VARIABILITY ANALYSIS OF THREE SYNTHETIC POPULATIONS OF NIGERIAN PEARL MILLET *(Pennisetum americanum* (L.) Leeke) AND IMPLICATIONS IN CROP IMPROVEMENT

BY

MARY Y. YEYE

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Department of Plant Science
Faculty of Agriculture
Ahmadu Bello University,
Zaria, Nigeria

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DECLARATION

I hereby declare that this dissertation was written by me and is a record of my own research findings. No part of this dissertation has previously been submitted for a degree or any other qualification. Reference made to published and unpublished literature have been duly acknowledged.

Mary Y. YEYE Date: 28/10/2000

The above declaration is confirmed.

Dr. C. ECHEKWU
Chairman, Supervisory committee Date: 6/11/2000

CERTIFICATION

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This dissertation titled: Variability Analysis of Three Synthetic Populations of Nigerian Pearl Millet *(Pennisetum .americanum* (L) Leeke) and Implications in Crop Improvement by Mary Yinka Yeye meets the regulations governing the award of the degree of doctor of philosophy of Ahmadu Bello University, Zaria, and is approved for its scientific contribution to knowledge and literary presentation.

Dr. C. ECHEKWU
Chairman, Supervisory committee

Date: 6/11/2000

Dr. S.O. Alabi
Member, Supervisory committee

Date: 6/11/2000

Dr. S.G. Ado
Head of Department
Plant Science

Date: 8/11/2000

Prof. S.B. Ojo
Dean,
Postgraduate School
Ahmadu Bello University, Zaria

Date: 24/03/01

DEDICATION

To God be the glory, great things He has done for me

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ABSTRACT

Three synthetic populations originally from the Nigerian germplasm collections were evaluated for variability in 9 traits using a simple 9 x 9 lattice design. Mean performance differed significantly in the two years of evaluation for some traits, while some means were not significantly different in the two years. Expression of all the characters exhibited a wide range among the the populations, though the coefficients of variation were generally low, a range of 10.52% -16.513% being the highest in the populations, observed for plant height. The phenotypic variance was consistently higher than the genotypic variance across the populations for all the traits, and by far, error was the largest variance component for all the traits. Broad sense heritability estimates were low to high (29.667% to 86.357%); but the accompanying genetic advance was very low. Expressed as a percentage of mean, the highest estimate was 4.91% obtained for grain yield. All correlation coefficients were positive in populations 1 and 2, with a few negative associations observed in population 3. For most of the associations, the genotypic correlation coefficients were slightly higher than the corresponding phenotypic correlation coefficients.

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CHAPTER 1

INTRODUCTION

Pearl millet is a robust annual bunch grass, one to five metres tall belonging to the family Poaceae. It is a crop of African origin, originating from somewhere on the borders of the Sudan Republic and the Ethiopian empire (Bilquez, 1970). It is one of the most drought tolerant of man's food crops (Jere *et al.*, 1977,Hoseney and Varriano, 1979), and because of its short maturation period, drought evading (Acland, 1977). These characteristics enable the crop to thrive in areas of poor sandy soils and low and uncertain rainfall which would be unsuitable for most other important cereals, (Burton and Fortson, 1966 and Arnon., 1972). Millet is grown primarily in the dry sahel zone across Africa and in the semi-arid areas of India. Africa and Asia produce about 98% of the world's millet crop (Thakare and Oyinloye, 1980). Throughout most of its region of distribution, mean annual rainfall varies between 250 and 800mm. Pearl millet therefore is well adapted to moisture conditions to which few other grain crops can survive (Jere *et al.* 1977).

Millets are consumed as grains and brewed as drinks from historic times in Africa and Asia (Thakare and Oyinloye, 1980). Millet grains supply 80 - 90 percent of calories for millions of people of the world. The grain of millet is equal or superior to grain of wheat, corn, sorghum and rice in protein and oil content. It contains similar amount of Ca and P and more Fe than these cereals. Except for a lysine deficiency, pearl millet has an excellent amino acid profile (Burton et al., 1972). The grains are ground into flour from which unleaven bread or "chapatis"

or "tuwo" is made. Sometimes it is eaten as porridge or cooked with other foods to make savourly desserts (Nwasike, 1983). The industrial potentials of millets for malting and brewing qualities are already being explored. Millets are ranked best over other cereals for their malting and keeping quality (Okonkwo, 1983). In the more advanced countries like the United States of America, however, millets are grown mainly as fodder crops and rarely enter into markets as commercial grains (Okonkwo, 1983).

There are conflicting reports on the actual hectarage put under cultivation. Burton and Fortson (1966) reported over 5 million hectares cultivated in Africa and India; in sahelian Africa, Bilquez (1970) reported an estimation of 10 million hectares under cultivation, while Kumar *et al.* (1983) indicated that millet is principally grown on 26 million hectares in the hot, drought prone arid and semi-arid regions of African and Indian sub-continent. On a world wide basis, there are about equal areas planted to millets (all types) as compared with grain sorghum (Hoseney and Varriano, 1979). In terms of annual production, pearl millet is the sixth most important cereal crop in the world (Jere *et al.* 1977). In Nigeria, sorghum and millet are grown on about 10 million hectares. In the far north where rainfall is less, with short growing season of about 80 days and where soils are infertile, rocky and acidic, millet superseeds sorghum and maize and gives reasonable grain yield where the latter two will fail to produce grains (Thakare and Oyinloye, 1979).

Millet is a crop with many cultivated races. Some authors consider them as a single collective species while others designate them as distinctive species, and

for this, the taxonomy of the crop is in a state of flux (Ferrais, 1973).

Taxonomists are now in general agreement that all pearl millets belong to a single species, although considerable confussion persists over its proper species name (Jere *et al.* 1977). In Nigeria, there are ecotypes of pearl millet, *Pennisetum americanum (L.)* Leeke, 2n=14, (*Syn. P. typhoides, P. typhoideum, P. spicatum*) grown in northern Nigeria:

i. Gero Millet - It is considered to be the most important and occupies almost 90% of the millet land (Khadr, 1977). It is an early maturing and non-photosensitive type sown early with the beginning of the rainy seasons, and matures in 75-100 days (Bhardwaj and Webster, 1971). It is harvested in August or early September and produces food before the main sorghum harvest in November. It is grown as a sole crop and staple food crop in the northern parts of Sokoto and Katsina, Kano, Bauchi and Bornu states (Okonkwo, 1983).

ii. "Maiwa" millet is a photosensitive, late maturing type, matures in over 120 days (Bhardwaj and Webster, 1971 and Nwasike, 1988) and is grown in limited areas of the savanna region (Labe and Egharevba, 1983).

iii. "Dauro" millet - It is similar to "Maiwa" but different in that it is transplanted. It is grown in a smaller and high altitude area which comprises the Jos Plateau and southern part of Kaduna state (Labe and Egharevba, 1983).

Other millets under cultivation belong to distinct genera:

-*Echinochloa frumentaea,* (Roxb) Link. (2n = 36, 54) (syn. *Panicum frumentaceum,* Roxb.). It is called "Barnyard" or sometimes "Sanwa" millet. It is the quickest growing of all millets. It will produce a crop in about six weeks. The crop is known in the Oriental region and India, but is not of great importance. In China and Japan, it may be grown as a substitute for rice when the paddy fails. It is grown as forage crop in U.S.A. and can produce as many as eight crops per year. In Asia, the grain is consumed mostly by the poorer classes.

-*Eleusine coracana (L)* Gaertn (2n = 36) . Also known as African millet or finger millet. The plants are short and carry two or more spikes or fingers at the top of the stem. It is an important staple food in parts of East and Central Africa and India. It is the principal cereal grain in northern parts of western Uganda and in north eastern Zambia. Beer is made from fresh or stored grain. Flour of malted grain is used in India as food for infants and invalids and is often fed to diabetic patients (Khidir and DeWet, 1976). The great merit of finger millet is that it can be stored for long periods of up to 10 years or more without deterioration or weevil damage, consequently, it is an important famine food. The growing crop is less susceptible to bird damage than most other millets. Finger millet is hardy and grows in almost any soil.

- *Panicum miliaceum* L. (2n = 36, 72). Known by the common name of Proso millet

and hog millet. It is a short, not very leafy plant with open panicles and slightly flattened "seeds". Proso millet is widely grown in the former Soviet Union, central Asia and some part of eastern Europe, where it constitutes a staple food and is sometimes used for animal feed. Proso millet matures in 60 - 90 days. Proso is an efficient water user in that it will use less water to produce a kilogramme of dry matter than most other crops. This efficiency, coupled with its short growing season and ability to withstand higher temperatures, makes proso well suited to production in low rainfall areas.

-*Panicum sumatrense* Roth ex Roem and Schult. (2n = 36) (Syn. *Panicum miliare).* This is called little millet. It is grown extensively in Southern India on the poorest lands which are unsuitable for other crops. It is both drought resistant and tolerant to water-logging.

-*Setaria italica* (L.) Beauv (2n = 18) (Syn. *Panicum italicum* L., and *Chaetochlora italia* (L) Scribon.). Known by the common name, Foxtail millet. It is very hardy and succeeds in many regions in which other cereals do not thrive. In North Africa, Southern Europe, Japan and India, it is grown for human food and brewed for beer. Its very short growing period makes it an excellent choice as an emergency forage crop.

Pearl millet has not attained a high level of significance in the national economy because the volume of production has been relatively low and most of the varieties in cultivation are land races which are affected by a high reported

cases of diseases and pests. Thakare and Oyinloye (1979) reported that although pearl millet is of high nutritive value, it is often characterised by low yields, small seed size and excessively tall stature. The low yield of the crop is emphasized by Bilquez (1970) who stated that an average grain yield of 500 kg per hectare is common under traditional farming. This means that the African farmer, in order to satisfy his cereal needs from millet, must devote twice the amount of land and work that would be necessary for growing cereals in a well-balanced agriculture.

It is only in the last few decades that plant breeders have made serious attempts at developing improved varieties of pearl millet, before then, pearl millet received comparatively little attention from the scientific community (Maiti and Bidinger, 1981). Thus, the comprehensive breeding programmes encountered in other cereal crops are rare for pearl millet. Adequate attention in the area of genetic studies such that foster better understanding of its adaptability to various environments and its components of variability which can furnish better information on how to enhance its improvement in breeding programmes are grossly inadequate.

In planning a breeding programme, the first problem that often concerns a breeder is the presence or absence of variation for the trait or traits of interest. Since the breeder is concerned with selecting superior genotypes, but of necessity must choose individuals based on their phenotypic expressions, there is the need for partitioning the overall variability into heritable and non-heritable components with the help of suitable genetic parameters (Gandhi *et al.*, 1964), since the breeder will only be able to work on the former portion of variability (Silva, 1974).

The quantification and subdivision of the genetic variance into its component parts provides a key to the types of gene action available for the improvement of various polygenic characters. Once the plant breeder ascertains the type of gene action, he should be able to determine an expidient and efficient breeding programme.

The present study is therefore designed to provide information on the variability present in three synthetic populations of pearl millet. The goals of population improvement are:

- to improve and release as a variety,
- to have a base population for lines extraction to produce hybrids.

The specific objectives are:

i. To estimate the amount of genetic and non-genetic components of variability for morphological and yield related characters in populations of pearl millet;

ii. To estimate the heritability and progress to be expected from selection for the traits;

iii. To estimate the phenotypic and genotypic correlations among the traits.

iv. To suggest the selection procedure to be adopted for the improvement of the millet populations.

CHAPTER 2

2.0 REVIEW OF LITERATURE

2.10 Estimates of Phenotypic and Genotypic Variances

Considerable amount of variation in different characters have been observed in pearl millet by different workers. Nwasike (1988) observed variations in the spike, some being very long, stout and very loose. Grain filling on these spike was however very sparce and the grain size were very large. In term of head shape, Nwasike found cylindrical shape common among Nigerian millets, although some conical or spindle-shaped heads were identified on farmers' field.

Using discriminant function analysis in pearl millet inbred populations, Mahadevappa and Ponnaiya (1967) observed moderate coefficients of variability in diameter of peduncle, density of grain, yield of primary ear and yield of straw, whereas the value was high for grain yield. Among these inbreds, mean values for plant height ranged from 118.2 to 182 cm, 40.3 - 60.8 days for days to heading, 5.9-11 for number of internodes, 21.6-32.5 cm for length of peduncle, 0.25-0.53cm for diameter of peduncle, 5.1 - 12.3gm for yield of primary ear and 5.25-9.26 gm for 1000 grain weight. In a variability study of six characters in six varieties of pearl millet, fodder yield, followed by grain yield showed the highest genotypic coefficient of variation (Sangha and Singh, 1973). From a two-year evaluation of millet hybrids, Diz and Schank (1995) observed phenotypic variation to be large in both years of testing for number of tillers, plant height, leaf length

and width, days to flowering, peduncle length, seed-set, seed yield per panicle, seed yield per plant and 100-seed weight. The amount of variation observed in these characters was generally larger in the first year than the second year except for number of tillers, plant height and panicle length. In a pearl millet population resulting from a line x tester cross, variability for yield, 500 grain weight and number of days to first ear emergence was higher in the male-sterile lines than in the pollinated (Tyagi et al., 1981). Sodani et al. (1981) evaluated twelve varieties of pearl millet for growth period, height , grain yield and four yield components. The varieties differed significantly for all the characters except number of tillers per plant, ear girth and 100-grain weight.

