STUDIES ON GENETIC VARIABILITY FOR YIELD AND OTHER VEGETATIVE AND FRUIT TRAITS IN PEPPER (*Capsicum annuum*, L. var. annuum).

BY

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D E C L A R A T I O N

I hereby declare that this thesis has been composed by myself and that it is a record of my own research work. It has not been accepted in any previous qualification for a higher degree. All quotations made are distinguished by quotation marks and the sources of information are specifically acknowledged by means of references.

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CHAPTER I

INTRODUCTION

The Genus Capsicum is one of the oldest crops grown by man throughout the New World tropics. Domestication of the wild species in different areas resulted in change, particularly in the fruits. Pepper is among the major vegetables grown by many farmers in Nigeria. Two main species (Capsicum annuum L. and C. frutescens L.) are the most widely cultivated, and Nigeria used to export the latter species to foreign markets. The crop is cultivated throughout the country especially in the northern states where it is grown as rainfed or under irrigation. The total area of land devoted to the crop is about 10-20,000 hectares annually, however, the production has been mainly limited to peasant farmers.

In Nigeria many different cultivars of pepper (Genus Capsicum) with distinct morphological characteristics are cultivated by the local farmers, and Capsicum annuum, L. var. annuum is very important. The variations in fruit shape and size may account to some degree for the differences in berry yields obtained. Thus if it is possible to partition the genetic variability, it might be possible to exploit this variability for producing higher yielding cultivars through appropriate selection and breeding procedures.

The objective of the present investigation was therefore to study the genetic variability of some vegetative and fruit traits among sixteen locally grown pepper cultivars (Capsicum annuum, L var. annuum). A second objective to the study was the estimation of heritabilities of the different traits, expected genetic advance from selection, genotype x environment interactions and correlations between traits. Genotype x environment refers to genotype x year since the experiment was conducted in only one location over two years.

CHAPTER II

LITERATURE REVIEW

Pepper belongs to the family Solanaceae, and the genus Capsicum. The classification of the genus is very confused. Over 100 species, and many botanical varieties have been erected from time to time; but two main species (Capsicum annuum, L. and Capsicum frutescens L.) have been generally recognised (Purseglove, 1968).

Capsicum annuum, L. is the most widely cultivated and economically the most important species. It includes the sweet peppers as well as most of those that are dried for hot peppers, chili powders and paprika.

2.1 GENETIC VARIABILITY

In plant breeding, the variability which exists within a given population is very important. More importantly is the additive genetic variability which could be exploited in crop improvement programmes. Different researchers in different places have shown that genetic variability exists in other pepper populations. Nandpuri et al. (1971) obtained highest genetic variance for yield per plant (1578.5) followed by number of fruits per plant (110.28) in pepper. Arya and Saini (1977) recorded highest genotypic variance for fruit yield per plant (87805.79), followed by number of seeds per fruit (5502.92), number of fruits per plant (1581.05) and fruit size per plant (508.97). However, Dutta et. al. (1979)

observed highest genotypic coefficient of variability for fruit weight (131.03) followed by number of fruits per plant (118.20). Their results have shown that a good amount of genetic variability exists for different characters in other pepper populations.

It was shown by Kirti et al. (1972) that considerable genetic variability was available for improvement of their pepper population. They obtained high genotypic coefficients of variability for fruit size (54.78), number of fruits per plant (31.90) and number of tertiary branches per plant (26.47). Singh and Singh (1977) observed that the genetic variances are greatly biased by the environmental influence and that the additive genetic variance appeared to be the major source of variation in most of their crosses for plant height. Nandpuri et al. (1971) reported that the genotype x environment interaction accounted for all the variations in fruit size.

2.2 HERITABILITY

In plant breeding, a knowledge of the proportion of the observed total variability that is genetic is important in terms of production of more desirable varieties. According to Burton and Devane (1963), heritability is a measure of the efficiency of a selection system in separating genotypes. Various researchers on pepper have obtained estimates of heritability for different traits. Most estimates were in the broad sense

rather than in the narrow sense. Nandpuri et al. (1971), obtained high broad sense heritabilities for days to flowering (87.15%), number of fruits per plant (80%), days to maturity (63.54%), yield per plant (61.19%) number of branches per plant (55.81%), 100-seed weight (54.54%) and plant height (54.22%). The heritability estimate for fruit size was 55.41% in the spring season and 68.43% in the monsoon season. In studies on genetic variability for ten traits in chillies, high broad sense heritability estimates were obtained (Kirti et al., 1972), for all traits studied. The highest estimate was for fruit size (97.96%) while the lowest estimate was for plant height (66.25%). The values obtained for other traits were: Days to first flowering (87.60%), fruit number per plant (83.98%), 100-seed weight (82.47%), fresh fruit weight (77.62%), and yield per plant (73.29%). Singh and Singh (1977) calculated heritability in the broad sense using four different methods and obtained the average for the various characters studied. The average recorded for number of fruits per plant was 84.68%; plant height (79.18%); yield per plant (79.01%); days to maturity (78.58%); number of branches per plant (72.60%); days to flowering (69.79%); and fruit length (61.51%). Their narrow sense heritability estimates were high for days to maturity (95.86%), plant height (88.27%), number of fruits per plant (84.34%) and number of branches per plant (76.32%). Low narrow sense heritability estimates were recorded for yield per plant (39.74%) and fruit

length (20.21%). The days to flowering had zero narrow sense heritablity.

In their variability studies in pepper varieties, Arya and Saini (1977) observed high broad sense heritability in all the traits they studied. The estimate recorded for fruit size per plant was 99.81%, followed by number of branches per plant (99.05%), fruit yield per plant (98.96%), days taken to flower (98.49%), days taken to fruit formation (97.54%) and plant height (88.07%). Working with seventy-nine F_3 lines from pepper cross, Legg and Lippert (1956), found that broad sense heritability estimates and the relative size of variances due to line differences and interactions of lines with locations indicated that a large portion of the phenotypic variability was genetic. However, Singh and Singh (1970) obtained low heritability estimates for berry yield, number, width and 1000-seed weight.

Dutta et al. (1979) obtained high broad sense heritability estimates in peppers for fruit weight (97.23%) followed by number of days to 50 per cent flowering (90.66%), plant height (82.32%) number of fruits per plant (77.09%) and green fruit yield (73.63%). The estimate recorded for length of fruits was low (27.27%).

2.3 EXPECTED GENETIC ADVANCE FROM SELECTION

Genetic advance is also an index of assessing genetic improvement from the selection of superior cultivars. Some workers on pepper attempted to estimate the expected

genetic advance as the result of selection. Nandpuri et al. (1971) obtained highest expected genetic advance for fruit number per plant (52.60), medium for number of branches per plant (31.95) followed by yield per plant (26.98), fruit size (25.56), plant height (24.54) and low for days to flowering (14.40) followed by 100-seed weight (13.20) and days to maturity (7.04). Kirti et al. (1972), obtained highest expected genetic advance for fresh weight per fruit (129.78) followed by fruit number per plant (95.21), fruit size (88.58) and 100-seed weight (73.00). Low values were recorded for yield per plant (34.06), plant height (11.73) and days to first flowering (6.96). From the results observed by Singh and Singh (1977) the highest value of expected genetic advance was shown by number of fruits per plant (109.85), followed by yield per plant (21.49). Low values were observed for plant height (13.75), days to maturity (6.63), and fruit length (0.55). However, Arya and Saini (1977) obtained highest estimates of genetic advance for fruit yield per plant (605.13) followed by number of seeds per fruit (148.655), and number of fruits per plant (78.06). Fruit size per plant had (46.445) followed by plant height (33.96), days taken to fruit formation (23.629), number of branches per plant (23.327) and days taken to flower (20.147).

2.4 EXPECTED GENETIC ADVANCE IN PER CENT OF MEAN

Many breeders prefer to think of advance in per cent of the mean of the population with which they work.

According to Burton and Devane (1963), the genetic advance in per cent of mean is a product of selection differential, the potential advance and the efficiency of the selection system. The genetic gain indicates the advance expected over the population mean as the result of selection for the superior genotypes of the population. Kirti *et al.* (1972) recorded highest genetic advance in per cent of mean for fruit size (111.75), followed by fruit number per plant (60.25) while the lowest value was for days to first flowering (9.90). They noted that the values of genetic advance in per cent of mean were generally higher than the corresponding values for genetic advance *per se* for all characters except 100-seed weight, fruit number per plant and fresh weight per fruit. In their variability studies in pepper, Arya and Saini (1977) recorded highest genetic gain for fruit size per plant (267.395), followed by fruit yield per plant (192.370), number of fruits per plant (154.510), number of branches per plant (144.475) and number of seeds per fruit (109.168). The lowest value was recorded for rind thickness per fruit (4.589). The genetic gain obtained by Singh and Singh (1977) for different characters were relatively low. The highest value was recorded for number of fruits per plant (47.06) followed by number of branches per plant (30.72). The lowest estimates were recorded for fruit length (5.67) and fruit thickness (5.41). Their results also showed that the estimates of genetic gain were higher

than the corresponding genetic advance estimates for all characters except number of fruits per plant and yield per plant.

