plants in the F2. After a marginal increase in the F4, yields were similar in subsequent generations. Plant height decreased and days to flowering and grain size increased in later generations. Heterosis over the better parent was highest for grain yield (27.3%) followed by 100-grain weight (23.4g). Grain yield was thought to be controlled by dominant genes.

In a study of selection for early flowering in three semi exotic synthetics, Troyer and Brown (1972) shifted days to silk 1 to 8 days earlier, decreased moisture content 1.2 percent and increased yield 1.00 q/ha per cycle of selection. In a later study (1976), they found that silking was shifted 1.7 days earlier per cycle for total of seven days for five cycle of selection in three early synthetics, and 2.0 days earlier per cycle for a total of 10 days for a late synthetic. The response to selection was less in advanced generation.

Chase (1964) concluded that higher yields were possible in early hybrids which flower late and loose moisture rapidly after physiological maturity, and that they would compare favourably with those that flower early and dry slowly later in the season. Bunting (1972) obtained 5 to 10 percent higher yield for early flowering as compared to plants flowering 7 to 10 days later. He also observed that an advance in the date of silking resulted in a corresponding reduction in the time from silk to harvest reaching in a harvestable condition (40% moisture).

Yield stability in 54 sorghum genotypes in relation to maturity was studied by Saeed and Francis (1983) in Nebraska and Kansas USA across 48 environments. They found significant genotype x environment interactions for yield and seeds per sq m. Stability analysis of all genotypes ignoring maturity groups showed a significant linear and quadratic relationship between days to flowering and stability parameters, regression coefficient and deviations from regression, respectively, and suggested that differences in yield stability among genotypes were largely a function of relative maturity. Separate stability analysis of genotypes in a maturity group revealed no such relationship in the early and the medium groups. Yield stable genotypes were identified in each group but proportionately fewer in the late group. A combined analysis of genotypes without grouping failed to detect this stability of individual genotypes. They suggested to consider seed weight and seed number when breeding for yield stability.

The inheritance of growth period was studied and analysed by Yang (1989), using generation means in the progenies of crosses of ten local cultivars. His results showed that the F1s had a similar growth period to that of the early-maturing parents but showed no transgressive effects. Additive effects appeared predominant and were the major factors influencing growth period. Gene(s) with negative dominance effects caused slightly earlier maturity in some F1s. The gene(s) for early maturity resulted from long-term domesticating selection. There were also dominant and epistatic effects in some crosses.

Ayyangar et al (1937) reported a case of dwarfness that was linked with early maturity but there is every likelihood that in this case there was segregation only for number of internodes, and not for a gene that influences elongation of internodes, while papers presented by various sorghum scientists and the one by Quinby and Karper (1945), showed that number of internodes as well as the length of internodes influences height. The genes that influence time of floral initiation and the consequent number of internodes are more correctly classified as maturity genes. In his report on height inheritance, only the genes that affect internode elongation are considered to be height genes. There is no indication in the literature that height in sorghum is inherited through the cytoplasm.

Based on results from the inheritance studies of maturity and other agronomic traits of sorghum, it has been reported that maturity is generally a dominant trait in tropical types. Tallness is partially dominant to dwarfness. Juiciness and sweetness are recessive characters with regard to stalk dryness and sweetness, while white midrib is dominant. Purple colour is dominant and tan colour is recessive. Normal sugar contents are said to be controlled by dominant genes while high sugar contents are controlled by recessive genes in sorghum (House, L.R 1985).

INHERITANCE OF NONSENESCENCE:

Sorghum is one of the major cereal crops in semi arid regions of the world where prolonged periods of drought are frequent. Sorghum exhibits two distinct responses to drought stress (Rosenow and Clark 1981; Rosenow et al 1983); one occurs when plants are stressed during the panicle development stage prior to flowering, called preflowering; and the second occurs when plants are stressed after anthesis and during grain development, called postflowering. Genetic variation for resistance to drought at each stage has been observed in sorghum germplasm. Many genotypes with a high level of resistance at one stage, are susceptible at the other stage (Rosenow et al 1983). Genotypes with resistance to postflowering stress, retain their leaves in an active photosynthetic state when subjected to water stress conditions during the grain filling period. Such genotypes are described as possessing the stay-green trait (Rosenow et al 1988). Sorghum genotypes with the stay-green trait continue to fill their grain normally under limited water conditions (Rosenow and Clark, 1981 and Duncan et al 1981). These genotypes also have increased resistance to charcoal rot (Duncan, 1984) and lodging (Woodfin et al 1988). The physiological mechanism of this trait is not yet well understood, although stay-green genotypes have been reported to contain greater amount of cytokinins than nonstay-green genotypes (McBee, 1984). Duncan (1981) and Duncan (1984) reported higher basal stem sugar content in stay-green sorghum genotypes compared with the nonstaty-green genotypes, especially during postanthesis growth.

Stay-green trait has also been reported in maize by Bhatti (1964). Some maize lines possess it and remain green even after the matured cobs are harvested, while a few others are reported to be having intermediate character of evergreenness; and still other lack this character. The mode of inheritance of evergreen character was studied by Hasan (1964-67) in crosses amongst four different inbreds of maize in F1, F2, F3 and backcross generations. In the crosses of evergreen x normal, normal condition was found to be dominant in F1. In F2 a ratio of 9 normal : 6 intermediate : 1 evergreen, was obtained. This suggested that the evergreen character was controlled by two recessive genes. In the crosses of intermediate x evergreen, intermediate was found to be dominant over evergreen in F1, and gave a ratio of 3 intermediate : 1 evergreen in F2. This suggested that the intermediate character was controlled by one dominant gene. In the crosses of normal x intermediate the normal character behaved as dominant in F1 and segregated into the ratio of 3 normal : 1 intermediate. This indicated that normal was controlled by two dominant genes. The evergreen lines, obtained from the F3 generation of evergreen x normal crosses indicated the possibility of incorporation of evergreen character into normal lines.

Duncan et al (1976) from a study on characteristics and inheritance of nonsenescence in Sorghum bicolor L. Moench, have reported that several characteristics were associated with nonsenescence in sorghum. The nonsenescing type generally took about two days longer to reach 50% anthesis and averaged 3 to 4 cm shorter in height than the senescing type. The nonsenescing type had a significantly larger stem diameter and maintained a higher sugar concentration in the stem from anthesis through harvest. The nonsenescing type produced and maintained more green leaves and fewer senesced leaves per plant throughout the reproductive phase of growth, and as a result, this type expectedly produced a greater leaf area index (LAI) and the LAI was maintained for a longer period of time as was reflected by the leaf area duration (LAD). The nonsenescing type maintained a higher chlorophyll content from panicle initiation to harvest. Senescence and stress are both associated with a decrease in chlorophyll content. Leaf area ratio LAR) was the only growth analysis parameter which was significantly different between the two types.

Recent studies on the relation between earliness and leaf number are in agreement with early research. The longer season hybrids produce larger leaf area per plant, and tend to maintain green leaf area for a longer time than early hybrids (Eik and Hanway, 1965). Bonciavelli and Monotti (1975) also obtained a larger leaf area index (LAI) value of 5 for late flowering compared to LAI of 4.0 for early hybrids.

Goldsworthy (1970) when compared a tall variety with a short variety of sorghum for leaf area duration and grain yield, found that the tall variety produced more dry weight after heading and had a larger leaf area duration than did the short variety, but its grain yield was not significant.

A co-efficient for estimating leaf area from linear measurements has been reported by McKee (1965). According to his research, "leaf area is calculated by summing the products of length and width of each leaf of a plant or of a plot and multiplying the total by 0.73. This method of calculating leaf area ignores the photosynthetic surface of the stalk and other plant parts".

In a study pertaining to inheritance of nonsenescence in sorghum, Duncan (1980) evaluated six populations viz: Psen, Pns, F1, F2, BCsen and BCns to estimate genetic variances for ratoon tiller regrowth. All data involving progeny of senescent and nonsenescent crosses were pooled for analysis using the joint scaling test. He reported that parental lines differed significantly in tiller production. Tiller production of a ratoon sorghum crop was used as a measure of nonsenescence and this character was quantitatively inherited with additive genetic effects with no indication of significant dominance genetic effects. The large estimates for additive genetic variation indicated that some progress could be made in selecting for tillers in a ratoon sorghum crop. However, heritability estimates were low (0.18 to 0.28) for number of tillers in ratooned sorghum. Estimates concerning the number of effective factors controlling tiller number in ratoon crop indicated that this characteristic is under the control of one major factor or chromosome segment. Zartman and Woyewodzic (1979) from their study on the rooting patterns of senescent and nonsenescent genotypes of sorghum reported that the nonsenescent hybrid had established its adventitious root system earlier than did the senescent hybrid. When nonsenescence lines were crossed with the senescencet lines it was observed by Henzell et al (1992) that the effects of moisture stress became increasingly evident after anthesis. There was a significant negative correlation between senescene ratings and grain yield, indicating that under these conditions, selection for nonsenescence would have a positive effect on yield.

Results of a 9 x 9 diallel trial among nonsenescent (stay-green) and senescent lines of sorghum presented by Jaychandran et al (1993), indicated that genotypes varied for time of onset, rate of progress, and final amount of leaf senescence. Nonsenescence was dominant over senescence as measured by the rate of senescence but not as measured by the time of onset of senescence. The best nonsenescent parents retained approximately 70% of the area of their upper six leaves green at 50 days after flowering (approximate harvest maturity), compared to 5-15% for the most senescent parents.

Rao (1969) has reported that a green midrib (dd) is associated with a juicy stalk, whereas a white midrib (DD, Dd) is correlated with a pithy stalk. The character is simply inherited and easily transferable. In another study Grewal et al (1988) has reported that when crosses of white midrib, green midrib and reciprocals alongwith their parents, BC1, BC2 and F2 were grown, segregation of midrib colour conformed to the 3 (white): 1 (green) ratio, indicating that white midrib colour is governed by a single dominant gene. The genetic control of leaf-midrib color (reflecting stem succulence), inflorescence shape, awnedness, glume length and grain colour was studied by Khusnetdenova and El'Konin (1987). They reported that in most cases the characters were controlled by 2-3 interacting genes influenced by the type of cytoplasm present.

Giriraj and Goud (1983) have reported that based upon component analysis and estimate of heritability, days to flowering was found to be predominantly under additive control. Number of leaves, leaf length, leaf breadth, leaf area, plant height, stem thickness, internode length and peduncle length were found to be governed both by additive and dominant components. Heritability estimates were medium to high for the characters studied.

Ma. H.T. et al (1988-90) from a study on inheritance of sugar content in sorghum stalks, have reported that the gene controlling low sugar content in the stalks was partially dominant. Correlations between sugar content and grain weight were negative (r=-0.472). The highest sugar content (20.3%, Brix), grain yield (2740 kg/ha) and biomass yield (8920 kg/ha) were found in the F2 generation.

Ayyangar and Nambiar (1941) from studies on inheritance of leaf colour reported that dark green was monogenic dominant to green, and green was monogenic dominant to light green. When there was segregation for all three characters, the ratio was 9:6:1 dark green, green and light green.

Leopord (1961) from a study on the chemistry of senesecnce in plant cells, has reported that in senesecing cells there is a gradual reduction in the endoplasmic reticulum and mitochondria as well as other organelles and membranes. The rate at which these natural changes occur depends greatly on the species, the part of the plant involved, and environmental conditions (photoperiod, temperature, soil fertility). Senescence may take place at about the same time in all parts of the plant or individual organ may senesce while the remainder of the plant retains vitality (leaf or fruit senescence). Leaf senescence may be characterized by involvement of all the leaves at the same time which is termed synchronous or simultaneous senescence. A "wave" of leaf senescence passing-up the stem is known as sequential senescence. Senescence of fruit occurs at a late stage in the ripening process and does not generally commence until the developing seeds are fully formed.

Results of the inheritance of chlorophyll for various crops have been reported by a number of scientists. They have reported that total chlorophyll content per unit leaf area and per unit leaf fresh weight in French beans is controlled by a single gene, with high content being dominant over low (Nakayama et al 1971).

Stay-green is an important trait associated with drought resistance in sorghum [Sorghum bicolor (L) Moench]. Walulu et al (1994) conducted trial to obtain preliminary information on the mode of gene action for the stay-green trait in sorghum. Stay-green lines, nonstay-green lines, and their F1, F2, and backcrosses were grown in field and under a rainout shelter. Moisture stress was allowed to develop in both trails during the grain filling period by withholding irrigation two weeks prior to flowering. Stay-green character was evaluated on an individual plant basis at or soon after physiological maturity by using a visual leaf and plant death rating score. The results obtained, suggest that the stay-green traits in the stay-green lines, is influenced by a major gene that exhibits varied levels of dominant gene action depending on the environment in which evaluations are made. In another study Moc, J.J (1979) reported that lines with high grain yields and strong stalks remained green longer during grain filling than those with low yields and weak stalks indicating that selection for the stay-green trait should produce similar results to select for photosynthetic rate. Benoit et al. (1965) observed that increased dry weight of kernels of defoliated plants was associated with corresponding decrease in the dry weight of the corn stalk and a decrease in stalk sugar content.

HERITABILITY STUDIES:

Naphade and Ailawar (1976-77) have reported from their research on variability, heritability and path analysis in sorghum that among 30 lines, the coefficient of variation of seven characters ranged from 10.2 percent for leaf-number to 30.4 percent for plant height; a figure of 27.8 percent was recorded for panicle length and 22.9 percent for grain yield. The range of heritability estimates was narrow, being 65.7 percent for leaf number and 96.8

percent for 100-grain weight. Estimates of genetic advance ranged from 16.7 percent for leaf number to 60.5 percent for plant height. Panicle weight was most highly correlated with grain yield, followed by 100-grain weight, panicle breadth and plant height. Path analysis revealed that the effect of panicle weight on grain yield was mainly due to its positive direct effect, and also, that it was a major factor contributing to yield. Leaf number also had a direct effect on yield. Based on their results they have recommended improvement by selection for panicle weight and leaf number.

In 57 F1-F3 hybrids from crosses involving 20 varieties and 8 lines, variation and heritability for the main yield characters were studied by Spivakov (1989). He reported that yield was closely correlated with weight of the main inflorescence ($r=0.88 + 0.07$) and number of grains in the main inflorescence ($r=0.93 + 0.05$). The coefficients of heritability for these two yield components were high (respectively 0.78 and 0.83), suggesting that selection for them in early generations would be effective. The genetic gain from selection for the two characters was respectively 4.4 and 5.6 percent. The greatest genetic gain was achieved in F2 hybrids. Yield was in most cases negatively correlated with growth period duration; the highest yielding types were midseason and late. However, some high-yielding early recombinants were selected in particular crosses. The genetic effect of earliness was on the average 4.9 percent and for height 12.5 percent. Plants taller than the parents could be readily selected in the F2. Rasmusson and Tew (1979), in a study with barley, also obtained intermediate to high heritability values of 0.54 to 0.99 for vegetative period.

Liang and Walter (1968) estimated gene effects based on parental, F1, F2 and backcross progenies, Additive gene effects seemed to make a minor contribution to the inheritance for grain yield, head weight and kernel weight. The additive x additive interaction effects, however, formed a major component. The dominance x dominance were also of high magnitude. Patel et al (1983) from a study on heritability estimates in grain sorghum have reported that selection through panicle length and 1000-grain weight would be most effective for further improvement of yield.

Inheritance of grain yield and panicle components was studied by Giriraj and Goud (1982) in F1 and F2 generations of eight-parent diallel cross in sorghum. Through component analysis, they reported that grain yield, panicle length, panicle breadth, number of whorls, number and length of primary branches, 100-grain weight and number of grains per panicle governed by both additive and non-additive components of genetic variation. For majority of the characters, estimate of heritability was high in F1 and low in F2 generation.

The F1-F2 from 10 crosses involving eight sorghum stocks of five major ecological types with a wide range of grain weight (17.1-40.9 g/1000 grains) were studied by Wang (1988). He reported that 1000-grain weight was governed by at least five pairs of genes. In the F1 of most combinations it tended to be intermediate between the parents, with a bias towards the better one. Most of the combinations showed a high broad-sense heritability for the trait, averaging 80.9 percent but ranging from 57.9 to 93.5 percent. Narrow-sense heritabilities in two of the combinations were estimated at 80.7 and 86.0 percent. This was taken to indicate that the effect of environmental factors on variation in grain weight was limited and it would be effective to start selection in early generation. The absolute and relative expected genetic advances for the trait, at a selection intensity of 5 percent averaged 3.7 g and 25.2 percent respectively, over the 10 combinations, but differed significantly among the combinations. Grain weight was significantly and positively correlated with grain length, but not significantly with grain width.

Nimbalkar and Bapat (1987) crossed three tall and five dwarf varieties in all possible combinations and the F1s and F2s were studied for number of leaves per plant, number of days to 50 percent flowering and plant height. They reported that the last two traits were controlled by additive and nonadditive gene action, where-as leaf number was controlled by nonadditive action. Overdominance was apparent for all the traits, each of which appeared to be controlled by a single group of dominant genes. Narrowsense heritability was moderate in the F1 for height and days to 50 percent flowering; and low for the number of leaves per plant. Kukadia et al (1983b) while studying the estimates of heritability and other related genetic parameters in sorghum reported that number of primaries and grain yield per plant showed high magnitude of expected genetic advance expressed as percentage of the mean accompanied by high heritability values. All the remaining characters showed high heritability with low expected genetic gain indicating that high heritability estimates may not necessarily mean an increased genetic advance in all cases. Prabkakar and Prasad (1984) presented tabulated data on genetic variance for grain yield per plant and six of its components in the F4 of three intervarietal crosses. The phenotypic coefficient of variability was high for grain yield and number of productive tillers, and gene action was mostly additive for these traits. Grain yield showed high heritability and genetic advance in all the crosses. Muhammad R. and A. Rahman (1982) have reported analysis of data on grain yield per plant and five related traits from a diallel cross, involving two exotic and two local lines giving high heritability estimates for plant height, number of days to anthesis and panicle length.

COMBINING ABILITY STUDIES:

When hybrid seed production is the objective of a breeding programme, it is essential for the breeder to determine selection criteria for parental lines and often the breeder chooses to classify the parental lines in terms of their combining ability. Griffing (1956) made a detailed examination of the concept of combining ability in relation to diallel methodology and presented four different diallel crossing systems with alternative methods of analyses for different types of materials. As grain yield is mostly used as a criterion for various estimates of combining ability, recently some research workers have tested the component analysis approach in estimating the combining ability for complex character and the genetic mechanism involved in heterosis. Grafius (1956, 1959, 1960) made favourable comments on the component analysis approach. According to his views, quantitative analysis of yield per se is inadequately indicative of the nature of genetic mechanism involved, remarking further that the study of individual yield components should result in better understanding of the genetic process.

According to the findings of Ramasamy et al (1986), specific combining ability was significant for grain yield, panicle components, plant height, days to flower and leaf number. Grain yield was positively and significantly correlated with weight. The number of leaves was negatively correlated with plant height (r=0.3), indicating that selection for short plants with many leaves was possible.

Studies by Reddy (1963) involving exotic females and Indian males also pointed towards the greater importance of general combining ability for yield and yield components. Kambal and Webster (1965) observed that both general and specific combining abilities were important in determining yield and related characters, but comparatively the GCA effects were more important and more stable over the years.

Deshmukh (1983) from combining ability studies on maintainer lines of sorghum reported that variances due to GCA and

SCA for various characters were significant. Higher magnitude of GCA variances revealed that additive gene action was dominant for plant height, days to 50 percent bloom, panicle length, panicle girth, grain yield and 1000-grain weight. For the characters like number of leaves, days to 50 percent bloom, GCA and SCA variances were equal in magnitude, indicating that additive as well as nonadditive gene action was equally important in expression of these characters. For leaf area and panicle weight, the variances due to SCA were higher, indicating the importance of nonadditive gene action. On the basis of GCA effects, he concluded that high heterotic hybrids involved the parents with high x high and high x low GCA effects to produce promising hybrids. Sprague and Tatum (1942) and Rojas and Sprague (1952) from their study on general and specific combining ability in corn, have reported that the specific combining ability variances were relatively greater than general combining ability variances.

Four rabi and two kharif improved varieties of sorghum and their F1, F2 and F3 progenies were evaluated for yield per plant and five other related characters. Data tabulated on the mean performance of the parents, genetic components of variance and on heterosis and inbreeding depression in the progenies revealed importance of additive effects and additive x additive interactions in most crosses and suggested that grain yield could be improved by selection (Thombre et al 1985). Johnson and Hayes (1940) and Cowan (1943) found that crosses between two low combiners tended to give lower yields than those between two high combining lines.

In a 13 X 13 diallel cross between the two types, highly significant general and specific combining ability effects indicated that genes with both additive and nonadditive effects were influencing yield and yield components. However, for number of days to flowering, additive effects alone played a significant part. While for height, additive effects alone were of greater magnitude than non-additive. For ear head weight and grain weight, non-additive effects were more important than additive (Subba Rao et al 1977). In another study Subba Rao et al (1976) has reported that variance due to general and specific combining ability effects was significant for all characters, the specific combining ability being generally greater. The exotic lines had the overall best general combining ability. Additive gene effects were predominant for days to flowering, whilst nonadditive gene effects were of most importance for plant height, head weight and 1000-grain weight.

From a study on combining ability in various forms of Kefir and Bantu corn conducted by Spivakov (1988), analysis of variance indicated that grain yield was controlled mainly by genes with additive effects. Good combinations of the main yield components were found in most of the hybrids. High general combining ability for grain yield was shown by the Kefir corn varieties. Yield was closely correlated with grain weight per main panicle (r=0.88) and grain number per main panicle (r=0.93), both of which showed high heritability (H2=0.78 and 0.83, respectively) and are recommended as selection criteria in breeding for high yield. Both components were mainly conditioned by additive genes.

Analysis of data on grain yield per plant and nine related traits from a 10X10 diallel cross revealed high genetic diversity, particularly for yield, plant height, peduncle length and number of primaries. Heterosis for yield averaged 29 percent. The best eight hybrids yielded 100-123 grams per plant. GCA and SCA variances were highly significant for all traits. Heritability was low (0.27) for grain yield. The parents CSV8R, M35-1 and SPV232 had significant positive GCA effects for yield and seven of the eight superior hybrids showed highly significant positive SCA effects as reported by Sahib et al (1986).

In a study of gene action in forage sorghum, Dangi and Paroda (1978) recorded ten quantitative characters in five F1 hybrids and their parental F2 and F3 generations planted at two sowing dates. Green and dry-matter yield per plant, number of leaves per plant and leaf length, width and weight were governed mainly by the dominance component of variance as well as by epistatic interactions, whereas additive gene action predominated for days to flowering, height and stem thickness. Epistasis was observed to vary in magnitude between sowing dates. Vasudeva and Goud (1977) in a study on inheritance of grain yield and its components in sorghum, has recorded data on grain yield, 1000-grain weight and number of seeds per panicle from a 5X5 complete diallel analysis involving two dwarf introductions two induced dwarfs and a local tall variety, revealed that overdominance conditioned grain yield. Maximum heterosis for grain yield occurred in IS 2226 (dwarf introduction) X Karad Local (tall), resulting from additive X additive gene interaction. They reported wide genetic differences among the parents for the traits studied. Heterosis appeared to be associated with differences in the geographical origin of the parents. Variances for both general combining ability and specific combining ability indicated that additive and nonadditive gene action conditioned the traits measured, but the nonadditive gene action was the most important.

In a study on heterosis in sorghum, Guzhov and Malyuzhenets (1986) reported highest heterosis effects for grain yield. The hybrids also showed heterosis for grain weight per main panicle and for productive tillering, and also the principal yield components were highly expressed and contrasted in parental forms. Heterosis was lower in the F2, being 46 percent lower than in the F1 for grain yield, 38 percnet for grain weight per main panicle, 16 percent for productive tillering, 10 percent for yield index and 14 percent for plant height.

Path and Thombre (1986) studied inheritance of grain yield components of rabi x rabi and rabi x kharif combinations in sorghum by crossing the rabi variety SPV 151 with three varieties grown in the rabi season (rabi x rabi crosses) and two grown in the kharif season (rabi x kharif crosses). Additive effects, dominance effects and dominance x dominance and additive x additive interactions were important for all components. Additive effects and additive x additive interactions in the majority of crosses suggested the feasibility of improvement of grain yield through 1000-grain weight when selecting for high yield.

F1 hybrids from a 6-parent diallel, without reciprocals, showed heterosis for grain yield 44 percent above the midparental value and 21 percent above the value for the best parent. Both general and specific combining abilities were important for 9 of the 12 yield-related traits as reported by Desai _et_ _al_ (1985).

The F1 and F2 of a 8 x 8 diallel cross, were evaluated by Shinde and Jagadeshwar (1986) for grain yield and yield components in three environments, namely early sowing rainfed, normal sowing rainfed and normal sowing irrigated. Both additive and nonadditive gene effects were estimated to be important for the inheritance of grain yield and yield components but nonadditive effects were predominant for most of the characters. Lines SPV 438 and SPV 86 had good GCAs in all the three environments. Genotype x environment interaction was significant for all the characters. Hybrids SPV 438 X SPV 440 and SPV 86 X SPV 440 displayed moderate stability over the different environments.

Patii and Thombre(1985) from trial results of six varieties, five F1 crosses, five F2 and five F3 generations, has reported that dominance effects were important for panicle length and weight, number of primary and secondary branches, 1000-grain weight and grain yield in kharif x kharif and kharif x rabi varietal crosses. Dominance x dominance interaction was important for grain yield. Whitehead (1962) reported the predominance of additive gene action for flowering date, plant height, head length and head opening in dwarf varieties. On the basis of the preponderance of cases where good parents have good hybrids, and poor parents resulted in poor hybrids, he suggested that general combining ability was more important than specific combining ability. Niehaus and Pickett (1966) have observed that general combining ability effects were larger than specific effects for seeds per head, while specific effects were larger for seed weight.

