COMBINING ABILITY AND HETEROSIS FOR GRAIN YIELD, PROTEIN CONTENT AND OTHER AGRONOMIC CHARACTERS IN PEARL MILLET *{Pennisetum glaucum* (L.) R. Br.)

BY

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of the requirement for the Degree of Master
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DECLARATION

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 Reference made to published and unpublished litereature have been duely acknowledged.

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Date

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CERTIFICATION

This thesis titled: Combining ability and Heterosis for grain yield, protein content and other Agronomic characters in Pearl Millet (*Pennisetum glaucum* (L.). R. Br.) by Angarawai, Ignatius Ijantiku meets the regulations governing the award of the degree of Master of Science of Ahmadu Bello University, Zaria and is approved for it's Scientific contribution to knowledge and literary presentation.

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DEDICATION

To my loving Son (Ijabada) and Daughter (Wadi)

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ABSTRACT

Fifty-seven F_1 hybrids obtained by crossing three varieties, of diverse genetic background, onto each of 19 inbred lines of pearl millet were evaluated in two locations.

Mean grain yield ranged from 667.50 - 2249.20 kg/ha with a grand mean = 1162.31 kg/ha. The general and specific combining ability moan squares were significant (P = 0.01) for number of tillers/plant, number of days to 50% flowering, plant height, panicle length, panicle width, head weight, grain weight and grain yield (kg/ha).

The GCA x Loc. Interactions (females) were significant for days to 50% flowering, head weight, grain weight and grain yield. GCA x Loc. Interactions (Males) were also significant for number of tillers/plant and number of days to 50% flowering and 1000-seed weight. SCA x Loc. Interactions were significant for days to 50% flowering.

The relatively smaller proportion of GCA to SCA ratio indicated predominance of non-additive genetic effects with respect to all the traits studied except for panicle length with ratio = 1.

The high GCA effects exhibited by some parents that are reflected in the SCA effects and per se performance of the hybrids for most of the traits especially grain yield suggested that these parents could be selected effectively for hybridisation.

Heterosis (both positive and negative) was observed among the crosses. Mean heterosis for grain yield was 60.44% HP, for 1000-

seed weight, 66.01%HP, for number of tillers/plant, 47.62% HP, for grain weight 35.55% HP and for protein content, 31.27% HP. Negative heterosis, for number of days to 50% flowering, - 47.22% HP and for plant height, -21.25% HP, which was considered advantageous was recorded. Three hybrids; the hybrids of G.I. 363-1 x GAB 8735, (2101.50 kg/ha) G.I. 47-3 X GB 8735 (2249.00 kg/ha) and ACC 364-1 x GB 8735 (2125.50 kg/ha), yielded more than the best variety. Yield superiority of these hybrids over the best variety (GB 3735, 17 32 kg/ha) suggested the possiblity of their exploitation for commerical hybrid production.

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CHAPTER ONE

INTRODUCTION

Pearl millet (*Pennisetum glaucaum*) (L.) R. Br.), though a second rated crop in terms of world economy, provides diet for over 400 million people who live in the arid and semi-arid tropics of Africa and India (Bilquez, 1970; Nwasike *et al.*, 1982, and Yayock *et al.*, 1988). This is why it deserves all attention, since the people for whom millet essentially provides food, live in regions, which from the point of view of Agriculture are amongst the least favoured (Bilquez, 1970).

Vavilov (1951) during his germplasm collection mentioned Africa as the primary centre of origin for pearl millet, particularly the regions of *Abyssinia* (Ethiopia) and Sudan. Burton and Powell (1966) found B-chromosomes in Nigerian pearl millet lines supporting the evidence that favour Africa as the centre of origin of millet.

Pearl millet does well on a wide range of soils, but well drained light sandy soils are best (Hulse *et al.*, 1980). The crop has the ability to thrive in areas of low rainfall (80 - 230mm) with soils low in fertility for successful cultivation of other cereals (Ferraris, 1973).

Areas of major production are the semi-arid region east and south-east of the desert in India and the sudano-Sahelian zones of West Africa (Nigeria, Chad, Mali, Sudan, Niger and Senegal). Others include mainland China, Ethiopia, Tanzania, and South eastern United State of America (Spencer and Sivakumar, 1986).

It is generally admitted that for the whole of the dry tropical areas in West Africa, the proportion of pearl millet and sorghum with regards to land area assigned to cereal

cultivation is approximatly equal (Bilquez, 1970). Pearl millet production supercedes that of as climate becomes drier because of its ability to withstand drought, whereas sorghum production predominates as rainfall increases (Khadr & Oyinloye, 1977 and Nwasike and Egharevba, 1982). The total land sown to pearl millet varies and estimates are difficult to make because the crop is almost invariably grown in mixture with other crops except in the sahel where it may be sown sole (Bhardwaj, 1977 and Nwasike *et al.*, 1982). Total annual production ranges between 1.75 and 3.2m tonnes. Africa and Asia together account for 98% of the world production of 42.34m tonnes of millet grain produced on 43 - 63 million hectares annually (Rachie & Majmudar, 1980 and Spencer & Sivakumar, 1986). Among the African producing countries, Nigeria contributes 31% of the 35% of African contribution to the world production (Rooney and Mcdonough, 1986).

Pearl millet is used for a variety of purposes primarily for its grain in Africa and India and as a forage crop in Southeastern USA. The grain when processed can be served as "tuwo", "kunu" and "Akamu", (a local poridge). It is more nutritious than sorghum, supplying about 9.1g protein/capita/day according to Khadr and Oyinloye, (1980). Burton and Powell (1968), Nwasike *et al.*, (1982), and Rooney and Mcdonough (1986) reported that the glutelin has high level of lysine and tryptophan that has high degestibility.

There are three types of pearl millet known locally as "Gero", "Maiwa" and "Dauro", cultivated in the Northern part of Nigeria. "Gero" and "Maiwa" are extensively grown, while "Dauro" is cultivated in restricted wetter areas of the southern portion of the savannah ecological zones. The most widely cultivated millet types differ in a number of characteristics, especially in maturity. Gero types are short season crop maturing between

75 and 100 days. Maiwa is photo-sensitive, while Gero is photo-period insensitive. Considerable amount of genetic variation has been observed among the Gero cultivars (Nwasike, 1988). The most striking evidence is the variability in the size of spikes. Pearl millet is normally the first grain crop grown by the farmers in most of the savannah region of Nigeria. The early planting coupled with early maturity ensures provision of grain for consumption when all grain reserve are exhausted (Nwasike and Egharevba,1981). Because of the importance of millet in the diet of the people of the savannah region of Nigeria, it is accorded a place of high priority in the National agricultural research programmes especially in areas of germplasm maintenance and genetic improvement.

Under traditional farming system yield varies from 500 - 2000 kg/ha on the farmers field but yield ranging from 2000 - 3,500 kg/ha were obtained by Khadr and Oyinloye (1977) and Nwasike (1983) under improved agronomic practices. The low yield obtained by farmers was attributable to a number of constraints, principal among which are use of local varieties which have low response to management practies, non application of fertilizer and poor land preparation.

The challenge facing millet researchers particularly breeders is to develop improved varieties or hybrids that will be within the reach of small scale resource poor farmers.

The choice of selection and breeding procedure adopted for the genetic improvement of any crop is largely influenced by the magnitude of genetic variability and the nature of gene action governing the nature of inheritance of the desirable traits. For a practical breeding programme, it is paramount for the breeder to be acquainted

with the potentials of local materials before embarking on population improvement. Thus knowledge of combining ability is essential for selection of suitable parents for hybridization and the identification of promising F_1 hybrids for further exploitation in a breeding programme. Such knowledge however, may be limited if the studies are not carried out over years and across locations because the combining ability and heterosis estimate may be confounded by the interaction of genotype with environment

The major objectives of this study are:

1. To determine the general combining ability (GCA) and specific combining ability (SCA) among genetically diverse varieties and inbred lines of pearl millet.
2. To determine the level of heterosis among the F_1 hybrids.

CHAPTER TWO

LITERATURE REVIEW

2.0 Combining Ability and Heterosis

2.1 Combining Ability:

To establish a sound basis for any breeding programme aimed at achieving higher yields, breeders must have genetic information on the nature of combining ability of parents, their behaviour and performance in the hybrid combinations (Chawla and Gupta, 1983). Such knowledge of combining ability is essential for selection of suitable parents for hydridization and the identification of promising hybrids for further exploitation in a breeding programme (Alabi *et al.*, 1987).

The term combining ability is commonly used by breeders to express the relative performance of a line in hybrid combination i.e. general and specific combining ability. General combining ability (GCA) in particular is directly related to the breeding value of the parents and is associated with additive gene action (Falconer, 1981). Specific combining ability (SCA) on the other hand is commonly associated with all effects which cannot be accounted for by the additive scheme such as dominance, epistasis and gentotype x environment interactions (Rosenow, 1970).

The *per se* performance of varieties in a large number of yield trials may give an idea of their relative superiority, but this would not necessarily reflect their ability to produce better combinations with a number of similar lines. The importance of genetic variability in the choice of parents when attempting intervariatal crosses have been

emphasized by various authors (Gupta and Singh, 1973; Singh *et al.*, 1973; 1980a; Nwasike *et al.*, 1982, Mathur and Mathur, 1983 and Nwasike and Oyejola, 1989). This is because useful information can be derived regarding the selection of suitable parents with high GCA effect, identification of cross combination with high SCA effect for effective hybridization and elucidation of the nature and magnitude of additive and non-additive gene action (Tyagi *et al.*, 1975, Singh *et al.*, 1980b, Nwasike and Oyejola, 1989, Niyhaivan and Yandav, 1993).

Estimates of GCA and SCA effects from a set of crosses relate to estimates of genetic effects of the base population from which the parent varieties are sampled (Matzinger and Kempthrone, 1956). GCA is relatively more important than the SCA in previously unselected materials while SCA assume greater importance in materials which have been perviously selected for GCA (Spraque and Tatum, 1942; Beil, 1965 and Kambal and Webster, 1965).

2.2 Heterosis:

The exploitation of hybrid vigour appears to be an alternative for making further increase in yield (Panwar *et al.*, 1983). In recent years, heterosis has been extensively explored and utilised for increase in a number of economically important crop species particularly the open pollinated ones (Dass and Rai, 1972). The basic information which would seem to be valuable from the heterosis breeding point of view would be the estimation of the amount of heterosis and the way to exploit it economically for commercial cultivation (Dass and Rai, 1972).

2.3 *Tillering ability*

Yield in pearl millet is a function of productive tillers accounting for the number of heads per plant (Allison, *et al* 1958 and Siband, 1983). Phull *et al.*, (1973) and Hapse *et al.*, (1986a), indicated high GCA for tillering ability and that additive genetic effects were predominant. In contrast Gill *et al.*, (1974) reported that non-additive effects were more important for number of tillers (ears). Mukharij *et al.*, (1984) indicated that effective tillers were controlled by partial dominance and that both additive and non additive effects were important. In a study by Hapse *et al.*, (1986b) on number of fertile tillers (number of heads/plant) up to 139% heterosis on the mid-parent value was recorded. Mukherij *et al.*, (1981) observed high heterosis for effective tillers.

2.4 Maturity:

Like in most cereals, maturity in pearl millet can be divided into two phases; the period of days to flowering and the length of grain filling. Studies of these two phases have shown the form of relationship that exist between them which indicates the approaches to genetic improvement towards developing appropriate, efficient and acceptable maturity types for the environment in which the millet crop is grown (Yayock *et al.*, 1988). Combining ability studies were carried out by Phull *et al.*, (1973) and Maciel *et al.*, (1988) on days to flowering; they reported significant ($P \leq 0.05$) GCA and SCA effects. Singh *et al.*, (1988) also reported high GCA effect for days to maturity in pearl millet.

Maturation in pearl millet is controlled by several genes exerting additive genetic effects (Burton, 1951 and Shinde and Patil, 1987). In contrast, Vyas and Pokhriyal (1985) and Hapse *et al.*, (1986a) reported that, days to flowering is controlled by non-additive genetic effects. According to Rai and Singh (1975) and Gill *et al.*, (1974), earliness in pearl millet is controlled by dominant genes and days to maturity appears simple in inhertance enchancing easy transfer of genes during breeding programms when developing early maturing hybrids. Significant ($P \leq 0.05$) positive heterosis for days to flowering or days to 50% heading duration and days to maturity were observed by Phull *et al.*, (1969, 1973) and Satija and Thakral (1989). In another study negative heterosis and heterobeltiosis regarded as favourable for days to flowering was observed by Thete *et al.*, (1986).

2.5 Plant Height:

In a combining ability study for plant height in pearl millet, Maciel *et al.*, (1986) indicated that combining ability effect is very important. Both GCA and SCA effects as reported by Phull *et al.*, (1973) were highly significant ($P \leq 0.01$) and differed considerably in four seasons. In two separate studies by Tyagi *et al.*, (1978) and Shinde and Debale (1984), estimates of both GCA and SCA for plant height were highly significant ($P \leq 0.01$). According to Vyas and Pokhriyal (1985) and Hapse *et al.*, (1986a), plant height is controlled by non-additive genetic effects. Similar observations were made by Shinde and Patil, (1987) who reported that a greater magnitude of dominance gene effects governs plant height in pearl millet. Thete *et al.*, (1986) reported

significant ($P \leq 0.05$) heterosis and heterobeltiosis for plant height, with heterosis ranging from 25.20%-80.62% while heterobeltiosis ranged from 42.28 - 59.87%.

2.6 Ear Length

Phull *et al.*, (1973) and Srivastava and Singh (1988) carried out a combining ability studies in pearl millet and they reported significant ($P \leq 0.05$) GCA and SCA effects for ear length. According to Vyas and Pokhriyal (1985) and Hapse *et al.*, (1986a) ear length was influenced by additive genetic effects. Mukherji (1981) on the other hand, reported that both additive and non-additive gene action were important. Thete *et al.*, (1986), in most hybrids studied, observed significant ($P \leq 0.05$) heterosis for ear length. Similar observations were made by Satija, *et al.*, (1989). Harer *et al.*, (1990) obtained about 41% heterosis for ear length in pearl millet.

2.7 Ear Girth (Diameter)

Phull *et al.*, (1973) reported significant ($P \leq 0.05$), general and specific combining ability estimates for ear girth in pearl millet. According to Gill *et al.*, (1974) and Mukherji *et al.*, (1981), ear girth is highly influenced by non-additive genetic effects. Rama *et al.*, (1973) reported that heritability for ear girth in pearl millet was high and the expected genetic advance for this trait was moderate. The trait is most suitable in indirect selection for high yield, though Tyagi *et al.*, (1978) and Shinde and Debale (1984) observed the contrary. Significant ($P \leq 0.05$) heterosis for ear diameter was reported by Murty *et al.*, (1967), Mukherji *et al.*, (1981) and Satija and Thakral (1989). Harer *et al.*, (1990) obtained about 30% heterosis over the mid-parent for this trait in pearl millet.

2.8 Grain Weight and Yield

The choice of the most suitable breeding procedure to be adopted for the improvement of any crop depends on the nature of gene action involved in the expression of quantitative traits of economic importance such as grain yield (Mathur and Mathur, 1983 and Prasad *et al.*, 1984). Several authors have reported significant ($P \leq 0.05$) GCA and SCA in pearl millet for grain yield (Phull *et al., 1973;* Tyagi *et al.*, 1978; Shinde and Debale, 1984 and Maciel *et al.*, 1988). Rao and Reddi (1982), Singh *et al.* (1984), Vyas and Pokheriyal (1985), Kunjir and Patil (1986) and Hapse *et al.*, (1986b) have indicated that additive genetic effects for grain weight were more important than the non-additive genetic effects. Both additive as well as non-additive genetic effects have been reported to be important in the expression of grain yield (Mathur and Mathur, 1986; Patil and Kukadia, 1988; Pethani and Dave, 1989; and Nwasike and Oyejola, 1989). Thete *et al.*, (1986) and Kunjir and Patil (1986) estimated 140% and 247% heterosis for grain yield, respectively, while Hapse *et al.*, (1986b) and Harer *et al.*, (1990) reported 90% and 85% heterosis for 500-grain weight, respectively. Low x low yielding crosses showed the greatest heterotic effect indicating interallelic interactions for grain yield.

2.9 Grain Protein Content

Probably the most promising approach to improving the millet crop is to improve yield quality in terms of protein content and a better balance of amino-acid (Nwasike *et al.*, 1982). Phull *et al.*, (1973); Mathur and Mathur (1986) and Paramjit and Gupta

(1989), reported significant GCA and SCA for both crude protein and soluble protein content. The importance of additive genetic components with the presence of complementary type of gene interactions have also been reported by Gill *et al.*, (1969) , Phull and Gill (1970) and Phull *et al.*, (1973).

Negative heterosis was observed by Phull *et al.*, (1969, 1973) and Sackchain and Phull (1990), in F_1 hybrids for grain protein content. In view of the fact that considerable amount of heterosis for grain yield is usually accompanied by a reduction in protein content, breeding programmes aimed at the production of high yielding varieties should give careful consideration to improving protein content. This is because according to Barneth (1976) and Gartan *et al.*, (1987), this trait is influenced by a dominant gene for low protein and possibly by maternal effects under the influence of the environment and low heritability.

CHAPTER THREE

3.0 MATERIAL AND METHODS

3.1 Origin and description of genetic materials

Nineteen inbred lines developed by the Lake Chad Research Institute Maiduguri and the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Kano during the 1995 main season (Table 1), were top-crossed with three widely cultivated open pollinated varieties of pearl millet at Dadin Kowa, in Gombe State between December, 1995 and April 1996. Pollination of the females by the male panicles was carried out. Twenty panicles per cross were obtained and threshed. Seeds obtained from the crosses were planted out and evaluated as F_1 hybrids during 1996 main season.

3.2 Experimental Design and Layout

Twenty-two parents (three varieties and 19 lines) and their 57 F_1 hybrids with two checks were grown in 1996 main season in two locations: Samaru (Northern guinea savannah) and Bagauda near Kano (Sudan savannah). The experimental design was randomized complete block design (RCBD) with two replications. Each plot consisted of 2 rows which were 5m in length. A spacing of 75cm x 50cm was used. Each plot was debbled and later thinned to two seedlings per hill three weeks after sowing. Missing hills were replaced by transplanting. Compound fertilizer (NPK 27:10:10) was applied 60kg N/ha in split doses.

Table 1: Origin and description of parent material

Pedigree	Source	Days to 50% flowering
(a) Inbreds (Females)		
1. G.I. 6-2	LCRI	62-medium
2. G.I. 75-1	LCRI	66-medium
3. G.I. 122-2	LCRI	67-medium
4. G.I. 165-6	LCRI	67-medium
5. G.I. 296-1	LCRI	58-medium
6. G.I. 359-3	LCRI	69-medium
7. G.I. 363-1	LCRI	64-medium
8. G.I. 363-4	LCRI	68-medium
9. G.I. 410-8	LCRI	66-medium
10. G.I. 435-4	LCRI	58-medium
11. ACC 1009-2	LCRI	65-medium
12. Buduma-Gero 712-2	LCRI	66-medium
13. ICMV-88908	LCRI/ICRISAT Kano	48 - early
14. G.I. 41-3	LCRI	76 - late
15. G.I. 47-3	LCRI	70 - late
16. ACC 364-1	LCRI	64-medium
17. ICMV 93501	LCRI/ICRISAT Kano	50 - early
18. ICMP 94592	LCRI/ICRISAT Kano	54 - early
19. ICMP911031	LCRI/ICRISAT Kano	45 - early
(b) Varieties (males)		
1. Ex-Borno	LCRI	60 - medium
2. Gwagawa	LCRI	68 - medium
3. GB 8735	ICRISAT Kano	45 - early

The first 35 kg N/ha was applied as basal while the second 25 kg/ha was applied as top dressing three weeks after sowing just after thinning. Weeds were controlled by hoeing twice, at three and seven weeks after sowing.

3.3 Data Collection

Data were collected for the following characters:

- **Number of Tillers:** Number of tillers (reproductive tillers) per hill was determined and divided by the number of plants to estimate number of tillers per plant.
- **Days to 50% Flowering:** Number of days from sowing to when 50% of the plants in a plot were at anthesis.
- **Plant Height**: Distance between the ground level to the base of the tip of panicle at maturity.
- **Panicle length (ear length)**: Distance between the base of the panicle to the tip.
- **Panicle width (ear width)**: Diameter of the head.
- **Head Weight**: Weight of the dry heads.
- **Grain Weight**: Weight of threshed heads.
- **Grain Yield**: Estimated grain yield in kg/ha.
- **1000-Seed mass**: Mass of 1000 seeds randomly selected for each plot after threshing.
- ***Crude protein %***: *Nitrogen in the dehulled and defacted samples was*

determined by micro-Kjedahl procedure (AOAC, 1970) and the crude protein content was calculated by the formula N x 6.25. Percentage protein was expressed as = Protein weight x 100 / grain weight

- **Threshing Percentage**: Weight of threshed seeds over weight of dry heads multiplied by 100 = Grain weight x 100 / Head weight

3.4 Statistical Analysis

Analyses of variances for individual location as well as locations combined using Genstat 5, 1994 were carried out. Forms of the General analyses of variances for individual location and combined locations are presented in Tables 2 and 3. Forms of analyses of variances for GCA and SCA for individual and combined locations are presented in Tables 4 and 5. The general combining ability analysis was carried out using array totals over replications following the procedure of Beil and Atkins (1967) and Singh and Chaudhary (1985). The mean squares for each source of variation were tested against error mean squares and mean squares due to lines (females) and varieties (males) were tested against mean squares due to line x variety to determine the level of significance.

Estimate of the general combining ability of a variety was obtained in terms of its performance in F_1 hybrid combination with all possible lines. Likewise estimate of the general combining ability of a line was determined in relation to its performance in hybrid combination with all possible varieties.

Table 2: Form of analysis variance for Individual location Samaru or Bagauda

Source of Variation	Degree of freedom (df)	Sum of Squares (ss)	Mean squares (ms)
Replication (R-1)	1	R	R/R-1
Genotypes (G-1)	80	G	G/G-1
Parents (P-1)	21	P	P/P-1
Lines (L-1)	18	L	L/L-1
Varieties (V-1)	2	V	V/V-1
Line Vs Variety (L vs V-1)	1	L vs V	L vs V/L vs V-1
Hybrids (H-1)	56	H	H/H-1
Checks (Ch-1)	1	CH	CH/CH-1
Parents VS Hybrids VS Checks	2	P vs H vs CH	P vs H vs CH/P vs H vs CH-1
Parents Vs Hybrids (P/H Vs H-1)	1	P	P vs H/P vs H-1
Hybrids Vs Checks (H Vs Ch-1)	1	P vs H	P vs CH/P vs CH-1
Error (R-1) (G-1)	80	H vs CH	e/(R-1)(G-1)
Total (RG-1)	161	E	

Table 3: Form of analysis of variance for combined Location

Source of Variation	Degrees of freedom (df)	Sum of Squares (ss)	Mean squares (ms)
Locations (L-1)	1	L	L/L-1
Reps within locations L (R-1)	2	R	R/L(R-1)
Genotypes (G-1)	80	G	G/G-1
Loc genotypes (L-1) (G-1)	80	LG	LG/L(G-1)
Parent (P-1)	21	P	P/P-1
Lines (L-1)	18	L	L/L-1
Varieties (V-1)	2	V	V/V-1
Lines Vs Varieties (L Vs V-1)	1	L VS V	L VS V/L VS V-1
Loc. Parents (L-1)(P-1)	21	LP	LP/(L-1)(P-1)
Loc. Lines (L-1)(P-1)	18	LL	LL/(L-1)(L-1)
Loc. Varieties (L-1)(V-1)	2	LV	LV/(L-1)(V-1)
Loc. Lines Vs Varieties (L-1) (L VS V-1)	1	L(L VS V)	L(L VS V)/(L-1)L VS V-1
Hybrids (H-1)	56	H	H/H-1
Loc. Hybrios (L-1) (H-1)	56	LH	LH/(L-1)(H-1)
Checks (Ch-1)	1	CH	CH/CH-1
Loc. Checks (L-1) (Ch-1)	1	LCH	LCH/(L-1)(CH-1)
Parent Vs Hybrid Vs Check (P Vs HVs CH-1)	2	P VS H VS CH	P VS H VS CH/(P VS H VS CH-1
Parent Vs Hybrid (P Vs H-1)	1	P VS H	P VS H/(P VS H-1)
Hybrid Vs Check (H Vs Ch-1)	1	H VS CH	H VS CH/(H VS CH-1)
Loc. Parents Vs Hybrids Vs Check (L-1) (P Vs H Vs Ch-1)	2	LP VS H VS CH	LP VS H VS CH/(L-1)(P VS H VS CH-1)
Loc. Parent Vs Hybrids (L-1) (P Vs H-1)	1	LP VS H	LP VS H/(L-1)(P VS H-1)
Loc. Hybrid Vs Checks (L-1) (H Vs Ch-1)	1	LH VS CH	LH VS CH/(L-1)(H VS CH-1)
Pooled error L(R-1) G-1)	160	E	E/L(R-1(G-1)
Total (LRG-1)	323	-	

Table 4: Form of analysis of variance for combining ability effect for individual locations, Samaru or Bagauda

Source of Variation	Degrees of freedom (df)	Sum of Squares (ss)	Mean squares (ms)
Hybrids (H-1)	56	H	H/(H-1)
GCA Females (F-1)	18	F_x	F(F-1)
GCA Male (M-1)	2	M	M/(M-1)
SCA (Females x Males) (f-1 M-1)	36	M x F	M x F/(M-1)(F-1)
Error (R-1)(G-1)	80	E	E/(R-1)(G-1)
Total RG-1	161		

Table 5: Form of combined analysis of variance for estimates of general (GCA) and specific (SCA) combining ability in pearl millet.

Source of Variation	Degrees of freedom (df)	Sum of square (SS)	Mean sum of Squares (MS)	Expected mean squares (EMS)
Hybrids (h-1)	56	H	H/(h-1)	
GCA (females) (f-1)	18	F	$F/(f-1) = M_7$	$\delta^2e + r\delta^2fme + rf\delta^2 me + re\delta^2mf + ref\delta^2 m$
GCA (males) (M-1)	2	M	$M/(M-1) = M_6$	$\delta^2e + r\delta^2fme + rm\delta^2fe + re\delta^2mf + rem\delta^2 f$
SCA (females x males) (f-1)(m-1)	36	F x M	$F \times M/(f-1)(m-1) = M_5$	$\delta^2e + r\delta^2fme + re\delta^2mf$
Loc Hyrids (L-1)(h-1)	56	LH	LH/(L-1)(h-1)	
Loc. GCA (females) (L-1) (f-1)	18	LF	$LF/(L-1)(f-1) = M_4$	$\delta^2e + r\delta^2fme + rf\delta^2me$
Loc. GCA (males) (L-1)(M-1)	2	LM	$LM/(L-1)(M-1) = M_3$	$\delta^2e + r\delta^2fme + rm\delta^2fe$
Loc. SCA (Male x Females) (L-1) (f-1) (M-1)	36	LF x M	$LF \times M/(L-1)(f-1)(M-1) = M_2$	$\delta^2e + r\delta^2fme$
Error (Lxg-1)(r-1)	160	E	$E/L(g-1)(r-1) = M_1$	δ^2e
Total Lgr-1	323			

The data analysis obtained in this manner is comparable to the analysis of a two way classification model with interactions; with the interaction components being a measure of the specific combining ability effects. The following linear model was assumed.

$$Yijkl = \mu + gi + gj + Sij + G + (gl)il + (gl)jl + (Sl)jil + eijkl.$$

Where i = 1, 2....3 (varieties)

j = 1, 2..... 19 (lines)

l = 1, 2 (locations)

k = 1, 2 replications

Yijkl - denotes the value of the K^{th} experiment unit of the progeny of a mating of the i^{th} variety and the j^{th} line in the l^{th} location.

μ - Population mean common to all hybrids in all replications within locations.

gi - An effect common to progeny of the i^{th} variety.

gj - An effect common to progeny of the j^{th} line.

Sij - An effect specific to the progeny of mating the i^{th} variety and the j^{th} line.

(gl)il - An effect common to progeny of the i^{th} varity in the l^{th} location

(gl)jl - An effect common to progeny of the j^{th} line in the l^{th} location

(sl)ij - An effect specific to the progeny of mating the i^{th} variery to the j^{th} line in the l^{th} location.

G - The average effect of all the l^{th} location.

eijkl - Random expected error.

Genetic components of variance were calculated from the expectations of mean squares as used by *Singh and Chaudhary (1985).*

$$\delta^2 m = \delta^2 GCAm = \frac{MSm - MSmxf}{rf} = gi = COV\ H\text{-}S = \tfrac{1}{4}\delta^2 A.$$

$$\delta^2 f = \delta^2 GCAf = \frac{MSf - MSmxf}{rm} = gj = COV\ H\text{-}S = \tfrac{1}{4}\delta^2 A$$

$$COV\ H.S\ (Average) = \frac{1}{r(2mf-mf)}\left[\frac{(f-1)\,MSf + (m-1)MSm - MSmxf}{m+f-2}\right]$$

$$\delta^2 GCA = Cov\ H.S = \frac{[(1+f)]^2\delta^2 A}{4}$$

$$\delta^2 mxf = \delta^2 SCA = \frac{MSmxf - MSe}{r} = COV\ (F.s) - 2\ Cov.H.S = \tfrac{1}{4}\delta^2 D$$

Variance ratio was calculated thus:

$\frac{GCA}{SCA}$ - to deterime gene action.

where MSm = Mean square males

MSf = Mean square females

MSmxf = Males x females interaction mean square

MSe = Error mean square.

r = Number of replication r = 2

f = Number of females = 19

m = Number of males = 3

A = Additive gene effect

D = Dominance gene effect

δ^2A = Average additive genetic effect.

Values for relative GCA and SCA effects were obtained for all characters in accordance with the formula as used by Singh and Chaudhary (1985). For each character, the mean for each cross was express to a percent of the mean of all crosses and general effect for each line and variety and specific effect for each hybrid was calculated as follows:

$$gi \text{ (gca tester)} = (\bar{Y}i - \bar{Y}..)$$

$$gj \text{ (gca line)} = (\bar{Y}j - \bar{Y}..)$$

$$Sij \text{ (sca line x tester)} = (\bar{Y}ij - \bar{Y}i - \bar{Y}.j - \bar{Y}..)$$

$\bar{Y}i$ - mean performance of hybrids with a given variety parent averaged over all replications within locations and lines.

$\bar{Y}j$ - Mean performance of hybrids with a given line averaged over all replications within locations, and varieties.

$\bar{Y}ij$ - Mean of a given hybrid averaged over all replications within locations

$\bar{Y}$ - Experimental mean.

The significance of general and specific combining ability effects for each character was tested using the formula of Cox and Frey (1984) and Monyo *et al.*, (1988).

$$t = \frac{GCA}{SE};\ SEgi = \sqrt{\frac{MSm\ (m-1)}{mfr}}$$

$$SEgj = \sqrt{\frac{MSf\,(f-1)}{mfr}}$$

where

Msm = Mean square males

Msf = Mean square females

SEgi - Standard error of GCA for males

SEgj - Standard error of GCA for females

r - Replication within location

f - Number of females

m - Number of males

Similarly significance of SCA effects

$$t = \frac{SCA}{S.E.\ SCA}\ ; \qquad S.E.\ SCA = \sqrt{\frac{MSmxf\,(M-1)(f-1)}{mfr}}$$

Where

MSmf = mean square male x females

S.E. SCA = Standard error for SCA.

Heterotic effect as an increase of F_1 mean over the high-parent (heterobeltiosis) and the mid-parent (heterosis) was expressed as a percentage and calculated as follows, using the formula of Liang *et al.*, (1972).

Over the high-parent:

$$\bar{H} = \frac{\bar{F}_1 - M\bar{H}_p}{\bar{M}h_p} \times 100$$

Over the mid-parent:

$$\bar{H} = \frac{\bar{F}_1 - (\bar{P}_1 + \bar{P}_2)/2}{(\bar{P}_1 + \bar{P}_2)/2} \times 100$$

where

$\bar{F}_1$ - mean performance of hybrid formed between the i^{th} male and the j^{th} female parent.

