HETEROSIS AND COMBINING ABILITY FOR GRAIN YIELD AND AGRONOMIC TRAITS IN SOME SORGHUM CROSSES (*Sorghum bicolor* (L.) Moench)

BY

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DECLARATION

I hereby declare that this thesis was written by me and it is a record of my own research work. It has not been presented in any previous application for a higher degree. References made to published and unpublished literature have been duly acknowledged.

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The above declaration is confirmed

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CERTIFICATION

This thesis titled Heterosis and combining ability for grain yield and agronomic traits in some sorghum crosses (*Sorghum bicolor* (L.) Moench) by Ebiloma, Musa Habila meets the regulations governing the award of the Master of Science in Crop Breeding of Ahmadu Bello University, Zaria and is approved for its contribution to scientific knowledge and literary presentation.

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DEDICATION

This work is dedicated to the strong women in my life, my father and my wonderful family.

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ABSTRACT

Eleven entries (consisting of lines, testers and hybrids), were used to study general, specific combining ability and heterosis. The male and female lines were mated in a Line x Tester mating Design. In the study, analysis of variance showed significant difference was observed for yield and agronomic traits among the entries. This signified that they characters studied can be selected for genetic improvement. Estimation of general combining ability (GCA) and Specific combining ability (SCA) were obtained for each male inbred, female parent and for all hybrids. The inbred lines 97-SBF5-DT-150A and Dangarko white contributed high GCA estimates for grain yield. It was observed that parents that showed high GCA effects for grain yield, also showed high to average GCA for other agronomic traits, suggesting that GCA effects for grain yield could be related to combining ability effects and agronomic traits studied.

The hybrid 97-SBF5-DT-150A x Dangarko white recorded the maximum SCA effects for two out of the six traits studied namely, panicle weight and grain yield.

High-parent heterosis was observed for grain yield and agronomic traits for all characters except plant height. Among the hybrids, 97-SBF5-DT-150A x Dangarko white expressed high-parent heterosis for days to anthesis, panicle length, panicle width, panicle weight, grain yield and threshing per- cent-age. Keeping in view mean performance, SCA and high-parent heterosis, the hybrid 97-SBF5-DT-150A x Dangarko white may be recommended for further testing over different locations.

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CHAPTER ONE

1.0 Introduction

Sorghum (Sorghum bicolour (L.) Moench) is one of the major cereals cultivated in the world. As an important food crop, the 'guinea' or 'kafir' race is commonly cultivated in West Africa especially in Northern Nigeria (House, 1985). Sorghum originated in Africa, probably cultured in Egypt from where it spread to India and the Middle East (Kent, 1983). Sorghum is grown mainly in the arid and semi-arid tropics. It ranks fifth among the important cereals in the world after wheat, rice, maize and barley and it forms an important dietary staple for more than 500 million people in more than 30 countries (ICRISAT, 2006). The Food and Agriculture Organisation (FAO) statistics division estimates sorghum yield in Nigeria to be 1.2 t/ha.(FAO, 2010).

Sorghum is prepared as food and drink, including unleavened bread, thick porridge ('Tuwo'), thin porridge ('Ogi,' or 'Akamu'), or boiled or steamed cooked grain eaten with seasoning and spices, alcoholic drinks (eg 'Burukutu' or 'Pito') and non alcoholic drinks ('Kunu') (Nwasike,1987). The leaves and stalks are used as livestock feed and the stalk for fencing, fuel, basket and hut in northern Nigeria and a variety of other uses (Aluko and Olugbemi, 1990). The emerging principal use of sorghum as industrial material include the production of biscuits and confectionery, beverages, weaning foods, feed and as malted drinks (Aribisala, 1989). Grit, flour, cakes, wax, syrups and starch meals from sorghum are now common items in the market.

Sorghum also is used extensively in brewing, and industrial demand by beer manufacturers is rising steadily, in step with rising demand for their products. Beer has been produced exclusively in Nigeria from sorghum, following a ban placed on barley and barley malt importation in mid-1980's. Although the ban was lifted in 1999, breweries have continue to

use sorghum as key ingredients. There are no official statistics on exports, but undocumented, cross-border movement in 2009/2010 was forecasted at 50,000 tonnes (Flakes and David, 2009).

Areas sown to Sorghum in the united states of America is low but productivity is high. Increased productivity of sorghum can be achieved in the developing countries by adopting improved agronomic practices and by the use of high yielding varieties. In the USA, sorghum production has tripled since the adoption of hybrid sorghum cultivars and exploitation of hybrid vigour in conjunction with intensive management practices (Dogget,1988).

The advantage of sorghum hybrids over open pollinated varieties was recognised in tropical countries, such as India with the release of the first commercial sorghum hybrid 1 (CSH 1). It was tested over several locations and years and was found to yield 50 to 100% higher than the farmers' local cultivars.(Dogget,1970).

Sorghum improvement will boost activities of sorghum growers due to increased demand by brewing and weaning food industries. The final goal of a crop improvement programme is to develop cultivars that perform better than the existing ones so as to achieve increased productivity for growing. A way to achieve this is through hybridization of inbred lines. The discovery of cytoplasmic genetic male sterility restorer system in sorghum should be exploited by breeders to develop superior sorghum hybrids.

This research is set out with the following objectives:

(i) To determine genetic variability among sorghum lines.

(ii) To determine combining abilities among sorghum crosses.

(iii) To identify parental lines for hybrid development.

(iv) To identify heterotic effects for yield and some agronomic traits in the crosses.

CHAPTER TWO

2.0 REVIEW OF LITERATURE

2.1 Floral Biology

A sorghum plant usually has a single solid erect stem supported by a strong adventitious root system. The culm or stem may be 0.5 to 5.0 cm in diameter at the base and 0.5 to 4.0m in height, exhibiting a series of nodes and internodes. Leaves are arranged alternately on the stem, usually in two ranks. Each leaf originates from a node and has a sheath and blade or lamina. The leaf sheath has overlapping margins and encircles the internodes above, depending on the internode length. The leaf blade may be 1.5 to 13cm in width and 30 to 135cm in length. Leaf number can vary from 7 to 30 depending on the cultivar and its growth duration. The uppermost internode bears the inflorescence and is called the peduncle. Sorghum is known as a short-day plant, ie long nights (dark period) are required for floral initiation and each cultivar needs a specific 'critical period ' of dark hours for its vegetative bud to transform into a floral bud. Length of maturity in sorghum is governed by four major genes (Ma1, Ma2, Ma3 and Ma4) called maturity genes, with multiple alleles at each of the four loci. Plant height is similarly controlled by four major genes called dwarfing genes (Dw1, Dw2, Dw3 and Dw4) which have a brachytic effect on the plant, ie, reduction in length of internodes. The interaction of height and maturity goes with photoperiod and temperature and results in significant variation in crop morphology and behaviour (Quinby, 1974).

2.1.1 Panicle

The young inflorescence or panicle is forced up through the sheath (boot) of the flag leaf or topmost leaf. The peduncle may be well exserted above the flag leaf or sometimes the lower portion may remain partly in the boot, surrounded by sheath. Poor exsertion is problematic

and encourages insect attack and grain mold development in the hidden portion of the panicle. Under extreme drought conditions such panicles may fail to emerge from the boot. The peduncle may be erect or may be recurved to give a pendent panicle or goose neck. Panicles may be short or long, compact to very lax and open, and oval, conical, long and slender or pyramidal. The panicle has a central axis or rachis that bears the primary branches that may give rise to secondary and even tertiary branches. The rachis may be striated and exhibits varying degrees of hairyness. The primary branches are often in whorls or may be spirally arranged. Variation in rachis length, branch length and thickness, the distance between whorls, and angle of branching give rise to a wide range of panicle shapes. (Quinby, 1974).