Liang (1967), from a diallel analysis found that general combining ability was significant for characters like yield, panicle components, plant height, leaf area, days to flower, threshing percentage, germination percentage, number of leaves and protein content, while (Rao 1970) has reported that specific combining ability was significant for grain yield, panicle components, plant height, days to flower and number of leaves per plant. Palmer and Fleming (1972) concluded that the high degree of heterosis for yield in maize was correlated with a high degree of heterosis for total chlorophyll, but hybrids varied in the extent of chlorophyll heterosis. Specific combining ability seemed to be important in the expression of chlorophyll content.

Beil and Atkins (1967) have found that the variance for general combining ability was larger than that for specific combining ability for all characters. Specific combining ability effects were usually more stable than general effects for grain yield and seeds per head over the range of environments in their experiments. Rao et al (1968) tested the general and specific combining ability effects of crosses based on male steriles developed in India. The new male steriles did not exhibit superiority over Kefir-60 with regard to mean yields or their general combining ability. Malm (1968) reported that both general and specific combining effects were important for the grain yield. He attributed hybrid vigour to the genetic diversity of the parents involved in the crosses.

According to Liang et al (1968), there are four groups of genes governing the inheritance of yield. For the time of anthesis, partial dominance was indicated with three genes involved. Both general and specific combining abilities were important for time of anthesis while only specific combining ability was important for grain yield. General combining ability showed significant interaction with location for grain yield.

CORRELATION STUDIES:

Fifty-four genotypes of sorghum (Sorghum bicolor L) Moench; were studied by Dost et al (1992) to determine the inter relationships among various traits relating to grain and forage yield and forage quality, as well as to establish the relative importance and high stover yield, low crude protein content and harvest index. High grain yield was associated with high harvest index and greater seed number and size. High crude protein was associated with high harvest index and short height, whereas more acid-detergent fibre was associated with greater height. Late maturity and more plant height, were associated with high harvest index.

In a study of genetic analysis of some quantitative characters in grain sorghum Kukadia et al (1983a) evaluated five parental lines and their ten single crosses, for yield components. Epistasis was identified for grain yield as regression coefficient deviated from unity. Correlation between parental measurements and the order of dominance were positive but non-significant for days to 50 percent bloom, plant height, days to maturity and ear circumference. The correlations were negative for the other traits.

Ramasamy et al (1986) established correlations between grain yield, plant height, leaf number, ear weight and 1000-grain weight of the parents and F2 of the crosses (2219A X PSV 351, 2219A X Usilampatti 2 and 2760A X Co24). Grain yield was positively and significantly correlated with 1000-grain weight in all cases. In cross 2760A X Co24, the number of leaves was negatively correlated with plant height (r=0.3), indicating that selection for short plants with many leaves was possible in the cross they tried.

Plants of the [male sterile] female parent of the sorghum hybrid CSH 5, ms 2077A, were grown at four soil moisture levels in the presence of CS 3541 plants and scored for grain yield per plant and eight agronomic traits. Data tabulated from the path coefficient analysis of these traits at each moisture level showed a high positive association of earhead weight with grain yield at all moisture levels and several other traits affected grain yield indirectly through earhead weight. The degree of association of the different traits with grain yield varied with moisture level (Krishnasamy 1984).

On the basis of height and maturity, correlations among the characters showed that early flowering and few leaves were negatively correlated with grain yield while height and days to flowering were positively correlated with fodder yield (Rana 1984).

Sanchez (1969) in a study of 306 progenies of four S_1 lines, got a negative correlation between the silking date and yield. Data presented by Eastin (1972) showed that the period from anthesis to maturity in sorghum, which varies among lines from 31 days to 56 days was consistently longer in the higher yielding hybrids, and there was a positive correlation between the lenght of the period and grain yield. Similar results were reported in spring oats by Mckee et al (1979) where they got a correlation value of r=0.69 for yield and grain filling period. Pande et al (1971) found a positive and significant correlation between yield and number of grains per ear, grain yield per plant and 1000-grain weight.

Chase (1967a) obtained a hihgly significant positive correlation between mean number of leaves per plant and mean days from planting to anthesis. A positive correlation between moisture at harvest and the above two traits was also noticed. Similar results were presented by Chase and Nanda (1967b) suggesting the number of leaves per plant as a criterion in the selection for maturity.

Cheralu and Rao (1989), from a study on genetic variability and character association for yield and yield components in sorghum have reported a highly significant positive correlation of yield with ear weight, number of primaries, secondaries and total dry matter. Jaganath et al (1975) have shown that yield in sorghum was more directly correlated with leaf area duration(LAD) and grain-leaf ratio than with leaf area ratio (LAR).

Kirby and Atkins (1968) have concluded from their studies on 24 sorghum hybrids that seeds per head was the character most highly associated with grain yield, while yield components, 1000-grain weight and seeds per plant were not strongly correlated with grain yield. Heritability value, determined by Chiang and Smith (1967) was high for number of tillers (43.2%) indicating that a rapid and effective selection could be made for this trait in sorghum while Patel et al (1983) reported that selection through panicle length and 1000-grain weight would be most effective for further improvement of yield.

MATERIALS AND METHODS

The inheritance study of early maturity and nonsenescence (stay-green character) in four local and three exotic cultivars of sorghum (Sorghum bicolor L) Moench; was carried-out at two locations namely, National Agricultural Research Centre (NARC) Islamabad (located at 33°N and 518m) and Maize & Millet Research Institute (MMRI) Yousafwala, (located at 29°N and 174m), during the period 1990 to 1994. The objectives of the research project were: a) to estimate mean and variance components (additive, dominance and epistasis) for early maturity and nonsenescence traits; b) to estimate narrow sense heritability of earliness and stay-green character; c) to estimate general and specific combining ability of the selected parental lines for earliness and nonsenescence traits; and d) to determine the potential effectiveness of selection for early maturity, stay-green character and their correlations. To achieve these objectives the following two separate studies were conducted at the two locations:

A. A Generation Means Analysis for Early Maturity and Nonsenescence (Stay-green) Traits in Sorghum.

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

In the first study one local pure line Pot 3-9 as a source of early maturity and two exotic ICRISAT pure lines ICSV 107 and ICSV 219 as source of high yield and stay-green character, were used as parental material for crosses. These are described as under:

DESCRIPTION OF PARENTAL LINES:

ICSV 107

ICSV 107 was introduced from ICRISAT as one of the entries of International Sorghum Variety and Hybrid Adaptation Trial (ISVHAT) and tested at NARC and other locations in the country. ICSV 107 emerged as a promising variety not only at NARC but also across locations combining high yield and stability of performance. ICSV 107 was developed at ICRISAT by pedigree selection from a cross SC 108-3 X CS 3541 made in 1975. The line was tested under different designations viz. SPV 351, ICSV 107, ICSV 1 and CSV 11. In 1984, the line was released in India as CSV 11 for cultivation in all sorghum growing areas of India. Its grain yield potential ranges from 2500 to 3000 kg per hectare. Based on the overall outstanding performance in Pakistan at NARC and across locations, this variety is a candidate variety for its general cultivation in the country.

ICSV 219

ICSV 219 is a pure line variety developed by pedigree selection made at ICRISAT. It was introduced from ICRISAT as one of the entries of ISVHAT. On the basis of its performance at NARC as well as at other locations in 1987 and the following season, ICSV 219 was recommended for testing in the National Uniform Sorghum Yield Trials. ICSV 219 when grown under irrigated condition at NARC in an off-season nursery (during spring season), its performance was outstanding and had good seed set despite the extremely high temperature prevailing at flowering in June that causes sterility in some varieties. In 1987, it was grown on farmers fields near Islamabad; they liked it not only because of its high grain yield (3400 kg/ha), but also because the stover remained green after grain maturity, providing good fodder which is important in the area.

Pot. 3-9

Pothwar 3-9 is a local adapted pure line developed from a local land-race of Pothwar tract by head-to-a-row selection. Pedigree selection in self pollinated progenies was done at NARC, using both spring and normal (kharif) seasons. The bulk was evaluated in 1987 in the Preliminary Sorghum Yield Trials at NARC and was observed to be a stable high yielder. Pot. 3-9 ranked first for earliness among the varieties tested in the Coordinated Multilocational Advanced Variety Trials. Overall, Pot. 3-9 mean grain yield performance was recorded 1000 kg/ha compared with 2800 kg/ha for the introduced variety (ICSV 107). By virtue of its tall height, Pot. 3-9 also yielded significant quantity of fodder (upto 8380 kg/ha). Pot. 3-9 is an early maturing variety. It takes about 40 days from planting to 50% flowering and matures in 80 to 85 days. The plants are 230 cm tall, having tan pigmentation, and leaves of medium size with white midribs. The panicle is semi compact and well exerted. The glumes are red coloured and cover more than half the grain and are free threshing. The line is moderately susceptible to foliar diseases and insect pests. Pot.3-9 can be sown to a population of 1,11,000 plants per hectare at a spacing of 75 X 15 cm. Pot. 3-9 has pear-shaped medium size (3.02 gm per 100 grains), light creamy coloured grains. The pericarp is thin and lustrous. This variety is suitable for cultivation as a rainfed crop in the rainy (monsoon) season in the Pothwar area of Pakistan.

The seed of the above mentioned three pure lines was obtained from the Coordinated Research Programme on Sorghum and Millet NARC Islamabad. The two high yielding ICRISAT type sorghum (Sorghum bicolor L.) parents namely ICSV 107 and ICSV 219 were crossed with Pot. 3-9, which is an early locally adapted pure line for a source of early maturity. Crosses were made in kharif 1990. F1 plants of each cross were grown in the field in kharif 1991 to produce F2 seeds. F1 plants were also back-crossed with female and male parents to generate two (BC1) and two (BC2) generations, respectively. Five BC1 and five BC2 plants were selfed to generate BC1(S) and BC2(S), respectively. The following eight generations so obtained, were evaluated in a field trial in kharif 1992 at NARC Islamabad and MMRI Yousafwala.

IDENTITY	GENERATION
Cross 1	
ICSV 107	P1
Pot. 3-9	P2
ICSV 107 X Pothwar 3-9	F1
(ICSV 107 X Pothwar 3-9) Selfed	F2
(ISCV 107 X Pothwar 3-9) X ICSV 107	BC1
(ICSV 107 X Pothwar 3-9) X Pothwar 3-9	BC2
[(ICSV 107 X Pothwar 3-9) X ICSV 107] Selfed	BC1(S)
[(ICSV 107 X Pothwar 3-9) X Pothwar 3-9] Selfed	BC2(S)

Cross 2

ICSV 219	P1
Pothwar 3-9	P2
ICSV 219 X Pothwar 3-9	F1
(ICSV 219 X Pothwar 3-9) Selfed	F2
(ISCV 219 X Pothwar 3-9) X ICSV 219	BC1
(ICSV 219 X Pothwar 3-9) X Pothwar 3-9	BC2
[(ICSV 219 X Pothwar 3-9) X ICSV 219] Selfed	BC1(S)
[(ICSV 219 X Pothwar 3-9) X Pothwar 3-9] Selfed	BC2(S)

In order to facilitate the classification of the parental and segregating populations, these were classified in early, medium and late maturity groups based on the physiological maturity - the colour of aleurone layer ranging from lightbrown to black. For the stay-green character, leaf area of upper six leaves per plant (LAUSL), percent green leaf area 50 days after flowering (%GLA 50DAF) and sugar content (including soluble salts) in the central portion of the stalk, were taken as criteria for the three distinct phenotypes. The moisture contents of the populations were recorded by moisture tester and sugar contents were estimated by refractometer. Harvesting was done 120 days after planting to get uniformity in classification.

The above sixteen entries were planted at the National Agricultural Research Centre, Islamabad and Maize & Millet Research Institute, Yousafwala on July 7 and July 17, 1992, respectively.

A randomized complete block design with four replications was used to conduct the trial at each location. Each plot was of four rows, 5m long for the P1, P2 and F1 generations, four rows 5m long plots for the BC1, BC2, and BC1(S) and BC2(S) and four rows for F2 generations. Standard cultural practices were followed during the growing season. 120 days after planting, all the plants of each entry and replication, were harvested separately. Grains were threshed from each plant separately and dried in the dryer for one week. Seeds from five randomly taken plants per head were bulked and the aleurone layer was checked for 30 seeds per plot and were grouped in three maturity classes based upon the colour of the aleurone layer ranging from lightbrown (MC1-late) to black (MC3-early), for maturity index. Seeds in each class were multiplied by its class number and summed up. Higher values of the maturity index reflect earlier maturity. Data on the following traits were recorded according to the data schedule:-

DESCRIPTION OF PARAMETERS

1.	Days to 50% flowering.	2.	Plant Height(cm).
3.	Head Length(cm)	4.	Number of seeds per head
5.	1000-grain weight.	6.	Yield per plant(gm).
7.	Threshing percentage.	8.	Maturity Index.
9.	Number of Leaves per plant.	10.	LAUSL per plant.
11.	% GLA 50 DAF.	12.	Sugar% in stem.

The data recorded on the above parameters is described as under:

1. Days to 50% flowering

The number of days taken by an entry from planting to when 50% of the plants in the two central rows of the plot have started shedding pollen.

2. Plant height

Average plant height was recorded in centimeters from the base of the plant to the tip of the panicle. This was effectively done by measuring the height of 3 to 5 random plants from the two central rows of the plot and averaging it for the purpose of final value of the entry. The correct time to note this character was at the grain filling stage.

3. Head length

Average head length was recorded in centimeters from the base of the head to the tip of the head. This was done by measuring the length of 5 to 10 random plants from the two central rows of the plot and averaging it for the purpose of final value of the entry. The correct time to note this character was at the grain filling stage.

4. Number of seeds per head

Number of seeds per head was arrived-at by counting the seeds of five heads per plot in the central two rows and dividing by the number of heads.

5. 1000-grain weight

1000-grain weight was taken as average of 10 samples of 1000 grains, each obtained at random from the bulk grain produce of each plant. Weight was measured in grams with electronic balance to the nearest 0.01 gram.

6. Yield per plant

Grain yield per plant was obtained in grams after threshing total heads of the central two rows and the mean calculated per plant.

7. Threshing percentage

Threshing percentage was calculated by dividing the total weight of seeds of five heads by the total weight of the five heads and multiplied by 100 at a uniform moisture content.

8. Maturity Index

120 days after planting all the plants in each entry and replication were harvested separately. Seeds from five randomly taken plants per head were bulked and the aleurone layer was

checked for 30 seeds per plot and were grouped in three maturity classes based upon the aleurone layer colour, ranging from light brown (MC1-late) to (MC3-early) dark brown. For maturity index, heads in each class were multiplied with its class number and summed up. The higher values of the maturity index reflect earlier maturity.

9. **Number of leaves per plant**

Number of green, possible functional leaves per plant were taken on weekly basis and extended up to the stage of panicle initiation, and the mean calculated accordingly.

10. **Leaf area of upper six leaves (LAUSL)**

The area of upper six leaves per plant was taken by calculating the leaf area of each of the six leaves and summed up. The area of each leaf was calculated by the formula following Mc Kee (1965) as under:

Length of leaf X breadth of leaf X 0.73.

11. **Percent green leaf area 50 days after flowering (%GLA 50DAF)**

Green leaf area of individual leaf was recorded in percentage visually and summed up for all the leaves per plant.

12. **Sugar percentage in stem**

Sugar content (including soluble salts) in the central portion of the stalk, was taken for three distinct phenotypes mentioned above, and percent basal stem sugar was determined from 5 plants per plot with the help of refractometer.

STATISTICAL ANALYSIS

To estimate variance components, generation means analysis were performed according to Mather and Jinks (1982). Narrow sense heritability was estimated from variance components in F2 generation and the two backcrosses, F1 and parents following (Allard 1960). The means of maturity, yield per plant, head length, seeds per head, 1000-grain weight, and threshing percentage for each generation in each cross was used to estimate parameters in the genetic model. Locations were considered random. Analysis of variance was performed on the means of each trait and a Waller-Duncan multiple range test was used to determine the significant differences among the means of various generations. The generation means analysis proposed by Mather and Jinks (1982) was followed.

M	=	Mid parent value
A	=	Pooled additive effects
D	=	Pooled dominance effects
AA	=	Pooled additive X additive effects
AD	=	Pooled additive X dominance effects
DD	=	Pooled dominance X dominance effects

The expectations of the generation means according to Mather and Jinks (1982) are:

P1	=	M + A + AA
P2	=	M - A + AA
F1	=	M + D + DD
F2	=	M + 0.5 D + 0.25 DD
BC11	=	M + 0.5 A + 0.50 D + 0.25 AA + 0.25 AD + 0.25 DD
BC12	=	M - 0.5 A + 0.50 D + 0.25 AA - 0.25 AD + 0.25 DD
BC11S	=	M + 0.5 A + 0.25 D + 0.25 AA + 0.125AD + 0.9625 DD
BC12S	=	M - 0.5 A + 0.25 D + 0.25 AA - 0.125AD + 0.0625 DD

A general linear model procedure (SAS, 1985) was used to estimate the genetic effects from the generation means of each cross at each location and combined over locations.

A full model including all genetic effects was fit to the data F-test of the sequential sum of squares for genetic effects was used to reduce the model. In the selected model, genetic parameters having significant effects were included and all the non-significant parameters were ignored. When any high order effect was significant the lower order effect was also included in the model, even if it was nonsignificant.

HERITABILITY ESTIMATE

An estimate of narrowsense heritability (h^2) was computed from the variance components in F_2 generation and for the two backcrosses as described by Allard (1960).

$$2V_{F2} = 2V_A + 2V_D + 2V_E$$

$$V_{BC1} + V_{BC2} = V_A + 2V_D + 2V_E$$

$$V_A = 2V_{F2} - V_{BC1} - V_{BC2}$$

$$h^2 = V_A/V_{F2}$$

Where: V_{F2} = Variance of F_2 generation

V_A = Additive variance

V_D = Dominance variance

V_E = Environmental variance

V_{BC1}, V_{BC2} = Variance of the two back crosses

h^2 = Estimate of narrowsense heritability.

Correlations among traits were computed on the basis of generation means in both the crosses.

B. Combining ability estimates for early maturity and nonsenescence traits in sorghum

In the second study, the genetic material comprised of the following seven pure lines of sorghum and F1 generation of straight crosses:-

1. Pot. 3-9
2. Red Janpur
3. Bagdar
4. DS-75
5. ICSV 107
6. ICSV 112
7. ICSV 219

The pure line Pot. 3-9, Red Janpur, Bagdar and DS-75 are local adapted pure lines. The lines ICSV 107, ICSV 112 and ICSV 219 were received from ICRISAT and have been maintained at NARC since 1984. As far as could be ascertained, these lines were not closely related in their origin and thus provided a good deal of genetic diversity. A brief description of the lines is given as below:-

DESCRIPTION OF PARENTAL LINES

Pot. 3-9

Pothwar 3-9 is a local adapted pure line developed from a local land-race of Pothwar tract by head-to-a-row selection. Pedigree selection in self pollinated progenies was done at NARC, using both spring and normal (kharif) seasons. The bulk was evaluated in 1987 in the Preliminary Sorghum Yield Trials at NARC and was observed to be a stable high yielder. Pot. 3-9 ranked first for earliness among the varieties tested in the Coordinated Multilocational Advanced Variety Trials. Overall Pot. 3-9 mean grain yield performance has been recorded 1000 kg/ha. By virtue of its tall height Pot. 3-9 also yielded significant quantity of fodder (8380 kg/ha). Pot. 3-9 is an early maturing variety. It takes about 40 days from planting to 50% flowering and matures in 80-85 days. The plants are 230 cm tall, having tan pigmentation, non juicy stalks and leaves of medium size with white midribs. The panicle is semi compact and well exerted. The glumes are red coloured and cover more than half the grain and are free threshing. The line is moderately susceptible to foliar diseases and insect pests. Pot.3-9 can be sown to a population of 1,11,000 plants per hectare at a spacing of 75 X 15 cm. Pot. 3-9 has pear-shaped medium size (3.02 gm per 100 grains) light creamy coloured grains. The pericarp is thin and lustrous. This variety is suitable for cultivation as a rainfed crop in the rainy (monsoon) season in the Pothwar area of Pakistan.

Red Janpur

Red Janpur is a dual purpose (grain-cum-fodder) variety of Sindh province which is characterized by the presence of red pigment in the dry leaves, stems and seeds. It is a relatively early maturing variety which takes about 100 days to mature. It is a drought tolerant variety and is grown in rainfed and high temperature areas of Sindh, particularly in districts of Jacobabad, Khairpur and Nawabshah. It has got tall, non juicy stems, red grain colour and is moderately resistant to foliar diseases. Its grain yield potential ranges from 1680 to 2000 kg/ha.

Bagdar

Bagdar is a dual purpose (grain-cum-fodder) variety of Balochistan province which is characterized by bold white grains. It is widely grown in Balochistan and also in Dadu and Larkana districts of Sindh. It is a tall variety (250 to 270cm), with non juicy stalks. It matures in 110 to 115 days and is moderately resistant to foliar diseases. Its grain yield potential ranges from 1800 to 2200 kg/ha.

DS -75 :

It was developed at Agricultural Research Institute, D.I. Khan (NWFP) by pure line selection from a sorghum entry No.954125 which was introduced from Purdue University USA in 1973 and was named in 1975. It is characterized by high grain yield (1800 to 2500 kg/ha), having medium maturity (90-100 days) and dwarf-to-intermediate height (130 to 150cm). It is moderately resistant to foliar diseases. Its grains are chalky white with a brown sub-coat which gives brownish "Chappati" (bread), whereas the local consumer preference is for pearly white grains.

ICSV 107

ICSV 107 was introduced from ICRISAT as one of the entries of ISVHAT and tested at NARC and other locations in the country. ICSV 107 emerged as a promising variety not only at NARC but also across locations combining high yield and stability of performance. Its grain yield potential is 3000-3500 kg/ha. ICSV 107 was developed at ICRISAT by pedigree selection from cross SC 108-3 X CS 3541 made in 1975. The line was tested under different designation viz SPV 351, ICSV 107, ICSV 1 and CSV 11. In 1984, the line was released in India as CSV 11 for cultivation in all areas of India where kharif sorghum is grown. Based on the outstanding performance in Pakistan at NARC and across locations this variety is a candidate variety for its general cultivation in the country.

ICSV 112

ICSV 112 (bred at ICRISAT; also released in Zimbabwe as SV 1) was developed by pedigree selection in the F2-F5 from a multiple cross involving 5 lines and bulking in the F6. It is photoperiod insensitive; and matures in 110-120 days. Its plant height is 1.5-1.8 meter, having an exerted, elliptic, semicompact panicle and medium-sized light-cream grains (100-grain weight = 2.5 gm), with a thin pericarp, which contain 9.6 percent protein (2.6 percent lysine per 100 gm of protein). Its average grain yield potential is 3432 kg/ha and 11.4t fodder/ha. It is suitable for intercropping with legumes during the rainy season.

ICSV 219

ICSV 219 is a pure line variety developed by pedigree selection made at ICRISAT. It was introduced from ICRISAT as one of the entries of ISVHAT. On the basis of its performance at NARC as well as at other locations in 1987 and the following season, ICSV 219 was recommended for testing in the National Uniform Sorghum Yield Trials. ICSV 219 when grown under irrigated condition at NARC in an off-season nursery (during spring season), its performance was outstanding and had good seed set despite the extremely high temperature prevailing at flowering in June which causes sterility in some varieties. In 1987, it was grown on farmers fields near Islamabad; they liked it not only because of its high grain yield (3400 kg/ha), but also because the stover remained green after grain maturity, providing good fodder which is important in the area.

These lines were grown in the field during the year 1990 and were crossed in a 3x4 factorial mating design using the exotic lines as female parents and the local ones as the male parents.

The female parents ICSV 107, ICSV 112 and ICSV 219, are late maturing cultivars with high yield potential introduced from ICRISAT. ICSV 107 is a high yielding cultivar developed and adapted to ICRISAT India. Its maturity is early relative to other ICRISAT cultivars, but substantially later than the male parents used in this study. The male parents were selected for having early maturity identified by the National Cooperative Research Programme, NARC Islamabad. All these lines have low yield potential ranging from 1000-2000 kg/ha. F1 seed of the following 12 hybrids was produced during kharif 1990-91.

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

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

FIELD TRIAL (F1 GENERATION)

The twelve F1 hybrids alongwith their parents were planted at NARC Islamabad on July 6 and at the MMRI, Yousafwala Sahiwal on July 10, 1993. A randomized complete block design with three replications was used at each location. At both the locations normal cultural practices were followed throughout the season. Fertilizer was applied at the rate of 60-30-0 kg/NPK in the form of nitrophos and urea.

Each plot consisted of two rows 5m long 75 cm apart with 25 cm spacing between the hills. Planting was made at the rate of two seeds per hill and when the seedlings reached six leaf stage, these were thinned to a stand of one plant per hill. At both the locations, the crop had a mild attack of shootfly. Furadan 3 G granules were applied at the rate of 16 kg/ha for control of the shootfly.

A random sample of twenty plants, regarded statistically adequate, was harvested from each plot and data were recorded for the following characters.

DESCRIPTION OF PARAMETERS

1. **Days to 50% flowering**

The number of days taken by an entry from planting to when 50% of the plants in the two central rows of the plot have started shedding pollen.

2. Plant height

Average plant height was recorded in centimeters from the base of the plant to the tip of the panicle. This was effectively done by measuring the height of 5 random plants from the two central rows of the plot and averaging it for the purpose of final value of the entry. The correct time to note this character was the grain filling stage.

3. Head length

Average head length was recorded in centimeters from the base of the head to the tip of the head. This was done by measuring the length of five random plants from the two central rows of the plot and averaging it for the purpose of final value of the entry. The correct time to note this character was the grain filling stage.

4. Number of seeds per head

Number of seeds per head was arrived-at by counting the seeds of five heads per plot in the central two rows and dividing by the number of heads.

5. 1000-grain weight

1000-grain weight was taken as average of 10 samples of 1000-grain each obtained at random from the bulk grain produce of each plant. Weight was measured in grams with electronic balance to the nearest 0.01. gram.

6. Yield per plant

Grain yield per plant was obtained in grams after threshing total heads of the central two rows and the mean calculated per plant.

