GENETIC ANALYSIS OF GRAIN YIELD AND OTHER AGRONOMIC TRAITS OF MAIZE (*Zea mays* L.) UNDER WATER STRESS AND NON-WATER STRESS CONDITION

BY

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APRIL, 2016

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DESSERTATION SUBMITTED TO THE SCHOOL OF POSTGRADUATE STUDIES, AHMADU BELLO UNIVERSITY, ZARIA IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE AWARD OF MASTER DEGREE IN PLANT BREEDING

DEPARTMENT OF PLANT SCIENCE,

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AHMADU BELLO UNIVERSITY, ZARIA

NIGERIA

APRIL, 2016

DECLARATION

I declare that the work in this thesis entitled 'GENETIC ANALYSIS OF GRAIN YIELD AND OTHER AGRONOMIC TRAITS OF MAIZE (*Zea mays* L.) UNDER WATER STRESS AND NON-WATER STRESS CONDITION' was carried out by me in the Department of Plant Science under the supervision of Prof. S.G. Ado, Prof. M.Y. Yeye and Dr. S.M. Bugaje. The information derived from literature has been duly acknowledged in the text and a list of references provided. No part of this dessertation was previously presented for another degree or diploma at any other institution.

Hadiza Ladi DAHIRU	....	....
Student	Signature	Date

DEDICATION

This research is dedicated to the Almighty Allah, my family, friends and to the entire human race.

CERTIFICATION

The thesis entitled 'GENETIC ANALYSIS OF GRAIN YIELD AND OTHER AGRONOMIC TRAITS OF MAIZE (*ZEA MAYS* L.) UNDER WATER STRESS AND NON-WATER STRESS CONDITIONS' by Hadiza Ladi DAHIRU meets the regulations governing the award of the Degree of Master of Science of Ahmadu Bello University Zaria, and is approved for its contribution to scientific knowledge and literary presentation.

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ACKNOWLEDGEMENTS

I thank Allah (SWT) for the knowledge and wisdom given to me and the ability to reach the end of this research work and His Holy Prophet Muhammad (SAW) who is forever a torch of guidance and knowledge for humanity as a whole.

I would like to thank Prof. S.G. Ado chairman of my supervisory team for sharing his expertise and for guiding me through out the research. He is a gifted advisor and I am pleased to have had the opportunity to study under his supervision. Prof. M.Y. Yeye has been a valuable mentor and role model. She was always available for consultation on issues related to the dessertation. Sincere thank is extended to Dr. S.M. Bugaje for his advice throughout this research. I would like to specialy thank Dr. A. Usman for his guidance, expertise, advice and the generosity shown to me during my studies and Dr. M. Oyekunle for his useful advice. My thanks also goes to the entire staff of Maize Improvement Unit in Samaru and Kadawa especially Alhaji Bashir Muhammad and his casual workers for the technical help rendered to me throughout my field work. My special gratitude goes to my partner in fieldwork Umar Umar Uwais for his endurance and countless help in completing this dessertation.

My sincere gratitude goes to my late father, Alhaji Dahiru Maikano and my mother Hajiya Hajiya Habiba Dahiru for thier parental advice, support, prayers and guidance. I am highly indebted to my brothers, sisters and their families for their prayers and always being there for me. My special appreciation goes to my husband and children for the patience and understanding given to me throughout my studies. I would like to appreciate my friends for their friendliness and prayers in the course of this study. I would also like to thank my classmates for their help and advice. I also acknowledge the International Institute of Tropical Agriculture Ibadan and the Institute for Agricultural Research Samaru for providing me with the testers and the varieties, respectively.

ABSTRACT

The study was set out to estimate heterosis, combining ability, heritability, gene action and correlation of grain yield and other agronomic traits under water stress and non-water stress conditions. Seven maize varieties were crossed to six inbred lines resulting in 42 top cross hybrids. The 13 parents, 42 hybrids and a check were evaluated for drought tolerance under water stress and non-water stress conditions at the Institute for Agricultural Research Station farms at Samaru and Kadawa during 2012/2013 dry season. Data were collected for number of days to 50% tasseling (DT), number of days to 50% silking (DS), anthesis-silking interval (ASI), plant height (PHT), ear height (EHT), leaf senescence (SEN), number of ears per plant (NEP) and grain yield (GY). Among the top cross hybrids, Sammaz 34 x P2 recorded the highest GY (2030.99kg/ha) which was 44.6% higher than the check under non-water stress condition and 143% increase relative to the check under severe-water stress condition. Sammaz 34 x P2 and Sammaz 36 x P2 recorded highest GY estimates under severe-water stress condition across locations (2031kg/ha and 1495kg/ha, respectively). All the traits recorded higher values of phenotypic coefficient of variation than genotypic coefficient of variation under the three different water stress conditions in both locations and across locations. This indicates presence of high variability for these traits and provides ample scope for selection of superior genotypes. Broad sense heritability estimates generally ranged from moderate to high in both locations and across locations under the three different water stress conditions indicating considerable potential for development of drought tolerant and high yielding varieties. The ratios of general combining ability to specific combining ability variances across locations were less than unity for all the traits under the three conditions indicating importance of non-additive gene action in controlling these traits. The results revealed that Sammaz 17 was a good general combiner among

the seven female parents while P3 was a good general combiner for GY among the male parents under water stress condition across locations. The top cross hybrid Flint Q x P8 which involved parents with high x low general combining ability effects was promising as it had highly significant positive heterosis for GY (181.48%) under severe-water stress condition and also exhibited positive specific combining ability status for GY (134.92) under severe-water stress conditions across locations. Correlations with grain yield showed that DT, DS and ASI were negatively correlated with GY while PHT, EHT and NEP were positively correlated with GY under the three water stress conditions. This indicates that corresponding increase in GY can be achieved through selection of the positively correlated traits under both non-water stress and stress conditions across locations. Molecular approaches which offer exciting ways of shortening the time for variety development is recommended along with the conventional breeding strategies to develop drought tolerant hybrids.

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ABBREVIATIONS

Analysis of variance	ANOVA
Anthesis-silking interval	ASI
Critical difference	CD
Coefficient of variability	CV
International Maize and Wheat Improvement Centre	CIMMYT
Drought Tolerant Maize for Africa	DTMA
Days to 50% silking	DS
Days to 50% tasseling	DT
Ear height	EHT
General combining ability	GCA
Genotypic coefficient of variability	GCV
Generalized linear model	GLM
Grain yield	GY
Institute for Agricultural Research Samaru	IAR
International Institute of Tropical Agriculture	IITA
Intermediate-water stress	IS
North Carolina Design II	NCDII
Number of ears per plant	NEP
Non-water stress	NS
Phenotypic coefficient of variability	PCV
Plant height	PHT
Quality Protein Maize	QPM
Specific combining ability	SCA
Leaf Senescence	SEN
Severe-water stress	SS

Weeks after planting	WAP
Water Efficient Maize for Africa	WEMA
Variance due genotypes	$\sigma^2 g$
Variance due phenotypes	$\sigma^2 p$
Variance due to general combining ability	$\sigma^2 GCA$
Variance due to specific combining ability	$\sigma^2 SCA$
Broad sense heritability	$h_b\%$
Narrow sense heritability	$h_n\%$
Standard error	±SE

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background

Maize (*Zea mays* L.) is a cross-pollinating plant with the female (silk) and male (tassel) flowers bound on two separate positions of the plant.Maize belongs to the grass family Poaceae and it is an annual plant. Maize stems resemble bamboo canes (Hari, 2011). Maize, whose origin is controversial, is said to have originated from Central America and Mexico (where it is known as corn) through domestication of the wild grass teosinte (*Zea mexicana),* being the closest wild relative of maize (Paliwal and Smith, 2002). It is a preferred staple food for about 900 million poor consumers and about one third of all malnourished children (Laurence and Peters, 2012). Maize has been in the diet of Nigerian's for centuries and it is consumed by both human and animals in many different ways as ground or pounded, baked or fried, boiled or fermented. It is a basic raw material for the production of starch, oil, protein, alcoholic drinks, beverages, food sweeteners and more recently fuel (Laurence and Peters, 2012). The dried grain can also be used in the production of livestock feeds as well as an important component of food, beverages, alcoholic drinks, cosmetics, pharmaceutical products and construction materials (Yitbarek, 1996).

Maize is grown in diverse regions and climates from 58^{o}north latitude in Canada and Russia to 40^{o}south latitude in South America with growing cycles ranging from 3 to 4 months. The spread of maize cultivation in the world was due to its high adaptability and versatility resulting from its diversity of types and the reasons for its popularity include its ability to withstand both biotic and abiotic stresses (Iken and Amusa, 2004). Maize is the most widely grown crop after wheat and rice. It is a principal agricultural commodity in the world with 844 million tonnes of production in 2010 with an average yield of more than 3t/ha (FAOSTAT, 2013). The average Africa's maize yield stood at 1.3t/ha compared to 3.0t/ha elsewhere (FAO, 2006). Nigeria's production in 2010 was estimated as 7.3 million tonnes with an average yield of 1.5t/ha (FAOSTAT, 2013).

Drought may be defined as periods in the natural cycle of stress and renewal during which the amount of moisture in the soil no longer meets the needs of a particular crop. Drought occurs frequently in the dry lands, not particularly because, average rainfall is low, ranging across locations and years from an average of 300-800mm per annum, but also because it may be erratic, with torrential storms during the cropping season, followed by long dry spells. Drought is second only to soil infertility as a constraint to maize production in developing countries. It is the major abiotic stress that adversely result in plant morphological, physiological and metabolic changes that occur as a result of loss of water and nutrients uptake into organs of the plants which directly affect the plant's performance. It was estimated that one quarter of the global maize grown area is affected by drought in any given year (Heisey and Edmeades, 1999). Additional constraints causing significant yield and economic losses in maize production annually include pests and diseases. It is therefore difficult to give an accurate figure on combined maize yield losses due to these stresses (Iken and Amusa, 2004).

1.2 Statement of the Problem

Achieving the Millennium Development Goals is the most serious challenge in rain-fed stress-prone environments where communities are confronted by poor market access, erratic rainfall and soil degradation. Tropical maize growing environments are affected by a wide range of stresses worsened by variable weather conditions, infertile and acidic soils, lack of inputs, labour shortages for other control methods, and soil degradation. Indeed maize yields in most low and middle income countries are far from economically attainable yields due to a wide range of abiotic and biotic stress factors and yield increases are therefore related to increasing the stress tolerance of new varieties. Possible climate change due to global warming could further increase the chances of drought as competition for water intensifies between human and crops. Therefore, the importance of finding genetic approaches which can stabilize and increase crop productivity in the face of climate change and increasing water scarcity should be widely acknowledged.

1.3 Justification

As steward of the world's maize genetic resources, International Maize and Wheat improvement Centre (CIMMYT) provides through some Project an effective access path for identifying and availing new sources of drought tolerance. The Center's accumulated maize research and breeding materials targeting stress environments are regarded as successes. International Institute of Tropical Agriculture (IITA) and Institute for Agricultural Research (IAR) Samaru and private seed companies are engaged in scale up of seed production and demonstrations and in some instances Non Governmental Organizations (NGOs) are also engaged in seed relief i.e., sourcing of seed of drought tolerant maize varieties from collaborating seed companies. Collaborative regional projects such as, Drought Tolerant Maize for Africa (DTMA), Water Efficient Maize for Africa (WEMA), greatly assist in knowledge transfer and more effective germplasm use and deployment. The hybrid maize project has made an impact in Nigeria. The yield advantages of hybrids appear to be sufficiently large to attract the attention of farmers. Improved high yielding maize variety can express its full genetic potential only when offered optimum resource management.

Therefore, to contribute to food and income security and better use of scarce resources (water, nutrients, labor, and land), in particular as climate change increases the area and frequency of unfavorable production conditions, incorporation of stress tolerance in germplasm with increasing yield potential is core to achieving maize productivity increases in low and lower middle income countries. This will also help to increase food and income security for resource poor farm families, decrease vulnerability to recurrent droughts and climate change, decrease need for food aid and irrigation water. Developing hybrid varieties that are drought tolerant would increase yields more than the open pollinated varieties. It is therefore, pertinent to develop and evaluate top cross-hybrids using adapted varieties and inbred lines.

1.4 Objectives

This study was set out:

1. To determine the mode of gene action in top'cross hybrids under non-water stress and water stress conditions.

2. To determine correlation of agronomic traits under non-water stress and water stress conditions.

3. To identify the best drought tolerant top'cross hybrids under water stress and non-water stress conditions.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Drought

Drought is a water deficit in the plant's environment that has the potential to reduce crop yield (Cooper *et al*., 2006). In water deficit conditions plant water potential and turgor are reduced enough to interfere with normal functions. When the deficit occurs before the crop is fully developed, it can also reduce vegetative growth. The negative impact of drought depends mainly on the timing, duration and intensity of the stress. However, the occurrence of natural drought is largely unpredictable, making it difficult or almost impossible to distinguish between water-limited and non-limited agricultural systems (Cooper *et al*., 2006). The unpredictability of drought events implies that improved genotypes should perform well not only under water-limited conditions but also when rainfall is adequate. The use of genetics to improve drought tolerance is important for stabilizing global maize production, although genetic improvements are unlikely to close more than 30 % of the gap between potential and realized yield under water stress (Edmeades *et al*., 2004).

Drought affects maize at different stages of development starting from crop establishment up to grain filling. Grain yield is affected to some degree at almost all growth stages; however, the crop is more susceptible during flowering (Banziger *et al*., 2000). Studies on the timing of drought stress have indicated that flowering is the most sensitive stage for yield determination in maize, and losses in grain yield and kernels per plant can exceed 50% when drought coincides with this period (Grant *et al.*, 1989). It is common for drought imposed at flowering to lengthen the anthesis-silking interval (ASI) (Bolanos and Edmeades, 1993). This is usually caused by a delay in silk emergence relative to emergence of the anthers, the latter being little affected by drought (Westgate and Boyer, 1986).

Delayed silk emergence may be due to reduced rate of silk elongation, a process that is strongly affected by water status (Westgate and Boyer, 1986). Extreme sensitivity seems confined to the period -2 to 22 days after silking, with a peak at seven days. Almost complete barrenness can occur if maize plants are stressed in the interval just before tassel emergence to the beginning of grain fill (Grant *et al*., 1989). Banziger *et al.* (2000) reported that drought can affect maize production by decreasing plant population during the seedling stage, by decreasing leaf area development and photosynthesis rate during the pre-flowering period, by decreasing ear and kernel set during the two weeks bracketing flowering, and by decreasing photosynthesis and inducing early senescence during grain filling. Additional reduction in production may come from increased energy and nutrient consumption of drought adaptive responses, such as increased root growth under drought. While irrigation could relieve smallholder farmers from the harsh effects of drought, land under irrigation in sub-Saharan Africa still constitutes a small fraction (7%) of cultivated land (Larsson, 2005).

2.2 Variability, Heritability and Other Genetic Parameters

Variability expressed by a genotype or a group of genotypes in any species can be portioned into genotypic and phenotypic components. The genotypic components being the heritable part of the total variability, its magnitude on yield and its component characters influences the selecting strategies to be adopted by the breeder. Fischer and Turner (1978) partitioned the total genetic variance into additive genetic variance, which is the sum of additive genetic variances contributed by individual loci,' dominance variance component which results from intra allelic interaction of genes at segregating loci and epistatic variance results from inter allelic interaction of genes at segregating loci. Hayman (1958) partitioned epistatic variance into additive × additive, additive × dominance and dominance × dominance components for two loci.

Lush (1940) defined heritability in both broad sense and narrow sense. In broad sense, heritability refers to the functioning of the whole genotype as a unit and is used in contrast with the environmental effects. In the narrow sense, heritability largely includes only the average effect of genes transmitted additively from parent to off spring. Warner (1952) suggested different techniques for estimating the degree of heritability in crop plants which is based on parent offspring regression, variance components from analysis of variance and approximation of non-heritable variance from genetically uniform population to estimate the total genetic variance. Comstock (1955) reported that phenotype associated with a given genotype varies with the environment. This leads to complete inconsistency of genotypic value, a different value of a given genotype relative to every variance of environment major or minor. Lonnquist (1964) reported that phenotype of a quantitative character was mainly due to the joint action of genotype and environment. Debnath and Azad (1993) studied a total of 25 varieties of maize which were grown in four (4) environments during 1987-88 and evaluated for five (5) yield components. Analysis of variance revealed significant genotype x environment interactions for all characters. Components of variance, genetic advance and broad sense heritability for each character were calculated for all environments and were shown to be higher than values obtained from a combined analysis after elimination of the genotype × environment interaction component. Heritability estimates were highest for ear height in all environments after the removal of the interactive effects. Abhirami *et al.* (2005) reported that genetic variance, heritability and genetic advance were studied in forty maize genotypes based on the data recorded on 20 quantitative traits and five biochemical characters. For all the characters studied, phenotypic variance was slightly higher than the genotypic variance. Genotypic and phenotypic coefficients of variance were higher for total sugar content, plant yield, weight of cob, oil content and ear height. Heritability estimates were high for all the characters investigated. High heritability coupled with high genetic advance was observed for number of grains per cob. Badu-Apraku *et al*. (2004) estimated heritability for drought adaptive traits and genetic correlations among them. Narrow sense heritability for ASI was 23% in non-water stress and ranged from 22% to 51% in stress environments, while the heritability for days to anthesis was 30% in non-water stress environments and ranged from 34% to 52% in stress environments. Ud-Din *et al*. (1992) estimated genetic parameters for grain production in drought stress and irrigated environments in a winter wheat population. They found that genetic variance for grain yield was greater in the irrigated environments than in the stress environments. They reported that the error variances were higher than genetic variances in drought-stressed and irrigated environments. Ud-Din *et al*. (1992) reported low genetic correlation between grain yields in drought-stressed and irrigated environments. The heritability estimates for grain yield in the irrigated environment was slightly higher than that in the dry land environment.

2.3 Combining Ability and Gene Action

Combining ability cannot be predicted from the parental phenotype and is assessed by progeny testing from controlled pollinations. It was initially a broad notion considered jointly for categorising an inbred line in relation to its hybrid performance, but was later refined as general combining ability (gca) and specific combining ability (sca). This had a major influence on inbred line evaluation and population development in maize breeding (Sprague and Tatum, 1942). Sprague and Tatum (1942) defined gca as the average performance of a line in hybrid combination and sca as those cases where some hybrid combinations are either superior or inferior than would be expected on the average performance of the parental inbred lines. In combination with hybrid performance sca effects and gca effects of particular parents should be used for selection (Shukla and Pandey, 2008).

The gca effects component is primarily a function of additive gene action while sca effect is mainly a function of dominance genes. Evaluation of gca effects of hybrid parents is essential to critic their appropriateness for hybrid development, since the mean performance of parental lines does not always translate to their gca effects. gca and sca effects are important tools used by breeders in selecting superior parents for developing crosses (Shukla and Pandey, 2008). Favourable alleles are combined through hybrid combination with high *per se* performance with good sca estimates and having at least one of the parents with high gca (Marilia *et al.*, 2001). In choosing ideal parents and crosses and to estimate the combining abilities of parents in early generations, plant breeders use the line x tester analysis method. Line x tester analysis provides an efficient approach for identification of suitable parents and crosses exhibiting good performance in traits under consideration (Ahuja and Dhayal, 2007).

The gca and sca variances are used to deduce gene action. It is defined as the way genes express themselves in which case gca effects represent additive gene action, whilst sca effects represent non-additive gene action.

Several mating designs have been used for estimating gene action amongst them the North Carolina Design II (NCDII) (Comstock and Robinson, 1948). The NCDII crosses are used for defining the cumulative gene effects of breeding populations and for estimating gca and sca effects. It is critical to understand gene action for grain yield and other secondary traits so that effective breeding strategies are developed for stress tolerance breeding without compromising on yield. Betran *et al*. (2003a) reported additive gene action being more important under drought conditions and non-additive gene action being important under low N conditions. Their results suggested potential benefits of incorporating drought tolerance in both parental inbred lines in order to enhance performance of hybrids under drought conditions. A higher specific combining ability variance compared to general combining ability was reported by Devi and Singh (2011), suggesting that non-additive gene action played a more important role in determining grain yield. Amount of heterosis realised in a cross depends among other things on the differences of gene frequency between the crossed lines (Falconer, 1981). Once ideal parents are identified it is important to assess the levels of heterosis and possible heterotic relationships among them.

2.4 Heterosis

Heterosis is the genetic expression of the superiority of a hybrid in relation to its parents (Miranda-Filho, 1999). This phenomenon is the opposite of inbreeding depression in that 'hybrid vigor' manifests in increased size, or other parameters resulting from the increase in heterozygosity in the F_1 generation of crosses between inbred lines (Sprague, 1983; Duvick, 1999; Miranda-Filho, 1999). When dealing with populations, inbreeding depression is an intra-population effect, while heterosis is expressed at the inter-population level. Many authors pointed out that genetic divergence between parents and non-additive genetic effects are required for heterosis expression (Hallauer and Miranda-Filho, 1988; Miranda-Filho, 1999). Although two major theories (dominance and over-dominance) of heterosis have been proposed, mechanisms underlying the phenomena are largely unknown (Hallauer and Miranda, 1988; Coors, 1999; Tsaftaris *et al*., 1999). In general, based on parents used, two major types of estimation of heterosis are reported 1) Mid-parent or average heterosis (MPH), which is the increased vigor of the F_1 over the mean of two parents; 2) High-parent or better parent heterosis (HPH), which is the increased vigor of the F_1 over the better parent (Sinha and Khan, 1975; Jinks, 1983). For HPH, the term heterobeltiosis has been suggested to describe the increased performance of the hybrid over the better parent (Fonseca and Patterson, 1968).

Maize hybrids typically yield two to three times as much as their parental lines. Hybrids are superior not only due to heterosis but also due to other heritable factors that are not influenced by heterosis. Heterosis is also modified by the interaction between genotypes and environment (Duvick, 1999; Chapman *et al*., 2000). Since inbreds are more sensitive to environmental differences, some traits have been found to be more variable among inbreds than among crossbreds (Falconer, 1989). Similarly, Jinks (1983) indicated that if homozygous and heterozygous genotypes respond differently to environmental change, the magnitude of heterosis would vary with the environment. Heterosis is dependent not only on the parent combinations but also on the effect of environmental conditions and species as well as the trait under consideration (Young and Virmani, 1990; Chapman *et al*., 2000). Young and Virmani (1990), for their particular study, reported that the extent of heterosis in rice was higher in a stress environment than in a favorable environment. For temperate maize, yield gains in hybrids are always accompanied by improvement in tolerance to biotic and abiotic stresses, and that improvement occurred in parental inbreds as well as in their hybrid progeny. Similarly for tropical maize, Betran *et al*. (2003b) reported extremely high expression of heterosis under stress, especially under severe drought stress because of the poor performance of inbred lines under these conditions. It is generally considered that inbred lines with superior yields under drought will result in superior hybrids under these stresses, even though their correlations are relatively weak (Vasal *et al*., 1992).

2.5 Correlation under Drought

Correlation is the proportion of variance that two traits share due to genetic causes. Genotypic and phenotypic correlations are important in determining the degree to which various yield contributing characters are associated. Several workers reported positive correlation of grain yield under drought conditions with root weight, root volume, root number and root length (Beck, 1986). High positive correlation was observed between 100-grain weight and grains per cob (Satovic, 1975). Singh and Nigam (1977) reported positive correlation of grain yield with 500-grain weight, grains per cob, cob length and cob girth. Schoper (1986) reported positive correlation of 500-grain weight with days to pollen shedding and negative correlation with interval between silking and pollen shedding and days to 75 per cent silking. Hemalatha Devi (1986) observed association of grain yield per plant with plant height, ear height, ear length, ear diameter and 100 grain weight under drought. Significantly positive association of yield was observed with 100-grain weight, ear height, plant height and canopy-air temperature difference but negatively correlated with days to 50 per cent silking, days to 50 per cent tasseling and anthesis-silking interval (Arefi, 1993).

Krishnan and Natarajan (1995) reported high positive correlation of grain yield with plant height, ear height, ear weight, number of kernels per row, dry matter production and harvest index. Path analysis revealed that selection on any trait in maize will influence the grain yield only through dry matter production. Bolanos and Edmeades (1996) observed genetic correlations between grain yield and kernels per plant of 0.86 to 0.88 under severe flowering drought stress. Similar results were reported by Otegui *et al.* (1995). Chapman and Edmeades (1999) reported that grain yield was strongly associated with grain number per square metre in both water stressed and well watered environments. Under drought, grain yield, cobs per plant and grain number per fertile ear were strongly associated with ASI. Edmeades *et al.* (1999), while reporting the improvement of drought tolerance in three late maturing tropical maize populations subjected to three cycles of S_1 recurrent selection indicated that stem biomass was negatively correlated with harvest index. Monneveux *et al.* (2006) reported that in two drought tolerant populations significant yield gains in the populations were associated with significant increase in number of cobs per plant and grains per ear and significant reductions in anthesis to silking interval, ovule number and abortion rate during grain filling. Association is assessed by correlation since correlation is a measure of association between two variables if the association is positive or negative or no association. Relationship is assessed by regression to predict the dependent variable when the independent variable is known as it has prediction capability.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Geographical Locations of the Experimental Sites

The research was carried out at the Institute for Agricultural Research (IAR), Ahmadu Bello University (A.B.U), Samaru-Zaria, Kaduna State (11^{o}11'N latitude, 07^{o}38'E longitude with an altitude of 686m above sea level, relative humidity 10am 50% and 4pm 34%, air temperature 34^{0}C Max and 21^{0}C Min, earth temperature(30$_{cm}$) 10am 27^{0}C and 4pm 28^{0}C, Sunshine(hour)6, wind speed(km/day) 105, total rainfall 3mm and open pan evaporation 7mm/day), situated in the Northern Guinea Savannah zone of Nigeria. The second site was the Irrigation Research Station of IAR/ABU, Kadawa, Kano State (11^{o}39'N latitude, 08^{o}26'E longitude with an altitude of 496m above sea level, relative humidity 10am 52%, air temperature 36^{0}C Max and 22^{0}C Min, Sunshine (hour)9, wind speed(km/day) 92, total rainfall 0mm and open pan evaporation 8mm/day) situated in the Sudan Savannah zone of Nigeria (IAR Metrological Data office).

3.2 Description of the Plant Materials

The plant materials for the study comprised of seven varieties of maize used as females and six drought tolerant inbred lines designated as P1, P2, P3, P4, P7 and P8 used as male parents. The varieties were obtained from IAR, Samaru and the male inbred lines were obtained from International Institute of Tropical Agriculture (IITA), Ibadan. The parents and their descriptions are presented in Table 3.1.

3.3 Development of Top Cross Populations

Both males and females were sowed in a staggered manner of one week interval to synchronize flowering for efficient pollination. The females were pollinated with the pollen from the males using North Carolina Design II method (Kempthorne, 1957), resulting in 42 Top cross hybrids. Pollination was controlled by covering the tassels and silks to avoid genetic contamination.

3.4 Evaluation of Populations

The 56 genotypes including 42 Top cross hybrids, 13 parents and a commercial check (Oba 98, Quality protein maize obtained from Premier Seed Company) were evaluated during the dry season of 2012/2013. The 56 entries were laid in a 7 x 8 lattice design with two replications in two locations. In each experimental field, lines and hybrids were evaluated separately in adjacent experiments to eliminate the effects of differences in vigor between inbreds and hybrids. The experimental fields were harrowed and ridged after which sowing was done on the 16th and 18th of February, 2013 at Kadawa and Samaru, respectively. Each entry was planted in a 3m row plot spaced at 0.75m interspacing and 0.25m intraspacing. The sowing was done by hand dibbling of two seeds per hill and the plots were immediately irrigated. The plants were thinned to 1 plant per hill after emergence. Fertilizer was applied at the recommended rates (120kg N/ha, 60kg P_2O_5/ha and 60kg K_2O/ha) per hectare using NPK 15:15:15 compound fertilizer at two and four weeks after sowing (WAP) while the remaining 60kg of N was also side placed at four weeks after sowing using Urea (46% N).Weed control was done manually three times at each location at 2, 4 and 6 weeks after sowing.

Table 3.1.Origin and descriptions of maize varieties and lines used in the studies

Varieties/Lines	Pedigree	Source	Parent	Response to drought
Sammaz 17	(Acr Sakatifu QPM-Y-S-S-S-S-S)	IAR	OPV, female	Susceptible
Sammaz 18	(Tillering Maize-S-S-S-S-S)	IAR	OPV, female	Susceptible
Sammaz 19	(S.14 DKD-DT-S-S-S-S-S)	IAR	OPV, female	Tolerant
Sammaz 34	(Multi-cob early TZEComp3-DT-S-S-S-S-S)	IAR	OPV, female	Tolerant
Sammaz 36	(Cm 2007 pool QPM-Y-S-S-S-S-S)	IAR	OPV, female	Susceptible
Dent Q	Dent	IAR	OPV, female	Susceptible
Flint Q	Flint	IAR	OPV, female	Susceptible
P1	(P43SRC9FS100-1-8-#1-B1-13-B1-B8)	IITA	Inbred line, male	Tolerant
P2	(1368×H1×4269-1×1368-7-2-B5)	IITA	Inbred line, male	Tolerant
P3	(9071-B-3)	IITA	Inbred line, male	Tolerant
P4	([TZM1501×K41414×501]-1-4-3-1-B-8)	IITA	Inbred line, male	Tolerant
P7	(1368×1CAL224-1×1368-3-1-B-11)	IITA	Inbred line, male	Tolerant
P8	(TZL-COMP3-C2-S2-34-4-1-2-B-7)	IITA	Inbred line, male	Tolerant
Oba 98(Commercial check)	(PH-6-QPM)	Premier Seed Company	Hybrid	Susceptible

The experimental field was divided into three blocks with three irrigation regimes at each location. Block 1 was non-water stress, Block 2 was intermediate-water stress and Block 3 was severe-water stress. The three blocks were separated from one another by 2.5m alley to prevent spill-over of water from the non-water stress block to the water stress blocks during the period of imposed stress. The replications were also separated by 1m alley and on both sides of the experimental fields non-experimental varieties were raised to minimize edge border effects. All the blocks received uniform recommended agronomic and cultural practices. Irrigation was applied to field capacity once a week to all the 3 blocks for 5 weeks (35 days) after sowing prior to the imposed water stress period.

Block 1 (Non-water stress (NS)): regular irrigation was carried out until physiological maturity.

Block 2 (Intermediate-water stress (IS)): water stress was imposed by withdrawing irrigation 6 weeks after sowing until the end of the growing season to ensure water stress at grain filling stage. The crop was allowed to reach physiological maturity by depending on stored soil moisture.

Block 3 (Severe-water stress (SS)): water stress was imposed by withdrawing irrigation 5 weeks after sowing to ensure water stress at flowering stage according to Banziger *et al*. (2000). The crop was allowed to reach physiological maturity, by depending on stored soil moisture.

3.5 Data Collection

Data were measured on the following traits:

1. Days to 50% tasseling (DT): this was recorded as the number of days from sowing to the date 50% of the plants in a plot have emerged tassels.

2. Days to 50% silking (DS): this was recorded as the number of days from sowing to the date when 50% of the plants in a plot have emerged silks.
3. Anthesis-silking interval (ASI): this was calculated as the difference in number of days between 50% silking and 50% tasseling.
4. Plant height (PHT) (cm): this was measured from six (6) random plants per plot from the base of each plant to base of tassel with a metre rule and the average recorded.
5. Ear height (EHT) (cm): this was measured from six (6) random plants per plot from the base of plant to the node which bears the upper most ear with a metre rule and the average recorded.
6. Leaf Senescence (SEN): Visual scores of leaf senescence from the lower leaves to the middle leaves were taken in each plot on two occasions 7 days apart during the latter stage of grain filling (72 and 79 days after sowing) on a scale of 0 to10 (dead leaf area) 0 = 0%, 1= 10%, 2 = 20%, 3= 30%, 4 = 40%, 5 = 50%, 6 = 60%, 7 = 70%, 8 = 80%, 9 = 90% and 10 =100% dead leaf area in the intermediate-water stress and severe-water stress blocks according to Banziger *et al*. (2000).
7. Number of ears per plant (NEP): this was obtained by counting the number of ears harvested from each plot divided by the number of plants harvested.
8. Grain yield (GY) (kg/ha): Harvested cobs were threshed and weighed per plot and then converted to yield per hectare using the following relation:

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

where: Plot area = Inter-row spacing x Length of row

Inter-row spacing = 0.75m; Length of row = 3.00m

Plot area = 0.75m x 3.00m = 2.25m^2

3.6 Statistical Analyses

3.6.1 Analysis of variance

Data collected were subjected to Analysis of variance (ANOVA) using the generalised linear model (GLM) procedure of the Statistical Analysis System (SAS Institute Inc.2008). Means were compared using standard errors. 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, respectively.

For individual location, variance components were computed from mean squares according to the formula given by Lush (1940) and Chaudhary and Prasad (1968) as follows:

$$\sigma_g^2 = \frac{M_g - M_e}{r}$$

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

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

Table 3.2. Form of ANOVA and Expected Mean Squares for one location

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

where: df = degree of freedom, M_g= Mean squares due to ge notypes

MS = Mean squares, M_e = error mean squares,

EMS= Expected Mean squares σ_g^2 = genotypic variance,

r = number of replications, σ_e^2 = error variance,

b = number of blocks, σ_{ph}^2 = phenotypic variance

g = number of genotypes,

For the combined locations, variance components were computed from mean squares according to the formula given by Lush (1940) and Chaudhary and Prasad (1968) as follows:

$$\sigma_g^2 = \frac{M_g - M_{gl}}{rl} \qquad \sigma_e^2 = M_e/rl$$

$$\sigma^2_{gl} = \frac{M_{gl} - M_e}{r} \qquad \sigma_{ph}^2 = \sigma_g^2 + \sigma_{gl}^2 + \sigma_e^2$$

Table 3.3. Form of Combined ANOVA and Expected Mean Squares across locations

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

where

l= number of locations,

r = number of replications,

b= number of blocks,

g = number of genotypes,

M_g = mean squares due to genotypes,

M_{gl} = mean squares due to genotype x location,

M_e = error mean squares,

σ_g^2 = genotypic variance,

σ_{gl}^2 = genotype x location variance,

σ_e^2 = error variance

σ_{ph}^2 = phenotypic variance

3.6.2 Estimation of genetic and phenotypic variability parameters and heritability

The genetic components of variance *viz.*, phenotypic and genotypic variances were used for the estimation of phenotypic coefficient of variability (PCV) and genotypic coefficient of variability (GCV) according Singh and Chaudhary (1985):

a. Phenotypic coefficient of variation (PCV) = $\frac{\sqrt{\sigma^2_{ph}}}{\overline{X}} x100$

b. Genotypic coefficient of variation (GCV) = $\frac{\sqrt{\sigma^2_{g}}}{\overline{X}} x100$

where: σ^2_{ph} = Phenotypic variance σ^2_{g} = Genotypic variance

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

GCV and PCV values were categorised as low (0 – 9 %), moderate (10 – 20 %) and high (> 20%) as indicated by Siva-Subramanian and Menon (1973).

c. Broad sense heritability as a ratio of genotypic variance to phenotypic variance was calculated according to Mohammed and Rasheed (2011).

$$\text{Broad sense heritability } (h_b\%) = \frac{\sigma^2{}_g}{\sigma^2{}_{ph}} x100$$

where: $\sigma^2{}_g$ = Genotypic variance σ^2_{ph} = phenotypic variance

3.6.3 Analysis of variance for North Carolina Design (NCD) II

In the ANOVA for NDCII, hybrids were partitioned into female, male and female x male mean squares for each location and combined across locations. The analysis for design II for one location was based on the following statistical model:

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

Where: Y_{ijk} = observation made on ixj^{th} progeny in the k^{th} replication

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

f_j = effect of the j^{th} female

$(fm)_{ij}$ = interaction effect of ixj^{th} progeny

r_k = replication effect

e_{ijk} = experimental error

The combined Analysis of variance across locations was based on the following statistical model:

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

Where: Y_{ijkl} = observation made on ixj^{th} progeny in the k^{th} replication at the l^{th} location, μ = general mean, m_i = effect of the i^{th} male,

f_j = effect of the j^{th} female

$(fm)_{ij}$ = interaction effect of ixj^{th} progeny,

s_l = effect of l^{th} location

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

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

$(fm)_{ij,l}$ = interaction effect of ixj^{th} progeny in l^{th} location,

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

e_{ijk} = experimental error

The forms of ANOVA, Expected Mean Squares and Covariance of relatives for NCDII for one location and combined across locations are presented in Table 3.4 and Table 3.5, respectively.

Table 3.4. Form of ANOVA, Expected Mean Squares and Covariance of relatives for NCD II in one location

Source of variation	df	MS	EMS	Covariance of Relatives
Replication	$(r-1)$			
Female	$(f-1)$	M_f	$\sigma_e^2+r\sigma_{fm}^2+rm\sigma_f^2$	$\sigma_e^2+r[COV(FS)-COV(HS_f)-COV(HS_m)]+rmCOV(HS_f)$
Male	$(m-1)$	M_m	$\sigma_e^2+r\sigma_{fm}^2+rf\sigma_m^2$	$\sigma_e^2+r[COV(FS)-COV(HS_f)-COV(HS_m)]+rfCOV(HS_m)$
Female x Male	$(m-1)(f-1)$	M_{fm}	$\sigma_e^2+r\sigma_{fm}^2$	$\sigma_e^2+r[COV(FS)-COV(HS_f)-COV(HS_m)]$
Error	$g-(rb-1)$	M_e	σ_e^2	
Total	rmf-1			

where: df = degrees of freedom, m = Number of males, $\sigma^2{}_f$ = Variance due to female,

MS = mean squares, M_m = males mean squares, $\sigma^2{}_m$ = variance due to males,

EMS = expected mean squares, M_{fm} = females x males mean squares, $\sigma^2{}_{fm}$ = variance due to females x males,

r = Number of replications, M_e = Error mean squares, COV = covariance,

f = Number of females, σ_e^2 = Variance due to error, FS = full sib, HS = half sib

Table 3.5. Form of Combined ANOVA, Expected Mean Squares and Covariance of relatives for NCDII across locations

Source of variation	df	MS	EMS	Covariance of Relatives
Location	$(l-1)$			
Replication(location)	$l(r-1)$			
Female	$(f-1)$	M_f	$\sigma_e^2 + r\sigma_{lfm}^2 + rm\sigma^2_{fl} + rl\sigma_{fm}^2 + rlm\sigma^2_f$	$\sigma_e^2 + rl[COV(FS) - COV(HS_f) - COV(HS_m)] + rlmCOV(HS_f)$
Male	$(m-1)$	M_m	$\sigma_e^2 + r\sigma_{lfm}^2 + rf\sigma_{ml}^2 + rl\sigma_{fm}^2 + rlf\sigma_m^2$	$\sigma_e^2 + rl[COV(FS) - COV(HS_f) - COV(HS_m)] + rlfCOV(HS_m)$
Female x Male	$(m-1)(f-1)$	M_{fm}	$\sigma_e^2 + r\sigma_{lfm}^2 + rl\sigma_{fm}^2$	$\sigma_e^2 + rl[COV(FS) - COV(HS_f) - COV(HS_m)]$
Location × Female	$(f-1)(l-1)$	M_{fl}	$\sigma_e^2 + r\sigma_{lfm}^2 + rm\sigma_{fl}^2$	
Location × Male	$(m-1)(l-1)$	M_{ml}	$\sigma_e^2 + r\sigma_{lfm}^2 + rf\sigma_{ml}^2$	
Location × Female x Male	$(m-1)(f-1)(l-1)$	M_{lfm}	$\sigma_e^2 + r\sigma_{lfm}^2$	
Error	$gl-2(rb-1)$	M_e	σ_e^2	
Total	l(rmf-1)			

where: df = degrees of freedom, M_m = males mean squares, σ^2_m = variance due to males,

MS = mean squares, M_{fm} = females x males mean squares, σ^2_{fm} = variance due to females x males,

EMS = expected mean squares, M_{fl} = females x locations mean squares, σ^2_{fl} = variance due to females × locations,

l = Number of locations, M_{ml} = males x locations mean squares, σ^2_{ml} = variance due to males × locations,

r = Number of replications, M_{lfm} = females x males x locations mean squares, σ^2_{fml} = variance due to females × males × locations,

f = Number of females, m = Number of males, M_e = Error mean squares, σ_e^2 = Variance due to error,

COV = covariance, M_f = females mean squares, σ^2_f = Variance due to female, FS = full sib, HS = half sib

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

For one locations:

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

Across location:

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

where: h^2_{ns} = Narrow sense heritability,

σ^2_f = Genetic variance of females

σ^2_m = Genetic variance of males,

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

σ^2_e = Error variance,

r = Number of replications,

l= number of locations

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

3.6.4 Estimation of GCA and SCA variances

From mean squares and expected mean squares, the covariance between half sibs COV(HS) and covariance between full sibs COV(FS) were obtained according to Singh and Chaudhary (1985) as shown below:

One location: σ^2_f = COV (HS) females = $\frac{MS_f - MS_{fm}}{rm}$

σ^2_m = COV (HS) males = $\frac{MS_m - MS_{fm}}{rf}$

$$\sigma^2_{fm} = \text{COV (FS)} = \frac{MS_{fm} - MS_e}{r}$$

Average of the COV (HS) was estimated following Dabholkar (1999):

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

Combined across locations: $\sigma^2_f = \text{COV (HS) females} = \dfrac{MS_f - MS_{fm}}{rlm}$

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

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

Average of the COV (HS) across locations was also obtained as follows:

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

The estimates of COV (HS) and COV (FS) were used to estimate GCA (σ^2_{GCA}) and SCA (σ^2_{SCA}) variances as described by Hallauer and Miranda-Filho (1988):

$$\sigma^2_{GCA} = 4 \text{ COV (HS) average}$$

$$\sigma^2_{SCA} = 4 \text{ COV (FS)} - \text{COV (HS) male} - \text{COV (HS) female}$$

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

3.6.5 Estimation of combining ability effects

The general combining ability (GCA) and specific combining ability (SCA) effects were calculated using the formula suggested by Singh and Chaudhary (1985) as shown below:

a. GCA effects of females $= g_j = \dfrac{x_{i..}}{mr} - \dfrac{x...}{fmr}$

b. GCA effects of males = $g_i = \frac{x_{.j.}}{fr} - \frac{x_{...}}{fmr}$

c. SCA effects of crosses = $s_{ij} = \frac{x_{ij.}}{r} - \frac{x_{i..}}{mr} - \frac{x_{.j.}}{fm} - \frac{x_{...}}{fmr}$

where: x. = grand total of crosses, $x_{j.}$ = total of all hybrids containing j^{th} females

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

f = number of females, m = number of males

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

3.6.6 Estimation of heterosis

Estimate of high-parent heterosis was obtained for each individual hybrid in each location and for the combined locations according to Fehr (1987) as follows:

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

where:

F_1= the mean performance of the hybrid averaged over replications,

H_P= the mean of the parent which gave the higher mean value over replications.

The differences in the magnitude of heterosis were tested following the procedure given by Panse and Sukhatme (1962) as follows:

Critical difference for high parent heterosis = $(2M_e/2r)^{1/2}$ x t

Where: M_e = Error mean squares for the experimental ANOVA

r = Number of replications,

t = T value of t test at error degrees of freedom corresponding to 5% or 1% level of significance.

3.6.7 Estimation of correlations

Correlation coefficients that measure the degree of association between one trait and another were estimated using the Pearson correlation coefficient formula given by Singh and Chaudhary (1985).

$$r_{xy} = \frac{\mathrm{Cov(xy)}}{\sqrt{\sigma^2(y)\sigma^2(x)}}$$

where: $Cov(xy)$ = covariance of traits x and y,

$\sigma^2(x)$ = variance of trait x

$\sigma^2(y)$ = variance of trait y

CHAPTER FOUR

4.0 RESULTS

4.1 Analysis of Variance and Mean Performance

4.1.1 Analysis of variance and mean performance at Samaru

Analyses of variance (ANOVA) for traits evaluated under non-water stress, intermediate-water stress and severe-water stress conditions at Samaru are presented in Table 4.1. The genotypes mean squares were highly significant at 1% level of probability ($P \leq 0.01$) for DT, DS, PHT, EHT and GY under the three water streess conditions. ASI under non-water stress was significant at 5% level of probability ($P \leq 0.05$) but highly significant ($P \leq 0.01$) under intermediate-water stress and severe-water stress conditions. Leaf senescence (SEN) and NEP were not significant under the stress conditions.