$\bar{M}H_p$ - mean performance of high-parent of a common hybrid.

$\bar{P}_1$ - mean of parent one

$\bar{P}_2$ - mean of parent two

The significance of heterosis was tested using the least significant difference (LSD) method from individual and the combined locations analysis for F_1 and better parent.

If the difference between the F_1 value and the high-parent; and the difference between the F_1 value and the mid-parent were greater than the LSD values at 5% and 1% value, heterobeltiosis and the heterosis estimates were considered significant.

Proportionate contributions of lines, varieties and line x variety interactions were calculated following Singh and Chaudhary (1985) formula as follows:

$$\text{contribution of lines} = \frac{SS(l)}{SS(Cross)} \times 100$$

$$\text{contribution of varieties} = \frac{SS(V)}{SS(Cross)} \times 100$$

$$\text{contribution of line x varieties} = \frac{SS(lxv)}{SS(Cross} \times 100$$

CHAPTER FOUR

4.0 RESULTS

4.1 General Analysis of Variance

The general analysis of variance for individual and combined locations revealed that the parents, hybrids and checks differed significantly ($P > .01$) among themselves for all the characters under consideration except for crude protein content. Partioning of the parent sum of squares into lines, varieties, and line vs variety further revealed significant differences among the lines and the varieties for the various characters measured as presented in Appendices 1,2 and table 6. Parent vs cross, which is a measure of heterosis was significant for all the traits except for number of tiliers/plant and protein content at Samaru (Appendix 1). At Bagauda, number of tillers/plant, panicle length, head weight, grain weight, 1000-seed weight threshing percentage and grain yield were significant (Appendix 2). For the two locations combined, however, significant differences were observed for number of tillers/plant, number of days to 50% flowering, plant height, panicle length, panicle width, head weight, threshing percentage, grain weight and grain yield (Table 6).

The general combining ability analyse for both lines and varieties at Samaru were significant for numbers of days to 50% flowering, plant height, panicle length, panicle width, head weight, 1000-seed weight, threshing percentage and grain weight. Specific combining ability analyse for number of tillers/plants, number of days to 50% flowering, panicle length, panicle width, head weight and grain weight were significant, (Appendix 3). At Bagauda, general combining ability

Table 6: Mean squares for eleven characters in pearl millet in the general combined analysis of variance (Samaru and Bagauda, 1996)

Source of variation	df	Number of Tillers	Days to 50% Flowering	Plant Height (cm)	Panicle Length (cm)	Panicle width (cm)	Head weight (Kg/ha)	Grain weight (Kg/ha)	Grain Yield (Kg/ha)	1000-seed weight (g)	Crude Protein (%)	Threshing (%)
Locations	1	308.20*	310.97**	171580.05**	1049.04**	2.300**	8702000**	69080000**	55540000**	514.82**	13.42*	5715.65**
Reps within location	2	51.74	6.36	134.7	15.82	0.024	735500	374800	623200	10.62	0.36	44.73**
Genotypes	80	1.23**	152.10**	1912.61**	59.13**	0.158**	557700**	502277**	697538**	12.59**	0.29	176.12**
Loc. Genotypes	80	0.99	18.12**	505.40	17.50	0.080	338850*	194063**	249863**	1.98*	0.31	75.86**
Parents	21	1.35**	120.01**	1987.13**	79.73**	0.221**	505000**	423900**	548300*	2.85*	0.35	162.04**
Line	18	0.99	82.04**	1077.47**	60.29**	0.180**	294092**	258166**	372821	6.13*	0.37	144.35**
Varieties	2	2.25*	500.33**	10238.58**	12.25	0.270**	105933	321238*	489673	26.88**	0.12	235.58**
Line vs Varieties	1	6.04*	42.92**	1858.22*	564.69**	0.880**	5098821**	36121017*	3823937	9.58*	0.47	333.41**
Loc. Parent	21	16.77	30.33**	732.52	43.69**	0.110**	218900**	171300	176200	2.85**	0.27	177.74**
Loc. Lines	18	0.84	602.52	602.52	48.56*	0.130*	227473	187855*	194670	3.16**	0.29	125.99**
loc varieties	2	0.75	1890.58**	1890.58*	15.08	0.010	54084	7563	9572**	1.42	0.04	3.73
Loc lines vs varieties	1	0.11	754.19	754.19	13.17	0.200	394219	201738	176317**	0.04	0.31	197.21*
Hybrids	56	1.12*	127.79*	1487.00*	29.93	0.136**	215000**	452700**	622100**	13.63**	0.27	145.94**
Loc Hybrids	56	1.05*	13.95*	410.50**	6.87	0.056	215000**	185900**	269400*	1.69	0.33	59.88
Checks	1	0.50	968.00**	55.13*	55.13*	0.045	286900*	214	42050	8.82**	0.08	860.65
Loc. Checks	1	0.50	12.50	351.10	36.13	0.180	827500	178000	210000	0.98	0.49	32.88
Parents vs cross vs checks	2	3.49*	761.72**	12344.23**	718.64**	0.158*	3866000**	264000**	4705000**	30.90**	0.21	26.62*
parents vs cross	1	6.97**	93.27**	11290.70**	222.68**	0.318*	6966000**	5891000**	9404000**	45.72**	0.27	925.69**
cross vs check	1	0.00	1430.18**	13397.80**	1214.59**	0.001	766000**	38020	7021	16.08**	0.15	727.55**
Loc parents vs cross vs checks	2	1.30	9.65	859.7	30.84*	0.340**	10980**	669700**	495200**	1.134	0.16	104.87
Loc. Parents vs cross	1	1.80	15.24	1677.70*	9.75	0.671**	1379000**	1124000**	679800*	0.18	0.13	165.12
Loc cross vs checks	1	0.80	4.06	41.6	51.94*	0.008	816900**	215000	310600	2.49	0.00	44.62
Pooled error	160	0.72	6.17	438.70	10.02	0.053	125200	108300	139600	1.35	0.34	50.17
Total	323											

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

analysis for both lines and varieties showed significant differences for the number of days to 50% flowering, plant height, head weight, 1000-seed weight, grain weight, threshing percentage and grain yield. Panicle width showed significant differences for varieties. Specific combining ability analysis was significant for number of tillers/plant, number of days to 50% flowering, plant height, panicle width, head weight, 1000-seed weight, threshing percentage and grain yield (Appendix 4) The general combining ability analysis for both lines and varieties for the two locations combined, showed significant differences for all the characters except for number of tillers/plant, 1000-seed weight, protein content (%) and threshing percentage. Specific combining ability analysis was significant for number of days to 50% flowering, panicle length, head weight, grain weight and grain yield. (Table 7). The GCA x Loc. (Females) was significant for number of days to 50% flowering, head weight, grain weight and grain yield. GCA x Loc. (Males) was significant for number of tillers/plant number of days to 50% flowering and 1000-seed weight. SCA x Loc. Was significant for number of days to 50% flowering and grain yield.

GCA/SCA predictability ratio for individual location and the two locations combined showed a preponderance of non-additive gene influence over additive gene effects for all the traits except for panicle width with the ratio=1 (Appendices 3,4 and Table 7).

4.2 Mean Performance and Combining Ability

The mean performance of the parents, hybrids and checks for the eleven characters

Table 7: Mean squares for eleven characters in pearl millet for general combining ability (GCA) and specific combining ability (SCA) for combined locations (Samaru and Bagauda, 1996)

Source of variation	df	Number of Tillers	Days to 50% flowering	Plant height (cm)	Panicle length (cm)	Panicle width (cm)	Head weight (kg/ha)	Grain weight (kg/ha)	Grain Yield (kg/ha)	1000-seed weight (g)	Crude Protein (%)	Threshing (%)
Hybrids	56	1.12*	127.79**	1487.00**	27.93**	0.136**	215000**	452700**	622100**	13.63	0.27	145.94**
GCA (lines)	18	0.94	120.94**	1403.20**	44.19**	0.267**	507500**	267300**	582000**	7.55	0.19	78.96
GCA (varieties)	2	1.22	2237.93**	19112.40**	94.08**	0.267**	2542000**	2001000**	5067000**	278.77	0.24	112.88
SCA (line x varieties)	36	1.20	13.98**	549.60	16.12*	0.064	326100**	151400**	395200**	1.93	0.31	73.99
Loc. hybrids	56	1.05*	13.95**	410.50	6.87	0.056	215000**	185900**	269400**	1.69	0.33	59.88
GCA. Loc (lines)	18	0.96	17.77**	519.70	6.63	0.057	309000**	165300**	367800*	1.40	0.37	78.39
GCA. Loc. (varieties)	2	3.58**	58.56**	20.30	10.93	0.204	167500	161400	181800	4.10*	0.27	136.31
SCA. Loc. (line x varieties)	36	0.96	9.56*	377.90	6.79	0.050	170600	71800	222500*	1.70	0.31	73.34
Error	160	0.72	6.17	438.70	10.02	0.053	827500	108300	149600	1.35	0.34	50.17
δ^2 gca	-	0.787	8.650	2.553	2.741	4.193	1.556	1.766	1.473	3.904	0.606	1.067
δ^2 sca	-	1.019	160.100	34.770	5.836	4.192	7.795	13.220	12.82	144.100	0.762	1.526
Predictability ratio gca/sca	-	0.768	0.054	0.073	0.470	1.000	0.200	0.134	0.115	0.027	0.795	0.700

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

measured for individual location and the locations combined are presented on Appendices 5,6 and Table 8, respectively. At Samaru, the parental range with respect to number of tillers was from 0-3 tillers/plant, while among the hybrids it ranged from 1-2 tillers/plant. At Bagauda, the range among the parent materials was between 2-5 tillers/plant; for hybrids, 2-6 tillers/plant and for checks, 3-4 tillers/plant. For the locations combined the parental range was from 1-4 tillers/plant; for hybrids, 2-4 tillers/plant, while for checks, 2-3 tillers/plant. GB 8735, one of the parent varieties produced the highest number of tillers/plant at Samaru while the hybrid H12.2 produced the highest number of tillers/plant among the hybrids. At Bagauda G.I. 122-2, an inbred parent produced the highest number of tillers/plant while among the hybrids, H 5.1 and H 15.2 produced the highest number of tillers/plant. GB 8735, parent variety produced the highest number of tillers/plant among the hybrids for the locations combined. At Samaru among the parents, GB 8735 had the highest GCA while G.I. 296-1 had the highest GCA among the female parents for number of tillers/plant (Appendix 7). At Bagauda, Gwagwa had the highest GCA among the male parents while G.I. 363-1 had the highest GCA effect among the female parents for number of tillers/plant (Appendix 8).

In the combined analysis for the two locations, Gwagwa, had the highest GCA among the male parents while G.I. 363-1, and ICMP 91103 had the highest GCA for number of tillers/plant (Table 9). Most of the hybrids at either individual location or the locations combined had negative SCA for number of tillers/plant

Table 8: Mean performances of parents, Hybrids and checks for eleven characters in pear millet for combined locations (Samaru and Bagauda, 1996)

Parents		Genotype	Number of Tillers	Days to 50% flowering	Plant height (cm)	Panicle length (cm)	Panicle width (cm)	Head weight (kg/ha)	Grain weight (kg/ha)	Grain Yield (kg/ha)	1000-seed weight (g)	Crude Protein (%)	Threshing (%)
A. Lines 1		G.I. 6-2	3.00	62.00	228.00	34.25	2.65	1347.49	831.67	1304.25	10.05	9.45	61.72
	2	G.I. 75-1	2.00	57.00	239.50	28.75	2.60	975.11	547.33	801.75	9.70	9.33	56.13
	3	G.I 122-2	3.00	64.00	258.00	29.25	2.40	1025.68	564.33	791.25	9.05	9.69	55.02
	4	G.I 165-6	2.00	60.00	246.25	35.5	2.30	1671.67	889.33	1092.50	8.67	8.93	53.20
	5	G.I 296-1	1.00	61.00	239.75	28.75	2.40	1354.65	758.33	946.00	10.60	9.91	55.90
	6	G.I 359-3	1.00	65.00	223.50	37.00	2.90	930.32	520.33	681.75	7.80	9.77	55.93
	7	G.I 363-1	3.00	56.00	222.25	26.00	2.23	1574.04	999.67	1330.25	9.65	9.48	63.51
	8	G.I 363-4	2.00	55.00	226.75	34.00	2.45	756.13	449.67	694.50	10.77	9.48	59.47
	9	G.I 410-8	2.00	65.00	231.50	25.75	2.28	746.78	398.33	540.50	8.02	9.70	53.34
	10	G.I 435-4	2.00	56.00	213.75	33.75	2.17	1364.29	849.00	978.25	10.07	9.54	62.23
	11	ACC 1009-2	2.00	54.00	230.00	33.25	2.37	1518.51	917.33	1100.50	9.26	9.24	60.41
	12	Buduna Gero 712-2	2.00	66.00	232.25	24.75	2.50	595.45	312.67	364.00	7.60	9.61	52.51
	13	ICMV 88908	2.00	52.00	187.75	23.50	2.65	933.91	585.00	728.00	11.60	9.21	62.64
	14	G.I 41-3	3.00	63.00	232.00	31.75	2.17	1325.86	805.33	1106.00	6.80	9.28	60.74
	15	G.I 47-3	2.00	63.00	195.75	27.00	2.68	380.86	189.67	375.75	9.70	9.65	48.75
	16	ACC 364-1	2.00	64.00	225.50	31.75	2.30	732.61	347.33	477.50	8.38	9.28	47.41
	17	ICMV 93501	3.00	58.00	227.50	28.00	2.40	1505.23	826.67	973.25	9.45	9.53	54.92
	18	ICMP 94592	2.00	53.00	214.25	31.25	2.83	434.29	177.67	355.75	7.72	8.86	40.91
	19	ICMP 91103	2.00	58.00	210.75	33.25	2.60	957.99	472.00	667.50	8.57	10.05	49.27
B. Varieties													
1		Ex-Borno	3.00	65.00	274.50	24.75	2.68	1740.73	924.33	1062.25	8.02	9.09	53.10
2		Gwagwa	2.00	63.00	261.25	23.00	2.55	1878.56	1164.33	1416.25	9.25	9.44	61.98
3		GB 8735	4.00	45.00	181.00	21.25	3.05	2177.54	1489.00	1762.00	13.00	9.26	68.38

Table 8 Cont:

Hybrids	Pedigree	Number of Tillers	Days to 50% flowering	Plant height (cm)	Panicle length (cm)	Panicle width (cm)	Head weight (kg ha)	Grain weight (kg ha)	Grain Yield (kg ha)	1000-seed weight (g)	Crude Protein (%)	Threshing (%)
H1.1	G.I 6-2 x Ex-Borno	3.00	67.00	253.50	25.75	2.48	1202.14	653.00	857.50	8.22	9.53	54.32
H1.2	G.I 6-2 x Gwagwa	2.00	66.00	266.25	28.00	2.40	1451.88	753.67	1065.50	7.80	9.09	51.91
H1.3	G.I 6-2 x GB 8735	3.00	58.00	220.25	30.00	2.37	1526.64	966.67	1332.75	6.75	9.63	63.32
H2.1	G.I 75-1 Ex-Borno	2.00	66.00	258.75	26.75	2.58	553.28	336.67	738.25	8.07	9.28	60.85
H2.2	G.I 75-1 x Gwagwa	2.00	58.00	242.75	31.25	2.40	1644.63	908.00	1169.50	8.15	9.41	55.21
H2.3	G.I 75-1 x GB 8755	3.00	52.00	207.00	29.75	2.33	2216.27	1517.00	1960.00	12.48	9.43	68.45
H3.1	G.I 122-2 x Ex-Borno	3.00	52.00	207.00	29.75	2.33	2216.27	1517.00	1960.00	12.48	9.43	68.45
H3.2	G.I 122-2 x Gwagwa	3.00	62.00	269.75	27.50	2.50	1110.38	680.33	871.75	9.40	9.7*	61.27
H3.3	G.I 122-2 x GB 8735	2.00	54.00	248.00	27.75	2.80	2026.23	1292.33	1438.00	12.55	10.24	63.78
H4.1	G.I 165-6 x Ex-Borno	2.00	66.00	280.25	27.50	2.48	1421.95	807.67	1065.25	8.30	9.66	56.80
H4.2	G.I 165-6 x Gwagwa	3.00	63.00	266.50	27.25	2.70	1884.97	1060.67	1282.75	8.50	9.56	56.27
H4.3	G.I 165-6 x GB 8735	2.00	55.00	221.25	30.75	2.50	1796.84	1175.67	1414.75	11.70	9.59	65.43
H5.1	G.I 296-1 x Ex-Borno	2.00	64.00	265.50	26.75	2.35	711.71	387.67	502.25	8.95	9.66	54.47
H5.2	G.I 296-1 x Gwagwa	2.00	60.00	253.50	25.75	2.43	1010.05	579.67	1110.00	10.07	9.13	57.39
H5.3	G.I 296.1 x GB 8735	2.00	51.00	233.50	31.50	2.53	2077.53	1402.33	1683.00	13.32	9.19	67.50
H6.1	G.I 359-3 x Ex-Borno	3.00	63.00	262.50	26.00	2.45	1694.84	922.33	1070.75	8.93	9.36	54.42
H6.2	G.I 359-3 x Gwagwa	2.00	61.00	255.50	27.75	2.50	1606.91	892.33	1316.25	8.32	9.26	55.60
H6.3	G.I 359-3 x GB 8735	3.00	54.00	220.00	28.75	2.37	1899.19	1264.67	1528.00	11.82	9.54	66.59
H7.1	G.I 363-1 x Ex-Borno	2.00	62.90	264.75	29.25	2.45	1134.51	673.67	811.50	8.80	9.56	59.38
H7.2	G.I 363-1 x Gwagwa	4.00	55.00	259.25	31.50	2.62	2081.79	1396.67	1776.25	10.42	9.40	67.09
H7.3	G.I 363-1 x GB 8735	3.00	51.00	250.75	27.50	2.73	2061.45	1433.33	2101.50	12.82	9.54	69.53
H8.1	G.I 363-4 x Ex-Borno	2.00	57.00	238.25	29.75	2.70	1985.06	1302.80	1558.25	10.87	9.27	65.59
H8.2	G.I 363-4 x Gwagwa	2.00	57.00	241.75	31.25	2.68	1976.25	1198.00	1423.00	9.57	10.11	60.62

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Table 8 contd:

Hybrids	Pedigree	Number of Tillers	Days to 50% flowering	Plant height (cm)	Panicle length (cm)	Panicle width (cm)	Head weight (kg ha)	Grain weight (kg ha)	Grain Yield (kg ha)	1000-seed weight (g)	Crude Protein (%)	Threshing (%)
H8.3	G.I 363-4 x GB8735	2.00	47.00	223.75	28.25	2.72	2119.32	1359.33	1627.25	13.07	9.78	64.14
H9.1	G.I 410-8 x Ex Borno	4.00	65.00	242.25	24.25	2.53	1363.55	680.00	897.50	7.17	9.44	49.87
H9.2	G.I 410-8 x Gwagwa	3.00	60.00	281.25	25.00	2.58	1256.03	651.00	791.75	8.97	9.54	51.83
H9.3	G.I 410-8 x GB 8735	2.00	57.00	236.75	26.75	2.65	1320.27	787.67	987.50	11.00	9.69	59.66
H10.1	G.I 435-4 x Ex-Borno	3.00	60.00	247.50	29.75	2.58	2239.85	1285.00	1619.25	8.45	9.23	57.37
H10.2	G.I 435-4 x Gwagwa	3.00	58.00	224.00	32.00	2.65	2492.32	1323.67	1495.00	8.57	9.56	53.11
H10.3	G.I 435-4 x GB 8735	3.00	47.00	216.75	33.25	2.58	2355.00	1622.00	1780.50	12.20	9.39	68.85
H11.1	ACC 1009-2 x Ex Borno	3.00	59.00	233.75	26.25	2.35	1838.49	1157.33	1478.50	9.42	9.54	62.95
H11.2	ACC 1009-2 x Gwagwa	2.00	59.00	230.50	27.25	2.45	1688.05	894.33	1147.75	10.50	9.28	52.98
H11.3	ACC 1009-2 x GB 8735	2.00	49.00	217.25	29.75	2.53	1780.89	1120.00	1435.25	12.00	9.45	62.89
H12.1	Buduma Gero 712-2 x Ex-Borno	2.00	66.00	240.25	27.25	2.40	578.65	285.33	426.25	8.20	9.56	49.31
H12.2	Buduma Gero 712-2 x Gwagwa	4.00	63.00	241.25	24.00	2.30	1319.01	700.00	1259.00	8.43	9.18	53.07
H12.3	Buduma Gero 712-2 GB8735	2.00	56.00	221.75	23.75	2.40	1538.71	952.00	1168.75	12.40	9.68	61.87
H13.1	ICMV 88908 x Ex Borno	3.00	61.00	239.50	23.00	2.95	1302.26	776.67	1145.50	9.65	9.35	59.64
H13.2	ICMV 88908 x Gwagwa	2.00	61.00	245.25	26.50	2.83	1593.18	979.33	1201.25	10.20	9.65	61.47
H13.3	ICMV 88908 x GB 8735	2.00	50.00	220.75	25.50	3.15	1637.52	1161.00	1531.50	14.27	9.52	70.90
H14.1	G.I 41-3 x Ex-Borno	3.00	65.00	264.25	26.25	2.60	1864.89	1038.00	1376.25	7.77	9.30	55.66
H14.2	G.I 41-3 x Gwagwa	3.00	56.00	248.50	31.00	2.33	1590.10	737.33	969.25	8.10	9.75	46.94
H14.3	G.I 41-3 x GB 8735	3.00	56.00	222.25	31.50	2.87	1955.31	1230.67	1572.00	12.63	9.42	62.94
H15.1	G.I 47-3 x Ex-Borno	3.00	65.00	264.25	26.25	2.60	1864.89	1038.00	1376.25	7.77	9.30	55.66
H15.2	G.I. 47-3 x Gwagwa	3.00	67.00	251.25	25.75	2.58	1265.93	761.33	1008.75	9.13	9.47	60.14
H15.3	G.I 47-3 x GB 8735	3.00	52.00	234.25	26.00	3.03	2672.88	1863.00	2249.00	12.15	9.33	69.70
H16.1	ACC 364-1 x Ex Borno	2.00	64.00	225.00	29.00	2.28	1689.02	957.00	1211.00	7.47	8.86	56.66

Table 8 Cont.

Hybrid	Pedigree	Number of Tillers	Days to 50% flowering	Plant height (cm)	Panicle length (cm)	Panicle width (cm)	Head weight (kg ha)	Grain weight (kg ha)	Grain Yield (kg ha)	1000-seed weight (g)	Crude Protein (%)	Threshing (%)
H16.3	ACC 364-1 x GB 8735	3.00	52.00	239.75	28.75	2.55	2036.57	1362.67	2125.50	13.13	9.65	66.91
H17.1	ICMV 93501 x Ex Borno	3.00	58.00	251.50	26.50	2.80	2130.43	1295.33	1543.75	9.50	10.19	60.81
H17.2	ICMV 93501 x Gwagwa	2.00	49.00	246.75	28.00	2.73	874.23	459.67	639.25	8.90	9.19	52.58
H17.3	ICMV 93501 x GB 8735	3.00	50.00	211.00	25.00	2.60	1348.32	887.33	1146.50	12.13	9.80	65.81
H18.1	ICMP 94592 x Ex Borno	2.00	61.00	244.00	25.25	2.62	17.37.08	995.67	1240.00	8.38	9.49	57.28
H18.2	ICMP 94592 x Gwagwa	2.00	59.00	235.25	32.25	2.58	1483.21	925.67	1127.00	9.43	9.44	62.41
H18.3	ICMP 94592 x GB 8735	2.00	5<.00	205.50	26.00	2.67	1564.24	845.00	994.75	10.85	9.36	54.02
H19.1	ICMP 91103 x Ex-Borno	3.00	58.00	245.25	25.00	2.53	1508.39	938.67	1335.75	11.22	9.45	62.23
H19.2	ICMP 91103 x Gwagwa	3.00	54.00	258.25	30.50	2.65	2260.80	1406.67	1583.75	10.50	9.62	62.22
H19.3	ICMP 91103 x GB 8735	3.00	49.00	198.75	23.75	2.90	1735.90	1227.67	1673.75	12.85	9.49	70.72
Checks	ICMV IS 88102	3.00	83.00	296.50	38.50	2.48	2371.16	900.33	977.75	7.17	9.44	37.97
	Local variety	2.00	61.00	255.75	43.75	2.62	1551.13	910.67	1222.75	9.27	9.24	58.71
	GRAND MEAN	2.00	59.00	238.70	28.59	2.56	1515.03	903.23	1162.31	9.80	9.48	58.55
	SE ±	0.85	2.48	20.95	3.17	0.23	353.84	329.09	386.78	1.16	0.58	7.08
	CV(%)	36.40	4.2	8.8	11.1	9.00	32.5	36.4	33.3	11.9	6.1	12.1

Note: (H1.1) = G.L. 6-2 x Ex-Borno, (H2.2) = G.L. 75 –1 x Gwagwa, (H3.3) = G.L. 12.2-2 x GBB 735

...combining ability (GCA) effect for eleven character in pear millet for location combined (Samaru and Baganda, 1996)

Lines	Genotype	Number of Tillers	Days to 50% flowering	Plant height (cm)	Panicle length (cm)	Panicle width (cm)	Head weight (kg ha)	Grain weight (kg ha)	Grain Yield (kg ha)	1000-seed weight (g)	Crude Protein (%)	Threshing (%)
1	G.I. 6-2	0.079	5.250**	4.895	0.070	-0.161	-179.100	-147.900*	-186.500	-1.477**	-0.090	1.209
2	G.I. 75-1	-0.004	0.333	-5.605	1.404	-0.144	-98.700	-50.800	17.500	-0.502	-0.134	1.561
3	G.I 122-2	0.079	2.250*	16.895*	-0.513	0.081	-180.200	-139.600	-307.300	0.365	0.275	0.020
4	G.I 165-6	-0.254	3.000**	14.228	0.487	-0.019	-42.5007	19.800	-17.500	-0.568	0.095	1.773
5	G.I 296-1	-0.338	-0.333	9.0615	0.154	-0.144	-241.500*	-148.800	-173.400	0.715	-0.177	-2.137
6	G.I 359-3	-0.004	1.083	4.1450	-0.346	-0.136	61.900	28.600	33.200	-0.377	-0.120	-3.431
7	G.I 363-1	0.496	-1.333	16.478	1.570	0.022	132.400	134.700	291.300	0.615	-0.005	2.754
8	G.I 363-4	-0.338	-4.417*	-7.189	1.904	0.122	257.500*	225.600*	264.400	1.107*	0.215	3.452
9	G.I 410-8	0.246	2.167*	1.645	-2.513	0.006	-268.100*	-211.500*	-379.500*	-1.018*	0.050	3.897
10	G.I 435-4	0.246	-3.083**	-12.355	3.820**	0.022	495.000**	316.500**	359.800*	-0.327	-0.115	-1.382
11	ACC 1009-2	-0.338	-2.917**	-14.605	-0.096	-0.136	85.3001	51.700	82.100	0.573	-0.080	2.667
12	Buduma Gero 712-2	0.079	3.250**	-7.355	-2.846*	-0.211*	-339.500*	-256.900*	-320.400*	-0.393	-0.035	-1.520
13	ICMV 88908	-0.254	-1.167	-6.605	-2.763*	0.397**	-85.800	-12.000	21.000	1.301**	-0.000	3.110
14	G.I 41-3	0.329	3.833**	3.2280	1.737	0.022	129.500	12.800	24.1000	-0.568	-0.015	-0.553
15	G.I 47-3	0.079	2.833**	17.978*	-2.263	0.131	166.700	138.300	179.200	-0.260	-0.050	-1.630
16	ACC 364-1	-0.088	0.333	-8.272	2.987*	-0.144	26.100	19.500	156.000	-0.235	0.030	-1.303
17	ICMV 93501	-0.088	-6.083**	-5.355	-1.346	0.131	-103.700	-80.600	-161.900	0.107	0.220	-0.388
18	ICMP 94592	-0.421	-0.250	-13.522	-0.013	0.047	-75.000	-49.600	-151.200	-0.518	-0.075	-4.993*
19	ICMP 91103	0.496	-4.750**	-7.689	-1.430	0.114	179.900	152.000	259.300	1.457**	0.017	-3.106
	SE ±	0.345	1.014	8.551	1.292	0.094	144.500	100.800	157.900	0.475	0.236	2.327

Table 9 contd:

Testers	Genotype	Number of Tillers	Days to 50% flowering	Plant height (cm)	Panicle length (cm)	Panicle width (cm)	Head weight (kg/ha)	Grain weight (kg/ha	Grain yield (kg/ha)	1000-seed weight (g)	Crude Protein (%)	Threshing (%)
	LSD (1%)	0.890	2.612	22.027	3.328	0.241	372.232	259.667	406.750	1.273	0.609	5.994
	LSD (5%)	0.677	1.987	16.760	2.532	0.184	238.22	197.568	307.720	0.930	0.463	4.561
1	Ex-Borno	-0.053	4.355**	11.310*	-1.215*	-0.036	-139.500*	-116.800**	-189.900**	-1.284**	-0.053	-1.407
2	Gwagwa	0.1454	1.724**	6.820*	0.969	-0.329	-67.600	-68.500	-104.200	-0.917**	-0.006	0.735
3	GB 8735	-0.092	-6.079**	-18.130**	-0.246	0.068	207.100**	185.300**	294.000**	2.201**	0.0595	0.672
	SE±	0.137	0.403	3.398	0.513	0.037	57.41	40.05	62.750	0.189	0.094	0.926
	LSD (1%)	0.3558	1.0383	8.7535	1.323	0.096	147.888	103.169	161.44	0.486	0.242	2.382
	LSD (5%)	0.269	0.790	6.656	1.006	0.073	121.524	78.498	122.99	0.370	0.184	1.812

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

(Appendices, 9, 10 and Table 10). At Samaru, the hybrid of Buduma Gero 712-2 x Gwagwa, had significant SCA for number of tillers/plant while at Bagauda and locations combined, the hybrids of G.I. 6-2 x Ex-Borno had the highest significant positive SCA for the same character. The hybrid of G.I. 75-1 x GB 8735, had the highest positive SCA for number of tillers/plant, respectively (Appendices 9 and 10).