7. Threshing percentage

Threshing percentage was calculated by dividing total weight of seeds of five heads by the total weight of(unshelled) five heads and multiplied by 100 at a uniform moisture content.

8. **Maturity Index**

120 days after planting all the plants in each entry and replication were harvested separately. Seeds from five randomly taken plants per head were bulked and the aleurone layer was checked for 20 seeds per plot and were grouped in three maturity classes based upon the aleurone layer colour, ranging from light-brown (MC1) to black (MC3). For maturity index, heads in each class were multiplied with its class number and summed- up. The higher values of the maturity index reflect earlier maturity.

9. **Number of leaves per plant**

Number of green, possible functional leaves per plant were taken on weekly basis and extended upto panicle initiation, and the mean calculated accordingly.

10. **Leaf area of upper six leaves (LAUSL)**

The area of upper six leaves per plant was taken by calculating the leaf area of each of the six leaves and summed up. The area of each leaf was calculated by the formula following Mc Kee (1965) as under:

Length of leaf X breadth of leaf X 0.73.

11. **Percent green leaf area 50 days after flowering**

Green leaf area of individual leaf was recorded in percentage visually and summed-up for all the leaves per plant.

12. **Sugar percentage in stem**

Sugar content (including soluble salts) in the central portion of the stalk, was taken for the three distinct phenotypes mentioned above, and percent basal stem sugar was determined from five plants per plot with the help of refractometer.

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

FIELD TRIAL (F2 GENERATION)

Seed from all replications of the F1 trial was bulked for each entry. A random sample from bulked seed of all the entries was taken to plant F2 trial. The F2 entries with the parents were planted in July 1994 at the same sites as for the F1 tests. The trial was conducted in randomized complete block design with three replications. The trial was conducted at NARC Islamabad and MMRI Yousafwala. At both the locations normal cultural practices were followed throughout the season. Fertilizer was applied at the rate of 60-30-0 kg/NPK in the form of nitrophos and urea.

Each plot consisted of four rows 5m long 75 cm apart with 25 cm spacing between the hills. Planting was made at the rate of two seeds per hill and when the seedlings reached six leaf stage, these were thinned to a stand of one plant per hill. At NARC the crop had been attacked by shootfly. Furadan 3 G granules were applied at the rate of 16 kg/ha for control of the shootfly. Each trial was harvested 120 days after planting. A sample of 5-10 heads was collected from each plot in each replication. The data was recorded on the parameters as described for F1 generation. Analysis for combining ability was carried out as described for the F1 generation.

RESULTS

A: GENERATION MEANS ANALYSIS

CROSS 1 (ICSV 107 X Pot.3-9)

The parents of this cross differed significantly for all the variables (Table 1). The early parent, Pot. 3-9 had the earliest average maturity (MI 144.00). ICSV 107 was significantly better parent than Pot. 3-9 for yield per plant, head length, number of seeds per head, leaves per plant, LAUSL, %GLA 50DAF and sugar percentage, while Pot. 3-9 was significantly better in 1000-grain weight, threshing percentage, plant height and maturity index. The F1 means were significantly higher than the better parent for yield, head length, seeds per head, and maturity index but not for leaves per plant, LAUSL and %GLA 50DAF. The F1 mean was close to the early parent for 1000-grain weight. The BC1 [(ICSV 107 X Pot. 3-9) ICSV 107)], means of 34.73, 33.83, 2150.50 and 34.342 for yield per plant, head Length, seeds per head and 1000-grain weight exceeded their higher parents significantly while the difference was not significant for number of leaves per plant. The BC2 [(ICSV 107 x Pot.3-9) X Pot.3-9] means for maturity index and seed weight were better than the early parent values (Table 1).

Generation means analysis indicated that additive mean squares were significant for yield per plant, head length, seeds per head, threshing percentage, maturity index, %GLA 50DAF and sugar percentage (Tables 3,4). Dominance mean squares were also significant for yield per plant, 1000-grain weight, maturity index, %GLA 50DAF. Epistasis means squares were significant for head length, 1000-grain weight, maturity index and sugar percentage, which had significant additive x additive epistasis in this cross. Epistasis mean squares were significant for yield per plant, 1000-grain weight and %GLA 50DAF which had significant dominance x dominance epistasis in this cross. Additive x location interaction was significant for maturity index and %GLA 50DAF.

Table 1. Generation means for maturity and nonsenescence traits in two crosses over two locations-1992.

Generation	Yield per plant (g)	Length of head (cm)	Seeds per head	1000-grain Weight (g)	Threshing %	Maturity Index
		CROSS 1 (ICSV 107 X Pot. 3-9)				
P1 (ICSV 107)	28.94cd	30.23c	1759.25c	26.902d	68.23f	117.50f
P2 (Pot.3-9)	15.55e	21.39d	496.87d	31.135abc	81.72a	144.00d
F1	32.60b	32.41b	3253.12a	33.392ab	73.63c	148.00bc
F2	29.05cd	30.36c	1990.37ab	30.392bc	72.58ed	146.00cd
BC1	34.73a	33.83c	2150.50a	34.342a	76.40bc	134.00e
BC2	29.48c	30.83c	1890.12bc	34.087a	69.48ef	151.50a
BC1(S)	32.86b	32.58ab	2056.50ab	29.313cd	77.09d	135.50e
BC2(S)	28.22d	30.02c	1893.25bc	31.686abc	72.77de	150.00ab
		CROSS 2 (ICSV 219 X Pot. 3-9)				
P1 (ICSV 219)	27.78e	30.83abc	1703.25c	27.662c	70.07e	111.50e
P2 (Pot.3-9)	14.83f	19.04d	502.87d	30.582bc	82.98a	142.00b
F1	32.67b	31.06abc	2182.87ab	34.477a	73.19bc	142.50ab
F2	31.08c	28.76c	2097.60ab	33.127ab	72.84bc	141.00b
BC1	35.97a	31.68ab	2210.00a	33.853ab	72.50bc	132.50c
BC2	31.11c	29.48bc	1998.37ab	34.011a	76.01b	146.00a
BC1(S)	33.03b	32.17a	2002.87ab	32.165ab	74.62b	127.50b
BC2(S)	29.53d	31.97a	1947.37b	35.483a	74.58b	144.00ab

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

Table 2. Generation means for maturity and nonsenescence traits in two crosses over two locations-1992.

Generation	Plant Height (cm)	Leaves per Plant	L A U S L (cm^2)	%GLA 50 DAF	Sugar%
		CROSS 1 (ICSV 107 X Pot. 3-9			
P1 (ICSV 107)	174.25f	14.25a	2983.87c	81.02b	12.53a
P2 (Pot.3-9)	239.00cd	9.75d	2350.12d	42.05e	4.02e
F1	242.75bc	13.62ab	3187.00abc	82.25b	8.45b
F2	240.50bc	12.87bc	3121.25abc	72.08c	6.26c
BC1	234.62d	14.00a	3325.50a	86.02a	9.13b
BC2	250.37a	12.25c	3290.62ab	66.75d	6.41c
BC1(S)	229.00e	13.62ab	3304.00ab	81.11b	6.65c
BC2(S)	245.37ab	12.62e	3022.25bc	66.85b	5.26d
		CROSS 2 (ICSV 219 X Pot. 3-9)			
P1 (ICSV 219)	171.37c	13.87a	3051.63cd	84.61a	14.24a
P2 (Pot.3-9)	235.75b	8.75d	2194.12e	37.42e	3.90f
F1	245.87a	12.37bc	3266.87b	84.36a	10.46c
F2	247.12a	12.25bc	3197.12b	68.89c	7.14e
BC1	244.37a	13.75a	3372.50a	87.26a	11.99b
BC2	248.50a	13.37ab	3081.12c	67.11cd	6.30e
BC1(S)	237.75b	12.62abc	3254.00b	80.47b	8.75d
BC2(S)	244.87a	11.50c	2964.00d	64.70d	

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

Table 3. Mean squares for maturity and nonsenescence traits for cross 1 (ICSV 107 X Pot.3-9) over two locations-1992.

Source	df	Yield per plant (g)	Length of head (cm)	Seeds per head	1000-grain Weight (g)	Threshing %	Maturity Index
Location	1	0.74	6.89*	296752.56**	1.35	19.58	110.25**
Rep (Loc)	6	1.34	6.16**	305561.03**	16.38	32.43**	5.83
Generations	7	277.15**	116.26**	2356955.92**	52.11**	151.13**	1034.82**
Additive (A)	1	83.27**	33.20**	521998.41**	31.08*	99.85**	251.61**
Dominance(D)	1	27.93**	2.49	208.30	88.85**	22.09	2.66*
AA	1	5.82	5.91*	353193.88*	30.16*	19.52	92.44**
AD	1	7.02	6.82*	183208.29	9.85	87.61**	11.43*
DD	1	15.13*	0.03	34.98	41.59*	9.14	0.08
Loc X Gen.	7	1.18	4.26*	29328.06	2.29	2.18	1.11
A X Loc.	1	0.41	0.04	3996.00	7.83	3.50	1.61*
D X Loc.	1	0.27	7.75*	147369.24*	3.74	1.38	10.64
AA X Loc.	1	0.70	0.83	151.11	1.01	9.74	27.28*
AD X Loc.	1	2.72	0.77	25821.54	4.36	0.35	1.14
DD X Loc.	1	0.29	7.60*	42995.91	2.39	0.14	0.43
Error	42	3.42	3.45	74334.30	10.28	12.87	9.14
CV(%)		6.39	6.15	15.16	10.21	4.85	2.15

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

Table 4. Mean squares for maturity and nonsenescence traits for cross 1 (ICSV 107 X Pot.3-9) over two locations-1992.

Source	df	Plant Height (cm)	Leaves per Plant	L A U S L (cm^2)	%GLA 50DAF	Sugar%
Location	1	19.14	0.01	106194.51	272.25**	17.74**
Rep.(Loc)	6	26.32	1.50	775.70	11.20	1.82*
Generation	7	4690.62	16.57**	814707.42**	1619.16**	56.32**
Additive (A)	1	1610.76	12.82	290251.72	1114.87*	33.46*
Dominance(D)	1	305.52	0.18	126993.08	157.55**	0.41
AA	1	424.72	2.19	22856.88	17.68	24.80**
AD	1	62.44	0.52	653.62	32.21	0.16
DD	1	194.86	0.05	71779.01	64.52*	0.15
Loc X Gen.	7	13.39	0.43	60776.91	48.78**	3.45**
A X Loc.	1	0.86	0.69	14685.17	85.32*	0.31
D X Loc.	1	2.06	0.35	26992.30	136.54**	10.97**
AA X Loc.	1	57.99	1.02	21452.43	7.37	0.02
AD X Loc.	1	11.61	0.07	33834.86	24.38	0.81
DD X Loc.	1	1.32	0.12	14108.16	58.20	3.14
Error	42	45.44	0.95	75389.36	17.54	1.18
CV(%)		2.90	7.55	13.24	5.80	14.80

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

Dominance x location interaction was significant for head length, seeds per head, %GLA 50 DAF and sugar percentage indicating that genetic estimates for these traits are not consistent over locations.

Non-significant parameters were removed from the full model to have the better estimates of the significant components.In the reduced model, additive effects were highly significantly different from zero for all the characters studied (Tables 5,6). Dominance effects were also significant for yield per plant, head length, 1000-grain weight, LAUSL and %GLA 50DAF. For maturity index additive effect was almost equal to AA. Epistasis was there for all the traits where additive x additive, additive x dominance and dominance x dominance type of epistasis were significant.

CROSS 2 (ICSV 219 X Pot. 3-9)

In this cross the parents differed significantly for all the traits, except 1000-grain weight. Parent Pot. 3-9 was the early parent with highest maturity index of 142.00 (Table 1). ICSV 219 was the better parent for yield per plant, head length and number of seeds per head. The F1 means were close to the better parent (ICSV 219) for yield per plant, head length, seeds per head, threshing percentage, leaves per plant, LAUSL and %GLA 50DAF, while the mean was close to the midparent value for sugar content. The F1 means were close to the parent Pot. 3-9, for 1000-grain weight and maturity index. Backcrossing of the F1 with the earlier parent, Pot. 3-9, increased earliness and with ICSV 219 delayed maturity and increased the mean yield per plant, head length and the number of seeds per head.

Generation means analysis indicated that additive mean-squares were significant for all the traits. Dominance was significant for yield per plant, maturity index, leaves per plant,LAUSL, %GLA 50 DAF and sugar percentage (Tables 7,8). Additive x additive type of epistasis was significant for head length, LAUSL and sugar

Table 5. Estimates of genetic effects on maturity and nonsenesence associated characters, in two crosses-1992.

Parameter	Yield per plant (g)	Length of head (cm)	Seeds per head	1000-grain Weight (g)	Threshing %	Maturity Index
			CROSS 1 (ICSV 107 X Pot. 3-9)			
M	22.97** ±0.45	26.28** ±0.45	2179.59** ±48.28	21.64** ±3.05	73.99** ±0.44	146.87** ±0.56
A	6.11** ±0.38	3.87** ±0.38	603.68** ±0.63	-1.76** ±0.63	-6.34** ±0.86	-13.17** ±0.78
D	27.16** ±2.14	18.24** ±2.15	-	29.79** ±8.67	-	-
AA	-	-	1015.58** ±91.03	7.61* ±3.15	-	-16.17** ±1.06
AD	-	-	-931.64** ±251.94	-	29.74** ±3.77	-8.00* ±3.41
DD	-18.01** ±2.13	12.42** ±2.14	-	-18.21** ±6.19	-	-
R2 (%)	0.89 (0.91)	0.78 (0.79)	0.78 (0.78)	0.36 (0.37)	0.55 (0.58)	0.92 (0.92)

Values in parentheses are R^2 for full model.
* Significant at 5% level.
** Significant at 1% level.

Table 6. Estimates of genetic effects on maturity and nonsenescence associated characters, in two crosses-1992.

Parameter	Plant Height (cm)	Leaves per Plant	L A U S L (cm^2)	%GLA 50DAF	Sugar%
			CROSS 1 (ICSV 107 X Pot. 3-9)		
M	227.67** ±6.397	13.38** ±0.17	1697.80** ±64.63	72.20** ±2.23	3.78** ±0.611
A	-31.64** ±1.595	1.96** ±0.19	264.02** ±55.34	18.58** ±0.96	4.06** ±0.313
D	60.29** ±18.29	- -	1887.55** ±309.49	10.00** ±3.32	4.97** ±0.907
AA	-20.16** ±6.605	-1.33** ±0.32	- -	-9.82** ±2.71	4.56** ±0.741
AD	37.64** ±6.989	- -	- -	- -	-4.26** ±1.372
DD	-45.80** ±13.009	-	-1418.88** ±308.29	- -	- -
R2 (%)	0.78 (0.94	0.66 (0.68)	0.54 (0.56)	0.89	0.80 (0.79)

Values in parentheses are R^2 for full model.
* Significant at 5% level.
** Significant at 1% level.

Table 7. Mean squares for maturity and nonsenescence traits for Cross 2 (ICSV 219 X Pot. 3-9) over two locations-1992

Source	df	Yield per plant (g)	Length of head (cm)	Seeds per head	1000-grain Weight (g)	Threshing %	Maturity Index
Location	1	5.76	1.96	6889.00	15.24	0.54	100.00**
Rep.(Loc)	6	2.76	2.81	209763.15**	4.53	47.79**	10.83
Generation	7	328.64**	151.07**	2502719.52**	50.61**	116.56**	1087.85**
Additive (A)	1	74.43**	55.29**	753776.85**	23.92*	154.64**	361.39*
Dominance(D)	1	70.35**	1.24	131711.85	4.71	0.09	80.25**
AA	1	11.08	35.01*	205815.24	5.09	5.90	1.62
AD	1	0.73	1.03	227937.15*	0.65	5.58*	1.40
DD	1	42.43**	0.11	125207.67	1.93	0.52	26.00
Loc X Gen.	7	2.21	2.22	33197.39	2.13	9.08	0.57
A X Loc.	1	0.28	0.08	19810.33	8.04	24.41*	1.15
D X Loc.	1	3.88	0.00	1550.55	2.84	0.00	14.29
AA X Loc.	1	0.00	1.80	19795.59	2.96	0.35	27.05
AD X Loc.	1	5.25	3.70	39405.54	0.24	0.06	0.29
DD X Loc.	1	1.44	0.00	4887.91	0.39	0.96	2.50
Error	42	4.19	7.49	75934.33	8.74	16.67	10.55
CV(%)		6.93	9.32	15.05	9.05	5.47	3.39

* Significant at 5% level

** Significant at 1% level.

Table 8. Mean squares for maturity and nonsenescence traits for Cross 2 (ICSV 219 X Pot. 3-9) over two locations-1992

Source	df	Plant Height(cm)	Leaves per Plant	L A U S L (cm^2)	%GLA 50DAF	Sugar%
Location	1	19.14	0.56	2388.76	125.72**	1.89
Rep.(Loc)	6	14.39	1.03	14939.70	17.44	1.97
Generation	7	5356.35	21.82**	1091598.67**	2173.70**	92.05**
Additive (A)	1	1619.44**	26.09**	385614.18**	1034.06**	28.21**
Dominance(D)	1	275.47	13.69**	104524.40**	232.30**	3.25*
AA	1	677.44	3.09	73401.19**	4.81	14.14**
AD	1	159.64	3.00	7279.22	29.44*	8.21
DD	1	191.44	3.87*	57103.57*	100.33*	0.23
Loc X Gen.	7	11.92	1.78	3879.12	8.54	2.64
A X Loc.	1	0.01	3.71*	6068.60	6.02	1.10
D X Loc.	1	2.88	0.60	645.64	93.99*	0.32
AA X Loc.	1	20.77	1.30	6564.28	14.42	0.05
AD X Loc.	1	37.79	0.16	67.54	6.18	10.68*
DD X Loc.	1	1.91	0.79	535.18	67.99*	0.00
Error		39.20	1.28	10766.69	23.78	2.42
CV(%)		2.67	9.18	5.07	6.79	17.94

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

percentage. After removing the nonsignificant parameters from the model the R^2 was still high, indicating that the parameters removed, made little contribution for the variation. The results from the reduced model indicated that dominance effects were significant and higher in magnitude than additive effects for yield per plant and the maturity index. Dominance effects were significant for yield, maturity index, leaves per plant, LAUSL, %GLA 50DAF and sugar in this cross. Additive x additive epistatic effects were significant for threshing percentage and leaves per plant (Tables 9,10). The same was true for threshing in the additive x dominance epistatic effect. Epistasis was negatively significant for all other traits.

HERITABILITY AND CORRELATION

CROSS-1 (ICSV 107 X Pot.3-9)

An estimate of narrowsense heritability (h^2) was computed from the components of variance in F2 generation and for the two back crosses as described by Allard (1960). As location effects were highly significant for some of the traits, the heritability estimates were also computed from components of variance after removing the location effects. The narrowsense heritability (h^2) estimates from the components of variance in F2, backcross 1 and backcross 2 ranged from zero to 76 percent (Table 11). The high heritability estimate of 72 percent was obtained for seeds per head, while it was low for yield per plant which was 7 percent. For 1000-grain weight and head length, heritabilities were 33 percent and 31 percent, respectively.

Phenotypic correlations of maturity with 1000-grain weight and threshing percentage was positive (Table 12). Though these phenotypic correlations were high but none was significant.

Table 9. Estimates of genetic effects on maturity and nonsenescence associated characters, in two crosses-1992

Parameter	Yield per plant (g)	Length of head (cm)	Seeds per head	1000-grain Weight (g)	Threshing %	Maturity Index
			Cross 2 (ICSV 219 X Pot. 3-9)			
M	25.89** ±1.99	31.69** ±0.47	2246.05** ±49.10	34.63** ±0.50	73.40** ±0.70	127.03** ±0.81
A	6.27** ±0.50	5.53** ±0.65	566.82** ±66.47	-1.55** ±0.18	5.98** ±0.96	-15.17** ±0.69
D	25.93** ±5.67	-	-	-	-	37.42** ±3.88
AA	-4.14* ±2.05	-6.16** ±0.88	-1107.72** ±90.82	5.23** ±0.95	3.25** ±1.31	-
AD	-4.46* ±2.17	-9.60** ±2.83	-977.37** ±291.28	-	8.76* ±4.21	-
DD	-19.44** ±4.05	-	-	-	-	-12.14** ±3.87
R2 (%)	0.90	0.68 (0.69)	0.79 (0.80)	0.38 (0.39)	0.92	0.44

Values in parentheses are R^2 for full model.
* Significant at 5% level.
** Significant at 1% level.

Table 10. Estimates of genetic effects on maturity and nonsenescence associated characters, in two crosses-1992

Parameter	Plant Height (cm)	Leaves per Plant	L A U S L (cm^2)	%GLA 50DAF	Sugar% aw
			Cross 2 (ICSV 219 X Pot. 3-9)		
M	233.59** ±5.97	8.34** ±1.15	1914.50** ±98.44	63.46** ±1.01	5.06** ±0.74
A	-31.14** ±1.49	2.53** ±0.29	922.08** ±24.54	21.72** ±1.05	4.76** ±0.32
D	64.44** ±17.01	13.50** ±3.27	1118.03** ±280.23	22.21** ±2.10	5.47** ±1.09
AA	-29.20** ±6.17	3.04** ±1.18	-279.19** ±101.63	- -	4.13** ±0.89
AD	62.43** ±6.52	-4.57** ±1.25	314.79** ±107.55	- -	- -
DD	-52.71** ±12.15	-9.51** ±2.33	-773.95** ±200.16	- -	- -
R2 (%)	0.94	0.653	0.928	0.899 (0.911)	0.809 (0.810)

Values in parentheses are R^2 for full model.
* Significant at 5% level.
** Significant at 1% level.

Table 11. Narrow sense heritability estimate for maturity and nonsenescence traits in two crosses on the basis of variance components-1992.

TRAIT	Cross 1 (ICSV 107 X Pot.3-9)		Cross 2 (ICSV 219 X Pot.3-9)	
	Including all effects	Excluding Location effects	Including all effects	Excluding location effects
Yield/plant	7%	11%	4%	17%
Head length	31%	33%	29%	22%
Seeds/head	72%	71%	18%	21%
1000-grain weight	33%	37%	zero	13%
Threshing%	zero	25%	17%	16%
Maturity index	zero	zero	zero	7%
Plant height	21%	19%	zero	9%
Leaves/plant	64%	67%	73%	74%
LAUSL	66%	zero	62%	61%
%GAL 50DAF	12%	zero	65%	59%
Sugar%	39%	31%	57%	53%

CROSS-2 (ICSV 219 X Pot.3-9)

In this cross the narrowsense heritability estimates computed from the variance components were higher than cross 1. The estimates ranged from zero percent to 73 percent. Heritability estimates in this cross were 62 percent for LAUSL, 65 percent for %GLA 50DAF, 57 percent for sugar content, 29 percent for head length, 13 percent for 1000-grain weight and only 7 percent for maturity index. Heritability estimates, after excluding location effects were not so different for yield per plant, seeds per head, 1000-grain weight and threshing percentage but there was much difference in stay-green traits - LAUSL, %GLA 50DAF and sugar percentage, showing genotypic x location interaction for these traits.

Positive and highly significant correlations were obtained between yield per plant, head length, seeds per head, 1000-grain weight, leaves per plant, LAUSL, %GLA 50DAF and sugar percentage (Table 13). Correlation of yield per plant was positive with maturity index but it was not significant.

There were positive and highly significant correlations between maturity index, 1000-grain weight, (r=0.54) and maturity index and threshing percentage (r=0.34).

Table 12. Correlation coeficients among different characters for two Crosses - Cross 1 (ICSV 107 X Pot. 3-9).

Character	Yield per plant (g)	Lenght of head (cm)	Seeds per head	1000-grain Weight (g)	Threshing %	Maturity Index	Plant Height (cm)	Leaves per Plant	LAUSL (cm^2)	%GLA 50DAF	Sugar%
Yield per Plant (g)	1.000	0.910**	0.871**	0.140	-0.359*	-0.149	-0.052	0.724**	0.754	0.904**	0.471**
Lenght of head (cm)		1.000	0.820**	0.106	-0.351*	-0.127	-0.038	0.715**	0.697**	0.820**	0.407**
Seed per head			1.000	0.106	-0.358*	-0.053	0.014	0.582**	0.684**	0.762**	0.429**
1000-Grain weight (g)				1.000	-0.836	0.434**	0.511**	-0.069	0.178	-0.014	-0.222
Threshing%					1.000	0.069**	0.267*	-0.331*	-0.294	-0.349*	-0.411**
Maturity Index						1.000	0.887**	-0.381*	-0.005	-0.381*	-0.714**
Plant Height (cm)							1.000	-0.333**	0.068	-0.306*	-0.699**
Leaves per plant								1.000	0.502**	0.814**	0.573**
L A U S L (cm^2)									1.000	0.609**	0.293**
%GLA 50DAF										1.000	0.634**
Sugar%											1.000

Table 13. Correlation coeficients among different characters for two Crosses - Cross 2 (ICSV 219 X Pot. 3-9).

Character	Yield per plant (g)	Lenght of head (cm)	Seeds per head	1000-grain Weight (g)	Threshing %	Maturity Index	Plant Height (cm)	Leaves per Plant	LAUSL (cm^2)	%GLA 50DAF	Sugar%
Yield per Plant	1.000	0.799**	0.857**	0.322*	-0.487**	0.087	0.193	0.679**	0.936**	0.829**	0.531**
Lenght of head		1.000	0.749**	0.213	-0.539**	-0.220	-0.036	0.556**	0.785**	0.772**	0.521**
Seeds per head			1.000	0.254*	-0.586**	-0.017	0.186	0.564**	0.879**	0.721**	0.398**
1000- Grain weight (g)				1.000	0.015	0.537**	0.572**	0.116	0.183	0.057	-0.176
Threshing%					1.000	0.340**	0.268**	-0.499**	-0.613**	-0.617**	-0.499**
Maturity Index						1.000	0.825**	-0.371*	-0.196	-0.467**	-0.678**
Plant height (cm)							1.000	0.204	0.091	-0.234*	-0.567*
Leaves per plant								1.000	0.670**	0.694**	0.572**
L A U S L (cm^2)									1.000	0.859**	0.562**
%GLA 50DAF										1.000	0.782**
Sugar%											1.000

B. COMBINING ABILITY ESTIMATES

Statistical analysis for all the characters were run both on the data for individual location as well as for the data combined over two locations. The average performance over two locations of the lines and crosses for the various characters alongwith their analysis of variance and combining ability analysis are presented in Tables 14 to 35. The mean values for individual location and their analysis are appended as Tables B1 to B26.