2.1.2 Anthesis

Flowering of the sorghum inflorescence normally starts as soon as the peduncle completes its elongation but in poorly exserted panicles it may start earlier. Usually a few spickelets at the tip of the panicle open on the first day and the blooming continues successively downwards for several days. Blooming of the spickelets occurs in a fairly regular manner with the florets in a horizontal plane across the panicle opening at the same time. Flowering of a panicle may be spread over a period of 4 to 9 days depending upon cultivar, panicle size, temperature and humidity. In cooler climates, panicle blooming period may be extended. The sorghum florets opens in response to pressure exerted by the swelling of two lodicles. The time at which florets open varies among regions and climates. Under tropical conditions it is usually between 0200 to 0800 hrs. As the glumes open, the stigma and anthers emerge outwards. Usually the stigmas and anthers protrude just before the glumes open and frequently anthers protrude first. However, there are cultivar differences in which the stigma and anthers emerge together or either one precedes or follows the other. As the stamens emerge out of the opening glumes, they rotate and spread outwards; the filaments elongate

rapidly, with the result that the anthers become pendent. The time from the commencement of the glume opening to completion of closing is about 1-2 hours and varies between cultivars. The time of dehiscence is very much dependent upon weather conditions. In the tropics, on clear days, dehiscence occurs around sunrise. If damp or cool weather prevails early in the morning, dehiscence could be delayed up to 1000 hrs. Anthers dehisce when they are dry and pollen is liberated. Usually, anthesis of the pedicelled spikelets occurs a few days after sessile spikelets (Quinby, 1974).

2.1.3 Pollination

Sorghum is considered to be a wind-pollinated crop. Pollen is normally viable for 3 to 6 hrs, so long as it is contained in the anther, even after dehiscence (Quinby, 1974). However, during field pollination, when pollen is collected in paper bags, its viability deteriorates rapidly and it may survive for less than 20 minutes. Pollen is shed rapidly when the weather is warm and a mild breeze is prevailing. Pollen can be collected from flowering panicles for a few hours after dehiscence. Pollen is usually available for a period of 4 to 10 days, since all the panicles in the field do not flower simultaneously. It has been estimated that each anther might contain approximately 5000 pollen grains(Quinby, 1974). Pollen collected in paper bags appears as yellow and may form clumps in damp weather. The amount of pollen shed by anthers is a highly variable trait, depending on the genotype. Tapping the panicles immediately after dehiscence can produce a small cloud of pollen, visible to the naked eye. The stigmas remain receptive up to a week or more after blooming depending upon the weather. However, they are most receptive during the first 3 days after their emergence. Sorghum is classified predominantly as a self pollinated crop, and the proportion of stigmas that are pollinated from the stamens in the same floret or from stamens of other florets within the same panicle varies between cultivars.The amount of cross-pollination is usually 2-10 %,

and is normally higher in the top quarter of the panicle, possibly because, according to the order of flowering, the stigmas emerging in this region have relatively less access to pollen from the same panicle (Quinby, 1974).

2.1.4 Fertilization and Seed Development

Pollen grain germinate as soon as they come in contact with a receptive stigma; the pollen tubes grow through the stigmatic papillae down to the ovary through the style. Only one pollen tube succeeds in reaching the micropyle. The sperm nucleus divides into two parts, one of which fertilizes the egg cell to give rise to the embryo (2n); the other joins two polar nuclei to form the endosperm (3n). Development of the embryo and endosperm continues along with starch accumulation for about 30 days until the seeds reach physiological maturity. Seed development is commonly divided into three phases, although in theory there is no sharp distinction between them : (1) milk stage, (2) early or soft dough stage, and (3) late or hard dough stage. There are cultivar differences in the number of days required to reach physiological maturity from the day of fertilization. Developing seeds appear creamy, light green to green in colour and exhibit their tissue colour as they approach physiological maturity (Quinby, 1974).

2.2 Cytoplasmic male sterility

Male sterility in plants caused by the interaction of sterility induced factors in the cytoplasm with genetic factors in the nucleus is called cytoplasmic genetic male sterility. In sorghum such system was discovered by Stephens and Holland in 1954 who observed from Milo x Kafir crosses, that cytoplasmic male-sterility (CMS) existed, resulting from an interaction between Milo cytoplasm (A_1) and kafir nuclear genome. The F_2 generation of the cross Milo x Kafir exhibited some male sterile plants, whereas the progenies of the reciprocal cross Kafir x Milo were all fertile. Male sterility was expressed only when Milo was used as the female

parent thereby indicating the importance of Milo cytoplasm. The ability to have 100 per cent male sterility resulting from a cross, quickly stimulated the interest of other agencies and the private industries to begin sorghum hybrid breeding programmes(Quinby, 1974).

2.3 Combining ability

General combining ability (GCA) refers to the average value of a line estimated on the basis of its performance when crossed with other lines. The performance of a particular cross can deviate from the average general combining ability of the parental lines. This deviation is defined as specific combining ability (SCA) (Falconer and Mackey, 1996).

Pathak and Sanghai (1992) derived information on combining ability and heterosis from data on 9 forage traits in sorghum. GCA effects were stable for fodder yield and a number of yield components but SCA effects were highly unstable for all the characters across environment. Sankarapandian *et al.* (1994) reported information on combining ability from data on six (6) quality and yield components in seventeen (17) lines and their F_1 hybrids. 2077A x FS35-1, 2077A x FS1, 2219A x FS1 were the best combiners. Can *et al.* (1997) studied general and specific combining ability in sorghum. GCA and SCA were highly significant for all the traits studied.

Bhavsar and Borikar (2002) evaluated the combining ability of 108 cytosterile lines of sorghum for 12 traits. The combining ability variance as affected by the hybrid status was significant for all the characters examined. The combining ability due to line x tester interaction was significant for all the characters. A relatively higher magnitude of specific combining ability variance than general combining ability variance was observed, indicating a higher magnitude of non-additive gene actions.

Hicks *et al.* (2002) evaluated eight lines of sorghum and their F_1 hybrids for crude protein, fat, starch, protein digestibility and in vitro dry matter disappearance (IVDMD). Significant GCA and SCA effects were noted for protein digestibility. Pandian and Doss (2001) evaluated parents and hybrids in Sorghum. Observations were recorded on the total soluble solids, extractable juice yield, crude protein and crude fibre at maturity stage. The testers KS 7657, SU 52 and IARI-13 contributed much to hybrid vigour in combination with Ms 430A or Ms 700A. Kenga *et al.* (2004) studied combining ability in tropical sorghum. Twenty lines including 15 restorers and 5 male-sterile lines were mated and data taken on grain yield, days to anthesis, plant height, inflorescence length, threshing percentage and seed mass. For each trait, GCA and SCA effects were estimated using the line x tester method of analysis. High significant GCA effects were found for all traits under study. Significant SCA was detected for all traits but inflorescence length.

Mohanraj *et al.* (2006) evaluated six lines and 4 testers and their 24 hybrids for hydrocyanic acid content in forage sorghum. The results indicated significant differences for HCN content for all the genotypes. It also clearly showed that SCA variance for HCN content was higher than GCA variance suggesting that the trait was controlled by non-additive gene action. The parents IS 3541, CO 27 and IS 0030 were found to be the best ones based on GCA effect for HCN content and the hybrids IS 1003 x TNS 52, IS 6354 x IS 0030, IS1003 x TNS 52 were found to have maximum negative SCA effects for HCN content. Heterotic breeding, recurrent selection and other population improvement procedures were suggested for getting varieties with reduced HCN contents.