At Samaru for number of days to 50% flowering, the range for parent material, was from 47-72 days; GB 8735 which flowered in 47 days, was the earliest. Among the hybrids, number of days to 50% flowering ranged from 46-&? days, the hybrid H 8.3, which flowered in 46 days was the earliest among the hybrids (Appendix 5). At Bagauda, number of days to 50% flowering ranged from 42 - 62 days among the parents while among the hybrids it ranged from 46-62 days. The variety GB 8735 flowered in 42 days while the hybrid H 9.3 flowered in 46 days as early materials (Appendix 6). For the locations combined, number of days to 50% flowering ranged from 45-65 days for the parents; 47-67 days for hybrids with GB 8735, the parent variety flowering in 45 days and the hybrid H 8.3 in 47 days (Table 8). The estimates of GCA for the number of days to 50% flowering at Samaru revealed that ICMV 93501 among the female parents had the highest significant negative GCA while GB 8735 among the male parents had the highest significant negative GCA (Appendix 7). At Bagauda ICMP 91103 had the highest significant negative GCA among the female parents while GB 8735 had the highest negative GCA (Appendix 8). For the locations combined, significant negative GCA was exhibited by the male parent GB 8735 and the female parent ICMV 93501 for the

Table 10 Estimates of Specific combining ability (SCA) effects for eleven characters in pear millet for combined locations (Samaru and Bagauda, 1996)

Hybrid	Pedigree	Number of Tillers	Days to 50% flowering	Plant height (cm)	Panicle length (cm)	Panicle width (cm)	Head weight (kg/ha)	Grain weight (kg/ha)	Grain Yield (kg/ha)	1000-seed weight (g)	Crude Protein (%)	Threshing (%)
H1.1	G.I. 6-2xEx-Borno	0.553	-1.355	-4.474	-0.952	0.094	11.400	13.200	-37.900	0.918	0.163	-4.010
H2.1	G.I. 75-1xEx-Borno	-0.614	2.561	11.276	-1.285	0.177	-523.800*	-321.200	361.100	-0.208	-0.034	5.871
H3.1	G.I 122-2xEx-Borno	0.053	0.645	-11.724	0.632	0.052	-252.500	-159.600	-190.900	0.201	-0.412	-5.504
H4.1	G.I 165-6xEx-Borno	-0.114	-0.105	12.943	0.382	0.048	-7.9007	-38.500	-0.900	0.084	0.113	7.041
H5.1	G.I 296-1xEx-Borno	-0.031	1.478	3.3605	-0.035	-0.048	-297.200	-184.900	-406.30	-0.549	0.385	-3.707
H6.1	G.I 359-3xEx-Borno	0.136	-1.189	5.0260	-0.285	0.044	48.700	38.700	-44.400	0.518	0.028	-1.643
H7.1	G.I 363-1xEx-Borno	-0.614	0.228	-4.807	1.048	-0.115	-331.800	-253.900	-561.700**	-0.599	0.108	-2.662
H8.1	G.I 363-4xEx-Borno	0.219	-0.939	-7.640	2.215	0.036	162.700	128.400	211.900	0.984	-0.397	0.534
H9.1	G.I 410-8xEx-Borno	0.886	0.228	-12.474	0.132	-0.023	190.200	97.100	195.100	-0.591	-0.067	5.108
H10.1	G.I 435-4xEx-Borno	-0.114	0.478	6.7765	-0.702	0.011	29.7009	22.000	177.500	-0.008	-0.112	-2.974
H11.1	ACC 1009-2xEx-Borno	0.469	-0.689	-4.724	-0.285	-0.056	260.700	191.800	314.500	0.068	0.168	3.458
H12.1	Buduna Gero 712-2 x Ex-Borno	-0.447	-0.105	-5.474	3.465	0.067	-265.200	-153.600	-335.200	-0.191	0.140	-7.335
H13.1	ICMV 88908xEx-Borno	0.386	-0.439	-6.974	-0.868	0.011	-28.700	-30.000	42.600	-0.441	-0.107	-2.916
H14.1	G.I 41-3xEx-Borno	0.053	-1.439	7.4430	-2.118	0.036	213.000	141.300	260.300	-0.441	-0.137	0.555
H15.1	G.I 47-3xEx-Borno	-0.947	-0.689	22.693	0.632	-0.148	-109.400	-92.500	-165.900	-0.374	0.168	0.255
H16.1	ACC 364-1xEx-Borno	-0.281	0.811	-19.807	-0.618	-0.123	109.200	73.800	-26.900	-1.074	-0.617	4.660
H17.1	ICMV 93501xEx-Borno	0.219	1.228	3.776	1.215	0.127	653.500**	427.700*	623.800*	0.629	0.513	2.642
H18.1	ICMP 94592xEx-Borno	0.053	-1.105	4.443	-1.368	0.036	231.700	171.900	309.300	0.109	0.118	0.344
H19.1	ICMP 91103xEx-Borno	0.136	0.395	-0.140	-0.202	-0.131	-93.800	-72.5	-5.500	0.948	-0.020	0.285
H1.2	G.I 6-2xGwagwa	-0.645	1.026	12.763	-0.886	0.016	115.000	40.4003	84.4005	0.125	09.319	1.065
H2.2	G.I. 75-1xGwagwa	-0.311	-2.057	-0.287	1.0313	-0.000	149.100	59.1000	-15.6000	-0.500	0.039	-2.013

Table 10 Cont.

Hybrid	Pedigrees	Number of Tillers	Days to 50% flowering	Plant height (cm)	Panicle length (cm)	Panicle width (cm)	Head weight (kg/ha)	Grain weight (kg/ha)	Grain Yield (kg/ha)	1000-seed weight (g)	Crude Protein (%)	Threshing (%)
H3.2	G.I. 122-2xGwagwa	0.605	0.026	4.263	-0.803	-0.125	-82.700	-222.800	11.400	-0.116	0.006	4.364
H4.2	G.I 165-6xGwagwa	0.689	0.276	3.6800	-2.053	0.175	125.200	103.000	132.700	-0.083	-0.039	-5.448
H5.2	G.I 296-1xGwagwa	0.022	-0.140	-4.154	-3.219	0.025	-127.800	-89.200	115.800	0.209	-0.193	7.901
H6.2	G.I 359-3xGwagwa	-0.561	0.193	2.7635	-0.719	0.091	-10.300	-32.100	115.400	-0.450	-0.124	-1.212
H7.2	G.I 363-1xGwagwa	0.439	-0.640	-5.820	1.114	0.058	296.700	240.100	317.300	0.659	-0.089	2.285
H8.2	G.I 363-4xGwagwa	0.022	1.693	0.3465	0.531	0.008	-6.2003	2.2000	-9.0000	-0.683	0.396	-5.380
H9.2	G.I 400-8xGwagwa	-0.311	-2.390	1.0130	-1.303	0.025	2.00027	27.1000	3.70000	0.842	-0.009	-1.741
H10.2	G.I 435-4xGwagwa	0.189	1.360	-12.237	-0.636	0.083	95.1007	3.60000	-32.400	-0.250	0.171	-2.899
H11.2	ACC 1009-2xGwagwa	-0.728	1.443	-3.487	-1.469	0.041	-111.200	53.700	-101.900	0.775	-0.134	-1.464
H12.2	Buduna Gero 712-2 x Gwagwa	0.855	-0.224	0.0130	-1.969	-0.034	175.400	109.200	411.800	-0.333	-0.285	3.689
H13.2	ICMV 88908xGwagwa	-0.061	1.693	3.2635	0.697	-0.117	102.700	73.800	12.700	-0.258	0.146	1.343
H14.2	G.I 41-3xGwagwa	-0.145	1.193	-3.320	0.447	-0.242	-160.400	-125.000	-263.400	0.483	0.266	3.110
H15.2	G.I 47-3xGwagwa	0.605	3.693*	-15.370	-0.803	-0.100	-315.600	-240.000	-338.100	0.234	0.016	1.785
H16.2	ACC 364-1xGwagwa	0.022	-0.057	-4.570	2.947	0.075	-221.000	-149.700	-376.800	-0.016	0.566	-2.2001
H17.2	ICMV 93501xGwagwa	-0.728	-4.890**	3.5130	0.531	0.050	-385.900	-247.300	366.400	-0.358	-0.524	-2.895
H18.2	ICMP 94592xGwagwa	0.105	-0.474	0.1800	3.447	-0.017	19.3003	71.2003	110.600	0.792	0.012	-0.115
H19.2	ICmp 91103xGwagwa	-0.061	-1.724	17.346	3.114	-0.009	340.700	230.300	156.500	-0.108	0.106	-0.168
H1.3	G.I 6-2 x GB 8735	0.092	0.329	-8.289	1.838	-0.110	-126.400	-53.600	-46.500	-1.043	0.157	2.945
H2.3	G.I 75-1xGB 8735	0.925	-0.504	-11.039	0.254	-0.177	374.700	262.100	376.700	0.707	-0.005	-3.858
H3.3	G.I 122-2xGB 8735	-0.658	-0.671	7.4615	0.191	0.073	335.200	182.400	179.500	-0.085	0.407	1.140
H4.3	G.I 165-6xGB 8735	-0.575	-0.171	-16.623	1.671	-0.127	-117.200	-64.500	-133.500	-0'001	-0.074	-1.593
H5.3	G.I 296-1xGB 8735	0.009	-1.338	0.7945	3.254	0.023	425.000	274.100	290.600	0.340	-0.192	-4.194
H6.3	G.I 359-3xGB 8735	0.425	0.996	-7.789	1.004	-0.0135	-38.400	-6.600	-71.000	-0.068	0.097	2.885
H7.3	G.I 363-1xGB 8735	0.175	0.412	10.627	-2.162	0.057	35.100	13.000	244.400	-0.060	-0.019	0.3[illegible]

Table 10 Cont.

Hybrid	Pedigrees	Number of Tillers	Days to 50% flowering	Plant height (cm)	Panicle length (cm)	Panicle width (cm)	Head weight (kg/ha)	Grain weight (kg/ha)	Grain Yield (kg/ha)	1000-seed weight (g)	Crude Protein (%)	Threshing (%)
H8.3	G.I. 363-4xGB 8735	-0.241	-0.754	7.294	-1.746	-0.043	-156.600	-130.600	-202.900	-0.301	0.002	4.846
H9.3	G.I 410-8xGB 8735	-0.575	2.162	11.461	1.1713	-0.002	-192.100	-124.200	-192.800	-0.251	0.0779	-3.362
H10.3	G.I 435-4xGB 8735	-0.075	-1.838	5.4614	1.3389	-0.093	-124.800	-26.400	-145.100	0.257	-0.059	5.873
H11.3	ACC 1009-2xGB 8735	0.259	-0.754	8.211	1.754	0.015	-149.100	-138.200	-212.600	-0.843	-0.034	-1.994
H12.3	Buduma Gero 712-2 x GB 8735	-0.408	0.3290	5.4610	-1.496	-0.035	89.8000	44.4000	-76.620	0.524	-0.146	3.647
H13.3	ICMV 88908xGB 8735	-0.325	-1.254	3.7115	0.171	0.107	-74.000	-43.800	-55.300	0.6993	-0.039	1.573
H14.3	G.I 41-3xGB 8735	0.092	0.246	-4.623	1.6713	0.207	-52.600	-16.300	-27.900	0.924	-0.129	-3.665
H15.3	G.I. 47-3xGB 8735	0.342	-3.004	-7.3737	0.1716	0.248	425.000	332.500	504.000	0.1400	-0.184	-2.039
H16.3	ACC 364-1xGB 8735	0.2598	-0.754	24.377	-2.329	0.048	111.9000	76.000	403.7000	1.090	0.0524	-2.458
H17.3	ICMV 93501xGB 8735	0.509	3.662*	-7.289	-1.746	-0.177	-267.600	-180.300	-257.400	-0.251	0.0125	0.253
H18.3	ICMP 94592xGB 8735	-0.158	1.579	-4.623	-2.096	-0.018	-251.100	-243.100	-419.900	-0.901	-0.129	-0.229
H19.3	ICMP 91103xGB 8735	-0.075	1.329	-17.206	-2.912	0.1402	-246.900	-157.800	-151.400	-0.876	-0.086	-0.117

number of days to 50% flowering (Table 9). The estimates of SCA effect for number of days to 50% flowering at Samaru revealed that the hybrid of Buduma Gero 712-2 x Gwagwa, had the highest significant negative SCA (Appendix 9). At Bagauda, the hybrids of G.I. 75-1 x GB 8735, G.I. 47-3 x GB 8735 and ICMP 91103 x Gwagwa, had the highest significant negative SCA (Appendix 10). For the two locations combined, however, the hybrid of ICMV 93501 x Gwagwa, had the highest significant negative SCA (Table 10).

Mean performances among the parents with respect to plant height at Samaru ranged from 159.00-278.00 cm with GB 8735 being the shortest (159.00cm) and Ex-Borno the tallest (278.00cm). Among the hybrids, plant height ranged from 175-266.00 cm with the hybrid of GI 435-4 x Ex-Borno, being the tallest (Appendix 5). At Bagauda plant height ranged between 203.00-301.00cm among the parents with GB 8735 being shortest (203.00cm) and Gwagwa being the tallest (301.00cm). Among the hybrids, the range was from 224.00-323.5 cm with hybrid H18.3 being the shortest while H15.1 was the tallest (Appendix 6). Plant height among parents for the locations combined, ranged from 181.00-274.5 cm and from 198.75-280.25cm for hybrids. GB 8735 was the shortst (181.0cm) among the parents while among the hybrids, H19.3, was the shortest (198.75cm). Ex-Borno (274.5cm) and the hybrid of G.I. 165 x Ex-Borno (280.25cm) were the tallest among the parents and the hybrids, respectively (Table 8).

The estimates of GCA for plant height at Samaru, showed that GB 8735 had the highest significant negative GCA among the male parents while ICMP 91103 had the

highest significant negative GCA among the female parents (Appendix 7). Among the male parents at Bagauda; GB 8735 had the highest significant negative GCA and ACC 364-1, among the female parents had the highest significant negative GCA (Appendix 8). GCA estimates for the locations combined revealed that GB 8735 had the highest signficant negative GCA among the male parents while ACC 1009-2 had the highest singificant negative GCA among the female parents (Table 9). The estimates of SCA for plant height at Samaru, revealed H19.3 as the highest significant specific combiner, for reducing plant height in pearl millet (Appendix 9). The hybrid, H3.1 at Bagauda was the highest sigificant specific combiner for reducing plant height (Appendix 10). For the locations combined, however, the hybrid of ACC 364-1 x Ex-Borno, among the hybrid was the best specific combination with a high negative SCA for plant height (Table 10).

The mean performance for panicle length at Samaru among the parents ranged from 17.50 - 47.00cm with GB 4735 having the shortest panicle (17.50cm) and G.I. 359-3 having the longest panicle. At the same location, hybrids panicle length ranged from 19.50-32.50 cm with hybrids H10.2 and H13.1 having the longest and shortst panicles, respectively (Appendix 5). At Bagauda panile length among the parents ranged from 24.00-38.50 cm; GI 6-2, had the longest panicle while Gwagawa hae the shortest panicle among the parents. Among the hybrids, however, panicle length ranged from 24.50-37.00 cm with H18.2 and H19.3 having the longest and shortest panicles, respectively (Table 13). For the locations combined the panicle length ranged from 21.25-37.00 cm among parentals, while among the

hybrids it ranged from 23.00-34.75 cm G.I. 359-3 had the longest panicle (37.26 cm) among the parents and H16.2 had the longest panicle (34.75 cm) among the hybrids. Comparatively, they were shorter than the checks (Table 8). The stimates of GCA for panicle length at Samaru showed that Gwagwa was the highest significant general combiner among the male parents for long panicle, while G.I. 165-6 was the highest general combiner among female parents (Appendix 7). At Baagauda, Gwagwa remained the highest general combiner for panicle length among the males while G.I. 435-4 was the highest general combiner among the females (Appendix 8) The stimate of GCA for panicle length for the locations combined; further showed Gwagwa as the highest general combiner among male parents for long panicle and G.I. 435-4 the highes general combiner among the female parents (Table 9). They hybrid of ACC 364-1 x Gwagwa, was the highest significant specific combination for panicle length at Samaru (Appendix 9) while at Bagauda, the hybrid of ICMP 94592 x Gwagwa, was the highest significant specific combination for the trait (Appendix 10). However, the hybrid of Buduma Gero 712-2 x Ex-Borno, for the combined locations, was the best specific combination for long panicle (Table 10).

Panicle width among the parents ranged from 1.90-3.35 cm at Samaru while among the hybrids, it ranged from 2.30-3.45cm with the hybrid, H5.3, having the largest diameter, exceeding the parents and checks (Appendix 5). At Bagauda among the parents panicle width ranged from 2.35 – 3.25cm, while among the hybrids it ranged from 2.20-3.20cm (Appendix 6). For the locations combined,

panicle width ranged from 2.17-3.5cm among the parents while among the hybrids it ranged from 2.30-3.15cm with the hybrid, H 13.3, having the largest diameter, exceeding the parents and checks for the locations combined (Table 8). The estimates of GCA for panicle width at Samaru showed that GB 8735 among the male parents had the highest significant general combining ability while ICMV 88908 among female parents was the highest general combiner (Appendix 7). Among the parents GB 8735 was the highest general combiner while ICMV 88908 remained the highest general combiner among the female parents at Bagauda (Appendix 8). The estimates of GCA for the locations combined for panicle width showed GB 8735 as the highest positive general combiner among the females (Table 9). The hybrid of G.I. 363-1 x GB 8735, was the best specific combination for panicle width at Samaru, Bagauda and for the locations combined (Appendices 9,10 and Table 10).

Parent performances for head weight, grain weight and grain yield ranged from 163.70 – 1576.34kg/ha; 69.35-1056.67kg/ha and 208-1364.50kg/ha, respectively, at Samaru. GB 8735, performed best for these traits among the parents. Also among the hybrids for head weight, grain weight, and grain yield, the range were from 328.65 – 1733.32kg/ha; 114.00-1148.67kg/ha and 331.50-2023.50kg/ha, respectively with the hybrids; H15.3 (1733.32kg/ha), H15.3 (1148.67kg/ha) and H16.3 (2023.50kg/ha) being the best specific combinations for head weight, grain weight and grain yield, respectively (Appendix 5). A similar trend was obtained among parents at Bagauda for head weight, grain weight, and grain yield which ranged from 405.95-2758.05kg/ha; 250.67-1917.33kg/ha and 508.00-2159.00kg/ha.

respectively, revealing GB 8735 as the best performer for all these traits. In the same vein among the hybrids, for head weight, grain weight and grain yield the ranges were from 480.48 – 3524.79kg/ha; 320.67-2577.33kg/ha and 836.20-3040.50kg/ha, respectively with hybrid H15.3 as the best performer for these traits (Appendix 6). For the locations combined, parental performances for head weight, grain weight and grain yield ranged from 380.86 – 2177.54kg/ha, 177.67-1489.00kg/ha and 355.75-1762.00kg/ha, respectively. GB 8735 was the best performer among the parental variety. Also among the hybrids for head weight grain weight and grain yield, the ranges were from 553.28-2672.88kg/ha; 285.33-1863.00kg/ha and 426.25-2249.00kg/ha, respectively.The hybrid, H15.3 performed highest for these characters. (Table 8). The estimates of GCA effect which was highly significant for head weight, grain weight and grain yield at Samaru, Bagauda and for the locations combined showed that GB 8735 was the best general combiner among the male parents (Appendices 7,8 and Table 9). Among the female parents, G.I. 363-1; G.I. 363-4 and G.I. 354-4 were the best general combiner for the same traits at Samaru, Bagauda and the locations combined, respectively, (Table 8).

The estimates of SCA at Samaru, indicated that H 1.2, H 11.1 and H 16.3 were the best specific combination for head weight grain weight and grain yield, respectively (Appendix 9). At Bagauda SCA estimates revealed the hybrid of G.I. 296-1 x GB 8735 and ICMV 93501 x Ex –Borno, as the best specific combination for head weight, grain weight and grain yield, respectively. However, for the two locations combined the hybrids of ICMV 93501 x Ex-Borno was observed to be the

highest significant specific combination for the same traits (Table 10).

For 1000-seed weight, the weight ranged from 6.55-11.50g among parents, while among the hybrids it ranged from 5.90-13.75g at Samaru (Appendix 5). At Bagauda, it ranged from 6.60-14.45g and from 8.10-14.80g, among the hybrids and the parents, respectively (Appendix 6). Among the parents, for the locations combined 1000-seed weight ranged from 6.80-13.0g and from 7.17-14.27g among hybrids ICMV 88908 and the hybrid H 13.3 had the highest weight of 11.60g and 14.27g, respectively. The estimates of GCA for 1000-seed weight was significant and revealed ICMP 91103 as the best general combiner among the female parents, while GB 8735 was the best general combiner among the male parents for increasing seed weight at individual location and for the locations combined (Appendices 7,8 and Table 9). The hybrid of ACC 364-1 x GB 8735 had the highest positive SCA for this same character for the locations combined (Table 10). At Samaru and Bagauda, however, the hybrids of G.I. 6-2 x Ex-Borno and G.I. 359-3 x Ex-Borno were the best significant specific combinations.

The Mean performances among the parents for crude protein content ranged from 8.84-10.41% with GB 8735 having the highest protein content, while among the hybrids, it ranged from 6.69-10.74% and the hybrid H 8.2 had the highest protein content at Samaru (Appendix 5). However, at Bagauda, protein content ranged from 8.91-10.17 among parents while among the hybrids it ranged from 8.61-11.16% with the hybrid H 17.1 having the highest protein content (Appendix 6). A range from 8.86-10.05% and from 8.86-10.74% was recorded among parents

and the hybrids, respectively for the locations combined. The line ICMP 91103 (10.05%) and the hybrid of G.I. 122-2 x GB 8735 (10.74%) gave the highest protein yield among the parents and the hybrids, respectively for the locations combined (Table 8). At individual or the locations combined, negative GCA and SCA were both recorded for crude protein content. At Samaru, G.I. 363-4 was the highest general combiner for protein content among female parents while Gwagwa was the best general combiner among the male parents (Appendix 7). At Bagauda, however, ICMV 93501 was the highest significant general combiner among the female parents while GB 8735 was the best general combiner for this trait among the male parents (Appendix 8). The variety GB 8735 recorded positive GCA for the same trait among female parents (Table 9). The hybrids of G.I. 363-4 x Gwagwa, ICMV 93501 x Ex-Borno and ACC 364-1 x Gwagwa were the best specific combinations with low, but positive SCA effect at Samaru, Bagauda and for the locations combined, respectively (Appendices 9, 10 and Table 10).

Threshing percentage value ranged from 30.86-67.,16% and from 40.73-72.49% among parents and hybrids, respectively at Samaru. The parent variety, GB 8735 and the hybrid of ICMV 91103 x GB 8735 had the highest threshing percentage (Table 5). Values ranging from 43-69.64% among the parents and from 50.13-73.12% among the hybrids were obtained at Bagauda. The line G.I. 6-2, among the parents and the hybrid of G.I. 47.3 x GB 8735 among the hybrids had the highest threshing percentage (Appendix 6). For the locations combined, however, values ranged from 40.91-68.38% and 46.94-70.92% among parents and hybrids.

respectively (Table 8). GB 8735 among the male parents had the highest GCA estimates at Samaru and Bagauda while Gwagwa, for the locations combined was the highest general combiner among the male parents in increasing threshing percentage. Among the female parents G.I. 363-1; G. I. 363-4 and G. I. 410-8 gave the highest GCA estimates at Samaru, Bagauda and for the two locations combined, respectively for threshing percentage (Appendices 7,8 and Table9). The hybrids of G.I. 122-2 x Ex-Borno and G.I. 75.1 x Ex-Borno were the best specific combinations for this trait at Samaru and Bagauda; respectively. However, for the locations combined, the hybrid of G.I. 269-1 x Gwagwa was the best specific combinations (Appendices 9,10 and Table 10).

There was no good relationship between GCA and per se performance of all the parents for all the traits (Table 11). The proportionate contribution of females, males and their interactions (male x female) to the total variance, expressed in percentage is presented on Table 12. Female parents contributed to the expression of number of days to 50% flowering (62.55%), plant height (45.90%) and 1000-seed weight (73.06%).

Table 11: Best Performing parents and hybrid on the basis of *per se* performance and combining ability for eleven characters in pearl millet in. 1996

Characters	Parent Per se Perfomance		General Combiners		Hybrid Per se Performance	Specific Combiners
	Lines	Varieties	Lines	Varieties	G.I. 363-1 x Gwagwa	
1. Number of tillers/plant	G.I. 6-2	GB 8735	G.I 363-1	Gwagwa	G.I 410-8 x Ex-Borno	G.I 75-1 x GB 8735
	G.I 122-2		*ICMP 91103*		*Buduma Gero 712-2 Gwagwa*	
2. *Days to 50% flowering*	ICMV 88908	GB 8735	ICMV 93501	GB 8735	G.I 363-1 x GB 8735	ICMV 93501 x Gwagwa
3. Plant height (cm)	ICMV 88908	GB 8735	*ACC 1009-2*	GB 8735	*ICMP 91103 x GB 8735*	ACC 364-1 x Ex-Borno
4. Panicle length (cm)	G.I 359-3	Ex-Borno	G.I 435-4	Gwagwa	ACC 364-1 x Gwagwa	Buduwa Gero 712-2 x Ex-Borno
5. Panicle width (cm)	ICMP 94592	GB 8735	ICMV 889-8	GB 8735	*ICMP 91103 x GB 8735*	G.I 47-3 x GB 8735
6. Head weight (kg/ha)	G.I 363-1	GB 8735	G.I 435-4	GB 8735	G.I 47-3 x GB 8735	ICMV 93501 x Ex-Borno
7. Grain weight (kg/ha)	G.I. 363-1	GB 8735	G.I 435-4	GB 8735	G.I 47-3 x GB 8735	ICMV 93501 x Ex-Borno
8. Grain Yield (kg/ha)	G.I 363-1	G3 8735	G.I 4354	GB 8735	G.I 473 x GB 8735	ICMV 93501 x Ex-Borno
9. 1000-seed weight (g)	ICMV 88908	GB 8735	ICMP 91103	GB 8735	G.I 296-1 x GB 8735	ACC 364-1 x GB 8735
10. Crude protein (%)	ICMP 91103	Gwagwa	G.I 122-2	GB 8735	G.I 75-1 x GB 8735	ACC 364-1 x Gwagwa
11. Threshing (%)	ICMV 88908	Gwagwa	G.I 4108	Gwagwa	ICMV 88908 x GB 8735	G.I 165-6 x Ex-Borno

Table 12: Proportionate Contribution of lines, varieties and their interaction to total variance (%)

Characters	Line (females)	Varieties (Males)	Lines x Varieties (Males x Females)
1. Number of Tillers	27.03	3.911	69.06
2. Days to 50% flowering	30.42	62.55	7.033
3. Plant height (cm)	30.33	45.90	23.76
4. Panicle length (cm)	50.86	12.03	37.11
5. Panicle width (cm)	62.97	6.995	30.04
6. Head weight (kg/ha)	35.19	19.59	45.23
7. Grain weight (kg/ha)	33.73	28.06	38.21
8. Grain yield (kg/ha)	30.07	29.09	40.84
9. 1000-seed weight (g)	17.81	73.06	9.125
10. Crude protein (%)	22.51	3.145	74.34
11. Threshing percentage	32.97	5.227	61.79

4.3 Heteorsis

Heterosis for individual crosses expressed as percentage increase or decrease of hybrid mean over the mean of the high-parent (heterobeltiosis, % HP) or the mid-parent (heterosis, % MP) for individual and combined locations are presented on Appendices 11.12 and Table 13. Estimates expressed as % HP were generally smaller than corresponding estimates expressed as % MP. It is therefore more meaningful to compare the F_1 vigour with the high –parent rather than with the mid-parent, since this gives an estimate of improvement made over the high parent.

Highest significant heterosis (66.6% HP, 100.00%) MP) for the number of tillers/plant was exhibited by the hybrid of Buduma Gero 712.2 x Gwagwa, at Samaru (Appendix 11) while at Bagauda, highest significant heterosis (80% HP, 80% MP) for these same traits was exhibited by the hybrids of G.I. 435-4 x Gwagwa and G.I. 41-3 x Gwagwa (Appendix 12). For the two locations combined, however, highest significant heterosis (47.62% HP, 75.00% MP) for the number of tillers/plant was exhibited by the hybride of Buduma Gero 712-2 x Gwagwa.

The hybrid of G.I. 6-2 x GB 8735, at Samaru had the highest significant negative heterosis (-75% HP, -69.25% MP) for the number of days to 50% flowering (Appendix 11) while at Bagauda, the hybrid of G.I. 296-1 x Ex-Borno, had the highest significant negative heterosis (-50.00% HP, - 38.46% MP) for the same trait (appendix 12). For the locations combined, the hybrid of Buduma Gero 712.2 x Ex-Borno expressed the highest significant negative heterosis (-48.22% HP, -47.76% MP) considered advantageous for the number of days to 50% flowering (Table 13).

Table 13: Heterosis of hybrids over mid-parent and superior-parent (MP% x HP%) for eleven characters in pearl millet for combined locations (Samaru and Bagauda, 1996)

Hybrids	Pedigree	Number of Tillers		Days to 50% flowering		Plant height (cm)		Panicle length (cm)		Panicle width (cm)	
		MP	HP	MP	HP	MP	HP	MP	HP	MP	HP
H1.1	G.I 6-2 x Ex-Borno	-12.38**	-18.79**	-40.56**	-33.34**	4.62	-18.45	8.05*	-7.53**	10.56**	-24.29**
H1.2	G.I 6-2 x Gwagwa	-9.52**	-21.43**	-37.88**	-44.05**	6.40	4.28	9.08**	3.10	-1.84	-17.53**
H1.3	G.I 6-2 x GB8735	-26.67**	-33.34**	-39.16**	-45.84**	8.49	-6.74	7.78**	-3.50	9.61**	-11.59**
H2.1	G.I 75-1 x Ex-Borno	-25.00**	-35.42**	-14.29**	-27.09**	7.25	0.78	1.15	-8.52**	0.54*	-7.02**
H2.2	G.I 75-1 x Gwagwa	16.65**	10.00**	-5.3*	-13.10**	-2.52	-6.73	-1.44	-6.09*	20.50**	8.61**
H2.3	G.I 75-1 x GB8735	19.45**	-10.42**	-8.34**	-21.14**	2.34	-8.59	0.01	-11.31**	20.39**	4.02**
H3.1	G.I 122-2 x Ex-Borno	-12.94**	-22.22**	-33.34**	-39.59**	1.35	0.06	-2.27	-7.98**	-0.16	-8.47**
H3.2	G.I 122-2 x Gwagwa	321.43**	5.55**	-9.79**	-21.43**	-1.77	-4.50	3.66	0.92	5.81**	-5.15**
H3.3	G.I 122-2 x GB8735	-38.97**	-52.78**	4.49	-13.40**	-0.55	-15.58	12.98	-3.98	11.10**	-4.69**
H4.1.	G.I 165-6 x Ex-Borno	-17.15**	-29.17**	4.45	-22.92**	4.95	0.78	3.08	2.17	-18.32**	-21.77**
H4.2	G.I 165-6 x Gwagwa	30.91**	16.67**	-6.16*	-21.43**	3.51	1.22	5.60	1.27	-6.48**	-22.49**
H4.3	G.I 165-6 x GB8735	-46.43**	-58.34**	9.79**	-13.40**	5.59	-7.91	3.83	-10.13	7.15**	-14.07**
H5.1	G.I 296-1 x Ex-Borno	20.46**	-18.75**	-32.87**	-41.67**	1.30	-2.02	2.85	-3.10	1.58**	-6.25**

Table 13 Cont

Hybrid	Pedigree	Head weight (kg/ha)		Grain weight (kg/ha)		Grain Yield (kg/ha)		1000-seed weight (g)		Crude Protein (%)		Threshing (%)	
		MP	HP	MP	HP	MP	HP	MP	HP	MP	HP	MP	HP
H1.1	G.I 6-2 x Ex-Borno	-6.65	-7.15	-30.19	-43.95	-32.49	-43.83	-26.44	-34.88	-5.44**	-15.53**	2.89	[illegible]
H1.2	G.I 6-2 x Gwagwa	-7.28	-9.04	-8.29	-20.98	-24.35	-32.01	-20.04	-25.69	-15.59**	-23.85**	-3.71	[illegible]
H1.3	G.I 6-2 x GB8735	-16.52	-21.96	-27.61	-43.84	-29.46	-45.89	-20.95	-31.21	15.91**	-25.58**	2.96	1.66
H2.1	G.I 75-1 x Ex-Borno	-1.68	-6.82	-48.96	-55.20	-44.07	-50.48	-21.89	-35.70	-7.90**	-16.68**	0.85	-0.16
H2.2	G.I 75-1 x Gwagwa	-5.3	-9.58	15.69	-9.09	7.45	-17.18	6.78**	-11.49	14.62**	-16.59**	0.34	-0.32
H2.3	G.I 75-1 x GB8735	-16.48	-23.28	41.99	1.24	48.06	2.25	54.21**	14.55**	10.17**	-3.50**	1.34	0.32
H3.1	G.I 122-2 x Ex-Borno	5.36	-0.09	-47.15	-59.04	-49.92	-59.96	-37.47	-45.55	8.71**	6.25**	-0.80	-3.81
H3.2	G.I 122-2 x Gwagwa	1.39	-1.62	-18.00	-38.66	-16.27	-40.49	-14.95	-34.79	3.6**	-1.78**	2.27	-0.22
H3.3	G.I 122-2 x GB8735	3.06	-7.91	30.06	-7.90	27.95	-14.24	14.65**	-18.48	14.36**	-3.33**	8.08	1.81
H4.1	G.I 165-6 x Ex-Borno	-5.37	-7.58	-11.96	-12.81	-3.47	-4.89	3.69**	1.45	-2.59**	-3.01**	6.97	5.76
H4.2	G.I 165-6 x Gwagwa	11.93	6.14	-14.75	-23.52	-17.36	-26.93	-7.71	-19.69	-5.34**	-8.92**	4.08	1.31
H4.3	G.I 165-6 x GB8735	-5.56	-17.46	-10.07	-25.56	-7.45	-28.02	-5.18	-24.58	7.90**	-10.17**	5.40	3.06
H5.1	G.I 296-1 x Ex-Borno	-7.65	-12.40	-51.22	-59.49	-45.64	-53.16	-42.37	-51.82	-2.76**	-15.22**	1.67	-2.38

Table 13 Cont .