EVALUATION OF PARENTAL LINES

As is apparent from the data presented in Tables 14,15; the pure lines included in the present study exhibited a considerable range of differences for yield, maturity and stay-green associated characters. In all cases, the differences among the lines were found to be highly significant. Line ICSV 107 produced the highest grain yield of 33.37 gm per plant and was 50.66 percent higher than Pot. 3-9 the line at the lowest extremes, yielding only 18.04 gm per plant. The second high yielding line was ICSV 219 followed by ICSV 112, yielding 31.56 gm and 28.92 gm per plant, respectively.

Bagdar with a weight of 37.72 gm per 1000-grain weight, produced the heaviest seeds among the male parents followed by Pot. 3-9, giving a mean weight of 34.51 gm per 1000 grain weight. Among the female parental pure lines ICSV 107 yielded 29.84 gm per 1000 grain weight. Rest of the lines were intermediate and the differences were not significant among them.

A fairly wide range of difference was exhibited by the female and male parents with regard to the number of seeds per head. The line ICSV 107 with a mean of 1221.50 seeds per head was the highest in number of seeds per head, followed by ICSV 219 with an average of 1197.13 seeds per head. Among the male parents DS-75 produced 895.25 seeds per head followed by Bagdar (711.63 seeds per head).

Table 14. Means of the pure lines for yield, yield components and stay-green character over two locations-1990.

Pure Lines	Yield per plant (g)	Length of head (cm)	Seeds per head	1000-grain Weight (g)	Threshing %	Maturity Index
ICSV 107	33.37a	30.84a	1221.50a	29.84b	76.52ab	123.50d
ICSV 112	28.92b	28.08a	1097.13b	25.90b	71.13b	115.25e
ICSV 219	31.56a	28.43a	1197.13a	26.93b	71.90b	117.25e
Pot. 3-9	18.04d	19.76b	633.75d	34.51a	79.47a	154.38a
Red Janpur	20.17c	18.09b	655.00d	29.53b	75.32ab	144.88b
Bagdar	23.78c	16.56b	711.63d	37.72a	70.92b	136.50c
DS-75	23.81c	22.53b	895.25c	25.71b	71.38b	134.13c

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

Table 15. Means of the pure lines for yield, yield components and stay-green character over two locations-1990.

Pure Lines	Plant Height (cm)	Leaves per Plant	L A U S L ((cm^2))	%GLA 50DAF	Sugar%
ICSV 107	173.74c	14.71a	3322.75b	75.73b	12.94b
ICSV 112	162.29c	14.19a	3259.50b	73.92b	12.15b
ICSV 219	178.16c	15.40a	3353.13a	82.14a	14.73a
Pot. 3-9	275.41a	10.86b	2469.25c	37.66e	5.15c
Red Janpur	226.94b	11.16b	2558.50c	42.68d	5.24c
Bagdar	258.91a	13.80a	3003.38b	50.39c	5.04c
DS-75	156.81d	12.95b	3002.13b	47.46c	4.55c

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

ICSV 107 with 30.84 cm head length was better in head length compared with rest of the male and female parents but the difference among the female parents was not significant. Among the male parents, the head length of DS-75 was 22.53 cm. The other male parents did not differ significantly from each other.

A perusal of the data in Table 14 indicates that a narrow range of difference existed for threshing percentage of all the lines studied. Pot. 3-9 with a mean value of 79.47 had the highest threshing percentage and was followed by ICSV 107 with threshing percentage of 76.52.

A considerable range was observed in maturity index of different lines. ICSV 107 among the female parents was earlier with regard to maturity having maturity index of 123.50; while among the male lines Pot. 3-9 a local adapted pure line, was the earliest one with maturity index of 154.38. Red Janpur was the next early maturing line. ICSV 112 and ICSV 219 with respective values of 115.25 and 117.25, did not differ significantly from each other.

In case of plant height the male line Pot. 3-9 produced the tallest plants with an average value of 275.41 cm and was 61.28 percent taller than DS-75, which is at the lowest extreme with a mean of 156.81 cm. The female parental lines ICSV 107, ICSV 219 and ICSV 112 were not significantly different from each other. Pot. 3-9 and Bagdar also did not differ significantly from each other.

As regards number of leaves per plant (Table 15) the ICRISAT type lines were having more number of leaves than the local lines, except Bagdar which was at par with the ICRISAT types sorghum lines.

The same trend was observed in leaf area of upper six leaves (LAUSL). ICSV 219 was having the highest leaf area of 3353.13 cm^2 and that of Pot. 3-9 with lowest leaf-area of 2469.25 cm^2/plant. Percent GLA 50 DAF was highest in case of ICRISAT type line ICSV 219 with a mean value of 82.14 percent. The local lines were lacking this character and none of the lines exceeded 50.39 percent. Highest sugar of 14.73 percent was recorded in ICSV 219 followed by ICSV 107 with sugar percent of 12.94. The sugar percent in the local lines was recorded very low, which ranged from 4.55 to 5.24 percent. The sugar percent of Pot. 3-9 was recorded 5.15. There was no significant difference in sugar content of local lines.

Referring to the analysis of variance of the lines over two locations (Tables 16,17), locations were significantly different for yield per plant, 1000-grain weight, threshing percentage, maturity index, plant height, leaves per plant, LAUSL and %GLA 50DAF. There were highly significant differences in the lines for all the traits studied. The lines x location interaction was also significant for yield per plant, threshing percentage, plant height, LAUSL and %GLA 50DAF.

COMBINING ABILITY STUDIES

F1 GENERATION

Like the parental lines, each of the twelve single crosses among them exhibited considerable range of differences for yield, maturity and stay-green associated characters as is evident from the pooled data presented in (Table 18). Locations were significantly different for yield per plant, seeds per head, 1000-grain weight, threshing percentage, maturity index, plant height, GLA 50DAF and sugar percentage. Highly significant differences were found among crosses for all the traits studied (Tables 18,19). Significant differences were also observed in male versus females,

Table 16. Analysis of variance of pure lines (Parents) over two locations-1990.

Source of variation:	Df	Yield per plant (g)	Length of head (cm)	Seeds per head	1000-grain Weight (g)	Threshing %	Maturity Index
Locations	1	123.76*	111.16	1921.14	69.15*	130.19*	1292.16**
Rep(Loc)	4	25.77	5.97	20187.12	7.67	2.09	5.78
Error	3	4.45	11.88	12294.38	5.37	3.85	17.16**
Lines	6	266.75**	254.92**	521586.27**	172.07**	66.46**	1681.39**
Loc X Lines	6	35.04**	3.47	13418.52	4.39	24.41**	8.45
Error	36	4.82	5.57	8865.19	5.30	5.57	7.08

* Significant at 5% level.

** Significant at 1% level.

Table 17. Analysis of variance of pure lines (Parents) over two locations-1990.

Source of variation:	Df	Plant Height (cm)	Leaves per Plant	L A U S L (cm^2)	%GLA 50DAF	Sugar%
Locations	1	2767.85**	2.84	500283.02*	55.84*	0.39
Rep(Loc)	4	119.75	1.84	16699.30	2.43	0.96
Error	3	53.30	2.38	50533.83	3.71	0.28
Lines	6	18919.69**	24.10**	1030264.23**	2620.78**	161.61**
Loc X Lines	6	1197.50**	1.11	99596.73**	20.31**	3.06
Error	36	42.97	0.89	12606.38	4.82	0.74

* Significant at 5% level.

** Significant at 1% level.

Table 18. Means squares of combining ability analysis of F1 hybrids over two locations-1993.

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

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

Table 19. Means squares of combining ability analysis of F1 hybrids over two locations-1993.

Source	df	Plant Height(cm)	Leaves per Plant	L A U S L (cm^2)	%GLA 50DAF	Sugar%
Locations	1	1259.53**	1.92	78496.22	243.38**	11.17**
Rep(Loc)	4	27.91	1.80	43910.59	4.42	0.51
Entries	18	9192.44**	9.30**	520180.50	940.11**	49.35**
Male vs Female	1	3120.62*	17.23*	194390.41**	352.60**	17.66**
Parent vs cross	1	3722.25	8.50	206870.37	361.58	13.52
Among Males	3	11767.16**	10.22	734462.49	102.55	0.88
Among Females	2	53.68*	0.61	29355.72	156.47	2.12
Among Cross	11	8439.01**	1.84*	232864.74**	135.08**	8.38**
Males	3	983.65**	0.21	374637.18	300.99	8.46
Females	2	25998.31**	4.79	243801.13	248.15	23.24
Male X Female	6	2144.48**	0.90	180139.07**	23.25**	0.92
Loc X Entry	18	255.77**	2.08**	17002aw17**	75.96**	2.75**
Loc X Parent	6	817.21	9.13	212356.66	198.39	5.41
Loc X Cross	11	374.72**	2.87**	214118.71**	109.42**	3.07*
Loc X Male	3	485.47**	0.33	554682.57**	43.12**	2.28*
Loc X Female	2	634.82**	8.21**	173423.01*	379.45**	8.40**
L X M X F	6	232.65**	2.35*	57402.01	52.56	1.69
L X P vs C	1	979.43	13.72	136219.33	149.19	4.77
Error	72	55.91	0.77	51672.39	6.42	0.79

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

for all the traits, while differences were significant for parents versus crosses for yield per plant, head length, seeds per head, and 1000-grain weight. Male and female parents also differed among themselves, but the differences were not significant. Male and female GCA mean squares were non-significant for all the traits except plant height. SCA was significant for head length, seeds per head, 1000-grain weight, threshing percentage, LAUSL, %GLA 50DAF and plant height and was non-significant for yield per plant, maturity index, leaves per plant and sugar percentage. The SCA mean squares were much smaller than GCA for all the traits which indicates that additive genetic variances were more important than nonadditive genetic variances. The genotype x environment interaction was significant for threshing percentage, leaves per plant, LAUSL, %GLA 50DAF, plant height and sugar percentage, which showed significant, interaction between location and GCA for females. Tables 18,19 also indicate that GCA and SCA estimates were consistent over locations for the same traits. Thus it appeared that yield and its components; and the stay-green associated characters were influenced by environmental interaction.

The grain yield per plant in F1(s) ranged from 32.80 gm to 37.56 gm. The maximum yield (37.56 gm) was obtained from the cross ICSV 107 X Pot. 3-9 which was 10.95 percent higher than the better parent and 29.87 percent than the mid-parent. The hybrid ICSV 107 X Pot. 3-9 showed significantly better performance than rest of the hybrids for plant height, yield per plant, seeds per head, head length, threshing percentage and maturity index. The mean value of this hybrid was greater than the better parent for yield per plant and mid-parental value for maturity index, seed weight and threshing percentage. Besides, six hybrids were such that these exceeded their mid-parental values for yield per plant, and seed weight and three hybrids exceeded mid-parents for maturity index (Tables 20,21). The 1000-grain weight for the crosses ranged between 26.606 and 40.498 gm. The heaviest seeds were recorded for

Table 20. Means of F1 hybrids and Parents for maturity and stay-green traits over two locations-1993.

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

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

Table 21. Means of F1 hybrids and Parents for maturity and stay-green traits over two locations-1993.

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

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

he cross ICSV 107 X Bagdar followed by cross ICSV 112 X Bagdar and CSV 219 X Bagdar with mean 1000-grain weight of 40.498, 40.360 and 6.183gm, respectively.

For the number of seeds per head, cross ICSV 107 X Pot. -9 with a mean value of 1858 seeds per head is the best one, which s closely followed by the cross ICSV 112 X DS-75 giving a mean of 819 seeds per head. The next best cross was ICSV 107 X DS-75 which as at par with ICSV 112 X DS-75. The minimum number of 1129 seeds er head were produced by the cross ICSV 219 X Bagdar, which was 9.24 percent lower than the best cross.

The data presented in Table 21 indicate that the various ross combinations exhibited differences of appreciable magnitude or the number of leaves per plant. The cross ICSV 219 X Bagdar ith an average of 14.72 leaves was at the top with regard to the umber of leaves per plant followed by ICSV 107 X Bagdar and ICSV 12 X DS-75 with mean values of 14.55 and 14.42, respectively.

Plant height in different cross combinations varied from 76.60 cm to 273.73 cm. Maximum height of 273.73 cm was exhibited y the cross ICSV 107 X Pot. 3-9 which was 35.16 percent higher han the lowest cross ICSV 219 X DS-75, with a mean plant height of 76.60 cm. The maturity index ranged from 126.67 to 142.17 among he crosses.

The maturity index recorded for the earliest cross (ICSV 07 X Pot. 3-9) was 142.17 and for the late cross (ICSV 112 X agdar) was 126.67. The threshing percentage observed for the arious cross combinations ranged from 66.73 to 79.56 percent. The ross ICSV 107 X Pot. 3-9 with a value of 79.56 percent gave the ighest threshing percentage and was 15.88 percent better than the owest cross combination. Crosses ICSV 219 X Pot. 3-9, ICSV 107 X S-75 and ICSV 112 X DS-75 were the next best crosses with regard o threshing percentage.

Analysis of variance, presented in Table 18 reveals that variation due to locations for maturity index, 1000-grain weight, seeds per head, %GLA 50DAF, sugar percentage, and plant height was significant, but it was not significant for head length, threshing percentage, LAUSL and leaves per plant. While the cross x loc interaction was found to be significant for all the characters studied. The interactions of both general and specific combining ability with locations were highly significant for majority of the characters except for yield per plant and seeds per head.

Relative general and specific combining ability effects and genotypic effects were calculated for all the characters. As is evident from the data in Table 22, the greatest relative general combining ability effects for grain yield were observed for the line Bagdar, the value being 1.46 followed by ICSV 107 and DS-75, with values of +0.67, and +0.20, respectively. The other lines were relatively poor combiners, the effects being -1.80,-0.30 and -0.36, respectively.

Bagdar, Pot. 3-9 with combining ability values of +6.961 and +1.336 were best combining lines among the male parents for 1000-grain weight, while ICSV 107 with the combining ability value of +0.419 was the best combining line among the female parents.

For number of seeds per head the line ICSV 107 had the maximum combining ability effects of +121.08, while DS-75 and Pot.3-9 were the other good combiners for number of seeds per head. Bagdar, ICSV 112 and ICSV 219 exhibited poor combining ability.

In case of maturity, Pot. 3-9, ICSV 107 and Red Janpur with values of +5.87, +2.21 and +2.68, showed high relative general combining ability, while Bagdar, DS-75, ICSV 112 and ICSV 219 showed relatively poor general combining ability.

Table 22. Estimates of general combining ability effects in F1 hybrids over two locations-1993.

Parents	Yield per plant (g)	Length of head (cm)	Seeds per head	1000-grain Weight (g)	Threshing %	Maturity Index
Male						
Pot. 3-9	-0.15	+0.35	+ 95.98	+1.336	+3.43	+5.87
Red Janpur	-1.80	-1.64	+ 2.58	-4.604	+3.39	+2.68
Bagdar	+1.46	+1.29	-204.75	+6.961	-4.83	-4.20
DS-75	+0.20	-0.02	+106.58	-2.791	-2.01	-4.32
Female						
ICSV 107	+0.67	+1.14	+121.08	+0.419	+1.85	+2.21
ICSV 112	-0.30	-0.81	- 26.42	+0.148	-0.61	-2.00
ICSV 219	-0.36	-0.35	- 94.67	-0.566	-1.24	-0.20

Table 23. Estimates of general combining ability effects in F1 hybrids over two locations-1993.

Parents	Plant Height (cm)	Leaves per Plant	L A U S L (cm^2)	%GLA 50DAF	Sugar%
<u>Male</u>					
Pot. 3-9	+42.69	-0.74	+307.67	+5.49	+1.31
Red Janpur	+ 5.42	-3.47	-277.33	-2.46	-0.90
Bagdar	+ 1.66	+0.34	- 5.37	-0.95	+0.58
DS-75	-49.79	+0.35	- 24.63	-2.09	-1.00
<u>Female</u>					
ICSV 107	+ 7.57	+0.05	-137.63	-2.41	-0.65
ICSV 112	- 5.29	-0.11	-196.93	-1.66	-0.15
ICSV 219	- 2.29	+0.05	+334.57	+4.07	+0.50

For threshing percentage, highest general combining ability was observed for the line Pot. 3-9 with a value +3.43 followed by Red Janpur having relative combining ability of +3.39. ICSV 107 was also a good combiner, while ICSV 112, ICSV 219, DS-75 and Bagdar exhibited low combining ability.

The relative general combining ability effects for the characters associated with nonsenescence indicated that ICSV 219 was the best combiner for LAUSL, %GLA 5DAF and Sugar percentage having valves of +334.57, +4.07 and +0.50, respectively. Pot. 3-9 was the next good combiner (Table 23). Pot. 3-9 was the best combining line for plant height, giving a general combining ability value of +42.69 followed by ICSV 107, Red Janpur, and Bagdar with values of +7.57, +5.42, and +1.66, respectively. The low combining ability for plant height was observed for the lines DS-75, ICSV 112 and ICSV 219, having value of -49.79,-5.29 and -2.29, respectively.

An inverse relationship seems to exist between the combining ability for yield and that of threshing percentage for the male parents. Similar general trend is also apparent from the combining ability effects calculated on individual location's data presented in appendix Tables B11 and B12.

The specific combining ability effects for yield and other agronomic traits are presented in Tables 24 and 25. Highest valves for specific effect for grain yield was obtained in the cross combination ICSV 107 X Pot. 3-9 with a value of +1.33. The lines involved in this cross had relatively high general combining ability for yield and yield components. Cross combinations ICSV 112 X Red Janpur, ICSV 112 X Bagdar, ICSV 219 X Bagdar and ICSV 219 X DS-75 with values of +0.60, +0.42, +0.01 and +1.00, also exhibited combining ability effects of considerable magnitude, while the other crosses showed negative specific effects for yield.

Table 24. Estimates of specific combining ability effects for yield, maturity and stay-green traits in F1 hybrids over two locations-1993.

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

Table 25. Estimates of specific combining ability effects for yield, maturity and stay-green traits in F1 hybrids over two locations-1993.

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

The highest specific combining ability effects for 1000-grain weight was exhibited by the cross ICSV 219 X DS-75, the value being +1.769 followed by the cross ICSV 219 X Pot.3-9 with specific combining ability value of +1.670. Cross ICSV 219 X Bagdar exhibited the lowest negative effects of -2.265. For the number of seeds per head, cross combinations ICSV 219 X Red Janpur, ICSV 112 X Bagdar, ICSV 107 X Bagdar, ICSV 219 X Pot.3-9, ICSV 112 X DS-75 and ICSV 107 x DS-75 gave positive high specific effects.

Referring to the general combining ability of the parental lines involved in the above crosses, it is evident that parental lines although had low general combining ability values for seeds per head, resulted in highest specific effects in hybrid combinations. The other cross combinations had either low or high negative values.

For maturity index, the highest value of +1.55 for specific effects was obtained in the cross ICSV 107 X Pot. 3-9. A perusal of data in Table-20, reveals that both the parents in this cross, (ICSV 107 and Pot.3-9) had a high general combining ability value for the maturity index. It was followed by crosses ICSV 107 X Bagdar, ICSV 107 X Red Janpur and ICSV 112 X DS-75. The expression of maturity duration in these crosses were largely due to specific effects. Highest negative specific combining ability effect of -1.76 was obtained by the cross ICSV 107 X DS-75.

The highest specific combining ability value (+5.06) of threshing percentage was for the cross ICSV 112 X DS-75. It was followed by the cross ICSV 219 X Red Janpur and ICSV 219 X Pot.3-9.

As regards plant height (Table 25), the highest value of +22.08 for specific effects was obtained in the hybrid ICSV 107 X Bagdar followed by ICSV 219 X Red Janpur with a value of +18.20.

A reference to Table 25 shows that the parents in the above crosses, viz Pot. 3-9, ICSV 107, Bagdar and Red Janpur had a relatively high general combining ability value for height, while the others were poor in general combining ability for this character. Six cross combinations showed negative values.

As far as the stay-green associated parameters are concerned (Table 25), the cross ICSV 112 X Red Janpur, ICSV 219 X Red Janpur, ICSV 112 X DS-75, and ICSV 107 X Red Janpur exhibited significant positive specific effects for the number of leaves. While the specific effects were positively significant for the crosses ICSV 219 X Pot. 3-9, ICSV 112 X DS-75, ICSV 107 X Red Janpur, ICSV 112 X Red Janpur and ICSV 112 X Bagdar, the values being +632.73, +257.03, +160.13, +140.93 and +116.13.

The specific combining ability effects for % GLA 50DAF were +2.70, +2.22, +1.20 and +1.11 for the cross combinations ICSV 107 X DS-75, ICSV 107 X Bagdar, ICSV 112 X Red Janpur and ICSV 112 X Pot. 3-9, respectively. For sugar percentage, the cross combinations, ICSV 112 X Pot.3-9, ICSV 219 X Pot.3-9 and ICSV 107 X Red Janpur exhibited significantly positive specific effects with values of +2.83, 2.43 and +0.47, respectively.

F2 GENERATION

Locations were significant for all traits except head length, 1000-grain weight, threshing percentage, plant height, leaves per plant and LAUSL (Tables 26,27). The differences among female parents were significant for all the traits except yield per plant and head length. The differences among the male parents were significant for yield per plant, maturity index and %GLA 50DAF and non-significant for rest of the traits studied, whereas the differences were significant for all the traits in the crosses except for yield and seeds per head.

Table 26. Means squares of combining ability analysis of F2 hybrids over two locations-1994.

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

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

Table 27. Means squares of combining ability analysis of F2 hybrids over two locations-1994.

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

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

Table 28. Means of F2 hybrids and Parents for maturity and stay-green traits over two locations-1994.

Parents.	Yield per plant (g)	Length of head (cm)	Seeds per head	1000-grain Weight (g)	Threshing %	Maturity Index
ICSV 107 X Pot.3-9	33.92ab	30.38ab	1525a	28.736defg	76.79abc	141.50b
ICSV 107 X R/Janpur	32.80ab	26.98abcd	1537a	24.046gh	74.52bcde	129.83efg
ICSV 107 X Badgar	36.10a	29.33ab	1401abcd	36.720ab	72.18def	129.50efg
ICSV 107 X DS-75	32.75ab	26.86abcd	1311abcd	28.675defg	72.55def	130.67def
ICSV 112 X Pot.3-9	33.55ab	27.27abcd	1294abcd	31.572cde	73.82cde	136.33c
ICSV 112 X R/Janpur	32.18b	24.48d	1374abcd	29.074def	74.23bcde	134.33cd
ICSV 112 X Bagdar	33.08ab	28.72abc	1244abcd	37.325a	74.48bcde	127.17fg
ICSV 112 X DS-75	32.63ab	26.42bcd	1463abc	29.117def	78.15ab	130.33efg
ICSV 219 X Pot.3-9	35.13ab	25.08cd	1377abcd	32.414bcd	78.28ab	135.50c
ICSV 219 X R/Janpur	3aw75ab	24.37d	1372abcd	26.479fgh	80.16a	131.17de
ICSV 219 X Bagdar	33.32ab	26.52bcd	1142cd	34.155abc	60.87f	126.67g
ICSV 219 X DS-75	33.50ab	26.92abcd	1495ab	28.366defg	70.92ef	131.33de
ICSV 107	31.92b	30.72a	1091cd	25.342fgh	74.30bcde	118.17h
ICSV 112	31.90b	29.73ab	1203abcd	24.956fgh	72.18def	108.33j
ICSV 219	35.35ab	29.37ab	1161bcd	27.390efgh	71.74def	112.17i
Pot. 3-9	19.55c	20.88ef	698f	34.047abc	77.62abc	145.67a
Red Janpur	21.08c	18.82f	638f	24.544fgh	75.14bcd	136.83c
Bagdar	19.83c	19.32f	717f	36.488ab	72.24def	129.00efg
DS-75	20.98c	23.55de	826ef	23.276h	71.92def	128.33efg

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

Table 29. Means of F2 hybrids and Parents for maturity and stay-green traits over two locations-1994.

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

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

GCA mean squares for females were highly significant for all the traits except yield per plant and seeds per head. Male GCA mean squares were non-significant for all the traits except head length. GCA for the maturity index was significant at 0.7 percent level. GCA mean squares for females were greater than for males for all traits except head length. SCA mean squares were significant for 1000-grain weight, threshing percentage, maturity index, plant height, LAUSL and sugar percentage. Estimates of GCA were larger in magnitude than SCA.

Interaction of crosses x location was found significant for maturity and %GLA 50DAF. Estimates of GCA effects indicated that the male parent Pot.3-9 which has the highest GCA effects in F1 for yield per plant, number of seeds per head, 1000-grain weight, and maturity index, remained the best general combiner in F2 generation for 1000-grain weight,seeds per head and maturity index (Tables 30,31).

The male parent Bagdar has shown the highest and significant GCA effects for yield per plant, head length, 1000-grain weight, leaves per plant, plant height, LAUSL, %GLA 50DAF and sugar percentage. Similarly female parent ICSV 107 has shown the highest and significant GCA effects for all the characters studied. Negative GCA estimates of Red Janpur, DS-75 and ICSV 112 for majority of the characters indicated that these are the poor parents for combining the desired traits.

Among female parents the highest estimates of GCA effects were shown by ICSV 107 for yield per plant, head length, seeds per head, threshing percentage and maturity index. It was observed that for maturity index, GCA effects were not consistent over the generation. Female parents ICSV 107 and ICSV 112 showed positive GCA effects for maturity index. ICSV 112 as a female parent had the lowest GCA effects for all the traits except 1000-grain weight and maturity index which was positive but non-significant.