Makanda *et al* (2009) estimated combining ability of parental lines for stem sugar traits in some sweet sorghum genotypes. Sixty-four hybrids were generated among 16 inbred lines using North Carolina design II mating design scheme. Eight parents were cytoplasmic male

sterile lines which were designated as females and were crossed with eight male fertile lines. The hybrids were evaluated at two sites in Mozambique and South Africa under off-season production conditions. There was significance (P=0.05) variation among genotypes for stem brix and associated traits. General and specific combining ability effects were significant for stem brix and associated traits which imply both additive and non-additive gene actions, respectively, were important for controlling the traits. The lines ZLRI and ICSVP3046 indicated significant and positive GCA effects for stem brix, while 13 crosses showed positive and significant SCA effects. These lines and the crosses ISCVP3046 x ICSA4, ICSV700 x ICSA731, ICSR165 x ICSSA307, ZLRI x ICSA474 and ICSR57 x ICSRA479, were recommended for use in breeding new varieties for tropical lowland environment.

Combining ability has also been studied in other cereals. Yahaya (2004) studied combining ability and heterosis of male sterile lines and their restorers in pearl millet. Data collected from a line x tester design showed significant mean squares observed from entries and hybrids for agronomic characters. Combining ability analysis of variance indicated that GCA (lines), GCA (tester) and SCA (line x tester) were significant for all agronomic characters. Ojo *et al.* (2007) evaluated a seven-parent diallel of white maize planted out in a randomised complete block design with three replications at the experimental station of the University of Agriculture, Makurdi. Data collected from the diallel were used to estimate combining ability for grain yield and yield components (ear length, ear diameter and shelling percentage). Hybrid means were significantly higher than parental means for all the traits except shelling percentage. GCA and SCA mean squares were not significantly different for yield components. GCA mean square were however, highly significant for grain yield. Additive gene action was more important than non-additive gene action for grain yield. The preponderance of additive gene action observed for grain yield indicated that there will be progress in selection from crosses involving Tzi 3:1368. This was because the performance of

a single cross can be adequately predicted on the basis of GCA when SCA mean squares are not significant. The Combining ability in for Zinc (Zn) content was studied in millet. Ten inbred lines with varying grain Zn contents and 90 F_1 hybrids (including reciprocals) derived from diallel crosses were evaluated in a randomised complete design with three replications (Rai *et al.*, 2005). Large and significant differences were observed for grain Zn content among parents (28.8-51.4 mg/kg) and hybrids (26.4-52.5 mg/kg). Differences in GCA and SCA among hybrids were also highly significant. The interaction of season with GCA was significant, and it was of smaller magnitude than the GCA variance. The predictability ratio (Baker, 1978) measured by $2\sigma^2$ gca/($2\sigma^2$gca + σ^2sca) was 0.88, implying preponderance of additive gene action. The correlation between Zinc content of inbred lines and their GCA for traits was positive and highly significant (r=0.94;p=0.01) indicating that the selection of lines with high Zn levels would be effective in selecting for a high GCA for this trait. Among the four hybrids been considered with significant positive SCA, three had 863 B in their parentage. Also, 836 B parented three hybrids with positive SCA. This could result from the high correlation observed between the performance of lines and their GCA since the former is a component in heterosis estimation and the latter is a SCA estimation component.

Perez-Grajales *et al.* (2009) studied six landraces of pepper (*Capsicum pubescens* R and P) and all their possible direct single crosses were evaluated, for general and specific combining ability (GCA and SCA) for fruit yield and quality. Significant GCA effect were found for fruit yield, fruit volume, pericarp thickness, seed number and weight per fruit, and locule number per fruit. The highest GCA values among the landraces were registered in the landrace 'Puebla.' These hybrids also showed high SCA values. Crosses including 'Puebla' were the best landrace as parent in the hybrids. It had the highest frequency of high yielding hybrids with high fruit volume and pericarp thickness, compared with the other five

landraces. Thus, hybridization can be a useful method for breeding Manzano hot pepper by exploiting combining ability and heterosis.

Saleem *et al.* (2009) conducted a line x tester experiment to evaluate the performance of 30 hybrids along with 13 parents in tomato. Variance due to treatment, crosses and line x testers were significant for days to fruiting, fruit weight, fruit length, fruit width, number of fruit per plant and yield per plant. The contribution of lines towards the total variance was more than that of testers. Line x tester interaction contributed more in days to fruiting, number of fruit per plant and yield per plant than that of lines and testers. Based on the mean performance and GCA effect, lines 88572 and UC-134 and tester Nagina were better for yield.

2.4 Heterosis in sorghum

The product of a cross between genetically dissimilar parents (F_1 generation) is called a 'hybrid', and hybrid vigour or heterosis is the associated phenomenon where expression of characters such as growth-related traits, flowering and grain yield fall outside the range of its parents (Murfy *et al.*, 1994). Teme *et al.* (2002) studied heterosis for grain yield in some sorghum crosses. He recorded average heterosis of 50% over mid-parent and the best hybrid over the best parent was estimated as 60%.

Revindrababu *et al.* (2002) reported high magnitude of heterosis for plant height in hybrids using 10 lines of sorghum in half diallel fashion. Heterosis was medium for fodder yield and grain yield, while it was low for seedling vigour, days to flowering, number of nodes per plant, leaf length, leaf breadth and stem thickness. Cross IS 18551 x Malwan had high heterosis for dry fodder yield. Primalatha *et al.*, (2006) studied heterosis in sorghum in F_1 hybrids with respect to grain yield using thirty-six hybrids. Among the hybrids, CSV 15 x SPV 1521 recorded maximum grain yield with 90, 86.89 and 33.45 per cent heterosis over mid-parent, better-parent and standard check respectively.

Heterosis has been studied in other crops. Rai *et al.* (2005) studied heterosis for zinc(Zn) content in pearl millet. Ten inbred lines with varying Zn content and Ninety F_1 hybrids (including reciprocals) derived from diallel crosses were evaluated in a randomised complete block design with three replications. Mid-parent heterosis was significant in eleven of the hybrids tested. Heterosis in a positive direction (18.8 to 22.4%) was observed for three hybrids and heterosis in negative direction (-10.9 to -18.2%) was observed for eight hybrids for Zn levels. None of the hybrids, exceeded the Zn level of their parents. This showed that there would be little opportunity, if any, to exploit heterosis for the trait, and that high Zn levels would be required in both parental lines to breed hybrids with high Zn content.

Malik *et al*. (2004) studied heterosis in maize using nine inbreds. Diallel excluding reciprocals was used to evaluate eleven biometric traits, viz; days to pollen shedding, plant height, leaves/plant, leaf area, ear/plant, ear weight, grain moisture at harvest, kernel/row, 100-kernel weight and grain yield. High heterotic effects were observed for plant height, ear/plant, ear weight, kernel/ row, 100-kernel weight, and grain yield. Average mid-parent and high-parent heterosis were 17.2 and 2.8%, respectively for grain yield. Hybrid NCML-1082 x NCML-1083 indicated heterosis for yield with values of over 82.6 and 74.5% for mid-parent and high- parent heterosis, respectively.

Khan *et al.* (2008) studied heterosis among some sunflower genotypes. The study was conducted using five cytoplasmic male sterile (CMS) lines and five restorers, in a line x tester fashion at two locations to determine the quality and magnitude of heterosis over environment. The traits studied were days to 50% flowering, days to maturity, 1000-seed weight, seeds/head, oil content and seed yield. Best cross combinations at Peshawer were TS-18 x TR-13 (-3.06) for early flowering, TS-18 x TR-602 (-37.91) for early maturity, TS-4 x TR-6 (47.56) for 1000-seed weight, TS-11 x TR-6023 (98.25) for oil content and T335 x TR-5 (117.97) for seed yield. At Mensehra the crosses identified for desirable heterosis were TS-

4 x TR-6 (-22.45) for days to flowering, T335 x TR-13 (-56.29) for days to maturity, TS-11 x TR-5 (117.97) for seed yield. At Mensehra the crosses identified for desirable heterosis were TS-4 x TR-6 (-22.45) for flowering, T335 x TR-13 (-56.29) for days to maturity, TS-11 x TR-6 (30.53) for seed yield (kg/ha). Some of the crosses exhibited positive heterosis for all traits, however, others depicted negative but desirable heterosis for traits like days to flowering and maturity.