Hybrids	Pedigree	Number of Tillers		Days to 50% flowering		Plant height (cm)		Panicle length (cm)		Panicle width (cm)	
		MP	HP	MP	HP	MP	HP	MP	HP	MP	HP
H5.2	G.I 296-1 x Gwagwa	62.50**	16.67**	-20.46**	-28.57**	-3.39	-4.81	1.83	-1.98	0.44	-8.98 **
H5.3	G.I 296-1 x GB8735	-11.69**	-43.75**	-8.39**	-20.84**	-4.01	-16.86	11.86**	-1.92	26.81**	9.79**
H6.1	G.I 359-3 x Ex-Borno	28.21**	16.67**	-5.56*	-22.92**	-3.26	-5.15	5.05	-4.25	15.18**	-28.27**
H6.2	G.I 359-3 x Gwagwa	26.67**	-6.67**	-1.67	-13.10**	-3.33	-6.50	7.00*	-0.15	-3.97**	-16.93**
H6.3	G.I 359-3 x GB 8735	20.51**	22.92**	-13.64**	-25.00**	-0.39	-15.61	9.33**	-1.18	0.70**	-14.41**
H7.1	G.I 363-1 x Borno	-21.43**	-31.25**	25.00**	-6.25**	2.25	-4.92	8.71**	-3.48	15.52**	10.19**
H7.2	G.I 363-1 x Gwagwa	48.06**	33.34**	2.78	-13.10**	-1.51	-7.24	8.48**	0.41	28.65**	21.51**
H7.3	GI 363-1 x GB8735	-2.86**	-16.67**	-8.34*	-27.09**	2.66	-7.18	24.86**	13.53**	18.48**	6.76**
H8.1	G.I 363-4 x Ex-Borno	-10.00**	-22.92**	-1.59	-20.84**	-4.44	-11.53	-5.27	-13.06**	2.15*	-12.24**
H8.2	G.I 363-4 x Gwagwa	-7.28**	-16.67**	-11.67**	-20.24**	-2.50	-8.27	0.18	-6.69*	10.27**	-7.06**
H8.3	GI 363-4 x GB8735	-39.29**	-52.09**	-13.64**	-25.00**	-5.35	-14.52	10.89**	0.33	2.89**	-16.71**
H9.1	G.I 410-8 x Ex-Borno	76.67**	29.17**	-25.00**	-39.59**	0.28	-0.71	-4.69	-11.23**	-3.05**	-5.37**
H9.2	G.I 410-8 x Gwagwa	18.34**	0.80	-16.67**	-28.57**	-5.72	-7.86	1.94	-3.86	1.93**	-3.12**
H9.3	G.I 410-8 x GB 8735	-35.00**	-45.84**	-28.34**	-39.59**	3.75	-12.33	16.39**	4.05	15.93**	9.46**

Table 13 Cont.

Hybrids	Pedigree	Head weight (kg/ha)		Grain weight (kg/ha)		Grain Yield (kg/ha)		1000-seed weight (g)		Crude Protein (%)		Threshing (%)	
		MP	HP	MP	HP	MP	HP	MP	HP	MP	HP	MP	HP
H5.2	G.I 296-1 x Gwagwa	-1.97	-4.87	-28.46	-43.24	-32.12	-47.92	22.46**	-10.31	1.27 *	-4.91**	-5.63	-7.75
H5.3	G.I 296-1 x GB8735	-7.13	-17.02	19.77	-8.02	24.70	-9.22	30.82**	-5.33	13.66**	6.24**	-4.76	-7.16
H6.1	G.I 359-3 x Ex-Borno	-11.49	-33.38	-9.63	-30.54	-1.97	-23.86	9.92**	-9.22	11.61**	9.39**	-0.77	-4.19
H6.2	G.I 359-3 x Gwagwa	-7.88	-16.22	-5.17	-28.42	-11.21	-35.82	10.62**	-18.50	-1.83**	-10.28**	-3.55	-5.16
H6.3	G.I 359-3 x GB 8735	-20.06	-21.10	20.76	-14.34	25.01	-16.16	27.97**	-11.04	15.57**	-8.57**	0.31	-2.29
H7.1	G.I 363-1 x Borno	0.06	-8.39	-27.93	-31.55	-24.68	-29.87	-32.21	-42.25	1.21*	-8.26**	3.05	0.98
H7.2	G.I 363-1 x Gwagwa	9.65	2.67	24.46	14.97	33.30	22.51	31.59**	22.81**	10.00**	7.57**	-0.48	-1.02
H7.3	G.I 363-1 x GB8735	4.24	-9.79	13.47	-4.61	19.89	-2.92	42.34**	25.12**	14.23**	-0.43	1.99	0.76
H8.1	G.I 363-4 x Ex-Borno	5.43	-1.16	45.13	5.24	77.47	35.22	66.14**	40.74**	15.79**	0.61	-0.17	-2.13
H8.2	G.I 363-4 x Gwagwa	6.71	3.52	14.57	-18.99	19.05	-17.48	20.57**	-10.56	-5.07**	-11.77**	7.37	5.80
H8.3	G.I 363-4 x GB8735	-0.95	-10.54	19.63	-36.25	22.40	-19.85	11.32**	-15.82	9.91**	-0.82	1.56	1.29
H9.1	G.I 410-8 x Ex-Borno	1.98	-5.62	25.82	-19.74	16.30	-23.90	14.66**	-16.78	-10.87**	-13.90**	0.11	-2.78
H9.2	G.I 410-8 x Gwagwa	6.63	0.93	-13.72	-43.96	-24.10	-50.58	-20.32	-46.39	1.75**	-4.42**	0.35	1.71
H9.3	G.I 410-8 x GB 8735	-0.30	-12.85	-21.76	-50.13	-30.42	-54.78	-21.93	-48.58	1.16**	-15.62**	2.35	0.09

Table 13 Cont.

Hybrids	Pedigree	Number of Tillers		Days to 50% flowering		Plant height (cm)		Panicle length (cm)		Panicle width (cm)	
		MP	HP	MP	HP	MP	HP	MP	HP	MP	HP
H10.1	G.I 435-4 x Ex-Borno	26.168**	-29.17**	5.56*	-14.59**	-0.13	-7.52	0.89	-0.66	1.94**	-11.58**
H10.2	GI 435-4 x Gwagwa	50.00**	40.00**	0.00	-14.29**	-1.28	-6.90	-5.17	-13.66**	12.77**	-5.01**
H10.3	G.I 435-4 x GB 8735	-8.66**	-31.25**	12.88**	-4.17	-5.16	-14.37	8.93**	0.63	20.90**	-1.03**
H11.1	ACC 1009-2 x Ex-Borno	26.16**	4.17**	5.56*	-14.59**	-0.66	-9.06	-7.37	-14.78**	-9.22**	-21.19**
H11.2	ACC 1009-2 x Gwagwa	-20.00**	-26.67	-28.34**	-36.91**	0.49	-6.64	-4.98	-10.13**	-3.54**	-17.46**
H11.3	ACC 1009-2 x GB 8735	-11.54**	-35.42	-4.55	-18.75**	-1.34	-9.74	5.38*	-5.91	10.21**	-10.32**
H12.1	Buduma Gero 712-2 x Ex-Borno	-20.00**	-29.17	-41.76**	-48.22**	0.05	-0.91	-5.31	-12.38**	12.22**	-8.79**
H12.2	Buduma Gero 712-2 x Gwagwa	75.00**	47.62**	-4.77**	-6.41**	-2.16	-4.85	-1.69	-6.41*	0.20	-4.06**
H12.3	Buduma Gero 712-2 x GB8735	-35.00**	-45.84	-38.34**	-39.59**	0.86	-15.67	7.61*	-4.49	6.56**	-1.68**
H13.1	ICMV 8890 x Ex-Borno	13.85**	-6.25**	-16.67**	-39.56**	4.37	-6.24	3.46	-12.62**	-2.76**	-7.09**
H13.2	ICMV 88908 x Gwagwa	10.00**	3.34**	12.34**	-11.91**	5.85	-1.64	0.29	-5.38*	9.18**	3.71**
H13.3	ICMV 88908 x GB8735	-36.54**	-52.09**	10.00**	-18.75**	3.38	-3.88	21.95**	-14.76**	18.66**	13.07**

Table 13. Cont

Hybrids	Pedigree	Head weight (kg/ha)		Grain weight (kg/ha)		Grain Yield (kg/ha)		1000-seed weight (g)		Crude Protein (%)		Threshing (%)	
		MP	HP	MP	HP	MP	HP	MP	HP	MP	HP	MP	HP
H10.1	G.I 435-4 x Ex-Borno	6.15	-3.84	69.69	-3.78	91.56	59.41	77.03**	66.01**	-7.05**	-16.78**	0.96	-3.18
H10.2	GI 435-4 x Gwagwa	11.83	3.59	54.51	21.20	28.57	4.13	17.32**	-1.94	-11.26**	-15.09**	0.73	-0.10
H10.3	G.I 435-4 x GB 8735	-1.14	-15.37	31.77	1.60	38.00	2.93	28.69**	-1.78	6.68**	-5.63**	-0.06	-1.53
H11.1	ACC 1009-2 x Ex-Borno	-6.49	-11.87	37.48	20.75	63.88	50.71	64.64	-58.41	11.61**	-7.84**	4.07	3.08
H11.2	ACC 1009-2 x Gwagwa	-0.61	-4.05	-27.38	-35.96	-33.88	-39.89	-22.01	-30.26	13.59**	6.57**	-0.76	-1.77
H11.3	ACC 1009-2 x GB 8735	-6.79	-17.13	-5.38	-23.51	-10.23	-29.63	2.34*	-19.39	8.83**	-7.40**	2.27	2.19
H12.1	Buduma Gero 712-2 x Ex-Borno	-7.00	-10.17	-50.99	-65.35	54.32	-66.35	-37.52	-54.76	4.40**	-4.17**	2.14	-6.21
H12.2	Buduma Gero 712-2 x Gwagwa	-8.20	-9.26	0.69	-31.71	-11.56	-42.64	36.69**	-12.38	-0.09	-10.23**	-3.62	-5.12
H12.3	Buduma Gero 712-2 x GB8735	-12.67	-20.65	-4.67	-39.86	-8.38	-45.48	1.50	-39.47	20.29**	-4.11**	2.51	0.10
H13.1	ICMV 8890 x Ex-Borno	10.61	10.09	-4.34	-31.30	5.23	-17.94	39.58**	16.20**	-2.77**	-22.76**	2.13	0.49
H13.2	ICMV 88908 x Gwagwa	7.82	6.90	-16.49	-30.61	-16.75	-29.78	-8.33	-22.43	-6.85**	-12.87**	2.13	0.49
H13.3	ICMV 88908 x GB8735	11.17	-3.95	2.64	-29.44	6.93	-55.83	17.75**	-15.73	16.79**	10.74**	3.19	1.09

Table 13 Cont.

Hybrids	Pedigree	Number of Tillers		Days to 50% flowering		Plant height (cm)		Panicle length (cm)		Panicle width (cm)	
		MP	HP	MP	HP	MP	HP	MP	HP	MP	HP
H14.1	G.I 41-3 x Ex-Borno	-0.96	-20.00**	1.59	-16.67**	1.69	0.00	4.15	-15.71**	-6.97 **	-17.55**
H14.2	G.I 41-3 x Gwagwa	15.00**	10.00**	-1.67	13.10**	3.71	3.01	0.32	-4.76	13.07**	-2.50**
H14.3	G.I 41-3 x GB8735	-9.79**	-22.92**	-12.88**	-27.09**	5.03	-10.27	7.32**	-4.51	19.57**	-0.75**
H15.1	G.I 47-3 x Ex-Borno	-38.34**	-52.09**	-12.50**	-37.50**	1.50	-0.42	24.63**	-12.21**	-2.05**	-6.88**
H15.2	G.I 47-3 x Gwagwa	62.22**	43.34**	-17.78**	-35.72**	6.34	5.50	10.90**	-3.12**	3.26**	-3.96**
H15.3	G.I 47-3 x GB8735	8.34**	-22.92**	50.00**	10.42**	-2.76	-16.76	25.33**	21.17**	9.33**	-2.92**
H16.1	ACC 364-1 x Ex-Borno	-13.85**	-29.17**	8.66**	-20.84**	-0.94	-1.92	-9.74**	-18.02**	5.34**	-6.81**
H16.2	ACC 364-1 x Gwagwa	20.00**	13.64**	-1.01	-21.43**	-4.54	-6.15	-2.03	-8.57**	28.84**	12.56**
H16.3	ACC 364-1 x GB8735	-8.66**	-31.25**	-5.46*	-25.00**	-3.87	-18.29	18.68**	7.10**	10.89**	7.74**
H17.1	ICMV 93501 x Ex-Borno	6.67**	4.17**	1.250	-14.59**	-5.42	-10.86	0.31	-9.62**	2.29**	-4.03**
H17:2	ICMV 93501 x Gwagwa	-25.00**	-30.95**	-16.57**	-28.50**	-17.72	-21.25	3.26	-4.76	10.45**	1.77**
H17.3	ICMV 93501 x GB8735	-8.89**	-22.92**	-16.67**	-35.42**	-2.49	-13.47	4.64	-11.25**	2.36**	-10.12**
H18.1	ICMP 94592 x Ex-Borno	1.67*	-18.75**	-16.35**	-37.50**	4.02	-5.72	-0.36	-10.99**	-9.07**	-19.17**
H18.2	ICMP 94592 x Gwagwa	17.78**	3.34**	10.10**	-14.29**	2.91	-5.19	-0.54	-8.97**	10.37**	2.76**

Table 13 Cont.

Hybrids	Pedigree	Head weight (kg/ha)		Grain weight (kg/ha)		Grain Yield (kg/ha)		1000-seed weight (g)		Crude Protein (%)		Threshing (%)	
		MP	HP	MP	HP	MP	HP	MP	HP	MP	HP	MP	HP
H14.1	G.I 41-3 x Ex-Borno	7.27	-2.94	15.01	-9.87	16.64	8.18	30.05**	15181**	4.35**	-9.58 **	1.22	0.20
H14.2	G.I 41-3 x Gwagwa	-0.88	-8.57	-18.19	-32.71	-36.81	-46.55	-32.28	-40.31	0.41	-13.48**	4.47	3.38
H14.3	G.I 41-3 x GB8735	10.70	-5.54	17.06	-14.96	11.03	-16.36	13.39**	-7.25	27.03**	-2.53 **	1.73	1.57
H15.1	G.I 47-3 x Ex-Borno	-51.5	-7.76	21.85	-23.98	47.36	-9.52	44.89**	-1.39	-5.49**	-11.5**	2.11	-0.89
H15.2	G.I 47-3 x Gwagwa	-0.86	-2.81	7.69	-33.70	8.84	-36.48	14.84**	-27.37	-0.68	-12.75**	-0.86	-1.99
H15.3	G.I 47-3 x GB8735	6.05	0.67	101.02	18.93	115.70	21.37	104.62**	23.81**	8.56**	-6.80**	-1.35	-3.41
H16.1	ACC 364-1 x Ex-Borno	-7.19	-14.64	21.06	-19.41	36.34	-10.23	43.47**	2.91**	-7.90**	-12.66**	-3.13	-1.18
H16.2	ACC 364-1 x Gwagwa	2.80	-2.89	-3.26	-37.26	-9.37	-43.14	1.61	-33.59	0.87	-3.99**	7.92	7.12
H16.3	ACC 364-1 x GB8735	-2.83	-15.71	50.69	-6.34	55.91	-8.07	104.95**	25.72**	23.59**	1.65**	4.08	2.36
H17.1	ICMV 93501 x Ex-Borno	10.40	4.73	88.50	35.55	130.46	60.44	93.97**	49.17**	14.49**	8.81**	9.32	6.95
H17.2	ICMV 93501 x Gwagwa	10.37	7.29	-40.95	50.46	-50.31	62.93	38.96	-54.26	6.84**	-17.70**	3.04	-4.39
H17.3	ICMV 93501 x GB8735	-4.19	-14.39	-11.39	-37.87	-9.87	-39.55	-2.32	-32.72	10.28**	-6.58**	1.20	1.96
H18.1	ICMP 94592 x Ex-Borno	-4.11	-6.28	29.00	-19.83	51.90	-9.19	61.78**	8.62**	6.02**	4.29**	5.83	2.70
H18.2	ICMP 94592 x Gwagwa	-3.36	-7.72	15.72	-29.05	24.86	-28.19	17.94**	-26.16	10.18**	1.15*	3.18	0.05

Table 13 Cont.

Hybrids	Pedigree	Number of Tillers		Days to 50% flowering		Plant height (cm)		Panicle length (cm)		Panicle width (cm)	
		MP	HP	MP	HP	MP	HP	MP	HP	MP	HP
H18.3	ICMP 94592 x GB8735	-29.17	-50.00	-24.55**	-39.59**	10.17	4.12	4.13	4.11	-0.60**	-16.86**
H19.1	ICMP 91103 x Ex-Borno	31.25**	6.25**	25.00**	-6.25**	-4.73	-10.20	0.82	-10.50	-13.59**	-24.03**
H19.2	ICMP 91103 x Gwagwa	61.54**	16.67**	44.45**	16.67**	-11.06	-14.52	9.44**	-0.64	8.19**	-8.48**
H19.3	ICMP 91103 x GB8735	0.90	-22.92	-8.34**	-27.19**	-4.54	-15.31	0.63	-6.47	-12.36**	-28.56**
	SE ±	0.85	0.73	2.49	2.15	20.95	18.14	3.17	2.74	0.23	0.21
	LSD 5%	1.66	1.44	4.87	4.22	41.05	35.55	6.20	5.37	0.45	0.40
	LSD 1%	2.18	1.89	6.40	5.54	53.95	46.73	8.15	7.06	0.59	0.53

Note: *, **: Significant at 5% and 1% level of probability respectively
(^{H}1.1) = G.I. x Ex-Borno, (^{H} 2.2) = G.I. 75-1 x Gwagwa, (^{H} 3.3) = G.I. 122-2 x GB8735

Table 13 Cont.

Hybrids	Pedigree	Head weight (kg/ha)		Grain weight (kg/ha)		Grain Yield (kg/ha)		1000-seed weight (g)		Crude Protein (%)		Threshing (%)	
		MP	HP	MP	HP	MP	HP	MP	HP	MP	HP	MP	HP
H18.3	ICMP 94592 x GB8735	-8.27	-11.86	-0.35	-40.90	-13.55	-51.31	-13.41	-47.86	4.78**	-16.75	3.37	1.74
H19.1	ICMP 91103 x Ex-Borno	-4.13	-5.45	26.74	-12.32	58.36	7.85	50.32**	20.37**	36.06**	31.27**	-1.26	-5.76
H19.2	ICMP 91103 x Gwagwa	2.78	1.78	84.60	23.56	90.39	22.82	59.70**	14.16**	16.65**	10.65**	-1.22	-4.09
H19.3	ICMP 91103 x GB8735	2.95	-4.51	19.67	-20.55	32.39	-17.82	47.28**	-2.18	21.04**	-0.17	-1.63	-5.41
	SE ±	353.84	306.43	246.86	213.79	386.78	334.96	1.16	1.01	0.58	0.50	7.07	6.13
	LSD 5%	693.52	600.60	483.85	419.02	758.09	656.52	2.28	1.98	1.14	0.98	13.86	12.02
	LSD 1%	911.48	789.36	635.91	550.72	996.35	862.86	3.00	2.60	1.49	1.29	18.21	15.80

*, **: Significant at 5% and 1% level of probability respectively

Note: (^{H}1.1) = G.I. x Ex-Borno, (^{H} 2.2) = G.I. 75-1 x Gwagwa, (^{H} 3.3) = G.I. 122-2 x GB8735

Highest significant negative heterosis (-37.00% HP, 5.4% MP) for plant height was exhibited by the hybrid of G.I. 6-2 x Ex-Borno at Samaru (Appendix 11) while at Bagauda it was exhibited by the hybrid of G.I. 75-1 x GB 8735 (-18.97% HP, -6.00% MP) (Appendix 12). The hybrid of ICMV 93501 x Gwagwa had the highest negative heterosis (-21-25% HP, -17.72% MP) for plant height, for the locations combined (Table 13).

Heterosis in most of the hybrids for panicle length was positive but the highest significant heterosis (26.73% HP, 33.89% MP) was exhibited by the hybrid of ICMV 88908 x GB 8735 at Samaru (appendix 11) and by the hybrid of G.I. 47-3 x Ex-Borno (19.37% HP, 29-66% MP) at Bagauda (Appendix 12). The hybrid of G.I. 47-3 x GB 8735, however had the highest significant heterosis (21.17% HP, 25.33% MP) for panicle length for the two locations combined (Table 13). For panicle width, the hybrid, H 13.3 had the highest significant heterosis (37.14% HP, 39.15% MP) at Samaru (Appendix 11) while at Bagauda, the hybrid, H 7.2 had the highest significant positive heterosis (17.54% HP, 27.62% MP)(Appendix 12). Generally, for the locations combined, the hybrid of G.I. 361-1 x Gwagwa, expressed the highest significant positive heterosis (21.54% HP) for panicle width, (Table 13).

Generally, low positive and negative heterosis were recorded for head weight (Appendices 11, 12 and Table 13). The hybrid, H 17.2 expressed the highest positive heterosis (14.56 % HP, 18.28% MP) at Samaru while the hybrid, H 13.1 recorded the highest heterosis (14.29% HP) at Bagauda. The hybrid of ICMV 88908 x Ex-Borno, expressed the highest positive heterosis (10.09% HP) among all the hybrids for the

two locations combined. The highest positive heterosis for grain weight was exhibited by the hybrids H 17.1 (64.41% HP, 161.36% MP), H 15.3 (28 .44% HP, 127.7% MP) and H 17.1 (35.55% HP) at Samaru, Bagauda and for the locations combined, respectively (Appendices 11,12 and Table 13). Among the hybrids at Samaru, the hybrid H 17.1 exhibited the highest heterosis (110.82% HP, 246.15% MP) for grain yield while the hybrid H 15.3 exhibited the highest heteroris (34.24% HP, 136.60% MP) for the same trait at Bagauda (appendices 12 and 13). Nine out of the 57 hybrids for the locations combined, recorded a very high positive heterosis for grain yield where the hybrid of ICMV 93501 x Ex-Borno had the highest heteroris (60.44% HP, 130.46% MP).

Significant positive heterosis over the high-parent (98.80% HP, 118.25% MP) was recorded by the hybrid H 10.1 at Samaru for 1000-seed weight while at Bagauda, the hybrid H 8.1 recorded the highest positive heterosis (55.13% HP, 102.17% MP) for the same trait (Appendices 11 and 12). Of the 57 hybrids only 13 recorded positive heterosis over the high parent for 1000-seed weight for the locations combined with the hybrid of ICMV 93501 x Ex-Borno exhibiting significant heterosis (49.17% HP, 93.97% MP), (Table 13).

For protein content (%), most of the hybrids were lower than their superior parents as indicated by the unfavourable (negative) heterosis at individual location as well as for the locations combined. However, the hybrid, H 17.1 expressed significant heterosis (34.88% HP, 35.94% MP), at Samaru (Appendix 11), while the hybrid H 19.1 expressed highly significant heterosis (29.21% HP, 31.82% MP) and (31.27%

HP, 36.06% MP) at Bagauda and for the locations combined, respectively (Appendices 12 and Table 13).

Heterosis for threshing percentage were generally low and some hybrids recorded negative heterosis. Favourable significant positive heterosis of upto 16.79% HP at Samaru, 17.35% HP at Bagauda and 7.62% HP for the locations combined over the high-parent were observed in the hybrids H 8.2, H 17.1 and H 16.2, respectively.

CHAPTER FIVE

5.0 DISCUSSION

The significant differences observed among the genotypes for all the traits except for protein content indicated that an appreciable amount of genetic variability exist in the parent materials used in this study. Falconer (1981), pointed out that the amount of improvement that can be achieved by selection among a number of crosses is dependent on the amount of variation between the crosses and the intensity of selection, since selection is ultimately applied to the crosses. In this study, the hybrids differed significantly for all the characters measured except for protein content, indicating that these materials could be selected for the genetic improvement of grain yield in peal millet. Top-cross test has been recommended as the most practical approach to survey the combining ability of lines when the number of lines under study or test is large (Simmond 1979). The data obtained from the present investigation showed that combining ability of lines may largely depend on the genetic nature of the tester. Perhaps, the average GCA estimates of 3-4 broad based tester may be much reliable as suggested by Simmond (1979). Since three broad based testers were used in the present investigation, it is assumed that the information generated with these testers were reliable.

Combining ability gives the relative importance of GCA or SCA effects to the total genetic variability present in a population. This serves as a useful tool to plant breeders since breeding methodologies depend upon the behaviour of gene action that controls a particular character within a population. A comparison of pollinators and their top crosses by Mahalkshmi *et al.*, (1992) showed that top crossing improved yield

potential while retaining the genetic heterogeneity in top crosses, and maintaining the yield stability. The top cross hybrids were high yielding with improved adaptability and stability. Increasing stability with increasing cultivar heterogeneity from a single, double or top cross have been reported in sorghum (Jewet, 1972, Patanothai and Atkin, 1974), maize (Weatherson, 1970) and Rye (Becker *et al.*, 1982).

In this study the significant GCA and SCA mean squares for males, for number of days to 50% flowering, plant height, panicle length, head weight, grain weight and grain yield revealed the importance of non-additive gene action in controlling these characters because the male x female interaction mean squares for these characters were significant. This indicated that the genes for the characters concerned may not be easily fixed and therefore may segregate which suggest a good index for selection in hybrid production.

For number of days to 50% flowering, the male parent GB 8735 and female parent, ICMV 93501 were very important in reducing flowering date as reflected by the significant negative GCA. Incidentaly, the hybrid of ICMV 93501 x Gwagwa, had significant negative SCA, suggesting that they could be used to improve earliness in millet hybrids. Similar results were obtained by Rai and Singh (1975) in pearl millet.

The estimates of GCA for plant height, showed that GB 8735 had significant negative GCA among the male parents while ACC 1009-2 among the female parents, had the highest negative GCA, thus indicating their importance in reducing plant height for the improvement of stem/grain ratio. The hybrid of ACC 364-1 x Ex-Borno, as specific combination had the highest negative SCA for plant height.

The estimates of GCA for panicle length showed that Gwagwa was the highest significant general combiner among male parents for long panicle while G.I. 435-4 was the highest general combiner among female parents. The hybrid of Buduma Gero 712-2 x Ex-Borno, proved to be the best specific combination for long panicle. In constrast the specific combination had negative SCA for head weight, grain weight, 1000-seed weight and grain yield, supporting Nwasike (1988), who reported that, the longer the panicle, the fewer the grain yield due to sparse grain filling and the shorter the panicle to a certain limit, the higher the proportionate grain yield due to compact grain filling which could be attributable to the source-sink relationship.

GCA estimates for panicle width revealed the male parent GB 8735 as the highest positive general combiner while ICMV 88908, was the highest significant general combiner among the females. This suggested that both genotypes could be used to increase panicle width, indirectly increasing grain yield. Incidently the hybrid of G.I. 47-3 x GB 8735, was the best specific combination, revealing GB 8735 as the best in increasing panicle size in both geneal and specific combining ability.

The estimates of GCA effects for head weight, grain weight and grain yield showed that GB 8735 was the most significant male parent while G.I. 435-4 was the most significant femal parent for the same traits indicating that they could be useful in improving grain yield. Interestingly, the hybrids of G.I. 363-1 x GB 8735: G.I. 47-3 x GB 8735 and ACC 364-1 x GB 8735, with a common general combiner (GB 8735) yielded better than the best parent. However, the hybrid of ICMV 93501 x Ex-Borno, was observed to be the highest significant specific combination for the same trait among the hybrids. The plant

breeder is more interested in those parents showing high GCA which is reflected in the SCA and per se performance of the subsequent hybrids.

The estimates of GCA for 1000-seed weight, revealed ICMP 91103 as the significant female parent while GB 8735 was significant among male parents for increasing seed weight. This is reflected in the hybrid of ACC 364-1 x GB 8735, which had the highest positive specific combining ability.

Negative GCA and SCA were both recorded for crude protein content (%). GB 8735 showed low but positive GCA among the male parents, likewise, G.I. 122-2 recorded low but positive GCA among the female parents. The hybrid of ACC 364-1 x Gwagwa, proved to be a specific combination with low but positive SCA. The hybrid could be useful in improving grain quality in pearl millet.

The parent line, G.I. 410-8, gave highest GCA estimates among the female parents while Gwagwa was the significant among the male parents in increasing threshing percentage i.e. they were important in increasing head weight/ grain weight ratio. The hybrid of G.I. 296-1 x Gwagwa was the best specific combination for the trait.

The proportionate contribution of females, males and their interactions (male x female), to total variance expressed in percentage revealed that female effects were more influential than the male effects in the expression of most characters in the hybrids, suggesting some maternal influence for these characters. The male parents were, however, important in the expression of number of days to 50% flowering (62.55%), plant height (45.50%) and 1000-seed weight (73.06). Abifarin, (1969) reported high variance for male effects for all characters studied, while Kambal and Webster (1965) on the other had

obtained larger variances for female effects for grain yield in sorghum. These authors attributed larger variances to a high level of genetic diversity within either the male or female parents. An examination of the GCA mean squares for comparison among the male and female parents showed that the male parents were generally more diverse in origin than the females. Considering the variation exhibited, the gi (male effects) were more important than the gj (female effects) for most characters. Falconer (1981) had earlier noted that the performance of an inbred line is correlated with its performance in crosses and to some extent depends on how much of the variation is due to additive genes.

The major character of focus in this study was grain yield. GCA and SCA effects, revealed that although the mean squares for female effects were significant for head weight, the presence of additive gene effects, the estimate of GCA/SCA (< 1) suggest that the degree of dominance was higher for total performance than for individual components which indicated that this character was more under the influence of non-additive genes. The ratio confirms that panicle length, panicle width, 1000-seed weight, number of tillers/plant and grain yield were predominantly under non-additive gene control. Thus, the inheritance of yield and its components followed the same trend. Grain yield is a quantitative character and its expression is complex based on the interaction of a few to many genes, although the inheritance of yield components may either be additive, non-additive or both.

The values of GCA/SCA ratio (< 1) obtained for plant height and number of days to 50% flowering stresses the importance of non-additive portion of genetic variance in controlling the inheritance of these traits. A similar trend was observed for protein

content (%) and threshing percentage, which suggest that the characters are under the influence of dominant genes. Similar result was obtained by Nwasike (1988).

In a study of this nature, heterosis is another main focus. As far as breeders of cross-pollinated crops are concerned, the major considerations are; first, whether or not, it is possible to obtain sufficient heterosis for a character of economic importance under conditions which also give high yield per unit area of land, and secondly, whether or not it is possible to fix such heterosis in a few breeding lines (Kraljevic-Balalic *et al.*, 1976). In this study, significant heterosis was exhibited for all characters except for protein percent as indicated from the comparison of the parent vs the hybrids. The expression of heterosis is expected since some amount of genetic variability exists between and among the parents.

