GENETICS OF DROUGHT TOLERANCE IN MAIZE (*ZEA MAYS* L) UNDER NON-STRESS AND WATER STRESS CONDITIONS

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DECLARATION

I declare that the work in this thesis entitled "GENETICS OF DROUGHT TOLERANCE IN MAIZE (*ZEA MAYS* L) UNDER NON-STRESS AND WATER STRESS CONDITIONS" has been carried out by me in the Department of Plant Science under the supervision of Prof. S.G. Ado, Prof. D.A. Aba and Dr. S.M. Bugaje. The information derived from the literature has been duly acknowledged in the text and a list of references provided. No part of this thesis was previously presented for another degree or diploma at this or any other Institution.

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Student	Signature	Date

CERTIFICATION

This thesis entitled "GENETICS OF DROUGHT TOLERANCE IN MAIZE (*ZEA MAYS* L) UNDER NON-STRESS AND WATER STRESS CONDITIONS" by Umar Uwais UMAR meets the regulations governing the award of the degree of Master of Science in Plant Breeding of Ahmadu Bello University, and is approved for its contribution to scientific knowledge and literary presentation.

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DEDICATION

To Allah (S.W.T) for wisdom, sound health, favour, guidance and protection during the course of the study and throughout my life and His noble Prophet Muhammad (Peace be upon Him). To the memory of my late father Alhaji Umar Uwais, may his soul continue to rest in perfect peace and may *Aljannah firdausi* be his final abode, ameen and my mother Hajiya Maimuna Hassan for her motherly care, love, guidance, support and prayers, I pray may Almighty Allah give her long life and prosperity, ameen.

ABSTRACT

The genetics of drought tolerance in maize was studied using seven drought susceptible maize inbred lines as female parents and six drought tolerant maize inbred lines as male parents, which were mated in a North Carolina Design II fashion. The resultant 42 F_1 hybrids, 13 parents and a check were evaluated at Samaru and Kadawa under non-stress, intermediate stress and severe water stress conditions in 2012/2013 dry season to determine their genetic variability, character association, combining abilities, heritability and heterosis. Significant differences were observed among genotypes for most of the traits studied under the different moisture conditions. Genotype x location interaction was also significant for most of the traits studied. The top performing hybrids for grain yield across locations were S3 x P3 (5878kg/ha) under non-stress and S7 x P8 (3389kg/ha and 2111kg/ha) under intermediate and severe stress conditions, respectively. Overall, the grain yield was reduced by 45% under intermediate stress and 70% under severe stress of what the average yield would have been under non-stress condition across the locations. High values of both genotypic and phenotypic coefficients of variation were obtained for grain yield, leaf senescence, anthesis-silking interval and number of ears per plant under the non-stress and water stress conditions. Moderate to high broad sense heritability were observed for all the traits studied. The broad sense heritability for days to 50% tasseling, days to 50% silking and grain yield decreased with increasing stress whereas, the heritability of anthesis-silking interval, plant height, ear height, leaf senescence and number of ears per plant increased with increasing stress. Narrow sense heritability was low for all the traits under the different conditions and ranged from 2.89% to 20.48%, 4.11% to 16.91% and 1.95% to 14.88% under non-stress, intermediate and severe stress conditions across locations, respectively. Days to 50% tasseling, days to 50% silking and anthesis-silking interval

were negatively correlated with grain yield while plant height, ear height and number of ears per plant were positively correlated with grain yield under the different conditions. Combining ability analysis showed that both additive and dominance gene actions were important for the inheritance of all the traits. The comparative variance due to additive and dominance revealed predominance of dominance gene action for all the traits studied. The ratio of additive to dominance variance portrays the importance and the predominance of dominance genetic effects as all the ratios were less than unity. The GCA status of parents revealed that S7 among females and P8 among males as good general combiners for grain yield and other traits. Among the 42 hybrids, only S7 x P8 exhibited the highest positive SCA effects and high parent heterosis for grain yield of 58.33%, 68.79% and 133.33% under severe, intermediate and non-stress conditions across the locations, respectively. These findings will be useful in planning maize breeding programmes for drought tolerance.

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CHAPTER ONE

1.0 INTRODUCTION

1.1 Preamble

Maize or corn (*Zea mays* L.; 2n=20), belongs to the grass family Poaceae and tribe Maydeae, originated 5,000 to 10,000 years ago (Paliwal and Smith, 2002). It is believed to have originated in the mid-altitude regions of Mexico and Guatemala or Mesoamerica (Paliwal and Smith, 2002). It is a monoecious tall annual plant with the male inflorescence, the tassel, forms at the top of the stem. It forms a seasonal root system bearing a single erect stem made up of nodes and short internodes and the ears arise from axillary bud apices. The ear is covered in a number of leaves called husks. The thick axis of the ear, the cob, bears an even number of rows of ovaries; each containing a single ovule (Farnham *et al*., 2003). Maize is one of the three most important cereal crops in the world together with wheat and rice. In industrialized countries, it is largely used as livestock feed and as raw material for industrial products, while in developing countries, it is mainly used for human consumption. Africans consume maize as a starchy base in a wide variety of porridges, pastes, grits, and beer. In sub-Saharan Africa, it is a staple food for an estimated 50% of the population. It is an important source of carbohydrate, protein, iron, vitamin B, and minerals. It is fast becoming a very important commodity in animal feed, food and beverage industries (USAID, 2010).

Maize is cultivated worldwide in an area of 159 million hectares with a production of 796.46 million metric tons (USDA, 2010). Maize production in Africa was estimated to be 41.6 million metric tons of which 27.7 million metric tons was produced in sub-Saharan Africa. The United States was the world's largest producer and exporter of

maize in 2003-2004 with the production put at 256 million metric tons (USDA, 2005). Other top producing countries include China, Brazil, Mexico, Argentina, India and France. Nigeria is the 10th largest producer of maize in the world, and the main producing country in tropical Africa (USAID, 2010).

1.2 Statement of the Problem

Maize has high potential for production and productivity in the savanna ecology of sub-Saharan Africa due to high solar radiation and low night temperatures (Undie *et al*., 2012). Despite the potential of the crop in the savanna ecology and the level of adaptation that maize displays, low yields are still obtained due to biotic and abiotic stresses. Biotic factors limiting maize production include insect pests, diseases, and parasitic weeds. The most important abiotic stresses limiting maize production are drought and low soil fertility, and these two are among the most important stresses threatening maize production, food security and economic growth in sub-Saharan Africa (Kamara *et al*., 2004). Drought remains the most important constraint to maize production and losses in maize yield of about 15% each year has been attributed to it in Sub-Saharan Africa (Badu-Apraku *et al*., 2005). Therefore, the need for breeding high yielding maize tolerant to drought conditions is very important.

1.3 Justification

The knowledge of the genetic make-up of complex quantitative traits and the magnitude of genetic variability that exists among available germplasm are important for breeding of high yielding drought tolerant maize genotypes. Thus, information regarding heterosis, combining ability and nature of gene action governing the inheritance of desirable traits is a basic requirement for breeding drought tolerant maize genotypes. It

is also important to be familiar with inter-relationships between yield and other traits among parental lines and hybrids.

1.4 Aim and Objectives

The main aim of this research work was to provide information for planning maize breeding programs for drought stress environments. The specific objectives were:

1. To estimate genetic variability and character association for grain yield and other traits under non-stress and water stress conditions.
2. To estimate general and specific combining ability effects of parents and crosses for grain yield and other traits under non-stress and water stress conditions.
3. To estimate heritability of grain yield and other traits under non-stress and water stress conditions.
4. To estimate heterosis of grain yield and other traits under non-stress and water stress conditions.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Drought Stress Conditions

Global climate change is now generally considered to be underway (Hillel and Rosenzweig, 2002), and is expected to result in a long-term trend towards higher temperatures, greater evapo-transpiration, and an increased incidence of drought in specific regions. Drought is an environmental condition caused by lack of rainfall and it is a multidimensional stress affecting plants at various levels of their organisation (Yordanov *et al.*, 2000). Drought can occur both above ground (atmospheric drought) and below ground (soil drought). The duration of drought is variable, sometimes lasting for a short time and without severe adverse physiological impact, sometimes lasting throughout an entire growing season or even years, resulting in complete devastation of crops. It is responsible for severe food shortages and famine in developing countries (Acquaah, 2007). Drought incidents are predicted to increase due to long term effects of global warming (Cook *et al*., 2007). Drought is believed to be one of the most important environmental factors that reduce growth, development and production of plants. It can be said that it is one of the most devastating environmental stresses (Khodarahmpour, 2012). Most tropical maize is produced under rain-fed conditions, in areas where drought is widely considered to be the most important abiotic constraint to production (Pingali and Pandey, 2000).

2.2 Effect of Drought Stress on Maize

Drought may occur at any stage of maize growth, but when it coincides with the flowering and grain filling periods it causes yield loss of 40-90% (Menkir and Akintunde, 2001). Drought at flowering may cause significant flower drop and low fruit

set. Similarly, when drought occurs at fruiting, there will be fruit drop and/or partially filled or shrivelled fruits. In the end, both quality and product yield will be decreased (Acquaah, 2007). Betran *et al*. (2003a), reported yield reduction of 13% and 50% under intermediate and severe drought stress, respectively, in one side and of 5% and 48% in another site during the same season. On the other hand, Banziger *et al*. (2000) reported yield reductions of under drought stress at flowering of 80-85% and under drought stress at grain filling of 50%. Flowering in maize is a crucial trait in breeding for drought tolerance. When maize flowers under drought, there is delay in silking and the period between male and female flowering increases giving rise to anthesis silking interval (ASI).

Studies done by Banziger *et al*. (1999) showed that high grain yield under a range of stress intensities was associated with a short ASI and earlier flowering dates, increased plant and ear height, increased number of ear per plant and delayed leaf senescence (Edmeades *et al*., 1999). Drought stress affects maize productivity most, when it occurs during the two weeks of the flowering period (Bolanos and Edmeades, 1996). In segregating genotypes under drought, lengthening of ASI period is an indicator of poor tolerance to drought stress. Richards (2006) reported that drought susceptible genotypes allocate less assimilate toward ear growth when the ears are quite small and this is well indicated by a delay in silking. According to Chapman and Edmeades (1999), recurrent selection for low ASI, small tassels and delayed senescence resulted in increased partitioning to early ear growth and high grain yields.

2.3 Genetic Variability under Drought Conditions

Genetic variability is a prerequisite for improvement in any breeding programme. Betran *et al.* (2003b) observed higher variability for anthesis-silking interval and number of ears per plant under stress versus non-stress conditions. Hussain *et al.* (2009) studied maize inbred lines under normal and drought conditions and reported significant differences among all lines for all characters studied. Saleem *et al*. (2011) also reported significant differences for number of days taken to 50% tasseling, number of days taken to 50% silking, number of ears per plant and 100-grain weight in maize under irrigated and drought conditions. Mhike *et al*. (2011a) reported significant differences in an across site analysis for environments, genotypes and genotype x environment interactions in maize under stress and non-stress conditions.

The extent of variability is measured by Genotypic Coefficient of Variation (GCV) and Phenotypic Coefficient of variation of Variation (PCV) which provides information about relative amount of variation in different characters. According to Roychowdhury and Tah (2011) the extent of variability is measured by GCV and PCV which provides information about relative amount of variation in different traits studied. Chaudhary (2001) found that GCV is not an absolute mean to know the heritable diversity present and should be considered together with heritability evaluations. A study of genetic diversity with suitable measured like GCV and heritability evaluations are essential to have an applicable breeding program (Al-Tabbal and Al-Fraihat, 2012). Bolanos and Edmeades (1996) suggested the use of secondary traits of adaptive value whose genetic variability increases under drought and could increase selection efficiency. They reported that genetic variances for grain yield, number of kernels per ear and kernel weight decreased with increasing drought, but those of anthesis-silking interval and

number of ears per plant increased. They concluded that secondary traits are not lacking genetic variability within the elite maize populations, but their correlation with grain yield tend to be low (Bolanos and Edmeades, 1996).

2.4 Heritability of Traits under Drought Conditions

Heritability provides an idea to the extent of genetic control for expression of a particular trait and the reliability of phenotype in predicting its breeding value (Tazeen *et al*., 2009). Heritability is further divided into broad sense and narrow sense, depending whether it refers to the genotypic value or breeding value, respectively. The ratio of genetic variance to phenotypic variance is called heritability in the broad sense. It expresses the extent to which individual phenotypes are determined by the genotypes. On the other hand, the ratio of additive variance to phenotypic variance is called heritability in the narrow sense. This expresses the extent to which phenotypes are determined by the genes transmitted from the parents. It also expresses the magnitude of genotypic variance in the population, which is mainly responsible for changing the genetic composition of a population through selection. High heritability indicates less environmental influence in the observed variation (Songsri *et al*., 2008). High heritability for a given trait also indicates that it is governed by additive gene action and, therefore, provides the most effective condition for selection (Tazeen *et al*., 2009).

Characters that are controlled largely by genes acting in an additive fashion have higher values of heritability than characters governed by genes with large non-additive effects (Dabholkar, 1992). According to this author, it is important to note that heritability is a property not only of the character being studied, but also the population being sampled and the environmental circumstances to which individuals have been subjected. More

variable environmental conditions reduce the magnitude of heritability while more uniform conditions increase it (Rosielle and Hamblin, 1981). Furthermore, in predicting response to selection, heritability estimates are used to identify optimum environments for selection (Singh and Ceccarelli, 1995). Whether direct or indirect selection is superior depends upon the heritability of the selected trait in stress and non-stress environments and the genetic correlation between stress and non-stress environments (Zavala-Garcia *et al*., 1992). However, many investigators reported a decline in heritability for grain yield under water stress conditions (Rosielle and Hamblin, 1981).

A number of reports on heritabilities are available for different traits of maize under drought stress. Bolanos and Edmeades (1996) reported broad sense heritability for grain yield of around 0.60, but fell to values near 0.40 at very low grain yield levels. They reported anthesis-silking interval as a highly heritable trait, and further concluded that secondary traits are valuable adjuncts in increasing the efficiency of selection for grain yield when broad-sense heritability of grain yield is low. It should be kept in mind that the estimate of heritabilities applies only to environments sampled (Hallauer and Miranda, 1988; Dabholkar, 1992). Thus, when planning to improve a locally available elite population, in addition to determining variability, priority should be given to estimation of heritabilities of the stress tolerant traits under targeted environmental conditions.

2.5 Correlation of Traits under Drought Conditions

Grain yield of plant is the net result of several genetic factors and their individual or combined interplay with environmental factors. Therefore, character association among themselves or with grain yield is of importance. It provides information that selection

for one trait will result in progress for all positively correlated characters. When there is positive association of major yield characters, component breeding would be very effective but when these characters are negatively associated, it would be difficult to exercise simultaneous selection for them in developing a variety (Nemati *et al*., 2009). Bolanos and Edmeades (1996) found genetic correlations between grain yield and anthesis-silking interval or number of per plant to be weak under well watered conditions, but approached -0.60 and 0.90, respectively under severe moisture stress. Jadhav *et al.* (1991) reported that grain yield was significantly and positively correlated with plant height, 100-kernel weight and leaves per plant.

Correlation coefficients indicated that grain yield of water stressed maize was significantly influenced by number of leaves, ear height, anthesis-silking interval, plant height and grains per row (Biasutti and Peiretti, 1992). Subba Rao (1992) reported that grain yield per plant exhibited significant positive correlation with plant height, ear height and all the yield components, whereas negative association was observed with days to 50 per cent tasseling, days to 50 per cent silking and wilt ratings at seedling stage. Phenotypic correlations between grain yield and days to tasseling and silking were mostly negative in both inbreds and hybrids under both stress and non-stress environments (Betran *et al*., 2003b). Mohammad *et al*. (2003) also determined the interrelationship between grain yield and its components from eighteen maize lines and hybrids, using genotypic correlation and path coefficient analysis. Grain yield was positively and significantly associated with plant and ear height, ear diameter, number of grains ear^{-1}, number of grains row^{-1} and 1000-grain weight. Tollenaar *et al.* (2004) and El-Shouny *et al.* (2005) identified different traits like ear length, ear diameter,

kernels per row, ears per plant, 100-seed weight and rows per ear as potential selection criteria in breeding programmes aiming at higher yield in maize.

2.6 Combining Ability and Gene Action under Drought Conditions

Combining ability studies provide information on the genetic mechanisms controlling the inheritance of quantitative traits and enable the breeders to select suitable parents for further improvement or use in hybrid breeding for commercial purposes. In biometrical genetics two types of combining abilities are considered i.e. general combining ability (GCA) and specific combining ability (SCA). GCA refers to the average performance of the genotype in a series of hybrid combinations and is a measure of additive gene action whereas SCA is the performance of a parent in a specific cross in relation to general combining ability (Sharief *et al*., 2009). SCA is due to genes showing non-additive effects. Selection of parents based on combining ability has been used as an important breeding approach in crop improvement. Developing of high yielding hybrids along with other favourable traits is receiving considerable attention.

The combining ability and gene effects of yield and its components under non-stress and water stress conditions were studied by several researchers. Basbag *et al.* (2007) suggested that combining ability analysis is an important tool for selection of desirable parents together with the information regarding nature and magnitude of gene action controlling quantitative traits. Aminu *et al*. (2014) reported significant differences of general combining ability (GCA) effects of parents and that of specific combining ability (SCA) effects of hybrids for grain yield and other agronomic traits and that both additive and non-additive gene effects controlled most traits, but non-additive genetic effect was more prevalent. Majid *et al*. (2010) showed both additive and dominance

variances were important for grain yield and other traits under drought stress conditions and that the ratios of GCA to SCA variances were less than unity for all studied traits which showed the predominant role of non-additive gene action in the inheritance. Aminu and Izge (2013) also reported that both additive and non-additive gene actions were responsible for the control of traits evaluated but the effects of non-additive genetic actions were preponderant in respect of the genetic control of grain yield and yield component traits. Shahrokhi *et al.* (2013) also showed the importance of dominance relative to additive genetic effects in maize.

Mhike *et al*. (2011a) reported significant GCA effects for all the traits measured except plant height and stem lodging with five lines identified as having good GCA effects for grain yield and non-additive genes were also predominant in most traits except for anthesis date, anthesis-silking interval and ear height. Atif *et al*. (2012) reported that both GCA and SCA variances were highly significant for most of the characters studied indicating importance of additive as well as non-additive types of gene action in controlling the traits. Moreover, variances due to SCA were higher in magnitude than GCA for yield and yield components except cob diameter, number of rows/cob, number of kernels/row and harvest index. GCA to SCA ratios were less than one for most of the traits except cob diameter, number of kernel rows/cob, number of kernels/row and harvest index indicating preponderance of additive over non-additive gene action. Badu-Apraku *et al*. (2013) reported gene action controlling grain yield and most other traits to be predominantly non-additive.

Hussain and Ali (2014) reported that dominance genetic variance was greater than additive genetic variance for all characters studied, which depicts the importance of

dominance gene effect for controlling these characters. Betran *et al.* (2003b) reported that under drought, additive effects were more important and the importance of additive effects increased with intensity of drought suggesting the need for drought tolerance in both parental lines to achieve acceptable hybrid performance under severe drought. Fu *et al.* (2008) reported that dominance effect was more important than additive effect for plant height, anthesis-silking interval, root weight, and the grain yield per plant, whereas, they were about equal for leaf emergence rate. The variances of SCA were about double that of the GCA for plant height, ASI and grain yield per plant.

2.7 Heterosis under Drought Conditions

Shull coined the term 'heterosis' in 1908 and interpreted it as increase in vigour, size, fruitfulness, speed of development, resistance to diseases and pests which is manifested by crossbred organisms as compared with corresponding inbreds as the specific results of unlikeness in the constitution of uniting gametes. Heterosis has been exploited in many cross pollinated crops especially maize. Breeding for enhanced drought tolerance is the most economical way of reducing the effect of drought on grain yield of maize. One approach to improve drought tolerance in different crop species is to utilize heterosis based on the principle that heterosis for yield and yield components may increase under water stress conditions. Heterosis works as a basic tool for improved production of crops in the form of F_1 hybrids. Plant breeders have widely exploited and used heterosis in boosting up yield of many crops.

In maize (Betran *et al*., 2003a) and pearl millet (Yadaw *et al*., 2000), high estimates of hybrid vigour for yield have been obtained under stress conditions. In barley, it has been observed that heterozygosity rather than heterogeneity was important for grain yield

under drought stress environment (Einfeldt *et al*., 2005). Betran *et al.* (2003a) observed greater expression of heterosis under drought stress than under non-stress environments. In a non-stress environment, Lata *et al.* (2008) reported high heterosis for grain yield and early maturity. On the other hand higher parent heterosis is usually taken into cognizance especially when the goal is to identify a better hybrid superior to either of the parents (Kurawa, 2012). For grain yield/plant, heterosis over better parent was found in the range of 8.23 to 25.78 percent (Uddin *et al.*, 2006). Aminu *et al*. (2014) reported higher values of high parent heterosis in terms of grain yield of maize under drought condition and that very high level of higher parent heterosis is considered advantageous for drought tolerance and yield improvement. Yield superiority of some hybrids over the higher parents suggested the possibility of their commercial exploitation.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Geographical Locations of Experimental Sites

The research was conducted at the Research Farm of the Institute for Agricultural Research (IAR), Ahmadu Bello University (ABU), Samaru-Zaria ($11^{o}11'$N, $07^{o}38'$ E and 686 m above sea level) in the northern Guinea savannah ecological zone of Nigeria (A.B.U., 2013) The second site was the Irrigation Research Station of IAR/ABU, Kadawa ($11^{o}39'$N, $08^{o}027'$E and 500 m above sea level) in the Sudan savannah ecological zone of Nigeria (Olanuga, 1979).

3.2 Genetic Materials

The genetic materials used in this study comprised of seven maize inbred lines designated as S1, S2, S3, S4, S5, S6, and S7 used as female parents and six drought tolerant maize inbred lines designated as P1, P2, P3, P4, P7 and P8 used as male parents. The female inbred lines were developed at IAR, Samaru and the male inbred lines were obtained from International Institute of Tropical Agriculture (IITA), Ibadan. The inbred lines, pedigree, source and descriptions are presented in Tables 3.1.

3.3 Development of Population

Both inbred lines were sown on 15th September, 2012 at the Research Farm of IAR at Samaru, Zaria using a staggered planting pattern of one week interval in order to synchronize the flowering and obtain adequate pollen for subsequent pollinations. The staggered planting was done on 22nd September, 2013. Each female line was crossed to the six male inbred lines and a total of forty two (42) single cross hybrids were generated from the seven female and six male inbred lines in a North Carolina mating design II (Comstock and Robinson, 1948).

Table 3.1 Description of genetic materials

S/n	Inbred line	Pedigree	Source	Parent	Description
1	S1	Acr97TZLComp1-W-S-S-S-S-S	IAR	Female	White grain with yield of 2.2 tons/ha and *Striga* resistant.
2	S2	TZEE-W-S-S-S-S-S	IAR	Female	White grain with yield of 1.8 tons/ha
3	S3	95TZEE-Y-S-S-S-S-S	IAR	Female	Yellow grain with yield of 1.8 tons/ha
4	S4	$IWDC_2SYNF_2$-S-S-S-S-S	IAR	Female	White grain with yield of 1.8 tons/ha, adapted to the *Striga hermonthica* prone zones and tolerant to maize streak virus.
5	S5	TZLComp1Syn W-S-S-S-S-S	IAR	Female	White grain with yield of 2.0 tons/ha, adapted to *Striga hermonthica* prone zones and is tolerant to maize streak virus.
6	S6	Tillering Maize-S-S-S-S-S	IAR	Female	White grain with yield of 2.7 tons/ha, tolerant to *Striga hermonthica* and maize streak virus.
7	S7	TZEComp3-S-S-S-S-S	IAR	Female	White grain with yield of 1.6 tons/ha and tolerant to maize streak virus.
8	P1	P43SRC9FS100-1-1-8-#1-B1-13-B1-B-B-B-B-B-B-B-B	IITA	Male	White grain with yield of 2.6 tons/ha and drought tolerant.
9	P2	1368×H1×4269-1×1368-7-2-B-B-B-B-B	IITA	Male	White grain with yield of 2.0 tons/ha and drought tolerant.
10	P3	9071-B-B-B	IITA	Male	White grain with yield of 1.9 tons/ha and drought tolerant.
11	P4	(TZM1501×KU1414×501)-1-4-3-1-B-B-B-B-B-B-B-B	IITA	Male	White grain with yield of 2.9 tons/ha and drought tolerant.
12	P7	1368×1CAL224-1×1368-3-1-B-B-B-B-B-B-B-B-B-B-B	IITA	Male	White grain with yield of 1.6 tons/ha and drought tolerant.
13	P8	TZL-COMP3-C2-S2-34-4-1-2-B-B-B-B-B-B-B	IITA	Male	White grain with yield of 2.1 tons/ha and drought tolerant.

3.4 Experimental Procedures

All experimental fields were harrowed and ridged after which sowings were done on 16 and 18 February, 2013 at Kadawa and Samaru, respectively. Each plot consisted of 1 row of 3m long with inter and intra row spacing of 0.75m and 0.25m, respectively and the plots were furrow irrigated after planting. Two seeds were sown in a hill and thinned to one plant per hill after emergence. Fertilizer was applied at the recommended rates of 120-60-60 kg N, P_2O_5 and K_2O per hectare using NPK 15:15:15 compound fertilizer. Half of the N and all of the P_2O_5 and K_2O were applied two weeks after sowing (WAS) and the remaining half of N was side placed at 4 WAS using Urea (46%). Weed control were done manually three times at each location at two, four and six WAS. The 42 F_1 hybrids, 13 parental lines along with a commercial check (Oba 98) obtained from Premier Seed Company making a total of 56 entries were laid in a 7 x 8 simple lattice design with two replications. They were evaluated under the following three environmental conditions during the dry season of 2012/2013 at each site:

1. Non-stress (NS): continued to receive irrigation water once every week until physiological maturity.
2. Intermediate stress (IS): water stress was imposed by withdrawing irrigation water as from 6 WAS until the end of the growing season, to ensure drought stress at grain filling stage. The crop was allowed to mature only on stored soil water.
3. Severe stress (SS): water stress was imposed by withdrawing irrigation water as from 5 WAS to ensure drought stress at flowering stage. Because the average anthesis-silking interval (ASI) was between 3-5 days at Samaru, an additional irrigation was applied at 14 days after the end of male flowering to ensure that the small amounts of grains formed were filled adequately according to Banziger *et al*. (2000).

Apart from the targeted stress, the management of the trials was the same in all the three environmental conditions. Irrigation water was applied uniformly to field capacity once every week to each of the three environmental conditions during the first 5 WAS. The three environmental conditions were separated from each other by 2.5m alley to prevent spill-over at the water stress sites during the period of imposed water stress. Non experimental lines were planted at the beginning and end of each replication to minimize the edge effects.

3.5 Data Collection

Data were collected on the following traits:

1. Days to 50% tasseling (DYTS): The number of days from sowing to when about half of the plants in a plot have shed pollen.
2. Days to 50% silking (DYSK): The number of days from sowing to when about half of the plants in a plot produced silks.
3. Anthesis silking interval (ASI): The difference in number of days between 50% silking and 50% tasseling.
4. Plant height (PLHT) (cm): This was obtained by measuring the height of six randomly plants per plot from the soil level to the base of the tassel with a metre rule and the average recorded.
5. Ear height (EHT) (cm): This was obtained by measuring from the soil level to the node bearing the top most ear of six randomly selected plants per plot and the average recorded.
6. Leaf senescence (SEN): This was scored after flowering under intermediate and severe stress only on a scale of 1 to 10. A score of 1 = 10% and 10 = 100% dead leaf area (Bänziger *et al*., 2000).

7. Number of ears per plant (EPP): This was obtained by counting the number of ears harvested from each plot divided by the number of plants in the plot.
8. Grain yield (GY) (kg/ha): Harvested cobs were threshed and weighed per plot and later converted to grain yield per hectare using the relation below:

$$\text{Grain yield (kg/ha)} = \frac{\text{Grain yield (kg/plot)} \times 10{,}000\ m^2}{\text{Plot size } (m^2)}$$

3.6 Statistical Analyses

3.6.1 Analyses of variance for simple lattice design

The data collected were subjected to both separate and combined analyses of variance (ANOVA) using individual plot means. All statistical analyses were computed using the generalised linear model (GLM) procedure of the Statistical Analysis System (SAS Institute, 2004). Mean comparison was done using Duncan Multiple Range Test (DMRT) according to Gomez and Gomez (1984). The form of the ANOVA and expected mean squares (EMS) for one location and combined across locations are shown in Tables 3.2 and 3.3.

Table 3.2 Form of ANOVA and EMS of simple lattice design for one location

Source of variation	df	MS	EMS
Block(Replication)	$r(b-1)$		
Replications	$(r-1)$		
Genotypes	$(g-1)$	MS_g	$\sigma_e^2 + r\sigma_g^2$
Error	$g-(rb-1)$	MS_e	σ_e^2

For the individual location, variance components were computed from mean squares and expected mean squares as follows:

$$\sigma_g^2 = \frac{MS_g - MS_e}{r}$$

$$\sigma_e^2 = MS_e/r$$

$$\sigma_{ph}^2 = \sigma_g^2 + \sigma_e^2$$

MS_g = mean squares due to genotypes

σ_g^2 = genotypic variance

MS_e = error mean square

σ_e^2 = error variance

σ_{ph}^2 = phenotypic variance

g = number of genotypes

r = number of replications

b = number of blocks

Table 3.3 Form of ANOVA and EMS of simple lattice design across locations

Source of variation	df	MS	EMS
Locations	$(l-1)$		
Block(Location x Rep)	$rl(b-1)$		
Replications (locations)	$l(r-1)$		
Genotypes	$(g-1)$	MS_g	$\sigma_e^2 + r\sigma_{gl}^2 + rl\sigma_g^2$
Genotypes × locations	$(g-1)(l-1)$	MS_{gl}	$\sigma_e^2 + r\sigma_{gl}^2$
Error	$gl-2(rb-1)$	MS_e	σ_e^2

For the combined locations, variance components were computed from mean squares and expected mean squares as follows:

$$\sigma_g^2 = \frac{MS_g - MS_{gl}}{rl}$$

$$\sigma_{gl}^2 = \frac{(MS_{gl} - MS_e)/r}{l}$$

$$\sigma_e^2 = MS_e/rl$$

$$\sigma_{ph}^2 = \sigma_g^2 + \sigma_{gl}^2 + \sigma_e^2$$

MS_{gl} = mean squares due genotype x location

σ_e^2 = error variance

MS_g = mean squares due to genotypes

σ_g^2 = genotypic variance

σ_{gl}^2 = genotype x location variance

MS_e = error mean square

r = number of replications

g = number of genotypes

l = number of locations

σ_{ph}^2 = phenotypic variance

b = number of blocks

3.6.2 Estimation of genetic variability parameters and heritability

Phenotypic and genotypic coefficients of variation as well as broad sense heritability were computed using the formulae given by Singh and Chaudhary (1985).

(a) Phenotypic coefficient of variation (P.C.V %) = $\frac{\sqrt{\sigma^2_{ph}}}{\overline{X}} \times 100$

(b) Genotypic coefficient of variation (G.C.V %) = $\frac{\sqrt{\sigma^2_{g}}}{\overline{X}} \times 100$

GCV and PCV values were classified as low (<10%), moderate (10-20%) and high (>20%) as indicated by Siva-Subramanian and Menon (1973).

(c) Broad sense heritability $(h^2_b\%) = \frac{\sigma^2_g}{\sigma^2_{ph}} \times 100$

Where; σ^2_{ph} = phenotypic variance σ^2_g = genotypic variance

$\overline{X}$ = mean of the character

(d) Narrow sense heritability was calculated using (Grafius *et al*., 1952) formula:

$$h^2_{ns}(\%) = \frac{\sigma^2_f + \sigma^2_m}{\sigma^2_f + \sigma^2_m + \sigma^2_{fm} + \sigma^2_e / r} \times 100$$

Where: σ^2_e = error variance σ^2_f = genetic variance of female

r = number of replication σ^2_m = genetic variance of male

σ^2_{fm} = genetic variance of females x males

The heritability values were classified as low (<30%), moderate (30-60%) and high (>60%) according to Johnson *et al*. (1955).

3.6.3 Estimation of correlation coefficients

Pearson's correlation coefficients were estimated using the formula given by Singh and Chaudhary (1985) as:

$$r_{xy} = \frac{Cov(xy)}{\sqrt{var(y)\,x\,var(x)}}$$

Where: $cov(xy)$ = covariance of traits x and y $var(x)$ = variance of trait x

$var(y)$ = variance of trait y

3.6.4 Analysis of variance for design II and combining ability variances

3.6.4.1 Analysis of variance for design II

In the ANOVA for design II, hybrids were partitioned into general combining ability due to female (GCA_f), general combining ability due to male (GCA_m) and specific combining ability (SCA) mean squares for each location and combined across locations. The analysis for design II for one location was based on the following statistical model:

$$Y_{ijk} = \mu + m_i + f_j + (mf)_{ij} + r_k + e_{ijk}$$ (Singh and Chaudhary, 1985)

Where: Y_{ijk} = observation made on ixjth progeny in the kth replication

μ = general mean m_i = GCA effect of the ith male

f_j = GCA effect of the jth female $(mf)_{ij}$ = SCA effect of ixjth progeny

r_k = replication effect e_{ijk} = experimental error

The form of the ANOVA for design II and EMS for one location is shown Table 3.4

Table 3.4 Form of ANOVA for design II and EMS for one location

Source of variation	df	MS	EMS
Replication	$(r-1)$		
GCA_f	$(f-1)$	MS_f	$\sigma_e^2 + r\sigma_{fm}^2 + rm\sigma_f^2$
GCA_m	$(m-1)$	MS_m	$\sigma_e^2 + r\sigma_{fm}^2 + rf\sigma_m^2$
SCA	$(m-1)\ (f-1)$	MS_{fm}	$\sigma_e^2 + r\sigma_{fm}^2$
Error	$(r-1)\ (fm-1)$	MS_e	σ_e^2

MS_f =mean squares due GCA_f σ^2_f =variance due to GCA_f

MS_m=mean squares due GCA_m σ^2_m=variance due to GCA_m

MS_{fm}=mean squares due to SCA σ^2_{fm} =variance due to SCA

f=number of females m=number of males

r=number of replications

The analysis for design II combined across locations was based on the following statistical model:

$$Y_{ijkl} = \mu + m_i + f_j + (mf)_{ij} + s_l + m_{il} + f_{jl} + (mf)_{ij,l} + r_{kl} + e_{ijkl}$$ (Kang, 1994)

Where: Y_{ijkl}=observation made on ixj^{th} progeny in the k^{th} replication at the l^{th} location

μ =general mean m_i =GCA effect of the i^{th} male

f_j =GCA effect of the j^{th} female s_l = effect of l^{th} location

$(mf)_{ij}$ =SCA effect of ixj^{th} progeny e_{ijkl} =experimental error

r_{kl} = effect of k^{th} replication in the l^{th} location

m_{il} =GCA effect of the i^{th} male in l^{th} location

f_{jl} =GCA effect of the j^{th} female in l^{th} location

$(mf)_{ij,l}$ =SCA effect in the l^{th} location

The form of combined ANOVA for design II and EMS across locations is shown Table 3.5

Table 3.5 Form of combined ANOVA for design II and EMS across locations

Source of variation	df	MS	EMS
Location	$(l-1)$		
Replication (location)	$l(r-1)$		
GCA_f	$(f-1)$	MS_f	$\sigma_e^2 + r\sigma_{lfm}^2 + rl\sigma_{fm}^2 + rlm\sigma_f^2$
GCA_m	$(m-1)$	MS_m	$\sigma_e^2 + r\sigma_{lfm}^2 + rl\sigma_{fm}^2 + rlf\sigma_m^2$
SCA	$(m-1)(f-1)$	MS_{fm}	$\sigma_e^2 + r\sigma_{lfm}^2 + rl\sigma_{fm}^2$
GCA_f x location	$(f-1)(l-1)$	MS_{lf}	$\sigma_e^2 + r\sigma_{lfm}^2 + rm\sigma_{lf}^2$
GCA_m x location	$(m-1)(l-1)$	MS_{lm}	$\sigma_e^2 + r\sigma_{lfm}^2 + rf\sigma_{lm}^2$
SCA x location	$(f-1)(m-1)(l-1)$	MS_{lfm}	$\sigma_e^2 + r\sigma_{lfm}^2$
Error	$l(r-1)(fm-1)$	MS_e	σ_e^2

MS_f =mean squares due GCA_f σ^2_f =variance due to GCA_f

MS_m=mean squares due GCA_m σ^2_m =variance due to GCA_m

MS_{fm}=mean squares due to SCA σ^2_{fm} =variance due to SCA

MS_{lf} =mean squares due to GCA_f x location m=number of males

σ^2_{lf} =variance due to GCA_f x location f =number of females

MS_{lm}=mean squares due to GCA_m x location r=number of replications

σ^2_{lm} =variance due to GCA_m x location σ^2_{lfm} = variance due to SCA x location

MS_{lfm} = mean squares due to SCA x location

3.6.4.2 Estimation GCA and SCA variances

The estimates of variances due to GCA_f, GCA_m and SCA were computed from mean squares according to Singh and Chaudhary (1985):

One location: COV (H.S) females = $\frac{MS_f - MS_{fm}}{rm}$

$$\text{COV (H.S) males} = \frac{MS_m - MS_{fm}}{rf}$$

$$\text{COV (F.S)} = \frac{MS_{fm} - MS_e}{r}$$

Average estimate of the COV (H.S) was estimated following Dabholkar (1999):

$$\text{COV (H.S) average} = \frac{MS_m + MS_f - 2MS_{fm}}{r(m+f)}$$

Combined across locations: σ^2_f = COV (H.S) females = $\frac{MS_f - MS_{fm}}{rlm}$

$$\sigma^2_m = \text{COV (H.S) males} = \frac{MS_m - MS_{fm}}{rlf}$$

$$\sigma^2_{fm} = \text{COV (F.S)} = \frac{MS_{fm} - MS_{lfm}}{rl}$$

Average estimate of the COV (H.S) was also estimated as follows:

$$\frac{MS_m + MS_f - 2MS_{fm}}{rl(m+f)}$$

The estimates of COV (H.S) and COV (F.S) were used to estimate GCA (σ^2_{GCA}) and SCA (σ^2_{SCA}) variances as described by Hallauer *et al*. (1988):

$$\sigma^2_{GCA} = 2 \text{ COV (H.S) average}$$

$$\sigma^2_{SCA} = \text{COV (F.S)} - \text{COV (H.S) male} - \text{COV (H.S) female}$$

After estimating the GCA and SCA variances as mentioned above, the $\sigma^2_{GCA}/\sigma^2_{SCA}$ ratio was computed to predict the type of gene action involved.

3.6.6 Estimation of combining ability effects

The general combining ability and specific combining ability effects were estimated using the formulae given by Singh and Chaudhary (1985).

(a) GCA effects of females = $g_f = \frac{x_{i..}}{mr} - \frac{x...}{fmr}$

(b) GCA effects of males = $g_m = \frac{x_{.j.}}{fr} - \frac{x...}{fmr}$

(c) SCA effects of crosses = $s_{ij} = \frac{x_{ij.}}{r} - \frac{x_{i..}}{mr} - \frac{x_{.j.}}{fr} + \frac{x...}{fmr}$

Where: $x...$ = grand total crosses $x_{i..}$ = total of all hybrids containing i^{th} females

r = number of replications $x_{.j.}$ = total of all hybrids containing j^{th} males

f = number of females m = number of males

$x_{ij.}$ = total of all hybrids containing i^{th} females with j^{th} males

The standard error (SE) for GCA effects of males and females and SCA effects of different combinations were also, calculated according to Singh and Chaudhary (1985).

(a) General Combining ability effect:

$$S.E_{GCA(male)} = (M_e / rf)^{1/2}$$

$$S.E_{GCA(female)} = (M_e / rm)^{1/2}$$

(b) Similarly, significance of SCA effect: $S.E_{SCA} = (M_e / r)^{1/2}$

Where: M_e = error mean square r = number of replication

f = number of females m = number of males

3.6.7 Estimation of high parent heterosis

High parent heterosis was estimated according to Hallauer *et al*. (1988):

$$\text{High parent heterosis (HPH)} = \frac{(F_1 - H_p)}{H_p} \times 100$$

Where: F_1 = mean performance of hybrid formed between i^{th} and j^{th} parents

H_p = mean performance of higher scoring parent

CHAPTER FOUR

4.0 RESULTS

4.1 Analyses of Variance and Mean Performance

4.1.1 Analyses of variance and mean performance at Samaru

Analyses of variance (ANOVA) for traits measured under non-stress, intermediate stress and severe stress conditions at Samaru are presented in Table 4.1. The mean squares for genotypes were highly significant difference ($P \leq 0.01$) for days to 50% tasseling, days to 50% silking and plant height under the three conditions, ear height under non-stress and severe stress and grain yield under intermediate stress. The genotype mean squares were also significant at $P \leq 0.05$ for anthesis-silking interval (ASI) under non-stress and severe stress, ear height under intermediate stress, number of ears per plant severe stress and grain yield under non-stress. The mean squares for genotype for ASI under intermediate stress, leaf senescence under intermediate stress and severe stress, number of ears per plant under non-stress and intermediate stress and grain yield under severe stress were not significantly different.

Mean performance for days to 50% tasseling, days to 50% silking, ASI and plant height under non-stress, intermediate stress and severe stress conditions at Samaru are presented in Table 4.2. The number of days to 50% tasseling showed significant differences among the parental genotypes as well as among the hybrids under the three conditions. It ranged from 54 days to 68 days, 52 days to 67 days and 53 days to 69 days under non-stress, intermediate stress and severe stress conditions, respectively. Under non-stress condition, the parent P8 took the highest number of days to 50% tasseling and the parent S7 and the hybrids S3 x P4, S5 x P7 and S6 x P2 were the earliest.