Table 30. Estimates of general combining ability effects in F2 generation over two locations-1994.

Parents.	Yield per plant (g)	Length of head (cm)	Seeds per head	1000-grain Weight (g)	Threshing %	Maturity Index
Male						
Pot. 3-9	+0.72	+0.64	+ 20.64	+2.101	+2.19	+5.75
Red Janpur	-0.90	-1.66	+ 49.98	-4.607	+0.89	-0.25
Bagdar	+0.69	+1.24	-115.52	+4.926	-3.57	-4.25
DS-75	-0.52	-0.21	+ 44.91	-2.421	+0.46	-1.25
Female						
ICSV 107	+0.41	+1.45	+ 65.71	+0.155	+1.08	+0.85
ICSV 112	-0.62	-0.22	- 34.01	+0.633	-0.24	+0.01
ICSV 219	+0.20	-1.22	- 31.69	-0.787	-0.85	-0.86

Table 31. Estimates of general combining ability effects in F2 generation over two locations-1994.

Parents	Plant Height (cm)	Leaves per Plant	L A U S L (cm^2)	%GLA 50DAF	Sugar%
Male					
Pot. 3-9	+12.62	-0.25	- 67.68	+1.96	+0.74
Red Janpur	- 0.23	-0.83	-211.07	-1.50	-0.66
Bagdar	+24.68	+0.84	+126.37	+2.20	+0.72
DS-75	-37.06	-0.27	+152.37	-2.66	-0.82
Female					
ICSV 107	+ 2.36	+0.03	+ 23.89	-0.41	-0.20
ICSV 112	- 5.53	-0.12	- 42.69	-3.44	-0.14
ICSV 219	+ 3.18	+0.09	+ 18.81	+3.03	+0.32

Table 32. Estimates of specific combining ability effects for yield, maturity and stay-green traits in F2 hybrids over two locations-1994.

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

Table 33. Estimates of specific combining ability effects for yield, maturity and stay-green traits in F2 hybrids over two locations-1994.

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

CORRELATION STUDIES

There was a positive and significant correlation of early maturity with seeds per head (r=0.35), 1000-grain weight (r=0.12) and threshing percentage (r=0.33) in F1 generation. The correlation of early maturity with yield per plant was negative with yield per plant (r=0.23), 1000-grain weight (r=0.18) and threshing percentage (r=0.30) in F2 generation (Tables 34,35) but the correlation coefficients were small in magnitude. Early maturity was also negatively correlated with yield per plant, head length, leaves per plant, LAUSL, and sugar percentage.

Table 34. **Correlation coefficients for different characters in F1 generation-1993.**

Character	Yield per plant (g)	Length of head (cm)	Seeds per head	1000-grain Weight (g)	Threshing %	Maturity Index	Plant Height (cm)	Leaves per Plant	LAUSL (cm^2)	%GLA 50DAF	Sugar%
Yield per Plant (g)	1.000	0.812*	0.742**	0.210*	0.053	-0.336**	-0.032	0.630**	0.576**	0.813**	0.562**
Length of head (cm)		1.000	0.643**	0.111	0.023	-0.332**	-0.143	0.537**	0.445**	0.799**	0.572**
Seeds per head			1.000	0.139	0.255	0.354	0.102	0.497**	0.534**	0.655**	0.181*
1000- Grain weight (g)				1.000	0.003	0.124	0.411**	0.131	0.270**	0.057	0.020
Threshing%					1.000	0.333	0.322	0.013	0.020	0.032	-0.082
Maturity Index						1.000	0.551**	-0.295*	-0.239**	0.249**	-0.616**
Plant hight (cm)							1.000	-0.065	-0.040	0.C31	-0.166
Leaves per plant								1.000	0.557*	0.622**	0.410**
L A U S L (cm^2)									1.000	0.542*	0.339**
%GLA 50DAF										1.000	0.642**
Sugar%											1.000

Table 35. **Correlation coefficients for different characters in F2 generation-1994.**

Character	Yield per plant (g)	Length of head (cm)	Seeds per head	1000-grain Weight (g)	Threshing %	Maturity Index	Plant Height (cm)	Leaves per Plant	LAUSL (cm^2)	%GLA 50DAF	Sugar%
Yield per plant(g)	1.000	0.6146**	0.6356**	0.0404*	0.0277	0.2264	0.0075	0.3398**	0.5292**	0.8199**	0.4428**
Length of head(cm)		1.000	0.4030*	0.0413	-0.1263	-0.4187**	0.6145**	0.4331**	0.4562**	0.6374**	0.5751**
Seeds per head			1.000	0.0143	0.1185	-0.03318	-0.0743	0.1011	0.4146**	0.5803**	0.1203
1000- Grain weight (g)				1.000	-0.1073	0.18493*	0.4293**	0.0926	0.1376	0.1419	-0.1096
Threshing%					1.000	0.30337**	0.1132	-0.3106**	-0.2136	-0.1470	-0.1272
Maturity Index						1.000	0.4671**	-0.4933**	-0.3615**	-0.4018**	-0.6973**
Plant Height (cm)							1.000	-0.1284	-0.1652	-0.0156	-0.2897**
Leaves per plant								1.000	0.4567**	0.4961**	0.4230**
L A U S L (cm^2)									1.000	0.6242**	0.2124*
%GLA 50DAF										1.000	0.5428**
Sugar%											1.000

DISCUSSION

A. GENERATION MEANS ANALYSIS

Cross 1 (ICSV 107 X Pot.3-9)

Generation means analysis for early maturity and nonsenescence associated traits in Sorghum (Sorghum bicolor L) Moench., were computed for sixteen entries consisting of two sets, each of eight populations. The analysis showed that additive mean squares were significant for yield per plant, head length, seeds per head, threshing percentage, maturity index, %GLA 50DAF and sugar percentage (Tables 3,4). Dominance mean squares were also significant for yield per plant, 1000-grain weight, maturity index, %GLA 50DAF. Epistasis means squares were significant for head length, 1000-grain weight, maturity index and sugar percentage, which had significant additive x additive epistasis in this cross. Epistasis mean squares were also significant for yield per plant, 1000-grain weight and %GLA 50DAF which had significant dominance x dominance epistasis in this cross. Additive x location interaction was significant for maturity index and %GLA 50DAF.

The dominance x location interaction was significant for head length, seeds per head, %GLA 50 DAF and sugar percentage, indicating that genetic estimates for these traits are not consistent over locations. These results suggest that evaluation for these characters should be practised in different environments. Thombre et al (1985) have also reported importance of additive effects and additive x additive interactions in most crosses and suggested that grain yield could be improved by selection. The results are also in agreement with Path and Thombre (1986) who have reported that additive effects, dominance effects and dominance x dominance and additive x additive interactions were important for all components. Additive effects and additive x additive interactions in the majority of crosses suggested the feasibility

of additive effects and additive x additive interaction in most of the crosses they tried, and suggested that grain yield could be improved by selection.

Accordingly the results reported herein suggest that selection for significant head length and seeds per head could be practised in early generations, but the presence of significant dominance effects suggest that selection for high yield and early maturity should be practised in later generations. Significant additive x location interaction suggested that for early maturity this population should be evaluated in different environments.

CROSS 2 (ICSV 219 X POT.3-9)

Generation means analysis in this cross indicated that additive mean squares were significant for all the traits. Dominance was significant for yield per plant, maturity index, leaves per plant, LAUSL, %GLA 50DAF and sugar percentage (Tables 7,8). Additive x additive type of epistasis was significant for head length, LAUSL and sugar percentage. These results showed that additive effects were important for the desirable traits. Thombre and Patel (1985) have also reported similar results while Patil and Thombre (1985) have reported dominance x dominance interaction for grain yield. The estimates of additive effects were consistent over locations for all traits. For yield per plant, head length, 1000-grain weight, seeds per head and maturity index none of the parameters showed interaction with location.

After removing the nonsignificant parameters from the model the R^2 was still high, indicating that the parameters removed, made little contribution for the variation. The results from the reduced model indicated that dominance effects were significant and higher in magnitude than additive effects for yield per plant and maturity index. Dominance effects were significant for yield, maturity index, leaves per plant, LAUSL, %GLA 50DAF and sugar percentage in this cross. Additive x additive epistatic effects were significant for threshing percentage and leaves per plant (Tables 9,10). The same was true for threshing in the additive x dominance epistatic effect. Epistasis was negatively significant for all other traits. Signs of estimates for additive effects were a function of which parent was assigned as P_1 or P_2. The negative sign of additive effects for the maturity index, indicated that P_2 (Pot.3-9) is the source of early maturity in this cross, as was expected. The positive sign for yield per plant, head length, seeds per head, leaves per plant, LAUSL and %GLA 50DAF indicated that ICSV 219 is contributing gene for higher yield and stay-green associated characters.

The negative sign of the additive effects for maturity indicated that additive is in the direction of early maturity, while positive sign for yield per plant indicates that additive effect is in the direction of high yield. The dominance x dominance effect is also in the direction of early maturity.

These results also indicated that additive effects were important for yield per plant, head length, 1000-grain weight and maturity index. Dominance x dominance effects were important only for maturity index but the magnitude of dominance effects was lower than additive effects. For head length, additive x additive epistasis was important indicating that transgressive segregant for head length could be selected from this population.

These results indicated that selection for high yield, early maturity and stay-green traits is possible in this cross. It is suggested that selection for yield, head length and 1000-grain weight should be practised in F2 generation. For the maturity index nonadditive effects were also important suggesting selection for early maturity in later generations.

In summary, results from the generation means analysis indicate that additive effects are important for yield per plant, head length, seeds per head, maturity index and 1000-grain weight in both the crosses. Dominance effects were important for yield in cross 1 (ICSV 107 X Pot.3-9) and for maturity index in both the crosses. Dominance was in the direction of high yield. Epistatic effects were also important for threshing percentage in cross 1 and head length in cross 2. For all other traits epistatic effects were negligible, whereas Liang and Walter (1968) have reported that additive gene effects made a minor contribution to the inheritance for grain yield, head weight and kernel weight. The additive x additive interaction effects, however, formed a major component. The dominance x dominance effects were also of high magnitude. In cross ICSV 219 X Pot. 3-9 only additive x additive epistasis was significant for head length. These results are in partial agreement with Subba Rao et al (1977) who reported that genes with both additive and nonadditive effects were influencing yield and yield componants. However, for number of days to flowering, additive effects alone played a significant part. While for height, additive effects alone were of greater magnitude than nonadditive. For ear head weight and grain weight, nonadditive effects were more important than additive. He has further reported that additive gene effects were predominant for days to flowering, while nonadditive gene effects were of most importance for plant height , head weight and 1000-grain weight. Patel et al (1988) have suggested that days to 50% flowering and 100-grain weight, were influenced by partially dominant gene effects and could be improved by breeding. Duncan (1980) has also reported that tiller production of a ratoon sorghum crop used as a measure of nonsenescence was quantitatively inherited with additive genetic effects with no indication of significant dominance genetic effects, suggesting that large estimates for additive genetic variation could be made in selecting for tillers in a ratoon sorghum crop. Thombre et al (1985) have also reported importance of additive effects and additive x additive interations in most corsses and suggested that grain yield could be improved by selection.

In conclusion, additive effects were more important for all the desired traits associated with yield and maturity in cross 1 and all the desired traits associated with nonsenescence in cross 2. Dominance effects were also important for some of the desired traits. Epistasis was negligible for all the desired traits such as yield, early maturity and nonsenescence associated traits in both the crosses. The presence of significant and large additive effects indicate that improvement for yield and early maturity is possible in cross 1 and improvement for the stay-green character is possible in cross 2. Selection for 1000-grain weight, threshing percentage, maturity, plant height, LAUSL and sugar percentage could be accomplished in F2 generation in both the crosses. These results also indicated that evaluation for early maturity and %GLA 50DAF should be carried out in different environment because of the significant additive x location effects.

HERITABILITY AND CORRELATION

Cross 1 (ICSV 107 X Pot.3-9)

Narrowsense heritability estimates were negative for threshing percentage and the maturity index which was because of negative estimates of additive variances. Heritability for these traits were zero. Yang (1989) has also reported that gene with negative dominance effects caused early maturity. As location effects were highly significant for head length, seeds per head and maturity index, narrowsense heritability estimates were also computed after excluding location effects. The estimates were similar for yield per plant, head length, seeds per head and maturity index, indicating that locations did not affect the variance estimates for these traits. For 1000-grain weight, and threshing percentage the estimates were higher indicating the effect of location interaction with the genotypes of its segregating generations. These results suggest that selection for seeds per head, and 1000-grain weight may be carried out in early generations, however selection for yield would be effective in later generations. These results further indicate that genotype effects were more important than environmental effects for all the characters. These findings are in agreement with that of Patel et al (1988), in whose opinion that genotype effects were more important than the environmental effects.

Phenotypic correlations of maturity with 1000-grain weight and threshing percentage were positive (Table 12). Though these phenotypic correlations were significant, but none was high. Significant correlation between maturity index and 1000-grain weight indicated that selection for early maturing and heavy seeded recombinant, are possible from these progenies. Yield per plant showed high positive correlations with head length, seeds per head, 1000-grain weight, leaves per plant, LAUSL, %GLA 50DAF and sugar percentage. Correlations of leaves per plant were positive and highly significant for LAUSL, %GLA 50DAF and sugar percentage. These results suggested that phenotypic selection for more number of leaves per plant, LAUSL, %GLA 50DAF and sugar percentage could result in nonsenescence character and that selection based upon any of these traits could indirectly increase yield.

Yield per plant has shown negative correlation with maturity index. Maturity index was significantly positively correlated with 1000-grain weight, and threshing percentage, but it was negatively correlated with seeds per head, leaves per plant, LAUSL, %GLA, and sugar percentage.

CROSS 2 (ICSV 219 X POT.3-9)

In this cross the narrowsense heritability estimates computed from the variance components were higher than cross 1. The estimates ranged from zero to 73 percent. Heritability estimates in this cross were 62 percent for LAUSL, 65 percent for %GLA 50DAF, 57 percent for sugar percentage, 29 percent for head length, 13 percent for 1000-grain weight and only 7 percent for maturity index. The high heritability estimates indicated that early generation selection for more LAUSL, %GLA 50DAF and sugar percentage, with more 1000-grain weight, would be effective in this cross. For maturity index, heritability was considered zero due to a negative estimate of additive variance for this trait in this cross. Heritability estimates, after excluding location effects were not so different for yield per plant, seeds per head, 1000-grain weight and threshing percentage but there was much difference in stay-green traits - LAUSL, %GLA 50DAF and sugar percentage, showing genotypic x location interaction for these traits. These results indicate that selection for desirable traits associated with stay-green character, is possible in this cross. Naphade and Ailawar (1976-77), they have also suggested improvement in yield by selecion for panicle weight and more number of leaves per plant, while Patel et al (1983) have suggested improvement in yield by selection through panicle length and 1000-grain weight. Path and Thombre (1986) are also of the same opinion.

Positive and highly significant correlations were obtained between yield per plant, head length, seeds per head, 1000-grain weight, leaves per plant, LAUSL, %GLA 50DAF and sugar percentage (Table 13). Correlation of yield per plant was negative with maturity index but it was not significant. These results support the findings of Sanchez (1969) who also observed a negative correlation between the silking date and yield; while Eastin (1972a) has reported a positive correlation between length of growth period and grain yield. However the results presented herein suggested that phenotypic selection for longer head, heavier and more number of seeds per head and more number of leaves could result in higher yields.

There were positive and highly significant correlations between maturity index, 1000-grain weight, (r=0.54) and maturity index and threshing percentage (r=0.34). Significant negative correlations of maturity index with leaves per plant, %GLA 50DAF, and sugar percentage indicate that selection of early maturing lines could reduce the number of seeds per head, leaves per plant, %GLA 50DAF and sugar percentage. The maturity index also showed a negative but non-significant correlation with seeds per head, which indicates that early maturing and high yielding recombinants can probably be selected in the segregating population of this cross. Rana (1984) has also reported that early flowering and few leaves were negatively correlated with grain yield while height and days to flowering were positively correlated with fodder yield.

Positive and highly significant correlations were observed between head length, seeds per head, leaves per plant, LAUSL, %GLA 50DAF and sugar percentage. These results suggested that phenotypic selection for longer head and heavier seeds could result in higher grain yield. Similar results have been reported by Ramasamy et al (1986) who reported that grain yield was positively and significantly correlated with 1000-grain weight and the number of leaves was negatively correlated with plant height (r=0.3), indicating that selection for short plants with many leaves was possible.

In conclusion it was found that narrowsense heritability estimates from variance components ranged from low to high in both the crosses. Selection in early generation would be effective for head length, seeds per head and seed weight in cross 1 and for head length, seeds per head, 1000-grain weight and threshing percentage in cross 2. Early generation selection for yield would not be effective in cross 1. Low phenotypic correlations of yield and maturity suggested that selection for favourable recombinant from among the progeny lines could be possible.

B. COMBINING ABILITY ESTIMATES

Evaluation of parental lines:

The average performance over two locations of the parental lines for various characters alongwith their analysis of variance presented in Tables 14 and 17 reveal that the ICRISAT line ICSV 107 was the best among the female lines for being highest in yield, number of seeds per head, head length and threshing percentage, while ICSV 219 was the best line having more number of leaves, more leaf area of the upper six leaves per plant and sugar content. ICSV 112 also showed significant performance with regard to yield and nonsenescence traits in comparison with the local pure lines. Among the local pure lines, Pot.3-9 was superior in plant height, 1000-grain weight, threshing percentage and earliest in maturity. Bagdar which was an intermediate grain yielding line, though ranked first in 1000-grain weight and second in plant height, was very low in threshing percentage.

Referring to the analysis of variance of the parental lines over two locations (Tables 16,17), locations were significantly different for yield per plant, 1000-grain weight, threshing percentage, maturity index, plant height, leaves per plant, LAUSL and %GLA 50DAF. There were highly significant differences in the lines for all the traits studied. The lines x location interaction was also significant for yield per plant, threshing percentage, plant height, LAUSL and %GLA 50DAF. The overall results show that the nonsenescing (ICRISAT) types generally took 10-12 days longer to reach 50% flowering and averaged 45-56 cm shorter in height than the senescing types. The nonsenescing lines had significantly more number of leaves, LAUSL, %GLA 50DAF and sugar percentage from flowering through harvest.

As the nonsenescing lines maintained more green leaves and more green leaf area and fewer senesced leaves per plant throughout the reproductive phase of growth, this type expectedly produced a greater leaf area index which was maintained for a longer period of time and was reflected by the leaf area duration. Similar observations have been reported by Jaganath et al (1975). They were of the opinion that yield in sorghum was more directly correlated with leaf area duration and grain leaf ratio, while Goldsworthy (1970) when compared a tall variety with a short variety of sorghum for leaf area duration and grain yield, found that the tall variety produced more dry weight after heading and had a larger leaf area duration than did the short variety, but its grain yield was not significant. The nonsenescing type maintained a higher chlorophyll content right from six leaf stage till harvesting. The senescence type showed decrease in chlorophyll content during its growth period. Duncan et al (1976) have also reported similar results from their study on characteristics of senescence and nonsenescence types of sorghum which are in agreement with the results reported here-in.

Combining Ability Studies

F1 Generation

Combining ability of the selected ICRISAT and local type parents for early maturity, and stay green associated characters, was estimated for a set of twelve straight crosses in sorghum. The results indicated that for the majority of the characters studied, both general and specific combining ability effects contributed significantly; the GCA effects being more pronounced than the SCA effects. The results presented in Tables 18 and 19 reveal that there were considerable range of differences for yield, maturity and stay-green characters between parents and crosses as well as among crosses. Locations were also significantly different for yield per plant, 1000-grain weight, threshing percentage, maturity index, plant height, %GLA 50DAF and sugar percentage. The SCA mean squares were much smaller than the GCA mean squares for all traits which indicate that additive genetic variances were more important than nonadditive genetic variances. Similar results have been reported by Nichaus and Pickette (1966) who observed that general combining ability effects were larger than specific effects. Reddy (1963) from his studies on combining ability involving exotic female and Indian males, has also pointed towards the greater importance of general combining ability for yield and yield components while Kambal and Webster (1965) have observed that both general and specific combining abilities were important in determining yield and related characters but comparatively the GCA effects were more important and more stable over the years. Rao (1970) found that specific combining ability was significant for grain yield, yield components, plant height, days to 50% flowering, and leaves per plant, indicating the importance of nonadditive genetic variance for these traits. Sprague and Tatum (1942) and Rojas and Sprague (1952) have also reported that specific combining ability variances were relatively greater than general combining ability variances. The lines used in the present study were all highly selected and represented adapted ecotypes of the regions in which these lines were developed and maintained. Therefore one might expect that specific combining ability should have a more pronounced effect than the general combining ability on the expression of various characters.

The data presented in this study reveal that for all the components of yield, maturity and stay-green character, the general combining ability effects are relatively more important than the specific combining ability except for head length, seeds per head, 1000-grain weight, threshing percentage, LAUSL, %GLA 50DAF and plant height. This also indicates that contribution of these characters is very little to the overall yield and as such the specific combining ability effects are more pronounced in these characters than others. These results are in agreement with those reported by Kambal and Webster (1965) and Nichaus and Pickette (1966). In the present study, the pure lines and the crosses involving ICSV 107 and ICSV 219 produced longer heads, heavier and more number of seeds per head, more number of leaves and more LAUSL, %GLA 50DAF and sugar percentage in comparison with rest of the pure lines studied. Number of seeds per head, 1000-grain weight, head length and threshing percentage showed relatively higher association with yield and LAUSL, %GLA 50DAF while sugar percentage, showed positive and significant association with nonsenescence.

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

An overall assessment of the data in Tables 20 and 21 indicate that the cross ICSV 107 X Pot. 3-9 was found to be the best cross, as it exhibited superiority over the other crosses for plant height, yield per plant, seeds per head, head length, threshing percentage and maturity. The cross ICSV 219 X Pot.3-9 was the best one for having significantly more area of upper six leaves per plant, %GLA 50 DAF and sugar percentage.

Analysis of variance, presented in Table 18 reveals that variation due to locations for maturity index, 1000-grain weight, seeds per head, %GLA 50DAF, sugar percentage, and plant height was significant, but not so for head length, threshing percentage, LAUSL and leaves per plant. While the cross x loc interaction was found to be significant for majority of the characters, studied. Thus it appears that yield and its components were influenced by environmental fluctuations. Shinde and Jagadeshwar (1986) have reported that both additive and nondditive gene effects were estimated to be important for the inheritance of grain yield and yield components but nonadditive effects were predominant for most of the characters. Genotype X invironment interaction was significant for all the characters.

It is evident, from Table 18 that the mean squares for both general and specific combining abilities were significant in all cases. This suggests that the genetic variability among crosses for yield and its various components was significantly associated with both general and specific combining ability. The interactions of both general and specific combining abilities with locations were highly significant for majority of the characters except for yield per plant and seeds per head, suggesting thereby a differential influence of environmental fluctuations on the combining ability of the lines for the characters studied.

Based on the overall results, it indicates that the nonadditive variances are not statistically significant they are still important. These results are in agreement with Subba Rao et al (1976) who reported that variance due to general and specific combining ability effects, was significant for all characters and they found that additive gene effects were predominant for days to flowering, while nonadditive gene effects were of most importance for plant height, head weight and 1000-grain weight.

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

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

Referring to the general combining ability of the parental lines involved in the crosses, it is evident that parental lines although had low general combining ability values for seeds per head, resulted in highest specific effects in hybrid combinations. The other cross combinations had either low or high negative values.

An over all assessment of the specific combining ability effects for the characters presented in Tables 24 and 25 indicate that the highest specific effects for yield in the cross combination ICSV107 X Pot.3-9 was accompanied by the high specific effects for number of seeds per head, 1000-grain weight and threshing percentage. The other cross combinations which also exhibited high specific effects for yield, had the highest specific effects for the number of seeds per head, 1000-grain weight and

F2 Generation:

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

Interaction of crosses x location was found significant for maturity and %GLA 50DAF. Estimates of GCA effects indicated that the male parent Pot.3-9 which has the highest GCA effects in F1 for yield per plant, number of seeds per head, 1000-grain weight and maturity index, remained the best general combiner in F2 generation for 1000-grain weight, seeds per head and maturity index (Tables 30,31).

The over all specific combining ability effects for the crosses studied (Tables 32,33), showed that cross combinations ICSV 107 X Pot.3-9 exhibited the highest specific combining ability effects for head length, seeds per head, 1000-grain weight, threshing percentage and maturity index while it exhibited poor combining ability effects for plant height, leaves per plant, LAUSL, %GLA 50DAF and sugar percentage, whereas the cross combinations ICSV 219 X Pot.3-9 exhibited the maximum specific effects for leaves per plant, LAUSL and sugar percentage. GCA estimates were highly significant for all traits except seeds per head and yield per plant in F1 generation.

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

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

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

Correlation Studies

There was a positive and significant correlation of early maturity with seeds per head (r=0.35), 1000-grain weight (r=0.12) and threshing percentage (r=0.33) in F1 generation. The correlation of early maturity with yield per plant was negative with yield per plant (r=0.23), 1000-grain weight (r=0.18) and threshing percentage (r=0.30) in F2 generation (Tables 34,35) but the correlation coefficients were small in magnitude. Early maturity was also negatively correlated with yield per plant, head length, leaves per plant, LAUSL, and sugar percentage. The values being small indicating that improvement for early maturity, and high yield coupled with stay-green character is possible in F2 generation. These results are in agreement with Rana et al (1984) who has reported that early maturity was negatively correlated with grain yield whereas Dalton (1967) has reported a positive regression between yield and maturity. Saeed and Francis (1983) have found that differences in yield stability among genotype were largely a function of relative maturity. As the yield per plant and head length were highly correlated with 1000-grain weight and the correlation between yield and head length was low, these results indicate that improvement for yield could be possible by selection from the progenies having more 1000-grain weight, while Liang (1967), who has obtained a low correlation of 100-grain weight with grain yield both phenotypically and genotypically, was of the opinion that seed weight (100-grain weight) had little predictive value in relation to grain yield.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions:

The major objective of this study was to choose the best parents among the selected lines, which can produce progenies with early maturity and high yield coupled with stay-green character. Therefore for maturity index 10% level of significance was used.