The highest significant heterosis was obtained for 1000-seed weight (66.01%HP) grain weight (35.55% HP) and grain protein (%) (31.27% HP). Grain yield had been observed to be the most heterotic character in pearl millet followed by grain weight. Similar results were obtained by Thete *et al.*, (1986), Kunjir and Patil, (1986) in pearl millet. Based on the values for heterosis, it would appear that the factor that contributed to grain yield included 1000-seed weight since the hybrid of ICMV 93501 x Ex-Borno that showed high heterosis for yield also exhibited significant heterosis for 1000-seed weight.

In heterosis studies, the breeder is also interested in the amount of heterosis that could be useful for improvement. He is particularly interested in the hybrid combinations that differ significantly from the mean performance of the parent, the best parent or from

the highest yielding commmercial variety. Parents of such hybrids are selected for their GCA or SCA since the ultimate goal in a hybrid programme is to identify genotypes which could excel in their combining ability. SCA, however, can only assume greater importance on materials that have been previously tested and selected for GCA. This was similarly observed in corn by Spraque and Tatum, (1942) and in sorghum by Beil, (1965) and Kambal and Webster, (1965) .

Hybrids formed with male parent GB 8735 gave consistently high grain yield, especially the three topmost that yielded above 2000 kg/ha; the hybrid of G.I. 47-3 x GB 8735, ACC 364-1 x GB 8735 and G.I. 363-1 x GB 8735, whose parents showed high GCA effects. This suggests that a portion of the SCA effect may be fixable, therefore the parents could be selected for their GCA in a hybrid programme since their high GCA effect was reflected in their SCA. However, the high heterosis and SCA effect exhibited by the hybrid of ICMV 93501 x EX -Borno, whose parents showed high negative GCA effect revealed the importance of genic interactions for this character. Such cross-combination are not likely to give good segregants but the parents could be selected for their SCA effects. Therefore crossing such lines with appropriate testers with subsequent selection in hybrid combination may be an effective breeding method.

Grain protein has been shown to be under non-additive gene influence. Among the hybrids, the hybrid of G.I. 122-2 (low) x GB8735 (medium) was the highest in percent potein which involved a good general combiner (GB 8735). Since the hybrid is a medium yielder, selection intensity for this character among the hybrids would be low unless the main objective of the breeding programme is for grain quality.

CHAPTER SIX

6.0 SUMMARY AND CONCLUSION

Three varieties of pearl millet were crossed with 19 inbred lines to obtain 57 F_1 hybrids. The hybrids and their parents including two checks were grown at two locations (Samaru-Zaria and Bagauda-Kano) in 2 row-plots, each replicated twice in a randomised complete block design.

Line x tester procedure as used by Singh and Chandhary (1985) using Genstats (1994) was used to estimate the GCA and SCA variances among the F_1 parents and the hybrids, respectively. The linear model assumed for the analysis included, effect due to the GCA of an inbred line, effect due to GCA of varieties and effect due to the SCA of the line x variety (male x female) interactions plus effect due to random error.

Significant differences among both male and female parents were observed in the GCA mean squares for number of days to 50% flowering, plant height, panicle length, panicle width, head weight, grain weight and grain yield. SCA mean squares was significant for number of days to 50% Flowering, Panicl length, Head weight, Grain weight and Grain yield. GCA x loc. (males) was significant for number of tillers/plant, number of days to 50% flowering and for 1000-seed weight. GCA x loc. (females) was significant for number of days to 50% flowering, head weight, grain weight and grain yield. SCA x loc. Was significant for number of days to 50% flowering and for grain yield.

A wide range in means was recorded for most of the characters. Grain yield ranged from 355.75 - 2249.00 kg/ha, while protein content (%) ranged from 8.86-10.24%.

The relative contribution of the male effects, female effects and male x female interactions effect to the total genetic variability present in the crosses revealed that the female effects were more important than the male effects for the expression of most of the character in the hybrids. However, males were more important in the expression for the number of days to 50% flowering, plant height and 1000-seed weight.

The variances due to GCA for both lines and varieties and the variance due to SCA were significant for head weight. However, GCA/SCA ratio suggested that non-additive type of gene action played a great role in the expression of head weight. The ratio confirmed that number of tillers/plant, number of days to 50% flowering, plant height, panicle length, 1000-seed weight and grain yield, were predominantly under non-additive gene control thus the inheritance of yield and its component followed the same trend.

The values for the general response of parental lines as expressed in hybrid combination indicated that for grain yield, lines G.I. 363-1, G.I. 47-3 and ACC 364-1 and variety GB 8735 are parents with high GCA and are expected to perform well when included in most hybrid programmes. Supported by the SCA effects and per se performance of the hybrids, the hybrids of G.I. 363-1 x GB 8735, G.I. 47-3 x GB 8735 and ACC 364-1 x GB 8735; the three topmost hybrids, yielded better than the highest yielding parent, thus they could be selected as superior hybrids for grain yield.

Heterosis response as expressed in the hybrid combination indicated that for earliness, the hybrid of Buduma Gero 712-2 x Ex-Borno, expressed the highest significant negative heterosis (- 48.22% HP-47.76% MP) considered advantageous for the number

of days to 50% flowering.

The hybrid of ICMV 93501 x Ex-Borno, as specific combiners for grain yield had the highest positive heterosis (60.44% HP, 130.46% MP) for the same trait and were high general combiner for earliness. However, protein percent had been shown to be under non-additive gene influence. The hybrid of G.I. 122-2 x GB 8735 whad the highest in percentage protein involving a high general combiner (GB 8735). However, the hybrid of ICMP 91103 x Ex-Borno, had the highest significant heterosis (31.27% HP) for grain protein. Since the hybrid gave medium yield it could be selected for grain quality in a breeding programme if the major objective is for improving grain protein in pearl millet.

The result from this study indicated that most of the characters measured in this population including grain yield are under the influence of non-additive gene effects. Selection of inbred lines and varieties to be used in hybrid programme should be on the basis of both GCA and SCA of the lines and varieties. Once some high yielding hybrids are identified they could be exploited for further testing and selection for the development of hybrids in pearl millet.

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APPENDICES

Appendix 1: Mean squares for eleven characters in pearl millet in the general analysis of variance (Samaru, 1996)

Source of variation	df	Number of Tillers	Days to 50% Flowering	Plant Height (cm)	Panicle Length (cm)	Panicle width (cm)	Head weight (Kg/ha)	Grain weight (Kg/ha)	Grain Yield (Kg/ha)	1000-seed weight (g)	Crude Protein (%)	Threshing (%)
Replication	1	0.06**	12.50	267.06	7.14	0.04	182273.81**	98765.44	8933.39	20.06	0.57	33.39
Genotypes	80	0.56**	110.49**	1289.04**	50.69**	0.13**	184783.48	162068.47**	351083.56**	7.79**	0.29	187.06*
Parents	21	0.81**	103.37**	1660.92**	94.31**	0.21**	152692.38**	119798.64**	204673.81**	4.53**	0.36	182.85*
Lines	18	0.66**	88.03**	1012.01**	88.06**	0.21**	87023.83	57714.35	142314.44	3.48**	0.36	168.59*
Variety	2	1.50**	283.50**	7086.50**	10.17	0.10**	155677.19	211832.00**	278738.00	13.56**	0.07	141.08
Line x Variety	1	3.91**	29.72*	7490.06**	375.16**	0.44**	1328756.75**	1053249.18**	1179013.87**	5.41	0.78	521.73*
Hybrids	56	0.47**	95.09**	878.31**	18.39**	0.08**	186298.88**	167582.02**	372313.50**	8.55**	0.22	61.05*
Checks	1	0.00	600.25	756.25**	90.25**	0.20**	69960.25	95225.13	219961.92	7.84**	0.18	61.05*
Parents vs cross vs checks	2	0.6279	366.447**	9151.27**	477.03**	0.48**	536720.81**	485030.88**	1359508.00**	20.71**	0.03	251.31*
Parent vs cross	1	0.8418	91.949**	10836.5**	69.620**	0.96**	1073000.00	934000.00**	2514000.00**	25.82**	0.00	930.36*
cross vs check	1	0.4140	640.944**	7466.0**	884.432*	0.01	40810.00	361100.00	205500.00	15.613	0.06	506.26*
Error	80	0.28806	7.32	275.07	5.84	0.03	70792.36	53608.48	112630.01	1.64	0.19	70.02
Total	161											

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

Appendix 2 Mean squares for eleven characters in pearl millet in the general analysis of variance (Baganda, 1996)

Source of variation	df	Number of Tillers	Days to 50% Flowering	Plant Height (cm)	Panicle Length (cm)	Panicle width (cm)	Head weight (Kg ha)	Grain weight (Kg ha)	Grain Yield (Kg ha)	1000-seed weight (g)	Crude Protein (%)	Threshing (%)
Replication	1	11.41	0.22	2.47	24.50	0.00	1288725.87	650813.69	1237514.12	1.18	0.14	56.08
Genotypes	80	1.63	59.73**	1129.07*	29.95**	0.11*	618242.94**	534320.81**	596310.13**	6.78**	0.30	64.97**
Parents	21	1.25	46.47**	1059.63*	29.11**	0.12	571176.75**	475426.56**	519776.56**	6.59**	0.27	96.91**
Lines	18	1.17	28.73**	667.97	20.79	0.10	434541.49**	388306.31**	425176.38**	5.81**	0.30	101.75**
Variety	2	1.50	222.17**	5042.67**	17.17	0.17	4340.17	116969.16	220446.57	17.73**	0.00	97.32
Line x Variety	1	2.24	14.55	122.37	202.70**	0.44**	4164283.25**	2760506.00**	2821240.00**	4.21*	0.01	8.98
Hybrids	56	1.70	46.64**	1019.17*	16.41	0.11*	492242.92**	471088.69**	519200.41**	6.77**	0.32	45.07*
Checks	1	1.00	380.250**	2916.00*	1.00	0.02	1044484.00**	82944.01	32041.00	1.96	0.09	278.56**
Parents vs cross vs checks	2	4.157*	404.925**	4052.6**	272.46**	0.02	4427000.00**	3149000.00**	3841000.00**	11.52**	0.34	180.18**
Parent vs cross	1	7.929**	16.534	2131.9*	162.81**	0.03	7272000.00**	6081000.00**	7570000.00**	20.08**	0.59	154.45*
cross vs check	1	0.384	793.296**	5973.3*	382.10**	0.00	1582000.00**	717000.00	112100.00	2.96	0.09	205.91*
Error	80	1.151	5.022	602.4	14.20	0.07	179707.32	163100.00	186600.00	1.07	0.28	30.33
Total	161											

*, ** Significant at 5% and 1% level of probability, respectively

Appendix 3. Means squares for eleven characters in pearl millet in the combining ability analysis of variance (Samaru, 1996)

Source of variation	df	Number of Tillers	Days to 50% Flowering	Plant Height (cm)	Panicle Length (cm)	Panicle width (cm)	Head weight (Kg/ha)	Grain weight (Kg/ha)	Grain Yield (Kg/ha)	1000-seed weight (g)	Crude Protein (%)	Threshing (%)
Hybrid	56	0.47 **	95.09 **	878.31 **	18.39 **	0.08 **	186298.88 **	16758.02**	372313.50 **	8.55 **	0.27	160.76 **
Line (GCA)	18	0.4318	96.927 **	1019.9 **	31.816 **	0.13371 **	1.842E+05 **	94727.0**	3.184E+05	4.60 **	0.29	134.86 **
Variety (GCA)	2	0.6930	1459.325 **	9188.5 *	58.325 **	0.46851 **	7.655E+05 **	619792.0**	2.478E+06	163.82 **	0.16	1781.43 **
Line & Variety (SCA)	36	0.4800 *	18.380 **	345.9	9.463 **	0.04240 **	1.552E+05 **	64835.0*	2.823E+04	1.90	0.27	83.67
Eror	80	0.2806	7.32	275.07	5.84	0.03	70792.36	53608.48	112630.94	1.64	0.39	70.02
δ^2 gca	-	0.899	5.273	2.949	3.362	2.918	1.187	1.461	1.128	2.43	1.07	1.612
δ^2 sca	-	1.444	79.397	26.567	6.163	11.050	4.933	9.560	8.777	86.38	0.58	21.292
ratio gca sca	-	0.623	0.066	0.111	0.546	0.264	0.241	0.153	0.129	0.03	1.84	0.076

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

Appendix 4. Mean squares for eleven characters in pearl millet in the combining ability analysis of variance (Baganda, 1996)

Source of variation	df	Number of Tillers	Days to 50% Flowering	Plant Height (cm)	Panicle Length (cm)	Panicle width (cm)	Head weight (Kg/ha)	Grain weight (Kg/ha)	Grain Yield (Kg/ha)	1000-seed weight (g)	Crude Protein (%)	Threshing (%)
Hybrid	56	1.70	46.64 **	1019.17 *	16.41	0.11 *	492242.92 **	471083.69 **	519200.41 **	6.77 **	0.32	45.07*
Line (GCA)	18	1.467	41.779 **	902.5 *	19.01	0.20037 **	6.323E+05 **	3.379E+05 **	6.315E+05 **	4.352 **	0.2717	64.04**
Variety (GCA)	2	4.114*	837.167 **	9944.2 **	46.29 *	0.00246	1.944E+05 **	1.542E+06 **	2.771E+06 **	119.048 **	0.3523	391.32**
Line & Variety (SCA)	36	1.679	5.157	581.7	13.45	0.07116	3.415E+05 *	1.576E+05 *	3.99E+05	1.739 *	0.3440	16.34
Error	80	1.151	5.022	602.4	14.20	0.07	179707.32	1.631E+05	1.866E+05	1.07	0.28	30.33
δ^2 gca	-	0.874	8.101	1.552	1.413	2.816	1.851	2.144	1.869	2.502	0.790	3.918
δ^2 sca	-	2.457	162.323	17.096	3.442	0.035	5.692	9.785	8.200	68.447	1.024	23.942
Ratio gca/sca	-	0.357	0.050	0.091	0.411	80.457	0.325	0.219	0.228	0.037	0.772	0.164

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

Appendix 5: Mean performances of parents, Hybrids and checks for eleven characters in pearl millet (Samaru, 1996)

Parents	Genotype	Number of Tillers	Days to 50% Flowering	Plant Height (cm)	Panicle Length (cm)	Panicle width (cm)	Head weight (Kg ha)	Grain weight (Kg ha)	Grain Yield (Kg ha)	1000-seed weight (g)	Crude Protein (%)	Threshing (%)
Lines												
1.	G.I.6-2	2.00	67.00	219.00	30.00	2.50	1245.59	670.00	1007.50	8.35	9.27	53.79
2.	G.I.75-1	1.50	56.00	191.50	26.00	2.20	905.51	460.00	803.50	9.15	9.09	50.80
3.	G.1122-2	1.00	70.50	232.50	26.50	2.25	473.57	224.00	456.50	7.55	9.90	47.30
4.	G.1165-6	1.00	62.50	230.50	36.00	2.05	507.21	227.33	393.50	7.45	8.94	44.02
5.	G.1296-1	0.50	65.00	213.00	25.50	2.25	526.53	262.00	313.50	9.35	10.10	49.76
6.	G.1359-3	0.00	71.50	200.00	47.00	3.35	564.45	328.00	545.00	5.85	9.36	58.11
7.	G.1363-1	2.00	62.00	189.00	23.50	2.10	880.81	533.33	1042.50	8.65	9.12	60.55
8.	G.1363-4	1.00	55.50	186.50	30.0	2.45	418.70	257.33	586.50	10.20	8.94	61.46
9.	G1410-8	1.00	70.50	196.50	22.00	2.20	163.19	71.33	208.00	6.90	9.45	43.71
10.	G1435-4	1.00	60.50	185.00	35.50	2.00	373.48	217.33	511.50	8.55	9.12	58.19
11.	ACC 1009-2	1.00	53.50	206.50	31.50	2.20	609.57	326.00	557.00	7.50	8.82	53.19
12.	Baduna Gero 712-2	1.00	70.50	216.00	21.50	2.30	494.67	303.33	379.00	8.10	9.66	61.32
13.	ICMV 88908	1.00	54.50	142.00	17.00	2.50	317.96	181.33	397.00	10.60	9.18	57.03
14.	G141-3	2.50	65.50	221.50	30.00	1.90	852.77	453.33	892.50	7.00	8.85	53.16
15.	G147-3	1.00	66.00	163.50	24.00	2.40	357.12	120.67	243.50	6.55	9.11	33.79
16.	ACC 364-1	1.00	68.50	195.00	27.00	1.90	176.01	69.33	211.50	7.50	9.18	39.39
17.	ICMV 93501	1.50	63.50	176.50	23.50	2.25	222.17	90.00	239.00	6.45	9.51	38.01
18.	ICMP 94592	1.00	48.50	195.50	30.00	2.55	291.64	90.00	243.00	6.30	9.16	38.56
19.	ICMP 91103	0.50	63.50	194.00	32.00	2.50	199.56	90.00	324.00	7.05	10.11	45.19
B. Varieties												
1.	Ex-Borno	1.50	69.50	278.00	20.00	2.55	816.36	412.67	622.50	6.35	8.85	49.44
2.	Gwagwa	1.50	65.00	221.50	22.00	2.30	1087.38	666.67	921.50	8.70	9.18	61.31
3.	GB 8735	1.00	47.00	159.00	17.50	2.85	1576.34	1058.67	1361.50	11.50	8.84	67.16

Appendix 5 Cont.

Hybrids	Pedigree	Number of Tillers	Days to 50% Flowering	Plant Height (cm)	Panicle Length (cm)	Panicle width (cm)	Head weight (Kg ha)	Grain weight (Kg ha)	Grain Yield (Kg ha)	1000-seed weight (g)	Crude Protein (%)	Threshing (%)
H1.1	G.I 6-2 x Ex-Borno	0.50	72.00	230.50	24.00	2.55	530.97	268.67	627.50	8.35	9.87	50.60
H1.2	G.I 6-2 x Gwagwa	2.00	70.50	245.50	26.50	2.45	1223.35	508.67	791.00	6.55	9.00	41.58
H1.3	G.I 6-2 x GB 8735	1.00	61.50	205.50	28.70	2.30	301.90	176.67	525.50	8.00	9.30	58.52
H2.1	G.I 75-1 Ex-Borno	1.00	70.00	250.00	24.00	2.50	641.69	352.67	523.00	7.75	9.15	54.96
H2.2	G.I 75-1 x Gwagwa	1.50	59.50	222.50	28.00	2.50	1270.23	628.00	971.50	6.65	9.51	49.44
H2.3	G.I 75-1 x GB 8755	2.00	57.00	191.50	28.50	2.40	1552.84	1096.00	1763.50	11.70	8.85	70.58
H3.1	G.I 122-2 x Ex-Borno	1.00	71.00	266.00	24.50	2.50	268.11	114.00	331.50	7.25	9.39	42.52
H3.2	G.I 122-2 x Gwagwa	1.50	66.50	231.00	27.50	2.50	663.39	419.33	697.00	9.05	9.48	63.21
H3.3	G.I 122-2 x GB 8735	1.50	54.00	221.00	26.50	2.75	1303.49	856.00	1108.00	11.30	9.45	65.67
H4.1	G.I 165-6 x Ex-Borno	1.00	70.50	268.50	24.50	2.50	837.40	484.00	801.00	7.90	9.48	57.66
H4.2	G.I 165-6 x Gwagwa	1.00	65.50	250.50	24.50	2.30	427.74	206.00	469.00	7.50	9.42	48.16
H4.3	G.I 165-6 x GB 8735	1.00	57.00	208.00	29.00	2.65	820.39	506.67	735.50	10.20	9.18	61.76
H5.1	G.I 296-1 x Ex-Borno	1.50	69.00	230.00	25.50	2.10	435.52	230.00	336.50	8.20	9.09	52.81
H5.2	G.I 296-1 x Gwagwa	2.00	62.00	231.50	26.50	2.30	692.06	383.33	1124.50	8.90	8.64	55.39
H5.3	G.I 296-1 x GB 8735	1.50	53.50	222.00	28.50	3.45	1201.93	822.00	1242.00	12.55	9.06	68.39
H6.1	G.I 359-3 x Ex-Borno	1.00	66.50	234.50	26.00	2.30	292.50	138.00	414.50	6.50	8.88	47.18
H6.2	G.I 359-3 x Gwagwa	1.00	64.00	251.00	25.00	2.45	465.02	234.00	489.00	7.40	9.06	56.32
H6.3	G.I 359-3 x GB 8735	2.00	58.50	205.00	26.50	2.40	1311.45	847.33	1350.00	11.05	9.18	64.61
H7.1	G.I 363-1 x Ex-Borno	1.00	66.00	253.50	25.50	2.35	725.23	405.33	563.00	8.40	9.66	55.89
H7.2	G.I 363-1 x Gwagwa	2.00	61.00	239.50	29.50	2.35	1333.13	856.67	1369.00	9.20	9.33	64.26
H7.3	G.I 363-1 x GB 8735	2.00	55.00	223.50	27.50	2.95	1508.51	1058.67	2062.00	12.45	9.48	70.18
H8.1	G.I 363-4 x Ex-Borno	1.00	57.50	209.50	27.00	2.70	821.92	516.00	786.50	9.65	8.88	62.78
H8.2	G.I 363-4 x Gwagwa	0.50	57.50	218.00	30.50	2.35	437.68	232.67	533.00	7.80	10.71	53.16
H8.3	G.I 363-4 x GB 8735	1.00	45.50	204.50	25.50	2.60	750.82	411.33	655.50	11.85	9.57	58.78
H9.1	G.I. 410-8 X Ex Borno	2.00	69.50	209.50	21.50	2.40	816.77	332.67	493.00	5.80	9.21	49.71
H9.2	GI 410-8 x Gwagwa	1.50	60.00	212.50	21.00	2.40	533.58	228.00	433.00	6.20	9.15	47.73
H9.3	G.I. 410-8 x GB 8735	1.00	58.50	227.50	25.50	2.60	367.13	197.33	423.00	9.50	9.69	43.74

Apendix 5 Cont.

Hybrids	Pedigree	Number of Tillers	Days to 50% Flowering	Plant Height (cm)	Panicle Length (cm)	Panicle width (cm)	Head weight (Kg/ha)	Grain weight (Kg ha)	Grain Yield (Kg ha)	1000-seed weight (g)	Crude Protein (%)	Threshing (%)
H10.2	G.I 363-4 x Gwagwa	1.50	62.00	200.00	32.50	2.35	1282.83	545.33	706.00	7.65	9.18	42.51
H10.3	G.I 363-4 x GB 8735	1.50	48.50	175.50	32.00	2.50	1246.78	870.00	1170.00	11.45	8.97	69.78
H11.1	ACC 1009-2 x Ex-Borno	2.00	61.50	222.50	24.00	2.40	1305.59	840.67	1336.50	8.60	9.12	64.39
H11.2	ACC 1009-2 x Gwagwa	1.00	64.50	223.00	23.50	2.25	340.69	140.67	344.00	9.25	8.43	41.29
H11.3	ACC 1009-2 x GB 8735	2.00	51.00	187.00	29.50	2.40	925.80	567.33	1049.00	11.00	9.18	61.28
H12.1	BUDUMA GERO 712-2xEx Borno	1.00	71.50	221.50	26.00	2.35	328.65	159.33	358.50	7.00	9.01	48.48
H12.2	BUDUMA GERO 712-2xGwagwa	2.50	66.50	225.50	21.00	2.40	731.79	339.33	774.00	5.90	9.15	46.37
H12.3	BUDUMA GERO 712-2xGB 8735	1.00	57.50	207.50	25.00	2.55	385.54	233.33	475.00	11.60	9.33	60.52
H13.1	ICMV 88908 x EX-BORNO	1.50	66.00	213.50	19.50	2.70	590.16	324.00	849.00	7.55	9.21	54.90
H13.2	ICMV 88908 x GWAGWA	1.00	64.00	220.50	24.00	2.80	448.92	252.00	523.50	8.25	9.18	56.16
H13.3	ICMV 88908 x GB 8735	1.00	52.50	201.50	24.00	3.25	839.78	586.00	878.50	13.75	9.36	69.78
H14.1	G.I. 41-3 x EX-BORNO	1.50	69.50	224.50	23.50	2.40	851.54	475.33	1063.00	6.60	8.94	55.82
H14.2	G.I. 41-3 x GWAGWA	1.00	69.00	212.50	28.50	2.30	472.62	189.33	319.00	6.00	10.14	40.06
H14.3	G.I. 41-3 x GB 8735	2.00	57.50	196.50	30.00	2.80	1479.11	922.67	1480.00	11.05	9.21	62.38
H15.1	G.I 47-3 x EX-BORNO	0.50	69.50	264.00	23.50	2.50	557.93	326.00	546.00	6.70	9.33	58.43
H15.2	G.I 47-3 x GWAGWA	1.00	70.50	225.00	24.50	2.55	643.31	394.67	706.00	8.75	9.15	61.35
H15.3	G.I 47-3 x GB 8735	2.00	54.50	213.00	25.00	2.90	1733.32	1148.67	1457.50	10.50	8.94	66.2
H16.1	ACC 364-1 x EX-BORNO	1.00	68.00	225.00	28.50	2.35	549.74	273.33	473.50	6.80	9.12	49.72
H16.2	ACC 364-1 x GWAGWA	1.00	63.50	220.00	36.00	2.35	589.82	297.33	600.00	8.05	10.23	50.41
H16.3	ACC 364-1 x GB 8735	1.50	51.00	220.00	28.00	2.70	1489.06	989.33	2023.50	12.45	9.48	66.11
H17.1	ICMV 93501 x EX-BORNO	2.00	59.00	230.50	24.50	2.70	1437.30	870.00	1151.50	8.70	9.21	60.53
H17.2	ICMV 93501 x Gwagwa	1.00	45.50	230.00	26.50	2.75	445.95	209.33	437.50	6.25	8.85	46.93
H17.3	ICMV 93501 x GB 8735	2.00	52.50	188.00	22.00	2.60	970.55	671.33	1051.50	10.95	9.48	69.17
H18.1	ICMP 94592 x Ex Borno	1.50	65.00	220.50	24.50	2.60	503.18	248.67	554.00	6.60	9.36	49.42
H18.2	ICMP 94592 x Gwagwa	1.00	61.50	216.00	27.50	2.65	638.43	358.67	529.00	7.70	9.36	56.18
H18.3	ICMP 94592 x GB 8735	1.50	56.50	187.00	24.50	2.70	520.09	220.00	450.00	9.40	9.27	42.3
H19.1	ICMP 91103 x Ex-Borno	1.50	60.50	215.50	23.00	2.50	806.16	492.00	668.00	9.40	9.18	61.07

Appendix 5 Cont.

Hybrids	Pedigree	Number of Tillers	Bays to 50% Flowering	Plant Height (cm)	Panicle Length (cm)	Panicle width (cm)	Head weight (Kg/ha)	Grain weight (Kg/ha)	Grain Yield (Kg/ha)	1000-seed weight (g)	Crude Protein (%)	Threshing (%)
H19.2	ICMP 91103 x Gwagwa	2.00	57.50	222.50	27.50	2.45	1533.29	850.67	1113.50	8.40	9.49	55.48
H19.3	ICMP 91103 x GB 8735	2.00	52.00	162.50	23.00	2.90	1186.37	860.00	1506.00	12.55	9.51	72.49
*Checks												
	ICMV IS 88102	1.00	87.00	268.00	37.00	2.25	538.94	156.67	230.00	5.00	9.57	29.07
	Local variety	1.00	62.50	240.50	46.50	2.70	863.80	465.33	699.00	7.80	8.82	53.87
Mean		1.35	61.92	215.69	26.79	2.47	812.33	441.50	748.28	8.54	9.28	54.35
SE ±		± .53	± 2.71	±16.59	± 2.42	± 0.17	±266.07	±231.54	±335.61	± 1.28	± 0.62	± 8.37

Note: (H1.1) = G.I. 6-2 x Ex-Borno, (H2.2) = G.I. 75 –1 x Gwagwa, (H3.3) = G.I. 12 2-2 x GBB 735

Appendix 6: Mean performances of parents, Hybrids and checks for eleven characters in pearl millet (Bagauda, 1996)

Parents	Genotype	Number of Tillers	Days to 50% flowering	Plant height (cm)	Panicle length (cm)	Panicle width (cm)	Head weight (kg/ha)	Grain weight (kg/ha)	Grain Yield (kg/ha)	1000-seed weight (g)	Crude Protein (%)	Threshing (%)
A. Lines 1	G.I. 6-2	3.50	57.00	237.00	38.50	2.80	1426.38	993.33	1601.00	11.75	9.63	69.64
2	G.I. 75-1	2.00	58.00	287.50	31.50	3.00	1032.82	634.67	800.00	10.25	9.57	61.45
3	G.I 122-2	4.50	58.00	283.50	32.00	2.55	1441.93	904.67	1126.00	10.55	9.48	62.74
4	G.I 165-6	3.00	57.00	262.00	34.50	2.55	2519.21	1551.33	1791.50	9.90	8.91	61.58
5	G.I 296-1	1.50	56.50	266.50	32.00	2.55	2016.83	1254.67	1578.50	11.85	9.72	62.21
6	G.I 359-3	2.50	57.50	247.00	27.00	2.45	1325.90	712.67	818.50	9.75	10.17	53.75
7	G.I 363-1	3.00	49.00	255.50	28.50	2.35	2205.84	1466.00	1618.00	10.65	9.84	66.46
8	G.I 363-4	3.00	54.50	267.00	38.00	2.45	1116.72	642.00	802.50	11.35	10.02	57.49
9	G.I 410-8	3.50	59.00	266.50	29.50	2.35	1151.87	725.33	873.00	9.15	9.96	62.97
10	G.I 435-4	2.50	50.50	242.50	32.00	2.35	2233.96	1480.67	1445.00	11.60	9.95	66.28
11	ACC 1009-2	2.50	54.00	253.50	35.00	2.55	2240.38	1508.67	1656.00	11.00	9.66	67.34
12	Buduna Gero 712-2	3.50	62.00	248.50	28.00	2.70	736.84	322.00	349.00	7.10	9.57	43.70
13	ICMV 88908	2.50	49.00	233.50	30.00	2.80	1448.39	988.67	1059.00	12.60	9.24	68.26
14	G.I 41-3	2.50	60.00	242.50	33.50	2.45	1693.74	1157.33	1319.50	6.60	9.72	68.33
15	G.I 47-3	2.00	59.00	228.00	30.00	2.95	405.95	258.67	508.00	12.85	9.87	63.72
16	ACC 364-1	2.50	59.00	256.00	36.50	2.70	1128.35	625.33	740.50	9.25	9.39	55.42
17	ICMV 93501	3.50	52.00	278.50	32.50	2.55	2254.91	1563.33	1707.50	12.45	9.51	69.33
18	ICMP 94592	2.00	57.00	233.00	32.50	3.10	520.66	265.33	468.50	9.15	8.55	50.96
19	ICMP 91103	4.00	52.00	227.50	34.50	2.70	1598.05	854.00	1011.00	10.10	9.69	53.44
Varieties												
1	Ex-Borno	4.00	60.50	271.00	29.50	2.70	2580.88	1436.00	1502.00	9.70	9.33	55.64
2	Gwagwa	2.50	60.00	301.00	24.00	2.80	2652.83	1662.00	1911.00	9.80	9.69	62.65
3	GB 8735	4.00	42.00	203.00	25.00	2.70	2758.05	1919.33	2159.50	14.45	9.67	69.59

