TUDIES ON THE INHERITANCE OF SOME QUANTITATIVE AND QUALITATIVE TRAITS OF PURPLE GENE MARKERS IN PEARL MILLET (Pennisetum typhoides (Burm) Stapf and Hubb).

BY

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A thesis submitted to the Postgraduate School, Ahmadu Bello University, in partial fulfillment of the requirements for the Degree of Master of Science in Crop Breeding

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DECLARATION

I hereby declare that this thesis has been written by me and that it is a record of my own research work. It has not been presented before in any previous application for higher degree.

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CERTIFICATION

This thesis entitled 'STUDIES ON THE INHERITANCE OF SOME QUANTITATIVE AND QUALITATIVE TRAITS OF PURPLE GENE MARKER IN PEARL MILLET (Pennisetum typhoides (Burm) Stapf and Hubb') by Miss Mary Yinka Yeye meets the regulations governing the degree of Master of Science of Ahmadu Bello University, Zaria and is approved for its contribution to scientific knowledge and literary presentation.

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DEDICATION

This work is dedicated to the affectionate memories of my late brother, Oluwasanmi and my late mother, Ibiyemi, whose untiring efforts and understanding have made me all that I am today and will probably be tomorrow.

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ABSTRACT

Investigation of the pattern of inheritance and nature of gene action governing the inheritance of some quantitative traits and the qualitative purple gene marker were carried out in pearl millet. Continuous variation was observed for plant height, ear length, ear girth and leaf area.

The gene number varied from as low as -5.77 to 3.98. There were involvements of both additive and non-additive gene actions in the inheritance of each of the quantitative traits. Apparent indications of skewness in some F_2 data distributions indicated the presence of complementary gene action. Low negative and positive heritability estimates were observed probably resulting from poor genetic diversity of parent materials. Similarly low heterosis and inbreeding depression were observed.

Discrete distribution and digenic inheritance of the purple gene marker on the seed, midribs and whole plant were observed. Probability values were low for each of the purple plant parts. Low probability values may have resulted from low level of homozygosity of the parents with the purple marker.

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CHAPTER I

INTRODUCTION

Pearl millet (Pennisetum typhoides (Burm) Stapf and Hubb) is indigenous to Africa (Bilquez, 1970). Millets are consumed as grains and brewed as drinks from prehistoric times in Africa and Asia (Thakare and Oyinloye, 1980) and are among the six leading cereals in the world in providing calories and spare proteins to humans. In the more advanced countries like the United States of America however, millets are grown mainly as fodder crops and rarely enter into markets for commercial grains (Okonkwo 1983).

Over 80% of all millets grown in Nigeria is the Gero type. In Northern Nigeria, millet is second to sorghum as a food crop, and in drier area, it supercedes sorghum in importance. It is grown as a sole crop and staple food in Northern Sokoto, Northern Katsina, Kano, Bauchi and Borno where the average annual rainfall is approximately 65.5 - 75.0 cm, and where sorghum will fail to produce grains. About five million hectares of millet are cultivated annually in Northern Nigeria with a production estimate of three million tonnes (Okonkwo, 1983).

In Nigeria, millet is consumed in a number of ways, either as whole grain or milled into flour. In many parts of Nigeria food preparations are made from millet flour, which also may be baked into unleavened bread or cake.

The crop has industrial potentials, (which is already being widely exploited in India) through its malting and brewing qualities and in being the best of all the cereals in having the best malting quality and keeping quality of its malt (Okonkwo, 1983).

In improvement programmes, knowledge concerning the inheritance of quantitative characters should increase the effectiveness of selection. The magnitudes of the estimated heritability of various plant characters suggest the extent to which improvement is economical and plausible and also provides the necessary information useful in choosing the most appropriate and effective breeding procedure. Because grain millet has gained a significant position as a food crop in Nigeria, it becomes necessary to investigate the inheritance of such characters that may be directly or indirectly related to grain yield. Hybridization programmes for varied plant characters have been initiated in pearl millet. Cytoplasmic male sterility has been exploited as a tool for identifying hybrid millets for grain production. The purple gene markers currently investigated can facilitate the identification of hybrid millets in various improvement programmes. Furthermore, understanding the pattern of inheritance of the anthocyanin pigmentation will be a step preceeding its incorporation into millet crops intended for forage crops since it has been established that anthocyanin is directly

associated with juiciness of plant parts and photoperiodic responses in plants (Murty and Ram, 1966).

The present study investigates the inheritance of some quantitative and qualitative traits of purple gene markers in pearl millet.

CHAPTER II

REVIEW OF LITERATURE

2.1 Pigmentation in Pearl Millet

Grain colour affects market acceptability. Certain colours being culturally preferred to others as it is thought they relate to quality of grain and the flour. In Proso millet (Panicum miliaceum) the red-grained forms are best for the quality of their kernels which are yellow or bright yellow in colour (Il'in et. al., 1975). Murty and Ram (1966), have indicated that anthocyanin, the pigment responsible for the purple pigmentation has been associated with economic characters such as juiciness of the stalk in sorghum, flowering time and resistance to leaf blast disease of rice. Also, they said that anthocyanin influences carbohydrate metabolism and that evidence of its involvement in photoperiodic response, particularly in short day plant, is now available. Homogenous green plants with the recessive gene trait bred true for that character when selfed.

A wide range of plant pigmentation occurs in pearl millet; gold, green, red and purple pigments can be found in most of the plant parts (Ferrais, 1973). Gill and Athwal (1970) indicated that the purple foliage in millet is determined by two complementary genes.

Gill (1969) crossed eitht genetic stocks with various pigmentation characters with a large number of testers possessing contrasting characters. His result indicated that two dominant complementary genes designated Bep_1 and Bep_2 controlled purple pigmented bristles. Red stem was found recessive to green and was inhibited by a non-allelic gene. Gill et al. (1969), worked with materials PYS7 possessing yellow striped purple leaves, GYSA possessing yellow-striped green leaves and GWS14 possessing white and yellow striped green leaves. They made Crosses with a number of tester lines. Results they obtained indicated that the yellow stripping of PYS7 and GYS8 was controlled by the same set of three complementary recessive genes. Yellow and white stripes on green leaves in GW14 was controlled by three sets of genes with duplicate complementary and inhibitory types of gene interaction. GWS14 was found to differ from the other two stocks by one of the three loci determining yellow stripes.

Monogenic inheritance of pigmentation on plant parts has been previously reported. Singh et al. (1967), studied the inheritance of leaf sheath colour in pearl millet. Their observation on the F_1 hybrids showed the incomplete dominance of purple leaf sheath colour. In F_2, 146 green, 245 light purple and 134 purple plant were observed. The data gave a good fit to 1:2:1 ratio.

Their result was confirmed by test cross data which gave a good fit of 1 green: 1 light purple ratio. Thus, they confirmed that the leaf sheath colour was governed by one gene difference. Singh et al. (1967), also indicated monogenic inheritance of the purple colour. Purple colour in the lemma, palea and bristles was found dominant over green colour and was expressed in a ratio of 3 purple: 1 green.

Yadav's (1971) report on inheritance of pigmentation of the node, leaf margin and leaf midrib revealed the presence of anthocyanin to be completely dominant over its absence. Pigmentation of the internode and leaf lamina was controlled by a single completely dominant gene. Yadav (1976) made crosses between the inbreds BS1 and BS3 with purple coleoptiles and BS2 with green coleoptiles. The presence of anthocyanin resulting in purple coleoptiles was found to be controlled by a single dominant gene. More recently, Shanthappa (1980) studied Elucine coracana. Segregation in the F_2 and F_3 from the crosses PR20 x IE927 and Indaf 1 x Purma indicated that purple pigmentation was dominant over green and was monogenically inherited. Phul et al. (1969) made crosses of five inbred lines of pearl millet exhibiting different grain colours in all possible combinations. Their results showed that a multiple allelic series exhibiting dominance in descending order

controlled deep yellow, amber, deep slate and light slate endosperm. The endosperm colours were only found apparent in the presence of colourless pericarp and the single gene controlling pericarp colour was inherited independently of the locus controlling endosperm colour. Lal and Singh (1971) reported that purple plant pigmentation, bristled spikes and yellow grains were dominant to green plant, bristled spikes and blue-green plants, respectively, and were each controlled by independent single genes.

Analysis of progenies from crosses of 13 varieties of pearl millet indicated that the grain colour was controlled by the interaction of a structural gene system (SGS) and a regulatory gene system (RGS) involving repression and depression (Yanshovskii, 1974). Dominant SGS responsible for the synthesis of yellow (Y), red (R) and dark (DK) pigments were revealed, whose function depended on the allelic state of the complementary activator and deactivator regulatory genes. The RGS was found to be responsible for the reversal of epistatic interaction between Y and R in different hybrids.

2.2 Quantitative Characters

2.2.1 Days to 5% flowering

The development of early flowering cultivars without an appreciable loss in yielding ability is an objective

of many breeding programmes. Yield losses due to certain diseases may be minimized in early flowering cultivars since they reach maturity before the diseases develop to severe levels. This is particularly true of polycyclic disease such as stem rust, leaf rust and powdery mildew (Avey et al. (1982). In the present day agriculture, there is an increasing interest amony farmers for growing more crops a year, thus an assessment of prospects for breeding short duration crops has become necessary. Information about the genetic architecture of the parents and the mode of gene action governing early flowering would be helpful in devising suitable breeding procedures for the development of early maturing and short duration varieties.

Bains (1973) in a top cross of 17 inbred lines of P. typhoides with three male sterile lines observed that general combing ability (gca) was more important than specific combing ability (sca) for days to flowering. He also indicated the significance of epistatic variation and additive gene effects. Singh et al. (1979) also found additive and non-additive components significant for days to 50% flowering in millet. They also observed over-dominance for the trait. In another separate study, Singh and Pandey (1973) again reported non-additive variance for earliness in pearl millet.

Diallel analysis of days to heading by Ram and Singh (1975), using six inbreds of pearl millet indicated that days to heading appeared to be simply inherited, earliness being primarily due to dominant genes. High heritability estimates for 50% heading were obtained in the Indian, African and American lines of pearl millet by Gupta and Dhillon (1976). Similarly, Lal and Singh (1973) indicated high heritability estimates in the broad sense in pearl millet for days to 50% flowring. Kumar et al. (1982) did a combining ability component analysis on data on days to heading and to maturity from a 15 x 15 diallel cross, ecluding reciprocals in Pennisetum americum grown in three environments. They found that although additive and non-additive genetic variances were important for both traits, non-additive variances predominated. The predominance of additive gene action for number of days to flowering in some genotypes of pearl millet was reported by Sreenivasulu and Sreeramulu (1980).