Effective selection for early maturity, head length, seeds per head, 1000-grain weight and yield, is possible in cross 1 and selection for leaves per plant, LAUSL, %GLA 50DAF and sugar percentage is possible in cross 2. Selection for early maturity would be more effective in later generations. In cross 2 selection for yield could also be practised in early generations.

Narrowsense heritability estimates from variance components ranged from low to high in both populations. Low heritability for yield suggested that selection in cross 1 should be practised in later generations.

Low correlation between yield and early maturity in both crosses indicated that selection for early and favourable recombinants could be possible from these crosses.

SCA was significant for head length, seeds per head, 1000-grain weight, threshing percentage, plant height, LAUSL and %GLA 50DAF in F1 generation, while in F2 generation SCA was significant for 1000-grain weight, threshing percentage, maturity index, plant height, LAUSL and sugar percentage.

The magnitude of GCA was much greater for all the traits in both generations, indicating that additive genetic effects were more important than nonadditive genetic effects. These results suggest that effective selection for early maturity and high yield is possible in early generation. 1000-grain weight, threshing percentage, maturity index, plant height, LAUSL and sugar percentage exhibited significant nonadditive genotypic variance in F2 but additive variance was many times greater in magnitude.

High and significant GCA effects suggested that among the selected parental lines Pot.3-9 and ICSV 107 were the best parents. Therefore selection for early maturity and high yield should be practised among the progenies of ICSV 107 X Pot.3-9 and selection for stay-green character should be practised among the progenies of ICSV 219 X Pot.3-9 in the Pothwar region of Pakistan. The ICRISAT line ICSV 112 did not prove to be good combiner for early maturity in the Pothwar environment, which may be due to lack of adaptation of this line. F3 progenies of these crosses will be evaluated at NARC Islamabad to identify the best ones under the prevailing agro-climatic conditions.

Recommendations:

The following recommendations have been formulated on the basis of present investigations:-

1. Further studies on the nonsenescence (stay-green) character in sorghum breeding for the on-going and future programme is needed in view of the nature of inheritance of this trait on the basis of the present as well as the previous investigations. Composition of segregating population involving many genes of small effect for inheritance of the nonsenescence not only depend on the number of such genes but also on the number of generations. Therefore selection of lines with better stay-green character should be practised in advance generations rather than early generation, because the frequency of homozygous genes increases with succeeding generations of selfing.

2. Crosses between nonsenescent parents should also be made to test gene complementation for obtaining better nonsenescent material.

3. As there is no clear evidence of the mode of inheritance of nonsenescence in sorghum, there is need to pursue these studies to have more information.

4. Large populations of F1, F2, BC1, BC2 and BC1(S) BC2(S) generations should be obtained to perform biometrical and statistical analysis to test linkage and higher order interactions for further understanding of the genetics of non-senescence.

5. The genetic studies of maturity pioneered by J.R. Quinby (1967) should be taken advantage of inheritance in association with nonsenescence in sorghum to have better selections with the desired traits.

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APPENDICES

APPENDIX-A

SUPPLEMENTARY TABLES FOR GENERATION MEANS ANALYSIS

Table A2. Generation means for maturity and nonsenescence traits for cross 1 (ICSV 107 X Pot.3-9)-1992.

Generation	Plant Height (cm)	Leaves per Plant	L A U S L (cm^2)	%GLA 50 DAF	Sugar%
			NARC, ISLAMABAD		
P1 (ICSV 107)	172.25d	14.25a	2963.50a	84.37a	12.62a
P2 (Pot.3-9)	237.25bc	9.25e	2315.75b	41.20d	4.10c
F1	242.25ab	13.75ab	3151.75a	83.92a	7.62bc
F2	240.75abc	13.00bcd	3111.75a	79.30b	5.90d
BC1	233.00bc	14.25a	3351.75a	86.42a	7.92b
BC2	251.75a	12.25d	3279.25a	68.15c	5.10d
BC1(S)	229.75c	13.50abc	3313.00a	83.85a	7.02c
BC2(S)	244.00ab	12.75cd	2772.00ab	67.42c	4.22e
			MMRI, YOUSAFWALA		
P1 (ICSV 219)	176.25e	14.25a	3004.25c	77.67b	12.45a
P2 (Pot.3-9)	240.75bc	10.25c	2384.50d	42.90d	3.95d
F1	242.75abc	13.50ab	3222.25ab	80.57b	9.27b
F2	240.25bc	12.75ab	3130.75bc	64.87c	6.62c
BC1	236.25c	13.75ab	3299.25a	85.62a	10.35b
BC2	249.00a	12.25b	3302.00a	65.35c	7.72c
BC1(S)	228.25d	13.75ab	3295.00a	78.37b	6.27c
BC2(S)	246.75ab	12.50ab	3272.50a	66.27c	6.30c

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

Table A3. Generation means for maturity and nonsenescence traits for cross 2 (ICSV 219 X Pot.3-9)-1992.

Generation	Yield per plant (g)	Length of head (cm)	Seeds per head	1000-grain Weight (g)	Threshing %	Maturity Index
			NARC, ISLAMABAD			
P1 (ICSV 107)	27.95d	31.22ab	1775.50b	27.325b	69.10b	113c
P2 (Pot.3-9)	14.57e	19.15c	511.00c	31.715ab	84.30a	143a
F1	33.07b	31.27ab	2091.50ab	35.144a	72.42b	144a
F2	31.27bc	28.42b	2124.00a	33.346a	73.22b	142a
BC1	37.37a	32.22a	2095.30ab	34.438a	71.02b	134b
BC2	30.82bcd	28.65b	1964.50ab	35.202a	75.62b	147a
BC1(S)	33.47b	32.85a	2027.80ab	32.283ab	73.62b	129b
BC2(S)	29.90cd	32.62a	1972.80ab	35.813a	76.10b	145a
			MMRI, YOUSAFWALA			
P1 (ICSV 219)	27.62f	30.45a	1631.00c	27.999c	71.05c	110d
P2 (Pot.3-9)	15.10g	18.92b	494.80d	29.448bc	81.67a	141a
F1	32.27bc	30.85a	2274.30ab	33.810a	73.95bc	141a
F2	30.90d	29.10a	2071.30ab	32.909ab	72.65bc	140a
BC1	34.57a	31.15a	2324.80a	33.268ab	73.97bc	131b
BC2	31.40cd	30.32a	2032.30ab	32.821ab	76.40b	145a
BC1(S)	32.60b	31.50a	1978.00abc	32.048ab	74.87bc	126c
BC2(S)	29.17e	31.32a	1922.00bc	35.153a	73.07bc	143a

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

Table A4. Generation means for maturity and nonsenescence traits for cross 2(ICSV 219 X Pot.3-9)-1992.

Generation	Plant Height (cm)	Leaves per Plant	L A U S L (cm^2)	%GLA 50 DAF	Sugar%
			NARC, ISLAMABAD		
P1 (ICSV 107)	170.25d	14.00a	3044.25cd	86.02ab	13.92a
P2 (Pot.3-9)	234.75c	8.00d	2153.75e	37.87e	4.00d
F1	246.00ab	13.25ab	3264.75ab	84.17b	10.00b
F2	247.50a	12.25bc	3170.75bc	70.57c	6.40cd
BC1	241.25abc	14.00a	3392.75a	87.87a	13.05a
BC2	249.00a	13.50a	3088.00c	68.92cd	5.67d
BC1(S)	237.25bc	13.00ab	3274.75ab	83.37b	8.50bc
BC2(S)	245.25ab	11.25c	2943.50d	66.72d	6.05cd
			MMRI, YOUSAFWALA		
P1 (ICSV 219)	172.50d	13.75a	3059.00c	83.20a	14.55a
P2 (Pot.3-9)	236.75c	9.50d	2234.50d	36.97d	3.80e
F1	245.75ab	11.50ab	3269.00a	84.55a	10.92b
F2	246.75a	12.25a	3223.50ab	66.20c	7.87cd
BC1	247.50a	13.50a	3352.25a	86.65a	10.52b
BC2	248.00a	13.25a	3074.25bc	65.30c	6.92d
BC1(S)	238.25bc	12.25a	3233.25ab	77.57b	9.00c
BC2(S)	244.50abc	11.75ab	2984.50c	62.67c	7.00d

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

Table A5. Mean squares for maturity and nonsenescence traits in cross 1 (ICSV 107 X Pot.3-9)-1992.

Source	df	Yield per plant (g)	Length of head (cm)	Seeds per head	1000-grain Weight (g)	Threshing %	Maturity Index
				NARC, ISLAMABAD			
Replication	3	1.72	1.36	15950.00	31.61	30.08	4.08
Generation	7	136.36**	58.19**	1018177.78**	32.35	78.50**	515.93**
A	1	380.29**	159.29**	2906837.38**	72.42*	388.00**	1388.57**
D	1	22.36*	23.14**	86130.45	49.50	13.22	053.00
AA	1	5.52	0.20	135984.64*	17.92	6.48	124.77**
AD	1	12.89	12.16*	532680.14**	16.54	403.56**	36.57
DD	1	20.63*	17.22**	84418.05	38.11	10.91	2.79
Error		0.88	1.27	7771.36	15.08	14.08	11.70
CV(%)		3.23	3.77	5.09	12.30	5.11	2.41
				MMRI, YOUSAFWALA			
Replication	3	0.96	10.97**	595172.03**	1.16	34.79**	7.58
Generation	7	141.97**	62.32**	1368106.21**	22.05**	74.82**	520.00**
A	1	345.86**	152.75**	3219666.69**	20.73*	290.75**	1525.50**
D	1	19.55*	2.03	18849.11	65.49**	13.39	0.02
AA	1	7.49	14.22	469128.98	41.27**	3.87	122.52**
AD	1	1.58	1.28	252605.01	1.25	370.48**	20.57
DD	1	16.68*	3.83	23161.05	45.85**	12.19	0.17
Error		0.80	1.87	57944.79	4.25	5.50	9.20
CV(%)		3.11	4.48	12.89	6.59	3.15	2.17

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

Table A6. Mean squares for maturity and nonsenescence traits in cross 1 (ICSV 107 X Pot.3-9)-1992.

Source	df	Plant Height(cm)	Leaves per Plant	L A U S L (cm^2)	%GLA 50DAF	Sugar%
			NARC, ISLAMABAD			
Replication	3	42.87	1.08	137428.03	14.29*	1.56**
Generation	7	2472.77**	10.57**	484765.21**	936.03**	30.60**
A	1	8290.86**	46.67**	1067717.50**	3794.40**	147.59**
D	1	250.34	0.09	419835.10	4.48	0.32
AA	1	230.82	0.64	30238.56	9.56**	8.79**
AD	1	505.75*	1.51	41195.57	32.57**	4.76**
DD	1	285.03*	0.02	419036.31	0.15	0.23
Error		68.33	0.39	128041.74	3.78	0.31
CV(%)		3.57	4.87	17.61	2.62	8.21
			MMRI, YOUSAFWALA			
Replication	3	9.78	1.92	3523.37	8.12	2.09
Generation	7	2231.24**	6.43**	390719.12**	731.91**	29.17**
A	1	8531.34**	32.02**	742917.09**	2355.72**	129.09**
D	1	218.75**	0.05	427793.99	51.41	20.81**
AA	1	169.92*	0.55	82561.29*	0.83	31.68**
AD	1	745.72**	0.72	214462.51**	1.63	11.96*
DD	1	245.67**	0.11	71871.53	15.71	10.09*
Error		24.28	1.27	7536.61	7.66	0.98
CV(%)		2.12	8.77	4.11	3.94	12.59

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

Table A7. Mean squares for maturity and nonsenescence traits in cross 2 (ICSV 219 X Pot.3-9)-1992.

Source	df	Yield per plant (g)	Length of head (cm)	Seeds per head	1000-grain Weight (g)	Threshing %	Maturity Index
				NARC, ISLAMABAD			
Replication	3	5.14	2.14	16476.86	5.89	63.88*	13.08
Generation	7	182.89**	82.01**	1168413.88**	30.69*	84.02**	527.35**
A	1	343.81**	263.53**	3035651.20**	47.99*	433.44**	2938.30**
D	1	49.90**	6.07	32031.44	5.27	9.78	35.52
A	1	7.91	50.28*	384233.21*	2.55	0.88	13.97
AD	1	1.77	24.89	619097.58**	1.25	31.61	3.57
DD	1	54.81**	2.81	56515.69	4.75	5.53	20.64
Error		3.76	3.69	43695.98	12.81	17.66	11.65
CV(%)		6.50	6.50	11.48	10.79	5.64	2.49
				MMRI, YOUSAFWALA			
Replication	3	1.17	3.48	403048.45**	3.16	31.70**	8.58
Generation	7	1035.71**	71.28**	1367503.03**	22.05**	41.61**	561.07**
A	1	316.60**	250.92**	2381659.50**	8.52	191.33**	2074.28**
D	1	37.23**	0.15	290645.13	0.08	6.38	37.24
AA	1	8.91*	21.72	102527.36	17.06	21.02	14.95
AD	1	20.91**	59.45**	256131.57	0.18	33.55	1.28
DD	1	41.13**	0.94	253264.87	0.00	4.55	24.53
Error		0.48	5.90	54475.25	5.61	6.02	11.06
CV(%)		2.38	8.32	12.67	7.36	3.28	2.47

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

Table A8. Mean squares for maturity and nonsenescence traits in cross 2 (ICSV 219 X Pot.3-9)-1992.

Source	df	Plant Height(cm)	Leaves per Plant	L A U S L (cm^2)	%GLA 50DAF	Sugar%
			NARC, ISLAMABAD			
Replication	3	21.11	0.95	14506.12	5.64	3.92
Generation	7	2745.99**	16.07**	596686.91**	1096.44**	52.00**
A	1	8128.29**	75.60**	1634257.85**	4683.18**	178.38**
D	1	183.24*	11.82**	105326.91**	48.49	11.49
AA	1	563.41**	3.79*	30034.38	7.29	23.86*
AD	1	1365.01**	10.93**	40965.75*	74.26*	3.19
DD	1	255.88*	9.51**	99539.25**	15.00	3.95
Error		42.02	0.49	7090.72	5.45	2.75
CV(%)		2.44	5.67	4.12	3.19	19.63
			MMRI, YOUSAFWALA			
Replication	3	7.67	1.11	15373.28	29.24	0.02
Generation	7	2622.29**	7.53*	498790.88**	1085.80**	42.68**
A	1	8159.43**	35.63**	1364719.24**	4220.16**	220.12**
D	1	367.88**	11.65*	59085.44*	93.51	0.38
AA	1	293.94**	5.35	47314.43*	6.85	3.77
AD	1	2082.94**	7.51	45805.58*	26.03	8.03**
DD	1	460.96**	13.47*	55041.25*	17.39	0.51
Error		37.36	2.25	10664.54	12.93	0.71
CV(%)		2.60	12.29	5.03	5.11	9.51

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

Table A9. Estimates of genetic effects on maturity and nonsenescence traits for two crosses over two locations-1992.

Parameter	Yield per plant (g)	Length of head (cm)	Seeds per head	1000-grain Weight (g)	Threshing %	Maturity Index
			CROSS 1 (ICSV 107 X Pot. 3-9)			
M	26.34** ±1.75	28.51** ±1.80	1908.82** ±268.79	21.64** ±3.03	78.02** ±3.66	191.73** ±58.98
A	6.57** ±0.43	4.31** ±0.45	603.68** ±67.02	-2.25* ±0.75	-6.33** ±0.91	120.01** ±14.71
D	18.24** ±4.98	12.28* ±5.13	848.49 ±765.18	29.80** ±8.63	-12.67 ±10.42	8.67 ±167.92
AA	3.59* ±1.81	-2.37 ±1.86	-752.71** ±277.51	7.61* ±3.13	-2.90 ±3.77	30.86 ±60.90
AD	-3.66 ±1.91	-3.49 ±1.97	-931.64** ±293.66	3.92 ±3.31	29.73** ±3.99	-161.14* ±14.44
DD	-12.43** ±3.56	8.59* ±3.67	-622.88 ±546.55	-18.21 ±6.17	7.22 ±7.44	34.51 ±119.94
R2 (%)	0.90	0.79	0.78	0.37	0.55	0.56

Values in parentheses are R^2 for full model.
* Significant at 5% level.
** Significant at 1% level.

Table A10. Estimates of genetic effects on maturity and nonsenescence traits for two crosses over two locations-1992.

Parameter	Plant Height(cm)	Leaves per Plant	L A U S L (cm^2)	%GLA 50DAF	Sugar%
			<u>CROSS 1 (ICSV 107 X Pot. 3-9)</u>		
M	227.67** ±6.39	13.17** ±0.93	1773.92** ±265.76	52.18** ±3.46	4.37** ±1.61
A	-31.64** ±1.59	2.15** ±0.23	326.95** ±65.51	9.72* ±0.86	3.91** ±0.40
D	60.29** 18.21	0.16 ±2.64	1683.72* ±748.02	24.37* ±9.85	1.83 ±4.58
AA	-10.16** ±6.61	1.10 ±0.95	-81.03 ±271.28	0.68 ±3.57	3.48* ±1.66
AD	37.64** 6.99	-1.57 ±1.01	-503.50 ±287.07	-4.17 ±3.78	-9.22 ±1.76
DD	-45.80** ±13.01	0.24 ±1.88	-1287.91* ±534.29	-14.67* ±7.04	-0.56 ±3.27
R2 (%)	0.93	0.67	0.56	0.79	0.67

Values in parentheses are R^2 for full model.
* Significant at 5% level.
** Significant at 1% level.

Table A11. Estimates of genetic effects on maturity and nonsenescence traits for two crosses over two locations-1992.

Parameter	Yield per plant (g)	Length of head (cm)	Seeds per head	1000-grain Weight (g)	Threshing %	Maturity Index
			CROSS 2 (ICSV 219 X Pot. 3-9)			
M	25.89**	33.82**	1646.92**	33.44**	74.00**	184.88**
	±1.99	±2.58	±302.50	±2.84	±3.91	±56.95
A	6.22**	5.53**	566.81*	-1.69*	-5.97*	158.76**
	±0.49	±0.64	±75.42	±0.71	±0.97	±14.20
D	25.93**	-4.07	1567.34	3.95	-1.18	148.40
	±5.66	±7.56	±861.16	±8.10	±11.14	±162.11
AA	4.14*	-8.39**	496.28	-4.09	2.60	63.38
	±2.05	±2.67	±312.32	±2.93	±4.04	±58.80
AD	-4.46	-9.60**	-977.35	1.17	8.75*	-71.92
	±2.17	±2.82	±330.49	±3.11	±4.27	±62.22
DD	-19.43**	0.98	-1063.11	-3.06	0.31	-68.51
	±4.04	±5.26	±615.10	±5.78	±7.96	±115.81
R2 (%)	0.90	0.68	0.73	0.38	0.44	0.73

Values in parentheses are R^2 for full model.
* Significant at 5% level.
** Significant at 1% level.

Table A12. Estimates of genetic effects on maturity and nonsenescence traits for two crosses over two locations-1992.

Parameter	Plant Height(cm)	Leaves per Plant	L A U S L (cm^2)	%GLA 50DAF	Sugar%
			CROSS 2 (ICSV 219 X Pot. 3-9)		
M	233.59** ±5.974	8.33** ±1.14	2188.72** ±116.94	44.86** ±4.52	4.18** ±1.40
A	-31.14 ±1.489	2.52** ±0.28	317.31* ±29.15	12.59* ±1.12	4.33** ±0.34
D	64.44** ±17.006	3.49** ±3.26	605.32 ±332.91	45.57** ±12.87	0.01 ±3.99
AA	-29.20** ±6.168	3.04* ±1.18	-642.07** ±120.73	6.38 ±4.66	3.92** ±1.44
AD	62.43** ±6.526	-4.57** ±1.25	-543.35** ±127.76	9.35* ±4.94	-9.11** ±1.53
DD	-52.71** ±12.147	9.50 ±2.33	-543.02* ±237.38	-25.97* ±9.19	1.30 ±2.85
R2 (%)	0.757	0.65	0.90	0.79	0.78

Values in parentheses are R^2 for full model.
* Significant at 5% level.
** Significant at 1% level.

Table A13. Estimates of genetic effects on maturity and nonsenescence traits based on three-parameter model in cross 1 (ICSV 107 X Pot.3-9)-1992.

Parameter	Yield per plant (g)	Length of head (cm)	Seeds per head	1000-grain Weight (g)	Threshing %	Maturity Index
			CROSS 1 (ICSV 107 X Pot. 3-9			
M	25.07** ±0.54	27.94** ±0.46	1417.28** ±72.94	29.49** ±0.64	74.81** ±0.98	134.46** ±0.91
A	6.11** ±0.56	3.87** ±0.47	487.23** ±75.33	-1.76* ±0.67	-2.62* ±1.01	-14.16** ±0.94
D	10.28** ±1.12	6.59** ±0.95	1017.25** ±150.66	5.11** ±1.34	-2.18 ±2.03	16.91** ±1.88
R2(%)	0.76	0.65	0.58	0.26	0.11	0.83
			CROSS 2 (ICSV 219 X Pot. 3-9			
M	25.06** ±0.71	27.41** ±0.65	1414.92** ±75.74	30.73** ±0.61	75.92** ±0.80	129.62** ±0.83
A	5.71** ±0.74	4.33** ±0.68	444.64** ±78.22	-1.55* ±0.63	-4.88** ±0.83	-15.16** ±0.85
D	11.85** ±1.48	5.24** ±1.36	1108.62** ±156.45	5.16** ±1.26	-3.50* ±1.67	16.66** ±1.71
R2(%)	0.66	0.47	0.57	0.27	0.38	0.87

Values in parentheses are R^2 for full model.
* Significant at 5% level. ** Significant at 1% level.

Table A14. Estimates of genetic effects on maturity and nonsenescence traits based on three-parameter model in cross 1 (ICSV 107 X Pot.3-9)-1992.

Parameter	Plant Height(cm)	Leaves per Plant	L A U S L (cm^2)	%GLA 50DAF	Sugar%
			CROSS 1 (ICSV 107 X Pot. 3-9		
M	217.91** ±2.38	12.31** ±0.19	1864.07** ±61.81	64.83** ±1.01	7.18** ±0.33
A	-26.94** ±2.46	1.96** ±0.19	264.02** ±63.84	18.58** ±1.05	3.52** ±0.34
D	37.52** ±4.92	1.50** ±0.39	557.35** ±127.69	19.82** ±2.09	0.41 ±0.69
R2(%)	0.74	0.64	0.37	0.86	0.63
			CROSS 2 (ICSV 219 X Pot. 3-9		
M	217.87** ±3.01	11.73** ±0.28	1795.80** ±34.98	63.46** ±1.02	8.15** ±0.35
A	-23.33** ±3.11	1.95** ±0.29	382.72** ±26.13	21.72** ±1.05	4.76** ±0.36
D	44.23** ±6.21	1.54* ±0.58	671.64** ±72.26	22.21** ±2.10	1.34 ±0.73
R2(%)	0.64	0.46	0.76	0.89	0.74

Values in parentheses are R^2 for full model.
* Significant at 5% level. ** Significant at 1% level.

Table A15. Estimates of genetic effects on maturity and nonsenescence traits for cross 1 (ICSV 107 X Pot.3-9)-1992.

Parameter	Yield per plant (g)	Length of head (cm)	Seeds per head	1000-grain Weight (g)	Threshing %	Maturity Index
			NARC, ISLAMABAD.			
M	26.31**	25.27**	1686.28**	22.96**	77.99**	148.08**
	±2.60	±2.03	±216.87	±5.67	±5.43	±4.42
A	6.72**	4.35**	588.26**	-2.93*	-6.79*	-12.85**
	±0.65	±0.50	±54.07	±1.41	±1.35	±1.10
D	18.63*	18.94**	1156.13	27.71	-14.32	-2.86
	±7.41	±5.78	±617.39	±16.16	±15.47	±12.58
AA	-3.35	0.64	-526.85*	6.04	-3.63	-15.95**
	±2.68	±2.09	±223.91	±5.86	±5.61	±4.56
AD	-5.42	-5.27*	-1103.42**	6.14	30.37**	-9.14*
	±2.84	±2.21	±236.94	±6.20	±5.94	±4.83
DD	12.78*	-11.67**	-817.54	-17.37	9.29	4.70
	±5.29	±4.13	±440.98	±11.54	±11.05	±8.99
R2 (%)	0.90	0.87	0.91	0.31	0.57	0.93

Values in parentheses are R^2 for full model.
* Significant at 5% level.
** Significant at 1% level.

Table A16. Estimates of genetic effects on maturity and nonsenescence traits for cross 1 (ICSV 107 X Pot.3-9)-1992.

Parameter	Plant Height(cm)	Leaves per Plant	L A U S L (cm^2)	%GLA 50DAF	Sugar%
			NARC, ISLAMABAD.		
M	227.34**	12.96**	1408.88**	76.55**	4.07**
	±11.42+	1.08	±497.56	±3.31	±0.97
A	-31.42**	2.35*	356.52**	21.25**	4.19**
	±2.85	±0.27	±124.05	±0.82	±0.24
D	62.33	1.19	2552.52	8.34	2.23
	±32.56	±3.09	±1416.44	±9.42	±2.77
AA	-21.71	-1.14	248.44	-13.59	4.23**
	±11.81	±1.12	±513.70	±3.41	±1.00
AD	34.00*	-1.85	-306.85	-8.62*	-3.30**
	±12.49	±1.19	±543.60	±3.61	±1.06
DD	-47.51*	-0.45	-1821.46	-1.08	1.35
	±23.26	±2.21	±1011.72	±6.73	±1.98
R2 (%)	0.90	0.81	0.48	0.97	0.94

Values in parentheses are R^2 for full model.
* Significant at 5% level.
** Significant at 1% level.