2.5 CORRELATIONS

Since most of the characters of economic importance, such as yield, are complex in inheritance and may involve several related characters, the degree of genotypic and phenotypic correlations of the characters is important. These correlations are of practical value since selection is usually concerned with changing two or more traits simultaneously. It has been pointed out (Johnson *et al.*, 1955b), that if a negative genetic correlation exists between yield and one or more other characters which are selected for, effective selection for the character other than yield in early generation would result in discarding some of the better genotypes for yield if selection pressure for the character in question were very strong. Nandpuri *et al.* (1970) showed that yield, in terms of fruit weight per plant, was positively correlated with 100-seed weight ($r = 0.404$), fruit size ($r = 0.571$), fruit number per plant ($r = 0.413$), branch number per plant ($r = 0.421$) and plant height ($r = 0.162$). A regression analysis showed that three characters, fruit number per plant, fruit size and 100-seed weight account for 92.53 per cent of phenotypic variation in yield and are the important selection criteria. Legg and Lippert (1956) showed that average fruit weight was highly correlated

with fruit length, fruit width and carotenoid level. Mature fruit number was negatively correlated with length and width of fruits, level of carotenoids and average fruit weight. From an analysis of 36 cross combinations of varieties differing in fruit size, Calson (1962), observed that leaf size was positively correlated with fruit size. Fruit size was however, negatively correlated with number of fruits. Singh and Singh (1970) showed that berry yield was positively correlated with the number, length, width and 100-seed weight of berries.

Gill et al. (1977) observed high negative correlation between the number of fruits per plant and total yield (r =-0.709). The days taken to flowering was also negatively correlated with early yield (r =-0.461). Kirti et al. (1972) observed that yield per plant was positively correlated with plant height, primary and tertiary branch number, fruit number and fresh weight. Fruit number was positively associated with fresh weight, branch number, plant height and days to flowering. Jo et al. (1973) reported that positive correlations occurred between fruit diameter and yield, and fruit weight and yield. Negative correlations occurred between vegetative growth and fruit weight, fruit number and total yield, and for days from sowing to flowering and yield, early maturing varieties giving higher yields. However, Arya and Saini (1976) obtained negative correlations between plant height and fruit number with yield.

Dutta et al. (1979) found that yield was significantly positively associated with number of fruits per plant (r =0.7168), and days to 50 per cent flowering (r = 0.4950), but negatively and insignificantly correlated with number of primary branches (r = - 0.1555), plant height (r =-0.0149) and weight of fruit (r = - 0.1273). More recently, Suthanthirapandian et al. (1981) observed that number of fruits, girth of fruit and weight of seeds per fruit were positively correlated with yield. High yield and days to first flower were negatively correlated.

CHAPTER III

MATERIALS AND METHODS

The experiment was carried out under field conditions for two years during the 1981 and 1982 wet seasons at the Institute for Agricultural Research Farm, Samaru. A collection of sixteen cultivars of Capsicum annuum var. annuum of different ecogeographical origins was used in the experiment. The variability for yield, vegetative and fruit characters were investigated among the sixteen cultivars. The seeds of the cultivars were collected from four different states of Nigeria namely Kaduna, Kano, Oyo and Sokoto states. The origin and descriptions of the experimental materials used are given in Table 1, while the climate of the ecogeographical zones as given by Buchanan and Pugh (1955), Kowal and Knabe (1972) and Hopkins (1974) is given in Table 2.

Table 1: Origin and descriptions of the experimental materials used in the study.

Ecogeographical zone	State	Cultivar Entry Number	Descriptions
Northern Guinea	Kaduna	KD1	Plants medium in height (36.30 cm), intermediate in maturity, poor in bearing, flower one in axil, calyx not enclosing the base of the fruit,

Table 1 (Cont'd)

Ecogeographical zone	State	Cultivar Entry Number	Descriptions
Northern Guinea	Kaduna	KD1	fruit long 8.30 cm x 2.20 cm, elongated, pendent, apex pointed and lobed, flesh thick, average weight of a fresh ripe fruit 18.50 grams.
Northern Guinea	Kaduna	KD2	Plants medium in height (37.50 cm), early in maturity, poor in bearing, flower one in the axil, calyx not enclosing the base of the fruit, fruit intermediate, 6.75 cm x 3.05 cm, elongated, quadrate in transverese section, pendent, apex blunt, flesh thick, average weight of a fresh ripe fruit 25.70 grams.
Northern Guinea	Kaduna	KD3	Plants tall (45.50 cm), intermediate in maturity, moderate in bearing,

Table 1 (Cont'd)

Ecogeographical zone	State	Cultivar Entry Number	Descriptions
Northern Guinea	Kaduna	KD3	flower one in the exil, calyx not enclosing the base of the fruit, fruit intermediate, 6.10 cm x 2.52 cm, elongated, pendent, apex pointed flesh thick, average weight of a fresh ripe fruit 18.50 grams.
Northern Guinea	Kaduna	KD4	Plants tall (47.70 cm) intermediate in maturity, moderate in bearing, flower one in the axil, calyx not enclosing the base of the fruit, fruit short, swollen, completely corrugated, globular, 5.20 cm x 2.80 cm., pendent, apex blunt, flesh thick, average weight of a fresh ripe fruit 17.65 grams.

Table 1 (Cont'd)

Ecogeographical zone	State	Cultivar Entry Number	Descriptions
Sudan	Kano	KN1	Plants medium in height (39.75 cm), intermediate in maturity, poor in bearing, flower one in the axil, calyx not enclosing the base of the fruit, fruit long, 7.90 cm x 2.90 cm, elongated, pendent, apex pointed, flesh thick, average weight of a fresh ripe fruit 29.16 grams.
Sudan	Kano	KN2	Plants medium in height (37.40 cm), intermediate in maturity, poor in bearing, flower one in the axil, calyx not enclosing the base of the fruit, fruit long, 7.79 cm x 3.31 cm, elongated, pendent, apex blunt, sometimes lobed, flesh thick,

Table 1 (Cont'd)

Ecogeographical zone	State	Cultivar Entry Number	Descriptions
Sudan	Kano	KN2	average weight of a fresh ripe fruit 31.85 grams.
Sudan	Kano	KN3	Plants medium in height (39.65 cm), intermediate in maturity, poor in bearing, flower one in axil, calyx not enclosing the base of the fruit, fruit long, 8.40 cm x 2.45 cm, elongated, pendent, apex acute flesh thick, average weight of fresh ripe fruit 22.84 grams.
Sudan	Kano	KN4	Plants medium in height (37.60 cm), intermediate in maturity, very poor in bearing, flower one in axil, calyx not enclosing the base of the fruit, fruit long 7.50 cm x 2.85 cm, elongated angular

Table 1 (Cont'd)

Ecogeographical zone	State	Cultivar Entry Number	Descriptions
Sudan	Kano	KN4	in transverse section, pendent, apex blunt and sometimes lobed, flesh thick, average weight of a fresh ripe fruit 29.67 grams.
Forest	Oyo	OY1	Plants short (31.65 cm), intermediate in maturity, poor in bearing, flower one in the axil, calyx not enclosing the base of the fruits, fruit short, 5.87 cm x 2.02cm, elongated, pendent, unripe green with some purple colour on the side facing the sun, becoming red when mature, apex acute, flesh thick average weight of a fresh ripe fruit 11.37 grams.
Forest	Oyo	OY2	Plants medium in height (35.70 cm), intermediate

Table 1 (Cont'd)

Ecogeographical zone	State	Cultivar Entry Number	Descriptions
Forest	Oyo	OY2	in maturity, poor in bearing, flower one in axil, calyx not enclosing the base of the fruit, fruits long 7.91 cm x 2.75 cm, elongated, pendent, apex blunt, flesh thick, average weight of a fresh ripe fruit 27.45 grams.
Forest	Oyo	OY3	Plants medium in height (35.85 cm), intermediate in maturity, prolific, flower one or two in the axil, calyx enclosing base of the fruit, fruit long, 7.57 cm x 0.80 cm, elongated, circular in transverse section, wrinkled, pendent, apex acute, flesh thin, average weight of a fresh ripe fruit 3.38 grams.