2.2.2 Plant height

Plant height is an important character in some crops since it is either of direct economic significance or can have a bearing on the yield of the plant. This has interested breeders for many years. Genes controlling height make possible plants that are short or of

intermediate height that can be hand harvested for grain in many parts of the world. Most of the millets cultivated today are very tall. Under the present day cultivation in which high fertilizer levels are common, many tall varieties perform poorly. The reasons being, among other weaknesses, their tallness which makes them susceptible to lodging. In three crosses derived from four diverse Pennisetum americum inbreds, using the F_1, F_2, BC_1 and BC_2 generations, heritability estimates of more than 60% were found for plant height in all the crosses (Chaudhary et al. (1982).

Sachdeva (1981) presented data on progenies and two standards from a diallel analysis of seven diverse lines of P. typhoides. He found additive components to be significant for height. Nine P. typhoides lines ranging in height from dwarf to tall were crossed in a diallel. The parents and 36 F_1's were evaluated for height, number of leaves per plant, stem girth, panicle length, girth and weight, straw and grain yields. High heterosis was estimated for height and additive gene action was predominant (Sreenivasulu and Sreeramulu, 1980). Yadav (1979) studied 31 varieties of millet at Agra, India. He indicated significant differences in height and some other morphological characters. Heterosis was shown for height. Gupta and Dhillon (1976) indicated moderately high heritability for plant height in millet. In pearl millet crosses involving

444 x 728 and 200 x 424, Singh et al. (1972) indicated high heritability estimates in the broad and narrow sense in plant height for both the crosses. Nanda and Phul (1974) and Singh et al. (1979) indicated the significance of both additive and dominance components in heigh genes.

2.2.3 Ear Length and Ear Girth

Since the ear (head) contains the grain, the ear length and girth become parts of yield components. Thus, these two factors have been included in the study to enhance the understanding of factors contributing to yield. Nanda and Phul (1974) found high heritability for ear length and ear girth in pearl millet, but found a higher value for the former. In another P. typhoides population, Lal and Singh (1970) estimated a higher narrow sense heritability.

Four hybrid combinations of 21 F_1 hybrids derived from seven inbred lines showed heterosis for spike length with a highly significant gca variance (Tewari, 1974). In a millet top cross involving 17 inbred lines, gca was more important than sca with significant epistatic variation and additive gene effects controlling ear girth (Bains, 1973).

Additive gene action was found predominant for panicle girth by Sreenivasulu and Sreeramulu (1980), but Singh and Lal (1969) in a diallel cross observed

overdominance for ear length and girth and also indicated that, though the magnitude of overdominance gene effects was high for spike length in millet, its contribution towards total heterosis was reduced by additive x additive, additive and additive x dominance gene effects.

2.2.4. Third Leaf Length and Breadth (Leaf Area)

Manifestations of greater leaf area is one of the important traits of heterosis in hybrids. The importance of this factor is in dry matter accumulation and grain yield. Large flag leaf lines produced significantly higher kernel weight than small leaf lines in small cereal grains. In wheat, Brinkman and Frey, (1978) reporting from several other earlier workers said that the Photosynthate contribution of plant tissues above the flag leaf node to grain yield ranged from 60-85%. This assertion was supported by Bilquez (1970) who said that the upper leaves of millet plant (second or third leaves which are nearest to the spike) play a part in the growth of the grain. Continuing further, he said that the leaves which are differentiated in the first stages of the development of the plant contribute only to the generation of the upper crowns, they practically have no influence upon growth of the grain itself.

In pearl millet, the third leaf was chosen for study because it is longer than the flag leaf or the second leaf and it is very close to the ear while still remaining very green at the time of grain formations and grain filling. Although there are accumulated literature on genetic aspects of leaf area and their contribution to yield in some crops, very little is known as to how leaf area is inherited and related to yield in pearl millet. Three Pennisetum typhoides parents, the F_1, F_2 BC_1 and BC_2 of two crosses of the parents were grown and studied by Chand and Ahmaz (1976). They observed no dominance for leaf length. Additive gene effects were found to be more important for leaf length, but less important for leaf width.

Lal and Singh (1970) studying six populations of P. typhoides, obtained in a broad sense high heritability estimates for leaf length and leaf breadth. They found leaf breadth to be under the control of two genes.

2.2.5 Grain Yield

Improvement for grain yield has not been achieved to the desired extent in millet. For increasing grain yield, information on the characters that contribute to yield is useful. Grain yield in pearl millet is dependant on such yield factors as heading date, number of ears, ear girth and length and plant height

(Singh and Murty (1974). Genetic information about the behaviour of these traits would be beneficial in breeding qualitatively better and high yielding varieties.

Progenies of biparental matings in a 22 x 22 diallel showed a predominantly non-additive type of gene action for yield components (Singh and Murty, 1974). The yield components included effective tillers per metre length and grain weight. Grain yield and earliness also demonstrated a high magnitude of non-additive genetic variance. Chaudhary et al. (1982) found among other physiological and morphological traits, heritability estimates of greater than 60% in H48 x H403, H48 x H91 and H48 x H403 for grain weight when heritability and genetic advance were considered together, they found maximum variation in plant height in H48 x H91, and for yield and number of days to maturity in H48 x H403.

Sreenivasulu and Sreenamulu (1980) obtained high heterosis for yield in millet which was predominantly governed by additive gene action.

Dashora et al. (1977) analysed 12 male fertile and two male sterile lines in millet, 15 F_1's from among them and two other varieties and three new hybrids. They found the hybrid forms to show increases of 52.4 , 39.4 and 134.4% over their parents for early growth vigour, forage yield and grain yield, respectively. Phenotypic and genotypic

correlations of early growth vigour with forage and grain yields were high and significant whereas narrow sense heritability estimates were low. Gupta and Dhillon (1976) obtained high heritability estimates for grain yield and grain size in their pearl millet collections with highest estimates in African lines. Yield was found to be positively correlated with grain density, grain size, plant height and tiller number, and negatively correlated with 50% heading. Partial regression analysis indicated that selection for tillers would improve yield.

Nanda and Phul (1974) did genetic analysis of yield factors of nine inbred lines in a diallel cross. Their analysis showed that the inheritance of grain yield and ear number was controlled mainly by genes showing dominance and epistasis. Examination of 21 hybrids derived from the main stem spike, and number of grains per cm^2 gave highly significant results for all the three characters. Significant variances were obtained for gca indicating the importance of additive genetic variances (Tewari, 1974).

CHAPTER III

3. MATERIALS AND METHODS

3.1 Experimental Materials

The Parental materials used in this study comprised indigenous millet cultivars. Their sources and brief descriptions of their major characters are given in Table 1.

Table 1: Sources and Description of millet cultivars used ing the studies

S/No.	Cultivars	Source	Description
1.	Ex-Borno	Former Bornu Province	Ex-Borno is an improved local selection from a local cultivar from former Borru Province. They are tall cultivars, ranging from 150-350 cm, The leaves are green with white midrib. The stigmas are white, and the seeds are variously coloured from light grey to grey and to deep slate.
2.	Purple ear	Selections from Ex-Benue	The purple ears are selections from Ex-Benue variety. They are also tall, with green leaves and white midribs. The grains are however purple at maturity.

Table 1 (Cont'd)

S/No.	Cultivars	Source	Description
3.	Purple Midrib	Selections from Ex-Benue	The plants of this selection have purple midribs but normal green leaves, The purple marker is identified right at seedling stage. This purple marker does not appear on any other plant part. The seeds have similar colours with Ex-Borro - light grey to grey and deep slate.
4.	Purple plant	Found in the local collections in ICRISAT breeding Nursery at Samaru	The purple plants in this selection are wholly purple including the culm, leaves and midribs. The stigma and seeds upon maturity are also purple. Seedling stage identification include weaker stems than the Ex-Borno. Some tend to grow taller, consequently there is a greater tendency to lodging.

3.2 Experimental Techniques and Field Layout

During the 1981 growing season, the three purple marker parents produced from two generations of selfing in the breeding nursery of 1980 rainy season and under irrigation were selfed again to obtain a higher degree of homozygosity. Ex-Borno (P_1) was crossed with the other parents with marker genes during the 1981 off-season in irrigated nursery of the Institute for Agricultural Research (IAR), Samaru-Zaria. The F_2's were obtained in 1982 rainy season by selfing the F_1's. First backcrosses to the purple ear and purple midrib parents were made during the same period. The remaining backcross to the purple plant parent was completed at irrigated nursery of IAR in 1982 off-season. The parents, F_1's, F_2's and first backcross generations were evaluated in 1983 rainy season. These six populations within each cross of contrasting characters were evaluated separately in a randomised complete block design (RCBD) with four replications per experiment. There were therefore three experiments in all comprising the three different colour mutants crossed to Ex-Borno. Each replication included all of the following progenies P_1, P_2 or P_3, P_4 as the case mabe, F_1, F_2, BC_1P_1 (F_1 x P_1) and BC_1P_2 (or BC_1P_3, BC_1P_4). Ex-Borno was designated P_1 in the three experiments and Purple ear as P_2, purple midrib as P_3 and purple plant as P_4 in

experiments one, two, and three, respectively. The complete set of crosses with respect to each character was grown as a separate experiment.

The experiments were laid out in an area of 180 M^2 experimental units consisted of four row plots five metres long with between row spacings of 0.75 metres and within row spacings were 0.30 metres. The plots were hand planted after ploughing and seeded at the rate of four seeds per hole (two to three centimetres deep) and later thinned down to one plant per hill, three weeks after germination giving a plant density of 44, 444 plants/ha. Nitrogenous fertilizer was applied in two splits. The first split was applied together with whole dose of superphosphate by broadcast before ploughing. The second dose of nitrogenous fertilizer (from calcium ammonium nitrate) was applied immediately after thinning by side placement. Total fertilizer applied on the experimental area was 4.68 kg each of the superphosphate and calcium ammonium nitrate.

3.3 Characters Observed

Data were taken on the two central rows of each plot and were from all measurable individual plants in the two rows. The following seven characters were observed.

3.3.1 Days to 50% heading: Number of days from sowing to the day when 50% of the panicles in a plot had emerged from the flag leaf sheath.

3.3.2 Ear Length: Measured in centimetres from the base of the ear to the tip of the ear.

3.3.3 Ear girth: Measured with a pair of dividers on the thickest position of the ear. The divider was placed against a ruler to obtain the actual measurement to the nearest millimetre.

3.3.4 Leaf area: The length (L) and and maximum breadth (B) of the third flag leaf was measured in centimetres with a tape line after anthesis. Leaf area was obtained by L x B x 0.7238 (Phul et al. 1974).

3.35 Grain yield: The two central rows were harvested, dried and threshed. Grain yield was expressed in grams per plant.

3.3.6 Purple ears: At harvest, ears from the segregating populations; F_2's and the backcrosses were separately collected and sorted out into purple and non-purple.