Table 4.1 ANOVA for traits measured under non-stress, intermediate stress and severe stress conditions at Samaru

		Days to 50% tasseling			Days to50% silking			Anthesis-silking interval			Plant height		
Source	df	NS	IS	SS	NS	IS	SS	NS	IS	SS	NS	IS	SS
Block(Rep)	14	3.41*	1.99	7.87*	4.24*	4.12	8.41*	0.64	1.60	2.84	118.67	185.52*	176.29*
Replications	1	26.04**	10.94**	38.90**	20.57**	2.89	2.29	64.51**	3.94**	6.50**	16791.32**	6736.77**	1346.57**
Genotype	55	11.99**	8.93**	16.73**	10.47**	33.51**	11.96**	9.35*	1.66	1.83*	494.01**	664.40**	418.88**
Error	41	1.77	1.46	3.59	1.40	5.24	2.38	2.73	0.41	0.44	108.66	83.58	59.61

		Ear height			Leaf senescence		Number of ears per plant			Grain yield		
		NS	IS	SS	IS	SS	NS	IS	SS	NS	IS	SS
Block(Rep)	14	203.94*	132.97	142.23*	0.68	2.47	0.12	0.04	0.18	1184829.80	975582.26*	588999.24
Replications	1	432.73**	5035.59**	1381.04**	41.29**	46.29**	0.25**	0.15**	0.14*	19444430.60**	11571435.00**	11571473.60**
Genotype	55	240.38**	323.75*	229.02**	2.38	2.47	0.06	0.04	0.15*	3221514.30*	1499310.24**	1834986.20
Error	41	70.28	54.69	32.32	1.02	0.82	0.04	0.02	0.01	987765.00	502060.60	651708.95

*and **-significant at 0.05 and 0.01 probability levels, respectively; NS=non-stress; IS=intermediate stress; SS=severe stress; df=degree of freedom; Rep=replication

Table 4.2 Mean performances for days to 50% tasseling, days to 50% silking, anthesis-silking interval and plant height under non-stress, intermediate stress and severe stress conditions at Samaru

Genotypes	Days to 50% tasseling			Days to 50% silking			Anthesis-silking interval			Plant height (cm)		
Parents	NS	IS	SS	NS	IS	SS	NS	IS	SS	NS	IS	SS
S1	62^{b}	58^{bf}	61^{bcd}	64^{b}	61^{b-f}	68^{a-e}	3^{a-e}	4	7^{a-e}	190.00^{a-f}	165.84^{e-h}	161.67^{a-f}
S2	57^{c-g}	58^{bf}	60^{b-f}	60^{b-g}	62^{b-e}	64^{c-j}	3^{a-e}	4	5^{a-e}	180.00^{a-g}	183.34^{a-h}	145.00^{c-g}
S3	56^{efg}	54^{ghi}	57^{c-g}	59^{d-h}	57^{efg}	60^{h-m}	3^{a-e}	3	3^{cde}	154.17^{fgh}	160.84^{ghi}	147.50^{c-g}
S4	58^{b-g}	59^{bcd}	60^{b-f}	62^{bcd}	63^{bcd}	66^{b-g}	5^{a}	5	6^{a-e}	181.67^{a-g}	174.17^{b-g}	145.00^{cg}
S5	55^{fg}	52^{i}	55^{d-g}	58^{d-h}	55^{g}	60^{h-m}	4^{abc}	3	5^{a-e}	148.34^{gh}	143.33^{ij}	140.84^{d-g}
S6	57^{c-g}	56^{c-h}	65^{ab}	62^{bcd}	61^{b-f}	75^{a}	5^{a}	5	10^{a-b}	128.34^{hi}	129.17^{jk}	124.17^{gh}
S7	54^{g}	54^{ghi}	55^{d-g}	58^{d-h}	60^{c-g}	64^{c-j}	5^{a}	6	9^{abc}	155.00^{e-h}	159.17^{hi}	137.50^{fg}
P1	60^{b-e}	61^{b}	62^{bc}	64^{b}	66^{ab}	68^{a-e}	4^{abc}	5	7^{a-e}	199.33^{a-d}	186.67^{a-f}	158.34^{a-f}
P2	60^{b-e}	57^{b-g}	62^{bc}	62^{bcd}	62^{b-e}	69^{a-e}	2^{cde}	5	7^{a-e}	179.17^{a-g}	181.67^{a-h}	173.33^{a-d}
P3	58^{b-g}	57^{b-g}	57^{c-g}	60^{b-g}	61^{b-f}	62^{e-m}	2^{cde}	5	5^{a-e}	182.50^{a-g}	177.50^{b-g}	164.17^{a-f}
P4	58^{b-g}	58^{bf}	58^{c-g}	62^{bcd}	62^{b-e}	64^{c-j}	4^{abc}	5	6^{a-e}	176.33^{a-g}	175.84^{b-g}	147.50^{c-g}
P7	59^{b-f}	60^{bc}	61^{bcd}	64^{b}	64^{bc}	72^{abc}	5^{a}	4	11^{a}	165.83^{b-g}	173.34^{b-g}	148.33^{c-g}
P8	68^{a}	67^{a}	69^{a}	70^{a}	70^{a}	73^{ab}	3^{a-e}	3	4^{b-e}	109.17^{i}	120.83^{k}	95.00^{h}
Hybrids												
S1 x P1	57^{c-g}	57^{b-g}	57^{c-g}	61^{b-e}	61^{b-f}	61^{f-m}	4^{abc}	4	4^{b-e}	207.50^{ab}	182.50^{a-h}	185.00^{ab}
S1 x P2	55^{fg}	56^{c-h}	58^{c-g}	59^{d-h}	60^{c-g}	60^{h-m}	4^{abc}	4	3^{cde}	184.17^{a-g}	190.83^{a-d}	175.00^{abc}
S1 x P3	57^{c-g}	56^{c-h}	60^{b-f}	61^{b-e}	60^{c-g}	66^{b-g}	4^{abc}	4	6^{a-e}	175.83^{a-g}	175.00^{b-g}	163.34^{a-f}
S1 x P4	59^{b-f}	56^{c-h}	58^{c-g}	62^{bcd}	60^{c-g}	63^{d-l}	4^{abc}	5	5^{a-e}	190.84^{a-f}	187.50^{a-e}	169.17^{a-f}
S1 x P7	56^{efg}	55^{e-i}	58^{c-g}	61^{b-e}	59^{c-g}	60^{h-m}	5^{a}	4	2^{de}	188.34^{a-g}	176.67^{b-g}	155.00^{b-g}
S1 x P8	57^{c-g}	58^{bf}	60^{b-f}	59^{d-h}	62^{b-e}	66^{b-g}	2^{cde}	4	6^{a-e}	192.50^{a-f}	191.67^{abc}	153.34^{b-g}
S2 x P1	57^{c-g}	56^{c-h}	60^{b-f}	60^{b-g}	55^{g}	63^{d-l}	3^{a-e}	-1	3^{cde}	194.17^{a-f}	186.67^{a-f}	169.17^{a-f}
S2 x P2	57^{c-g}	57^{b-g}	60^{b-f}	61^{b-e}	61^{b-f}	63^{d-l}	4^{abc}	4	4^{b-e}	190.00^{a-f}	190.83^{a-d}	172.50^{a-e}
S2 x P3	59^{b-f}	57^{b-g}	59^{b-g}	62^{bcd}	61^{b-f}	62^{e-m}	4^{abc}	4	3^{cde}	197.50^{a-d}	191.67^{abc}	175.00^{abc}
S2 x P4	57^{c-g}	57^{b-g}	58^{c-g}	60^{b-g}	62^{b-e}	62^{e-m}	3^{a-e}	5	4^{b-e}	211.17^{a}	175.83^{b-g}	160.00^{a-f}
S2 x P7	58^{b-g}	56^{c-h}	55^{d-g}	61^{b-e}	59^{c-g}	62^{e-m}	3^{a-e}	3	7^{a-e}	195.84^{a-f}	186.67^{a-f}	169.17^{a-f}
S2 x P8	57^{c-g}	57^{b-g}	60^{b-f}	60^{b-g}	62^{b-e}	64^{c-j}	4^{abc}	5	4^{b-e}	202.00^{abc}	195.83^{ab}	177.50^{abc}
S3 x P1	56^{efg}	55^{e-i}	57^{c-g}	60^{b-g}	61^{b-f}	64^{c-j}	4^{abc}	6	7^{a-e}	205.84^{abc}	186.67^{a-f}	159.17^{a-f}
S3 x P2	55^{fg}	54^{ghi}	55^{d-g}	58^{d-h}	57^{efg}	58^{g-m}	3^{a-e}	3	3^{cde}	192.50^{a-f}	174.17^{b-g}	167.50^{a-f}
S3 x P3	57^{c-g}	55^{e-i}	59^{b-g}	60^{b-g}	59^{cg}	64^{c-j}	3^{a-e}	4	6^{a-e}	184.17^{a-g}	175.84^{b-g}	153.33^{b-g}

Means with same letter(s) in a column are not significantly different according to DMRT at 5% level of probability and values in parenthesis are transformed
NS=non-stress; IS=intermediate stress; SS = severe stress

Table 4.2 Continued

Hybrids	Days to 50% tasseling			Days to 50% silking			Anthesis-silking interval			Plant height (cm)		
	NS	IS	SS	NS	IS	SS	NS	IS	SS	NS	IS	SS
S3 x P4	54^{g}	56^{c-h}	59^{b-g}	59^{d-h}	60^{c-g}	64^{c-j}	5^{a}	4	5^{a-e}	192.50^{a-f}	175.00^{b-g}	173.34^{a-d}
S3 x P7	56^{efg}	55^{e-i}	53^{g}	59^{d-h}	61^{b-f}	55^{m}	3^{a-e}	6	2de	191.67^{a-f}	170.83^{c-h}	168.33^{a-f}
S3 x P8	60^{b-e}	55^{e-i}	59^{b-g}	62^{bcd}	58^{d-g}	63^{d-l}	3^{a-e}	3	4^{b-e}	196.67^{a-d}	186.67^{a-f}	157.50^{b-f}
S4 x P1	57^{c-g}	56^{c-h}	57^{c-g}	60^{b-g}	60^{c-g}	65^{c-i}	3^{a-e}	4	8^{a-d}	199.17^{a-d}	188.34^{a-e}	182.50^{ab}
S4 x P2	57^{c-g}	57^{b-g}	55^{d-g}	60^{b-g}	60^{c-g}	57^{i-m}	4^{abc}	4	3^{cde}	170.05^{b-g}	190.83^{a-d}	161.67^{a-f}
S4 x P3	61^{bcd}	57^{b-g}	58^{c-g}	63^{cb}	60^{c-g}	62^{e-m}	2^{cde}	4	4^{b-e}	173.17^{b-g}	178.34^{a-h}	166.17^{a-f}
S4 x P4	56^{efg}	56^{c-h}	59^{b-g}	58^{d-h}	59^{c-g}	63^{d-l}	2^{cde}	3	4^{b-e}	200.84^{a-d}	192.50^{abc}	175.00^{abc}
S4 x P7	55^{fg}	56^{c-h}	59^{b-g}	57^{e-h}	58^{d-g}	62^{e-m}	2^{cde}	3	3^{cde}	187.50^{a-g}	190.00^{a-d}	160.00^{a-f}
S4 x P8	58^{b-g}	57^{b-g}	57^{c-g}	60^{b-g}	61^{b-f}	60^{h-m}	3^{a-e}	4	3^{cde}	181.67^{a-g}	185.00^{a-g}	170.00^{a-e}
S5 x P1	55^{fg}	54^{ghi}	56^{c-g}	57^{e-h}	57^{efg}	58^{g-m}	3^{a-e}	3	3^{cde}	198.34^{a-d}	184.17^{a-g}	157.50^{b-f}
S5 x P2	55^{fg}	53^{hi}	53^{g}	57^{e-h}	55^{g}	56^{klm}	2^{cde}	2	3^{cde}	182.50^{a-g}	172.50^{b-h}	174.17^{abc}
S5 x P3	56^{efg}	57^{b-g}	57^{c-g}	57^{e-h}	60^{c-g}	60^{h-m}	1^{e}	3	3^{cde}	160.00^{e-h}	175.00^{b-g}	174.17^{abc}
S5 x P4	56^{efg}	56^{c-h}	55^{d-g}	59^{d-h}	59^{c-g}	56^{klm}	3^{a-e}	3	2de	187.00^{a-g}	183.33^{a-h}	161.67^{a-f}
S5 x P7	54^{g}	55^{e-i}	55^{d-g}	55^{h}	58^{d-g}	56^{klm}	2^{cde}	3	1^{e}	180.00^{a-g}	178.34^{a-h}	169.17^{a-f}
S5 x P8	56^{efg}	54^{ghi}	55^{d-g}	57^{e-h}	57^{efg}	61^{f-m}	1^{e}	3	6^{a-e}	185.84^{a-g}	183.34^{a-h}	139.17^{efg}
S6 x P1	57^{c-g}	56^{c-h}	54^{fg}	60^{b-g}	58^{d-g}	60^{h-m}	3^{a-e}	3	6^{a-e}	197.67^{a-d}	179.17^{a-h}	165.84^{a-f}
S6 x P2	54^{g}	55^{e-i}	55^{d-g}	56^{gh}	59^{c-g}	57^{i-m}	2^{cde}	4	2de	198.34^{a-d}	175.00^{b-g}	173.34^{a-d}
S6 x P3	57^{c-g}	55^{e-i}	57^{c-g}	60^{b-g}	58^{d-g}	61^{f-m}	3^{a-e}	3	4^{b-e}	176.67^{a-g}	176.67^{b-g}	170.84^{a-e}
S6 x P4	55^{fg}	56^{c-h}	56^{c-g}	59^{d-h}	60^{c-g}	58^{g-m}	4^{abc}	4	3^{cde}	183.34^{a-g}	173.33^{b-g}	175.84^{abc}
S6 x P7	56^{efg}	56^{c-h}	58^{c-g}	59^{d-h}	58^{d-g}	60^{h-m}	3^{a-e}	3	3^{cde}	185.00^{a-g}	181.67^{a-h}	177.50^{abc}
S6 x P8	57^{c-g}	57^{b-g}	60^{b-f}	59^{d-h}	61^{b-f}	65^{c-i}	2^{cde}	4	5^{a-e}	175.00^{a-g}	172.50^{b-h}	172.50^{a-e}
S7 x P1	56^{efg}	57^{b-g}	55^{d-g}	59^{d-h}	61^{b-f}	60^{h-m}	3^{a-e}	4	5^{a-e}	198.33^{a-d}	202.50^{a}	190.83^{a}
S7 x P2	56^{efg}	54^{ghi}	56^{c-g}	59^{d-h}	58^{d-g}	59^{g-m}	3^{a-e}	4	4^{b-e}	180.84^{a-g}	162.50^{f-i}	160.84^{a-f}
S7 x P3	58^{b-g}	56^{c-h}	56^{c-g}	61^{b-e}	60^{c-g}	61^{f-m}	3^{a-e}	4	5^{a-e}	191.67^{a-f}	175.83^{b-g}	175.83^{abc}
S7 x P4	55^{fg}	56^{c-h}	54^{fg}	59^{d-h}	59^{c-g}	62^{e-m}	4^{abc}	3	8^{a-d}	187.50^{a-g}	184.17^{a-g}	165.00^{a-f}
S7 x P7	56^{efg}	55^{e-i}	56^{c-g}	59^{d-h}	60^{c-g}	60^{h-m}	4^{abc}	5	4^{b-e}	184.17^{a-g}	193.34^{abc}	169.17^{a-f}
S7 x P8	56^{efg}	56^{c-h}	55^{d-g}	60^{b-g}	60^{c-g}	58^{g-m}	4^{abc}	4	3^{cde}	194.50^{a-f}	166.67^{d-h}	165.67^{a-f}
Oba 98 (Check)	58^{b-g}	59^{bcd}	61^{bcd}	60^{b-g}	61^{b-f}	62^{e-m}	2^{cde}	2	2de	196.67^{a-d}	185.00^{a-g}	171.67^{a-e}
MEAN	57	56	58	60	60	62	3	4	4	183.91	177.90	162.82
CV (%)	3.00	2.73	4.65	2.80	3.65	5.22	14.45	18.17	27.72	8.02	6.14	7.94

Means with same letter(s) in a column are not significantly different according to DMRT at 5% level of probability and values in parenthesis are transformed
NS=non-stress; IS=intermediate stress; SS = severe stress

Under intermediate stress condition, the parent P8 took the highest number of days to 50% tasseling and the parent S5 was the earliest. Under severe stress condition, the parent P8 also took the highest number of days to 50% tasseling and the hybrids S3 x P7 and S5 x P2 were the earliest. Days to 50% silking showed significant differences among the genotypes under the three conditions (Table 4.2). It ranged from 55 days to 70 days, 55 days to 70 days and 55 days to 75 days under non-stress, intermediate stress and severe stress conditions, respectively. Under non-stress condition, the parent P8 took maximum number of days to 50% silking and the hybrid S5 x P7 was the earliest. The parent P8 took the maximum number of days to 50% silking and the parent S5 and the hybrid S5 x P2 were the earliest under intermediate stress condition. The parent S6 took the maximum took the maximum number of days to 50% silking and the hybrid S3 x P7 was the earliest under severe stress condition.

Similarly, anthesis-silking interval (ASI) showed significant differences among the genotypes under non-stress and severe stress conditions while under intermediate stress statistical significant did not exist (Table 4.2). It ranged from 1 day to 5 days, -1 day to 6 days and 1 day to 11 days under non-stress, intermediate stress and severe stress conditions, respectively. The parents S4, S6, S7, P7 and the hybrids S1 x P7 and S3 x P4 showed the maximum ASI while the hybrids S5 x P3 and S5 x P8 showed the minimum under non-stress condition. The parent S7 and the hybrids S3 x P1 and S3 x P7 showed the maximum ASI while the minimum was showed by the hybrid S2 x P1 which was statistically the same with all the rest under intermediate stress condition. Under severe stress condition, the parent P7 had the longest ASI and the hybrid S5 x P7 had the shortest ASI and were statistically different from the rest. Statistically significant differences existed for plant height under the three conditions

which ranged from 109.17cm to 211.17cm, 120.83cm to 202.50cm and 95cm to 190.83cm under non-stress, intermediate stress and severe stress conditions, respectively (Table 4.2). The hybrid S2 x P4 was the tallest under non-stress condition while the parent P8 was the shortest. The hybrid S7 x P1 was the tallest and the parent P8 was the shortest under intermediate stress and severe stress conditions, respectively.

Mean performance for ear height, leaf senescence, number of ears per plant and grain yield under non-stress, intermediate stress and severe stress conditions at Samaru are presented in Table 4.3. Ear height showed significant differences among the genotypes under the three conditions. The heights ranged from 66.67cm to 117.50cm, 54.17cm to 110.84 and 47.50cm to 121.67cm under non-stress, intermediate stress and severe stress conditions, respectively. The hybrid S1 x P2 had the highest ear height and the parent P8 had the lowest under non-stress condition. Under intermediate stress condition, the hybrid S2 x P4 had the highest ear height and the parent S6 had the shortest. Under severe stress, the hybrid S4 x P1 had the highest ear height and the parent P8 had the shortest ear placement. Leaf senescence showed no statistical difference among the genotypes under intermediate stress and severe stress conditions (Table 4.3). However, the genotypes with the most leaf senescence (3.5) under intermediate stress were the parent S5 and the hybrids S6 x P1, S6 x P3 and S7 x P1, while the least (1.00) were the parents S7, P1, P4, P7 and P8. Also, under intermediate stress, the hybrids S1 x P1, S1 x P4, S3 x P3, S3 x P8, S4 x P2, S4 x P1, S4 x P8, S5 x P1, S6 x P4, S6 x P7 and S7 x P8 had the least leaf senescence. Under severe stress, the genotypes with the most leaf senescence (5.50) were the parent S3 and the hybrids S2 x P2 and S5 x P8, while the least (1.50) were the parent P8 and the hybrids S3 x P8, S4 x P4 and S5 x P3.

Table 4.3 Mean performances for ear height, leaf senescence, number of ears per plant and grain yield under non-stress, intermediate stress and severe stress conditions at Samaru

	Ear height (cm)			Leaf senescence (1-10)		Number of ears per plant			Grain yield (kg/ha)		
Parents	NS	IS	SS	IS	SS	NS	IS	SS	NS	IS	SS
S1	94.17^{c-f}	95.83^{a-f}	95.00^{a-f}	1.50 (1.24)	2.50 (1.60)	1.00 (1.11)	1.00 (0.95)	1.07^{a-e} (1.04)	1778^{f}	1667^{cde}	1556
S2	100.84^{a-f}	86.67^{a-f}	90.00^{a-f}	3.00 (1.78)	4.00 (1.95)	1.25 (1.05)	1.11 (1.12)	1.00^{a-e} (0.85)	2889^{def}	2000de	1222
S3	87.50^{d-i}	77.50^{d-h}	85.83^{b-g}	1.50 (1.13)	5.50 (2.20)	1.14 (1.08)	1.00 (0.99)	0.59^{cde} (0.84)	2222^{def}	2000de	1111
S4	98.34^{a-f}	96.67^{a-f}	84.17^{b-g}	1.50(1.28)	2.50 (1.19)	1.11 (1.03)	1.05 (1.04)	0.93^{a-e} (1.03)	2667^{def}	2000de	1556
S5	70.83^{ghi}	76.67^{e-h}	78.34^{d-g}	3.50 (1.68)	4.00 (2.18)	1.05 (0.96)	1.05 (1.03)	0.90^{a-e} (0.91)	2333^{def}	2111^{a-e}	667
S6	68.33^{hi}	54.17^{h}	58.34^{gh}	1.50 (1.19)	4.50 (2.28)	1.00 (1.10)	1.50 (1.20)	0.79^{b-e} (0.98)	1778^{f}	667^{e}	444
S7	78.34^{f-i}	79.17^{c-h}	71.67^{fgh}	1.00 (1.73)	3.00 (1.74)	1.00 (1.02)	1.10 (1.06)	0.70^{b-e} (0.73)	2111^{ef}	1444^{a-e}	667
P1	100.83^{a-f}	95.84^{a-f}	91.67^{a-f}	1.00 (0.97)	4.00 (1.87)	1.05 (0.99)	1.00 (1.01)	1.00^{a-e} (0.89)	2111^{ef}	1667^{a-d}	1222
P2	98.34^{a-f}	85.84^{a-g}	110.00^{ab}	2.50 (1.24)	4.00 (2.25)	1.67 (1.36)	1.12 (0.97)	0.80^{b-e} (0.97)	2111^{ef}	1111^{a-e}	1111
P3	90.00^{c-g}	82.50^{b-g}	82.50^{b-g}	1.50 (1.18)	2.00 (1.62)	1.59 (1.17)	1.00 (0.96)	0.88^{b-e} (0.92)	2556^{def}	2222^{a-e}	1111
P4	89.17^{d-h}	80.83^{b-g}	76.67^{d-g}	1.00 (1.08)	3.00 (1.48)	1.32 (1.15)	1.06 (1.05)	1.03 $^{a-e}$ (0.90)	2444^{def}	1944^{a-e}	1556
P7	85.00^{e-i}	75.00^{fgh}	75.84^{d-g}	1.00 (1.11)	2.00 (1.27)	1.00 (1.02)	1.15 (1.10)	1.54^{ab} (1.27)	2111^{ef}	1556^{cde}	1556
P8	66.67^{i}	58.33^{gh}	47.50^{h}	1.00 (0.98)	1.50 (1.15)	1.75 (1.27)	1.84 (1.35)	1.50^{abc} (1.09)	1889^{f}	1444^{cde}	667
Hybrids											
S1 x P1	102.50^{a-e}	98.34^{a-f}	91.67^{a-f}	1.00 (0.94)	2.50 (1.74)	1.00 (0.93)	1.00 (1.01)	0.95^{a-e} (0.99)	4484^{a-f}	3242^{abc}	1468
S1 x P2	117.50^{a}	97.50^{a-f}	93.00^{a-f}	3.00 (1.49)	3.50 (2.28)	1.35 (1.30)	1.15 (0.99)	0.59^{cde} (0.85)	6262^{ab}	3687^{abc}	2468
S1 x P3	102.50^{a-e}	85.00^{a-g}	89.17^{a-f}	2.00 (1.37)	4.50 (2.02)	1.05 (0.99)	1.00 (1.01)	1.25^{a-d} (1.17)	3818^{b-f}	3464^{abc}	1580
S1 x P4	115.83^{ab}	93.34^{a-f}	85.00^{b-g}	1.00 (0.96)	3.00 (1.97)	1.31 (1.17)	1.09 (1.02)	0.75^{b-e} (0.87)	3818^{b-f}	1909^{cde}	1580
S1 x P7	102.50^{a-e}	93.33^{a-f}	77.50^{d-g}	1.50 (1.24)	2.50 (1.60)	1.10 (1.16)	1.00 (0.95)	1.84^{a} (1.34)	3595^{c-f}	2353^{a-e}	691
S1 x P8	112.50^{abc}	94.17^{a-f}	88.34^{b-f}	2.50 (1.65)	4.00 (2.01)	1.15 (1.04)	1.17 (1.05)	0.96^{a-e} (0.97)	4484^{a-f}	4353^{a}	2468
S2 x P1	98.34^{a-f}	99.17^{a-f}	86.67^{b-g}	1.50 (0.95)	2.50 (1.56)	1.44 (1.18)	1.09 ((1.07)	0.76^{b-e} (0.81)	4929^{a-d}	3909^{ab}	2024
S2 x P2	115.83^{ab}	95.00^{a-f}	95.00^{a-f}	1.50 (1.11)	5.50 (2.18)	1.11 (1.07)	1.00 (1.03)	1.04^{a-e} (1.04)	4040^{b-f}	3464^{abc}	2246
S2 x P3	105.84^{a-e}	95.00^{a-f}	100.00^{a-f}	2.50 (1.51)	3.50 (1.91)	1.05 (0.94)	1.00 (0.99)	0.65^{b-e} (0.76)	3151^{c-f}	2798^{a-d}	1357
S2 x P4	98.34^{a-f}	110.84^{a}	80.00^{c-f}	2.00 (1.53)	2.50 (1.52)	1.21 (1.03)	1.00 (1.06)	1.46^{abc} (1.06)	4484^{a-f}	3464^{abc}	3135
S2 x P7	101.67^{a-e}	105.83^{abc}	99.17^{a-f}	2.00 (1.27)	3.00 (2.02)	1.00 (0.94)	1.00 (1.00)	0.84^{b-e} (0.88)	4706^{a-d}	3242^{abc}	2913
S2 x P8	109.17^{a-d}	101.67^{a-f}	97.50^{a-f}	2.50 (1.60)	4.00 (1.52)	1.00 (1.11)	1.43 (1.15)	1.03^{a-e} (0.97)	4706^{a-d}	3242^{abc}	2913
S3 x P1	105.00^{a-e}	100.00^{a-f}	84.17^{b-g}	3.00 (1.66)	3.50 (2.15)	1.34 (1.04)	1.00 (0.99)	1.00^{a-e} (0.97)	6929^{a}	2353^{a-e}	1357
S3 x P2	98.33^{a-f}	100.83^{a-f}	76.67^{d-g}	1.50 (1.16)	4.00 (1.90)	1.30 (1.14)	1.17 (1.09)	1.28^{a-d} (1.08)	4706^{a-d}	3242^{abc}	2691
S3 x P3	105.84^{a-e}	101.67^{a-f}	72.50^{fgh}	1.00 (1.07)	5.00 (1.92)	1.30 (1.11)	1.00 (1.02)	0.47^{e} (0.72)	5373^{abc}	3909^{ab}	1135

Means with same letter(s) in a column are not significantly different according to DMRT at 5% level of probability and values in parenthesis are transformed
NS=non-stress; IS=intermediate stress; SS = severe stress

Table 4.3 Continued

	Ear height (cm)			Leaf senescence (1-10)		Number of ears per plant			Grain yield(kg/ha)		
Hybrids	NS	IS	SS	IS	SS	NS	IS	SS	NS	IS	SS
S3 x P4	97.50^{a-f}	98.33^{a-f}	102.50^{a-e}	3.00 (1.66)	3.50 (1.74)	1.00 (0.95)	1.00 (1.00)	1.03^{a-e} (0.97)	6262^{ab}	2798^{a-d}	1357
S3 x P7	100.84^{a-f}	91.67^{a-f}	89.17^{a-f}	2.00 (1.52)	4.00 (2.05)	1.00 (0.98)	1.05 (1.00)	0.50^{de} (0.69)	5373^{abc}	2798^{a-d}	1802
S3 x P8	99.17^{a-f}	96.67^{a-f}	74.17^{e-h}	1.00 (0.98)	1.50 (1.05)	1.00 (0.95)	1.10 (1.11)	1.24^{a-d} (1.04)	4484^{a-f}	3242^{abc}	1357
S4 x P1	103.34^{a-e}	108.33^{ab}	121.67^{a}	2.50 (1.29)	2.50 (1.87)	1.09 (1.02)	1.00 (0.95)	0.65^{b-e} (0.62)	3818^{b-f}	3464^{abc}	2468
S4 x P2	107.50^{a-e}	85.83^{a-g}	91.67^{a-f}	1.00 (0.94)	3.00 (1.80)	1.20 (1.12)	1.00 (1.03)	0.96^{a-e} (0.69)	3818^{b-f}	3464^{abc}	2468
S4 x P3	105.00^{a-e}	84.17^{a-g}	101.67^{a-e}	2.50 (1.16)	4.50 (2.11)	1.07 (1.09)	1.00 (1.01)	1.03^{a-e} (1.06)	3151^{c-f}	2798^{a-d}	2468
S4 x P4	100.83^{a-f}	101.67^{a-f}	95.84^{a-f}	1.50 (1.37)	1.50 (1.82)	1.05 (0.94)	1.22 (1.13)	0.66^{b-e} (0.68)	4706^{a-d}	3464^{abc}	2024
S4 x P7	111.67^{a-d}	92.50^{a-f}	95.84^{a-f}	1.00 (0.97)	3.50 (1.56)	1.26 (1.06)	1.18 (1.09)	0.98^{a-e} (0.96)	4484^{a-f}	3242^{abc}	2024
S4 x P8	110.00^{a-d}	108.34^{ab}	102.50^{a-e}	1.00 (1.12)	3.50 (2.21)	1.00 (1.21)	1.00 (0.98)	1.00^{a-e} (1.02)	4040^{b-f}	3464^{abc}	3135
S5 x P1	94.17^{c-f}	93.34^{a-f}	84.17^{b-g}	1.00 (1.10)	2.00 (1.48)	1.00 (0.93)	1.05 (1.03)	0.81^{b-e} (0.91)	3818^{b-f}	3242^{abc}	1580
S5 x P2	90.94^{c-g}	89.17^{a-f}	91.67^{a-f}	1.50 (1.13)	2.50 (1.43)	1.00 (1.01)	1.00 (0.99)	1.23^{a-e} (1.16)	3818^{b-f}	3464^{abc}	2913
S5 x P3	90.00^{c-g}	100.00^{a-f}	80.84^{c-g}	1.50 (0.98)	1.50 (1.74)	1.20 (0.97)	1.22 (1.14)	0.75^{b-e} (0.71)	5818^{abc}	4131^{ab}	1691
S5 x P4	108.33^{a-d}	92.50^{a-f}	81.67^{b-g}	2.50 (1.17)	4.00 (1.94)	1.15 (1.14)	1.00 (1.00)	0.67^{b-e} (0.80	4262^{a-f}	2131^{c-e}	468
S5 x P7	99.17^{a-f}	95.00^{a-f}	91.67^{a-f}	2.50 (1.52)	4.00 (1.69)	1.33 (1.13)	1.00 (1.01)	1.00^{a-e} (1.04)	6040^{ab}	2353^{a-e}	2246
S5 x P8	99.17^{a-f}	85.00^{a-g}	77.50^{d-g}	2.50 (1.53)	5.50 (2.63)	1.16 (1.21)	1.05 (0.94)	0.81^{b-e} (1.01)	4484^{a-f}	2575^{a-e}	1357
S6 x P1	90.00^{c-g}	97.50^{a-f}	103.34^{a-e}	3.50 (1.58)	3.00 (1.74)	1.06 (1.09)	1.00 (1.00)	0.63^{b-e} (0.80)	5373^{abc}	1687^{cde}	1357
S6 x P2	95.00^{a-f}	96.67^{a-f}	91.67^{a-f}	2.00 (1.49)	3.50 (1.52)	1.22 (1.08)	1.00 (1.02)	0.76^{b-e} (0.94)	6040^{a-e}	3242^{abc}	2246
S6 x P3	105.00^{a-e}	80.00^{a-g}	110.00^{ab}	3.50 (1.58)	4.00 (2.35)	1.42 (1.18)	1.15 (1.03)	0.95^{a-e} (0.99)	4484^{a-f}	2353^{a-e}	1801
S6 x P4	101.67^{a-e}	89.17^{a-f}	103.33^{a-e}	1.00 (0.85)	2.50 (1.99)	1.30 (1.13)	1.00 (0.96)	0.91^{a-e} (0.97)	6484^{a}	3020^{abc}	2246
S6 x P7	109.17^{a-d}	95.83^{a-f}	90.00^{a-f}	1.00 (1.25)	4.50 (1.99)	1.05 (0.99)	1.00 (1.02)	0.66^{b-e} (0.78)	4706^{a-d}	3242^{abc}	802
S6 x P8	95.00^{a-f}	85.00^{a-g}	105.00^{a-d}	2.00 (1.49)	4.50 (1.79)	1.00 (0.98)	1.07 (1.05)	0.50^{de} (0.78)	5373^{abc}	3242^{abc}	913
S7 x P1	115.00^{ab}	91.67^{a-f}	103.34^{a-e}	3.50 (1.98)	5.00 (2.28)	1.09 (1.03)	1.00 (0.98)	0.50^{de} (0.69)	3818^{b-f}	2575^{a-e}	2024
S7 x P2	90.83^{c-g}	94.17^{a-f}	90.84^{a-f}	1.50 (1.14)	4.50 (1.74)	1.16 (1.14)	1.00 (1.04)	1.05^{a-e} (0.98)	5373^{abc}	2353^{a-e}	2024
S7 x P3	105.84^{a-e}	92.50^{a-f}	102.50^{a-e}	1.50 (1.24)	3.00 (1.51)	1.25 (1.12)	1.00 (1.03)	0.80^{b-e} (0.95)	4040^{b-f}	2131^{c-e}	1802
S7 x P4	107.50^{a-e}	105.00^{abc}	97.50 $^{a-f}$	2.50 (1.51)	5.00 (2.20)	1.00 (1.03)	1.00 (1.00)	0.83^{b-e} (0.98)	5595^{abc}	2464^{a-e}	2024
S7 x P7	110.00^{a-d}	89.17^{a-f}	90.83^{a-f}	2.50 (1.63)	3.50 (1.62)	1.11 (1.06)	1.05 (1.01)	1.13^{a-e} (1.17)	4706^{a-d}	4353^{a}	3357
S7 x P8	99.17^{a-f}	95.84^{a-f}	83.34^{b-g}	1.00 (1.08)	2.00 (1.36)	1.34 (1.16)	1.00 (1.00)	1.25^{a-d} (1.03)	6040^{ab}	5020^{a}	2913
Oba 98 (Check)	96.67^{a-f}	85.00^{a-g}	99.17^{a-f}	2.00 (0.94)	2.00 (1.97)	1.38 (1.10)	1.00 (1.01)	0.74^{b-e} (0.87)	4929^{a-d}	3333^{abc}	1890
MEAN	99.26	91.73	89.59	1.87	3.39	1.17	1.07	0.92	4175	2778	1778
CV (%)	10.54	12.4	13.23	26.56	26.88	10.05	8.71	20.04	31.37	31.61	57.19

Means with same letter(s) in a column are not significantly different according to DMRT at 5% level of probability and values in parenthesis are transformed
NS=non-stress; IS=intermediate stress; SS = severe stress

Number of ears per plant showed significant difference among the genotypes only under severe stress condition (Table 4.3) and ranged from 1.00 to 1.75, 1.00 to 1.84 and 0.47 to 1.84 under non-stress, intermediate stress and severe stress conditions, respectively. The parents S1, S6, S7, P7 and the hybrids S1 x P1, S2 x P7, S3 x P4, S3 x P7, S3 x P8, S4 x P8, S5 x P1, S5 x P2, S6 x P8 and S7 x P4 had the lowest number of ears per plant while the parent P8 had the highest number of ears per plant and were statistically the same with all the rest. Under intermediate stress condition, the hybrid S1 x P7 had the highest number of ears per plant and the hybrid S3 x P3 recorded the lowest number of ears per plant and were statistically the same with all the rest. Under severe stress, the hybrid S1 x P7 had the highest number of ears per plant while the hybrid S3 x P3 had the lowest number of ears per plant and were statistically different from the rest.

Statistical significant differences exist for grain yield under non-stress and intermediate stress conditions (Table 4.3). It ranged from 1778kg/ha to 6929kg/ha, 667kg/ha to 5020kg/ha and 444kg/ha to 3357kg/ha under non-stress, intermediate stress and severe stress conditions, respectively. The hybrid S3 x P1 had the highest grain yield which was not statistically different from S6 x P4 under non-stress condition while the parents S1 and P6 recorded the lowest grain yield and were not statistically different from P8. Under intermediate stress condition, the hybrid S7 x P8 recorded the highest grain yield which was not statistically different from S1 x P8 and S7 x P7 while parent S6 had the lowest grain yield. The hybrid S7 x P7 had the highest yield which was not statistically different from S2 x P4 and S4 x P8 under severe stress while the parent S6 had the lowest yield and was not significantly different from S4 x P4.

4.1.2 Analyses of variance and mean performance at Kadawa

Analyses of variance for traits measured under non-stress, intermediate stress and severe stress conditions at Kadawa are presented in Table 4.4. The genotypes mean squares were highly significant ($P \leq 0.01$) for days to 50% tasseling and days to 50% silking under non-stress and intermediate stress and ear height under intermediate stress and severe stress. The genotype mean squares were also significant at $P \leq 0.05$ for days to 50% tasseling, days to 50% silking and leaf senescence under severe stress, ear height under non-stress, plant height and grain yield under the three conditions. The mean squares for genotype for ASI and number of ears per plant under the three conditions and leaf senescence under intermediate were not significantly different.

Mean performance for days to 50% tasseling, days to 50% silking, ASI and plant height under non-stress, intermediate stress and severe stress conditions at Kadawa are presented in Table 4.5. The number of days to 50% tasseling showed significant differences among genotypes under the three conditions. It ranged from 57 days to 71 days, 54 days to 72 days and 58 days to 75 days under non-stress, intermediate stress and severe stress conditions, respectively. Under non-stress condition, the hybrid S2 x P1 took the highest number of days to 50% tasseling and the hybrid S7 x P7 was the earliest. Under intermediate stress condition, the parent P1 took the highest number of days to 50% tasseling and the hybrid S6 x P2 was the earliest. S6 x P2 was statistically the same with S1 x P1, S4 x P3, S4 x P4 and S7 x P3. Under severe stress condition, the parent S7 also took the highest number of days to 50% tasseling and the hybrids S5 x P3 was the earliest genotypes.

Table 4.4 ANOVA for traits measured under non-stress, intermediate stress and severe stress conditions at Kadawa

		Days to 50% tasseling			Days to50% silking			Anthesis-silking interval			Plant height		
Source	df	NS	IS	SS	NS	IS	SS	NS	IS	SS	NS	IS	SS
Block(Rep)	14	11.92	16.49*	18.26	11.50	16.43*	18.33	0.71	0.76	1.45*	319.90*	719.68	477.17*
Replications	1	137.29**	45.01**	32.14**	130.72**	55.72**	31.08**	0.14	0.08	0.08	1460.61**	56.64	4007.79**
Genotype	55	50.89**	30.47**	24.16*	51.55**	28.65**	28.15*	0.96	0.83	0.97	429.95**	819.73*	777.27*
Error	41	7.56	7.57	8.65	7.86	8.01	9.15	0.40	0.30	0.30	199.04	186.93	113.47

		Ear height			Leaf senescence		Number of ears per plant			Grain yield		
		NS	IS	SS	IS	SS	NS	IS	SS	NS	IS	SS
Block(Rep)	14	379.44	84.45*	74.64	0.54	2.81*	0.02	0.02	0.11*	3086024.50*	4417817.00*	156845.41
Replications	1	253.98**	540.41**	662.27**	8.04**	8.58**	0.01	0.92**	0.01	5630083.50**	11146848.53**	112879.51
Genotype	55	304.79	153.91**	284.18**	0.74	3.19*	0.02	0.11	0.04	4587458.00*	1163565.50*	686740.66
Error	41	95.10	39.48	64.56	0.28	0.20	0.01	0.01	0.01	1203363.80	381045.50	258501.14

*and **-significant at 0.05 and 0.01 probability level, respectively; NS=non-stress; IS=intermediate stress; SS=severe stress; df=degree of freedom; Rep=replication

Table 4.5 Mean performances for days to 50% tasseling, days to 50% silking, anthesis-silking interval and plant height under non-stress, intermediate stress and severe stress conditions at Kadawa

Genotypes	Days to 50% tasseling			Days to 50% silking			Anthesis-silking interval			Plant height (cm)		
Parents	NS	IS	SS	NS	IS	SS	NS	IS	SS	NS	IS	SS
S1	62^{a-d}	67^{a-f}	74^{ab}	65^{a-f}	70^{a-f}	77^{ab}	3	3	4	122.50^{d-l}	140.00^{ab}	67.69^{g}
S2	65^{a-d}	70^{a-d}	69^{a-e}	68^{abc}	72^{a-d}	73^{a-d}	3	2	4	113.67^{g-l}	146.67^{ab}	112.67^{a-f}
S3	69^{ab}	71^{ab}	72^{a-d}	72^{ab}	73^{a-c}	75^{abc}	3	2	3	114.50^{f-l}	143.33^{ab}	111.50^{a-f}
S4	59^{bcd}	69^{a-e}	73^{abc}	62^{def}	72^{a-d}	76^{abc}	3	3	3	95.50^{jkl}	130.84^{ab}	115.67^{a-f}
S5	59^{bcd}	66^{a-g}	71^{a-d}	62^{def}	70^{a-f}	73^{a-d}	3	4	3	129.00^{a-k}	98.34^{ab}	121.67^{a-f}
S6	69^{ab}	63^{a-h}	69^{a-e}	71^{ab}	66^{a-i}	72^{a-d}	3	3	3	126.33^{a-k}	145.00^{ab}	105.34^{a-g}
S7	62^{a-d}	69^{a-e}	75^{a}	64^{b-f}	73^{abc}	78^{a}	2	4	3	104.00^{i-l}	110.00^{ab}	93.17^{d-g}
P1	61^{a-d}	72^{a}	65^{a-e}	64^{b-f}	74^{a}	68^{a-d}	3	3	4	125.34^{b-k}	153.34^{ab}	93.33^{c-g}
P2	69^{ab}	58^{fgh}	65^{a-e}	71^{ab}	61^{e-i}	67^{a-d}	2	4	3	124.00^{c-l}	120.00^{ab}	119.83^{a-f}
P3	60^{bcd}	60^{d-h}	71^{a-d}	63^{c-f}	62^{d-i}	74^{abc}	3	3	3	140.33^{a-j}	139.17^{ab}	108.00^{a-g}
P4	63^{a-d}	69^{a-e}	71^{a-d}	66^{a-f}	71^{a-e}	76^{abc}	3	3	5	91.84^{kl}	156.67^{ab}	88.84^{efg}
P7	64^{a-d}	71^{ab}	72^{a-d}	67^{a-d}	73^{abc}	74^{abc}	3	3	3	121.00^{d-l}	128.33^{ab}	98.84^{b-g}
P8	63^{a-d}	67^{a-f}	68^{a-e}	66^{a-e}	70^{a-f}	71^{a-d}	3	3	3	117.50^{e-l}	125.00^{ab}	103.00^{a-g}
Hybrids												
S1 x P1	63^{a-d}	55^{h}	66^{a-e}	66^{a-e}	57^{i}	69^{a-d}	3	3	3	161.67^{a-e}	121.67^{ab}	93.34^{c-g}
S1 x P2	64^{a-d}	56^{gh}	63^{a-e}	66^{a-e}	59^{ghi}	67^{a-d}	3	3	4	144.00^{a-i}	129.17^{ab}	137.50^{ab}
S1 x P3	70^{ab}	61^{c-h}	69^{a-e}	75^{a}	64^{a-i}	72^{a-d}	5	3	3	148.67^{a-i}	92.50^{b}	126.84^{a-e}
S1 x P4	60^{bcd}	56^{gh}	63^{a-e}	63^{c-f}	60^{f-i}	65^{bcd}	3	5	3	157.67^{a-g}	128.33^{ab}	82.17^{fg}
S1 x P7	65^{a-d}	56^{gh}	63^{a-e}	69^{abc}	59^{ghi}	67^{a-d}	4	3	4	153.67^{a-h}	126.67^{ab}	110.00^{a-f}
S1 x P8	60^{bcd}	60^{d-h}	64^{a-e}	62^{def}	63^{c-i}	69^{a-d}	2	3	5	144.00^{a-i}	140.84^{ab}	126.34^{a-e}
S2 x P1	71^{a}	61^{c-h}	62^{b-e}	74^{ab}	64^{a-i}	65^{bcd}	3	3	4	160.67^{a-f}	108.34^{ab}	128.84^{a-e}
S2 x P2	65^{a-d}	60^{d-h}	70^{a-e}	68^{abc}	64^{a-i}	72^{a-d}	3	4	2	142.34^{a-i}	131.67^{ab}	116.17^{a-f}
S2 x P3	60^{bcd}	58^{fgh}	70^{a-e}	62^{def}	60^{f-i}	72^{a-d}	2	3	2	163.67^{a-e}	138.33^{ab}	110.17^{a-f}
S2 x P4	65^{a-d}	58^{fgh}	63^{a-e}	68^{abc}	61^{e-i}	66^{a-d}	3	3	3	150.17^{a-i}	121.67^{ab}	120.50^{a-f}
S2 x P7	60^{bcd}	56^{gh}	68^{a-e}	62^{def}	59^{ghi}	72^{a-d}	3	3	4	132.34^{a-k}	160.84^{ab}	96.67^{b-g}
S2 x P8	60^{bcd}	58^{fgh}	65^{a-e}	62^{def}	61^{e-i}	69^{a-d}	2	3	4	157.67^{a-g}	133.34^{ab}	127.00^{a-e}
S3 x P1	67^{abc}	57^{gh}	65^{a-e}	69^{c-f}	59^{ghi}	68^{a-d}	2	2	3	152.83^{a-h}	114.17^{ab}	131.00^{a-d}
S3 x P2	60^{bcd}	60^{d-h}	64^{a-e}	63^{c-f}	63^{c-i}	67^{a-d}	3	3	3	150.17^{a-i}	130.00^{ab}	113.17^{a-f}
S3 x P3	69^{ab}	56^{gh}	67^{a-e}	74^{ab}	58^{hi}	69^{a-d}	5	2	2	164.34^{a-d}	105.00^{ab}	128.34^{a-e}

Means with same letter(s) in a column are not significantly different according to DMRT at 5% level of probability and values in parenthesis are transformed
NS=non-stress; IS=intermediate stress; SS = severe stress

Table 4.5 Continued

Hybrids	Days to 50% tasseling			Days to 50% silking			Anthesis-silking interval			Plant height (cm)		
	NS	IS	SS	NS	IS	SS	NS	IS	SS	NS	IS	SS
S3 x P4	58^{cd}	63^{a-h}	70^{a-e}	61^{ef}	66^{a-i}	73^{a-d}	3	3	3	107.50^{h-l}	114.17^{ab}	122.17^{a-f}
S3 x P7	58^{cd}	62^{b-h}	66^{a-e}	61^{ef}	64^{a-i}	69^{a-d}	4	3	3	143.83^{a-i}	124.83^{ab}	123.00^{a-f}
S3 x P8	63^{a-d}	58^{fgh}	60de	66^{a-e}	61^{e-i}	63^{cd}	3	3	3	160.50^{a-f}	144.17^{ab}	124.50^{a-f}
S4 x P1	59^{bcd}	60^{d-h}	65^{a-e}	62^{def}	62^{d-i}	67^{a-d}	4	2	3	112.84^{g-l}	159.17^{ab}	119.67^{a-f}
S4 x P2	60^{bcd}	60^{d-h}	62^{b-e}	62^{def}	64^{a-i}	65^{bcd}	2	4	3	163.17^{a-e}	133.34^{ab}	110.34^{a-f}
S4 x P3	64^{a-d}	55^{h}	72^{a-d}	67^{a-d}	57^{i}	74^{a-d}	3	3	3	143.84^{a-i}	132.50^{ab}	102.17^{a-g}
S4 x P4	58^{cd}	55^{h}	66^{a-e}	61^{ef}	58^{hi}	69^{a-d}	3	3	3	143.17^{a-i}	154.17^{ab}	106.00^{a-g}
S4 x P7	64^{a-d}	64^{a-h}	70^{a-e}	65^{def}	66^{a-i}	73^{a-d}	2	3	3	138.00^{a-j}	173.33^{a}	128.17^{a-e}
S4 x P8	61^{a-d}	56^{gh}	66^{a-e}	63^{c-f}	58^{hi}	70^{a-d}	2	3	4	157.17^{a-g}	147.50^{ab}	129.50^{a-d}
S5 x P1	60^{bcd}	58^{fgh}	66^{a-e}	64^{b-f}	60^{f-i}	69^{a-d}	4	3	4	149.17^{a-i}	149.17^{ab}	100.67^{a-g}
S5 x P2	60^{bcd}	56^{gh}	71^{a-d}	63^{c-f}	58^{hi}	73^{a-d}	3	3	3	169.84^{abc}	92.50^{b}	123.25^{a-f}
S5 x P3	60^{bcd}	62^{b-h}	58^{e}	62^{def}	64^{a-i}	61^{d}	3	2	3	158.34^{a-g}	119.17^{ab}	119.67^{a-f}
S5 x P4	60^{bcd}	60^{d-h}	66^{a-e}	63^{c-f}	63^{c-i}	69^{a-d}	3	4	3	154.17^{a-g}	156.67^{ab}	114.17^{a-f}
S5 x P7	61^{a-d}	57^{gh}	65^{a-e}	63^{c-f}	60^{f-i}	68^{a-d}	2	3	3	166.00^{a-d}	126.67^{ab}	136.17^{ab}
S5 x P8	64^{a-d}	60^{d-h}	64^{a-e}	67^{a-d}	63^{c-i}	66^{a-d}	3	3	2	138.00^{a-j}	152.50^{ab}	118.67^{a-f}
S6 x P1	60^{bcd}	60^{d-h}	63^{a-e}	61^{ef}	63^{c-i}	67^{a-d}	2	3	4	114.50^{f-l}	121.67^{ab}	138.50^{ab}
S6 x P2	61^{a-d}	54^{h}	69^{a-e}	63^{c-f}	57^{i}	72^{a-d}	2	3	3	145.00^{a-i}	153.34^{ab}	122.50^{a-f}
S6 x P3	58^{cd}	56^{gh}	71^{a-d}	61^{ef}	58^{hi}	73^{a-d}	3	3	3	154.67^{a-g}	95.00^{ab}	102.00^{a-g}
S6 x P4	64^{a-d}	63^{a-h}	62^{b-e}	67^{a-d}	68^{a-h}	65^{bcd}	3	5	4	146.34^{a-i}	143.34^{ab}	123.67^{a-f}
S6 x P7	63^{a-d}	57^{gh}	66^{a-e}	67^{a-d}	59^{ghi}	70^{a-d}	4	2	4	164.34^{a-d}	159.17^{ab}	141.33^{a}
S6 x P8	66^{a-d}	58^{fgh}	70^{a-e}	68^{abc}	61^{e-i}	72^{a-d}	2	3	2	148.67^{a-i}	106.67^{ab}	109.34^{a-g}
S7 x P1	58^{cd}	56^{gh}	60^{a-e}	61^{ef}	58^{hi}	64^{cd}	3	3	4	171.67^{ab}	105.84^{ab}	117.33^{a-f}
S7 x P2	58^{cd}	61^{c-h}	64^{a-e}	60^{f}	65^{a-i}	66^{a-d}	3	4	3	141.34^{a-j}	150.83^{ab}	126.17^{a-e}
S7 x P3	61^{a-d}	55^{h}	61^{cde}	63^{c-f}	58^{hi}	65^{bcd}	3	3	4	147.67^{a-i}	145.00^{ab}	109.34^{a-g}
S7 x P4	60^{bcd}	57^{gh}	62^{b-e}	62^{def}	61^{e-i}	64^{cd}	2	4	2	140.17^{a-j}	101.67^{ab}	116.50^{a-f}
S7 x P7	57^{cd}	56^{gh}	69^{a-e}	60^{f}	59^{ghi}	71^{a-d}	3	3	3	156.50^{a-g}	147.50^{ab}	106.17^{a-g}
S7 x P8	59^{bcd}	63^{a-h}	63^{a-e}	62^{def}	66^{a-i}	67^{a-d}	3	3	4	172.84^{a}	164.17^{ab}	113.50^{a-f}
Oba 98 (Check)	66^{a-d}	71^{ab}	67^{a-e}	70^{abc}	74^{a}	70^{a-d}	4	3	3	135.50^{a-j}	100.00^{ab}	133.84^{abc}
MEAN	62	60	66	65	63	69	3	3	3	142.04	132.02	114.75
CV (%)	6.71	6.44	7.18	6.61	6.34	7.00	16.66	14.91	13.71	13.61	18.37	16.08

Means with same letter(s) in a column are not significantly different according to DMRT at 5% level of probability and values in parenthesis are transformed
NS=non-stress; IS=intermediate stress; SS = severe stress

Days to 50% silking showed significant differences among the genotypes under the three conditions (Table 4.5). It ranged from 60 days to 71 days, 57 days to 74 days and 61 days to 78 days under non-stress, intermediate stress and severe stress conditions, respectively. Under non-stress condition, the hybrid S1 x P3 took maximum number of days to 50% silking while the hybrids S7 x P2 and S7 x P7 were the earliest. The parent P1 took the maximum number of days to 50% silking and the hybrids S4 x P3 and S6 x P2 were the earliest under intermediate stress condition. Under severe stress condition, the parent S7 took the maximum took the maximum number of days to 50% silking and the hybrid S5 x P3 was the earliest.