Table 1 (Cont'd)

Ecogeographical zone	State	Cultivar Entry Number	Descriptions
Forest	Oyo	OY4	Plants medium in height (36.88 cm), intermediate in maturity, moderate in bearing, flower one in the axil, calyx not enclosing the base of the fruit, fruit short, 5.85 cm x 1.77 cm, elongated, pendent, unripe green with some purple colour, becoming red when mature, apex blunt, flesh thick, average weight of a fresh ripe fruit 8.90 grams.
Sudan	Sokoto	SO1	Plants tall (43.23 cm), late maturing, prolific in bearing, flower one in axil, calyx not enclosing the base of the fruit, fruit intermediate in length, 6.85cm x

Table 1 (Cont'd)

Ecogeographical zone	State	Cultivar Entry Number	Descriptions
Sudan	Sokoto	SO1	2.06 cm, elongated, pendent, apex acute, flesh thick average weight of a fresh ripe fruit 14.82 grams.
Sudan	Sokoto	SO2	Plants tall (44.93 cm), intermediate in maturity, moderate in bearing, flower one in the axil, calyx not enclosing the base of the fruit, fruit intermediate in length, 6.96 cm x 2.49 cm, elongated, pendent, apex acute, sometimes lobed, flesh thick, average weight of a fresh ripe fruit 19.63 grams.
Sudan	Sokoto	SO3	Plants medium in height (36.25 cm), late maturing, moderate in bearing, flower one in the axil, calyx not enclosing the

Table 1 (Cont'd)

Ecogeographical zone	State	Cultivar Entry Number	Descriptions
Sudan	Sokoto	SO3	base of the fruit, fruit intermediate in length, 6.31 cm x 2.00 cm, elongated, pendent, apex conical, flesh thick, average weight of a fresh ripe fruit 13.25 grams.
Sudan	Sokoto	SO4	Plants tall (44.83 cm), early maturing, flower one or two in the axil, calyx not enclosing base of the fruit, fruit short, 4.50 cm x 1.15 cm, elongated, conical in shape, apex pointed, flesh thin, average weight of a fresh ripe fruit 4.50 grams.

Table 2: Descriptions of the climate of the ecogeographical zones from which the experimental materials have been collected.

Ecogeographical zone	Descriptions
1. Sudan	The mean annual rainfall is about 500-870 mm and is seasonally distributed. The rainfall starts around middle of May and stops around September ending giving a riny period of 100-130 days. The mean monthly minimum and maximum temperatures are normally 55-60°F and 100-105°F respectively. The mean monthly minimum relative humidity at 12.00 hours (Buchanan and Pugh, 1955) is 10-20 per cent while the mean annual is about 30-40 per cent. The daily sunshine is about eight hours with a mean monthly range of about four to ten hours. The mean annual values for evaporation range from 1500-1750 mm (Kowal and Knabe, 1972).
2. Northern Guinea	The mean annual rainfall is more than 1000 mm and is seasonally distributed so that during four or five months of the year 1000 mm or more of rain fall and there are not more than five or six months with less than 25 mm of rain.

Table 2 (Cont'd)

Ecogeographical zone	Descriptions
2. Northern Guinea	The mean monthly minimum and maximum temperatures are normally 55-70°F and 95-105°F respectively. The mean monthly minimun relative humidity at 06.00 hours (Hopkins, 1974) is about 30 per cent and may fall to below 10 per cent at about noon. The mean annual values of evaporation and evapotranspiration appear to fall between 1800-2300mm for evaporation and over 1800mm for evapotranspiration.
3. Forest	The mean annual rainfall is above 1250 mm and is seasonally distributed. While during each of at least six months of the year, 100 mm or more of rain fall, there are not more than two or rarely three months with less than 25 mm of rain. The mean monthly minimum and maximum temperatures are normaly 65-75°F and 85-95°F respectively. The mean monthly relative humidity at 09.00 hours appears to be at least 70 per cent. Despite the fairly constant twelve-hour day, the mean daily sunshine is usually less than seven hours even in the dry season. These low values are due mainly to excessive cloud cover. Data for mean annual evapotranspiration recorded reach the order of 1300mm and potential evapotranspiration may be as high as 1800 mm per year.

3.1 NURSERY MANAGEMENT PRACTICES

Seedlings for the 1981 field planting were raised in nursery beds in the last week of April, 1981, at the irrigation site, Institute for Agricultural Research Farm. Four beds of 1.20m x 24m each were raised. The area was cleared free from weeds, soil clods were pulverized and boronated super phosphate was added at the rate of 25g per square metre. The fertilizer was thoroughly mixed with the soil and the beds were raked to remove stones and straw. The beds were ready for sowing after wetting.

Seedlings for the 1982 field planting were similarly raised in nursery beds in the last week of April, 1982 at the Horticultural Section Field, I.A.R.

Seeds were sown in the nursery after wetting the beds and allowing for excess water to drain. Small drills of about two centimetres deep and 10cm between drills were made and the seeds were sown in the drills with about one seed per centimetre. The seeds were lightly covered with soil and the beds were mulched. The mulching material used was dried grass. The mulching material was removed two weeks after sowing. The seedlings were carefully looked after and weed control measures were taken. Weeding was done by hand. The beds were irrigated regularly during the 1981 planting season because there was a short drought for about four weeks. In the 1982 planting season, the beds were watered manually using watering cans.

3.2 FIELD CULTURAL PRACTICES

In the dry season, remnants of previous crop, shrubs and weeds were cut down, dried in the air and burnt down. About one week before transplanting, the land was harrowed using tractor drawn disc harrow. Super phosphate fertilizer was applied at the rate of 250kg per hectare before ridging. The fertilizer was broadcast using fertilizer broadcaster. Ridges of 75cm were made by tractor drawn ridgers. The land was then ready for transplanting. The methods of land preparation described were used in both 1981 and 1982 trials.

Pepper seedlings are usually ready for transplanting four to five weeks after sowing. However, in the 1981 trial the seedlings were transplanted seven weeks after sowing owing to a short drought which caused a delay in field preparation. In 1982 transplanting was done five weeks after sowing.

Water was applied to wet the nursery beds before transplanting so as to facilitate easy lifting of the seedlings. The seedlings were carefully lifted with ball of earth using hand trowel. This method of lifting the seedlings reduces damage to the young roots and facilitated rapid root growth after transplanting. The seedlings were transplanted on 75cm ridges with spacing of 60cm between stands soon after lifting.

A top dressing of compound fertilizer (NPK 15:15:15) at 250kg per hectare was given, 125kg at two weeks after

transplanting and the other 125kg at the first set of fruits (five weeks after transplanting). Weeding was done four times in each year. Fruits were harvested when fully red-ripe . Picking was done by snapping off the brittle stem manually at weekly intervals over a period of eight weeks.

3.3 EXPERIMENTAL DESIGN AND LAYOUT

The field experiment was conducted in the 1981 and 1982 wet seasons at the Agricultural Research Station Farm, Samaru. The experimental design used was a randomised complete block design with four replications. The sixteen cultivars were randomized within each block. Gross plot size of 3.0m x 5.4m and net plot size of 1.5m x 3.0m were used in the experiment. Each of the gross plots contained four rows and the two border rows formed the discards. Also one plant on either edge of the two middle rows was discarded leaving ten plants per plot for the experiment. Each of the ten experimental plants was tagged with a number serially from one to ten. The ten plants per plot were used in taking the following records:-

1) Yield per plant: Cumulative fresh weight (g) of ripe fruits.
2) Number of fruits per plant: Total number of fruits picked per plant.
3) Average fruit weight per plant: The cumulative fresh fruit weight divided by the total number of fruits produced per plant expressed in grams.

4) Mean Fruit diameter: The mean readings of top, middle and bottom portions of five fruits per plant recorded in centimetres.

5) Mean Fruit length: The mean length (cm) of five fruits per plant.

6) Mean fruit size: The mean volume (cm^3) of five fruits per plant assuming the fruits were conical in shape.

7) 100-seed weight: The weight (g) of 100 air-dried seeds per plant.

8) Plant height: The height (cm) of each plant from soil level to the uppermost shoot tip bearing a flower.

9) Number of branches per plant: The number of branches per plant at the time when full vegetative growth had been attained (when the uppermost shoot tip bore a flower).

10) Days to 50 per cent flowering: The number of days from sowing to the date 50 per cent of the plants in a plot bore flowers.

11) Days to maturity: The number of days from sowing to the date of first picking of the fully ripe fruits.

3.4 STATISTICAL ANALYSES

The data for each trait for the two years were analysed.

The statistical model used for the combined analysis of variance was:-

$Y_{ijk} = \mu + E_i + R_{ij} + G_k + (GE)_{ik} + e_{ijk}$

where,

μ = overall mean

E_i = the effect of ith year; i = 1,2

R_{ij} = the effect of the jth replication in the ith year;

j = 1,2,3,4

G_k = effect of the k^{th} cultivar; k = 1,2,.....16

$(GE)_{ik}$ = the interaction effect between the k^{th} cultivar in the i^{th} environment (year), and assuming

$E_i \sim NID(0, \sigma^2_E)$

$G_k \sim NID(0, \sigma^2_G)$

$e_{ijk} \sim NID(0, \sigma^2)$

NID = Normally and Independently Distributed

The analysis for each character was computed on per plant basis. Entries (cultivars) and years (environments) were treated as random effects.