3.3.7 Purple Midribs and Purple Plants: Since the pigmentations were noticeable at seedling stage, plants within the two central rows were sorted out and counted on the basis of the pigmentation.

3.4 Statistical Analysis

Data taken on individual plant in respect of quantitative traits were used to construct frequency tables for each trait. Class values for the data were chosen based on the calculated value of standard deviations of the F_2 generations as suggested by Steel and Torrie (1960). Means were computed for the six entries for each trait for the three experiments. Standard deviations and standard errors were obtained in respect of these traits for P_1, P_2, F_1, F_2, BC_1P_1 and BC_1P_2 Heterosis as percent over the mid-parent was computed using the formula suggested by Liang et al. (1972):

$$H(\%) = \frac{\bar{F}_1 - MP}{MP} \times 100$$

where H = heterosis estimated over mid-parent in percentage,

$\bar{F}_1$ = mean of F_1,

MP = mid-parent value of a particular cross combination and is represented by $\frac{\bar{P}_1 + \bar{P}_2}{2}$ where $\bar{P}_1$ and $\bar{P}_2$ are the means of P_1 and P_2.

Inbreeding as percent in F_2 from F_1 was calculated using the formula (Sinha and Khanna 1975):

$$D(\%) = \frac{\bar{F}_1 - \bar{F}_2}{\bar{F}_1} \times 100$$

where D is the percentage depression estimated for the second filial generation. The $\bar{F}_1$ and $\bar{F}_2$ are the mean values of F_1 and F_2, respectively. Heritability estimates in the narrow sense were obtained by the formula (Ketata et al. 1976):

$$h^2 = 2V_{F_2} - (V_{B_1} + V_{B_2})/V_{F_2}$$

where V_{F_2}, V_{B_1} and V_{B_2} are the variances of the F_2, B_1 and B_2 generations and B_1 is backcross to P_1 and B_2 is backcross to P_2.

The minimum number of genes controlling the expression of each quantitative character was estimated using Burton's (1951) formula:

$$n = \frac{0.25(0.75 - h + h^2)\, D^2}{\sigma^2_{F_2} - \sigma^2_{F_1}}$$

where $h = \dfrac{\bar{F}_1 - \bar{P}_1}{\bar{P}_2 - \bar{P}_1}$

$D = \bar{P}_2 - \bar{P}_1$

n = the minimum number of genes controlling the expression of a character

$\bar{F}_1$ = mean value of F_1

$\bar{P}_1$ = mean value of the smaller parent

$\bar{P}_2$ = mean value of the larger parent.

Assumptions in using the formula are:

i) No linkage between pertinent genes.

ii) One parent supplies only plus factors and the other minus factors among those in which they differ.

iii) All genes are equally important.

iv) The degree of dominance of the plus factors is the same for all.

v) No interaction exists between pertinent non-allelic genes.

A second method proposed by Mather and Jinks (1971) was also used to estimate the minimum number of genes involved in the expression of each quantitative character:

$$K_1 = \frac{\frac{1}{2}(\bar{P}_1 - \bar{P}_2)^2}{D}$$

where K_1 = minimum number of genes controlling the expression of the character in question.

$\bar{P}_1$ and $\bar{P}_2$ = means of P_1 and P_2 respectively.

D = Square of deviations of either parents from MP.

MP = mid-parent value.

Assumptions in using the formula are:

a) No linkage

b) No interaction

c) Equal increaments for the different alleles; that is all the d's are equal.

Traits that showed discrete observations (qualitative traits) were analysed using the standard Chi-square (x^2) method. For a two class segregation, the formula used was that a LeClerg *et al*. (1962):

$$x^2 = \frac{(1_2 a_1 - 1_1 a_2)^2}{1_1 1_2 . n}$$

where x^2 = Chi-square value.

a_1 and a_2 = observed frequencies in classes expected to be in a ratio $1_1 : 1_2$, respectively.

n = the summation of the two frequencies.

For example, the formula takes the following forms for the commonly occuring two class ratios:

Ratio $1_1 : 1_2$	x^2 value
1 : 1	$\frac{(a_1 - a_2)^2}{n}$
3 : 1	$\frac{(a_1 - 3a_2)^2}{3n}$
9 : 7	$\frac{(7a_1 - 9a_2)^2}{63n.}$
15 : 1	$\frac{(a_1 - 15a_2)^2}{15n.}$
J : K	$\frac{(Ka_1 - Ja_2)^2}{JKn.}$

The nature of gene action was determined by the fit of the observed F_1 amd F_2 means to calculated theoritical arithmetical and geometrical means, using the formulae:

$X^2 = \frac{(O-E)^2}{E}$ where

O = observed F_1 or F_2 mean.

E = expected or calculated theoritical F_1 or F_2 mean.

Theoretical arithmetic and geometric means were calculated according to Burton (1951):

Theoretical arithmetic mean of $F_2 = \frac{P_1 + 2\bar{F}_1 + \bar{P}_2}{4}$

Theoretical geometric mean of F_2 = anti log of

$$\frac{\log \bar{P}_1 + 2 \log \bar{F}_1 + \log \bar{P}_2}{4}$$

CHAPTER IV

4. RESULTS

4.1 Frequency Distributions

Frequency distributions for the three crosses in respect of height, ear length, ear girth and leaf area are pressented in Tables 2, 3, 4 and 5, respectively. The data for frequency distribution in the cross Ex-Borno x Purple ear followed the pattern for a normal distribution in respect of plant height (Table 2). Mean value of the F_1 population indicated dominance of tallness over shortness. Transgressive segregation below the shorter parent was observed only in the F_2 distribution and above the taller parent in the BC_1P_2 of the same cross. Data distributions in cross two for plant height for the parents and the progenies were unimodal except in BC_1P_3 which was polymodal. Height values for P_1 and P_4 distributions in cross 3 were bimodal. The other generations were however unimodal. Dominance of tallness was also expressed in crosses two and three from their F_1 mean values.

Apparent normality of data distribution was displaced in respect of ear length among the three crosses. (Table 3). Transgressive segregations were negligible and were shown only in F_2 of crosses two and there. Data distribution of the P_3 and P_4 materials had a

Table 2. Frequency Distribution of Height in three Pearl millet crosses

Parentage	Class centres i.. Centimetres for Plant height														Population		
	107	122	137	152	167	182	197	212	227	242	257	272	287	302	N	Mean	S
P_1	0	3	6	34	35	58	43	22	9	2	0	0	0	0	212	181.22	2
P_2	0	2	6	1[illegible]	29	42	55	27	17	7	3	3	0	0	209	191.33	2
F_1	0	1	4	19	25	67	48	29	20	12	5	2	0	0	232	193.12	2
F_2	6	11	17	22	26	59	40	20	10	6	2	1	0	0	220	181.47	
BC_1P_1	0	3	6	6	18	45	22	13	9	4	1	1	0	0	128	186.92	2
BC_1P_2	0	1	2	6	18	52	68	44	22	14	5	4	2	0	238	200.97	2
Cross 2	106.5	122.5	138.5	154.5	170.5	186.5	202.5	218.5	234.5	250.5	282.5	298.5	314.5	330.5	346.5	N	Mean	S
P_1	2	3	19	18	32	37	26	25	8	8	3	0	0	0	0	181	186.50	3
P_3	0	0	[illegible]	8	13	17	43	22	36	18	29	18	6	4	1	215	233.53	4
F_1	1	4	12	25	32	49	45	25	18	10	2	2	2	0	0	227	192.56	3
F_2	1	5	10	20	20	22	27	11	4	1	1	0	1	0	0	123	181.82	3
BC_1P_1	3	5	6	7	25	46	49	22	18	10	6	1	0	0	0	198	197.09	3
BC_1P_3	0	7	2	8	12	28	22	20	29	17	19	3	[illegible]	0	0	169	213.20	3
Cross 3	106.5	122.5	188.5	154.5	170.5	186.5	202.5	218.5	234.5	250.5	266.5	282.5	298.5			N	Mean	S
P_1	1	2	6	14	7	16	29	11	3	1	0	0	0			90	184.90	2
P_4	0	5	9	26	18	36	36	20	9	7	4	2	0			172	190.78	3
F_1	1	1	2	9	15	46	30	25	22	7	8	1	0			167	202.98	3
F_2	2	3	5	13	27	50	45	27	11	5	2	2	0			192	193.50	2
BC_1P_1	2	3	12	15	33	53	37	27	14	7	4	1	0			208	193.83	2
BC_1P_4	1	1	4	6	18	22	41	39	28	11	9	1	2			183	209.32	3

Table 3. Frequency distribution of ear length in three pearl millet crosses

Percentage	Class centres in centimetres for ear length															Population		
	19.7	22.2	24.7	27.2	29.7	32.2	34.7	39.7	42.2	44.7	47.2	49.7	52.2	54.7	57.2	N	Mean	S
Cross 1	1	5	7	26	28	41	45	30	17	10	2	2	2	0	0	216	33.43	5.
P_1	1	4	12	25	30	41	26	26	14	18	4	2	2	5	0	210	33.89	6.
P_2	1	8	19	25	25	32	46	18	20	12	8	7	4	5	1	232	34.04	7.
F_1	2	26	31	48	33	27	13	10	8	4	2	3	4	1	0	219	29.53	6.
F_2	9	6	12	25	34	37	41	26	19	16	7	5	3	0	0	233	33.77	6.
BC_1P_1	2	1	2	7	9	14	25	22	17	15	7	5	1	0	0	126	37.78	6.