The relative performance of a genotype for drought related traits and in turn grain yield will give an idea of drought tolerance ability of the genotype. The performance of 42 top cross hybrids at Samaru under non-water stress, intermediate-water stress and severe-water stress conditions is presented in Table 4.2. Under non-water stress condition, the grand mean for days to 50% tasseling was 54.54 days and the mean value ranged from 48.89days (Sammaz 17 x P4) to 62.61 days (Sammaz 17 x P3) for the top cross hybrids. Under intermediate-water stress condition, Sammaz 36 x P8 recorded the lowest mean value 46.19 days and Sammaz 36 x P7 (62.25 days) recorded the maximum for days to 50% tasseling with an overall mean of 55.54 days. Under severe-water stress condition, the grand mean for days to 50% tasseling was 55.45 days and ranged from 48.29 days (Dent Q x P4) to 63.68 days (Sammaz 17 x P3) for the top cross hybrids. For days to 50% silking under non-water stress condition, the grand mean was 58.37 days and the mean value ranged from 54.50 days (Dent Q x P2) to 62.50 days (Sammaz 17 x P1) for the top cross hybrids.

Table 4.1. Mean squares for grain yield and other agronomic traits under non-water stress, intermediate-water stress and severe-water stress conditions at Samaru

		DT			DS			ASI			PHT		
Source of variation	df	NS	IS	SS	NS	IS	SS	NS	IS	SS	NS	IS	SS
Replication	1												
Block(Rep)	14	7.64	19.25	12.40	7.50	19.64	21.34	2.96	20.63	10.55*	525.96	709.62*	243.32
Genotype	55	19.02**	19.71**	18.34**	15.70**	18.42**	14.37**	3.97*	25.73**	13.96**	433.60**	572.12**	321.90**
Error	41	5.17	9.59	9.77	5.07	8.82	7.02	1.87	10.76	3.27	171.60	155.80	155.81

		EHT			SEN			NEP			GY		
Source of variation	df	NS	IS	SS	NS	IS	SS	NS	IS	SS	NS	IS	SS
Replication	1												
Block (Rep)	14	328.30	140.54*	243.85	-	0.20**	0.21*	0.06**	0.01	0.03*	4505332.41**	597147.85	1024091.63
Genotype	55	260.64**	176.65**	357.49**	-	0.10^{NS}	0.13^{NS}	0.02^{NS}	0.03^{NS}	0.04^{NS}	784945.66**	812427.32**	388579.39**
Error	41	89.00	71.97	199.90	-	0.03	0.10	0.01	0.01	0.01	62563.40	68695.59	35667.93

* and ** = significant at $P \leq 0.05$ and $P \leq 0.01$, probability level respectively, DT = days to 50% tasseling, DS = days to 50% silking, ASI = anthesis-silking interval, PHT = plant height, EHT = ear height, NEP = number of ears per plant, GY = grain yield, SEN = leaf senescence, NS = non-water stress, IS = intermediate-water stress, SS = severe-water stress, Rep = Replication

Table 4. 2. Mean Performance of top cross hybrids and check under non-water stress, intermediate-water stress and severe-water stress conditions at Samaru

	DT			DS			ASI			PHT(cm)		
Top cross hybrid	NS	IS	SS	NS	IS	SS	NS	IS	SS	NS	IS	SS
Sammaz 17 x P1	53.42	53.26	55.63	58.98	62.69	63.85	5.79	9.76	8.17	191.41	183.69	186.33
Sammaz 17 x P2	53.84	55.71	54.63	58.07	59.63	62.20	4.32	3.93	7.38	176.53	185.46	154.14
Sammaz 17 x P3	62.61	54.42	63.68	64.03	61.69	69.19	1.39	7.33	5.51	191.54	218.43	184.12
Sammaz 17 x P4	48.89	61.50	56.01	53.18	65.43	62.97	4.37	3.91	6.99	158.20	175.31	156.88
Sammaz 17 x P7	55.94	54.26	52.11	60.47	56.66	56.97	4.63	2.13	4.84	170.40	207.00	181.62
Sammaz 17 x P8	54.16	52.95	54.47	58.81	54.66	60.19	4.69	1.70	6.72	188.39	200.45	173.18
Sammaz 18 x P1	51.10	57.05	54.64	54.74	61.95	59.95	3.84	5.01	5.31	166.33	195.96	192.60
Sammaz 18 x P2	52.13	51.58	57.68	57.34	53.77	64.19	5.20	1.89	6.51	205.63	206.30	162.12
Sammaz 18 x P3	54.82	53.71	55.55	58.91	57.13	60.89	4.07	3.43	5.35	191.82	186.96	172.57
Sammaz 18 x P4	58.33	56.79	54.61	61.02	64.71	60.97	2.40	7.92	6.34	182.59	211.87	163.12
Sammaz 18 x P7	57.11	54.97	60.63	59.94	55.85	64.70	2.91	0.85	3.88	189.81	194.83	147.64
Sammaz 18 x P8	52.24	54.81	58.01	56.58	60.70	63.19	4.40	5.85	5.31	179.07	200.85	180.87
Sammaz 19 x P1	58.78	54.02	51.89	62.54	56.62	56.18	3.79	2.56	4.13	189.74	195.19	174.49
Sammaz 19 x P2	52.30	56.45	52.67	56.13	57.16	58.20	4.07	0.70	5.47	199.17	210.45	180.83
Sammaz 19 x P3	56.81	52.28	57.92	61.71	53.35	63.32	4.77	0.78	5.39	157.60	211.39	177.15
Sammaz 19 x P4	54.16	53.03	58.66	58.31	60.69	64.93	4.19	7.92	6.31	198.39	193.11	171.27
Sammaz 19 x P7	53.12	55.08	55.49	56.30	57.07	61.27	3.17	1.94	5.82	145.14	192.87	178.84
Sammaz 19 x P8	58.01	57.65	58.38	61.02	62.60	64.15	2.66	4.96	5.79	157.42	144.75	150.15
Sammaz 34 x P1	50.90	57.30	56.33	55.17	60.51	63.47	4.32	2.95	7.29	191.75	192.53	182.77
Sammaz 34 x P2	52.66	56.74	58.62	57.19	59.91	61.59	4.57	3.17	2.98	155.00	210.20	172.92
Sammaz 34 x P3	52.30	54.00	52.28	59.63	55.43	56.93	7.57	1.41	4.51	187.67	176.31	181.17
Sammaz 34 x P4	55.82	56.79	55.30	58.46	66.94	62.35	4.07	10.41	7.07	204.29	210.24	167.10
Sammaz 34 x P7	51.47	53.93	55.39	53.12	59.63	59.18	1.70	5.76	3.82	180.31	152.54	172.33
Sammaz 34 x P8	54.89	50.64	55.33	58.68	57.73	66.47	3.87	7.02	11.29	191.20	200.27	166.27

DT = days to 50% tasseling, DS = days to 50% silking, ASI = anthesis-silking interval, PHT = plant height, NS = non-water stress, IS = intermediate-water stress, SS = severe-water stress, ±SE = standard error

Table 4. 3. Continued

Top cross hybrid	DT			DS			ASI			PHT(cm)		
	NS	IS	SS	NS	IS	SS	NS	IS	SS	NS	IS	SS
Sammaz 36 x P1	51.39	54.72	52.44	54.79	59.39	57.18	3.53	4.71	4.72	182.78	220.81	169.68
Sammaz 36 x P2	51.63	57.86	53.72	56.34	59.17	59.12	4.7	1.2	5.39	205.13	185.33	172.43
Sammaz 36 x P3	55.94	58.82	53.43	57.97	63.96	59.49	2.13	5.17	6.07	174.4	196.87	178.98
Sammaz 36 x P4	52.99	58.71	54.43	56.94	63.63	57.49	4.19	4.93	3.07	175.43	192.46	182.98
Sammaz 36 x P7	54.66	62.25	55.20	58.91	65.64	59.29	4.17	3.36	4.15	195.12	222.87	161.50
Sammaz 36 x P8	51.89	46.19	59.26	55.18	62.6	63.95	3.37	16.61	4.69	172.7	209.57	183.80
Dent Q x P1	52.49	59.65	54.29	54.94	63.10	59.94	2.19	3.46	5.68	197.93	188.25	195.55
Dent Q x P2	56.81	55.27	55.64	60.71	60.02	59.95	3.77	4.77	4.31	177.60	200.98	177.60
Dent Q x P3	52.34	53.72	53.03	58.07	59.89	56.85	5.82	6.21	3.85	155.53	219.31	171.86
Dent Q x P4	54.34	57.90	48.29	58.57	60.57	52.72	4.32	2.37	4.47	169.53	191.92	142.82
Dent Q x P7	55.63	54.56	52.53	59.71	57.44	59.35	4.00	2.83	6.85	187.28	235.98	178.86
Dent Q x P8	59.31	53.90	55.33	62.21	65.43	59.64	2.77	11.51	4.30	182.60	182.40	209.67
Flint Q x P1	55.62	60.25	56.58	57.80	62.64	62.89	2.17	2.36	6.46	209.64	196.37	174.57
Flint Q x P2	54.68	48.95	56.33	59.52	53.22	62.14	4.57	4.25	5.80	192.62	133.95	182.67
Flint Q x P3	56.97	59.82	53.13	61.21	66.04	58.70	4.17	6.17	5.38	152.80	199.61	163.14
Flint Q x P4	53.96	55.92	55.92	57.80	63.19	63.51	3.84	7.33	7.64	204.66	204.43	176.97
Flint Q x P7	52.29	51.62	56.80	56.14	59.56	63.14	3.80	5.94	6.48	210.61	197.18	167.13
Flint Q x P8	56.94	52.76	56.79	60.04	59.19	63.30	3.12	6.76	6.50	192.21	190.19	175.17
Oba 98	56.92	61.95	57.24	60.98	66.16	61.89	4.29	4.20	4.63	210.91	200.95	189.53
Range	48.89-62.61	46.19-62.25	48.29-63.68	53.12-64.03	53.22-66.94	52.72-69.19	1.39-7.57	0.70-16.67	2.72-11.29	145.14-221.81	133.95-232.98	142.82-209.67
Grand Mean	54.54	55.54	55.45	58.37	60.4	61.14	3.87	4.83	5.72	182.83	195.59	173.94
±SE	1.61	2.51	2.21	1.59	2.43	2.45	0.97	2.32	1.28	13.63	12.95	8.83
CV (%)	2.95	4.52	3.99	2.72	4.02	4.01	25.06	48.03	22.38	7.46	6.62	5.08

DT = days to 50% tasseling, DS = days to 50% silking, ASI = anthesis-silking interval, PHT = plant height, NS = non-water stress, IS = intermediate-water stress, SS = severe-water stress, ±SE = standard error

Table 4. 2. Continued

Top cross hybrid	EHT(cm)			SEN			NEP			GY(kg/ha)		
	NS	IS	SS	NS	IS	SS	NS	IS	SS	NS	IS	SS
Sammaz 17 x P1	79.23	87.61	102.97	-	2.12	1.89	1.30	1.27	1.10	3829.89	1767.59	597.98
Sammaz 17 x P2	97.47	101.16	79.19	-	2.08	1.85	1.44	1.20	1.14	5219.76	1810.13	878.75
Sammaz 17 x P3	101.77	102.13	99.88	-	1.81	2.02	1.28	1.24	1.09	3953.04	1290.44	425.91
Sammaz 17 x P4	96.64	77.20	101.65	-	2.36	1.61	1.38	1.23	1.13	4898.80	1953.82	2073.97
Sammaz 17 x P7	89.85	95.80	92.33	-	2.23	1.80	1.31	1.25	1.22	4394.22	2378.89	1114.26
Sammaz 17 x P8	121.30	88.40	73.99	-	2.52	2.14	1.47	1.22	1.14	3277.42	1774.99	366.47
Sammaz 18 x P1	103.92	86.94	74.38	-	2.18	2.41	1.26	1.25	1.21	6035.43	3107.03	822.25
Sammaz 18 x P2	102.86	85.39	101.38	-	2.20	2.23	1.35	1.23	1.12	3621.40	2877.16	870.36
Sammaz 18 x P3	102.47	86.16	94.03	-	1.87	1.59	1.41	1.21	1.08	3434.89	921.24	410.23
Sammaz 18 x P4	102.25	116.66	95.33	-	2.06	2.50	1.43	1.18	1.17	4832.64	2228.87	1114.26
Sammaz 18 x P7	106.57	91.04	99.69	-	2.38	2.06	1.33	1.19	1.15	4298.43	2791.24	434.31
Sammaz 18 x P8	94.59	94.33	83.65	-	2.30	2.43	1.26	1.19	1.08	4824.93	2498.30	1273.58
Sammaz 19 x P1	116.74	92.34	110.39	-	2.41	2.13	1.41	1.19	1.27	4455.90	1858.96	1629.92
Sammaz 19 x P2	90.18	91.90	94.35	-	2.52	1.93	1.38	1.23	1.09	4938.05	2886.10	1119.19
Sammaz 19 x P3	101.73	92.94	106.23	-	2.18	1.76	1.34	1.33	1.01	4872.72	2061.80	612.70
Sammaz 19 x P4	102.30	94.22	90.31	-	2.00	1.91	1.23	1.35	1.05	3944.09	1902.14	1464.14
Sammaz 19 x P7	59.99	107.30	97.87	-	1.73	2.15	1.14	1.22	1.07	4210.70	2887.31	957.40
Sammaz 19 x P8	111.73	93.31	93.13	-	2.10	2.21	1.19	1.21	1.10	3669.4	2253.86	548.93
Sammaz 34 x P1	95.66	93.52	85.45	-	1.69	1.92	1.12	1.28	1.12	4380.59	2580.81	423.19
Sammaz 34 x P2	80.19	81.64	73.73	-	2.12	1.93	1.42	1.24	1.05	5119.62	1431.52	3004.27
Sammaz 34 x P3	88.18	102.2	102.22	-	2.67	2.00	1.34	1.20	0.95	5604.72	842.70	648.27
Sammaz 34 x P4	89.69	93.36	88.28	-	2.66	2.19	1.24	1.60	1.14	4657.36	1135.69	1159.25
Sammaz 34 x P7	91.58	105.05	101.30	-	2.20	1.45	1.43	1.24	1.07	5306.12	3231.13	1169.39
Sammaz 34 x P8	98.64	90.75	61.45	-	2.28	2.19	1.32	1.17	1.00	4898.80	708.61	645.42

EHT = ear height, SEN = leaf senescence, NEP = number of ears per plant, GY = grain yield, NS = non-water stress, IS = intermediate-water stress, SS = severe-water stress, ±SE = standard error

Table 4.2.Continued

Top cross hybrid	EHT(cm) NS	EHT(cm) IS	EHT(cm) SS	SEN NS	SEN IS	SEN SS	NEP NS	NEP IS	NEP SS	GY(kg/ha) NS	GY(kg/ha) IS	GY(kg/ha) SS
Sammaz 36 x P1	96.26	97.43	89.55	-	2.23	1.67	1.28	1.2	1.27	4196.49	2638.59	1203.69
Sammaz 36 x P2	107.86	86.26	97.95	-	2.14	1.76	1.36	1.23	1.13	3843.61	900.76	2330.54
Sammaz 36 x P3	99.85	98.55	87.95	-	2.11	1.63	1.48	1.22	1.17	5283.12	2352.69	1166.44
Sammaz 36 x P4	94.59	103.66	85.95	-	2.35	1.63	1.38	1.21	1.24	3469.87	2476.80	1166.44
Sammaz 36 x P7	116.5	94.67	108.19	-	1.85	1.93	1.34	1.17	1.18	4043.15	3117.80	1521.83
Sammaz 36 x P8	104.64	91.98	89.36	-	2.46	1.68	1.36	1.27	1.05	6676.58	2480.85	831.54
Dent Q x P1	110.59	89.81	88.91	-	2.01	1.77	1.58	1.21	1.15	3247.65	2031.64	950.19
Dent Q x P2	109.73	106.02	79.38	-	2.11	1.66	1.36	1.24	1.06	4428.28	1879.28	822.25
Dent Q x P3	92.47	79.43	73.01	-	2.01	2.30	1.31	1.15	1.02	4997.54	2416.37	999.95
Dent Q x P4	90.97	99.69	85.66	-	2.12	2.59	1.58	1.15	1.06	4997.54	2157.88	368.71
Dent Q x P7	103.26	88.47	82.51	-	2.25	2.30	1.47	1.21	1.07	4035.96	3731.86	1222.17
Dent Q x P8	112.73	95.91	106.83	-	2.30	1.84	1.34	1.23	0.95	3983.83	1880.50	544.09
Flint Q x P1	89.99	88.17	80.05	-	2.12	2.66	1.23	1.45	1.09	4877.37	2673.35	917.39
Flint Q x P2	104.20	85.21	83.33	-	2.54	1.84	1.60	1.19	0.96	4616.70	1413.56	1210.75
Flint Q x P3	99.70	90.79	80.69	-	1.57	2.33	1.43	1.17	1.18	3375.58	1118.75	1323.20
Flint Q x P4	101.43	85.63	81.71	-	2.30	2.18	1.24	1.17	0.98	4661.44	2401.55	1858.83
Flint Q x P7	98.09	97.58	134.05	-	2.30	2.25	1.38	1.30	1.10	3117.64	1783.94	1067.09
Flint Q x P8	90.29	96.11	119.46	-	2.33	1.80	1.26	1.32	1.09	4449.61	3323.15	245.10
Oba 98	86.73	107.4	100.75	-	2.43	1.94	1.39	1.28	1.15	4274.33	2441.65	985.23
Range	59.99-121.30	77.2-116.66	61.45-61.13	-	1.57-2.67	1.35-2.66	1.12-1.72	1.15-1.60	0.95-1.45	2439.22-6676.58	708.61-3731.86	245.10-3004.27
Grand Mean	98.15	93.81	91.42	-	2.16	1.98	1.36	1.24	1.1	4420.63	2206.35	1011.9
±SE	8.04	6.00	10.41	-	0.12	0.22	0.10	0.00	0.00	559.3	586.07	422.30
CV (%)	8.19	6.40	11.39	-	5.56	11.11	7.35	0	0.00	12.65	26.56	41.73

EHT = ear height, SEN = leaf senescence, NEP = number of ears per plan,; GY = grain yield, NS = non-water stress, IS = intermediate-water stress, SS = severe-water stress, ±SE = standard error

Under intermediate-water stress condition, Flint Q x P2 recorded the lowest mean value 53.22 days and Sammaz 34 x P4 (66.94 days) recorded the maximum for days to 50% silking with an overall mean of 60.40 days. Under severe-water stress condition, the grand mean for days to 50% silking was 61.14 days and ranged from 52.72 days (Dent Q x P4) to 69.19 days (Sammaz 17 x P3) for the top cross hybrids.

For anthesis-silking interval under non-water stress condition, the grand mean was 3.87 days and the mean value ranged from 1.39 days (Sammaz 17 x P3) to 7.57 days (Sammaz 34 x P3) for the top cross hybrids. Under intermediate-water stress condition, Sammaz 36 x P2 recorded the lowest mean value 1.20days and Sammaz 36 x P8 (16.61 days) recorded the maximum for anthesis-silking interval with an overall mean of 4.83 days. Under severe-water stress condition, the grand mean for anthesis-silking interval was 5.72 days and ranged from 2.98 days (Sammaz 34 x P2) to 11.29 days (Sammaz 34 x P8) for the top cross hybrids.

For plant height under non-water stress condition, the grand mean was 182.83cm and the mean value ranged from 145.14cm (Sammaz 19 x P7) to 210.61cm (Flint Q x P7) for the top cross hybrids. Under intermediate-water stress condition, Sammaz 17 x P4 recorded the lowest mean value 175.31cm and Dent Q x P7 (235.98cm) recorded the maximum for plant height with an overall mean of 195.59cm. Under severe-water stress condition, the grand mean for plant height was 173.94cm and ranged from 147.64cm (Sammaz 18 x P7) to 209.67cm (Dent Q x P8) for the top cross hybrids.

For ear height under non-water stress condition, the grand mean was 98.15cm and the mean value ranged from 79.23cm (Sammaz 17 x P1) to 121.30cm (Sammaz 17 x P8) for the top cross hybrids. Under intermediate-water stress condition, Sammaz 34 x P2 recorded the lowest mean value 81.64cm and Sammaz 18 x P4 (116.66cm) recorded the maximum for ear height with an overall mean of 93.81cm. Under severe-water stress condition, the grand mean for ear height was 91.42cm and ranged from 73.01cm (Dent Q x P3) to 134.05cm (Flint Q x P7) for the top cross hybrids.

For grain yield under non-water stress condition, the grand mean was 4420.63kg/ha and the mean value ranged from 3117.64kg/ha (Flint Q x P7) to 6676.58kg/ha (Sammaz 36 x P8) for the top cross hybrids. Under intermediate-water stress condition, Sammaz 34 x P8 recorded the lowest mean value 708.61kg/ha and Dent Q x P7 (3731.86kg/ha) recorded the maximum for grain yield with an overall mean of 2206.35kg/ha. Under severe-water stress condition, the grand mean for grain yield was 1011.90kg/ha and ranged from 245.10kg/ha (Flint Q x P8) to 3004.27kg/ha (Sammaz 34 x P2) for the top cross hybrids.

4.1.2 Analysis of variance and mean performance at Kadawa

Analysis of variance (ANOVA) for traits evaluated under non-water stress, intermediate-water stress and severe-water stress conditions at Kadawa is presented in Table 4.3. The genotypes mean squares were highly significant ($P \leq 0.01$) for DT, DS, PHT, EHT, and GY under the three environmental conditions. ASI was significant ($P \leq 0.05$) under non-water stress condition. Leaf senescence (SEN) and NEP were not significant under the stress conditions.

The performance of 42 top cross hybrids under non-water stress, intermediate-water stress and severe-water stress conditions is presented in Table 4.4. Under non-water stress condition, the grand mean for days to 50% tasseling was 59.50 days and the mean value ranged from 56.29 days (Sammaz 17 x P7) to 63.45 days (Sammaz 17 x P2) for the top cross hybrids. Under intermediate-water stress condition, Sammaz 19 x P1 recorded the lowest mean value 57.67 days and Sammaz 36 x P8 (67.51 days) recorded the maximum for days to 50% tasseling with an overall mean of 62.00 days.

Table 4. 4. Mean squares for grain yield and other agronomic traits under non-water stress, intermediate-water stress and severe-water stress conditions at Kadawa

		DT			DS			ASI			PHT		
Source of variation	df	NS	IS	SS	NS	IS	SS	NS	IS	SS	NS	IS	SS
Replication	1												
Block(Rep)	14	17.80*	12.15	8.16	19.92*	14.79	9.49	0.85	0.64	1.07	2635.22**	340.47	473.54
Genotype	55	9.30**	9.65**	17.32**	19.51**	20.64**	15.11**	0.91*	0.99^{NS}	0.71^{NS}	424.67**	312.44**	295.88**
Error	41	1.14	2.78	6.39	5.93	9.66	7.36	0.29	0.30	0.10	120.55	153.90	165.70

		EHT			SEN			NEP			GY		
Source of variation	df	NS	IS	SS	NS	IS	SS	NS	IS	SS	NS	IS	SS
Replication	1												
Block (Rep)	12	745.9**	58.57	53.99	-	0.22	0.15	0.00	0.00	0.02*	1647156.92	810051.62	376969.19
Genotype	55	124.4**	76.19**	79.41**	-	0.12^{NS}	0.09^{NS}	0.02^{NS}	0.03^{NS}	0.04^{NS}	1608637.24**	445234.78**	155983.55**
Error	43	59.9	40.27	45.18	-	0.05	0.01	0.01	0.01	0.01	157953.90	203069.79	106647.10

* and ** = significant at $P \leq 0.05$ and $P \leq 0.01$, probability level respectively, DT = days to 50% tasseling, DS = days to 50% silking, ASI = anthesis-silking interval, PHT = plant height, EHT = ear height, NEP = number of ears per plant, GY = grain yield, SEN = leaf senescence, NS = non-water stress, IS = intermediate-water stress SS = severe-water stress, Rep = Replication

Table 4. 5. Mean Performance of top cross hybrids and check under non-water stress, intermediate-water stress and severe-water stress conditions at Kadawa

	DT			DS			ASI			PHT(cm)		
Top cross hybrid	NS	IS	SS	NS	IS	SS	NS	IS	SS	NS	IS	SS
Sammaz 17 x P1	59.28	59.39	59.58	62.60	62.93	62.12	3.32	3.62	2.53	148.27	118.31	105.60
Sammaz 17 x P2	63.45	59.46	60.31	66.26	62.46	63.18	2.81	2.93	2.87	109.56	147.61	108.51
Sammaz 17 x P3	59.72	61.23	58.35	62.09	63.69	61.26	2.36	2.48	2.91	146.16	126.11	97.84
Sammaz 17 x P4	61.72	61.92	55.82	63.48	64.86	59.22	1.76	2.92	3.40	171.04	115.92	123.94
Sammaz 17 x P7	56.29	64.47	60.27	60.10	67.89	62.21	3.81	3.43	1.94	164.81	117.65	139.8
Sammaz 17 x P8	63.07	59.33	60.60	67.60	62.52	63.03	4.53	3.21	2.42	123.90	105.12	118.69
Sammaz 18 x P1	56.72	62.68	58.74	60.60	65.33	61.76	3.88	2.64	3.02	130.97	108.63	130.25
Sammaz 18 x P2	57.12	62.86	57.57	59.95	65.12	60.09	2.83	2.27	2.52	124.76	132.64	135.05
Sammaz 18 x P3	57.85	56.96	59.68	61.76	59.97	62.64	3.91	3.02	2.97	139.15	122.67	116.58
Sammaz 18 x P4	60.39	63.08	62.93	63.07	65.71	65.08	2.68	2.61	2.15	130.70	124.52	141.73
Sammaz 18 x P7	57.36	63.56	62.20	60.90	67.83	65.49	3.54	4.22	3.29	142.76	115.83	118.03
Sammaz 18 x P8	63.17	64.91	63.74	67.04	67.60	67.27	3.87	2.79	3.53	145.79	111.64	123.81
Sammaz 19 x P1	58.23	57.67	60.74	60.20	59.55	63.78	1.97	1.84	3.05	135.82	129.64	138.87
Sammaz 19 x P2	59.01	62.05	58.40	61.71	64.38	61.48	2.70	2.33	3.08	143.18	121.08	129.70
Sammaz 19 x P3	57.39	60.58	63.85	60.65	63.71	66.38	3.26	3.11	2.53	140.89	140.52	126.32
Sammaz 19 x P4	59.68	63.32	60.43	62.61	65.95	63.08	2.93	2.63	2.65	143.60	105.25	142.73
Sammaz 19 x P7	60.42	59.62	60.40	63.53	61.96	63.98	3.11	2.40	3.58	132.78	101.09	112.70
Sammaz 19 x P8	60.90	63.91	60.84	63.37	66.44	64.41	2.47	2.51	3.57	150.34	133.44	117.45
Sammaz 34 x P1	62.17	58.75	61.27	64.84	61.37	63.79	2.67	2.65	2.52	152.81	116.94	148.77
Sammaz 34 x P2	57.55	60.07	57.32	59.94	63.28	59.72	2.39	3.13	2.40	167.03	142.72	136.44
Sammaz 34 x P3	61.07	59.75	61.35	64.60	61.87	63.88	3.53	2.15	2.53	141.40	116.44	135.32
Sammaz 34 x P4	61.76	59.11	59.51	65.39	62.53	61.48	3.63	3.49	1.97	155.80	125.62	148.87
Sammaz 34 x P7	58.95	64.04	60.84	61.26	67.04	62.41	2.31	2.51	1.57	165.56	113.63	116.95
Sammaz 34 x P8	58.73	64.91	58.47	63.16	67.60	61.46	4.43	2.79	2.98	152.52	119.64	123.91

DT = days to 50% tasseling, DS = days to 50% silking, ASI = anthesis-silking interval, PHT = plant height, NS = non-water stress, IS = intermediate-water stress, SS = severe-water stress, ±SE = standard error

Table 4.4.Continued

Top cross hybrid	DT			DS			ASI			PHT(cm)		
	NS	IS	SS	NS	IS	SS	NS	IS	SS	NS	IS	SS
Sammaz 36 x P1	58.35	60.01	60.51	60.26	63.75	63.25	1.91	3.72	2.74	153.15	144.28	148.74
Sammaz 36 x P2	61.16	62.88	58.27	63.15	66.23	61.29	1.99	3.35	3.02	107.05	116.74	148.27
Sammaz 36 x P3	60.70	59.89	59.63	63.77	64.41	64.01	3.07	4.52	4.38	160.57	148.99	124.34
Sammaz 36 x P4	58.27	63.95	59.35	61.68	68.21	61.76	3.42	4.25	2.41	137.70	132.53	110.34
Sammaz 36 x P7	60.89	61.23	57.26	64.15	64.19	60.76	3.26	2.98	3.51	155.39	129.11	114.65
Sammaz 36 x P8	58.94	67.51	57.88	62.00	70.25	60.40	3.07	2.72	2.52	142.45	128.28	123.78
Dent Q x P1	57.35	61.25	63.10	60.06	63.54	65.70	2.72	2.32	2.61	145.17	128.69	140.30
Dent Q x P2	59.01	61.52	62.47	61.12	64.66	64.96	2.12	3.14	2.48	143.22	164.77	112.91
Dent Q x P3	62.66	63.04	60.40	65.43	66.45	62.39	2.77	3.41	1.99	146.14	143.10	150.46
Dent Q x P4	57.73	63.33	59.51	61.66	65.94	62.25	3.93	2.52	2.74	157.52	155.46	148.74
Dent Q x P7	57.35	64.90	61.24	60.22	67.93	63.26	2.87	3.02	2.02	173.54	133.18	115.25
Dent Q x P8	61.35	63.42	61.82	63.56	67.36	64.72	2.22	3.92	2.90	131.17	126.42	121.44
Flint Q x P1	60.97	64.95	63.38	63.97	67.21	66.30	3.00	2.25	2.92	178.53	135.03	99.69
Flint Q x P2	59.98	59.57	59.19	62.73	61.28	61.23	2.75	1.63	2.03	136.80	121.72	131.10
Flint Q x P3	60.11	60.55	61.55	62.37	63.38	64.02	2.26	2.83	2.46	131.78	156.08	99.05
Flint Q x P4	61.14	63.46	63.13	63.18	66.97	66.51	2.03	3.52	3.38	128.37	127.17	129.34
Flint Q x P7	60.78	58.86	59.85	64.10	60.62	63.26	3.32	1.77	3.41	175.77	160.64	112.84
Flint Q x P8	60.39	63.02	63.38	63.81	67.16	67.83	3.41	4.14	4.45	159.13	149.27	141.46
Oba 98	59.98	59.96	55.88	62.73	63.97	58.30	2.75	4.02	2.42	160.80	125.17	118.19
Range	54.56-64.41	56.96-67.57	55.82-63.86	57.65-67.60	70.65-70.25	58.30-67.83	1.15-4.54	1.63-4.52	0.97-4.45	107.05-178.53	101.09-164.77	97.84-150.46
Grand Mean	59.50	62.00	60.16	62.48	64.90	62.92	2.98	2.89	2.76	146.20	128.95	126.82
±SE	1.60	2.10	1.79	1.72	2.20	1.92	0.32	0.51	0.55	14.50	11.27	11.53
CV (%)	2.69	3.39	2.98	2.75	3.39	3.05	10.74	17.65	19.93	9.92	8.74	9.09

DT = days to 50% tasseling, DS = days to 50% silking, ASI = anthesis-silking interval, PHT = plant height, NS = non-water stress, IS = intermediate-water stress, SS = severe-water stress, ±SE = standard error

Table 4.4.Continued

	EHT(cm)			SEN			NEP			GY(kg/ha)		
Top cross hybrid	NS	IS	SS	NS	IS	SS	NS	IS	SS	NS	IS	SS
Sammaz 17 x P1	69.82	51.90	54.72	-	0.98	0.84	1.11	1.17	0.97	2561.18	1716.83	595.04
Sammaz 17 x P2	63.31	62.69	42.10	-	0.82	0.73	1.21	1.16	1.05	2287.82	1727.38	1253.29
Sammaz 17 x P3	76.57	57.79	53.89	-	0.89	0.86	1.22	1.16	0.81	2250.47	1317.60	379.14
Sammaz 17 x P4	80.39	45.85	57.73	-	0.63	0.63	1.25	1.24	0.90	3138.24	1566.94	835.48
Sammaz 17 x P7	83.44	43.97	58.16	-	0.73	0.55	1.25	1.21	0.92	4179.71	1517.81	1299.28
Sammaz 17 x P8	62.53	60.15	54.59	-	1.16	0.79	1.19	1.16	0.90	452.25	2715.63	1107.21
Sammaz 18 x P1	64.93	49.52	70.63	-	0.93	1.28	1.21	1.22	0.91	3611.27	2320.95	406.64
Sammaz 18 x P2	66.80	56.77	60.94	-	0.24	1.30	1.15	1.12	0.93	2434.02	1128.42	957.96
Sammaz 18 x P3	63.04	56.24	62.05	-	1.44	0.89	1.26	1.28	0.90	1784.19	1865.41	533.20
Sammaz 18 x P4	62.58	51.37	56.43	-	0.88	0.77	1.37	1.20	0.98	2536.12	948.83	869.03
Sammaz 18 x P7	68.25	46.82	57.08	-	0.81	0.54	1.23	1.26	0.94	2565.82	428.52	827.50
Sammaz 18 x P8	63.68	56.61	48.48	-	0.68	1.11	1.35	1.17	0.97	2234.79	1816.42	500.18
Sammaz 19 x P1	76.77	56.84	51.15	-	1.08	0.58	1.22	1.15	0.93	3181.67	1863.94	371.13
Sammaz 19 x P2	67.73	53.76	53.12	-	1.16	1.04	1.22	1.12	0.98	2980.46	973.13	1008.79
Sammaz 19 x P3	68.72	59.37	50.44	-	0.88	0.72	1.25	1.18	0.89	1860.65	590.94	100.49
Sammaz 19 x P4	71.90	37.32	62.93	-	0.84	1.20	1.23	1.13	0.98	1594.06	1234.14	1091.25
Sammaz 19 x P7	56.34	45.73	52.12	-	1.11	0.60	1.24	1.22	1.20	3008.56	1407.26	1231.02
Sammaz 19 x P8	69.01	54.12	54.30	-	0.90	0.65	1.16	1.17	1.07	3260.48	581.21	754.87
Sammaz 34 x P1	60.98	46.50	67.72	-	1.47	0.70	1.28	1.13	0.96	4056.97	2306.09	659.21
Sammaz 34 x P2	86.10	60.49	64.23	-	1.21	1.07	1.29	1.19	0.95	2108.43	941.70	1057.71
Sammaz 34 x P3	57.53	57.50	50.44	-	0.60	0.72	1.24	1.10	1.03	1563.36	1417.20	232.72
Sammaz 34 x P4	66.58	64.00	56.37	-	0.95	0.91	1.25	1.24	1.00	3603.66	1310.42	417.85
Sammaz 34 x P7	72.31	48.66	45.30	-	0.77	1.36	1.18	1.11	1.07	3398.94	1494.84	754.87
Sammaz 34 x P8	68.61	52.61	50.13	-	1.12	0.89	1.37	1.19	0.98	2102.17	2260.86	258.82

EHT = ear height, SEN = leaf senescence, NEP = number of ears per plant, GY = grain yield, NS = non-water stress, IS = intermediate-water stress, SS = severe-water stress, ±SE = standard error

Table 4.4.Continued

Top cross hybrid	EHT(cm) NS	EHT(cm) IS	EHT(cm) SS	SEN NS	SEN IS	SEN SS	NEP NS	NEP IS	NEP SS	GY(kg/ha) NS	GY(kg/ha) IS	GY(kg/ha) SS
Sammaz 36 x P1	70.04	57.91	58.67	-	1.23	0.75	1.24	1.13	0.86	2228.64	570.45	1079.69
Sammaz 36 x P2	33.41	57.92	55.72	-	1.23	0.70	1.47	1.16	0.98	2491.08	880.52	659.21
Sammaz 36 x P3	78.15	61.78	42.10	-	1.37	0.87	1.25	1.09	1.07	5069.61	723.63	1189.13
Sammaz 36 x P4	67.80	57.95	55.89	-	0.49	0.86	1.24	1.28	0.83	3865.55	1646.30	379.14
Sammaz 36 x P7	70.22	64.29	55.46	-	0.89	0.86	1.35	1.09	0.89	1860.65	650.93	696.67
Sammaz 36 x P8	56.79	52.41	52.18	-	0.79	1.18	1.32	1.11	0.95	4106.24	348.23	1280.63
Dent Q x P1	68.35	48.35	59.37	-	1.17	0.73	1.24	1.22	0.97	1828.59	1038.08	1129.57
Dent Q x P2	81.35	67.40	66.63	-	1.01	0.89	1.25	1.16	0.82	2925.48	913.56	703.27
Dent Q x P3	63.83	64.53	61.01	-	0.99	1.23	1.28	1.22	0.90	1562.35	876.29	657.80
Dent Q x P4	74.11	58.78	66.17	-	0.72	1.18	1.26	1.18	0.80	1213.28	1654.53	1301.91
Dent Q x P7	76.38	52.61	59.13	-	1.27	0.84	1.25	1.18	0.98	2935.98	1133.91	406.62
Dent Q x P8	69.35	51.35	52.73	-	1.07	0.63	1.24	1.24	0.90	2273.04	1122.50	1057.71
Flint Q x P1	59.55	69.95	38.17	-	0.93	1.12	1.23	1.21	0.93	2800.90	979.63	682.29
Flint Q x P2	59.70	46.49	65.18	-	0.78	0.45	1.19	1.19	1.03	3407.69	941.70	772.02
Flint Q x P3	51.82	74.76	54.52	-	1.16	0.71	1.20	1.13	0.89	3673.13	1639.80	237.68
Flint Q x P4	63.15	55.24	45.60	-	1.00	0.43	1.20	1.30	0.84	142.00	754.30	744.68
Flint Q x P7	84.32	67.77	59.89	-	0.68	0.86	1.24	1.14	0.96	1450.07	906.20	379.14
Flint Q x P8	71.31	62.90	58.70	-	1.45	0.57	1.22	1.21	0.79	1952.59	2246.89	282.19
Oba 98	75.70	50.74	49.17	-	1.00	0.68	1.19	1.33	0.96	3185.46	976.52	682.29
Range	33.41-86.10	37.32-74.76	38.17-70.63	-	0.24-1.47	0.43-1.36	1.11-1.47	1.09-1.33	0.79-1.23	142.00-5069.61	348.23-2715.63	100.49-1301.91
Mean	68.38	55.81	55.73	-	0.93	0.84	1.25	1.18	0.96	2555.56	1333.33	714.28
±SE	7.78	6.05	6.13	-	0.23	0.07	0.00	0.00	0.07	888.69	448.93	251.64
CV (%)	11.38	10.84	11.00	-	24.73	8.33	0.00	0.00	7.29	34.77	33.67	35.23

EHT = ear height, SEN = leaf senescence, NEP = number of ears per plant, GY = grain yield, NS = non-water stress, IS = intermediate-water stress, SS = severe-water stress, ±SE = standard error

Under severe-water stress condition, the grand mean for days to 50% tasseling was 60.16 days and ranged from 55.82 days (Sammaz 17 x P4) to 63.85 days (Sammaz 19 x P3) for the top cross hybrids.

For days to 50% silking under non-water stress condition, the grand mean was 62.48 days and the mean value ranged from 59.94 days (Sammaz 34 x P2) to 67.60days (Sammaz 17 x P8) for the top cross hybrids. Under intermediate-water stress condition, Sammaz 18 x P3 recorded the lowest mean value 59.97 days and Sammaz 36 x P8 (70.25 days) recorded the maximum for days to 50% silking with an overall mean of 64.90 days. Under severe-water stress condition, the grand mean for days to 50% silking was 62.92 days and ranged from 59.22 days (Sammaz 17 x P4) to 67.27 days (Sammaz 18 x P8) for the top cross hybrids.

For anthesis-silking interval under non-water stress condition, the grand mean was 2.98 days and the mean value ranged from 1.76 days (Sammaz 17 x P4) to 4.53 days (Sammaz 17 x P8) for the top cross hybrids.

For plant height under non-water stress condition, the grand mean was 146.20cm and the mean value ranged from 107.05cm (Sammaz 36 x P2) to 178.53cm (Flint Q x P1) for the top cross hybrids. Under intermediate-water stress condition, Sammaz 19 x P7 recorded the lowest mean value 101.09cm and Dent Q x P2 (164.77cm) recorded the maximum for plant height with an overall mean of 128.95cm. Under severe-water stress condition, the grand mean for plant height was 126.82cm and ranged from 97.84cm (Sammaz 17 x P3) to 140.56cm (Dent Q x P3) for the top cross hybrids.

For ear height under non-water stress condition, the grand mean was 68.38cm and the mean value ranged from 33.41cm (Sammaz 36 x P2) to 86.10cm (Sammaz 34 x P2) for the top cross hybrids. Under intermediate-water stress condition, Sammaz 19 x P4 recorded the lowest mean value 37.32cm and Flint Q x P3 (74.76cm) recorded the maximum for ear height with an overall mean of 55.81cm. Under severe-water stress condition, the grand mean for ear height was 55.73cm and ranged from 38.17cm (Flint Q x P1) to 70.63cm (Sammaz 18 x P1) for the top cross hybrids.

For grain yield under non-water stress condition, the grand mean was 2555.56kg/ha and the mean value ranged from 142.00kg/ha (Flint Q x P4) to 5069.61kg/ha (Sammaz 36 x P3) for the top cross hybrids. Under intermediate-water stress condition, Sammaz 36 x P8 recorded the lowest mean value 348.kg/ha and Sammaz 17 x P8 (2715.63kg) recorded the maximum for grain yield with an overall mean of 1333.33kg/ha. Under severe-water stress condition, the grand mean for grain yield was 714.28kg/ha and ranged from 100.49kg/ha (Sammaz 19 x P3) to 1301.91kg/ha (Dent Q x P4) for the top cross hybrids.

4.1.3 Combined analysis of variance and mean performance across locations

Combined analysis of variance for traits measured under non-water stress, intermediate-water stress and severe-water stress conditions across locations is presented in Table 4.5. The location mean squares were highly significant ($P \leq 0.01$) for all the traits under each condition. Under non-water stress condition the mean squares due to genotypes were highly significant ($P \leq 0.01$) for days to 50% tasseling, days to 50% silking, plant height, ear height and grain yield. Under intermediate-water stress, the differences were highly significant for days to 50% tasseling, days to 50% silking, anthesis-silking interval, ear height, plant height and grain yield while under severe-water stress condition, highly significant differences were observed for days to 50% tasseling, days to 50% silking, plant height, ear height and grain yield.