A combined Anova for the experiment in the two years for each character reduces error and provides more valid estimates of the variance components including the genotype X environment interaction. The combined analysis of variance table with the expected mean squares is given in Table 3.

Table 3: Form of Anova with Expected Mean Squares (EMS) in two years for each character

Source of Variation	df	MS	EMS
Years	(y-1)		
Replications in years	y(r-1)		
Entries	(g-1)	Mg	$\sigma^2 + r\sigma^2_{gy} + ry\sigma^2_g$
Entries x years	(g-1)(y-1)	Mgy	$\sigma^2 + r\sigma^2_{gy}$
Error	y(g-1)(r-1)	Me	σ^2

where,

y = number of years

r = number of replications

g = number of entries

MS = observed mean square of the subscripted effect

σ^2_{gy} = genotype x environment interaction variance

σ^2_g = total genetic variance among entries

σ^2 = error variance

The components of variance and their standard errors (S.E.) were estimated from the EMS using observed MS values of each character, thus:

$\hat{\sigma}^2$ = Me with S.E. = $\sqrt{\frac{2(Me)^2}{df + 2}}$

$\hat{\sigma}^2_{gy} = \frac{Mgy - Me}{r}$ with S.E. = $\sqrt{(\frac{1}{r})^2 \left[\frac{2(Mgy)^2}{df + 2} + \frac{2(Me)^2}{df + 2}\right]}$

$\hat{\sigma}^2 g = \frac{Mg - Mgy}{ry}$ with S.E. $\sqrt{(\frac{1}{ry})^2 \left[\frac{2(Mg)^2}{df + 2} + \frac{2(Mgy)^2}{df + 2}\right]}$

The phenotypic variance was estimated as:

$\hat{\sigma}^2 ph = \frac{Mg - Mgy}{ry} + Me$

with S.E. $\sqrt{(\frac{1}{ry})^2 \frac{2(Mg)^2}{df + 2}}$

F-testswere used in order to determine if the variation among entries and their interaction with the environment (year) were statistically significantly different from zero. The F-tests were used for the combined Anova as follows:-

$F = \frac{Mg}{Me}$ with (g-1), y(r-1) (g-1) d.f. and

$F = \frac{Mgy}{Me}$ with (g-1) (y-1), y(r-1) (g-1) d.f.

For the purpose of multiple comparisons between the entries, the cultivar means were arranged in order of decreasing yield and the least significant difference (L.S.D.) or Critical difference (C.D.) was computed according to the formular given by Bliss (1967).

$L.S.D. = t\sqrt{\frac{2s^2}{ry}}$

where,

s^2 = error mean square

r = number of blocks

y = number of years

t = tabular value of the student's t for P=0.05 or 0.01 and the error d.f. (for the LSD values at 5% and 1% levels of significance respectively)

The genotypic coefficient of variability was estimated by the formular suggested by Burton (1952) and Hanson et al. (1956).

$$G.C.V.\ (\%) = \frac{\sqrt{\sigma^2 g}}{\bar{X}} \times 100$$

where,

$\sigma^2 g$ = genotypic variance of the character

$\bar{X}$ = Mean of the character

G.C.V.= genotypic coefficient of variability

Broad sense heritability estimates (h^2) were obtained by using the formular:-

$$h^2 = \frac{\sigma^2 g}{\frac{\sigma^2}{ry} + \frac{\sigma^2 gy}{r} + \sigma^2 g} \quad \text{with S.E.} = \frac{\text{S.E. } \sigma^2 g}{\sigma^2 ph}$$

where,

$\sigma^2 g$ = genotypic variance

σ^2 = environmental variance

$\sigma^2 gy$ = component of variance due to interaction of genotypes with years.

The expected genetic advance (ΔG) under selection and the expected genetic advance in per cent of mean were estimated by the methods given by Johnson et al.(1955) and Burton and Devane (1963):-

$$\Delta G = h^2 . k . \sigma ph$$

and

$$\Delta G \text{ in } \% \text{ of mean} = \frac{\Delta G}{\bar{X}} \times 100$$

where,

ΔG = expected genetic advance

k = selection intensity (in this study 20 per cent selection pressure was assumed i.e. k = 1.40)

h^2 = heritability

σph = phenotypic standard deviation among the entries

$\bar{X}$ = Mean of character

According to Mode and Robinson (1959) the expectations of mean products in analysis of covariance have the same form as the expected mean squares of Anova and therefore the procedure for the analysis of covariance are analogous to those used for Anova. Table 4 shows the form of analysis of variance and covariance of a pair of characters (a and b) with the expected mean cross-products for two years.

Genotypic and phenotypic correlation coefficients were estimated for pairs of traits measured. The genotypic correlation coefficients were calculated from components of variance and covariance using the foumulae of Mode and Robinson (1959):-

$$r_{gab} = \frac{\sigma gagb}{\sqrt{\sigma^2 ga . \sigma^2 gb}}$$

where

$\sigma gagb$ = genotypic covariance of characters a and b

$\sigma^2 ga$ = genotypic variance of character a

$\sigma^2 gb$ = genotypic variance of character b

r_{gab} = correlation coefficient of characters a and b.

Table 4: Analysis of variance and covariance with observed expected Mean Products for two traits (a and b)

Source of variance	d.f.	Trait a	Trait b	Mean Product ab	Expected Mean Product
Entries	(g-1)	Mga	Mgb	Mgagb	$\sigma ab + \sigma gyagyb + ry\sigma gagb$
Entries x years	(g-1)(y-1)	Mgya	Mgyb	Mgyagyb	$\sigma ab + r\sigma gyagyb$
Error	y(g-1)(r-1)	Mea	Meb	Meaeb	σab

The phenotypic correlations were computed using mean squares and mean cross-products in the formular:-

$$r_{ph} = \frac{Mgagb}{\sqrt{Mga.\ Mgb}}$$

where

Mga = entry mean square of character a

Mgb = entry mean square of character b

Mgagb = entry mean product of characters a and b.

The environmental correlation coefficients were also computed for a pair of characters using the error mean squares and error covariance values. The environmental correlation is the measure of the effect of environment (year) on the association of the characters in each pair:

$$r_{eab} = \frac{\sigma ab}{\sqrt{\sigma^2 a.\ \sigma^2 b}}$$

where,

r_{eab} = environmental correlation coefficient for characters a and b

σab = environmental covariance for characters a and b

$\sigma^2 a$ = environmental variance for character a

$\sigma^2 b$ = environmental variance for character b.

CHAPTER IV

RESULTS

4.1. PHENOTYPIC VARIATION:

The general means for the eleven characters measured among the 16 cultivars including the standard error of the mean, range and the coefficient of variation are given in Table 5. The cultivars showed considerable variation for the different characters. The coefficient of variation ranged from 5.35% to 93.92% for days to maturity and number of fruits per plant respectively. The traits which showed a high level of variation were number of fruits per plant, number of branches per plant, fruit size and fruit weight. Medium level of variation was recorded for yield per plant, fruit diameter and 100-seed weight, while the other characters had low values. The high coefficient of variation recorded for number of fruits per plant showed that there was plant to plant variation in fruit production. Wide ranges in the means were observed for yield per plant, number of branches per plant and number of fruits per plant. In all cases the standard error of the mean was lower than the mean. In general, the characters studied exhibited a wide range of phenotypic variation.

4.2 CULTIVAR MEANS

The cultivar means for the 11 characters measured for each of the 16 cultivars including the standard error of the mean, the least significant differences at

Table 5: General Mean ($\bar{X}$) standard error of the mean (S.E.), range and coefficient of variation (C.V.) for the eleven characters studied.

Characters	$\bar{X}$	S.E.	Range	C.V.%
Yield per plant (g)	240.97	± 7.18	135.24 - 333.99	33.70
No.of fruits per plant	20.34	± 1.69	8.05 - 70.86	93.92
Average fruit weight per plant (g)	16.82	± 0.75	3.33 - 28.61	50.22
Fruit diameter (cm)	2.20	± 0.06	0.77 - 2.92	30.28
Fruit length (cm)	6.80	± 0.10	4.65 - 8.15	16.73
Fruit size (cm^3)	9.64	± 0.47	4.35 - 16.35	55.36
100-seed weight (g)	0.44	± 0.01	0.41 - 0.56	23.57
Plant height (cm)	39.71	± 0.43	33.93 - 47.78	12.31
No.of branches per plant	43.12	± 3.58	22.28 - 178.24	93.79
Days to 50% flowering	84.45	± 0.41	73.88 - 92.75	5.49
Days to maturity	131.95	± 0.62	127.13 - 137.13	5.35

five per cent and one per cent levels of significance are given in Tables A1, A2 and A3 of the appendix for the data of 1981, 1982 and 1981/82 combined respectively. However, from the combined data KD3 was the highest yielder (333.90g) and OY4 (135.20g) was the lowest yielder. The combined analysis showed that the differences in yield per plant for KD2, SO2, SO1, SO4 and KD4 were not statistically significant, but they were significantly different from others. The differences in yield per plant for KN1, KN3, KN2, SO3, OY3 and KD2 were not significant but were significantly higher than the other five cultivars, while OY2, KD1, KN4 and OY1 were not significantly different from each other but were significantly better than OY4.