	13.48	16.44	19.40	22.26	25.34	28.28	31.24	34.20	37.16	40.12	43.08	46.04	49.00	51.96	54.92	57.88	60.84	63.80	66.76	69.72	N	Mean	S.I
Cross 2	0	1	3	9	34	42	34	29	18	3	6	1	1	0	0	0	0	0	0	0	181	30.50	5.1
P_1	0	0	1	5	11	25	34	29	37	29	21	10	5	4	1	0	1	0	1	2	216	36.33	7.9
P_2	0	1	1	2	3	15	20	27	28	11	6	3	3	1	0	0	0	0	0	0	121	34.76	5.9
F_1	0	2	8	28	27	27	36	33	24	23	5	5	3	2	1	0	0	0	0	0	227	31.36	7.6
F_2	3	1	1	11	13	24	33	27	34	20	9	12	2	1	1	0	0	0	0	0	189	34.15	6.8
BC_1P_1	0	1	0	6	11	17	23	34	23	26	15	9	2	2	0	0	0	0	0	0	169	35.21	6.5

	13.35	15.95	18.55	21.15	23.75	26.35	28.45	31.55	34.15	36.75	39.35	41.95	44.55	47.15	49.75	52.35	54.95	57.55	60.15	62.75	N	Mean	S.D
BC_1P_3	0																						
Cross 3		1	4	17	19	19	27	27	23	15	10	5	3	1	1	0	0	0	0	0	172	30.27	6.45
P_1	0	0	0	1	0	1	7	3	18	14	15	7	7	5	3	3	1	2	0	3	90	39.67	8.16
P_4	0	0	1	2	9	17	23	25	25	23	19	18	7	10	5	5	1	1	0	1	192	35.67	7.87
F_1	0	1	2	7	11	9	15	24	27	18	19	6	6	2	2	2	1	0	0	0	166	34.04	7.81
F_2	2	3	2	10	20	20	48	25	25	15	7	12	10	4	4	3	0	0	0	0	208	31.98	7.54
BC_1P_1	0	0	0	2	4	7	15	21	24	39	27	16	12	4	6	1	3	1	1	0	183	36.95	6.86
BC_1P_4	0																						

Table 4. Frequency distribution of ear girth in three pearl millet crosses

Percentage	Class centres in centimetres for ear girth																
Cross 1	1.49	1.67	1.85	2.03	2.21	2.39	2.57	2.75	2.93	3.11	3.29	3.47	3.65				
P_1	2	8	19	51	35	33	36	15	11	2	2	0	0				
P_2	12	14	25	39	21	30	33	14	10	4	4	3	0				
F_1	15	12	25	47	23	37	36	24	14	2	3	2	1				
F_2	9	8	19	50	33	37	23	18	12	7	3	1	1				
BC_1P_1	5	6	13	12	13	29	22	15	4	3	2	1	0				
BC_1P_2	7	7	26	60	24	39	39	16	17	1	2	0	0				
Cross 2	1.11	1.25	1.39	1.53	1.67	1.81	1.95	2.09	2.23	2.37	2.51	2.65	2.79	2.93	3.07	3.21	3.35
P_1	1	0	1	0	2	4	13	14	29	24	26	16	11	9	7	5	3
P_3	0	0	2	3	5	3	28	12	17	32	25	22	7	17	24	5	3
F_1	0	1	2	3	14	11	36	21	24	41	18	17	8	7	12	4	2
F_2	0	0	0	1	3	2	21	6	9	19	20	10	4	6	15	1	3
BC_1P_1	2	1	3	1	12	12	25	21	20	25	19	17	9	8	12	5	4
BC_1P_3	0	1	0	2	2	3	16	9	13	15	32	20	13	7	19	4	2
Cross 3	1.07	1.20	1.33	1.46	1.59	1.72	1.85	1.98	2.11	2.24	2.37	2.50	2.63	2.76	2.89	3.02	3.15
P_1	0	2	1	11	8	9	34	12	15	21	13	11	13	13	3	1	2
P_4	1	3	0	6	7	7	16	16	10	14	4	5	1	0	0	0	0
F_1	1	1	2	9	3	6	22	21	19	18	15	15	8	13	4	3	3
F_2	1	1	2	7	3	6	30	34	25	18	20	19	11	7	3	3	2
BC_1P_1	0	0	0	9	3	5	10	32	36	32	19	29	13	9	3	2	4
BC_1P_4	2	3	6	10	5	9	22	25	20	21	15	25	8	7	5	0	0

Population				
		N	Mean	S.D
		214	2.28	0.35
		209	2.26	0.45
		241	2.28	0.43
		221	2.29	0.42
		125	2.34	0.39
		238	2.27	0.37
3.49	3.63	N	Mean	S.D
3	1	179	2.45	0.40
5	0	210	2.49	0.46
4	2	227	2.32	0.21
1	0	121	2.45	0.10
6	3	205	2.34	0.41
2	2	162	2.52	0.19
3.28		N	Mean	S.D
3		172	2.22	0.43
0		90	1.94	0.33
4		167	2.21	0.45
0		192	2.15	0.38
2		208	2.24	0.36
0		183	2.10	0.41

Table 5. Frequency distribution of Leaf area in three pearl millet crosses

Parentage	Class centres in square centimetres for Leaf area															
	97.70	113.00	128.30	143.60	158.90	174.20	189.50	204.80	220.10	234.40	250.70	266.00	281.30	296.60	311.90	327.20
P_1	3	2	11	16	23	23	25	29	33	14	18	9	7	3	0	0
P_2	1	9	7	16	26	30	21	25	20	21	12	9	6	2	3	2
F_1	1	4	11	17	16	19	26	29	18	21	22	15	9	15	14	0
F_2	1	3	7	12	23	24	33	26	20	21	18	12	7	5	2	2
BC_1P_1	1	0	1	6	9	12	16	18	21	13	9	10	3	3	2	1
BC_1P_2	1	2	2	8	17	20	24	30	48	25	18	10	13	10	5	2
Cross 2	93.25	109.73	126.21	142.69	159.17	175.65	192.13	208.61	225.09	241.57	258.05	274.53	291.01	307.49	323.97	340.45
P_1	3	6	8	12	15	28	33	25	13	10	9	7	5	2	2	1
P_3	4	4	7	20	24	28	31	19	19	14	15	13	9	4	1	2
F_1	4	7	6	18	14	33	42	29	26	15	11	7	4	3	2	2
F_2	2	1	3	7	11	22	18	16	12	9	10	4	2	2	1	2
BC_1P_1	2	3	8	10	12	13	18	20	21	20	9	8	8	7	5	3
BC_1P_3	3	2	5	11	18	20	30	35	25	22	15	6	4	2	2	1
Cross 3	97.50	111.50	125.50	139.50	153.50	167.50	181.50	195.50	209.50	223.50	237.50	251.50	265.50	279.50	293.50	307.50
P_1	0	5	5	11	16	14	22	34	14	13	7	14	5	4	5	2
P_4	2	4	3	3	5	13	11	11	15	13	4	3	1	2	0	0
BC F_1	0	2	1	5	5	9	20	26	32	16	22	10	7	5	3	2
F_2	3	1	3	0	10	22	28	32	28	16	19	8	8	3	2	1
BC_1P_1	1	3	3	6	10	15	23	27	46	27	14	13	12	5	1	0
BC_1P_4	2	3	3	5	11	14	17	43	30	18	12	9	7	4	2	2

				Population		
342.50				N	Mean	S.D.
0				216	198.50	43.1
0				210	197.00	47.0
1				238	215.13	53.8
0				222	203.12	45.8
0				125	212.77	43.6
0				235	217.19	43.8
356.93	373.41	389.98	406.37	N	Mean	S.D.
1	0	0	0	180	197.34	49.4
1	0	0	1	216	195.10	54.5
1	1	0	0	227	199.31	49.9
1	0	0	0	123	196.60	49.4
3	0	0	0	170	217.92	58.3
2	0	0	0	205	199.71	47.0
321.50	335.50	349.50		N	Mean	S.D.
1				172	197.86	45.0
0				90	190.06	39.4
2				167	200.14	61.9
0				192	199.36	38.4
2				208	206.40	38.3
0				182	201.81	38.8

larger spread to the right in crosses two and three, denoting that individuals with long ear were more prevalent among these parent materials.

Table 4 shows data distribution for ear girth. Except for the P_1 in cross two, none of the parents in the three crosses and their other generations showed a normal distribution.

The distributions of the F_1's tended towards the larger parents, thus demostrating heterosis and dominance of wide over narrow ear girth. Backcrosses made to parents with larger ear girth values had greater proportions of their population towards the greater parental values, so that in cross one, 60.80% of BC_1P_2 had values equal to or greater than the mean value of P_2. Transgressive segregation in respect of ear girth was unimportant.

The data distribution for leaf area (table 5) was bimodal in P_1, F_2, BC_1P_1 and BC_1P_2 in cross one and polymodal in the P_2 and F_1. In cross two, only the F_1 data showed a bimodal distribution, others showed at least an apparent unimodality of data distribution. The two parent materials and the F_2 in cross three showed polymodal distributions. The F_1 values had a bimodal distribution, while the backcrosses to the two parents had a unimodal distribution. Larger leaf area was

found dominant over small area from the larger distributions of values towards the greater values in the three crosses.

4.2 Mean Performance

The mean performance of six generations (the parentals, F_1, F_2 and first backcrosses to the two parents) in respect of height, ear length, ear girth and leaf area is presented in Table 6. One of the parents; Ex-Borno, used in the three Crosses as P_1 was in itself not stable with respect to height. In the three crosses involved, mean height performance of Ex-Borno (P_1) varied from 181.2 to 186.5 cm, Compared with the other three parents Ex-Borno was shortest, the highest mean height was recorded for the purple midrib parent P_3 (233.53 cm). Two of the three F_1 hybrids (P_1 x P_2 and P_1 x P_4) exceeded even the mean value of the taller parent, indicating overdominance of tallness over shortness. The value of F_1 of cross P_1 x P_3 (192.56 cm) assumed a value midway between the parents.

The parents varied greatly with respect to ear length. The Ex-Borno was shortest for ear length (30.27 cm) and purple plant longest (39.67 cm). The F_1 mean values were towards parents with longer ears in all the crosses. The F_2 mean value (29,53 cm) for ear length is smaller than the smaller parent (30.27 cm) in the

Table 6. Mean Performance, Standard Error (S.E.) and Standard Deviation (S.D.) of Parents, First and Second filial generations and First Backcross generations of the Parents for four traits in three millet crosses.