Ganapathy and Ganesh (2008) investigated the level of heterosis manifested by 40 hybrids derived from eight inbreds Lines and five Testers for physio-morphological traits in rice. The results indicated, maximum desirable heterosis over mid-parent for root: shoot ratio (100%) , leaf drying (-66.10%) followed by root length (60.56%), root dry weight (60.00%), days to attain 70% relative water content (70% RWC) (51.87%) and chlorophyll stability index (44.19%). Heterosis over better parent was observed for root:shoot ratio (71%) and leaf drying (62.96%) followed by leaf rolling (-47.50%), root length (42.42%) and root dry weight (39.22%). Among the hybrids, CPMP ACM 03 017 x MDU 5 had considerably higher desirable heterosis over mid-parent and better parent for physiological traits but CT 9993 x IR 50, CT999 x ASD 18, CPMP ACM 03 015 x ASD 18 and Moroberekan x ASD 16 exhibited positive and significant favourable heterosis over mid-parent and better-parent for root traits. Verma *et al*. (2002) reported heterosis in crosses in rice (*Oryza sativa* L.) for five important quantitative traits including grain yield/plant. Majority of the crosses manifested significant heterosis over Mahsuri and Sarjoo 52 for grain yield, number of productive tillers plant^{-1} and 100-grain weight Mahsuri, only. Heterosis for grain yield over better parent ranged from -3.8% to 75.55%. Yield could be further improved by employing the direct selection of traits viz.,days to 50% flowering and number of productive tillers plant-^{1} as revealed by coefficient between heterosis (over better parent) and inbreeding depression with significant values (r=+0.758), and (r=+0.564), respectively. The strong heterotic effect for

grain yield plant^{-1} were noted in the cross combination involving diverse ecotypes such as NDR 359/T 21, Mahsuri/IR 24, Sarjoo 52/NDR 359 and NDR 359/Jal lahri.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Genetic materials

The plant materials used in the study were obtained from various sources. Dio-1 is a regional germplasm material exchanged in a collaboration programme with ICRISAT-Mali while Dangarko white was a germplasm material collected by the Sorghum Unit of Institute for Agricultural Research. The A-lines; ICSA 38, IS 3534A and 97-SBF5-DT-150A were developed at the International Crop Research Institute for Semi Arid Tropics (ICRISAT). The R-lines and A-lines used in this study are shown in Table 3.1. Crosses were carried out in 2007 cropping season at the Institute for Agricultural Research (IAR) farm, Samaru, Zaria. The male (R-Lines) were crossed to each of the three females (A-lines) in a line x tester design to produce $6F_1$ hybrids. The six F_1 hybrids and their 5 parents were evaluated at Zaria.

Table 3.1: Parental materials used in the study

S/No	Parents	Varieties	Characteristics
		Male parents (R-lines)	
1	P1	Dio-1	218cm tall and flowers in 87 days, early maturing.
2	P2	Dangarko white	262cm tall and flowers in 92 days, medium maturing.
		Female Lines (A-lines)	
3	P3	ICSA 38	117cm and flowers in 77 Days, early maturing.
4	P4	IS 3534	212cm tall, flower in 95 Days, medium maturing, cream coloured and very small seeds.
5	P5	97-SBF5-DT-150A	140cm tall, semi dwarf and flowers in 77 days, early maturing.
		Maintainer Lines (B-lines)	
6		ICSB-38	
7		IS 3534 B	
8		97-SDF5-DT-150B	

3.2 Experimental Design and Procedures

The eleven entries were laid out in the field at Samaru in 2008 using a randomised complete block design with 3 replications. Each plot consisted of 2 rows, 3m long. Inter row spacing was 75cm and intra row spacing was 30cm. One row was left unsown between each plot for spacing. The plot were over sown (about 5 seeds/hill) and later thinned down to two seedlings per stand two weeks after sowing, during which time missing hills were compensated for by transplanting. Split application of compound NPK fertilizer (20:10:10) 80 Kg/ha was done three (3) and six (6) weeks after sowing. Weeds were controlled manually by hoeing.

3.3 Data Collection

The following data were recorded:

(i) Days to anthesis: Number of days from sowing in the field to the day when at least 50% of plants in each plot reached shed pollen.

(ii) Plant height: The average length in cm from the ground to the tip of the panicle of five randomly selected tagged plants in rows on each plot.

(iii) Panicle width: Distance of the diameter of the panicle, measured at the middle of the panicle, to the nearest cm.

(iv) Panicle length: Average length (cm) from the first panicle node to the tip of the panicle on five randomly selected tagged plant in rows in each plot at maturity.

(v) Panicle weight/plot: All the panicles in a plot are harvested and dried. The dried panicles are measured to the nearest g/plot using a Mettler balance.

(vi) Grain yield : All panicle harvested (at maturity) in each plot were allowed to dry and were threshed. Weights were recorded in grams for each plot after threshed using a Mettler balance. Grain yield was converted to kg/ha based on the land area of the two rows.

(vii) Threshing percentage: Weight of threshed seed over the weight of dry panicle multiplied by 100.

$$\text{Threshing \%} = \frac{\text{grain yield/plot}}{\text{Panicle weight/plot}} \times 100$$

Table 3.2: Pedigree of sorghum Hybrid

S/No	Crosses	Pedigree
1	P3 x P1	ICSA 38 x Dio-1
2	P4 x P1	IS 3534A x Dio-1
3	P5 x P1	97-SBF5-DT-150A x Dio-1
4	P3 x P2	ICSA 38 x Dangarko White
5	P4 x P2	IS 3534A x Dangarko White
6	P5 x P2	97-SBF5-DT-150A x Dangarko White

3.4 Statistical Analysis

3.4.1 Analyses of variances and means

Analysis of variance was conducted using individual plot means. All statistical analyses were computed using the General Linear Model (GLM) in SAS (SAS Institute, 2006). The following linear additive model was used:

$$\mathbf{Y_{ik} = \mu + G_i + b_k + e_{ik}}$$

Where;

$\mathbf{Y}_{ik}$ is the observation on the i^{th} entry in the k^{th} block

$\boldsymbol{\mu}$ is the general mean.

$\mathbf{G_i}$ is the effect of the i^{th} entry; i = 1,2,3,.....11.

$\mathbf{b_k}$ is the block effect of the k^{th} replication; k=1,2,3 and

$\mathbf{e_{ik}}$ is the residual variation contributed by the k^{th} replication for the i^{th} entry.

Entry main effects and their interactions was further partitioned into various components; parents, hybrids and parents versus hybrids. The sum of squares of hybrids was partitioned into variations due to lines, testers, and line x tester interactions. The mean squares due to lines and testers are to be tested against the mean squares due to line x tester. The latter is, in turn, tested against the mean squares due to error.