In a path analysis in proso millet, phenotypic coefficient of variability was generally slightly higher than the genotypic coefficient. In the same study, the coefficient of variation, both genotypic and phenotypic, was high for number of tillers per plant, number of leaves per plant and grain yield (Saxena et. al., 1979). A wide range of variation was displayed by 14 varieties of finger millets for plant height (57.9-97cm), leaf number (7.4-15.6), peduncle length (1.8-30.6cm), panicle length (8-12.3cm), finger number (4.8-32) and yield (3.5-19.1). In these materials, the genotypic coefficient of variation for all the characters varied from 7.68 for stalk diameter to 117.25 for grain yield. Plant height,panicle length, panicle weight and grain yield showed high genotypic coefficient of variation (91.87, 48.58, 49.53, and 177.25, respectively), while panicle width and stalk diameter showed very low value (10.29 and 7.69, respectively)(Rao and Pardhasathi, 1968). An evaluation

study for variability in some lines and varieties of finger millets indicated that grain yield had the maximum phenotypic variation (27.46%). For the other traits, the values were 16.00% (grain density), 16.31% (number of productive tillers), 13.91% (number of fingers per ear), 12.36% (plant height), 10.60% (length of fingers), 10.06% (1000-grain weight) and 3,65 (heading date). The highest genotypic variation in 54 lines of finger millet was indicated for yield (15.30%) followed by plant height (10.19%), 1000-grain weight (8.94%), grain density (7.15%) and heading date (3.22%) (Patnaik, 1968). In another 20 diverse genotypes of finger millet evaluated for genetic variability, phenotypic and genotypic coefficients of variation were high for effective tillers per plant, grain yield per plant, 1000-grain weight and fingers per ear (Abraham et al., 1989).

Sixty four fox tail millet varieties were involved in an interrelationships study carried out by Sandhu et. al. (1974). They recorded significant differences among the varieties for days to 50% flowering and maturity, plant height, primary and secondary tillers, ear length, circumference of ear and 1000-seed weight. Range of variation were 47-68 for days to flowering, 78.5-97.7 for days to maturity, 52.0 - 147.2 cm for plant height, 6.7 - 31.0cm for ear length of the main ear, 2.0 - 8.7cm for circumference of the main ear and 1.87 - 3.12 gm for 1000-seed weight. The genotypic coefficient of variation for the traits ranged from 6.55% for days to maturity to 69.21% for secondary tillers.

2.12 Genotype-Environment Interaction and other variance Components

Three populations of pearl millet (Ex-Bornu, Nigerian composite and world composite) were subjected to recurrent selections. Genotypic differences were found to be highly significant. In four out of seven cases, the interaction with locations were also highly significant. In all the methods of selection practised in these populations, the genotypic variance component was greater than the interaction component (Khadr, 1977).

Six sub-populations developed from two synthetic populations (PSB3 and PSB8) of *Pennisetum americanum* were evaluated by Manake et al. (1987). From their results, the highest genetic variances were obtained for plant height, number of tillers per plant, ear length and yield per plant in S_1 families and reciprocal half-sib progenies. Zaveri et al. (1989) studied response to selection methods in two *P. americanum* populations and found the genotypic component of variance among S_1 families and S_1 x locality interactions to be significant. In pearl millet hybrids, family differences were not significant for leaf length and seed-related traits (except 100-seed weight) among families in one of the two years evaluations were conducted (Diz and Schank, 1995). In selection work involving 14 finger millet varieties, plant height, leaf number, tiller number, width of panicle and grain yield showed greater phenotypic variances than the genotypic variance (Rao and Pardhasarathi, 1968).

2.2 Heritability and Genetic Advance

In a series of crosses involving inbred lines of pearl millet, narrow sense

heritability estimates varied from 0.07 to 0.89 for plant height, 0.52 to 0.93 for maturity date, 0.20 to 0.67 for number of leaves per stem and 0.14 to 0.64 for leaf width. In one cross only, heritability estimates for plant yield, reproductive tillers, stem diameter and head length were -0.56, 0.38, 0.52 and 0.98, respectively (Burton, 1951).

Fourty nine uniform inbreds (S_{13}) of pearl millet were investigated by Mahadevappa and Ponnaiya (1967) and they reported high heritability in diameter of peduncle, and moderate values in respect of surface area of primary ear, yield of primary ear, plant height, yield of straw and yield of grain. Working with seven generations of a pearl millet cross involving inbred lines, Phul and Athwal (1969) indicated the superdominance of large size and hardness of grain. They also found that whereas heritability in the broad sense was high for both grain size (78.60%) and grain hardness (82.22%) narrow sense heritability estimates were much lower (19.39% and 37.47%, respectively). In 204 lines of pearl millet which were of Indian, African and American origin, heritability estimates were high for grain yield, grain size and 50% ear emergence, and moderately high for grain density and plant height. Heritability estimates were highest in the African lines because of wide range of genetic diversity in that region (Gupta and Dhillon, 1974). In another 200 breeding lines including both varieties and inbreds of pearl millet of India and exotic origin, Gupta and Sidhu (1972) obtained low broadsense heritability for grain density and hardness and tiller number, but higher values for grain yield, plant height and days to 50% ear emergence. In three populations of

pearl millet (Ex-Bornu, Nigerian composite and World composite) subjected to recurrent selection, heritability estimates were in general high, ranging from 53 percent for S_1 selection in world composite to 79 percent for S_5 and half-sib selection in the Nigerian collection (Khadr, 1977). In the same materials, expected gains from selection ranged from 18% to 32% of their respective population means for the top crosses and the S_5 selection in the Nigerian collections, respectively. High heritability estimated were obtained in panicum millets for tillers per plant, panicle length, test weight and grain yield (Saxena et. al., 1979). Low heritability was estimated in panicum hybrids for grain weight per panicle and weight of the unthreshed panicle (0.15 - 0.30)(Resh, 1979). In four generations (F_1, F_2, BC_1 and BC_2) of three crosses involving diverse *Pennisetum americanum* inbreds, Chaudhary et al. (1980) reported heritability estimates of more than 60% for plant height in all the crosses, for number of days to flowering and grain yield in H48 x H403, for 1000 grain weight in H48 x H91 and for number of days to maturity in H48 x H91 and H48 x H403. High heritability was also estimated for ear length (89.97%) and number of days to flowering in 12 varieties of pearl millet (Sodani et al., 1981). S_4 lines of a pearl millet land races depicted high broad sense heritability estimates in days to ear emergence, days to maturity, ear length, ear circumference, protein content and yield per plant (Reddy and Sharma, 1982). In a diallel analysis involving seven diverse pearl millet lines, their progeny and two standards, moderare narrow sense heritability was estimated for days to flowering, ear length and fat content, (Sachdeva, 1981). In S_1 progenies derived from three composites of pearl millet, heritability estimates on a single plant basis were

highest for panicle length (0.64), plant height (0.58) and seed weight (0.52); intermediate for straw yield (0.40) and lowest for grain yield (0.29), threshing ratio (0.24) and harvest index (0.23) averaged across composites (Rattunde et al., 1989). Also on progeny lines under two different spacings (60cm and 30cm between rows), Gupta et al. (1988) evaluated S_3 and S_4 lines of pearl millet and obtained broad sense heritability that was high for days to 50% flowering, plant height and ear length (both spacings) and moderate for grain yield per plant in S_4 progenies under 60cm spacing. In the same study, expected genetic advance as percentage of mean was high for 100-grain weight in the S_3 (30cm spacing) and was moderate for grain yield per plant in S_4 (60cm spacing). An evaluation of seven S_1 families of pearl millet was carried out in a factorial experiment by Diz and Schank (1995). They obtained heretability estimates (combined over the two years of study) which varied from very low (0.04) to moderate (0.24) for the eleven traits evaluated. In thier first year of testing, the highest heritability estimates were obtained for seed weight (0.30), seed per panicle (0.29) and days to flowering (0.23). The estimated values were much lower in the second year. The highest expected response to selection, after one cycle was recorded in the first year for seed set (28.2%), seed yield per panicle (42.6%), seed per panicle (36.6%), seed yield per plant (28.0%) and 100-seed weight (16.9%). High heritability estimates were obtained in 14 varieties of finger millet for panicle weight (93.39), plant height (87.84), peduncle length (85.69), finger number (67.33) and grain yield (52.83), whereas panicle width and tiller number showed much lower values (24.26 and 30.14, respectively). In these same materials, the expected genetic advance was

high for panicle length (52.67%), grain yield (40.85%), panicle weight (38.40%), moderate for tiller number (23.14%), plant height (20.33%) finger number per ear (18.05), and least for panicle width (5.32%) (Rao and Pardhasarathi, 1968). High broad sense heritability estimates were obtained in 54 lines and two varieties of finger millet for heading date (78%) 1000-grain weight (78.9%) and plant height (68.4%). Estimated values were moderate for length of fingers (42.6%) and grain yield per plant (31.0%). For number of fingers per head, number of productive tillers and grain density (number of grains per unit length (cm) of finger), the heritability estimates varied between 15 - 20% (Patnaik, 1968). In 480 indigenous types of finger millet, heritability estimates ranged from 66.1% for number of fingers per ear to 99% for number of days to maturity. The predicted genetic advance for these materials at 5% selection intensity was moderate (less than 30%) for number of days to heading and to maturity, plant height, number of fingers per ear and finger length, and very high (greater than 48%) for number of effective tillers and yield (Mishra et al., 1980). Grain yield and number of ears per plant indicated high heritability estimates in 23 accessions of finger millet investigated by Verma (1989). In 20 diverse genotypes of finger millet were obtained high broad sense heritability for days to maturity (99.5%), days to 50% flowering (97.7%), fingers per ear (83.3%) and 1000-grain weight (98.1%). Genetic advance in these genotypes was high for grain yield per plant (56.3%), 1000-grain weight (39.77%) and fingers per ear (33.9%) (Abraham et. al., 1989).

A study of 64 foxtail millet varieties indicated high broad sense heritability estimates for days to 50% flowering, days to maturity, plant height, primary and secondary tillers, ear length, circumference of ear, 1000-seed weight and grain yield; with heritability estimates varying variously between 65.58% for primary tillers to 93.23% for days to maturity. For the same study, the expected genetic advance at 5% selection, was highest for number of secondary tillers per plant (134.92%), followed by grain yield per plant (84.74%) length of the main ear (50.41%) and circumference of the main ear (53.96%). For the other traits studied, the expected genetic advance varied from 13.01 - 47.25% (Sandhu et al., 1974).

In 19 strains of foxtail millet, high heritability estimates were obtained for days to heading and maturity, grain weight, plant height and tiller number, while values were low for ear length, ear girth and grain yield. For these materials, high genetic gains were expected in tiller number, grain yield, 1000-grain weight, days to heading and plant height (Cill and Randhawa, 1975).

2.3 Character Interrelationships

In populations of several pearl millet selections and their F_1 and F_2 hybrids, Burton (1951) indicated in one of the crosses highly significant positive genotypic correlations of yield with stem diameter (0.19), stem number (0.55), plant height (0.31) and leaf width (0.24). In the same cross, highly significant positive correlations were observed between plant height and head length (0.31); plant

height and leaf width (0.31) and stem diameter and width (0.62). Across all the crosses but one, plant height was negatively correlated with heading date. Heading date and leaf number were positively correlated in all the crosses, with genotypic correlation coefficients varying from 0.26 to 0.89 among the crosses. For these crosses 50% heading date and internode length were negatively correlated. In 49 uniform inbreds of pearl millet, grain yield was positively and genotypically correlated with the length of peduncle (0.321), diameter of peduncle (0.269), density of grain (0.196), yield of primary ear (0.524), tillering capacity (0.589) and yield of straw (0.409). For these inbreds, days to heading, number of internodes, surface area of primary ear, plant height and 1000-grain weight did not show significant correlation with grain yield (Mahadevappa and Ponnaiya, 1967).

In seven generations of a pearl millet cross involving two inbred lines, grain size had significant positive phenotypic correlation with grain hardness (0.51). Grain hardness in turn had a significant negative correlation with protein content (-0.64). Grain size and protein content were negatively correlated though not significantly. For each of these three associations the genotypic correlation was higher than the corresponding phenotypic correlation (0.65, -0.81 and -0.17, respectively)(Phul and Athwal, 1969).

Estimates of phenotypic and genotypic correlations among plant height, yielding ability and four components of yield (spike length and girth, density and seed size) in a pearl millet population were reported by Shankar et al (1963). All

the four direct components of yield as well as plant height showed positive significant correlations with yield. A majority of other correlation coefficients were also highly significant. In six varieties of pearl millet, grain yield did not show simple correlation with any of its components, but the latter showed significant correlations with each other (Sangha and Singh, 1973).