Statistical significant differences did not exist for ASI under the three conditions (Table 4.5). However, the genotype with the highest ASI (5 days) were S1 x P3 and S3 x P3, while the least (2 days) were S7, P2, S1 x P8, S2 x P3, S2 x P8, S3 x P1, S4 x P2, S4 x P7, S4 x P8, S5 x P7, S6 x P1, S6 x P2, S6 x P8 and S7 x P4 under non-stress. Under intermediate stress, the genotypes with the highest ASI (5 days) were S6 x P4, S1 x P3 and S3 x P7, while the least (2 days) were S2, S3, S3 x P1, S3 x P3, S4 x P1, S5 x P3 and S6 x P7. Under severe stress, the genotypes with the highest ASI (5 days) were P4 and S1 x P8, while the least (2 days) were S3 x P3, S2 x P2, S2 x P3, S5 x P8, S6 x P8 and S7 x P4. Statistically significant differences existed for plant height under the three conditions which ranged from 91.84cm to 172.84cm, 92.50cm to 173.33cm and 67.69cm to 141.33cm under non-stress, intermediate stress and severe stress conditions, respectively (Table 4.5). The hybrid S7 x P8 was the tallest under non-stress condition while the parent P4 was the shortest. The hybrid S4 x P7 was the tallest and the hybrids S5 x P2 and S1 x P3 were the shortest under intermediate conditions. Under

severe stress condition, the hybrid S6 x P7 was the tallest and the parent S1 was the shortest genotype.

Mean performance for ear height, leaf senescence, number of ears per plant and grain yield under non-stress, intermediate stress and severe stress conditions at Kadawa are presented in Table 4.6. Ear height showed significant difference among the genotypes under the three conditions. The heights ranged from 46.67cm to 95.00cm, 39.83cm to 88.50cm and 34.00cm to 69.34cm under non-stress, intermediate stress and severe stress conditions, respectively. The hybrid S4 x P7 had the highest ear height and the hybrid S5 x P2 had the lowest under non-stress condition. Under intermediate stress condition, the hybrid S3 x P3 had the highest ear height and the parent S2 had the shortest. Under severe stress, the S3 x P1 had the highest ear height and the parent S1 had the shortest ear placement. S1 was statistically the same with S7, P4, P7, S1 x P1 and S1 x P4 but statistically different from the rest.

Leaf senescence showed statistical difference among the genotypes under severe stress conditions (Table 4.6). The genotypes with the most leaf senescence (2.50) under intermediate stress were S4 and S5 x P4, while the least (1.00) were 8 parents, 27 hybrids and the check and were statistically the same with the rest. Under severe stress, the genotypes with the most leaf senescence (6.50) were P2 and S1, while the least (1.00) were S3 x P4 and S4 x P7. Number of ears per plant showed no significant difference among the genotypes the three conditions (Table 4.6). However, the genotype with the highest number of ears per plant under the non-stress condition was S6 x P1 (1.77), while the least (1.00) were 12 parents, 18 hybrids and check which were statistically the same with the rest.

Table 4.6 Mean performances for ear height, leaf senescence, number of ears per plant and grain yield under non-stress, intermediate stress and severe stress conditions at Kadawa

	Ear height (cm)			Leaf senescence (1-10)		Number of ears per plant			Grain yield (kg/ha)		
Parents	NS	IS	SS	IS	SS	NS	IS	SS	NS	IS	SS
S1	80.00^{ab}	56.83^{c-l}	34.00^{e}	1.50 (1.13)	6.50^{a} (2.97)	1.00 (1.01)	1.00 (0.99)	0.65 (0.82)	1111^{e-h}	889^{b-e}	667^{bc}
S2	85.84^{ab}	39.83^{l}	51.50^{a-e}	1.00 (1.04)	2.50^{b-e} (1.69)	1.00 (0.98)	1.00 (1.00)	0.82 (0.82)	667^{h}	667de	667^{bc}
S3	70.00^{ab}	52.17^{e-l}	48.34^{a-e}	1.00 (1.30)	3.50^{a-e} (1.82)	1.00 (1.02)	1.00 (0.98)	0.68 (0.72)	1556^{c-h}	889^{b-e}	444^{c}
S4	72.50^{ab}	43.50^{kl}	40.84^{b-e}	2.50 (1.56)	3.00^{b-e} (1.82)	1.00 (0.97)	1.00 (0.99)	0.82 (0.86)	1111^{e-h}	667de	444^{c}
S5	53.34^{ab}	54.34^{d-l}	51.17^{a-e}	1.50 (1.39)	4.00^{a-e} (1.84)	1.00 (1.03)	1.00 (0.98)	0.72 (0.74)	1889^{c-h}	1556^{a-e}	667^{bc}
S6	68.34^{ab}	62.33^{a-l}	46.34^{a-e}	1.00 (1.13)	3.50^{a-e} (1.48)	1.00 (0.97)	1.00 (1.03)	0.72 (0.87)	889^{gh}	889^{b-e}	556^{bc}
S7	63.17^{ab}	43.00^{kl}	35.67^{e}	1.00 (0.89)	3.50^{a-e} (1.89)	1.00 (1.00)	1.00 (1.00)	0.54 (0.66)	889^{gh}	778^{cde}	667^{bc}
P1	76.67^{ab}	56.17^{c-l}	41.34^{a-e}	1.00 (0.87)	3.00^{b-e} (1.62)	1.00 (0.99)	1.00 (1.03)	0.59 (0.93)	1000^{fgh}	444^{e}	444^{c}
P2	60.00^{ab}	46.67^{h-l}	58.83^{a-e}	1.00 (0.96)	6.50^{a} (2.65)	1.00 (1.02)	1.07 (1.02)	0.48 (0.83)	1333^{d-h}	667de	444^{c}
P3	73.33^{ab}	60.17^{a-l}	46.84^{a-e}	1.50 (1.10)	3.50^{a-e} (1.78)	1.10 (1.08)	1.00 (1.01)	0.35 (0.81)	2556^{a-h}	667de	667^{bc}
P4	88.33^{ab}	50.50^{f-l}	35.00^{e}	1.00 (0.96)	1.50^{cde} (0.97)	1.00 (0.99)	1.00(1.01)	0.75 (0.84)	1111^{e-h}	667de	667^{bc}
P7	63.33^{ab}	46.00^{i-l}	37.17^{e}	1.00 (1.13)	2.50^{b-e} (1.19)	1.00 (1.00)	1.00(1.01)	0.45 (0.55)	667^{h}	667de	667^{bc}
P8	71.67^{ab}	48.33^{g-l}	54.34^{a-e}	1.50 (1.45)	3.50^{a-e} (2.09)	1.00 (1.00)	1.00 (0.96)	0.59 (0.69)	1444^{e-h}	778^{cde}	556^{bc}
Hybrids											
S1 x P1	75.00^{ab}	77.00^{a-f}	33.83^{e}	1.00 (0.90)	4.50^{abc} (2.21)	1.07 (0.98)	1.00 (0.99)	0.84 (0.86)	4514^{a-e}	1111^{b-e}	667^{bc}
S1 x P2	83.34^{ab}	73.67^{a-g}	56.33^{a-e}	1.00 (0.91)	3.00^{b-e} (1.62)	1.00 (1.06)	1.07 (1.06)	0.85 (1.03)	3403^{a-h}	1778^{a-e}	444^{c}
S1 x P3	51.34^{ab}	62.17^{a-l}	49.00^{a-e}	1.50 (1.10)	1.50^{cde} (1.71)	1.00 (1.00)	1.00 (0.98)	0.59 (0.77)	2737^{a-h}	667de	444^{c}
S1 x P4	66.67^{ab}	77.00^{a-f}	37.34^{e}	1.00 (0.93)	2.40^{cde} (1.36)	1.15 (1.08)	1.00 (1.02)	0.60 (0.77)	4514^{a-e}	1333^{b-e}	667^{bc}
S1 x P7	70.00^{ab}	79.33^{a-e}	52.34^{a-e}	2.00 (1.13)	2.00^{cde} (2.01)	1.05 (1.03)	1.00 (0.99)	0.68 (0.83)	3403^{a-h}	889^{b-e}	667^{bc}
S1 x P8	85.84^{ab}	64.83^{a-l}	48.33^{a-e}	1.00 (0.98)	5.00^{abc} (1.95)	1.07 (1.06)	1.00 (0.99)	0.91 (0.90)	3626^{a-h}	1556^{a-e}	1111^{abc}
S2 x P1	63.34^{ab}	76.34^{a-f}	53.83^{a-e}	1.00 (1.05)	2.50^{b-e} (1.50)	1.00 (0.98)	1.15 (1.09)	0.56 (0.68)	2070^{b-h}	1111^{b-e}	889^{abc}
S2 x P2	88.34^{ab}	72.17^{a-j}	40.50^{cde}	2.00 (1.13)	2.50^{b-e} (1.56)	1.00 (1.00)	1.00 (1.01)	0.76 (0.75)	2737^{a-h}	667de	444^{c}
S2 x P3	75.00^{ab}	75.50^{a-g}	47.67^{a-e}	1.50 (1.42)	2.00^{cde} (1.10)	1.06 (1.07)	1.00 (1.03)	0.65 (0.81)	3848^{a-h}	1333^{b-e}	889^{abc}
S2 x P4	60.00^{ab}	74.00^{a-h}	57.50^{a-e}	1.00 (1.24)	1.50^{cde} (1.53)	1.11 (1.04)	1.00 (1.00)	0.52 (0.63)	3848^{a-h}	1333^{b-e}	1111^{abc}
S2 x P7	94.17^{ab}	63.17^{a-l}	38.00^{de}	1.50 (1.02)	2.00^{cde} (1.56)	1.07 (1.06)	1.11 (1.03)	0.78 (0.80)	1626^{c-h}	1556^{a-e}	1333^{abc}
S2 x P8	71.67^{ab}	74.67^{a-g}	53.17^{a-e}	2.00 (1.15)	4.00^{a-e} (1.68)	1.16 (1.05)	1.11 (1.06)	0.85 (1.02)	5403^{ab}	1111^{b-e}	1111^{abc}
S3 x P1	62.00^{ab}	76.50^{a-f}	69.34^{a}	2.00 (1.30)	3.50^{a-e} (2.34)	1.00 (1.03)	1.06 (1.03)	0.39 (0.69)	4959^{abc}	2222^{a-e}	444^{c}
S3 x P2	58.33^{ab}	75.83^{a-f}	50.00^{a-e}	2.00 (1.24)	3.00^{b-e} (2.19)	1.31 (1.16)	1.00(1.00)	0.64 (0.73)	2070^{b-h}	889^{b-e}	444^{c}
S3 x P3	56.67^{ab}	88.50^{a}	43.67^{a-e}	1.50 (1.06)	2.00^{cde} (1.68)	1.10 (1.02)	1.00 (0.99)	0.47 (0.60)	5626^{a}	1556^{a-e}	667^{bc}

Means with same letter(s) in a column are not significantly different according to DMRT at 5% level of probability and values in parenthesis are transformed
NS=non-stress; IS=intermediate stress; SS = severe stress

Table 4.6 Continued

	Ear height (cm)			Leaf senescence (1-10)		Number of ears per plant			Grain yield (kg/ha)		
Hybrids	NS	IS	SS	IS	SS	NS	IS	SS	NS	IS	SS
S3 x P4	59.17^{ab}	45.84^{jkl}	57.67^{a-e}	1.00 (1.14)	1.00^{e} (0.73)	1.10 (1.08)	1.15 (1.07)	0.38 (0.47)	2292^{a-h}	1778^{a-e}	444^{c}
S3 x P7	63.34^{ab}	70.34^{a-k}	68.83^{ab}	1.00 (0.92)	3.00^{b-e} (1.57)	1.11 (1.06)	1.00 (1.01)	0.84 (0.98)	4070^{a-g}	1556^{a-e}	889^{abc}
S3 x P8	83.34^{ab}	83.34^{abc}	61.00^{a-e}	1.00 (1.17)	1.50^{cde} (1.53)	1.00 (0.99)	1.00 (0.98)	0.85 (0.88)	3626^{a-h}	2222^{a-e}	1333^{abc}
S4 x P1	87.50^{ab}	55.00^{d-l}	51.84^{a-e}	1.00 (0.91)	2.50^{b-e} (0.90)	1.17 (1.04)	1.00 (0.99)	0.87 (1.04)	4959^{abc}	1556^{a-e}	1111^{abc}
S4 x P2	72.50^{ab}	67.17^{a-k}	51.34^{a-e}	1.00 (0.93)	1.50^{cde} (1.55)	1.00 (1.06)	1.00 (0.99)	0.62 (0.85)	2514^{a-h}	1556^{a-e}	1556^{abc}
S4 x P3	85.00^{ab}	66.50^{a-l}	42.00^{a-e}	1.00 (0.83)	3.50^{a-e} (1.53)	1.00 (1.02)	1.00 (1.00)	0.58 (0.71)	4292^{a-f}	889^{b-e}	444^{c}
S4 x P4	88.33^{ab}	69.67^{a-k}	41.34^{a-e}	1.00 (0.97)	2.50^{b-e} (2.20)	1.11 (1.05)	1.00 (1.00)	0.73 (0.76)	3848^{a-h}	2445^{a-d}	444^{c}
S4 x P7	95.00^{a}	60.50^{a-l}	49.84^{a-e}	1.00 (1.25)	1.00^{e} (1.63)	1.00 (0.98)	1.28 (0.96)	0.95 (0.79)	2737^{a-h}	2222^{a-e}	1556^{ab}
S4 x P8	90.83^{ab}	69.83^{a-k}	48.84^{a-e}	1.00 (0.91)	3.50^{a-e} (1.21)	1.00 (1.00)	1.00 (1.15)	0.64 (1.02)	3403^{a-h}	1667^{a-e}	667^{bc}
S5 x P1	90.00^{ab}	68.50^{a-k}	39.84^{a-e}	1.50 (1.05)	2.00^{cde} (1.64)	1.00 (1.01)	1.34 (1.10)	0.30 (0.55)	1848^{c-h}	1333^{b-e}	889^{abc}
S5 x P2	46.67^{b}	71.67^{a-j}	51.33^{a-e}	1.00 (1.30)	1.50^{cde} (1.17)	1.36 (1.17)	1.00 (0.98)	0.43 (0.74)	3626^{a-h}	667de	444^{c}
S5 x P3	74.17^{ab}	68.33^{a-k}	46.00^{a-e}	1.00 (1.21)	2.00^{cde} (1.56)	1.13 (1.07)	1.19 (1.10)	0.46 (0.83)	2514^{a-h}	2000^{a-e}	889^{abc}
S5 x P4	81.67^{ab}	68.67^{a-k}	41.17^{a-e}	2.50 (1.62)	2.50^{b-e} (1.49)	1.34 (1.12)	1.00 (0.99)	0.67 (0.46)	3626^{a-h}	1556^{a-e}	667^{bc}
S5 x P7	65.00^{ab}	84.50^{ab}	60.34^{a-e}	1.00 (1.22)	4.50^{abc} (2.13)	1.38 (1.19)	1.00 (1.00)	0.29 (0.87)	4292^{a-f}	1333^{b-e}	444^{c}
S5 x P8	89.17^{ab}	58.50^{b-l}	57.67^{a-e}	1.00 (0.91)	2.00^{cde} (1.37)	1.00 (1.00)	1.00 (1.03)	0.59 (0.86)	1848^{c-h}	1778^{a-e}	1445^{ab}
S6 x P1	68.34^{ab}	49.84^{f-l}	67.00^{abc}	1.00 (1.12)	2.00^{cde} (1.40)	1.77 (1.30)	1.45 (1.17)	0.70 (0.90)	3181^{a-h}	2667^{ab}	1333^{abc}
S6 x P2	78.34^{ab}	74.00^{a-h}	48.17^{a-e}	1.00 (1.06)	5.50^{ab} (2.45)	1.50 (1.19)	1.00 (0.99)	0.88 (1.06)	4959^{abc}	1333^{b-e}	889^{abc}
S6 x P3	55.00^{ab}	80.17^{a-d}	46.17^{a-e}	1.00 (1.05)	4.00^{a-e} (1.74)	1.06 (1.04)	1.00 (1.05)	0.78 (1.18)	3181^{a-h}	1556^{a-e}	889^{abc}
S6 x P4	76.67^{ab}	61.17^{a-l}	49.34^{a-e}	1.50 (1.05)	1.50^{cde} (1.02)	1.00 (1.01)	1.00 (1.05)	1.00 (0.93)	4070^{a-g}	889^{b-e}	556^{bc}
S6 x P7	85.84^{ab}	80.50^{a-d}	53.00^{a-e}	1.00 (0.93)	2.50^{b-e} (1.48)	1.11 (1.02)	1.00 (1.01)	1.00 (0.94)	4737^{a-d}	2000^{a-e}	889^{abc}
S6 x P8	60.00^{ab}	71.17^{a-j}	43.00^{a-e}	1.50 (1.27))	2.00^{cde} (1.52)	1.00 (0.97)	1.00 (0.99)	1.08 (1.35)	1848^{c-h}	1111^{b-e}	444^{c}
S7 x P1	64.17^{ab}	80.50^{a-d}	66.17^{a-d}	1.00 (0.92)	4.50^{abc} (1.96)	1.05 (1.03)	1.13 (1.06)	1.75 (1.06)	4514^{a-e}	3333^{a}	1333^{abc}
S7 x P2	90.00^{ab}	64.84^{a-l}	59.00^{a-e}	1.00 (1.16)	2.50^{b-e} (1.22)	1.00 (0.95)	1.00 (1.02)	1.07 (0.78)	2959^{a-h}	2000^{a-e}	444^{c}
S7 x P3	78.33^{ab}	66.67^{a-l}	40.84^{b-e}	1.50 (1.18)	2.00^{cde} (1.15)	1.00 (0.95)	1.00 (1.00)	0.71 (0.97)	4292^{a-f}	1111^{b-e}	1111^{abc}
S7 x P4	62.50^{ab}	61.00^{b-l}	46.84^{a-e}	1.00 (0.97)	2.00^{cde} (1.08)	1.29 (1.12)	1.00 (1.00)	0.82 (0.79)	4515^{a-e}	2222^{a-e}	1778^{ab}
S7 x P7	85.83^{ab}	73.34^{a-i}	43.67^{a-e}	2.00 (1.51)	4.00^{a-e} (2.04)	1.00 (0.97)	1.00 (0.97)	0.75 (0.67)	4737^{a-d}	1778^{a-e}	444^{c}
S7 x P8	87.50^{ab}	76.50^{a-f}	55.34^{a-e}	1.00 (0.95)	2.00^{cde} (1.45)	1.00 (1.02)	1.22 (1.09)	0.74 (0.68)	2737^{a-h}	2556^{abc}	2222^{a}
Oba 98 (Check)	66.67^{ab}	56.67^{c-l}	53.67^{a-e}	1.00 (0.90)	2.00^{cde} (1.46))	1.00 (1.02)	1.00 (0.99)	0.50 (0.85)	4656^{a-d}	2556^{abc}	1444^{ab}
MEAN	73.55	65.63	49.17	1.27	2.85	1.08	1.04	0.70	3038	1411	819
CV (%)	26.52	17.31	22.13	20.93	25.25	13.27	13.53	22.73	45.76	52.7	59.52

Means with same letter(s) in a column are not significantly different according to DMRT at 5% level of probability and values in parenthesis are transformed
NS=non-stress; IS=intermediate stress; SS = severe stress

Under intermediate stress condition, the hybrid S6 x P1 had the highest number of ears per plant (1.45), while the least (1.00) were 12 parents, 30 hybrids and check and were the same with the rest statistically. Under severe stress, the hybrid S7 x P1 had the highest number of ears per plant (1.75) while the hybrid S5 had the lowest number of ears per plant (0.29) and were statistically the same with the rest.

Statistical significant differences exist for grain yield under the three conditions (Table 4.6). It ranged from 667kg/ha to 5626kg/ha, 444kg/ha to 3333kg/ha and 444kg/ha to 2222kg/ha under non-stress, intermediate stress and severe stress conditions, respectively. The hybrid S3 x P3 had the highest grain yield under non-stress condition while the parents S1 and P7 recorded the lowest grain yield and were statistically different from rest. Under intermediate stress condition, the hybrid S7 x P1 had the highest yield while parent P1 had the lowest grain yield and were statistically different from rest. The hybrid S7 x P8 had the highest grain yield while parents S3, S4, P1 P2 and the hybrids S1 x P2, S1 x P3, S2 x P2, S3 x P1, S3 x P2, S3 x P4, S4 x P3, S4 x P4, S4 x P2, S5 x P7, S6 x P8, S7 x P2 and S7 x P7 had the lowest grain yield and were significantly different from the rest.

4.1.3 Combined analyses of variance and mean performance across locations

Combined analyses of variance for traits measured under non-stress, intermediate stress and severe stress conditions across locations are presented in Table 4.7. The locations mean squares were highly significant ($P \leq 0.01$) for all traits measured under the three conditions except number of ears per plant under intermediate stress.

Table 4.7 Combined ANOVA for traits measured under non-stress, intermediate stress and severe stress conditions across locations

		Days to 50% tasseling			Days to50% silking			Anthesis-silking interval			Plant height		
Source	df	NS	IS	SS	NS	IS	SS	NS	IS	SS	NS	IS	SS
Loc	1	1032.86**	4296.25**	1481.14**	3068.04**	661.72**	1455.54**	111.45**	6.79**	48.29**	117883.15**	129398.67**	98171.33**
Blk(Locxrep)	28	7.66	9.24	13.07	7.87	10.27	13.37*	0.68	1.18*	2.14*	219.29	452.60*	326.73*
Rep (Loc)	2	112.86**	83.79**	58.02**	16.61**	83.79**	51.11**	30.02**	2.79**	4.02**	977.79**	4173.64**	176.17
Genotypes	55	57.47**	43.26**	32.12**	60.93**	61.49**	33.72**	7.20**	2.16	2.33*	1046.09**	847.88*	1439.93**
Geno x Loc	55	14.34*	12.24*	9.83*	14.36*	15.01*	10.75*	3.69	0.79*	0.75	360.81*	239.14*	321.15*
Error	82	3.49	5.97	4.04	4.16	4.22	6.81	1.27	0.32	0.49	183.08	101.51	118.23

		Ear height			Leaf senescence		Number of ears per plant			Grain yield		
		NS	IS	SS	IS	SS	NS	IS	SS	NS	IS	SS
Loc	1	91516.14**	36999.01**	38142.54**	50.16**	8.25**	0.41**	0.06	2.77**	75446417.00**	112074486.30**	52500838.80**
Blk(Locxrep)	28	291.69*	108.71	108.44*	0.61	2.64	0.07	0.03	0.15	2135427.20*	2696699.60**	372922.32
Rep (Loc)	2	1138.37**	674.88**	65.30	6.45**	7.36**	0.11	0.09	0.89**	2074285.80*	1984.00	4699293.25
Genotypes	55	385.73*	521.67**	533.33**	2.45	4.77	0.18	0.25	0.15	7825972.35**	2408797.50*	1910725.97*
Geno x Loc	55	147.01*	131.60	105.10*	0.99	1.65	0.04	0.02	0.03	1727771.60*	704673.87	831939.67
Error	82	51.68	51.68	97.95	1.17	0.57	0.03	0.02	0.01	876451.52	554066.68	415784.28

*and **-significant at 0.05 and 0.01 probability level, respectively; NS=non-stress; IS=intermediate stress; SS=severe stress; df=degree of freedom; Rep=replication; Loc=location; Blk=block; Geno=genotype

The mean squares for genotypes were highly significant difference (P≤0.01) for days to 50% tasseling and days to 50% silking under the three conditions, ASI and grain yield under non-stress, plant height under non-stress and severe stress and ear height under intermediate stress and severe stress. The mean squares for genotypes were significant at P≤0.05 for ASI under severe stress, plant height under intermediate stress, ear height under non-stress and grain yield under intermediate stress and severe stress. The mean squares for genotypes were not significant for anthesis-silking interval and leaf senescence under intermediate stress and severe stress and number of ears per plant under the three conditions. The genotypes x locations mean squares were significant (P≤0.05) for all traits except ASI under non-stress and severe stress, ear height under intermediate stress, number of ears per plant under the three conditions and leaf senescence and grain yield under intermediate stress and severe stress.

Mean performance for days to 50% tasseling, days to 50% silking, ASI and plant height under non-stress, intermediate stress and severe stress across locations are presented in Table 4.8. The number of days to 50% tasseling showed significant differences among genotypes under the three conditions. It ranged from 56 days to 65 days, 54 days to 67 days and 58 days to 68 days under non-stress, intermediate stress and severe stress conditions, respectively. Under non-stress condition, the parent P8 took the highest number of days to 50% tasseling and the hybrid S3 x P4 and S7 x P7 were the earliest. Under intermediate stress condition, the parent P8 took the highest number of days to 50% tasseling and the hybrids S5 x P2 and S6 x P2 were the earliest. Under severe stress condition, the same parent P8 also took the highest number of days to 50% tasseling and the hybrids S4 x P2, S5 x P3, S7 x P1 and S7 x P4 were the earliest genotypes.

Table 4.8 Mean performances for days to 50% tasseling, days to 50% silking, anthesis-silking interval and plant height under non-stress, intermediate stress and severe stress conditions across locations

	Days to 50% tasseling			Days to 50% silking			Anthesis-silking interval			Plant height (cm)		
Parents	NS	IS	SS	NS	IS	SS	NS	IS	SS	NS	IS	SS
S1	62^{a-d}	62^{a-f}	67^{ab}	64^{a-f}	66^{a-d}	73^{ab}	3^{c-f}	3	5^{abc}	156.25^{a-h}	152.92^{a-f}	114.68^{fg}
S2	61^{a-f}	64^{abc}	64^{a-e}	64^{a-f}	67^{abc}	68^{a-g}	3^{c-f}	3	4^{a-d}	146.84^{d-i}	165.00^{a-d}	128.83^{c-g}
S3	62^{a-d}	63^{a-d}	65^{a-d}	65^{a-d}	65^{a-e}	68^{a-g}	3^{c-f}	3	3^{bcd}	134.33^{g-j}	152.08^{a-f}	129.50^{c-g}
S4	58^{c-g}	64^{abc}	67^{ab}	62^{b-g}	67^{abc}	71^{a-d}	4^{abc}	4	4^{a-d}	138.58^{f-j}	152.50^{a-f}	130.33^{b-g}
S5	57^{efg}	59^{a-g}	63^{a-f}	60^{efg}	62^{c-h}	67^{a-h}	3^{c-f}	3	4^{a-d}	138.67^{f-j}	120.83^{f}	131.25^{b-g}
S6	63^{a-d}	59^{b-g}	67^{ab}	66^{abc}	63^{b-g}	74^{a}	4^{abc}	4	7^{a}	127.33^{ij}	137.09^{a-f}	114.75^{fg}
S7	58^{c-g}	62^{a-f}	65^{a-d}	61^{c-g}	67^{abc}	71^{a-d}	3^{c-f}	5	6^{ab}	129.50^{hij}	134.59^{c-f}	115.33^{efg}
P1	61^{a-f}	66^{a}	63^{a-f}	64^{a-f}	70^{a}	68^{a-g}	3^{c-f}	4	5^{abc}	162.33^{a-g}	170.00^{abc}	125.83^{d-g}
P2	63^{abc}	57^{d-g}	63^{a-f}	65^{a-d}	62^{c-h}	68^{a-g}	3^{c-f}	4	5^{abc}	151.59^{b-i}	150.83^{a-f}	146.58^{b-f}
P3	59^{b-g}	58^{c-g}	64^{a-e}	61^{c-g}	62^{c-h}	68^{a-g}	2^{def}	4	4^{a-d}	161.42^{a-g}	158.33^{a-f}	136.08^{b-g}
P4	60^{a-g}	63^{a-d}	65^{a-d}	64^{a-e}	67^{abc}	70^{a-f}	4^{abc}	4	5^{abc}	134.08^{g-j}	166.25^{a-d}	118.17^{efg}
P7	61^{a-f}	65^{ab}	66^{abc}	65^{a-d}	68^{ab}	73^{ab}	4^{abc}	3	7^{a}	143.42^{e-i}	150.83^{a-f}	123.58^{d-g}
P8	65^{a}	67^{a}	68^{a}	68^{a}	70^{a}	72^{abc}	3^{c-f}	3	4^{a-d}	113.33^{j}	122.92^{ef}	99.00^{g}
Hybrids												
S1 x P1	60^{a-g}	56^{efg}	61^{c-f}	63^{a-g}	59^{fgh}	65^{a-j}	4^{abc}	3	4^{a-d}	184.59^{a}	152.09^{a-f}	139.17^{b-g}
S1 x P2	59^{b-g}	56^{efg}	60^{def}	63^{a-g}	59^{fgh}	63^{c-j}	3^{c-f}	3	3^{bcd}	164.08^{a-f}	160.00^{a-e}	156.25^{ab}
S1 x P3	63^{abc}	59^{b-g}	65^{a-d}	68^{a}	62^{c-h}	69^{a-e}	5^{a}	3	4^{a-d}	162.25^{a-g}	133.75^{c-f}	145.09^{b-f}
S1 x P4	59^{b-g}	56^{efg}	60^{def}	62^{b-g}	60^{e-h}	64^{b-j}	3^{c-f}	5	4^{a-d}	174.25^{a-d}	157.92^{a-f}	125.67^{d-g}
S1 x P7	61^{a-f}	55^{fg}	60^{def}	65^{a-d}	59^{fgh}	63^{c-j}	4^{abc}	3	3^{bcd}	171.00^{a-e}	151.67^{a-f}	132.50^{b-g}
S1 x P8	59^{b-g}	59^{b-g}	62^{b-f}	61^{c-g}	62^{c-h}	67^{a-h}	2^{def}	3	6^{ab}	$168.25^{a–f}$	166.25^{a-d}	139.84^{b-g}
S2 x P1	64^{ab}	59^{b-g}	61^{c-f}	67^{ab}	59^{fgh}	64^{b-j}	3^{c-f}	1	3^{bcd}	177.42^{abc}	147.50^{a-f}	149.00^{b-f}
S2 x P2	61^{a-f}	59^{b-g}	65^{a-d}	64^{a-f}	62^{c-h}	68^{a-g}	3^{c-f}	4	3^{bcd}	166.17^{a-f}	161.25^{a-e}	144.34^{b-f}
S2 x P3	59^{c-g}	57^{d-g}	65^{a-d}	62^{b-g}	60^{e-h}	67^{a-h}	3^{c-f}	3	3^{bcd}	180.58^{ab}	165.00^{a-d}	142.58^{b-f}
S2 x P4	61^{a-f}	57^{d-g}	60^{def}	64^{a-f}	61^{d-h}	64^{b-j}	3^{c-f}	4	3^{bcd}	180.67^{ab}	148.75^{a-f}	140.25^{b-f}
S2 x P7	59^{c-g}	56^{efg}	61^{c-f}	61^{c-g}	59^{fgh}	67^{a-h}	3^{c-f}	3	5^{abc}	164.09^{a-f}	173.75^{ab}	132.92^{b-g}
S2 x P8	58^{c-g}	57^{d-g}	63^{a-f}	61^{c-g}	61^{d-h}	66^{a-i}	3^{c-f}	4	4^{a-d}	179.83^{abc}	164.58^{a-d}	152.25^{a-d}
S3 x P1	61^{abc}	56^{efg}	61^{c-f}	64^{a-f}	60^{e-h}	66^{a-i}	3^{c-f}	4	5^{abc}	179.33^{abc}	150.42^{a-f}	145.09^{b-f}
S3 x P2	58^{c-g}	57^{d-g}	59^{c-g}	60^{efg}	60^{e-h}	62^{d-j}	3^{c-f}	3	3^{bcd}	171.34^{a-e}	152.08^{a-f}	140.33^{b-f}
S3 x P3	63^{abc}	56^{efg}	63^{a-f}	67^{ab}	59^{fgh}	66^{a-i}	4^{abc}	3	4^{a-d}	174.25^{a-d}	140.42^{a-f}	140.83^{b-f}

Means with same letter(s) in a column are not significantly different according to DMRT at 5% level of probability and values in parenthesis are transformed
NS=non-stress; IS=intermediate stress; SS = severe stress

Table 4.8 Continued

	Days to 50% tasseling			Days to 50% silking			Anthesis-silking interval			Plant height (cm)		
Hybrids	NS	IS	SS	NS	IS	SS	NS	IS	SS	NS	IS	SS
S3 x P4	56^{g}	59^{b-g}	64^{a-e}	60^{efg}	63^{b-g}	68^{a-g}	4^{abc}	3	4^{a-d}	150.00^{c-i}	144.58^{a-f}	147.75^{b-f}
S3 x P7	57^{efg}	58^{c-g}	59^{ef}	60^{efg}	62^{c-h}	62^{d-j}	3^{c-f}	4	3^{bcd}	167.75^{a-f}	147.83^{a-f}	145.67^{b-f}
S3 x P8	62^{a-d}	57^{d-g}	59^{ef}	62^{b-g}	59^{fgh}	63^{c-j}	0^{f}	3	4^{a-d}	178.59^{abc}	165.42^{a-d}	141.00^{b-f}
S4 x P1	58^{c-g}	58^{c-g}	61^{c-f}	61^{c-g}	61^{d-h}	66^{a-i}	3^{c-f}	3	5^{abc}	156.00^{a-h}	173.75^{ab}	151.09^{a-e}
S4 x P2	58^{c-g}	58^{c-g}	58^{d-g}	61^{c-g}	62^{c-h}	61^{e-j}	3^{c-f}	4	3^{bcd}	166.61^{a-f}	162.08^{a-d}	136.00^{b-g}
S4 x P3	63^{abc}	56^{efg}	65^{a-d}	64^{a-f}	59^{fgh}	68^{a-g}	1^{ef}	3	3^{bcd}	158.50^{a-h}	155.42^{a-f}	134.17^{b-g}
S4 x P4	57^{efg}	56^{efg}	62^{b-f}	59^{fg}	58^{gh}	66^{a-i}	2^{def}	3	4^{a-d}	172.00^{a-e}	173.33^{ab}	140.50^{b-f}
S4 x P7	59^{b-g}	60^{b-g}	64^{a-e}	61^{c-g}	62^{c-h}	67^{a-h}	2^{def}	3	3^{bcd}	162.75^{a-g}	181.67^{a}	144.08^{b-f}
S4 x P8	59^{b-g}	56^{efg}	62^{b-f}	61^{c-g}	59^{fgh}	65^{a-j}	2^{def}	3	3^{bcd}	169.42^{a-e}	166.25^{a-d}	149.75^{a-f}
S5 x P1	57^{efg}	56^{efg}	61^{c-f}	60^{efg}	58^{gh}	64^{b-j}	3^{c-f}	3	3^{bcd}	173.75^{a-e}	166.67^{a-d}	129.09^{c-g}
S5 x P2	57^{efg}	54^{g}	62^{b-f}	60^{efg}	57^{h}	64^{b-j}	2^{def}	2	3^{bcd}	176.17^{a-d}	132.50^{def}	148.71^{b-f}
S5 x P3	58^{c-g}	59^{b-g}	58^{f}	60^{efg}	62^{c-h}	61^{e-j}	2^{def}	2	3^{bcd}	159.17^{a-g}	147.08^{a-f}	146.92^{b-f}
S5 x P4	58^{c-g}	58^{c-g}	60^{def}	61^{c-g}	61^{d-h}	63^{c-j}	3^{c-f}	3	2^{cd}	170.59^{a-e}	170.00^{abc}	137.92^{b-g}
S5 x P7	57^{efg}	56^{efg}	60^{def}	59^{fg}	59^{fgh}	62^{d-j}	2^{def}	3	2^{cd}	173.00^{a-e}	152.50^{a-f}	152.67^{a-d}
S5 x P8	60^{a-g}	57^{d-g}	59^{ef}	62^{b-g}	60^{e-h}	63^{c-j}	2^{def}	3	4^{a-d}	161.92^{a-g}	167.92^{a-d}	128.92^{c-g}
S6 x P1	58^{c-g}	58^{c-g}	59^{ef}	60^{efg}	60^{e-h}	64^{b-j}	2^{def}	3	5^{abc}	156.08^{a-h}	150.42^{a-f}	152.17^{a-d}
S6 x P2	58^{c-g}	54^{g}	62^{b-f}	60^{efg}	58^{gh}	64^{b-j}	2^{def}	4	2^{cd}	171.67^{a-e}	164.17^{a-d}	147.92^{b-f}
S6 x P3	57^{c-g}	55^{fg}	64^{a-e}	60^{efg}	58^{gh}	67^{a-h}	3^{c-f}	3	3^{bcd}	165.67^{a-f}	135.84^{b-f}	136.42^{b-g}
S6 x P4	60^{a-g}	59^{b-g}	59^{c-g}	63^{a-g}	64^{a-f}	62^{d-j}	3^{c-f}	5	3^{bcd}	164.84^{a-f}	158.33^{a-f}	149.75^{a-f}
S6 x P7	59^{b-g}	56^{efg}	62^{b-f}	63^{a-g}	58^{gh}	65^{a-j}	3^{c-f}	2	3^{bcd}	174.67^{a-d}	170.42^{abc}	159.42^{a}
S6 x P8	62^{a-d}	57^{d-g}	65^{a-d}	64^{a-f}	61^{d-h}	68^{a-g}	2^{def}	4	3^{bcd}	161.83^{a-g}	139.58^{a-f}	140.92^{b-f}
S7 x P1	57^{efg}	56^{efg}	58^{f}	60^{efg}	59^{fgh}	62^{d-j}	3^{c-f}	3	5^{abc}	185.00^{a}	154.17^{a-f}	154.08^{abc}
S7 x P2	57^{efg}	57^{d-g}	60^{def}	59^{fg}	61^{d-h}	63^{c-j}	3^{c-f}	4	3^{bcd}	161.09^{a-g}	156.67^{a-f}	143.50^{b-f}
S7 x P3	59^{b-g}	56^{efg}	59^{ef}	62^{b-g}	59^{fgh}	63^{c-j}	3^{c-f}	3	4^{a-d}	169.67^{a-e}	160.42^{a-e}	142.58^{b-f}
S7 x P4	57^{efg}	56^{efg}	58^{d-g}	60^{efg}	60^{e-h}	63^{c-j}	3^{c-f}	3	5^{abc}	163.83^{a-f}	142.92^{a-f}	140.75^{b-f}
S7 x P7	56^{g}	55^{fg}	62^{b-f}	59^{fg}	59^{fgh}	66^{a-i}	3^{c-f}	4	3^{bcd}	170.33^{a-e}	170.42^{abc}	137.67^{b-g}
S7 x P8	57^{efg}	60^{b-g}	59^{ef}	61^{c-g}	63^{b-g}	62^{d-j}	3^{c-f}	3	3^{bcd}	183.67^{a}	165.42^{a-d}	139.58^{b-g}
Oba 98 (Check)	62^{a-d}	65^{ab}	64^{a-e}	65^{a-d}	67^{abc}	66^{a-i}	3^{c-f}	2	2^{cd}	166.08^{a-f}	142.50^{a-f}	152.75^{abc}
MEAN	59	58	62	62	61	66	3	3	4	162.97	154.96	138.78
CV (%)	5.35	5.08	6.24	5.22	5.25	6.28	15.54	16.88	22.57	10.55	13.81	11.48

Means with same letter(s) in a column are not significantly different according to DMRT at 5% level of probability and values in parenthesis are transformed
NS=non-stress; IS=intermediate stress; SS = severe stress

Days to 50% silking showed significant differences among the genotypes under the three conditions (Table 4.8). It ranged from 59 days to 68 days, 57 days to 70 days and 61 days to 74 days under non-stress, intermediate stress and severe stress conditions, respectively. Under non-stress condition, the parent P8 and the hybrid S1 x P3 took maximum number of days to 50% silking while the hybrids S4 x P4, S5 x P7, S7 x P2 and S7 x P7 were the earliest. The parents P1 and P8 took the maximum number of days to 50% silking and the hybrid S5 x P2 was the earliest under intermediate stress condition. Under severe stress condition, the parent S6 took the maximum took the maximum number of days to 50% silking while the hybrids S4 x P2 and S5 x P3 were the earliest genotypes.

Statistical significant differences exist for ASI under the non-stress and severe stress conditions (Table 4.8). The genotype with the highest ASI (5 days) was S1 x P3, while the least (0 day) was S3 x P8 under non-stress. Under intermediate stress, the genotypes with the highest ASI (5 days) were S7, S1 x P4 and S6 x P4, while the least (1 day) was S2 x P1. Under severe stress, the genotypes with the highest ASI (7 days) were S6 and P4, while the least (2 days) were S4 x P4, S5 x P7, S6 x P2 and check. Statistically significant differences existed for plant height under the three conditions which ranged from 113.33cm to 185.00cm, 120.83cm to 181.67cm and 99.00cm to 159.42cm under non-stress, intermediate stress and severe stress conditions, respectively (Table 4.8). The hybrid S7 x P1 was the tallest under non-stress condition and was statistically the same with S7 x P8 while the parent P8 was the shortest. The hybrid S4 x P7 was the tallest and the parent S5 was the shortest under intermediate conditions. Under severe stress condition, the hybrid S6 x P7 was the tallest and the parent P8 was the shortest genotype.