Table 4. 6. Mean squares for grain yield and other agronomic traits under non-water stress, intermediate-water stress and severe-water stress conditions across locations

Source of variation	df	DT NS	DT IS	DT SS	DS NS	DS IS	DS SS	ASI NS	ASI IS	ASI SS	PHT NS	PHT IS	PHT SS
Location	1	1350.49**	2290.17**	1190.30**	930.23**	1171.82**	180.76**	42.34**	179.90**	449.10**	237963.83**	241869.48**	118796.50**
Rep (Loc)	2	6.03	55.84**	11.53	0.00	12.85	1.97	7.39**	20.68*	8.98*	66572.96	926.61*	4650.71**
Blk (Loc*Rep)	24	12.72**	15.70	10.28	13.71**	17.21	15.41	1.91	10.63	5.81**	22312.31	525.10*	358.43
Genotype	55	7.81**	19.51**	9.46**	9.30**	19.40**	15.49**	2.67*	9.15**	5.96*	26232.11**	519.73**	379.57**
Loc*Gen	55	3.56**	9.45**	5.57**	5.40*	11.61**	9.56*	1.25NS	3.44**	1.97NS	2336.00**	239.20**	265.79**
Error	82	1.65	6.68	2.58	3.00	8.74	5.69	1.53	1.74	1.03	20840.37	94.74	143.22

Source of variation	df	EHT NS	EHT IS	EHT SS	SEN NS	SEN IS	SEN SS	NEP NS	NEP IS	NEP SS	GY NS	GY IS	GY SS
Location	1	49546.28**	79569.42**	67980.43**	-	83.60**	68.82**	0.60**	0.18**	1.23**	194856035.80**	40996791.93**	5131805.17**
Rep (Loc)	2	2496.57**	647.26	1150.45**	-	2.60**	0.25	0.01	0.00	0.01	7097886.30**	527713.21	244361.81
Blk (Loc*Rep)	24	537.09**	99.55	148.92	-	0.21**	0.18*	0.03**	0.01	0.02**	3076244.20**	703599.73	700529.91**
Genotype	55	256.05**	150.29**	260.37**	-	0.19NS	2.14NS	0.02NS	0.03NS	0.04NS	13479590.80**	1203000.07**	368256.77**
Loc*Gen	55	133.62**	80.55**	156.38**	-	0.08NS	0.08NS	0.01NS	0.01NS	0.01NS	956591.30**	609999.95**	201154.34**
Error	82	183.55	72.62	157.54	-	0.05	0.10	0.01	0.01	0.01	12582.10	645010.2	341660.01

* and ** = significant at P ≤ 0.05 and P ≤ 0.01, probability level respectively, DT = days to 50% tasseling, DS = days to 50% silking, ASI = anthesis-silking interval, PHT = plant height, EHT = ear height, NEP = number of ears per plant, GY = grain yield, SEN = leaf senescence, NS = non-water stress, IS = intermediate-water stress, SS = severe-water stress, Blk = block, Rep = replication, Loc = location, Gen = genotype

Table 4. 6. Mean Performance of top cross hybrids and check under non-water stress, intermediate-water stress and severe-water stress conditions across locations

	DT			DS			ASI			PHT(cm)		
Top cross hybrid	NS	IS	SS	NS	IS	SS	NS	IS	SS	NS	IS	SS
Sammaz 17 x P1	56.35	60.95	57.61	60.79	65.06	62.99	4.56	4.11	5.35	168.81	163.06	145.96
Sammaz 17 x P2	58.65	56.32	57.47	62.16	62.81	62.69	3.56	6.69	5.13	129.82	151.00	131.32
Sammaz 17 x P3	61.17	57.58	61.01	63.06	61.05	65.22	1.88	3.43	4.21	217.15	166.54	140.98
Sammaz 17 x P4	55.31	57.82	55.92	58.33	62.69	61.10	3.07	4.90	5.19	154.64	172.27	140.41
Sammaz 17 x P7	56.12	61.71	56.19	60.29	65.15	59.59	4.22	3.41	3.39	159.43	145.61	160.71
Sammaz 17 x P8	58.61	59.36	57.53	63.21	62.28	61.61	4.61	2.78	4.57	166.51	162.32	145.94
Sammaz 18 x P1	53.91	56.14	56.69	57.67	58.59	60.86	3.86	2.46	4.16	182.22	152.78	161.43
Sammaz 18 x P2	54.63	59.87	57.63	58.64	63.64	62.14	4.01	3.82	4.51	180.32	152.29	148.59
Sammaz 18 x P3	56.34	57.22	57.62	60.34	59.45	61.77	3.99	2.08	4.16	226.94	169.47	144.57
Sammaz 18 x P4	59.36	55.33	58.77	62.04	58.55	63.02	2.54	3.22	4.24	155.20	154.82	152.43
Sammaz 18 x P7	57.24	59.94	61.41	60.42	65.21	65.09	3.22	5.27	3.59	166.67	168.19	132.83
Sammaz 18 x P8	57.71	59.27	60.88	61.81	61.84	65.23	4.14	2.54	4.42	194.17	155.33	152.34
Sammaz 19 x P1	58.50	59.86	56.31	61.37	64.15	59.98	2.88	4.32	3.59	214.26	156.24	156.68
Sammaz 19 x P2	55.66	55.84	55.54	58.92	58.09	59.84	3.38	2.20	4.27	164.82	162.42	155.27
Sammaz 19 x P3	57.10	59.25	60.88	61.18	60.77	64.85	4.01	1.51	3.96	168.69	165.76	151.74
Sammaz 19 x P4	56.92	56.43	59.55	60.46	58.53	64.00	3.56	1.95	4.48	181.36	175.95	157.00
Sammaz 19 x P7	56.77	58.18	57.95	59.91	63.32	62.62	3.14	5.28	4.70	164.63	149.18	145.77
Sammaz 19 x P8	59.46	57.35	59.61	62.19	59.51	64.28	2.57	2.17	4.68	209.66	146.98	133.80
Sammaz 34 x P1	56.53	60.78	58.80	60.01	64.52	63.63	3.50	3.73	4.91	151.42	139.10	165.77
Sammaz 34 x P2	55.10	58.02	57.97	58.57	60.94	60.65	3.48	2.80	2.69	207.17	154.73	154.68
Sammaz 34 x P3	56.69	58.41	56.81	62.12	61.59	60.40	5.55	3.15	3.52	158.18	176.46	158.24
Sammaz 34 x P4	58.79	56.87	57.40	61.93	58.65	61.91	3.85	1.78	4.52	186.50	146.37	157.99
Sammaz 34 x P7	55.21	57.95	58.11	57.19	64.74	60.79	2.00	6.95	2.70	172.76	167.93	144.64
Sammaz 34 x P8	56.81	58.98	56.90	60.92	63.33	63.96	4.15	4.14	7.14	161.87	133.08	145.09

DT = days to 50% tasseling, DS = days to 50% silking, ASI = anthesis-silking interval, PHT = plant height, NS = non-water stress, IS = intermediate-water stress, SS = severe-water stress, ±SE = standard error

Table 4.6.Continued

	DT			DS			ASI			PHT(cm)		
Top cross hybrid	NS	IS	SS	NS	IS	SS	NS	IS	SS	NS	IS	SS
Sammaz 36 x P1	54.87	57.77	56.47	57.53	62.66	60.21	2.72	4.91	3.73	158.01	159.95	159.21
Sammaz 36 x P2	56.4	57.37	56	59.74	61.57	60.21	3.34	4.22	4.21	171.22	182.55	160.35
Sammaz 36 x P3	58.32	60.37	56.53	60.87	62.7	61.75	2.6	2.27	5.23	159.31	151.03	151.66
Sammaz 36 x P4	55.63	59.35	56.89	59.31	64.18	59.62	3.81	4.84	2.74	169.19	172.93	146.66
Sammaz 36 x P7	57.78	61.33	56.23	61.53	65.92	60.03	3.71	4.59	3.83	233.53	162.49	138.07
Sammaz 36 x P8	55.42	61.74	58.57	58.59	64.92	62.18	3.22	3.17	3.61	147.59	175.99	153.79
Dent Q x P1	54.92	56.85	58.69	57.5	66.43	62.82	2.46	9.67	4.14	184.17	168.93	167.92
Dent Q x P2	57.91	60.45	59.06	60.92	63.32	62.45	2.94	2.89	3.4	179.86	158.47	145.26
Dent Q x P3	57.5	58.39	56.72	61.75	62.34	59.62	4.3	3.96	2.92	137.61	182.87	161.16
Dent Q x P4	56.04	58.38	53.9	60.12	63.17	57.49	4.13	4.81	3.6	150.3	181.21	145.78
Dent Q x P7	56.49	60.61	56.89	59.97	63.26	61.31	3.44	2.45	4.43	142.62	173.69	147.06
Dent Q x P8	60.33	59.73	58.58	62.89	62.69	62.18	2.49	2.93	3.6	176.33	184.58	165.55
Flint Q x P1	58.3	58.66	59.98	60.88	66.4	64.59	2.58	7.71	4.69	119.75	154.41	137.13
Flint Q x P2	57.33	62.6	57.76	61.12	64.92	61.69	3.66	2.31	3.92	223.67	165.7	156.88
Flint Q x P3	58.54	54.26	57.34	61.79	57.25	61.36	3.22	2.94	3.92	164.91	127.83	131.09
Flint Q x P4	57.55	60.18	59.52	60.49	64.71	65.01	2.94	4.5	5.51	122.34	177.84	153.15
Flint Q x P7	56.53	59.69	58.32	60.12	65.08	63.2	3.56	5.42	4.95	169.48	165.8	139.99
Flint Q x P8	58.67	55.24	60.08	61.92	60.09	65.57	3.27	3.86	5.48	166.74	178.91	158.31
Oba 98	58.45	57.89	56.56	61.85	63.17	60.1	3.52	5.45	3.52	184.82	169.73	153.86
Range	53.91-61.17	54.26-62.60	53.90-61.41	57.19-63.21	57.25-66.43	57.49-65.57	1.88-5.55	1.51-9.67	1.97-7.14	119.75-242.29	127.83-184.58	129.06-168.23
Mean	57.02	57.8	57.8	60.42	62.65	62.03	3.42	3.86	4.24	180	162.27	150.38
±SE	1.82	2.52	2.3	1.87	2.52	2.42	0.87	1.84	1.23	102.08	12.14	11.03
CV (%)	3.19	4.36	3.98	3.1	4.02	3.9	25.44	47.67	29.01	56.71	7.48	7.33

DT = days to 50% tasseling, DS = days to 50% silking, ASI = anthesis-silking interval, PHT = plant height, NS = non-water stress, IS=intermediate-water stress, SS=severe-water stress, ±SE = standard error

Table 4.6.Continued

Top cross hybrid	EHT(cm)			SEN			NEP			GY(kg/ha)		
	NS	IS	SS	NS	IS	SS	NS	IS	SS	NS	IS	SS
Sammaz 17 x P1	74.52	79.07	78.85	-	1.72	1.36	1.20	1.30	1.04	3195.53	1709.09	596.51
Sammaz 17 x P2	80.39	69.75	60.64	-	1.55	1.29	1.32	1.22	1.09	3753.79	1742.21	1066.02
Sammaz 17 x P3	89.17	81.93	76.89	-	1.45	1.44	1.25	1.18	0.95	3101.75	1768.76	402.52
Sammaz 17 x P4	88.52	79.96	79.69	-	1.35	1.12	1.31	1.20	1.02	4018.52	1304.02	1454.73
Sammaz 17 x P7	86.65	61.52	75.25	-	1.50	1.18	1.28	1.23	1.07	4286.97	1760.38	1206.77
Sammaz 17 x P8	91.92	69.88	64.29	-	1.48	1.47	1.33	1.23	1.02	1864.84	1948.35	736.84
Sammaz 18 x P1	84.42	74.27	72.51	-	1.84	1.85	1.24	1.19	1.06	4823.35	2245.31	614.45
Sammaz 18 x P2	84.83	68.23	81.16	-	1.55	1.77	1.25	1.23	1.03	3027.71	2713.99	914.16
Sammaz 18 x P3	82.76	71.08	78.04	-	1.22	1.24	1.33	1.18	0.99	2609.54	2002.79	471.71
Sammaz 18 x P4	82.42	71.20	75.88	-	1.66	1.63	1.40	1.25	1.08	3684.38	1393.33	991.64
Sammaz 18 x P7	87.41	84.01	78.39	-	1.47	1.30	1.28	1.19	1.05	3432.12	1588.85	630.90
Sammaz 18 x P8	79.13	68.93	66.06	-	1.60	1.77	1.31	1.23	1.03	3529.86	1609.88	886.88
Sammaz 19 x P1	96.75	75.47	80.77	-	1.49	1.36	1.32	1.18	1.10	3818.78	2157.36	1000.53
Sammaz 19 x P2	78.96	74.59	73.73	-	1.74	1.48	1.30	1.17	1.03	3959.25	1861.45	1063.99
Sammaz 19 x P3	85.23	72.83	78.33	-	1.84	1.24	1.30	1.17	0.95	3366.69	1929.61	311.60
Sammaz 19 x P4	87.10	76.15	76.62	-	1.53	1.56	1.23	1.26	1.01	2769.08	1060.87	1277.70
Sammaz 19 x P7	58.16	65.77	74.99	-	1.42	1.37	1.19	1.24	1.14	3609.63	1568.14	1094.21
Sammaz 19 x P8	90.37	76.51	73.71	-	1.42	1.43	1.17	1.22	1.09	3464.94	2147.29	651.90
Sammaz 34 x P1	78.32	73.72	76.59	-	1.50	1.31	1.20	1.19	1.04	4218.78	1417.54	541.20
Sammaz 34 x P2	83.15	70.01	68.98	-	1.58	1.50	1.35	1.21	1.00	3614.03	2443.45	2030.99
Sammaz 34 x P3	72.86	71.07	76.33	-	1.67	1.36	1.29	1.21	0.99	3584.04	1186.61	440.50
Sammaz 34 x P4	78.13	79.85	72.33	-	1.63	1.55	1.25	1.15	1.07	4130.51	1129.95	788.55
Sammaz 34 x P7	81.94	78.68	73.30	-	1.80	1.40	1.30	1.42	1.07	4352.53	1223.06	962.13
Sammaz 34 x P8	83.62	76.85	55.79	-	1.49	1.54	1.35	1.18	0.99	3500.49	2362.99	452.12

EHT = ear height, SEN = leaf Senescence, NEP = number of ears per plant, GY = grain yield, NS = non-water stress, IS = intermediate-water stress, SS = severe-water stress, ±SE = standard error

Table 4.6.Continued

Top cross hybrid	EHT(cm)			SEN			NEP			GY(kg/ha)		
	NS	IS	SS	NS	IS	SS	NS	IS	SS	NS	IS	SS
Sammaz 36 x P1	83.15	71.68	74.11	-	1.70	1.21	1.26	1.18	1.06	3212.57	1484.74	1141.69
Sammaz 36 x P2	70.64	77.67	76.84	-	1.73	1.23	1.41	1.16	1.06	3167.35	1604.52	1494.88
Sammaz 36 x P3	89.00	72.09	65.02	-	1.68	1.25	1.36	1.19	1.12	5176.36	1890.64	1177.78
Sammaz 36 x P4	81.19	80.16	70.92	-	1.74	1.24	1.31	1.16	1.04	3667.71	1538.16	772.79
Sammaz 36 x P7	93.36	80.80	81.82	-	1.42	1.40	1.34	1.25	1.04	2951.90	2061.55	1109.25
Sammaz 36 x P8	80.72	79.48	70.77	-	1.37	1.43	1.34	1.13	1.00	5391.41	1884.37	1056.09
Dent Q x P1	89.47	72.20	74.14	-	1.63	1.25	1.41	1.19	1.06	2538.12	1414.54	1039.88
Dent Q x P2	95.54	69.08	73.01	-	1.59	1.27	1.31	1.22	0.94	3676.88	1534.86	762.76
Dent Q x P3	78.15	86.71	67.01	-	1.56	1.76	1.30	1.20	0.96	3279.95	1396.42	828.88
Dent Q x P4	82.54	71.98	75.91	-	1.50	1.89	1.42	1.19	0.93	3105.41	1646.33	835.31
Dent Q x P7	89.82	79.24	70.82	-	1.42	1.57	1.36	1.16	1.02	3485.97	1906.20	814.39
Dent Q x P8	91.04	70.54	79.78	-	1.76	1.24	1.29	1.20	0.93	3128.44	2432.88	800.90
Flint Q x P1	74.77	73.63	59.11	-	1.68	1.89	1.23	1.23	1.01	3839.14	1501.50	799.84
Flint Q x P2	81.95	79.06	74.26	-	1.52	1.15	1.39	1.33	1.00	4012.19	1826.49	991.39
Flint Q x P3	75.76	65.85	67.60	-	1.66	1.52	1.31	1.19	1.04	3524.36	1177.63	780.44
Flint Q x P4	82.29	82.78	63.65	-	1.36	1.31	1.22	1.15	0.91	3040.72	1379.28	1301.76
Flint Q x P7	91.21	70.44	96.97	-	1.65	1.55	1.31	1.23	1.03	2283.85	1577.92	723.12
Flint Q x P8	80.80	82.67	89.08	-	1.49	1.18	1.24	1.22	0.94	3201.10	1345.07	121.14
Oba 98	81.21	79.51	74.96	-	1.89	1.31	1.29	1.26	1.06	3729.90	2785.02	833.76
Range	58.16-96.75	61.52-86.71	55.79-96.97	-	1.21-1.89	1.06-1.89	1.17-1.54	1.13-1.42	0.91-1.21	1864.84-5391.41	1060.87-2785.02	121.14-2030.99
Mean	83.27	74.81	73.58	-	1.54	1.41	1.30	1.21	1.03	3488.10	1769.84	863.09
±SE	0.07	6.03	8.88	-	0.23	0.22	9.58	0.07	0.07	742.49	567.90	413.32
CV (%)	0.08	8.06	12.07	-	14.94	15.60	736.92	5.79	6.80	21.29	32.09	47.89

EHT = ear height, SEN = leaf Senescence, NEP = number of ears per plant, GY = grain yield, NS = non-water stress, IS= intermediate-water stress, SS=severe-water stress, ±SE = standard error

The mean squares due to genotypes were significant ($P \leq 0.01$) for anthesis-silking interval under non-water stress and severe-water stress conditions but were non-significant for leaf senescence and number of ears per plant. The genotype x location mean squares under non-water stress condition were highly significant ($P \leq 0.01$) for days to 50% tasseling, plant height and grain yield.

Under intermediate-water stress, highly significant differences were observed for days to 50% tasseling, days to 50% silking anthesis-silking interval, plant height, ear height and grain yield while under severe-water stress condition, the genotype x location interactions were highly significant for days to 50% tasseling, plant height, ear height and grain yield. The mean squares due to genotypes x locations were significant ($P \leq 0.05$) for days to 50% silking but were non-significant for anthesis-silking interval, leaf senescence and number of ears per plant under intermediate-water stress and severe-water stress conditions.

The performance of 42 top cross hybrids under non-water stress, intermediate-water stress and severe-water stress conditions across Samaru and Kadawa is presented in Table 4.6. Under non-water stress condition, the grand mean for days to 50% tasseling was 57.02 days and the mean value ranged from 54.63 days (Sammaz 18 X P2) to 61.17 days (Sammaz 17 x P3) for the top cross hybrids. Under intermediate-water stress condition, Flint Q x P3 recorded the lowest mean value 54.26 days and Flint Q x P2 (62.25 days) recorded the maximum for days to 50% tasseling with an overall mean of 57.80 days. Under severe-water stress condition, the grand mean for days to 50% tasseling was 57.80 days and ranged from 53.90 days (Dent Q x P4) to 61.41 days (Sammaz 18 x P7) for the top cross hybrids.

For days to 50% silking under non-water stress condition, the grand mean was 60.42 days and the mean value ranged from 57.19 days (Sammaz 34 xP7) to 63.21 days

(Sammaz 17 x P8) for the top cross hybrids. Under intermediate-water stress condition, Flint Q x P3 recorded the lowest mean value 57.25 days and Dent Q x P1 (66.43 days) recorded the maximum for days to 50% silking with an overall mean of 62.65 days. Under severe-water stress condition, the grand mean for days to 50% silking was 62.03 days and ranged from 61.26 days (Sammaz 36) to 63.99 days (Flint Q) for the top cross hybrids.

For anthesis-silking interval under intermediate-water stress condition, the grand mean was 3.86 days and the mean value ranged from 1.51 days (Sammaz 19 x P3) to 9.67 days (Dent Q x P1) for the top cross hybrids.

For plant height under non-water stress condition, the grand mean was 180.00cm and the mean value ranged from 51.42cm (Sammaz 34 x P1) to 122.34cm (Flint Q x P4) for the top cross hybrids. Under intermediate-water stress condition, Flint Q x P3 recorded the lowest mean value 127.83cm and Dent Q x P8 (184.58cm) recorded the maximum for plant height with an overall mean of 162.27cm. Under severe-water stress condition, the grand mean for plant height was 150.38cm and ranged from 131.32cm (Sammaz 17 x P2) to 167.92cm (Dent Q x P1) for the top cross hybrids.

For ear height under non-water stress condition, the grand mean was 83.27cm and the mean value ranged from 58.16cm (Sammaz 19 x P7) to 95.54cm (Dent Q x P2) for the top cross hybrids. Under intermediate-water stress condition, Sammaz 17 x P7recorded the lowest mean value 61.52cm and Dent Q x P3 (86.71cm) recorded the maximum for ear height with an overall mean of 74.81cm. Under severe-water stress condition, the grand mean for ear height was 73.58cm and ranged from 55.79cm (Sammaz 34 x P8) to 96.97cm (Flint Q x P7) for the top cross hybrids.

For grain yield under non-water stress condition, the grand mean was 3488.10kg/ha and the mean value ranged from 1864.84kg/ha (Sammaz 17 x P8) to 5391.41kg/ha (Sammaz 36 x P8) for the top cross hybrids. Under intermediate-water stress condition, Sammaz 19 x P4 recorded the lowest mean value 1060.87kg/ha and Sammaz 18 x P2 (2713.99kg/ha) recorded the maximum for grain yield with an overall mean of 1769.84kg/ha. Under severe-water stress condition, the grand mean for grain yield was 863.09kg/ha and ranged from 121.14kg/ha (Flint Q x P8) to 2030.99kg/ha (Sammaz 34 x P2) for the top cross hybrids.

Under non-water stress condition, thirteen top cross hybrids yielded higher than the check with the highest yielding giving 45% yield advantage (Sammaz 36 x P8) which produced 5391.41kg/ha. Under intermediate-water stress condition, none of the top cross hybrids produced grains more than the check. However, under severe-water stress condition twenty-one top cross hybrids produced higher than the check, with the highest yielder (Sammaz 34 x P2) producing 2030.99kg/ha which is 144% increase over the commercial hybrid check. Across all the conditions, the average performance of Sammaz 34 x P2 was 2696.16kg/ha was 10% over the check which was 2450.00kg/ha.

4.2 Analyses of Variance of NCDII

4.2.1 Analysis of variance for NCDII at Samaru

Analysis of variance for traits evaluated under non-water stress, intermediate-water stress and severe-water stress conditions at Samaru is presented in Table 4.7. Under non-water stress condition, the mean squares due to females were highly significant ($P \leq 0.01$) for days to 50% tasseling, plant height, ear height and grain yield

Table 4. 7. Mean squares from NCDII ANOVA for grain yield and other agronomic traits measured under non-water stress, intermediate-water stress and severe-water stress conditions at Samaru

		DT			DS			ASI			PHT		
Source of variation	df	NS	IS	SS	NS	IS	SS	NS	IS	SS	NS	IS	SS
Replication	1												
Female	6	6.39**	12.21**	7.91**	5.22*	15.46**	15.97**	2.50*	5.55*	5.63**	332.94**	728.56**	239.62**
Male	5	8.14**	19.45**	12.30**	2.69^{NS}	10.53**	18.24**	4.76**	12.49**	15.76**	140.01**	659.87**	1026.34**
Female x Male	30	8.93**	10.68**	12.24**	6.65**	16.78**	14.07**	2.20*	3.91^{NS}	7.07**	509.07**	548.67**	243.57**
Error	41	6.47	14.62	10.46	7.18	14.88	13.89	1.93	12.46	3.90	354.28	420.76	188.32
Total													
		EHT			SEN			NEP			GY		
Source of variation	df	NS	IS	SS	NS	IS	SS	NS	IS	SS	NS	IS	SS
Replication	1												
Female	6	145.12**	52.58**	300.02**	-	0.14^{NS}	0.21^{NS}	0.02*	0.01^{NS}	0.02^{NS}	1017442.70**	562024.29**	810506.27**
Male	5	1105.93**	101.39**	463.53**	-	1.31**	0.24^{NS}	0.06*	0.02*	0.02^{NS}	10279578.30**	2957326.60**	1996478.62**
Female x Male	30	145.69**	113.80**	239.17**	-	0.14**	0.17**	0.02^{NS}	0.01^{NS}	0.01^{NS}	911149.85**	794358.10**	555597.65**
Error	41	204.12	98.45	225,00	_-	0.06	0.07	0.02	0.01	0.01	463299.45	642746.96	348085.99

* and ** = significant at P ≤ 0.05 and P ≤ 0.01, probability level respectively, DT = days to 50% tasseling, DS = days to 50% silking, ASI = anthesis-silking interval, PHT = plant height, EHT = ear height, NEP = number of ears per plant, GY = grain yield, SEN = leaf senescence, NS = non-water stress, IS = intermediate-water stress, SS = severe-water stress

and significant ($P \leq 0.05$) for days to 50% silking, anthesis-silking interval and number of ears per plant. The mean squares due to males were highly significant for days to 50% tasseling, anthesis-silking interval, plant height, ear height and grain yield and they were significant for number of ears per plant. The mean squares due to females by males interaction were highly significant for days to 50% tasseling, days to 50% silking, plant height, ear height and grain yield but significant for anthesis-silking interval.

Under intermediate-water stress, the mean squares due to females were highly significant for days to 50% tasseling, days to 50% silking, plant height, ear height and grain yield but significant for anthesis-silking interval. The mean squares due to males were highly significant for days to 50% tasseling, days to 50% silking, anthesis-silking interval, plant height, ear height, leaf senescence and grain yield and significant for number of ears per plant. The mean squares due to females by males interaction were highly significant for days to 50% tasseling, days to 50% silking, plant height, ear height, leaf senescence and grain yield.

Under severe-water stress condition, the mean squares due to females were highly significant for days to 50% tasseling, days to 50% silking, anthesis-silking interval, plant height, ear height and grain yield. The mean squares due to males were highly significant for days to 50% tasseling, days to 50% silking, anthesis-silking interval, plant height, ear height and grain yield. The mean squares due to females by males interaction were highly significant for days to 50% tasseling, days to 50% silking, anthesis-silking interval, plant height, ear height, leaf senescence and grain yield.

4.2.2 Analysis of variance of NCDII at Kadawa

Analysis of variance for traits measured under non-water stress, intermediate-water stress and severe-water stress conditions at Kadawa is presented in Table 4.8.

Table 4. 8. Mean squares from NCD II ANOVA for grain yield and agronomic traits measured under non-water stress, intermediate-water stress and severe-water stress conditions at Kadawa

		DT			DS			ASI			PHT		
Source of variation	df	NS	IS	SS	NS	IS	SS	NS	IS	SS	NS	IS	SS
Replication	1												
Female	6	21.27**	18.08**	10.91**	18.33**	19.44**	17.97**	0.71^{NS}	0.57*	1.23*	224.60**	279.91**	73.82**
Male	5	15.34**	20.34**	8.34**	15.93**	29.41**	11.08**	1.81*	1.79**	0.7^{NS}	5312.44**	194.05**	1535.36**
Female x Male	30	10.89**	9.47*	9.97*	11.68**	9.94**	10.02*	0.91^{NS}	0.65*	0.84^{NS}	638.36*	328.48**	300.98**
Error	41	4.89	12.37	5.70	5.75	13.00	6.13	1.17	0.58	0.76	340.39	279.39	322.31

		EHT			SEN			NEP			GY		
Source of variation	df	NS	IS	SS	NS	IS	SS	NS	IS	SS	NS	IS	SS
Replication	1												
Female	6	153.73**	70.23**	31.66*	-	0.02^{NS}	0.10^{NS}	0.00	0.00	0.01*	739955.54*	1037035.57**	227319.33**
Male	5	1583.79**	187.34**	224.25**	-	0.37^{NS}	0.09^{NS}	0.01^{NS}	0.00	0.01*	4889831.98**	1488070.24*	365435.14**
Female x Male	30	182.20*	90.69**	120.92**	-	0.17^{NS}	0.10^{NS}	0.01^{NS}	0.00	0.01*	1203682.16**	530041.91**	155831.14**
Error	41	110.40	71.08	61.23	-	0.13	0.09	0.01	0.00	0.01	1681193.20	548983.35	164055.28

*= significant at P ≤ 0.05, ** = significant at P ≤ 0.01, probability level respectively, DT = days to 50% tasseling, DS = days to 50% silking, ASI = anthesis-silking interval, PHT = plant heigh, EHT = ear height, NEP = number of ears per plant, GY = grain yield, SEN = leaf senescence, NS = non-water stress, IS = intermediate-water stress, SS = severe-water stress

Under non-water stress condition, the mean squares due to females were highly significant ($P \leq 0.01$) for days to 50% tasseling; days to 50% silking; plant height and ear height but significant ($P \leq 0.05$) for grain yield. The mean squares due to males were highly significant for days to 50% tasseling; days to 50% silking; plant height; ear height and grain yield but significant for anthesis-silking interval. The mean squares due to interaction between females by males were highly significant for days to 50% tasseling; days to 50% silking and grain yield but significant for plant height and ear height.

Under intermediate-water stress condition, the mean squares due to females were highly significant for days to 50% tasseling, days to 50% silking, plant height and ear height and grain yield and significant for anthesis-silking interval. The mean squares due to males were highly significant for days to 50% tasseling, days to 50% silking, anthesis-silking interval, plant height and ear height but significant for grain yield. The mean squares due to interaction between females by males were highly significant for days to 50% silking, plant height and ear height and grain yield but significant for days to 50% tasseling and anthesis-silking interval.

Under severe-water stress condition, the mean squares due to females were highly significant for days to 50% tasseling; days to 50% silking; plant height, grain yield but significant for anthesis-silking interval, ear height and number of ears per plant. The mean squares due to males were highly significant for days to 50% tasseling, days to 50% silking, plant height and ear height but significant for number of ears per plant. The mean squares due to interaction between females by males were highly significant for plant height, ear height and grain yield but significant for days to 50% tasseling, days to 50% silking and number of ears per plant.

4.2.3 Combined analysis of variance for NCDII across locations

Analysis of variance for traits measured under non-water stress, intermediate-water stress and severe-water stress conditions across locations is presented in Table 4.9. The mean squares due to locations were highly significant ($P \leq 0.01$) for all the traits under the three water stress conditions except ear height which was significant ($P \leq 0.05$)) under non-water stress condition.

Under non-water stress condition, the mean squares due to females were highly significant for days to 50% silking, plant height, ear height, number of ears per plant and grain yield but significant for days to 50% tasseling. The mean squares due to males were highly significant for days to 50% silking; number of ears per plant and significant for days to 50% tasseling, plant height, ear height and grain yield. The mean squares due to interaction between females by males were highly significant for days to 50% silking, plant height, ear height, number of ears per plant and grain yield but significant for days to 50% tasseling. The mean squares due to interaction between locations by females were highly significant for plant height, ear height and grain yield. The mean squares due to interaction between locations by males were highly significant for days to 50% tasseling, plant height, ear height, number of ears per plant and grain yield but significant for days to 50% silking. The mean squares due to interaction between locations by females by males were highly significant for days to 50% tasseling, days to 50% silking, plant height, ear height and grain yield but significant for anthesis-silking interval.

Under intermediate-water stress condition, the mean squares due to females were highly significant for days to 50% tasseling, days to 50% silking, ear height and number of ears per plant but significant for plant height and grain yield.

Table 4. 9. Mean squares from combined ANOVA for NCD II of grain yield and other agronomic traits measured under non-water stress, intermediate-water stress and severe-water stress conditions across locations

		DT			DS			ASI			PHT	
Source of variation	df	NS	IS	SS	NS	IS	SS	NS	IS	SS	NS	IS
Replication	2											
Location	1	790.89**	1362.54**	885.98**	528.29**	641.57**	51.89**	29.63**	128.93**	516.04**	31127.46**	204831.54**
Female	6	3.49*	13.15**	7.82*	4.43**	11.44**	12.50*	0.95^{NS}	1.04^{NS}	2.11**	311.18**	661.93*
Male	5	5.54*	16.14**	12.22**	8.98**	19.99**	10.79**	1.01^{NS}	1.26^{NS}	1.90^{NS}	190.63*	829.51**
Female x Male	30	8.20*	7.59**	8.68**	9.77**	9.21**	12.69*	1.19^{NS}	2.33^{NS}	2.33*	334.69**	361.76**
Loc x Female	6	0.76^{NS}	2.92^{NS}	11.29**	1.89^{NS}	3.25^{NS}	17.06*	0.64^{NS}	1.25^{NS}	2.71*	173.23**	324.06**
Loc x Male	5	5.30**	8.49**	12.29**	3.33*	12.23**	23.65**	0.96^{NS}	0.70^{NS}	3.24*	158.02**	171.11**
Loc x F x M	30	4.99**	5.64**	6.84*	7.04**	6.38*	8.62**	1.97*	1.89^{NS}	2.80*	371.52**	373.15**
Error	82	5.21	8.92	5.60	4.92	11.34	7.22	1.59	2.99	2.62	258.78	369.13

		EHT			SEN			NEP			GY	
Source of variation	df	NS	IS	SS	NS	IS	SS	NS	IS	SS	NS	IS
Replication	2											
Location	1	28869.86*	68199.18**	57694.66**	_	55.63**	46.82**	0.54**	0.06**	1.01**	168960063.00**	29926873.25**
Female	6	111.47**	118.68**	108.16*	_	0.15^{NS}	0.09^{NS}	0.02**	0.01**	0.01**	1478127.70**	451928.10*
Male	5	172.05*	143.16**	267.62**	_	0.15^{NS}	0.34**	0.14**	0.01**	0.02*	3125758.80*	1602717.68*
Female x Male	30	122.81**	111.65**	201.94**	_	0.11^{NS}	0.15**	0.00	0.02**	0.02**	1266885.40**	579556.98**
Loc x Female	6	175.19**	142.05**	423.65**	_	0.07^{NS}	0.04*	0.01^{NS}	0.00	0.02*	1111087.90**	524159.54**
Loc x Male	5	62.37**	60.78*	59.35**	_	0.12^{NS}	0.08*	0.05**	0.00	0.01^{NS}	1292741.10**	1604029.48*
Loc x F x M	30	84.71**	86.77**	214.79**	_	0.15^{NS}	0.19**	0.01^{NS}	0.01*	0.03*	1306425.00**	828747.03**
Error	82	206.66	76.54	152.23	_	0.12	0.07	0.05	0.01	0.02	1130195.90	699917.80

* = significant at $P \leq 0.05$, ** = significant at $P \leq 0.01$, probability level respectively, DT = days to 50% tasseling, DS = days to 50% silking, ASI = anthesis-silking interval, PHT = plant height, EHT = ear height, NEP = number of ears per plant, GY = grain yield, SEN = leaf senescence, NS = non-water stress, IS = intermediate-water stress, SS = severe-water stress, F = female, M = male, Loc = location

The mean squares due to males were highly significant for days to 50% tasseling, days to 50% silking, plant height, ear height and number of ears per plant but significant for grain yield. The mean squares due to interaction between females and males were highly significant for days to 50% tasseling, days to 50% silking, plant height, ear height, number of ears per plant and grain yield. The mean squares due to interaction between locations by females were highly significant for plant height, ear height; grain yield. The mean squares due to interaction between locations by males were highly significant for days to 50% tasseling, days to 50% silking and plant height but significant for ear height and grain yield. The mean squares due to interaction between locations by females by males were highly significant for days to 50% tasseling and plant height, ear height and grain yield but significant for days to 50% silking and number of ears per plant.

Under severe-water stress condition, the mean squares due to females were highly significant for anthesis-silking interval, plant height, number of ears per plant and grain yield but significant for days to 50% tasseling, days to 50% silking and ear height. The mean squares due to males were highly significant for days to 50% tasseling, days to 50% silking, plant height, ear height, leaf senescence and grain yield but significant for number of ears per plant. The mean squares due to interaction between females by males were highly significant for days to 50% tasseling, plant height, ear height, leaf senescence, number of ears per plant and grain yield but significant for days to 50% silking and anthesis-silking interval. The mean squares due to interaction between locations by females were highly significant for days to 50% tasseling, plant height, ear height and grain yield but significant for days to 50% silking, anthesis-silking interval, leaf senescence and number of ears per plant. The mean squares due to interaction between locations by males were highly significant for days to 50% tasseling, days to

50% silking, plant height, ear height and grain yield but significant for anthesis-silking interval and leaf senescence. The mean squares due to interaction between locations by females by males were highly significant for days to 50% silking, plant height, ear height, leaf senescence and grain yield but significant for days to 50% tasseling, anthesis-silking interval and number of ears per plant.

4.3 Genetic Estimates

4.3.1 Components of variances for females x males

The females x males variance components under non-water stress, intermediate-water stress and severe-water stress conditions for Samaru, Kadawa and across locations are presented in Table 4.10. At Samaru under non-water stress condition, the magnitudes of $\sigma^2{}_{fm}$ variances were positive for DT, ASI, PHT and GY while were negative for DS and EHT. Under the intermediate-water stress condition, the magnitudes of $\sigma^2{}_{fm}$ variances were positive for DS, PHT, EHT, SEN and GY while were negative for DT and ASI. Under the severe-water stress condition, the magnitudes of $\sigma^2{}_{fm}$ variances were positive for seven traits (DT, DS, ASI, PHT, EHT SEN and GY).

At Kadawa, under non-water stress condition, the magnitudes of $\sigma^2{}_{fm}$ variances were positive for DT, DS, PHT and EHT while were negative for ASI and GY. Under the intermediate-water stress condition, the magnitudes of $\sigma^2{}_{fm}$ variances were positive for ASI, PHT, EHT and SEN while were negative for DT, DS and GY. Under the severe-water stress condition, the magnitudes of $\sigma^2{}_{fm}$ variances were positive for DT, DS, ASI, EHT and SEN while were negative for PHT and GY.

Table 4. 10. Components of variances for females x males for grain yield and other agronomic traits under non-water stress, intermediate-water stress and severe-water stress conditions at Samaru, Kadawa and across locations

	σ^2_{fm}							
Traits	Days to 50% tasseling	Days to 50% silking	Anthesis-silking interval	Plant height	Ear height	Leaf senescence	Number of ears per plant	Grain yield
Samaru								
NS	1.23	-0.27	0.14	77.40	-29.20	-	0.00	223925.00
IS	-1.97	0.95	-4.26	63.95	7.68	0.04	0.00	75806.00
SS	0.89	0.09	1.59	27.65	7.10	0.05	0.00	103756.00
Kadawa								
NS	3.00	2.97	-0.13	149.00	35.90	-	0.00	-238755.50
IS	-1.45	-1.53	0.04	24.55	9.81	0.02	0.00	-9471.00
SS	2.14	1.95	0.04	-10.70	29.84	0.01	0.00	-4112.00
Across locations								
NS	0.80	0.68	-0.20	-9.20	9.52	-	0.00	-9885.00
IS	0.49	0.71	0.11	-2.85	6.23	-0.01	0.00	-62297.76
SS	0.46	1.02	-0.12	33.05	-3.23	-0.01	0.00	6967.81

NS = non-water stress, IS = intermediate-water stress, SS = severe-water stress, σ^2_{fm} = females by males variance components

Across location under non-water stress condition, the magnitudes of $\sigma^2{}_{fm}$ variances were positive for DT, DS and EHT while were negative for ASI, PHT and GY. Under the intermediate-water stress condition, the magnitudes of $\sigma^2{}_{fm}$ variances were positive for DT, DS, ASI and EHT while were negative for PHT, SEN and GY. Under the severe-water stress condition, the magnitudes of $\sigma^2{}_{fm}$ variances were positive for DT, DS, PHT and GY while were negative for ASI, EHT and SEN.

4.3.2 General combining ability variances and specific combining ability variances

The estimates of variances for general combining ability and specific combining ability for grain yield and other agronomic traits at Samaru, Kadawa and Across Samaru and Kadawa are presented in Table 4.11. At Samaru under non-water stress condition, the magnitudes of GCA variances were greater than SCA variances for ASI, EHT, NEP and GY. The ratios of GCA to SCA variances were therefore more than unity for DS, ASI and GY. Under the intermediate-water stress condition, the magnitudes of GCA variances were greater than those of the SCA variances for DT, ASI, SEN and GY. The ratios of the GCA to the SCA variances were more than unity for SEN and GY. Under the severe-water stress condition, the magnitudes of SCA variances were greater than the GCA variances for DT, ASI, SEN and GY. The ratios of the GCA to the SCA variances were less than unity for DT, DS, ASI, SEN, NEP and GY.

At Kadawa, under non-water stress condition, the magnitudes of GCA variances were greater the than SCA variances for ASI, PHT, EHT and GY. The ratios of the GCA to the SCA variances were therefore less than unity for DT, DS, ASI, NEP and GY except PHT and EHT which were more than unity.

Table 4. 11. Estimate of GCA variances, SCA variances and their ratios for grain yield and other agronomic traits under non-water stress, intermediate-water stress and severe-water stress conditions at Samaru, Kadawa and across locations

	$\sigma^2 GCA$			$\sigma^2 SCA$			$\sigma^2 GCA / \sigma^2 SCA$		
Traits	NS	IS	SS	NS	IS	SS	NS	IS	SS
Samaru									
Days to 50% tasseling	-0.51	1.58	-0.66	5.19	-8.63	3.92	-0.10	-0.18	-0.17
Days to 50% silking	-0.83	-1.16	0.93	-0.66	4.36	-0.10	1.26	-0.27	-9.30
Anthesis-silking interval	0.44	1.57	1.12	0.33	-17.85	5.84	1.33	-0.09	0.19
Plant height	-83.89	44.78	119.75	350.65	232.87	55.05	-0.24	0.19	2.18
Ear height	147.49	-11.33	43.87	-185.27	36.69	7.31	-0.80	-0.31	6.00
Leaf senescence	-	0.18	0.02	-	0.08	0.19	_	2.25	0.11
Number of ears per plant	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Grain yield	1457649.54	297020.66	260890.77	217668.75	168087.43	290861.51	6.70	1.77	0.90
Kadawa									
Days to 50% tasseling	2.28	3.00	-0.11	10.82	-7.29	8.58	0.21	-0.41	-0.01
Days to 50% silking	1.68	4.46	1.39	11.00	-8.30	7.04	0.15	-0.54	0.20
Anthesis-silking interval	0.11	0.16	0.04	-0.57	0.07	0.14	-0.19	2.29	0.29
Plant height	655.35	-28.15	154.93	296.65	111.85	-112.03	2.21	-0.25	-1.38
Ear height	211.25	11.72	2.18	45.86	34.02	119.39	4.61	0.34	0.02
Leaf senescence	-	0.01	0.00	-	0.08	0.02	_	0.13	0.00
Number of ears per plant	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Grain yield	495757.23	225388.15	43244.92	-1179674.44	-148564.14	-37377.05	-0.42	-1.52	-1.16
Across Locations									
Days to 50% tasseling	-0.57	1.09	0.21	3.50	1.41	1.75	-0.16	0.77	0.12
Days to 50% silking	-0.47	1.00	-0.16	2.98	2.35	4.15	-0.16	0.43	-0.04
Anthesis-silking interval	-0.03	-0.18	-0.05	-0.76	0.53	-0.45	0.04	-0.34	0.11
Plant height	-12.89	59.06	3.08	-30.67	-40.61	130.79	0.42	-1.45	0.02
Ear height	2.92	2.96	-2.15	36.80	23.51	-11.34	0.08	0.13	0.19
Leaf senescence	-	0.01	0.01	-	-0.04	-0.04	_	-0.25	-0.25
Number of ears per plant	0.01	0.00	0.00	-0.02	0.01	-0.01	-0.50	0.00	0.00
Grain yield	159239.62	68887.15	132686.46	-114730.07	-280414.66	-34387.22	-1.39	-0.25	-3.86

NS = non-water stress, IS = intermediate-water stress, SS = severe-water stress, σ^2 GCA= GCA variance, σ^2 SCA = SCA variance

Under the intermediate-water stress condition, the magnitudes of GCA variances were greater than the SCA variances for DT, DS, ASI and GY. The ratios of the GCA to the SCA variances were therefore less than unity for DT, DS, PHT, EHT, SEN, NEP and GY except ASI which were more than unity. Under the severe-water stress condition, the magnitudes of SCA variances were greater than the GCA variances for DT, DS, ASI, EHT and SEN. The ratios of the GCA to the SCA variances were therefore less than unity for all the traits.

Across location under non-water stress condition, the magnitudes of GCA variances were greater than SCA variances for ASI, PHT, NEP and GY. The ratios of the GCA to the SCA variances were therefore less than unity for all the traits. Under the intermediate-water stress condition, the magnitudes of SCA variances were more than GCA variances for DT, DS, ASI, EHT and NEP. The ratios of the GCA to the SCA variances were therefore less than unity for all the traits. Under the severe-water stress condition, the magnitudes of GCA variances were less than the SCA variances for DT, DS and PHT. The ratios of the GCA to the SCA variances were therefore less than unity for all the traits.

4.4 Estimates of Genetic and Phenotypic Variability Parameters and Heritability

4.4.1 Estimates of genetic and phenotypic variability parameters and heritability at Samaru. The estimates of genotypic variances, phenotypic variances, genotypic coefficient of variation, phenotypic coefficient of variation and heritability for grain yield and other agronomic traits measured under non-water stress, intermediate-water stress and severe-water stress condition at Samaru are presented in Table 4.12. At Samaru under non-water stress condition, the phenotypic variances where higher than genotypic variances for DT, DS, ASI, PHT, EHT and GY and were positive indicating low variances in the parents as compared to crosses.