4.3 CULTIVAR VARIABILITY

The analysis of variance for the different characters is shown in Table 6. The highly significant differences among the entries for all the characters shows that genetic variability exists among the cultivars.

The combined analysis of variance and the result of the F-test for the deviation of the mean squares from zero are also presented in Table 6. Differences between years were highly significant for fruit yield per plant, number of fruits per plant, average fruit weight per plant, fruit diameter, fruit size, 100-seed weight and days to maturity. Significant difference between years was also observed for

Table 6: Combined analysis of variance for different characters of sixteen pepper cultivars grown in Samaru.

Source	d.f	Mean Squares										
		Yield per plant	Number of fruits per plant	Average fruit weight per plant	Fruit diameter	Fruit length	Fruit size	100-seed weight	plant height	Number of branches per plant	Days to 50% flowering	Days to Maturity
Blocks in years	3											
Years	1	47172.865**	580.04**	5370.182**	2.086	1.048*	219.792**	0.959**	14.988	86.790	11.281	2169.758**
Entries	15	31028.467**	2859.278**	428.526**	3.016**	8.516**	170.744**	0.014**	115.240**	1290.660**	155.415**	72.833**
Entries x years	15	8919.880**	55.624*	54.520*	0.203**	1.000**	30.427**	0.009**	15.611	132.966	1.215	53.474**
Error	45	2059.374	29.004	2.229	0.049	0.193	2.688	0.000	9.170	95.467	3.203	11.434

* = Significant at .05 level

** = Significant at .01 level

fruit length, while no significant differences between years were observed for plant height, number of branches per plant and days to 50% flowering. The non-significant genotype x year mean squares for plant height, number of branches per plant and days to 50% flowering suggest the stability of these characters among the cultivars. The variance due to genotype x environment interaction was very large for yield per plant and this indicated that yield per plant was greatly influenced by the environment. The genotype x year interaction variance was also highly significant for fruit diameter , fruit length, fruit size, 100-seed weight and days to maturity. Significant genotype x year interaction was observed for number of fruits per plant and average fruit weight per plant, while non-significant genotype x year interaction was recorded for plant height, number of branches per plant and days to 50% flowering.

4.4 ESTIMATES OF GENETIC VARIANCE COMPONENTS

The components of genetic variance were computed from the results of the analysis of variance. Table 7 shows the estimates of genotypic variance, genotype x environment (year) interaction variance, phenotypic variance and environmental variance with their respective standard errors. All the characters studied had positive genetic variance estimates. In all cases the standard errors were less than the estimates except for days to maturity.

Table 7: Estimates of phenotypic variance (σ^2_{ph}), Genotypic variance (σ^2_{g}), Genotype X Environment interaction variance (σ^2_{gy}) and environmental variance (σ^2_{e}) with their respective Standard Errors (±)

Characters	σ^2_{ph}	σ^2_{g}	σ^2_{gy}	σ^2_{e}
Yield per plant	3449.78 ± 1334.22	2763.57 ± 1384.88	1715.13 ± 266.61	2059.37 ± 424.23
No. of fruits per plant	355.75 ± 122.95	350.46 ± 122.67	6.66 ± 2.14	29.00 ± 5.98
Average fruit weight per plant	50.75 ± 18.43	46.75 ± 18.53	12.57 ± 1.51	4.23 ± 0.87
Fruit diameter	0.37 ± 0.13	0.35 ± 0.13	0.04 ± 0.01	0.05 ± 0.01
Fruit length	1,02 ± 0.37	0.94 ± 0.37	0.02 ± 0.03	0.19 ± 0.04
Fruit size	19.61 ± 7.34	17.54 ± 7.44	6.94 ± 0.85	2.67 ± 0.55
Plant height	14.00 ± 4.96	12.45 ± 4.99	1.16 ± 0.64	9.17 ± 1.89
No. of branches per plant	1611.49 ± 555.15	1597.21 ± 553.84	9.38 ± 6.15	95.47 ± 19.67
Days to 50% flowering	19.55 ± 6.68	19.28 ± 6.67	0.50 ± 0.17	3.20 ± 0.66
Days to maturity	6.48 ± 3.13	2.42 ± 3.88	10.51 ± 1.58	11.43 ± 2.36

The phenotypic, genotypic and environmental variance estimates were high for yield per plant, number of branches per plant and number of fruits per plant, while the genotype x year interaction variance estimate was high for only yield per plant. Generally, the phenotypic variance estimates were higher than those of the genotypic, genotype x year and environmental variance estimates. The phenotypic standard errors were higher than the genotypic standard errors for number of fruits per plant, number of branches per plant and days to 50% flowering. Also the environmental variance estimates were higher than genotype x year interaction variance for all the traits except average fruit weight per plant and fruit size.

4.5 ESTIMATES OF GENOTYPIC COEFFICIENT OF VARIATION, HERITABILITY, EXPECTED GENETIC ADVANCE AND EXPECTED GENETIC ADVANCE IN PERCENT OF MEAN

The estimates of genotypic coefficient of variation, expected genetic advance, expected genetic advance in per cent of mean and broad-sense heritability with their standard errors for the 11 traits are presented in Table 8. The results showed that the characters with high phenotypic coefficient of variation (Table 5) also had high genotypic coefficient of variation (Table 8).

As the data for individual plants within plots were available, the broad-sense heritability estimates were computed on per plant basis rather than on per plot.

All the heritability estimates were high except for days to maturity and 100-seed weight. The heritability estimates obtained ranged from 37.36% for days to maturity to 99.11% for number of branches per plant. The standard error for days to maturity was however, higher than the heritability estimate.

The expected genetic advance, ranged from 0.03 to 65.87 for 100-seed weight and yield per plant respectively. The results indicate that high heritability estimates are not necessarily associated with high expected genetic advance estimates. The expected genetic advance in per cent of mean ranged from 1.01 to 129.17 for days to maturity and number of branches per plant respectively. It has been noted that characters which had lowest heritability estimates also had lowest expected genetic advance in per cent of mean, however, characters having high heritability estimates were not in all cases having high expected genetic advance in per cent of mean. The traits which had high heritability as well as high genetic advance in per cent of mean were yield per plant and number of branches per plant, while number of fruits per plant had moderate estimates. The traits with high genetic gain were number of fruits per plant and number of branches per plant while fruit size had moderate genetic gain.

Table 8: Estimates of Genetic Coefficient of variability (G.C.V.) in per cent, Broad sense Heritability (h^2) with Standard Error (±), Expected Genetic Advance (ΔG) and Expected Genetic Advance in per cent of Mean.

Characters	G.C.V. %	h^2	Δ G	Δ G in per cent of mean
Yield per plant	21.82	0.8011 ± 0.501	65.87	27.34
No. of fruits per plant	92.03	0.9851 ± 0.345	26.01	127.88
Average fruit weight per plant	40.65	0.9272 ± 0.368	9.22	54.82
Fruit diameter	27.10	0.9565 ± 0.353	0.81	36.82
Fruit length	14.26	0.9261 ± 0.363	1.31	19.27
Fruit size	43.45	0.8944 ± 0.379	5.55	57.57
100-seed weight	7.20	0.5000 ± 0.500	0.03	6.82
Plant height	8.89	0.8894 ± 0.356	4.66	11.74
No. of branches per plant	92.68	0.9911 ± 0.344	55.70	129.17
Days to 50% flowering	5.20	0.9859 ± 0.341	6.10	7.22
Days to maturity	1.18	0.3736 ± 0.598	1.33	1.01

4.6 CORRELATIONS

Correlation coefficients (r) were computed from the analyses of variance and covariance. All possible phenotypic, genotypic and environmental correlations of the different characters were computed from the means. The phenotypic, genotypic and environmental correlation coefficients are presented in Table 9. All correlation coefficients obtained were positive. From the result, significant positive phenotypic correlations were observed between yield per plant with number of fruits per plant (rph = 0.273) and number of branches per plant (rph = 0.586). The number of fruits per plant was phenotypically significantly correlated with average fruit weight per plant (rph = 0.192), plant height (rph = 0.203), number of branches per plant (rph = 0.271), days to 50% flowering (rph = 0.227) and days to maturity (rph = 0.183).