Mean performance for ear height, leaf senescence, number of ears per plant and grain yield under non-stress, intermediate stress and severe stress across locations are presented in Table 4.9. Ear height showed statistical difference among the genotypes under the three conditions. The heights ranged from 62.08cm to 103.33cm, 53.33cm to 95.08cm and 50.92cm to 86.75cm under non-stress, intermediate stress and severe stress conditions, respectively. The hybrid S4 x P7 had the highest ear height and the parent S5 had the lowest under non-stress condition. Under intermediate stress condition, the hybrid S3 x P3 had the highest ear height and the parent P8 had the shortest. Under severe stress, the S4 x P1 had the highest ear height and the parent P8 had the shortest ear placement. S1 was statistically the same with S7, P4, P7, S1 x P1 and S1 x P4 but statistically different from the rest. Leaf senescence did not showed statistical difference among the genotypes under intermediate stress and severe stress conditions (Table 4.9). However, the genotypes with the most leaf senescence (2.50) under intermediate stress were S3 x P1 and S5 x P4, while the least (1.00) were S7, P1, P4, P7, S1 x P1, S1 x P4, S3 x P8, S4 x P2, S4 x P7, S4 x P8 and S7 x P8 and are statistically the same with the rest. Under severe stress, the genotype with the most leaf senescence (5.25) was P2, while the least (1.50) was S3 x P8 and were statistically the same with the rest.

Number of ears per plant showed no significant difference among the genotypes the three conditions (Table 4.9). However, the genotype with the highest number of ears per plant under the non-stress condition was S6 x P1 (1.41), while the least (1.00) were S1, S6, S7, P7, S3 x P8, S4 x P8, S5 x P1, S6 x P8 and check which were statistically the same with the rest. Under intermediate stress condition, the parent P8 had the highest number of ears per plant (1.42), while the least (1.00) were 4 parents, 20 hybrids and check which were statistically the same with the rest.

Table 4.9 Mean performances for ear height, leaf senescence, number of ears per plant and grain yield under non-stress, intermediate stress and severe stress conditions across locations

	Ear height (cm)			Leaf senescence (1-10)		Number of ears per plant			Grain yield (kg/ha)		
Parents	NS	IS	SS	IS	SS	NS	IS	SS	NS	IS	SS
S1	87.08^{a-f}	76.33^{a-l}	64.50^{c-g}	1.50 (1.19)	4.50 ((2.28)	1.00 (1.06)	1.00 (0.97)	0.86 (0.93)	2278^{e-h}	1444^{b-e}	1222^{a-d}
S2	93.34^{a-e}	63.25^{i-m}	70.75^{b-f}	2.00 (1.41)	3.25 (1.82)	1.13 (1.01)	1.06 (1.06)	0.91 (0.83)	1889^{fgh}	1444^{b-e}	1111^{a-d}
S3	78.75^{a-f}	64.83^{h-m}	67.08^{b-g}	1.25 (1.22)	4.50 (2.01)	1.07 (1.05)	1.00 (0.98)	0.64 (0.78)	1778^{gh}	1500^{b-e}	833^{bcd}
S4	85.42^{a-f}	70.08^{d-m}	62.50^{c-g}	2.00 (1.42)	2.75 (1.51)	1.06 (1.00)	1.03 (1.01)	0.88 (0.95)	1833^{fgh}	1444^{b-e}	1222^{a-d}
S5	62.08^{f}	65.50^{g-m}	64.75^{c-g}	2.50 (1.53)	4.00 (2.01)	1.03 (0.99)	1.03 (1.00)	0.81 (0.83)	2000^{fgh}	1333^{cde}	778^{bcd}
S6	68.33^{ef}	58.25^{lm}	52.34^{fg}	1.25 (1.16)	4.00 (1.88)	1.00 (1.04)	1.25 (1.12)	0.75 (0.93)	2722^{d-h}	1667^{b-e}	1556^{a-d}
S7	70.75^{c-f}	61.08^{j-m}	53.67^{fg}	1.00 (1.31)	3.25 (1.82)	1.00 (1.01)	1.05 (1.03)	0.62 (0.70)	1556^{h}	1278de	1000^{a-d}
P1	88.75^{a-f}	76.00^{a-l}	66.50^{b-g}	1.00 (0.92)	3.50 (1.75)	1.03 (0.99)	1.00 (1.02)	0.79 (0.91)	2556^{d-h}	1444^{b-e}	722^{bcd}
P2	79.17^{a-f}	66.25^{f-m}	84.42^{abc}	1.75 (1.10)	5.25 (2.45)	1.33 (1.19)	1.09 (1.00)	0.64 (0.90)	2000^{fgh}	1444^{b-e}	778^{bcd}
P3	81.67^{a-f}	71.34^{c-m}	64.67^{c-g}	1.50 (1.14)	2.75 (1.70)	1.34 (1.13)	1.00 (0.99)	0.61 (0.86)	1889^{fgh}	1556^{b-e}	778^{bcd}
P4	88.75^{a-f}	65.67^{g-m}	55.83^{efg}	1.00 (1.02)	2.25 (1.22)	1.16 (1.07)	1.03 (1.03)	0.89 (0.87)	2889^{fgh}	1778^{b-e}	667^{bcd}
P7	74.17^{b-f}	60.50^{klm}	56.50^{d-g}	1.00 (1.12)	2.25 (1.23)	1.00 (1.01)	1.07 (1.05)	0.99 (0.91)	1556^{h}	611^{e}	444^{d}
P8	69.17^{def}	53.33^{m}	50.92^{g}	1.25 (1.21)	2.50 (1.62)	1.38 (1.13)	1.42 (1.16)	1.04 (0.89)	2056^{fgh}	1611^{b-e}	611^{cd}
Hybrids											
S1 x P1	88.75^{a-f}	87.67^{a-e}	62.75^{c-g}	1.00 (0.92)	3.50 (1.98)	1.03 (0.99)	1.00 (1.00)	0.89 (0.92)	3656^{a-h}	1611^{b-e}	1222^{a-d}
S1 x P2	100.42^{ab}	85.58^{a-f}	74.67^{b-f}	2.00 (1.20)	3.25 (1.95)	1.18 (1.15)	1.11 (1.03)	0.72 (0.94)	4433^{a-f}	2222^{a-d}	1056^{a-d}
S1 x P3	76.92^{a-f}	73.59^{b-l}	69.09^{b-g}	1.75 (1.24)	3.00 (1.87)	1.03 (1.00)	1.00 (0.99)	0.92 (0.97)	4767^{a-d}	2667^{a-d}	1444^{a-d}
S1 x P4	91.25^{a-e}	85.17^{a-f}	61.17^{c-g}	1.00 (0.94)	2.70 (1.67)	1.23 (1.13)	1.05 (1.02)	0.68 (0.82)	3878^{a-h}	1444^{b-e}	889^{a-d}
S1 x P7	86.25^{a-f}	86.33^{a-e}	64.92^{c-g}	1.75 (1.19)	2.25 (1.80)	1.07 (1.10)	1.00 (0.97)	1.26 (1.09)	4100^{a-h}	1667^{b-e}	1000^{a-d}
S1 x P8	99.17^{abc}	79.50^{a-k}	68.33^{b-g}	1.75 (1.31)	4.50 (1.98)	1.11 (1.05)	1.08 (1.02)	0.94 (0.93)	3433^{a-h}	1556^{b-e}	667^{bcd}
S2 x P1	80.84^{a-f}	87.75^{a-e}	70.25^{b-f}	1.25 (1.00)	2.50 (1.53)	1.22 (1.08)	1.12 (1.08)	0.66 (0.74)	4433^{a-f}	2889^{abc}	1444^{a-d}
S2 x P2	102.08^{ab}	83.58^{a-h}	67.75^{b-g}	1.75 (1.12)	4.00 (1.87)	1.06 (1.03)	1.00 (1.02)	0.90 (0.89)	3544^{a-h}	2556^{a-d}	1222^{a-d}
S2 x P3	90.42^{a-e}	85.25^{a-f}	73.83^{b-f}	2.00 (1.47)	2.75 (1.50)	1.05 (1.00)	1.00 (1.01)	0.65 (0.79)	3767^{a-h}	1667^{b-e}	1222^{a-d}
S2 x P4	79.17^{a-f}	92.42^{ab}	68.75^{b-g}	1.50 (1.38)	2.00 (1.52)	1.16 (1.03)	1.00 (1.03)	0.99 (0.84)	3544^{a-h}	1889^{a-e}	1167^{a-d}
S2 x P7	97.92^{abc}	84.50^{a-g}	68.58^{b-g}	1.75 (1.15)	2.50 (1.54)	1.03 (1.00)	1.06 (1.02)	0.81 (0.84)	4433^{a-f}	2667^{a-d}	1833^{abc}
S2 x P8	90.42^{a-e}	88.17^{a-e}	75.34^{a-f}	2.25 (1.38)	4.00 (1.71)	1.08 (1.08)	1.27 (1.11)	0.94 (1.00)	3322^{b-h}	2667^{a-d}	1333^{a-d}
S3 x P1	83.50^{a-f}	88.25^{a-e}	76.75^{a-f}	2.50 (1.48)	3.50 (2.24)	1.17 (1.04)	1.03 (1.01)	0.70 (0.83)	4989^{abc}	2500^{a-d}	1333^{a-d}
S3 x P2	78.33^{a-f}	88.33^{a-d}	63.33^{c-g}	1.75 (1.20)	3.50 (2.04)	1.31 (1.15)	1.08 (1.04)	0.96 (0.90)	5878^{a}	1889^{a-e}	889^{a-d}
S3 x P3	81.25^{a-f}	95.08^{a}	58.08^{d-g}	1.25 (1.07)	3.50 (1.80)	1.20 (1.06)	1.00 (1.00)	0.47 (0.66)	3322^{b-h}	2778^{a-d}	1667^{a-d}

Means with same letter(s) in a column are not significantly different according to DMRT at 5% level of probability and values in parenthesis are transformed
NS=non-stress; IS=intermediate stress; SS = severe stress

Table 4.9 Continued

	Ear height (cm)			Leaf senescence (1-10)		Number of ears per plant			Grain yield (kg/ha)		
Hybrids	NS	IS	SS	IS	SS	NS	IS	SS	NS	IS	SS
S3 x P4	78.33^{a-f}	72.08^{c-l}	80.08^{a-d}	2.00 (1.48)	2.25 (1.24)	1.05 (1.02)	1.07 (1.04)	0.71 (0.72)	5433^{ab}	2889^{abc}	778^{bcd}
S3 x P7	82.09^{a-f}	81.00^{a-i}	79.00^{a-e}	1.50 (1.22)	3.50 (1.81)	1.06 (1.02)	1.03 (1.00)	0.67 (0.83)	4211^{a-g}	2222^{a-d}	889^{a-d}
S3 x P8	91.25^{a-e}	90.00^{abc}	67.59^{b-g}	1.00 (1.07)	1.50 (1.29)	1.00 (0.97)	1.05 (1.04)	1.04 (0.96)	5100^{abc}	1778^{b-e}	1222^{a-d}
S4 x P1	95.42^{a-e}	81.67^{a-h}	86.75^{a}	1.75 (1.10)	2.50 (1.38)	1.13 (1.03)	1.00 (0.97)	0.76 (0.83)	3989^{a-h}	2667^{a-d}	1333^{a-d}
S4 x P2	90.00^{a-e}	76.50^{a-l}	71.50^{b-f}	1.00 (0.94)	2.25 (1.67)	1.10 (1.09)	1.00 (1.01)	0.79 (0.92)	3878^{a-h}	1778^{b-e}	444^{d}
S4 x P3	95.00^{a-e}	75.34^{b-l}	71.83^{b-f}	1.75 (1.00)	4.00 (1.82)	1.04 (1.06)	1.00 (1.00)	0.80 (0.88)	4100^{a-h}	2778^{a-d}	1889^{ab}
S4 x P4	94.58^{a-e}	85.67^{a-f}	68.59^{b-g}	1.25 (1.17)	2.00 (2.01)	1.08 (1.00)	1.11 (1.06)	0.69 (0.72)	4433^{a-f}	2444^{a-d}	778^{bcd}
S4 x P7	103.33^{a}	76.50^{a-l}	72.84^{b-f}	1.00 (1.11)	2.25 (1.59)	1.13 (1.02)	1.23 (1.03)	0.97 (0.88)	4322^{a-g}	2778^{a-d}	1333^{a-d}
S4 x P8	100.42^{ab}	89.08^{abc}	75.67^{a-f}	1.00 (1.02)	3.50 (1.71)	1.00 (1.10)	1.00 (1.06)	0.82 (1.02)	3433^{a-h}	2333^{a-d}	889^{a-d}
S5 x P1	92.08^{a-e}	80.92^{a-i}	62.00^{c-g}	1.25 (1.08)	2.00 (1.56)	1.00 (0.97)	1.19 (1.06)	0.55 (0.73)	3767^{a-h}	2556^{a-d}	1667^{a-d}
S5 x P2	68.80^{ef}	80.42^{a-i}	71.50^{b-f}	1.25 (1.22)	2.00 (1.30)	1.18 (1.09)	1.00 (0.98)	0.83 (0.86)	3656^{a-h}	2444^{a-d}	1333^{a-d}
S5 x P3	82.08^{a-f}	84.17^{a-h}	63.42^{c-g}	1.25 (1.09)	1.75 (1.65)	1.16 (1.02)	1.21 (1.12)	0.60 (0.73)	3989^{a-h}	2111^{a-e}	1222^{a-d}
S5 x P4	95.00^{a-e}	80.58^{a-i}	61.42^{c-g}	2.50 (1.39)	3.25 (1.71)	1.24 (1.13)	1.00 (0.99)	0.67 (0.81)	4211^{a-g}	3000^{ab}	1333^{a-d}
S5 x P7	82.09^{a-f}	89.75^{abc}	76.00^{a-f}	1.75 (1.37)	4.25 (1.91)	1.35 (1.16)	1.00 (1.00)	0.64 (0.75)	3878^{a-h}	1778^{b-e}	556^{d}
S5 x P8	94.17^{a-e}	71.75^{c-m}	67.59^{b-g}	1.75 (1.22)	3.75 (2.00)	1.08 (1.11)	1.02 (0.98)	0.70 (0.94)	5100^{abc}	1778^{b-e}	1333^{a-d}
S6 x P1	79.17^{a-f}	73.67^{b-l}	85.17^{ab}	2.25 (1.35)	2.50 (1.57)	1.41 (1.20)	1.22 (1.09)	0.66 (0.83)	3767^{a-h}	1944^{a-e}	889^{a-d}
S6 x P2	86.67^{a-f}	85.34^{a-f}	69.92^{b-g}	1.50 (1.27)	4.50 (1.99)	1.36 (1.13)	1.00 (1.00)	0.82 (0.92)	4989^{abc}	1778^{b-e}	889^{a-d}
S6 x P3	80.00^{a-f}	80.09^{a-j}	78.08^{a-f}	2.25 (1.31)	4.00 (2.05)	1.24 (1.11)	1.07 (1.04)	0.87 (1.02)	5433^{ab}	2370^{a-d}	1444^{a-d}
S6 x P4	89.17^{a-f}	75.17^{b-l}	76.33^{a-f}	1.25 (0.95)	2.00 (1.50)	1.15 (1.07)	1.00 (1.01)	0.96 (1.08)	3767^{a-h}	2000^{a-e}	1278^{a-d}
S6 x P7	97.50^{a-d}	88.17^{a-e}	71.50^{b-f}	1.00 (1.09)	3.50 (1.74)	1.08 (1.00)	1.00 (1.01)	0.83 (0.85)	5211^{abc}	2111^{a-e}	1167^{a-d}
S6 x P8	77.50^{a-f}	78.09^{a-k}	74.00^{b-f}	1.75 (1.38)	3.25 (1.65)	1.00 (0.97)	1.03 (1.02)	0.79 (0.86)	4656^{a-e}	2667^{a-d}	833^{bcd}
S7 x P1	89.58^{a-f}	86.08^{a-e}	84.75^{abc}	2.25 (1.45)	4.75 (2.12)	1.07 (1.03)	1.06 (1.02)	1.13 (1.02)	3656^{a-h}	2000^{a-e}	667^{bcd}
S7 x P2	90.42^{a-e}	79.50^{a-k}	74.92^{b-f}	1.25 (1.15)	3.50 (1.48)	1.08 (1.05)	1.00 (1.03)	1.06 (1.02)	4322^{a-g}	2889^{abc}	1500^{a-d}
S7 x P3	92.08^{a-e}	79.58^{a-k}	71.67^{b-f}	1.50 (1.27)	2.50 (1.33)	1.13 (1.04)	1.00 (1.02)	0.76 (0.86)	4100^{a-h}	2333^{a-d}	1111^{a-d}
S7 x P4	85.00^{a-f}	83.00^{a-h}	72.17^{b-f}	1.75 (1.22)	3.50 (1.64)	1.14 (1.08)	1.00 (1.00	0.82 (0.98)	4100^{a-h}	1889^{a-e}	1111^{a-d}
S7 x P7	97.92^{abc}	81.25^{a-i}	67.25^{b-g}	2.25 (1.57)	3.75 (1.83)	1.05 (1.01)	1.02 (0.99)	0.94 (0.98)	4989^{abc}	2333^{a-d}	1889^{ab}
S7 x P8	93.33^{a-e}	86.17^{a-e}	69.34^{b-g}	1.00 (1.01)	2.00 (1.40)	1.17 (1.09)	1.11 (1.04)	1.00 (0.89)	4656^{a-e}	3389^{a}	2111^{a}
Oba 98 (Check)	81.67^{a-f}	70.83^{c-m}	76.42^{a-f}	1.50 (0.92)	2.00 (1.72)	1.19 (1.06)	1.00 (1.00)	0.62 (0.77)	5000^{abc}	2111^{a-e}	1111^{a-d}
MEAN	86.41	78.68	69.38	1.57	3.12	1.13	1.06	0.81	3762	2078	1127
CV (%)	18.11	14.45	16.4	24.4	26.61	8.46	7.71	21.28	37.3	42.08	60.74

Means with same letter(s) in a column are not significantly different according to DMRT at 5% level of probability and values in parenthesis are transformed
NS=non-stress; IS=intermediate stress; SS = severe stress

Under severe stress, the hybrid S1 x P7 had the highest number of ears per plant (1.26) while the hybrid S3 x P3 had the lowest number of ears per plant (0.49) and were statistically the same with the rest.

Statistical significant differences exist for grain yield under the three conditions (Table 4.9). It ranged from 1556kg/ha to 5878kg/ha, 611kg/ha to 3389kg/ha and 444kg/ha to 2111kg/ha under non-stress, intermediate stress and severe stress conditions, respectively. The hybrid S3 x P2 had the highest grain yield under non-stress condition while the parents S7 and P7 recorded the lowest grain yield and were statistically different from rest. Under intermediate stress condition, the hybrid S7 x P8 had the highest grain yield while parent P7 had the lowest grain yield and were statistically different from rest. The hybrid S7 x P8 had the highest yield while parent P7 and the hybrid S4 x P2 had the lowest grain yield and were significantly different from the rest. P7 and S4 x P2 were statistically the same with S5 x P7 but statistically different from the rest.

4.2 Genetic Variability Parameters and Heritability

4.2.1 Genetic variability parameters and heritability at Samaru

Genetic variability parameters and heritability of traits measured under non-stress, intermediate and severe stress at Samaru are presented in Table 4.10. The genotypic variance ranged from 0.01 for number of ears per plant under non-stress and intermediate stress to 1116875 for grain yield under non-stress. The phenotypic variance ranged from 0.02 for number of ears per plant under intermediate stress to 1610757 for grain yield under non-stress.

Table 4.10 Genetic variability parameters and heritability of traits measured under non-stress, intermediate stress and severe stress at Samaru

	Days to 50% tasseling			Days to 50% silking			Anthesis-silking interval			Plant height		
Parameters	NS	IS	SS	NS	IS	SS	NS	IS	SS	NS	IS	SS
σ_e^2	0.59	0.73	1.80	0.70	2.62	1.19	1.37	0.21	0.22	54.33	41.79	29.81
σ_g^2	5.41	3.74	6.57	4.54	14.14	4.79	3.31	0.63	0.70	192.7	290.4	179.6
σ_{ph}^2	6.00	4.47	8.37	5.24	16.76	5.98	4.68	0.84	0.92	247.0	332.2	209.4
GCV (%)	4.08	3.45	4.42	3.55	6.27	3.47	60.64	19.76	20.84	7.55	9.58	8.23
PCV (%)	4.30	3.77	4.99	3.81	6.82	3.88	72.07	22.78	23.91	8.55	10.25	8.89
h_b^2 (%)	90.24	83.65	78.54	86.63	84.36	80.10	70.80	75.30	75.96	78.00	87.42	85.77
h_n^2 (%)	26.48	26.28	27.88	25.67	18.65	27.99	16.17	16.39	8.78	23.93	14.13	0.89

	Ear height			Leaf senescence		Number of ears per plant			Grain yield		
	NS	IS	SS	IS	SS	NS	IS	SS	NS	IS	SS
σ_e^2	35.14	27.35	16.16	0.51	0.41	0.02	0.01	0.01	493883	251030	325854
σ_g^2	85.05	134.53	98.35	0.68	0.82	0.01	0.01	0.07	1116875	498625	591639
σ_{ph}^2	120.2	161.9	114.5	1.19	1.23	0.03	0.02	0.08	1610757	749655	917493
GCV (%)	9.29	12.64	11.07	38.71	24.82	8.55	9.35	28.76	25.53	25.75	42.41
PCV (%)	11.04	13.87	11.94	51.21	30.36	14.80	13.22	29.77	30.66	31.58	52.82
h_b^2 (%)	70.76	83.11	85.89	57.14	66.80	33.33	50.00	93.33	69.34	66.51	64.48
h_n^2 (%)	20.06	12.59	33.49	4.81	6.67	7.18	13.40	4.16	11.36	9.84	10.72

NS=non-stress; IS=intermediate stress; SS=severe stress; σ_e^2 =error variance; σ_g^2 =genotypic variance; σ_{ph}^2 =phenotypic variance;

h_b^2 =broad sense heritability; h_n^2 =narrow sense heritability; GCV=genotypic coefficient of variation; PCV=phenotypic coefficient of variation

The estimates of genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) were highest for ASI (60.64% and 72.07%) under non-stress followed by grain yield (42.41% and 52.82%) under severe stress and leaf senescence (38.71% and 51.21%) under intermediate stress, respectively. The GCV and PCV were lowest for days to 50% tasseling (3.45% and 3.77%) under intermediate stress followed by days to 50% silking (3.47% and 3.81%) and (3.55% and 3.88) under non-stress and severe stress, respectively. The GCV were high for ASI (60.64% and 20.84%) under non-stress and severe stress, leaf senescence (38.71% and 24.82%) under intermediate stress and severe stress, number of ears per plant (28.76%) under severe stress and grain yield (25.53%, 25.75% and 42.41%) under non-stress, intermediate stress and severe stress, respectively. The GCV were moderate for ASI (19.76%) under intermediate stress, ear height (12.64% and 11.07%) under intermediate stress and severe stress, respectively and were low for other traits. The PCV were high for ASI (72.07%, 22.78% and 23.91%) under non-stress, intermediate stress and severe stress, leaf senescence (51.21% and 30.36%) under intermediate stress and severe stress, number of ears per plant (29.77%) under severe stress and grain yield (30.66%, 31.58% and 52.82%) under non-stress, intermediate stress and severe stress, respectively. The PCV were moderate for plant height (10.25%) under intermediate stress, ear height (11.04%, 13.87% and 11.94%) under non-stress, intermediate stress and severe stress and number of ears per plant (14.80% and 13.22%) under non-stress and intermediate stress, respectively, and were low for other traits.

Broad sense heritability ranged from 33.33% to 93.33% for number of ears per plant under non-stress and severe stress, respectively. Broad sense heritability estimates were high for all the traits studied under the three conditions except leaf senescence (57.14%) under intermediate stress and number of ears per plant (33.33% and 50.00%) under non-stress and intermediate stress, respectively, were moderate. However, as for narrow

sense heritability the trend was generally low for all the traits studied except ear height (33.49%) under severe stress, which was moderate. The narrow sense heritability ranged from 4.81% to 26.48%, 4.81% to 26.28% and 0.89% to 33.49% under non-stress, intermediate stress and severe stress conditions, respectively.

4.2.2 Genetic variability parameters and heritability at Kadawa

Genetic variability parameters and heritability of traits measured under non-stress, intermediate stress and severe stress at Kadawa are presented in Table 4.11. The genotypic variance ranged from 0.01 for number of ears per plant under non-stress to 1692047 for grain yield under non-stress. The phenotypic variance ranged from 0.02 for number of ears per plant under non-stress to 2293729 for grain yield under non-stress. The estimates of GCV and PCV were highest for grain yield (57.73% and 73.10%) under severe stress followed by leaf senescence (47.96% and 60.83%) under intermediate stress and grain yield (45.49% and 55.47%) under intermediate stress, respectively. The GCV and PCV were lowest for days to 50% tasseling (4.22% and 5.27%) under severe stress followed by days to 50% silking (4.47% and 5.44%) under severe stress and days to 50% silking (5.10% and 6.01%) under intermediate stress, respectively.

The GCV were high for ear height (21.31%) under severe stress, leaf senescence (47.96% and 40.76%) under intermediate stress and severe stress, number of ears per plant (20.90%) under intermediate stress, grain yield (43.74%, 45.49% and 57.73%) under non-stress, intermediate stress and severe stress, respectively. The GCV were moderate for ASI (17.64%, 17.16% and 19.29%) under non-stress, intermediate stress and severe stress, plant height (13.47% and 15.88%) under intermediate stress and severe stress, ear height (13.92% and 11.53%) under non-stress and intermediate stress, and number of ears per plant (17.50%) under severe stress and were low for other traits.

Table 4.11 Genetic variability parameters and heritability of traits measured under non-stress, intermediate stress and severe stress at Kadawa

	Days to 50% tasseling			Days to 50% silking			Anthesis-silking interval			Plant height		
Parameters	NS	IS	SS	NS	IS	SS	NS	IS	SS	NS	IS	SS
σ_e^2	3.78	3.79	4.33	3.93	4.01	4.58	0.20	0.15	0.15	99.52	93.47	56.74
σ_g^2	21.67	11.45	7.76	21.85	10.32	9.50	0.28	0.27	0.34	115.5	316.4	331.9
σ_{ph}^2	25.45	15.24	12.09	25.78	14.33	14.08	0.48	0.42	0.49	214.9	409.9	388.6
GCV (%)	7.51	5.61	4.22	7.19	5.10	4.47	17.64	17.16	19.29	7.56	13.47	15.88
PCV (%)	8.14	6.51	5.27	7.81	6.01	5.44	23.09	21.47	23.21	10.32	15.33	17.18
h_b^2(%)	85.14	75.16	64.20	84.75	72.04	67.50	58.33	63.86	69.07	53.71	77.20	85.40
h_n^2(%)	2.49	10.98	5.11	5.05	3.66	1.50	13.95	6.07	9.63	1.44	15.46	3.48

	Ear height			Leaf senescence		Number of ears per plant			Grain yield		
	NS	IS	SS	IS	SS	NS	IS	SS	NS	IS	SS
σ_e^2	47.55	19.74	32.28	0.14	0.10	0.01	0.01	0.01	601682	190523	129251
σ_g^2	104.9	57.22	109.8	0.23	1.50	0.01	0.05	0.02	1692047	391260	214119
σ_{ph}^2	152.4	76.96	142.1	0.37	1.60	0.02	0.06	0.03	2293729	581783	343370
GCV (%)	13.92	11.53	21.31	47.96	40.76	6.55	20.90	17.50	43.74	45.49	57.73
PCV (%)	16.78	13.37	24.24	60.83	42.10	9.26	21.92	20.20	50.92	55.47	73.10
h_b^2(%)	68.80	74.35	77.28	62.16	93.73	50.00	90.91	75.00	73.77	67.25	62.36
h_n^2(%)	10.41	4.23	9.86	3.70	3.09	6.25	4.55	47.61	4.06	21.21	4.09

NS=non-stress; IS=intermediate stress; SS=severe stress; σ_e^2 =error variance; σ_g^2 =genotypic variance; σ_{ph}^2 =phenotypic variance;

h_b^2 =broad sense heritability; h_n^2 =narrow sense heritability; GCV=genotypic coefficient of variation; PCV=phenotypic coefficient of variation

The PCV were high for ASI (23.09%, 21.47% and 23.21%) under non-stress, intermediate stress and severe stress, ear height (24.24%) under severe stress, leaf senescence (60.83% and 42.10%) under intermediate stress and severe stress, respectively. The PCV were also high for number of ears per plant (21.92% and 20.20%) under intermediate stress and severe stress, and grain yield (50.92%, 55.47% and 73.10%) under non-stress, intermediate stress and severe stress, respectively. The PCV were moderate for plant height (10.32%, 15.33% and 17.18%) under non-stress, intermediate stress and severe stress, ear height (16.78% and 13.37%) under non-tress and intermediate stress, and number of ears per plant (17.50%) under severe stress and were low for other traits.

Broad sense heritability ranged from 50.00% for number of ears per plant under no-stress to 93.73% leaf senescence under severe stress. Broad sense heritability estimates were high for all the traits studied under the three conditions ASI (58.33%), plant height (53.71%) and number of ears per plant (50.00%) under non-stress which were moderate. However, as for narrow sense heritability the trend was generally low for all the traits studied except number of ear per plant (47.61%) under severe stress which was moderate. The narrow sense heritability ranged from 1.44% to 13.95%, 3.66% to 21.21% and 1.44% to 47.61% under non-stress, intermediate stress and severe stress conditions, respectively.

4.2.3 Genetic variability parameters and heritability across locations

Genetic variability parameters and heritability of traits measured under non-stress, intermediate stress and severe stress across locations are presented in Table 4.12. The genotypic variance ranged from 0.01 for number of ears per plant under non-stress and intermediate stress to 1524550 for grain yield under non-stress.

Table 4.12 Genetic variability parameters and heritability of traits measured under non-stress, intermediate stress and severe stress across locations

	Days to 50% tasseling			Days to 50% silking			Anthesis-silking interval			Plant height		
Parameters	NS	IS	SS	NS	IS	SS	NS	IS	SS	NS	IS	SS
σ_e^2	0.87	1.49	1.01	1.04	1.06	1.70	0.32	0.08	0.12	45.77	25.38	29.56
σ_g^2	10.78	7.76	5.57	11.64	11.62	5.74	0.88	0.34	0.39	171.3	152.2	279.7
σ_{gl}^2	2.72	1.57	1.45	2.55	2.70	0.99	0.61	0.12	0.07	44.44	34.41	50.73
σ_{ph}^2	14.37	10.82	8.03	15.23	15.37	8.43	1.80	0.54	0.58	261.5	211.9	359.9
GCV (%)	5.57	4.80	3.81	5.50	5.59	3.63	31.22	20.00	15.71	8.03	7.96	12.05
PCV (%)	6.42	5.67	4.57	6.29	6.43	4.40	44.72	24.49	19.08	9.92	9.40	13.67
h_b^2 (%)	75.05	71.71	69.40	76.43	75.59	68.12	48.75	63.43	67.81	65.51	71.80	77.70
h_n^2 (%)	15.54	12.72	14.87	20.42	12.53	14.87	15.89	1.95	14.88	5.89	13.79	12.64

	Ear height			Leaf senescence		Number of ears per plant			Grain yield		
	NS	IS	SS	IS	SS	NS	IS	SS	NS	IS	SS
σ_e^2	12.92	12.95	24.49	0.29	0.14	0.01	0.01	0.00	219113	138517	103946
σ_g^2	59.68	97.52	107.06	0.37	0.78	0.01	0.01	0.03	1524550	426031	269697
σ_{gl}^2	23.83	19.95	1.79	-0.05	0.27	0.00	0.00	0.01	212830	37652	104039
σ_{ph}^2	96.43	130.4	133.3	0.61	1.19	0.02	0.02	0.04	1956493	602199	477682
GCV (%)	8.94	12.55	14.91	30.21	29.44	8.85	8.17	21.38	34.72	31.48	40.17
PCV (%)	11.36	14.51	16.64	39.13	36.40	12.52	10.55	23.91	39.33	37.43	53.47
h_b^2 (%)	61.89	74.77	80.29	59.59	65.41	50.00	60.00	80.00	77.92	70.75	56.46
h_n^2 (%)	8.88	4.11	3.24	2.58	7.89	9.35	14.29	1.45	6.75	16.91	3.85

NS=non-stress; IS=intermediate stress; SS=severe stress; σ_e^2 =error variance; σ_g^2 =genotypic variance; σ_{gl}^2 = genotype x location variance

σ_{ph}^2 =phenotypic variance; h_b^2 =broad sense heritability; h_n^2 =narrow sense heritability; GCV=genotypic coefficient of variation;
PCV=phenotypic coefficient of variation

The genotype x location variance ranged from -0.05 for leaf senescence under intermediate stress to 212830 for grain yield under non-stress. The phenotypic variance ranged from 0.02 for number of ears per plant under non-stress to 1956493 for grain yield under non-stress. The estimates of GCV and PCV were highest for grain yield (40.17% and 53.47%) under severe stress followed by grain yield (34.72% and 39.33%) under non-stress and grain yield (31.48% and 37.43) under intermediate stress. The GCV were high for ASI (31.22%) under non-stress, leaf senescence (30.21% and 29.44%) under intermediate stress and severe stress, number of ears per plant (21.38%) under severe stress and grain yield (34.72, 31.48% and 40.17%) under non-stress, intermediate stress and severe stress, respectively. The GCV were moderate for ASI (20.00% and 15.71%) under intermediate stress and severe stress, plant height (12.05%) under severe stress and ear height (12.55% and 14.91%) under intermediate stress and severe stress, respectively, and were low for other traits.

The PCV were high for ASI (44.72% and 24.49%) under non-stress and intermediate stress, leaf senescence (39.13% and 36.40%) under intermediate stress and severe stress, number of ears per plant (23.91%) under severe stress and grain yield (39.33%, 37.43% and 53.47%) under non-stress, intermediate stress and severe stress, respectively. The PCV were moderate for ASI (19.08%) under severe stress, plant height (13.67%) under severe stress, ear height (11.36, 14.51% and 16.64%) under non-stress, intermediate stress and severe stress and number of ears per plant (12.52% and 10.55%) under non-stress and intermediate stress, respectively, and were low for other traits.

Broad sense heritability ranged from 48.75% for ASI under non-stress to 80.29% for ear height under severe stress. Broad sense heritability estimates were high for all the traits

studied under the three conditions except ASI (48.75%) under non-stress, leaf senescence (59.59%) under intermediate stress, number of ears per plant (50.00%) under non-stress and grain yield (56.46%) under severe stress were moderate. However, as for narrow sense heritability the trend was generally low for all the traits studied. The narrow sense heritability ranged from 5.89% to 20.42%, 1.95% to 16.91% and 1.45% to 14.88% under non-stress, intermediate stress and severe stress conditions, respectively.

4.3 Correlation Coefficients

4.3.1 Correlation coefficients between grain yield and other traits at Samaru

Correlation coefficients between grain yield and other traits under non-stress, intermediate stress and severe stress at Samaru are presented in Tables 4.13. Highly significant ($P \leq 0.01$) and negative correlation was observed between grain yield and days to 50% tasseling under non-stress while under intermediate stress and severe stress were negative but not significant. Highly significant ($P \leq 0.01$) and negative correlation was observed between grain yield and days to 50% silking under non-stress while under intermediate stress and severe stress were negative but not significant. The correlation between grain yield and ASI under severe stress was negative and significant at $P \leq 0.05$ while under non-stress and intermediate stresses were negative but not significant. Highly significant ($P \leq 0.01$) and positive correlations were observed between grain yield and plant height under non-stress and intermediate stress while under severe stress was positive and significant at $P \leq 0.05$. Highly significant ($P \leq 0.01$) and positive correlations were observed between grain yield and ear height under intermediate stress while under non-stress and severe stress were positive and significant at $P \leq 0.05$.

Table 4.13 Correlation coefficients between grain yield and other traits under non-stress, intermediate stress and severe stress at Samaru

Traits		DYSK	ASI	PLHT	EHT	SEN	EPP	GY
DYTS	NS	0.74**	-0.02	-0.16	-0.08	-	0.22*	-0.38**
	IS	0.83**	-0.01	-0.12	-0.17	-0.24*	0.31**	-0.14
	SS	0.80**	0.10	-0.22*	-0.17	-0.15	0.14	-0.01
DYSK	NS	1.00	0.35**	-0.17	-0.11	-	0.06	-0.37**
	IS	1.00	0.43**	-0.17	-0.15	-0.11	0.26*	-0.17
	SS	1.00	0.67**	-0.39**	-0.24*	-0.13	0.09	-0.12
ASI	NS		1.00	-0.15	0.01	-	-0.14	-0.16
	IS		1.00	-0.11	-0.01	0.14	-0.01	-0.17
	SS		1.00	-0.36**	-0.19*	-0.01	-0.02	-0.21*
PLHT	NS			1.00	0.54**	-	-0.03	0.33**
	IS			1.00	0.60**	-0.08	-0.30**	0.42**
	SS			1.00	0.81**	-0.20*	-0.25*	0.27*
EHT	NS				1.00	-	0.01	0.23*
	IS				1.00	-0.14	-0.28*	0.48**
	SS				1.00	-0.03	-0.31**	0.19*
SEN	IS					1.00	-0.03	-0.18
	SS					1.00	-0.10	-0.22*
EPP	NS						1.00	0.13
	IS						1.00	0.09
	SS						1.00	0.27*

*P≤0.05; **P≤0.01; NS = non-stress; IS=intermediate stress; SS=severe stress; DYTS=days to 50% tasseling; DYSK=days to 50% silking; GY=grain yield; ASI=anthesis-silking interval; PLHT=plant height; EHT=ear height; SEN = leaf senescence; EPP = number of ears per plant

The correlation between grain yield and leaf senescence under severe stress was negative and significant at P≤0.05 while coefficient under intermediate stress was negative but not significant. The correlation between grain yield and number of ears per plant under severe stress was positive and significant at P≤0.05 while under non-stress and intermediate stresses were positive but not significant.

Days to 50% tasseling correlated positively and significantly (P≤0.01) with days to 50% silking under the three conditions and number of ears per plant under intermediate stress, while with number of ears per plant under non-stress was positive and significant at P≤0.05. The correlations of days to 50% tasseling with plant height under severe stress and leaf senescence under intermediate stress were negative and significant at P≤0.05. Days to 50% silking correlated positively and significantly (P≤0.01) with ASI under the three conditions while with number of ears per plant under intermediate stress was significant at P≤0.05. ASI had significant negative correlations with plant height and ear height under severe stress at P≤0.05. Plant height correlated positively and significantly (P≤0.01) with ear height under the three conditions while with number of ears per plant under intermediate stress was highly negative and significant at P≤0.01. Plant height also had significant negative correlations (P≤0.05) with leaf senescence and number of ears per plant under severe stress condition. Ear height correlated negatively and highly significant (P≤0.01) with number of ears per plant under severe stress while under intermediate stress was significant at P≤0.05.

4.3.2 Correlation coefficients between grain yield and other traits at Kadawa

Correlation coefficients between grain yield and other traits under non-stress, intermediate stress and severe stress at Kadawa are presented in Tables 4.14. Highly significant ($P \leq 0.01$) and negative correlation was observed between grain yield and days to 50% tasseling under intermediate stress while under severe stress was negative and significant at $P<0.05$ and under non-stress was not significant. Highly significant ($P \leq 0.01$) and negative correlation was observed between grain yield and days to 50% silking under intermediate stress while under non-stress and severe stress were negative but not significant. The correlation between grain yield and ASI under non-stress, intermediate stress and severe stress were negative but not significant. Highly significant ($P \leq 0.01$) and positive correlation was observed between grain yield and plant height under non-stress, while under intermediate stress and severe stress were positive but not significant. The correlations between grain yield and ear height under intermediate stress and severe stress were positive and significant while under non-stress was positive but not significant. The correlation between grain yield and leaf senescence under intermediate stress it was negative and significant at $P \leq 0.05$ while under severe stress was negative but not significant. Highly significant ($P \leq 0.01$) and positive correlations was observed between grain yield and number of ears per plant under non-stress while under intermediate stress was positive and significant and under severe stress was positive but not significant.

Days to 50% tasseling correlated positively and significantly ($P \leq 0.01$) with days to 50% silking under the three conditions, while with plant height under severe and ear height under the three conditions stress were positive and highly significant ($P \leq 0.01$).

Table 4.14 Correlation coefficients between grain yield and traits under non-stress, intermediate stress and severe stress environments at Kadawa

Traits		DYSK	ASI	PLHT	EHT	SEN	EPP	GY
DYTS	NS	0.98**	0.18	0.01	-0.36**	-	-0.14	-0.17
	IS	0.99**	-0.01	0.03	-0.65**	0.01	-0.08	-0.42**
	SS	0.98**	-0.17	-0.35**	-0.52**	0.10	-0.16	-0.19*
DYSK	NS	1.00	0.36**	0.01	-0.34**	-	-0.16	-0.18
	IS	1.00	0.14	0.03	-0.65**	0.01	-0.11	-0.43**
	SS	1.00	0.01	-0.35**	-0.51**	0.09	-0.14	-0.18
ASI	NS		1.00	0.01	0.01	-	-0.19*	-0.08
	IS		1.00	0.02	-0.10	-0.02	-0.16	-0.12
	SS		1.00	0.11	0.07	-0.10	0.13	-0.06
PLHT	NS			1.00	-0.08	-	0.08	0.43**
	IS			1.00	-0.07	-0.05	0.07	0.03
	SS			1.00	0.75**	-0.12	0.18	0.14
EHT	NS				1.00	-	-0.24*	0.07
	IS				1.00	0.06	0.03	0.28*
	SS				1.00	-0.04	0.21*	0.25*
SEN	IS					1.00	-0.10	-0.21*
	SS					1.00	0.04	-0.01
EPP	NS						1.00	0.41**
	IS						1.00	0.23*
	SS						1.00	0.10

*P≤0.05; **P≤0.01; NS = non-stress; IS=intermediate stress; SS=severe stress; DYTS=days to 50% tasseling; DYSK=days to 50% silking; GY=grain yield; ASI=anthesis-silking interval; PLHT=plant height; EHT=ear height; SEN = leaf senescence; EPP = number of ears per plant

The correlations of days to 50% tasseling with plant height under severe stress and ear height under three conditions were negative and highly significant (P≤0.01). ASI correlated negatively and highly significant (P≤0.01) with number of ears per plant under non-stress. Plant height correlated positively and significantly (P≤0.01) with ear height under severe stress. Ear height correlated negatively and significant (P≤0.05) with number of ears per plant under non-stress while under severe stress was significant at P≤0.05.

4.3.3 Correlation coefficients between grain yield and other traits across locations

Correlation coefficients between grain yield and other traits under non-stress, intermediate stress and severe stress across locations are presented in Tables 4.15. Highly significant (P≤0.01) and negative correlations were observed between grain yield and days to 50% tasseling under non-stress, intermediate stress and severe stress. Highly significant (P≤0.01) and negative correlations were observed between grain yield and days to 50% silking under non-stress and severe stress while under intermediate stress the correlation was negative and significant at P≤0.05. Highly significant (P≤0.01) and negative correlation was observed between grain yield and ASI under severe stress while under non-stress and severe stress were negative but not significant. Highly significant (P≤0.01) and positive correlations were observed between grain yield and plant height under non-stress, intermediate stress and severe stress. Highly significant (P≤0.01) and positive correlations were observed between grain yield and ear height under intermediate stress and severe stress while under non-stress the association was positive and significant at P≤0.05. The correlation between grain yield and leaf senescence under intermediate stress and severe stress were negative but not significant.

Table 4.15 Correlation coefficients between grain yield and other traits under non-stress, intermediate stress and severe stress across locations

Traits		DYSK	ASI	PLHT	EHT	SEN	EPP	GY
DYTS	NS	0.94**	-0.02	-0.41**	-0.53**	-	-0.08	-0.39**
	IS	0.96**	-0.17	-0.31**	-0.61**	-0.19*	0.01	-0.31**
	SS	0.94**	-0.22*	-0.67**	-0.71**	-0.14	-0.22*	-0.41**
DYSK	NS	1.00	0.18	-0.40**	-0.52**	-	-0.15	-0.39**
	IS	1.00	0.07	-0.25*	-0.56**	-0.13	0.01	-0.29*
	SS	1.00	0.13	-0.65**	-0.65**	-0.13	-0.19*	-0.40**
ASI	NS		1.00	0.06	0.11	-	-0.12	-0.04
	IS		1.00	0.24*	0.22*	0.19*	-0.02	-0.05
	SS		1.00	0.10	0.19*	0.03	0.10	-0.30**
PLHT	NS			1.00	0.51**	-	0.13	0.52**
	IS			1.00	0.56**	0.16*	0.00	0.31**
	SS			1.00	0.91**	0.03	0.18*	0.52**
EHT	NS				1.00	-	0.04	0.27*
	IS				1.00	0.14	-0.05	0.43**
	SS				1.00	0.13	0.17	0.53**
SEN	IS					1.00	-0.02	-0.02
	SS					1.00	0.02	-0.03
EPP	NS						1.00	0.29*
	IS						1.00	0.03
	SS						1.00	0.33**

*P≤0.05; **P≤0.01; NS = non-stress; IS=intermediate stress; SS=severe stress; DYTS=days to 50% tasseling; DYSK=days to 50% silking; GY=grain yield; ASI=anthesis-silking interval; PLHT=plant height; EHT=ear height; SEN = leaf senescence; EPP = number of ears per plant

Highly significant (P≤0.01) and positive correlations was observed between grain yield and number of ears per plant under severe stress while under non-stress was positive and significant at P≤0.05 and under intermediate stress was positive but not significant.