Table 4. 12. Genetic and phenotypic variability parameters and heritability of grain yield and other agronomic traits under non-water stress, intermediate-water stress and severe-water stress conditions at Samaru

	DT			DS			ASI			PHT		
Variances	NS	IS	SS	NS	IS	SS	NS	IS	SS	NS	IS	SS
σ_e^2	2.59	4.80	4.89	2.54	4.41	3.51	0.94	5.38	1.64	85.80	117.80	77.90
σ_g^2	6.93	5.06	4.29	5.32	4.80	3.68	1.05	7.49	5.35	131.00	168.25	83.05
σ_{ph}^2	9.51	9.86	9.17	7.85	9.21	7.19	1.99	12.87	6.98	216.80	286.05	160.95
GCV (%)	4.82	4.05	3.73	3.95	3.63	3.14	26.48	56.64	40.42	6.26	6.63	5.24
PCV (%)	5.65	5.65	5.46	4.80	5.02	4.38	36.41	74.26	46.19	8.05	8.65	7.29
h_b^2 (%)	72.82	51.34	46.73	67.71	52.12	51.15	52.90	58.18	76.58	60.42	58.82	51.60
h_n^2 (%)	-	12.37	-	-	-	6.09	15.89	27.71	12.41	-	7.71	31.32

	EHT			SEN			NEP			GY		
Variances	NS	IS	SS	NS	IS	SS	NS	IS	SS	NS	IS	SS
σ_e^2	44.50	35.99	99.95	-	0.02	0.01	0.01	0.01	0.01	31281.50	34347.50	17833.50
σ_g^2	85.80	52.37	78.80	-	0.04	0.06	0.01	0.01	0.02	361191.00	371866.00	176456.00
σ_{ph}^2	130.30	88.35	178.75	-	0.05	0.07	0.01	0.02	0.02	392472.50	406213.50	194289.50
GCV (%)	9.44	7.71	9.71	-	8.66	12.37	5.20	8.06	11.13	13.60	27.64	41.51
PCV (%)	11.63	10.02	14.62	-	10.35	12.88	7.35	9.88	12.86	14.17	28.89	43.56
h_b^2 (%)	65.85	59.27	44.08	-	70.00	92.31	50.00	66.67	75.00	92.03	91.54	90.82
h_n^2 (%)	48.45	-	14.99	-	54.42	8.93	22.22	12.50	23.64	43.65	25.39	30.89

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

GCV = genotypic coefficient of variability, PCV = phenotypic coefficient of variability h_b^2 = broad sense heritability, h_n^2 = narrow sense heritability

Hence, the genetic parameters were estimable in the crosses under non-water stress condition. The variation as revealed by GCV and PCV ranged between low to moderate (3.95% for DS to 13.60% for GY) and (4.80% for DS to 14.17% for GY) respectively. PCV estimates were slightly higher than GCV for all the traits. PCV were moderate for ASI, EHT and GY and low for DT, DS, PHT and NEP. Broad sense heritability were higher than narrow sense heritability. Moderate to high heritability (50.00% for NEP to 92.03% for GY) were recorded under non-water stress condition. The broad sense heritability estimates were high for DT, DS, PHT, EHT and GY and moderate for ASI and NEP under non-water stress condition.

Under intermediate-water stress condition, the phenotypic variances where higher than genotypic variances for DT, DS, ASI, PHT, EHT, SEN and GY and were positive indicating low variances in the parents as compared to crosses. Hence, the genetic parameters were estimable in the crosses under intermediate-water stress condition. The variation as revealed by GCV and PCV ranged between low to high (3.63% for DS to 56.64% for ASI) and (5.02% for DS to 74.26% for ASI) respectively. PCV estimates were slightly higher than GCV for all the traits. PCV were high for ASI, moderate for EHT, SEN and GY while low estimates were recorded for DT, DS, PHT and NEP. Broad sense heritability estimates (51.34% for DT to 91.54% for GY) were higher than narrow sense heritability. Moderate to high heritability were recorded under intermediate-water stress condition. The broad sense heritability estimates were high for SEN, NEP and GY and moderate for DT, DS, ASI, PHT, and EHT under intermediate-water stress condition.

Under severe-water stress condition, the phenotypic variances where higher than genotypic variances for DT, DS, ASI, PHT, EHT, SEN and GY and were positive indicating low variances in the parents as compared to crosses. Hence, the genetic parameters were estimable in the crosses under severe-water stress condition. The variation as revealed by GCV and PCV ranged between low to high (3.14% for DS to 41.51% for GY) and (4.38% for DS to 46.19% for ASI) respectively. PCV estimates were slightly higher than GCV for all the traits. PCV were high for ASI and GY, moderate for EHT, SEN and NEP while low estimates were recorded for DT, DS and PHT. Broad sense heritability estimates were higher than narrow sense heritability. Moderate to high heritability (44.08% for EHT to 90.82% for GY) were recorded under severe-water stress condition. The broad sense heritability estimates were high for ASI, SEN, NEP and GY and moderate for DT, DS PHT and EHT under severe-water stress condition.

4.4.2 Estimates of genetic and phenotypic variability parameters and heritability at Kadawa

The estimates of genotypic variances, phenotypic variances, genotypic coefficient of variation, phenotypic coefficient of variation and heritability for grain yield and other agronomic traits measured under non-water stress, intermediate-water stress and severe-water stress condition at Samaru are presented in Table 4.13. At Kadawa under non-water stress condition, the phenotypic variances where higher than genotypic variances for DT, DS ASI, PHT, EHT and GY and were positive indicating low variances in the parents as compared to crosses. Hence, the genetic parameters were estimable in the crosses under non-water stress condition. The variation as revealed by GCV and PCV ranged between low to high (3.39% for DT to 33.33% for GY) and (3.62% for DT to 35.09% for GY) respectively. PCV estimates were slightly higher than GCV for all the traits. PCV were high for GY, moderate for ASI and EHT and low for DT, DS, PHT and NEP. Broad sense heritability estimates were higher than narrow sense heritability.

Table 4. 13. Genetic and phenotypic variability parameters and heritability for grain yield and other agronomic traits under non-water stress, intermediate-water stress and severe-water stress at Kadawa

	DT			DS			ASI			PHT		
Variances	NS	IS	SS	NS	IS	SS	NS	IS	SS	NS	IS	SS
σ_e^2	0.57	1.39	3.20	2.97	4.83	3.68	0.15	0.15	0.05	60.30	76.95	82.85
σ_g^2	4.08	3.44	5.47	6.79	5.49	3.88	0.31	0.35	0.31	152.05	79.30	65.10
σ_{ph}^2	4.65	4.83	8.66	9.76	10.32	7.56	0.46	0.50	0.36	212.35	156.25	147.95
GCV (%)	3.39	2.99	3.89	4.17	3.61	3.13	18.68	20.32	20.01	8.43	6.91	6.36
PCV (%)	3.62	3.54	4.89	5.00	4.95	4.37	22.64	24.34	21.59	9.97	9.69	9.59
h_b^2 (%)	87.74	71.19	63.11	69.61	53.20	51.29	68.13	69.70	85.92	71.60	50.75	44.00
h_n^2 (%)	17.85	23.98	-	12.81	30.51	12.84	9.47	18.70	5.08	48.40	-	31.51

	EHT			SEN			NEP			GY		
Variances	NS	IS	SS	NS	IS	SS	NS	IS	SS	NS	IS	SS
σ_e^2	29.95	20.14	22.59	-	0.03	0.01	0.01	0.01	0.01	78976.50	101534.50	53323.50
σ_g^2	32.25	17.96	17.12	-	0.04	0.04	0.01	0.01	0.02	725342.00	121082.50	24668.00
σ_{ph}^2	62.20	38.10	39.71	-	0.06	0.05	0.01	0.02	0.02	804318.50	222617.00	77991.50
GCV (%)	8.30	7.59	7.42	-	20.12	23.81	5.66	8.47	12.76	33.33	26.10	21.99
PCV (%)	11.53	11.06	11.31	-	26.34	25.25	8.00	10.38	14.73	35.09	35.39	39.10
h_b^2 (%)	51.85	47.15	43.11	-	58.33	88.89	50.00	66.67	75.00	90.18	54.39	31.63
h_n^2 (%)	51.76	10.28	-	-	2.06	-	-	-	-	27.18	29.46	21.17

NS = non-water stress, IS = intermediate-water stress, SS = severe-water stress, σ_e^2 = error variance, σ_g^2 = genotypic variance, σ_{ph}^2 = phenotypic variance, GCV = genotypic coefficient of variability, PCV = phenotypic coefficient of variability h_b^2 = broad sense heritability, h_n^2 = narrow sense heritability

Moderate to high heritability (50.00% for NEP to 90.18% for GY) were recorded under non-water stress condition. The broad sense heritability estimates were high for DT, DS, ASI, PHT, EHT, NEP and GY under non-water stress condition.

Under intermediate-water stress condition, the phenotypic variances where higher than genotypic variances for DT, DS, ASI, PHT, EHT, SEN and GY and were positive indicating low variances in the parents as compared to crosses. Hence, the genetic parameters were estimable in the crosses under intermediate-water stress condition. The variation as revealed by GCV and PCV ranged between low to moderate GCV (2.99% for DT to 26.10% for GY) and low to high PCV (3.54% for DT to 35.39% for GY). PCV estimates were slightly higher than GCV for all the traits. PCV were high for GY, moderate for ASI, EHT and SEN while low estimates were recorded for DT, DS and PHT. Broad sense heritability estimates were higher than narrow sense heritability. Moderate to high heritability (47.15% for EHT to 71.19% for DT) were recorded under intermediate-water stress condition. The broad sense heritability estimates were high for DT, ASI and NEP and moderate fo DS, PHT, EHT, SEN and GY under intermediate-water stress condition.

Under severe-water stress condition, the phenotypic variances where higher than genotypic variances for DT, DS, ASI, PHT, EHT, SEN and GY and were positive indicating low variances in the parents as compared to crosses. Hence, the genetic parameters were estimable in the crosses under severe-water stress condition. The variation as revealed by GCV and PCV ranged between low to moderate for GCV (3.13% to 23.81% for SEN) and low to high for PCV (4.37% for DS to 39.10% for GY). PCV estimates were slightly higher than GCV for all the traits. PCV were high for GY, moderate for ASI, EHT and SEN while low estimates were recorded for DT, DS and PHT. Broad sense heritability estimates were higher than narrow sense heritability.

Moderate to high heritability (531.63% for GY to 85.92% for ASI) were recorded under severe-water stress condition. The broad sense heritability estimates were high for DT, ASI, SEN and NEP and moderate for DS, PHT, EHT and GY under severe-water stress condition.

4.4.3 Estimates of genetic and phenotypic variability parameters and heritability across locations

Across location, under non-water stress condition, the phenotypic variances where higher than genotypic variances for DT, DS, ASI, PHT, EHT and GY and were positive indicating low variances in the parents as compared to crosses. Hence, the genetic parameters were estimable in the crosses under non-water stress condition. The variation as revealed by GCV and PCV ranged between low to moderate (1.63% for DS to 50.73% for GY) and (2.45% for DT to 52.63% for GY) respectively. PCV estimates were slightly higher than GCV for all the traits. PCV were moderate for ASI, PHT and GY and low for DT, DS, EHT and NEP. Broad sense heritability estimates were higher than narrow sense heritability. Moderate to high heritability (41.94% for DS to 92.90% for GY) were recorded under non-water stress condition. The broad sense heritability were high for PHT and GY and moderate for DT, DS, ASI, EHT and NEP under non-water stress condition.

Under intermediate-water stress condition, the phenotypic variances where higher than genotypic variances for DT, DS, ASI, PHT, EHT, SEN and GY and were positive indicating low variances in the parents as compared to crosses. Hence, the genetic parameters were estimable in the crosses under intermediate-water stress condition. The variation as revealed by GCV and PCV ranged between low to high (2.23% for DS to 30.95% for ASI) and (3.52% for DS to 39.18% for ASI) respectively. PCV estimates were slightly higher than GCV for all the traits. PCV were high for ASI, moderate for SEN and GY while low estimates were recorded for DT, DS, PHT, EHT and NEP.

Table 4. 14. Genetic and phenotypic variability parameters and heritability for grain yield and other agronomic traits under non-water stress, intermediate-water stress and severe-water stress across locations

	DT			DS			ASI			PHT		
Variances	NS	IS	SS	NS	IS	SS	NS	IS	SS	NS	IS	SS
σ_e^2	0.41	1.67	0.65	0.75	2.19	1.42	0.38	0.44	0.26	5210.00	23.69	35.81
σ_{gl}^2	0.48	0.69	0.75	0.60	0.72	0.97	-0.07	0.43	0.24	-4626.00	36.12	30.62
σ_g^2	1.06	2.52	0.97	0.98	1.95	1.48	0.36	1.43	1.00	5974.00	70.13	28.48
σ_{ph}^2	1.95	4.88	2.37	2.33	4.85	3.87	0.67	2.29	1.49	6558.00	129.93	94.90
GCV (%)	1.81	2.74	1.71	1.63	2.23	1.96	17.42	30.95	23.56	42.94	5.16	3.55
PCV (%)	2.45	3.82	2.66	2.52	3.52	3.17	23.89	39.18	28.79	44.99	7.02	6.48
h_b^2(%)	54.42	51.56	41.12	41.94	40.15	38.28	53.18	62.40	66.95	91.09	53.97	30.01
h_n^2(%)	-	16.50	4.64	-	11.89	-	-	-	-	-	24.62	1.25

	EHT			SEN			NEP			GY		
Variances	NS	IS	SS	NS	IS	SS	NS	IS	SS	NS	IS	SS
σ_e^2	45.88	18.16	39.38	-	0.01	0.03	0.00	0.00	0.00	3145.50	162525.00	8541.50
σ_{gl}^2	-12.48	1.98	-0.27	-	0.01	-0.01	0.00	0.00	0.00	236002.25	-10025.25	41747.00
σ_g^2	30.63	17.44	26.00	-	0.03	0.04	0.00	0.01	0.01	3130749.75	148250.25	41775.50
σ_{ph}^2	64.03	37.57	65.10	-	0.05	0.06	0.01	0.01	0.01	3369897.50	300750.00	92064.00
GCV (%)	6.65	5.58	6.93	-	10.77	14.18	3.85	5.84	8.41	50.73	21.76	23.68
PCV (%)	9.61	8.19	10.97	-	14.15	17.37	5.44	7.16	9.71	52.63	30.99	35.16
h_b^2(%)	47.83	46.40	39.94	-	57.89	66.67	50.00	66.67	75.00	92.90	49.29	45.38
h_n^2(%)	2.06	5.29	-	-	13.40	36.36	36.84	-	-	21.62	21.70	43.60

NS = non-water stress, IS = intermediate-water stress, SS = severe-water stress, σ_e^2 = error variance, σ_g^2 = genotypic variance, σ_{ph}^2 = phenotypic variance, GCV = genotypic coefficient of variability, PCV = phenotypic coefficient of variability h_b^2 = broad sense heritability, h_n^2 = narrow sense heritability

Broad sense heritability estimates were higher than narrow sense heritability. Moderate to high heritability (40.15% for DS to 66.67% for NEP) were recorded under intermediate-water stress condition. The broad sense heritability estimates were high for ASI and NEP and moderate for DT, DS, PHT, EHT, SEN and GY under intermediate-water stress condition.

Under severe-water stress condition, the phenotypic variances where higher than genotypic variances for DT, DS, ASI, PHT, EHT, SEN and GY and were positive indicating low variances in the parents as compared to crosses. Hence, the genetic parameters were estimable in the crosses under severe-water stress condition. The variation as revealed by GCV and PCV ranged between low to moderate for GCV (1.71% for DT to 23.68% for GY) and for PCV (2.66% for DT to 35.16% for GY). PCV estimates were slightly higher than GCV for all the traits. PCV were high for GY, moderate for ASI, EHT and SEN while low estimates were recorded for DT, DS, PHT and NEP. Broad sense heritability estimates were higher than narrow sense heritability. Moderate to high heritability (30.01% for PHT to 75.00% for NEP) were recorded under severe-water stress condition. The broad sense heritability estimates were high for ASI, SEN and NEP and moderate for DT, DS PHT, EHT and GY under severe-water stress condition.

4.5 General Combining Ability Effects

4.5.1 General combining ability effects for Samaru

The general combining ability effects of parents for eight agronomic traits are presented in Table 4.15. Under the non-water stress condition, the gca effects for days to 50% tasseling ranged from -0.83 (Dent Q) to 0.92 (Sammaz 17) for the female and from-0.86 (P7) to 0.9 (P3) for the males.

Table 4. 15. General combining ability effects of parents for grain yield and other agronomic traits under non-water stress, intermediate-water stress and severe-water stress conditions at Samaru

	DT			DS			ASI			PHT		
Parents	NS	IS	SS	NS	IS	SS	NS	IS	SS	NS	IS	SS
Females												
Sammaz 17	0.92	0.44	0.88	0.88	-0.56	1.45	-0.08	-0.95	0.55	0.50	7.50	6.01
Sammaz 18	-0.58	0.02	0.30	0.38	0.27	-0.21	0.92	0.30	-0.54	8.75	-4.25	0.93
Sammaz 19	0.42	1.44	0.88	-0.04	1.61	1.12	-0.50	0.21	0.21	-3.25	11.00	-6.57
Sammaz 34	0.83	0.27	0.13	0.55	0.44	-0.38	-0.33	-0.12	-0.54	-4.42	-0.42	-1.32
Sammaz 36	-0.67	0.27	-1.37	-0.79	-0.23	-1.38	0.17	-0.45	-0.04	3.17	-6.58	4.60
Dent Q	-0.83	-1.81	-0.20	-0.87	-2.06	0.79	-0.08	-0.20	1.13	-6.75	-10.67	0.43
Flint Q	-0.08	-0.64	-0.62	-0.12	0.52	-1.38	-0.08	1.21	-0.79	2.00	3.42	-4.07
Males												
P1	0.43	0.88	0.15	-0.29	-0.24	-0.35	-0.76	-1.07	-0.38	-2.94	2.58	10.36
P2	0.21	1.74	0.44	-0.07	0.55	0.08	-0.33	-1.14	-0.38	3.92	11.08	9.79
P3	0.93	-0.76	-0.49	0.57	-0.02	-1.92	-0.40	0.79	-1.45	-3.94	-8.77	-10.86
P4	0.29	0.31	1.58	0.50	1.40	1.44	0.45	1.14	-0.17	1.77	0.73	-5.64
P7	-0.86	-0.83	-0.85	-0.50	-0.88	0.80	0.31	0.00	1.62	-1.23	-5.35	0.07
P8	-1.00	-1.33	-0.85	-0.21	-0.81	-0.06	0.74	0.29	0.76	2.42	-0.27	-3.71

DT = days to 50% tasseling, DS = days to 50% silking, ASI = anthesis-silking interval, PHT = plant height NS = non-water stress, IS = intermediate-water stress; SS = severe-water stress

Table 4.15.Continued

Parents	EHT			SEN			NEP			GY		
	NS	IS	SS	NS	IS	SS	NS	IS	SS	NS	IS	SS
Females												
Sammaz 17	3.32	1.71	-0.48	-	-0.09	-0.04	-0.02	0.03	-0.02	179.90	5.29	-137.57
Sammaz 18	1.07	-2.37	0.11	-	-0.06	-0.09	-0.03	-0.01	-0.01	365.08	42.33	492.06
Sammaz 19	3.49	2.13	8.61	-	-0.06	-0.22	-0.05	-0.02	0.04	68.78	153.44	47.62
Sammaz 34	-2.68	-2.45	-7.89	-	0.15	0.15	0.03	-0.01	0.01	31.75	227.51	-26.45
Sammaz 36	-6.35	2.46	2.44	-	0.03	0.14	-0.02	-0.01	-0.05	-338.63	-216.93	121.69
Dent Q	0.32	-0.79	-2.73	-	0.14	0.07	0.05	0.02	-0.04	142.86	153.44	-211.64
Flint Q	0.82	-0.70	-0.06	-	-0.11	0.00	0.02	0.00	0.07	-449.74	-365.08	-285.72
Males												
P1	10.26	1.54	-2.62	-	-0.49	-0.13	-0.02	-0.01	0.01	1021.16	793.65	396.83
P2	11.69	4.18	-2.05	-	-0.25	0.08	0.00	-0.03	-0.04	100.53	0.00	-333.33
P3	-9.02	-3.61	-8.05	-	0.26	0.20	-0.02	-0.02	-0.05	-1328.04	-571.43	-269.84
P4	-1.10	-1.75	-0.33	-	0.26	-0.01	0.13	0.06	0.05	-153.44	-158.73	-142.86
P7	-5.88	0.18	5.02	-	0.19	-0.15	-0.04	0.01	0.04	798.94	158.73	555.56
P8	-5.95	-0.54	8.02	-	0.03	0.01	-0.05	-0.01	-0.01	-439.15	-222.22	-206.35

EHT = ear height, SEN = leaf senescence, NEP = number of ears per plant, GY = grain yield, NS = non-water stress, IS = intermediate-water stress, SS = severe-water stress

Six parents (four females and two males) exhibited negative gca effects while the other seven parents (three females and four males) exhibited positive gca effects. The gca effects for days to 50% silking ranged from -0.87 (Dent Q) to 0.88 (Sammaz 17) for the females and from -0.50 (P7) to 0.57 (P3) for the males. Eight parents (four females and four males) exhibited negative gca effects while the other five parents (three females and two males) exhibited positive gca effects. The gca effects for anthesis-silking interval ranged from -0.50 (Sammaz 19) to 0.92 (Sammaz 18) for the females and from -0.76 (P1) to 0.74 (P8) for the males. Eight parents (five females and three males) exhibited negative gca effects while five parents (two females and three males) exhibited positive gca effects for ASI. The gca effects for plant height ranged from -6.75 (Dent Q) to 8.75 (Sammaz 18) for the females and from -3.94 (P3) to 3.92 (P2) for the males. Six parents (three females and three males) exhibited negative gca effects while seven parents (four females and three males) exhibited positive gca effects. The gca effects for ear height ranged from -6.35 (Sammaz 36) to3.49 (Sammaz 19) for the females and from -9.02 (P3) to 11.69 (P2) for the males. Six parents (two females and four males) exhibited negative gca effects while seven parents (five females and two males) exhibited positive gca effects for the trait. The gca effects for number of ears per plant ranged from-0.05 (Sammaz 19) to 0.05 (Dent Q) for the females and from -0.05 (P8) to 0.13 (P4) for the males. Eight parents (four females and four males) exhibited negative gca effects for NEP while five parents (three females and two males) exhibited positive gca effects. The gca effects for grain yield ranged from -449.74 (Flint Q) to 365.08 (Sammaz 18) for the females and from -1328.04 (P3) to 1021.16 (P1) for the males. Five parents (two females and three males) exhibited negative gca effects while eight parents (five females and three males) exhibited positive gca effects for GY.

Under the intermediate-water stress condition, the gca effects for days to 50% tasseling ranged from -1.81 (Dent Q) to 1.44 (Sammaz 19) for the females and from -1.33 (P8) to 1.74 (P2) for the males. Five parents (two females and three males) exhibited negative gca effects while eight parents (five females and three males) exhibited positive gca effects for the trait. The gca effects for days to 50% silking ranged from -2.06 (Dent Q) to 1.61 (Sammaz 19) for the females and from -0.88 (P7) to1.41 (P4) for the males. Seven parents (three females and four males) exhibited negative gca effects while six parents (four females and two males) exhibited positive gca effects. The gca effects for anthesis-silking interval ranged from -0.95 (Sammaz 17) to 1.21 (Flint Q) for the females and from -1.14 (P2) to 1.14 (P4) for the males. Seven parents (four females and three males) exhibited negative gca effects while six parents (three females and three males) exhibited positive gca effects for the trait. The gca effects for plant height ranged from -10.67 (Dent Q) to 11.00 (Sammaz 19) for the females and from -8.77 (P3) to 11.08 (P2) for the males. Seven parents (four females and three males) exhibited negative gca effects for PHT while six parents (three females and three males) exhibited positive gca effects for the trait. The gca effects for ear height ranged from -2.45 (Sammaz 34) to 2.46 (Sammaz 36) for the females and from -3.60 (P3) to 4.18 (P2) for the males. Seven parents (four females and three males) exhibited negative gca effects while six parents (three females and three males) exhibited positive gca effects for EHT. The gca effects for leaf senescence ranged from -0.11 (Flint Q) to 0.15 (Sammaz 34) for the females and from -0.49 (P1) to 0.26 (P3) for the males. Six parents (four females and two males) exhibited negative gca effects while seven parents (three females and four males) exhibited positive gca effects for SEN. The gca effects for number of ears per plant ranged from -0.02 (Sammaz 19) to 0.03 (Sammaz 17) for the females and from -0.03 (P2) to 0.06 (P4) for the males with eight parents (four females and four males) that exhibited negative gca effects and five parents (three females and two males) exhibited positive gca effects. The gca effects for grain yield ranged from -365.08 (Flint Q) to 227.51 (Sammaz 34) for the females and from -571.43 (P3) to 793.65 (P2) for the males. Five parents (two females and three males) exhibited negative gca effects and eight parents (five females and three males) exhibited positive gca effects for GY.

Under the severe-water stress condition, the gca effects for days to 50% tasseling ranged from -1.37 (Sammaz 36) to 0.88 (Sammaz 17 and Sammaz 19) for the females and from -0.85 (P8) to 1.58 (P4) for the males. Six parents (three females and three males) exhibited negative gca effects while seven parents (four females and three males) exhibited positive gca effects for DT. The gca effects for days to 50% silking ranged from -1.38 (Sammaz 36 and Flint Q) to 1.45 (Sammaz 17) for the females and from -1.92 (P3) to 1.44 (P4) for the males. Seven parents (four females and three males) exhibited negative gca effects while six parents (three females and three males) exhibited positive gca effects for DS. The gca effects for anthesis-silking interval ranged from -0.79 (Flint Q) to 1.13 (Dent Q) for the females and from -1.45 (P3) to 1.62 (P7) for the males. Eight parents (four females and four males) exhibited negative gca effects while five parents (three females and two males) exhibited positive gca effects for ASI.The gca effects for plant height ranged from -6.57 (Sammaz 19) to 6.01 (Sammaz 17) for the females and from -10.86 (P3) to 10.36 (P1) for the males. Six parents (three females and three males) exhibited negative gca effects for PHT while seven parents (four females and three males) exhibited positive gca effects. The gca effects for ear height ranged from -7.89 (Sammaz 34) to 8.61 (Sammaz 19) for the females and from -8.05 (P3) to 8.02 (P8) for the males. Eight parents (four females and four males) exhibited negative gca effects while five parents (three females and two males) exhibited positive gca effects for EHT. The gca effects for leaf senescence ranged from -0.22 (Sammaz 19) to 0.15 (Sammaz 34) for the females and from -0.15 (P7) to 0.20 (P3) for the males. Six parents (three females and three males) exhibited negative gca effects for SEN while six parents (three females and three males) exhibited positive gca effects for the trait. The gca effects for number of ears per plant ranged from -0.05 (Sammaz 36) to 0.07 (Flint Q) for the females and from -0.05 (P3) to 0.05 (P4) for the males. Seven parents (four females and three males) exhibited negative gca effects while six parents (three females and three males) exhibited positive gca effects for NEP. The gca effects for grain yield ranged from -285.72 (Flint Q) to 492.06 (Sammaz 18) for the females and from -333.33 (P2) to 555.56 (P7) for the males. Eight parents (four females and four males) exhibited negative gca effects while five parents (three females and two males) exhibited positive gca effects for GY.

4.5.2 General combining ability effects for Kadawa

The general combining ability effects of parents for eight agronomic traits are presented in Table 4.16. Under the non-water stress condition, the gca effects for days to 50% tasseling ranged from -1.80 (Dent Q) to 1.37 (Sammaz 17 and Sammaz 18) for the females and from -0.86 (P7) to 2.00 (P3) for the males. Six parents (three females and three males) exhibited negative gca effects while seven parents (four females and two males) exhibited positive gca effects for DT. The gca effects for days to 50% silking ranged from -1.87 (Dent Q) to 1.38 (Sammaz 17) for the females and from -1.27 (P1) to 1.87 (P3) for the males. Eight parents (four females and four males) exhibited negative gca effects while five parents (three females and two males) exhibited positive gca effects for DS.

Table 4. 16. General combining ability effects of parents for grain yield and other agronomic traits under non-water stress, intermediate-water stress and severe-water stress conditions at Kadawa

	DT			DS			ASI			PHT		
Parents	NS	IS	SS	NS	IS	SS	NS	IS	SS	NS	IS	SS
Females												
Sammaz 17	1.37	-1.00	1.23	1.38	-1.17	1.46	0.01	-0.15	0.24	-2.25	1.32	-3.49
Sammaz 18	1.37	-1.33	0.89	1.30	-1.58	1.46	-0.07	-0.24	0.57	4.17	-0.93	1.60
Sammaz 19	1.04	1.58	0.39	0.88	1.42	0.46	-0.15	-0.24	0.07	-1.00	2.57	2.35
Sammaz 34	0.20	1.33	-0.19	-0.12	1.42	-0.45	-0.32	0.10	-0.26	-6.92	5.40	2.26
Sammaz 36	-1.38	0.83	0.06	-0.95	0.92	-0.12	0.43	0.10	-0.18	6.33	-9.10	-0.65
Dent Q	-1.80	-1.08	-1.44	-1.87	-1.00	-1.79	-0.07	0.10	-0.35	-0.83	-2.68	-3.15
Flint Q	-0.80	-0.33	-0.94	-0.62	0.00	-1.04	0.18	0.35	-0.10	0.50	3.40	1.10
Males												
P1	-0.64	0.96	-1.14	-1.27	0.92	-1.19	-0.63	-0.11	-0.05	6.13	-3.32	-11.81
P2	0.00	0.32	0.36	-0.06	-0.01	0.24	-0.06	-0.32	-0.12	5.20	-4.04	-7.88
P3	2.00	1.75	0.79	1.87	2.42	1.24	-0.13	0.68	0.45	-39.30	5.61	2.12
P4	0.07	-0.96	0.71	0.37	-1.23	0.60	0.30	-0.25	-0.12	5.06	0.11	0.05
P7	-0.86	-0.82	-0.07	-0.56	-0.80	-0.12	0.30	0.04	-0.05	11.92	-1.32	18.48
P8	-0.57	-1.25	-0.64	-0.35	-1.30	-0.76	0.23	-0.04	-0.12	10.99	2.96	-0.95

DT = days to 50% tasseling, DS = days to 50% silking, ASI = anthesis-silking interval, PHT = plant height, NS = non-water stress, IS = intermediate-water stress; SS = severe-water stress

Table 4.16.Continued

Parents	EHT			SEN			NEP			GY		
	NS	IS	SS	NS	IS	SS	NS	IS	SS	NS	IS	SS
Females												
Sammaz 17	-1.68	0.10	-1.55	-	0.00	-0.12	-0.01	-0.01	0.04	15.87	-111.11	105.82
Sammaz 18	2.49	-1.32	-0.88	-	0.00	0.02	-0.01	0.02	0.03	-206.35	-407.41	-190.48
Sammaz 19	1.90	0.76	-1.71	-	0.00	-0.05	-0.01	-0.01	0.04	-169.31	-185.18	-79.36
Sammaz 34	-3.18	3.18	2.79	-	-0.07	0.02	0.03	0.00	-0.03	-354.50	518.52	142.86
Sammaz 36	4.99	-4.57	-0.46	-	0.00	0.17	0.01	0.01	-0.02	201.06	-37.04	105.82
Dent Q	0.82	1.10	0.70	-	0.07	-0.05	0.01	0.01	-0.01	238.09	185.19	68.78
Flint Q	-5.35	0.76	1.12	-	0.00	0.02	-0.01	-0.01	-0.04	275.13	37.04	-153.44
Males												
P1	1.98	-3.89	-5.88	-	-0.09	-0.06	0.00	0.00	0.02	693.12	84.66	174.60
P2	1.90	-3.46	-0.81	-	-0.22	-0.12	0.00	-0.01	-0.01	629.63	243.39	-111.11
P3	-21.17	4.04	0.55	-	-0.09	0.06	0.01	-0.02	-0.04	-894.18	-582.01	-206.35
P4	3.40	4.18	-1.45	-	0.09	0.06	0.03	0.01	0.00	-195.77	-169.31	-15.87
P7	5.90	-2.11	6.40	-	0.22	0.00	-0.01	0.02	0.04	-68.78	275.13	206.35
P8	7.98	1.25	1.19	-	0.09	0.06	-0.03	-0.01	-0.01	-164.02	148.15	-47.62

EHT = ear height, SEN= leaf senescence, NEP = number of ears per plant, GY= grain yield, NS = non-water stress, IS = intermediate-water stress, SS = severe-water stress

The gca effects for anthesis-silking interval ranged from -0.32 (Sammaz 34) to 0.43 (Sammaz 36) for the females and from -0.63 (P1) to 0.30 (P4 and P7) for the males. Seven parents (four females and three males) exhibited negative gca effects while six parents **(**three females and three males) exhibited positive gca effects for the trait. The gca effects for plant height ranged from **-**6.92 (Sammaz 34) to 6.33 (Sammaz 36) for the females and from -39.30 (P3) to 11.92 (P7) for the males. Five parents (four females and one male) exhibited negative gca effects while eight parents (three females and five males) exhibited positive gca effects for PHT. The gca effects for ear height ranged from -5.35 (Flint Q) to 4.99 (Sammaz 36) for the females and from -21.17 (P3) to 7.98 (P8) for the males. Four parents (three females and one male) exhibited negative gca effects while nine parents (four females and five males) exhibited positive gca effects for EHT. The gca effects for number of ears per plant ranged from -0.01 (Sammaz 17, Sammaz 18, Sammaz 19 and Flint Q) to 0.03 (Sammaz 34) for the females and from -0.03 (P8) to 0.03 (P4) for the males. Six parents (four females and two males) exhibited negative gca effects while seven parents (three females and four males) exhibited positive gca effects for NEP. The gca effects for grain yield ranged from -354.50 (Sammaz 34) to 275.13 (Flint Q) for the females and from -894.18 (P3) to 693.12 (P1) for the males. Seven parents (three females and four males) exhibited negative gca effects while six parents (four females and two males) exhibited positive gca effects for GY.

Under the intermediate-water stress condition, the gca effects for days to 50% tasseling ranged from -1.33 (Sammaz 18) to 1.58 (Sammaz 19) for the females and from -1.25 (P8) to 1.75 (P3) for the males. Seven parents (four females and three males) exhibited negative gca effects while six parents (three females and three males) exhibited positive gca effect for DT. The gca effects for days to 50% silking ranged from

-1.58 (Sammaz 18) to 1.42 (Sammaz 19 and Sammaz 34) for the females and from -1.30 (P8) to 2.42 (P3) for the males. Seven parents (three females and four males) exhibited negative gca effects while five parents (three females and two males) exhibited positive gca effects for DS. The gca effects for anthesis-silking interval ranged from -0.24 (Sammaz 18 and Sammaz 19) to 0.35 (Flint Q) for the females and from -0.32 (P2) to 0.68 (P3) for the males. Seven parents (three females and four males) exhibited negative gca effect while six parents (four females and two males) exhibited positive gca effects for ASI. The gca effects for plant height ranged from -9.10 (Sammaz 36) to 5.40 (Sammaz 34) for females and from - 4.04 (P2) to 5.61 (P3) for the males. Six parents (three females and three males) exhibited negative gca effects while seven parents (four females and three males) exhibited positive gca effects for the trait. The gca effects for ear height ranged from -4.57 (Sammaz 36) to 3.18 (Sammaz 34) for the females and from -3.89 (P1) to 4.18 (P4) for the males. Five parents (two females and three males) exhibited negative gca effects for EHT while eight parents (five females and three males) exhibited positive gca effects. The gca effects for leaf senescence ranged from -0.07 (Sammaz 34) to 0.07 (Dent Q) for the females and from -0.22 (P2) to 0.22 (P7) for the males. Four parents (one female and three males) exhibited negative gca effects for SEN while four parents (one female and three males) exhibited positive gca effects. The gca effect for number of ears per plant ranged from -0.01 (Sammaz 17, Sammaz 19 and Flint Q) to 0.02 (Sammaz 18) for females and from -0.02 (P3) to 0.02 (P7) for the males. Six parents (three females and three males) exhibited negative gca effects while five parents (three females and two males) exhibited positive gca effects for NEP. The gca effects for grain yield ranged from -407.41 (Sammaz 18) to 518.52 (Sammaz 34) for the females and from -582.01 (P3) to 275.13 (P7) for the males. Six parents (four females and two males) exhibited negative gca effects while seven parents (three females and four males) exhibited positive gca effects for GY.

Under the severe-water stress condition, the gca effects for days to 50% tasseling ranged from -1.44 (Dent Q) to 1.23 (Sammaz 17) for the females and from -1.14 (P1) to 0.79 (P1) for the males. Six parents (three females and three males) exhibited negative gca effects while seven parents (four females and three males) exhibited positive gca effects for the trait. The gca effect for days to 50% silking ranged from -1.79 (Dent Q) to 1.46 (Sammaz 17 and Sammaz 18) for the females and from -1.19 (P1) to 1.24 (P3) for the males. Seven parents (four females and three males) exhibited negative gca effects while six parents (three females and three males) exhibited positive gca effects. The gca effects for anthesis-silking interval ranged from -0.35 (Dent Q) to 0.57 (Sammaz 18) for the females and from -0.12 (P2) to 0.45 (P3) for the males. Nine parents (four females and five males) exhibited negative gca effects for ASI while four parents (three females and one male) exhibited positive gca effects. The gca effect for plant height ranged from -3.49 (Sammaz 17) to 2.35 (Sammaz 19) for the females and from -11.81 (P1) to 18.48 (P7) for the males. Six parents (three females and three males) exhibited negative gca effect while seven parents (four females and three males) exhibited positive gca effects for PHT. The gca effects for ear height ranged from -1.71 (Sammaz 19) to 2.79 (Sammaz 34) for the females and from -5.88 (P1) to 6.40 (P7) for the males. Seven parents (four females and three males) exhibited negative gca effects while six parents (three females and three males) exhibited positive gca effects for EHT. The gca effect for leaf senescence ranged from -0.12 (Sammaz 17) to 0.17 (Sammaz 36) for the females and from -0.12 (P2) to 0.06 (P3, P4 and P8) for the males. Five parents (three females and two males) exhibited negative gca effects while seven parents (four females and three males) exhibited positive gca effects for SEN. The gca effects for number of ears per plant ranged from -0.04 (Flint Q) to 0.04

(Sammaz 17 and Sammaz 19) for the females and from -0.04 (P3) to 0.04 (P7) for the males. Seven parents (four females and three males) exhibited negative gca effects while five parents (three females and two males) exhibited positive gca effects for NEP. The gca effects for grain yield ranged from -190.48 (Sammaz 18) to 105.82 (Sammaz 17 and Sammaz 36) for the females and from -206.35 (P3) to 206.35 (P7) for the males. Seven parents (three females and four males) exhibited negative gca affect while six parents four females and two males) exhibited positive gca effects for GY.

4.5.3 General combining ability effects across locations

The general combining ability effects of parents for eight agronomic traits across Samaru and Kadawa are presented in Table 4.17. Under the non-water stress condition, the gca effects for days to 50% tasseling ranged from -0.44 (Sammaz 18) to 0.48 (Flint Q) for the females and from -0.28 (P4) to 0.90 (P1) for the males. Nine parents (four females and five males) exhibited negative gca effects for DT while four parents (three females and one male) exhibited significant positive gca effects. The gca effects for days to 50% silking ranged from -0.41 (Sammaz 34) to 0.71 (Flint Q) for the females and from -0.46 (P4) to 1.04 (P1) for the males. Seven parents (four females and three males) exhibited negative gca effects while six parents (three females and three males) exhibited positive gca effects for DS. The gca effects for anthesis-silking interval ranged from -0.28 (Sammaz 19) to 0.34 (Flint Q) for the females and from -0.20 (P3 and P4) to 0.23 (P1 and P7) for the males. Seven parents (four females and three males) exhibited negative gca effects while six parents (three females and three males) exhibited positive gca effects for ASI. The gca effects for plant height ranged from -3.72 (Sammaz 36) to 5.67 (Sammaz 17) for the females and from -3.25 (P4) to 4.18 (P2) for the males.

Table 4. 17. General combining ability effects of parents for grain yield and other agronomic traits under non-water stress, intermediate-water stress and severe-water stress conditions across locations

	DT			DS			ASI			PHT		
Parents	NS	IS	SS	NS	IS	SS	NS	IS	SS	NS	IS	SS
Females												
Sammaz 17	-0.02	0.19	-0.13	0.05	0.35	-0.58	0.09	0.18	-0.47	5.67	-7.42	5.95
Sammaz 18	-0.44	-1.43	-0.50	-0.33	-1.40	-0.13	0.09	0.06	0.36	-0.33	-6.76	-4.26
Sammaz 19	0.13	0.18	-0.15	-0.12	0.11	-0.13	-0.28	-0.04	0.10	-2.69	4.73	-0.18
Sammaz 34	-0.32	0.27	0.67	-0.41	0.60	0.67	-0.12	0.31	-0.01	4.01	4.41	-2.67
Sammaz 36	-0.25	0.68	-0.18	-0.31	0.36	-0.36	-0.09	-0.29	-0.19	-3.72	3.72	-0.41
Dent Q	0.43	-0.48	-0.58	0.42	-0.32	-0.71	-0.04	0.02	-0.14	-3.12	2.20	3.74
Flint Q	0.48	0.57	0.88	0.71	0.30	1.25	0.34	-0.23	0.36	0.21	-0.84	-2.17
Males												
P1	0.90	0.86	0.93	1.04	1.22	1.04	0.23	0.39	0.10	-1.79	3.39	-5.98
P2	-0.24	-1.04	-0.68	-0.35	-1.10	-0.36	-0.10	-0.04	0.31	4.18	-0.79	-0.55
P3	-0.21	0.93	0.14	-0.39	0.76	-0.11	-0.20	-0.18	-0.26	-0.93	0.50	2.88
P4	-0.28	-0.43	-0.86	-0.46	-0.53	-0.82	-0.20	-0.07	0.10	-3.25	-10.21	-2.08
P7	-0.14	-0.14	0.14	0.11	-0.21	0.29	0.23	-0.18	0.13	0.50	1.82	2.81
P8	-0.03	-0.18	0.32	0.04	-0.14	-0.04	0.05	0.07	-0.37	1.29	5.29	2.92

DT = days to 50% tasseling, DS = days to 50% silking, ASI = anthesis-silking interval, PHT = plant height, NS = non-water stress, IS = intermediate-water stress, SS = severe-water stress

Table 4.17.Continued

Parents	EHT			SEN			NEP			GY		
	NS	IS	SS	NS	IS	SS	NS	IS	SS	NS	IS	SS
Females												
Sammaz 17	1.98	-1.93	-0.57	-	0.06	0.07	0.01	0.01	0.01	-142.86	-124.34	251.32
Sammaz 18	-1.86	-1.39	-0.98	-	0.06	0.04	0.00	0.00	-0.01	523.81	-31.75	-119.05
Sammaz 19	3.84	0.73	0.35	-	-0.01	-0.05	0.04	0.03	0.02	-58.32	11.73	-7.94
Sammaz 34	0.02	-0.23	4.43	-	-0.03	-0.11	-0.02	-0.01	0.03	-13.23	-198.41	-137.57
Sammaz 36	-0.78	1.81	-1.49	-	-0.09	-0.03	-0.02	-0.01	-0.01	-78.41	123.81	-25.71
Dent Q	0.60	-0.02	0.35	-	0.12	0.03	0.04	0.00	-0.01	-253.97	190.48	-63.49
Flint Q	-3.61	0.98	-2.02	-	-0.10	0.04	-0.04	-0.01	-0.02	23.81	23.81	103.18
Males												
P1	-0.07	-0.56	-5.76	-	0.05	0.05	0.01	0.02	0.01	-119.05	-190.48	-55.56
P2	2.72	2.23	1.02	-	-0.06	-0.07	0.13	0.02	0.00	103.18	-158.73	-87.30
P3	0.61	-1.81	0.81	-	-0.03	-0.12	-0.03	0.01	0.02	531.75	428.57	436.51
P4	-4.57	-3.27	-0.30	-	0.01	-0.05	-0.04	0.00	0.03	39.68	126.98	182.54
P7	-0.14	1.26	3.60	-	-0.09	0.00	-0.05	-0.03	-0.03	-515.87	-190.48	-230.16
P8	1.43	2.15	0.63	-	0.12	0.19	-0.03	-0.01	-0.04	-39.68	-15.87	-246.03

EHT = ear height, SEN = leaf senescence, NEP = number of ears per plant, GY = grain yield, NS = non-water stress IS = intermediate-water stress, SS = severe-water stress

Seven parents (four females and three males) exhibited negative gca effects while six parents (three females and three males) exhibited positive gca effects for PHT. The gca effect for ear height ranged from -3.61 (Flint Q) to 3.84 (Sammaz 19) for the females and from -4.57 (P4) to 2.72 (P2) for the males. Six parents (three females and three males) exhibited negative gca effects while seven parents (four females and three males) exhibited positive gca effects for EHT. The gca effect for number of ears per plant ranged from -0.04 (Flint Q) to 0.04 (Sammaz 19) for the females and -0.05 (P7) to 0.13 (P2) for the males. Seven parents (three females and four males) exhibited negative gca effects while six parents (three females and two males) exhibited positive gca effects for NEP. The gca effect for grain yield ranged from -253.97 (Dent Q) to 523.81 (Sammaz 18) for the females and from -515.87 (P7) to 531.75 (P3) for the males. Eight parents (five females and three males) exhibited negative gca effects while five parents (two females and three males) exhibited positive gca effects for GY.