Generations		Traits: T_1 Height			T_2 Ear Length			T_3 Ear Girth			T_4 Leaf Area		
		Mean	S.E.	S.D.	Mean	S.E.	S.D.	Mean	S.E	S.D.	Mean	S.E.	S.D
Cross 1	P_1	181.22	± 1.61	23.47	33.43	± 0.36	5.24	2.28	± 0.02	0.35	198.51	± 2.93	43.11
Cross 2	P_1	186.50	± 2.45	33.18	30.50	± 0.40	5.43	2.45	± 0.03	0.40	197.34	± 3.71	49.84
Cross 3	P_1	184.90	± 3.00	28.49	30.27	± 0.45	6.45	2.22	± 0.03	0.43	197.87	± 3.44	45.09
	P_2	191.33	± 1.93	27.65	33.88	± 0.44	6.40	2.26	± 0.03	0.45	197.00	± 3.24	47.03
	P_3	233.53	± 3.04	39.54	36.33	± 0.54	7.91	2.49	± 0.03	0.46	196.00	± 3.71	54.59
	P_4	190.78	± 2.56	33.55	39.67	± 0.86	8.16	1.94	± 0.03	0.33	190.06	± 4.16	39.47
Crosses	F_1												
$P_1 \times P_2$		193.12	± 1.78	27.18	34.04	± 0.47	7.13	2.28	± 0.03	0.43	215.13	± 4.49	53.81
$P_1 \times P_3$		192.56	± 2.21	33.38	34.76	± 0.54	5.93	2.32	± 0.03	0.46	199.31	± 3.32	49.95
$P_1 \times P_4$		202.98	± 2.37	30.64	35.67	± 0.57	7.87	2.21	± 0.03	0.45	200.14	± 4.80	61.98
Segregating F_2 Population of:													
$P_1 \times P_2$		181.47	± 0.61	9.08	29.53	± 0.44	6.56	2.29	± 0.03	0.42	203.12	± 3.08	45.88
$P_1 \times P_3$		181.82	± 2.94	32.50	31.36	± 0.50	7.60	2.45	± 0.04	0.43	196.60	± 4.46	49.48
$P_1 \times P_4$		193.50	± 2.11	29.27	34.04	± 0.60	7.81	2.15	± 0.03	0.38	199.36	± 2.77	38.42
Backcrosses to P_1													
Cross1	BC_1P_1	186.92	± 2.38	26.96	33.77	± 0.40	6.07	2.34	± 0.03	0.39	212.77	± 3.90	43.67
Cross2	BC_1P_1	197.09	± 2.32	32.65	34.15	± 0.50	6.84	2.34	± 0.04	0.64	217.92	± 4.49	58.36
Cross3	BC_1P_1	193.83	± 1.76	25.37	31.98	± 0.52	7.54	2.24	± 0.03	0.36	206.40	± 2.66	33.36
Backcrosses to marker Parents													
	BC_1P_2	202.97	± 1.70	26.36	37.76	± 0.60	6.68	2.27	± 0.02	0.37	217.19	± 2.86	43.86
	BC_1P_3	213.19	± 3.03	39.41	35.21	± 0.51	6.58	2.52	± 0.03	0.44	199.70	± 3.28	47.01
	BC_1P_4	209.32	± 2.37	32.06	36.95	± 0.51	6.86	2.10	± 0.30	0.41	201.81	± 2.88	38.87

cross P_1 x P_2. The F_2 means in the other two crosses approached the larger parental values. BC_1P_2 mean value (37.76 cm) in cross one was higher than the original parent with longer ear (33.88 cm). The BC_1P_3 and BC_1P_4 mean values approached the larger parents. (35.21 cm and 36.95, respectively).

The F_1 mean values showed dominance of wide ear girth over narrow girth. The F_1 mean value of cross P_1 x P_2 (2.28 cm) had the same value with the wider parent (2.28 cm) but the two parents approached each other in their mean values (2.26 cm and 2.28 cm). Purple plant parent (P_4) had the least girth (1.94 cm) among the parent materials; consequemtly, its F_1 and F_2 hybrids exhibited the least girth (2.21 cm and 2.15 cm, respectively). Segregation in the F_2 resulted in mean values lower than the higher parents except in cross two (P_1 xP_3), where the mean value of 2.45 cm slighily exceeded the higher parent of 2.42 cm. Backcrosses to Ex-Borno in crosses one and two had the same mean. This may be as a result of the closeness of the mean values of the two parent materials. BC_1P_1 mean value (2.24 cm) in cross P_1 x P_4 approached the value of Ex-Borno. The backcross to purple midrib (BC_1P_3) had a mean value exceeding the parents, thus showing over-dominance. The least mean value of the backcross generation to the larger parent (2.10 cm) was observed

in cross three (P_1 x P_4). This is not surprising because the purple plant had the smallest girth.

Ex-Borno, purple ear and purple midrib (parent materials) were close in their mean values for leaf area (198, 197 and 196 cm^2, respectively). Mean value for the purple plant parent was 190 cm^2. The F_1 mean values for all the crosses exceeded the larger mean values of their parents. The F_1 hybrids of crosses two and three were however closer, their mean values being 199.31 and 200.14 cm^2, respectively.

The F_1 hybrid of cross one had a mean value of 215.13 cm^2. The F_2 generations for the three crosses showed reduced mean values than F_1 values. Backcross generations for the three crosses had mean values higher than the larger parents and also exceeded F_1 mean values.

4.3 Heterosis and Inbreeding Depression (%)

Cross two (P_2 x P_3) showed a negative (-8.31%) heterosis for plant height and was 3.67% and 8.06% for Ex-Borno x purple ear and Ex-Borno x purple plant, respectively (Table 7).

All the three crosses showed some amount of inbreeding depression. Positive heterosis was obtained for ear length in all the three crosses. Heterotic values were 1.13, 4.02 and 2.00% in crosses one, two and three, respectively for ear length.

Similarly, inbreeding depression was shown by all the three crosses for ear length, the highest value (13.25%) was shown by the Ex-Borno x purple ear cross. Only Ex-Borno x purple midrib showed negative heterosis for ear girth while others had positive heterosis. Ex-Borno x purple plants had a higher heterotic value of 6.12%.

Inbreeding depression was least (0.44%) in cross one and is negative in cross two (-6.07%) for ear girth. Leaf area and grain yield showed positive heterosis and inbreeding depressions for all the crosses. Highest heterotic value (8.79%) for leaf area was recorded in cross one and least (1.57%) in cross two. The least inbreeding depression for leaf area was 0.39% and occured in Ex-Borno x purple plant. Highest heterotic values compared with all the other traits observed occured in grain yield, similarly, the highest inbreeding depressions were also recorded in this trait. Heterotic values of 18.15, 15.81 and 11.99% were observed for crosses three, two and one, respectively. Correspondingly inbreeding depression values of 14.21, 11.11 and 9.56% were also observed for the same character.

Zero heterosis and inbreeding depression were observed for days to 50% heading in cross three. Ex-Borno x purple ear showed 0.85 and 1.69% for

heterosis and inbreeding depression respectively for this trait. Negative heterosis was however shown by Ex-Borno x purple midrib, with an inbreeding depression of 3.64%.

4.4 Estimated gene Number, gene Action and Heritability

Plant height:

The estimated gene number using Mather and Jinks' formula gave approximately two genes for plant height for the three crosses. Except in the cross three wich had gene number of 1.24 Burton's method gave gene number for height of less than unity. The calculated arithmetic and geometric means of F_1 and F_2 of the cross Ex-Borno x purple ear showed a X^2 goodness test to the expected means of 0.25 with a probability vaue of .50-.70. This fit indicates that both additive and dominance gene actions are in operation. The cross Ex-Borno x purple midrib had F_1 and F_2 means fitting to the expected with probability value of .20-.30, both in the arithmetic for the F_1 and artithmetic and geometric scales for the F_2. This may mean that gene actions other than additivity were in operation. The observed F_1 and F_2 means of Ex-Borno x purple plant is an indication that additive and non additive gene actions were involved. Heritability in the narrow sense has been calculated because this is the portion of heritability that is useful in breeding programmes. Negative heritabilities for plant height were calculated for the three crosses.

Table 8. Plant Height, Ear length, Ear girth, Leaf area estimated gene number , gene action and heritability estimates in pearl millet crosses.

Crosses	F_1 Population: Minimum number of genes B*	MJ**	Observed mean	Estimated Arithmetic mean	X^2	P Value		F_2 Population: Observed mean	Arithmetic mean	X^2	P Value	Geometric mean	X^2	P Value	h^2***
P_1xP_2	0.07	2.00	193.12	186.28	0.25	.50-.70	Plant Height	181.47	189.70	0.36	.50-.70	189.63	0.36	.50-.70	-15.17
P_1xP_3	-5.77	2.00	192.56	210.02	1.45	.20-. 3		181.82	201.29	1.88	.10-.20	200.46	1.73	.10-.20	- 0.48
P_1xP_4	1.24	1.99	202.98	187.84	1.22	.20-.30		193.50	195.41	0.02	.80-.90	195.25	0.016	00.90	- 0.05
P_1xP_2	0.02	1.99	34.04	33.66	0.00	> .99	Ear Length	29.53	33.85	0.55	.30-.50	33.84	0.55	.30-.50	0.10
P_1xP_3	-0.19	1.99	34.76	33.42	0.05	.80-.90		31.36	34.09	0.22	.50-.70	34.01	0.21	.50-.70	0.44
P_1xP_4	3.98	2.00	35.67	34.97	0.01	.90-.95		34.04	35.32	0.046	.80-.90	35.15	0.04	.80-.90	- 0.30
P_1xP_2	-0.22	2.00	2.28	2.27	0.00	> .99	Ear Girth	2.29	2.28	0.00	>.99	2.27	0.00	>.99	0.36
P_1xP_3	0.33	2.00	2.32	2.47	0.01	.90-.95		2.45	2.40	0.00	>.99	2.39	0.00	>.99	- 3.66
P_1xP_4	0.35	2.00	2.21	2.08	0.01	.90-.95		2.15	2.15	0.02	.90-.95	2.14	0.05	.80-.90	- 0.12
P_1xP_2	0.11	2.00	215.13	197.75	1.53	.20-.30	Leaf Area	203.12	206.44	0.05	.80-.90	206.26	0.05	.80-.90	0.18
P_1xP_3	0.13	2.00	199.31	196.22	0.05	.80-.90		196.60	197.77	0.01	.90-.95	197.76	0.01	.90-.95	- 0.29
P_1xP_4	0.01	2.00	200.14	193.96	0.20	.50-.70		199.36	197.05	0.03	.80-.90	197.00	0.03	.80-.90	- 0.03

* Number of Genes After Burton (1951)

* * Number of Genes After Mather and Jinks (1971)

* * * Heritability, Narrow sense $(2VF_2 - (VB_1 + VB_2)/VF_2.)$

Ear Length:

Mather and Jinks (1971) estimated the number of genes for ear length as two for all the crosses. Using the method of Burton (1951), the values were less than one for Ex-Borno x purple ear and Ex-Borno x purple midrib (0.02 and -0.19, respectively) but a value of 3.98 was obtained in Ex-Borno x purple plant. Calculated mean values for the F_1's and F_2's of all the three crosses fitted well to the expected arithmetic and geometric means, thus suggesting additive and non-additive gene actions. Similarly the good fitting of the F_2 geometric means indicated the skewness of data distribution. Negative heritability was obtained for Ex-Borno x purple plant. The other two crosses have positive heritability values, but the higher value of 0.44 was shown in Ex-Borno x purple midrib.

Ear Girth:

Burton's formula gave gene numbers of less than one for the three crosses. On the other hand, Mather and Jinks' formula gave a value of two for the three crosses. Probability values for the observed F_1 means were high for the three crosses. P-values ranged from .90 to .99. The same high trend of probability values were maintained for the F_2 means on arithmetic and geometric scales. This is an indication of additive and non-additive gene

actions. Heritability for ear girth was, however, low. Ex-Borno x purple ear had an heritability estimate of 0.33; the other two crosses had negative estimates of -3.66 and -0.12 indicating an absence of genetic gain.