Table 3.3: Form of analysis of variance and expected mean squares

Sources of variation	Df	Expected mean square
Replication	2	
Entry	10	$\sigma^2_e + rh\,\sigma^2_p + rp\,\sigma^2_h$
Parent	4	$\sigma^2_e + rh\,\sigma^2_p$
Male (Tester)	1	
Female (Lines)	2	
Female x Male (Line x Tester)	1	
Hybrid	5	$\sigma^2_e + rp\sigma^2_h$
Parents vs hybrids	1	
Error	20	σ^2_e

Key: h=hybrid, p=parents, e=entry, r= replication

3.4.2 Genetic Analysis

3.4.2.1 Combining ability analysis

In the analyses of combining ability, hybrids were partitioned into male effects, female effects and male x female effects. Analyses of combining ability was based on the following statistical model by Singh and Chaudhary (1977):

$$\mathbf{Y_{ijk} = \mu + M_i + F_j + (M + F)_{ij} + e_{ijk}}$$

Where;

Y_{ijk} = k^{th} observation on the i^{th} and j^{th} progeny

μ = general mean

M_i = effect of the i^{th} male

F_j = effect of the j^{th} female

$(M+F)_{ij}$ =interaction effect and

e_{ijk} = error associated with each observation.

3.5.0 Estimation of General combining ability(GCA) and Specific combining ability(SCA) effects:

Estimation of GCA Effect

(a) Lines:

$$\text{gca(line)} = g_i = \frac{xi.}{tr} - \frac{x..}{ltr}$$

where,

g_i = general combining ability
l = number of lines
t = number of testers
r = number of replications
x_i = total of all the hybrids containing an i^{th} female
x.. = Grand total of crosses

(b) Testers:

$$\text{gca(tester)} = g_j = \frac{x.j}{lr} - \frac{x..}{ltr}$$

where,

g_j = general combining ability
l = number of lines

t = number of testers
r = number of replications
x_j = total of all the hybrids containing an j^{th} male
x.. = Grand total of crosses

Estimation of SCA Effects:

(c)Line x Tester

$$s_{ij} = \frac{xij.}{r} - \frac{xi.}{tr} - \frac{x.j}{lr} - \frac{x..}{ltr}$$

where,

s_{ij} = specific combining ability effects
l = number of lines
t = number of testers
r = number of replications
x_i = total of all the hybrids containing an i^{th} female
xj = total of all the hybrids containing a j^{th} male
xij = total of all the hybrids containing an i^{th}(female) x j^{th}(male)
x.. = Grand total of crosses

The values of GCA(males), GCA(females) and SCA effects were estimated based on the procedure described by Singh and Chaudhary (1977).

The significance of general and specific combining ability effects was tested using the formula of Cox and Frey (1984).

(a) General Combining ability effect:

$$t = \frac{GCA}{SEgca(male)} \quad \text{where,} \quad S.E_{(gca\ male)} = \frac{(Me)1/2}{r \times f}$$

$$t = \frac{GCA}{SEgca(female)} \quad \text{where,} \quad S.E_{(gca\ female)} = \frac{(Me)1/2}{r \times m}$$

Where:

M_e = error mean square
r = number of replication
f = number of females
m = number of males
S.E = standard error

(b) Similarly, significance of SCA effect:

$$t = \frac{SCA}{SEsca(line \times tester)} \quad \text{where,} \quad S.E_{(SCA)} = \frac{(Me)1/2}{r}$$

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

3.5.1 Heterosis

The estimate of mid-parent and high-parent heterosis were calculated for each cross as follows:

$$\text{Mid-parent(MP)} = \frac{(F1 - MP)}{MP} \times 100$$

$$\text{High-parent(HP)} = \frac{(F1 - HP)}{HP} \times 100$$

Where F_1 denotes the mean performance of the hybrid averaged over three replications. The parent which gave the higher mean value was used as high parent in the calculation of high-parent heterosis. The average between the two parents was used as the mid-parent.

Test of significance were performed on the differences. Significant differences were determined using standard error.

The standard error for high parent heterosis was calculated as :

$$\frac{(2\text{EMS})1/2}{\text{r}}$$

Mid-parent heterosis was calculated as :

$$\frac{(3\text{EMS})1/2}{2\text{r}}$$

(Kaur *et al.* 2000).

Where EMS = error mean squares, and r = number of replication.

CHAPTER FOUR

4.0 RESULTS

4.1 Analyses of variance

A read-through of the results (Table 4.1), shows that the entries exhibited high significant differences for plant height, days to anthesis, panicle length, panicle width, panicle weight, grain yield and threshing percentage. Female parents (lines) revealed highly significant differences for plant height and panicle width, and no significant difference for days to anthesis, panicle length, panicle weight, grain yield and threshing percentage; while, male parents (testers) showed significant differences for plant height and panicle length, and no significant differences for days to anthesis, panicle width, panicle weight, grain yield and threshing percentage. Interaction of line x tester was highly significant for panicle weight and significant for days to anthesis, panicle width, grain yield and threshing per-cent-age; plant height and panicle length showed no significant difference.

4.2 Mean performance

Mean performance of sorghum lines and hybrids for difference agronomic traits are shown in table 4.1. Mean performance for plant height showed no significant difference for IS 3534A, ICSA 38 x Dio-1 and IS 3534A x Dio-1. The remaining entries showed significant difference for the trait plant height. The mean performance for days to anthesis showed no significant difference for ICSA 38, 97-SBF5-DT-150A and ICSA 38 x Dio-1, while Dio-1, IS 3534A x Dio-1, 97-SBF5-DT-150A x Dio-1 and 97-DTF5-DT-150A x Dangarko white showed no significant difference for days to anthesis. Mean performance for panicle length showed no significant difference for ICSA 38, 97-SBF5-DT-150A, Dangarko white, 97-SBF5-DT-150A x Dio-1 while, Dio-1, ICSA 38 x Dio-1, IS 3534A x Dio-1,

Table 4.1: Analysis of variance for line x tester for yield and agronomic traits in sorghum

Source of Variation	df	Plant height (cm)	Days to anthesis (days)	Panicle length (cm)	Panicle width (cm)	Panicle weight (g/plot)	Grain yield (kgh^{-1})	Threshing percentage (%)
Replication	2	1676.27	4.76	5.33	1.24	250.76	1216.48	2.03
Entry	10	8218.19**	192.95**	207.65**	72.29**	340757.42**	790600.42**	253.42**
Parents	4	9940.43*	239.90**	227.65**	69.40**	69.40**	489150.10**	309.43**
Hybrid	5	8154.59*	186.77**	212.62**	81.70**	508058.06**	1102125.42**	220.72**
Line	2	4530.06**	93.39	288.00	346.72	621612.50	769693.06	29.39
Tester	1	4530.06	290.17	320.89	7.26	480759.72	714410.89	40.39
Line x Tester	2	1255.72	130.06*	66.67	23.61*	478579.16**	1628415.06*	496.72*
P vs H	1	1647.20	36.08	102.79	36.7724	151207.30	438776.73	192.89
Error	20	1335.90	4.72	4.31	0.88	1714.92	2805.45	11.2970

*****,****** Significant at 0.5 and 0.1 probability respectively

and 97-SBF5-DT-150A x Dangarko white showed no significant difference for the same trait. For the trait panicle width, ICSA 38, Dio-1, Dangarko white, ICSA 38 x Dio-1, IS 3534A x Dio-1 and 97-SBF5-DT-150A x Dio-1 showed no significant difference while, IS 3534A, ICSA 38 x Dangarko white, IS 3534A x Dangarko white and 97-SBF5-DT-150A x Dangarko white showed significant difference for the same trait. Mean performance for panicle weight, grain yield and threshing per-cent-age showed significant difference for all entries.