Under the intermediate-water stress condition, the gca effect for days to 50% tasseling ranged from -1.43 (Sammaz 18) to 0.68 (Sammaz 36) for the females and from -1.04 (P2) to 0.93 (P3) for the males. Six parents (two females and four males) exhibited negative gca effects while seven parents (five females and two males) exhibited positive gca effects for DT. The gca effect for days to 50% silking ranged from -1.40 (Sammaz 18) to 0.60 (Sammaz 34) for the females and from -1.10 (P2) to 1.22 (P1) for the males. Six parents (two females and four males) exhibited negative gca effects while seven parents (five females and two males) exhibited positive gca effects for DS. The gca effect for anthesis-silking interval ranged from -0.29 (Sammaz 36) to 0.31 (Sammaz 34) for the females and from -0.18 (P3 and P7) to 0.39 (P1) for the males. Seven parents (three females and four males) exhibited negative gca effects while six parents (four females and two males) exhibited positive gca effects for ASI. The gca effect for plant height ranged from -7.42 (Sammaz 17) to 4.73 (Sammaz 19) for the females and from -10.21 (P4) to 5.29 (P8) for the males. Five parents (three females and two males) exhibited negative gca effects while eight parents (four females and four males) exhibited positive gca effects for PHT. The gca effect for ear height ranged from -1.9 (Sammaz 17) to 1.81 (Sammaz 36) for the females and from -3.27 (P4) to 2.23 (P2) for the males. Seven parents (four females and three males) exhibited negative gca effects while six parents (three females and three males) exhibited positive gca effects for EHT. The gca effect for leaf senescence ranged from -0.10 (Flint Q) to 0.12 (Dent Q) for the females and from -0.09 (P7) to 0.12 (P8) for the males. Seven parents (four females and three males) exhibited negative gca effects while six parents (three females and three males) exhibited positive gca effects for the trait. The gca effect for number of ears per plant ranged from -0.01 (Sammaz 34, Sammaz 36 and Flint Q) to 0.03 (Sammaz 19) for the females and from -0.03 (P7) to 0.02 (P1 and P2) for the males. Five parents (three females and two males) exhibited negative gca effects while five parents (two females and three males) exhibited positive gca effects for NEP. The gca effect for grain yield ranged from -198.41 (Sammaz 34) to 190.48 (Dent Q) for the females and from -190.48 (P1 and P7) to 428.57 (P3) for the males. Seven parents (three females and four males) exhibited negative gca effects while six parents (four females and two males) exhibited positive gca effects for GY.

Under the severe-water stress condition, the gca effect for days to 50% tasseling ranged from -0.58 (Dent Q) to 0.88 (Flint Q) for the females and from -0.86 (P4) to 0.93 (P1) for the males. Seven parents (five females and two males) exhibited negative gca effects for DT while six parents (two females and four males) exhibited positive gca effects. The gca effect for days to 50% silking ranged from -0.71 (Dent Q) to 0.88 (Flint Q) for the females and from -0.82 (P4) to 1.04 (P1) for the males. Nine parents (five females and four males) exhibited negative gca effects while four parents (two females and two males) exhibited positive gca effects for DS. The gca effect for anthesis-silking interval ranged from -0.19 (Sammaz 36) to 0.36 (Sammaz 18 and Flint Q) for the females and from -0.37 (P8) to 0.31(P2) for the males. Six parents (four females and two males) exhibited negative gca effects for ASI while seven parents (three females and four males) exhibited positive gca effects. The gca effect for plant height ranged from -4.26 (Sammaz18) to 5.95 (Sammaz 17) for the females and from -5.98 (P1) to 2.92 (P8) for the males. Eight parents (five females and three males) exhibited negative gca effects while five parents (two females and three males) exhibited positive gca effects for PHT. The gca effect for ear height ranged from -2.02 (Flint Q) to 4.43 (Sammaz 34) for the females and from -5.76 (P1) to 3.60 (P7) for the males. Six parents (four females and two males) exhibited negative gca effects for EHT while seven parents (three females and four males) exhibited positive gca effects. The gca effect for leaf senescence ranged from -0.11 (Sammaz 34) to 0.07 (Sammaz 17) for the females and from -0.12 (P3) to 0.19 (P8) for the males. Six parents (three females and three males) exhibited negative gca effects for SEN while six parents (four females and two males) exhibited positive gca effects. The gca effect for number of ears per plant ranged from -0.02 (Flint Q) to 0.03 (Sammaz 34) for the females and from -0.04 (P8) to 0.03 (P4) for the males. Six parents (four females and two males) exhibited negative gca effects while six parents (three females and three males) exhibited positive gca effects for NEP. The gca effect for grain yield ranged from -137.57 (Sammaz 34) to 251.32 (Sammaz 17) for the females and from -246.03 (P8) to 436.51 (P3) for the males. Nine parents (five females and four males) exhibited negative gca effects while four parents (two females and two males) exhibited positive gca effects for GY.

4.6 Specific Combining Ability Effects

4.6.1 Specific combining ability effects for Samaru

The specific combining ability effects for eight agronomic traits evaluated under non-water stress, intermediate-water stress and severe-water stress conditions at Samaru are presented in Table 4.18. Under the non-water stress condition, the sca effects for days to 50% tasseling ranged from -5.76 (Sammaz 34 x P1) to 4.24 (Sammaz 19 x P8) . Twenty-one top cross hybrids exhibited negative sca effects while twenty one top cross hybrids exhibited positive sca effects for DT. The sca effects for days to 50% silking ranged from -4.57 (Sammaz 34 x P1) to 3.57 (Sammaz 18 x P8). Twenty-six top cross hybrids exhibited negative sca effects while sixteen top cross hybrids exhibited positive sca effects for DS. The sca effects for anthesis-silking interval ranged from -1.99 (Flint Q x P1) to 2.80 (Sammaz 34 x P7). Twenty top cross hybrids exhibited negative sca effects while twenty two top cross hybrids exhibited positive sca effects for ASI. The sca effects for plant height ranged from -30.44 (Sammaz 36 x P1) to 33.89 (Sammaz 36 x P3). Twenty one top cross hybrids exhibited negative sca effects while twenty one top cross hybrids exhibited positive sca effects for PHT. The sca effects for ear height ranged from -18.11 (Sammaz 18 x P2) to 14.39 (Sammaz 19 x P1). Nineteen top cross hybrids exhibited negative sca effects while twenty three top cross hybrids exhibited positive sca effects for the trait. The sca effects for number of ears per plant ranged from -0.21 (Sammaz 34 x P4) to 0.35 (Sammaz 36 x P3). Twenty one top cross hybrids exhibited negative sca effects for NEP while eighteen top cross hybrids exhibited positive sca effects and three top cross hybrids exhibited zero sca effects. The sca effects for grain yield ranged from -1169.31 (Sammaz 18 x P1) to 1529.10 (Sammaz 19 x P2). Eighteen top cross hybrids exhibited negative sca effects while twenty six top cross hybrids exhibited positive sca effects for GY.

Table 4. 18. Specific combining ability effects of top cross hybrids for grain yield and other agronomic traits under non-water stress, intermediate-water stress and severe-water stress conditions at Samaru

	DT			DS			ASI		
Top cross hybrids	NS	IS	SS	NS	IS	SS	NS	IS	SS
Sammaz 17 x P1	2.15	-0.17	0.83	1.62	-0.20	4.81	-0.49	-0.08	4.00
Sammaz 17 x P2	0.65	3.01	-0.65	-0.38	2.27	-0.71	-0.99	-0.45	-0.20
Sammaz 17 x P3	1.15	-0.80	5.15	1.04	0.82	4.17	-0.07	1.57	-0.96
Sammaz 17 x P4	-2.26	0.93	-2.24	-1.05	-0.38	-3.52	1.26	-1.36	-1.26
Sammaz 17 x P7	-1.26	1.67	1.01	-0.71	1.06	-1.90	0.26	-0.37	-3.04
Sammaz 17 x P8	-0.10	-0.07	-1.77	-0.13	2.69	-0.33	0.01	2.71	1.46
Sammaz 18 x P1	-0.35	2.27	-2.08	-0.38	3.68	-1.36	0.01	1.36	0.58
Sammaz 18 x P2	1.37	-1.63	0.26	0.90	-2.51	-1.05	-0.42	-0.60	-1.29
Sammaz 18 x P3	-1.63	-0.40	-1.10	-0.60	-0.80	-1.33	1.08	-0.44	-0.21
Sammaz 18 x P4	-0.13	-0.98	1.26	-0.68	-1.15	-0.55	-0.50	-0.23	-1.79
Sammaz 18 x P7	-2.55	3.26	-0.65	-1.76	4.94	-1.57	0.83	1.63	-0.20
Sammaz 18 x P8	3.45	-1.56	0.73	3.57	-0.49	-0.83	-0.17	1.02	-1.54
Sammaz 19 x P1	0.12	0.00	0.76	-0.85	0.05	1.10	-0.92	0.00	0.21
Sammaz 19 x P2	-0.63	-0.30	-0.74	-0.60	0.49	0.31	0.08	0.74	1.07
Sammaz 19 x P3	-0.85	2.35	-3.49	-0.74	1.77	-2.90	0.15	-0.62	0.46
Sammaz 19 x P4	1.15	3.01	-1.35	0.26	3.37	0.17	-0.85	0.31	1.54
Sammaz 19 x P7	1.15	1.87	0.35	1.18	2.15	0.43	0.07	0.24	-0.04
Sammaz 19 x P8	4.24	0.35	0.56	3.10	-0.96	1.00	-1.10	-1.36	0.46
Sammaz 34 x P1	-5.76	1.12	1.08	-4.57	0.65	1.31	0.90	-0.51	0.25
Sammaz 34 x P2	0.90	-3.81	-2.02	1.01	-5.49	-2.33	0.15	-1.73	-0.29
Sammaz 34 x P3	-0.85	-2.65	1.51	-0.24	-3.89	0.81	0.65	-1.29	-0.68
Sammaz 34 x P4	-1.20	-1.42	1.98	-0.67	-1.94	3.17	0.30	-1.95	1.21
Sammaz 34 x P7	-3.81	0.00	0.85	2.33	-5.49	-0.21	2.80	-1.73	-1.04
Sammaz 34 x P8	-0.70	-0.05	-2.08	-0.25	0.99	-2.36	0.21	0.99	-0.25
Sammaz 36 x P1	2.88	-0.24	1.76	1.67	-0.13	3.62	-1.45	0.06	1.88
Sammaz 36 x P2	1.38	-1.58	-1.24	-0.50	-1.37	-2.69	-0.45	0.17	-1.43
Sammaz 36 x P3	-0.95	1.00	1.99	-1.42	2.98	3.00	-0.70	2.21	1.04
Sammaz 36 x P4	-0.70	2.44	-1.92	-1.17	4.35	-1.69	-0.70	2.19	0.25
Sammaz 36 x P7	0.44	-0.40	2.51	0.33	-0.73	2.31	-0.06	-0.37	-0.18
Sammaz 36 x P8	-1.06	-1.08	-0.10	-1.17	-1.44	-1.33	-0.06	-0.12	-1.21
Dent Q x P1	0.44	2.08	-1.01	1.25	1.23	-2.00	0.86	-0.62	-1.13
Dent Q x P2	-2.48	-1.64	-2.02	-1.83	-2.74	-1.67	0.69	-1.14	0.38
Dent Q x P3	0.02	-2.08	-0.24	-0.50	-2.11	2.76	-0.81	0.21	2.88
Dent Q x P4	0.69	-1.42	-2.17	1.58	-2.37	-2.19	0.94	-0.67	0.00
Dent Q x P7	1.94	-0.17	-1.65	0.33	0.23	-1.86	-1.56	0.63	-0.18
Dent Q x P8	-1.92	2.92	2.26	-1.45	2.46	2.10	0.51	-0.50	-0.29
Flint Q x P1	1.58	-5.49	-2.49	-0.45	-7.06	-3.05	-1.99	-1.62	-0.54
Flint Q x P2	-1.92	-0.99	6.33	-2.54	0.20	1.48	-0.57	1.48	-4.83
Flint Q x P3	0.17	3.27	1.85	-0.12	1.85	4.64	-0.24	-1.48	2.65
Flint Q x P4	2.17	-2.65	2.56	2.71	-1.30	1.00	0.26	1.31	-1.70
Flint Q x P7	-0.67	0.08	-3.60	-0.20	0.80	-2.67	0.51	0.67	0.95
Flint Q x P8	0.58	1.00	-0.99	2.05	2.98	1.95	1.51	2.21	2.96

DT = days to 50% tasseling, DS = days to 50% silking, ASI = anthesis-silking interval, NS = non-water stress, IS = intermediate-water stress, SS = severe-water stress

Table 4.18.Continued

Top cross hybrids	PHT NS	PHT IS	PHT SS	EHT NS	EHT IS	EHT SS	SEN NS	SEN IS	SEN SS
Sammaz 17 x P1	-10.64	8.18	-11.36	-3.18	-5.35	-7.75	_	0.24	0.14
Sammaz 17 x P2	-0.39	-12.73	-13.57	9.07	-15.48	6.73	_	0.06	0.30
Sammaz 17 x P3	-7.39	5.00	-24.89	1.65	-7.20	4.46	_	-0.06	0.05
Sammaz 17 x P4	-2.73	14.58	-16.87	-6.18	0.49	-5.52	_	0.30	-0.32
Sammaz 17 x P7	27.19	52.52	4.48	12.99	-4.71	18.70	_	-0.23	0.18
Sammaz 17 x P8	-9.39	-2.56	1.46	-10.18	-8.23	10.96	_	-0.48	0.38
Sammaz 18 x P1	3.36	-3.64	10.64	-4.18	-0.92	16.08	_	-0.05	-0.42
Sammaz 18 x P2	1.50	2.92	4.43	-18.11	-0.62	-4.94	_	-0.26	-0.20
Sammaz 18 x P3	-16.25	7.17	-12.14	0.14	2.57	-14.04	_	0.05	0.21
Sammaz 18 x P4	8.75	-32.48	6.93	-5.77	1.00	6.39	_	-0.03	0.02
Sammaz 18 x P7	16.92	11.61	-4.86	2.39	3.94	-10.13	_	-0.04	0.19
Sammaz 18 x P8	-8.67	11.94	3.05	-2.44	-2.75	-9.37	_	0.08	-0.31
Sammaz 19 x P1	-1.25	2.01	3.14	14.39	4.49	-0.80	_	-0.14	-0.22
Sammaz 19 x P2	-1.00	6.00	5.71	9.39	2.21	7.56	_	-0.03	-0.09
Sammaz 19 x P3	3.86	10.86	-3.11	9.61	20.86	1.04	_	-0.02	-0.37
Sammaz 19 x P4	24.61	-7.92	6.69	4.36	2.32	-5.37	_	-0.12	-0.15
Sammaz 19 x P7	-14.39	13.08	5.14	-4.06	4.96	6.04	_	0.39	0.14
Sammaz 19 x P8	9.77	-5.00	-1.79	-3.89	9.15	-2.04	_	-0.30	-0.34
Sammaz 34 x P1	-17.31	-22.75	-0.11	-2.73	9.30	-8.25	_	-0.05	0.05
Sammaz 34 x P2	-13.39	2.61	7.21	-4.39	-2.42	-6.04	_	0.17	-0.22
Sammaz 34 x P3	6.86	-6.64	9.96	1.11	-3.56	-2.11	_	0.26	0.24
Sammaz 34 x P4	-7.36	-7.73	-0.29	3.18	7.95	4.13	_	-0.02	0.11
Sammaz 34 x P7	18.89	2.61	-5.57	-13.07	-2.42	-10.61	_	0.17	-0.11
Sammaz 34 x P8	-12.11	5.17	-2.36	-0.49	-3.29	13.25	_	0.02	0.02
Sammaz 36 x P1	-30.44	5.75	2.85	3.18	-3.35	8.98	_	-0.29	-0.16
Sammaz 36 x P2	6.98	4.93	7.71	-0.65	-1.43	28.89	_	0.05	-0.14
Sammaz 36 x P3	33.89	-15.56	4.36	-0.82	2.70	9.96	_	0.33	0.29
Sammaz 36 x P4	-9.86	11.27	-4.52	8.68	8.67	-2.08	_	0.06	-0.21
Sammaz 36 x P7	20.64	-0.98	2.05	2.96	4.86	-1.44	_	0.06	-0.01
Sammaz 36 x P8	-9.11	-3.64	-11.14	0.71	-8.71	-1.87	_	0.21	0.20
Dent Q x P1	5.39	-20.56	14.36	0.80	1.54	-1.20	_	-0.66	-0.63
Dent Q x P2	2.56	10.94	-11.87	1.96	5.92	3.05	_	0.00	0.14
Dent Q x P3	-8.52	0.36	-6.44	3.63	3.37	-7.38	_	0.40	0.09
Dent Q x P4	-1.11	3.35	-1.86	-9.54	7.24	-4.08	_	-0.18	0.20
Dent Q x P7	-9.86	-5.39	0.21	-0.54	-2.13	-16.61	_	-0.03	0.00
Dent Q x P8	-8.00	9.93	1.64	5.54	-0.85	-7.46	_	-0.25	0.00
Flint Q x P1	-17.75	0.44	16.68	-1.21	-2.39	-6.11	_	0.17	-0.35
Flint Q x P2	19.75	2.92	9.56	7.87	-7.76	-7.17	_	0.35	0.23
Flint Q x P3	3.92	-0.64	-8.79	2.54	-9.50	-10.77	_	-0.23	0.32
Flint Q x P4	0.33	-17.50	2.21	-10.80	-3.43	-0.70	_	0.01	0.24
Flint Q x P7	-8.75	3.01	22.77	10.54	-3.68	8.05	_	0.14	0.03
Flint Q x P8	10.50	-15.56	-11.74	-14.46	2.70	-0.44	_	0.33	0.51

PHT = plant height, EHT = ear height, SEN = leaf senescence, NS = non-water stress, IS = intermediate-water stress, SS = severe-water stress

Table 4.18.Continued

Top cross hybrids	NEP			GY		
	NS	IS	SS	NS	IS	SS
Sammaz 17 x P1	0.05	-0.02	0.00	645.50	-232.81	-301.59
Sammaz 17 x P2	0.08	0.03	0.02	-206.35	-576.72	-518.52
Sammaz 17 x P3	0.00	-0.03	0.11	89.95	-89.95	-100.53
Sammaz 17 x P4	0.03	0.03	0.07	349.21	1000.00	835.98
Sammaz 17 x P7	-0.01	-0.02	0.06	52.90	259.26	195.77
Sammaz 17 x P8	-0.08	0.01	0.03	238.10	15.87	-37.04
Sammaz 18 x P1	-0.07	-0.05	-0.09	-1169.31	-26.46	-42.33
Sammaz 18 x P2	0.11	0.00	-0.04	-1100.53	-164.02	-222.22
Sammaz 18 x P3	-0.02	0.02	-0.03	-396.83	925.93	492.07
Sammaz 18 x P4	0.04	0.04	0.09	-322.75	-248.68	-333.34
Sammaz 18 x P7	-0.08	0.02	0.01	-730.16	719.58	306.88
Sammaz 18 x P8	-0.01	-0.05	0.01	84.65	-100.53	-185.19
Sammaz 19 x P1	-0.03	0.01	-0.08	936.51	-492.06	-507.94
Sammaz 19 x P2	0.00	-0.01	-0.06	1529.10	58.20	95.24
Sammaz 19 x P3	0.02	-0.08	-0.07	772.48	89.95	121.69
Sammaz 19 x P4	0.07	0.00	-0.02	142.86	-481.48	-470.90
Sammaz 19 x P7	0.07	0.00	0.08	216.93	58.20	47.62
Sammaz 19 x P8	-0.01	-0.01	-0.03	253.97	-629.63	-555.56
Sammaz 34 x P1	0.03	0.03	-0.06	-486.77	910.05	439.16
Sammaz 34 x P2	-0.12	-0.06	-0.04	-746.03	84.66	111.11
Sammaz 34 x P3	-0.08	0.03	-0.03	-153.44	608.46	280.42
Sammaz 34 x P4	-0.21	0.01	-0.06	-1068.78	407.41	222.22
Sammaz 34 x P7	-0.19	-0.06	0.06	-587.30	84.66	444.44
Sammaz 34 x P8	-0.11	0.02	-0.09	375.66	132.27	142.86
Sammaz 36 x P1	0.02	0.02	-0.07	190.47	-740.74	-592.59
Sammaz 36 x P2	-0.02	-0.06	0.01	338.63	-195.77	-238.10
Sammaz 36 x P3	0.35	0.00	0.01	301.59	-333.33	-396.82
Sammaz 36 x P4	0.16	-0.04	0.02	449.74	-322.75	-375.66
Sammaz 36 x P7	0.05	-0.03	0.01	-21.16	-58.20	-89.95
Sammaz 36 x P8	0.01	-0.03	-0.07	460.32	-37.04	-63.49
Dent Q x P1	-0.03	0.01	-0.02	89.95	851.85	306.88
Dent Q x P2	0.04	-0.04	0.03	349.21	714.29	296.30
Dent Q x P3	-0.03	0.02	0.03	52.91	-407.41	-433.86
Dent Q x P4	-0.05	0.03	0.31	-873.02	915.35	476.19
Dent Q x P7	0.00	0.00	-0.03	-58.20	-740.74	-682.54
Dent Q x P8	-0.02	0.04	-0.03	772.48	544.98	269.84
Flint Q x P1	0.05	0.02	0.02	587.30	-798.94	-703.70
Flint Q x P2	0.03	-0.05	-0.08	-449.73	-259.26	-338.63
Flint Q x P3	-0.01	0.19	0.03	-412.70	-100.53	-201.06
Flint Q x P4	0.04	-0.01	0.05	-42.32	185.19	148.15
Flint Q x P7	-0.07	0.02	0.01	142.85	470.90	232.81
Flint Q x P8	-0.02	0.00	-0.09	-597.88	-333.33	925.93

NEP = number of ears per plant, GY = grain yield, NS = non-water stress, IS = intermediate-water stress, SS = severe-water stress

Under the intermediate-water stress condition, the sca effects for days to 50% tasseling ranged from -5.49 (Flint Q x P1) to 3.26 (Sammaz 18 x P7). Twenty three top cross hybrids exhibited negative sca effects while, nineteen top cross hybrids exhibited positive sca effects for DT. The sca effects for days to 50% silking ranged from -7.06 (Flint Q x P1) to 4.94 (Sammaz 18 x P7). Twenty top cross hybrids exhibited negative sca effects while twenty two top cross hybrids exhibited positive sca effects for DS. The sca effects for anthesis-silking interval ranged from -1.95 (Sammaz 34 x P4) to 2.71 (Sammaz 17 x P8).Twenty top cross hybrids exhibited negative sca effects for ASI while twenty one top cross hybrids exhibited positive sca effects and one top cross hybrid exhibited zero sca effects. The sca effects for plant height ranged from -32.48 (Sammaz 18 x P4) to 52.52 (Sammaz 17 x P7). Sixteen top cross hybrids exhibited negative sca effects while twenty six top cross hybrids exhibited positive sca effects for PHT. The sca effects for ear height ranged from -15.48 (Sammaz 17 x P2) to 20.86 (Sammaz 19 x P3). Twenty top cross hybrids exhibited negative sca effects while twenty two top cross hybrids exhibited positive sca effects for EHT. The sca effect for leaf senescence ranged from -0.66 (Dnt Q x P1) to 0.40 (Dent Q x P3). Twenty top cross hybrids exhibited negative sca effects while twenty one top cross hybrids exhibited positive sca effects and one top cross hybrid exhibited zero sca effects for SEN. The sca effects for number of ears per plant ranged from -0.08 (Sammaz 19 x P3) to 0.19 (Flint Q x P3). Seventeen top cross hybrids exhibited negative sca effects while nineteen top cross hybrids exhibited positive sca effects and six top cross hybrids exhibited zero sca effects for NEP. The sca effects for grain yield ranged from -798.94 (Flint Q x P1) to 1000.00 (Sammaz 17 x P4). Twenty one top cross hybrids exhibited negative sca effects for GY while twenty one top cross hybrids exhibited sca in positive direction.

Under severe-water stress condition, the sca effects for days to 50% tasseling ranged from -3.60 (Flint Q x P7) to 6.33 (Flint Q x P2). Twenty two top cross hybrids exhibited negative sca effects while twenty top cross hybrids exhibited positive sca effects for DT. The sca effects for days to 50% silking ranged from -3.52 (Sammaz 17 x P4) to 4.81 (Sammaz 17 x P1). Twenty three top cross hybrids exhibited negative sca effects while nineteen top cross hybrids exhibited positive sca effects for DS. The sca effects for anthesis-silking interval ranged from -4.83 (Flint Q x P2) to 4.00 (Sammaz 17 x P1). Twenty three top cross hybrids exhibited negative sca effects while eighteen top cross hybrids exhibited positive sca effects and one top cross hybrid exhibited zero sca effects for ASI. The sca effects for plant height ranged from -24.89 (Sammaz 17 x P3) to 22.77 (Flint Q x P7). Seventeen top cross hybrids exhibited negative sca effects while twenty five top cross hybrids exhibited positive sca effects for PHT. The sca effects for ear height ranged from -16.61(Dent Q x P7) to 28.89 (Sammaz 36 x P2). Twenty five top cross hybrids exhibited negative sca effects while seventeen top cross hybrids exhibited positive sca effects for EHT. The sca effects for leaf senescence ranged from -0.63 (Dent Q x P1) to 0.51 (Flint Q x P8). Seventeen top cross hybrids exhibited negative sca effects while twenty three top cross hybrids exhibited positive sca effects and two top cross hybrids exhibited zero sca effects for SEN. The sca effects for number of ears per plant ranged from -0.09 (Flint Q x P8) to 0.31 (Dent Q x P4). Nineteen top cross hybrids exhibited negative sca effects while twenty two top cross hybrids exhibited positive sca effects and one top cross hybrid exhibited zero sca effects for NEP. The sca effects for grain yield ranged from -703.70 (Flint Q x P1) to 925.93 (Flint Q x P8). Twenty one top cross hybrids exhibited negative sca effects while twenty one top cross hybrids exhibited positive sca effects for GY.

4.6.2 Specific combining ability effects for Kadawa

The specific combining ability effects for eight agronomic traits evaluated under non-water stress, intermediate-water stress and severe-water stress conditions at Kadawa are presented in Table 4.19.

Table 4. 19. Specific combining ability effects of top cross hybrids for grain yield and other agronomic traits under non-water stress, intermediate-water stress and severe-water stress conditions at Kadawa

	DT			DS			ASI		
Top cross hybrids	NS	IS	SS	NS	IS	SS	NS	IS	SS
Sammaz 17 x P1	1.06	1.74	0.06	0.69	1.80	-0.32	-0.37	0.05	-0.38
Sammaz 17 x P2	1.56	0.90	-0.77	2.27	1.21	-1.31	0.71	0.30	-0.54
Sammaz 17 x P3	-0.11	-1.37	1.73	-0.31	-0.77	1.43	-0.20	0.67	-0.30
Sammaz 17 x P4	-3.77	-0.62	4.39	-3.81	-0.27	3.11	-0.04	0.33	-1.29
Sammaz 17 x P7	-1.19	1.35	0.15	-1.48	1.51	0.29	-0.29	0.24	0.13
Sammaz 17 x P8	1.73	2.10	-0.61	1.44	2.01	-0.39	-0.29	-0.10	0.21
Sammaz 18 x P1	0.73	0.83	-1.13	1.19	0.30	-1.43	0.46	-0.55	-0.30
Sammaz 18 x P2	-1.58	2.93	-2.44	-2.02	2.60	-2.32	-0.44	-0.35	0.12
Sammaz 18 x P3	1.42	2.21	1.73	1.06	2.31	2.26	-0.36	0.08	0.54
Sammaz 18 x P4	-0.75	-3.00	-0.96	-0.02	-3.33	-0.68	0.73	-0.35	0.29
Sammaz 18 x P7	-1.92	1.17	1.48	-0.52	1.80	1.10	1.39	0.62	-0.38
Sammaz 18 x P8	-0.83	0.51	-0.44	-1.19	0.93	0.11	-0.36	0.40	0.55
Sammaz 19 x P1	1.08	0.37	0.65	0.73	0.50	1.12	-0.36	0.19	0.46
Sammaz 19 x P2	2.58	-2.90	-2.20	1.98	-3.49	-3.32	-0.61	-0.60	-1.12
Sammaz 19 x P3	-2.08	-1.42	-0.20	-2.45	-0.79	-0.07	-0.37	0.62	0.13
Sammaz 19 x P4	-1.58	-0.62	-1.63	-1.37	-0.27	-2.10	0.21	0.33	-0.46
Sammaz 19 x P7	1.25	2.00	3.46	0.55	1.88	3.68	-0.70	-0.13	0.21
Sammaz 19 x P8	4.08	-1.10	3.05	4.05	-1.70	3.60	-0.04	-0.62	0.55
Sammaz 34 x P1	0.67	-2.01	-1.02	0.88	-1.70	-0.98	0.21	0.38	0.05
Sammaz 34 x P2	-0.92	2.83	-2.38	-0.70	2.21	-2.26	0.21	-0.63	0.12
Sammaz 34 x P3	-1.42	-0.17	2.23	-0.95	1.00	1.68	0.46	1.15	-0.55
Sammaz 34 x P4	2.35	0.07	-1.51	2.05	0.38	-1.46	-0.30	0.30	0.05
Sammaz 34 x P7	-2.65	-0.83	2.65	-3.87	-0.92	2.54	-1.21	-0.10	-0.12
Sammaz 34 x P8	3.18	1.05	0.32	3.55	1.23	1.04	0.37	0.17	0.71
Sammaz 36 x P1	1.01	1.17	1.39	1.05	1.58	1.18	0.04	0.40	-0.21
Sammaz 36 x P2	-1.90	0.62	-2.27	-2.12	1.08	-1.82	-0.21	0.52	0.45
Sammaz 36 x P3	-1.49	-2.33	-0.10	-0.20	-2.20	-0.55	1.29	0.12	-0.45
Sammaz 36 x P4	-0.49	-1.35	-0.77	-0.45	-1.29	-0.64	0.04	0.05	0.13
Sammaz 36 x P7	-1.73	-0.88	0.04	-0.52	-1.50	0.32	1.20	-0.56	0.29
Sammaz 36 x P8	3.77	0.30	-0.77	4.06	-0.86	0.11	0.29	-1.17	0.88
Dent Q x P1	-0.89	-3.08	-1.20	-1.52	-3.20	-0.24	-0.63	-0.05	0.96
Dent Q x P2	-2.56	0.83	0.37	-3.52	1.08	0.82	-0.96	0.24	0.45
Dent Q x P3	1.52	-1.74	-1.02	2.31	-1.57	-0.90	0.79	0.15	0.12
Dent Q x P4	-1.06	1.74	1.23	-1.77	1.30	0.26	-0.71	-0.45	-0.96
Dent Q x P7	0.94	-2.24	-1.37	0.98	-1.99	-1.32	0.04	0.24	0.05
Dent Q x P8	1.99	-4.21	-2.18	2.26	-3.83	-2.96	0.27	0.44	-0.79
Flint Q x P1	-2.51	-0.95	-1.54	-2.15	-1.36	-2.32	0.36	-0.42	-0.79
Flint Q x P2	-2.68	-0.55	-0.61	-2.24	-0.92	0.68	0.44	-0.31	1.29
Flint Q x P3	3.15	0.42	0.23	2.76	-0.92	0.43	-0.39	-1.26	0.20
Flint Q x P4	1.74	4.70	-2.61	1.60	5.08	-2.82	-0.14	0.02	-0.21
Flint Q x P7	0.65	-0.05	-1.11	0.51	-0.42	-0.82	-0.14	-0.31	0.29
Flint Q x P8	-2.35	1.58	5.70	-2.74	1.50	5.32	-0.39	-0.10	-0.38

DT = days to 50% tasseling, DS = days to 50% silking, ASI = anthesis-silking interval,
NS = non-water stress, IS = intermediate-water stress, SS = severe-water stress

Table 4.19.Continued

Top cross hybrids	PHT			EHT			SEN		
	NS	IS	SS	NS	IS	SS	NS	IS	SS
Sammaz 17 x P1	13.54	-0.76	2.13	6.61	-6.89	2.48	_	-0.36	0.12
Sammaz 17 x P2	-8.38	6.74	13.73	-2.56	1.52	1.96	_	0.00	0.21
Sammaz 17 x P3	-23.71	-3.86	2.37	-4.48	6.24	-3.27	_	-0.31	0.30
Sammaz 17 x P4	8.20	12.81	11.73	4.11	-4.18	-4.79	_	0.20	-0.01
Sammaz 17 x P7	8.45	11.79	6.94	-3.56	2.88	-8.99	_	0.00	-0.07
Sammaz 17 x P8	-0.38	-0.55	-8.52	-5.39	3.96	-4.12	_	0.07	-0.08
Sammaz 18 x P1	2.29	16.79	7.37	5.27	8.75	13.37	_	-0.31	-0.14
Sammaz 18 x P2	-0.54	-6.96	-20.80	0.68	-2.45	-10.52	_	0.00	-0.06
Sammaz 18 x P3	-6.95	26.39	-4.20	0.51	17.40	2.89	_	0.56	-0.17
Sammaz 18 x P4	1.71	-6.11	-0.88	2.60	-10.45	-4.05	_	-0.12	0.67
Sammaz 18 x P7	11.63	20.95	-1.12	6.68	2.00	-14.86	_	0.12	-0.02
Sammaz 18 x P8	-5.62	-9.46	-1.94	-4.99	-4.95	4.05	_	-0.07	0.06
Sammaz 19 x P1	4.55	-0.68	-16.06	-2.32	-0.52	1.68	_	-0.20	0.15
Sammaz 19 x P2	-4.79	3.95	13.05	-3.15	3.71	4.95	_	0.00	0.23
Sammaz 19 x P3	45.46	-2.96	-9.70	26.25	-3.67	-11.13	_	0.49	-0.14
Sammaz 19 x P4	16.55	-12.19	7.87	4.08	-0.93	-3.46	_	-0.31	0.08
Sammaz 19 x P7	-3.79	-14.46	-4.95	-9.83	-5.67	-5.55	_	-0.31	-0.21
Sammaz 19 x P8	-26.37	12.57	7.38	-6.25	9.11	17.29	_	0.44	0.23
Sammaz 34 x P1	-13.12	-5.43	13.81	-5.42	-3.98	-1.29	_	0.44	-0.08
Sammaz 34 x P2	-27.45	-8.55	-8.55	-7.25	4.17	-1.21	_	-0.31	-0.21
Sammaz 34 x P3	8.71	6.81	-6.38	-1.58	-0.12	-6.19	_	0.31	0.23
Sammaz 34 x P4	-37.89	2.32	12.77	-20.82	0.69	4.76	_	0.00	0.00
Sammaz 34 x P7	14.69	-4.69	4.69	10.01	8.46	2.60	_	-0.05	-0.15
Sammaz 34 x P8	2.86	-14.86	-5.06	0.60	-13.68	1.93	_	0.12	-0.07
Sammaz 36 x P1	-5.23	10.81	8.05	-10.32	2.71	9.81	_	0.31	-0.02
Sammaz 36 x P2	22.52	2.07	2.05	17.51	-0.11	2.31	_	-0.12	-0.02
Sammaz 36 x P3	2.19	-2.55	5.52	5.68	0.75	0.43	_	0.20	0.29
Sammaz 36 x P4	0.86	1.82	-17.77	-2.65	9.19	5.80	_	-0.07	-0.01
Sammaz 36 x P7	-9.25	-8.76	-12.63	-2.32	-1.69	-7.21	_	0.31	-0.14
Sammaz 36 x P8	-6.17	-10.61	-11.02	-3.49	-2.60	-1.62	_	0.05	-0.08
Dent Q x P1	25.00	-9.21	-11.20	11.10	-6.33	-4.96	_	0.12	-0.35
Dent Q x P2	10.92	-16.36	-2.38	4.68	-2.54	-2.05	_	-0.12	-0.21
Dent Q x P3	-17.83	1.45	-17.05	-8.49	-1.62	-0.36	_	0.00	-0.21
Dent Q x P4	-3.17	-17.26	9.87	-1.82	-9.64	1.89	_	-0.44	0.08
Dent Q x P7	0.50	-0.21	-1.37	0.35	-1.54	-5.38	_	0.00	-0.06
Dent Q x P8	-11.32	-1.18	-8.81	-10.39	0.48	-2.40	_	-0.12	-0.15
Flint Q x P1	-9.74	2.31	6.80	-8.56	-2.26	4.79	_	-0.31	0.30
Flint Q x P2	-2.07	-6.26	16.87	0.02	2.14	12.14	_	0.31	-0.14
Flint Q x P3	0.85	-12.36	10.80	1.11	-0.62	4.23	_	-0.12	0.05
Flint Q x P4	5.60	19.07	-17.70	4.94	1.81	-6.86	_	-0.12	0.05
Flint Q x P7	24.26	-4.26	15.12	11.11	-2.11	6.31	_	-0.05	-0.21
Flint Q x P8	-7.57	21.89	9.20	1.77	2.55	4.62	_	-0.20	-0.06

PHT = plant height, EHT = ear height, SEN = leaf senescence, NS = non-water stress, IS = intermediate-water stress, SS = severe-water stress

Table 4.19.Continued

Top cross hybrids	NEP			GY		
	NS	IS	SS	NS	IS	SS
Sammaz 17 x P1	0.03	0.00	-0.09	-396.82	465.61	148.15
Sammaz 17 x P2	0.06	0.02	-0.09	269.84	502.65	306.88
Sammaz 17 x P3	-0.01	0.03	0.04	1121.69	-164.02	-100.53
Sammaz 17 x P4	-0.03	0.02	0.08	-470.90	-423.28	-174.60
Sammaz 17 x P7	0.02	-0.03	0.03	84.66	312.17	89.95
Sammaz 17 x P8	-0.06	-0.05	-0.08	269.84	-613.76	-285.72
Sammaz 18 x P1	-0.01	-0.01	-0.04	-878.31	-259.26	-132.28
Sammaz 18 x P2	0.07	0.06	0.09	555.55	682.54	529.10
Sammaz 18 x P3	0.00	-0.10	0.11	-1222.22	-15.87	-74.07
Sammaz 18 x P4	0.00	-0.01	0.13	-148.15	-47.62	-95.24
Sammaz 18 x P7	-0.06	-0.01	0.03	259.26	-629.63	-333.33
Sammaz 18 x P8	-0.02	0.02	0.08	-296.30	-280.42	-137.56
Sammaz 19 x P1	0.01	-0.04	-0.05	-333.33	100.53	52.91
Sammaz 19 x P2	0.01	-0.03	-0.01	1185.18	164.02	58.20
Sammaz 19 x P3	0.02	-0.01	-0.05	968.25	259.26	58.20
Sammaz 19 x P4	0.01	-0.02	0.03	746.03	132.27	52.91
Sammaz 19 x P7	0.03	0.02	0.05	-179.90	333.33	95.24
Sammaz 19 x P8	-0.05	-0.02	-0.02	-439.15	-608.47	-238.10
Sammaz 34 x P1	0.04	0.01	0.01	116.40	502.65	269.84
Sammaz 34 x P2	-0.04	-0.02	0.02	-1031.74	-481.48	-206.35
Sammaz 34 x P3	-0.01	-0.01	-0.10	-179.90	-195.77	-100.53
Sammaz 34 x P4	-0.12	-0.01	-0.09	714.29	-904.76	-391.54
Sammaz 34 x P7	-0.10	0.04	0.10	936.51	-677.25	-354.50
Sammaz 34 x P8	0.00	0.02	0.08	-1322.75	58.20	15.87
Sammaz 36 x P1	0.06	0.02	-0.09	-26.46	544.97	444.45
Sammaz 36 x P2	0.00	0.02	0.02	306.88	26.45	-37.04
Sammaz 36 x P3	0.11	-0.01	-0.10	-396.83	1259.26	682.54
Sammaz 36 x P4	0.03	0.00	-0.02	-211.64	354.50	121.69
Sammaz 36 x P7	0.00	-0.06	-0.10	-1412.70	26.46	15.87
Sammaz 36 x P8	-0.01	0.02	0.02	-523.81	-89.95	-100.53
Dent Q x P1	-0.03	0.05	0.02	994.71	-481.48	-201.06
Dent Q x P2	0.08	0.01	-0.02	735.45	693.12	534.39
Dent Q x P3	-0.03	0.04	0.06	-264.55	-354.50	-174.60
Dent Q x P4	-0.02	0.00	-0.03	809.53	-312.17	-137.57
Dent Q x P7	0.01	-0.01	0.04	-338.62	89.95	21.16
Dent Q x P8	0.00	0.04	0.03	-428.57	-47.62	-95.24
Flint Q x P1	0.04	0.03	-0.03	-206.35	502.64	206.35
Flint Q x P2	0.01	0.04	-0.01	-465.61	100.53	47.62
Flint Q x P3	0.00	-0.06	0.03	-58.20	26.45	-37.04
Flint Q x P4	-0.01	-0.01	-0.01	52.91	-195.77	-111.11
Flint Q x P7	0.00	0.01	-0.05	682.54	-10.58	-63.49
Flint Q x P8	-0.03	0.01	-0.02	423.28	-343.92	-169.31

NEP = number of ears per plant, GY = grain yield, NS = non-water stress, IS = intermediate-water stress, SS = severe-water stress

Under the non-water stress condition, the sca effects for days to 50% tasseling ranged from -3.77 (Sammaz 17 x P4) to 4.08 (Sammaz 19 x P8). Twenty two top cross hybrids exhibited negative sca effects while twenty top cross hybrids exhibited positive sca effects for DT. The sca effects for days to 50% silking ranged from -3.87 (Sammaz 34 x P7) to 4.06 (Sammaz 36 x P8). Twenty two top cross hybrids exhibited negative sca effects while twenty top cross hybrids exhibited positive sca effects for DS. The sca effects for anthesis-silking interval ranged from -1.21 (Sammaz 34 x P7) to 1.39 (Sammaz 18 x P7). Twenty three top cross hybrids exhibited negative sca effects while nineteen top cross hybrids exhibited positive sca effects for ASI. The sca effects for plant height ranged from -37.89 (Sammaz 34 x P4) to 45.46 (Sammaz 19 x P3). Twenty one top cross hybrids exhibited negative sca effects while twenty one top cross hybrids exhibited positive sca effects for PHT. The sca effects for ear height ranged from -20.82 (Sammaz 34 x P4) to 26.25 (Sammaz 19 x P3). Twenty one top cross hybrids exhibited negative sca effects while twenty-one top cross hybrids exhibited positive sca effects for EHT. The sca effects for number of ears per plant ranged from -0.12 (Sammaz 34 x P4) to 0.11 (Sammaz 36 x P3). Twenty-one top cross hybrids exhibited negative sca effects while eighteen top cross hybrids exhibited positive sca effects and three top cross hybrids exhibited zero sca effects for NEP. The sca effects for grain yield ranged from -1412.70 (Sammaz 36 x P7) to 1185.18 (Sammaz 19 x P2). Eighteen top cross hybrids exhibited negative sca effects while twenty four top cross hybrids exhibited positive sca effects for GY.