Leaf Area:

Estimated gene number by Burton's method was less than unity for the three crosses. By Mather and Jinks' method, gene number was two for all the crosses. Ex-Borno x purple ear had a fitted probability value to the expected for the F_1 mean (.20 - .30), but the mean values of the F_2 on both arihmetic and geometric scales had higher probability levels of .80 - .90) suggesting a skewed data distribution. The F_1 and F_2 mean values also suggest the presence of additive and dominance gene actions.

The observed F_1 means of the other two crosses, and also their F_2 means on arithmetic and geometric scales fitted well to the expected. Leaf area showed negative heritability for two of the crosses (Crosses two and three). Only cross one had a positive heritability estimate of 0.18. This low value suggests that a low genetic advance will be expected in breeding programmes for this character with respect to these materials.

4.5 Segregation Ratio, Chi-Square Tests and Probability Values

The segregation for the purple marker is presented in Table 9. In each case, the purple marker was dominant over its absence. For the purple ear, the F_2 under the proposed 9:7 epistatic ratio had a probability value of 0.05-0.10, thus fitting poorly to this ratio. The BC_1P_1 fits to the proposed 1:2 ratio with a probability value of 0.30-0.50. The BC_1P_3 under the proposed 3:1 ratio had a probability value of 0.10-0.20 thus fitting to the proposed ratio.

The purple midrib segregation gave probability value of 0.20-0.30 for the F_2 with the proposed 9:7 segregation ratio. The < 0.001 probability value for the BC_1P_1 does not fit to the proposed 1:2 ratio, but a probability value of 0.30-0.50 for the BC_1P_3 fits to the proposed 9:7 ratio, thus indicating a complementary gene action.

Proposed segregation ratios of the purple plant are the same as for the purple ear. Thus, probability values of 0.02-0.05, 0.05-0.10 and 0.01-0.02 were obtained for the F_2, BC_1P_1 and BC_1P_3 generations respectively under the corresponding segregation ratios of 9:7, 1:2 and 3:1. The F_2 and BC_1P_4 therefore do not fit to their proposed segregation ratios, and BC_1P_1 fitting only very poorly to the 1:2 ratio.

The probability values obtained in the three crosses were generally low. This may not be too surprising however, as the genes were relatively unfixed.

Table 9. Proposed Segregation Ratio, Chi-Square (X^2) Test and Probability (P) Values for the purple colour Segregation in F_2 and Backcross Progenies in Three Pearl Millet Crosses.

Parentage	Phenotypic Classification: Purple Pigmented	Normal	Total (N)	Segregation ratio	X^2	P Value
Cross 1						
P_1	-	251	251			
P_2	217	-	217			
F_1	125	-	125			
F_2	174	110	284	9:7	2.91	0.05-0.10
BC_1P_1	39	63	102	1:2	1.10	0.30-0.50
BC_1P_2	223	90	313	3:1	2.35	0.10-0.20
Cross 2						
P_1	-	547	547			
P_3	223	-	223			
F_1	211	-	211			
F_2	209	142	351	9:7	1.55	0.20-0.30
BC_1P_1	175	252	427	1:2	11.25	<0.001
BC_1P_3	253	179	432	9:7	0.94	0.30-0.50
Class 3						
P_1	-	528	528			
P_4	304	-	304			
F_1	346	-	346			
F_2	394	258	652	9:7	4.63	0.02-0.05
BC_1P_1	192	294	466	1:2	3.13	0.05-0.10
BC_1P_4	462	190	652	3:1	5.96	0.01-0.02

CHAPTER V

DISCUSSION

5.1 Frequency Distribution

The apparent normality and unimodality of the F_2 distribution indicate continuous variation and multiple factor inheritance for the quantitative traits studied. The additivity of gene action in the inheritance of some of the traits presently investigated has been reported by Sachdeva (1981), Sreenivasulu and Sreeramulu (1980), Nanda and Phul (1974), Singh *et al.* (1979) for height in millet and for ear length and girth by Bains (1973), and Sreenivasulu and Sreeramulu (1980). However, the apparent disposition of the data values towards the larger parents in the backcross generations in respect of ear length, ear girth, plant height and leaf area, indicate the presence of dominant gene actions for these traits.

The F_1 distributions in cross one showed heterosis for ear length and leaf area. Among the four traits whose frequency distributions are given, only leaf area did not show any form of transgressive segregation. Transgressive segregations below the shorter parents were observed for plant height in cross one and for ear length in crosses two and three, thus indicating some

amount of complementary gene action. Transgressive segregation for ear girth was only observed in cross one above the larger parent.

5.2 Mean performance, heterosis and inbreeding depression

The F_1 hybrids mean performance in all the three crosses for the four traits, relative to the mid-parent values, showed dominance of different magnitudes except F_1 of cross two for ear girth. Tall plants, long ears and large leaves were found to be dominant traits in all the crosses, and large ear girth was dominant in two of the crosses. In cross two where the F_1 hybrid did not exhibit dominance of large ear girth over narrow, the F_2 mean however had a value greater than the larger parent and represented the highest value recorded in the F_2 generation. The dominance in this case was evident in the backcross generation to the larger parent. The better performance of F_2 over F_1 generation was earlier reported in a cotton cross for yeild by Meredith and Bridge (1972). Mean values for the parents indicated that P_3 and P_4 can be source materials in selection for ear girth and ear length, respectively.

The phenomenon of heterosis has been known for long and has been described for many economic crop plants. It manifests itself in the form of superiority of hybrids over parent forms. In contrast to the common recombination

effect, heterosis is displayed mainly in F_1 progreny and falls off sharply in the following generations. The best results are achieved due to definite combination of inbred lines obtained as a result of directed selection in combining ability according to commercially valuable characters (Konarev 1976). The materials involved in the crosses were not selected for combining ability and this may in part explain why heterosis was low for most of the characters. However, this not withstanding heterosis as much as 0.39 to 11.15% is good enough. Further, this relatively low heterosis observed may also suggest lack of genetic diversity in some characters among the parent materials, for example Days to 50% heading where negative and zero heterotic effects were estimated (Table 7). The highest heterosis was obtained in grain yield, plant height and leaf area in descending order. Heterosis varied from cross to cross and from character to character, but relative to the other crosses, heterotic gain for all the traits was lowest in the cross Ex-Borno x Purple ear (except for leaf area). Purple ear is of Ex-Borno origin and Ex-Borno and Ex-Benue are local cultivars that are very similar with respect to many phenotypic traits. This may in part explain the low heterotic gain recorded for this particular cross. Days to 50% heading had zero heterosis and zero inbreeding

depression in cross three. Sing (1966) obtained zero depression in two populations of Zea mays L. His explanation for zero depression were

1) the number of segregating loci affecting the trait is not large,
ii) favourable allele is dominant and the recessive is at a low freguency,
iii) inbreeding depression is chiefly the result of loci expressing partial to complete dominance,
iv) Negative heterosis was observed for each of the traits studied.

Heterosis had been variously reported in pearl millet for many agronomic characters. Singh and Lal (1969), Yadav (1979) and Sreenivasulu and Sreeramulu (1980) have reported high positive heterosis for plant height. Tewari (1974) reported heterosis for ear length and Sreenivasulu and Sreeramulu (1980) also reported heterosis for yield.

The mean values of the F_2 generations were expected to be smaller than those of the F_1 generations but no losses were recorded in the F_2's in crosses number one and two in respect of ear girth. A depression is expected in situations where F_1 superiority results from heterosis. However, the magnititude of inbreeding depression is not the same for all the crosse across the traits, When lines receive more of the favourable genes than others differences

are observed in the degree of inbreeding depression in these lines. Similarly, wherever heterosis is largely responsible for increase in phenotypic measurement or appearance in F_1 in highly inbred lines, theoretically a loss of about half of the increase is expected in the F_2 generation (Bello,1983). This loss is a consequence of dominance at the loci concerned. The higher the heterosis the greater is the inbreeding depression. The highest heterotic values were recorded for plant height, ear length and yield in order of magnitude. Inbreeding depression consequently was highest in these traits and followed that same order of magnitude for heterosis. The explanation for the depression is however not very clear. It is probable that the mode of reproduction of millet, (protogyny) where the female part matures before the male part may be responsible for the level of depression even though heterosis should have been expected. Stigmas which did not receive pollens when the crosses were made might have been pollinated by pollens of the same plant that were shed later when the anthers became mature. In this case, selfing has taken place. In yield, what is lost in the F_2 is well above 50% of what was gained by heterosis for the three crosses. Inbreeding depression for plant height, ear length and days to 50% heading was greater than heterosis in cross one. In cross two inbreeding depression was greater than heterosis

for plant height and ear length, and in cross three it was in ear length, that this type of situation was observed. Ear girth for cross three followed approximately the expected 50% loss of heterosis in the F_2 generation. For Ex-Borno x Purple plant, inbreeding depression was far below the expected 50% loss (Heterosis = 3.18%, inbreeding depression = 0.39%). Zero depression was recorded for plant yield in the Ex-Borno x Purple plant. Similar zero depression was reported by Bello (1983) for head length in a sorghum cross. A probable explanation for this situation could be the varying proportion of dominance and additive components of gene action and differential environmental influence on the expression of these characters in the cross concerned here. Makura (1973) explained that differential response to inbreeding in crosses for the same traits could mean that the average effects of dominant alleles differ in each of the crosses in respect of the traits or that fewer loci may be concerned where depressions are highest.

5.3 Estimated gene number, gene action and heritability.

The estimated gene numbers were very small in all cases and less than one except two instances for plant height when Burton's formula was applied to the data. However, Burton (1951) also recorded gene numbers as low as 0.2 for head length and 0.4 for leaf width in millet crosses. These unusually low gene numbers obtained by

Burton's formula may be that the assumptions of no linkage, no interaction between non-allelic genes, all genes are equal and equal distributions of positive and negative genes did not hold. Incidentally, Mather and Jinks's formula estimated the gene number as two in almost all the cases for the trait. Lal and Singh (1973) also reperted two genes for leaf width in millet. This apparent differences in estimation of number of genes and gene action suggests that a more acurate formula has to be devised for these estimations.

Heterosis generally is attributed to the effects of dominance and overdominance gene action. The values of heterotic expression obtained in the crosses for all the traits studied is an indicator of the magnitide of dominance and overdominance gene action. A comparison of the observed and calculated F_1 means reveals the degree of additivity expressed in the inheritance of each trait. Large amount of additive gene action exists for ear girth and ear length for all the crosses and moderately for plant height and leaf area. The extent of the agreement between the observed and the computed F_2 mean, arithmetic or geometric, furnishes information about the kind of gene action controlling the inheritance of each trait. There is a good agreement between the observed mean and calculated arithmetic and geometric means for ear girth and leaf area for all the crosses and ear length among

crosses in three and two and for plant height in one and three. Some amount of non-additive gene action exist for plant height in Ex-Borno x purple midrib and for ear length in Ex-Borno x purple ear. This indicates that dominance and other non-additive gene action predominate for these crosses in respect of the traits mentioned. Dominance gene action for some millet traits had been reported. Singh and Lal (1969) reported dominance gene action for ear girth and length, but they also indicated the importance of additive x additive and additive x dominance gene actions using specific methods that could identify these types of gene action.