Table A17. Estimates of genetic effects on maturity and nonsenescence traits for cross 2 (ICSV 219 X Pot.3-9)-1992.

Parameter	Yield per plant (g)	Length of head (cm)	Seeds per head	1000-grain Weight (g)	Threshing %	Maturity Index
			MMRI, YOUSAFWALA			
M	26.45** ±2.56	31.74** ±2.92	2131.35** ±489.20	20.32** ±2.78	78.70** ±4.54	145.37** ±3.99
A	6.41** ±0.63	4.26** ±0.72	619.10** ±121.97	-1.57* ±0.69	-5.88** ±1.13	-13.47** ±0.99
D	-17.42** ±7.29	5.61 ±8.31	540.84 -1392.65	31.88** ±7.92	-14.41 ±12.94	-0.56 ±11.37
AA	-3.91 ±2.64	-5.38 ±3.01	-978.57* ±505.08	9.17** ±2.87	-2.81 ±4.69	-15.81** ±4.12
AD	-1.90 ±2.80	-1.71 ±3.19	-759.95 ±534.47	1.68 ±3.04	29.10** ±4.96	-6.85 ±4.36
DD	-11.49** ±5.21	-5.50 ±5.94	-428.22 ±994.73	-19.05** ±5.65	9.82 ±9.24	1.15 ±8.12
R2 (%)	0.91	0.77	0.74	0.57	0.62	0.94

Values in parentheses are R^2 for full model.
* Significant at 5% level.
** Significant at 1% level.

Table A18. Estimates of genetic effects on maturity and nonsenescence traits for cross 2 (ICSV 219 X Pot.3-9)-1992.

Parameter	Plant Height(cm)	Leaves per Plant	L A U S L (cm^2)	%GLA 50DAF	Sugar%
			MMRI, YOUSAFWALA		
M	26.45** ±2.56	13.37** ±1.58	2138.95** ±190.96	62.57** ±7.33	0.20** ±1.83
A	6.42** ±0.64	1.95** ±0.39	297.39* ±47.61	16.74** ±1.82	3.92** ±0.45
D	17.42* ±7.29	-0.86 ±4.50	814.93 ±543.63	28.24 ±20.87	17.97** ±2.22
AA	-3.91 ±2.64	-1.06 ±1.63	-410.52* ±197.16	-0.93 ±7.57	8.04** ±1.89
AD	-1.90 ±2.80	-1.28 ±1.72	-700.14** ±208.63	1.92 ±8.00	-5.22* ±2.02
DD	-11.49 ±5.21	0.94 ±3.21	-754.35 ±388.30	-11.15 ±14.90	-8.94* ±3.73
R2 (%)	0.91	0.56	0.83	0.86	-

Values in parentheses are R^2 for full model.
* Significant at 5% level.
** Significant at 1% level.

Table A19. Estimates of genetic effects on maturity and nonsenescence traits based on three-parameter model for cross 1 (ICSV 107 X Pot.3-9)-1992.

Parameter	Yield per plant (g)	Length of head (cm)	Seeds per head	1000-grain Weight (g)	Threshing %	Maturity Index
			NARC, Islamabad.			
M	25.28** ±0.80	27.12** ±0.55	1386.95** ±80.15	29.53** ±1.15	74.54** ±1.55	223.35** ±18.87
A	6.05** ±0.86	3.69** ±0.56	450.33** ±82.77	-2.16 ±1.19	-3.00 ±1.61	98.50** ±19.49
D	10.00** ±1.65	7.35** ±1.13	916.54** ±165.55	5.38* ±2.38	-3.59 ±3.21	-40.87 ±38.98
R2(%)	0.75	0.74	0.67	0.22	0.14	0.47
			MMRI, YOUSAFWALA.			
M	24.91** ±0.78	28.35** ±0.75	1447.61** ±122.09	29.44** ±0.64	75.44** ±1.34	198.32** ±15.65
A	6.17** ±0.81	4.05** ±0.77	524.12** ±126.09	-1.36* ±0.66	-2.24** ±1.38	99.75** ±16.16
D	10.35** ±1.61	5.83** ±1.55	1117.95** ±252.18	4.84** ±1.33	-2.39 ±2.76	61.21 ±32.33
R2(%)	0.77	0.58	0.56	0.37	0.10	0.58

Values in parentheses are R^2 for full model.
* Significant at 5% level. ** Significant at 1% level.

Table A20. Estimates of genetic effects on maturity and nonsenescence traits based on three-parameter model for cross 1 (ICSV 107 X Pot.3-9)-1992.

Parameter	Plant Height(cm)	Leaves per Plant	L A U S L (cm^2)	%GLA 50DAF	Sugar%
			CROSS 1 (ICSV 107 X Pot. 3-9		
M	216.62** ±3.72	12.15** ±0.23	1808.67** ±106.52	55.29** ±0.96	6.81** ±0.31
A	-27.17** ±3.85	2.12** ±0.24	318.16** ±110.02	10.36** ±0.99	3.70** ±0.32
D	39.50 ±7.69	1.91** ±0.48	596.45** ±220.04	10.05** ±1.99	-2.66** ±0.64
R2(%)	0.72	0.76	0.35	0.82	0.83
			CROSS 2 (ICSV 219 X Pot. 3-9		
M	219.20** ±3.15	12.46** ±0.31	1919.46** ±65.02	53.55** ±1.02	7.28** ±0.72
A	-26.71** ±3.25	1.79** ±0.32	209.87** ±67.15	8.04** ±1.06	1.81* ±0.74
D	35.54** ±6.50	1.08 ±0.63	518.25** ±134.31	8.80** ±2.12	-1.69 ±1.48
R2(%)	0.77	0.54	0.46	0.72	0.20

Values in parentheses are R^2 for full model.
* Significant at 5% level. ** Significant at 1% level.

Table A21. Estimates of genetic effects on maturity and nonsenescence traits for cross 2 (ICSV 219 X Pot.3-9)-1992.

Parameter	Yield per plant (g)	Length of head (cm)	Seeds per head	1000-grain Weight (g)	Threshing %	Maturity Index
			NARC, ISLAMABAD.			
M	25.76** ±3.51	35.88** ±3.83	2044.77** ±296.66	32.05** ±4.77	78.09** ±6.60	113.31** ±4.62
A	6.39** ±0.87	5.60* ±0.95	601.15** ±73.96	-2.39* ±1.19	-7.18** ±1.64	-15.19** ±1.15
D	27.82** ±10.00	-9.70 ±10.91	705.08 ±844.54	9.05 ±13.60	-12.32 ±18.80	23.47 ±13.16
AA	-4.01 ±3.62	-10.13** ±3.95	-885.61** ±306.29	-2.28 ±4.93	-1.34 ±6.82	-5.34 ±4.77
AD	-2.01 ±3.84	-7.54 ±4.18	-1189.57** ±324.11	-1.69 ±5.22	8.50 ±7.21	2.85 ±5.05
DD	20.83** ±7.14	4.71 ±7.79	-668.92 ±603.23	6.13 ±9.71	6.61 ±13.43	-12.78 ±9.40
R2 (%)	0.87	0.69	0.87	0.38	0.48	0.92

Values in parentheses are R^2 for full model.
* Significant at 5% level.
** Significant at 1% level.

Table A22. Estimates of genetic effects on maturity and nonsenescence traits for cross 2 (ICSV 219 X Pot.3-9)-1992.

Parameter	Plant Height(cm)	Leaves per Plant	L A U S L (cm^2)	%GLA 50DAF	Sugar%
			NARC, ISLAMABAD.		
M	237.17** ±8.97	8.31** ±1.08	1863.04** ±193.77	66.90** ±5.95	2.13** ±2.66
A	-31.10** ±2.23	3.00** ±0.27	441.08** ±34.85	23.61* ±1.48	4.60** ±0.66
D	53.32* ±25.53	13.54** ±3.07	1278.49** ±397.90	27.43 ±16.92	13.35 ±7.59
AA	-33.91** ±9.26	2.78* ±1.11	-247.60 ±144.31	-3.85 ±6.13	6.98* ±2.75
AD	55.86** ±9.80	-5.00** ±1.18	-306.00* ±152.71	-13.02* ±6.49	2.70 ±2.91
DD	-45.01* ±18.24	-8.68 ±2.19	-887.75** ±284.21	-10.89 ±12.08	5.59 ±5.42
R2 (%)	0.94	0.87	0.94	0.93	0.77

Values in parentheses are R^2 for full model.
* Significant at 5% level.
** Significant at 1% level.

Table A23. Estimates of genetic effects on maturity and nonsenescence traits for cross 2 (ICSV 219 X Pot.3-9)-1992.

Parameter	Yield per plant (g)	Length of head (cm)	Seeds per head	1000-grain Weight (g)	Threshing %	Maturity Index
			MMRI, YOUSAFWALA			
M	26.02** ±1.99	31.75** ±3.77	1548.05** ±451.28	34.82** ±3.33	69.92** ±4.49	130.94** ±4.43
A	6.13** ±0.49	5.46* ±0.94	532.47** ±112.52	-1.00 ±0.83	-4.77** ±1.12	-15.71** ±1.10
D	24.03** ±5.68	1.55 ±10.77	2123.79 ±1284.70	-1.15 ±9.50	9.95 ±12.78	24.04 ±12.63
AA	-4.26* ±2.06	-6.65 ±3.89	-457.47 ±465.92	5.90 ±3.34	6.55 ±4.63	-5.52 ±4.58
AD	-6.91* ±2.18	-11.65** ±4.12	-765.14 ±493.04	0.64 ±3.64	9.01 ±4.90	1.71 ±4.84
DD	18.04** ±4.06	-2.74 ±7.67	-1416.06 ±917.62	-0.00 ±6.78	6.00 ±9.13	-13.93 ±9.02
R2 (%)	0.95	0.69	0.77	0.46	0.47	0.94

Values in parentheses are R^2 for full model.
* Significant at 5% level.
** Significant at 1% level.

Table A24. Estimates of genetic effects on maturity and nonsenescence traits for cross 2 (ICSV 219 X Pot.3-9)-1992.

Parameter	Plant Height(cm)	Leaves per Plant	L A U S L (cm^2)	%GLA 50DAF	Sugar%
			MMRI, YOUSAFWALA		
M	230.01** ±8.46	8.35** ±1.95	1965.95** ±149.29	57.45** ±7.46	6.45** ±1.39
A	-31.17** ±2.11	2.05* ±0.48	403.07** ±37.22	22.41** ±1.86	5.12** ±0.34
D	75.56** ±24.08	13.44* ±5.56	957.57* ±424.99	38.09 ±21.25	2.43 ±3.98
AA	-24.49** ±8.73	3.30 ±2.01	-310.774* ±154.13	3.73 ±7.71	2.76* ±1.44
AD	69.00** ±9.24	-4.14 ±2.13	-323.57* ±163.10	-7.71 ±8.15	-4.28** ±1.52
DD	-60.41** ±17.20	-10.33* ±3.97	-660.14* ±303.56	-11.73 ±15.18	2.00 ±2.84
R2 (%)	0.95	0.50	0.92	0.90	0.91

Values in parentheses are R^2 for full model.
* Significant at 5% level. ** Significant at 1% level.

Table A25. Estimates of genetic effects on maturity and nonsenescence traits based on three-parameter model for cross 2 (ICSV 219 X Pot.3-9)-1992.

Parameter	Yield per plant (g)	Length of head (cm)	Seeds per head	1000-grain Weight (g)	Threshing %	Maturity Index
			NARC, Islamabad.			
M	25.18** ±1.12	27.73** ±0.93	1427.70** ±104.70	31.06** ±0.97	76.31** ±1.30	245.96** ±17.43
A	6.14** ±1.15	4.65** ±0.97	452.45** ±108.13	-2.17* ±1.00	-6.12 ±1.34	141.01** ±18.00
D	12.31** ±2.31	4.84* ±1.94	880.21** ±916.27	5.58** ±2.00	-4.78 ±2.69	17.75 ±36.01
R2(%)	0.66	0.50	0.54	0.30	0.45	0.68
			MMRI, Yousafwala.			
M	24.93** ±0.93	27.08** ±0.96	1370.89** ±115.13	30.40** ±0.74	75.54** ±0.95	234.93** ±15.56
A	5.27** ±0.96	4.00** ±0.99	436.83** ±118.91	-0.92 ±0.76	-3.64* ±0.98	158.50** ±16.07
D	11.38** ±1.93	5.64** ±1.99	1253.70** ±237.81	4.75** ±1.53	-2.22 ±1.97	23.83 ±32.14
R2(%)	0.69	0.45	0.58	0.27	0.34	0.77

Values in parentheses are R^2 for full model.
* Significant at 5% level. ** Significant at 1% level.

Table A26. Estimates of genetic effects on maturity and nonsenescence traits based on three-parameter model for cross 2 (ICSV 219 X Pot.3-9)-1992.

Parameter	Plant Height(cm)	Leaves per Plant	L A U S L (cm^2)	%GLA 50DAF	Sugar%
			NARC, Islamabad.		
M	217.02** ±4.30	11.42** ±0.31	1756.37** ±68.81	54.04** ±1.26	6.40** ±0.47
A	-24.13** ±4.44	2.37** ±0.32	269.50** ±71.06	11.98** ±1.30	3.16** ±0.48
D	45.04** ±8.89	2.62** ±0.65	760.50** ±142.13	16.07** ±2.61	-3.58** ±0.97
R2(%)	0.65	0.70	0.59	0.81	0.65
			MMRI, Yousafwala.		
M	218.72** ±4.41	12.04** ±0.44	1785.23** ±66.68	51.35** ±1.39	7.53** ±0.55
A	-22.54** ±4.55	1.54** ±0.46	229.29** ±68.87	10.87** ±1.44	3.22** ±0.56
D	43.42** ±9.11	0.45 ±0.92	716.12 ±137.74	13.60** ±2.88	-1.80** ±1.13
R2(%)	0.62	0.28	0.56	0.73	0.54

Values in parentheses are R^2 for full model.
* Significant at 5% level. ** Significant at 1% level.

APPENDIX-B

SUPPLEMENTARY TABLES FOR COMBINING ABILITY ESTIMATES

Table B1: Means values of seven pure lines for yield, maturity and stay-green traits at two locations-1990.

Pure Lines	Yield per plant (g)	Length of head (cm)	Seeds per head	1000-grain Weight (g)	Threshing %	Maturity Index
			NARC Islamabad.			
ICSV 107	36.13a	32.33a	1220a	26.69b	79.32a	119.0d
ICSV 112	32.45d	29.73a	1080b	25.18b	73.52b	110.3e
ICSV 219	35.80a	29.60a	1209a	26.65b	75.06b	114.0e
Pot. 3-9	18.75d	21.10b	691d	33.83a	76.51ab	150.5a
Red Janpur	21.30c	20.52b	635d	26.98b	75.89ab	138.8b
Bagdar	22.80c	18.13b	724d	36.75a	72.84b	131.5c
DS-75	22.83c	22.75b	821c	24.25b	72.27b	128.3c

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

Table B2: Means values of seven pure lines for yield, maturity and stay-green traits at two locations-1990.

Pure Lines	Plant Height (cm)	Leaves per Plant	L A U S L ((cm^2)	%GLA 50DAF	Sugar%
			NARC Islamabad.		
ICSV 107	169.5c	14.93a	3215a	75.96b	12.16b
ICSV 112	167.6c	14.38a	3055b	76.10b	12.07b
ICSV 219	167.1c	15.30a	3094b	82.28a	14.23a
Pot. 3-9	233.4d	11.72b	2418c	36.07e	6.13c
Red Janpur	251.8a	11.57b	2472c	43.37d	5.85c
Bagdar	237.1b	14.10a	2978b	53.29c	5.03c
DS-75	156.6d	12.65b	3076b	49.92c	4.93c

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

Table B3 Means values of seven pure lines for yield, maturity and stay-green traits at two locations-1990.

Pure Lawes	Yield per plant (g)	Length of head (cm)	Seeds per head	1000-grain Weight (g)	Threshing %	Maturity Index
			MMRI Yousafwala.			
ICSV 107	30.62a	29.35a	1283.0a	27.17d	72.50bc	128.0d
ICSV 112	25.39b	26.42a	1172.0a	26.61d	68.75c	120.3e
ICSV 219	27.32ab	27.25a	1114.0a	29.02cd	68.75c	120.5e
Pot. 3-9	17.33c	18.42c	676.3c	35.19b	79.75a	158.3a
Red Janpur	19.03c	15.65c	674.8c	32.07bc	74.75b	151.0b
Bagdar	24.75b	15.02c	699.3c	38.70a	69.00c	141.5c
DS-75	24.80b	22.30b	969.3b	27.17d	70.50bc	140.0c

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

Table B4 Means values of seven pure lines for yield, maturity and stay-green traits at two locations-1990.

Pure Lines aw	Plant Height (cm)	Leaves per Plant	L A U S L ((cm^2)	%GLA 50DAF	Sugar%
			MMRI Yousafwala.		
ICSV 107	178.0d	14.50a	3431a	75.50b	13.73ab
ICSV 112	157.0e	14.00a	3465a	71.75c	12.23b
ICSV 219	189.3d	15.50a	3613a	82.00a	15.23a
Pot. 3-9	220.5c	10.00b	2521c	39.25f	4.18c
Red Janpur	299.0a	10.75b	2645c	42.00ef	4.63c
Bagdar	280.8b	13.50a	3029b	47.50d	5.05c
DS-75	157.0e	13.25a	2928b	45.00de	4.18c

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

Table B5 Analysis of variance of pure lines (Parents) at two locations-1990.

Source of variation:	Df	Yield per Plant (g)	Length of head (cm)	Seeds per head	1000-grain Weight (g)	Threshing %	Maturity Index
			NARC Islamabad.				
Replications	3	5.00	16.55	30344.89	10.13	4.21	17.85
Lines	6	217.25**	123.07**	246396.70**	89.58**	24.04*	816.12**
Error	18	2.51	8.46	14093.23	7.87	6.93	7.93
Non-additivity	1	12.26*	3.32	3626.59	9.33	4.70	8.04
Residual	17	1.93	8.77	14708.91	7.78	7.06	7.92
			MMRI Yousafwala.				
Replications	3	25.23*	1.30	2136.61	2.91	1.71	5.10
Lines	6	84.55**	135.32**	288608.08**	86.89**	66.83**	873.73**
Error	18	6.06	2.68	3637.16	2.73	4.21	6.23
Non-additivity	1	0.09*	0.54	6151.55	0.81	0.15	0.55
Residual	17	6.41	2.80	3489.26	2.84	4.45	5.57

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

Table B6 Analysis of variance of pure lines (Parents) at two locations-1990.

Source of variation:	Df	Plant Height (cm)	Leaves per Plant	L A U S L (cm^2)	%GLA 50DAF	Sugar%
NARC Islamabad.						
Replications	3	70.14	1.31	13992.29	4.43	0.77
Lines	6	6723.53**	9.32**	408750.42**	1336.53**	64.19**
Error	18	32.06	0.58	6684.59	6.30	0.91
Non-additivity	1	18.29	1.75	723.76	-	0.18
Residual	17	32.87	0.51	7035.23	6.67	0.95
MMRI Yousafwala.						
Replications	3	102.91	2.91	53240.89	1.71	0.47
Lines	6	13393.66**	15.89**	721110.54**	1304.56**	100.48**
Error	18	53.88	1.21	18528.17	3.35	0.58
Non-additivity	1	0.37	1.64	32239.99	1.32	0.18
Residual	17	57.02	1.19	17721.59	3.47	0.60

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

Table B7 Means squares of combining ability analysis of F1 hybrids at NARC 1993.

Source	df	Yield per plant (g)	Length of head (cm)	Seeds per head	1000-grain Weight (g)	Threshing %	Maturity Index
Reps	2	8.73	1.20	19738.51	4.65	9.13	8.96
Etries	18	112.69**	73.13**	472314.20**	51.39**	61.90**	353.43**
Males vs Females	1	30.09*	318.29*	212727.79**	134.23	191.81	1970.02
Parents vs Cross	1	77.99	84.73	2751359.11	1.74	1145.51	562.00
Among Males	3	4.07	12.43	60962.91	83.73**	64.36*	159.14**
Among Females	2	9.65	55.94**	62112.58	24.71	0.74	5.02
Among Crosses	11	28.95*	78.68	165509.40	116.22	89.13	197.41**
Males	3	35.99**	32.39**	216180.47**	160.06**	262.81**	468.44**
Females	2	0.61*	15.87	263777.69**	8.31	67.79*	42.52*
Males X Females	6	4.72	6.52	47281.47*	3.82	7.56	27.86*
Error	72	5.98	3.62	10618.66	4.46	12.46	10.26

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

Table B8 Means squares of combining ability analysis of F1 hybrids at NARC 1993.
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Source	df	Plant Height(cm)	Leaves per Plant	L A U S L (cm^2)	%GLA 50DAF	Sugar%
Reps	2	34.46	2.25*	50126.74	0.06	0.75
Entries	18	4546.63**	6.70**	349557.19**	501.25**	26.88**
Males vs Females	1	2913.11	9.31	993256.23	1473.59	84.65
Parents vs Cross	1	3943.23	7.36	181710.59	279.13	14.19
Among Males	3	11212.70**	6.51*	427818.25**	465.28**	4.26**
Among Females	2	1144.83	1.14	5315.11	39.61*	0.45
Among Crosses	11	16062.92*	8.63	501402.80	560.18**	10.09*
Males	3	12607.80**	3.46*	330634.02**	149.12**	4.48*
Females	2	117.86	4.31*	338947.19**	56.07**	16.67**
Males X Females	6	1545.88**	2.70*	145135.41*	17.30*	0.84
Error	72	87.61	0.72	49294.79	7.75	0.80

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

Table B9 Means squares of combining ability analysis of F1 hybrids at MMRI, Yousafwala 1993.

Source	df	Yield per plant (g)	Length of head (cm)	Seeds per head	1000-grain Weight (g)	Threshing %	Maturity Index
Reps	2	1.79	3.27	45911.39	5.82	23.81	9.60
Entries	18	124.89**	58.26**	683956.09**	86.88**	89.77**	294.78**
Males vs Females	1	32.92	146.38	765780.80	900.62	275.42	1543.37
Parents vs Cross	1	71.00	91.00	3153210.50	13.37	1077.00	694.81
Among Males	3	17.41	25.52**	62900.25	240.46**	25.64*	162.47**
Among Females	2	0.43	10.19	39627.02	9.99	23.01*	14.33
Among Crosses	11	19.87	41.42	267553.85	265.58	114.38**	185.91
Males	3	6.89	8.73	147601.66	251.70	88.79**	86.25**
Females	2	8.28	20.24*	62320.75	1.01*	46.77*	68.69**
Males X Females	6	4.01	11.02*	137534.41*	27.63*	101.90**	26.47*
Error	72	4.24	3.53	37942.33	9.17	8.99	11.63

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

Table B10. Means squares of combining ability analysis of F1 hybrids at MMRI, Yousafwala 1993.

Source	df	Plant Height(cm)	Leaves per Plant	L A U S L (cm^2)	%GLA 50DAF	Sugar%
Reps	2	21.36	1.35	37694.44	8.78	0.26
Entries	18	4941.17**	4.60**	344335.17**	507.76**	25.18**
Males vs Females	1	4731.77	13.96	1008732.20	1718.73	119.29
Parents vs Cross	1	3832.50	7.68	194290.13	320.52	12.19
Among Males	3	3279.58**	4.74**	309661.96**	142.81**	5.91**
Among Females	2	980.78**	0.23	89028.00*	12.00	0.53
Among Crosses	11	7270.13**	6.13	444091.25	191.23*	6.73
Males	3	13875.98**	1.66	467849.66**	142.15**	18.03**
Females	2	1500.60**	4.11*	209113.00*	624.36**	0.18
Males X Females	6	831.24**	0.55	92405.66	58.51	1.76*
Error	72	24.21	0.82	54049.99	5.08	0.78

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

Table B11. Estimates of general combining ability effects in F1 generation at two locations-1993.

Parentage	Yield per plant (g)	Length of head (cm)	Seeds per head	1000-grain Weight (g)	Threshing %	Maturity Index
			NARC, ISALAMABAD			
Male						
Pot. 3-9	+0.69	-0.23	+ 76.18	+1.587	+4.85	+7.78
Red Janpur	-2.41	-2.32	+ 78.58	-4.580	+3.47	+4.45
Bagdar	+1.76	+2.21	-242.42	+4.890	-4.69	-5.33
DS-75	-0.09	+0.35	+ 87.58	-1.900	-3.63	-6.88
Female						
ICSV 107	+0.17	+1.40	+176.08	+0.918	+0.04	+1.78
ICSV 112	-0.57	-0.25	- 54.92	+0.751	-1.78	-1.97
ICSV 219	+0.38	-1.14	-121.22	-1.669	+1.73	-0.20
			MMRI, YOUSAFWALA			
Male						
Pot. 3-9	-0.38	+1.39	+116.16	+2.280	+1.97	+4.37
Red Janpur	-1.11	-1.12	+ 48.50	-5.434	+1.62	+0.76
Bagdar	+1.09	+0.18	-228.50	+6.314	-4.08	-2.24
DS-75	+0.39	-0.45	-394.67	-3.158	+0.49	-2.90
Female						
ICSV 107	+0.85	+1.17	+104.33	+1.114	-1.44	+3.06
ICSV 112	-0.17	-1.44	+ 7.08	-0.261	+2.61	-1.73
ICSV 219	-0.69	+0.28	-111.42	-0.851	+1.19	-1.32

Table B12. Estimates of general combining ability effects in F1 generation at two locations-1993.