Under the intermediate-water stress condition, the sca effects for days to 50% tasseling ranged from -4.21(Dent Q x P8) to 4.70 (Flint Q x P4). Twenty top cross hybrids exhibited negative sca effects while twenty two top cross hybrids exhibited positive sca effects for DT. The sca effects for days to 50% silking ranged from -3.83 (Dent Q x P8) to 5.08 (Flint Q x P4). Twenty one top cross hybrids exhibited negative sca effects while twenty one top cross hybrids exhibited positive sca effects for DS. The sca effects for anthesis-silking interval ranged from -1.26 (Flint Q x P3) to 1.15 (Sammaz 34 x P3). Eighteen top cross hybrids exhibited negative sca effects while twenty four top cross hybrids exhibited positive sca effects for ASI. The sca effect for plant height ranged from -17.26 (Dnt Q x P4) to 26.39 (Sammaz 18 x P3). Twenty five top cross hybrids exhibited negative sca effects while seventeen top cross hybrids exhibited positive sca effects for PHT. The sca effects for ear height ranged from -13.68 (Sammaz 34 x P8) to 17.40 (Sammaz 18 x P3). Twenty three top cross hybrids exhibited negative sca effects while nineteen top cross hybrids exhibited positive sca effects for EHT. The sca effects for leaf senescence ranged from -0.44 (Dent Q x P4) to 0.56 (Sammaz 18 x P3). Twenty top cross hybrids exhibited negative sca effects while fifteen top cross hybrids exhibited positive sca effects and seven top cross hybrids exhibited zero sca effects for SEN. The sca effects for number of ears per plant ranged from -0.10 (Flint Q x P4) to 0.06 (Sammaz 18 x P2). Sixteen top cross hybrids exhibited negative sca effects while twenty top cross hybrids exhibited positive sca effects and six top cross hybrids exhibited zero sca effects for NEP. The sca effects for grain yield ranged from -904.76 (Sammaz 34 x P4) to 1259.26 (Sammaz 36 x P3). Twenty one top cross hybrids exhibited negative sca effects while twenty one top cross hybrids exhibited positive sca effects for GY.

Under the severe-water stress condition, the sca effects for days to 50% tasseling ranged from -2.61 (Flint Q x P4) to 5.70 (Flint Q x P8). Twenty four top cross hybrids exhibited negative sca effects while eighteen top cross hybrids exhibited positive sca effects for DT. The sca effects for days to 50% silking ranged from -3.32 (Sammaz 19 x P2) to 5.32 (Flint Q x P8). Twenty two top cross hybrids exhibited negative sca effects while twenty top cross hybrids exhibited positive sca effects for DS. The sca effects for anthesis-silking interval ranged from -1.29 (Sammaz 17 x P4) to 1.29 (Flint Q x P2). Seventeen top cross hybrids exhibited negative sca effects while twenty five top cross hybrids exhibited positive sca effects for ASI. The sca effects for plant height ranged from -20.80 (Sammaz 18 x P2) to 16.87 (Flint Q x P2). Twenty one top cross hybrids exhibited negative sca effects while twenty one top cross hybrids exhibited positive sca effects for PHT. The sca effects for ear height ranged from -14.86 (Sammaz 18 x P7) to 17.29 (Sammaz 19 x P8). Twenty one top cross hybrids exhibited negative sca effects while twenty one top cross hybrids exhibited positive sca effects for EHT. The sca effects for leaf senescence ranged from -0.35 (Dent Q x P1) to 0.67 (Sammaz 18 x P4). Twenty six top cross hybrids exhibited negative sca effects while fifteen top cross hybrids exhibited positive sca effects and one top cross hybrid exhibited zero sca effects for SEN. The sca effects for number of ears per plant ranged from -0.10 (Sammaz 36 x P7) to 0.13 (Sammaz 18 x P4). Nineteen top cross hybrids exhibited negative sca effects while twenty two top cross hybrids exhibited positive sca effects and one top cross hybrid exhibited zero sca effects for NEP. The sca effects for grain yield ranged from -391.54 (Sammaz 34 x P4) to 682.54 (Sammaz 36 x P3). Twenty one top cross hybrids exhibited negative sca effects while twenty one top cross hybrids exhibited positive sca effects for GY.

4.6.3 Specific combining ability effects across locations

The specific combining ability effects for eight agronomic traits evaluated under non-water stress, intermediate-water stress and severe-water stress conditions across Samaru and Kadawa are presented in Table 4.20. Under the non-water stress condition, specific combining ability effects for days to 50% tasseling ranged from -3.04 (Dent Q x P3) to 2.28 (Sammaz 36 x P1). Twenty one top cross hybrids exhibited negative sca effects while twenty one top cross hybrids exhibited positive sca effects for DT. The sca effects for days to 50% silking ranged from -3.03 (Dent Q x P3) to 2.47 (Sammaz 18 x P3).

Table 4. 20. Specific combining ability effects of top cross hybrids for grain yield and other agronomic traits under non-water stress, intermediate-water stress and severe-water stress conditions across locations

	DT			DS			ASI		
Top cross hybrids	NS	IS	SS	NS	IS	SS	NS	IS	SS
Sammaz 17 x P1	-0.19	0.06	-0.55	0.92	0.15	0.30	0.98	0.07	0.86
Sammaz 17 x P2	-1.05	-1.05	-0.70	-1.44	-0.02	-1.31	-0.20	0.99	-0.60
Sammaz 17 x P3	1.92	-2.26	0.48	1.85	-2.13	0.44	-0.09	0.14	-0.03
Sammaz 17 x P4	-1.76	1.85	0.23	-1.58	1.65	0.90	0.16	-0.22	0.61
Sammaz 17 x P7	-0.15	-0.44	0.48	-0.40	-0.67	0.55	-0.27	-0.11	0.08
Sammaz 17 x P8	1.24	1.85	0.05	0.67	1.01	-0.88	-0.59	-0.86	-0.92
Sammaz 18 x P1	-1.52	-1.57	-1.43	-1.96	-2.85	-1.91	-0.52	-1.31	-0.47
Sammaz 18 x P2	0.62	1.58	-1.32	1.43	2.23	-2.27	0.80	0.62	-0.93
Sammaz 18 x P3	1.83	0.61	1.11	2.47	0.12	0.98	0.66	-0.49	-0.11
Sammaz 18 x P4	-1.60	-0.78	-0.64	-1.96	-0.35	-0.55	-0.34	0.40	0.03
Sammaz 18 x P7	1.01	-0.57	1.61	1.22	-0.42	1.84	0.23	0.26	0.24
Sammaz 18 x P8	-0.35	0.72	0.68	-1.21	1.26	1.91	-0.84	0.51	1.24
Sammaz 19 x P1	1.91	0.07	-0.03	1.84	0.64	0.34	-0.15	0.54	0.30
Sammaz 19 x P2	-1.20	0.46	-0.17	-1.27	-0.79	-0.26	-0.08	-1.28	-0.17
Sammaz 19 x P3	0.26	0.75	-0.49	0.02	1.85	-0.51	-0.22	1.11	-0.10
Sammaz 19 x P4	0.08	-0.40	0.76	0.34	-0.11	0.70	0.28	0.26	0.30
Sammaz 19 x P7	0.44	1.65	-0.82	0.02	1.82	-1.49	-0.40	0.28	-0.74
Sammaz 19 x P8	-1.42	-2.15	0.58	-0.91	-3.00	0.92	0.53	-0.89	0.26
Sammaz 34 x P1	-1.15	0.48	3.40	-0.38	-0.10	4.30	0.69	-0.56	0.90
Sammaz 34 x P2	-0.26	-1.38	-0.99	-1.23	-1.52	-0.81	-0.99	-0.13	0.19
Sammaz 34 x P3	1.71	2.40	1.44	1.55	2.12	1.69	-0.13	-0.49	0.26
Sammaz 34 x P4	1.03	0.26	0.94	1.38	-0.10	-0.35	0.37	-0.35	-1.35
Sammaz 34 x P7	-1.36	-0.27	-2.81	-1.45	-0.92	-2.70	-0.06	-0.49	0.12
Sammaz 34 x P8	0.03	-1.49	-1.99	0.13	0.51	-2.13	0.12	2.01	-0.13
Sammaz 36 x P1	2.28	0.07	-0.25	2.03	1.14	-0.18	-0.34	1.04	0.08
Sammaz 36 x P2	-0.58	1.97	0.11	0.42	1.96	-0.78	0.99	-0.03	-0.88
Sammaz 36 x P3	-1.61	-1.50	-1.21	-1.79	-1.90	-1.03	-0.16	-0.39	0.19
Sammaz 36 x P4	0.46	-1.39	-0.71	-0.22	-0.86	-0.32	-0.66	0.50	0.33
Sammaz 36 x P7	-0.18	-0.18	1.74	-0.59	-0.63	1.47	-0.39	-0.34	-0.25
Sammaz 36 x P8	-0.29	1.11	-0.14	0.28	0.50	0.40	0.59	-0.64	0.55
Dent Q x P1	-0.15	1.48	1.40	-0.46	1.57	0.17	-0.39	0.23	-1.22
Dent Q x P2	1.49	-0.88	0.51	1.43	-1.61	1.07	-0.07	-0.59	0.57
Dent Q x P3	-3.04	0.40	-0.81	-3.03	0.29	-1.18	0.04	0.05	-0.36
Dent Q x P4	0.78	0.01	-0.06	0.79	-0.68	0.53	0.04	-0.55	0.53
Dent Q x P7	0.89	-0.02	0.19	1.22	1.00	0.42	0.36	0.30	0.24
Dent Q x P8	0.03	-0.99	-1.24	0.04	-0.57	-1.01	0.04	0.55	0.24
Flint Q x P1	-1.19	-0.57	-2.55	-2.00	-0.55	-3.04	-0.27	-0.02	-0.47
Flint Q x P2	0.95	-0.67	2.55	0.64	-0.23	4.36	-0.45	0.41	1.82
Flint Q x P3	-1.08	-0.39	-0.52	-1.07	-0.34	-0.39	-0.09	0.05	0.14
Flint Q x P4	0.99	0.47	-0.52	1.25	0.45	-0.93	0.16	-0.05	-0.47
Flint Q x P7	-0.40	0.18	-1.02	0.18	0.38	-0.79	0.48	0.30	0.24
Flint Q x P8	0.74	0.97	2.05	1.00	0.30	0.79	0.16	-0.70	-1.26

DT = days to 50% tasseling, DS = days to 50% silking, ASI = anthesis-silking interval,
NS = non-water stress, IS = intermediate-water stress SS=severe-water stress

Table 4.20.Continued

Top cross hybrids	PHT			EHT			SEN		
	NS	IS	SS	NS	IS	SS	NS	IS	SS
Sammaz 17 x P1	1.08	8.32	-7.52	-2.48	-2.07	0.64	-	0.20	0.00
Sammaz 17 x P2	1.36	11.99	4.80	5.49	3.90	-4.90	-	0.00	0.25
Sammaz 17 x P3	-6.78	-12.79	10.12	2.10	8.68	-3.93	-	0.06	-0.18
Sammaz 17 x P4	2.79	-5.08	-8.42	1.77	-2.85	8.17	-	0.15	0.23
Sammaz 17 x P7	-3.46	2.64	2.69	-1.15	-4.89	-3.97	-	-0.21	-0.17
Sammaz 17 x P8	5.01	-5.08	-1.67	-5.73	-2.78	3.99	-	-0.20	-0.12
Sammaz 18 x P1	10.33	1.90	3.18	-0.14	-5.61	2.05	-	-0.10	0.17
Sammaz 18 x P2	2.11	-22.17	7.26	-0.43	-0.64	8.77	-	0.09	-0.21
Sammaz 18 x P3	1.72	13.79	-9.42	-0.32	-2.86	6.98	-	0.07	-0.02
Sammaz 18 x P4	-1.21	-9.74	4.54	-4.64	5.61	-2.41	-	0.20	0.31
Sammaz 18 x P7	-13.46	12.72	-3.85	-0.32	1.82	-9.05	-	-0.21	-0.28
Sammaz 18 x P8	0.51	3.51	-1.71	5.86	1.68	-6.34	-	-0.06	0.03
Sammaz 19 x P1	3.69	-5.84	5.36	-3.09	-0.23	5.97	-	-0.14	0.03
Sammaz 19 x P2	10.72	-4.91	-11.07	-2.62	2.48	4.18	-	-0.06	-0.12
Sammaz 19 x P3	-16.42	1.05	0.25	-1.02	2.52	-5.35	-	0.14	-0.07
Sammaz 19 x P4	-6.35	-0.73	7.21	-2.84	0.48	0.00	-	-0.13	-0.14
Sammaz 19 x P7	6.49	14.82	11.99	3.82	8.69	4.03	-	0.20	0.25
Sammaz 19 x P8	3.62	-0.23	-10.04	6.66	-11.45	-6.92	-	0.01	0.11
Sammaz 34 x P1	-4.01	0.23	-5.40	5.48	3.98	-7.11	-	-0.15	-0.18
Sammaz 34 x P2	-10.97	0.91	-14.58	-2.30	-0.56	-15.15	-	0.09	0.21
Sammaz 34 x P3	9.89	9.63	-8.26	3.55	-5.52	5.32	-	-0.09	0.00
Sammaz 34 x P4	-7.79	-2.66	18.46	-5.52	0.19	2.42	-	-0.01	-0.08
Sammaz 34 x P7	9.96	5.30	2.57	5.30	5.15	14.03	-	0.20	-0.13
Sammaz 34 x P8	2.92	-13.41	7.21	-6.52	-3.24	0.49	-	-0.04	0.17
Sammaz 36 x P1	-9.78	9.18	10.59	4.78	9.69	-0.19	-	0.16	0.13
Sammaz 36 x P2	-0.75	6.11	-0.34	0.74	1.40	2.53	-	-0.09	0.13
Sammaz 36 x P3	1.11	-6.43	1.48	-4.15	-2.06	-9.26	-	0.00	-0.08
Sammaz 36 x P4	12.18	10.03	-0.81	9.03	0.40	-1.65	-	0.06	-0.15
Sammaz 36 x P7	-0.02	-14.70	-3.25	-5.10	-7.18	3.00	-	0.02	0.01
Sammaz 36 x P8	-2.86	-0.97	-7.56	-3.97	-0.77	3.92	-	-0.13	-0.04
Dent Q x P1	-17.38	-3.81	-10.07	-10.60	-5.73	-4.28	-	0.10	-0.04
Dent Q x P2	9.40	8.12	15.51	8.11	2.23	8.68	-	0.03	-0.20
Dent Q x P3	3.26	-1.92	5.58	-2.78	-0.48	-3.60	-	-0.32	0.07
Dent Q x P4	0.08	3.05	-9.71	-4.10	0.48	-3.49	-	-0.13	-0.08
Dent Q x P7	7.83	-3.49	-3.60	3.22	-1.80	0.86	-	0.24	0.43
Dent Q x P8	-3.20	-1.95	2.29	6.15	5.30	1.83	-	0.07	-0.18
Flint Q x P1	16.04	-10.02	3.85	5.86	0.02	2.85	-	-0.07	-0.10
Flint Q x P2	-11.93	-0.09	-1.58	-9.18	-8.77	-4.19	-	-0.07	-0.07
Flint Q x P3	7.18	-3.38	0.24	2.43	-0.23	9.77	-	0.15	0.28
Flint Q x P4	0.25	5.09	-11.29	6.11	-4.27	-3.12	-	-0.15	-0.09
Flint Q x P7	-5.50	-9.70	-2.68	-2.57	1.95	-8.26	-	-0.18	-0.05
Flint Q x P8	-6.04	18.09	11.46	-2.64	11.30	2.95	-	0.32	0.03

PHT = plant height, EHT = ear height, SEN = leaf senescence, NS = non-water stress, IS = intermediate-water stress, SS=severe-water stress

Table 4.20.Continued

Top cross hybrids	NEP			GY		
	NS	IS	SS	NS	IS	SS
Sammaz 17 x P1	-0.06	-0.02	-0.08	396.83	505.29	-92.59
Sammaz 17 x P2	0.01	-0.03	-0.02	-492.06	-415.34	-505.29
Sammaz 17 x P3	0.04	0.00	0.05	79.37	108.47	637.57
Sammaz 17 x P4	0.00	0.02	0.02	238.09	187.83	558.20
Sammaz 17 x P7	-0.01	0.02	0.06	238.09	-494.71	-362.44
Sammaz 17 x P8	0.03	0.01	-0.03	-460.32	108.47	-235.45
Sammaz 18 x P1	-0.12	-0.02	0.03	841.27	190.48	-166.67
Sammaz 18 x P2	0.10	0.00	0.03	285.71	269.84	87.30
Sammaz 18 x P3	-0.03	0.02	0.00	-698.41	-650.80	119.05
Sammaz 18 x P4	0.00	-0.03	-0.03	126.99	317.46	-71.43
Sammaz 18 x P7	0.03	0.02	-0.07	-539.68	-253.97	7.94
Sammaz 18 x P8	0.01	0.01	0.03	-15.87	126.98	23.81
Sammaz 19 x P1	-0.05	0.00	0.03	-354.38	-297.45	-277.78
Sammaz 19 x P2	0.27	0.04	-0.11	-576.61	-329.19	87.30
Sammaz 19 x P3	-0.08	-0.05	0.07	-338.51	-27.60	7.94
Sammaz 19 x P4	-0.07	0.02	-0.01	598.00	51.76	150.80
Sammaz 19 x P7	-0.04	-0.02	0.03	412.82	-260.41	-66.14
Sammaz 19 x P8	-0.05	0.00	-0.01	232.92	750.17	23.81
Sammaz 34 x P1	-0.05	-0.01	-0.02	-510.58	-198.41	-37.04
Sammaz 34 x P2	0.03	0.00	0.11	600.53	325.40	216.93
Sammaz 34 x P3	-0.04	-0.01	0.02	1060.85	182.54	-306.88
Sammaz 34 x P4	0.00	-0.01	-0.02	-1002.65	-182.54	-52.91
Sammaz 34 x P7	0.04	0.00	0.00	-113.76	246.03	248.68
Sammaz 34 x P8	0.01	0.02	-0.09	-34.39	-373.02	-68.79
Sammaz 36 x P1	0.00	0.01	0.02	-334.29	-520.63	184.44
Sammaz 36 x P2	-0.11	0.00	0.01	-112.06	225.40	105.08
Sammaz 36 x P3	0.11	0.01	-0.04	-651.75	193.65	-85.40
Sammaz 36 x P4	0.02	-0.01	-0.01	284.76	-282.54	-609.21
Sammaz 36 x P7	0.00	-0.02	0.01	106.98	368.25	336.83
Sammaz 36 x P8	-0.01	0.02	0.02	808.57	-28.57	41.59
Dent Q x P1	0.16	0.02	0.00	-492.06	-31.75	111.11
Dent Q x P2	-0.17	-0.02	-0.01	396.82	-63.49	253.97
Dent Q x P3	-0.02	0.01	-0.02	746.04	460.32	-158.73
Dent Q x P4	0.04	-0.01	0.02	-317.46	-349.21	-126.98
Dent Q x P7	-0.02	0.02	-0.01	-428.57	412.70	-158.73
Dent Q x P8	0.01	-0.02	0.02	95.24	-428.57	79.37
Flint Q x P1	0.10	0.02	0.02	452.38	357.14	277.78
Flint Q x P2	-0.12	0.01	-0.01	-103.17	-7.94	-246.03
Flint Q x P3	0.01	0.01	-0.08	-198.41	-261.91	-214.29
Flint Q x P4	0.01	0.01	0.03	71.43	261.91	150.79
Flint Q x P7	0.00	-0.02	-0.01	404.76	-198.41	-103.18
Flint Q x P8	0.00	-0.04	0.06	-626.99	-150.79	134.92

NEP = number of ears per plant, GY = grain yield, NS = non-water stress, IS = intermediate-water stress, SS = severe-water stress

Eighteen top cross hybrids exhibited negative sca effects while twenty four top cross hybrids exhibited positive sca effects for DS. The sca effects for anthesis-silking interval ranged from -0.99 (Sammaz 34 x P2) to 0.99 (Sammaz 36 x P2). Twenty three top cross hybrids exhibited negative sca effects while nineteen top cross hybrids exhibited positive sca effects for ASI. The sca effects for plant height ranged from -17.38 (Dent Q x P1) to 16.04 (Flint Q x P1). Eighteen top cross hybrids exhibited negative sca effects while twenty four top cross hybrids exhibited positive sca effects for PHT. The sca effects for ear height ranged from -10.60 (Dent Q x P1) to 9.03 (Sammaz 36 x P4). Twenty four top cross hybrids exhibited negative sca effects while eighteen top cross hybrids exhibited positive sca effects for EHT. The sca effects for number of ears per plant ranged from -0.17 (Dent Q x P2) to 0.27 (Sammaz 19 x P2). Sixteen top cross hybrids exhibited negative sca effects while, nineteen top cross hybrids exhibited positive sca effects and seven top cross hybrids exhibited zero sca effects for NEP. The sca effects for grain yield ranged from -1002.65 (Sammaz 34 x P4) to 1060.85 (Sammaz 34 x P3). Twenty one top cross hybrids exhibited negative sca effects while, twenty one top cross hybrids exhibited positive sca effects for GY.

Under the intermediate-water stress condition, the sca effects for days to 50% tasseling ranged from -2.26 (Sammaz 17 x P3) to 2.40 (Sammaz 34 x P3). Nineteen top cross hybrids exhibited negative sca effects while twenty three top cross hybrids exhibited positive sca effects for the trait. The sca effects for days to 50% silking ranged from -3.00 (Sammaz 19 x P8) to 2.23 (Sammaz 18 x P2). Twenty one top cross hybrids exhibited negative sca effects while twenty one top cross hybrids exhibited positive sca effects for DS. The sca effects for anthesis-silking interval ranged from -1.31 (Sammaz 18 x P1) to 0.12 (Sammaz 34 x P8). Twenty top cross hybrids exhibited negative sca effects while twenty two top cross hybrids exhibited positive sca effects for ASI. The sca effects for plant height ranged from -22.17 (Sammaz 18 x P2) to 18.09 (Flint Q x P8). Twenty one top cross hybrids exhibited negative sca effects while twenty one top cross hybrids exhibited positive sca effects for the trait. The sca effects for ear height ranged from -11.45 (Sammaz 19 x P8) to 11.30 (Flint Q x P8). Twenty top cross hybrids exhibited negative sca effects while twenty two top cross hybrids exhibited positive sca effects for EHT. The sca effects for leaf senescence ranged from -0.32 (Dent Q x P3) to 0.32 (Flint Q x P8). Nineteen top cross hybrids exhibited negative sca effects while twenty one top cross hybrids exhibited positive sca effects and two top cross hybrids exhibited no sca effects for SEN. The sca effects for number of ears per plant ranged from -0.05 (Sammaz 19 x P3) to 0.04 (Sammaz 19 x P1). Fifteen top cross hybrids exhibited negative sca effects while twenty top cross hybrids exhibited positive sca effects and seven top cross hybrids exhibited zero sca effects for the trait. The sca effects for grain yield ranged from -650.80 (Sammaz 18 x P3) to 750.17 (Sammaz 19 x P8). Twenty one top cross hybrids exhibited negative sca effects while twenty one top cross hybrids exhibited positive sca effects for GY.

Under the severe-water stress condition, the sca effects for days to 50% tasseling ranged from -2.81 (Sammaz 34 x P7) to 3.40 (Sammaz 34 x P1). Twenty two top cross hybrids exhibited negative sca effects while twenty top cross hybrids exhibited positive sca effects for DT. The sca effects for days to 50% silking ranged from -3.04 (Flint Q x P1) to 4.36 (Flint Q x P2). Twenty one top cross hybrids exhibited negative sca effects while twenty one top cross hybrids exhibited positive sca effects for DS. The sca effects for anthesis-silking interval ranged from -1.35 (Sammaz 34 x P4) to 1.82 (Flint Q x P2). Seventeen top cross hybrids exhibited negative sca effects while twenty five top cross hybrids exhibited positive sca effects for ASI. The sca effects for plant height ranged from -14.58 (Sammaz 34 x P2) to 18.46 (Sammaz 34 x P4). Twenty top cross hybrids exhibited negative sca effects while twenty two top cross hybrids exhibited positive sca effects for PHT. The sca effects for ear height ranged from -15.15 (Sammaz 34 x P2) to 14.03 (Sammaz 34 x P7). Eighteen top cross hybrids exhibited negative sca effects while twenty three top cross hybrids exhibited positive sca effects and one top cross hybrid exhibited zero sca effects for the trait. The sca effects for leaf senescence ranged from -0.28 (Sammaz 18 x P7) to 0.43 (Dent Q x P7). Twenty two top cross hybrids exhibited negative sca effects while eighteen top cross hybrids exhibited positive sca effects and two top cross hybrids exhibited no sca effects for SEN. The sca effects for number of ears per plant ranged from -0.11 (Sammaz 19 x P2) to 0.11 (Sammaz 34 x P2). Eighteen top cross hybrids exhibited sca in negative direction while twenty one top cross hybrids exhibited positive sca effects and three top cross hybrids exhibited zero sca effects for NEP. The sca effects for grain yield ranged from -609.21 (Sammaz 36 x P4) to 637.57 (Sammaz 17 x P3). Nineteen top cross hybrids exhibited negative sca effects while twenty three top cross hybrids exhibited positive sca effects for GY.

4.7 Heterosis

4.7.1 Heterosis for Samaru

Heterosis for eight traits evaluated under non-water stress, intermediate-water stress and severe-water stress conditions at Samaru are presented in Table 4.21. Under the non-water stress condition, the magnitude of better parent heterosis for days to 50% tasseling ranged from -14.51% (Sammaz 36 x P1) to 13.96% (Sammaz 17 x P3). Eleven hybrids expressed significant negative heterosis for DT whereas two hybrids expressed significant positive heterosis over the better parent.The magnitude of better parent heterosis for days to 50% silking ranged from -12.95% (Sammaz 36 x P1) to 9.51% (Sammaz 17 x P3). Eleven hybrids expressed significant negative heterosis whereas one hybrid expressed significant positive heterosis over the better parent for DS. The magnitude of better parent heterosis for anthesis-silking interval ranged from -75.04% (Sammaz 17 x P3) to 59.50% (Sammaz 17 x P1).

Table 4. 21. Heterosis for grain yield and other agronomic traits under non-water stress, intermediate-water stress and severe-water stress conditions at Samaru

	DT			DS			ASI		
Top cross Hybrids	NS	IS	SS	NS	IS	SS	NS	IS	SS
Sammaz 17 x P1	-2.77	-6.61	1.26	0.87	3.14	-3.83	59.50**	162.37**	-21.89**
Sammaz 17 x P2	-2.00	-2.09	3.19	-0.68	-2.36	-6.31	-6.70**	1.55	-29.45**
Sammaz 17 x P3	13.96**	-7.01	14.72**	9.51*	-2.27	4.22	-75.04**	60.75**	-47.32**
Sammaz 17 x P4	-11.01**	8.70	6.91	-9.05*	10.39	-5.15	20.39**	-10.93*	-33.17**
Sammaz 17 x P7	1.82	-4.10	-4.24	1.39	-5.09	-14.19*	-3.54	-46.08**	-53.73**
Sammaz 17 x P8	-7.43*	-6.42	-3.80	-5.18	-8.79	-9.34	29.20**	-71.71**	-35.76**
Sammaz 18 x P1	-6.80	0.04	-4.84	-5.65	0.05	-8.92	14.97**	-38.00**	-36.71**
Sammaz 18 x P2	-4.92	-9.35	4.53	-1.17	-13.16*	4.90	12.31**	-76.61**	8.32**
Sammaz 18 x P3	-0.02	-8.22	0.07	1.53	-9.49	-0.49	-26.93**	-57.55**	-10.98**
Sammaz 18 x P4	6.38	4.05	-1.03	5.17	4.51	-0.36	-30.64**	-1.98	5.49
Sammaz 18 x P7	4.16	1.05	9.88*	0.50	-9.80	5.74	-39.38**	-89.48**	-41.21**
Sammaz 18 x P8	-10.72*	1.26	2.45	-8.77*	-1.97	3.27	39.24**	-27.60**	-11.65**
Sammaz 19 x P1	1.68	-5.28	-12.94*	1.35	-6.84	-14.65*	0.53	-59.11**	-50.77**
Sammaz 19 x P2	-9.53*	-0.79	-11.63*	-9.04*	-6.40	-9.39	-12.10**	-88.82**	17.63**
Sammaz 19 x P3	-1.73	-10.66	-2.82	0.00	-15.48*	-1.42	-14.36**	-87.54**	15.91**
Sammaz 19 x P4	-6.31	-3.16	-1.58	-5.51	0.00	1.09	11.14**	26.52**	12.08**
Sammaz 19 x P7	-8.11*	0.58	-6.90	-8.77*	-5.96	-4.61	-33.96**	-69.01**	-11.82**
Sammaz 19 x P8	-0.85	5.28	-2.05	-1.61	3.15	-0.12	-29.44**	-20.77**	24.52**
Sammaz 34 x P1	-7.79*	0.47	-1.90	-6.06	-0.44	-3.57	14.89**	-20.70**	-13.11**
Sammaz 34 x P2	-4.60	-0.28	8.50	-2.62	-1.90	2.41	-1.30	-18.09**	-52.09**
Sammaz 34 x P3	-5.25	-7.72	-5.82	1.53	-12.18*	-5.34	35.91**	-69.08**	-27.49**
Sammaz 34 x P4	1.12	1.50	2.35	-0.46	12.94*	3.67	8.25**	137.13**	13.67**
Sammaz 34 x P7	-6.76	-3.61	1.78	-10.93**	0.69	-3.24	-64.58**	45.82**	-54.47**
Sammaz 34 x P8	-6.19	-9.49	-2.28	-5.39	-3.67	10.52	2.93	16.81**	81.51**
Sammaz 36 x P1	-14.51**	-4.05	-6.57	-12.95**	-2.29	-13.13*	5.69*	-20.57**	-43.74**
Sammaz 36 x P2	-14.11**	1.69	-4.29	-10.49*	-3.11	-0.76	1.51	-79.76**	55.33**
Sammaz 36 x P3	-6.94	0.51	-4.81	-7.90*	1.33	-0.75	-61.76**	-12.82**	37.33**
Sammaz 36 x P4	-11.84**	7.57	-3.03	-9.53*	7.36	-3.49	21.10**	-16.86**	-45.47**
Sammaz 36 x P7	-9.07*	14.43*	-1.66	-6.40*	11.01*	-3.06	-13.13**	-43.34**	-37.12**
Sammaz 36 x P8	-13.67**	-14.30*	4.66	-12.33**	4.46	7.32	6.65**	176.37**	35.16**
Dent Q x P1	-0.89	4.59	-5.45	-3.12	3.82	-8.93	-59.37**	-6.99	-32.30**
Dent Q x P2	9.02*	-3.02	1.18	7.05	-1.72	-2.47	-30.06**	23.26**	-33.28**
Dent Q x P3	1.89	-8.20	-4.47	2.04	-5.12	-7.52	4.49*	36.18**	-40.40**
Dent Q x P4	3.92	1.60	-12.18*	3.28	2.19	-14.23*	-19.85**	-46.01**	-30.80**
Dent Q x P7	1.53	-4.26	-4.47	0.12	-2.46	-3.45	-25.79**	-28.35**	3.79
Dent Q x P8	1.37	-5.42	-2.28	0.31	9.18	-2.98	-48.61**	91.51**	-33.44**
Flint Q x P1	1.46	-2.98	-1.46	1.96	-2.63	-4.45	-35.03**	-36.56**	-23.00**
Flint Q x P2	-0.26	-21.18**	5.27	4.97	-17.27**	2.76	-1.30	9.82	-17.02**
Flint Q x P3	3.92	-3.67	-4.29	7.56	2.66	-2.93	-25.13**	35.31**	-23.03**
Flint Q x P4	-1.57	-9.95	4.50	1.96	-1.77	5.03	10.98**	66.97**	9.30**
Flint Q x P7	-4.62	-16.88**	4.37	-5.87	-7.41	3.24	-20.83**	50.38**	-7.30*
Flint Q x P8	-2.68	-15.04*	0.30	-3.19	-7.99	4.68	-1.27	12.48*	-7.01*
±SE	3.60	5.41	4.57	3.79	5.46	5.27	1.96	4.99	2.79

* and ** = significant at $P \leq 0.05$ and $P \leq 0.01$, probability level respectively, DT = days to 50% tasseling, DS = days to 50% silking, ASI = anthesis-silking interval, NS = non-water stress, IS = intermediate-water stress, SS = severe-water stress, ±SE = standard error

Table 4. 21. Continued

Top cross Hybrids	PHT			EHT			SEN		
	NS	IS	SS	NS	IS	SS	NS	IS	SS
Sammaz 17 x P1	4.50	-80.18*	8.87	-62.65**	-30.07*	86.76**	-	16.48**	-13.30**
Sammaz 17 x P2	-4.18	-9.31	-5.83	-9.86	-1.01	-22.78	-	32.48**	-15.14**
Sammaz 17 x P3	1.44	6.81	0.55	-3.51	41.81*	76.65**	-	-13.81**	-9.82**
Sammaz 17 x P4	-62.71*	-84.28*	-3.15	0.39	-54.12**	51.23*	-	3.06**	-26.15**
Sammaz 17 x P7	-6.69	1.22	8.13	-13.68	1.02	1.53	-	-3.88**	-17.43**
Sammaz 17 x P8	6.80	-1.99	-1.84	55.82*	-2.76	-73.51**	-	45.66**	-1.83**
Sammaz 18 x P1	-9.19	-3.31	72.53**	0.16	-60.76**	-50.77*	-	-2.68**	37.71**
Sammaz 18 x P2	60.62*	1.80	-0.95	-4.87	-76.44**	-1.14	-	-1.79**	18.62**
Sammaz 18 x P3	1.59	-7.75	-5.76	-2.84	-50.53**	0.16	-	-16.52**	-29.02**
Sammaz 18 x P4	0.75	4.54	0.70	-1.45	71.14**	1.54	-	-10.04**	42.86**
Sammaz 18 x P7	3.94	-3.86	-62.10**	2.38	-5.46	6.19	-	2.59**	3.52**
Sammaz 18 x P8	4.36	-0.89	2.52	-9.68	-2.05	-13.52	-	2.68**	25.91**
Sammaz 19 x P1	3.59	-2.50	-7.47	73.97**	-5.21	85.90**	-	3.43**	42.95**
Sammaz 19 x P2	8.11	5.13	-4.10	-56.60*	-60.07**	-8.00	-	8.16**	2.66**
Sammaz 19 x P3	-16.53	5.59	-6.06	-3.55	1.75	74.07**	-	-6.44**	-21.43**
Sammaz 19 x P4	9.47	-3.54	-9.17	1.06	4.56	-1.18	-	-14.16**	20.13**
Sammaz 19 x P7	-80.52**	-3.66	-5.16	-42.37*	73.15**	7.62	-	-25.75**	8.04**
Sammaz 19 x P8	-12.59	-97.69**	-70.37**	6.68	2.64	-3.72	-	-9.87**	14.51**
Sammaz 34 x P1	4.69	1.95	6.79	-6.61	-4.00	-1.35	-	-17.56**	-11.93**
Sammaz 34 x P2	-85.87**	82.44*	1.22	-95.84**	-80.11**	-58.10**	-	3.42**	-11.47**
Sammaz 34 x P3	-0.61	-80.81*	-1.06	-86.39**	71.89**	78.01**	-	27.14**	-10.71**
Sammaz 34 x P4	12.72	9.05	-2.19	-6.83	2.92	-3.40	-	16.16**	0.46
Sammaz 34 x P7	-1.26	-89.93**	0.87	-72.02	50.78**	61.39**	-	-5.17**	-33.49**
Sammaz 34 x P8	79.65	7.12	-5.75	-5.81	-0.18	-36.47	-	11.22**	0.46
Sammaz 36 x P1	-77.60*	82.97*	-68.44**	-6.02	0.01	8.64	-	7.21**	12.08**
Sammaz 36 x P2	-7.52	-5.18	-77.12	-0.25	-55.59**	-4.49	-	2.89**	-6.38**
Sammaz 36 x P3	-81.37**	-0.41	-73.97	-5.33	7.89	2.72	-	0.48	-27.23**
Sammaz 36 x P4	-0.91	-1.53	-62.05**	-1.73	75.32**	-5.95	-	2.62**	2.52**
Sammaz 36 x P7	-12.03	94.02**	-20.37	51.92*	-0.17	78.97**	-	-20.26**	-3.02**
Sammaz 36 x P8	-82.14**	7.22	-41.66*	-0.09	1.18	-7.62	-	18.27**	-12.95**
Dent Q x P1	8.06	-0.31	64.26**	7.97	-86.49**	2.61	-	-4.74**	-25.63**
Dent Q x P2	-3.60	9.99	6.53	1.48	-1.41	-62.59**	-	0.00	-30.25**
Dent Q x P3	-17.63	80.94*	-6.14	-52.33*	-26.14	-75.74**	-	-4.74**	-3.36**
Dent Q x P4	-6.46	-0.46	-14.34	-5.50	-7.30	-6.27	-	-7.42**	8.82**
Dent Q x P7	2.56	93.87**	6.48	-0.80	-67.73**	-9.27	-	-3.02**	-3.36**
Dent Q x P8	2.62	-1.62	58.85**	7.64	-70.81**	50.44**	-	9.00**	-22.69**
Flint Q x P1	64.46*	-9.04	-1.31	-62.14**	-9.49	-75.29**	-	4.43**	41.49**
Flint Q x P2	4.55	-97.95**	63.27**	-3.63	-86.62**	-52.23*	-	25.12**	-2.13**
Flint Q x P3	-79.08*	-7.54	-0.91	-5.47	-0.60	-64.69**	-	-25.24**	4.02**
Flint Q x P4	62.93*	-5.31	0.05	3.76	-51.74**	-53.74*	-	0.44	15.96**
Flint Q x P7	85.33**	-8.67	-5.51	-5.76	2.90	85.10**	-	-0.86*	13.06**
Flint Q x P8	76.90*	-71.90*	-0.97	-63.79**	-0.94	61.49*	-	14.78**	-6.74**
±SE	26.62	29.01	19.41	20.20	14.03	21.21	_	0.35	0.37

* and ** = significant at P ≤ 0.05 and P ≤ 0.01, probability level respectively, PHT= plant height, EHT = ear height, SEN = leaf Senescence, NS = non-water stress, IS = intermediate-water stress, SS = severe-water stress, ±SE = standard error

Table 4.21.Continued

Top cross Hybrids	NEP			GY		
	NS	IS	SS	NS	IS	SS
Sammaz 17 x P1	-24.42	5.83**	0.92**	-20.85	-47.46	-47.53
Sammaz 17 x P2	15.20**	0.84**	3.64**	-2.91	-46.19	-38.37
Sammaz 17 x P3	-9.86	1.64**	-24.83	-18.30	-61.64	-62.63
Sammaz 17 x P4	10.40**	2.50**	0.00	1.24	-41.92	145.45
Sammaz 17 x P7	-10.27	0.81**	5.17**	-9.19	-29.28	-2.23
Sammaz 17 x P8	17.60**	-2.40	4.59**	-32.27	-47.24	-167.84
Sammaz 18 x P1	-26.74	-4.58	11.00**	130.91*	9.41	-5.53
Sammaz 18 x P2	8.00**	-6.11	1.82**	-32.64	1.31	-38.96
Sammaz 18 x P3	-0.70	-7.63	-25.52	-25.50	-167.56*	-163.42
Sammaz 18 x P4	14.40**	-9.92	3.54**	4.82	-21.52	-6.01
Sammaz 18 x P7	-8.90	-9.16	-0.86	-6.77	-14.15	-51.39
Sammaz 18 x P8	0.80**	-9.16	-0.92	4.65	-12.03	146.33*
Sammaz 19 x P1	-18.02	-7.75	16.51**	0.62	8.63	74.99
Sammaz 19 x P2	-5.48	-4.65	-0.91	-8.15	68.44	-21.51
Sammaz 19 x P3	-8.22	3.10**	-30.34	10.04	33.42	-45.36
Sammaz 19 x P4	-15.75	4.65**	-7.08	-12.43	-21.81	23.51
Sammaz 19 x P7	-21.92	-5.43	-7.76	-4.91	-11.20	2.79
Sammaz 19 x P8	-18.49	-6.20	7.84**	-17.14	-11.51	-41.07
Sammaz 34 x P1	-34.88	6.67**	-0.88	-1.12	12.09	-62.06
Sammaz 34 x P2	5.97**	4.20**	-7.08	-4.77	-37.83	110.69*
Sammaz 34 x P3	-5.63	-1.64	-34.48	126.51*	-63.40	-42.19
Sammaz 34 x P4	-7.46	33.33**	0.89**	3.41	-53.32	-2.21
Sammaz 34 x P7	-2.05	0.00	-7.76	19.77	-0.62	4.84
Sammaz 34 x P8	-1.49	-6.40	-11.50	10.58	-72.18	-42.13
Sammaz 36 x P1	-25.58	-2.44	11.40**	2.95	29.83	196.46**
Sammaz 36 x P2	9.68**	0.00	-0.88	-28.51	-55.68	63.44
Sammaz 36 x P3	4.23**	-0.81	-19.31	29.61	15.76	4.02
Sammaz 36 x P4	11.29**	-1.63	8.77**	-22.96	1.81	-1.61
Sammaz 36 x P7	-8.22	-5.65	1.72**	-0.81	-4.11	70.33
Sammaz 36 x P8	9.68**	1.60**	-7.89	163.79*	-2.60	48.54
Dent Q x P1	-8.14	0.83**	5.51**	-38.05	7.82	33.22
Dent Q x P2	-2.16	4.20**	-3.64	-17.63	-0.26	-42.34
Dent Q x P3	-7.75	-5.74	-29.66	-4.68	28.24	-10.82
Dent Q x P4	13.67**	-4.17	-6.19	-4.68	-11.30	-168.90*
Dent Q x P7	0.69**	-2.42	-7.76	-23.02	14.78	36.79
Dent Q x P8	-3.60	-1.60	-6.86	-24.01	-26.17	-23.72
Flint Q x P1	-28.49	15.08**	0.00	4.47	-16.09	-22.59
Flint Q x P2	9.59**	-5.56	-12.73	-14.13	-55.63	-15.09
Flint Q x P3	-2.05	-7.14	-18.62	-27.70	-64.89	11.65
Flint Q x P4	-15.07	-7.14	-13.27	-0.16	-24.63	156.80*
Flint Q x P7	-5.48	3.18**	-5.17	-33.23	-145.13*	-9.96
Flint Q x P8	-13.70	4.76**	4.81**	-4.70	4.30	-79.32
±SE	0.20	0.14	0.14	962.60	1133.80	834.37

* and ** = significant at $P \leq 0.05$ and $P \leq 0.01$, probability level respectively, NEP = number of ears per plant GY = grain yield, NS = non-water stress, IS = intermediate-water stress, SS = severe-water stress, ±SE = standard error

Nineteen hybrids expressed significant negative heterosis whereas fifteen hybrids expressed significant positive heterosis over the better parent for ASI. The magnitude of better parent heterosis for plant height ranged from -85.87% (Sammaz 34 x P2) to 85.33% (Flint Q x P7). Seven hybrids expressed significant negative heterosis whereas twenty five hybrids expressed positive heterosis over the better parent for PHT. The magnitude of better parent heterosis for ear height ranged from -95.84% (Sammaz 34 x P2) to 73.97% (Sammaz 19 x P1). Eight hybrids expressed significant negative heterosis whereas three hybrids expressed positive heterosis over the better parent for EHT. The magnitude of better parent heterosis for number of ears per plant ranged from -34.88% (Sammaz 34 x P1) to 17.60% (Sammaz 17 x P8). Fourteen hybrids expressed significant positive heterosis over the better parent for NEP. The magnitude of better parent heterosis for grain yield ranged from -38.05% (Dent Q x P1) to 163.79% (Sammaz 36 x P8). Three hybrids expressed significant positive heterosis and nine hybrids expressed positive heterosis over the better parent for GY.