Heritability estimates provide information on the transmission of characters from parent to progeny, and the estimates can also be used to predict genetic advance under selection. Heritability estimates obtained were low. The only appreciable amounts were obtained in ear length for cross two (0.44) and in ear girth (0.36) for cross one. Since heritability estimates obtained were low, it means individual genotypes cannot be readily assessed from their phenotypic expressions. There were variations among crosses and their heritability estimates for the same trait. This variation suggests that additive genetic variability differed among parents. Another explanation could be that the parents are not

fixed with respect to the characters and in fact may vary in their relationship to each other. Negative heritability estimates were obtained for plant height in all the crosses, for ear length in cross three only, for ear girth in crosses two and three and for leaf area also in crosses two and three. The negative heritability estimates could have possibly arisen from a number of situations:

i) They may results from the absence of genetic variability in the affected characters in the two parents concerned.

ii) The negative estimates could be the result of the higher variances of the F_1 hybrids over the F_2, which were observed in most of the cases. This situation is possible because the parent materials involved in the crosses were not pure inbred lines, therefore there were likely to be fluctuations in later generations which would allow a better performance of the F_2 over the F_1.

iii) Negative heritability estimates will result when $2VF_2$ was less than the sum of the variances for the two backcrosses, that is $2VF_2 < (VB_1 + VB_2)$. Shin, (1972) reporting from Liang and Walter, said that since the difference between the F_2 variance and the sum of backcross variance is a measure of the amount of variation due to additive gene effects; it would be

logical to assume that the additive gene effects was negligible. He, however, cautioned that although negative heritability estimates were obtained, they have only been calsulated from generation variances and not from the manipulation of additive, dominance and error variances. (D, H, and E, respectively) and that negative values for H biases upwards the heritability estimates. At this point it is worthwhile to mention that heritability estimates obtained in this study have been calculated only from the F_2 and backcross variances. Negative heritability estimates exist in literature for pearl millet. Burton (1951) obtained negative heritability in millet for plant yield and internode length. He also obtained low values of 0.14 and 0.28 as estimates of heritability in leaf width. Much higher estimates have, however, been reported by Nanda and Phul (1974) and Lal and Singh (1973) for ear length in millet.

5.4 Segregation Pattern, Chi-Square Tests Probability Values.

The presence of anthocyanin, either on the pericarp, midrib or the entire plant has demonstrated dominance over its absence in the pearl millet crosses studied. The probability values obtained under the postulated segregation ratios were low. The highest probability value obtained was 0.30 - 0.50 for the BC_1P_3 in cross two for the purple midrib. Anthocyanin pigmentation on

plant parts or entire plant has been widely reported in cereal crops as a dominant trait. The point of disagreement has been on the number of genes controlling the character. For this study, a two gene factor with an epistatic effect has been proposed, although some previous reports of monogenic gene actions had been made in pearl millet by Singh et al. (1967), Lal and Singh (1971), Yadav (1976) and Shanthappa (1980). However, Majumder et al. (1969) reported single recessive gene action of purple pigmentation in lemma and palea in rice plants. Also, in rice, Sastry and Seethocram (1975), reported zebra banding of purple marker on the leaf blade as a single recessive gene linked to another recessive gene controlling dwarf habits.

The Chi-square tests as far as this study is concerned may not be held as the truest indication of the nature of gene actions in operation. This is because the genes were not yet fixed, but the values obtained may help in visualising the possible kinds of gene action. The unfixed state of the genes was made manifest by the parents that were still segregating for the purple character. Before the Chi-square data were taken, the parents were only selfed for four generations. The level of homozygosity previously attained might not have been enough for genes to fix. However six to seven generations may not necessarily fix all genes at

different loci. Further investigations may be needed to validate the proposed segregation ratios. A good fitting of the BC_1P_1 in cross one to a 1:2 segregation ratio suggests the possibility of some colour variations that were missed and not counted or probably there were some lethals which died before reaching maturity.

It was also observed in this study that the purple pigmentation, whether on the ear, midrib or entire plants, varied in intensity. This varying shades of the purple colour may indicate the presence of complementary gene factors which may modify the true segregation ratios. The varying shades of the purple colour is illustrated in Plate I for the ear, and in Plate II for the wholly purple plants. The different shades of purple could not have been the effect of the environment because the materials were grown under the same soil conditions and environment. For this study, no grouping was attempted among the different shades of purple, instead they were pooled together and simply classified as purple. Ayyangar and Rao (1931a) obtained different shades of purple in millet which they called purple and light purple. They postulated that the green types were of various kinds of purple pigment producing potential. Ayyangar and Ponnaiya (1938), postulated that an intensifier factor I, makes the difference between the purple and light purple types. Further they said that the former is dominant



Plate 1.1 Different shades of purple among the purple ear plants.



Plate II Plants segregating for the normal green plants and different shades of purple.

to the latter and designated PPII and PPii, respectively. Presence of intensifier genes has also been indicated by Bhatt and McMaster (1976) in wheat. Some of the plants carrying the purple midribs had purple culm, but the rest of the foliage or the ear was not pigmented. This is shown in Plate III. It is probable that the genes responsible for the purple midrib are in the same linkage group with those controlling the pigmentation on the culm. The Ex-Borno (P_1) and purple midrib (P_3) could not be distinguished on the basis of their ear types, and this is illustrated in Plate IV. Plate V shows the leaves of Ex-Borno, purple plant and purple midrib parents. The presence of the purple pigment all over the plant is not desirable economically for grain yield. This is because of the attendant high lodging susceptibility resulting from the thin and brittle stems which also bear very narrow and sometimes loose ear types. It must be recalled that data on ear girth distribution (Table 4) show the purple plant and its crosses as having the least ear girth. Similarly, grain yield was least among the wholly purple plant materials.

Apart from the genetic interest of the purple marker, it may be of practical utility as genetic stock marker in breeding programmes. The popular cytoplasmic sterility used in developing most grain crops can be used together with this purple marker in identifying hybrid seeds for commercial cultivation.



Plate III Purple midrib plants with purple culm contrasted with Ex-Borno possessing green culm and white midrib.



Plate IV Leaves and ear types of purple plant, purple midrib plant and Ex-Borno. Ears of purple midrib and Ex-Borno cannot be distinguished on the basis of pigmentation.

Plate V Leaves of purple plant, purple midrib and Ex-Borno parents.

CHAPTER VI

SUMMARY AND CONCLUSIONS

This investigation was carried out in order to determine the mode of inheritance and nature of gene actions involved in some quantitative traits and the qualitative purple gene markers in pearl millet (Pennisetum typhoides (Burm) Staph and Hubb). Five populations (parentals, F_1's, F_2's and the first backcross to the two parents in each cross) were used.

Continuous variation was observed for plant height ear length, ear girth and leaf area. Varying degrees of gene additivity and dominance were observed for each of these characters in the three crosses.

Differential response to heterosis and inbreeding depression were shown among the crosses for plant height, ear length, ear girth, leaf area, grain yield and days to 50% heading. The low heterosis that was generally observed suggests a low genetic diversity among parent materials. Heterosis was negative only in cross two for plant height, ear girth and days to 50% heading, and was zero for days to 50% heading in cross three.

Esti..ated gene numbers were low and were always less than one in the three crosses using Burton's (1951) formula except for the trait controlling ear length in

cross two which had a value of 3.98. Mather and Jinks' (1951) formula estimated the number of genes as two or almost two in all the cases.

Heritability estimates were generally low for all the traits in the three crosses and sometimes negative. The only appreciable amounts were obtained for ear length in cross two with an estimated value of 0.44 and also for ear girth in cross one with a value of 0.36. Negative heritability estimates were observed for plant height in all three crosses; for ear length in cross three; for ear girth and leaf area in crosses two and three.

Discrete variation was observed for the purple pigmentation. The purple character was dominant over its absence whether on the ear, midrib or the entire plant. Based on the data obtained, segregation for the purple pigmentation fitted a digenic ratio better. The varying shades of the purple pigmentation may be an indication of complementary genes factor. The low probability values might have resulted from the low level of fittness of segregating ratio attained in the F_2 and backcross generations in respect of these traits. Purple plants are undesirable economically as far as grain yield is concerned because of their high rate of lodging and loose ear types.

From the results obtained, it can be concluded that the parents used have not shown an impressive genetic diversity in respect of the agronomic traits considered. Low heritability estimates which were sometimes negative is an indication that no appreciable amount of improvement can be achieved in respect of each trait except ear length and ear girth. The negative estimates might have resulted because their calculations were derived from generation variances only.

The level of homozygosity must be pushed forward in the parent materials in respect of the purple character in order to ascertain the true segregation pattern. However, the anthocyanin pigmentation can form a useful identification tool in improvement programmes.

Appendix 1. Dry seed weight per ear in grams in three crosses of pearl millet.

	Cross -1	Cross -2	Cross -3
P_1	23.35	24.16	23.96
*P_2	23.35	25.11	12.01
F_1	26.15	27.53	21.25
F_2	22.65	22.36	18.23
BC_1P_1	25.97	23.30	22.70
**BC_1P_2	22.58	29.76	16.33

*P_2 will be P_3 in cross -2 and P_4 in cross -3
**BC_1P_2 will be BC_1P_3 in cross -2 and BC_1P_4 in cross -3

Appendix 2. Averaged number of days from sowing time to 50% heading in three crosses of pearl millet.

	Cross -1	Cross -2	Cross -3
P_1	59	58	56.50
*P_2	57.50	64.50	56.50
F_1	59	54.50	56.75
F_2	60.25	56.75	56.75
BC_1P_1	57	61.50	56.75
**BC_1P_2	61	59.50	58.50

* P_2 will be P_3 and P_4 in crosses two and three respectively
** BC_1P_2 will be BC_1P_3 and BC_1P_4 in crosses two and three respectively.

REFERENCES

1. Ahluwalia, M., Solomon, S., Khanna, P.P. (1978). Pattern of anthocyanin pigmentation in Seteria italica Andhra Agricultural Journal 18 (5): 195-199.

2. Ahmad Ziauddin and Murty, B.R. (1972). Inheritance of protein and some essential amino acid in a 22 x 22 partial diallel of Pennisetum typhoides. India Journal of Genetics and Plant Breeding 32(3): 400.