Appendix 6: *Cont.*

Hybrids	Pedigree	Number of Tillers	Days to 50% flowering	Plant height (cm)	Panicle length (cm)	Panicle width (cm)	Head weight (kg/ha)	Grain weight (kg/ha)	Grain Yield (kg/ha)	1000-seed weight (g)	Crude Protein (%)	Threshing (%)
H1.1	G.I 6-2 x Ex-Borno	5.50	61.00	276.50	27.50	2.48	1786.96	1037.33	1087.50	8.10	9.18	58.05
H1.2	G.I 6-2 x Gwagwa	2.00	62.00	287.00	29.50	2.35	1604.55	998.67	1340.00	9.05	9.18	62.34
H1.3	G.I 6-2 x GB 8735	4.00	54.00	235.00	31.50	2.45	2579.17	1756.67	2140.00	11.50	9.96	68.11
H2.1	G.I 75-1 Ex-Borno	2.50	61.00	267.50	29.50	2.65	840.48	320.67	953.50	8.40	9.42	66.74
H2.2	G.I 75-1 x Gwagwa	3.00	57.00	263.00	34.50	2.30	1948.18	1188.00	1367.50	9.65	9.30	60.98
H2.3	G.I 75-1 x GB 8755	4.50	47.00	222.50	31.00	2.25	2922.20	1938.00	2156.50	13.25	10.00	66.32
H3.1	G.I 122-2 x Ex-Borno	4.00	60.00	250.50	29.00	2.85	1337.37	753.33	836.00	11.45	9.24	56.33
H3.2	G.I 122-2 x Gwagwa	5.00	58.00	308.50	27.50	2.50	1586.60	941.33	1046.50	9.75	10.08	59.33
H3.3	G.I 122-2 x GB 8735	2.00	53.50	275.00	29.00	2.85	2793.13	1728.67	1768.00	13.80	11.04	61.89
H4.1	G.I 165-6 x Ex-Borno	3.00	61.00	292.00	30.50	2.65	2022.28	1131.33	1329.50	8.70	9.84	55.93
H4.2	G.I 165-6 x Gwagwa	5.00	61.00	282.50	30.00	2.75	2975.50	1915.33	2096.50	9.50	9.69	64.37
H4.3	G.I 165-6 x GB 8735	2.00	53.00	234.50	31.50	2.40	2669.57	1844.67	2094.00	13.20	9.99	69.10
H5.1	G.I 296-1 x Ex-Borno	2.50	58.50	301.00	28.00	2.60	971.72	545.33	668.00	9.70	10.23	56.12
H5.2	G.I 296-1 x Gwagwa	2.50	57.00	275.50	25.00	2.55	1306.84	776.00	1095.50	11.25	9.62	59.38
H5.3	G.I 296.1 x GB 8735	2.50	47.50	245.00	34.50	2.60	2976.54	1982.67	2124.00	14.10	9.33	66.61
H6.1	G.I 359-3 x Ex-Borno	4.00	58.50	290.00	26.00	2.60	2767.87	1706.67	1727.00	11.35	9.84	61.66
H6.2	G.I 359-3 x Gwagwa	3.00	58.50	260.00	30.50	2.55	2546.67	1550.67	2183.50	9.25	9.45	60.89
H6.3	G.I 359-3 x GB 8735	3.50	50.00	235.00	31.00	2.35	2452.61	1682.00	1706.00	12.60	9.90	68.58
H7.1	G.I 363-1 x Ex-Borno	3.50	57.00	276.00	33.00	2.55	1498.57	942.00	1060.00	9.20	9.45	62.86
H7.2	G.I 363-1 x Gwagwa	5.00	55.00	279.00	33.50	2.90	2770.23	1936.67	2183.50	11.65	9.48	69.91
H7.3	G.I 363-1 x GB 8735	4.00	47.50	278.00	27.50	2.50	2624.85	1808.00	2141.00	13.20	9.60	68.88
H8.1	G.I 363-4 x Ex-Borno	3.50	57.00	267.00	32.50	2.70	3052.63	2088.00	2330.00	12.10	9.66	68.40
H8.2	G.I 363-4 x Gwagwa	4.00	57.00	265.50	32.00	3.00	3178.10	2163.33	2313.00	11.35	9.48	68.07

Appendix 6: Cont

Hybrid	Pedigree	Number of Tillers	Days to 50% flowering	Plant height (cm)	Panicle length (cm)	Panicle width (cm)	Head weight (kg ha)	Grain weight (kg ha)	Grain Yield (kg ha)	1000-seed weight (g)	Crude Protein (%)	Threshing (%)
H8.3	G.I.363-4 x GB 8735	2.50	48.5	243.00	31.00	2.85	3277.21	2277.33	2599.00	14.30	9.99	69.49
H9.1	G.I. 410-8 X Ex Borno	5.00	60.50	275.00	27.00	2.65	1740.94	1027.33	1296.00	8.55	9.66	59.01
H9.2	G.I. 410-8 x Gwagwa	3.50	59.50	290.00	29.00	2.75	1762.68	1074.00	1150.50	11.75	9.93	60.93
H9.3	G.I. 410-8 x GB 8735	3.00	54.50	246.00	28.00	2.70	2101.25	1378.00	1552.00	12.50	6.69	65.58
H10.1	G.I. 435-4 x Ex Borno	3.00	57.50	283.50	30.00	2.75	2763.74	1738.67	2001.00	10.15	9.48	62.91
H10.2	G.I. 435-4 x Gwagwa	4.50	54.50	248.00	31.50	2.95	3299.84	2102.00	2284.00	9.50	9.93	63.70
H10.3	G.I. 435-4 x GB 8735	3.50	46.00	258.00	34.50	2.65	3495.29	2374.00	2391.00	12.95	9.81	67.92
H11.1	ACC 1009-2 x Ex-Borno	3.00	56.50	245.00	28.50	2.30	2395.97	1474.00	1620.50	10.25	9.96	61.52
H11.2	ACC 1009-2 x Gwagwa	2.00	52.50	238.00	31.00	2.65	2548.72	1648.00	1951.50	11.95	10.44	64.66
H11.3	ACC 1009-2 x GB 8735	2.50	46.00	247.50	30.00	2.65	2592.88	1672.67	1821.50	13.00	9.72	64.51
H12.1	BUDUMA GERO 712-2XEx-Borno	3.00	60.00	259.00	28.50	2.45	820.53	411.33	494.00	9.40	10.11	50.13
H12.3	BUDUMA GERO 712-2XGwagwa	4.50	59.50	257.00	27.00	2.20	1774.29	1060.67	1744.00	10.95	9.21	59.78
H12.3	BUDUMA GERO 712-2xGB8735	3.00	54.00	236.00	22.50	2.25	2642.63	1670.67	1862.50	13.20	10.02	63.22
H13.1	ICMV 88908 X EX-BORNO	3.50	56.00	265.50	26.50	3.20	1909.49	1229.33	1442.00	11.75	9.48	64.38
H13.2	ICMV 88908 X GWAGWA	3.50	57.00	270.00	29.50	2.85	2555.66	1706.67	1879.00	12.15	10.11	66.78
H13.3	ICMV 88908 X GB 8735	2.50	47.00	240.00	27.00	3.05	2410.11	1736.00	2184.50	14.80	9.69	72.03
H14.1	G.I. 41-3 X EX-BORNO	4.00	60.50	304.00	29.00	2.80	2884.61	1600.67	1689.50	8.95	9.66	55.49
H14.2	G.I. 41-3 X GWAGWA	4.50	61.00	284.50	33.50	2.35	2425.81	1305.33	1619.50	10.20	9.36	53.81
H14.3	G.I. 41-3 X GB 8735	3.50	55.00	248.00	33.00	2.95	2423.48	1538.67	1664.00	14.20	9.63	63.49
H15.1	G.I. 47-3 X EX-BORNO	2.50	60.00	323.50	26.50	2.55	2385.84	1461.33	1644.50	9.60	9.81	61.25
H15.2	G.I. 47-3 X GWAGWA	5.50	62.50	277.50	27.00	2.60	1914.14	1128.00	1311.50	9.50	9.78	58.93
H15.3	G.I. 47-3 X GB 8735	3.50	49.50	255.50	27.00	3.15	3524.79	2577.33	3040.50	13.80	9.72	73.12
H16.1	ACC 364-1 X EX-BORNO	3.00	59.50	225.00	29.50	2.20	2580.08	1640.67	1948.50	8.15	8.61	63.59
H16.2	ACC 364-1 X GWAGWA	4.00	57.00	251.50	33.50	2.60	1839.81	1149.33	1293.50	9.75	9.96	62.47
H16.3	ACC 364-1 X GB 8735	3.50	52.50	259.50	29.50	2.40	2576.05	1736.00	2227.50	13.80	9.81	67.39
H17.1	ICMV 93501 X EX-BORNO	3.00	56.50	272.50	28.50	2.90	2817.08	1720.67	1936.00	10.30	11.16	61.08

Appendix 6: Cont.

Hybrids	Pedigree	Number of Tillers	Days to 50% flowering	Plant height (cm)	Panicle length (cm)	Panicle width (cm)	Head weight (kg/ha)	Grain weight (kg/h)	Grain Yield (kg/ha)	1000-seed weight (g)	Crude Protein (%)	Threshing (%)
H17.2	ICMV 93501 x Gwagwa	2.50	52.50	263.50	29.50	2.70	1219.51	710.00	841.00	11.55	9.54	58.22
H17.3	ICMV 93501 x GB 8735	3.50	47.00	234.00	28.00	2.60	1766.74	1103.33	1241.50	13.30	10.11	62.45
H18.1	ICMP 94592xEx Borno	2.50	57.50	267.50	26.00	2.65	2675.27	1742.67	1926.00	10.15	9.63	65.14
H18.2	ICMP 94592 x Gwagwa	3.50	57.00	254.54	37.00	2.58	2174.32	1492.67	1725.00	11.15	9.51	68.65
H18.3	ICMP 94592 x GB 8735	2.00	50.50	224.00	27.50	2.65	2236.08	1470.00	1539.50	12.30	9.45	65.74
H19.1	ICMP 91103xEx-Borno	4.50	56.00	275.00	27.00	2.55	2184.03	1385.33	2003.50	13.05	9.72	63.43
H19.2	ICMP 91103 x Gwagwa	4.00	49.50	289.00	33.50	2.85	2846.51	1962.67	2054.00	12.60	9.75	68.95
H19.3	ICMP 91103 x GB 8735	3.50	45.50	235.00	24.50	2.90	2313.75	1595.33	1841.50	13.15	9.48	68.95
Checks	ICMV IS 88102	4.00	79.50	325.00	40.00	2.70	3507.57	1644.00	1725.50	9.35	9.36	46.87
	Local variety	3.00	60.00	271.00	41.00	2.55	2133.42	1356.00	1546.50	10.75	9.66	63.56
	Mean	3.30	55.73	261.72	30.39	2.64	2175.24	1364.96	1576.35	11.07	9.69	62.75
	SE ±	1.07	2.24	24.54	3.37	0.27	423.92	403.81	432.02	1.03	0.53	5.51

Note: (H1.1) = G.I. 6-2 x Ex-Borno, (H2.2) = G.I. 75 –1 x Gwagwa, (H3.3) = G.I. 12 2-2 x GBB 735

Appendix 7. Estimates of general combining ability effects for eleven characters in pearl millet L1 (Samaru, 1996)

Lines	Genotype	Number of Tillers	Days to 50% flowering	Plant height (cm)	Panicle length (cm)	Panicle width (cm)	Head weight (kg ha)	Grain weight (kg ha)	Grain Yield (kg ha)	1000-seed weight (g)	Crude Protein (%)	Threshing (%)
1.	G.I. 6-2	-0.2368	6.781 **	6.99	0.219	-0.0886	-119.9	-130.3	-183.9	-1.1956*	0.1086	- 5.859
2.	G.I. 75-1	0.0968	0.947	1.16	0.719	-0.0553	-206.6	150.4*	254.1	-0.1289	-0.1114	2.231
3.	G.I. 1222-1	-0.0702	2.614*	19.16**	0.053	0.0614	- 62.7	- 21.4	-119.7	0.3711	0.1586	1.040
4.	G.I. 165-6	-0.4035	2.947**	22.16**	0.114	-0.0053	- 95.7	- 69.6	-163.4	-0.2956	0.0786	- 0.234
5.	G.I. 296-6	0.2632	0.281	7.66	0.719	-0.2386**	- 52.0	- 9.9	69.1	1.0544*	-0.3514	2.771
6.	G.I. 359-3	-0.0702	1.781	9.99	-0.281	-0.1308*	-106.0	- 63.9	- 94.0	-0.5123	-0.2414	- 2.059
7.	G.I. 363-1	0.2632	-0.553	18.66**	1.386	0.0281	-269.0*	211.4**	499.5**	1.1877*	0.2086	7.350*
8.	G.I. 363-4	-0.5702*	-2.719**	- 9.51	1.553	0.0281	-128.2	- 71.3	-173.5	0.9377	0.4486	2.145
9.	G.I. 410-8	0.0965	1.447	- 3.68	-3.447**	-0.0553	-204.9	-179.3*	-380.2**	-1.6623**	0.0686	-10.354**
10.	G.I. 435-4	0.2632	-3.553**	-24.51**	5.219**	-0.1053	356.0**	-192.9**	206.0	-0.2123	-0.2414	- 1.385
11.	ACC 1009-2	0.2632	-2.219*	- 9.34	-0.447	-0.1719*	21.1	18.4	78.0	0.7877	-0.3714	- 0.442
12.	BUDUNA GERO712-2	0.0965	3.942**	- 2.01	-2.114*	-0.0886	-160.0	-185.8*	-296.0*	-0.6623	-0.1197	- 4.304
13.	ICMV 88908	-0.2368	-0.386	- 8.34	-3.614**	0.3947**	-157.0	- 78.3	- 81.5	1.0211	-0.0314	4.186
14.	G.I. 41-3	0.0965	4.114**	- 9.01	1.219	-0.0219	58.1	28.1	122.9	-0.9456	0.1486	- 3.338
15.	G.I. 47-3	-0.2368	3.614**	13.82*	-1.781*	0.1281	102.8	98.6	71.3	-0.1789	0.1414	5.922
16.	ACC 364-1	-9.2368	-0.386	1.49	4.719**	-0.0553	34.0	21.2	200.5	0.2711	0.3386	- 0.571
17.	ICMV 93501	0.2632	-8.886**	- 4.01	-1.781*	0.1614*	86.3	68.9	48.3	-0.1956	-0.1014	2.787
18.	ICMP 94592	-0.0702	-0.219	-12.34	-0.614	0.1281	190.2	-161.9*	-320.9*	-0.9289	-0.0486	- 6.796*
19.	ICMP 91103	0.4298	-4.553**	-18.34**	-1.614	0.0947	243.3*	181.9*	264.0	1.2877*	0.1136	6.929
SE ±		0.2228	1.0310	6.3679	0.8836	0.0682	114.4855	73.3014	146.7780	0.5259	0.2589	3.1672
LSD 5%		0.4367	2.021	12.481	1.732	0.1337	224.392	143.107	278.685	1.031	0.507	6.2077
LSD 1%		0.5739	2.656	16.404	2.276	0.1756	294.915	188.824	378.100	1.3547	0.667	8.159

Appendix 7 Contd.

Testers	Pedigree	Number of Tillers	Days to 50% Flowering	Plant height (cm)	Panicle length (cm)	Panicle width (cm)	Head weight (kg/ha)	Grain weight (kg/ha	Grain yield (kg/ha	1000-seed weight (g)	Crude Protein (%)	Threshing (%)
1.	EX-BORNO	-0.11404	5.335**	11.46**	-1.4298**	-0.06930*	- 89.7*	- 65.54**	-141.3*	-1.224**	-0.0678	-2.426
2.	GWAGWA	-0.03509	1.465**	6.25*	0.7544*	0.05877*	- 74.0	- 81.64**	-153.5**	-1.174**	0.06044	-5.303**
3.	GB 8735	0.14912	-6.798**	-17.70**	0.6754	0.12807*	163.6*	147.18**	294.8**	2.397**	0.00754	7.730**
SE ±		0.0885	0.4097	2.5303	0.3511	0.0271	45.4918	29.9217	58.3237	0.2090	0.1029	1.2585
LSD 5%		0.174	0.803	4.9594	0.6882	0.0532	89.164	58.646	114.315	0.4096	0.2016	2.467
LSD 1%		0.228	1.0554	6.518	0.9044	0.0698	117.187	77.078	150.24	0.5384	0.068	3.242

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

Appendix 8. Estimates of general combining ability effects for eleven characters in pearl millet (Bagauda, 1996)

Lines	Genotype	Number of Tillers	Days to 50% flowering	Plant height (cm)	Panicle length (cm)	Panicle width (cm)	Head weight (kg ha)	Grain weight (kg ha)	Grain Yield (kg/ha)	1000-seed weight (g)	Crude Protein (%)	Threshing (%)
1.	G.I. 6-2	0.3947	3.719**	2.80	-0.079	-0.2333*	-238.4	-165.5	-189.2	-1.7579**	-0.2895	-0.098
2.	G.I. 7-5-1	-0.1053	-0.281	-12.37	2.088	-0.2333*	-404.1*	-252.0	-219.2	-0.8746*	-0.1561	1.181
3.	G.I. 122-2	0.2281	1.886*	14.63	-1.079	0.1000	-297.7	-257.8	-494.9**	0.3588*	0.3905	-4.315*
4.	G.I. 165-6	-0.1053	3.053**	6.30	1.088	-0.0333	180.6	109.2	128.3	-0.8412*	0.1105	-0.366
5.	G.I. 296-1	-0.9386*	-0.947	10.46	-0.412	-0.0500	-431.1*	-287.6	-415.9**	0.3754*	-0.0028	-2.794
6.	G.I. 359-3	0.0614	0.386	- 1.70	-0.412	-0.1333	229.8	121.2	160.5	-0.2412	0.0005	0.210
7.	G.I. 363-1	0.7281	-2.114	14.30	1.254	0.0167	- 4.2	58.0	83.1	0.0421*	-0.2195	3.217*
8.	G.I. 363-4	-0.1053	-1.114	- 4.87	2.254	0.2167	643.3**	518.5**	702.3**	1.2754**	-0.0195	5.156**
9.	G.I. 410-8	0.3947	2.886**	6.96	-1.579	0.0667	-331.4	-243.8	-378.9*	-0.3746*	0.0305	-1.659*
10.	G.I. 435-4	0.2281	-2.614**	- 0.20	2.421	0.1500	634.1*	440.0**	513.6**	-0.4412*	0.0105	1.347*
11.	ACC 1009-2	-0.9386*	-3.614**	-19.87*	0.254	-0.100	149.4	85.0	86.1	0.3588*	0.2105	0.063
12.	BUDUNA GERO 712-2	0.0614	2.553**	-12.70	-3.579*	-0.3333**	-419.1*	-328.0*	-344.9	-0.1246*	0.0505	-5.790**
13.	ICMV 88908	-0.2719	-1.947*	- 4.87	-1.912	0.400**	- 13.7	54.4	23.5	1.5921**	0.0305	4.229**
14.	G.I. 41-3	0.5614	3.553**	15.46	2.254	0.0667	200.9	- 2.5	- 54.0	-0.1912*	-0.1795	-5.902**
15.	G.I. 47-3	0.3947	2.053*	22.13*	-2.746	0.1333	230.6	178.0	287.1	-0.3412*	0.0405	0.934
16.	ACC 364-1	0.0614	1.053	-18.04*	1.254	-0.2333*	18.3	17.9	111.5	-0.7412*	-0.2695	0.983
17.	ICMV 93501	-0.4386	-3.281**	- 6.70	-0.912	0.1000	-293.7	-230.1	-372.2*	0.4088*	0.5405*	-2.917
18.	ICMP 94592	-0.7719	-0.281	-14.70	0.588	-0.0333	40.3	62.7	18.5	-0.1079*	-0.1995	3.011
19.	ICMP 91103	0.5614	-4.947**	2.96	-1.246	0.1333	106.4	122.2	254.6	1.6254**	-0.0795	3.609**
SE ±		0.4510	0.8980	9.0853	1.5553	0.1137	181.9572	127.1380	188.8970	0.4123	0.2136	1.6802
LSD 1%		1.162	2.313	23.404	4.007	0.2929	468.72	327.507	486.599	1.062	0.5302	4.328
LSD 5%		0.884	1.7601	17.807	3.048	0.2229	356.636	249.191	370.238	0.0808	0.4187	3.293

Appendix 8: cont.

Tester	Genotype	Number of Tillers	Days to 50% flowering	Plant height (cm)	Panicle length (cm)	Panicle width (cm)	Head weight (kg/ha)	Grain weight (kg/ha)	Grain yield (kg/ha)	1000-seed weight (g)	Crude protein (%)	Threshing (%)
1.	EX-BORNO	0.0088	3.377	11.16**	-1.000	-0.001754	-189.3	-168.0**	-238.4**	-1.345**	0.0389	-2.761**
2.	GWAGWA	0.3246	1.982	7.39*	1.1842	-0.007018	- 61.2	- 55.4	- 54.9	-0.661**	-0.07158	-0.760
3.	GB 8735	-0.3333	-5.360	-18.55**	-0.1842	0.008772	250.5**	223.3**	293.3**	2.005**	0.10947	3.521**
SE ±		0.1792	0.3568	3.6101	0.6180	0.0452	72.3025	50.5195	75.0601	0.1638	0.0849	0.6677
LSD 5%		0.3512	6.619	7.075	1.2113	0.0886	141.713	99.018	147.118	0.3210	0.166	1.3087
LSD 1%		0.4616	8.699	9.2996	1.592	0.1164	186.251	130.138	193.355	0.4219	0.2187	1.8000

*, ** Significant of 5% and 1% level of probability respectively

Appendix 9 Estimates of Specific Combining Ability (SCA) effects for eleven characters in pearl millet (Samaru, 1996)

Hybirds	Pedigree	Number of Tillers	Days to 50% flowering	Plant height (cm)	Panicle length (cm)	Panicle width (cm)	Head weight (kg/ha)	Grain weight (kg/ha)	Grain Yield (kg/ha)	1000-seed weight (g)	Crude Protein (%)	Threshing (%)
H.1.1	G.I.6-2xEX-BORNO	-0.5526	- 1.333	- 8.123	-0.904	0.18596	- 13.5	28.5	120.8	1.9404*	0.5480	2.792
H.1.2	G.I.6-2xGWAGWA	0.8684*	1.035	12.088	-0.588	0.07544	460.8**	224.6	296.5	0.0904	-0.4504	-3.349
H.1.3	G.I.6-2xGB 8735	-0.3158	0.298	-3.965	1.491	-0.26140*	-447.3**	-253.2	-417.3	-2.0307*	-0.0975	0.557
H.2.1	G.I.75x-1 E-BORNO	-0.3860	2.500	17.211	-1.404	0.10263	-279.5	-189.1	-421.7	0.2737	0.0480	-0.943
H.2.2	G.I.75-1xGWAGWA	0.0351	- 4.132*	-5.079	0.412	0.09211	107.8	33.5	39.0	-0.8763	0.2796	-3.582
H.2.3	G.I.75-1xGB 8735	0.3509	1.632	-12.132	0.991	-0.19474	171.7	155.7	382.7	0.6026	-0.3275	4.525
H.3.1	G.I.122-2xEX-BORNO	-0.2193	1.833	15.211	0.237	-0.01404	-270.2	-196.3	-239.3	-0.7263	0.0180	-12.186*
H.3.2	G.I.122-2x GWAGWA	0.2018	1.202	-14.579	0.579	-0.02456	11.6	48.8	138.3	1.0237	-0.0204	11.379*
H 3.3	G.I.122-2xGB8735	0.0175	- 3.035	- 0.632	-0.342	0.03860	258.5	147.5	101.1	-0.2974	0.0025	0.307
H.4.1	G.I.165-6xEX-BORNO	0.1140	0.500	14.711	-0.070	-0.14737	199.3	129.4	273.8	0.5904	0.1880	4.227
H.4.2	G.I.165-6xGWAGWA	0.0381	- 0.132	1.921	-2.254	0.19211	-124.9	- 63.0	- 46.0	0.1404	-0.0004	-2.392
H.4.3	G.I.165-6xGB8735	-0.1491	- 0.368	-16.632	2.325	-0.04474	- 74.5	- 66.3	-227.8	-0.7307	-0.1875	-1.835
H.5.1	G.I.296-1xEX-BORNO	-0.0526	2.167	- 9.289	0.096	-0.11404	-185.8	-120.8	-423.2	-0.4596	0.2280	-3.624
H.5.2	G.I.296-1xGWAGWA	0.3684	- 0.965	- 2.579	-1.088	0.07544	22.0	10.3	377.0	0.1904	-0.3504	1.833
H.5.3	G.I.296-1xGB8735	-0.3158	- 1.202	11.868	0.991	0.03860	-163.9	110.5	46.2	0.2693	0.1225	1.791
H.6.1	G.I.359-3xEX-BORNO	-0.2193	- 1.833	- 7.123	-0.570	-0.01404	-207.3	-135.8	-182.0	-0.5930	-0.0920	-4.432
H.6.2	G.I.359-3xGWAGWA	-0.2982	- 0.465	14.588	1.246	0.42544	- 90.5	- 47.2	-135.4	-0.2570	-0.0404	1.587
H.6.3	G.I.359-3xGB8735	0.5175	2.298	- 7.465	-0.675	-0.11140	-297.9	183.5	317.4	0.3360	0.1325	2.845
H.7.1	G.I.363-1xEX-BORNO	-0.5526	0.00	3.211	0.763	-0.13070	-255.8	-210.6	-627.0*	-0.3930	0.2380	-5.124
H.7.2	G.I.363-1xGWAGWA	0.3684	- 1.132	- 5.579	2.079	-0.14123	179.0	144.0	191.1	0.3570	-0.2204	6.122
H.7.3	G.I.363-1xGB8735	0.1842	1.132	2.368	-2.842	0.27193*	76.9	66.7	435.9	0.0360	-0.0175	-0.998
H.8.1	G.I.363-4xEX-BORNO	0.2807	- 1.333	-12.623	0.763	0.21930	203.3	155.0	269.5	1.1070	-0.7820	6.965
H.8.2	G.I.363-4xGWAGWA	-0.2982	2.535	1.088	2.079	-0.14123	83.9	- 41.4	28.1	-0.7930	0.9496*	0.221
H.8.3	G.I.363-4xGB8735	0.0175	- 1.202	11.535	-2.842	-0.07807	-119.5	-113.7	-297.6	-0.3140	-0.1675	-7.189
H.9.1	G.I.410-8xEX-BORNO	0.6140	1.500	-18.456	0.263	0.00263	284.5	125.5	188.7	-0.1430	-0.0720	-2.579
H.9.2	G.I.410-8xGWAGWA	0.0351	- 4.132*	-10.246	-2.421	-0.00789	- 18.8	63.1	134.8	0.2070	-0.2604	2.298

Appendix 9 Cont.

Hybrids	Pedigree	Number of Tillers	Days to 50% flowering	Plant height (cm)	Panicle length (cm)	Panicle wideht (cm)	Head weight (kg/ha)	Grain weight (kg/ha)	Grain yield (kg/ha)	1000-seed weight (g)	Crude Protein (%)	Threshing (%)
H.9.3	G.I.410-8xGB8735	-0.6491	2.o32	28.702	2.158	.0.00526	-303.3	-188.7	-323.4	-0.0640	0.3325	0.281
H.10.1	G.I.435-4xEX-BORNO	0.4474	- 0.500	4.377	-0.404	0.05263	168.7	127.4	341.0	-0.6430	0.0020	-0.450
H.10.2	G.I.435-4xGWAGWA	-0.1316	2.868	- 1.912	0.412	-0.00789	44.0	- 71.0	-178.4	0.2070	0.0796	-6.894
H.10.3	G.I.435-4xGB8735	-0.3158	- 2.368	- 2.465	-0.009	-0.04474	-212.6	- 56.3	-162.6	0.4360	-0.0775	7.343
H.11.1	ACC 1069-2xEX-BORNO	0.4474	- 2.833	0.211	-0.237	0.11930	420.0**	308.9*	568.0	0.2070	0.2780	11.162**
H.11.2	ACC 1009-2xGWAGWA	-0.1316	4.035*	5.921	-2.921	-0.04123	-314.2	-200.0	-412.4	0.8070	-0.5404	-9.057
H.11.3	ACC 1009-2x GB8735	-0.1842	- 1.202	- 6.132	3.158*	-0.07807	-105.8	-180.8	-155.6	-1.0140	0.2625	-2.105
H.12.1	BUDUMA GERO 712-2 x EX-BORNO	-0.3860	1.000	- 8.123	3.430*	-0.01404	- 26.3	2.0	- 36.0	0.0570	-0.0887	-0.886
H.12.2	BUDUMA GERO 712-2 x GWAGWA	1.0351**	-10.132**	1.088	-3.754*	0.02544	262.0	153.1	391.6	-1.0930	-0.0721	-0.119
H.12.3	BUDUMA GERO 712-2 x GB 8735	-0.6491	-0.868	7.035	0.325	-0.01140	- 235.6	-155.2	-355.6	1.0360	0.1608	1.005
H.13.1	ICMV88908xEX-BORNO	0.4474	-0.167	- 9.789	-1.570	-0.14737	50.0	18.0	240.0	-1.0765	0.0280	-2.954
H.13.2	ICMV88908 x GWAGWA	-0.1316	1.702	2.421	0.746	-0.05789	- 50.7	- 19.9	- 73.4	-0.4263	-0.1304	1.182
H.13.3	ICMV88908 x GB8735	-0.3158	-1.535	7.368	0.825	0.20526	0.7	1.8	-166.6	1.5026	0.1025	1.772
H.14.1	G.I.41-3x EX-BORNO	0.1140	-1.165	1.877	-2.404	-0.03070	- 5.0	25.2	250.3	-0.0596	-0.4220	5.491
H.14.2	G.I.41-3x GWAGWA	-0.4649	2.202	- 4.912	0.412	-0.14123	- 258.7	-173.2	-481.5	-0.7096	0.6496	-2.388
H.14.3	G.I.41-3x GB8735	0.3509	-1.055	3.035	1.991	0.17193	263.7	148.0	231.2	0.7693	-0.2275	1.897
H.15.1	G.I.47-3x EX-BORNO	-0.5526	-0.667	18.544	0.596	-0.08070	- 237.2	-157.3	-215.8	-0.7263	0.2580	-1.157
H.15.2	G.I.47-3x GWAGWA	-0.1316	4.202*	-15.246	-0.588	-0.04123	- 173.9	- 89.7	- 43.7	1.2737	-0.0504	4.634
H.15.3	G.I.47-3x GB8735	0.6842	-3.535	- 3.298	-0.009	0.12193	-411.0*	247.0	259.6	-0.5474	-0.2075	-3.477
H.16.1	ACC 364-1x EX-BORNO	-0.0526	1.833	- 8.123	-0.904	-0.04737	- 156.3	-119.5	-417.5	-1.0763	-0.4220	-3.376
H.16.2	ACC 364-1xGWAGWA	-0.1316	1.202	- 7.912	4.412**	-0.05789	- 138.0	- 85.4	-278.9	0.1237	0.5596	0.191
H.16.3	ACC 364-1x GB8735	0.1842	-3.035	16.035	-3.509*	0.10526	294.4	204.8	696.4**	0.9526	-0.1375	3.185
H.17.1	ICMV 93501xEX-BORNO	0.4474	1.333	2.877	1.596	0.08596	-447.8**	280.4*	412.7	1.2904	0.0980	4.072

Appendix 9 Cont.