Most of the genotypic correlations were low, but the following traits were positively and significantly correlated:- yield per plant with number of fruits per plant (rg = 0.324), average fruit weight per plant (rg = 0.150), and number of branches per plant (rg = 0.692); number of fruits per plant with average fruit weight (rg = 0.154), plant height (rg = 0.201), number of branches per plant (rg = 0.258) and days to 50% flowering (rg = 228); average fruit weight per plant with plant height (rg = 0.516), days to 50% flowering (rg = 0.633)

Table 9: Phenotypic, Genotypic and Environmental Correlations between different characters for 1981/82 [1]

	Number of fruits per plant	Average fruit weight per plant	Fruit diameter	Fruit length	Fruit size	100-seed weight	Plant height	Number of branches	Days to 50% flowering	Days to maturity
Yield per plant	0.273***	0.133	0.010	0.017	0.014	0.001	0.016	0.586***	0.071	0.048
	0.324***	0.150*	0.011	0.019	0.080	0.000	0.016	0.692***	0.083	0.055
	0.059	0.051	0.006	0.010	0.051	0.000	0.072	0.264**	0.047	0.140
Number of fruits per plant		0.192*	0.011	0.046	0.097	0.002	0.203*	0.271***	0.227**	0.183*
		0.154*	0.009	0.043	0.059	0.000	0.201*	0.258**	0.228**	0.138*
		0.448***	0.047	0.092	0.451***	0.000	0.652***	0.350***	0.397***	0.000
Average fruit weight per plant			0.019	0.095	0.023	0.006	0.522***	0.128	0.594***	0.12***
			0.019	0.097	0.002	0.023	0.516***	0.113	0.638***	0.224**
			0.110	0.228**	0.886***	0.000	0.779***	0.247**	0.000	0.709***
Fruit diameter				0.556***	0.853***	0.068	0.158*	0.008	0.139	0.203*
				0.574***	0.378***	0.053	0.164*	0.007	0.134	0.381***
				0.576***	0.119	0.000	0.085	0.026	0.144	0.076
Fruit length		0.170*	0.038	0.247**	0.020		0.233**	0.220**	0.344***	
		0.193*	0.033	0.247**	0.019		0.220**	0.220**	0.629***	
		0.242**	0.000	0.162*	0.051		0.277***	0.144		
Fruit size			0.009	0.820***	0.066		0.000	0.654***		
			0.008	0.820***	0.051		0.943***	0.371***		
			0.000	0.771***	0.249**		0.000	0.718***		
100-seed weight				0.008	0.001		0.009	0.014		
				0.000	0.000		0.007	0.020		
				0.000	0.000		0.000	0.000		
Plant height					0.090		0.874***	0.000		
					0.084		0.815***	0.000		
					0.376***		0.000	0.000		
Number of branches							0.100	0.076		
							0.100	0.041		
							0.220**	0.719***		
Days to 50% flowering								0.519***		
								0.025		
								0.633***		

[1] The upper, middle and lower correlations in each cell refer to the phenotypic, genotypic and environmental correlations respectively.

* = significant at .05 level, ** = significant at .01 level and *** = significant at .001 level.

and days to maturity (rg = 0.224); fruit diameter with fruit length (rg = 0.574), fruit size (rg = 0.378), plant height (rg = 0.164) and days to maturity (rg = 0.381). Very highly significant environmental correlations were obtained between number of fruits per plant with average fruit weight (re = 0.448), fruit size (re = 0.451), plant height (re = 0.652), number of branches per plant (re = 0.350) and days to 50% flowering (re = 0.397); average fruit weight per plant with fruit size (re = 0.886), plant height (re = 0.779) and days to maturity (re = 0.709); fruit diameter with fruit length (re = 0.576); fruit length with days to 50% flowering (re = 0.277); fruit size with plant height (re = 0.771), and days to maturity (re = 0.718); and days to maturity with number of branches per plant (re = 0.719) and days to 50% flowering (re = 0.633). The environmental correlations were also highly significant between yield per plant with number of branches per plant (re = 0.264); average fruit weight per plant with fruit length (re = 0.228) and number of branches per plant (re = 0.247); fruit length with fruit size (re = 0.242); and number of branches per plant with days to 50% flowering (re = 0.220).

CHAPTER V

DISCUSSION

The results of the present investigation revealed the presence of considerable variability in all the characters studied. The phenotypic means of the different cultivars also showed a wide range of variation for the different traits measured (Tables A1, A2 and A3 of the appendix). The cultivars also showed differential performance in the two years except K^{D3}. This is because KD3 is the local material and might be more adapted to the area. For fruit size the differences were also large, and the 1981 fruits were mostly larger than those for 1982. On the other hand, the mean number of fruits per plant for the two years was almost the same and only few cultivars showed differential performance in the two years. A wide variation in some of these characters in different collections of pepper genotypes have been reported by Nandpuri et al. (1971), Arya and Saini (1977) and Dutta et al. (1979). The range in the days taken to reach maturity was lower than that in the days taken to reach 50 per cent flowering (Table 5). Similar result have been reported by Nandpuri et al. (1971) and Arya and Saini (1977) in other pepper varieties. The high phenotypic coefficients of variability obtained for number of fruits per plant, number of branches per plant, fruit size and fruit weight conforms to the results obtained by Kirti et al. (1972).

The analysis of variance (Table 6) showed highly

significant differences for all the characters measured. Year differences were not significant for plant height, number of branches per plant and days to 50 per cent flowering, but for all other characters these variations were significant. This indicates that plant height, number of branches per plant and days to 50 per cent flowering will not change much in different environments and are relatively more stable. The genotype x environment (year) interaction variance was not significant for plant height, number of branches per plant and days to 50 per - cent flowering, but was significant for number of fruits per plant, and average fruit weight per plant and highly significant for yield per plant, fruit diameter, fruit length, fruit size, 100-seed weight and days to maturity. This shows that the environment plays a great role in determining yield per plant as well as the fruit diameter, fruit length, fruit size, 100-seed weight and days to maturity. As yield is a quantitative trait involving so many related characters in its composition, it should be expected to be greatly influenced by the environment. Nandpuri et al. (1971) reported that the genotype x environment interaction accounted for all the variations in fruit size.

As the presence of genetic variability is of importance to plant breeders, genetic variances as well as phenotypic and environmental variances were computed to study the available variability in the population. It has

been reported by Arya and Saini (1977) and Dutta et al. (1979) that a good amount of genetic variability exists in other pepper populations. From Table 7, it could be seen that high phenotypic, genotypic and environmental variances exist for yield per plant, number of branches per plant and number of fruits per plant, while the genotype x environment interaction variance was high for only yield per plant. As the genotypic variances in all cases were higher than their respective environmental variances, the result revealed that considerable genetic variability was available for improvement. However, the high genotype x environment interaction variance for yield per plant indicates that this trait would vary with years over a wide area. Cockerham (1963) indicated that a large interaction component of variance could be the result of the genetic variance being larger in one environment than the other, and this could be true in this investigation. It was also reported (Singh and Singh, 1977), that the genetic variances are greatly biased by the environmental influence. The additive genetic variance appeared to be the major source of variation in most of their crosses for plant height. However, in the present study, all traits except yield per plant had relatively low genotype x environment interaction variances when compared with their respective phenotypic and environmental variances.

The genetic variance estimated from the present investigation was however, the total genetic variance because it was impossible to separate it into its component parts

(additive, dominance and epistatic variances) owing to the experimental materials and design used.

Even though the genetic variance estimate for yield per plant was high, its corresponding genotypic coefficient of variability was relatively low indicating that the range of genetic variability existent in the trait was relatively low. However, the genotypic coefficient of variation does not indicate the amount of variation that is heritable. Heritability estimates are used for the determination of the proportion of the total variation that is genetic. In other words, heritability indicates the effectiveness with which selection of genotypes can be based on phenotypic performance. Broad sense heritability estimates were high for most of the characters, moderate for 100-seed weight and low for days to maturity. Similar results have been obtained by Nandpuri *et al.* (1971), Kirti *et al.* (1972) and Dutta *et al.* (1979). The high estimates of heritability recorded are encouraging, because the population can be subjected to mass selection or any other suitably modified selection procedure to exploit any additive effect. The standard error for days to maturity was higher than the actual heritability estimate and hence the estimate was not different from zero.

It has been shown by Johnson *et al.* (1955a) that heritability estimates along with genetic advance and genetic gain are more useful in predicting the resultant effect of selecting the best individuals in a given population than heritability estimates alone. It has also

been pointed out (Swarup and Chaugale, 1962), that high heritability is not always accompanied with high genetic advance. If heritability is mainly due to non-additive gene effects, the expected genetic advance would be low, and if there are additive gene effects, high genetic advance may be expected (Panse, 1957). Broad sense heritability estimates are useful when high genetic gain in a particular trait is also possible (Kaul and Bahn, 1974). Hence high heritability estimates along with high genetic advance estimates are more effective for selection purposes and should therefore be considered jointly. From the results of this study, the traits which have high heritability estimates as well as high genetic advance and high genetic advance in per cent of mean are yield per plant, number of branches per plant and number of fruits per plant. This shows that yield per plant as well as number of branches per plant and number of fruits per plant could be improved upon through selection for these characters. Similar results have been reported by Arya and Saini (1977). The other characters which show low genetic advance but high heritability (fruit diameter and 100-seed weight in particular), indicate that the expression of these traits was conditioned by non-additive genes.