Days to 50% tasseling correlated positively and significantly (P≤0.01) with days to 50% silking under the three conditions, while with plant height and ear height under the three conditions the associations were negative and highly significant (P≤0.01). The correlations of days to 50% tasseling with ear height under the three conditions were negative and highly significant (P≤0.01), while with plant height under non-stress and severe stress and number of ears per plant under severe stress were negative and significant at P≤0.05. ASI had significant positive correlations (P≤0.05) with plant height and leaf senescence under intermediate stress and ear height under intermediate stress and severe stress. Plant height correlated positively and significantly (P≤0.01) with ear height under the three conditions while with leaf senescence under intermediate stress and number of ears per plant under severe stress were significant at P≤0.05.

4.4 Analyses of Variance (ANOVA) for Design II and Combining Ability Variances

4.4.1 ANOVA for design II and combining ability variances at Samaru

Mean squares from ANOVA for design II of the traits measured under non-stress, intermediate stress and severe stress at Samaru are presented in Table 4.16. The GCA_f mean squares were highly significant difference (P≤0.01) for days to 50% tasseling and days to 50% silking under the three conditions and ASI under non-stress and intermediate stress. The GCA_f mean squares were also highly significant difference (P≤0.01) for plant height under intermediate stress and severe stress and ear height and grain yield under non-stress and severe stress conditions.

Table 4.16 Mean squares from ANOVA for design II of traits measured under non-stress, intermediate stress and severe stress at Samaru

		Days to 50% tasseling			Days to 50% silking			Anthesis-silking interval			Plant height		
Source	df	NS	IS	SS	NS	IS	SS	NS	IS	SS	NS	IS	SS
Rep	1	13.76**	2.68*	32.19**	4.76**	0.76	0.05	3.86**	11.44**	29.76**	4551.13**	1952.87**	15147.70**
GCA_f	6	8.38**	6.44**	23.47**	18.76**	9.94**	34.47**	4.81**	3.53**	4.47	360.96*	246.38**	186.32**
GCA_m	5	15.40**	3.35*	11.89**	5.34**	4.62*	33.10**	1.14*	0.73	9.10**	674.34**	133.23*	168.37*
SCA	30	5.37*	2.33	8.06	5.94**	4.30*	15.00*	1.92*	1.37	5.04*	250.72	126.77*	181.09*
Error	41	1.72	0.87	2.34	0.99	2.09	4.09	0.44	0.72	1.98	133.03	65.26	70.74

		Ear height			Leaf senescence		Number of ears per plant			Grain yield		
		NS	IS	SS	IS	SS	NS	IS	SS	NS	IS	SS
Rep	1	493.00**	933.00**	5738.89**	51.86**	19.05**	0.40**	0.07*	0.12	21222827.98**	6605534.26**	11195806.14**
GCA_f	6	212.09**	156.41*	651.24**	3.25*	3.01*	0.05	0.03	0.18*	4695262.78**	1855176.19*	2187150.14**
GCA_m	5	126.56*	109.50*	93.85	3.34*	3.85*	0.05	0.03	0.21*	1255261.52	1932510.60*	2403766.25**
SCA	30	95.32*	91.96	149.99**	2.83	2.76	0.04	0.02	0.17*	2197922.02*	1397805.16*	1647932.77*
Error	41	60.81	76.20	46.24	1.70	0.97	0.02	0.01	0.07	961298.3	1051032.65	792706.05

*and **-significant at 0.05 and 0.01 probability level, respectively; NS=non-stress; IS=intermediate stress; SS=severe stress; df=degree of freedom; Rep=replication; GCA_f=general combining ability due to females; GCA_m=general combining ability due to males; SCA = specific combining ability

The GCA_f mean squares were significant at P≤0.05 for plant height under non-stress, ear height and grain yield under intermediate stress, leaf senescence under intermediate and severe stress and number of ears per plant under severe stress. The GCA_f mean squares were not significant for ASI under severe stress and number of ears per plant under non-stress and severe stress.

The GCA_m mean squares were highly significant (P≤0.01) for days to 50% tasseling and days to 50% silking under non-stress and severe stress, ASI under severe stress, plant height under non-stress and grain yield under severe stress. The GCA_m mean squares were significant at P≤0.05 for days to 50% tasseling, days to 50% silking and grain yield under intermediate stress, ASI under non-stress. The GCA_m mean squares were also significant at P≤0.05 for plant height and leaf senescence under intermediate stress and severe stress, ear height under non-stress and intermediate stress and number of ears per plant under severe stress. The GCA_m mean squares were not significant for ASI under intermediate stress, ear height under severe stress, number of ears per plant under non-stress and intermediate stress and grain yield under non-stress condition.

The SCA mean squares were highly significant (P≤0.01) for days to 50% silking under non-stress and ear height under severe stress. The SCA mean squares were significant at P≤0.05 for days to 50% silking and plant height under intermediate stress and severe stress, ASI under non-stress and severe stress. The SCA mean squares were also significant at P≤0.05 for days to 50% tasseling and ear height under non-stress, number of ears per plant under severe stress and grain yield under the three conditions. The SCA mean squares were not significant for days to 50% tasseling under intermediate stress and severe stress, ASI and ear height intermediate stress, plant height under

non-stress, leaf senescence under intermediate stress and severe stress and number of ears per plant under non-stress and intermediate stress.

GCA and SCA variances of traits measured under non-stress, intermediate stress and severe stress at Samaru are presented in Table 4.17. The magnitudes of SCA variance were greater than GCA variance for all the traits under the three conditions except for days to 50% tasseling and ear height under the three conditions, days to 50% silking under severe stress and plant height under non-stress. The magnitudes of GCA variance were greater than SCA for days to 50% tasseling and ear height under the three conditions, days to 50% silking under severe stress and plant height under non-stress. The ratios of the GCA to the SCA variance for all the traits were less than unity except for days to 50% tasseling and ear height under three conditions, days to 50% silking under severe stress and plant height under non-stress which were greater than unity.

4.4.2 ANOVA for design II and combining ability variances at Kadawa

Mean squares from ANOVA for design II of traits measured under non-stress, intermediate stress and severe stress at Kadawa are presented in Table 4.18. The GCA_f mean squares were highly significant ($P \leq 0.01$) for days to 50% tasseling and days to 50% silking under non-stress, plant height under non-stress and intermediate stress. The GCA_f mean squares were also highly significant ($P \leq 0.01$) for ear height under three conditions, number of ears per plant under severe stress and grain yield under intermediate stress. The GCA_f mean squares were significant at $P \leq 0.05$ for days to 50% tasseling and days to 50% silking under intermediate stress and severe stress, ASI under non-stress and severe stress.

Table 4.17 GCA and SCA variances of traits measured under non-stress, intermediate stress and severe stress at Samaru

	σ^2_{GCA}			σ^2_{SCA}			$\sigma^2_{GCA}/\sigma^2_{SCA}$		
Traits	NS	IS	SS	NS	IS	SS	NS	IS	SS
Days to 50% tasseling	1.003	0.395	1.480	0.858	0.315	1.302	1.169	1.254	1.136
Days to 50% silking	0.940	0.458	2.890	1.450	0.612	2.540	0.648	0.749	1.138
Anthesis-silking interval	0.162	0.117	0.268	0.555	0.191	1.288	0.293	0.613	0.209
Plant height	41.066	9.698	0.808	19.400	20.326	54.362	2.117	0.477	0.015
Ear height	11.385	6.307	34.239	5.293	1.256	14.114	2.151	5.020	2.426
Leaf senescence	-	0.072	0.103	-	0.494	0.796	-	0.145	0.129
Number of ears per plant	0.002	0.002	0.004	0.008	0.003	0.046	0.182	0.446	0.083
Grain yield	119590.789	76313.575	99619.296	477533.023	97078.757	328690.473	0.250	0.786	0.303

NS=non-stress; IS=intermediate stress; SS=severe stress; σ^2_{GCA}=GCA variance; σ^2_{SCA}=SCA variance

Table 4.18 Mean squares from ANOVA for design II of traits measured under non-stress, intermediate stress and severe stress at Kadawa

		Days to 50% tasseling			Days to50% silking			Anthesis-silking interval			Plant height		
Source	df	NS	IS	SS	NS	IS	SS	NS	IS	SS	NS	IS	SS
Rep	1	33.44**	74.30**	74.30**	29.76**	80.05**	66.96**	0.43	0.11	0.19	1804.41*	1.11	1729.65**
GCA_f	6	36.00**	25.85*	32.87*	43.37**	23.50*	22.47*	1.07*	0.69	1.60*	488.33**	1039.61**	402.45*
GCA_m	5	10.91	24.48*	22.82*	17.19	21.28*	21.07*	2.02**	3.15**	1.25*	494.05**	1401.18**	412.94*
SCA	30	22.56*	18.03*	24.05*	26.70*	20.02*	20.80*	0.99	1.51	1.07	468.87**	758.45*	364.85*
Error	41	8.78	7.60	11.11	8.68	8.31	12.01	0.39	0.39	0.44	150.29	432.42	169.32

		Ear height			Leaf senescence		Number of ears per plant			Grain yield		
		NS	IS	SS	IS	SS	NS	IS	SS	NS	IS	SS
Rep	1	298.47	185.06**	796.67**	3.44**	3.05**	0.01	0.01	0.85**	5646096.90**	7910666.71**	235161.67
GCA_f	6	586.10**	200.59**	196.02**	3.30*	0.97	0.07*	0.03	0.37**	3931410.30*	2718606.15**	902761.59
GCA_m	5	475.46*	214.39**	178.00*	3.14*	0.90	0.05*	0.04	0.08	3752968.80*	1868082.14**	1013997.33**
SCA	30	389.05*	181.09**	138.67*	2.87	0.85	0.05*	0.03	0.06	3385615.50*	1243935.27*	838684.99
Error	41	180.99	74.09	46.18	1.34	0.44	0.02	0.02	0.06	1315067	367847.64	497585.38

*and **-significant at 0.05 and 0.01 probability level, respectively; NS=non-stress; IS=intermediate stress; SS=severe stress; df=degree of freedom; Rep=replication; GCA_f=general combining ability due to females; GCA_m=general combining ability due to males; SCA = specific combining ability

The GCA_f mean squares were also significant at P≤0.05 plant height under severe stress, leaf senescence under intermediate stress and number of ear per plant and grain yield under non-stress. The GCA_f mean squares were not significant for other traits for ASI and number of ears per plant under intermediate stress, leaf senescence and grain yield under severe stress.

The GCA_m mean squares were highly significant (P≤0.01) for ASI and plant height under non-stress and intermediate stress, ear height under intermediate stress and grain yield under intermediate and severe stress. The GCA_m were significant at P≤0.05 for days to 50% tasseling and days to 50% silking under intermediate stress and severe stress. The GCA_m mean squares were also significant at P≤0.05 for ASI and plant height severe stress, ear height under non-stress and severe stress, leaf senescence under intermediate stress, number of ears per plant and grain yield under non-stress. The GCA_m mean squares were not significant for days to 50% tasseling and days to 50% silking under non-stress, leaf senescence under severe stress and number of ears per plant under intermediate stress and severe stress conditions.

The SCA mean squares were highly significant (P≤0.01) for plant height under non-stress and ear height under intermediate stress. The SCA mean squares were significant at P≤0.05 for days to 50% tasseling and days to 50% silking under the three conditions, plant height under intermediate stress and severe stress, ear height under non-stress and severe stress, number of ears per plant under non-stress and grain yield under non-stress and intermediate stress. The SCA mean squares were not significant for ASI under three conditions, leaf senescence and number of ears per plant under intermediate stress and severe stress and grain yield under severe stress.

GCA and SCA variances of traits measured under non-stress, intermediate stress and severe stress at Kadawa are presented in Table 4.19. The magnitudes of SCA variance were greater than GCA variance for all the traits under both the conditions except for leaf senescence under severe stress which was negative. The ratios of the GCA to the SCA variance for all the traits were less than unity except for leaf senescence under severe stress which was negative.

4.4.3 Combined ANOVA for design II and combining ability variances across locations

Mean squares from combined ANOVA for design II of traits measured under non-stress, intermediate stress and severe stress across locations are presented in Table 4.20. The location mean squares were highly significant ($P \leq 0.01$) for all traits except ASI and number of ears per plant under non-stress that were significant at $P \leq 0.05$ and number of ears per plant under intermediate stress and severe stress that were not significant. The GCA_f mean squares were highly significant ($P \leq 0.01$) for days to 50% tasseling and days to 50% silking under non-stress and severe stress, ASI under non-stress, ear height under severe stress. The GCA_f mean squares were significant at $P \leq 0.05$ for days to 50% tasseling, days to 50% silking and ASI under intermediate stress, plant height and ear height under non-stress and intermediate stress, leaf senescence under severe stress and grain yield under the three conditions. The GCA_f mean squares were not significant for ASI and plant height under severe stress, leaf senescence under intermediate stress and number of ears per plant under three conditions. The GCA_m mean square was highly significant ($P<0.01$) for days to 50% silking under non-stress. The GCA_m mean squares for days to 50% tasseling, plant height and grain yield under non-stress and intermediate stress, days to 50% silking under intermediate stress, ASI under the three conditions.

Table 4.19 GCA and SCA variances of traits measured under non-stress, intermediate stress and severe stress at Kadawa

	σ^2_{GCA}			σ^2_{SCA}			$\sigma^2_{GCA}/\sigma^2_{SCA}$		
Traits	NS	IS	SS	NS	IS	SS	NS	IS	SS
Days to 50% tasseling	0.138	1.098	0.584	6.602	4.103	5.823	0.021	0.268	0.100
Days to 50% silking	0.551	0.365	0.149	8.300	5.475	4.237	0.066	0.067	0.035
Anthesis-silking interval	0.085	0.063	0.055	0.220	0.511	0.258	0.389	0.123	0.212
Plant height	3.434	71.068	6.592	155.870	93.676	91.197	0.022	0.759	0.072
Ear height	21.805	4.062	7.437	81.437	49.496	38.657	0.268	0.082	0.192
Leaf senescence	-	0.054	0.013	-	0.710	0.191	-	0.076	0.068
Number of ears per plant	0.002	0.001	0.025	0.013	0.004	-0.027	0.115	0.179	-0.931
Grain yield	70242.162	161447.519	18414.534	963551.829	270572.656	152687.778	0.073	0.597	0.121

NS=non-stress; IS=intermediate stress; SS=severe stress; σ^2_{GCA}=GCA variance; σ^2_{SCA}=SCA variance

Table 4.20 Mean squares from combined ANOVA for design II of traits measured under non-stress, intermediate stress and severe stress across locations

		Days to 50% tasseling			Days to50% silking			Anthesis-silking interval			Plant height		
Source	df	NS	IS	SS	NS	IS	SS	NS	IS	SS	NS	IS	SS
Rep (L)	2	23.6**	38.49**	53.24**	17.26*	40.40**	33.51*	2.14*	5.77**	14.98**	3177.77**	976.99*	8438.67**
Location	1	1126.34**	272.50**	2958.48**	1131.52**	141.17**	2415.29**	2.88*	27.52**	27.52**	65547.09**	103934.22**	105525.66**
GCA_f	6	30.37**	13.42*	31.87**	45.92**	14.56*	36.42**	3.81**	2.41*	3.09	317.96*	896.16*	356.78
GCA_m	5	23.34*	14.85*	16.47	19.67**	19.79*	15.41	2.27*	1.90*	5.86*	287.57*	869.22*	336.09
SCA	30	20.18*	10.70*	17.95*	22.95**	13.17*	18.66*	2.08*	2.06*	2.94	262.13	647.10*	258.20
GCA_f x L	6	14.01*	8.87	12.47	16.22*	8.88	18.51	2.06*	1.80	1.98	331.33*	389.83	232.00
GCA_m x L	5	2.97	2.98	18.24*	2.87	6.11	36.76**	0.90	1.98	4.50*	806.25**	665.19*	245.21
SCA x L	30	13.75	8.66	12.61	14.69*	10.15	12.42	0.83	0.83	1.62	197.02	438.12	187.75
Error	82	5.25	4.23	6.73	4.83	5.20	8.05	0.42	0.55	1.21	141.66	248.84	120.03

		Ear height			Leaf senescence		Number of ears per plant			Grain yield		
		NS	IS	SS	IS	SS	NS	IS	SS	NS	IS	SS
Rep (L)	2	395.74*	559.03**	3267.78**	27.65**	11.05**	0.20**	0.06	0.48	13434462.43**	7258100.49**	5715483.90**
Location	1	34720.80**	26149.85**	73096.78**	19.34**	40.02**	0.06*	0.03	1.38	38095190.48**	90869039.57**	47502673.86**
GCA_f	6	536.52*	159.46*	297.59**	0.86	2.01*	0.05	0.01	1.21	3472460.99*	2137663.48*	1880267.09*
GCA_m	5	238.08*	140.80	234.46*	7.61*	2.51*	0.05	0.02	1.13	3148619.42*	2773663.21*	1228692.58
SCA	30	314.92*	138.50	251.15*	3.70*	2.00*	0.04	0.03	1.08	2813089.89*	1570646.44*	1474917.98*
GCA_f x L	6	261.67	97.54	549.67**	0.69	0.97	0.03	0.01	0.28	3154212.11*	2436118.86*	1609644.64*
GCA_m x L	5	163.94	203.09*	137.39*	1.87	0.44	0.02	0.04	0.07	1859610.93*	1026929.54*	2189071.00*
SCA x L	30	169.45	124.56	137.50*	2.00	1.83	0.03	0.01	0.18	1770447.67*	971093.99	1311699.77*
Error	82	120.90	75.14	46.21	1.52	0.70	0.02	0.01	1.06	1138182.65	709440.15	645145.70

*and **-significant at 0.05 and 0.01 probability level, respectively; NS=non-stress; IS=intermediate stress; SS=severe stress; df=degree of freedom; Rep=replication; L=location; GCA_f=general combining ability due to females; GCA_m=general combining ability due to males; SCA = specific combining ability

The GCA_m mean squares were significant at P≤0.05 for ear height under non-stress and severe stress and leaf senescence under intermediate stress and severe stress were significant at P≤0.05. The SCA mean square was highly significant (P≤0.01) for days to 50% tasseling under non-stress. The SCA mean squares were significant at P<0.05 for days to 50% tasseling and grain yield under the three conditions, days to 50% silking and leaf senescence under intermediate stress and severe stress, ASI under non-stress and intermediate stress, plant height under intermediate stress and ear height under non-stress and severe stress.

The GCA_f x location mean squares was highly significant (P≤0.01) for ear height under severe stress. GCA_f x location mean squares were significant at P≤0.05 for days to 50% tasseling, days to 50% silking, ASI and plant height under non-stress and grain yield under the three conditions. The GCA_m x location mean squares were highly significant for days to 50% silking under severe stress and plant height under non-stress. The GCA_m x location mean squares were significant at P≤0.05 for days to tasseling and ASI under severe stress, plant height under intermediate stress, ear height under intermediate stress and severe stress and grain yield under the three conditions. The SCA x location mean squares were significant at P≤0.05 for days to silking under non-stress, ear height under severe stress and grain yield under non-stress and severe stress.

GCA and SCA variances of traits measured under non-stress, intermediate stress and severe stress across locations are presented in Table 4.21. The magnitudes of SCA variance were greater than GCA variance for all the traits under the three conditions. The ratios of the GCA to the SCA variance for all the traits were less than unity.

Table 4.21 GCA and SCA variances for traits measured under non-stress, intermediate stress and severe stress across locations

	σ^2_{GCA}			σ^2_{SCA}			$\sigma^2_{GCA}/\sigma^2_{SCA}$		
Traits	NS	IS	SS	NS	IS	SS	NS	IS	SS
Days to 50% tasseling	0.513	0.242	0.478	1.070	0.343	0.808	0.480	0.705	0.592
Days to 50% silking	0.757	0.308	0.558	1.225	0.461	0.936	0.618	0.669	0.596
Anthesis-silking interval	0.074	0.007	0.118	0.234	0.299	0.219	0.316	0.024	0.538
Plant height	3.126	18.122	6.787	13.043	33.935	10.723	0.240	0.534	0.633
Ear height	5.568	0.895	1.144	29.878	2.530	27.074	0.186	0.354	0.042
Leaf senescence	-	0.041	0.020	-	0.404	0.024	-	0.102	0.838
Number of ears per plant	0.001	0.001	0.007	0.002	0.004	0.218	0.446	0.308	0.032
Grain yield	38265.409	68078.223	6120.143	221203.562	83297.518	32708.771	0.173	0.817	0.187

NS=non-stress; IS=intermediate stress; SS=severe stress; σ^2_{GCA}=GCA variance; σ^2_{SCA}=SCA variance

4.5 Combining Ability Effects

4.5.1 General combining ability (GCA) effects at Samaru

The GCA effects of seven female and six male parents for days to 50% tasseling, days to 50% silking, ASI and plant height under non-stress, intermediate stress and severe stress conditions at Samaru are presented in Table 4.22.

4.5.1.1 Days to 50% tasseling

The female parents S5 under the three conditions, S4 under intermediate stress and S7 under severe stress showed significant negative GCA effects, whereas S1 under intermediate stress and severe stress, S4 under non-stress and S6 under intermediate stress showed significant positive GCA affects. The male parents, P2 under the three conditions and P4 and P7 under non-stress showed significant negative GCA effects, whereas P3 under non-stress and severe stress and P8 under the three conditions showed significant positive GCA effects.

4.5.1.2 Days to 50% silking

Among the female parents, only S5 recorded significant negative GCA effects under the three conditions, whereas S1 under the three conditions and S2 under non stress and severe stress recorded significant positive GCA effects. Among the male parents, P2 under both the conditions, P7 under non-stress and severe stress showed significant negative GCA effects, whereas P3 under non-stress and severe stress and P8 under severe stress recorded significant negative GCA effects.

Table 4.22 GCA effects of parents for days to 50% tasseling, days to 50% silking, anthesis-silking interval and plant height under non-stress, intermediate stress and severe stress at Samaru

	Days to 50% tasseling			Days to 50% silking			Anthesis-silking interval			Plant height		
Parents	NS	IS	SS	NS	IS	SS	NS	IS	SS	NS	IS	SS
Females												
S1	-0.42	1.61**	1.46**	0.83**	0.95*	1.80**	0.95**	0.34	0.33	-4.84	1.98	-1.23
S2	0.93*	-0.56*	1.80**	1.50**	0.62	1.71**	0.29	0.42	-0.08	10.00**	5.87*	2.52
S3	0.43	0.52	0.05	0.09	-0.13	0.55	0.20	0.58*	0.50	5.44	-3.85	-4.85*
S4	1.10**	-0.89**	0.55	0.25	0.45	0.55	-0.30	-0.42	0.00	-3.05	5.46*	1.18
S5	-1.24**	-0.98**	-1.87**	-2.25**	-1.80**	-3.04**	-1.21**	-0.92**	-1.17**	-6.17	-2.60	-5.40*
S6	-0.40	0.69*	-0.45	-0.50	-0.38	-0.70	-0.38*	-0.25	-0.25	-2.45	-5.65*	4.60
S7	-0.40	-0.39	-1.54**	0.08	0.29	-0.87	0.45*	0.25	0.67	1.07	-1.21	3.18
SE±	0.38	0.27	0.44	0.29	0.42	0.58	0.19	0.24	0.41	3.33	2.33	2.43
Males												
P1	-0.31	-0.02	-0.36	0.00	-0.40	0.67	0.02	0.77*	1.02**	9.91**	5.10*	4.82*
P2	-0.81*	-1.74**	-1.14**	-0.57*	-0.76*	-2.19*	-0.05	-0.30	-1.05**	-2.13	-2.52	1.25
P3	1.62**	0.05	1.07**	1.00**	0.38	1.38*	0.10	-0.23	0.31	-9.19**	-3.71	0.34
P4	-0.74*	0.33	0.07	-0.07	0.45	0.38	0.38*	0.20	0.31	3.32	-0.38	0.53
P7	-0.81*	-0.38	-0.71	-0.57*	-0.34	-1.62**	-0.05	0.07	-0.90*	-2.61	0.46	-1.14
P8	1.05**	1.76**	1.07**	0.21	0.67	1.38*	-0.40*	-0.51*	0.31	0.70	1.05	-5.80*
SE±	0.35	0.25	0.41	0.27	0.39	0.54	0.18	0.23	0.38	3.08	2.16	2.25

*P≤0.05; **P≤0.01; NS=non-stress; IS=intermediate stress; SS=severe stress

4.5.1.3 Anthesis-silking interval

Among the female parents, S5 under the three conditions and S6 under non-stress recorded significant negative GCA effects, whereas S1 and S7 under non-stress and S3 under intermediate stress showed significant positive GCA effects. Among the male parents, P2 and P7 under severe stress and P8 under non-stress and intermediate stress showed significant negative GCA effects, whereas P1 under intermediate stress and severe stress and P4 under non-stress showed significant positive GCA effects.

4.5.1.4 Plant height

The female parents S3 and S5 under severe stress and S6 under intermediate stress recorded significant negative GCA effect, whereas S2 under non-stress and intermediate stress and S4 under intermediate stress showed significant positive GCA effects. Among the male parents, P3 under non-stress and P8 under severe stress recorded significant negative GCA effects, whereas only P1 under the three conditions showed significant positive GCA effects.

The GCA effects of seven female and six male parents for ear height, leaf senescence, number of ears per plant and grain yield under non-stress, intermediate stress and severe stress conditions at Samaru are presented in Table 4.23.

4.5.1.5 Ear height

Among the female parents, S5 under non-stress and severe stress and S1 and S3 under severe stress recorded significant negative GCA effects, whereas S2 under intermediate stress, S4 under non-stress and severe stress and S6 under severe stress

Table 4.23 GCA effects of parents for ear height, leaf senescence, number of ears per plant and grain yield under non-stress, intermediate stress and severe stress at Samaru

	Ear height			Leaf senescence		Number of ears per plant			Grain yield		
Parents	NS	IS	SS	IS	SS	NS	IS	SS	NS	IS	SS
Females											
S1	-2.15	-1.79	-4.71*	0.06	-0.35	0.01	-1.79**	0.15	-174.60	-404.76	15.88
S2	2.99	5.85*	0.90	-0.12	0.25	-0.01	5.85**	0.06	-448.68	132.28	386.24
S3	-0.76	2.80	-8.96**	0.21	-0.10	0.01	2.80**	0.01	529.10	391.53	-576.72
S4	4.52*	1.41	9.37**	-0.20	-0.57*	-0.04	1.41**	-0.04	-1063.49**	576.72	386.24
S5	-4.91*	-2.90	-7.57**	-0.04	-0.40	-0.01	-2.90**	-0.03	-411.64	-15.87	-324.87
S6	-2.56	-4.70	8.40**	-0.04	0.57*	0.03	-4.70**	-0.17*	825.40**	-460.32	-447.09
S7	2.87	-0.67	2.57	0.13	0.60*	0.01	-0.67**	0.02	743.91**	-219.58	560.32
SE±	2.25	2.52	1.96	0.38	0.28	0.04	0.03	0.08	283.03	295.95	257.02
Males											
P1	-1.03	4.95*	4.27*	-0.43	0.33	0.09*	2.95**	-0.15*	-300.54	-248.68	-352.91
P2	-1.14	-1.23	-2.09	0.50	-0.38	0.05	-1.23**	0.08	185.19	-296.30	740.74**
P3	0.40	-6.21**	1.66	0.36	0.05	0.05	-4.21**	-0.07	-427.51	-201.06	-259.26
P4	1.35	3.29	0.11	-0.50	0.12	-0.09*	3.29**	-0.01	343.92	-385.19	-338.62
P7	0.87	-0.64	-1.56	0.14	-0.17	-0.06	-0.64**	0.08	-322.75	592.59*	-291.01
P8	-0.45	-0.16	-2.39	-0.07	0.05	-0.04	-0.16**	0.07	521.69*	538.64*	501.06*
SE±	2.08	2.33	1.82	0.35	0.26	0.04	0.03	0.07	262.04	274.00	237.95

*P≤0.05; **P≤0.01; NS=non-stress; IS=intermediate stress; SS=severe stress

showed significant positive GCA effects. Among the male parents, only P3 recorded significant negative GCA effect under intermediate stress, whereas P1 under intermediate stress and severe stress showed positive significant GCA effects.

4.5.1.6 Leaf senescence

Only the female parent S4 recorded significant negative GCA effect under severe stress, whereas S6 and S7 under severe stress showed positive significant GCA effects. None of the male parents showed significant GCA effect in either direction.

4.5.1.7 Number of ears per plant

Among the female parents, S2, S3, S4 and S7 under intermediate stress recorded significant positive GCA effects, whereas S5 and S7 under intermediate stress and S6 under intermediate stress and severe stress showed negative positive GCA effects. Among the male parents, P1 under non-stress and intermediate stress and P4 under intermediate stress showed significant positive GCA effects, whereas P2, P3, P7 and P8 under intermediate stress and P4 under non-stress showed significant negative GCA effects.

4.5.1.8 Grain yield

Among the female parents, S6 and S7 under non-stress recorded significant positive GCA effects, whereas S4 under non-stress showed significant negative GCA effect. Among the male parents, P8 under the three conditions, P2 under severe stress and P7 under intermediate stress showed significant positive GCA effects.

4.5.2 General combining ability (GCA) effects at Kadawa

The GCA effects for seven female and six male parents for days to 50% tasseling, days to 50% silking, ASI and plant height under non-stress, intermediate stress and severe stress conditions at Kadawa are presented in Table 4.24.

4.5.2.1 Days to 50% tasseling

Among the female parents, only S7 under non-stress and severe stress recorded significant negative GCA effect, while S1 and S2 under non-stress showed significant negative GCA effects. Among the male parents, only P8 recorded significant negative GCA effect under severe stress, while P3 under severe stress showed significant positive GCA effect.

4.5.2.2 Days to 50% silking

Only, the female parent S7 under non-stress and severe stress recorded significant negative GCA effect, whereas S1 under non-stress showed significant positive GCA effect. Among the male parents, only P3 exhibited significant positive GCA effect.

4.5.2.3 Anthesis-silking interval

Only the female parent S3 under intermediate stress recorded significant negative GCA effect, while S1 under non-stress and severe stress and S3 under non-stress showed significant positive GCA effects. Among the male parents, P1 under intermediate stress, P2 and P8 under non-stress and P3 under intermediate stress and severe stress showed significant negative GCA effects, whereas P2 and P4 under intermediate stress and P3 under non-stress showed significant positive GCA effects.

Table 4.24 GCA effects of parents for days to 50% tasseling, days to 50% silking, anthesis-silking interval and plant height under non-stress, intermediate stress and severe stress at Kadawa

	Days to 50% tasseling			Days to 50% silking			Anthesis-silking interval			Plant height		
Parents	NS	IS	SS	NS	IS	SS	NS	IS	SS	NS	IS	SS
Females												
S1	1.88*	-1.02	-0.76	2.42**	-0.88	-0.29	0.43*	0.14	0.48*	1.78	-9.11	-5.22
S2	1.88*	0.31	0.90	1.65	0.45	0.88	-0.24	0.14	-0.03	1.32	0.07	-1.36
S3	0.63	1.14	-0.26	1.07	0.79	-0.45	0.43*	-0.36*	-0.19	-3.31	-10.24	5.78
S4	-0.87	-0.02	1.32	-1.18	-0.22	1.30	-0.15	-0.19	-0.03	-6.81	17.70**	-1.94
S5	-0.95	0.39	-0.51	-1.01	0.20	-0.70	-0.08	-0.19	-0.19	6.08	0.48	0.85
S6	0.38	-0.44	1.49	0.15	-0.21	1.46	-0.24	0.23	-0.02	-4.25	-2.44	4.97
S7	-2.95**	-0.36	-2.18*	-3.10*	-0.13	-2.20*	-0.15	0.23	-0.02	5.19	3.54	-3.08
SE±	0.86	0.80	0.96	0.85	0.83	1.00	0.18	0.18	0.19	3.54	6.00	3.76
Males												
P1	0.82	-0.18	-1.61	0.88	-0.6	-1.27	0.05	-0.42*	0.33	-3.64	-6.58	0.56
P2	-0.54	-0.18	0.61	-0.90	0.26	0.37	-0.45**	0.44**	-0.24	1.00	-0.75	3.38
P3	1.25	-0.82	2.46**	1.81*	-1.24	1.08	0.55**	-0.42*	-0.38*	4.62	-14.08*	-3.84
P4	-0.89	0.54	-0.96	-0.90	1.27	-1.13	-0.03	0.73**	-0.17	-7.10*	-0.87	-5.75
P7	-0.75	-0.11	1.25	-0.62	-0.31	1.51	0.26	-0.20	0.27	0.83	13.27	2.30
P8	0.11	0.75	-1.75*	-0.27	0.62	-0.56	-0.38*	-0.13	0.19	4.29	9.01	3.35
SE±	0.79	0.74	0.89	0.79	0.77	0.93	0.17	0.17	0.18	3.28	5.56	3.48

*P≤0.05; **P≤0.01; NS=non-stress; IS=intermediate stress; SS=severe stress

4.5.2.4 Plant height

Only the female parent S4 recorded significant positive GCA effect under intermediate stress. Among the male parents, P4 under non-stress and P3 under intermediate stress recorded significant negative GCA effects.

The GCA effects for seven female and six male parents for ear height, leaf senescence, number of ears per plant and grain yield under non-stress, intermediate stress and severe stress conditions at Kadawa are presented in Table 4.25.

4.5.2.5 Ear height

The female parents S3 under non-stress, S4 under intermediate stress and S1 under severe stress recorded significant negative GCA effects, whereas S3 under severe stress and S4 under non-stress showed significant positive GCA effects. Among the male parents, only P4 under intermediate stress and P3 under severe stress recorded significant negative GCA effects.

4.5.2.6 Leaf senescence

Among the female parents, only S4 under severe stress recorded significant negative GCA effect, whereas S3 under severe stress and S4 under non-stress showed significant positive GCA effects. Among the male parents, only P4 under intermediate stress recorded significant negative GCA effect under severe stress.

Table 4.25 GCA effects of parents for ear height, leaf senescence, number of ears per plant and grain yield under non-stress, intermediate stress and severe stress at Kadawa

	Ear height			Leaf senescence		Number of ears per plant			Grain yield		
Parents	NS	IS	SS	IS	SS	NS	IS	SS	NS	IS	SS
Females											
S1	-2.40	1.89	-4.24*	0.48	-0.04	-0.05	-0.04	0.02	259.26	-709.00**	-216.93
S2	0.99	2.19	-1.99	-0.28	0.46*	-0.04	0.02	-0.05	-370.37	-486.77**	5.29
S3	-10.62**	2.95	7.98**	-0.36	0.23	-0.02	-0.02	-0.13	333.34	1068.78**	190.48
S4	12.11**	-5.67*	-2.91	-0.19	-0.45*	-0.06	-0.01	0.00	111.11	161.38	-216.94
S5	0.02	-0.42	-1.05	-0.19	-0.04	0.09*	0.03	-0.27**	-681.49*	-634.92**	60.85
S6	-3.73	-0.97	0.67	0.31	-0.12	0.13**	0.02	0.18**	-370.37	142.86	60.85
S7	3.63	0.03	1.54	0.23	-0.04	-0.05	0.00	0.25**	718.52*	457.67**	116.40
SE±	3.88	2.48	1.96	0.33	0.19	0.04	0.04	0.07	331.04	175.08	203.63
Males											
P1	-1.52	-1.35	4.11*	0.46	-0.05	0.04	0.11**	0.05	58.20	-238.10	502.65**
P2	-0.50	0.89	0.52	0.11	-0.05	0.06	-0.04	0.02	-259.27	-587.30**	-291.01
P3	-6.50	2.10	-5.39**	-0.18	0.18	-0.06	-0.03	-0.12	343.92	-746.03**	-5.29
P4	-3.71	-5.11*	-3.13	-0.68*	-0.05	0.05	-0.03	-0.06	-68.78	174.60	-284.66
P7	5.46	2.65	1.85	0.11	-0.05	-0.01	0.00	0.03	153.44	-111.11	-332.28
P8	6.77	0.82	2.04	0.18	0.02	-0.08*	-0.01	0.08	-227.51	1507.94**	410.59*
SE±	3.60	2.30	1.82	0.31	0.18	0.04	0.04	0.07	306.49	162.10	188.53

*P≤0.05; **P≤0.01; NS=non-stress; IS=intermediate stress; SS=severe stress

4.5.2.7 Number of ears per plant

The female parents S5 under non-stress, S6 under non-stress and severe stress and S7 severe stress recorded significant positive GCA effects, whereas only S5 under severe stress showed significant negative GCA effect. Among the male parents, only P1 under non-stress exhibited significant positive GCA effects while P8 under non-stress showed significant negative GCA effect.

4.5.2.8 Grain yield

Among the female parents, S3 under intermediate stress and S7 under non-stress and intermediate stress recorded significant positive GCA effects, whereas S2 and S2 under intermediate stress and S5 under non-stress and intermediate stress exhibited significant negative GCA effects. Among the male parents, P1 under severe stress and P8 under intermediate stress and severe stress showed significant positive GCA effects, whereas P2 and P3 under intermediate stress showed significant negative GCA effects.

4.5.3 General combining ability (GCA) effects across locations

The GCA effects for seven female and six male parents for days to 50% tasseling, days to 50% silking, ASI and plant height under non-stress, intermediate stress and severe stress conditions across locations are presented in Table 4.26.

4.5.3.1 Days to 50% tasseling

The female parents S7 under the three conditions, S5 under non-stress intermediate stress and S6 under intermediate stress exhibited significant negative GCA effects, whereas S1 under non-stress, S2 under intermediate stress and S4 under intermediate stress and severe stress exhibited significant positive GCA effects.

Table 4.26 GCA effects of parents for days to 50% tasseling, days to 50% silking, anthesis-silking interval and plant height under non-stress, intermediate stress and severe stress across locations

	Days to 50% tasseling			Days to 50% silking			Anthesis-silking interval			Plant height		
Parents	NS	IS	SS	NS	IS	SS	NS	IS	SS	NS	IS	SS
Females												
S1	1.55*	-0.55	0.18	1.92**	0.02	0.38	0.27	0.12	0.21	0.57	-11.78**	-1.61
S2	0.67	1.31*	0.68	0.77	1.27	1.65*	0.40*	0.14	-0.03	7.60*	10.48*	6.29*
S3	0.24	1.09	-0.06	1.27*	0.16	1.02	0.17	0.06	0.08	0.32	-3.52	0.23
S4	1.03	1.20*	1.47*	-0.25	0.06	0.46	-0.10	-0.15	-0.01	-7.69*	10.79*	-0.19
S5	-1.58*	-1.18*	-0.60	-1.83**	-1.40*	-1.93*	-0.39*	-0.58**	-0.34	-0.24	-9.53*	-7.14*
S6	-0.04	-1.17*	0.26	-0.11	-0.15	0.19	-0.44*	-0.01	-0.07	-1.90	-6.02	2.39
S7	-1.87**	-1.61**	-1.93*	-1.77**	0.04	-1.77*	0.09	0.42*	0.16	1.34	9.58*	0.03
SE±	0.66	0.59	0.75	0.63	0.66	0.82	0.19	0.21	0.32	3.44	4.55	3.16
Males												
P1	1.15	-0.06	-1.49*	0.27	-1.25*	-0.15	0.23	-0.04	0.34	8.79**	-0.37	10.35**
P2	-1.57**	-0.20	-1.36*	-1.39*	-0.13	-1.46*	-0.11	1.05**	-0.32	-0.71	-0.82	6.16*
P3	0.72	-0.10	1.66*	1.72**	-0.21	0.62	0.17	-0.16	-0.03	-8.22**	-8.45*	-7.88*
P4	-0.38	1.18*	-1.42*	-0.23	0.43	-0.19	0.08	0.23	1.04**	-0.78	-0.31	-1.31
P7	-1.38*	-1.15*	1.33	-0.30	-0.16	-0.03	0.25	-1.04**	-1.16**	-0.25	7.43	0.29
P8	1.46*	0.33	1.28	-0.07	1.32*	1.21	-0.52**	-0.04	0.13	1.17	2.52	-7.61**
SE±	0.61	0.55	0.69	0.59	0.61	0.76	0.17	0.20	0.29	3.18	4.22	2.93

*P≤0.05; **P≤0.01; NS=non-stress; IS=intermediate stress; SS=severe stress

Among the male parents, P1 and P4 under severe stress, P2 under non-stress and severe stress and P7 under non-stress and intermediate stress exhibited significant negative GCA effects P3 under severe stress, P4 under intermediate stress and P8 under non-stress showed significant positive GCA effects.

4.5.3.2 Days to 50% silking

The female parents S5 under the three conditions, S7 under non-stress and severe stress exhibited significant negative GCA effects, whereas S1 and S3 under non-stress S2 under severe stress exhibited significant positive GCA effects. Among the male parents, P1 under non-stress and P2 under non-stress and severe stress exhibited significant negative GCA effects, whereas P3 under non-stress and P8 under intermediate stress showed significant positive GCA effects.

4.5.3.3 Anthesis-silking interval

The female parents S5 under non-stress and intermediate stress and S6 under non-stress recorded significant negative GCA effect, whereas S2 under non-stress and S7 under intermediate stress recorded significant positive GCA effects. The male parents P7 under intermediate stress and severe stress and P8 under non-stress exhibited significant negative GCA effects, whereas P2 under intermediate stress and P4 under severe stress showed significant positive GCA effects.

4.5.3.4 Plant height

Among the female parents, S4 under non-stress, S1 intermediate stress and S5 under intermediate stress and severe stress recorded significant negative GCA effects, whereas S2 under the three conditions, S4 and S7 under intermediate stress showed significant

positive GCA effects. The male parents P3 under the three conditions and P8 under severe stress recorded significant negative GCA effects, whereas P1 under non-stress and severe stress and P2 under severe stress recorded significant positive GCA effects.

The GCA effects for seven female and six male parents for ear height, leaf senescence, number of ears per plant and grain yield under non-stress, intermediate stress and severe stress conditions across locations are presented in Table 4.27.

4.5.3.5 Ear height

The female parents S5 under non-stress and severe stress, S7 under intermediate stress and S2 under severe stress recorded significant negative GCA effects, whereas S1 under intermediate stress, S2 under non-stress and intermediate stress, S5 and S7 under severe stress showed significant positive GCA effects. Only the male parent P4 recorded significant negative GCA effects under the three conditions, whereas P7 under severe stress and P8 under non-stress and intermediate stress showed significant positive GCA effects.

4.5.3.6 Leaf senescence

Only the female parent S4 recorded significant negative GCA effect under severe stress, whereas S6 recorded significant positive GCA effect under severe stress. None of the male parents exhibited significant GCA effect in either direction.

Table 4.27 GCA effects of parents for ear height, leaf senescence, number of ears per plant and grain yield non-stress, intermediate stress and severe stress across locations

	Ear height			Leaf senescence		Number of ears per plant			Grain yield		
Parents	NS	IS	SS	IS	SS	NS	IS	SS	NS	IS	SS
Females											
S1	0.83	5.03*	-2.24	0.13	-0.10	-0.01	-0.01	0.04	-1052.90**	-464.15*	-330.95
S2	7.67*	5.01*	-4.27*	-0.10	0.18	-0.02	0.01	0.01	-182.54	-527.12*	123.68
S3	-3.17	1.44	-0.26	-0.04	0.03	0.05	0.00	-0.73*	243.39	528.44*	-544.84*
S4	3.83	-1.06	1.62	-0.10	-0.64**	-0.12**	0.00	-0.01	-173.28	697.88*	623.68**
S5	-8.55**	-3.83	-5.15*	-0.06	-0.07	0.02	0.01	-0.08	-164.02	-354.89	-398.56
S6	-1.90	-1.42	5.27*	0.08	0.51*	0.09*	0.00	0.00	187.83	-364.15	-126.32
S7	1.29	-5.17*	4.03*	0.09	0.09	-0.01	-0.01	0.77*	1141.53**	483.99*	653.31**
SE±	3.17	2.50	1.96	0.36	0.24	0.04	0.03	0.30	307.97	243.15	231.87
Males											
P1	-0.88	0.40	2.10	0.01	0.07	0.01	0.08**	-0.03	34.39	145.63	-148.28
P2	-0.35	-0.09	-0.39	0.15	-0.11	0.03	-0.07*	0.02	-168.78	-625.79*	50.93
P3	-1.70	-0.53	-0.93	0.04	0.05	0.00	-0.01	-0.65*	-268.78	-165.48	-111.77
P4	-6.65*	-5.45*	-4.76**	-0.29	0.02	0.01	-0.07*	-0.01	645.50*	-461.51*	-164.15
P7	1.82	0.51	4.07*	0.06	-0.05	-0.02	0.00	0.03	34.39	513.89*	-108.61
P8	7.76**	5.16*	-0.09	0.03	0.02	-0.03	0.07*	0.64*	-276.72	593.26*	481.88*
SE±	2.94	2.32	1.82	0.33	0.22	0.04	0.03	0.28	285.13	225.11	214.67

*P≤0.05; **P≤0.01; NS=non-stress; IS=intermediate stress; SS=severe stress

4.5.3.7 Number of ears per plant

The female parents S6 under non-stress and S7 under severe stress recorded significant positive GCA effects, whereas S3 under severe stress and P4 under intermediate stress exhibited significant negative GCA effects. Among male parents, P1 under intermediate stress and P8 under intermediate stress and severe stress exhibited significant positive GCA effects, whereas P2 and P4 under intermediate stress and P3 under severe stress showed significant negative GCA effects.