In 204 lines of pearl millet which were of diverse origins, the estimated genotypic correlation coefficients were generally higher than phenotypic correlation coefficients. Yield of these lines was positively correlated with grain density, grain size, plant height and tiller number, but negatively correlated with 50% earing. Grain density and grain size were most strongly correlated (Gupta and Dhillon, 1974). In another study by Sachdeva (1981), grain yield was positively correlated with ear dry weight, fodder weight and ear length in seven diverse lines of pearl millet subjected to a diallel analysis. 51 pearl millet inbreds evaluated by Mukherji et al. (1981) indicated positive correlation of yield with plant height, ear length, ear girth and 1000-grain weight. From this evaluation number of days to 50% flowering contributed indirectly to yield through a positive association with ear length. Among S_4 lines of a land race was observed positive correlations of yield per plant and yield per plot with plant height, tillers per plant, ears per plant and ear length (Reddy and Sharma, 1982). In an evaluation study involving quantitative characters in pearl millet was reported significant and positive correlation coefficients between yield and six characters; correlation coefficient being highest with number of nodal tillers (0.79), panicle numbers per plant (0.78) and internode

number (0.54) (Kamala et al., 1986). In another study involving an unspecified number of pearl millet genotypes grown under different water levels, yield was positively and significantly correlated, with grain number per head, grain size and number of leaves on the main stem (Ibrahim, et al., 1986). In an investigation involving six varieties of pearl millet, grain yield and plant height indicated a positive phenotypic correlation. High phenotypic correlation estimates were also observed between yield and days to 50% heading and dry head weight per plant (0.473 and 0.819 respectively). This study also showed that the genotypic correlation between number of plants at harvest and days to 50% heading was negative, though not significant. Number of plants at harvest was however positively correlated with plant height (0.072 and 0.373 respectively) (Nwasike et al., 1982). Among 44 varieties of pearl millet, fodder yield was positively correlated with plant height, stem thickness, internode number, leaf width and days to flowering. Yield components were highly correlated among themselves. Internode number was found to have the maximum effect on yield in these varieties (Mangath, 1986). In dwarf composite versions of seven morphologically diverse tall pearl millets, plant height was positively correlated with the yield in the dwarf, but not in the tall composite (Rai, 1990). Twenty six *P. americanum*, populations which were subdivided into large (L), medium (M) and small (S) seed size groups were evaluated by Mangat and Satija (1991). Head yield was positively correlated with grain yield, with higher correlation coefficient in the M and S seed size groups. Tiller number showed the highest correlation with grain yield in the L and M groups. In a factorial experiment involving seven S_1 families of

pearl millet, Diz and Schank (1995) obtained genotypic and phenotypic correlation coefficients which in some cases differed in magnitude and in sign; in others, the two had the same sign and were not very different in magnitude. They reported that number of tillers was negatively associated genotypically with plant height and leaf characters, but positively associated phenotypically with plant height and leaf length. Their results also showed that, days to flowering was negatively associated with all other traits. Panicle length, seed set, seed yield panicle, seed yield per plant and 100 seed weight were highly correlated among themselves genotypically and phenotypically, with genotypic correlation coefficients ranging between 1.02 for correlation between panicle length and seed weight to 0.38 for correlation between panicle length and 100 seed weight. Plant height and leaf length were also consistently correlated with panicle length, seed set, seed yield panicle and seed yield per plant.

In 14 varieties of finger millets, which differed widely for many characters, were reported genotypic correlation coefficients which were generally higher than phenotypic and environmental coefficients. Genotypically and phenotypically grain yield was positiviely and significantly related to leaf number, number of tillers and number of fingers, the genotypic correlation coefficients being 0.876, 0.674 and 0.624, respectively. Plant height indicated significant and positive phenotypic and genotyic correlation with the length of panicle (0.403 and 0.388 for phenotypic and genotypic coefficients, respectively). Leaf number was also positively and genotypically correlated with finger number (0.460), which in turn was negatively

correlated with length of panicle both genotypically and phenotypically (Rao and Pardharadhi, 1968). In an evaluation involving 54 promising early flowering lines and two varieties of finger millet, grain yield was positively and significantly associated with the number of fingers (0.443) and finger length (0.416). Also in these materials, plant height was significantly but negatively correlated with number of tillers (-0.419) and density (number of grains per unit length (cm) of finger) of grain (-0.277). Grain density was also negatively and significantly correlated with length of fingers (Patnaik, 1968). In another ten varieties of finger millet grain yield was significantly and positively correlated with length of the main inflorescence, number of spikes per inflorescence and grain weight from the main inflorescence. Path coefficient analysis of these varieties indicated that grain weight from the main inflorescence was the only character with a high positive direct effect on yield. Other charcaters contributed indirectly through grain weight from the main inflorescence (Agalodia et al., 1979). An investigation involving 20 diverse genotypes of finger millets indicated that grain yield was significantly and positively correlated with days to 50% flowering, days to maturity, effective tillers per plant and 1000-grain weight (Abraham et. al., 1989). A study of interrelationships between yield and yield components in 64 varieties of foxtail millet, which were collected from different geographic regions, indicated that grain yield had positive and significant correlations with primary tillers (0.34), plant height (0.40) and length of ear (0.33). Primary tillers were negatively correlated with length of main ear (-0.28) and ear circumference (-0.40) phenotypically, and environmentally with plant height (-0.54). Secondary tillers also indicated negative

phenotypic associations with ear length (-0.041), circumference of ear (-0.55) and plant height (-0.31).

In an evaluation of 19 promising strains of foxtail millet, Cill and Randhawa (1975) reported that the yield had significant and positive association with tiller number and ear girth, but had a negative association with days to heading, maturity, plant height and ear length. Their results also showed heading date to have a positive and significant correlation with maturity, plant height, ear length, ear girth and 1000-grain weight. They also observed a negative association between plant height, ear characters and grain weight. In 19 varieties of foxtail millet were established positive genotypic correlations of grain yield per plant with number of ears per plant, ear length, 1000-grain weight and number of days to maturity (Godawat, 1980).

An evaluation of 14 strains of proso millet (*Panicum miliacum*), indicated positive genotypic correlations between yield and its components (Saxena et al., 1979). Grain weight per panicle was also indicated to be highly correlated with weight of unthreshed panicle, moderately correlated with 1000-grain weight and panicle length and weakly correlated with number of first order panicle branches (Resh, 1979).

CHAPTER 3

MATERIALS AND METHODS

The materials that make up the populations for this study were originally selections from the Nigerian millet germplasm collections made in 1984 by late Professor Nwasike and his co-workers. These collections were yield tested and the best germplasm materials were selected. The selected materials were evaluated for general combining ability (GCA). After the evaluation for GCA, they were selfed for three generations, after which selections were made again. The individual plant selections which were made based on desirable phenotypic expressions were bulked and constituted into synthetic populations. Three of such populations were chosen which are designated:

Population 1 - pedigree 332

population 2 - pedigree 351

population 3 - pedigree 370

Amongst these synthetic populations, top crosses had been made in all possible combination to produce the F_1S. Random single-head selections were made among the F_1S in each of the three populations to constitute the family lines. Over one hundred lines were selected initially from each population, but because of the incidence of fungal attack, germination failure and loss due to bird menace, especially at irrigated nurseries during the off-season, each of the three populations has been reduced to less than a hundred lines. There were left 72, 81 and 78 family lines for population 1, population 2 and population 3, respectively.

Each family line was selfed for four generations. Selfing started during the off-season at irrigated nurseries of the Institute for Agricultural Research (IAR) in 1989 to produce S_1s. The S_1s were advanced to S_2 and S_3 during the 1990 rainy season and off-season at irrigated nurseries respectively. The S_3s were advanced to S_4 during the 1991 rainy season. At S_5, the lines consisting of 72, 81 and 78 for populations, 1, 2 and 3, respectively were evaluated at the IAR farm, Samaru. In addition, population 3 was evaluated at Kano

The plots were single rows 8 meters long and 100cm apart. The plots were arranged in a simple 9x9 lattice design.To make a balanced 9 x 9 lattice design, dummies were used in populations 1 and 3. Hills which were spaced at 30cm apart were over planted and seedlings were thinned to two plants per hill. There were two replications at each location, each year. Six bags of NPK (20:10:10) fertilizer per hectare was applied (as recommended by Egharevba, 1983) in two splits. Hoe weeding was carried out two times. Data were collected on five randomly selected plants per plot. Data taken on each family line were on nine agronomic characters viz:-

- Plant height - length in centimetres from the base of the culm to the tip of the spike of the tallest culm at maturity.
- Number of nodes per plant of the tallest culm.
- Number of days to ear emergence - number of days from sowing to the day when spikes on half the tillers were fully exerted from the flag leaf sheath.
- Days to 50% flowering - number of days from sowing to the date when 50%

of the spikes have flowered in a plot.

- The length of ear/spike on the main tiller measured in centimeters from the base of ear setting to the tip.
- The ear girth on the main tiller measured in millimetre at the widest point using a pair of compass (of a mathematical set).
- Ear density/threshing percentage - measured as a ratio of grain weight (gm) to the total weight of the ear.
- Grain weight (gm) per plant

Statistical Analyses

The general statistical procedure that was followed for analysing the variability of the materials used in the study is that of Shivaji and Gritton (1975). The linear statistical model used for analysis in each location, each year was:

$X_{ij} = \mu + G_i + R_j + E_{ij}$

where,

X_i = observation of the i^{th} line in I^{th} replication

μ = the population mean

G_i = genotypic effect of the i^{th} line

E_{ij} = Random experimental error

The statistical model used for the combined analysis, two years and two locations was;

$$X_{ijkr} = \mu + G_i + L_j + Y_k + (LY)_{jk} + (GL)_{ij} + (GY)_{ik} + (GLY)_{ijk} + R_l + E_{ijkl}$$

where;

i = 1, 2, ..., 78 (lines)

j = 1, 2 (locations)

k = 1,2 (years)

r = 1,2 (replications)

X_{ijkr} = the observation of the i^{th} line in r^{th} replication, j^{th} location and k^{th} year

μ = the population mean

G_i = the genotypic effect for the i^{th} line

L_j = the effect of the j^{th} location

Y_k = the effect of the k^{th} year

$(LY)_{jk}$ = the interaction effect of j^{th} location and k^{th} year

$(GL)_{ij}$ = the interaction effect of i^{th} line and j^{th} location

$(GY)_{ik}$ = the interaction effect of i^{th} line and k^{th} year

$(GLY)_{ijk}$ = the interaction effect of i^{th} line in j^{th} location and k^{th} year.

R_l = the effect of l^{th} replication

E_{ijkl} = random experimental error.

For all the statistical models used, a random sample of lines and years was assumed. Individual plant values were used in computing all mean squares. The form of the analysis of variance (ANOVA) for one year and one location is presented in Table 1.

Table 1: Form of analysis of variance for one year in one location

Source of variance	df	MS	Expected mean square (EMS)
Replication	r-1	M_2	-
Line	g-1	M_1	$\delta_e^2 + r\delta^2_g$
Error	(r-1)(g-1)		δ_e^2

where r and g is the number of replication and lines, respectively and δ_e^2 and δ^2_g are the error and genotypic variances, respectively.

Table two shows the forms of analyss of variance (ANOVA) and covariance (ANCOVA) for the combined years over one location.

Table 2: Form of ANOVA and ANCOVA with the expected mean square and cross products for two years over one location.

Source of variance	df	MS	Expected mean square (EMS)	Expected mean cross products (EMCP)
Years	y-1			
Replication in years	y(r-1)			
Lines	(g-1)	m_3	$\delta_e^2 + r\delta^2_{gy} + ry\delta^2_g$	$Cov_e + rCov_{gy} + ryCov_g$
Lines x years	(g-1)(y-1)	m_2	$\delta_e^2 + r\delta^2_{gy}$	$Cov_e + rCov_{gy}$
Error	y(r-1)(g-1)	m_1	δ_e^2	Cov_e

G, y and r refer to number of lines, years and replications, respectively. Subscripts e, g and gy on variance and covariance components refer to error, genotypic and genotype x year effects, respectively.

The ANOVA for two years and two locations with the expected mean squares and their mean cross products are presented in Table 3.

Table 3: Form of ANOVA and ANCOVA with EMS and EMCP for two years and two locations

Source of variance	df	Ms	Expected mean square (EMS)	Expected mean cross product
Years	y-1			
Locations	l-1			
Replication *in* years and location				
Genotypes	y(r-l)			
	g-1	M_6	$\delta_e^2 + r\delta^2_{gly} + ry\delta^2_{gl} + rl\delta^2_{gy} + rly\delta^2_g$	$Cov_e + rCov_{gly} + ryCov_{gl} + rlCov_{gy} + rlyCov_g$
Years x locations			$\delta_e^2 + r\delta^2_{gly} + ry\delta^2_{gy}$	$Cov_e + rCov_{gly} + ryCov_{gl}$
Genotypes x years	(y-1)(l-1)	M_4	$\delta_e^2 + r\delta^2_{gly} + rl\delta^2_{gy}$	$Cov_e + rCov_{gly} + rlCov_{gy}$
Genotypes x years x locations	(g-1)(y-1)	M_3		
Error			$\delta_e^2 + r\delta^2_{gly}$	
	(g-1)(y-1)(l-1)	M_2	δ_e^2	$Cov_e + rCov_{gly}$
	r(g-1)(y-1)(l-1)	M_1		Cov_e

where;

δ^2_g = Variance component due to genetic difference among lines.