Under the intermediate-water stress condition, better parent heterosis for days to 50% tasseling ranged from -21.18% (Flint Q x P2) to 14.43% (Sammaz 36 x P7). Three hybrids expressed significant negative heterosis whereas two hybrids expressed significant positive heterosis over the better parent for DT. The better parent heterosis for days to 50% silking ranged from -17.27% (Flint Q x P2) to 12.94% (Sammaz 34 x P4). Four hybrids expressed significant negative heterosis whereas two hybrids expressed significant positive heterosis over the better parent for DS. The better parent heterosis over the better parent for anthesis-silking interval ranged from -89.48% (Sammaz 18 x P7) to 176.37% (Sammaz 36 x P8).Twenty three hybrids expressed significant negative heterosis whereas fourteen hybrids expressed significant positive heterosis over the better parent for ASI. For plant height, better parent heterosis ranged from -97.95% (Flint Q x P2) to 94.02% (Sammaz 36 x P7). Seven hybrids expressed significant negative heterosis whereas five hybrids expressed positive heterosis for PHT. The magnitude of better parent heterosis for ear height ranged from

-86.62% (Flint Q x P2) to 75.32% (Sammaz 36 x P4). Thirteen hybrids expressed significant negative heterosis whereas six hybrids expressed significant positive heterosis over the better parent for EHT. The magnitude of better parent heterosis for leaf senescence ranged from -25.75% (Sammaz 19 x P7) to 45.66% (Sammaz 17 x P8). Nineteen hybrids expressed significant negative heterosis whereas twenty hybrids expressed significant positive and twenty hybrids expressed positive heterosis over the better parent for SEN. The magnitude of better parent heterosis for number of ears per plant ranged from - 9.92% (Sammaz 18 x P4) to 33.33% (Sammaz 34 x P4). Sixteen hybrids expressed significant positive heterosis over the better parent for NEP. The magnitude of better parent heterosis for grain yield ranged from -167.56% (Sammaz 18 x P3) to 68.44% (Sammaz 19 x P2). Two hybrids expressed significant positive heterosis and seven hybrids expressed positive heterosis over the better parent for GY.

Under severe-water stress condition, better parent heterosis over for days to 50% tasseling ranged from -12.94% (Sammaz 19 x P1) to 14.72% (Sammaz 17 x P3). Three hybrids expressed significant negative heterosis whereas two hybrids expressed significant positive heterosis over the better parent for DT.The magnitude of better parent heterosis for days to 50% silking ranged from -14.65% (Sammaz 19 x P1) to 10.52% (Sammaz 34 x P8). Four hybrids expressed significant negative heterosis over the better parent for DS. The magnitude of better parent heterosis for anthesis-silking interval ranged from -54.47% (Sammaz 34 x P7) to 81.51% (Sammaz 34 x P8). Twenty nine hybrids expressed significant negative heterosis whereas ten hybrids expressed significant positive heterosis over the better parent. For plant height, better parent hetrosis ranged from -77.12% (Sammaz 36 x P2) to 72.53% (Sammaz 18 x P1). Five hybrids expressed significant negative heterosis whereas four hybrids expressed positive heterosis over the better parent for PHT. The better parent heterosis for ear height ranged from -75.74% (Dent Q x P3) to 86.76% (Sammaz 17 x P1). Nine hybrids expressed significant negative heterosis whereas eleven hybrids expressed significant positive heterosis over the better parent for EHT. The magnitude of better parent heterosis for leaf senescence ranged from -33.49% (Sammaz 34 x P7) to 42.95% (Sammaz 19 x P1). Twenty three hybrids expressed significant negative heterosis whereas seventeen hybrids expressed significant positive heterosis over the better parent for SEN. The better parent heterosis for number of ears per plant ranged from -34.48% (Sammaz 34 x P3) to 16.51% (Sammaz 19 x P1). Fifteen hybrids expressed significant positive heterosis over the better parent for NEP. The magnitude of better parent heterosis for grain yield ranged from -168.90% (Dent Q x P4) to 196.46% (Sammaz 36 x P1). Five hybrids expressed significant positive heterosis and four hybrids expressed positive heterosis over the better parent for GY.

4.7.2 Heterosis for Kadawa

Heterosis values for eight traits evaluated under non-water stress, intermediate-water stress and severe-water stress conditions at Kadawa are presented in Table 4.22. Under the non-water stress condition, the better parent heterosis for days to 50% tasseling ranged from -6.90%(Sammaz 17 x P7) to 8.65% (Sammaz 34 x P1). Three hybrids expressed significant negative heterosis whereas six hybrids expressed significant positive heterosis for DT over the better parent. The better parent heterosis for days to 50% silking ranged from -6.78% (Sammaz 17 x P7) to 8.58% (Dent Q x P3). One hybrid expressed significant negative heterosis whereas five hybrids expressed positive heterosis over the better parent for DS. The better parent heterosis for anthesis-silking interval ranged from -60.27% (Sammaz 17 x P4) to 38.11% (Sammaz 17 x P8). Thirty one hybrid expressed significant negative heterosis whereas eight hybrids expressed significant positive heterosis over the better parent for the trait.The better parent heterosis for plant height ranged from -85.25% (Sammaz 36 x P2) to 77.62% (Sammaz 17 x P4). Eleven hybrids expressed significant negative heterosis for PHT while two hybrids expressed significant positive heterosis over the better parent.

Table 4. 22. Heterosis for grain yield and other agronomic traits under non-water stress, intermediate-water stress and severe-water stress conditions at Kadawa

Top cross Hybrids	DT			DS			ASI		
	NS	IS	SS	NS	IS	SS	NS	IS	SS
Sammaz 17 x P1	3.60	-0.87	1.76	3.85	0.78	0.98	8.50**	29.75**	-29.13**
Sammaz 17 x P2	8.39*	-3.44	1.02	5.02	-3.48	2.08	-38.11**	-5.79**	-3.04
Sammaz 17 x P3	4.24	-4.89	-3.52	3.66	-4.56	-3.47	-9.58**	-1.59	-2.35
Sammaz 17 x P4	3.33	-2.99	-4.66	-1.06	-2.38	-3.74	-60.27**	15.87**	-2.58*
Sammaz 17 x P7	-6.90*	0.23	2.94	-6.78*	1.66	1.12	-4.99**	36.11**	-34.46**
Sammaz 17 x P8	6.81*	-4.15	3.27	8.46*	-3.71	2.45	38.11**	6.29**	-18.24**
Sammaz 18 x P1	-0.87	1.16	-2.86	-2.85	1.33	-1.12	1.04	-5.38**	-15.41**
Sammaz 18 x P2	-2.43	1.45	-4.80	-4.98	0.63	-3.79	-37.67**	-27.01**	14.55**
Sammaz 18 x P3	0.98	-11.53*	-1.32	-0.99	-10.13	-1.29	1.82*	19.84**	-0.34
Sammaz 18 x P4	1.10	-1.17	4.07	-1.70	-1.10	4.19	-39.50**	3.57**	-38.40**
Sammaz 18 x P7	-5.13	-1.18	2.86	-5.54	1.57	4.85	-11.72**	67.46**	66.16**
Sammaz 18 x P8	6.98*	4.76	5.41	7.47*	4.11	7.70*	0.78	-7.62**	78.28**
Sammaz 19 x P1	-2.80	-7.45	-0.74	-4.88	-8.17	-1.47	-41.72**	-34.05**	-14.57**
Sammaz 19 x P2	-1.50	-0.42	-4.56	-2.50	-0.72	-5.02	-40.53**	-25.08**	-12.75**
Sammaz 19 x P3	-4.21	-5.90	4.35	-4.17	-4.53	2.55	-3.55**	21.96**	-28.33**
Sammaz 19 x P4	-0.38	-0.80	-1.24	-2.42	-0.74	-2.55	-33.86**	3.14**	-24.93**
Sammaz 19 x P7	-0.07	-7.31	-1.29	-1.46	-7.22	-1.16	-22.44**	-5.88**	1.42**
Sammaz 19 x P8	1.65	2.57	-0.57	0.13	2.33	-0.49	-26.92**	-16.89**	1.13*
Sammaz 34 x P1	8.65*	-12.44*	1.31	7.57*	-13.14*	-0.79	-13.59***	-25.56**	-33.86**
Sammaz 34 x P2	-1.69	-10.48*	-5.22	-4.99	-10.43*	-7.12*	-47.36**	-12.08**	-37.01**
Sammaz 34 x P3	6.60*	-10.95*	1.44	7.85*	-12.43*	-0.65	14.24**	-39.61**	-33.60**
Sammaz 34 x P4	3.40	-11.91*	-1.60	1.92	-11.49*	-4.39	-18.06**	-1.97	-48.29**
Sammaz 34 x P7	-2.50	-4.56	0.60	-4.98	-5.11	-2.94	-42.39**	-29.49**	-58.79**
Sammaz 34 x P8	-0.54	-3.26	-3.32	1.33	-4.32	-4.42	35.06**	-21.63**	-21.78**
Sammaz 36 x P1	1.62	-3.37	-0.75	-0.03	-1.39	0.46	-37.58**	33.33**	-23.25**
Sammaz 36 x P2	4.48	1.26	-4.43	0.10	2.35	-2.65	-56.17**	7.72**	37.27**
Sammaz 36 x P3	5.71	-6.97	-2.20	6.00	-3.48	0.87	12.04**	76.56**	46.98**
Sammaz 36 x P4	-2.44	0.19	-2.66	-3.87	2.66	-1.91	-22.80**	66.02**	-30.95**
Sammaz 36 x P7	0.71	-4.80	-6.08	-0.50	-3.88	-3.49	-18.70**	16.41**	77.27**
Sammaz 36 x P8	-0.19	8.71	-5.07	-0.53	8.19	-4.07	-6.40**	-9.93**	27.27**
Dent Q x P1	-1.71	-7.11	0.99	-0.36	-7.02	1.92	-11.11**	-16.85**	-26.89**
Dent Q x P2	0.80	-6.70	-0.02	-3.12	-5.38	0.78	-53.30**	0.96	12.73**
Dent Q x P3	7.39*	-4.40	-3.33	8.58*	-2.77	-3.21	6.13**	41.49**	-33.22**
Dent Q x P4	-3.35	-3.96	-4.75	-3.90	-3.51	-3.43	-11.29**	0.00	-21.49**
Dent Q x P7	-5.14	-1.58	-1.98	-6.59	-0.60	-1.86	-28.43**	22.76**	2.02**
Dent Q x P8	3.90	-3.82	-1.06	1.97	-1.43	0.40	-32.32**	29.80**	46.47**
Flint Q x P1	-5.34	3.28	-0.75	-3.50	1.94	-1.79	-1.96	-27.88	-20.00**
Flint Q x P2	-6.88*	-5.28	-7.31*	-5.37	-7.05	-9.30*	-39.43**	-47.76	-44.38**
Flint Q x P3	-6.68*	-5.95	-3.62	-5.91	-5.02	-5.17	-13.41**	-9.29	-32.60**
Flint Q x P4	-5.08	-0.58	-1.14	-4.69	0.80	-1.48	-54.18**	12.82**	-7.40**
Flint Q x P7	-5.64	-8.49	-6.28	-3.30	-9.22	-6.30	-17.21**	-43.27	-6.58**
Flint Q x P8	-6.24	0.21	-0.75	-3.74	1.87	0.47	3.96*	32.69**	21.92**
±SE	3.13	4.97	3.38	3.39	5.10	3.50	1.53	1.08	1.23

* and ** = significant at $P \leq 0.05$ and $P \leq 0.01$, probability level respectively, DT = days to 50% tasseling, DS = days to 50% silking, ASI = anthesis-silking interval, NS = non-water stress, IS = intermediate-water stress, SS = severe-water stress, ±SE = standard error

Table 4. 22. Continued

Top cross Hybrids	PHT NS	PHT IS	PHT SS	EHT NS	EHT IS	EHT SS	SEN NS	SEN IS	SEN SS
Sammaz 17 x P1	-14.57	-6.44	-0.33	-4.60	-6.11	4.19	-	36.11**	18.31**
Sammaz 17 x P2	-8.56	66.72*	-74.97*	3.45	43.40**	-19.84	-	-6.82**	2.82**
Sammaz 17 x P3	-55.43*	-0.28	-82.48**	-9.65	4.28	2.61	-	12.66**	-24.56**
Sammaz 17 x P4	77.62*	-53.79*	-13.17	31.36*	-26.97*	-11.52	-	-12.50**	-11.27**
Sammaz 17 x P7	0.43	-10.53	81.79**	12.99	-30.46*	-2.33	-	1.39**	-38.20**
Sammaz 17 x P8	-62.07*	-73.65**	-5.11	-18.52	8.81	-5.96	-	39.76**	-11.24**
Sammaz 18 x P1	-64.54*	-12.14	-10.43	-11.29	-9.32	16.49	-	-35.42**	43.82**
Sammaz 18 x P2	-55.48*	7.82	-7.12	-7.94	7.38	0.51	-	-83.33**	46.07**
Sammaz 18 x P3	-69.49*	-1.66	-79.83**	-25.62*	1.48	2.34	-	0.00	-21.93**
Sammaz 18 x P4	-51.46	-7.39	-2.53	-13.75	-28.17*	-13.52	-	-38.89**	-13.48**
Sammaz 18 x P7	-13.00	-11.92	-78.83**	-7.58	-11.22	-5.86	-	-43.75**	-39.33**
Sammaz 18 x P8	-8.30	-78.91**	-64.85*	-17.02	6.59	-20.04	-	-52.78**	24.72**
Sammaz 19 x P1	-81.74**	-3.46	-1.93	4.89	-4.36	-25.52*	-	-3.57**	-34.83**
Sammaz 19 x P2	-0.21	-9.84	-10.32	8.28	-9.54	-22.66*	-	31.82**	16.85**
Sammaz 19 x P3	-68.48*	4.64	-52.82*	-18.91	-0.10	-26.56*	-	11.39**	-36.84**
Sammaz 19 x P4	0.08	-71.72**	-0.01	14.95	-40.55**	-8.37	-	16.67**	34.83**
Sammaz 19 x P7	-59.09*	-84.72**	-20.41	-53.71**	-23.05*	-24.11*	-	58.57**	-32.58**
Sammaz 19 x P8	-5.44	-0.63	-17.06	-10.07	-8.93	-20.94	-	8.43**	-26.97**
Sammaz 34 x P1	-11.96	-5.42	87.39**	-17.69	-27.11*	52.39**	-	31.25**	1.45**
Sammaz 34 x P2	77.24*	76.01**	-5.66	16.21	7.83	27.75*	-	37.50**	55.07**
Sammaz 34 x P3	-18.19	-6.65	-6.61	-52.12**	2.50	0.68	-	-24.05	-36.84**
Sammaz 34 x P4	9.36	-6.57	4.29	-10.14	1.94	-13.61	-	31.94**	31.88**
Sammaz 34 x P7	0.89	-63.59*	8.01	-2.40	-33.26*	-43.93**	-	10.00**	52.81**
Sammaz 34 x P8	-4.07	-13.10	-0.94	-50.59**	-6.22	-23.64*	-	34.94**	0.00
Sammaz 36 x P1	-11.76	-2.46	55.83*	-4.30	2.31	0.93	-	9.82**	-15.73**
Sammaz 36 x P2	-85.25**	-71.08**	2.52	-46.17	2.33	-4.15	-	39.77**	-21.35**
Sammaz 36 x P3	-7.09	0.72	-54.19*	-7.79	9.15	-47.58**	-	69.14**	-23.68**
Sammaz 36 x P4	-3.85	-10.40	-72.70*	9.23	-7.69	-14.34	-	-39.51**	-3.37**
Sammaz 36 x P7	-5.31	-62.72*	-60.72*	-4.92	13.59	-6.87	-	9.88**	-3.37**
Sammaz 36 x P8	-10.40	-63.28*	-3.61	-46.00**	-7.40	-10.24	-	-4.82**	32.58**
Dent Q x P1	-16.36	0.75	6.77	-6.61	-11.46	5.83	-	4.46**	-35.96**
Dent Q x P2	0.75	79.00**	-71.93*	59.04**	37.48**	38.77**	-	14.77**	-21.93**
Dent Q x P3	-15.44	12.03	3.84	-24.68*	26.44*	8.75	-	25.32**	7.90**
Dent Q x P4	10.81	75.62**	4.20	37.56*	-6.37	1.41	-	0.00	3.51**
Dent Q x P7	5.75	1.28	-62.29*	3.43	3.26	-0.71	-	81.43**	-26.32**
Dent Q x P8	-67.50*	-8.18	-7.58	-9.63	-3.31	-9.16	-	28.92**	-44.74**
Flint Q x P1	2.86	2.44	-82.54**	-38.64*	25.81*	-39.70**	-	-16.96**	64.71**
Flint Q x P2	10.34	-7.65	-11.29	-4.56	-30.03*	2.97	-	-11.36**	-33.82**
Flint Q x P3	-83.75**	68.41*	-82.97**	-8.86	33.78*	-23.87*	-	46.84**	-37.72**
Flint Q x P4	-9.69	-5.42	-12.48	0.96	-12.01	-40.11**	-	38.898*	-36.76**
Flint Q x P7	7.11	71.87**	-73.64*	34.18*	12.20	-5.39	-	-2.86**	-3.37**
Flint Q x P8	0.09	8.42	-4.28	-7.08	4.14	-7.27	-	74.70**	-35.96
±SE	26.09	23.64	25.39	14.86	11.92	11.07		0.51	0.42

* and ** = significant at P ≤ 0.05 and P ≤ 0.01, probability level respectively, PHT = plant height; EHT = ear height, SEN = leaf senescence, NS = non-water stress, IS = intermediate-water stress, SS = severe-water stress, ±SE = standard error

Table 4. 22. Continued

Top cross Hybrids	NEP			GY		
	NS	IS	SS	NS	IS	SS
Sammaz 17 x P1	-18.38**	0.00	-3.96**	0.13	19.86	-21.17
Sammaz 17 x P2	-8.33**	-3.33**	3.96**	-10.56	20.60	427.30**
Sammaz 17 x P3	-7.58**	-0.85**	-19.80**	-12.02	-25.53	-56.39
Sammaz 17 x P4	-5.30**	4.20**	-10.89**	22.69	9.40	-30.21
Sammaz 17 x P7	-5.30**	4.31**	-8.91**	49.56	-5.92	143.68*
Sammaz 17 x P8	-9.85**	0.00	-10.89**	-182.32**	172.05**	46.57
Sammaz 18 x P1	-11.03**	0.83**	-8.08**	22.38	41.25	-46.13
Sammaz 18 x P2	-8.73**	-7.44**	-3.12**	-17.51	-31.33	270.13**
Sammaz 18 x P3	1.61**	5.79**	-7.22**	-39.53	5.43	-38.67
Sammaz 18 x P4	10.48**	-0.83**	-2.97**	-14.05	-42.26	-27.41
Sammaz 18 x P7	-0.81**	4.13**	-2.08**	-13.05	-173.92**	255.20**
Sammaz 18 x P8	8.87**	-3.31**	1.04**	-24.26	10.54	-33.79
Sammaz 19 x P1	-10.29**	-2.54**	-9.71**	26.46	-4.38	-50.84
Sammaz 19 x P2	-3.17**	-6.67**	-4.85**	87.08	-50.08	283.48**
Sammaz 19 x P3	1.63**	0.00	-13.59**	-16.34	-69.69	-88.44
Sammaz 19 x P4	1.65**	-5.04**	-4.85**	0.06	-36.69	-8.84
Sammaz 19 x P7	0.00	3.39**	16.51**	7.65	-27.81	123.90*
Sammaz 19 x P8	-4.13**	-0.85**	3.88**	30.23	-70.18	-0.07
Sammaz 34 x P1	-5.88**	-3.42**	-3.03**	61.25	168.08*	-12.67
Sammaz 34 x P2	2.38**	-0.83**	-1.04**	121.13	-9.54	161.54*
Sammaz 34 x P3	0.81**	-5.98**	6.19**	-29.71	-19.91	-73.23
Sammaz 34 x P4	1.63**	4.20**	-0.99**	197.02	-8.51	-65.1
Sammaz 34 x P7	-4.84*	-3.48**	13.83**	21.62	-7.34	15.29
Sammaz 34 x P8	11.38**	2.59**	4.26**	-16.04	43.24	-65.74
Sammaz 36 x P1	-8.82**	-3.42**	-13.13**	-41.34	-58.42	43.03
Sammaz 36 x P2	13.95**	-3.33**	2.08**	-34.43	-30.30	37.04
Sammaz 36 x P3	-3.10**	-6.84	10.31**	33.44	-59.10	36.78
Sammaz 36 x P4	-3.88**	7.56**	-17.82**	1.75	14.94	-68.33
Sammaz 36 x P7	4.65**	-6.03**	-4.30**	-51.02	-59.65	30.66
Sammaz 36 x P8	2.33**	-4.31**	1.06**	8.08	-177.94*	169.52*
Dent Q x P1	-8.82**	4.27**	-21.14**	-36.84	-24.34	3.48
Dent Q x P2	-6.72**	-3.33**	-33.33**	1.04	-12.25	-35.57
Dent Q x P3	-4.48**	4.27**	-26.83**	-46.04	-50.48	-39.74
Dent Q x P4	-5.97**	-0.84**	-34.96**	-158.09*	15.51	8.75
Dent Q x P7	-6.72**	0.85**	-20.33**	1.41	-29.71	-62.75
Dent Q x P8	-7.46**	5.98**	-26.83**	-21.49	-28.88	-3.11
Flint Q x P1	-9.56**	3.42**	-6.06**	11.32	-49.48	-9.61
Flint Q x P2	-5.56**	-0.83**	7.29**	187.71	-51.43	103.64*
Flint Q x P3	-3.23**	-3.42**	-8.25**	165.15	-15.43	-72.66
Flint Q x P4	-3.23**	9.24**	-16.83**	-92.18	-61.1	-37.79
Flint Q x P7	0.00	-0.87**	2.13**	-48.11	-53.27	-28.89
Flint Q x P8	-1.61**	4.31**	-15.96	-22.01	15.88	-62.65
±SE	0.14	0.00	0.14	1833.68	1047.84	572.81

* and ** = significant at $P \leq 0.05$ and $P \leq 0.01$, probability level respectively, NEP = number of ears per plant GY = grain yield, NS = non-water stress, IS = intermediate-water stress, SS = severe-water stress, ±SE = standard error

For ear height, better parent heterosis ranged from -53.71% (Sammaz 19 x P7) to 59.04% (Dent Q x P2). Seven expressed significant negative heterosis while four hybrids expressed significant positive heterosis over the better parent for EHT. The better parent heterosis for number of ears per plant ranged from -18.38% (Sammaz 17 x P1) to 13.95% (Sammaz 36 x P2). Two hybrids expressed significant negative heterosis whereas none of the hybrids expressed significant positive heterosis for NEP over the better parent.The magnitude of better parent heterosis for GY for grain yield ranged from -182.32% (Sammaz 17 x P8) to 197.02% (Sammaz 34 x P4). Twelve hybrids expressed positive heterosis over the better parent.

Under intermediate-water stress condition, the better parent heterosis for days to 50% tasseling ranged from -12.44% (Sammaz 34 x P1) to 8.71% (Sammaz 36 x P8). Five hybrids expressed significant negative heterosis over the better parent for DT. For days to 50% silking, better parent heterosis ranged from -13.14% (Sammaz 34 x P1) to 8.19% (Sammaz 36 x P8). Four hybrids expressed significant negative heterosis for DS whereas none of the hybrids expressed significant positive heterosis over the better parent. The magnitude of better parent heterosis for anthesis-silking interval ranged from -47.76 % (Flint Q x P2) to 76.56% (Sammaz 36 x P3). Fifteen hybrids expressed significant negative heterosis whereas nineteen hybrids expressed significant positive heterosis over the better parent for ASI. The better parent heterosis for plant height ranged from -84.72% (Sammaz 19 x P7) to 79.00% (Dent Q x P2). Nine hybrids expressed significant negative heterosis whereas six hybrids expressed significant positive heterosis for PHT. The magnitude of better parent heterosis for ear height ranged from -40.55% (Sammaz 19 x P4) to 43.40% (Sammaz 17 x P2). Eight hybrids showed significant negative heterosis whereas five hybrids expressed significant positive heterosis over the better parent.The magnitude of better parent heterosis for leaf senescence ranged from -83.33% (Sammaz 18 x P2) to 81.43% (Dent Q x P7). Thirteen expressed significant negative heterosis whereas twenty six hybrids expressed significant positive heterosis for SEN. The better parent heterosis for number of ears per plant ranged from -7.44% (Sammaz 18 x P2) to 9.24% (Flint Q x P4). Twenty two hybrids expressed significant negative heterosis for NEP while sixteen hybrids expressed significant positive heterosis over the better parent. The magnitude of better parent heterosis over better parent for grain yield ranged from -177.94% (Sammaz 36 x P8) to 172.05% (Sammaz 17 x P8). Two hybrids expressed significant negative heterosis whereas two hybrids expressed positive heterosis over the better parent for GY.

Under severe-water stress condition, the better parent heterosis for days to 50% tasseling ranged from -7.31% (Flint Q x P2) to 5.41% (Sammaz 18 x P8). One hybrid expressed significant negative heterosis for DT whereas none of the hybrids expressed positive heterosis over the better parent. The better parent heterosis for days to 50% silking ranged from -9.30% (Flint Q x P2) to 7.70% (Sammaz 18 x P8). Two hybrids expressed significant negative heterosis whereas one hybrid expressed significant positive heterosis over the better parent for DS. For anthesis-silking interval, the better parent heterosis ranged from -58.79% (Sammaz 34 x P7) to 78.28% (Sammaz 18 x P8). Twenty six hybrids expressed significant negative heterosis whereas sixteen hybrids expressed significant positive heterosis over the better parent for ASI. The magnitude of better parent heterosis for plant height ranged from -82.97% (Flint Q x P3) to 87.39% (Sammaz 34 x P1). Fourteen hybrids expressed significant negative heterosis whereas three hybrids expressed significant positive heterosis for PHT over the better parent.The better parent heterosis for ear height ranged from -47.58% (Sammaz 36 x P3) to 52.39% (Sammaz 34 x P1). Ten hybrids expressed significant negative heterosis whereas three hybrids expressed significant positive heterosis over the better parent for the trait. The magnitude of better parent heterosis for leaf senescence ranged from -44.74% (Dent Q x P8) to 64.71% (Flint Q x P1). Twenty five hybrids expressed significant negative heterosis whereas fifteen hybrids expressed significant positive heterosis for SEN over the better parent. The better parent heterosis for number of ears per plant ranged from

-34.96% (Dent Q x P4) to 7.29% (Flint Q x P2). Twenty nine hybrids expressed negative heterosis for NEP whereas twelve hybrids expressed significant positive heterosis over the better parent. The magnitude of better parent heterosis for grain yield ranged from -88.44% (Sammaz 19 x P3) to 427.30% (Sammaz 17 x P2). None of the hybrids expressed significant negative heterosis whereas nine hybrids expressed significant positive heterosis for GY over the better parent.

4.7.3 Heterosis across locations

Heterosis for eight traits evaluated under non-water stress, intermediate-water stress and severe-water stress conditions across Samaru and Kadawa is presented in Table 4.23. Under the non-water stress condition, the magnitude of better parent heterosis for days to 50% tasseling ranged from -9.72% (Sammaz 36 x P8) to 10.23% (Sammaz 17 x P3). Six hybrids expressed significant negative heterosis whereas six hybrids expressed significant positive heterosis over the better parent for DT. The magnitude of better parent heterosis for days 50% silking ranged from -8.73% (Sammaz 19 x P2) to 10.14% (Sammaz 17 x P3). Four hybrids expressed significant negative heterosis for DS whereas two hybrids expressed significant positive heterosis over the better parent. The better parent heterosis for anthesis-silking interval ranged from -54.65% (Sammaz 34 x P7) to 43.17% (Sammaz 17 x P8). Twenty seven hybrids expressed significant negative heterosis whereas eight hybrids expressed significant positive heterosis for ASI over the better parent. The better parent heterosis for plant height ranged from -103.20% (Dent Q x P3) to 150.55% (Flint Q x P2). Fifteen hybrids expressed significant negative heterosis whereas five hybrids expressed significant positive heterosis for PHT over the better parent. For ear height, better parent heterosis ranged from -94.63% (Sammaz 19 x P7) to 84.69% (Sammaz 17 x P4). Twelve hybrids expressed significant negative heterosis whereas three hybrids expressed significant positive heterosis over the better parent for the trait.

Table 4.23.Heterosis for grain yield and other agronomic traits under non-water stress, intermediate-water stress and severe-water stress conditions across locations

	DT			DS			ASI		
Top cross Hybrids	NS	IS	SS	NS	IS	SS	NS	IS	SS
Sammaz 17 x P1	-0.30	4.24	-0.03	3.28	5.46	-1.50	42.50**	26.46**	-20.27**
Sammaz 17 x P2	7.77*	-8.93*	2.04	3.79	-0.13	-1.97	-22.44**	91.69**	-23.55**
Sammaz 17 x P3	10.23**	-11.30*	7.21*	10.14**	-11.8*	1.99	-54.03**	-0.58	-37.26**
Sammaz 17 x P4	-2.14	-2.35	2.47	-2.67	-0.27	-4.46	-22.08**	41.62**	-22.65**
Sammaz 17 x P7	-2.60	3.96	1.15	-2.84	4.19	-12.82**	-4.31*	6.56**	-49.48**
Sammaz 17 x P8	-0.29	1.99	-0.21	1.67	-0.24	-3.66	43.17**	-38.50**	-31.89**
Sammaz 18 x P1	-7.90*	-3.98	-1.97	-4.20	-9.29*	-4.32	14.54**	-53.58**	-30.43**
Sammaz 18 x P2	-3.63	1.06	-0.35	-2.59	0.70	0.52	-12.64**	-20.00**	12.75**
Sammaz 18 x P3	-0.62	-12.88*	-0.64	0.23	-8.44	-0.08	-2.44	-60.75**	4.00*
Sammaz 18 x P4	8.71*	-9.55	1.63	3.06	-10.36*	1.94	-35.53**	-39.25**	-7.02**
Sammaz 18 x P7	-0.66	0.98	7.19*	-2.63	3.18	9.29*	-26.98**	-0.57	-16.12**
Sammaz 18 x P8	-1.82	2.12	8.27*	-0.58	-2.15	5.52	22.85**	-52.08**	10.50**
Sammaz 19 x P1	-0.61	2.27	-13.77**	-1.81	2.20	-11.98**	-19.33**	-1.82	-39.97**
Sammaz 19 x P2	-7.44*	-5.74	-15.05**	-8.73*	-7.63	-10.20*	-26.36**	-50.00**	4.40**
Sammaz 19 x P3	-2.99	-3.58	0.79	-2.11	-6.41	0.57	-1.96	-65.68**	-3.18
Sammaz 19 x P4	-3.30	-4.70	-1.41	-3.26	-9.89*	-0.74	-9.64**	-55.68**	-1.75
Sammaz 19 x P7	-3.55	-1.99	-4.06	-4.14	0.88	-2.88	-28.80**	20.00**	9.81**
Sammaz 19 x P8	1.02	-2.02	-1.31	-0.50	-5.19	-0.31	-28.01**	-51.99**	14.43**
Sammaz 34 x P1	2.61	-1.20	2.03	2.95	-0.65	0.03	2.34	9.71**	-17.89**
Sammaz 34 x P2	-0.42	-5.69	1.24	-2.20	-9.16	-2.52	-24.18**	-19.77**	-46.41**
Sammaz 34 x P3	3.30	-5.06	-2.03	8.35*	-5.16	-2.93	35.70**	-8.70**	-29.88
Sammaz 34 x P4	8.96*	-11.56*	0.24	3.34	-11.69*	-0.50	-2.28	-48.55**	-9.96**
Sammaz 34 x P7	-4.18	-10.80*	1.48	-7.83*	-0.31	-2.30	-54.65**	104.41**	-46.22**
Sammaz 34 x P8	-3.35	-4.13	-1.30	-2.01	-2.48	2.80	21.35**	-8.41**	42.23**
Sammaz 36 xP1	-7.64*	-1.20	-3.55	-8.53*	1.24	-8.35*	-15.00**	15.80**	-37.63
Sammaz 36 x P2	-4.03	-3.16	-4.36	-2.94	-2.10	-1.71	-27.23**	-0.47	54.21**
Sammaz 36 x P3	-0.77	-1.76	-3.45	-1.10	-3.43	0.08	-36.43**	-46.46**	41.35**
Sammaz 36 x P4	-7.34*	0.24	-2.84	-3.64	2.10	-2.68	-3.30	14.15**	-39.91**
Sammaz 36 xP7	-1.68	0.32	-11.96**	-0.84	8.42	-2.01	-15.87**	8.26**	-10.51**
Sammaz 36 xP8	-9.72**	8.63	0.03	-7.76*	3.99	1.50	0.00	-29.87**	32.23**
Dent Q x P1	-0.31	-11.52*	-0.07	-1.69	4.42	-1.24	-32.60**	197.54**	-30.77**
Dent Q x P2	9.66*	-1.66	0.56	1.72	-0.47	-0.81	-35.95**	-17.19**	-19.43**
Dent Q x P3	8.81*	-5.01	-3.42	5.57	-2.01	-8.30*	5.13*	14.78**	-30.81**
Dent Q x P4	0.05	-5.03	-8.22*	0.32	-0.71	-20.69**	4.82*	39.02**	-21.05**
Dent Q x P7	-1.96	-1.40	-3.13	-3.35	-0.57	-2.62	-22.00**	-23.44**	4.51*
Dent Q x P8	2.64	-2.83	-0.26	1.16	-1.46	-1.24	-31.78**	-35.18**	-14.69**
Flint Q x P1	-2.20	-9.14*	7.22*	-0.99	1.95	0.94	-19.38**	137.23**	-21.57**
Flint Q x P2	-3.82	0.16	-1.57	-0.60	-0.32	-3.59	-20.26**	-33.81**	-26.32**
Flint Q x P3	-1.80	-23.18**	-2.28	0.49	-22.10**	-4.11	-21.27**	-14.78**	-26.32**
Flint Q x P4	-3.46	-3.71	1.43	-1.63	-0.64	1.59	-25.38**	30.06**	4.57*
Flint Q x P7	-7.17*	-4.50	-0.61	-3.11	-0.08	-1.23	-19.27**	69.38**	-6.95**
Flint Q x P8	-1.58	-21.68**	2.39	-0.40	-9.74*	2.47	1.55	-14.60**	4.01*
±SE	3.23	4.22	3.35	3.14	4.76	3.80	1.78	2.45	2.29

* and ** = significant at $P \leq 0.05$ and $P \leq 0.01$, probability level respectively, DT = days to 50% tasseling, DS = days to 50% silking, ASI = anthesis-silking interval, NS = non-water stress, IS = intermediate-water stress, SS = severe-water stress, ±SE = standard error

Table 4.23.Continued

Top cross Hybrids	PHT			EHT			SEN		
	NS	IS	SS	NS	IS	SS	NS	IS	SS
Sammaz 17 x P1	2.66	-1.46	5.35	-85.13**	4.03	76.59**	-	17.01**	-5.56**
Sammaz 17 x P2	-48.42*	-8.75	-54.82*	-3.57	-30.03*	-75.64**	-	13.14**	-10.42**
Sammaz 17 x P3	-40.38	0.64	-54.04*	-6.25	41.65**	63.31**	-	0.69	-14.79**
Sammaz 17 x P4	-49.71*	4.10	-7.85	84.69**	4.74	1.75	-	-10.60**	-22.22**
Sammaz 17 x P7	6.54	-82.01**	77.29**	-2.61	-45.32**	0.00	-	-0.66	-18.06**
Sammaz 17 x P8	-73.44**	-1.91	-3.19	1.30	-2.96	-66.93**	-	8.03**	2.08**
Sammaz 18 x P1	40.81	-6.08	4.64	-4.24	-2.29	-6.14	-	0.00	40.15**
Sammaz 18 x P2	43.31	-6.38	-3.68	-3.78	-32.00*	5.06	-	-15.76**	34.09**
Sammaz 18 x P3	-6.34	4.18	-6.29	-82.98**	-4.62	1.02	-	-33.70**	-26.63**
Sammaz 18 x P4	-49.42*	-5.38	-1.19	-6.51	-6.73	-3.12	-	-9.78**	23.49**
Sammaz 18 x P7	5.38	3.39	-53.90*	-1.75	52.73**	1.48	-	-20.11**	-9.72**
Sammaz 18 x P8	-40.72	-4.51	-1.25	-72.79**	-7.50	-54.64**	-	-13.04**	25.53**
Sammaz 19 x P1	60.05*	-6.58	-5.09	70.18**	-0.71	8.36	-	1.36**	21.43**
Sammaz 19 x P2	-7.65	-2.88	-5.95	-5.29	-3.79	-3.51	-	19.18**	21.31**
Sammaz 19 x P3	-70.38**	-0.88	-8.09	-70.39**	-2.59	5.08	-	26.03**	-26.63**
Sammaz 19 x P4	-5.84	5.21	-4.90	6.36	-0.25	-2.17	-	1.33**	39.29**
Sammaz 19 x P7	-7.76	-70.80*	-61.70*	-94.63**	-42.04**	-0.35	-	-5.96**	-4.86**
Sammaz 19 x P8	8.86	-72.11*	-68.95*	-0.41	2.33	-4.76	-	-2.74**	1.42**
Sammaz 34 x P1	-7.92	-70.97*	78.78**	-10.81	-3.01	56.88**	-	2.04**	-9.03**
Sammaz 34 x P2	80.18**	4.59	0.34	-0.26	-40.70**	-9.72	-	28.46**	4.17**
Sammaz 34 x P3	-84.71**	9.46	-3.51	-83.39**	-3.17	42.48*	-	15.97**	-19.53**
Sammaz 34 x P4	-3.17	-70.55*	3.69	-4.95	4.60	-7.65	-	7.95**	7.64**
Sammaz 34 x P7	55.45*	4.30	3.64	-7.90	25.19*	-2.59	-	19.21**	-2.78**
Sammaz 34 x P8	-75.57**	-87.62**	-3.75	-7.85	4.70	-67.91**	-	16.41**	6.94**
Sammaz 36 xP1	-33.60	-6.84	-5.36	-5.31	-5.70	5.45	-	15.65**	8.04**
Sammaz 36 x P2	-6.38	6.33	-4.68	-65.27**	0.18	0.56	-	19.31**	0.82*
Sammaz 36 x P3	-84.25**	-72.03*	-9.85	-6.42	-1.76	-7.48	-	15.86**	-26.04**
Sammaz 36 x P4	-12.15	0.72	-62.82*	5.20	5.00	-43.45*	-	15.23**	10.71**
Sammaz 36 xP7	77.69**	-5.36	-77.93**	4.93	31.22*	8.73	-	-5.96**	-2.78**
Sammaz 36 xP8	-82.14**	2.50	-8.58	-71.04**	30.37*	-37.55*	-	-5.52**	1.42**
Dent Q x P1	12.00	8.12	72.65*	1.89	-8.88	3.87	-	10.88**	-28.98**
Dent Q x P2	13.02	2.09	-5.77	74.60**	-32.82*	-4.45	-	13.57**	-27.84**
Dent Q x P3	-103.20**	73.44	-1.73	-87.83**	9.43	-6.12	-	8.33**	0.00
Dent Q x P4	-71.96**	70.74*	-4.32	6.94	-35.16*	-3.08	-	-0.66	7.39**
Dent Q x P7	-7.88	7.88	-1.34	0.96	0.00	-30.89*	-	-5.96**	-10.80**
Dent Q x P8	-18.92	74.26*	57.82*	0.33	-40.98**	3.09	-	25.71**	-29.55**
Flint Q x P1	-77.18**	-71.18*	-85.52**	-84.85**	-6.45	-30.65*	-	14.29**	47.66**
Flint Q x P2	150.55**	-4.69	-3.36	-1.70	0.44	-42.87*	-	17.83**	-10.16**
Flint Q x P3	-81.94**	-96.47**	-80.07**	-70.34**	-46.34**	-60.69**	-	15.28**	-10.06**
Flint Q x P4	-96.48**	2.30	-5.66	2.67	5.17	-65.32**	-	-9.93**	2.34**
Flint Q x P7	13.26	-4.63	-83.76**	2.52	-40.51**	43.77*	-	9.27**	7.64**
Flint Q x P8	-83.33**	2.91	-2.48	-70.95**	5.03	4.52	-	15.50**	-16.31**
±SE	22.75	27.17	25.05	20.33	12.37	17.45		0.49	0.37

* and ** = significant at $P \leq 0.05$ and $P \leq 0.01$, probability level respectively, PHT = plant height, EHT = ear height, SEN = leaf senescence, NS = non-water stress, IS = intermediate-water stress, SS = severe-water stress, ±SE = standard error

Table 4.23.Continued

Top cross Hybrids	NEP			GY		
	NS	IS	SS	NS	IS	SS
Sammaz 17 x P1	-22.08**	10.17**	-0.95**	-13.60	-28.73	-13.38
Sammaz 17 x P2	3.13**	2.52**	3.81**	1.50	-27.35	29.42
Sammaz 17 x P3	-5.30**	-0.84**	-21.49**	-16.13	-26.25	-59.56
Sammaz 17 x P4	2.34**	0.84**	-4.67**	8.66	-145.62**	22.11
Sammaz 17 x P7	-5.19**	2.50**	1.90**	15.92	-27.63	169.17**
Sammaz 17 x P8	3.91**	1.65**	-2.86**	-49.58	-18.76	7.00
Sammaz 18 x P1	-19.48**	-5.56**	1.92**	127.58**	0.17	-10.14
Sammaz 18 x P2	0.00	-2.38**	0.00	-19.91	21.08	10.98
Sammaz 18 x P3	0.76**	-6.35**	-18.18**	-30.98	-110.65*	-52.61
Sammaz 18 x P4	12.00**	-0.79**	0.94**	-2.54	-37.84	-16.76
Sammaz 18 x P7	-5.19**	-5.56**	0.96**	-9.22	-34.68	-11.56
Sammaz 18 x P8	4.80**	-2.38**	0.00	-6.63	-28.18	34.86
Sammaz 19 x P1	-14.29**	-4.84**	5.77**	26.84	23.46	35.09
Sammaz 19 x P2	-2.99**	-5.65**	0.00	25.10	6.53	29.17
Sammaz 19 x P3	-2.99**	-5.65**	-21.49**	110.32*	10.43	-68.69
Sammaz 19 x P4	-8.21	1.61**	-5.61**	-8.03	-45.10	7.25
Sammaz 19 x P7	-11.85	0.00	9.62**	6.15	-35.53	153.39**
Sammaz 19 x P8	-12.69	-1.61	6.86**	8.36	4.10	-11.98
Sammaz 34 x P1	-22.08	0.85**	0.00	59.41	-15.21	-38.85
Sammaz 34 x P2	4.65**	1.68**	-2.91**	14.19	46.16	129.47**
Sammaz 34 x P3	-2.27**	1.68**	-18.18**	17.44	-29.02	-155.74**
Sammaz 34 x P4	-3.10**	-3.36**	0.00	44.49	-41.53	-33.81
Sammaz 34 x P7	-3.70**	18.33**	2.88**	27.99	-49.72	8.71
Sammaz 34 x P8	4.65**	-2.48	-3.88**	9.47	14.55	-48.92
Sammaz 36 xP1	-18.18**	-0.84**	1.92**	-18.41	-9.90	66.97
Sammaz 36 x P2	11.90**	-2.52**	2.91**	-19.56	-2.63	181.48**
Sammaz 36 x P3	3.03**	0.00	-7.44**	31.46	14.74	18.33
Sammaz 36 x P4	3.97**	-2.52**	-2.80**	-6.86	-20.41	-35.13
Sammaz 36 xP7	-0.74*	4.17**	0.00	-25.03	-15.24	155.50**
Sammaz 36 xP8	6.35**	-6.61**	-2.91**	36.92	-8.65	60.59
Dent Q x P1	-8.44**	0.85**	-5.36**	-37.62	-108.24*	15.23
Dent Q x P2	-3.68**	2.52**	-16.07**	-9.64	4.94	-15.48
Dent Q x P3	-4.41**	0.84**	-20.66**	-19.39	-5.7	-16.73
Dent Q x P4	4.41**	0.00	-16.96**	-23.68	-14.81	-29.88
Dent Q x P7	0.00	-3.33**	-8.93**	-14.33	-21.63	-9.76
Dent Q x P8	-5.15**	-0.83**	-16.96**	-23.12	117.94*	-11.25
Flint Q x P1	-20.13**	1.65**	-2.88**	18.41	-41.41	2.27
Flint Q x P2	2.96**	9.93**	-2.91**	23.75	-28.73	140.36**
Flint Q x P3	-2.96**	-1.65**	-14.05**	8.70	-54.05	-21.59
Flint Q x P4	-9.63**	-4.96**	-14.95**	-6.21	-46.18	9.27
Flint Q x P7	-2.96**	1.65**	-0.96**	-32.84	-38.43	-7.54
Flint Q x P8	-8.15**	0.83**	-5.05**	-1.27	-47.51	-184.51
±SE	0.32	0.14	0.20	1503.46	1183.15	767.16

* and ** = significant at P ≤ 0.05 and P ≤ 0.01, probability level respectively, NEP = number of ears per plant, GY = grain yield, NS = non-water stress, IS = intermediate-water stress, SS = severe-water stress ±SE = standard error

The better parent heterosis for number of ears per plant ranged from -22.08% (Sammaz 17 x P1) to 12.00% (Sammaz 18 x P4). Twenty two hybrids expressed significant negative heterosis while fourteen hybrids expressed significant positive heterosis over the better parent for NEP. The magnitude of better parent heterosis over better parent for grain yield ranged from -49.58% (Sammaz 17 x P8) to 127.58% (Sammaz 18 x P1). Two hybrids expressed significant positive heterosis over the better parent for GY.