Table 4.2: Mean performance of sorghum lines and hybrids for yield and agronomic traits at Samaru in 2008 raining season

Parents	Plant Height (cm)	Days to anthesis (days)	Panicle length (cm)	Panicle width (cm)	Panicle weight (g/plot)	Grain yield (kgh^{-1})	Threshing percentage (%)
Female(lines)							
ICSA 38	119.33g	77.00c	31.33c	5.06b	1408.33f	1378.00g	65.33c
IS 3534A	208.70d	95.00a	50.00a	18.00a	1240.01i	1000.30k	51.00e
97-SBF5-DT-150A	142.00e	77.00c	30.00c	7.30b	1820.00b	1911.33c	71.00 b
Male(testers)							
Dio-1	216.00d	87.00b	39.50b	8.43b	1515.00c	1688.66e	77.33a
Dangarko white	261.00a	92.00a	29.70c	8.90b	1221.67j	1081.60j	59.67d
Crosses							
ICSA 38 x Dio-1	213.00d	76.30c	36.33b	8.23b	1416.67e	1466.33f	67.33c
IS 3534A x Dio-1	210.00d	81.00b	43.66b	8.90b	1368.33h	1377.66g	80.67a
97-SBF5-DT-150A x Dio-1	137.66f	81.33b	26.33c	4.50b	1388.33g	1274.00i	64.67c
ICSA 38 x Dangarko white	226.00c	72.66d	37.66b	13.53a	1510.00d	2414.66b	66.33c
IS 3534A x Dangarko white	260.33a	95.66a	51.66a	16.83a	1369.33h	1355.33h	59.33d
97-SBF5-DT-150A x Dangarko white	245.66b	84.00b	41.00b	17.60a	2410.00a	2844.33a	79.67a
Means	203.60	83.54	37.92	10.66	1515.24	1617.47	67.48
CV(%)	23.10	9.66	6.30	44.36	21.21	33.47	3.92
S.E±	14.18	2.28	2.38	1.43	96.88	163.20	2.64

Means with the same letter in a column are not statistically different.

4.3. Genetic Analyses

4.3.1 General Combining Ability

Estimates of variation due to GCA were partitioned for both male and female parents for yield and agronomic traits to seek out potential parents for further breeding and results are given in table 4.3.

The GCA estimates for lines (females) and testers (males) revealed that: Dio-1 showed a negative significant GCA value (-40.28) for plant height. Dangarko white (40.28) and IS 3534A (31.44) showed significant positive GCA for plant height. The female parent ICSA 38 (-7.33) showed high negative significant GCA for days to anthesis while the male parent Dio-1 (-2.28) showed negative significant GCA for days to anthesis. The female parent IS 3534A (8.22) showed high positive significant GCA for plant height while the female parent 97-SBF5-DT-150A (-5.78) and ICSA 38 (-2.44) showed high negative significant GCA for plant height. The male parent Dio-1 (4.00) and Dangarko white (4.00) showed high positive significant GCA for plant height. Among the females, the parent IS 3534A (1.27) showed high positive significant GCA for panicle width. Female parent ICSA 38 (-0.72) and 97-SBF5-DT-150A (-0.55) showed negative significant GCA for panicle width. The male parent Dangarko white (4.39) showed high positive significant GCA for panicle width, while Dio-1 showed high negative GCA for panicle width.

Among the female parents, ICSA 38 showed high positive significant GCA for panicle weight while IS 3534A (-208.61) showed high negative significant GCA for panicle weight. The male parent Dangarko white showed high positive significant GCA for panicle weight (185.83) ,while Dio-1 (-185.83) showed high negative GCA for panicle weight. The female

Table 4.3: Estimate of GCA for yield and agronomic traits in sorghum.

Parents	Plant height (cm)	Days to anthesis (days)	Panicle length (cm)	Panicle width (cm)	Panicle weight (g/plot)	Grain yield (kgh^{-1})	Threshing percentage (%)
Female							
ICSA 38	-19.39	-7.33**	-2.44**	-0.72*	113.61**	-188.61**	-2.72*
IS 3534A	31.44*	6.50**	8.22**	1.27**	-208.61**	-224.44**	0.28
97-SBF5-DT-150A	-12.06	0.83	-5.78 **	-0.55 *	322.22**	413.06**	2.44*
S.E. GCA(male)	7.98	0.47	0.45	0.20	9.04	11.56	0.73
Male							
Dio-1	-40.28*	-2.28*	4.00**	-4.39**	-185.83**	-199.22**	1.28
Dangarko white	40.28*	2.28*	4.00 **	4.39 **	185.83**	199.22**	-1.28
S.E GCA(female)	10.55	0.63	0.59	0.27	11.95	15.29	0.97

*****,****** Significant at 0.5 and 0.1 probability respectively

parents showed high positive significant GCA for grain yield in 97-SBF5-DT-150A (413.06) and negative high significant GCA for IS 3534A (-224.44) and ICSA 38 (-188.61) for grain yield. Among the male parents, Dangarko white (199.22) showed high positive significant GCA for grain yield, while Dio-1 (-199.22) showed high negative significant GCA for grain yield. Among the female lines, 97-SBF5-DT-150A (2.44) showed positive significant GCA for threshing per cent while ICSA 38 (-2.72) showed negative significant GCA for threshing per cent. There was no significant GCA among the female lines for threshing per cent.

4.3.2 Specific combining ability studies

The results for SCA effects for yield and agronomic traits is presented in table 4.4. No cross for plant height showed significant SCA. Dio-1 x IS 3534A (-5.06) showed high negative SCA for days to anthesis, while ICSA 38 x Dangarko white (-4.11) showed negative significant SCA for days to anthesis. IS 3435A x Dangarko white (5.06) showed high positive significant SCA for days to anthesis, while ICSA 38 x Dio-1 (4.11) showed positive significant SCA for days to anthesis. The estimates of SCA showed that two hybrids ICSA 38 x Dio-1 (3.33) and 97-SBF5-DT-150A x Dangarko white (3.33) showed significant positive SCA for panicle length. The estimates of SCA also showed that two hybrids, 97-SBF5-DT-150A x Dio-1 (-3.33) and ICSA 38 x Dangarko white (-3.33) showed significant negative SCA for panicle length. The hybrids ICSA 38 x Dio-1 (1.74) and 97-SBF5-DT-150A x Dangarko white (2.16) showed significant SCA for panicle width, while the hybrids 97-SBF5-DT-150A x Dio-1 (-2.16) and ICSA 38 x Dangarko white (-1.74) showed significant SCA for panicle width.

The estimate of SCA showed that three hybrids 97-SBF5-DT-150A x Dangarko white (380), IS 3534A x Dio-1 (185.85) and ICSA 38 x Dio-1 (139.17) showed high positive

Table 4.4: Estimates of SCA for yield and agronomic traits in sorghum.

Parents	Plant height (cm)	Days to anthesis (days)	Panicle length (cm)	Panicle width (cm)	Panicle weight (g/plot)	Grain yield (kgh^{-1})	Threshing percentage (%)
Crosses							
ICSA 38 x Dio-1	-1.39	4.11*	3.33 *	1.74*	139.17**	175.06**	-0.61
IS 3534A x Dio-1	15.11	-5.06**	0.01	0.42	185.83**	410.89**	9.39**
97-SBF5-DT-150A x Dio-1	-13.7	0.94	-3.33*	-2.16*	-325.00**	-585.94**	-8.78**
ICSA 38 x Dangarko white	1.39	-4.11*	-3.33*	-1.74*	-139.17**	-175.06**	0.61
IS 3534A x Dangarko white	-15.11	5.06 **	0.01	-0.42	-185.83**	-410.89**	-9.39**
97-SB-F5-150A x Dangarko white	13.72	-0.94	3.33 *	2.16*	325.00**	585.94 **	8.79**
S.E SCA	21.10	1.25	1.20	0.54	23.91	30.58	1.94

*****,****** Significant at 0.5 and 0.1 probability respectively

significant SCA for panicle weight, while 97-SBF5-DT-150A x Dio-1 (-325.0), ICSA x Dangarko white 38 (-139.17) and IS 3534A x Dangarko white (-185.83) showed high negative significant SCA for panicle weight. The hybrids, 97-SBF5-DT-150A x Dangarko white (585.94), IS 3534A x Dio-1 (410.89) and ICSA 38 x Dio-1 (175.06) showed high significant SCA for yield, while 97-SBF5-DT-150A x Dio-1 (-585.94), IS 3534A x Dangarko white (-410.89) and ICSA 38 x Dangarko white (-175.06) showed high negative significant SCA for grain yield. The estimates for specific combining ability showed that IS 3534A x Dio-1 (9.39) and 97-SBF5-DT-150A x Dangarko white (8.79) showed high positive significant SCA for threshing percentage, while IS 3534A x Dangarko white (-9.39) and 97-SBF5-DT-150A x Dio-1 (-8.78) showed high negative significant SCA for threshing per cent.