4.5.3.8 Grain yield

Among the female parents, S7 under the three conditions, S3 under intermediate stress and S4 under intermediate stress and severe stress recorded significant positive GCA effects, whereas S1 under non-stress and intermediate stress and S2 under intermediate stress showed significant negative GCA effects. Among male parents, P4 under non-stress, P7 under intermediate stress and P8 under intermediate stress and severe stress exhibited significant positive GCA effects, P2 and P4 under intermediate stress exhibited significant negative GCA effects.

4.5.4 Specific combining ability (SCA) effects at Samaru

The SCA effects of the 42 hybrids for days to 50% tasseling, days to 50% silking and ASI under non-stress, intermediate stress and severe stress conditions at Samaru and the results are presented in Table 4.28.

4.5.4.1 Days to 50% tasseling

Among the hybrids, S5 x P8 under the three conditions, S7 x P4 under intermediate stress and severe stress and S7 x P8 under non-stress and severe stress recorded significant negative SCA effects. Also, the hybrids S3 x P3, S4 x P8 and

Table 4.28 SCA effects of hybrids for days to 50% tasseling, days to 50% silking and anthesis-silking interval under non-stress, intermediate stress and severe stress at Samaru

	Days to 50% tasseling			Days to 50% silking			Anthesis-silking interval		
Hybrids	NS	IS	SS	NS	IS	SS	NS	IS	SS
S1 x P1	-0.52	-0.89	-1.39	-0.83	0.90	-2.58	-0.02	-0.19	-1.19
S1 x P2	0.14	1.77**	1.77	-1.50*	-4.26**	-0.50	-1.36**	-1.27*	-2.27*
S1 x P3	-0.36	-0.81	0.52	0.42	1.99	1.67	0.23	1.56**	1.14
S1 x P4	-0.52	-1.39*	0.02	2.25**	2.40*	3.67*	1.23**	2.06**	2.64**
S1 x P7	-0.19	0.19	0.94	0.25	-0.35	-0.25	0.64	0.06	-1.19
S1 x P8	1.48	0.52	-1.98	1.00	-0.26	-0.58	-0.19	-1.11	1.39
S2 x P1	-0.02	0.61	0.11	-0.58	1.57	-0.42	-1.52**	-2.11**	-2.52
S2 x P2	-0.02	-2.18**	0.39	-0.26	0.26	-0.23	0.05	-0.12	-0.62
S2 x P3	0.64	-1.01	2.06	1.07	1.60	2.86*	0.71	-0.20	0.80
S2 x P4	-0.86	-0.10	-0.69	-1.51*	-2.65*	-2.98*	-0.20	-1.37*	-0.29
S2 x P7	-0.02	1.82**	-1.69	1.32	1.26	-1.98	0.80	0.63	-0.29
S2 x P8	0.31	1.40*	-0.77	0.32	-1.49	0.11	0.21	-0.37	0.88
S3 x P1	-1.02	0.74	-0.69	-1.93**	0.60	-1.23	-0.62	0.96	-0.54
S3 x P2	1.98*	-0.68	1.39	-0.01	-0.57	1.44	-0.95*	0.46	0.05
S3 x P3	-1.95*	2.04**	0.68	-1.83**	-0.38	1.70	-0.10	0.31	2.04*
S3 x P4	-0.29	-0.30	-0.65	0.50	0.45	-1.71	0.07	-0.27	-1.06
S3 x P7	-1.29	-1.38*	0.60	-0.08	-0.30	1.45	-0.35	0.06	0.86
S3 x P8	3.55**	2.04**	-0.40	0.75	0.12	-1.05	0.65	0.06	-0.64
S4 x P1	-0.12	-0.38	1.01	-0.75	2.87**	1.04	-0.93**	0.06	0.02
S4 x P2	-0.95	-1.05	-0.90	0.00	-1.55	-0.8	0.24	-0.11	0.11
S4 x P3	0.55	-0.96	-0.32	1.42	-0.21	-0.63	0.4	-0.11	-0.31
S4 x P4	1.90*	0.25	-0.32	1.24	-0.45	0.20	-0.38	0.38	0.52
S4 x P7	2.07*	0.42	-0.65	-0.93	1.38	-1.21	-0.71	0.80	-0.56
S4 x P8	-1.93*	0.33	2.10	-0.51	0.13	3.45*	0.87	-0.37	0.36
S5 x P1	-0.60	1.25	1.60	-2.18**	-2.95**	3.45*	-1.13*	-0.37	-0.14
S5 x P2	1.24	-1.17	-0.49	1.82**	0.80	-1.96	0.79	0.13	-1.48
S5 x P3	-0.10	-2.83**	-0.90	2.07**	0.38	-2.3	0.45	1.46	-1.39
S5 x P4	-0.60	1.75**	-1.32	-2.51**	-2.29*	1.37	0.12	-1.04*	2.69**
S5 x P7	-0.12	1.96**	-2.08	0.74	-1.17	-3.30*	1.05	0.03	-1.26
S5 x P8	-1.84*	-1.87**	-2.87**	0.57	-0.33	0.79	-0.29	-1.06	3.65**
S6 x P1	0.14	0.07	-3.12**	0.49	2.92**	-4.55**	-0.2	1.77**	-1.43
S6 x P2	-1.92*	-1.04	1.88	-1.68*	-2.17*	1.95	-0.7	-0.73	0.07
S6 x P3	-0.69	1.55*	1.80	-1.18	0.58	-0.46	-0.29	0.27	-1.26
S6 x P4	0.48	1.88**	1.88	1.57*	-0.33	1.7	0.38	-0.89	-0.18
S6 x P7	0.48	-2.54**	2.46*	0.49	0.50	1.87	1.05*	0.61	0.4
S6 x P8	0.62	-1.18	0.68	-0.08	2.83*	2.20	-0.6	-0.41	2.52*
S7 x P1	-1.73	0.99	0.35	-0.71	1.17	-0.21	0.57	1.01	-0.56
S7 x P2	4.29**	1.90*	2.60*	0.20	-2.08*	-0.05	-0.35	-1.65**	-0.64
S7 x P3	-0.88	-2.68**	-1.40	0.54	0.33	-3.05*	0.17	0.35	-1.64
S7 x P4	-0.55	-1.60*	-2.49*	-0.46	-2.42*	1.54	-0.43	-0.15	3.02**
S7 x P7	1.10	0.74	2.60*	0.29	1.17	3.20*	-0.26	0.68	0.61
S7 x P8	-1.88*	1.82**	-2.32*	0.20	0.00	-3.63*	0.9	0.18	-2.31*
SE±	0.93	0.66	1.08	0.70	1.02	1.43	0.47	0.6	0.99

*P≤0.05; **P≤0.01; NS=non-stress; IS=intermediate stress; SS=severe stress

S6 x P2 under non-stress, S1 x P4, S2 x P2, S3 x P7, S5 x P3, S6 x P7, and S7 x P3 under intermediate stress and S6 x P1 under severe stress recorded significant negative SCA effects. S7 x P2 under the three conditions, S3 x P8 under non-stress and intermediate stress and S3 x P2, S4 x P4 and S4 x P7 under non-stress showed significant positive SCA effects. S1 x P2, S2 x P7, S2 x P8, S3 x P3, S5 x P7, S6 x P3, S6 x P4 and S7 x P8 under intermediate stress and S6 x P7 and S7 x P7 under severe stress also showed significant positive SCA effects.

4.5.4.2 Days to 50% silking

Among the hybrids, S2 x P4 under the three conditions, S1 x P2, S5 x P1, S5 x P4 and S6 x P2 under non-stress and intermediate stress and S3 x P1 and S3 x P3 under non-stress recorded significant negative SCA effects. Also, S7 x P2 and S7 x P4 under intermediate stress and S5 x P7, S6 x P1, S7 x P3 and S7 x P8 under severe stress recorded significant negative SCA effects. S1 x P4 under the three conditions, S5 x P2, S5 x P3 and S6 x P4 under non-stress, S4 x P1, S6 x P1 and S6 x P8 under intermediate stress and S2 x P3, S4 x P8, S5 x P1 and S7 x P7 under severe stress showed significant positive SCA effects.

4.5.4.3 Anthesis-silking interval

The hybrids S1 x P2 under the three conditions, S2 x P1 under non-stress and intermediate stress and S3 x P2, S4 x P1, S5 x P1 under non-stress recorded significant negative SCA effects. S2 x P4, S5 x P4 and S7 x P2 under intermediate stress and S7 x P8 under severe stress also recorded significant negative SCA effects. S1 x P4 under non-stress and intermediate stress, S6 x P7 under non-stress, S1 x P3 and S6 x P1

under intermediate stress and S3 x P3, S5 x P4, S5 x P8, S6 x P8 and S7 x P4 showed significant positive SCA effects.

The SCA effects of the 42 hybrids for plant height, ear height and leaf senescence under non-stress, intermediate stress and severe stress conditions at Samaru and the results are presented in Table 4.29.

4.5.4.4 Plant height

The hybrids S3 x P2 under the three conditions, S4 x P7 under intermediate stress and severe stress and S1 x P2 and S4 x P8 under non-stress recorded significant negative SCA effects. S2 x P4 and S7 x P8 under intermediate stress and S3 x P7, S5 x P7 and S7 x P4 under severe stress also recorded significant negative SCA effects. S1 x P1 under non-stress and severe stress, S2 x P1 under intermediate and severe stress, S5 x P1 under non-stress, S6 x P7 under intermediate stress and S4 x P1, S4 x P8 and S7 x P1 exhibited significant positive SCA effects.

4.5.4.5 Ear height

The hybrids S3 x P2 and S5 x P7 under non-stress and S1 x P2, S3 x P7 and S4 x P7 under severe stress recorded significant negative SCA effects. S2 x P1, S2 x P3 and S5 x P2 under non-stress, S4 x P1 and S7 x P3 under intermediate stress and S1 x P4 and S4 x P8 under severe stress exhibited significant positive SCA effects.

Table 4.29 SCA effects of hybrids for plant height, ear height and leaf senescence under non-stress, intermediate stress and severe stress at Samaru

	Plant height			Ear height			Leaf senescence	
Hybrids	NS	IS	SS	NS	IS	SS	IS	SS
S1 x P1	21.48**	-6.63	13.38*	1.31	1.79	-0.05	-0.40	-1.58*
S1 x P2	-16.19*	-6.35	-6.20	-5.49	-5.02	-10.66*	-1.24	-0.17
S1 x P3	2.03	3.38	-8.84	4.92	-1.13	-3.30	-0.07	1.17
S1 x P4	3.86	-4.26	8.46	-2.02	8.59	15.86**	-0.15	0.58
S1 x P7	6.15	-0.38	-9.96	-1.76	-2.10	-4.69	-0.82	-1.67*
S1 x P8	1.75	-2.32	-11.62	-8.27	3.87	-1.49	0.68	1.00
S2 x P1	-1.08	16.57**	14.79*	11.31*	-5.99	4.34	2.01*	0.67
S2 x P2	8.52	9.32	6.95	8.09	5.12	7.64	-0.33	1.63*
S2 x P3	-6.32	15.44**	0.70	12.11*	-5.02	4.03	1.83*	-0.45
S2 x P4	0.74	-11.51*	3.06	-1.64	3.87	-4.45	0.00	-0.12
S2 x P7	-13.22	5.85	-8.80	2.25	-9.75	-7.78	-0.58	-0.20
S2 x P8	2.35	-4.42	10.28	-4.89	-2.10	9.17	-1.25	0.05
S3 x P1	14.46	1.13	-0.55	-3.17	7.21	-6.81	-0.25	-0.29
S3 x P2	-16.54*	-15.81**	-11.63*	-12.75*	0.67	-1.80	0.58	-0.62
S3 x P3	-2.76	-5.32	-3.81	-1.79	-4.41	0.07	0.81	0.20
S3 x P4	8.24	7.46	4.10	0.58	-2.04	5.29	-0.02	0.12
S3 x P7	-0.54	1.35	-12.21*	4.33	7.68	-12.35*	1.14	-1.05
S3 x P8	-3.05	-5.46	-3.39	-1.78	-8.43	-1.52	1.06	0.87
S4 x P1	-13.09	-0.73	12.19*	-7.36	11.71*	-5.40	-2.11*	-0.38
S4 x P2	-0.15	3.99	-2.15	5.30	-6.49	7.79	-0.11	1.29
S4 x P3	11.35	-1.29	4.27	0.72	1.98	6.12	-0.77	-1.05
S4 x P4	-6.93	3.85	1.83	7.26	-3.57	-2.55	0.17	-0.87
S4 x P7	9.41	-11.71*	-12.09*	-7.87	6.29	-13.16**	-0.17	-0.45
S4 x P8	-16.71*	-2.82	12.00*	-4.96	-3.16	19.20**	0.50	0.88
S5 x P1	16.12*	5.38	5.24	-6.90	1.57	-5.80	-2.08*	-0.20
S5 x P2	1.40	4.26	-1.50	11.02*	-3.29	-3.02	1.25	0.55
S5 x P3	-5.98	-2.68	2.66	1.01	-4.82	2.67	-0.25	-2.29**
S5 x P4	-5.32	3.71	-6.75	1.43	6.98	2.67	-0.42	2.38**
S5 x P7	-4.33	-7.81	-11.67*	-13.92*	0.35	-8.39	-0.98	-0.08
S5 x P8	0.04	-1.71	-0.25	-4.07	5.22	7.67	-1.31	0.83
S6 x P1	0.39	-7.82	6.27	-1.15	-5.89	7.53	0.36	0.17
S6 x P2	4.71	2.04	-8.09	4.41	-3.67	-4.13	0.27	-0.42
S6 x P3	0.33	-1.57	7.66	1.35	3.14	8.64	0.61	0.83
S6 x P4	1.61	4.82	6.60	8.99	5.77	-8.99	1.11	-1.50*
S6 x P7	-2.72	12.05*	-0.94	4.41	-4.92	-2.35	-0.06	0.17
S6 x P8	4.02	6.59	-7.68	-1.95	0.71	3.28	0.74	0.70
S7 x P1	2.86	6.86	12.75*	4.74	0.57	6.84	0.90	0.12
S7 x P2	2.08	7.42	0.11	-1.51	-1.37	-6.63	-1.93*	-1.05
S7 x P3	-4.43	-3.55	6.58	4.05	11.69*	3.36	0.49	-0.63
S7 x P4	2.86	2.84	-17.67**	2.65	-7.34	-4.69	2.32*	0.62
S7 x P7	-11.70	-4.94	5.66	-3.87	-5.54	6.84	-1.18	1.79*
S7 x P8	4.30	-15.22**	0.25	-5.12	1.27	-9.00	-2.35*	-1.55*
SE±	8.16	5.71	5.95	5.51	6.17	4.81	0.92	0.70

*P≤0.05; **P≤0.01; NS=non-stress; IS=intermediate stress; SS=severe stress

4.5.4.6 Leaf senescence

Among the hybrids, S7 x P8 under intermediate stress and severe stress, S4 x P1, S5 x P1 and S7 x P2 under intermediate stress and S1 x P1, S1 x P7, S5 x P3 and S6 x P4 recorded significant negative SCA effects. S2 x P1, S2 x P3 and S7 x P4 under intermediate stress and S2 x P2, S5 x P4 and S7 x P7 under severe stress exhibited significant positive SCA effects.

The SCA effects of the 42 hybrids for number of ears per plant and grain yield under non-stress, intermediate stress and severe stress conditions at Samaru and the results are presented in Table 4.30.

4.5.4.7 Number of ears per plant

The hybrids S6 x P3 and S7 x P8 under the three conditions, S1 x P8, S4 x P7 and S5 x P7 under intermediate stress and severe stress, S2 x P2 under non-stress and intermediate stress and S1 x P2 and S4 x P2 under non-stress recorded significant positive SCA effects. S1 x P1, S1 x P4, S2 x P4, S3 x P1, S3 x P2, S3 x P7, S4 x P1, S4 x P3, S5 x P1, S5 x P1, S5 x P4, S5 x P8, S6 x P4, S6 x P8, S7 x P1 and S7 x P3 under intermediate stress recorded significant positive SCA effects. S1 x P2 and S5 x P2, S6 x P1 under intermediate stress and severe stress, S2 x P8 under non-stress and intermediate stress, S1 x P4, S2 x P2, S3 x P7 and S5 x P4 under severe stress exhibited significant negative SCA effects. Other 17 hybrids under intermediate stress also exhibited significant negative SCA effects for number of ears per plant.

Table 4.30 SCA effects of hybrids for number of ears per plant and grain yield under non-stress, intermediate stress and severe stress at Samaru

	Number or ears per plant			Grain yield		
Hybrids	NS	IS	SS	NS	IS	SS
S1 x P1	-0.15	1.79**	0.05	396.82	-769.84	904.76
S1 x P2	0.31**	-5.02**	-0.55**	693.12	1026.46	-576.72
S1 x P3	0.18	-1.13**	0.23	1915.35	-788.36	-280.43
S1 x P4	-0.02	8.59**	-0.38*	396.83	137.57	-132.28
S1 x P7	-0.14	-2.10**	0.08	-2455.03	952.38	1145.50
S1 x P8	-0.12	3.87*	0.44*	63.48	-603.18	-410.05
S2 x P1	-0.07	-5.99**	-0.27	-1010.58	44.97	-650.79
S2 x P2	0.19*	5.12**	-0.54**	1000.00	1388.89	-555.56
S2 x P3	-0.08	-5.02**	0.00	-481.48	-481.48	-37.04
S2 x P4	0.09	3.87**	0.28	-592.60	-296.29	703.71
S2 x P7	0.04	-9.75**	0.00	111.11	-703.71	-37.03
S2 x P8	-0.19*	-2.10**	0.27	-740.74	333.33	574.07
S3 x P1	-0.01	7.21**	-0.06	444.45	111.11	574.07
S3 x P2	-0.05	0.67**	0.05	259.26	-351.85	-1222.23
S3 x P3	-0.10	-4.41**	0.26	523.81	-706.35	1333.33*
S3 x P4	-0.14	-2.04**	-0.25	-957.67	-132.27	-1037.04
S3 x P7	0.09	7.68**	-0.39*	486.77	719.58	-296.30
S3 x P8	-0.09	-8.43**	0.21	-365.08	-798.94	518.52
S4 x P1	0.01	11.71**	-0.06	1671.96	1449.21**	-92.59
S4 x P2	0.19*	-6.49**	0.28	-698.41	15.87	240.74
S4 x P3	0.04	1.98**	-0.06	-661.38	-447.09	-666.67
S4 x P4	-0.11	-3.57**	-0.30	-936.50	-500.00	-365.08
S4 x P7	0.12	6.29**	0.50**	-195.77	518.52	820.11
S4 x P8	-0.11	-3.16**	0.12	804.23	-407.41	5.29
S5 x P1	-0.02	1.57**	-0.22	-269.84	1185.19	-291.00
S5 x P2	0.06	-3.29**	-0.40*	-455.03	-666.66	-1235.45*
S5 x P3	0.17	-4.82**	0.18	730.16	0.00	1431.22*
S5 x P4	-0.11	6.98**	-0.49**	322.75	-129.63	-365.08
S5 x P7	0.06	0.35**	0.70**	-714.29	-833.33	-1301.59*
S5 x P8	-0.12	5.22**	-0.21	693.12	-481.48	550.27
S6 x P1	-0.14	-5.89**	-0.50**	-1862.43**	1259.26	402.12
S6 x P2	0.16	-3.67**	0.42	174.60	185.19	-338.63
S6 x P3	0.20*	3.14**	0.44*	1989.42**	-1222.22	494.71
S6 x P4	-0.11	5.77**	-0.16	-380.95	111.12	-727.51
S6 x P7	-0.04	-4.92**	0.12	100.53	981.48	920.65
S6 x P8	0.13	0.71**	-0.16	-269.84	1420.64**	-15.87
S7 x P1	-0.09	0.57**	0.01	248.68	-449.74	280.42
S7 x P2	-0.11	-1.37**	0.26	-751.32	-486.77	-534.39
S7 x P3	-0.07	11.69**	0.06	-47.62	-5.29	280.43
S7 x P4	0.06	-7.34**	-0.13	-1010.58	-746.08	-886.24
S7 x P7	-0.13	-5.54**	-0.29	-158.73	365.08	-1108.47
S7 x P8	0.22*	1.27**	0.46*	1989.42**	-197.88	1984.12**
SE±	0.10	0.07	0.19	693.29	724.93	629.57

*P≤0.05; **P≤0.01; NS=non-stress; IS=intermediate stress; SS=severe stress

4.5.4.8 Grain yield

Among the hybrids, S7 x P8 under non-stress and severe stress, S6 x P3 under non-stress, S4 x P1 and S6 x P8 under intermediate stress and S3 x P3 and S5 x P3 under severe stress recorded significant positive SCA effects. S6 x P1 under non-stress, S6 x P8 under intermediate stress and S5 x P2 and S5 x P7 under severe stress exhibited significant negative SCA effects.

4.5.5 Specific combining ability (SCA) effects at Kadawa

The specific combining ability (SCA) effects of the 42 hybrids for days to 50% tasseling, days to 50% silking and ASI under non-stress, intermediate stress and severe stress conditions at Kadawa and the results are presented in Table 4.31.

4.5.5.1 Days to 50% tasseling

Among the hybrids, S7 x P1 under the three conditions, S4 x P2 under non- stress, S3 x P1 and S7 x P3 under intermediate and S4 x P1, S4 x P3, S5 x P7, S6 x P4, S7 x P2 under severe stress recorded significant negative SCA. S4 x P8 under intermediate stress and severe stress, S1 x P2, S3 x P3 and S3 x P7 under non-stress, S4 x P1, S5 x P3, S6 x P2 and S7 x P8 under intermediate stress and S1 x P1, S2 x P8 and S7 x P3 under severe stress exhibited significant positive SCA effects.

4.5.5.2 Days to 50% silking

The hybrids S7 x P1 under the three conditions, S1 x P8, S3 x P4, S4 x P8 and S6 x P8 under non-stress, S2 x P8, S3 x P1 and S5 x P1 under intermediate stress and S2 x P7 and S4 x P1 under severe stress recorded significant negative SCA effects. S6 x P2 under the three conditions, S3 x P3 under non-stress and intermediate stress,

Table 4.31 SCA effects of hybrids for days to 50% tasseling, days to 50% silking and anthesis-silking interval under non-stress, intermediate stress and severe stress at Kadawa

	Days to 50% tasseling			Days to 50% silking			Anthesis-silking interval		
Hybrids	NS	IS	SS	NS	IS	SS	NS	IS	SS
S1 x P1	-1.24	-2.40	5.19*	-1.55	-2.40	2.36	-0.21	1.00*	-0.83
S1 x P2	6.76**	2.76	-2.98	7.20**	2.76	-2.81	0.45	0.00	0.17
S1 x P3	3.51	-2.07	1.19	2.29	-2.07	1.02	-1.21**	0.00	-0.17
S1 x P4	-2.99	2.10	-0.39	-1.96	1.93	-1.23	0.87*	-0.17	-0.83
S1 x P7	-1.40	-0.82	2.44	-0.63	-0.49	2.77	0.79	0.33	0.33
S1 x P8	-3.24	2.51	-2.06	-4.30*	2.43	-1.39	-1.05*	-0.08	0.67
S2 x P1	-1.40	-2.07	-1.39	-1.05	-2.15	-0.73	0.37	-0.08	0.67
S2 x P2	0.62	-0.90	-2.52	0.24	-1.76	-1.79	-0.71	-0.86*	0.74
S2 x P3	2.12	1.76	3.31	2.49	2.4	2.55	0.45	0.64	-0.76
S2 x P4	-1.63	0.93	-2.02	-1.93	1.07	-1.62	-1.21**	0.14	0.40
S2 x P7	-0.13	2.1	-5.61	-0.18	2.57	-5.37*	-0.13	0.48	0.24
S2 x P8	-0.05	-2.82	5.23*	0.15	-3.35**	5.13*	0.29	-0.52	-0.10
S3 x P1	-0.38	-3.99*	1.73	-0.51	-4.43**	1.46	-0.05	-0.44	-0.26
S3 x P2	-0.55	2.93	-0.11	-0.26	3.49	-0.37	0.37	0.56	-0.26
S3 x P3	4.83*	4.74	3.12	6.02**	4.74**	3.00	1.29**	0.00	-0.12
S3 x P4	-4.67	-0.1	2.45	-5.73**	-0.1.0	1.83	-1.05*	0.00	-0.62
S3 x P7	5.08*	-2.43	0.12	6.36**	-2.43	-0.33	1.29**	0.00	-0.45
S3 x P8	1.58	-2.76	3.54	1.61	-2.43	3.42	-0.13	0.33	-0.12
S4 x P1	-2.33	3.82*	-8.13**	-3.06	3.65	-7.58**	-0.71	-0.17	0.55
S4 x P2	-5.17*	-1.35	2.37	-5.23	-1.43	2.25	-0.05	-0.08	-0.12
S4 x P3	0.67	-1.93	-4.45*	0.02	-2.01	-2.58	-0.63	-0.08	0.88
S4 x P4	-3.02	-2.12	-0.95	-3.26	-1.26	-1.79	-0.14	0.86*	-0.83
S4 x P7	2.48	-0.95	-2.62	2.99	-1.60	-2.45	0.52	-0.64	0.17
S4 x P8	-3.27	4.21*	5.55*	-4.43*	4.57*	5.88*	-0.14	-0.64	0.33
S5 x P1	-1.77	-3.62	-0.04	-1.68	-4.43*	0.13	-0.06	-0.81	0.17
S5 x P2	0.31	0.46	2.30	0.15	0.65	2.63	-0.14	0.19	0.33
S5 x P3	2.98	4.30*	-4.20	3.49	5.57**	-3.54	0.52	1.27**	0.67
S5 x P4	2.31	-1.29	-0.04	1.74	-1.51	-0.87	-0.56	-0.23	-1.83**
S5 x P7	2.33	-0.98	-4.67*	2.95	-1.19	-2.93	0.57	-0.21	-0.26
S5 x P8	-3.17	-2.31	0.17	-3.30	-2.02	1.90	-0.26	0.29	0.74
S6 x P1	-3.92	2.36	-0.67	-3.71	4.64*	-0.76	0.07	0.29	-0.10
S6 x P2	3.58	5.52**	2.25	4.54*	5.67**	5.99*	-0.35	0.12	-0.26
S6 x P3	0.67	-1.39	-1.42	-0.13	-1.27	-1.51	-0.93*	0.12	-0.10
S6 x P4	1.83	-1.06	-4.92*	2.70	-1.86	-1.18	0.74	-1.80**	0.74
S6 x P7	-1.33	-2.14	4.26	-1.05	-1.94	3.49	0.15	0.20	-0.76
S6 x P8	-3.52	1.67	-0.17	-4.40*	1.88	1.16	-0.79	0.21	1.31**
S7 x P1	-4.52*	-4.17*	-5.33*	-4.65*	-5.45*	-5.02*	-0.12	-0.29	0.31
S7 x P2	0.23	-2.00	-6.17**	0.43	-1.79	-4.19	0.21	0.21	-0.05
S7 x P3	-0.29	-4.33*	5.25*	-0.33	-3.29	1.06	-0.21	0.05	0.81
S7 x P4	2.81	0.75	-0.42	3.51	0.80	-1.44	0.71	0.05	-1.02*
S7 x P7	3.98	-0.42	5.08	3.85	-0.29	2.39	-0.12	0.13	-1.69**
S7 x P8	1.31	4.50*	0.74	0.60	4.13*	1.06	1.30*	-0.37	1.31*
SE±	2.10	1.95	2.36	2.08	2.04	2.45	0.44	0.44	0.47

*P≤0.05; **P≤0.01; NS=non-stress; IS=intermediate stress; SS=severe stress

S1 x P2, S3 x P7 under non-stress, S4 x P8, S5 x P3, S6 x P1 and S7 x P8 under intermediate stress and S2 x P8 and S4 x P8 under severe stress exhibited significant positive SCA effects.

4.5.5.3 Anthesis-silking interval

Among the hybrids, S1 x P3, S1 x P8, S2 x P4, S3 x P4 and S6 x P3 under non-stress, S2 x P2 and S6 x P4 under intermediate stress and S5 x P4, S7 x P4 and S7 x P7 under severe stress recorded significant negative SCA effects for ASI. S7 x P8 under non-stress and severe stress, S1 x P4, S3 x P3 and S3 x P7 under non-stress, S1 x P1, S4 x P4 and S5 x P3 under intermediate stress and S6 x P8 and S7 x P7 exhibited significant positive SCA effects for ASI.

The specific combining ability (SCA) effects of the 42 hybrids for plant height, ear height and leaf senescence under non-stress, intermediate stress and severe stress conditions at Kadawa and the results are presented in Table 4.32.

4.5.5.4 Plant height

The hybrids S5 x P8 under non-stress and severe stress, S1 x P4, S1 x P8, S3 x P2, S4 x P8 and S7 x P4 under non-stress, S2 x P8, S3 x P3, S4 x P2, S5 x P4 and S7 x P8 under intermediate stress and S1 x P1, S1 x P7 and S7 x P8 under severe stress recorded significant negative SCA effects. S6 x P4 under the three conditions, S7 x P8 under non-stress and intermediate stress, S2 x P1 and S2 x P7 under non-stress and S2 x P2 and S4 x P7 exhibited significant positive SCA effects for plant height.

Table 4.32 SCA effects of hybrids for plant height, ear height and leaf senescence under non-stress, intermediate stress and severe stress at Kadawa

	Plant height			Ear height			Leaf senescence	
Hybrids	NS	IS	SS	NS	IS	SS	IS	SS
S1 x P1	13.70	5.06	-19.92*	4.49	6.02	-16.47**	0.95	-0.54
S1 x P2	13.17	-17.44	11.72	-10.56	5.04	1.27	-0.30	-0.54
S1 x P3	9.95	-1.31	6.74	-0.29	4.46	6.81	0.79	0.71
S1 x P4	-26.55**	15.75	3.14	2.49	-8.43	0.19	-0.38	-0.12
S1 x P7	-3.11	22.97	-18.66*	17.07	-0.18	-13.67**	-0.88	0.46
S1 x P8	-27.44**	-1.61	15.05	-0.84	-18.29**	11.78*	-1.38	0.05
S2 x P1	20.28*	-23.42	1.94	-12.37	11.38	10.09*	1.20	-0.04
S2 x P2	-8.61	6.72	21.42*	11.80	0.44	9.62*	-0.19	-0.54
S2 x P3	-9.80	0.06	-3.77	13.41	-1.36	-8.46	-0.44	0.96*
S2 x P4	2.64	8.70	-13.91	-4.98	1.55	-8.93	0.64	0.71
S2 x P7	19.14*	-15.91	-9.02	-13.53	1.50	3.29	-1.02	-0.12
S2 x P8	12.92	-39.53**	1.10	-27.28**	0.75	1.43	-1.02	-1.04*
S3 x P1	-1.58	24.22	-3.77	8.14	3.64	-3.46	2.48**	0.05
S3 x P2	-16.69*	15.75	7.95	12.44	-6.53	6.51	-0.44	-0.04
S3 x P3	-7.56	-29.61*	17.98	-14.20	-12.27*	8.20	-1.40	0.25
S3 x P4	7.91	20.05	-2.55	6.08	0.76	4.61	-0.15	-0.25
S3 x P7	13.19	-2.97	8.48	-0.64	13.01	-9.36	-0.07	0.00
S3 x P8	-3.81	-3.42	-9.96	4.97	-0.38	-0.14	1.26	0.17
S4 x P1	-2.20	0.47	4.75	6.22	-3.80	2.00	-0.24	-0.25
S4 x P2	4.47	-30.78*	-17.05	-9.20	8.59	0.44	1.26*	-0.17
S4 x P3	-11.98	23.25	-1.65	6.77	-5.91	-5.75	-0.65	0.25
S4 x P4	13.15	6.00	-24.78	-1.65	9.78	-5.73	0.10	-0.04
S4 x P7	6.13	-9.82	19.69*	-11.71	6.47	12.18*	-0.15	-0.54
S4 x P8	-31.93**	-7.02	4.22	-0.93	-22.44**	2.38	-0.57	-0.79
S5 x P1	7.23	5.03	-4.22	5.51	10.00	-3.07	0.76	-0.12
S5 x P2	5.35	24.76	1.15	10.94	3.75	-5.10	0.76	1.46**
S5 x P3	7.85	14.34	6.52	9.68	-3.20	1.35	-0.74	0.59
S5 x P4	-7.77	-33.29*	7.42	-11.84	-4.36	-2.01	-0.15	-0.54
S5 x P7	1.22	-9.80	-4.99	-7.48	4.35	4.29	-1.19	0.99*
S5 x P8	-19.64*	15.20	-22.19*	13.29	-12.12*	-12.29*	-0.44	-0.04
S6 x P1	-3.53	-10.50	-2.99	-5.93	-5.70	8.57	0.64	-0.79
S6 x P2	-5.86	10.06	9.89	3.02	-6.93	0.46	-1.52	0.38
S6 x P3	9.25	-19.38	15.10	-14.90	11.82	9.10	1.98*	-0.54
S6 x P4	17.92*	29.03*	26.14**	9.68	8.38	0.04	-0.52	-0.95*
S6 x P7	0.64	-1.61	-10.97	2.32	0.21	-10.16*	1.06	0.98*
S6 x P8	-13.90	8.63	10.29	7.04	-8.32	0.10	1.74*	-0.11
S7 x P1	2.24	-8.04	7.10	-10.51	1.21	2.69	1.49	0.39
S7 x P2	9.69	13.10	-2.54	12.76	9.13	0.54	-1.43	0.14
S7 x P3	9.86	-11.51	10.18	-2.46	4.24	-0.75	0.90	-0.19
S7 x P4	-22.20*	10.71	-3.45	7.96	-12.35	6.24	-0.60	-0.11
S7 x P7	-1.26	-32.21*	-16.90	-17.46	0.88	-10.15*	-1.13	0.48
S7 x P8	17.52*	29.32*	-24.68**	2.68	5.21	1.32	-1.01	-0.61
SE±	8.67	14.70	9.20	9.51	6.09	4.81	0.82	0.47

*P≤0.05; **P≤0.01; NS=non-stress; IS=intermediate stress; SS=severe stress

4.5.5.5 Ear height

The hybrids S5 x P8 under intermediate stress and severe stress, S2 x P8 under non-stress stress, S1 x P8, S3 x P3 and S4 x P8 under intermediate stress and S1 x P1, S1 x P7, S6 x P7 and S7 x P7 under severe stress recorded significant negative SCA effects. S2 x P1 and S4 x P7 under severe stress exhibited significant positive SCA effects.

4.5.5.6 Leaf senescence

Among the hybrids, S2 x P8 and S6 x P4 recorded significant negative SCA effects under severe stress, whereas S3 x P1, S4 x P2, S6 x P3 and S6 x P8 under intermediate stress and S5 x P2, S5 x P7 and S6 x P7 exhibited significant positive SCA effects for leaf senescence.

The specific combining ability (SCA) effects of the 42 hybrids for number of ears per plant and grain yield under non-stress, intermediate stress and severe stress conditions at Kadawa and the results are presented in Table 4.33.

4.5.5.7 Number of ears per plant

The hybrids S1 x P8 under non-stress and intermediate stress, S3 x P1 under non-stress, S6 x P2 under intermediate stress and S2 x P1 under severe stress recorded significant positive SCA effects. Only S1 x P7 under non-stress exhibited significant negative SCA effects for number of ears per plant.

Table 4.33 SCA effects of hybrids for number of ears per plant and grain yield under non-stress, intermediate stress and severe stress at Kadawa

	Number of ears per plant			Grain yield		
Hybrids	NS	IS	SS	NS	IS	SS
S1 x P1	-0.03	-0.12	0.05	756.61	423.28	-798.94
S1 x P2	-0.10	-0.02	-0.17	-2169.32**	201.06	312.17
S1 x P3	-0.14	-0.08	-0.25	1126.98	-2021.17**	349.21
S1 x P4	0.08	-0.15	0.10	1349.21	-2.65	-354.50
S1 x P7	-0.24*	0.14	-0.20	-1169.31	126.99	-410.06
S1 x P8	0.49**	0.27**	-0.25	-391.53	-206.35	1367.72**
S2 x P1	-0.05	-0.04	0.73**	497.36	1478.83**	-465.61
S2 x P2	-0.11	0.10	0.09	-37.03	105.82	1105.82*
S2 x P3	-0.12	-0.02	0.05	-74.07	105.82	-449.74
S2 x P4	0.15	0.01	0.02	-1444.45	-1227.51**	-634.92
S2 x P7	-0.10	0.00	-0.14	-777.78	346.56	883.60
S2 x P8	0.10	-0.04	-0.05	925.93	31.74	-283.07
S3 x P1	0.20*	-0.03	-0.05	2148.15**	142.86	-60.84
S3 x P2	-0.11	-0.01	0.07	-740.74	494.71	-560.85
S3 x P3	0.01	0.01	-0.03	-1306.88	264.55	-291.01
S3 x P4	0.05	-0.04	0.08	433.87	931.22*	-291.01
S3 x P7	0.06	-0.01	0.00	1507.93	-1291.00**	190.48
S3 x P8	0.02	-0.02	-0.03	396.82	-161.38	-513.23
S4 x P1	-0.01	0.13	0.12	-788.36	634.92	764.55
S4 x P2	-0.12	-0.05	0.00	-232.80	-142.85	320.11
S4 x P3	0.01	-0.03	-0.14	-10.58	-235.45	-179.89
S4 x P4	0.05	0.02	-0.09	883.60	232.80	-211.64
S4 x P7	0.00	-0.03	-0.11	846.56	-211.64	232.81
S4 x P8	-0.05	0.14	-0.16	-1412.70	-2433.87**	492.06
S5 x P1	0.02	-0.01	0.05	365.08	473.55	-433.86
S5 x P2	0.09	-0.06	0.26	735.45	380.95	-489.42
S5 x P3	-0.29	-0.04	0.15	-2042.33*	2047.62**	-600.53
S5 x P4	0.18	-0.03	-0.10	624.34	-489.42	1010.58*
S5 x P7	0.00	-0.01	-0.10	-449.74	-148.15	58.20
S5 x P8	0.01	0.05	0.07	-1597.88	518.52	280.42
S6 x P1	0.01	-0.04	0.22	142.86	-1037.04*	-349.21
S6 x P2	-0.04	0.23*	0.19	-1412.70	981.48*	724.87
S6 x P3	0.19	-0.09	-0.20	1179.89	-444.45	224.87
S6 x P4	-0.12	-0.08	0.07	1513.23	333.34	-219.58
S6 x P7	-0.05	-0.06	-0.25	624.34	-203.70	-719.58
S6 x P8	0.09	-0.01	0.09	153.44	-878.31	137.57
S7 x P1	0.17	0.05	0.08	2560.85**	-1544.97**	-84.66
S7 x P2	-0.03	-0.03	0.17	79.37	8010.58**	-47.62
S7 x P3	0.03	-0.04	-0.17	79.36	-1637.56**	-306.88
S7 x P4	-0.16	-0.08	0.06	-883.60	-730.16	193.12
S7 x P7	-0.16	-0.07	0.09	-994.72	-2174.60**	-876.88
S7 x P8	0.02	0.19	-0.32	-994.71	-1044.97*	985.37*
SE±	0.10	0.10	0.17	810.88	428.86	498.79

*P≤0.05; **P≤0.01; NS=non-stress; IS=intermediate stress; SS=severe stress

4.5.5.8 Grain yield

The hybrids S3 x P1 and S7 x P1 under non-stress, S2 x P1, S3 x P4, S5 x P3, S6 x P2 and S7 x P2 under intermediate stress and S1 x P8, S2 x P2, S5 x P4 and S7 x P8 under severe stress recorded significant positive SCA effects. S7 x P7 under intermediate stress and severe stress, S1 x P2 and S5 x P3 under non-stress and S1 x P3, S2 x P4, S3 x P7, S4 x P8, S6 x P1, S7 x P1, S7 x P3, S7 x P7 and S7 x P8 under intermediate stress showed significant negative SCA effects for grain yield.

4.5.6 Specific combining ability (SCA) effects across locations

The specific combining ability (SCA) effects of the 42 hybrids for days to 50% tasseling, days to 50% silking and ASI under non-stress, intermediate stress and severe stress conditions across locations and the results are presented in Table 4.34.

4.5.6.1 Days to 50% tasseling

Among the hybrids, S7 x P1 under the three conditions, S1 x P7 under intermediate stress and severe stress, S6 x P3 under non-stress and intermediate stress and S7 x P8 under non-stress and severe stress recorded significant negative SCA effects. S3 x P4 under non-stress, S5 x P2 under intermediate stress and S4 x P2 and S6 x P4 under severe stress also recorded significant negative SCA effects. S5 x P4 under the three conditions, S3 x P1 under non-stress and severe stress, S1 x P3 and S3 x P8 under non-stress, S3 x P2, S4 x P7 and S7 x P8 under intermediate stress and S2 x P2 and S3 x P4 under severe stress exhibited significant positive SCA effects.

Table 4.34 SCA effects of hybrids for days to 50% tasseling, days to 50% silking and anthesis-silking interval under non-stress, intermediate stress and severe stress across locations

	Days to 50% tasseling			Days to 50% silking			Anthesis-silking interval		
Hybrids	NS	IS	SS	NS	IS	SS	NS	IS	SS
S1 x P1	-0.30	-0.46	0.45	-0.38	-0.38	-0.06	0.01	-1.05*	-2.51**
S1 x P2	-0.03	-0.19	-0.53	-0.11	-0.38	-0.50	-0.10	-0.24	0.03
S1 x P3	3.88*	1.07	0.95	1.40	4.09*	1.18	0.37	0.08	0.23
S1 x P4	-0.14	-0.69	-0.32	-0.40	-0.43	-0.40	-0.17	0.31	-0.08
S1 x P7	0.61	-4.50*	-4.68*	0.92	-0.59	-1.06	0.37	-0.05	-0.38
S1 x P8	-1.03	0.77	0.13	-1.43	3.68*	4.84*	-0.49	-0.05	1.71*
S2 x P1	1.70	0.58	-0.30	1.64	-0.38	-0.83	0.01	-0.07	-0.53
S2 x P2	0.72	0.72	5.34**	0.91	1.00	4.35*	0.28	0.11	0.01
S2 x P3	-1.24	-0.01	0.45	-1.32	0.09	4.03*	-0.26	-0.07	-0.42
S2 x P4	0.61	-0.28	-0.82	3.50*	-0.05	-0.92	-0.04	1.04*	-0.10
S2 x P7	-0.51	-0.58	-0.68	-0.68	-0.59	0.42	-0.13	-0.19	2.10**
S2 x P8	-1.28	-0.44	1.00	-1.04	-0.07	-0.06	0.14	0.18	-0.06
S3 x P1	3.76*	-0.57	4.43*	0.64	-0.02	0.67	-0.26	0.39	0.24
S3 x P2	-0.59	4.20*	-0.68	-3.59*	-4.15**	-4.65*	-0.12	-0.31	0.03
S3 x P3	0.94	-0.65	0.18	3.55*	-0.68	0.28	0.22	0.01	0.10
S3 x P4	-4.32**	0.95	4.91**	-1.00	3.68*	2.08	0.19	-0.25	0.17
S3 x P7	-0.95	0.65	-0.95	-0.81	4.14*	-1.33	-0.03	0.51	-0.38
S3 x P8	4.16*	-0.58	-0.89	0.21	-0.97	-1.06	-0.01	-0.36	-0.17
S4 x P1	-0.90	0.48	-0.09	-0.46	0.58	0.36	0.26	-0.03	0.45
S4 x P2	-0.01	0.74	-3.82*	0.30	0.96	-1.84	1.15*	0.28	-0.01
S4 x P3	1.28	-0.74	0.78	0.57	-0.58	0.59	0.12	0.10	-0.19
S4 x P4	-0.62	-1.01	0.39	-0.73	-2.35	0.40	-0.29	-0.29	0.01
S4 x P7	0.51	4.32*	1.03	0.21	1.12	0.99	-0.26	-0.15	-0.05
S4 x P8	-0.26	-0.79	-0.29	0.11	-0.74	-0.50	1.01*	0.10	-0.21
S5 x P1	-0.42	-0.46	0.85	-0.13	-0.21	0.63	0.35	0.10	-0.21
S5 x P2	0.10	-3.94*	1.11	3.14*	-1.21	4.31*	0.11	-0.22	0.20
S5 x P3	-0.62	1.45	-1.78	-0.97	1.38	-1.64	-0.42	-0.03	0.14
S5 x P4	4.36**	4.31*	5.45**	0.48	0.36	0.17	0.17	0.08	-0.29
S5 x P7	-0.01	-0.25	-0.15	-0.33	-0.17	-0.49	-0.30	1.10*	-0.34
S5 x P8	0.60	-0.10	-0.48	0.82	-0.15	0.02	0.91*	-0.03	0.50
S6 x P1	-0.46	1.68	-1.01	-3.86*	0.54	-5.49**	-1.32**	-0.30	0.51
S6 x P2	-0.32	-1.05	0.26	-0.59	-0.96	0.06	-0.18	1.13*	-0.20
S6 x P3	-3.54*	-3.65*	0.37	-3.32*	-3.74*	5.36**	0.04	-0.05	0.00
S6 x P4	0.70	1.08	-4.28*	3.87*	1.49	-1.46	0.25	0.43	-0.18
S6 x P7	0.57	-0.10	-0.01	0.82	-0.55	0.13	0.29	-0.42	2.14**
S6 x P8	1.05	0.04	1.67	1.09	0.22	1.40	-0.07	0.20	-0.27
S7 x P1	-4.38**	-5.25*	-4.32*	-0.44	-4.15**	-5.29**	-0.05	-0.05	0.04
S7 x P2	0.14	0.51	0.32	-0.08	0.73	0.27	-0.16	0.26	-0.05
S7 x P3	0.30	-0.47	-0.95	0.09	-0.56	-0.80	-1.07	-1.05*	0.14
S7 x P4	0.40	-0.36	-0.34	0.29	-0.70	0.13	-0.91*	-0.32	0.47
S7 x P7	-0.22	-0.54	1.45	-3.14*	-0.36	1.35	0.07	0.23	-0.09
S7 x P8	-4.24**	4.11*	-4.15*	0.25	1.06	-5.64**	0.32	-1.06*	-2.50**
SE±	1.62	1.83	1.83	1.55	1.61	2.01	0.46	0.52	0.78

*P≤0.05; **P≤0.01; NS=non-stress; IS=intermediate stress; SS=severe stress

4.5.6.2 Days to 50% silking

The hybrids S3 x P2 under the three conditions, S6 x P1 under non-stress and severe stress, S6 x P3 under non-stress and intermediate stress, S7 x P1 under intermediate stress and severe stress, S7 x P7 under non-stress and S7 x P8 under severe stress recorded significant negative SCA effects. S1 x P8 under intermediate stress and severe stress, S5 x P2 under non-stress and severe stress, S2 x P4, S3 x P3, S5 x P2 and S6 x P4 under non-stress, S1 x P3, S3 x P4 and S3 x P7 under intermediate stress and S2 x P2, S2 x P3 and S6 x P3 under severe stress exhibited significant positive SCA effects.