δ^2_{gl} = Variance component arising from interaction of lines and locations.

δ^2_{gy} = Variance component arising from interaction of lines and years.

δ^2_{gly} = Variance component arising from interaction of lines, locations and years.

δ^2_e = Variance component arising from a composite of remaining effects including plot effects, error due to sampling within plots and error of measurements.

r = number of replications.

l = number of locations.

y = number of years.

g = number of lines.

Estimation of Variance Components

The combined analysis of variance computed over locations and two years were used to estimate pertinent variance components by equating the observed mean squares to their expectations. Thus, the genotypic variance was calculated using the formular:

$$\sigma^2_g = \frac{Ms_g - Ms_e}{r}$$

where, σ^2_g = genotypic variance

Ms_g = mean square estimate for lines

Ms_e = mean square estimate for error

r = replication

Phenotypic variance for populations one and two, which were evaluated for two years in one location only was estimated thus:

$$\delta^2_{ph} = \delta^2_g + \frac{\delta^2_{gy}}{y} + \frac{\delta^2_e}{ry}$$

The phenotypic variance for population three which was evaluated for two years and two locations, was estimated as:

$$\delta^2_{ph} = \delta^2_g + \frac{\delta^2_{gl}}{l} + \frac{\delta^2_{gy}}{y} + \frac{\delta^2_{gly}}{ly} + \frac{\delta^2_e}{rly}$$

COEFFICIENT OF VARIATION

The component of variance, namely, genotypic (δ^2g) and phenotypic

(δ^2_{ph})variance, were used to estimate the genotypic and phenotypic coefficient of variation as suggested by (Burton, 1951). Thus, the genotypic coefficient of variation (GCV) was estimated by the formula:

$$GCV = \frac{\sqrt{\delta^2_g} \times 100}{\bar{x}}$$

where

GCV = Genotypic coefficient of variation

σ^2_g = genotypic variance of the trait

$\bar{x}$ = mean value of the trait

Phenotypic coefficient of variation (PCV) was estimated as:

$$PCV = \frac{\sqrt{\delta^2_{ph}} \times 100}{\bar{x}}$$

where

PCV = Phenotypic coefficient of variation

σ^2_{ph} = phenotypic variance of the trait

$\bar{x}$ = mean value of the trait

CORRELATIONS

The estimates of genotypic, phenotypic and environmental correlations were estimated for all pairs of characters measured. Correlation coefficients were calculated from components of variance and covariance according to Shivaji and Gritton (1975). The genotypic components were computed by equating the

genotypic variances and covariances to their expected mean squares and cross products, and from these the genotypic correlations were estimated using the formula:

$$rg = \frac{Cov_{g\,1.2}}{\sqrt{(\delta^2_{g\,1})\,(\delta^2_{g\,2})}}$$

where

rg = genotypic correlation coefficient

$cov_{g\,1.2}$= the estimate of genotypic covariance for traits 1 and 2

δ^2_{g1} = estimate of the genotypic variance of trait 1

δ^2_{g2} = estimate of the genotypic variance of trait 2

Phenotypic correlations were calculated using the following equation:

$$rp = \frac{Cov_{ph\,1.2}}{\sqrt{(\delta^2_{ph\,1})\,(\delta^2_{ph\,2})}}$$

where

rp = phenotypic correlation coefficient

$cov_{ph\,1.2}$ = estimate of the phenotypic covariance for traits 1 and 2.

δ^2_{ph1} = estimate of the phenotypic variance for trait 1

δ^2_{ph2} = estimate of the phenotypic variance for trait 2

Environmental correlations were estimated thus:

$$re = \frac{Cov_{e\,1.2}}{\sqrt{(\delta^2_{e\,1})\,(\delta^2_{e\,2})}}$$

where

re = Environmental correlation coefficient

$Cov_{e1.2}$ = the estimate of environmental covariance for traits 1 and 2

σ^2_{e1} = estimate of the environmental variance for trait 1

σ^2_{e2} = estimate of the environmental variance for trait 2

HERITABILITY

Heritability estimate (broad sense) was estimated after Eckebil *et al.* (1977) using the formula:

$$h^2 = \frac{\delta^2_g}{\delta^2_{ph}}$$

where

h^2 = broad sense heritability

δ^2_g = the genotypic variance.

δ^2_{ph} = the phenotypic variance

GENETIC ADVANCE

Estimate of the appropriate variance components were substituted for the parameter in the following formula to predict genetic advance from selection among lines (Liang et al., 1968):

$$GS = \frac{\delta^2_g}{\delta^2_{ph}} \times K\delta_{ph} = \frac{\delta^2_g}{\delta_{ph}} \times K$$

where

GS = Genetic advance

δ^2_{ph} is the phenotypic variance among the means of lines compared in r replicates, l locations and y years.

$k\delta_{ph}$ is the selection differential expressed in phenotypic standard deviations. For this study, k = 1.75, which is the expectation in the case of 10% selection in large samples (Falconer, 1989).

CHAPTER 4

4.0 RESULTS

4.1 Mean Performance

The mean performance of population 1 for the nine agronomic traits, for the two separate years, the range, the phenotypic and genotypic coefficients of variation are presented in Appendix 1. Mean performance for the two years were similar for some traits, and in some other different. For many of the traits, the mean values were higher in the second than the first year. Each trait portrayed a wide range, especially the ear characters. As a trend, the phenotypic coefficients of variation were higher than the genotyic coefficient of variation for both years. Mean values were higher in the second year for plant height, ear length, ear weight, grain yield, threshing percentage and days to 50% heading in population 2 (Appendix 2 . The same were true for population three (Appendix 3). Highest phenotypic coefficient of variation, and the corresponding genotypic coefficient of variation was observed for grain yield in the three populations. The mean values across years and location and the range are presented in Table 4. The tallest plants were recorded among population 3; similarly the widest range for height was found within this population. Mean values for height in population 2 and population 1 were very close (156.52cm and 152.75cm, respectively) and their spread was similar too.

The range for the number of nodes per plant was 4-9, 3-9 and 3-11 in population 2, 1 and 3, respectively. Thus, higher number of nodes were observed among the population with taller plants (population 3). For population 3 the mean ear length was 37.04cm, closely followed by 35.25cm of population 1. The widest range of ear length was also associated with population 3, the least range being among population 1. The fattest ears, expressed as ear girth, were found among population 1; mean ear girth value being 25.05mm, but the greatest range for ear girth was associated with population 3. Mean ear weight was highest in population 3 (53.49 gm), similarly, the widest range of ear weights was recorded among this population. Mean value of population 1 closely followed that of population 3, but the upper range is much smaller than what was recorded for population 3 (112.32gm and 186.80gm for populations 2 and 3 respectively). The mean grain yield per ear followed a similar trend as expressed for ear weight; highest mean being recorded for population 3 (30.93gm) followed closely by population 1 (30.06gm). The range was also widest in population 3, but the highest upper limit was recorded for population 1 rather than population 3. Panicle or ear types in terms of their compactness appeared similar in the three populations because of the closeness of their values for threshing percentages; the mean values being 56.43, 55.52 and 54.71 for population 3, 1 and 2 respectively. The number of days to 50% heading was longest in population 1 (50.22 days). Even though heading and flowering were initiated earliest in population 3 (after 37 and 45 days, from sowing, respectively), the period for 50% heading and blooming was longest in the same, and also the range was widest, being 45-82 days from sowing for

50% blooming. The shortest mean days to 50% blooming (51.84 days) was recorded for population 2, but the blooming period had a wider spread over time (49-65 days) than population 1 (46-59 days).

The phenotypic coefficient of variations (PCV) were generally low. Among the three populations, and for each character studied, the differences were small (Table 4). The highest PCV was recorded for grain yield per ear, and of the three populations, population 2 had the highest value. Next in magnitude was the PVC estimates for ear weight. Again, population 2 had the highest value (13.867) and closely followed by population 2 (11.643), while population 3 had a value of 10.274. For plant height, number of nodes, ear length and girth and threshing percentage, the PCV values ranged from 2.410 to 9.000. Days to 50 percent heading and days to 50 percent blooming all had values slightly above one except for days to 50 percent blooming in population 1 where value is less than one (0.684).

The genotypic coefficient of variation (GCV) followed a trend similar to that of PCV. The highest values were recorded for grain yield. Next highest value was ear weight, with population 2 having the highest value among the three populations. For the remaining characters, the GCV values ranged variously from less than one to 6.772.

Table 4: Mean, Range, phenotypic and genotypic coefficients of variation across two years in three populations of pearl millet

Trait	Population	Mean	Range	Phenotypic coeff. of var. (PCV)	Genotypic coeff. variation (GCV)
Plant height (cm)	P370	181.26±1.539	80-280	4.217	3.480
	P351	156.52±2.849	80-245	5.865	3.940
	P332	152.75±2.625	92-230	4.360	3.157
Number of nodes per plant	P370	6.34±0.064	3-11	3.303	2.543
	P351	6.12±0.112	4-9	4.985	3.057
	P332	6.15±0.117	3-9	4.58	3.309
Ear length (cm)	P370	37.04±0.581	12-101	7.258	5.947
	P351	33.95±0.922	13-80	7.608	4.621
	P332	35.28±0.880	14-59	7.082	4.739
Ear girth (mm)	P370	24.50±0.290	12-40	5.218	4.312
	P351	23.08±0.732	12-37	9.000	6.772
	P332	25.05±0.533	14-36	5.173	2.818
Ear weight (gm)	P370	53.49±1.281	11.02-186.80	10.274	8.721
	P351	47.59±2.128	12.48-115.29	13.867	10.688
	P332	52.27±1.812	16.10-112.32	11.643	8.329
Grain yield per ear (gm)	P370	30.93±0.779	4.97-85.86	10.528	8.155
	P351	26.54±1.405	7.19-72.00	16.513	12.590
	P332	30.06±1.428	7.66-92.05	13.943	9.929
Grain yield per hectare (extrapolated) `000kg	P370	4.639±0.779	4.124-5.155	10.528	8.155
	P351	3.980±1.405	3.539-4.423	16.513	12.590
	P332	4.509±1.428	4.008-5.010	13.943	12.570
					9.929
Threshing percentage	P370	56.43±0.235	46.52-68.60	2.615	2.350
	P351	54.71±0.461	48.15-64.64	2.410	1.797
	P332	55.52±0.431	48.15-64.56	2.410	1.219
Days to 50% heading	P370	47.70±0.635	36-67	1.147	0.942
	P351	48.21±0.798	41-62	1.305	1.162
	P332	50.22±0.818	46-58	1.363	1.072
Days to 50% blooming	P370	55.51±0.521	45-82	1.315	0.926
	P351	51.84±0.958	46-65	1.187	1.093
	P332	54.23±0.706	46-65	0.684	0.639

4.2 Estimates of Variance Components

The estimates of phenotypic, genotypic and environmental variances for the nine traits for each of the separate years are presented in Appendices 4, 5 and 6 for populations 1, 2 and 3 respectively. Generally, the highest estimates of variance components were observed for plant height. Ear weight, grain yield and ear length, in that order, followed plant height in magnitude of the estimates of the variance components. The least estimates were observed for the number of nodes per plant. The estimated variance components for the other traits were very low. Environmental variance was the largest component for each of the nine traits, followed by the phenotypic variance. The genotypic variance was negative for days to 50% heading in the second year and days to 50% blooming in the second year of evaluation for population 1 (Appendix 4). Negative genotypic variances was similarly observed in population 3 for days to 50% heading in the second year (Appendix 6).

The variance component estimates for the two years combined and across locations for the three population, is presented in Table 5.

The phenotypic variance for each trait across the populations was much larger than the genotypic variance which was generally low. The highest genotypic variance was obtained for plant height in the three populations, the values varying between 10.385 to 4.741. Next in order of magnitude was the

genotypic variance for ear weight. The genotypic variance for each of the traits nodes per plant, threshing percentage, days to 50% heading, days to 50% blooming and ear girth, in the three populations was less than unity. For the latter trait, the genotypic variance assumed a negative value in population 1.

As obtained in the genotypic variance for height, the highest genotype x year interaction was obtained in plant height in populations 3 and 2 (2.300, 57.087 respectively) Genotype x year value was 19.407 and 18.116 in population 2 and 1 respectively, for ear weight, but the same interaction variance estimate was negative in population 3 (-5.233). Other traits in population 3 with negative values for the genotype x year interaction component were ear length, ear girth, ear weight and grain yield per ear. For population 2, negative genotype x year interaction variance component was obtained for 50% heading and blooming, while in population 1 it was obtained for threshing percentage, 50% heading and blooming dates.

Genotype x location and genotype x year x location components were applicable only in population P370 which was evaluated over two locations. Genotype x location interaction variance was negative for plant height, nodes per plant and ear length, and estimates were less than unity in all other traits except grain yield per ear where it was also insignificant. The second order interaction variance (genotype x year x location) was largest in plant height followed by ear weight and grain yield in that order (68.289, 30.558 and 13.335, respectively).