4.4 Heterosis

In this study, estimates of heterosis for seven agronomic characters in sorghum are shown in table 5. The mid-parent heterosis for plant height ranged from -15.16 to 22.02 per cent. None of the hybrids showed significant mid-parent heterosis. Best parent heterosis for plant height ranged from -36.27 to -0.26 per cent. None of the hybrids showed significant high parent heterosis for plant height. For days to anthesis, ICSA 38 x Dangarko white (-14.17) and Dio-1 x IS 3534A (-6.36) had significant negative heterosis for days to anthesis. Days to anthesis for mid-parent heterosis ranged from -14.17 to 6.36 per cent. ICSA 38 x Dangarko white (-21.30), IS 3534A x Dio-1 (-14.74) and 97-SDF5-DT-150A x Dangarko white (-9.03) had significant negative high parent heterosis for days to anthesis. High parent heterosis for days to anthesis ranged from -21.30 to 4.27 per cent. Mid-parent heterosis for panicle length range from -24.22 to 24.86 per cent.

Table 4.5: Heterosis(%) over the Mid-parent for seven traits in some sorghum crosses.

Crosses	Plant Height (cm) Mid-Parents	Days to anthesis (days) Mid-Parent	Panicle length (cm) Mid-Parent	Panicle width (cm) Mid-Parent	Panicle weight (g/plot) Mid-Parent	Grain yield (kgh^{-1}) Mid-Parent	Threshing percentage (%) Mid Parent
ICSA 38 x Dio 1	-15.16	-1.51	3.56	21.98*	-3.08	-7.59**	-5.14
IS3534A x Dio-1	-1.10	-6.36**	-2.06	-31.80**	-0.67	20.50**	25.71**
97-SBF5-DT-150A x Dio-1	-23.02	4.72	-24.22**	-42.92**	-16.74**	-30.09**	-12.81**
ICSA 38 x Dangarko white	18.53	-14.17**	24.86**	93.79**	14.83**	20.94**	6.13
IS3534A x Dangarko white	10.86	2.14	30.25**	26.73**	11.17**	17.51**	7.23
97-SBF5-DT-150A x Dangarko white	22.02	-0.98	37.43**	116.84**	58.47**	90.07**	21.94**

*,** Significant at 0.5 and 0.1 probability respectively

Table 4.6: Heterosis(%) over the High-parent for seven traits in some sorghum crosses.

Crosses	Plant Height (cm) Mid-Parents	Days to anthesis (days) Mid-Parent	Panicle length (cm) Mid-Parent	Panicle width (cm) Mid-Parent	Panicle weight (g/plot) Mid-Parent	Grain yield (kgh^{-1}) Mid-Parent	Threshing percentage (%) Mid-Parent
ICSA 38 x Dio 1	-33.95	-2.14	-8.02	-2.37	-6.49**	-17.31**	-12.5**
IS3534A x Dio-1	-2.78	-14.74**	-12.08**	-49.62**	-9.68**	-5.77	4.31
97-SBF5-DT-150A x Dio-1	-36.27*	4.27	-33.33**	-46.64**	-23.72**	-33.34**	-16.38**
ICSA 38 x Dangarko white	-13.41	-21.30**	22.83**	52.06**	7.22**	8.26	1.53
IS3534A x Dangarko white	-0.26	0.70	4.03	-4.72	10.35**	11.86**	-0.56
97-SBF5-DT-150A x Dangarko white	-5.87	-9.03**	36.67**	97.75**	32.42**	48.81**	12.21**

*,** Significant at 0.5 and 0.1 probability respectively

One hybrid, 97-SBF5-DT-150A x Dio-1 (-24.22) expressed significant negative heterosis for mid-parent heterosis. Three hybrids ICSA38 x Dangarko white (24.86), 97-SBF5-DT-150A x Dangarko white (37.43) and IS 3534A x Dangarko white (30.25) had significant positive mid-parent heterosis for panicle length. For high parent heterosis, 97-SBF5-DT-150A x Dio-1 (-33.33) and IS 3534A x Dio-1 (-12.08) showed significant negative best parent heterosis, while 97-SBF5-DT-150A x Dangarko white (36.67) and ICSA 38 x Dangarko white (22.83) showed significant positive best parent heterosis. High parent ranged from -33.33 to 36.67 per cent. 97-SBDT-F5- 150A x Dio-1 (-42.92) and IS 3534A x Dio-1 (-31.80) had significant negative heterosis for panicle width, while 97- SBDT-F5-150A x Dangarko white (116.84), ICSA 38 x Dangarko white (93.79) and IS 3534A x Dangarko white (26.73) expressed significant positive heterosis for panicle width. Mid-parent heterosis ranged from -42.92 to 116.84 per cent. Hybrid, IS 3534A x Dio-1 (-49.62) and 97-SBF5-DT-150A x Dio-1 (-46.64) had significant negative best parent heterosis for panicle width. Hybrid, 97-SBF5-DT-150A x Dangarko white (97.75) and ICSA 38 x Dangarko white (52.06) had significant positive best parent heterosis for panicle width . Best parent heterosis for panicle width ranged from -49.75 to 97.75 per cent. For panicle weight, 97-SBF5-DT-150A x Dio-1 (-16.74) had significant negative heterosis for panicle weight. 97-SBF5-DT-150A x Dangarko white (58.47), ICSA 38 x Dangarko white (14.83) and IS 3435A x Dangarko white (11.17) had significant positive heterosis for panicle weight. Mid-parent heterosis for panicle weight ranged from -16.74 to 58.47 per cent. 97-SBF5-DT-150A x Dio-1(-23.72), 3534A x Dio-1 (-9.68) and ICSA 38 x Dio-1 (-6.49) had significant nagative high parent heterosis for panicle weight. 97-SBF5-DT-150A x Dangarko white (32.42), IS 3534A x Dangarko white (10.35) and ICSA 38 x Dangarko white (7.22) had significant positive high parent heterosis for panicle weight. High parent heterosis for panicle weight ranged from -23.72 to 32.42 per cent. 97-SBF5-DT-150A x Dangarko white (-30.09) and ICSA x Dio-1

(-7.59) expressed significant negative mid-parent heterosis for grain yield. 97-SBF5-DT-150A x Dagarko white (90.07), ICSA 38 x Dangarko white (20.94), IS 3534A x Dangarko white (20.50) and IS 3534A x Dio-1 (17.51) had significant positive mid-parent heterosis for grain yield. Mid-parent heterosis for grain yield ranged from -30.09 to 90.07 per cent. 97-SBF5-DT-150A x Dio-1 (-33.34) and ICSA 38 x Dio-1 (-17.31) expressed significant negative high parent heterosis for grain yield. 97-SBF5-DT-150A x Dangarko white (48.81) and IS3534A x Dangarko white (11.86) expressed significant high parent heterosis for grain yield. High parent heterosis for grain yield ranged from -17.31 to 48.81 per cent. 97-SBF5-DT-150A x Dio-1 (-12.81) had significant negative mid- parent heterosis for threshing per-cent-age. IS 3534A x Dio-1 (25.71) and 97-SBF5-DT-150A x Dangarko white (21.94) had significant positive mid-parent heterosis for threshing per-cent-age. Mid-parent heterosis for threshing per-cent-age ranged from from -12.81 to 25.71 per cent. 97-SBDT-F5-150A x Dio-1 (-16.38), ICSA 38 x Dio-1 (-12.50) and IS 3534A x Dangarko white (-0.56) expressed significant negative high parent heterosis for threshing per-cent-age. 97-SBF5-DT-150A x Dangarko white (12.21) had significant positive high parent heterosis for threshing per-cent-age. High parent heterosis for threshing per-cent-age ranged from -12.50 to 12.21 per cent.