4.5.6.3 Anthesis-silking interval

The hybrids S1 x P1 and S7 x P8 under intermediate stress and severe stress, S6 x P1 and S7 x P4 under non-stress and S7 x P3 under intermediate stress recorded significant negative SCA effects. S4 x P2, S4 x P8 and S5 x P8 under non-stress, S2 x P4, S5 x P7 and S6 x P2 under intermediate stress and S1 x P8, S2 x P7 and S6 x P7 under severe stress exhibited significant positive SCA effects for ASI.

The specific combining ability (SCA) effects of the 42 hybrids for plant height, ear height and leaf senescence under non-stress, intermediate stress and severe stress conditions across locations and the results are presented in Table 4.35.

4.5.6.4 Plant height

Among the hybrids, S4 x P3 and S6 x P8 under the three conditions, S2 x P7 under non-stress and severe stress, S1 x P2, S3 x P4, S4 x P1 and S6 x P1 under non-stress, S5 x P2 and S7 x P4 under intermediate stress and S5 x P1 and S5 x P8 under severe stress recorded significant negative SCA effects. S2 x P3, S6 x P7 and

Table 4.35 SCA effects of hybrids for plant height, ear height and leaf senescence under non-stress, intermediate stress and severe stress across locations

	Plant height			Ear height			Leaf senescence	
Hybrids	NS	IS	SS	NS	IS	SS	IS	SS
S1 x P1	5.13	-0.39	-1.64	0.02	1.95	-4.13	0.14	-0.53
S1 x P2	-17.61*	4.01	17.09*	15.33	1.39	4.31	-0.13	0.27
S1 x P3	-3.03	-5.48	3.54	-5.07	-4.17	2.07	-0.15	0.11
S1 x P4	16.54*	2.46	-5.74	1.05	1.55	-2.07	0.07	-0.23
S1 x P7	0.38	-4.40	-3.92	-3.92	1.18	-1.02	-0.54	0.22
S1 x P8	-2.41	3.80	0.66	2.59	-1.90	0.84	0.62	0.15
S2 x P1	-0.48	-5.95	1.38	-3.78	0.01	-2.35	-0.38	-0.18
S2 x P2	-3.60	1.37	-0.77	6.32	-1.60	-1.11	0.35	0.13
S2 x P3	16.11*	26.88*	15.39*	1.84	-0.32	2.47	-0.04	-0.03
S2 x P4	3.72	-5.38	-0.35	-4.84	3.19	-0.24	-0.08	-0.25
S2 x P7	-25.10**	3.37	-15.61*	2.07	-1.73	-1.16	-0.44	0.20
S2 x P8	1.35	-0.29	17.96*	-1.62	0.45	2.38	0.60	0.13
S3 x P1	2.77	0.52	-0.52	1.40	0.83	0.88	0.18	0.47
S3 x P2	1.28	1.80	-2.71	-1.71	1.36	-3.34	0.16	0.15
S3 x P3	3.24	-0.41	-0.43	1.10	5.17	-5.43	0.27	-0.26
S3 x P4	-20.32*	-2.46	3.46	-1.41	-6.40	10.39*	-0.02	0.02
S3 x P7	-0.98	-4.58	0.82	-2.01	-2.90	4.02	0.25	-0.15
S3 x P8	3.02	5.13	-0.61	2.64	1.94	-1.52	-0.84	-0.23
S4 x P1	-16.90*	2.87	2.90	0.36	0.04	4.01	-0.13	0.12
S4 x P2	1.91	-2.52	-4.46	-2.88	-2.06	-1.12	-0.40	-0.08
S4 x P3	-16.64*	-22.22*	-23.34**	0.98	-2.20	-0.41	0.58	0.26
S4 x P4	24.67**	22.60*	15.25*	-0.29	2.89	-2.22	-0.08	-0.08
S4 x P7	-0.48	3.02	0.45	1.62	-2.65	-0.92	-0.31	-0.01
S4 x P8	1.43	-3.77	4.19	0.22	3.98	0.66	0.35	-0.21
S5 x P1	0.54	5.65	-17.15*	4.07	-0.57	-9.59*	-0.43	-0.30
S5 x P2	22.25**	-20.99*	2.85	-8.10	-0.34	2.65	-0.57	-0.25
S5 x P3	-3.75	-0.07	3.98	-0.11	1.98	-0.85	-0.59	-0.16
S5 x P4	1.52	7.26	-0.09	5.30	0.11	-2.03	0.50	0.50
S5 x P7	2.20	-5.24	5.69	-3.63	3.74	4.43	0.65	0.07
S5 x P8	-4.76	3.39	-15.28*	2.47	-4.92	0.39	0.43	0.13
S6 x P1	-16.65*	-0.98	0.86	-2.04	-3.61	2.57	-0.18	0.26
S6 x P2	3.65	6.34	-1.08	1.18	2.71	-2.57	0.56	-0.06
S6 x P3	1.15	-4.20	-4.80	-0.80	0.53	2.06	0.29	0.28
S6 x P4	0.30	2.92	2.30	2.73	-2.01	1.00	-0.25	-0.43
S6 x P7	16.69*	25.21*	15.54*	4.43	3.54	-2.24	0.15	-0.61
S6 x P8	-17.15*	-24.29*	-15.81*	-15.50*	-1.16	-0.83	-0.57	0.57
S7 x P1	4.58	-1.71	4.18	-0.03	1.35	3.61	0.80	0.16
S7 x P2	-4.88	-0.02	-0.92	-0.14	-1.46	1.18	0.04	-0.16
S7 x P3	-0.08	5.49	0.65	2.05	-0.98	0.09	-0.36	-0.20
S7 x P4	-3.43	-22.40*	0.17	-2.54	0.66	0.18	-0.16	0.46
S7 x P7	-0.71	2.61	-2.97	1.45	-1.19	-3.12	0.25	0.29
S7 x P8	24.53**	1.05	-1.11	-0.79	1.62	-1.92	-0.59	-0.54
SE±	8.42	11.15	7.75	7.77	6.13	4.81	0.87	0.59

*P≤0.05; **P≤0.01; NS=non-stress; IS=intermediate stress; SS=severe stress

S4 x P4 under the three conditions, S1 x P4, S2 x P2, S6 x P7 and S7 x P8 under non-stress and S2 x P8 under severe stress exhibited significant positive SCA effects.

4.5.6.5 Ear height

Among the hybrids only S6 x P8 under non-stress and S5 x P1 under severe stress recorded significant negative SCA effects, whereas S3 x P4 exhibited significant positive SCA effect for ear height.

4.5.6.6 Leaf senescence

None of the hybrids recorded significant SCA effect in either direction. The range of the SCA was from -0.84 (S3 x P8) to 0.80 (S7 x P1) and -0.61 (S6 x P7) to 0.57 (S6 x P8) under intermediate and severe stress, respectively.

The specific combining ability (SCA) effects of the 42 hybrids for number of ears per plant and grain yield under non-stress, intermediate stress and severe stress conditions across locations and the results are presented in Table 4.36.

4.5.6.7 Number of ears per plant

The hybrids S2 x P8 under the three conditions, S7 x P8 under non-stress and intermediate stress, S5 x P7 and S6 x P1 under non-stress and S3 x P1 under severe stress recorded significant positive SCA effects. S6 x P8 under non-stress and severe stress, S1 x P1 and S4 x P4 under non-stress, S4 x P1 and S6 x P7 under intermediate stress and S2 x P1 under severe stress exhibited significant negative SCA effects.

Table 4.36 SCA effects of hybrids for number of ears per plant and grain yield under non-stress, intermediate stress and severe stress across locations

	Number or ears per plant			Grain yield		
Hybrids	NS	IS	SS	NS	IS	SS
S1 x P1	-0.25*	-0.04	0.02	187.83	-54.90	-11.90
S1 x P2	0.01	0.05	-0.11	1557.67*	1294.31*	83.33
S1 x P3	-0.04	-0.01	0.06	-320.11	0.66	23.81
S1 x P4	0.05	0.01	-0.10	-89.95	-1225.53*	31.75
S1 x P7	-0.01	-0.02	0.15	-312.17	-1300.92*	-246.03
S1 x P8	0.03	0.01	-0.02	1976.72**	286.38	1119.05*
S2 x P1	0.05	0.00	-1.56*	-182.54	74.74	-72.09
S2 x P2	-0.05	-0.02	0.01	-1534.92*	-76.06	-226.85
S2 x P3	-0.02	-0.03	-0.04	-79.37	-36.38	-175.26
S2 x P4	0.02	-0.03	0.10	39.68	1126.32*	1277.12*
S2 x P7	-0.02	-0.01	-0.04	-349.20	50.93	221.56
S2 x P8	0.22*	0.18**	1.52*	1106.35	-139.55	-1024.47*
S3 x P1	0.01	-0.03	1.50*	613.76	-91.93	-81.35
S3 x P2	0.06	0.03	0.07	-1560.85*	-131.61	152.78
S3 x P3	0.04	-0.01	-0.10	494.71	241.40	-17.86
S3 x P4	-0.05	0.03	-0.01	-330.69	15.21	-65.48
S3 x P7	-0.03	-0.01	-0.07	2.64	-115.74	101.19
S3 x P8	-0.03	-0.01	0.11	-219.58	82.67	-89.29
S4 x P1	0.02	-0.15*	0.00	252.65	-50.27	94.58
S4 x P2	-0.01	-0.02	-0.03	-255.29	21.17	106.48
S4 x P3	-0.02	-0.02	0.05	22.49	-1272.49*	-8.60
S4 x P4	-0.24*	0.04	-0.04	85.98	279.10	-167.33
S4 x P7	0.03	0.09	0.05	-136.24	92.59	54.89
S4 x P8	-0.01	-0.04	-0.03	30.42	-70.10	-80.03
S5 x P1	-0.09	0.04	-0.03	-1534.39*	-8.60	39.02
S5 x P2	-0.02	-0.02	0.06	13.23	-48.28	162.04
S5 x P3	0.00	0.07	0.02	235.45	491.40	130.29
S5 x P4	0.03	-0.02	0.02	-1589.95*	-1323.68*	-1278.44*
S5 x P7	0.21*	-0.03	-0.04	632.27	-199.08	54.89
S5 x P8	-0.01	-0.04	-0.02	-256.61	-111.77	-107.80
S6 x P1	0.21*	0.07	-0.05	-1664.02*	-54.89	122.36
S6 x P2	0.05	-0.01	-0.03	550.26	72.09	134.26
S6 x P3	0.02	0.02	0.07	-283.07	-54.89	185.85
S6 x P4	-0.04	-0.02	0.08	224.87	-58.86	166.01
S6 x P7	-0.05	-0.22**	-0.02	1558.20*	1199.08*	-1167.33*
S6 x P8	-0.27**	-0.03	-1.55*	-386.24	-102.52	-441.14
S7 x P1	-0.03	0.00	0.11	-173.28	185.85	-90.61
S7 x P2	-0.04	0.00	0.03	-70.11	-131.61	-412.04
S7 x P3	0.01	-0.01	-0.05	-70.11	-369.71	-138.23
S7 x P4	0.01	-0.01	-0.05	160.05	-12.57	36.38
S7 x P7	-0.02	0.00	-0.03	104.52	273.15	-19.19
S7 x P8	0.27**	0.22**	-0.01	1548.94*	1254.89*	1623.68**
SE±	0.10	0.07	0.73	754.38	595.58	567.95

*P≤0.05; **P≤0.01; NS=non-stress; IS=intermediate stress; SS=severe stress

4.5.6.8 Grain yield

Among 42 hybrids, S7 x P8 under the three conditions, S1 x P2 and S6 x P7 under non-stress and intermediate stress, S1 x P8 under non-stress and severe stress and S2 x P4 intermediate stress and severe stress recorded significant positive SCA effects. S5 x P4 under the three conditions, S2 x P2, S3 x P2, S5 x P1 and S6 x P1 under non-stress, S1 x P4, S1 x P7 and S4 x P3 under intermediate stress and S2 x P8 and S6 x P7 under severe stress exhibited significant negative SCA effects for grain yield.

4.6 Heterosis

4.6.1 High parent heterosis at Samaru

High parent heterosis (HPH) of hybrids for days to 50% tasseling, days to 50% silking and anthesis-silking interval under non-stress, intermediate stress and severe stress conditions at Samaru are presented in Table 4.37.

4.6.1.1 Days to 50% tasseling

Under non-stress, 39 hybrids showed negative HPH while 3 showed positive HPH and ranged from -17.78% (S5 x P8 and S7 x P8) to 8.70% (S4 x P3). Under intermediate stress, 41 hybrids showed negative HPH while 1 showed positive HPH and ranged from -18.80% (S5 x P8) to 0.88% (S5 x P3). Under severe stress, 39 hybrids showed negative HPH, 2 expressed positive HPH while 1 did not show heterosis and ranged from -20.44% (S5 x P8) to 2.63% (S3 x P3).

4.6.1.2 Days to 50% silking

Under non-stress, 38 hybrids showed negative HPH while 4 showed positive HPH and ranged from -19.29% (S5 x P8) to 4.20% (S2 x P3).

Table 4.37 Estimates of heterosis of hybrids for days to 50% tasseling, days to 50% silking and anthesis-silking interval under non-stress, intermediate stress and severe stress at Samaru

	Days to 50% tasseling			Days to 50% silking			Anthesis-silking interval		
Hybrids	NS	IS	SS	NS	IS	SS	NS	IS	SS
S1 x P1	-8.13	-6.61	-8.13	-5.47	-7.63	-11.03	14.29	-20.00	-42.86
S1 x P2	-10.57	-3.48	-6.50	-7.81	-4.03	-12.41	14.29	-30.00	-66.67
S1 x P3	-7.32	-2.61	-1.64	-4.69	-1.64	-3.68	60.00	-11.11	-21.43
S1 x P4	-4.88	-3.48	-4.92	-3.13	-3.23	-7.35	-12.50	0.00	-28.57
S1 x P7	-8.94	-8.40	-5.74	-5.47	-7.87	-16.78	-10.00	0.00	-81.82
S1 x P8	-15.56	-12.78	-12.41	-15.71	-11.51	-8.97	-20.00	0.00	-14.29
S2 x P1	-5.00	-7.44	-2.44	-5.51	-16.03	-8.09	-14.29	-20.00	-61.54
S2 x P2	-7.32	-0.87	-3.25	2.52	-2.42	-8.03	14.29	-30.00	-53.33
S2 x P3	1.74	-0.87	-0.84	4.20	-1.63	-3.13	40.00	-22.22	-40.00
S2 x P4	-1.74	-1.74	-2.52	-3.25	-0.81	-3.91	-25.00	11.11	-41.67
S2 x P7	-1.71	-5.88	-9.09	-4.72	-7.09	-13.99	-40.00	-25.00	-40.91
S2 x P8	-16.30	-15.04	-12.41	-14.29	-11.51	-12.41	40.00	25.00	-22.22
S3 x P1	-6.67	-9.92	-7.32	-6.30	-7.63	-6.62	0.00	20.00	0.00
S3 x P2	-10.57	-5.26	-10.57	-2.52	-8.87	-15.33	-14.29	-50.00	-60.00
S3 x P3	-0.87	-2.65	2.63	0.84	-3.28	3.23	0.00	-11.11	10.00
S3 x P4	-6.09	-3.48	1.72	-4.88	-4.03	0.00	12.50	-11.11	-16.67
S3 x P7	-4.27	-8.40	-12.40	-7.09	-4.72	-23.08	-40.00	50.00	-81.82
S3 x P8	-8.15	-17.29	-14.60	-15.00	-17.27	-13.79	-16.67	-16.67	0.00
S4 x P1	-5.83	-7.44	-7.32	-6.30	-9.16	-5.15	-33.33	-30.00	15.38
S4 x P2	-8.13	-3.42	-11.38	-3.23	-4.76	-16.79	-22.22	-30.00	-66.67
S4 x P3	8.70	-3.42	-3.33	-1.61	-4.76	-6.11	-22.22	-33.33	-36.36
S4 x P4	-2.61	-4.27	-1.67	-6.45	-6.35	-3.82	-55.56	-33.33	-33.33
S4 x P7	-5.98	-6.72	-3.31	-10.24	-8.66	-13.99	-60.00	-44.44	-72.73
S4 x P8	-14.81	-14.29	-16.79	-14.29	-12.95	-17.93	-44.44	-22.22	-54.55
S5 x P1	-9.17	-11.57	-9.76	-10.24	-13.74	-14.71	-28.57	-40.00	-61.54
S5 x P2	-11.38	-7.02	-13.82	-5.04	-11.29	-18.98	-42.86	-60.00	-66.67
S5 x P3	-1.74	0.88	0.00	-4.20	-2.46	-3.23	-71.43	-44.44	-40.00
S5 x P4	-3.48	-3.48	-6.03	-4.88	-5.65	-12.50	-25.00	-33.33	-75.00
S5 x P7	-8.55	-8.40	-9.09	-13.39	-9.45	-22.38	-70.00	-25.00	-95.45
S5 x P8	-17.78	-18.80	-20.44	-19.29	-18.71	-16.55	-71.43	-16.67	20.00
S6 x P1	-5.00	-8.26	-16.92	-6.30	-11.45	-20.00	-44.44	-50.00	-40.00
S6 x P2	-12.20	-4.39	-16.15	-8.94	-5.65	-24.67	-55.56	-20.00	-80.00
S6 x P3	-1.74	-3.54	-13.08	-3.25	-5.74	-19.33	-33.33	-40.00	-60.00
S6 x P4	-4.35	-3.48	-14.62	-4.88	-4.03	-22.67	-22.22	-20.00	-75.00
S6 x P7	-5.13	-6.72	-11.54	-7.87	-8.66	-20.00	-40.00	-50.00	-77.27
S6 x P8	-15.56	-15.04	-12.41	-15.71	-12.95	-14.00	-55.56	-20.00	-55.00
S7 x P1	-7.50	-6.61	-10.57	-7.87	-7.63	-11.76	-33.33	-33.33	-44.44
S7 x P2	-8.94	-5.26	-9.76	-1.68	-6.45	-13.87	-44.44	-33.33	-61.11
S7 x P3	0.87	-0.88	-1.75	1.68	-2.46	-5.47	-11.11	-41.67	-50.00
S7 x P4	-5.22	-3.48	-6.90	-4.88	-5.65	-3.91	-11.11	-50.00	-16.67
S7 x P7	-5.13	-7.56	-7.44	-7.09	-6.30	-16.08	-30.00	-25.00	-63.64
S7 x P8	-17.78	-15.79	-19.71	-15.00	-13.67	-20.69	-11.11	-33.33	-72.22

NS=non-stress; IS=intermediate stress, SS=severe stress

Under intermediate stress, the entire hybrids showed negative HPH and ranged from -18.71% (S5 x P8) to -0.81% (S2 x P4). Under severe stress, 40 hybrids showed negative HPH, only one showed positive HPH while 1 did not show heterosis and ranged from -24.67% (S6 x P2) to 3.23% (S3 x P3).

4.6.1.3 Anthesis-silking interval

Under non-stress, 33 hybrids showed negative HPH, 7 showed positive HPH while 2 did not show heterosis and ranged from -71.43% (S5 x P8 and S5 x P3) to 60.00% (S1 x P3). Under intermediate stress, 35 hybrids showed negative HPH, 4 showed positive HPH while 3 did not show heterosis and ranged from -60.00% (S5 x P2) to 50.00% (S3 x P7). Under severe stress, 37 hybrids showed negative HPH, 3 showed positive HPH while 2 did not show heterosis and it ranged from -95.45% (S5 x P7) to 20.00% (S5 x P8).

High parent heterosis (HPH) of hybrids for plant height, ear height and leaf senescence under non-stress, intermediate stress and severe stress conditions at Samaru are presented in Table 4.38.

4.6.1.4 Plant height

Under non-stress, 12 hybrids showed negative HPH, 29 showed positive HPH while 1 did not show heterosis and ranged from -12.33% (S5 x P3) to 36.36% (S6 x P8). Under intermediate stress, 16 hybrids showed negative HPH, 24 hybrids showed positive HPH while 2 hybrids did not show heterosis and ranged from -10.55% (S7 x P2) to 33.54% (S6 x P8). Under severe stress, 10 hybrids showed negative HPH, 31 showed positive HPH while 1 did not show heterosis and ranged from -7.21% (S7 x P2) to 38.92% (S6 x P8).

Table 4.38 Estimates of percent heterosis of hybrids for plant height, ear height and leaf senescence under non-stress, intermediate stress and severe stress at Samaru

	Plant height			Ear height			Leaf senescence	
Hybrids	NS	IS	SS	NS	IS	SS	IS	SS
S1 x P1	4.10	-2.23	14.43	1.66	2.61	-3.51	-37.50	-66.67
S1 x P2	-3.07	5.05	0.96	16.53	1.74	-15.45	40.00	-25.00
S1 x P3	-7.46	-1.41	-0.51	8.85	-11.30	-6.14	80.00	0.00
S1 x P4	0.44	6.63	4.64	23.01	-2.60	-10.53	0.00	-33.33
S1 x P7	-0.88	1.92	-4.13	8.85	-2.61	-18.42	0.00	0.00
S1 x P8	1.32	15.58	-5.16	19.47	-1.74	-7.02	60.00	66.67
S2 x P1	-2.59	0.00	6.84	-2.48	3.47	-5.46	-62.50	-16.67
S2 x P2	5.56	4.09	-0.48	14.87	9.61	-13.64	37.50	-62.50
S2 x P3	8.22	4.54	6.60	4.96	9.61	11.11	-12.50	-16.67
S2 x P4	17.32	-4.09	8.47	-2.48	27.88	-11.11	-37.50	-33.33
S2 x P7	8.80	1.82	14.05	0.82	22.11	10.18	-50.00	0.00
S2 x P8	12.22	6.82	22.41	8.26	17.30	8.33	0.00	-16.67
S3 x P1	3.26	0.00	0.53	4.14	4.35	-8.19	-45.45	133.33
S3 x P2	7.44	-4.13	-3.36	-2.48	17.47	-30.30	-27.27	-62.50
S3 x P3	0.91	-0.94	-6.60	17.59	23.23	-15.53	-9.09	-50.00
S3 x P4	9.17	-0.47	17.52	9.34	21.65	19.42	-36.36	100.00
S3 x P7	15.58	-1.45	13.48	15.24	18.28	3.89	-27.27	33.33
S3 x P8	27.57	16.06	6.78	13.33	24.73	-13.58	-72.73	-33.33
S4 x P1	-0.08	0.89	15.26	2.48	12.07	32.72	-37.50	66.67
S4 x P2	-6.39	5.05	-6.73	6.62	-11.21	-16.67	20.00	-75.00
S4 x P3	-5.12	0.47	1.22	6.78	-12.93	20.79	80.00	25.00
S4 x P4	10.55	9.48	18.64	2.54	5.18	13.87	-50.00	0.00
S4 x P7	3.21	9.09	7.87	13.56	-4.31	13.87	40.00	-33.33
S4 x P8	0.00	6.22	17.24	11.86	12.07	21.78	40.00	-33.33
S5 x P1	-0.50	-1.34	-0.53	-6.61	-2.61	-8.19	-50.00	-87.50
S5 x P2	1.86	-5.05	0.48	-9.81	3.88	-16.67	-28.57	-62.50
S5 x P3	-12.33	-1.41	6.09	0.00	21.21	-2.02	-57.14	-62.50
S5 x P4	6.05	4.26	9.61	21.49	14.44	4.25	14.29	-37.50
S5 x P7	8.54	2.88	14.05	16.67	23.91	17.02	14.29	-37.50
S5 x P8	25.28	27.91	-1.19	40.01	10.86	-1.07	57.14	-37.50
S6 x P1	-0.84	-4.02	4.74	-10.74	1.74	12.72	-22.22	166.67
S6 x P2	10.70	-3.67	0.00	-5.78	12.62	-16.67	-22.22	-50.00
S6 x P3	-3.20	-0.47	4.06	16.67	-3.03	33.33	-22.22	100.00
S6 x P4	3.97	-1.42	19.21	14.01	10.31	34.78	-44.44	-66.67
S6 x P7	11.56	4.81	19.67	28.43	27.77	18.68	0.00	-33.33
S6 x P8	36.36	33.54	38.92	39.03	45.72	79.99	-55.56	200.00
S7 x P1	-0.50	8.48	20.52	14.05	-4.35	12.72	25.00	40.00
S7 x P2	0.93	-10.55	-7.21	-9.92	9.70	-17.42	50.00	-62.50
S7 x P3	5.02	-0.94	7.11	17.59	12.12	24.24	0.00	-40.00
S7 x P4	6.33	4.74	11.86	20.56	29.90	27.18	-16.67	100.00
S7 x P7	11.06	11.54	14.05	29.41	12.64	19.77	16.67	0.00
S7 x P8	25.49	4.71	20.48	26.59	21.06	16.28	-33.33	-60.00

NS=non-stress; IS=intermediate stress; SS=severe stress

4.6.1.5 Ear height

Under non-stress, 8 hybrids showed negative HPH, 33 showed positive heterosis while 1 did not show heterosis and ranged from -10.74% (S6 x P1) to 40.01% (S5 x P8). Under intermediate stress, 10 hybrids showed negative HPH while 32 showed positive HPH and ranged from -12.93% (S4 x P3) to 45.72% (S6 x P8). Under severe stress, 20 hybrids showed negative HPH and 22 showed positive HPH and ranged from -30.30% (S3 x P2) to 79.99% (S6 x P8).

4.6.1.6 Leaf senescence

Under intermediate stress, 23 hybrids showed negative HPH, 14 showed positive HPH while 5 did not show heterosis and ranged from -72.73% (S3 x P8) to 80.00% (S1 x P3 and S4 x P3). Under severe stress, 26 hybrids showed negative HPH, 11 showed positive HPH while 5 did not show heterosis and ranged from -87.50% (S5 x P1) to 200.00% (S6 x P8).

High parent heterosis (HPH) of hybrids for number of ears per plant and grain yield under non-stress, intermediate stress and severe stress conditions at Samaru are presented in Table 4.39.

4.6.1.7 Number of ears per plant

Under non-stress, 32 hybrids showed negative HPH, 9 showed positive HPH while 1 did not show heterosis and ranged from -42.86% (S2 x P8, S3 x P8, S4 x P8 and S6 x P8) to 26.19% (S5 x P7). Under intermediate stress, 31 hybrids showed negative HPH, 6 showed positive HPH while 5 did not show heterosis and ranged from -45.50% (S4 x P8 and S7 x P8) to 16.19% (S5 x P3).

Table 4.39 Estimates of percent heterosis of hybrids for number of ears per plant and grain yield under non-stress, intermediate stress and severe stress at Samaru

	Number of ears per plant			Grain yield		
Hybrids	NS	IS	SS	NS	IS	SS
S1 x P1	-4.76	0.00	-11.21	35.71	16.67	-35.00
S1 x P2	-18.92	3.14	-44.86	92.86	60.00	57.14
S1 x P3	-33.75	0.00	16.82	0.00	50.00	0.00
S1 x P4	-0.38	3.32	-29.91	45.45	-27.27	0.00
S1 x P7	10.00	-12.66	19.54	7.14	33.33	-57.14
S1 x P8	-34.29	-36.51	-36.00	46.15	72.73	57.14
S2 x P1	15.20	-2.25	-24.00	-4.55	41.67	-10.00
S2 x P2	-33.33	-10.31	4.00	-22.73	50.00	81.82
S2 x P3	-33.75	-9.91	-35.00	-40.91	20.00	9.09
S2 x P4	-8.37	-9.91	42.44	-13.64	36.36	100.00
S2 x P7	-20.00	-12.66	-45.60	-9.09	55.56	85.71
S2 x P8	-42.86	-22.07	-31.33	-9.09	27.27	136.36
S3 x P1	17.11	0.00	0.00	50.00	-16.67	-40.00
S3 x P2	-21.92	4.48	59.38	0.00	40.00	140.00
S3 x P3	-17.98	0.00	-46.86	15.00	70.00	0.00
S3 x P4	-23.95	-5.21	0.49	35.00	9.09	-14.29
S3 x P7	0.00	-8.30	-67.43	15.00	33.33	14.29
S3 x P8	-42.86	-40.05	-17.33	-5.00	27.27	20.00
S4 x P1	-1.80	-4.76	-35.00	14.29	25.00	10.00
S4 x P2	-27.93	-10.31	3.23	14.29	50.00	57.14
S4 x P3	-32.49	-4.76	10.22	-18.75	20.00	57.14
S4 x P4	-20.53	15.17	-36.10	66.67	36.36	28.57
S4 x P7	13.51	3.06	-36.16	35.71	55.56	28.57
S4 x P8	-42.86	-45.50	-33.33	30.77	36.36	100.00
S5 x P1	-4.76	0.00	-19.50	6.67	0.00	-30.00
S5 x P2	-39.94	-10.31	36.11	6.67	7.14	160.00
S5 x P3	-24.61	16.19	-16.67	56.25	28.57	50.00
S5 x P4	-12.55	-5.21	-35.12	20.00	-35.71	-71.43
S5 x P7	26.19	-12.66	-34.85	73.33	-28.57	42.86
S5 x P8	-34.00	-43.05	-46.33	26.67	-21.43	100.00
S6 x P1	0.48	-33.33	-37.50	64.28	-41.67	-40.00
S6 x P2	-27.03	-33.33	-5.63	85.71	40.00	100.00
S6 x P3	-10.73	-23.67	8.57	18.75	0.00	60.00
S6 x P4	-1.14	-33.33	-11.22	154.54	18.18	42.86
S6 x P7	5.00	-33.33	-57.33	42.86	100.00	-50.00
S6 x P8	-42.86	-41.96	-66.67	76.92	27.27	33.33
S7 x P1	3.81	-9.09	-50.00	14.29	-8.33	-10.00
S7 x P2	-30.33	-10.31	31.25	64.29	-9.09	80.00
S7 x P3	-21.14	-9.09	-8.57	6.25	-18.18	60.00
S7 x P4	-23.95	-9.09	-19.02	71.43	-4.55	28.57
S7 x P7	10.50	-8.73	-26.71	42.86	72.73	114.29
S7 x P8	-23.71	-45.50	-16.67	85.71	18.18	233.33

NS=non-stress; IS=intermediate stress; SS=severe stress

Under severe stress, 30 hybrids showed negative HPH, 11 showed positive HPH while 1 did not show heterosis and ranged from -67.43% (S3 x P7) to 59.38% (S3 x P2).

4.6.1.8 Grain yield

Under non-stress, 8 hybrids showed negative HPH, 32 showed positive HPH, while 2 did not showed heterosis and ranged from -40.91% (S2 x P3) to 154.54% (S6 x P4). Under intermediate stress, 10 showed negative HPH, 30 showed positive HPH while 2 did not show heterosis and ranged from -41.67% (S6 x P1) to 100.00% (S6 x P7). Under severe stress, 10 showed negative HPH while 29 showed positive HPH while 3 did not show heterosis and ranged from -71.43% (S5 x P4) to 633.33% (S7 x P8).

4.6.2 High parent heterosis at Kadawa

High parent heterosis of hybrids for days to 50% tasseling, days to 50% silking and anthesis-silking interval under non-stress, intermediate stress and severe stress conditions at Kadawa are presented in Table 4.40.

4.6.2.1 Days to 50% tasseling

Under non-stress, 33 hybrids showed negative HPH, 7 showed positive HPH while 2 did not show heterosis and ranged from -16.67% (S7 x P2) to 13.01% (S1 x P3). Under intermediate stress, the entire hybrids showed negative HPH and ranged from -23.78% (S1 x P1) to -6.82% (S5 x P3). Under severe stress, 37 hybrids showed negative HPH, 2 expressed positive HPH while 3 did not show heterosis and ranged from -19.46% (S7 x P1) to 1.45% (S2 x P2 and S6 x P8).

Table 4.40 Estimates of percent heterosis of hybrids for days to 50% tasseling, days to 50% silking and anthesis-silking interval under non-stress, intermediate stress and severe stress at Kadawa

	Days to 50% tasseling			Days to 50% silking			Anthesis-silking interval		
Hybrids	NS	IS	SS	NS	IS	SS	NS	IS	SS
S1 x P1	2.44	-23.78	-10.20	2.33	-22.97	-10.39	0.00	-16.67	-14.29
S1 x P2	-7.97	-16.42	-14.97	-7.04	-16.43	-13.64	-33.33	-28.57	60.00
S1 x P3	13.01	-8.96	-6.12	15.50	-9.29	-6.49	66.67	-16.67	0.00
S1 x P4	-4.80	-18.98	-14.97	-4.58	-15.49	-15.58	0.00	50.00	-44.44
S1 x P7	2.36	-20.57	-14.29	3.76	-19.86	-13.64	33.33	-16.67	40.00
S1 x P8	-4.00	-11.19	-13.61	-5.34	-10.71	-11.04	-33.33	0.00	150.00
S2 x P1	10.08	-14.69	-10.87	9.63	-14.19	-10.34	0.00	0.00	0.00
S2 x P2	-5.80	-14.29	1.45	-4.93	-10.49	-0.69	-16.67	14.29	-42.86
S2 x P3	-6.98	-17.86	-0.71	-8.15	-16.08	-2.04	-33.33	0.00	-42.86
S2 x P4	0.78	-17.14	-11.97	0.74	-14.69	-13.25	0.00	20.00	-33.33
S2 x P7	-7.75	-20.57	-5.59	-8.15	-19.18	-3.38	-16.67	20.00	14.29
S2 x P8	-6.98	-17.14	-5.80	-8.15	-15.38	-5.52	-33.33	-16.67	0.00
S3 x P1	-2.92	-20.28	-10.42	-4.20	-20.27	-10.00	-33.33	-20.00	-14.29
S3 x P2	-13.04	-15.49	-11.81	-12.59	-13.70	-11.33	-16.67	-14.29	0.00
S3 x P3	0.00	-21.13	-7.64	2.80	-20.55	-8.67	66.67	-20.00	-33.33
S3 x P4	-15.33	-11.27	-3.47	-14.69	-10.27	-3.97	0.00	0.00	-33.33
S3 x P7	-16.06	-12.77	-9.03	-14.69	-12.33	-8.67	16.67	0.00	0.00
S3 x P8	-8.76	-18.31	-16.67	-8.39	-17.12	-16.00	0.00	-16.67	0.00
S4 x P1	-4.10	-16.08	-11.64	-3.13	-16.22	-11.26	16.67	-33.33	-28.57
S4 x P2	-13.04	-12.41	-15.75	-12.68	-11.19	-14.57	-20.00	0.00	20.00
S4 x P3	5.83	-20.44	-2.05	6.40	-20.28	-1.99	20.00	-16.67	-16.67
S4 x P4	-7.20	-19.71	-10.27	-7.63	-19.58	-9.27	-16.67	-16.67	-33.33
S4 x P7	0.00	-9.93	-4.11	-2.26	-9.59	-3.31	-16.67	-16.67	20.00
S4 x P8	-3.20	-18.98	-9.59	-4.58	-18.88	-7.28	-33.33	-16.67	60.00
S5 x P1	-1.64	-19.58	-7.09	-0.78	-18.92	-5.48	16.67	-28.57	0.00
S5 x P2	-13.04	-15.91	0.00	-11.97	-16.55	0.00	0.00	-28.57	0.00
S5 x P3	-0.83	-6.82	-17.73	-0.80	-8.63	-17.01	0.00	-42.86	0.00
S5 x P4	-4.00	-13.14	-7.04	-4.58	-11.27	-8.61	-16.67	0.00	-33.33
S5 x P7	-4.72	-19.15	-9.79	-6.02	-18.49	-8.78	-33.33	-28.57	20.00
S5 x P8	1.60	-10.45	-9.93	1.53	-10.71	-10.27	0.00	-28.57	-20.00
S6 x P1	-13.14	-16.08	-8.70	-14.08	-15.54	-6.94	-50.00	-16.67	14.29
S6 x P2	-11.59	-14.40	0.00	-11.27	-13.74	-0.69	-20.00	-14.29	-16.67
S6 x P3	-15.33	-11.20	0.00	-14.08	-11.45	-0.68	20.00	-16.67	-16.67
S6 x P4	-6.57	-8.76	-13.38	-5.63	-4.93	-13.91	0.00	66.67	-22.22
S6 x P7	-8.03	-19.86	-7.69	-6.34	-19.86	-5.41	16.67	-33.33	33.33
S6 x P8	-3.65	-13.43	1.45	-4.23	-12.86	-0.69	-33.33	0.00	-50.00
S7 x P1	-6.45	-22.38	-19.46	-4.69	-21.62	-17.42	0.00	-37.50	14.29
S7 x P2	-16.67	-12.32	-14.77	-15.49	-11.64	-14.84	25.00	0.00	-16.67
S7 x P3	-2.42	-20.29	-18.12	-1.56	-21.23	-16.77	0.00	-37.50	16.67
S7 x P4	-4.00	-17.39	-16.78	-5.34	-17.12	-17.42	-33.33	-12.50	-55.56
S7 x P7	-11.02	-21.28	-8.05	-10.53	-19.86	-8.39	0.00	-25.00	-16.67
S7 x P8	-5.60	-8.70	-15.44	-6.11	-10.27	-14.19	-16.67	-37.50	16.67

NS=non-stress; IS=intermediate stress; SS=severe severe

4.6.2.2 Days to 50% silking

Under non-stress, 34 hybrids showed negative HPH while 8 showed positive HPH and ranged from -15.49% (S7 x P2) to 15.50% (S1 x P3). Under intermediate stress, the entire hybrids showed negative HPH and ranged from -22.97% (S1 x P1) to -4.93% (S6 x P4). Under severe stress, 41 hybrids showed HPH while 1 did not show heterosis and ranged from -17.42% (S7 x P1 and S7 x P4) to 0.00% (S5 x P2).

4.6.2.3 Anthesis-silking interval

Under non-stress, 19 hybrids showed negative HPH, 10 showed positive HPH while 13 did not show heterosis and ranged from -50.00% (S6 x P1) to 66.67% (S1 x P3 and S3 x P3). Under intermediate stress, 28 hybrids showed negative HPH, 5 showed positive HPH while 9 did not show heterosis and ranged from -42.86% (S5 x P3) to 66.67% (S6 x P4). Under severe stress, 20 hybrids showed negative HPH, 9 showed positive high-parent heterosis while 13 did not show heterosis and ranged from -55.56% (S7 x P4) to 150.00% (S1 x P8).

High parent heterosis of hybrids for plant height, ear height and leaf senescence under non-stress, intermediate stress and severe stress conditions at Kadawa are presented in Table 4.41.

4.6.2.4 Plant height

Under non-stress, 3 hybrids showed negative HPH while 39 showed positive HPH and ranged from -9.97% (S4 x P1) to 49.91% (S4 x P4). Under intermediate stress, 27 hybrids showed negative HPH, 14 hybrids showed positive HPH while 1 hybrids did not show heterosis and ranged from -35.10% (S7 x P4) to 32.48% (S4 x P7).

Table 4.41 Estimates of percent heterosis of hybrids for plant height, ear height and leaf senescence under non-stress, intermediate stress and severe stress at Kadawa

	Plant height			Ear height			Leaf senescence	
Hybrids	NS	IS	SS	NS	IS	SS	IS	SS
S1 x P1	28.99	-20.65	0.01	-6.25	35.49	-18.16	-30.77	-66.67
S1 x P2	16.13	-7.74	14.75	4.17	29.62	-4.25	-53.85	-66.67
S1 x P3	5.94	-33.93	17.44	-35.83	3.32	4.62	-76.92	0.00
S1 x P4	28.71	-18.09	-7.50	-24.53	35.49	6.67	-61.54	-33.33
S1 x P7	25.44	-9.52	11.30	-12.50	39.59	40.80	-69.23	33.33
S1 x P8	17.55	0.60	22.66	7.29	14.08	-11.05	-23.08	-33.33
S2 x P1	28.19	-29.35	14.35	-26.21	35.90	4.52	-16.67	0.00
S2 x P2	14.79	-10.22	-3.05	2.91	54.63	-31.16	-69.23	150.00
S2 x P3	16.63	-5.68	-2.22	-12.62	25.48	-7.45	-42.86	0.00
S2 x P4	32.11	-22.34	6.95	-32.07	46.53	11.65	-40.00	0.00
S2 x P7	9.37	9.66	-14.20	9.70	37.32	-26.21	-20.00	50.00
S2 x P8	34.18	-9.09	12.72	-16.50	54.50	-2.14	14.29	33.33
S3 x P1	21.94	-25.55	17.49	-19.13	36.19	43.45	0.00	300.00
S3 x P2	21.10	-9.30	-5.56	-16.67	45.37	-15.01	-53.85	300.00
S3 x P3	17.11	-26.74	15.10	-22.73	47.08	-9.66	-42.86	0.00
S3 x P4	-6.11	-27.13	9.57	-33.02	-12.13	19.30	-71.43	0.00
S3 x P7	18.87	-12.91	10.31	-9.52	34.83	42.40	-14.29	0.00
S3 x P8	36.60	0.58	11.66	16.28	59.75	12.27	-71.43	0.00
S4 x P1	-9.97	3.80	3.46	14.13	-2.08	25.40	-16.67	-80.00
S4 x P2	31.58	1.91	-7.92	0.00	43.91	-12.74	-76.92	-80.00
S4 x P3	2.50	-4.79	-11.67	15.91	10.52	-10.32	0.00	-60.00
S4 x P4	49.91	-1.60	-8.36	0.00	37.95	1.22	-16.67	-80.00
S4 x P7	14.05	32.48	10.81	31.03	31.52	22.04	-66.67	-60.00
S4 x P8	33.76	12.74	11.96	25.28	44.49	-10.12	0.00	-80.00
S5 x P1	15.63	-2.72	-17.26	17.39	21.95	-22.14	-50.00	0.00
S5 x P2	31.66	-22.92	1.30	-22.23	31.89	-12.75	-76.92	-100.00
S5 x P3	12.83	-14.37	-1.64	1.14	13.56	-10.09	-50.00	-33.33
S5 x P4	19.51	0.00	-6.16	-7.54	26.37	-19.54	-37.50	66.67
S5 x P7	28.68	-1.29	11.92	2.64	55.52	17.92	12.50	-66.67
S5 x P8	6.98	22.00	-2.47	24.43	7.67	6.14	-50.00	-33.33
S6 x P1	-9.36	-20.65	31.49	-10.87	-20.05	44.60	-42.86	0.00
S6 x P2	14.78	5.75	2.23	14.63	18.72	-18.13	-15.38	0.00
S6 x P3	22.43	-34.48	-5.56	-25.00	28.62	-1.43	14.29	-33.33
S6 x P4	15.84	-8.51	17.40	-13.21	-1.87	6.47	-57.14	50.00
S6 x P7	30.08	9.77	34.17	25.61	29.15	14.38	-28.57	-100.00
S6 x P8	17.68	-26.44	3.80	-16.28	14.18	-20.86	-42.86	0.00
S7 x P1	36.97	-30.98	25.72	-16.30	43.31	60.08	28.57	0.00
S7 x P2	13.98	25.69	5.29	42.47	38.92	0.29	-61.54	0.00
S7 x P3	5.23	4.19	1.24	6.82	10.79	-12.81	-42.86	0.00
S7 x P4	34.77	-35.10	25.05	-29.24	20.79	31.32	-42.86	-50.00
S7 x P7	29.34	14.94	7.42	35.53	59.42	17.47	14.29	100.00
S7 x P8	47.09	31.33	10.19	22.10	58.29	1.84	-42.86	-66.67

NS=non-stress; IS=intermediate stress; SS=severe stress

Under severe stress, 13 hybrids showed negative HPH while 29 showed positive HPH and ranged from -17.26% (S5 x P1) to 34.17% (S6 x P7).

4.6.2.5 Ear height

Under non-stress, 21 hybrids showed negative HPH, 19 showed positive heterosis while 2 did not show heterosis and ranged from -35.83% (S1 x P3) to 42.47% (S7 x P2). Under intermediate stress, 4 hybrids showed negative HPH while 38 showed positive HPH and ranged from -20.05% (S6 x P1) to 59.75% (S3 x P8). Under severe stress, 20 hybrids showed negative HPH and 22 showed positive HPH and ranged from -31.16% (S2 x P2) to 60.08% (S7 x P1).

4.6.2.6 Leaf senescence

Under intermediate stress, 34 hybrids showed negative HPH, 5 showed positive HPH while 3 did not show heterosis and ranged from -76.92% (S1 x P3, S4 x P2 and S5 x P2) to 28.57% (S7 x P1). Under severe stress, 18 hybrids showed negative HPH, 9 showed positive HPH while 15 did not show heterosis and ranged from -100.00% (S5 x P2 and S6 x P7) to 300.00% (S3 x P1 and S3 x P2).