3. Athwal, D.S. and Gill, S.S. (1966). Inheritance of bristling and purple pigmentation in Pennisetum typhoides, J. Res. (India).

4. Avey, D.P., Ohm, H.W., Patterson, F.R., Nyquist, W.E. (1982). Advanced generation analysis of days to heading in three winter wheat crosses. Crop Science 22: 912.

5. Ayyangar, G.N.R. and Rao, P.K. (1931a). The inheritance of characters in raji, Eleucine coracana (Gaertn) Part 1. Purple pigmentation. Indian Journal of Agricultural Science 1: 434-444.

6. Ayyangar, G.N.R. and Ponnaiya, B.W. (1938). Studies in millet, Panicum miliaceum Linn. Madras Agric. J. 26: 195-206.

7. Bains, K.S. (1973). Genetic analysis for certain plant and ear characters in pearl millet top crosses. Plant Breeding Abstract 42: 925.

8. Bello, S.A. (1983). "Inheritance study of some quantitative and qualitative traits in sorghum". Sorghum bicolor (L) Moench. Unpublished M.Sc. thesis, Ahmadu Bello University, Zaria, Nigeria.

9. Bhatt, G.M. and McMaster, G.J. (1976). Variation in pigment content of flour colour in bread wheat (T. aestivum L.) Plant Breeding Abstract 47(7): 532.

10. Bilquez, A.F. (1970). General features of the research on millets in Africa. Millet-Sorghum Semina. Bambey 31 August - 4 September.

11. Burton, G.W., (1951). Quantitative inheritance in pearl millet. Agronomy Journal 43: 409-417.

12. Brinkman, M.A. and Frey, K.J. (1978). Physiological Analysis of isolines that differ in grain yield from their recurrent parents. Crop Science 18: 69.

13. Chand, H. and Ahmad, Z. (1976). Genetic studies in pearl millet. Plant Breeding Abstract 48 (1): 39.

14. Chaudhary, M.S., Yandav, H.R., Khairwal, I.S., Hood, R.S. (1982). Heritability estimates of some productivity trait. Plant Breeding Abstract 52(5):353.

15. Dashora, S.L., Sharma, R.K., Singh, S.P. and Mathur, J.R. (1977). Variability and heritability of early growth vigour and its association with forage and grain yields in bajra Pennisetum typhoides Plant Breeding Abstract 48(1): 452.

16. Ferrasis, R. (1973). Pearl millet (Pennisetum typhoides) Review series No. 1. Commenwealth Bureau of Pastures and Field Crops, Huiley Maidenhead, Berks SL65LR. U.K. pp. 70.

17. Gill, B.S. (1969). Inheritance of pigmentation in some plant parts in pearl millet, Indian Journal of Genetics and Plant Breeding 29(3): 468-472.

18, Gill, B.S., Athwal, R.S. (1970). Genetics of some ear characters and plant pigmentation in pearl millet. Plant Breeding Abstract 42(2): 307.

19. Gill, B.S., Virmani, S.S., Phul, P.S. (1969). Inheritance of foliage stripping in pearl millet. Indian Journal of Genetics and Plant Breeding 29(3): 473-477.

20. Gupta, V.P and Dhillon, B.S. (1976). Variation and covariance of some plant and grain traits in pearl millet. Plant Breeding Abstract 46(7): 531.

21. Il'in, V.., Mikhailova Yu.Ya. (1975). Relation of grain colour to the colour of their meal in panicum millet. Sb.n'auchtakhn. Inform. NIIs. k.h. Yugo-Vost: 47-49.

22. Ketata, H., Edwards, L.H. and Smith, E.L. (1976). Gene action of heading data, plant height and other characters in two winter wheat crosses. Crop Science. 16: 273-276.

23. Konarev, V. G. (1976). "Physiological and biometrical aspects of heterosis. Heterosis in plant breeding" In Janossy, A. and Lupton, F.G.H. (Ed). Proceeding of the seventh Congress of Eucarpia. Budapest. 81-91 Ekevier Scientific Publishing Company, Amsterdam, 1976.

24. Kumar, P, Kapoor, R.L., Dass, S. and Chandra, S. (1982), Genetics of heading and maturity in pearl millet Plant Breeding Abstract. 53(1): 37.

25. Lal, S. and Singh, D.(1973). Heritability, genetic advance and minimum number of genes in pearl millet. Indian Journal of Genetics and Plant Breeding 30(2): 315-321.

26. Lal, S. and Singh, D. (1971). Inheritance of some qualitative characters in pearl millet. Pennisetum typhoides.(Burm.f) Stapf and C.E. Hubb). Indian Journal of Agricultural Science 41(5): 461-466.

27. Le Clerg,E.L., Warren, H.L. and Andrew, G.C. (1962). Field Plot Technique. Burgess Publishing Company, Minneapolis, pp.350.

28. Liang, G.H. Reddy, C.R. and Dayton, A.D. (1972). Heterosis, inbreeding depression and heritability estimates in a systematic Series of grain sorghum genotypes. Crop Science. 12: 409-411.

29. Majumder, M.K., Datta, S.K. and Benerjee, S.P. (1969). Inheritance of pigmentation in Dular x Tainan - rice cross. Plant Breeding Abstract 42 (3): 615.

30. Makuru, S. (1973). Estimates of genetic components, heritability, genetic advance and interrelationships of kernel weight and volume, protein, lysine and oil content and certain other traits in four segregation populations of grain sorghum. Ph.D. Dessertation. Purdue Univ. Univ. Microfilm. Ann Arbor. Michigan.

31. Mather, K. and Jinks, J.L. (1971). Biometrical genetics Cord University, Ithacu, N.Y. pp. 382.

32. Meredith, W.R. and Bridge, R.R. (1972). Heterosis and gene action in cotton, Gossypium hirsutum L.Crop Science 12:304-309.

33. Murty, B.R. and Ram, J. (1966). Pattern of anthocyanin pigment in a world collection of sorghum. Indian Journal of Genetics and Plant Breeding 26(3):251.

34. Nanda, G.S. and Phul, P.S. (1974). Genetic analysis of yield factors and protein content in pearl millet. Plant Breeding Abstract.45(2):99.

35. Okonkwo, N.J. (1983). "Insect Pests of Stored Pearl" millet (Pennisetum americum (2). K. Schum) in Northern Nigeria. Unpublished M.Sc. thesis. Ahmadu Bello University, Zaria Nigeria.

36. Phul, P.S., Athwal, D.S. and Gill, B.S. (1969). Genetics of grain colour in pearl millet. Indian Journal of Genetics and Plant Breeding 29(3): 438-445.

37. Phul, P.S. Gupta K.S., and Gill, K.S., (1974) Association analysis of some morphological and physiological traits in pearl millet. Indian Journal of Genetics and Plant Breeding 34(3): 346.

38. Ram H.H. and Singh A. (1975). Genetics of days to heading in pearl millet. Indian Journal of Genetics and Plant Breeding 35(1): 54-59.

39. Sachdevd, A.K. (1981). Genetics of yield and some quality traits in pearl millet (Pennisetum tyhoides (Burnn) Stapf and Hubb). Plant Breeding Abstract. 52(6): 439.

40. Sastry, M. V. S. and Seethocram, R. (1975). Inheritance of zebra banding pattern and dwarf habits in rice. Indian Journal of Genetic and Plant Breeding. 35(1): 1-7.

41. Shin, H. (1972). Gene action in the inheritance of agronomic traits in intervatietal diallel crosses and relative importance of gene effects for quantitative characters in Zea mays L. Ph.D. dissertation, University of Hawail. Univ. Microfilms. Ann Arbor. Michagan.

42. Sing, C.F. (1966). A study of inbreeding depression in two populations of Zea mays L. Ph. D. Dissertation. North Carolina State of University of North Carolina, Releigh Univ. Microfilms. Ann. Arbor. Michagan.

43. Singh, D., Mishra, S.N., Singh, A.B.,and Singh, S.P. (1967) Inheritance in pearl millet. Indian Journal of Genetics and Plant Breeding 27(3): 426-428.

44. Singh D.and Lal, S. (1969). Gene effects and heterosis in pearl millet Indian Journal of Genetics and Plant Breeding 29(1): 18-23.

45. Singh, D. Lal, S., and Yadav, H.R. (1972). Inheritance of some qualitative characters in pearl millet. Pennisetum typhoides L.) Plant Breeding Abstract 44(1): 8

46. Singh, B.B. and Murty, B.R. (1974). Variation for yield and development characters in pearl millet Indian Journal of Genetics and Plants Breeding 34(3): 417-421.

47. Singh, D. and Pandey, B. P. (1973). Note on Inheritance in pearl millet. Indian Journal of Agricultural Science 43(6): 623-624.

48. Singh, F., Singh, R.M., Singh,R.K. and Singh, R.B. (1979). Genetic architecture of yield and its components in pearl millet. Indian Journal of Genetics and Plant Breeding 39(2): 292-299.

49. Shanthappa, M.B. (1980). Inheritance studies in Eleucine coracana Gaetn. Crosses. Plant Breeding Abstract. 51(11): 851.

50. Sinha, S.K. and Khanna R. (1975). Physiological, biochemical and genetic basis of heterosis. Advances in Agronomy 27: 123-174.

51. Sreenivasulu, M.R. and Sreeramulu, C. (1980). Heterosis and combining ability in pearl millet genotypes (Pennisetum typhoides S. and H) Plant Breeding Abstract 52(10): 768.

52. Steel, R.G.D and Torrie, J.H. (1960). Principles and procedure of statistics with special reference to the biological sciences. Mcgraw-Hill, New York pp 481.

53. Tewari, S.N. (1974). Studies on heterosis and combining ability for some yield characters in pearl millet. Plant Breeding Abstract 44(12): 713.

54. Thakare, R.B and Oyinloye A.K. (1980). Plant Breeding Techniques for millet Improvement in Nigeria. Paper presented at the 6th National Improvement Course A. B. U., Zaria 26th August - 27th September.

55. Walton, P.D. (1971). Heterosis in Spring Wheat. Crop Science 11:422-425.

56. Yadav, R.P. (1971). Study on the inheritance of anthocyanin pigmentation in Pennisetum glaccum (L) R.Br. Plant Breeding Abstract 42(3):607.

57. Yadav, R.P. (1976). A note on the inheritance of pigmentation in coleoptilar leaf of millet (Pennisetum typhoides S and H) Current Science 45(5): 197.

58. Yadav, R.P. (1979). Breeding studies in pearl millet with reference to inheritance of male sterility and its use in hybrid seed production. Plant Breeding Abstract 42(2): 898.

59. Yashovskii, I.V., (1974). Interaction of structural and regulatory genes controlling the grain colour of millet (Panicum milliaceum L)I. Inheritance of Yellow and red grained colour. Plant Breeding Abstract. 44(11): 639.

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