This interaction variance was negative for days to 50% heading and less than unity for nodes per plant, ear girth, threshing percentage and days to 50% blooming. The error components were by far the largest of the variance components across the three populations, and for all the traits.

Table 5: Estimate of Variance components across two years and two locations for nine characters in three populations of pearl millet

Plant character	Components of variance						
	Plant population	Phenotype	Genotype (G)	Genotype x year (GY)	Genotype x location (GL)	Genotype x year x location	Error
Plant height	P370	58.420±17.739	6.802±1.539	2.300±3.077	-6.263±3.151	66.289±6.303	387.365±15.076
	P351	84.276±19.640	4.741±4.029	57.087±5.698	-	-	425.022±13.955
	P332	44.288±20.839	10.385±3.713	4.912±5.251	-	-	446.523±12.861
Number of nodes per plant	P370	0.044±0.947	0.005±0.064	0.001±0.128	-0.004±0.132	0.031±0.263	0.933±0.629
	P351	0.093±0.841	0.004±0.112	0.054±0.224	-	-	0.746±0.549
	P332	0.093±0.825	0.0003±0.117	0.042±0.235	-	-	0.743±0.576
Ear length	P370	7.227±6.971	0.975±0.581	-1.551±1.161	-0.084±1.154	10.344±2.324	58.213±5.691
	P351	6.697±6.193	2.186±0.922	4.922±1.845	-	-	42.000±4.519
	P332	6.233±6.018	0.510±0.880	3.543±1.761	-	-	40.085±4.312
Ear girth	P370	1.635±3.595	0.150±0.059	-0.063±0.581	0.373±0.674	0.832±1.348	15.174±2.846
	P351	4.315±4.061	0.680±0.732	2.030±1.463	-	-	20.565±3.584
	P332	1.682±3.501	-0.053±0.533	1.210±1.065	-	-	13.869±2.609
ear weight	P370	30.204±16.139	4.723±1.306	-5.233±2.613	0.464±2.736	30.558±1.730	306.179±12.798
	P351	43.553±12.570	8.085±2.130	19.407±4.261	-	-	191.413±10.436
	P332	37.034±14.549	4.983±1.812	18.116±3.625	-	-	216.562±8.877
Grain yield per ear	P370	10.603±8.530	0.788±0.780	-1.716±1.559	1.593±1.635	13.335±3.270	92.985±7.636
	P351	19.206±8.488	3.262±1.405	9.281±2.810	-	-	85.926±6.883
	P332	17.567±9.913	2.373±1.428	8.326±2.857	-	-	107.877±6.996
Threshing %	P370	2.177±2.767	0.076±0.048	0.058±0.469	0.445±0.472	0.284±0.943	9.276±2.298
	P351	1.739±2.988	0.310±0.133	0.695±0.922	-	-	10.191±2.259
	P332	0.290±3.114	0.423±0.411	-1.225±0.862	-	-	16.043±2.110
Days to 50% heading	P370	0.299±3.597	0.049±0.367	0.056±0.734	0.031±0.752	-0.325±1.55	12.938±0.901
	P351	0.396±2.124	0.210±0.434	-0.213±0.867	-	-	4.511±0.521
	P332	0.469±2.312	0.167±0.512	-0.088±0.944	-	-	5.344±0.530
Days to 50% blooming	P370	0.533±3.117	0.056±0.342	0.068±0.570	0.004±0.573	0.057±1.120	19.839±2.052
	P351	0.379±1.997	0.205±0.472	-0.180±0.815	-	-	3.538±1.198
	P332	0.138±2.709	0.124±0.553	-0.257±1.106	-	-	7.337±1.149

4.3 Mean Squares

4.3.1 Population 1

In the first year of evaluation, genotypic mean squares were highly significant for plant height, number of nodes, ear length and grain yield. Mean squares estimates were however not significant for threshing percentage, days to 50% and flowering (Appendix 7). In the second year (Appendix 8), mean square estimates attributable to the genotype were highly significant for all the traits except nodes per plant and days to 50% blooming. The mean square estimates for the combined analysis of S_5 lines of 332 pearl millet population are shown in Table 6 and the relative contribution of different effects to total variation in respect of each character is presented in table 7. Of the all the characters evaluated, the genotypes x year interaction effects were only significant at 5% level of probability for ear weight. Genotypes effects were significant at 1% level of probability for ear weight and grain yield, and at 5% level of probability for threshing percentage and days to 50% heading. In all the characters studied in this population, the mean square due to error was the largest contribution to total variation, ranging from 41.98% in days to 50% heading to 74.64% in plant height.

Table 6: Mean square estimates from the combined analyses of nine characters in S_5 lines of P332 pearl millet population

Plant character	Source of variation				
	Replication	Year	Genotype	Genotype x year	Error
df	1	1	71	71	718
Plant height	3266.7*	10514.1*	725.245	475.992	446.523
No of nodes/plant	16.946**	63.918**	1.237	1.002	0.743
Ear length	127.96	153.77*	73.579	61.342	40.085
Ear girth	191.72**	810.84**	19.859	21.130	13.869
Ear weight	2899.7**	0.00	444.859**	325.259*	216.562
Grain yield per ear	2860.46**	255.61	214.794**	157.835	107.877
Threshing %	116.711**	6.477	18.856*	8.694	16.043
Days to 50% heading	36.125*	40.500**	8.821*	4.817	5.344
Days to 50% bloom	5.556	190.125**	8.766	5.794	7.337

* Significant at 5%
** Significant at 1%

Table 7: Percentage contribution of pertinent Variance Components to Total Variance (%) in P332 Population of Pearl Millet

Plant character	Source of variation				
	Replication	Year	Genotype	Genotype x year	Error
Plant height	0.94	2.72	12.57	9.12	74.64
No of nodes/plant	2.23	8.20	11.34	9.12	69.03
Ear length	0.32	0.35	20.57	9.39	69.18
Ear girth	1.38	5.69	9.75	10.25	68.24
Ear weight	1.45	0.00	15.38	7.65	74.34
Grain yield per ear	2.45	0.15	14.40	10.03	70.98
Threshing %	1.53	0.06	13.96	6.50	77.36
Days to 50% heading	2.00	2.24	34.64	18.92	41.98
Days to 50% bloom	0.24	8.35	27.33	18.07	45.76

4.32 **Population 2**

The mean squares for the separate two years for population 2 are presented in Appendices 9 and 10. In the first year, mean squares for genotype were highly significant for all the traits, except for days to 50% heading. The genotypic mean squares in the second year were similarly highly significant for plant height, ear length and ear weight. For both years, genotypic mean square were by far larger than the other mean squares.

Table 8 contains the combined analysis of mean squares estimates for two years for population 2. For each of the traits, mean square estimate for the year was highly significant except for number of nodes per plant that was insignificant. Genotypic mean squares were significant at 1% probability level for ear length,

ear weight, grain yield, days to 50% heading and blooming and significant at 5% probability level for plant height and threshing percentage. The mean square estimates for the genotype x year interaction was non significant for all the traits.

For all the traits, error had by far the largest percentage contribution to total variance, value varying from 34.80% for days to 50% blooming to 75.14% for nodes per plant (Table 9). Relative to the other sources of variation, the year and replication contributed far less proportion to the total variance (except in plant height).

Table 8: Mean squares estimates from the combined analyses of nine characters in S_5 lines of P351 pearl millet population

	Source of variation				
Plant character	Year	Replication	Genotype	Genotype x Year	Error
df	1	1	80	80	808
Plant height	70244.0**	592.7ns	881.311*	767.525ns	425.022
No of nodes/plant	0.926ns	12.448*	1.165ns	1.078ns	0.746
Ear length	1733.34**	6.92ns	124.004**	71.534ns	42.000
Ear girth	1028.81**	245.00*	49.078ns	32.746ns	20.565
Ear weight	8438.6**	2683.7**	501.89**	307.854ns	191.413
Grain yield per ear	4212.92**	1001.54**	219.907**	141.613ns	85.926
Threshing %	762.162**	154.777*	21.791*	14.359ns	10.191
Days to 50% heading	68.522**	0.694ns	8.280**	3.234ns	4.411
Days to 50% bloom	206.722**	14.222*	8.326**	2.772ns	3.987

* Significant at 5%

** Significant at 1%

Table 9: Percentage contribution of pertinent variance components to total variance (%) in P351 population of pearl millet

Plant character	Replication	Year	Genotype	Genotype x Year	Error
df	1	80	80	80	808
Plant height	0.1	12.81	12.74	11.47	62.47
No of nodes/plant	1.5	0.1	11.69	10.64	75.14
Ear length	0.02	3.36	19.11	10.88	66.53
Ear girth	0.81	4.2	15.88	10.12	69.64
Ear weight	1.16	3.69	17.07	10.7	66.82
Grain yield per ear	0.97	4.04	16.88	10.80	66.98
Threshing %	1.51	5.75	13.35	9.72	68.24
Days to 50% heading	0.03	3.66	35.40	13.82	38.56
Days to 50% bloom	0.87	12.71	36.34	12.10	34.8

* Significant at 5%

** Significant at 1%

4.33 Population 3

Population 3 was evaluated at two locations and for two years. In the two separate years, the genotypic mean squares were significant or highly significant except for days to 50% heading and blooming in the second year (Appendix 11 and 12).

The mean square estimates of the combined analysis across years and locations are presented in Table 10. Genotypic mean square estimates were

significant at 1% level of probability for plant height, ear length, ear weight and threshing percentage, and at 5% level of probability for grain yield per ear, days to 50% heading and days to 50% blooming. The mean square estimate due to the year x location interaction were highly significant for ear length and days to 50% heading, and significant at 5% level of probability for plant height only. The mean square estimates were significant at 1% level over the location for plant height, ear length and days to 50% blooming, and at 5% level for nodes per plant and threshing percentage. Of all the characters studies, mean square estimates for the year component were significant only for the ear girth and days to 50% heading at 1% level and plant height at 5% level of probability.

The percentage contribution to total variance of each pertinent variance component is presented in Table 11. By far, the location contributed the largest (65.40%) to the variation observed in plant height. Error and year x location contributed 19.29% and 5.36%, respectively, to the same trait. For all the other traits studied except days to 50% blooming, error contributed the largest to the variance. For all the traits except days to 50% heading, the percentage contribution of the year effect to the total variance observed was less than unity. After error, location contributed next in magnitude to the total variance for most of the characters studied. The percentage contribution of the location varied from 1.52% for ear girth to 65.40% for plant height. The contribution of genotypes to total variance varied among the nine traits. For the interaction components (year x location, genotype x year, genotype x location and genotype x year x location),

the contribution to total variance did not exceed 10% for any of the traits, except the year x location interaction for days to 50% heading.

Table 10 - Mean square estimates for the combined analyses of Nine characters in S_5 lines of P370 pearl millet population.

Plant character	Sources of Variation								
	Replication	Year	Location	Yr. Loc	Genotypes	Genotype x year	Genotype x location	Genotype x year x location	Error
	df 1	1	1	1	77	77	77	77	1556
Plant height	3470.80	5877.40*	2043825.30**	167639.5*	1342.44**	840.30	634.28	785.09	387.365
Nodes per plant	21.580	2.398	155.93*	1.08	1.58	1.16	10.04	1.14	0.953
Ear length	986.56**	0.06	26845.04**	5673.65**	174.67**	83.05	118.26	120.28	58.213
Ear girth	990.94	300.48**	551.42	748.85	41.96	18.59	29.05	20.11	15.174
Ear weight	15286.10	102.9	64641.3	8732.1	828.45**	131.82	500.68	489.53	306.179
Grain yield per ear	3730.16	519.58	26129.24	1815.65	245.67*	12.33	211.22	172.99	92.985
Threshing percentage	203.27	7.66	2701.71*	237.21	30.37**	12.36	21.65*	10.98	9.276
Days to 50% heading	59.69	497.19**	483.01**	1182.50**	17.79*	12.33	11.74	10.99	12.94
Days to 50% blooming	293.56	68.01	6893.39	1005.23	27.35*	21.83	18.43	14.85	19.85

* Significant at 5%

** Significant at 1%

Table 11: Percentage Contribution of Pertinent variance Components to Total Variance (%) in P370 Population of Pearl Millet

Plant character	Sources of Variation								
	Replication	Year	Location	Yr. Loc	Genotypes	Genotype x year	Genotype x location	Genotype x year x location	Error
Plant height	0.11	0.19	65.40	5.36	3.31	2.07	1.56	1.93	19.29
Nodes per plant	1.05	0.12	7.55	0.05	5.91	4.35	3.91	4.27	72.13
Ear length	0.60	0.00	16.45	3.48	8.24	3.92	5.58	5.67	55.50
Ear girth	2.73	0.83	1.52	2.06	8.89	3.94	6.16	4.26	64.98
Ear weight	2.06	0.01	8.71	1.18	8.59	3.77	5.19	5.08	64.16
Grain yield per ear	1.56	0.22	10.95	0.76	7.93	4.25	6.82	5.58	60.64
Threshing percentage	0.87	0.03	11.52	1.01	9.97	4.06	7.11	3.61	61.57
Days to 50% heading	0.57	4.75	4.61	11.29	13.08	9.05	8.63	8.08	38.06
Days to 50% blooming	1.46	0.36	31.09	4.49	9.70	7.15	5.58	6.603	28.76

4.4 Heritability and Genetic Advance

Heritability estimates (broad sense) and genetic advance (G.A) including the G.A expressed as a percentage of the mean are all indicated in Table 12. High heritability estimates were obtained in most cases across the three populations. The least estimate (29.667%) was recorded in population 1 for ear girth. Moderate values were obtained in population 2 for plant height, number of nodes and ear length, and in population 1 for nodes per plant and ear length. In population 3, moderate heritability value (49.568) was obtained for days to 50% blooming. The rest of the estimates for the populations were high, ranging from 56.616% for ear girth in population 2 to 86.357% for days to 50% blooming in population 1.