High parent heterosis of hybrids for number of ears per plant and grain yield under non-stress, intermediate stress and severe stress conditions at Kadawa are presented in Table 4.42.

4.6.2.7 Number of ears per plant

Under non-stress, 5 hybrids showed negative HPH, 21 showed positive HPH while 16 did not show heterosis and ranged from -9.09% (S1 x P3, S4 x P3, and S7 x P3) to 76.50% (S6 x P1).

Table 4.42 Estimates of heterosis of hybrids for number of ears per plant and grain yield under non-stress, intermediate stress and severe stress at Kadawa

	Number of ears per plant			Grain yield		
Hybrids	NS	IS	SS	NS	IS	SS
S1 x P1	6.50	0.00	28.46	300.00	25.00	0.00
S1 x P2	0.00	7.00	30.77	150.00	100.00	-33.33
S1 x P3	-9.09	0.00	-10.00	-25.00	-25.00	-33.33
S1 x P4	15.00	0.00	-19.46	300.00	50.00	0.00
S1 x P7	4.50	0.00	3.85	200.00	0.00	0.00
S1 x P8	7.00	0.00	40.00	45.45	75.00	66.67
S2 x P1	0.00	7.98	-31.90	100.00	66.67	33.33
S2 x P2	0.00	-6.10	-7.36	100.00	0.00	-33.33
S2 x P3	-4.09	-6.10	-20.86	6.25	100.00	33.33
S2 x P4	11.00	-6.10	-36.20	240.00	100.00	66.67
S2 x P7	6.50	4.23	-4.29	133.33	133.33	100.00
S2 x P8	15.50	4.23	3.68	118.18	42.86	66.67
S3 x P1	0.00	5.50	-42.65	214.28	150.00	0.00
S3 x P2	31.00	0.00	-6.62	28.57	0.00	0.00
S3 x P3	0.00	0.00	-30.88	56.25	75.00	0.00
S3 x P4	10.00	14.50	-48.99	42.86	100.00	-33.33
S3 x P7	11.00	0.00	23.53	157.14	75.00	33.33
S3 x P8	0.00	0.00	24.26	45.45	150.00	140.00
S4 x P1	16.50	0.00	6.10	340.00	133.33	150.00
S4 x P2	0.00	0.00	-25.00	83.33	133.33	250.00
S4 x P3	-9.09	0.00	-29.88	18.75	33.33	-33.33
S4 x P4	11.00	0.00	-10.98	240.00	266.67	-33.33
S4 x P7	0.00	27.50	15.85	140.00	233.33	133.33
S4 x P8	0.00	0.00	-22.56	36.36	114.29	20.00
S5 x P1	0.00	33.50	-58.04	-38.46	-14.29	33.33
S5 x P2	35.50	0.00	-39.86	23.08	-57.14	-33.33
S5 x P3	2.27	19.00	-36.36	-31.25	28.57	33.33
S5 x P4	33.50	0.00	-10.74	23.08	0.00	0.00
S5 x P7	38.00	0.00	-60.14	46.15	-14.29	-33.33
S5 x P8	0.00	0.00	-17.48	-38.46	14.29	116.67
S6 x P1	76.50	44.50	-2.10	211.11	200.00	140.00
S6 x P2	50.00	0.00	22.38	266.67	50.00	60.00
S6 x P3	-4.09	0.00	9.09	-12.50	75.00	33.33
S6 x P4	0.00	0.00	34.23	260.00	0.00	-16.67
S6 x P7	11.00	0.00	39.86	425.00	125.00	33.33
S6 x P8	0.00	0.00	50.35	-27.27	25.00	-20.00
S7 x P1	4.50	12.50	199.15	344.45	328.57	100.00
S7 x P2	0.00	0.00	99.07	116.67	157.14	-33.33
S7 x P3	-9.09	0.00	32.71	18.75	42.86	66.67
S7 x P4	28.50	0.00	9.40	300.00	185.71	166.67
S7 x P7	0.00	0.00	40.19	425.00	128.57	-33.33
S7 x P8	0.00	22.00	26.50	9.09	228.57	233.33

NS=non-stress; IS=intermediate stress; SS=severe stress

Under intermediate stress, 3 hybrids showed negative HPH, 12 showed positive HPH while 27 did not show heterosis and ranged from -6.10% (S2 x P2 S2 x P3 and S2 x P4) to 44.50% (S6 x P1). Under severe stress, 22 hybrids showed negative HPH while 20 showed positive HPH and ranged from -60.14% (S5 x P7) to 199.15% (S7 x P1).

4.6.2.8 Grain yield

Under non-stress, 6 hybrids showed negative HPH, 36 showed positive HPH and ranged from -38.46% (S5 x P1 and S5 x P8) to 425.00% (S6 x P7 and S7 x P7). Under intermediate stress, 4 showed negative HPH, 33 showed positive HPH while 5 did not show heterosis and ranged from -54.14% (S5 x P2) to 328.57% (S7 x P1). Under severe stress, 12 showed negative HPH, 23 showed positive HPH while 7 did not show heterosis and ranged from -33.33% (10 hybrids) to 250.00% (S4 x P2).

4.6.3 High parent heterosis across the locations

High parent heterosis of hybrids for days to 50% tasseling, days to 50% silking and ASI under non-stress, intermediate stress and severe stress conditions across locations are presented in Tables 4.43.

4.6.3.1 Days to 50% tasseling

Under non-stress, 36 hybrids showed negative HPH, 5 showed positive HPH while 1 did not show heterosis and ranged from -13.03% (S7 x P2) to 7.23% (S4 x P3). Under intermediate stress, 41 hybrids showed negative HPH while 1 showed positive HPH and ranged from -15.91% (S5 x P1 and S1 x P1) to 0.42% (S5 x P3). Under severe stress, 40 hybrids showed negative HPH while 2 expressed positive HPH and ranged from -13.55% (S5 x P8 and S7 x P8) to 0.78% (S2 x P2).

Table 4.43 Estimates of percent heterosis of hybrids for days to 50% tasseling, days to 50% silking and anthesis-silking interval under non-stress, intermediate stress and severe stress across locations

	Days to 50% tasseling			Days to 50% silking			Anthesis-silking interval		
Hybrids	NS	IS	SS	NS	IS	SS	NS	IS	SS
S1 x P1	-2.85	-15.91	-8.92	-1.56	-15.77	-10.69	7.69	-13.33	-30.00
S1 x P2	-9.20	-10.44	-10.78	-4.21	-9.92	-12.76	9.09	-29.41	-35.00
S1 x P3	2.85	-6.02	-4.09	5.45	-5.73	-5.17	63.64	-7.14	-5.56
S1 x P4	-4.07	-11.90	-10.41	-3.11	-9.77	-11.72	-7.14	28.57	-28.57
S1 x P7	-1.63	-15.00	-10.41	-0.38	-14.29	-13.40	6.25	0.00	-59.26
S1 x P8	-10.00	-11.99	-9.52	-10.70	-11.11	-6.27	-27.27	0.00	22.22
S2 x P1	5.35	-11.36	-5.45	5.10	-15.05	-6.59	-7.69	-13.33	-40.00
S2 x P2	-6.51	-8.24	0.78	-1.53	-6.39	-1.10	18.18	-11.76	-45.00
S2 x P3	-2.47	-10.20	0.39	-2.36	-9.40	-1.83	0.00	-14.29	-37.50
S2 x P4	0.00	-10.20	-6.59	0.39	-7.89	-8.96	-14.29	14.29	-38.10
S2 x P7	-3.70	-13.85	-7.20	-5.77	-13.55	-8.59	-31.25	-7.69	-22.22
S2 x P8	-4.12	-14.23	-8.42	-9.96	-12.54	-8.01	0.00	25.00	-12.50
S3 x P1	-1.21	-15.53	-5.81	-1.54	-14.34	-3.68	-15.38	6.67	-5.00
S3 x P2	-11.88	-8.80	-8.14	-7.31	-8.08	-8.12	-8.33	-35.29	-40.00
S3 x P3	1.21	-11.20	-3.10	2.69	-10.00	-2.21	33.33	-14.29	-6.25
S3 x P4	-9.68	-5.95	-0.39	-8.08	-6.02	-2.15	7.14	-7.14	-23.81
S3 x P7	-8.47	-10.77	-10.23	-7.69	-8.79	-15.12	-18.75	30.77	-62.96
S3 x P8	-4.23	-15.36	-13.19	-7.75	-15.41	-12.54	-8.33	-16.67	16.67
S4 x P1	-4.96	-12.12	-8.65	-4.71	-12.90	-6.74	-7.14	-26.67	0.00
S4 x P2	-10.73	-8.27	-12.78	-6.51	-8.18	-13.83	-21.43	-17.65	-45.00
S4 x P3	7.23	-12.60	-2.63	3.24	-13.01	-3.90	-7.14	-26.67	-25.00
S4 x P4	-5.00	-12.60	-6.39	-6.69	-13.38	-6.74	-35.71	-26.67	-33.33
S4 x P7	-2.87	-8.46	-3.38	-6.15	-9.16	-7.56	-43.75	-33.33	-55.56
S4 x P8	-9.23	-15.73	-9.89	-9.59	-15.05	-9.76	-35.71	-20.00	-18.75
S5 x P1	-5.37	-15.91	-3.97	-5.49	-16.49	-6.62	-7.69	-26.67	-40.00
S5 x P2	-12.26	-8.05	-1.98	-8.81	-9.24	-5.17	-25.00	-47.06	-50.00
S5 x P3	-1.28	0.42	-9.80	-2.46	-1.20	-10.70	-41.67	-35.71	-25.00
S5 x P4	-3.75	-8.73	-6.59	-4.72	-8.65	-10.39	-21.43	-7.14	-57.14
S5 x P7	-6.56	-14.23	-9.47	-9.62	-14.29	-15.46	-56.25	-15.38	-74.07
S5 x P8	-8.46	-14.61	-13.55	-9.23	-14.70	-12.20	-33.33	-23.08	6.67
S6 x P1	-7.17	-12.50	-12.69	-9.06	-13.62	-13.61	-42.86	-37.50	-23.08
S6 x P2	-11.88	-8.86	-7.84	-10.19	-9.09	-12.93	-42.86	-17.65	-65.38
S6 x P3	-8.76	-7.17	-5.22	-9.06	-8.70	-9.18	-14.29	-31.25	-50.00
S6 x P4	-5.18	-6.35	-12.69	-5.28	-4.51	-16.33	-7.14	12.50	-53.85
S6 x P7	-5.58	-13.85	-7.84	-5.66	-14.65	-11.56	-18.75	-43.75	-51.85
S6 x P8	-5.38	-14.23	-4.76	-6.27	-12.90	-7.48	-42.86	-12.50	-53.85
S7 x P1	-6.20	-15.15	-11.20	-6.27	-15.05	-12.37	-7.69	-35.00	-25.00
S7 x P2	-13.03	-6.91	-8.11	-9.20	-7.89	-11.66	-23.08	-20.00	-50.00
S7 x P3	0.85	-9.76	-9.65	1.23	-12.03	-11.66	0.00	-40.00	-33.33
S7 x P4	-4.58	-10.71	-10.42	-5.12	-10.53	-11.31	-14.29	-35.00	-20.83
S7 x P7	-8.20	-15.00	-5.68	-8.85	-13.55	-9.97	-18.75	-25.00	-51.85
S7 x P8	-11.92	-10.86	-13.55	-10.70	-10.04	-13.59	0.00	-35.00	-50.00

NS=non-stress; IS=intermediate stress; SS=severe stress

4.6.3.2 Days to 50% silking

Under non-stress, 36 hybrids showed negative HPH while 6 showed positive HPH and ranged from -10.70% (S1 x P8 and S7 x P8) to 5.45% (S1 x P3). Under intermediate stress, the entire hybrids showed negative HPH and ranged from -16.49% (S5 x P1) to -1.20% (S5 x P3). Under severe stress, the entire hybrids showed negative HPH and ranged from -16.33% (S6 x P4) to 1.10% (S2 x P2).

4.6.3.3 Anthesis-silking interval

Under non-stress, 31 hybrids showed negative HPH, 7 showed positive HPH while 4 did not show heterosis and ranged from -56.25% (S5 x P7) to 63.64% (S1 x P3). Under intermediate stress, 34 hybrids showed negative HPH, 6 showed positive HPH while 2 did not show heterosis and ranged from -47.06% (S5 x P2) to 30.77% (S3 x P7). Under severe stress, 38 hybrids showed negative HPH, 3 showed positive high-parent heterosis while 1 did not show heterosis and ranged from -74.07% (S5 x P7) to 22.22% (S1 x P8).

High parent heterosis of hybrids for plant height, ear height and leaf senescence under non-stress, intermediate stress and severe stress conditions across locations are presented in Tables 4.44.

4.6.3.4 Plant height

Under non-stress, 4 hybrids showed negative HPH while 38 showed positive HPH and ranged from -3.90% (S4 x P1) to 41.83% (S7x P8). Under intermediate stress, 21 hybrids showed negative HPH, 19 showed positive HPH while 2 did not show heterosis and ranged from -15.53% (S1 x P3) to 36.61% (S5 x P8).

Table 4.44 Estimates of heterosis of hybrids for plant height, ear height and leaf senescence under non-stress, intermediate stress and severe stress across locations

	Plant height			Ear height			Leaf senescence	
Hybrids	NS	IS	SS	NS	IS	SS	IS	SS
S1 x P1	13.71	-10.54	10.60	0.00	14.85	-5.64	-22.22	-66.67
S1 x P2	5.01	4.63	6.60	15.31	12.12	-11.55	-27.78	-22.22
S1 x P3	0.52	-15.53	6.62	-11.67	-3.60	6.83	-33.33	0.00
S1 x P4	11.52	-5.01	6.35	2.81	11.58	-5.17	-38.89	-33.33
S1 x P7	9.44	-0.82	7.22	-0.96	13.10	0.65	-50.00	16.67
S1 x P8	7.68	8.72	21.94	13.88	4.15	5.94	0.00	16.67
S2 x P1	9.29	-13.24	15.66	-13.39	15.46	-0.71	-42.86	-12.50
S2 x P2	9.62	-2.27	-1.53	9.37	26.16	-19.74	-16.67	-11.11
S2 x P3	11.87	0.00	4.78	-3.13	19.51	4.36	-15.38	0.00
S2 x P4	23.04	-10.53	8.86	-15.18	40.74	-2.83	-38.46	-25.00
S2 x P7	11.75	5.30	3.17	4.91	33.59	-3.06	-38.46	12.50
S2 x P8	22.47	-0.25	18.18	-3.13	39.40	6.48	23.08	12.50
S3 x P1	10.47	-11.52	12.03	-5.91	16.11	14.41	-27.78	175.00
S3 x P2	13.03	0.00	-4.26	-1.06	33.32	-24.97	-22.22	-22.22
S3 x P3	7.95	-11.31	3.49	-0.51	33.29	-13.42	-22.22	-28.57
S3 x P4	11.66	-13.03	14.09	-11.74	9.77	19.38	-50.00	75.00
S3 x P7	16.97	-2.80	12.48	4.23	24.94	17.76	-22.22	25.00
S3 x P8	32.94	8.77	8.88	15.87	38.82	0.75	-72.22	0.00
S4 x P1	-3.90	2.21	15.92	7.52	7.45	30.45	-28.57	-25.00
S4 x P2	9.91	6.28	-7.22	5.36	9.15	-15.30	-50.00	-66.67
S4 x P3	-1.81	-1.84	-1.41	11.22	5.61	11.08	45.45	-12.50
S4 x P4	24.11	4.26	7.80	6.57	22.24	9.74	-27.27	-50.00
S4 x P7	13.48	19.12	10.55	20.97	9.16	16.54	-18.18	-50.00
S4 x P8	22.25	9.01	14.90	17.56	27.11	21.07	27.27	-62.50
S5 x P1	7.03	-1.96	-1.65	3.76	6.47	-6.77	-46.67	-63.64
S5 x P2	16.22	-12.15	1.45	-13.10	21.38	-15.30	-55.56	-72.73
S5 x P3	-1.39	-7.11	7.96	0.51	17.99	-2.06	-53.33	-54.55
S5 x P4	23.02	2.25	5.08	7.04	22.72	-5.15	-13.33	-9.09
S5 x P7	20.63	1.11	16.32	10.68	48.35	17.37	13.33	-45.45
S5 x P8	16.77	36.61	-1.78	36.15	9.54	4.38	0.00	-36.36
S6 x P1	-3.85	-11.52	20.93	-10.79	-3.07	28.07	-31.25	100.00
S6 x P2	13.25	8.84	0.91	9.47	28.80	-17.18	0.00	-33.33
S6 x P3	2.63	-14.21	0.25	-2.04	12.27	20.74	-6.25	42.86
S6 x P4	22.94	-4.76	26.73	0.47	14.47	36.72	-50.00	-20.00
S6 x P7	21.79	12.98	28.99	31.46	45.73	26.54	-12.50	-60.00
S6 x P8	27.09	1.82	22.80	12.05	34.05	41.40	-50.00	140.00
S7 x P1	13.96	-9.31	22.45	0.94	13.26	27.44	35.71	28.57
S7 x P2	6.27	3.87	-2.10	14.21	20.00	-11.25	-22.22	-44.44
S7 x P3	5.11	1.32	4.78	12.76	11.56	10.82	-23.08	-14.29
S7 x P4	22.19	-14.03	19.11	-4.23	26.40	29.26	-30.77	57.14
S7 x P7	18.77	12.98	11.40	32.02	33.02	19.02	15.38	28.57
S7 x P8	41.83	22.91	21.03	31.91	41.07	29.20	-38.46	-57.14

NS=non-stress; IS=intermediate stress; SS=severe stress

Under severe stress, 7 hybrids showed negative HPH while 35 showed positive HPH and ranged from -7.22% (S4 x P2) to 28.99% (S6 x P7).

4.6.3.5 Ear height

Under non-stress, 14 hybrids showed negative HPH, 27 showed positive heterosis while 1 did not show heterosis and ranged from -15.18% (S2 x P4) to 35.15% (S5 x P8). Under intermediate stress, 2 hybrids showed negative HPH while 40 showed positive HPH and ranged from -3.60% (S1 x P3) to 48.35% (S5 x P7). Under severe stress, 16 hybrids showed negative HPH while 26 showed positive HPH and ranged from -24.97% (S3 x P2) to 41.40% (S6 x P8).

4.6.3.6 Leaf senescence

Under intermediate stress, 33 hybrids showed negative HPH, 6 showed positive HPH while 3 did not show heterosis and ranged from -72.22% (S3 x P8) to 45.45% (S4 x P3). Under severe stress, 26 hybrids showed negative HPH, 13 showed positive HPH while 3 did not show heterosis and ranged from -72.73% (S5 x P2) to 175.00% (S3 x P1).

High parent heterosis of hybrids for number of ears per plant and grain yield under non-stress, intermediate stress and severe stress conditions across locations are presented in Tables 4.45.

4.6.3.7 Number of ears per plant

Under non-stress, 27 hybrids showed negative HPH, 14 showed positive HPH while 1 did not show heterosis and ranged from -27.27% (S3 x P8, S4 x P8 and S6 x P8) to 37.56% (S6 x P1).

Table 4.45 Estimates of percent heterosis of hybrids for number of ears per plant and grain yield under non-stress, intermediate stress and severe stress across locations

	Number of ears per plant			Grain yield		
Hybrids	NS	IS	SS	NS	IS	SS
S1 x P1	0.73	0.00	3.78	110.81	35.71	-20.83
S1 x P2	-11.82	1.83	-16.28	110.00	84.62	30.00
S1 x P3	-23.65	0.00	6.69	-12.50	38.46	-10.00
S1 x P4	6.26	1.70	-23.73	125.00	0.00	0.00
S1 x P7	7.25	-6.76	26.77	76.47	21.74	-40.00
S1 x P8	-19.27	-23.63	-10.31	45.83	79.31	60.00
S2 x P1	8.44	5.92	-27.55	20.00	57.14	8.33
S2 x P2	-20.83	-8.26	-1.10	16.00	38.46	41.18
S2 x P3	-21.60	-5.21	-28.65	-6.25	38.46	17.65
S2 x P4	0.00	-5.21	9.09	44.00	50.00	90.00
S2 x P7	-8.22	-1.63	-18.43	8.00	75.00	90.00
S2 x P8	-21.64	-10.41	-10.07	76.00	31.03	111.76
S3 x P1	9.11	2.75	-12.30	92.59	42.86	-33.33
S3 x P2	-2.06	-0.69	49.80	7.41	38.46	100.00
S3 x P3	-10.61	0.00	-26.38	50.00	84.61	0.00
S3 x P4	-9.29	4.38	-20.34	37.04	42.86	-20.00
S3 x P7	-1.40	-4.43	-32.32	51.85	46.15	20.00
S3 x P8	-27.27	-25.93	0.00	29.63	65.52	71.43
S4 x P1	6.87	-2.44	-13.14	105.41	57.14	33.33
S4 x P2	-17.45	-8.26	-10.00	35.00	69.23	100.00
S4 x P3	-22.91	-2.44	-8.57	0.00	23.08	44.44
S4 x P4	-6.91	8.05	-21.75	117.65	85.71	10.00
S4 x P7	7.11	14.45	-2.53	82.35	100.00	60.00
S4 x P8	-27.27	-29.45	-21.58	33.33	55.17	88.89
S5 x P1	-2.44	16.34	-31.58	-14.29	42.86	-8.33
S5 x P2	-11.63	-8.26	2.48	14.29	-14.29	114.29
S5 x P3	-13.59	17.56	-25.39	12.50	28.57	43.75
S5 x P4	7.34	-2.44	-24.86	21.43	-23.81	-50.00
S5 x P7	31.95	-6.76	-35.10	60.71	-23.81	20.00
S5 x P8	-21.64	-27.87	-33.09	-3.57	-9.52	108.33
S6 x P1	37.56	-2.20	-16.40	100.00	35.71	0.00
S6 x P2	1.88	-20.00	8.31	140.00	53.85	100.00
S6 x P3	-8.01	-14.20	14.95	3.13	30.77	50.00
S6 x P4	-0.65	-20.00	7.91	187.50	21.43	25.00
S6 x P7	8.00	-20.00	-16.41	141.18	130.00	-25.00
S6 x P8	-27.27	-27.16	-24.46	29.17	31.03	9.09
S7 x P1	4.15	1.19	41.96	94.59	79.31	25.00
S7 x P2	-18.95	-8.26	65.88	80.00	31.03	57.14
S7 x P3	-16.20	-4.76	22.76	12.50	-3.45	62.50
S7 x P4	-1.30	-4.76	-7.06	144.44	41.38	70.00
S7 x P7	5.25	-4.66	-5.30	127.78	86.21	70.00
S7 x P8	-15.09	-21.69	-4.56	58.33	68.97	133.33

NS=non-stress; IS=intermediate stress; SS=severe stress

Under intermediate stress, 29 hybrids showed negative HPH, 10 showed positive HPH while 3 did not show heterosis and ranged from -29.45% (S4 x P8) to 17.56% (S5 x P3). Under severe stress, 29 hybrids showed negative HPH, 12 showed positive HPH while 1 did not show heterosis and ranged from -35.10% (S5 x P7) to 65.88% (S7 x P2).

4.6.3.8 Grain yield

Under non-stress, 4 hybrids showed negative HPH, 37 hybrids showed positive HPH while 1 hybrid did not showed heterosis and ranged from -14.29% (S5 x P1) to 187.50% (S6 x P4). Under intermediate stress, 5 hybrids showed negative HPH, 36 showed positive HPH while 1 did not show heterosis and ranged from -23.81% (S5 x P7 and S5 x P4) to 130.00% (S6 x P7). Under severe stress, 8 hybrids showed negative HPH, 31 showed positive HPH while 1 did not show heterosis and ranged from -50.00% (S5 x P4) to 133.33% (S7 x P8).

CHAPTER FIVE

5.0 DISCUSSION

5.1 Population Variability

The amount of genetic improvement that can be achieved in a given set of genotypes depends on the amount of genetic diversity that is present within the population (Falconer and Mackey, 1996). In this study, there were significant differences among the genotypes for most of the traits measured under the three environmental conditions at individual and across locations. This indicates the presence of appreciable variability in them which is a pre-requisite for any crop improvement program. The significant differences observed for locations for all traits measured under the three conditions except number of ears per plant under intermediate stress indicates that the conditions in the two locations were not similar in many respect and that is why the genotypes did not perform in the same manner. Similar results were reported by Mhike *et al*. (2011a) who reported environmental differentials indicated that the environments were unique. The genotype × location interaction were significant for all traits except ASI under non-stress and severe stress, ear height under intermediate stress, number of ears per plant under both conditions and leaf senescence and grain yield under intermediate stress and severe stress. For that reason, suitable hybrids could be developed for specific environments. This was in agreement with the findings of Showemimo *et al.* (2000) who reported performance or expression of genes controlling maize characters to be strongly influenced by environmental variation.

The mean performances of the hybrids for the traits studied under non-stress, intermediate stress and severe stress at individual and across locations show similar trend. Generally, grain yield varied appreciably among crosses in each condition at

individual and across locations. Across the locations, under non-stress the top-ranking hybrid for grain yield was S3 x P2 and it out-yielded the check by 18%. Under intermediate stress, the top ranking hybrid for grain yield was S7 x P8 and out-yielded the check by 69%. Under severe stress, the top ranking hybrid for grain yield was S7 x P8 and it out-yielded the check by 90%. Overall, the grain yield was reduced by 45% and 70% under intermediate and severe stress conditions, respectively, of what the average yield would have been in the same environment under non-stress condition across the two locations. Similar results were reported by Betran *et al*. (2003a) who reported yield reductions of 13 and 50% under intermediate and severe drought stress, respectively, in one site and of 5 and 48% in another site during the same season. Banziger *et al*. (2000) also reported yield reductions under drought stress at flowering of 80-85% and under drought stress at grain filling of 50%. The reduced yield under water stress could be due to reduced plant height, ear height and number of ears per plant and increased days to 50% tasseling, days to 50% silking, anthesis-silking interval and leaf senescence.

5.2 Genetic Variability Parameters and Heritability

Effectiveness of selecting and assessing the potential worth of a genotype depends on the magnitude of genetic variability in a particular character. It is therefore necessary to study variability with respect to quantitative characters from components of variation. An assessment of heritable and non-heritable components of the total variability observed is indispensable in adopting suitable breeding procedure. The heritable portion of the observed variation can be ascertained by estimating the heritability. In this study, the phenotypic variances and PCVs were slightly higher than genetic variances and GCVs for all the traits under the different conditions, suggesting the least influence of

environment in the expression of the traits. Similar results have been reported by Bello *et al*. (2012). High values of both GCV and PCV were obtained for grain yield under the three conditions, leaf senescence under intermediate stress and severe stress at individual and across locations. High values of GCV and PCV were also obtained for ASI under non-stress and severe stress at Samaru and under non-stress and intermediate stress across locations and number of ears per plant under intermediate stress at Kadawa and severe stress at Samaru and across location. This indicates the presence of high variability for these traits and provides ample scope for selection of superior and desired genotypes which is in conformity with the findings of Abhirami *et al*. (2005) and Pradeepa (2007). On the other hand, very low values of PCV and GCV were recorded for days to 50% tasseling, days to 50% silking under the three conditions at individual and across locations and plant height under non-stress and severe stress at Samaru and across locations and number of ears per plant under severe stress across locations revealed that the variability among the genotypes was very low for these traits.

The most important function of heritability in genetic study of quantitative characters is its predictive role to indicate the reliability of the phenotypic value as a guide to breeding value (Al-Tabbal and Al-Fraihat, 2012). Estimates of broad-sense heritability were high for most of the traits studied under the different conditions at individual and across locations which indicates better opportunities for selecting plant material regarding these traits. The high broad-sense heritability obtained for most traits revealed that variations were transmitted to the progeny and indicated potential for developing high yielding varieties through selection of desirable plants in succeeding generations. These results were in agreement with those of Aminu and Izge (2012), Saleem *et al*. (2008) and Swati and Ramesh (2004). The broad sense heritability of anthesis-silking

interval, plant height, ear height, leaf senescence, and number of ears per plant increased with increasing drought stress, whereas, that of days to 50% tasseling, days to 50% silking and grain yield decreased with increasing drought stress. An increase in error variance under stress conditions has been reported to cause decrease in heritability estimates by Hulmel *et al*. (2005), which was similar to the results obtained in this study. Decreased heritability for these traits under stress conditions were reported earlier by Bolanos and Edmeades (1996). The decreased heritability for traits under stress indicates the need for selection of genotypes under specific environmental conditions for rapid genetic improvement.

Narrow sense heritability measures the proportion of phenotypic variance among individuals in a population that is due to heritable genetic effects while broad sense heritability measures the proportion of phenotypic variance that is attributable to an effect for the whole genotype, comprising sum of additive, dominance and epistatic effects (Nyquist, 1991; Falconer and Mackey, 1996). A high value of narrow sense heritability therefore, indicates that additive gene action is important for controlling the character, while a low value signifies non-additive gene influence. Moderate narrow sense heritability would mean that both additive and non-additive actions are important in influencing the expression of the character, and that an appreciable amount of additive effect exist for improvement. The relatively low narrow sense heritability estimates for most of the traits in this study under the different conditions are an indication that the studied traits are mainly controlled by non-additive genes. The best exploitation of this type of gene action would be in F_1 hybrids implying that breeding gains can be made through inbreeding then crossbreeding, with selection being made in later generations. Mhike *et al*. (2011a) reported heritability estimates that were above

50% for anthesis days; ear height, ASI and ear position and the rest were below 50%. The heritability estimates of grain yield reported in this study was lower than values reported by Bolanos and Edmeades (1996) (60% under optimal and 40% under drought conditions). However, the magnitudes of heritability estimates are products of the population being tested, environments within which the testing is done and traits being measured (Falconer and Mackay, 1996). To this end therefore the differences in magnitudes observed here are manifestations of the differences in these three determinants of the heritability estimates. It should, therefore, be understood that heritability values reported for a given trait, are specific to a particular population under particular conditions (Hallauer and Miranda, 1981). Hence, it would be better to evaluate genotypes in different target environments.

5.3 Correlation

The knowledge of correlation between traits of economic importance are not only of interest from theoretical consideration of quantitative inheritance of characters, but of practical value since selection is usually concerned with changing two or more traits simultaneously. In this study, significant negative correlations between grain yield with days to 50% tasseling, days to 50% silking and anthesis-silking interval under the different conditions were observed. These results indicate that an increase in any of these traits may results in a corresponding decrease in grain yield. These findings are consistent with the findings by other investigators (Betran *et al.*, 2003a; Gissa, 2008). The results further suggest that yield under stress can be improved by selecting for early tasseling, silk emergence and shorter anthesis-silking interval. Significant positive correlations between grain yield with plant height, ear height and number of ears per plant under the different conditions were observed in this study. These results show that an increase in any of these traits may results in a corresponding increase in grain yield

and therefore selection for these traits may result in improving grain yield. This report is consistent with the findings by Gissa (2008) and Bello *et al*. (2010).

5.4 Analysis of Variance for Design II and Combining ability Variances

The significance of mean squares of GCA_f and GCA_m for most of the traits reported in this study under the different conditions suggested the prevalence of additive variance for these traits. The significant SCA mean squares detected in this study under the different conditions suggested that dominance variance was important for these traits. These results are in general agreement with those reported by Aminu and Izge (2013) and Badu-Apraku *et al*. (2013). The fact that both additive and non-additive gene actions were important in genetic control of most traits studied under the different conditions means that there is tremendous amount of variability in the genetic materials evaluated, confirming the results of Aminu and Izge (2013), Bello and Olaoye (2009) and Olaoye *et al.* (2005). Even though, additive and non-additive gene actions were responsible in the genetic control of most traits, the comparative variance due to GCA and SCA revealed the predominance of non-additive gene action for majority of the traits. This corroborate with the findings of Mohammed (2009) and Meseka *et al*. (2006).

The ratio of GCA to SCA variance also portrays the importance and the predominance of non-additive genetic effects because the SCA variance was higher than the GCA variance and most of the ratios were less than unity, confirming the results of Aminu and Izge (2013), Majid *et al*. (2010). However, the results contradict the view reported by Sharma *et al*., (2004) who found the preponderance of additive genetic effects in the control of most traits in maize. The expression of the traits being controlled by

non-additive genes in this study has an implication in breeding in that good parent cannot be identified using these traits; instead good specific combiners are the ones that can be selected for. The inbred lines used in this study can therefore be exploited under drought conditions through targeting the SCA effects.

GCA_f x L, GCA_m x L and SCA x L were significant for grain yield and some other traits in across locations analysis in this study and results were consistent with the findings by other scientists (Gissa, 2008; Mhike *et al*., 2011b and Thokozile, 2012). It appears that G x E effects would present challenges in the breeding of materials for different environments. This highlights the need to use several environments in the estimation of genetic effects. Genetic component estimates based on data from single environment were found to be unreliable. Results show that GCA effects associated with the parents and SCA effects associated with crosses were not consistent over environments. Banziger *et al*. (2000) reported that stress environments produce high G x E interactions.

5.5 Combining Ability Effects

The GCA effects of parents under non-stress, intermediate and severe stress conditions exhibited variation both in direction and magnitude. The combining ability effects revealed that different parents were general combiners for different traits under different conditions. In this study negative GCA effects are desirable for traits such as days to 50% tasseling, days to 50% silking, plant height and ear height, while in the case of other characters like grin yield and number of ears per plant positive GCA effects are most desirable. The female inbred line S7 showed consistency in its performance exhibiting good GCA effects for grain yield under the three conditions across location.

This line was also a good general combiner for other traits including days to 50% tasseling, days to 50% silking, ear height and number of ears per plant under different conditions across locations. Minimum days to 50% tasseling, days to 50% tasseling are needed for crop early maturing while minimum plant height and ear height are required lodging resistance. Hence, it is the best general combiner.

On the other hand the male inbred line P8 was consistent in its GCA effects, again proving to be a good general combiner for grain yield and other traits across locations. The female inbred line S4 and male inbred lines P4 and P7 also showed good GCA effects in the desirable direction for most of the traits. These inbred lines (S7, S4, P8, P7 and P4) could be considered as good combiners for yield and most of the yield attributing traits under different conditions. These parents could therefore be utilized for the development of either synthetic varieties or an elite breeding population by allowing thorough mixing among them to achieve novel genetic recombination and the resultant populations could then be subjected to recurrent selection. These populations could invariably serve as a source of new desirable inbred lines.

Like GCA effects, SCA effects of hybrids under non-stress, intermediate and severe stress across location exhibited variation both in direction and magnitude. The hybrid (S7 x P8) was a good specific combiner as indicated by significant positive SCA effects for grain yield under the three conditions across locations. Other traits with significant SCA effect for the same hybrid were days to 50% tasseling under non-stress and severe stress, days to 50% silking under severe stress, ASI under intermediate stress and severe stress and number of ears per plant under non-stress and intermediate stress. Other hybrids with significant positive SCA effects for grain yield are S1 x P8 (non-stress and

severe stress), S2 x P4 (intermediate and severe stress), S1 x P2 and S6 x P7 (non-stress and intermediate stress). However, only S1 x P2 among them had additional significant and negative SCA effects for plant height under non-stress. The hybrids S7 x P1 expressed negative and significant SCA effects for days to 50% tasseling under the three conditions and days to 50% silking under intermediate and severe stress while S6 x P3 had negative and significant SCA effects for the same traits under non-stress and severe stress. Negativity of these traits is important, implying that these hybrids could mature earlier and could escape drought. Similar results were reported by Aminu and Izge (2013).

With regard to number of ears per plant only S2 x P8 showed positive and significant SCA effects under the three conditions. With respect to anthesis silking interval, S1 x P1 under intermediate stress and severe stress, S7 x P3 under intermediate stress had negative and significant SCA effects. Anthesis silking interval is a trait used mostly in screening for tolerance to stresses. It is a measure of nicking (synchronization) of pollen shed with silking. This report is in accordance with finding of Aminu *et al*. (2014). The hybrids S6 x P8 expressed significant negative SCA effect for plant height under the three conditions and ear height under non-stress conditions while S5 x P1 had negative SCA effect for plant height and ear height under severe stress. However, S4 x P3 had negative and significant SCA effects for plant height under the three conditions. Negative SCA effects in stress environments for plant height and ear height are desirable especially in drought prone and windy areas against drought and lodging. Similar results were reported by Aminu and Izge (2013) and Aminu *et al*. (2014).

This study revealed hybrids that were found with high and desirable SCA effects for different traits. Some of the superior hybrids were from both parents with high x high general combiners such as S7 x P8 or either one of the parents with high GCA effect (high x low or low x high) such as S6 x P7 and or parents that are low × low general combiners such as S1 x P2 for desirable agronomic traits including grain yield. The above crosses involved high x high and low x high combining parents. This was supported by Xingming *et al.* (2002), who reported the involvement of good parents in high yielding crosses. The superiority of average x low or high x low combiners as parents could be explained on the basis of interaction between positive alleles from good/average combiners and negative alleles from the poor combiners as parents. The high yield of such crosses or hybrids would be non fixable and thus could be exploited for heterosis breeding. The superior cross combinations involving low x low GCA could result from over dominance or epistasis (Hallauer and Miranda, 1988; Majid *et al*., 2010). Such type of gene action may be exploited in cross–pollinated crops like maize.

5.6 Heterosis

In this study, the degree of heterosis varied from hybrid to hybrid and from traits to traits. Both positive and negative heterotic values were recorded for all other traits studied. This study showed that great potentials for increased maize yield exist because of the high level of heterosis observed. The hybrids S6 x P4, S6 x P7 and S7 x P8 under non-stress, intermediate stress and severe stress respectively had superior high parent heterosis in respect to grain yield. High heterotic values are desirable for grain yield in maize. High heterotic values for grain yield have also been reported in maize by Aminu and Izge (2013) and Joshi *et al*. (2002). The low heterosis for desirable traits including grain yield was observed in S5 x P1 under non-stress, S5 x P7 under intermediate stress

and S5 x P4 under intermediate and severe stress. This could be attributable to similar genetic base of the materials used in the development of the parents. This result is in conformity with Saxena *et al.* (1998) who reported that hybrids produced from inbred lines having different origins tend to have greater yield levels than hybrids of parental lines originating from the same source population.

The highest positive and desirable heterotic effects in number of ears per plant were exhibited by S6 x P1, S5 x P3 and S7 x P2 under non-stress, intermediate and severe stress, respectively. The hybrids S7 x P2 under non-stress, S1 x P1 under intermediate stress, S5 x P8 under severe stress had high level of desirable negative heterosis for days to 50% tasseling while S5 x P1 had high level of desirable heterosis for days to 50% tasseling and days to 50% silking under intermediate stress. S7 x P8 had high level of desirable negative heterosis for days to 50% tasseling under severe stress and days to 50% silking under non-stress while S1 x P8 under non-stress and S6 x P4 under severe stress had high level of desirable negative for days to 50% silking. S5 x P7 under non-stress and severe stress and S5 x P2 under intermediate stress had high level of desirable negative heterosis for ASI. Negative heterosis are actually desirable for days to 50% tasseling, days to 50% silking and anthesis-silking implying that these hybrids would mature earlier and could escape drought. Negative heterotic values for these traits were reported by Aminu and Izge (2013).

S1 x P3 had high negative desirable heterosis for plant height and ear height under non-stress while S4 x P1 under non-stress and S4 x P2 under severe stress had high negative desirable heterosis for plant height. S2 x P4 under non-stress and S3 x P2 under severe stress also had high level of desirable negative heterosis for ear height. The

negative heterosis observed for plant height and ear height are desirable in breeding short statured hybrid that could resist lodging confirming the results of Aminu *et al*. (2014). The hybrids S3 x P8 and S5 x P2 exhibited the highest level of negative heterotic effects for leaf senescence under intermediate and severe stress. These hybrids which featured prominently in the expression of higher level heterosis could form an initial gene pool for further breeding programme in developing high yielding varieties for cultivation in the Nigerian savannas.

CHAPTER SIX

6.0 SUMMARY, CONCLUSION AND RECOMENDATIONS

6.1 Summary

The study was conducted to estimate the genetic variability, character association, combining ability, heritability and heterosis for grain yield and other traits in maize. The parental materials used comprised six drought tolerant inbred lines used as male parents and seven drought susceptible maize inbred lines used as female parents, which were crossed using North Carolina mating design II. The resultant 42 F_1 hybrids, 13 parents and a commercial check (Oba 98) were evaluated at Samaru and Kadawa under non-stress, intermediate and severe water stress environmental conditions in 2012/2013 dry season using simple lattice design with two replications under each condition.

Significant differences were observed for most of the traits studied under different conditions indicating the presence of appreciable variability within the genotypes, which is a pre-requisite for any crop improvement program. The significant genotype x location interaction observed for most of the traits studied indicated that suitable hybrids could be produced for specific environments. The top-ranking hybrids for grin yield were S3 x P2 under non-stress and S7 x P8 under intermediate stress and severe stress across locations, respectively. Overall, the grain yield was reduced by 45% and 70% under intermediate and severe stress conditions, respectively, of what the average yield would have been in the same environment under non-stress condition across the two locations. High values of both GCV and PCV were obtained for grain yield, leaf senescence, anthesis-silking interval and number of ears per plant under the different conditions indicating the presence of high variability for these traits and provide ample scope for selection of superior and desired genotypes. Estimates of broad-sense

heritability were high for most of the traits studied under the different conditions which revealed that variations could be transmitted to the progeny and further indicated the potential for developing high yielding varieties through selection of desirable plants in succeeding generations. The broad sense heritability of flowering traits and grain yield decreased with increasing drought stress which indicates the need for selection of genotypes under specific environmental conditions for rapid genetic improvement. The relatively low narrow sense heritability estimates for most of the traits in this study under the different conditions are an indication that the studied traits are mainly controlled by non-additive genes and so imply that breeding gains can be made through inbreeding then crossbreeding, with selection being made in later generations. The significant negative correlations between grain yield and flowering traits observed indicate that increase in any of these traits may results in a corresponding decrease in grain yield. The significant positive correlations between grain yield and plant height, ear height and number of ears per plant show that selection for them may result in improving grain yield.

Combining ability analysis showed that both additive and non-additive gene effects were important for the inheritance of most traits, which means that there is tremendous amount of variability in the genetic materials evaluated. The ratio of additive to dominance variance portrays that dominance variance was higher than the additive variance and most of the ratios were less than unity. GCA_f x L, GCA_m x L and SCA x L were significant for grain yield and some other traits across locations analysis indicating that G x E effects would present challenges in the breeding of materials for different environments. The female inbred lines S7 and P8 were the best general combiners for yield and flowering traits indicating that these parents could be useful in hybrid

breeding programme with a view to increase yield and early maturity. Other good general combiners for grain yield are S4, P7 and P4. S7 x P8 was a good specific combiner for grain yield, days to 50% tasseling, days to 50% silking under severe stress, ASI and number of ears per plant. Other good specific combiners for grain yield are S1 x P8 under non-stress and severe stress, S2 x P4 under intermediate and severe stress, S1 x P2 and S6 x P7 under non-stress and intermediate stress. It was observed that one or both of their parents were good combiners for desirable agronomic traits including grain yield except S1 x P2 with both parents that are poor combiners. S6 x P4, S6 x P7 and S7 x P8 under non-stress, intermediate stress and severe stress, respectively had superior high parent heterosis with respect to grain yield. These hybrids may be selected and improved for grain yield. They also showed negative heterosis for days to days to 50% flowering, days to 50% silking and ASI which are desirable in breeding for drought tolerance.

6.2 Conclusion

In conclusion, the study revealed that the greater the genetic variability, the higher would be the broad sense heritability, hence the better the chances of success to be achieved through proper selection. Most of the traits showed high heritability indicating considerable potential for development of drought tolerance and high yielding varieties through selection of desirable traits in succeeding generations. The decreased broad sense heritability of grain yield and flowering traits under drought reminds breeders about selection of genotypes under specific environmental conditions for better results. The higher values of both GCV and PCV obtained for grain yield, leaf senescence, ASI and number of ears per plant indicates that selection based on these traits would be possible. The correlations between grain yield and ear height, plant height and number

of ears per plant were positive and these traits may be considered as selection criteria for maize yield improvement under non-stress and water stress conditions.

The study also revealed that both additive and non-additive gene actions were important in controlling grain yield and other traits in maize under non-stress and water stress conditions, although non-additive gene action was more important in controlling these traits. The best exploitation of non-additive gene action would be in F_1 hybrids implying that breeding gains can be made through inbreeding then crossbreeding, with selection being made in later generations. Parents that exhibit high combining abilities (S7 and P8) could be more useful in hybridization programmes and vigorous F_1 are more useful to breeders than those with low combining abilities. Although parents that are best combiners did not always produce best hybrids combinations. For this reason, the complexity in predicting the productivity level of hybrids should require testing of specific parents combinations. Heterosis studies revealed a persistent heterotic performance of some hybrids within and across locations. So the performance of the hybrids was based on unrelatedness of the parents. The crosses, S6 x P4, S6 x P7 and S7 x P8 had the best level of high parent heterosis in grain yield and flowering traits. Desirable heterotic levels in days to silking and tasseling are of tremendous advantage in areas with marginal rainfall like the study areas.

6.3 Recommendations

Based on the results of this study, it is recommended that the female inbred line S7 and the male inbred line P8 are the best general combiners for grain yield and flowering traits. They are recommended for use to produce high yielding and early maturing hybrids. Considering mean performance, SCA and heterosis, S7 x P8, S6 x P7 and

S6 x P4 were best performing hybrids in grain yield and flowering traits. Therefore, recommended for further testing under various drought conditions at different locations for their drought tolerance and high yielding ability.

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