Under the intermediate-water stress condition, the better parent heterosis over better parent for days to 50% tasseling ranged from -23.18% (Flint Q x P3) to 8.63% (Sammaz 36 x P8). Nine hybrids expressed significant negative heterosis whereas none of the hybrids expressed significant positive heterosis over the better parent for DT. For days to 50% silking, better parent heterosis ranged from -22.10% (Flint Q x P3) to 8.42% (Sammaz 36 x P7). Seven hybrids expressed significant negative heterosis whereas none of the hybrids expressed significant positive heterosis over the better parent. The better parent heterosis for anthesis-silking interval ranged from -65.68% (Sammaz 19 x P3) to 197.54% (Dent Q x P1). Twenty two hybrids expressed significant negative heterosis whereas sixteen hybrids expressed significant positive heterosis over the better parent for ASI. The better parent heterosis for plant height ranged from -96.47% (Flint Q x P3) to 74.26% (Dent Q x P8). Nine hybrids expressed significant negative heterosis for PHT while two hybrids expressed significant positive heterosis over the better parent. The better parent heterosis for ear height ranged from -46.34% (Flint Q x P3) to 52.73% (Sammaz 18 x P7). Ten hybrids expressed significant negative heterosis whereas five hybrids expressed significant positive heterosis over the better parent for EHT. The better parent heterosis for leaf senescence ranged from -33.70% (Sammaz 18 x P3) to 28.46% (Sammaz 34 x P2). Twelve hybrids expressed significant negative heterosis whereas twenty six hybrids expressed significant positive heterosis for SEN over the better parent. The magnitude of better parent heterosis for number of ears per plant ranged from -6.61% (Sammaz 36 x P8) to 18.33% (Sammaz 34 x P7).

Nineteen hybrids expressed significant negative heterosis whereas eighteen hybrids expressed significant positive heterosis over the better parent for NEP. The magnitude of better parent heterosis for grain yield ranged from -145.62% (Sammaz 17 x P4) to 117.94% (Dent Q x P8). Three hybrids expressed significant negative heterosis whereas one hybrid expressed significant positive heterosis over the better parent for GY.

Under the severe-water stress condition, the better parent heterosis for days to 50% tasseling ranged from -15.05% (Sammaz 19 x P2) to 8.27% (Sammaz 18 x P8). Four hybrids expressed significant negative heterosis whereas four hybrids expressed significant positive heterosis over the better parent for DT. The better parent heterosis for days to 50% silking ranged from -20.69% (Dent Q x P4) to 9.29% (Sammaz 18 x P7). Six hybrids expressed significant negative heterosis whereas one hybrid expressed significant heterosis over the better parent for DS. The magnitude of better parent heterosis for anthesis-silking interval ranged from -49.48% (Sammaz 17 x P7) to 54.21% (Sammaz 36 x P2). Twenty five hybrids expressed significant negative heterosis whereas thirteen hybrids expressed significant positive heterosis over the better parent for ASI. For plant height, better parent heterosis ranged from -85.52% (Flint Q x P1) to 78.78% (Sammaz 34 x P1). Ten hybrids expressed significant negative heterosis whereas four hybrids expressed significant positive heterosis over the better parent for the trait. The better parent heterosis for ear height ranged from -75.64% (Sammaz 17 x P2) to 76.59% (Sammaz 17 x P1). Eleven hybrids expressed significant negative heterosis whereas five hybrids expressed significant positive heterosis over the better parent for EHT. The magnitude of better parent heterosis for leaf senescence ranged from -29.55% (Dent Q x P8) to 47.66% (Flint Q x P1). Twenty one hybrids expressed significant negative heterosis whereas twenty hybrids expressed significant positive heterosis for SEN over the better parent. The better parent heterosis for number of ears per plant ranged from -21.49% (Sammaz 19 x P3) to 9.62% (Sammaz 19 x P7). Twenty five hybrids expressed significant negative heterosis whereas eleven hybrids expressed significant positive heterosis over the better parent for NEP. The magnitude of heterosis for grain yield ranged from -184.51% (Flint Q x P8) to 181.48% (Sammaz 36 x P2). One hybrid expressed significant negative heterosis whereas six hybrids expressed significant positive heterosis over the better parent for GY.

4.8 Correlations

4.8.1 Estimates of correlation coefficients at Samaru

The correlation coefficients between grain yield and seven yield component traits under three different water stress regimes at Samaru are presented in Table 4.24. At Samaru under non-water stress condition, the correlations analysis between grain yield and DT (r = -0.09) and ASI (r = -0.17), indicated that there was a negative and non-significant correlation while between grain yield and DS (r = -0.20) indicated a negative and significant correlation at 1% level of probaility. Positive and non-significant correlations were recorded between grain yield and PHT (r = -0.11) and NEP (r = -0.01) while Positive and significant correlations at 1% level of probability was recorded between grain yield and EHT (r = -0.33).

Under intermediate-water stress condition, the correlations analysis between grain yield and DS (r = -0.06), ASI (r = -0.12), SEN (-0.17) and NEP (-0.07) indicated that there was a negative and non-significant correlation while between grain yield and DT (r = 0.04), PHT (r = 0.10) and EHT (r = 0.16) indicated a positive and non-significant correlation.

Under severe-water stress condition, the correlations analysis between grain yield and DT (r = -0.04), PHT (r = -0.06), EHT (r = -0.03) and SEN (r = -0.11) indicated that there was a negative and non-significant correlation. Positive and non-significant correlation between grain yield and DS (r = 0.03) and ASI (r = 0.10) were recorded, while between GY and NEP (r = 0.19) a positive and significant correlation at 5% level of probability was estimated.

Table 4.24.Correlation Coefficients between yield and other agronomic traits under non-water stress, intermediate-water stress and severe-water stress conditions at Samaru

Traits		DS	ASI	PHT	EHT	SEN	NEP	GY
Days to 50% tasseling	NS	0.84**	-0.36**	0.10	0.10	-	0.09	-0.09
	IS	0.59**	-0.46**	0.14	0.16	-0.30**	0.05	0.04
	SS	0.79**	-0.16	-0.06	-0.09	0.01	0.09	-0.04
Days to 50% silking	NS	1.00	0.19*	0.09	-0.05	-	0.02	-0.20**
	IS	1.00	0.44**	0.08	0.04	-0.16	0.10	-0.06
	SS	1.00	0.47**	-0.13	-0.01	-0.05	0.06	0.03
Anthesis-silking interval	NS		1.00	0.00	-0.28**	-	-0.14	-0.17
	IS		1.00	-0.06	-0.13	0.16	0.06	-0.12
	SS		1.00	-0.13	0.10	-0.10	-0.04	0.10
Plant height	NS			1.00	0.22**	-	0.07	0.11
	IS			1.00	0.08	-0.22**	0.00	0.10
	SS			1.00	0.10	-0.19*	-0.08	-0.06
Ear height	NS				1.00	-	0.17	0.33**
	IS				1.00	-0.17	-0.12	0.16
	SS				1.00	-0.24**	0.04	-0.03
Leaf Senescence	NS					-	-	-
	IS					1.00	0.10	-0.17
	SS					1.00	-0.06	-0.11
Number of ears per plant	NS						1.00	-0.01
	IS						1.00	-0.07
	SS						1.00	0.19*

* and ** = significant at P ≤ 0.05 and P ≤ 0.01, probability level respectively, DT = days to 50% tasseling, DS = days to 50% silking, ASI = anthesis-silking interval, PHT = plant height, EHT = ear height, SEN = leaf senescence, NEP = number of ears per plant, GY = grain yield, NS = non-water stress, IS = intermediate-water stress, SS = severe-water stress

4.8.2 Estimates of correlation coefficients at Kadawa

The correlation coefficients between grain yield and seven yield component traits under three different water stress regimes at Kadawa are presented in Table 4.25. At Kadawa under non-water stress condition, the correlations analysis between grain yield and DT (r = -0.28) and DS (r = -0.34) indicated that there was a negative and significant correlation at 1% level of probability while between grain yield and ASI (r = -0.20) indicated a negative and significant correlation at 5% level of probaility. Positive and significant correlations at 1% level of probability were recorded between grain yield and PHT (r = 0.39) and EHT (r = 0.24) while negative and non-significant correlations at was recorded between grain yield and NEP (-0.09).

Under intermediate-water stress condition, the correlations analysis between grain yield and DT (r = -0.20) indicated that there was a negative and significant correlation 5% level of probability while between grain yield DS (r = -0.23) negative and significant correlation 1% level of probability. ASI (r = -0.13), PHT (r = -0.12) and EHT (r = -0.09) had negative and non-significant correlation with grain yield. SEN (r = 0.10) and NEP (r = 0.12) indicated had positive and non-significant correlation with grain yield.

Under severe-water stress condition, the correlations analysis between grain yield and DT (r = -0.24) and DS (r = -0.27) indicated that there was a negative and significant correlation 1% level of probability. ASI (r = -0.15) had negative and non-significant correlation with grain yield while PHT (r = 0.07), EHT (r = 0.05), SEN (r = 0.05) and NEP (0.06) correlation estimates with grain yield were positive and non-significant.

Table 4. 25. Correlation Coefficients between yield and other agronomic traits under non-water stress, intermediate-water stress and severe-water stress conditions at Kadawa

Traits		DS	ASI	PHT	EHT	SEN	NEP	GY
Days to 50% tasseling	NS	0.94**	-0.13	-0.43**	-0.40**	-	-0.03	-0.28**
	IS	0.97**	0.09	-0.08	-0.08	-0.16	-0.05	-0.20*
	SS	0.96**	0.05	-0.04	-0.10	0.06	0.02	-0.24**
Days to 50% silking	NS	1.00	0.21**	-0.40**	-0.38**	-	-0.07	-0.34**
	IS	1.00	0.32**	-0.04	-0.06	-0.11	-0.03	-0.23**
	SS	1.00	0.34**	-0.08	-0.11	0.03	0.02	-0.27**
Anthesis-silking interval	NS		1.00	0.07	0.06	-	-0.09	-0.20*
	IS		1.00	0.14	0.08	0.17	0.09	-0.13
	SS		1.00	-0.16	-0.03	-0.10	0.00	-0.15
Plant height	NS			1.00	0.80**	-	0.00	0.39**
	IS			1.00	0.60**	0.18*	-0.22**	-0.12
	SS			1.00	0.57**	0.04	0.08	0.07
Ear height	NS				1.00	-	-0.05	0.24**
	IS				1.00	0.05	-0.14	-0.09
	SS				1.00	0.10	-0.03	0.05
Leaf senescence	NS					-	-	-
	IS					1.00	0.02	0.10
	SS					1.00	-0.08	0.05
Number of ears per plant	NS						1.00	-0.09
	IS						1.00	0.12
	SS						1.00	0.06

* and ** = significant at $P \leq 0.05$ and $P \leq 0.01$, probability level respectively, DT = days to 50% tasseling, DS = days to 50% silking, ASI = anthesis-silking interval, PHT = plant height, EHT = ear height, SEN = leaf senescence, NEP= number of ears per plant, GY = grain yield, NS = non-water stress, IS = intermediate-water stress, SS=severe-water stress

4.8.3 Estimates of correlation coefficients across location

The correlation coefficients between grain yield and seven yield component traits under three different water stress regimes across location are presented in Table 4.26. across location under non-water stress condition, the correlations analysis between grain yield and DT (r = -0.51) and DS (r = -0.53) indicated that there was a negative and significant correlation at 1% level of probaility while between grain yield and ASI (r = -0.06) indicated a negative and non-significant correlation. Positive and significant correlations at 1% level of probability were recorded between grain yield and PHT (r = -0.23) and EHT (r = -0.58) while NEP (r = -0.21) had positive and significant correlation at 5% level of probability with grain yield.

Under intermediate-water stress condition, the correlations analysis between grain yield and DT (r = -0.34) and DS (r = -0.34) and SEN (r = -0.36) indicated that there was a negative and significant correlation at 1% level of probaility while between grain yield and ASI (r = -0.07) indicated a negative and non-significant correlation. Positive and significant correlations at 1% level of probability were recorded between grain yield and PHT (r = 0.40) and EHT (r = 0.43) while NEP (r = 0.15) had positive and non- significant correlation with grain yield.

Under severe-water stress condition, the correlations analysis between grain yield and DT (r = -0.23) and ASI (r = -0.20) indicated that there was a negative and significant correlation at 1% level of probaility while between grain yield and DS (r = -0.12) indicated a negative and non-significant correlation. SEN (r = -0.19) had negative and significant correlation at 5% level of probability with grain yield. Positive and significant correlations at 1% level of probability were recorded between grain yield and PHT (r = 0.20) and EHT (r = 0.20) while NEP (r = 0.26) had positive and significant correlation at 5% level of probaility with grain yield.

Table 4. 26. Correlation Coefficients between yield and other agronomic traits measured under non-water stress, intermediate-water stress and severe-water stress conditions across locations

Traits		DS	ASI	PHT	EHT	SEN	NEP	GY
Days to 50% tasseling	NS	0.94**	-0.40**	-0.20*	-0.54**	-	-0.23**	-0.51**
	IS	0.83**	-0.46**	-0.55**	-0.57**	-0.65**	-0.21**	-0.34**
	SS	0.82**	-0.45**	-0.51**	-0.53**	-0.50**	-0.30**	-0.23**
Days to 50% silking	NS		-0.05	-0.17	-0.54**	-	-0.24**	-0.53**
	IS		0.11	-0.43**	-0.46**	-0.50**	-0.14	-0.34**
	SS		0.15	-0.26**	-0.23**	-0.22**	-0.11	-0.12
Anthesis-silking interval	NS			0.15	0.13	-	0.02	-0.06
	IS			0.29**	0.28**	0.37**	0.17	-0.07
	SS			0.46**	0.56**	0.51**	0.34**	-0.20**
Plant height	NS				0.21**	-	0.00	0.23**
	IS				0.83**	0.71**	0.26**	0.40**
	SS				0.75**	0.67**	0.46**	0.20**
Ear height	NS					-	0.33**	0.58**
	IS					0.73**	0.25**	0.43**
	SS					0.65**	0.46**	0.20**
Leaf senescence	NS						-	-
	IS						0.32**	-0.36**
	SS						0.45**	-0.19*
Number of ears per plant	NS							0.21*
	IS							0.15
	SS							0.26*

* and ** = significant at $P \leq 0.05$ and $P \leq 0.01$, probability level respectively, DT = days to 50% tasseling, DS = days to 50% silking, ASI= anthesis-silking interval, PHT = plant height, EHT = ear height, SEN= leaf senescence, NEP = number of ears per plant, GY= grain yield, NS = non-water stress, IS = intermediate-water stress, SS = severe-water stress

CHAPTER FIVE

5.0 DISCUSSION

5.1 Variability Studies

The analysis of variance at Samaru showed significant variability among the genotypes for DT, DS, ASI, PHT, EHT and GY under the three different water stress conditions. At Kadawa it showed significant differences for DT, DS, PHT, EHT and GY under the three different water stress conditions while the differences were not significant for ASI under intermediate and severe-water stress conditions. In Samaru and Kadawa the mean squares due to genotypes were not significant for SEN and NEP under the three different conditions. The significant differences observed among the genotypes in the different locations indicated the presence of genetic variability in them, while the non-significant ones indicate that they may be conditioned by the same genes and are genetically related for these characters. It might be possible that the genotypes are related through some remote ancestors. These results indicated that there is significant genetic variability for the traits in each of the locations thus genetic improvement can be achieved for these traits under the three different water stress conditions for each location. For that reason, suitable hybrids could be developed for specific locations. This was in agreement with the findings of Showemimo *et al.* (2000a and 2000b) who reported performance or expression of genes controlling maize characters to be strongly influenced by environmental variation.

Across the locations, the result indicated highly significant location differences for all the traits under the three different water stress conditions. There were highly significant genotypes and genotypes by locations interactions differences for all the traits under the three different water stress conditions except for SEN and NEP. The presence of significant effects of locations and water stress for most of the traits showed that the phenotypic expression for the different traits was influenced by environmental factors. The significant differences observed for locations for all the traits measured under the three different water stress conditions indicated that the two locations were not similar and that is why the genotypes did not perform in the same way. The significant genotype by location interactions indicated that some traits (DT, DS, PHT, EHT and GY), were influenced by the different locations. For that reason, suitable hybrids could be developed for specific locations. Similar results were reported by Aghaei *et al*. (2012). The genotypes differed significantly for all the traits. Availability of significant variability for morphological, yield and yield related traits in the genotypes would facilitate screening of the genotypes to moisture stress tolerance and to assess the character contribution towards stress tolerance

The mean performance of the top cross hybrids for the traits studied under non-water stress, intermediate-water stress and severe-water stress conditions at individual locations and across locations show similar trend. Generally, grain yield varied appreciably among the crosses in each location and across locations. Across the locations, under non-water stress condition the top-ranking top cross hybrid for grain yield was Sammaz 36 x P8 and it out-yielded the commercial check by 45%. Under intermediate-water stress, the top ranking top cross hybrid for grain yield was Sammaz 18 x P2 and it under-yielded the check by 3%. Under severe-water stress, the top ranking top cross hybrid for grain yield was Sammaz 34 x P2 and it out-yielded the check by 144%. Most of the top cross hybrids were taller and flowered earlier than their parents in the two locations which was consistent with other studies (Hallauer and Miranda-Filho, 1988; Betran *et al*., 2003a). Overall, the grain yield was reduced from non-water stress to intermediate-water stress condition by 49% and from non-water stress to severe-water stress condition by 75% across the two locations while there was an overall reduction of 51% from intermediate-water stress to severe-water stress condition. Similar results were observed 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. With regard to secondary traits (number of ears per plant, plant height and ear height), they were reduced by water stress. This was consistent with other studies, especially those that reported reduced number of ears per plant due to drought (Betran *et al*., 2003a) and increased days to 50% tasseling, days to 50% silking, anthesis-silking interval and leaf senescence. The top cross hybrids having high values for mean performance may be used in further drought tolerant breeding programme. The implication of reduced ear height is that, the shorter the ear height, the closer the ear to the ground level and the more it is prone to rodents attack and on the other hand, the longer the ear height, the farther the ear to the ground level and the more it is prone lodging. It is therefore, better when the ear is situated in the middle of the plant that is having a moderate ear height value when compared to the plant height.

5.2 Analysis of NCD II and Combining Ability Variances

The highly significant mean squares for females and males for all the traits implied that the genotypes were genetically diverse and therefore contributed differently in the crosses in which they were involved. On the other hand, the significant mean squares for females x males interaction indicate that there were hybrid combinations that had performance different from that expected from the means of the parents. These results are in agreement with the conclusions reached by Mosa *et al.* (2008).

Across the location, the mean squares for females x males x locations were highly significant under non-water stress condition for DT, DS, PHT, EHT and GY. Under intermediate-water stress condition for DT, PHT, EHT and GY and for DS, PHT, EHT, SEN and GY. The results were consistent with the findings by other scientists such as Gissa (2008); Mhike *et al*. (2011) and Thokozile (2012). The genotypes x locations effects indicate the challenges in 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. The results show that gca effects associated with the parents and sca effects associated with crosses were not consistent across the locations. Banziger *et al*. (2000) reported that stress environments produce high G x E interactions. The females x males x locations is more important in this work for more reliable choice of parents by targeting their sca effects.

The variance components for the male parents showed high positive values for GY and other traits of importance in both Samaru and Kadawa than the females under the three different water stress conditions. This means that the males are more diverse genetically than the females showing the hybrid vigor manifested by the inbred lines. The females x males variance estimates were higher in Samaru than Kadawa. This indicates that the genetic divergence of the parental varieties is inferred from the heterotic patterns manifested in the series of variety crosses. These hybrids may be selected as suitable parents to be utilized and improved for the traits in hybridization program. Across the locations, the variance components for the females recorded positive values for GY under the three stress conditions while males showed positive values for GY under non-water stress and severe-water stress conditions. The females x males variance estimates showed positive values for DT, DS, EHT under non-water stress condition, positive for DT, ASI and PHT under intermediate-water stress and negative values for GY. Under severe-water stress condition, the variance estimates for the females, males and females x males were positive for DT, PHT and GY. Negative estimates were recorded for females x males and this could be due to the similar performance of the parents across locations or as a result of inadequate experimental techniques (Hallauer and Miranda, 1981).

The result revealed that at Samaru the magnitudes of the SCA variance were much higher than the GCA variance for DT, DS, ASI, EHT, SEN and GY. At Kadawa, the SCA variances were also higher than the GCA variance for DT, DS, ASI, EHT and SEN under the three water stress conditions, indicating the predominance of non-additive gene action controlling the traits. It also denotes that non-additive genetic effects were largely influencing the expression of these traits hence heterosis and use of hybrid vigor could be applied to improve them. Across location, the GCA variances were much higher than the SCA variances for ASI, EHT, SEN and GY. Though, the ratios of GCA to SCA were less than unity for all the traits. This is an indication of the importance and the predominance of non-additive g enetic effects. Across locations, the SCA variances were higher than the GCA variances for DT, DS and EHT under non-water stress, DT, DS, PHT, EHT and NEP under intermediate-water stress and DT, DS and PHT under severe-water stress condition. All the $\sigma^2 GCA / \sigma^2 SCA$ ratios were less than unity confirming the results of Aminu and Izge (2013) and Majid *et al*. (2010). The $\sigma^2 GCA / \sigma^2 SCA$ ratio were negative for DS, SEN and GY because the $\sigma^2 SCA$ values were negative for the traits. The preponderance of non-additive gene action in this study has an implication in breeding in that non-additive genetic effects were largely influencing the expression of these traits; hence, heterosis, good specific combining ability and the use of hybrid vigor could be applied for improving and selecting good parents. The parents used in this study can therefore be exploited under drought conditions through targeting the SCA effects and heterosis.

5.3 Genetic and Phenotypic Variability Parameters and Heritability

The phenotypic variances (σ^2_{ph}) and PCVs were slightly higher than their respective genetic variances (σ^2_g) and GCVs for all the traits under the different water stress conditions, suggesting some influence of environment in the expression of these characters. Similar results have been reported by Nelson and Somers (1992), and Bello *et al*. (2012).

Genotypic and phenotypic coefficients of variation (PCV and GCV) showed that all the traits recorded higher values of phenotypic coefficient of variation than genotypic coefficient of variation under the three different water stress conditions in both locations and across locations. This indicates the presence of high variability for these traits and provides ample scope for selection of superior genotypes which is in conformity with the findings of Abhirami *et al.* (2005) and Pradeepa (2007).

Broad sense heritability estimates generally ranged from moderate to high in each location and across locations under the three different water stress conditions. This showed that their genetic variances were relatively large which may be as a result of major genes controlling the traits which could easily be inherited. At Samaru, ASI, PHT, SEN, NEP and GY recorded higher broad sense heritability estimates than at Kadawa indicating that selection of these traits will be easier at Samaru. Across locations estimates also ranged from moderate to high and the traits ASI, SEN and NEP recorded high values indicating that the genetic improvement of these traits will be easy at either location. The moderate heritability recorded indicates that there is little influence of environment on the trait. The genetic components of variation revealed that under drought, anthesis-silking interval followed by grain yield per plant and kernels per row showed higher variability as indicated by their PCV and GCV. The heritability of most the traits except anthesis to silking interval, number of ears per plant and leaf snescence decreased under drought suggesting the essentiality of target specific selection for better results Prakash *et.al* (2010). Such selected genotypes could be subjected to further genetic improvement through repeated mass selection or recurrent selection. The high estimates of broad-sense heritability for most traits revealed that variations were transmitted to the progeny and indicate good opportunities for selecting traits. High estimates of broad-sense heritability revealed that the genes can be transmitted to the progenies for developing improved varieties through selection of desirable plants in succeeding generations. These results were similar to those of Aminu and Izge (2012). The broad sense heritability of some traits across locations (DT, DS and GY) decreased under drought, whereas, the heritability of some traits (ASI, PHT, EHT, SEN, and NEP) increased with increasing stress. Decreased heritability for various traits under stress and non-water stress were reported earlier (Bolanos and Edmeades, 1996; Prakash, 2010). The decreased heritability for various traits under stress reminds the breeders about selection of genotypes under specific environment as being tolerant or non-tolerant under drought or any other stress in question.

Generally, estimates for narrow sense heritability ranged from low to moderate. Narrow sense heritability for Samaru showed low estimates for ASI, EHT and NEP but high estimates for GY under non-water stress condition. At Kadawa, the estimates were low for all the traits except EHT under non-water stress condition. Across locations, all the traits indicated either zero or low narrow sense heritability estimates except NEP under non-water stress condition and SEN and GY under severe-water stress condition. Variation of narrow sense heritability estimates between the locations indicated interaction of genotypes with locations. The relatively low narrow sense heritability estimates for most of the traits under the different conditions is an indication that the studied traits were mainly controlled by non-additive genes, similar to the report of Thokozile (2012). Moderate narrow sense heritability would mean that additive genes are important in influencing the expression of the traits such as SEN and GY under severe-water stress condition and NEP under non-water stress condition. Negative heritability values as recorded for DT, DS, ASI and PHT under non-water stress condition, ASI and NEP under intermediate-water stress condition and DS, ASI, EHT and NEP under severe-water stress condition, indicate that the model used could be inadequate (genetic design) or inadequate sampling (small numbers) or inadequate experimental techniques (competition among progenies). According to Sabal *et al.* (2001), traits with high heritability are easier to be improved than those with low heritability. Genetic variation and heritability of kernel yield is lesser under stress than normal condition (Banziger and Cooper, 2001).

5.4 Combining Ability Effects

The gca effects of parents under non-water stress, intermediate and severe-water stress conditions exhibited variation both in direction and magnitude. The combining ability effects across locations revealed that different parents were general combiners for different traits under different conditions. Lowest negative gca effects are more desirable for traits such as days to 50% tasseling, days to 50% silking, anthesis-silking interval, leaf senescence, plant height and ear height while in the case of other traits like grain yield and number of ears per plant positive gca effects are more desirable. Therefore, female varieties Sammaz 18, Dent Q and Sammaz 17 exhibited good gca effects for grain yield under non-water stress, intermediate-water stress and severe-water stress conditions, respectively, across locations. These varieties were consistent in their performance as good general combiners for days to 50% tasseling, days to 50% silking, anthesis-silking interval, ear height and number of ears per plant under different conditions across locations. Generally, early tasseling and silking are needed for possible early maturity while medium plant height and ear height are required for lodging resistance. Across the two locations condition, under non-water stress, among the female parents, Sammaz 17, Sammaz 18, Sammaz 34, Sammaz 36 had the highest desirable gca effects for DT, Sammaz 18, Sammaz 19, Sammaz 34, Sammaz 36 for DS, for ASI (Sammaz 19, Sammaz 34, Sammaz 36, Dent Q), for PHT (Sammaz 18, Sammaz 19, Sammaz 36, Dent Q), for EHT (Sammaz 18, Sammaz 36, Flint Q), for NEP (Sammaz 19, Dent Q), for GY (Sammaz 19, Flint Q). Among the male parents for DT P2, P3, P4, P7, P8), for DS (P2, P3, P4), for ASI (P2, P3, P4), for PHT (P1,P3,P4), for EHT (P1,P4,P7), for NEP(P1,P2), for GY(P2,P3,P4) had the highest desirable gca effects under non-water stress condition.The females, Sammaz 18 and among the males P3 were the best general combiners for grain yield improvement.

Under intermediate-water stress condition, among the female parents, for DT (Sammaz 18, Dent Q), for DS (Sammaz 18,Dent Q,), for ASI (Sammaz 19, Sammaz 36, Flint Q), for PHT(Sammaz 17, Sammaz 18,Flint Q), for EHT(Sammaz 17, Sammaz 18, Sammaz 34, Dent Q,), for SEN (Sammaz 19, Sammaz 34, Sammaz 36,Flint Q), for NEP (Sammaz 17, Sammaz 19), for GY (Sammaz 19, Sammaz 36,Dent Q, Flint Q). Among the male parents for DT(P2,P4,P7,P8), for DS(P2,P4,P7,P8, for ASI (P2,P3,P4,P7), for PHT (P2,P4), for EHT (P1,P3,P4), for SEN (P2,P3,P7), for NEP (P1,P2,P3), for GY (P3,P4) had the highest desirable gca effects .The female line Dent Q and male line P3 were the best general combiners for grain yield improvement.

Under severe-water stress condition, among the female parents, for DT (Sammaz 17, Sammaz 18, Sammaz 19,3 Sammaz 36 Dent Q), for DS (Sammaz 17, Sammaz 18, Sammaz 19 Sammaz 36, Dent Q), for ASI (Sammaz 17, Sammaz 34, Sammaz 36, Dent Q), for PHT(Sammaz 18, Sammaz 19, Sammaz 34, Sammaz 36,Flint Q), for EHT(Sammaz17, Sammaz 18, Sammaz 36,Flint Q), for SEN (Sammaz 19, Sammaz 34, Sammaz 36), for NEP (Sammaz 17, Sammaz 19, Sammaz 34), for GY (Sammaz 17, Flint Q). Among the male parents, for DT (P2,P4,), for DS (P2,P3,P4,P8), for ASI (P3,P8), for PHT(P1,P2,P4), for EHT (P1,P4), for SEN (P2,P3,P4), for NEP (P1,P3,P4), for GY(P3,P4) had the highest desirable gca effects Under severe-water stress condition.The female line Sammaz 17 and male line P3 were the best general combiners for grain yield improvement.

The gca is considered as the intrinsic genetic value of the parent for a trait which is due to additive genetic effects and is fixable (Simmondes, 1979). The parents with a high gca effects for traits could produce superior segregants in the F_2 as well as in later generations. The presence of high gca effects indicates that continued progress should be possible when breeding for yield. Griffing (1956) suggested that the high gca effects might be due to additive gene action as well as additive x additive types of epitasis gene action.

On the other hand, the male inbred line P3 was consistent in its gca effects proving to be a good general combiner for grain yield and other traits across locations. The male inbred lines P3 and P4 also showed good gca effects in desirable direction for most of the traits under the three different stress conditions. These females (Sammaz 17, Sammaz 18, and Dent Q) and males (P3, P4 and P7) could be considered as good combiners for yield and most of the yield attributing traits under the three different water stress conditions. Hence, these parents can be utilized for developing drought tolerant hybrids by extensively testing their specific combining ability under both conditions for selection of superior crosses that could invariably serve as a source of new desirable inbred lines.

Better specific combining crosses might involve two good general combining parents but this is not a rule for all crosses. Sometimes two poor combiners may result to good specific combination. Across locations, under non-water stress, Sammaz 17 x P1 had the highest sca effects for ASI, Flint Q x P1 for PHT, Sammaz 36 x P4 for EHT; Sammaz 19 x P2 for NEP and Sammaz 34 x P3 for GY. Under intermediate-water stress, Sammaz 34 x P8 had the highest desirable sca effects for ASI, Flint Q x P8 for PHT and EHT, Sammaz 19 x P2 for NEP. Sammaz 19 x P8 was the best specific combiner for grain yield under intermediate-water stress condition. Under severe-water stress, Flint Q x P2 had the highest desirable sca effects for ASI, Sammaz 34 x P4 for PHT, Sammaz 34 x P7 for EHT, Dent Q x P7 for SEN, Sammaz 34 x P2 for NEP and Sammaz 17 x P3 was the best specific combiner for grain yield under severe-water stress condition. These parents could be used in hybridization to improve yield as well tolerance to drought and as donor parents for the accumulation of favorable genes.

The study revealed hybrids with high desirable sca effects for different traits. Some of the superior hybrids were from parents with high x high general combining ability as in Sammaz 18 x P4, Flint Q x P4 and Sammaz 17 x P3 under non-water stress, intermediate-water stress and severe-water stress conditions, respectively, or either one of the parents with high gca effects ie., high x low (Sammaz 18 x P1, Dent Q x P7 and Flint Q x P1) or low x high (Sammaz 34 x P3, Sammaz 17 x P3 and Sammaz 19 x P4) under non-water stress, intermediate-water stress and severe-water stress conditions, respectively. The parents can be low × low general combiners such as Sammaz 36 x P8, Sammaz 17 x P1 and Sammaz 36 x P7 under non-water stress, intermediate-water stress and severe-water stress conditions, respectively. Sammaz 36 x P7 is a superior hybrid from parents with low x low gca effects but recorded high estimates of sca effects for GY under the severe-water stress condition across locations. Such superior cross combinations involving parents with low x low gca effects could be as a result of over dominance or epistasis (Hallauer and Miranda-Filho, 1988, Majid *et al*. 2010). Such type of gene action may be exploited in cross–pollinated crops like maize. The superiority of high x low or low x high 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 top cross hybrids would be non fixable and thus could be exploited for heterosis breeding. Similar work was reported by Aminu and Izge (2013), Kanta *et al*. (2005), Majid *et al*. (2010) Prakash (2010), Premlatha and Kalamani (2010). The crosses with high x low gca combinations were reported earlier in wheat by Rajara and Maheshwari (1996) and in sorghum by Patil (2001) indicating the presence of additive x additive and/or additive x dominance genetic interactions in the crosses. The superiority of hybrids involving parents with high x high general combining ability effects could be as result of the combination of parents that are both good combiners for the trait. This was supported by Xingming *et al.* (2002), who reported the involvement of good parents in high yielding crosses. 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).

5.5 Heterosis

The degree of heterosis varied from hybrid to hybrid and from trait to trait. Both positive and negative heterotic values were recorded in traits studied. The study showed that great potentials for increased maize yield exists because of the high level of heterosis observed. Across the locations, under non-water stress, the top cross hybrids Sammaz 36 x P8, Sammaz 19 x P2, Sammaz 34 x P7, Dent Q x P3, Sammaz 19 x P7, Sammaz 18 x P4 and Sammaz 18 x P1 exhibited the highest better parent heterosis for DT,DS ASI, PHT, EHT, NEP and GY, respectively. Under intermediate-water stress, Flint Q x P3, Flint Q x P3, Sammaz 19 x P3, Flint Q x P3, Flint Q x P3, Sammaz 18 x P3, Sammaz 34 x P7 and Dent Q x P8 had the highest level of better parent heterosis for DT, DS, ASI, PHT, EHT, SEN, NEP and GY, respectively. Under severe-water stress, the hybrids Sammaz 19 x P2, Dent Q x P4, Sammaz 17 x P7, Flint Q x P1, Sammaz 17 x P2, Dent Q x P8, Sammaz 19 x P7 and Sammaz 36 x P2 had the highest level of better parent heterosis for DT, DS, ASI, PHT, EHT, NEP and GY respectively. High heterosis estimates are desirable for grain yield in maize.

The hybrids Sammaz 18 x P1, Dent Q x P8 and Sammaz 36 x P2 under non-water stress, intermediate-water stress and severe-water stress conditions across locations, respectively, had the most highly significant positive heterosis for grain yield. Similar results were reported for grain yield in maize by Aminu (2012). The yield superiority of these top crosses might be due to the opportunity for segregation and recombination that exists in the single cross/F1 parent of a three way cross resulting in genetically heterogeneous populations unlike single cross hybrids, which are heterozygous and homogeneous in their genetic constitution (Kide *et al.,* 1985; Walsh and Atkins, 1973) Low heterosis is more desirable for agronomic traits such as DT, DS, PHT, EHT and SEN was observed in Dent Q x P3, Flint Q x P3 and Flint Q x P1 for PHT, Sammaz 19 x P7, Flint x P3 and Sammaz 17 x P2 for EHT, heterotic values under non-water stress, intermediate-water stress and severe-water stress conditions across locations, respectively. Negative heterosis are actually desirable for DT, DS and ASI implying that these hybrids would mature earlier and for SEN so that the hybrids can stay green for longer period and this can as well contribute to high grain yield as observed in Sammaz 17 x P2. 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. Negative desirable heterosis for agronomic traits were observed in Sammaz 36 x P8, Flint Q x P3 and Sammaz 19 x P2 for DT, Sammaz 19 x P2, Flint Q x P3 and Dent Q x P4 for DS, Sammaz 34 x P7, Sammaz 19 x P3 and Sammaz 17 x P7 for ASI under non-water stress, intermediate-water stress and severe-water stress conditions, respectively. Sammaz 18 x P3 and Dent Q x P8 recorded the lowest heterosis for SEN under intermediate and severe-water stress conditions across locations, respectively. Negative heterotic values for these traits were also reported by Aminu and Izge (2013). These parents could therefore be utilized for development of either synthetic varieties or an elite breeding population by allowing thorough recombinations among them to achieve desirable genetic populations which could further be subjected to recurrent selection. These populations could invariably serve as a source of new desirable inbred lines. The exploitation of hybrid vigor, *per se* performance, sca effects and the extent of heterosis among top cross hybrids could be very important in selection because a hybrid with high *per se* performance may not always reveal high sca effects.

5.6 Correlations

Across locations, correlation coefficients indicated that grain yield had highly significant negative correlations between with DT and DS under all the three water stress conditions and ASI under severe-water stress condition were reported in this study indicating the fact that an increase in any of these traits may result in a corresponding decrease in GY. Biasutti and Peiretti, (1992). Dash *et al.* (1992) reported that yield was significantly but negatively correlated with maturity traits. Significant positive correlation between NEP with the GY under non-water stress and severe-water stress conditions were recorded in this study. Jadhav *et al.* (1991) reported that grain yield was significantly and positively correlated with plant height. Short period of water shortage at flowering stage reduces the fertilization, seed set and grain yield and ear size and that the reduced yield under water stress could be due to reduced grain number (Hall *et al.*, 1981). Drought stress delayed silking and anthesis-dates and reduced grain filling period. Drought during this period results in an easily measured increase in the anthesis- silking interval (ASI) as the silk emergence is delayed (Edmeades *et al.*, 2000).

These findings are also consistent with the findings of other investigators Banziger *et al*. (1997), Betran *et al*. (2003), Zaidi *et al*. (2004), Derera, (2005) Gissa, (2008), Pswarayi and Vivek, (2008). Therefore, breeding and increasing of grain yield can be performed by selection of hybrids which have more number of ear per plant, medium sized plants, and lower ear height with short anthesis-silking intervals, negative days 50% tasseling and silking with this,it can be said that the hybrids have potential to produce higher yield. This report is consistent with findings of Banziger *et al*. (1997) and Gissa (2008). ASI and NEP are considered important traits used in selection of drought tolerant materials (Bolanos and Edmeades, (1996), Vasal *et al*. (1997), Banziger and Lafitte, (1997), Edmeades *et al*. (1997) Banziger *et al*. (2000) and Mhike *et al*. (2011). The highly significant positive correlation of GY with PHT and EHT under the three conditions shows that selection for either of these traits may result in corresponding increase in grain yield. Similar results were reported by Bello *et al*. (2010) and Wannows *et al*. (2010).

CHAPTER SIX

6.0 SUMMARY, CONCLUSION AND RECOMMENDATIONS

6.1 Summary

The study was conducted to estimate the gene action, correlation among and grain yield and agronomic traits and to identify the best top cross hybids under non-water stress and water stress conditions in maize. The parental materials used comprised seven maize varieties and six drought tolerant top cross inbrd lines which were crossed using North Carolina design II. Fifty six genotypes comprising the fouty two top cross hybrids, thirteen parents and a commercial check were evaluated at Samaru and Kadawa during the dry season of 2012/13.

The experiment was laid out in a 7 x 8 simple lattice design with two replications under each condition. The genetics of eight agronomic traits (days to 50% tasseling, days to 50% silking, anthesis-silking interval, plant height, ear height, leaf senescence, number of ears per plant and grain yield) under non-water stress, intermediate and severe-water stress conditions was studied.

Highly significant differences observed for most of the traits studied under the different conditions indicated presence of appreciable variability among the genotypes which is pre-requisite for any crop improvement program. Across locations, PCV estimates were slightly higher than GCV estimates for all the traits suggesting the slight influence of environment in the expression of the traits under the three water stress conditions. High broad sense heritability estimates were recorded for the traits *viz.*, DT and ASI under the three stress conditions, high for DS and GY under non-water stress condition. Broad sense heritability was also high for NEP under intermediate-water stress conditions while high for SEN and NEP under severe condition. This revealed that variations were transmitted to the progeny and indicated potential for developing high yielding varieties through selection of desirable plants in succeeding generations. Among the top cross hybrids *viz.* Sammaz 36 x P8, Sammaz 18 x P2, Sammaz 34 x P2, topped the list in terms of performance for grain yield under non-water stress, intermediate-water stress and severe-water stress conditions, respectively, across locations.

Combining ability analysis showed that non-additive gene effects were important for the inheritance of all the traits under non-water stress, intermediate-water stress and severe-water stress conditions across the locations. This is further confirmed from the ratios of GCA variance to SCA variances which were less than unity for all the traits. Estimates of narrow sense heritability were low for all the traits under the three different water stress conditions. Parents that exhibited high combining abilities could be useful in hybridization programmes. However, parents that are good combiners do not always produce best hybrid combinations. For this reason, the specific combining abilities of the top cross hybrids should be considered in selecting the best parents. General combining ability of parents showed that Sammaz 18, Flint Q, Sammaz 17 (females) and P3 (male) were identified as good general combiners for grain yield under non-water stress, intermediate-water stress and severe-water stress conditions, respectively, across locations. In terms of specific combining ability effects, the top cross hybrids Sammaz 34 x P3, Sammaz 19 x P8 and Sammaz 17 x P3 were identified as the best specific combiners for grain yield under non-water stress, intermediate-water stress and severe-water stress conditions, respectively, across locations. Heterosis studies revealed a persistent heterotic performance of some hybrids within and across locations. The hybrids with good heterotic performance evolved from diverse genetic backgrounds. The top cross hybrids Sammaz 19 x P8, Sammaz 19x P7 and Flint Q x P8 recorded the highest values of heterosis for grain yield under non-water stress, intermediate-water stress and severe-water stress conditions, respectively, across locations. Negative desirable heterosis was recorded for DT, DS, ASI and SEN implying that these hybrids could mature early and could escape drought. Correlation coefficients with grain yield showed that DT, DS, ASI and SEN were negatively correlated while PHT, EHT and NEP were positively correlated with GY under the three water stress conditions across locations.

6.2 Conclusion

In conclusion, the study revealed that both GCA and SCA effects significantly contributed to hybrid yield however, the influence of SCA effects was greater than GCA under the three water stress conditions indicating that non-additive(dominant) gene action played a major role in influencing the hybrid yield. Grain yield was positive and significantly correlated with PHT, EHT and NEP while DT, DS, ASI and SEN were negatively correlated with GY under the three water stress conditions across locations.

Under non-water stress 55% of the top cross hybrids generated in this study perform similarly to the check. Such performance is encouraging given the fact that the parents were significantly inferior to the check.

Under intermediate-stress, three top cross hybrids Sammaz 18 x P2 (2714 kg/ha), Sammaz 34 x P2 (2443 kg/ha) and Dent Q x P8 (2433 kg/ha) were comparable to the checks (2785 kg/ha).

Under severe-water stress 62% of the top cross hybrids generated in this study perform similarly to the checSammaz 34 x P2, yield advantage of 144% over the check while Sammaz 36 x P2, Sammaz 17 x P4 Flint Q x P4 and Sammaz 19 x P4 were 79%, 74%, 56 % and 53% respectively over the check.

6.3 Recommendations

Based on the above highlights, the following recommendations are considered:

1. The best top cross hybrids (Sammaz 36 x P8, Sammaz 17 x P2 and Sammaz 34 x P2) are to be tested further under various water regimes at different locations especially under rain fed conditions with terminal drought for their drought tolerance and yielding ability. This could be done by testing the hybrids under productive environments in farmers' fields as part of participatory varietal selection scheme.
2. Female parents with high general combining ability (Sammaz 18, Flint Q and Sammaz 17) and male parent (P3) can be considered for further breeding programmes to produce top cross hybrids and populations which that can be screened for favourable alleles across Samaru and Kadawa for recurrent selection scheme.
3. Molecular approaches which offer exciting ways of shortening the time for variety development is recommended along with the conventional breeding strategies to develop drought tolerant hybrids.

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