Hybrids	PEDEGREE	Tillers	Days to 50% flowering	Plant height (cm)	Panicle length (cm)	Panicle width (cm)	Head weight (kg/ha)	Grain weight (kg/ha)	Grain Yield (kg/ha)	1000-seed weight (g)	Crude Protein (%)	Threshing (%)
H.17.2	ICMV 93501xGWAGWA	-0.6316	-8.298**	2.588	1.412	0.12544	-306.4	-199.0	-289.2	-1.2096	-0.3904	-6.636
H.17.3	ICMV 93501xGB 8735	0.1842	6.965**	-10.465	-3.009*	-0.21140	-141.5	-81.3	-123.4	-0.0807	0.2925	2.565
H.18.2	ICMP 94592xGWAGWA	-0.2982	-0.965	1.921	1.246	0.05877	118.6	143.8	171.5	0.9737	-0.0301	12.185
H.18.3	ICMP 94592xGB 8735	0.0175	2.298	- 3.132	-1.675	-0.07807	- 157.5	-189.0	-355.8	-0.8974	-0.0675	-14.73*
H.19.1	ICMP 91103xEX-BORNO	-0.2193	-1.500	2.211	-0.070	-0.04737	175.7	-116.1	286.5	-0.5070	0.1470	0.455
H.19.2	ICMP 91103 x GWAGWA	0.2018	-0.632	19.421	2.246	-0.10789	316.6	169.0	171.1	-0.5430	0.0396	- 2.216
H.19.3	ICMP 91103xGB 8735	0.0175	2.132	-21.632*	-2.175	0.15526	- 141.0	- 52.8	115.4	0.0360	0.1075	1.761
SE ±		0.3860	1.7857	11.0205	1.5304	0.1186	161.9069	130.4258	254.2270	0.9109	0.4184	5.1897
LSD 5%		0.7560	3.47997	21.618	2.9996	0.2325	317.338	255.635	498.285	1.7854	0.8729	10.9711
LSD 1%		0.9943	4.59996	28.41	3.9423	0.3055	417.072	335.927	654.889	2.3465	1.155	16.4571

*, ** Significant of 5% and 1% level of probability respectively.

Note: (H1.1) = G.L 6-2 x Ex-Borno, (H2.2) = G.L 75 -1 x Gwagwa, (H 3.3) = G.L 12.2-2 x GBB 735

Appendix 10: Estimates of Specific Combining Ability (SCA) effects for eleven characters in pearl millet (Uganda, 1996)

Hybrids	PEDEGREE	Number of Tillers	Days to 50% flowering	Plant height (cm)	Panicle length (cm)	Panicle width (cm)	Head weight (kg/ha)	Grain weight (kg/ha)	Grain Yield (kg/ha)	1000-seed weight (g)	Crude Protein (%)	Threshing (%)
H1.1	G.I.6-2xEX-BORNO	1.6579*	1.377**	- 0.82	-1.000	0.0018	36.3	-2.2	-196.6	-0.1053	-0.2221	-1.992
H1.2	G.I.6-2xGWAGWA	-2.1579**	1.018	13.44	-1.184	-0.0430	-230.8	-143.8	-127.6	0.1605	0.1884	0.200
H1.3	G.I.62xGB8735	0.500	0.360	-12.61	2.184	-0.0412	194.5	146.0	324.2	-0.0553	0.4105	1.792
H2.1	G.I.75-1xEX-BORNO	-0.8421	2.623**	5.34	-1.167	0.2518	-768.0*	-453.2*	-300.6	-0.6886	-0.1154	4.821
H2.2	G.I.75-1xGWAGWA	-0.6579	0.018	4.61	1.649	-0.0930	190.3	84.7	- 70.1	-0.1228	-0.2018	-2.943
H2.3	G.I.75-1xGB8735	1.500	-2.640**	- 9.95	-0.482	-0.1588	577.7	368.5	370.7	0.8114	0.3172	-1.877
H3.1	G.I.122-2x-BORNO	0.3246	-0.540	-38.66*	1.500	0.1184	-234.9	-122.9	-142.4	1.1281	-0.8421*	-0.090
H3.2	G.I.122-2x-GWAGWA	1.0088	-1.149*	23.11	-2.184	-0.2263	-177.0	- 94.5	-115.4	-1.2561	0.0316	0.908
H3.3	G.I.122-2x-GB8735	-1.3333	1.693**	15.55	0.684	0.1079	411.9	217.3	257.9	0.1281	0.8105*	-0.818
H4.1	G.I.165-6x-BORNO	-0.3421	-0.711	11.18	0.833	0.0518	-215.2	-206.4	-222.1	-0.4219	0.0379	-4.439
H4.2	G.I.165-6xGWAGWA	1.3421	0.684	5.44	-1.851	0.1570	375.2	269.9	311.4	-0.3061	-0.0724	1.995
H4.3	G.I.165-6xGB8735	-1.000	0.026	-16.61	1.018	-0.2088	-160.0	- 62.7	- 39.3	0.7281	0.0405	2.444
H5.1	G.I.296-1xEX-BORNO	-0.0088	0.789	16.01	-0.167	0.0184	-408.5	-249.0	-389.4	-0.6386	0.5412	-1.822
H5.2	G.I.296-1xGWAGWA	-0.3246	0.684	- 5.73	-5.351*	-0.0263	-277.7	-188.6	-145.4	0.2272	-0.0351	-0.563
H5.3	G.I.296-1xGB8735	0.3333	-1.474**	-10.18	5.518*	0.0079	686.2*	437.7*	534.9	0.4114	-0.5061	2.385
H6.1	G.I.359-3xEX-BORNO	0.4912	-0.544	17.18	-2.167	0.1018	304.6	213.1	93.2	1.6281*	0.1479	0.712
H6.2	G.I.359-3xGWAGWA	-0.8246	0.851	- 9.06	0.149	0.0570	70.0	- 16.5	366.2	-1.1561	-0.2084	-2.061
H6.3	G.I.359-3xGB8735	0.3333	-0.307	- 8.11	2.018	-0.1588	-374.6	-196.7	-459.4	-0.4719	0.0605	1.348
H7.1	G.I.363-1xEX-BORNO	-0.6754	0.456	-12.82	2.667	-0.0982	-407.9	-297.2	-496.4	-0.8053	-0.0221	-1.599
H7.2	G.I.363-1xGWAGWA	0.5088	-0.149	- 6.06	0.982	0.2570	414.5	336.2	443.6	0.9605	0.0416	3.155
H7.3	G.I.363-1xGB8735	0.1667	-0.307	18.89	-3.649	-0.1588	- 6.6	- 39.0	52.9	-0.1553	-0.0195	-1.856
H8.1	G.I.363-4xBORNO	0.1579	-0.544	- 2.06	1.667	-0.1482	122.1	101.8	154.1	0.8611	-0.0121	2.505

Appendix 10 Cont.

Hybrids	PEDEGREE	Number of Tillers	Days to 50% flowering	Plant height (cm)	Panicle length (cm)	Panicle width (cm)	Head weight (kg/ha)	Grain weight (kg/ha)	Grain Yield (kg/ha)	1000-seed weight (g)	Crude Protein (%)	Threshing (%)
H8.2	G.I.363-4xGWAGWA	0.3421	0.851	- 0.39	-1.018	0.1570	71.5	45.7	- 46.1	-0.5728	-0.1584	0.179
H8.3	G.I.363-4xGB8735	-0.500	-0.307	3.05	-0.649	-0.0088	-193.6	-147.5	-108.3	-0.2886	0.1705	-2.683
H9.1	G.I.410-8xEX-BORNO	1.1579	-1.044*	- 6.49	0.000	-0.0482	95.8	68.6	201.6	-1.0386	-0.0621	-0.067
H9.2	G.I.410-8xGWAGWA	-0.6579	-0.649	12.77	-0.184	0.0570	- 14.8	- 9.0	127.4	1.4772*	0.2416	-0.147
H.9.3	G.I.410-8xGB8735	-0.500	1.693**	- 5.78	0.184	-0.0088	- 81.0	- 59.7	- 74.1	-0.4386	-0.1795	0.214
H10.1	G.I.435-4xEX-BORNO	-0.6754	1.456**	9.18	-1.000	-0.0316	-109.2	- 81.7	14.1	0.6281	-0.2221	0.828
H10:2	G.I.435-4xGWAGWA	0.5088	-0.149	-22.56	-1.684	0.1737	146.2	78.2	113.6	-0.7061	0.2616	-0.382
H10.3	G.I.435-4xGB8735	0.1667	-1.307*	13.39	2.684	-0.1421	- 37.0	3.5	-127.6	0.0781	-0.0395	-0.446
H11.1	ACC 1009-2xEX-BORNO	0.4912	1.456**	- 9.66	-0.333	-0.2316	100.5	74.8	61.1	-0.0719	0.0579	0.714
H11.2	ACC 1009-2xGWAGWA	-0.8246	-1.149*	-12.89	-0.018	0.1237	91.8	92.7	208.6	0.7439	0.2716	1.862
H11.3	ACC 1009-2xGB 8735	0.3333	-0.307	22.55	0.351	0.1079	-192.3	-167.5	-269.6	-0.6719	-0.3295	-2.577
H12.1	BUDUMA GERO 712-2 x EX-BORNO	-0.5088	-1.211*	-2.82	3.500	0.1518	-504.0	-309.2	-634.4	-0.4386	0.3679	-4.817
H12.2	BUDUMA GERO 712-2 x GWAGWA	0.6754	-0.316	-1.06	-0.184	-0.0930	88.8	65.2	432.1	0.4272	-0.4984	2.827
H12.3	BUDUMA GERO 712-2 x GB 8735	-0.1667	1.526**	3.89	-3.316	-0.0588	415.2	244.0	202.4	0.0114	0.1305	1.990
H13.1	ICMV 88908 x EX-BORNO	0.3246	-0.711	-4.16	-0.167	0.1084	-107.4	-28.0	-154.4	0.1947	-0.2421	-0.585
H13.2	ICMV 88908xGWAGWA	0.0088	1.684**	4.11	0.649	-0.1763	256.0	167.4	98.7	-0.0895	0.4216	-0.193
H13.3	ICMV 88908xGB 8735	-0.3333	-0.974	0.05	-0.482	0.0079	-148.6	-89.3	56.1	-0.1053	-0.1795	0.778
H14.1	G.I. 41-3xEX-BORNO	-0.0088	-1.711**	14.01	-1.833	0.1018	431.0	257.3	170.2	-0.8219	0.1479	0.656
H14.2	G.I. 41-3xGWAGWA	0.1754	0.184	-1.73	0.482	-0.3430	-62.2	-76.8	16.7	-0.2561	-0.1184	-3.032
H14.3	G.I. 41-3xGB 8735	-0.1667	1.526**	-12.28	1.351	0.2412	-368.8	-120.5	-286.9	1.0781	-0.0395	2.375
H15.1	G.I. 47-3xEX-BORNO	-1.3421	-0.711	26.84	0.667	-0.2149	18.3	-27.7	-115.9	-0.0219	0.0779	-0.421

Appendix 10 Cont.

Hybrids	PEDEGREE	Number of Tillers	Days to 50% flowering	Plant height (cm)	Panicle length (cm)	Panicle width (cm)	Head weight (kg/ha)	Grain weight (kg/ha)	Grain Yield (kg/ha)	1000-seed weight (g)	Crude Protein (%)	Threshing (%)
H15.2	G.I. 47-3xGWAGWA	1.3421	3.184**	-15.39	-1.018	-0.1596	-457.3	-390.3	-632.4	-0.8061	0.0816	-4.746
H15.3	G.I. 47-3xGB 8735	0.0000	-2.474**	-11.45	0.351	0.3746	439.0	418.0	748.4*	0.8281	-0.1595	5.170
H16.1	ACC 364-1xEX-BORNO	-0.5088	-0.211	-31.49*	-0.333	-0.1982	374.6	267.0	363.7	-1.0719	-0.8121*	1.870
H16.2	ACC 364-1xGWAGWA	0.1754	-1.316*	-1.23	1.482	0.2070	-304.0	-214.1	-474.8	-0.1561	0.5716	-1.252
H16.3	ACC 364-1xGB 8735	0.3333	1.526**	32.72*	-1.149	-0.0088	-70.6	-52.8	111.1	1.2281	0.2405	-0.618
H17.1	ICMV 93501xEX-BORNO	-0.0088	1.123*	4.68	0.833	0.1684	859.1**	575.0**	834.9*	-0.0719	0.9279*	3.255
H17.2	ICMV 93501xGWAGWA	-0.8246	-1.482**	-0.56	-0.351	-0.0263	-465.5	-295.6	-443.6	0.4939	-0.6584	-1.603
H17.3	ICMV 93501xGB 8735	0.8333	0.3600	-4.11	-0.482	-0.1421	-393.6	-279.3	-391.9	-0.4219	-0.2695	-1.652
H18.1	ICMP 94592xEX-BORNO	-0.1754	0.877	7.68	-3.167	0.0518	424.6	298.6	434.2	0.2947	0.1379	1.392
H18.2	ICMP 94592xGWAGWA	0.5088	0.018	-1.56	5.649*	-0.0930	-80.0	-1.5	49.7	0.6105	0.0516	2.898
H18.3	ICMP 94592xGB 8735	-0.3333	0.860	-6.11	-2.482	-0.0412	-344.6	-297.2	-483.9	-0.9053	0.1895	-1.290
H19.1	ICMP 91103xEX-BORNO	0.4912	2.289**	-2.49	-0.333	-0.2149	-12.0	-28.9	275.6	1.4614*	0.1079	-0.918
H19.2	ICMP 91103xGWAGWA	-0.3246	-2.816**	15.27	3.982	0.0904	364.8	291.5	142.6	0.3272	0.1716	2.599
H19.3	ICMP 91103xGB 8735	-0.1662	0.526	-12.78	-3.649	0.1246	-352.8	-262.7	-418.1	-1.7886*	-0.2795	-1.681
SE ±		0.7811	1.5554	15.7362	2.6939	0.1964	315.1591	220.2094	327.1793	0.7140	0.3700	2.9103
LSD 5%		1.531	1.031	30.843	5.2800	0.3859	617.712	431.610	641.271	1.3994	0.7252	5.704
LSD %		2.012	1.355	40.5365	6.9395	0.507	811.943	567.260	842.814	1.8393	0.953	7.4970

*, ** Significant of 5% and 1% level of probability respectively.

Note: (H1.1) = G. I. 6-2 x Ex-Borno, (H2.2) = G.I. 75 -1 x Gwagwa, (H 3.3) = G.I. 12 2-2 x GBB 735

Appendix 11: Heterosis of hybrids over mid-parent and superior-parent (MP% x HP%) for eleven characters in pearl millet (Samaru, 1996)

Hybrids	Pedigree	Number of Tillers		Days to 50% flowering		Plant height (cm)		Panicle length (cm)		Panicle width (cm)	
		MP	HP	MP	HP	MP	HP	MP	HP	MP	HP
H1.1	G.I 6-2 x Ex-Borno	-71.43**	75.00**	-63.64**	-66.67**	5.4	-37.72**	7.74**	-17.09**	-4.00**	-20.00**
H1.2	G.I 6-2 x Gwagwa	14.29**	0.00	-66.67**	-71.43**	6.82	5.22	11.46**	10.84**	1.92**	-11.67**
H1.3	G.I 6-2 x GB8735	-60.00**	-66.67**	-69.23**	-75.00**	7.89	-8.21	8.73**	-6.16*	20.00**	-5.00**
H2.1	G.I 75-1 x Ex-Borno	-33.33**	-33.33**	0.00	-16.67**	11.55	0.72	6.50*	-10.07**	4.35**	-7.9**
H2.2	G.I 75-1 x Gwagwa	0.00	0.00	-27.27**	-42.86**	-1.65	-8.46	7.75**	0.45	16.67**	7.69**
H2.3	G.I 75-1 x GB8735	-11.11**	-33.33**	0.00	-25.60**	10.68	1.79	9.27**	0.00	31.05**	9.62**
H3.1	G.I 122-2 x Ex-Borno	-20.00**	-33.33**	-60.00**	-66.67**	1.43	0.71	4.21	-4.32*	5.38**	-7.55**
H3.2	G.I 122-2 x Gwagwa	20.00**	0.00	-27.27**	-42.86**	-1.85	-5.67	1.76	-0.65	13.40**	-3.77**
H3.3	G.I 122-2 x GB8735	-25.00**	-50.00**	-16.67**	-12.50**	8.09	-23.40	12.90**	-4.95*	20.45**	0.00
H4.1	G.I 165-6 x Ex-Borno	-20.00**	-33.33**	-11.11**	-33.33**	6.06	0.72	-3.42	-3.42	-31.94**	-31.94**
H4.2	G.I 165-6 x Gwagwa	20.00**	-33.33**	-20.00**	-42.86**	2.75	0.77	10.84**	8.68**	-15.52**	-31.94**
H4.3	G.I 165-6 x GB8735	-50.00**	-66.67**	27.27**	-12.50**	-7.11	-8.80	6.80*	9.76**	8.41**	-19.44**
H5.1	G.I 296-1 x Ex-Borno	50.00**	0.00	-27.27**	-33.33**	2.60	-0.72	-6.31*	-17.27**	12.09**	0.00

Appendix II Cont

Hybrids	Pedigree	Head weight (kg/ha)		Grain weight (kg/ha)		Grain Yield (kg/ha)		1000-seed weight (g)		Crude Protein (%)		Threshing(%)	
		MP	HP	MP	HP	MP	HP	MP	HP	MP	HP	MP	HP
H1.1	G.I 6-2 x Ex-Borno	0.99	0.00	-48.48	-55.71	-50.37	-59.90	-23.01**	-37.72**	13.61**	0.00	8.94	6.47
H1.2	G.I 6-2 x Gwagwa	0.00	-2.00	4.94	-1.39	-23.89	-24.08	-17.99**	-21.49**	-23.17**	-24.71**	-2.44	-2.91
H1.3	G.I 6-2 x GB8735	-14.02	-19.30	-79.24	-81.57	-79.56	-83.31	-55.69**	-61.49**	-19.60**	-30.74**	2.71	0.33
H2.1	G.I 75-1 x Ex-Borno	5.26	1.96	-24.81	-29.12	-19.17	-23.33	-26.65**	-34.91**	0.00	-15.30**	2.01	0.66
H2.2	G.I 75-1 x Gwagwa	8.70	4.17	26.17	8.76	11.48	-5.80	12.64**	5.43**	-25.49**	-27.32**	4.11	3.59
H2.3	G.I 75-1 x GB8735	-4.95	-15.79	32.14	-1.98	44.34	3.53	62.68**	29.24**	13.04**	1.30**	-1.28	-2.64
H3.1	G.I 122-2 x Ex-Borno	4.17	-1.96	-60.38	-69.18	-64.19	-72.37	-38.55**	-46.75**	4.32**	-3.97**	0.16	-5.15
H3.2	G.I 122-2 x Gwagwa	7.53	4.17	-13.28	-37.30	-5.84	-37.10	1.16**	-24.36**	11.38**	4.02**	-0.63	-4.74
H3.3	G.I 122-2 x GB8735	7.84	-3.51	26.83	-17.43	33.47	-19.14	21.69**	-18.80**	18.32**	-2.16**	0.85	-1.55
H4.1	G.I 165-6 x Ex-Borno	-9.80	-9.80	-1.93	-1.93	17.29	17.29	26.67**	28.67**	6.04**	6.04**	6.01	6.01
H4.2	G.I 165-6 x Gwagwa	19.10	10.42	-44.12	-58.66	-53.91	-69.10	-28.67**	-49.10**	-7.12**	-13.79**	3.97	2.61
H4.3	G.I 165-6 x GB8735	6.12	-8.77	-21.45	-48.15	-21.20	-52.14	-16.33**	-46.10**	7.37**	-11.69**	3.26	2.68
H5.1	G.I 296-1 x Ex-Borno	12.50	-17.65	-42.75	-54.55	-31.82	-44.26	-28.10**	-45.94**	4.46**	-12.3**	-4.08	-10.00

Appendix 11 Cont.

Hybrids	Pedigree	Number of Tillers		Days to 50% flowering		Plant height (cm)		Panicle length (cm)		Panicle width (cm)	
		MP	HP	MP	HP	MP	HP	MP	HP	MP	HP
H5.2	G.I 296-1 x Gwagwa	100.00**	33.33**	-50.00**	-57.14**	-4.62	-4.62	6.56*	4.51*	11.58**	3.92**
H5.3	G.I 296-1 x GB8735	-14.19**	-50.00**	-7.69**	-25.00**	-4.46	-17.79	19.35**	4.23*	32.56**	11.76**
H6.1	G.I 359-3 x Ex-Borno	33.33**	-33.33**	-11.11**	-33.33**	-5.67	-6.99	-1.88	-15.65**	-22.39**	-44.68**
H6.2	G.I 359-3 x Gwagwa	33.33**	-33.33**	-70.00**	-42.86**	-6.23	-10.49	19.10**	13.32**	-27.54**	-46.81**
H6.3	G.I 359-3 x GB 8735	33.33**	-33.33**	-27.27**	-50.00**	-1.27	-18.18	14.21**	2.50	-17.83**	43.62**
H7.1	G.I 363-1 x Borno	-42.86**	-50.00**	50.00**	0.00	0.38	-5.04	8.57**	-8.81**	17.24**	8.51**
H7.2	G.I 363-1 x Gwagwa	14.29**	0.00	11.11**	-42.86**	-3.94	-6.15	16.69**	8.13**	29.67**	25.53**
H7.3	GI 363-1 x GB8735	-20.00**	-33.33**	0.00	-37.50**	-0.92	-11.29	28.45**	18.25**	34.15**	17.02**
H8.1	G.I 363-4 x Ex-Borno	-20.00**	-33.33**	11.11**	-16.67**	-8.00	-17.27	-9.80**	-24.64**	8.00**	-10.00**
H8.2	G.I 363-4 x Gwagwa	-60.00**	-66.67**	-40.00**	-57.14**	-4.56	-11.54	6.86*	-1.58	17.31**	1.67**
H8.3	G.I 363-4 x GB8735	-50.00**	-66.67**	-27.27**	-50.00**	-11.22	-18.02	18.38**	9.65**	7.37**	-15.00**
H9.1	G.I 410-8 x Ex-Borno	60.00**	33.33**	-50.00**	-66.67**	-0.71	-1.42	-11.70**	-24.64**	2.38**	-2.27**
H9.2	G.I 410-8 x Gwagwa	20.00**	0.00	-33.33**	-57.14**	-11.44	-14.89	1.67	-4.06	-4.55**	-4.55**
H9.3	G.I 410-8 x GB 8735	-50.00**	-66.67**	-40.00**	-62.50**	-0.43	-17.02	27.99**	15.78**	29.11**	-15.91**

Appendix 11 Cont.

Hybrids	Pedigree	Head weight (kg/ha)		Grain weight (kg/ha)		Grain Yield (kg/ha)		1000-seed weight (g)		Crude Protein (%)		Threshing (%)	
		MP	HP	MP	HP	MP	HP	MP	HP	MP	HP	MP	HP
H5.2	G.I 296-1 x Gwagwa	-1.08	-4.17	-11.74	-34.66	-17.44	-42.50	82.11**	22.03**	-1.39*	-4.81**	-10.37	-14.46
H5.3	G.I 296-1 x GB8735	-3.92	-14.04	14.43	-24.41	24.48	-22.36	48.03**	-8.98**	20.10**	8.66**	-4.33	-10.30
H6.1	C.I 359-3 x Ex-Borno	22.03	-31.34	-59.03	-66.18	-62.74	-66.56	-28.99**	-33.41**	6.56**	2.36**	-2.46	-5.13
H6.2	G.I 359-3 x Gwagwa	-14.78	-26.87	-42.11	-55.64	52.20	-64.90	-38.77**	-51.28**	1.72*	-14.94**	-2.27	-3.21
H6.3	G.I 359-3 x GB 8735	22.58	-28.36	21.45	-17.68	22.21	-19.96	41.40**	-1.06	27.01**	-4.33**	0.88	-1.92
H7.1	G.I 363-1 x Borno	1.08	-7.84	-18.11	-20.29	-14.31	24.00	-32.37**	-46.00**	12.00**	-2.89**	7.51	5.92
H7.2	G.I 363-1 x Gwagwa	4.44	-2.08	34.80	25.58	42.78	28.50	39.41**	31.32**	6.05**	-5.75**	1.97	1.63
H7.3	GI 363-1 x GB8735	19.19	3.51	20.88	-4.71	33.00	0.00	71.33**	51.12**	23.27**	-7.79**	5.52	3.95
H8.1	G.I 363-4 x Ex-Borno	8.00	5.88	26.27	-6.32	54.03	25.04	30.11**	26.35**	16.62**	-5.39**	-0.17	-0.67
H8.2	G.I 363-4 x Gwagwa	-3.09	-4.08	-39.23	-57.59	-49.64	-65.10	-29.31**	-42.16**	-17.46**	-23.53**	18.54*	16.99*
H8.3	G.I 363-4 x GB8735	-1.89	-8.77	-28.30	-54.67	-32.93	-58.31	-32.80**	51.96**	-8.97**	2.60**	7.65	7.05
H9.1	G.I 410-8 x Ex-Borno	1.05	-5.88	58.88	-5.62	37.4-	-19.39	20.17**	19.84**	-12.45**	-15.94**	0.65	-2.54
H9.2	G.I 410-8 x Gwagwa	4.35	0.00	-20.81	-54.32	-38.21	-65.80	-23.33**	53.01**	-20.51**	-28.74**	-1.77	3.17
H9.3	G.I 410-8 x GB 8735	2.97	-8.77	-57.56	-76.60	-65.07	-81.36	-46.20**	69.00**	2.98**	-17.75**	5.96	2.54

Appendix II Cont.

Hybrids	Pedigree	Number of Tillers		Days to 50% flowering		Plant height (cm)		Panicle length (cm)		Panicle width (cm)	
		MP	HP	MP	HP	MP	HP	MP	HP	MP	HP
H10.1	G.I 435-4 x Ex-Borno	60.00**	33.33**	11.11**	-16.67**	-3.85	-10.07	-8.64**	-23.92**	6.31**	-16.90**
H10.2	GI 435-4 x Gwagwa	20.00**	0.00	0.00	-28.57**	-1.20	-4.62	1.60	-9.71**	13.04**	-8.45**
H10.3	G.I 435-4 x GB 8735	-25.00**	-50.00**	9.09**	-25.00**	-9.77	-19.83	2.03	-5.14*	20.75**	-9.86**
H11.1	ACC 1009-2 x Ex-Borno	60.00**	33.33**	11.11**	-16.67**	0.00	-11.51	-8.15**	-19.96**	-6.80**	-23.81**
H11.2	ACC 1009-2 x Gwagwa	-20.00**	-33.33**	-40.00**	-57.14**	8.86	-0.77	4.21	0.68	-12.15**	-25.40**
H11.3	ACC 1009-2 x GB 8735	-0.00	-33.33**	-9.09**	-37.50**	1.49	-4.67	2.33	-9.44**	20.41**	-6.35**
H12.1	Buduma Gero 712-2 x Ex-Borno	-20.00**	-33.33**	-69.23**	-71.43**	2.14	1.42	-10.32**	-20.32**	25.30**	20.98**
H12.2	Buduma Gero 712-2 x Gwagwa	100.00**	66.67**	-42.86**	-42.86**	-1.85	-5.67**	3.09**	1.81	-3.45**	-4.55**
H12.3	Buduma Gero 712-2 x GB8735	-50.00**	-66.67**	-60.00**	-62.50**	-2.13	-18.44	10.67	-3.94**	28.21**	16.28**
H13.1	ICMV 8890 x Ex-Borno	20.00**	0.00	-50.00**	-66.67**	6.45	-5.04	1.67	-23.20**	5.41**	-2.50**
H13.2	ICMV 88908 x Gwagwa	-20.00**	-33.33**	-33.33**	-57.14**	7.11	-1.54	-0.45	-0.45	9.09**	9.09**
H13.3	ICMV 88908 x GB8735	-50.00**	-66.67**	0.00	-37.50**	3.45	-3.67	33.89**	26.73**	39.13**	37.14**

Appendix 11 Cont.

Hybrids	Pedigree	Head weight (kg/ha)		Grain weight (kg/ha)		Grain Yield (kg/ha)		1000-seed weight (g)		Crude Protein (%)		Threshing (%)	
		MP	HP	MP	HP	MP	HP	MP	HP	MP	HP	MP	HP
H10.1	G.I 435-4 x Ex-Borno	5.49	-5.88	127.05	2.94	163.92	101.45	118.25**	98.80**	-9.40**	-21.05**	-0.17	-1.64
H10.2	GI 435-4 x Gwagwa	6.82	-2.08	76.30	19.53	23.38	-18.20	-1.47**	-23.39**	-11.30**	-12.07**	0.33	0.00
H10.3	G.I 435-4 x GB 8735	3.09	-12.28	26.42	21.76	36.36	-17.82	24.73**	-14.25**	13.93**	-0.87	0.11	-1.64
H11.1	ACC 1009-2 x Ex-Borno	1.05	-5.88	76.77	50.08	127.62	103.72	126.67**	-114.70**	24.19**	14.67**	3.23	3.05
H11.2	ACC 1009-2 x Gwagwa	-2.17	-6.25	-59.01	-67.80	-71.66	-78.90	-53.47**	-62.67**	14.20**	6.32**	-6.33	-8.17
H11.3	ACC 1009-2 x GB 8735	-4.95	-15.79	-14.50	-40.95	-18.05	-46.41	9.19**	-23.12**	15.49**	-4.76**	3.96	3.85
H12.1	Buduma Gero 712-2 x Ex-Borno	-3.09	-7.84	-51.67	-62.02	-55.49	-61.39	-28.41**	-42.41**	-3.11**	-13.58**	-2.70	-6.78
H12.2	Buduma Gero 712-2 x Gwagwa	2.13	0.00	-5.45	-30.62	-30.03	-49.10	19.03**	-16.01**	-29.76**	-32.18**	-2.87	-5.28
H12.3	Buduma Gero 712-2 x GB8735	-0.97	-10.53	-62.73	-75.55	-65.74	-77.96	-45.51**	-65.19**	18.07**	0.43	0.86	3.42
H13.1	ICMV 8890 x Ex-Borno	6.93	5.88	-1.45	-34.51	9.09	-21.49	66.55**	-36.39**	-10.91**	-28.77**	2.16	0.33
H13.2	ICMV 88908 x Gwagwa	12.00	12.00	-57.15	-57.15	-62.20	-62.20	-43.19**	-43.19**	-22.17**	-22.17**	0.00	0.00
H13.3	ICMV 88908 x GB8735	21.50	14.04	-10.24	-47.05	-5.48	-44.65	-0.26**	-32.62**	24.15**	19.05**	3.88	1.50

Appendix 11 Cont.

Hybrids	Pedigree	Number of Tillers		Days to 50% flowering		Plant height (cm)		Panicle length (cm)		Panicle width (cm)	
		MP	HP	MP	HP	MP	HP	MP	HP	MP	HP
H14.1	G.I 41-3 x Ex-Borno	-25.00**	-40.00**	-11.11**	-33.33**	2.96	0.00	-10.11	-19.24**	-6.00**	-21.67**
H14.2	G.I 41-3 x Gwagwa	-50.00**	-60.00**	-20.00**	-42.86**	5.75	5.34	-4.06	-4.06	9.62**	-5.00**
H14.3	G.I 41-3 x GB8735	-27.27**	-33.33**	-9.09**	-37.50**	2.22	-12.21	3.29	-11.29**	26.32**	0.00
H15.1	G.I 47-3 x Ex-Borno	-60.00**	-66.67**	-25.00**	-50.00**	2.58	0.00	19.59**	-5.04*	6.82**	-2.08**
H15.2	G.I 47-3 x Gwagwa	-20.00**	-33.33**	-55.56**	-71.43**	7.63	6.82	16.88**	1.58	6.52**	-2.08**
H15.3	G.I 47-3 x GB8735	0.00	-33.33**	40.00**	-12.50**	-3.54	-17.42	32.09**	30.28**	20.48**	4.17**
H16.1	ACC 364-1 x Ex-Borno	-20.00**	-33.33**	25.00**	-16.67**	-1.45	-2.16	-4.86*	-19.06**	21.28**	5.56**
H16.2	ACC 364-1 x Gwagwa	-20.00**	-33.33**	-11.11**	-42.86**	4.87	-7.30	5.64*	-0.68	46.94**	33.33**
H16.3	ACC 364-1 x GB8735	-25.00**	-50.00**	-20.00**	-50.00**	-11.69	-25.55	24.29**	12.82**	25.84**	3.70**
H17.1	ICMV 93501 x Ex-Borno	33.33**	33.33**	-25.00**	-16.67**	11.28	-15.11	1.43	-17.09**	12.64**	4.26**
H17.2	ICMV 93501 x Gwagwa	-33.33**	-33.33**	-33.33**	-57.14**	-29.18	-30.00	15.58**	3.84	16.48**	12.77**
H17.3	ICMV 93501 x GB8735	-11.11**	-33.33**	0.00	-37.50**	-4.98	-17.32	12.07**	-1.52	7.32**	-6.38**
H18.1	ICMP 94592 x Ex-Borno	20.00*	0.00	-25.00**	-50.00**	10.17	-6.47	-6.86*	-20.68**	-2.00**	-18.33**
H18.2	ICMP 94592 x Gwagwa	-20.00**	-33.33**	-11.11**	-28.57**	8.37	-5.38	3.60	-2.48	5.77**	-8.33**

Appendix 11 Cont.