Robinson et al. (1951) have stated that most of the characters of economic importance such as yield, are complex in inheritance and may involve several related characters and hence the degree of phenotypic and genotypic

correlations of the characters is important. The coefficients of genetic correlations are a measure of the commonness of genes governing the determination of two characteristics. That is, if two characteristics have no genes in common, we would expect them to be uncorrelated (Mode and Robinson, 1959). To the plant breeder, the most important correlations are those between yield and other related traits. These correlations are not only of interest from a theoretical consideration of the quantitative inheritance of these characters, but of practical value as well aince selection usually involves the changing of two or more traits simultaneously. The selection for one character results in a progress for all positively correlated but in a regress to all negatively correlated characters. For these reasons the phenotypic, genotypic and environmental correlation coefficients were computed for all possible combinations (Table 9).

Phenotypically, significant positive correlations were observed between yield per plant with number of fruits per plant. Genotypic correlations were significant between yield per plant with number of fruits per plant, average fruit weight per plant and number of branches per plant. These correlations indicate that yield improvement is closely associated with number of fruits, average fruit weight and number of branches. As the yield showed no significant phenotypic correlations with days taken to 50 per cent

flowering and days to maturity, it should be relatively easy to select early maturing cultivars without appreciable decrease in yield. Similar results have also been noted by Kirti et al. (1972). Yield per plant again showed no significant environmental correlations with all traits except number of branches per plant. This shows that the environmental influence on yield is only through the number of branches produced per plant.

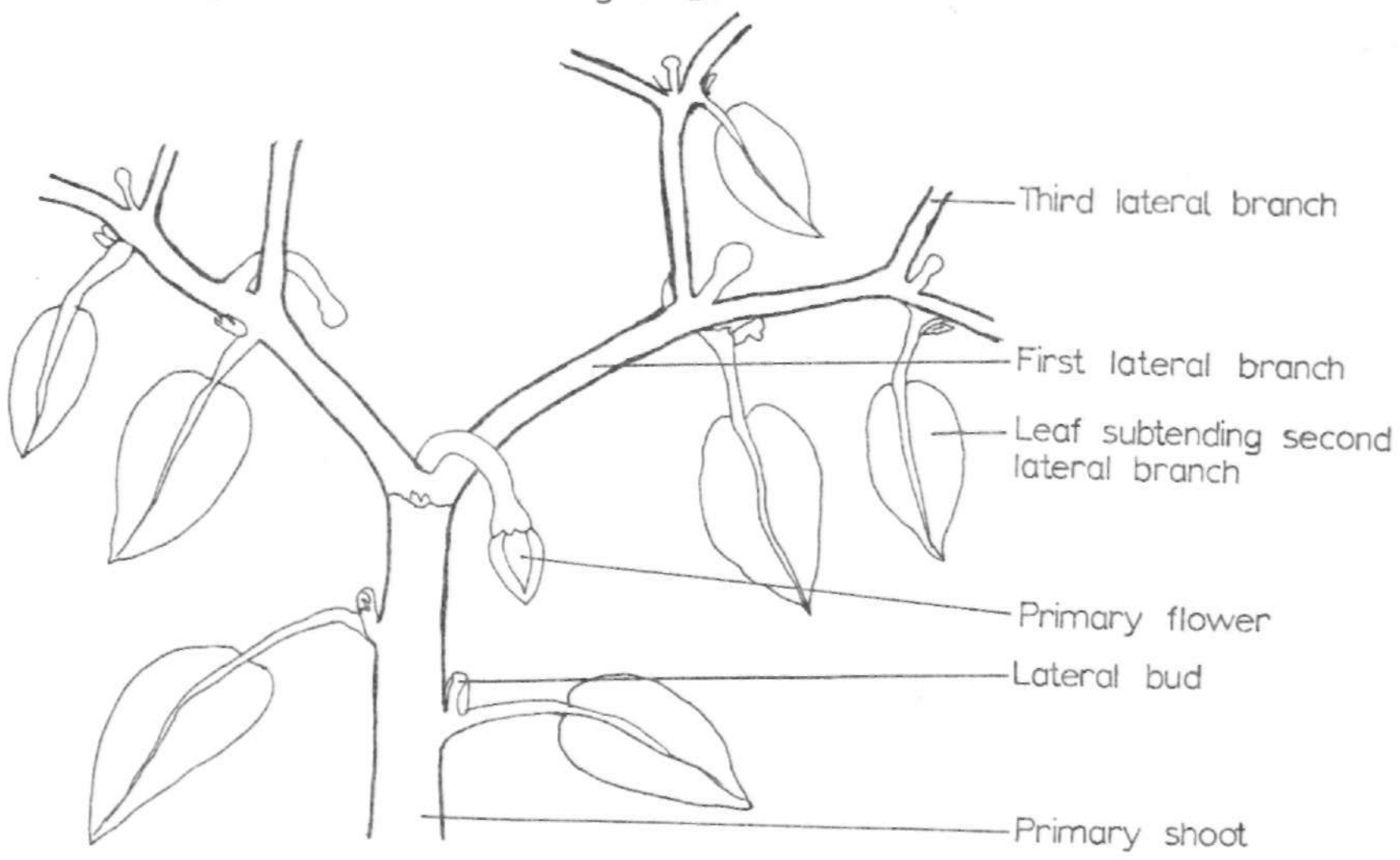
Gill et al. (1977) indicate that multiple regression analysis in pepper have confirmed the importance of the number of fruits per plant as it alone accounted for about 50 per cent of the variability in yield. For this reason the degree of correlation between number of fruits per plant with other related traits will be of benefit here. The phenotypic correlations were significant between number of fruits per plant, with average fruit weight per plant, plant height, number of branches per plant, days to 50 per - cent flowering and days to maturity (Table 9). Similar results have been reported by Kirti et al. (1972). Also the genotypic correlations were significant for number of fruits per plant with average fruit weight per plant, plant height, number of branches per plant and days to 50 per cent flowering. This result shows that the increase in the magnitude of average fruit weight, plant height, number of branches per plant and days to 50 per cent flowering may be regarded as indicative of increase in fruit yield.

However, the days to 50 per cent flowering is generally considered as the indirect yield component which influences the other factors which are directly related to the growth and development of the crop plant (Dutta et al., 1979). The environmental correlations were, however, highly significant between number of fruits per plant with average fruit weight, fruit size, plant height, number of branches per plant and days to 50 per cent flowering. This means that the environment which affects average fruit weight, fruit size, plant height, number of branches per plant and days to 50 per cent flowering also affects the yield per plant through the number of fruits produced per plant.

From the results obtained, it could be seen that there is an opportunity for improving yield per plant through its components (number of fruits per plant, average fruit weight per plant and number of branches per plant). Continuous selection for these traits will therefore indirectly increase yield. The most correlated trait with yield per plant from this study both phenotypically and genotypically was found to be number of branches per plant contrary to Nandpuri et al. (1970) and Kirti et al. (1972) who found that fruit number per plant was the most correlated trait with yield per plant in Chillies. Critical observation however, will indicate that these results are not entirely contradictory, for the

association of number of branches per plant with fruit yield can be explained on the basis of the branching system in pepper (Fig. 1). The branching system simulates a dichotomy where flower buds terminate the growth of a shoot and at the same time initiate the development of two lateral branches (Olarewaju, 1980). For this reason it would be apparent that a larger number of branches per plant would give more flowers per plant and hence a larger number of fruits produced per plant.

Fig. 1. A diagrammatic representation of a typical pepper (Capsicum annuum, L.) plant showing dichotomous branching (x ½)



CHAPTER VI

SUMMARY

Sixteen cultivars of peppers collected from different ecogeographical zones of Nigeria were grown in a randomized complete block design with four replications at Samaru, Nigeria during the wet seasons of 1981 and 1982. Each plot within a replication consisted of four rows and the two border rows formed the discards. Also one plant on either edge of the two middle rows was discarded leaving 10 plants per plot from which measurements were taken. The data collected on 11 quantitative traits were combined and analysed. Analyses of variance and covariance were computed for all traits.

The variations observed within each trait were highly significant. The traits which indicated a high level of variation were number of fruits per plant, number of branches per plant, fruit size and average fruit weight per plant. Population means were significantly different for each trait. Significant differences were also observed for years in most of the traits. The cultivar x year interactions were also significant for all traits except plant height, number of branches per plant and days to 50 per cent flowering.

Genetic variance estimates obtained were all positive for every trait. The genetic variance estimates for yield per plant, number of branches per plant and number of fruits per plant were highest and the genotype x year interaction variance was highest for yield per plant.

The estimates of genetic coefficient of variation, heritability, expected genetic advance and expected genetic advance in per cent of mean for various traits revealed that the range of variability in the population was large indicating that improvement through selection is possible.