Genetic advance is the expected gain from selection. For all the characters except ear girth in population 1, positive genetic advances were estimated, although the estimates of GA were rather generally very low. In many of the instances, the estimates were less than one; values above one only ranged between 1.303 for grain yiled per ear in population 2 to 2.731 for plant height in population 3. Expressed as a percentage of the mean, the highest genetic advance were only 4.910, 4.505 and 4.353% for grain yield, ear weight and ear length, respectively, all reported in population 2. Other estimates above unity ranged variously between 1.079% for days to 50% blooming to 3.297% for grain yield in population 1.

Table 12: Broad sense heritability estimates and Genetic Advance in three populations of pearl millet.

Plant character	Millet population	Heritability (%) broad sense	Genetic advance (GA)	Genetic advance in percentage of mean
Plant height (cm)	P370	68.115	1.557	0.859
	P351	45.117	0.9041	0.578
	P332	52.436	2.731	1.788
Number of nodes per plant	P370	59.091	0.042	0.662
	P351	37.634	0.023	0.376
	P332	44.086	0.002	0.033
Ear length (cm)	P370	67.137	0.635	1.714
	P351	36.885	1.478	4.353
	P332	44.778	0.357	1.012
Ear girth (mm)	P370	68.257	0.205	0.837
	P351	56.616	0.573	2.483
	P332	29.667	-0.073	-0.287
Ear weight (gm)	P370	72.040	1.504	2.810
	P351	59.408	2.144	4.505
	P332	51.177	1.433	2.742
Grain yield per ear (gm)	P370	60.000	0.424	1.371
	P351	58.133	1.303	4.910
	P332	50.714	0.991	3.297
Threshing percentage	P370	80.753	0.090	0.159
	P351	55.607	0.411	0.751
	P332	73.151	1.373	2.473
Days to 50% heading	P370	67.513	0.157	0.329
	P351	79.373	0.584	1.211
	P332	61.860	0.427	0.850
Days to 50% blooming	P370	49.568	0.134	0.241
	P351	84.786	0.582	1.123
	P332	86.357	0.585	1.079

Foot note: 10% selection is assumed where K-value is 1.75

4.5 Correlations

4.5.1 Population 1

Genotypic, phenotypic and environmental correlations between the various characters, computed from the combined data for two years are presented in Tables 13,14 and 15 for population 1, 2 and 3, respectively. All asssociations were positive in populations 1 and 2.

In most cases, the genotypic correlation coefficients were higher than the phenotypic correlation coefficients. The genotypic, phenotypic and environmental correlation coefficients between the ear weight and grain yield in population 1 were about the same. In four associations in the same population, that is, ear length and ear girth, ear girth and grain yield per ear, ear girth and threshing percent, and grain yield and threshing percent, the phenotypic correlation coefficients were slightly higher than the genotypic correlation coefficients. Highest genotypic correlation coefficients observed for population 1 were between the number of nodes and threshing percentage (1.001), between ear weight and threshing percentage (0.994), ear weight and grain yield per ear (0.935), ear length and threshing percentage (0.908) and ear length and grain yield per ear (0.903). The other genotypic correlation coefficients ranged variously between 0.265 to 0.871.

4.52 Population 2

As depicted by population 1, genotypic correlation coefficients were higher than phenotypic correlation coefficients in population 2 except between number of nodes and ear weight, grain yield per ear and threshing percentage. For these latter three associations, genotypic correlation coefficients were not only lower than their respective phenotypic and environmental correlation coefficients, but were also non-significant. The correlation coefficient between number of nodes and ear girth also was non-significant, both genotypically and phenotypically.

All other correlation coefficients were significant, with the highest values being between ear weight and grain yield per ear (1.001), between ear weight and threshing percentage (0.972) and between grain yield per ear and threshing percentage (0.959). Other genotypic coefficients ranged between 0.267 to 0.766.

4.53 Population 3

Significant negative genotypic correlation coefficients were observed in the population between plant height and ear weight and between ear length and threshing percentage. Other negative genotypic correlation coefficients, though non significant, were observed between nodes per plant and ear weight, and between ear girth and grain yield. At the environmental level, nodes per plant were negatively associated with ear length, but non significantly. The other associations were positive, though some of the correlation coefficients were non-significant. The highest correlation coefficient was obtained between the ear

weight and threshing percentage (1.001). The tallest plants in this population were associated with the higest plant noding (0.910). Other significant genotypic correlation coefficients ranged between 0.286 and 0.528.

Table 13: Genotypic, phenotypic and Environmental correlation coefficients among seven Agronomic characters in population 1 of Pearl millet.

	Number of nodes per plant	Ear length	Ear girth	Ear weight	Grain yield per ear	Threshing percentage
Plant height	0.805** 0.722** 0.714**	0.512** 0.338** 0.318**	0.482** 0.281** 0.267**	0.543** 0.348** 0.328**	0.568** 0.343** 0.321**	0.578** 0.542** 0.581**
Number of nodes/plant		0.419** 0.304** 0.055ns	0.525** 0.270** 0.081*	0.403** 0.344** 0.339**	0.405** 0.316** 0.097*	1.001** 0.357** 0.295**
Ear length			0.265* 0.314** 0.329**	0.908** 0.794** 0.779**	0.903** 0.774** 0.756**	0.908** 0.737** 0.720**
Ear girth				0.618** 0.689** 0.748**	0.468** 0.723** 0.750**	0.669** 0.719** 0.725**
Ear weight					0.935** 0.934** 0.934**	0.994** 0.802** 0.897**
Grain yield/ear						0.871** 0.891** 0.893**

First, Second and Third figure in each column indicate the genotypic, phenotypic and environmental correlation coefficient, respectively.

* = significant at 5%
** = highly significant at 1%
ns = not significant

Table 14: Genotypic, phenotypic and Environmental correlation coefficients among seven Agronomic characters in population 2 of pearl millet.

	Number of nodes per plant	Ear length	Ear girth	Ear weight	Grain yield per ear	Threshing percentage
Plant height	0.553** 0.536** 0.501**	0.468** 0.303** 0.239**	0.472** 0.173** 0.128**	0.545** 0.254** 0.218	0.574** 0.226** 0.263**	0.545** 0.254** 0.355**
Number of nodes/plant		0.325** 0.176** 0.161**	0.175ns 0.030ns 0.142**	0.166ns 0.205** 0.210**	0.187ns 0.194** 0.197**	0.176ns 0.185** 0.187**
Ear length			0.266* 0.149** 0.134**	0.766** 0.702** 0.689**	0.764** 0.699** 0.686**	0.583** 0.237** 0.557**
Ear girth				0.752** 0.670** 0.655**	0.757** 0.651** 0.633**	0.564** 0.510** 0.515**
Ear weight					1.001** 0.981** 0.977**	0.972** 0.816** 0.795**
Grain yield/ear						0.959** 0.831** 0.815**

First, Second and Third figure in each column indicate the genotypic, phenotypic and environmental correlation coefficient, respectively.
* = significant at 5%
** = highly significant at 1%
ns = not significant

Table 15: Genotypic, phenotypic and environment correlation coefficients among seven Agronomic characters in population 3 of pearl millet.

	Number of nodes per plant	Ear length	Ear girth	Ear weight	Grain yield per ear	Threshing percentage
Plant height	0.905** 0.778** 0.778**	0.171ns 0.034ns 0.026ns	0.108ns 0.145** 0.168**	-0.262* 0.120** 0.010ns	0.230* 0.025ns 0.005ns	0.259* 0.105* 0.097*
Number of nodes/plant		0.060ns 0.039ns 0.038ns	0.309** 0.102** 0.093*	-0.119ns 0.051ns 0.053ns	0.365** 0.039ns 0.021ns	1.005** 0.176** 0.140**
Ear length			0.018ns 0.026ns 0.031ns	0.519** 0.168** 0.161**	0.910** 0.837** 0.830**	-0.247** 0.0.017ns 0.031ns
Ear girth				0.085ns 0.005ns 0.291**	-0.080ns 0.023ns 0.053ns	0.286** 0.524** 0.638**
Ear weight					0.52488 0.528** 0.587*	1.001** 0.822** 0.784*
Grain yield/ear						0.528** 0.322** 0.305**

First, Second and Third figure in each column indicate the genotypic, phenotypic and environmental correlation coefficient, respectively.
* = significant at 5%
** = highly significant at 1%
ns = not significant

CHAPTER 5

5.0 DISCUSSION

5.1.0 Mean Performances

Mean performances in the two years of study for ear length, ear girth and ear weight were similar in population 1. However, in population 2, mean performances for these same characters were better in the second year. With reference to population 3, most higher mean performances were in Kano location in the first year, while in the second year, higher mean values were mostly in Zaria location. Environmental factors were most likely to be responsible for these variations, unfortunately, these are variables over which the breeder has very little control.

The choice of a population and breeding system to use in initiating an improvement programme will depend on the mean performance of the population and on the magnitude and quality of genetic variation present (Eckebil, et al., 1977). For all the characters considered, the mean values were very close and the differences observed would probably not amount to any significant difference among the populations. Population 3 is a much taller population than either 2 or 1, the latter two being close in their height expression. However, as close as these various mean values have been for each trait, each population exhibited a wide range for the expression of each of these characters. This may be partly explained by the fact that the populations are synthetic which have been developed from

different selections. The wide range however, suggests the possibility of selection upwards or downwards as may be pertinent for each character. But for an improved population, a wide range in the expression of a character may not be desirable. For instance, uniform height may be desirable, especially where harvesting will be done mechanically. Besides, it is conventional to breed for shorter plants that are higher yielding to reduce the problem of stem lodging except where cultural demand for stalk residue is of high premium. Heading and flowering date exhibited an undesirable range for a population that is expected to have been improved. For instance, heading and flowering date had a range of 37-61 days and 45-82 days respectively in population 3. What this means is that, selection for different maturity pearl millet groups may be practicable. But for an improved population, the implication is that plants on the same field will be at varying stages of maturity. Ears that mature earlier are prone to birds attack, and if a farmer chooses to harvest in mass, some grains will be unfilled. Leaving plants until all grains are fully filled means incurring a higher birds menace. This may be a serious area that research has to address in millet, for even on a single ear, synchronization of flowering is still a problem. Millet is planted much earlier than most other cereals with the first rains so that the earlier the flowering and maturity period the better. This will ensure timely harvesting of the crop to give room to succeeding crops on the same field within the same cropping season.

In the drier sahel region, where millet is more popular, millet crops showing a wide range in heading and flowering may prove disastrous if there is any serious

drought. Saeed and Francis (1983) pointed out that the development of yield components in grain crops is a series of sequential events, so stress due to environmental factors at any stage may affect final yield; although the effects of stress on yield may vary from one genotype to another, depending on the length of growing period and the growth stage in which it occurs.

For each of the three populations and each character, the phenotypic coefficient of variation (PCV) was slightly higher than the corresponding genotypic coefficient of variation (GCV). For the characters studied, and across the three populations, the greatest variability, whether phenotypic or genotypic, were recorded for grain yield per ear, unthreshed ear weight and ear length in that order, which are important yield components. For each of these traits, the values were close, comparing the populations. The overall picture suggests that only little amount of variability or diversity exists among the lines that constitute the populations for virtually all the traits. In other words, they are similar in their genetic base. This may not be totally surprising because they were derived from local collections from agro-ecological zones that might not have geographical diversity which would warrant adaptive variabilities, hence the absence of much variability among them. Dudley and Moll (1969) indicated that germplasm collections from remote geographical regions are more variable than highly selected populations of local origin, and and the if several populations have similar types of ancestry, the genetic variance are likely to be similar. Since variability in a population suggests a possibility of improvement through selection, it means on

a relative term, the greatest amount of improvement can be obtained in ear weight and grain yield. Presence of genetic variability in the base population is an essential requirement for achieving success in a selection programme (Singh, 1970).

Coefficient of variation describes the amount of variation in a population. High phenotypic and genetic coefficient of variation suggests high degree of phenotypic and genetic variabilities in those characters exhibiting them. Thus, with reference to this study, the largest potentials for selection lie within the characters grain yield and ear weight. However the genetic coefficient of variation alone cannot determine the amount of variation that is heritable. The heritable portion can be found out with the help of heritability estimates and genetic gain. Johnson et al. (1955) emphasised that heritability, GCV and PCV estimates along with the estimates of genetic advance are usually more helpful in predicting the resultant effect of selection.