Hybrids	Pedigree	Head weight (kg/ha)		Grain weight (kg/ha)		Grain Yield (kg/ha)		1000-seed weight (g)		Crude Protein (%)		Threshing (%)	
		MP	HP	MP	HP	MP	HP	MP	HP	MP	HP	MP	HP
H14.1	G.I 41-3 x Ex-Borno	7.87	-5.88	-9.08	-9.71	9.78	4.85	40.33**	19.10**	-1.12	-5.71**	1.02	1.02
H14.2	G.I 41-3 x Gwagwa	6.98	-4.17	-51.45	-56.14	66.19	-71.60	-64.83**	-65.38**	-23.57**	-31.03**	12.48	10.46
H14.3	G.I 41-3 x GB8735	17.89	-1.75	21.23	-6.73	72.05	-12.85	31.15**	8.46¶*	19.14**	-4.33**	4.13	4.07
H15.1	G.I 47-3 x Ex-Borno	1.01	-1.96	-13.28	-38.60	22.25	-21.00	26.10**	12.29**	3.88**	2.29**	2.02	-1.17
H15.2	G.I 47-3 x Gwagwa	6.25	6.25	-10.20	-39.82	0.25	-40.80	21.20**	-23.39**	14.75**	0.57	-1.72	-3.07
H15.3	G.I 47-3 x GB8735	10.48	1.75	78.33	9.43	94.80	8.50	81.28**	6.82**	16.02**	-9.09**	-2.19	-5.30
H16.1	ACC 364-1 x Ex-Borno	5.62	-7.84	5.12	-36.75	13.42	-33.76	13.14**	23.94**	-1.81*	-9.33**	1.16	-0.65
H16.2	ACC 364-1 x Gwagwa	9.30	-2.08	-3.94	-43.98	-19.20	-55.40	-5.63**	34.89**	-0.62	-7.47**	11.44	11.44
H16.3	ACC 364-1 x GB8735	13.68	-5.26	68.86	-6.19	75.41	-6.55	156.30**	48.30**	30.71**	-7.19**	5.22	3.27
H17.1	ICMV 93501 x Ex-Borno	12.50	5.88	161.36	64.41	246.15	110.82	167.32**	84.98**	35.94**	34.88**	0.16	-3.46
H17.2	ICMV 93501 x Gwagwa	18.28	14.58	-31.63	-58.60	44.67	-68.60	-24.60**	-52.52**	-17.49**	-28.16**	-5.45	-7.23
H17.3	ICMV 93501 x GB8735	1.96	-8.77	7.86	-38.47	16.89	-36.59	31.15**	-22.94**	21.67**	-5.19**	3.16	-0.63
H18.1	ICMP 94592 x Ex-Borno	1.96	1.96	-11.74	-41.22	-1.06	-39.74	28.02**	-11.00**	4.35**	3.94**	3.94	2.18
H18.2	ICMP 94592 x Gwagwa	7.07	3.92	-5.45	-39.89	-5.20	-46.20	-9.15**	-42.59**	2.67**	-11.49**	2.07	1.96

Appendix 11 Cont.

Hybrids	Pedigree	Number of Tillers		Days to 50% flowering		Plant height (cm)		Panicle length (cm)		Panicle width (cm)	
		MP	HP	MP	HP	MP	HP	MP	HP	MP	HP
H18.3	ICMP 94592 x GB8735	-25.00**	-50.00**	-40.00**	-62.50**	18.32	16.49	5.50*	-4.35	3.16**	-18.33**
H19.1	ICMP 91103 x Ex-Borno	50.00**	0.00	50.00**	0.00	-9.02	-12.95	-8.69*	-22.48**	-11.54**	-28.12**
H19.2	ICMP 91103 x Gwagwa	100.00**	33.33**	55.56**	0.00	-10.51	-11.54	9.51**	2.71	1.85**	-14.06**
H19.3	ICMP 91103 x GB8735	14.29**	-33.33**	0.00	-37.50	-5.88	-18.11	-7.93**	-16.24**	-7.07**	-28.12**
	SE ±	0.529	0.459	2.706	2.329	16.585	14.364	2.417	2.092	0.173	0.153
	LSD 5%	1.058	0.918	5.412	4.658	33.170	28.728	4.834	4.184	0.346	0.306
	LSD 1%	1.587	1.377	8.118	6.987	49.755	430.092	7.251	6.276	0.519	0.459

*, **: Significant at 5% and 1% level of probability respectively

Note: ($H_{1.1}$) = G.I. 6-2 x Ex-Borno, ($H_{2.2}$) = G.I.75-1 x Gwagwa, ($H_{3.3}$) =G.I.122-2 x GB8735

Appendix 11 Cont.

Hybrids	Pedigree	Head weight (kg/ha)		Grain weight (kg/ha)		Grain Yield (kg/ha)		1000-seed weight (g)		Crude Protein (%)		Threshing (%)	
		MP	HP	MP	HP	MP	HP	MP	HP	MP	HP	MP	HP
H18.3	ICMP 94592 x GB8735	0.00	-5.26	-37.51	-63.09	-61.69	-79.22	-44.01**	-67.02**	5.32**	-18.61**	3.00	1.20
H19.1	ICMP 91103 x Ex-Borno	0.99	-1.96	50.13	-7.47	95.76	19.22	41.15**	7.31**	40.30**	33.33**	-4.67	-11.82
H19.2	ICMP 91103 x Gwagwa	0.00	-2.00	134.73	39.70	124.85	27.60	78.80**	20.84**	6.67**	-3.45**	-3.06	-8.79
H19.3	ICMP 91103 x GB8735	8.41	1.75	32.71	25.21	49.74	18.77	78.38**	10.37**	34.95**	8.66**	-1.19	-8.65
	SE ±	431.624	230.418	231.535	200.518	335.605	290.603	1.281	0.954	0.625	0.542	8.368	7.256
	LSD 5%	863.248	460.836	463.070	401.036	671.210	581.206	2.562	1.914	1.250	1.084	16.736	14.512
	LSD 1%	1294.872	691.284	694.605	601.554	1006.815	871.809	3.843	2.871	1.875	1.626	25.104	21.768

*, **: Significant at 5% and 1% level of probability respectively

Note: ($H_{1.1}$) = G.I. 6-2 x Ex-Borno, ($H_{2.2}$) = G.I.75-1 x Gwagwa, ($H_{3.3}$) =G.I.122-2 x GB8735

Appendix 12: Heterosis of hybrids over mid-parent and superior-parent (MP% x HP%) for eleven characters in pearl millet (Bagauda, 1996).

Hybrids	Pedigree	Number of Tillers		Days to 50% flowering		Plant height (cm)		Panicle length (cm)		Panicle width (cm)	
		MP	HP	MP	HP	MP	HP	MP	HP	MP	HP
H1.1	G.I 6-2 x Ex-Borno	46.67**	-37.50**	23.08**	0.00	3.83	0.83	8.86*	2.03	-17.12**	-28.57**
H1.2	G.I 6-2 x Gwagwa	-33.33**	-42.86**	-9.09**	-16.67**	5.98	3.33	6.69	-4.65	-5.60**	-23.38**
H1.3	G.I 6-2 x GB8735	6.67**	0.00	-9.09**	-16.67**	9.09	-5.26	6.82	-0.84	-0.79**	-18.18**
H2.1	G.I 75-1 x Ex-Borno	-16.67**	-37.50**	-28.57**	-37.50**	2.95	0.83	-4.21	-6.96*	-3.28**	-6.35**
H2.2	G.I 75-1 x Gwagwa	33.33**	20.00**	-16.67**	-.67	-3.39	-5.00	-10.62**	-12.62**	24.32**	9.52**
H2.3	G.I 75-1 x GB8735	50.00**	12.50**	-16.67**	-16.67**	-6.00	-18.97	-9.28**	-22.61**	9.73**	-1.59**
H3.1	G.I 122-2 x Ex-Borno	-5.88**	-11.11**	-6.67**	-12.50**	1.27	-0.83	-9.65**	-11.64**	-5.69**	-9.38**
H3.2	G.I 122-2 x Gwagwa	42.86**	11.11**	-7.69**	0.00	-1.69	-3.33	5.56	2.49	-1.79**	-14.06**
H3.3	G.I 122-2 x GB8735	-52.94**	-55.56**	-7.69**	-14.29**	7.00	-7.76	13.05**	-3.00	1.75**	-9.38**
H4.1	G.I 165-6 x Ex-Borno	-14.29**	-25.00**	20.00**	-12.50**	3.83	0.83	9.57*	7.75*	-4.69**	-11.59**
H4.2	G.I 165-6 x Gwagwa	81.82**	66.67**	7.69**	0.00	4.27	1.67	0.36	-6.15	2.56**	-13.04**
H4.3	G.I 165-6 x GB8735	-42.86**	-50.00**	-7.69**	-14.29**	7.07	-7.02	0.86	-10.50**	5.88**	-8.70**
H5.1	G.I 296-1 x Ex-Borno	-9.09**	-37.50**	-38.46**	-50.00**	0.00	-3.31	12.00**	11.07**	-8.94**	-12.50**

Appendix 12 Cont.

Hybrids	Pedigree	Head weight (kg/ha)		Grain weight (kg/ha)		Grain Yield (kg/ha)		1000-seed weight (g)		Crude Protein (%)		Threshing (%)	
		MP	HP	MP	HP	MP	HP	MP	HP	MP	HP	MP	HP
H1.1	G.I 6-2 x Ex-Borno	-14.29	-14.29	-11.90	-32.19	-14.60	-27.76	-29.87**	-32.04**	-24.48**	-31.06**	-3.16	-4.62
H1.2	G.I 6-2 x Gwagwa	-14.55	-16.07	-21.50	-39.77	-24.80	-39.94	-23.69**	-29.88**	-16.01**	-22.98**	-4.97	-5.26*
H1.3	G.I 6-2 x GB8735	-19.01	-24.62	23.83	-6.10	20.64	-8.47	13.80**	-0.93**	-12.21**	-20.42**	3.21	3.00
H2.1	G.I 75-1 x Ex-Borno	-8.62	-11.67	-73.11	-81.28	-68.96	-77.62	-17.12**	-36.48**	-15.79**	-18.05**	-0.32	-1.57
H2.2	G.I 75-1 x Gwagwa	-19.30	-23.33	5.20	-26.93	3.42	-28.55	0.92**	-28.41**	-3.74**	-5.85**	-3.43	-4.02
H2.3	G.I 75-1 x GB8735	-28.00	-30.77	51.83	4.46	51.77	0.97	45.74**	-0.14**	7.29**	-8.30**	3.95	3.41
H3.1	G.I 122-2 x Ex-Borno	6.54	1.79	-33.92	-48.89	-35.65	-47.54	-36.38**	-44.34**	13.09**	8.53**	-1.75	-2.53
H3.2	G.I 122-2 x Gwagwa	-4.76	-7.41	-22.21	-40.02	-26.69	-43.88	-31.05**	-45.21**	-4.18**	-7.58**	5.16	4.02
H3.3	G.I 122-2 x GB8735	-1.72	-17.31	33.29	1.55	22.42	-9.33	7.61**	-18.15**	10.40**	-4.50**	15.30**	14.17**
H4.1	G.I 165-6 x Ex-Borno	-0.93	-5.36	-21.99	-23.68	-24.23	-27.06	-19.25**	-25.78**	-11.22**	-12.12**	7.89**	5.47*
H4.2	G.I 165-6 x Gwagwa	4.76	1.85	14.62	11.63	19.20	15.24	13.26**	9.73**	-3.55**	-4.04**	4.19	0.00
H4.3	G.I 165-6 x GB8735	-17.24	-26.15	1.32	-2.96	6.30	-3.89	5.97**	-3.06**	8.42**	-8.65**	7.53*	3.31
H5.1	G.I 296-1 x Ex-Borno	-2.80	-7.14	-59.69	-64.42	-59.46	-62.02	-56.64**	-57.69**	-9.98**	-18.14**	7.40*	5.25*

Appendix 12 Cont.

Hybrids	Pedigree	Number of Tillers		Days to 50% flowering		Plant height (cm)		Panicle length (cm)		Panicle width (cm)	
		MP	HP	MP	HP	MP	HP	MP	HP	MP	HP
H5.2	G.I 296-1 x Gwagwa	25.00**	0.00	9.09**	0.0	-2.15	-5.00	-2.91	-8.47**	-10.71**	-21.87**
H5.3	G.I 296-1 x GB8735	-9.09 **	-37.50**	-9.09**	-16.67**	-3.55	-15.93	4.37	-8.07**	21.05**	7.81**
H6.1	G.I 359-3 x Ex-Borno	23.08**	0.00	0.00	-12.50**	-0.85	-3.31	11.97**	7.01**	-7.96**	-11.86**
H6.2	G.I 359-3 x Gwagwa	20.00**	20.00**	16.67**	16.67**	-0.43	-2.50	-5.11	-13.62**	19.61**	12.96**
H6.3	G.I 359-3 x GB 8735	7.69**	-12.50**	0.00	0.00	0.50	-13.04	4.44	-4.86	19.23**	14.81**
H7.1	G.I 363-1 x Borno	-2.00	-12.50**	0.00	-12.50**	4.11	-5.79	8.84*	1.85	13.79**	11.86**
H7.2	G.I 363-1 x Gwagwa	81.82**	66.67**	16.67**	16.67**	0.92	-8.33	0.27	-7.31	27.62**	17.54**
H7.3	GI 363-1 x GB8735	-14.29**	-0.00	-16.67**	-16.67**	4.40	-3.06	21.26**	8.81*	2.80**	-3.51**
H8.1	G.I 363-4 x Ex-Borno	0.00	-12.50**	-14.29**	-25.00**	-0.87	-5.79	-0.74	-1.48	-3.70**	-11.47**
H8.2	G.I 363-4 x Gwagwa	45.45**	33.33**	16.67**	16.67**	-0.44	-5.00	-6.51	-11.79**	3.23**	-15.79**
H8.3	G.I 363-4 x GB8735	-28.57**	-37.50**	0.00	0.00	0.52	-11.01	3.40	-8.99*	-1.59**	-18.42**
H9.1	G.I 410-8 x Ex-Borno	33.33**	25.00**	0.00	-12.50**	1.26	0.00	2.33	1.48	-8.47**	-8.47**
H9.2	G.I 410-8 x Gwagwa	16.67**	0.00	0.00	0.00	0.00	-0.83	2.20	-3.65	8.41**	-1.69**
H9.3	G.I 410-8 x GB 8735	-20.00**	-25.00**	-16.67**	-16.67**	7.93	-7.63	4.79	-7.69*	2.75**	-5.08**

Appendix 12 Cont.

Hybrids	Pedigree	Head weight (kg/ha)		Grain weight (kg/hs)		Grain Yield (kg/ha)		1000-seed weight (g)		Crude Protein (%)		Threshing (%)	
		MP	HP	MP	HP	MP	HP	MP	HP	MP	HP	MP	HP
H5.2	G.I 296-1 x Gwagwa	-2.86	-5.56	-45.18	-51.81	-46.80	-53.33	-37.19**	42.65**	3.93**	-5.06**	-0.88	-1.03
H5.3	G.I 296-1 x GB8735	-10.34	-20.00	25.11	8.38	24.91	3.26	13.61**	-1.67	7.22**	-2.42**	-3.76	-4.01
H6.1	G.I 359-3 x Ex-Borno	-0.95	-7.14	39.77	5.11	58.81	18.85	48.82**	14.98**	16.17**	16.41**	0.92	-3.24
H6.2	G.I 359-3 x Gwagwa	-0.97	-5.56	31.77	-1.20	30.53	-6.74	60.00**	14.29**	-5.37**	-5.61**	4.83	-7.08**
H6.3	G.I 359-3 x GB 8735	-17.54	-27.67	20.07	-11.00	27.80	-12.36	14.54**	21.02**	4.13**	-12.80**	-0.20	-2.65
H7.1	G.I 363-1 x Borno	-0.97	-8.93	-37.72	-42.81	-35.05	-35.73	-32.05**	-34.49**	-9.58**	-13.62**	-1.41	-3.96
H7.2	G.I 363-1 x Gwagwa	14.85	7.41	14.12	4.36	23.82	16.52	23.77**	-14.29**	13.94**	9.39**	-2.92	-3.66
H7.3	GI 363-1 x GB8735	-10.71	-23.08	6.05	-4.51	6.77	-5.83	13.34**	0.88	5.18**	-8.65**	-1.59	-2.44
H8.1	G.I 363-4 x Ex-Borno	2.86	-3.57	63.98	16.80	100.90	45.40	102.17**	55.13**	14.96**	6.61**	-0.16	-3.59
H8.2	G.I 363-4 x Gwagwa	16.50	11.11	68.37	19.61	87.74	30.15	70.45**	21.04**	7.33**	0.00	-3.01	-5.39
H8.3	G.I 363-4 x GB8735	0.00	-12.31	69.55	17.83	77.73	18.61	75.43**	20.32**	10.85**	-1.04**	1.47	-0.30
H9.1	G.I 410-8 x Ex-Borno	2.91	-5.36	-7.24	-33.86	-4.87	-28.41	9.14**	-13.72**	-9.28**	-11.86**	0.16	-3.01
H9.2	G.I 410-8 x Gwagwa	8.91	1.85	-6.63	-33.60	-9.59	-35.36	-17.31**	-39.77**	24.01**	19.90**	1.07	-0.30
H9.3	G.I 410-8 x GB 8735	-3.57	-16.92	8.05	-23.93	4.23	-28.19	2.34**	-28.15**	5.93**	-13.49**	-1.27	-2.71

Appendix 12 Cont.

Hybrid	Pedigree	Number of Tillers		Days to 50% flowering		Plant height (cm)		Panicle length (cm)		Panicle width (cm)	
		MP	HP	MP	HP	MP	HP	MP	HP	MP	HP
H10.1	G.I 435-4 x Ex-Borno	-7.67**	-25.00**	0.00	-12.50**	3.60	-4.96	10.42*	4.61	-2.44**	-6.25**
H10.2	GI 435-4 x Gwagwa	80.00**	80.00**	0.00	0.00	1.36	-9.17	-8.74*	-17.71**	12.50**	-1.56**
H10.3	G.I 435-4 x GB 8735	7.69**	-12.50**	16.67**	16.67**	-0.54	-8.91	15.82**	6.39	21.05**	7.81**
H11.1	ACC 1009-2 x Ex-Borno	-7.67**	-25.00**	0.00	-12.50**	-1.31	-6.61	-6.58	-9.59*	-11.63**	-18.57**
H11.2	ACC 1009-2 x Gwagwa	-20.00**	-20.00**	-16.67**	-16.67**	-7.89	-12.50	-14.16**	-20.93**	5.08**	-11.43**
H11.3	ACC 1009-2 x GB 8735	-23.08**	-37.50**	0.00	0.00	-4.17	-14.81	8.43*	-2.37	0.00	-14.29**
H12.1	Buduma Gero 712-2 x Ex-Borno	-20.00**	-25.00**	-14.29**	-25.00**	-2.04	-3.23	-0.29	-4.43	-0.87**	-3.39**
H12.2	Buduma Gero 712-2 x Gwagwa	50.00**	28.57**	33.33**	33.33**	-2.46	-4.03	-6.46	-14.62**	3.85**	-3.57**
H12.3	Buduma Gero 712-2 x GB8735	-20.00**	-25.00**	-16.67**	-16.67**	3.85	-12.90	4.54	-5.03	-15.09**	-19.64**
H13.1	ICMV 8890 x Ex-Borno	7.69**	-12.50**	16.67**	-12.50**	2.28	-7.44	5.25	-2.03	-10.92**	-11.67**
H13.2	ICMV 88908 x Gwagwa	40.00**	40.00**	60.00**	33.33**	4.59	-5.00	1.03	-10.30**	9.26**	-1.67**
H13.3	ICMV 88908 x GB8735	-23.08**	-37.50**	20.00**	0.00	3.30	-4.08	9.97*	2.78	-1.82**	-10.00**

Appendix 12 Cont.

Hybrids	Pedigree	Head weight (kg/ha)		Grain weight (kg/ha)		Grain Yield (kg/ha)		1000-seed weight (g)		Crude Protein (%)		Threshing (%)	
		MP	LP	MP	HP	MP	HP	MP	HP	MP	HP	MP	HP
H10.1	G.I 435-4 x Ex-Borno	6.80	-1.79	12.52	4.61	19.20	17.37	35.80**	33.22**	-4.69**	12.50**	-1.66	-4.72
H10.2	GI 435-4 x Gwagwa	16.83	9.26	32.72	22.87	33.76	26.46	36.11**	19.52**	-11.21**	-18.10**	1.12	-0.20
H10.3	G.I 435-4 x GB 8735	-5.36	-18.46	37.11	24.95	39.63	23.68	32.65**	10.69**	-0.58	-10.38**	0.00	-1.41
H11.1	ACC 1009-2 x Ex-Borno	-14.02	-17.86	-1.81	-9.31	0.14	-2.30	2.66**	-2.11**	-0.97	-6.82**	4.90	3.11
H11.2	ACC 1009-2 x Gwagwa	0.95	-1.85	4.25	-4.11	3.91	0.88	9.45**	2.15**	12.98**	6.82**	4.81	4.64
H11.3	ACC 1009-2 x GB 8735	-8.62	-18.46	3.75	-6.06	-2.41	-12.85	-4.51**	-15.65**	2.16**	-10.03**	0.57	0.52
H12.1	Buduma Gero 712-2 x Ex-Borno	-10.91	-12.50	-50.30	-68.67	-58.15	-71.31	-46.62**	-67.11**	11.90**	-3.09**	6.98*	5.64*
H12.2	Buduma Gero 712-2 x Gwagwa	-18.52	-18.52	6.82	-32.80	6.92	-36.17	54.34**	-8.74**	29.59**	11.73**	-4.36	-4.95
H12.3	Buduma Gero 712-2 x GB8735	-24.37	-30.77	53.39	-4.17	48.99	-12.99	48.51**	-13.75**	22.51**	-8.65**	4.16	3.62
H13.1	ICMV 8890 x Ex-Borno	14.29	14.29	-7.22	-28.09	1.37	-14.39	12.61**	-3.99**	5.38**	-6.75**	2.10	1.61
H13.2	ICMV 88908 x Gwagwa	3.64	1.79	24.18	-4.06	28.71	2.65	26.53**	-1.67**	8.48**	-3.57**	6.81*	4.33
H13.3	ICMV 88908 x GB8735	0.83	-6.15	16.52	-11.82	19.34	-9.58	35.76**	1.16**	9.43**	2.42**	2.49	0.21

Appendix 12 Cont.

Hybrids	Pedigree	Number of Tillers		Days to 50% flowering		Plant height (cm)		Panicle length (cm)		Panicle width (cm)	
		MP	HP	MP	HP	MP	HP	MP	HP	MP	HP
H14.1	G.I 41-3 x Ex-Borno	-23.08**	0.00	14.29**	0.00	0.41	0.00	18.40**	12.18**	-7.94**	-13.43**
H14.2	G.I 41-3 x Gwagwa	80.00**	80.00**	16.67**	16.67**	1.67	1.67	4.69	-5.48	16.52**	0.00
H14.3	G.I 41-3 x GB8735	-7.69**	-12.50**	-16.67**	-16.67**	7.84	-8.33	11.34**	2.27	12.82**	-1.49**
H15.1	G.I 47-3 x Ex-Borno	-16.67**	-37.50**	0.00	-25.00**	0.42	-0.83	29.66**	19.37**	-10.92**	-11.67**
H15.2	G.I 47-3 x Gwagwa	144.44**	12.00**	20.00**	0.00	5.04	4.17	4.91	7.81*	0.00	-10.00**
H15.3	G.I 47-3 x GB8735	16.67**	-12.50**	60.00**	33.33**	-1.98	-16.10	18.56**	12.06**	-1.82**	-10.00**
H16.1	ACC 364-1 x Ex-Borno	-7.67 **	-25.00**	-7.69**	-25.00**	-0.42	-1.65	-14.61**	-16.97**	-10.61**	-19.18**
H16.2	ACC 364-1 x Gwagwa	60.00**	60.00**	9.09**	0.00	-4.20	-5.00	-9.69*	-16.45**	10.74**	-8.22**
H16.3	ACC 364-1 x GB8735	-7.67**	-12.50**	9.09**	0.00	3.96	-11.02	13.07**	1.37	-4.07**	-19.18**
H17.1	ICMV 93501 x Ex-Borno	-20.00**	-25.00**	0.00	-12.50**	0.44	-6.61	0.82	-2.15	-8.06**	-12.31**
H17.2	ICMV 93501 x Gwagwa	-16.67**	-28.57**	0.00	0.00	-6.25	-12.50	-9.06*	-12.46**	4.42**	-9.23**
H17.3	ICMV 93501 x GB8735	-6.67**	-12.50**	-33.33**	-33.33**	0.00	-9.62	-2.80	-15.98**	-2.61**	-13.85**
H18.1	ICMP 94592 x Ex-Borno	-16.67**	-37.50**	-7.69**	-25.00**	-2.13	-4.96	6.15	1.29	-16.13**	-20.00**
H18.2	ICMP 94592 x Gwagwa	55.56**	40.00**	9.09**	0.00	-2.56	-5.00	-4.68	-15.45**	30.97**	-13.85**

Appendix 12 Cont.

Hybrids	Pedigree	Head weight (kg/ha)		Grain weight (kg/ha)		Grain Yield (kg/ha)		1000-seed weight (g)		Crude Protein (%)		Threshing (%)	
		MP	HP	MP	HP	MP	HP	MP	HP	MP	HP	MP	HP
H14.1	G.I 41-3 x Ex-Borno	6.67	0.00	39.09	10.02	23.50	11.51	19.77**	12.52**	9.82**	-7.73**	1.42	-0.62
H14.2	G.I 41-3 x Gwagwa	-8.74	-12.96	15.08	-9.28	-7.42	-21.49	0.28**	-15.23**	24.39**	4.08**	-3.55	-3.70
H14.3	G.I 41-3 x GB8735	3.51	-9.23	12.88	-12.11	0.00	-19.86	-4.37**	-22.96**	34.92**	-1.73**	-0.67	-0.93
H15.1	G.I 47-3 x Ex-Borno	-11.30	-13.56	56.97	-9.36	72.46	1.76	63.68**	9.52**	-14.86**	-25.29**	2.19	-0.61
H15.2	G.I 47-3 x Gwagwa	-7.96	-11.86	25.57	-27.58	17.42	32.16	8.47**	-31.34**	-16.11**	-26.07**	0.00	-0.91
H15.3	G.I 47-3 x GB8735	1.61	-3.08	123.71	28.44	136.60	-34.24	27.96**	40.79**	1.10*	-4.50**	-0.51	-1.52
H16.1	ACC 364-1 x Ex-Borno	-20.00	-21.43	36.99	-2.07	59.25	14.30	73.79**	29.76**	-13.98**	-15.98**	-8.01**	-8.31**
H16.2	ACC 364-1 x Gwagwa	-3.70	-3.70	-2.57	-30.54	0.47	-30.87	-2.41**	32.29**	2.36**	-0.51	4.40	2.79
H16.3	ACC 364-1 x GB8735	-19.33	-26.15	32.51	-6.49	-36.41	-9.58	53.60**	3.15**	16.46**	-4.50**	2.94	1.45
H17.1	ICMV 93501 x Ex-Borno	8.41	3.57	15.63	6.68	14.76	10.06	20.62**	13.35**	7.00**	-17.27**	18.47**	17.35**
H17.2	ICMV 93501 x Gwagwa	2.86	0.00	-50.27	-54.31	55.95	-57.26	-53.32**	-55.99**	3.82**	-7.23**	0.63	-1.55
H17.3	ICMV 93501 x GB8735	-10.34	-20.00	-30.64	-37.26	36.62	-42.50	-35.78**	-42.50**	-1.12*	-7.96**	5.42	4.55
H18.1	ICMP 94592 x Ex-Borno	10.17	-14.52	69.73	1.54	104.86	21.36	95.53**	-28.23**	7.69**	4.64**	7.72*	3.22
H18.2	ICMP 94592 x Gwagwa	-13.79	-19.35	36.89	-18.20	54.91	-10.18	45.00**	-9.73**	17.88**	13.78**	4.28	-1.86

Appendix 12 Cont.

Hybrids	Pedigree	Number of Tillers		Days to 50% flowering		Plant height (cm)		Panicle length (cm)		Panicle width (cm)	
		MP	HP	MP	HP	MP	HP	MP	HP	MP	HP
H18.3	ICMP 94592 x GB8735	-33.33**	-50.00**	-9.09**	-16.67**	2.02	-11.40	2.75	-3.86	-4.35**	-15.38**
H19.1	ICMP 91103 x Ex-Borno	12.50**	12.50**	0.00	-12.50**	-0.44	-7.44	10.33**	1.48	-15.63**	-21.74**
H19.2	ICMP 91103 x Gwagwa	23.08**	0.00	33.33**	33.33**	-11.61	-17.50	9.37*	-3.99	14.53**	-2.90**
H19.3	ICMP 91103 x GB8735	-12.50**	-12.50**	-16.67*	-16.87**	-3.19	-12.50	9.18*	3.30	-17.65**	-28.99**
	SE ±	1.073	0.929	2.241	1.941	24.544	21.256	3.768	3.260	0.272	0.236
	LSD 5%	2.146	1.858	4.482	3.882	49.088	42.512	7.536	6.520	0.544	0.472
	LSD 1%	3.219	2.787	6.723	5.823	73.632	63.768	11.304	9.780	0.816	0.708

*, **: Significant at 5% and 1% level of probability respectively

Note: ($H_{1.1}$) = G.I. 6-2 x Ex-Borno, ($H_{2.2}$) = G.I.75-1 x Gwagwa, ($H_{3.3}$) =G.I.122-2 x GB8735

Appendix 12 Cont.

Hybrids	Pedigree	Head weight (kg/ha)		Grain weight (kg/ha)		Grain Yield (kg/ha)		1000-seed weight (g)		Crude Protein (%)		Threshing (%)	
		MP	HP	MP	HP	MP	HP	MP	HP	MP	HP	MP	HP
H18.3	ICMP 94592 x GB8735	-16.54	-18.46	36.81	-18.70	34.59	-23.40	17.20**	28.70**	4.24**	-14.88**	3.73	2.28
H19.1	ICMP 91103 x Ex-Borno	-7.27	-8.93	3.35	-17.16	20.95	-3.53	59.49**	33.42**	31.82**	29.21**	2.21	0.31
H19.2	ICMP 91103 x Gwagwa	5.56	5.56	34.46	7.42	55.93	18.04	40.59**	7.48**	26.63**	24.75**	0.62	0.62
H19.3	ICMP 91103 x GB8735	-2.52	10.77	6.63	-15.89	15.04	-16.87	16.18**	-14.72**	7.13**	-9.00**	-2.07	-2.17
	SE ±	423.910	367.112	403.856	349.750	431.972	374.099	1.033	0.895	0.528	0.457	5.507	4.769
	LSD 5%	847.810	734.724	807.712	699.500	863.944	748.198	2.066	1.790	1.056	0.914	11.014	9.538
	LSD 1%	1271.730	1101.336	1211.568	1049.250	1295.916	122.297	3.099	2.685	1.584	1.371	16.521	14.307

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

Note: ($H_{1.1}$) = G.I. 6-2 x Ex-Borno, ($H_{2.2}$) = G.I.75-1 x Gwagwa, ($H_{3.3}$) =G.I.122-2 x GB8735