Fruit yield per plant was positively and significantly correlated with average fruit weight per plant, plant height, number of branches per plant and days to 50 per - cent flowering. The positive and significant phenotypic and genotypic correlations between yield per plant and its components (number of fruits per plant, average fruit weight per plant, and number of branches per plant) suggests that selection for these yield components would indirectly increase yield per plant.

On basis of the performance of individual cultivars for yield per plant and its components, KD3, S02, S01, S04 and KD4 were the best types and could be useful for future breeding programmes.

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Table A1: Mean performance of the sixteen cultivars grown in Samaru in 1981

Cultivar	Yield per plant (g)	Number of fruits per plant	Average fruit weight per plant (g)	Fruit diameter (cm)	Fruit length (cm)	Fruit size (cm^3)	100-seed weight (g)	Plant height (cm)	Number of branches per plamt	Days to 50% flowering	Days to maturity
S01	367.35	24.80	13.72	2.06	6.83	6.10	0.35	43.23	38.50	92.00	132.75
KD3	347.14	18.85	16.99	2.52	6.09	10.16	0.40	45.40	44.38	85.00	132.75
S04	337.96	74.75	4.39	1.13	4.49	1.39	0.48	44.83	172.90	77.00	133.25
KD4	294.70	16.70	15.47	2.78	5.17	10.49	0.37	47.73	35.78	83.25	133.75
S02	294.22	14.88	19.24	2.49	6.96	12.16	0.38	44.93	31.85	84.00	133.75
KN1	257.07	8.83	27.84	2.91	7.90	17.37	0.35	39.73	27.78	85.00	133.00
KN2	216.48	6.78	35.64	3.31	7.79	22.26	0.36	37.38	25.45	85.00	133.00
KN3	214.23	9.38	24.94	2.44	8.36	13.17	0.38	39.65	29.93	85.00	133.25
OY3	186.38	55.18	3.31	0.79	7.57	1.23	0.39	35.85	87.83	85.00	134.25
S03	184.09	13.53	12.46	2.00	6.31	7.86	0.33	36.25	34.35	92.75	134.25
OY2	171.42	6.25	28.10	2.74	7.91	15.30	0.29	35.70	24.78	85.75	143.25
KN4	170.57	5.75	30.75	2.86	8.18	17.53	0.36	37.53	23.88	85.00	133.75
KD2	152.88	5.95	28.60	3.04	6.74	16.45	0.28	37.03	25.45	72.75	145.00
KD1	133.57	7.25	20.17	2.22	8.28	10.78	0.30	36.15	42.30	81.50	144.75
OY4	120.52	13.60	8.82	1.77	5.82	4.81	0.32	36.88	28.95	83.50	143.25
OY1	102.35	8.98	11.49	2.02	5.87	8.14	0.31	31.63	21.35	84.00	133.00
Mean	221.78	18.21	18.87	2.32	6.89	10.95	0.35	39.37	42.30	84.16	136.06
S.E. ±	11.67	2.41	1.22	0.09	0.15	0.76	0.01	0.70	4.91	0.61	0.60
L.S.D. 5%	71.68	6.93	2.76	0.95	0.63	3.07		4.97	20.32	2.75	1.45
L.S.D. 1%	95.74	9.25	3.69	1.27	0.84	4.11		6.64	27.14	3.67	1.94

Table A2: Mean performance of the sixteen cultivars grown in Samaru in 1982

Cultivar	Yield per plant (g)	Number of fruits per plant	Average fruit weight per plant (g)	Fruit diameter (cm)	Fruit length (cm)	Fruit size (cm^3)	100-seed weight (g)	Plant height (cm)	Number of branches per plant	Days to 50% flowering	Days to maturity
SO2	344.80	19.70	16.40	2.51	6.93	11.48	0.50	44.43	35.54	85,75	125.00
KD3	320.66	19.70	16.18	2.25	6.04	8.03	0.53	43.00	30.40	86.00	130.00
KD4	316.41	17.75	17.40	3.07	5.13	12.65	0.58	47.83	35.08	83.25	131.25
KD2	308.25	10.93	24.81	2.53	8.15	14.12	0.59	40.55	29.20	75.00	129.00
SO3	286.35	21.23	11.93	1.54	6.28	6.89	0.49	40.23	42.85	92.75	123.25
SO4	281.39	66.98	3.88	1.06	4.81	1.42	0.64	41.28	183.58	78.50	131.00
KN3	278.33	13.98	18.54	2.22	7.28	9.36	0.49	40.30	35.95	85.50	121.00
OY3	275.12	72.05	3.35	0.75	7.68	1.15	0.45	38.55	107.23	84.75	131.00
SO1	258.96	22.73	10.85	2.11	6.48	7.62	0.51	40.83	31.33	91.25	129.00
KN2	258.50	12.03	21.58	2.44	6.49	10.44	0.59	42.13	21.60	85.00	126.25
KN1	252.43	12.32	18.17	2.15	7.54	9.18	0.54	41.03	23.55	85.25	128.75
OY2	232.90	10.55	22.58	2.54	7.80	13.22	0.49	37.58	22.65	86.00	129.50
OY1	214.41	19.15	10.99	1.92	6.24	6.02	0.53	36.23	32.35	85.00	126.75
KD1	210.82	12.73	18.31	2.14	8.03	9.63	0.59	36.48	20.95	82.25	129.50
KN4	173.45	10.35	14.23	2.18	6.59	8.17	0.46	33.63	22.85	85.75	127.25
OY4	149.95	17.40	17.19	1.58	5.92	3.89	0.45	36.78	28.03	84.00	126.75
Mean	260.17	22.47	14.77	2.06	6.71	8.33	0.53	40.05	43.94	84.75	127.83
S.E. ±	7.74	2.35	0.79	0.08	0.13	0.51	0.01	0.51	5.24	0.55	0.82
L.S.D. 5%	45.27	5.52	2.19	0.41	0.67	2.64	0.05	3.64	10.11	2.73	6.46
L.S.D. 1%	60.47	7.37	2.93	0.55	0.89	3.53	0.06	4.86	13.51	3.65	8.63

Table A3: Mean performance of the sixteen cultivars grown in Samaru for 1981/82 combined

Cultivar	Yield per plant (g)	Number of fruits per plant	Average fruit weight per plant (g)	Fruit diameter (cm)	Fruit length (cm)	Fruit size (cm^3)	100-seed weight (g)	Plant height (cm)	Number of branches per plant	Days to 50% flowering	Days to maturity
KD3	333.90	19.28	16.58	2.38	5.06	9.10	0.47	44.20	37.39	85.50	131.38
S02	318.26	17.29	17.82	2.50	6.95	11.82	0.44	44.68	33.70	84.88	129.38
S01	313.16	23.76	12.28	2.01	6.66	6.86	0.43	42.03	34.91	91.63	130.88
S04	309.67	70.86	4.13	1.10	4.65	1.41	0.56	43.05	178.24	77.75	132.13
KD4	305.55	17.23	16.44	2.92	5.15	11.57	0.47	47.78	35.43	83.25	132.50
KN1	254.74	10.57	23.00	2.53	7.72	13.28	0.45	40.38	25.66	85.13	130.88
KN3	246.28	11.68	21.74	2.32	7.82	11.26	0.44	39.98	32.94	85.25	127.13
KN2	237.49	9.40	28.61	2.87	7.14	16.35	0.47	39.75	23.53	85.00	129.63
S03	235.22	17.38	12.19	1.77	6.30	7.37	0.41	38.24	38.60	92.75	128.75
OY3	230.75	63.61	3.33	0.77	7.62	1.19	0.42	37.20	97.53	84.88	132.63
KD2	230.56	8.44	26.70	2.78	7.45	15.29	0.43	38.79	27.33	73.88	137.00
OY2	202.16	8.40	25.34	2.64	7.85	14.26	0.39	36.64	23.71	85.88	136.38
KD1	172.20	9.99	19.24	2.18	8.15	10.20	0.45	36.31	22.28	81.88	137.13
KN4	172.01	8.05	22.49	2.52	7.38	12.85	0.41	35.58	23.36	85.38	130.50
OY1	158.38	14.06	11.24	1.97	6.05	7.08	0.42	33.93	26.85	84.50	129.88
OY4	135.24	15.50	8.00	1.67	5.87	4.35	0.38	36.83	28.49	83.75	135.00
Mean	240.97	20.34	16.82	2.19	6.80	9.64	0.44	39.71	43.12	84.45	131.95
S.E. ±	7.18	1.69	0.75	0.06	0.10	0.47	0.01	0.43	3.58	0.41	0.62
L.S.D. 5%	45.70	5.42	2.07	0.23	0.44	1.65		3.05	9.84	1.80	3.41
L.S.D. 1%	61.04	7.24	2.77	0.30	0.59	2.21		4.07	13.14	2.41	4.48