5.2 Estimates of Variance and Variance Components

Variances are pertinent to population improvement since they directly relate to the amount of variability a population contains. Accurate estimates of components of variance provide a basis for critically evaluating breeding and testing procedures. It can be inferred of the populations in this study that the genotypic variance was generally low compared with the phenotypic variance, thus indicating that an overall appreciable amount of improvement will be difficult. Plant

height, with the highest genotypic variance is of little use to a breeder who intends to breed shorter and higher yielding cereals. Johnson et al. (1955) noted that improvement in one trait as a result of selection for another depends not only upon the genotypic and phenotypic variances associated with them, but Dudley and Moll (1969) also adds that as well as their relative economic values. The only characters associated with yield with appreciable genotypic variance are the ear weights and ear length. The overall picture shown is however not surprising because the corresponding coefficient of variations were similarly low. Since genetic variation is small, what it then means is that further improvement of these populations is feasible only via hybridization with inbred lines or other cultivars with diverse genetic base. Habgood (1983) noted that in self pollinated cereals, effective breeding for yield improvement demands the maximum release of useful genetic variation from hybridization in order to provide the widest opportunities for selection. Nwasike et al. (1982) obtained much taller millet plants with heavier ear weight and greater grain yield per plant and slightly higher threshing percentage. Heading dates they obtained were however close to the results obtained here. For the three populations, the variances attributable to the genotype x year interaction was either very small or negative and insignificant. Interactions containing genotype x year terms are particularly interesting to applied plant breeders. This is because they reflect fluctuations in environments which for the most part cannot be predicted in advance (Allard and Bradshaw, 1964). In this study, genotype x year was significant only in population 1 and then for only one character; ear weight. The overall non-significant genotype x year interaction for the populations

indicates that the relative performance among genotypes for each of the two years of testing was the same, therefore, testing over several years would have been unnecessary.

For population 3, the genotype x location variance was negative for three characters, and low and insignificant for the rest, except for threshing percentage. Lack of significant genotype x location interaction variance indicates adequate buffering capacity of the genotype for the two environments of testing. Erickson et al (1982) explained that non-significant genotype x location is an expectation in a population showing little genetic variation or according to Miller, et al. (1962), as a result of non-random sampling of genotypes. The former explanation is more likely to hold true for this study. The second order interaction; genotype x year x location was negative for most of the traits, but positive and insignificant for plant height, ear length and days to 50 percent blooming. This low values suggest that the genetic variance will have a high predictive value across the environments, but their insignificant level indicates little genetic variation (Erickson et al., 1982). For the negative interaction components of GE, Miller et al. (1958) and Dudley and Moll (1969) explained that since the true parameters cannot be negative, these values are interpreted as being estimates of variances which are zero or small positive quantities. Such negative estimates are suggestive of the size of the sampling errors involved. Lukhele and Obilana (1984) also obtained negative estimates of variance which they explained could have resulted from one of the following; deficiency in the genetic model, sampling and sampling size, assortative

mating, linkage and estimation of actual zero values.

5.3 Heritability and Genetic Advance

Heritability is of interest to the plant breeder, primarily because of its predictive role, expressing the reliability of the phenotypic value as a guide to the breeding value (Falconer, 1989). A broad sense heritability estimate however, provides information on the relative magnitude of the genetic and environmental variation in the germplasm pool, but is not an indication of progress which might be made with a particular population (Dudley and Moll, 1969). Genetic advance on the other hand gives an indication of expected genetic progress for a particular trait under suitable selection procedure and is also useful for evaluating resource allocation because it takes into account the length of time involved in evaluating genotypes for release as new cultivars. The rate of progress in genetic advance depends on the amount of genetic variability, magnitude of the masking effect of the environmental components of variability on the genetic variability and the intensity of selection that is practised (Allard, 1960). This progress from selection is realised only to the extent that the superior genotypes in a population may be readily identified (Miller et al., 1958). For this study, heritability estimates were moderate to high for many traits but the genetic advances were small. Since the genotypic -environment components of variance were very small, thus having little or no interference on the amount of heritabilities estimated, this paradox may be explained on the basis of the low level of variabilities and probably also, low additive component of variance that prevailed among the populations. Though

heritability indicates the effectiveness with which selection of genotypes can be based on phenotypic performance, heritability value in itself provides no indication of the amount of progress that would result from selection of the best individuals (Johnson et al., 1955). The fact that the selected had not resulted in an outstanding genetic advance suggested the possibility that the frequency of favourable genes in the populations was too low to permit the extraction of exceptionally good lines (Allard, 1960). Rao and Pardhasarathi (1968) obtained in finger millet high heritability estimates for plant height and peduncle length, which were accompanied by low genetic advance. Similarly, Sandhu et al. (1974) obtained a high heritability esimate (93.23%) for number of days to maturity in foxtail millet, for which the corresponding genetic advance was low (13.01). The explanation they advanced was that genetic variability for the trait was low. Rao and Pardhasarathi (1968) indicated that such characters with high heritability estimates but low genetic advance are unreliable as selection indices.

Miller et al (1958) pointed out that the amount of genetic advance which is equated to the amount of superiority of a selection over the mean, will be realised in subsequent generations only if all the genetic effects are of the additive type. Non additive effect (epistasis, dorminance and interractions) may decrease the amount of genotypic superiority transmitted. Non additive genetic effect may not be excluded in millet which is highly outcrossing. With repeated cycles of selfing and selection to reconstitute the next cycle, some variance component governed by dominance or epistatic effect might have been lost. The generally low genetic

advance in this study implies that early generation selection and recombining may not be effective.

5.4 Correlations

Knowledge of correlations between traits of economic importance are not only of interest from a theoretical consideration of quantitative inheritance of characters, but of practical value since selection is usually concerned with changing two or more traits simultaneously. Selection for one trait invariably results in correlated responses in other traits. Therefore one needs to know how his population will respond when selection pressure is applied for a single trait. Improvement in one trait as a result of selection for another depends not only upon the genotypic and phenotypic correlations between them, but also upon the genotypic and phenotypic variances associated with them (Shivaji and Gritton, 1975).

Genotypic correlation coefficient provides a measure of genetic association between traits and thus helps to identify the more important as well as less important traits to be considered in breeding programmes. For a larger number of associations among the populations, the genotypic correlation coefficients were slightly higher than the phenotypic correlation coefficients. Phul and Athwal (1969) had reported higher genotypic correlation of characters than phenotypic correlation among crosses involving inbred lines in millet, just as is the case in most instances in this study. Similarly Rao and Pardhasardhi (1968) in finger millet and Gupta and

Dhillon (1974) in pearl millet also obtained a generally higher genotypic coefficients. Diz and Schank (1995) obtained genotypic and phenotypic correlation coefficients which in some cases differed in magnitude and sign, and in other cases, did not differ and had the same sign. Where genotypic correlation coefficients are higher than the phenotypic correlation coefficients, Johnson et al. (1955) explained that there are strong inherent relationships between those characters. When the opposite is the case, Sidwel (1975) asserts that environmental effect and or nonadditive genetic effects are acting on the characters in the same direction.

The internode number was positively and significantly correlated with many of the plant characters. Theoritically, it means plant noding could used as a selection index in any of the populations. Correlation between internode length and internode number with economic traits in pearl millet have been reported. Kamala et al. (1986) reported significant and positiove correlation between grain and internode number, while Mangath (1986) indicated a positive correlation of fodder yield with internode number, and that internode number had the maximum effect on yield. Mahadevappa and Ponnaiya (1967) on the other hand indicated that the number of internodes did not show any significant correlation with grain yield in millet inbred.

Plant height was positively and significantly correlated with grain yield. Burton (1951), Gupta and Dhillon (1974), Gupta and Sidhu (1972) and Nwasike

(1982) reported similar situations. Rai (1990), however, indicated that plant height was positively correlated with yield only in the dwarf, but not in the tall composites of pearl millet.

All the yield components were positively and significantly correlated among themselves in population 1 and 2. Correlation between grain yield and ear dry weight and ear length in pearl millet have been reported by Sachdeva (1981) and between grain yield ear length, ear girth and 1000 grain weight by Mukherji et al (1981). Reddy and Sharma (1982) and Kamala et al (1986) reported similar situations. In other millets, correlation of grain yield with panicle weight, panicle length, width of the main inflorescence, number of spickes per inflorescence, have been variously reported by Agalodia et al (1979),Resh (1979), Saxena et al. (1979) and Godawat (1980). The negative genotypic correlation coefficients observed in population 3 between nodes and ear weight and between ear girth and grain yield deserve no serious attention since they were not significant. However, the negative genotypic correlation coefficients between plant height and ear weight and between ear length and threshing percentage were significant. The implication of this is that, within this population, the longer the ears on the plant, the more loose the grains were on the ear, and that as plants became increasingly taller, the weight of the ear became smaller. This latter condition may also be related to the loose ears which obviously would weigh less than the compact ears. Rao and Pardhasardhi (1968) observed negative correlation between yield and length of panicles, while Sanhu et al. (1974) observed negative association

between primary tillers and length of ear and circumference of the ear.

The correlations obtained in this study indicated that apart from plant noding ear characters especially for population 1 and 2 would be the best selection indices in obtaining a high yielding millet population. And because of the closeness between magnitudes of the phenotypic and genotypic correlation coefficients for these characters, any selection based on their phenotypes will be very effective. Since all correlations are positive, in both populations 1 and 2, it means that theoretically, any of the traits could be used as a selection index. In practice, however, where their values are low progress from selection will be very slow and selection based on the phenotype may not be efficient.

5.5 Summary and Conclusion

Three populations, originally derived from the Nigerian germplasm collections were evaluated for variability in nine characters and associations between these characters using a simple 9 x 9 lattice design.

Mean performance differed significantly in the two years of evaluation for some traits, while for some others, mean performances were not significantly different from each other. Each trait exhibited a considerable range for its expression across the three populations.

The coefficients of variation observed were generally low, the highest

phenotypic coefficient of variation ranging from 10.525% to 16.513% for plant height in the populations. The phenotypic variance components were consistently higher than the genotypic variances which were very small for virtually all the traits. Error variance also consistently formed the largest proportion of the total variance for all the traits and across the three populatiopns. The magnitude of the genotypic variance and genotypic coefficients of variation in the populations is suggestive of very small amount of improvement that is feasible via selection in these traits. The closeness of the estimates of genotypic variances in the populations also probably indicate similarity of the populations or absence of genetic diversity among them.

On a relative term, plant height indicated the highest genotypic variance, but this may not be useful to a breeder where it is conventional to breed for shorter plants. The only yield-related traits with appreciable amounts of genotypic variance were ear weight and ear length.

The variances attributable to the genotype x year interaction was either very small or negative and non-significant. Negative variances for the interaction of genotype x year was observed in population 3 for ear length, ear girth, ear weight and grain yield; in population 1, for threshing percentage and for days to 50% heading and blooming in populations 1 and 2. This non-significant genotype x year interaction variance indicates that testing over several years would have been unncessary.

In population 3, genotype x location (GL) variance was also negative, but not significant for plant height, number of nodes and ear length. The lack of significant genotype x location interaction variance is an indication of adequate buffering capacity of the genotype for the two environments of testing. Besides, this is an expectation in a population showing little genotypic variation. Population three also indicated negative variance for genotype x year x location for certain traits. This was interpreted as being estimates of actual zero values or small quantities.

In the combined analyses, genotypic mean square estimates were highly significant for two traits and significant for another two traits in population 1. The genotypic mean square estimates were highly significant for most of the traits in the other two populations. Genotype x year mean squares were non-significant in the three populations, except for ear weight in population 1. Mean square estimates for year were significant for most of the traits across the populations. In population 3, plant height, ear girth and days to 50% heading had mean square estimates that were highly significant for location. The above three traits also had highly significant mean squares for year x location interaction.

Heritability estimates for the traits ranged from low to very high. The highest estimate of 86.357% was observed for days to 50% blooming in population 1, while the least, 29.667% was recorded for ear girth in the same population. Very low genetic advance accompanied the high heritability estimates observed. The

highest genetic advance obtained was 2.731 for plant height in population 1. Expressed as a percentage of the mean, 4.91% was the highest genetic advance recorded for grain yield per ear. This situation related to the generally low genetic variability for the traits and probably low additive genetic component that prevailed in the populations.

All correlation coefficients between pairs of characters were positive in populations 1 and 2. A few negative associations were however observed in population 3. Generally, genotypic correlation coefficients were higher than the phenotypic correlation coefficients, a situation indicating a strong inherent reationships between those characters. From the correlation coefficients, apart from stem noding, ear characters would be the best selection indices for obtaining a high yielding millet population.

In conclusion therefore, because the genotypic variance for virtually all the traits in these populations were small, the best improvement programmes will be by hybridization through the use of inbred lines, or broad based testers. Because error variance formed the largest proportion of the total variance for each trait, a more efficient genetic model may be required to reduce the error component.

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APPENDICES

Appedix 1: Mean, Range, phenotypic and genotypic coefficients of variation of pearl millet population 332 S_5 lines in two.