CHAPTER FIVE

Discussion

The amount of genetic improvement that can be achieved among a given set of genotypes depends on the amount of genetic diversity that is present within the population (falconer and Mackey, 1996). The significant difference observed for yield and agronomic traits among the entries showed that they characters studied can be selected for genetic improvement.

Harer and Bapat (1982) stated that the per se performance of the parents and the nature of combining ability provide the criteria for choice of parents for hybridization. On this basis, those parents which performed well for both per se performance and general combining ability effects can be considered as good parents.

Among the testers (males), Dio-1 showed low mean value and negative significant GCA effect for plant height. It may be useful in breeding for shortness in further improvement programmes. This result is in agreement with the findings of Premalatha et al., 2006 and Tadesse et al., 2008. For days to anthesis, the line (female parent), ICSA 38, showed low value and negative high significant GCA, which might be useful in breeding for earliness. Among the testers (males), Dio-1, showed high mean value and negative high significant GCA for days to anthesis. It can be useful in further breeding for earliness. The findings of Kenga et al., 2004 and Premalatha et al., 2006 support the result in this study. For panicle length, the line (female), IS3534A, had high mean value and positive significant GCA. It could be a source for longer panicles in a breeding programme. Among the testers (males), Dangarko white, showed low value and significant high positive significant GCA which could be used in further improvements for panicle length. The finding is in line with Premalatha et al., 2006.

Among the lines (females), IS 3534A showed high value and positive significant value for panicle width which could be used for improvements for this trait. Among the testers (males), Dangarko white showed high mean values and high significant positive GCA for this trait which could be used for improvement in a breeding programme.

Among the lines (females), 97-SBF5-DT-150A, showed high mean value and positive high significant GCA for panicle weight and grain yield. It also showed high positive significant GCA for threshing per-cent-age. It can be used in a breeding programme for improvements for these traits. The tester (male), Dangarko white showed low mean yield but high positive significant GCA for panicle weight and grain yield. The finding of Kenga et al., 2004 and Tadesse et al., 2008 agree with this findings.

The hybrids 97-SBF5-DT-150A x Dangarko white recorded the maximum SCA effect for two out of six trait studied namely, panicle weight and grain yield. This hybrid was one of the top ranking hybrids. It was a derivative of high x high parental combination in terms of GCA and it might produce desirable segregants. Hence, these hybrids might be desirable for biparental selection. This finding agree with yahaya (2004) and Primalatha et al., 2006. The hybrids, ICSA 38 x Dio-1 for panicle weight and 97-SBF5-DT-150A x Dangarko white for panicle width and panicle length, IS 3534A x Dio-1 for threshing percentage were derived from low x low parental combination in terms of GCA and these hybrids might be suitable for selection in later generations. This is in agreement with Primalatha., 2006. The hybrids, ICSA 38 x Dio-1 for panicle length, ICSA 38 x Dio-1 for panicle width, IS 3534A x Dio-1 for panicle weight, ICSA 38 x Dio-1 and IS 3534A x Dio-1 for grain yield, and 97- SBF5-DT-150A x Dangarko white for threshing percentage were the derivatives of low x high or high by low parental combination in terms of GCA and these hybrids also recorded SCA effects. This findings are in line with Primalatha., 2006.

Heterosis has been described as the increased vigor of a hybrid over the mean of its parent or over the high-parent. From a practical point of view, increase over high-parent is more useful because it implies the improvement of a desirable trait over existing maximal. In the present study, the highest expression of heterosis resulted in higher grain yield and improvement in some agronomic traits over parents. Similar findings have been reported by Haussmann (1998) and Kenga (2004). The potential of a hybrid might be judged by comparing its per se performance and heterotic vigour (Premalatha et al., 2006). Close association between per se performance of hybrids and high--parent heterosis was observed for all the traits except plant height, suggesting selection based on per se performance would be more realistic in sorghum. Positive and negative heterotic values were recorded for all agronomic characters studied. While negative heterosis were observed for days to anthesis and plant height and are desirable because of their breeding value in developing early crops and crops susceptible to lodging, negative heterosis recorded for crops like panicle length, panicle width, panicle weight, threshing percentage and grain yield could be due to sampling variation, linkage, inadequate statistical and genetic models and inadequate experimental procedures.

For days to anthesis, hybrids namely, ICSA 38 x Dangarko white, IS 3534A x Dio-1 and 97-SBF5-DT-150A x Dangarko white recorded high negative significant heterosis. Among these three hybrids, only ICSA 38 x Dangarko white had low per se and sca performance. This findings agree with Premalatha, 2006. The hybrid, 97-SBF5-DT-150A x Dangarko white recorded significant high-parent heterosis for threshing per-cent-age, combined with significant SCA and per se performance. Hence this hybrid could be utilized to develop hybrids with good threshing per-cent-age. Premalatha et al., 2006 obtained similar results.

CHAPTER SIX

Summary and Conclusion

This work was carried out to critically examine combining ability and heterosis of male sterile lines and their restorers in sorghum and to identify promising parents with good breeding value for developing high yielding hybrids in the northern-guinea agro-ecological zone . Eleven entries consisting of five parents and six hybrids were arranged in a randomised complete block design with three replication. The experiments was undertaken to ascertain the relative amount of genetic variation and combining ability effect in sorghum, to obtain information on heterotic pattern, identify and select lines that show promising breeding value for yield and agronomic traits under study and identify high yielding hybrids.

Analysis of variance was carried out for plant height, days to anthesis, panicle length, panicle width, panicle weight, grain yield and threshing per-cent-age. Estimation of general and specific combining ability were obtained for each male inbred, female parent and for all hybrids. The inbred lines 97-SBF5-DT-150A and Dangarko white contributed high GCA estimates for grain yield. It was observed that parents that showed high GCA effects for grain yield, also showed high to average GCA for other agronomic traits, suggesting that GCA effects for grain yield could be related to combining ability effects of agronomic traits studied.

The effects of specific combining ability (SCA) studied indicated that a good number of cross combinations involved either high x high, high x low or low x low combinations in terms of GCA. Parents which were best general combiners did not always produce the best hybrid combinations. For this reason, the complexity in predicting the productivity level of the hybrid should require testing of specific male x female combinations.

In this study, improved yield observed indicated that there is potential to improve sorghum yield in northern guinea agro-ecological zone. A strong relationship between per se performance of the inbred and hybrid did not exist. To explain further, high x high crosses gave lower yield and high x low crosses gave higher yield. The highest grain yielding entry was 97-SBF5-DT-150A x Dangarko white.

High-parent heterosis was observed for grain yield and agronomic traits for all characters except plant height. Among the hybrids, 97-SBF5-DT-150A x Dangarko white expressed high-parent heterosis for days to anthesis, panicle length, panicle width, panicle weight, grain yield and threshing per-cent-age.

Recommendation

The hybrid, 97-SBF5-DT-150A x Dangarko white yielded better than the average yield in Nigeria, but it is still lower than some open pollinated materials grown in the northern guinea savannah. More lines should be included for further improvement programmes to search for higher yielding hybrids. Considering the mean performances, SCA and high-parent heterosis, the hybrid 97-SBF5-DT-150A x Dangarko white may be recommended for further testing over different locations.

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