Parentage	Plant Height (cm)	Leaves per Plant	L A U S L (cm^2)	%GLA 50DAF	Sugar%
			NARC, ISALAMABAD		
Male					
Pot. 3-9	+44.08	-0.92	-26.75	+6.68	+0.48
Red Janpur	- 2.24	+0.16	-38.75	-4.13	-0.63
Bagdar	+ 5.22	+0.25	+31.25	-0.73	+0.45
DS-75	-47.09	+0.50	+34.25	-1.83	-0.29
Female					
ICSV 107	+ 1.57	-0.55	+24.33	+0.33	-1.17
ICSV 112	- 3.67	-0.21	-230.92	-2.47	+0.41
ICSV 219	+ 2.08	-0.75	+206.58	+2.14	+0.78
			MMRI, YOUSAFWALA		
Male					
Pot. 3-9	+39.43	+0.91	-19.83	-4.34	+1.44
Red Janpur	+13.32	+0.36	-230.83	+0.26	-0.93
Bagdar	- 0.54	+0.20	+99.17	+1.88	+0.94
DS-75	-52.24	+0.36	+151.17	+2.22	-1.46
Female					
ICSV 107	+13.12	+0.34	+ 4.17	-2.23	-0.05
ICSV 112	- 7.57	-0.24	+243.83	-4.73	-0.30
ICSV 219	- 5.57	-0.09	+240.17	+6.97	+0.35

Table B13. Means squares of combining ability analysis of F2 generation at NARC Islamabad-1994.

Source	df	Yield per plant (g)	Length of head (cm)	Seeds per head	1000-grain Weight (g)	Threshing %	Maturity Index
Reps	2	1.59	2.56	67049.26	1.07	29.11	1.07
Entries	18	95.63**	35.85**	267207.56**	44.24**	25.22*	257.82**
Males vs Females	1	1208.93	324.79	508.07	12.74	17.68	2312.45
Parents vs Cross	1	62.86	1.71	32211.00	4.83	110.08	424.36
Among Males	3	4.41	418.22	93545.14	2443.88	110.08	424.36
Among Females	2	7.66	3.09	8432.35	1.40	0.12	1.30
Among Crosses	11	18.44	82.81	58551.58	91.28	41.88	139.21
Males	3	4.07	12.43	60962.91	24.72	0.74	5.03
Females	2	9.65	55.94**	62112.58	83.73**	64.36*	159.14**
Males X Females	6	15.23*	10.31	42433.91	77.83	24.03	33.25**
Error	72	4.99	6.14	19175.91	8.68	11.75	6.97

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

Table B14. Means squares of combining ability analysis of F2 generation at NARC Islamabad-1994.

Source	Df	Plant Height (cm)	Leaves per Plant	L A U S L (cm^2)	%GLA 50DAF	Sugar%
Reps	2	107.12	0.89	3714.68	25.57	2.66
Entries	18	4444.79**	3.82**	246386.23**	582.32**	23.31**
Males vs Females	1	3862.53	7.94	1048388.63	1757.56	54.35
Parents vs Cross	1	4994.52	6.13	173140.55	347.01	11.85
Among Males	3	9637.13	78.68	10245202.71	801.82	4.90
Among Females	2	508.95	0.04	252.55	91.00	1.53
Among Crosses	11	25028.47	11.20	566887.17	452.14	5.63
Males	3	1144.82	1.15	5315.11	39.61*	0.45
Females	2	11212.70**	6.51*	427818.25**	465.28**	7.26**
Males X Females	6	1555.40**	0.98	68269.44*	55.29**	2.38*
Error	72	294.20	1.24	17370.15	9.08	0.75

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

Table B15. Means squares of combining ability analysis of F2 hybrid at MMRI Yousafwala-1994.

Source	df	Yield per plant (g)	Length of head (cm)	Seeds per head	1000-grain Weight (g)	Threshing %	Maturity Index
Reps	2	6.28	5.79	84012.17	1.31	3.76	11.42
Entries	18	97.56**	51.29**	281275.35**	36.37**	35.71*	243.05**
Males vs Females	1	1291.33	149.12	1828.96	85.59	24.86	1811.23
Parents vs Cross	1	88.09	0.93	36915.60	31.42	51.87	1248.19
Among Males	3	3.11	5.10	66982.84	838.56	143.85	1348.10
Among Females	2	9.91	2.14	17533.39	0.89	0.64	0.88
Among Crosses	11	14.47	52.56	117102.00	98.26	87.64	189.19
Males	2	0.43*	10.19**	36627.03	9.99*	23.01*	14.33**
Females	3	17.41*	25.52**	62900.25	240.46**	25.64*	162.47**
Males X Females	6	2.03*	5.71	165026.58	15.13	25.73**	9.11
Error	72	11.87	7.29	101955.30	11.56	6.48	4.79

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

Table B16. Means squares of combining ability analysis of F2 hybrid at MMRI Yousafwala-1994.

Source	Df	Plant Height (cm)	Leaves per Plant	L A U S L (cm^2)	%GLA 50DAF	Sugar%
Reps	2	29.25	1.67	10489.81	22.22	1.87
Entries	18	4384.03**	3.43**	216795.12**	642.86**	18.64**
Males vs Females	1	6068.56	11.47	1064723.66	2035.24	35.17
Parents vs Cross	1	4465.17	6.17	185127.27	398.00	10.15
Among Males	3	5.04	91.01	13314530.22	1013.15	8.72
Among Females	2	0.71	2.35	535.37	111.38	4.13
Among Crosses	11	113.19	9.39	15371.11	739.99	2.78
Males	3	980.78**	0.24	89028.00*	12.00*	0.54
Females	2	3279.58**	4.75**	309661.96**	142.81**	5.91**
Males X Females	6	3009.77**	1.16	45401.29	36.42	0.29
Error	72	16.44	0.85	17564.95	11.49	0.83

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

Table B17. Estimates of general combining ability effects in F2 generation at two locations-1994.

Parentage	Yield per plant (g)	Length of head (cm)	Seeds per head	1000-grain Weight (g)	Threshing %	Maturity Index
			NARC, ISALAMABAD			
Male						
Pot. 3-9	+0.79	-0.13	+ 31.91	+0.007	+2.11	+6.06
Red Janpur	+0.06	-1.62	+ 12.24	-3.321	+1.85	-0.61
Bagdar	-0.01	+0.98	-117.42	+4.044	-3.65	-3.61
DS-75	-0.86	+0.74	+ 73.24	-0.734	-0.34	-1.72
Female						
ICSV 107	+0.70	+1.92	+ 74.58	-1.488	+0.01	+0.56
ICSV 112	-1.01	+0.41	- 69.17	+1.377	-0.28	+0.22
ICSV 219	+0.30	-2.34	- 5.42	+0.108	+0.16	-0.69
			MMRI, YOUSAFWALA			
Male						
Pot. 3-9	+0.65	+1.39	+ 8.58	+0.604	+1.24	+5.47
Red Janpur	-1.85	-1.72	+ 87.92	-4.726	+1.62	+0.14
Bagdar	+1.38	+1.50	- 11.34	+6.980	-1.81	-4.86
DS-75	-0.18	-1.17	+ 16.92	-2.941	-1.06	-0.75
Female						
ICSV 107	+0.12	+0.97	+ 57.25	-0.537	-1.27	+1.17
ICSV 112	-0.22	-0.86	+ 1.25	+1.054	+1.48	-0.16
ICSV 219	+0.09	-0.11	- 58.75	-0.515	-0.21	-1.00

Table B18. Estimates of general combining ability effects in F2 generation at two locations-1994.

Parentage	Plant Height (cm)	Leaves per Plant	L A U S L (cm^2)	%GLA 50DAF	Sugar%
			NARC, ISALAMABAD		
Male					
Pot. 3-9	+13.71	+0.21	-149.83	+7.06	+0.63
Red Janpur	- 2.98	-0.94	-224.17	-5.68	-0.68
Bagdar	+36.37	+1.06	+189.17	+5.30	+0.89
DS-75	-47.09	-0.35	+184.83	-6.70	-0.87
Female					
ICSV 107	- 6.13	+0.27	+ 19.17	-0.32	-0.22
ICSV 112	- 5.14	+0.06	+ 3.42	-1.65	+0.03
ICSV 219	+51.26	-0.34	- 22.58	+1.95	+0.17
			MMRI, YOUSAFWALA		
Male					
Pot. 3-9	+11.04	-0.71	-185.58	-3.25	+0.85
Red Janpur	+ 2.03	-0.38	-131.58	-3.27	-0.61
Bagdar	+14.47	+0.95	+130.42	+4.85	+0.54
DS-75	-27.53	+0.15	+186.42	+1.68	-0.77
Female					
ICSV 107	+10.34	+0.12	+ 95.17	+1.04	-0.18
ICSV 112	- 6.42	+0.04	- 22.08	-0.96	-0.02
ICSV 219	- 3.92	-0.15	- 73.08	+2.01	+0.21

Table B19. Means of F1 and parents for maturity and nonsenescence traits at NARC Islamabad-1993.

Cross/Parents.	Yield per plant (g)	Length of head (cm)	Seeds per head	1000-grain Weight (g)	Threshing %	Maturity Index
ICSV 107 X Pot.3-9	36.63ab	31.60a	1867a	36.571abc	80.33a	147.00c
ICSV 107 X R/Janpur	32.07d	30.61ab	1942a	28.164efgh	75.24bcd	143.67cd
ICSV 107 X Bagdar	35.50bc	33.25a	1636a	37.000ab	66.69f	132.67h
ICSV 107 X DS-75	34.93bc	29.53abcd	1785a	29.900efgh	66.91f	128.67i
ICSV 112 X Pot.3-9	35.67bc	29.08abcd	1550ab	32.168cdef	74.31cde	137.67efg
ICSV 112 X R/Janpur	31.57dc	25.55d	1522ab	29.066efgh	74.93cde	140.33e
ICSV 112 X Bagdar	36.03ab	31.80a	1410abc	37.810a	64.37f	130.33h
ICSV 112 X DS-75	32.90cd	31.81a	1724a	31.922cdef	68.29ef	128.67i
ICSV 219 X Pot. 3-9	33.60cd	28.15abcde	1631ab	31.922cdef	76.67bcd	147.33c
ICSV 219 X R/Janpur	33.03cd	26.29bcde	1619ab	25.000gh	77.00abc	138.00efg
ICSV 219 X Bagdar	37.60a	31.10ab	1046bc	35.837abcd	71.62def	129.67i
ICSV 219 X DS-75	35.73bc	29.24de	1573ab	28.457efgh	70.65ef	130.67h
ICSV 107	37.36a	31.00ab	1235abcd	28.151efgh	69.48ef	120.00j
ICSV 112	33.20cd	30.90ab	1139abcd	25.585gh	72.17ef	110.33k
ICSV 219	33.00cd	29.60abc	1124abcd	26.861fgh	70.46ef	114.67k
Pot. 3-9	17.60d	21.00ef	552d	34.331bcde	77.63ab	152.20a
Red Janpur	18.73d	15.40f	528d	25.889gh	71.84def	144.33cd
Bagdar	12.53e	17.00f	650cd	36.428abcd	70.27ef	134.00cd
DS-75	20.57d	21.90ef	875bc	26.399fgh	72.17ef	132.00h

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

Table B20. Means of F1 and parents for maturity and nonsenescence traits at NARC Isalamabad-1993.

Cross/Parents	Plant Height (cm)	Leaves per Plant	L A U S L (cm^2)	%GLA 50DAF	Sugar%
ICSV 107 X Pot.3-9	263.76ab	11.63def	3281bc	81.78b	5.60cde
ICSV 107 X R/Janpur	184.90d	13.77bcdef	3135cde	70.79cd	5.00cde
ICSV 107 X Bagdar	248.57abc	14.44abcd	3114bcde	76.80bc	5.70cd
ICSV 107 X DS-75	177.26d	14.08abcdef	3293bc	71.11cd	4.54de
ICSV 112 X Pot.3-9	272.13a	12.79def	2891ef	74.33cd	7.83b
ICSV 112 X Red Janpur	220.66c	14.69abcde	2906def	68.63de	5.39cde
ICSV 112 X Bagdar	200.31c	13.31bcdef	3011cde	72.39cd	7.52b
ICSV 112 X DS-75	160.43d	14.50abcd	2994def	73.91cd	6.40bc
ICSV 219 X Pot.3-9	247.51abc	14.90a	3292bc	88.31a	7.15b
ICSV 219 X R/Janpur	238.87abc	14.10abcdef	3387ab	72.55cd	6.87bc
ICSV 219 X Bagdar	217.94c	15.10a	3513a	73.00cd	7.28b
ICSV 219 X DS-75	172.20d	15.00a	3360ab	73.87cd	7.33b
ICSV 107	172.46d	11.63def	2880ef	74.15cd	12.27a
ICSV 112	166.66d	13.77bcdef	2941ef	69.21de	11.80a
ICSV 219	171.17d	14.26abcdef	3349ab	80.00ab	13.43a
Pot. 3-9	244.77abc	10.05f	2316g	40.71h	3.73c
Red Janpur	232.76bc	13.07cdef	2412g	41.39h	7.27b
Bagdar	240.37abc	13.31bcdef	3169bcde	47.80g	4.00d
DS-75	147.58d	11.03f	2626fg	47.31g	3.20e

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

Table B21. Means of F1 hybrid and parents for maturity and nonsenescence traits at MMRI Yousafwala-1993.

Cross/Parents.	Yield per plant (g)	Length of head (cm)	Seeds per head	1000-grain Weight (g)	Threshing %	Maturity Index
ICSV 107 X Pot.3-9	38.52a	32.64a	2037a	40.073ab	78.35cde	137.83b
ICSV 107 X R/Janpur	34.43bc	31.60ab	1874ab	29.532fgh	79.24bcd	134.33cd
ICSV 107 X Bagdar	38.23a	31.00ab	1738ab	43.720a	66.80f	131.67de
ICSV 107 X DS-75	36.40ab	29.10ab	1849ab	30.015efgh	66.92f	130.67def
ICSV 112 X Pot.3-9	33.70abc	31.30ab	1800ab	34.138cdef	74.32ef	137.00e
ICSV 112 X R/Janpur	35.73abc	26.50cde	1721ab	30.117efgh	74.95def	128.67efg
ICSV 112 X Bagdar	37.83ab	26.60cde	1674abc	43.186a	73.08ef	123.00gh
ICSV 112 X DS-75	36.23abc	29.50abc	1914a	30.401efgh	85.15a	126.67fgh
ICSV 219 X Pot.3-9	34.76abc	30.00ab	1822ab	36.794bcde	79.57bc	130.00def
ICSV 219 X R/Janpur	34.63abc	28.30ab	1861ab	28.212fgh	77.00cde	131.00de
ICSV 219 X Bagdar	35.33abc	32.70a	1213bc	36.196bcde	74.20ef	130.33def
ICSV 219 X DS-75	36.66ab	29.80ab	1739ab	34.273defgh	75.73def	125.67gh
ICSV 107	35.20abc	30.50ab	1247bc	31.443cdefgh	65.60f	115.67h
ICSV 112	36.96ab	30.90ab	1176bc	28.386fgh	70.80f	107.67hj
ICSV 219	34.33bc	30.80ab	1162bc	26.819h	70.47f	107.67hj
Pot. 3-9	19.17d	21.80ef	693d	34.751cdef	74.62def	147.67a
Red Janpur	18.25d	18.10f	555ef	25.642h	69.13f	138.67b
Bagdar	22.13d	17.70f	615d	36.384bcde	66.50g	125.67gh
DS-75	24.78cd	24.40de	900d	26.363h	72.18f	127.33fgh

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

Table B22. Means of F1 hybrid and parents for maturity and nonsenescence traits at MMRI Yousafwala-1993.

Cross/Parents	Plant Height (cm)	Leaves per Plant	L A U S L (cm^2)	%GLA 50DAF	Sugar%
ICSV 107 X Pot.3-9	281.00a	14.00abc	3681a	63.33ef	9.31c
ICSV 107 X R/Janpur	237.00cd	15.00a	3092bc	64.00e	7.10efg
ICSV 107 X Bagdar	256.77b	14.66a	3589a	65.00e	7.80def
ICSV 107 X DS-75	185.33f	14.66a	3465b	65.00e	6.10fg
ICSV 112 X Pot.3-9	269.00a	13.66abc	2855c	60.00f	9.80c
ICSV 112 X R/Janpur	235.67de	13.66abc	2980c	62.00e	6.80fg
ICSV 112 X Bagdar	215.00e	14.33ab	3369bc	61.33f	8.90cde
ICSV 112 X DS-75	157.87h	14.33ab	3630a	64.00e	5.60gh
ICSV 219 X Pot.3-9	249.00c	12.33cd	3763a	63.33ef	8.10d
ICSV 219 X R/Janpur	248.00c	15.14a	3593b	74.45abcd	6.20fg
ICSV 219 X Bagdar	207.33ef	14.33ab	3699a	79.00a	9.10c
ICSV 219 X DS-75	181.00g	14.80a	3718a	77.33ab	6.80fg
ICSV 107	174.00gh	14.80a	3397bc	75.00abcd	13.60b
ICSV 112	167.67g	13.80abc	2950c	70.67de	11.70b
ICSV 219	171.69g	13.33abc	3061bc	70.00de	14.60a
Pot. 3-9	243.33cd	10.33de	2373e	39.66g	3.10h
Red Janpur	227.67de	12.00cd	3443e	41.66g	3.60h
Bagdar	238.83de	13.33abc	3067bc	48.06f	4.40gh
DS-75	151.51h	11.33de	2831c	48.00f	3.70h

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

Table B23. Means of crosses in F2 generation and parents for maturity and nonsenescence traits at NARC Islamabad-1994.

Cross/Parents.	Yield per plant (g)	Length of head (cm)	Seeds per head	1000-grain Weight (g)	Threshing %	Maturity Index
ICSV 107 X Pot.3-9	33.73abc	29.10ab	1523ab	26.031bcdef	77.34abc	143.33ab
ICSV 107 X R/Janpur	32.80bc	24.30bcde	1429abcd	22.984f	75.69abcde	129.00de
ICSV 107 X Bagdar	37.66a	28.67ab	1460abcd	32.852a	73.17abcde	132.66d
ICSV 107 X DS-75	32.00bc	26.73abc	1532ab	28.543abcde	73.01abcde	131.66d
ICSV 112 X Pot.3-9	32.56bc	25.20abcde	1490abc	31.184ab	74.32abcde	137.33c
ICSV 112 X R/Janpur	33.97abc	24.30bcde	1348bcde	28.798abcd	74.95abcde	137.66c
ICSV 112 X Bagdar	30.47c	27.76ab	1222def	33.551a	70.34de	128.66cd
ICSV 112 X DS-75	32.33bc	25.50abcde	1309bcdef	28.331abcdef	78.09abc	131.66d
ICSV 219 X Pot.3-9	36.10ab	21.17def	1317bcdef	30.076abc	78.89ab	138.33c
ICSV 219 X R/Janpur	33.43bc	22.40cdef	1494abc	25.527bcdef	79.03a	132.33d
ICSV 219 X Bagdar	31.90bc	22.36cdef	1200def	32.996a	69.66e	128.66de
ICSV 219 X DS-75	33.13bc	25.83abcd	1613a	28.195abcdef	71.99cde	132.33d
ICSV 107	31.43c	29.17a	1060fg	23.515def	75.89abcde	118.66f
ICSV 112	32.24bc	28.13ab	1256cdef	23.218def	72.19bcde	110.00g
ICSV 219	34.56abc	28.73ab	1150ef	25.537bcdef	71.54cde	112.66g
Pot. 3-9	19.73d	19.10f	687h	32.207a	77.63abc	145.35e
Red Janpur	21.73d	18.70f	651h	25.031cdef	76.94abcde	139.33bc
Bagdar	19.71d	20.77f	756h	33.690a	72.19cde	129.33de
DS-75	20.20d	22.77cdef	869g	22.712f	73.60abcde	125.66c

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

Table 24. Means of crosses in F2 generation and parents for maturity and nonsenescence traits at NARC Islamabad-1994.

Cross/Parents	Plant Height (cm)	Leaves per Plant	L A U S L (cm^2)	%GLA 50DAF	Sugar%
ICSV 107 X Pot.3-9	233.57bc	13.57abcd	2841.70ef	73.82cd	6.00cd
ICSV 107 X R/Janpur	171.90d	12.33bcdef	2707.00f	69.31de	6.73bc
ICSV 107 X Bagdar	266.87a	14.50ab	3445.00a	77.28bc	6.96bc
ICSV 107 X DS-75	165.13d	12.20cdef	3322.00ab	56.88ef	4.70de
ICSV 112 X Pot.3-9	219.93c	13.53abcde	2858.00def	76.34bc	7.93b
ICSV 112 X R/Janpur	224.40c	11.77def	2957.00cde	66.59ef	4.80de
ICSV 112 X Badgar	224.80c	14.10abc	3133.00bc	75.30bc	7.00bc
ICSV 112 X DS--75	172.30d	12.36bcdef	3305.00ab	63.76f	5.63cde
ICSV 219 X Pot.3-9	234.10bc	12.17cdef	3030.30cde	87.45a	6.90bc
ICSV 219 X R/Janpur	241.23abc	11.73def	2843.00ef	63.49f	5.36cde
ICSV 219 X Bagdar	263.93ab	13.23abcdef	3168.70bc	79.74b	7.66b
ICSV 219 X DS-75	167.77d	13.03abcdef	3107.00bcd	55.68ef	6.00cd
ICSV 107	168.23d	14.80a	3091.00bcde	76.27bc	13.16a
ICSV 112	165.70d	14.73a	2940.00cdef	72.30cd	12.20a
ICSV 219	162.33d	14.10abc	3173.00bc	85.78a	12.83a
Pot. 3-9	229.57c	11.23f	2369.00g	38.18h	4.80de
Red Janpur	250.67abc	11.37f	2342.30g	40.10h	4.30c
Bagdar	226.43c	13.37abcdef	2936.00def	52.55g	4.76de
DS-75	154.80d	12.66abcdef	3012.00cde	48.37g	4.63de

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

Table B25. Means of crosses in F2 generation and parents for maturity and nonsenescence traits at MMRI Yousafwala-1994.

Cross/Parents.	Yield per plant (g)	Length of head (cm)	Seeds per head	1000-grain Weight (g)	Threshing %	Maturity Index
ICSV 107 X Pot.3-9	34.10a	31.67a	1526a	31.441cdefg	76.06bcd	139.66b
ICSV 107 X R/Janpur	32.80a	29.67abc	1646a	25.108gh	73.36cde	130.66de
ICSV 107 X Bagdar	34.53a	30.00ab	1342ab	40.588ab	71.19def	126.33fgh
ICSV 107 X DS-75	33.50a	27.00abcd	1090abcd	28.806efgh	72.08def	129.66efg
ICSV 112 X Pot.3-9	34.53a	29.33abce	1098abcd	31.959cdef	73.32cde	135.33c
ICSV 112 X R/Janpur	30.41a	24.67cde	1400ab	29.350defgh	73.52cde	131.00de
ICSV 112 X Bagdar	35.70a	29.67abcd	1266abc	41.099a	78.62ab	125.66gh
ICSV 112 X DS-75	32.93a	27.33abcd	1616a	29.903cdefgh	78.21ab	129.00efg
ICSV 219 X Pot.3-9	34.16a	29.00abce	1436a	34.752bcde	77.67ab	132.66cde
ICSV 219 X R/Janpur	32.06a	26.33bcde	1249abc	27.430fgh	81.29a	130.00e
ICSV 219 X Bagdar	34.73a	30.67ab	1083abcd	35.313abcd	68.09f	124.66h
ICSV 219 X DS-75	33.86a	28.00abce	1376ab	28.537efgh	69.85ef	130.33def
ICSV 107	32.40a	32.27a	1123abcd	27.168fgh	72.71def	117.66i
ICSV 112	31.56a	31.33ab	1150abcd	26.693fgh	72.18def	106.66k
ICSV 219	36.13a	30.00ab	1171abcd	29.243defgh	71.94def	111.66j
Pot. 3-9	19.36b	21.67ef	708cd	35.887abc	77.62abc	146.00a
Red Janpur	20.43b	19.43f	624d	24.056h	73.35cde	134.33cd
Bagdar	19.96b	17.67f	678cd	39.286ab	72.29def	128.66efg
DS-75	21.76b	24.33de	783bc	23.839h	70.24ef	131.00de

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

Table B26. Means of crosses in F2 generation and parents for maturity and nonsenescence traits at MMRI Yousafwala-1994.

Cross/Parents	Plant Height(cm)	Leaves per Plant	L A U S L (cm^2)	%GLA 50DAF	Sugar%
ICSV 107 X Pot.3-9	241.36cd	12.33cd	2888.30bc	80.97abcd	7.93cde
ICSV 107 X R/Janpur	229.66e	12.66bcd	2960.00bc	76.18cde	6.70def
ICSV 107 X Bagdar	247.33c	13.66abc	3448.00a	84.76a	7.80cde
ICSV 107 X DS-75	271.33a	14.20abc	3342.70a	76.53bcde	6.16efg
ICSV 112 X Pot.3-9	256.33b	12.33cd	2850.00bc	72.36e	8.80c
ICSV 112 X R/Janpur	240.66cd	13.00abc	2980.00bc	74.67de	6.93def
ICSV 112 X Bagdar	238.00d	13.66abc	3106.00b	80.79abcd	7.86cde
ICSV 112 X DS-75	187.66f	13.33abc	3345.00a	82.63ab	6.66def
ICSV 219 X Pot.3-9	246.66c	12.33cd	2899.00bc	72.62e	7.80cde
ICSV 219 X R/Janpur	247.00c	12.33cd	2960.00bc	75.05de	6.53def
ICSV 219 X Bagdar	269.33a	14.66a	3031.00bc	84.70a	7.96cd
ICSV 219 X DS-75	169.66g	13.23cd	3076.00bc	81.60abc	6.86def
ICSV 107	172.77g	14.33ab	3046.00bc	76.30cde	13.60a
ICSV 112	169.83g	13.66abc	2943.00bc	74.83de	11.70b
ICSV 219	167.63g	14.00abc	2983.30bc	85.37a	11.93b
Pot. 3-9	236.23de	11.00de	2356.00d	39.50g	5.76fg
Red Janpur	248.30c	15.56e	2397.00d	40.36g	5.50fg
Bagdar	241.30cd	13.33abc	2832.00c	52.31f	4.63gh
DS-75	156.63h	12.66bcd	3025.00bc	50.39f	3.60h

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