Trait	Years	Mean	Range	Phenotypic coeff. of var. (PCV)	Genotypic coeff. of variation (GCV)
Plant height (cm)	1	149.100±8.371	92-230	7.013	4.202
	2	156.391±8.735	80-210	6.574	3.637
Nodes per plant	1	6.421±0.309	4-9	6.589	4.487
	2	5.879±0.390	3-9	7.743	3.444
Ear length (cm)	1	34.885±2.501	14-59	10.134	7.162
	2	35.681±2.480	17-59	10.732	8.177
Ear girth (mm)	1	24.074±1.462	15-33	7.153	3.775
	2	26.035±1.576	14-36	7.663	4.695
Ear weight (gm)	1	52.258±6.280	16.10-100.920	14.547	8.197
	2	52.240±6.019	20.50-112.32	14.844	9.359
Grain yield per ear	1	30.459±4.299	7.66-92.05	18.565	12.060
	2	29.601±4.035	9.94-72.11	18.045	11.822
Threshing percentage	1	55.482±1.302	49.41-64.30	2.539	0.971
	2	55.635±1.242	49.37-64.56	2.752	1.610
Days to 50% heading	1	49.847±1.614	46-58	2.996	1.230
	2	50.597±1.655	47-59	4.234	2.689
Days to 50% blooming	1	55.042±1.652	50-65	3.493	1.784
	2	53.417±2.146	46-60	3.545	1.892

Appendix 2: Mean, Range, phenotypic and genotypic coefficients of variation of pearl millet population 351 S_5 lines in two years.

Trait	Years	Mean	Range	Phenotypic coeff. of var. (PCV)	Genotypic coeff. of variation (GCV)
Plant height (cm)	1	148.099±7.731	90-200	7.913	5.948
	2	165.128±9.058	80-245	7.092	4.295
Nodes per plant	1	6.146±0.332	4-9	5.752	1.925
	2	6.088±0.371	4-9	6.911	3.244
Ear length (cm)	1	32.604±2.748	13-80	12.611	9.464
	2	35.289±2.598	20-63	11.210	8.452
Ear girth (mm)	1	24.105±1.914	13-36	12.325	9.426
	2	22.027±1.835	12-35	9.838	5.236
Ear weight (gm)	1	44.614±5.581	12.48-115.29	19.681	15.193
	2	50.560±5.745	20.59-107.80	14.932	9.797
Grain yield per ear	1	24.458±3.602	7.19-72.00	23.525	18.346
	2	28.614±3.966	11.05-69.39	21.315	11.624
Threshing percentage	1	53.841±1.164	48.15-64.20	3.253	2.430
	2	55.579±1.520	48.15-64.64	3.149	1.556
Days to 50% heading	1	47.747±1.666	41-62	4.935	1.737
	2	48.667±1.317	45-58	3.113	1.536
Days to 50% blooming	1	52.759±1.484	47-65	3.113	1.386
	2	51.019±1.285	46-60	3.097	1.803

Appendix 3: Mean, Range, phenotypic and genotypic coefficients of variation of pearl millet population 370 S_5 lines in two years.

Trait	Years	Mean	Range	Phenotypic coeff. of var. (PCV)	Genotypic coeff. of variation (GCV)
Plant height (cm)	1	179.469±4.990	140-280	5.459	3.756
	2	183.002±6.286	80-245	6.795	4.295
Nodes per plant	1	6.423±0.286	3-11	6.857	2.741
	2	6.351±0.281	4-9	7.060	3.188
Ear length (cm)	1	37.037±1.911	20-101	10.263	7.092
	2	37.600±3.182	12-78	14.071	7.220
Ear girth (mm)	1	24.901±1.146	15-36	7.928	4.441
	2	24.031±1.115	12-40	8.326	5.037
Ear weight (gm)	1	53.692±3.854	26.60-186.80	12.491	7.115
	2	59.461±41.123	11.02-135.60	100.150	18.189
Grain yield per ear	1	31.083±2.592	14.78-85.86	15.229	9.440
	2	37.876±4.761	4.97-70.98	159.012	17.792
Threshing percentage	1	56.104±0.849	46.52-66.26	2.808	1.790
	2	56.877±0.885	49.53-68.60	2.751	1.613
Days to 50% heading	1	46.808±1.190	46-58	3.665	3.009
	2	48.651±2.138	36-67	3.338	1.368
Days to 50% blooming	1	55.872±2.082	45-82	4.485	3.273
	2	55.144±2.475	42-82	4.315	2.253

Appendis 4: Estimates of Variance Components of the separate Years for Nine Traits in population 332 Pearl millet

Plant character		Phenotypic variance (δ^2_{ph})	Genotypic variance (δ^2_g)	Error variance (δ^2_e)
Plant height	1	109.341	39.260	420.483
	2	105.713	29.413	457.800
Nodes per plant	1	0.179	0.083	0.573
	2	0.193	0.041	0.913
Ear length	1	12.499	6.243	37.538
	2	14.663	8.513	36.901
Ear girth	1	2.965	0.826	12.833
	2	3.980	1.494	14.910
Ear weight	1	57.787	18.350	236.623
	2	60.132	23.906	217.356
Grain yield per ear	1	31.977	13.494	110.900
	2	28.531	12.247	97.703
Threshing percentage	1	1.984	0.290	10.615
	2	2.345	0.802	9.256
Days to 50% heading	1	2.230	-0.376	5.211
	2	4.590	1.851	5.477
Days to 50% blooming	1	3.696	0.964	5.463
	2	3.585	-1.021	9.211

1 - 1st year estimates
2 - 2nd year estimates

Appendix 5: Estimates of Variance Components of the separate Years for Nine Traits in population 351 of Pearl millet

Plant character		Phenotypic variance (δ^2_{ph})	Genotypic variance (δ^2_g)	Error variance (δ^2_e)
Plant height	1	137.357	77.590	358.603
	2	137.145	55.105	492.237
Nodes per plant	1	0.125	0.014	0.668
	2	0.177	0.039	0.825
Ear length	1	16.906	9.522	45.306
	2	15.648	8.897	40.508
Ear girth	1	8.826	5.163	21.976
	2	4.696	1.330	20.195
Ear weight	1	77.094	45.943	186.907
	2	57.538	24.538	197.998
Grain yield per ear	1	33.106	20.134	77.831
	2	37.197	11.063	94.379
Threshing percentage	1	3.067	1.712	8.127
	2	3.063	0.754	13.854
Days to 50% heading	1	3.464	0.688	5.552
	2	2.295	0.559	3.471
Days to 50% blooming	1	3.094	0.535	4.406
	2	2.497	0.846	3.301

1 - 1st year estimates

2 - 2nd year estimates

Appendix 6: Estimates of Variance Components of the separate Years for Nine Traits in population 370 of Pearl millet

Plant character		Phenotypic variance (δ^2_{ph})	Genotypic variance (δ^2_g)	Error variance (δ^2_e)
Plant height	1	96.370	44.448	298.799
	2	154.648	73.713	474.176
Nodes per plant	1	0.194	0.031	0.958
	2	0.201	0.041	0.948
Ear length	1	14.449	6.899	43.814
	2	27.990	7.370	121.515
Ear girth	1	3.897	1.223	15.753
	2	4.004	1.465	14.912
Ear weight	1	44.980	14.592	178.223
	2	3546.202	116.973	20293.215
Grain yield per ear	1	22.336	8.574	80.626
	2	3627.373	45.411	21219.575
Threshing percentage	1	2.482	1.008	8.643
	2	2.449	0.842	9.394
Days to 50% heading	1	2.943	1.984	5.663
	2	2.637	-0.443	18.293
Days to 50% blooming	1	6.278	3.345	17.354
	2	5.663	1.544	24.503

1 - 1st year estimates

2 - 2nd year estimates

Appendix 7: Mean squares estimates of the first year analyses for nine characters in S_5 lines of P332 pearl millet population.

Plant character	Source of variation		
	Replication	Genotype	Error
	1	71	359
Plant height	1708.058*	656.045**	420.483
No of nodes/plant	5.787	1.070**	0.573
Ear length	3.273	74.998**	37.538
Ear girth	71.704*	17.788*	12.833
Ear weight	5739.920**	346.721*	236.623
Grain yield per ear	4665.029**	191.864**	110.900
Threshing percentage	181.054**	11.905	10.165
Days to 50% heading	8.028	4.460	5.211
Days to 50% blooming	11.111	7.391	5.463

* Significant at 5%

** Significant at 1%

Appendix 8: Mean squares estimates of second year analyses for nine characters in S_5 lines of P332 pearl millet population.

Plant character	Source of variation		
	Replication	Genotype	Error
	1	71	359
Plant height	2300.947*	634.278*	457.800
No of nodes/plant	12.00	1.156	0.913
Ear length	192.000*	87.980**	36.901
Ear girth	814.002**	23.319**	14.910
Ear weight	10.798	360.792**	217.356
Grain yield per ear	13.129	171.185**	97.703
Threshing percentage	10.047	14.065**	9.256
Days to 50% heading	32.111	9.178**	5.477
Days to 50% blooming	0.000	7.169	9.211

* Significant at 5%

** Significant at 1%

Appendix 10: Mean squares estimates of the second year analyses for nine characters in S_5 lines of P351 pearl millet population.

Plant character	Source of variation		
	Replication	Genotype	Error
df	1	80	404
Plant height	25662.667*	840.869**	492.237
No of nodes/plant	19.360**	1.059	0.825
Ear length	8.828	93.888**	40.508
Ear girth	0.101	28.174*	20.195
Ear weight	122.572	345.228**	197.998
Grain yield per ear	89.561	160.759**	94.379
Threshing percentage	77.042*	18.376*	13.854
Days to 50% heading	69.358**	4.588	3.471
Days to 50% blooming	87.414**	4.993*	3.301

* - Significant at 5%

** - Significant at 1%

Appendix 11: Mean squares of the first year analyses for nine characters in S_5 lines of P370 pearl millet population

Plant character		Source of variation			
	Replication	Location	Genotype	Genotpe x loc	Error
df	1	1	77	77	778
Plant height (cm)	2724.796	1689205.309*	844.180**	534.270**	298.799
Nodes per plant	9.822	65.005ns	1.315*	1.288ns	0.958
Ear length (cm)	0.007	29239.949*	126.600**	116.296**	43.814
Ear girth (cm)	1225.471	7.360ns	30.431**	23.854*	15.753
Ear weight (gm)	4287.875	60932.376ns	393.125*	320.307*	178.223
Grain yield per ear (gm)	1005.961	24728.026ns	183.514**	151.405**	80.626
Threshing percentage	139.556	1483.827*	20.741**	15.449**	8.643
Days to 50% heading	0.115	1588.513ns	13.597**	7.143ns	5.663
Days to 50% blooming	0.321	1337.55ns	30.732	18.973ns	17.354

* Significant at 5%

** Significant at 1%

Appendix 12: Mean squares of the second year analyses for nine characters in S_5 lines of P370 pearl millet population

Plant character	Source of variation				
	Replication	Location	Genotype	Genotpe x loc	Error
df	1	1	77	77	778
Plant height (cm)	18542.261*	519447.115**	1358.732**	892.050**	474.176
Nodes per plant	11.779ns	91.719*	1.434**	0.901ns	0.948
Ear length (cm)	1645.916*	7323.687**	209.953**	171.805**	121.515
Ear girth (cm)	106.009ns	1395.779ns	32.496**	25.333*	14.912
Ear weight (gm)	5997.974ns	92168.515ns	21696.895ns	22009.013ns	20293.219
Grain yield per ear (gm)	66187.205ns	91361.743ns	20674.642ns	21231.400ns	21219.575
Threshing percentage	33.759ns	1230.052ns	19.496**	19.099**	9.394
Days to 50% heading	156.542ns	95.926ns	16.522ns	14.537ns	18.292+
Days to 50% blooming	629.003ns	6636.926ns	18.328ns	16.491ns	24.502+

ns Not significant

* Significant at 5%

** Significant at 1%

Appendix 13- Metereological data for Samaru - Zaria for June to September, 1992 and 1993

Year 1992	Total monthly rainfall (mm)	Mean daily temperature		Mean daily relative humidity (%)	Mean daily sunshine (hr)
		Minimum	Maximum		
June	112.4	30.6	20.4	71.3	6.4
July	243.6	28.4	19.8	82.6	6.2
Aug	286.9	27.5	20.0	83.0	5.0
Sept	229.7	29.5	20.2	78.6	5.7
Year 1993					
June	158.8	31.7	20.9	72.7	7.3
July	269.0	29.5	20.2	78.4	6.6
Aug	300.8	28.4	19.5	81.8	5.0
Sept	181.8	30.23	19.1	76.7	7.0

Appendix 14: Metereological data of Kano from June to September, 1992 and 1993

Year 1992	Total monthly rainfall (mm)	Mean daily temperature		Mean daily relative humidity (%)	Mean daily sunshine (hr)
		Minimum	Maximum		
June	46.2	35	22	60	1.9
July	227.0	31	20	77	2.8
Aug	404.4	30	19	80	2.9
Sept	158.9	31	20	76	3.4
Year 1993					
June	213.7	34.0	21	63.3	Record not
July	141.2	31	19	74.8	avoilable
Aug	343.0	31	18	78.8	6.3
Sept	74.1	32	20	74.8	7.5