GENETIC VARIABILITY STUDIES USING LINE x TESTER ANALYSIS IN OKRA [*Abelmoschus esculentum* (L.) Moench] IN NORTERN GUINEA SAVANNAH OF NIGERIA

By

GARBA, Yusuf Mwada,

PhD/CP/14/O804

A THESIS SUBMITTED TO THE DEPARTMENT OF CROP PRODUCTION AND HORTICULTUE, SCHOOL OF AGRICULTURE AND AGRICULTURAL TECHNOLOGY YOLA, IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF DEGREE OF PHILOSOPHY (PH.D) OF THE MODIBBO ADAMA UNIVERSITY OF TECHNOLOGY YOLA

JUNE 2019

Declaration

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

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Garba, Yusuf Mwada Date

Dedication

This piece of work is dedicated to all those who struggle to make agriculture profitable.

Approval

This thesis entaitled 'Genetic Variability Studies Using Line x Tester Analysis in Okra [*Abelmoschus esculentum* (L.) Moench] meets the regulations governing the award of Doctor of Philosophy of the Modibbo Adama University of Technology Yola and is approved for its contribution to knowledge and its literary presentation.

Prof. A. M. Kadams — Date
Supervisor

Prof. S. Y. Simon, — Date
Co-supervisor

Dr. A. B Mustapha — Date

Internal examiner

Prof. D. Aminu Date
DateUniversity of Maiduguri
External Examiner

Dr. A. B. Mustapha Date
Head of Department

Prof. A. A. U. Jongur Date
Dean, School of the SAAT

Prof. A. A. Adebayo Date
Dean, School of Postgraduate Studies

Acknowledgement.

In the preparation of this thesis, quite a number of individuals have contributed in one way or the other to its successful conclusion. First of all I wish to extend my unreserved gratitude to my thesis supervisors Profs A. M. Kadams and Simon, S. Y. whose fatherly advice, patience, tolerance, assistance and fruitful criticisms encouraged me to make this work as it is. May God continue to encourage them to encourage others. I am greatly indebted to Dr. A .B. Mustapha the Head of Department for his humility, support and encouragement. The entire academic staff of Department of Crop Production and Horticulture including Professor D. T. Gungula, the Postgarduate Co-odinator Professor J. B. Abakura, Professor B. B. Jakusko and Dr. V. T. Tame are being appreciated for their supports and fruitful criticisms.

I am greatly indebted and highly appreciated the patience, understanding and the prayerfulness of my wife, Mallama Aishatu Audu and our children; Halima, Zulihat, Jamila, Umar, Abubakar, Mohammed – Faisal, Maryam and Hajara throughout my studies. I pray to Allah to continue be with us all to enjoy the fruits of this work. I also wish to extend my appreciation to Mallam Mahmoud Adamu Gella and his family members for helps they rendered to me during the study.

I thank the management of Adamawa State College of Education, Hong for granting me the fellowship to pursue this study most especially Professor. Pongri who has encouraged the entire staff of the College to pursue further education. I also appreciated the support and encouragement of the College Registrar Mallam Abdullahi Abubakar and the Deputy Provost Dr. (Mrs). Isa Nemmi. I am also thankful to my colleagues in the Department of Agricultural Education Adamawa State College of Education, Hong for their understanding and encouragement.

Abstract.

This study was undertaken to examine the general and specific combining ability effects, genetic components, correlation, heritability, genetic advance and path coefficient in forty four (44) okra genotypes (parent and crosses) to investigate and establish vital genetic information for identifying promising parents and crosses with good breeding values of important agronomic characters for developing high yielding okra varieties. The line by tester mating design was used to cross four male testers with eight female lines. The twelve parents and thirty two cross combinations were evaluated in two locations viz: Hong and Yola in a randomized complete block design (RCBD) with three replications in the 2017 cropping season. The result obtained revealed that the variances for entries, parents and crosses were significant for most of the characters implying that the genotypes used were highly variable and amenable to selection procedures. The GCA and SCA variances being significant for some characters suggests that both additive and none-additive gene effects were important in the genetic control of these characters. The none-additive gene effect was more predominant with a relatively higher proportion of SCA was responsible for the expression of all the characters signifying that the prevalence of non-additive gene action determining these characters further suggests that a breeding strategy must be adapted that would take cognizance of the gene effects simultaneously. Genetic components analysis revealed that ðpcv was higher than ðgcv for all the characters indicating that environmental influence was low suggesting that selection for these characters con be done based on their phenotypic performances. Gella 1 and Dirbuni (the best general combiners) were good parents that can be used for multiple crossing programmes. Gella 1 x Pukum 2 and Pukum 2 x Dirbuni were good cross combinations that could generate a population with large gene pool from which superior varieties could be produced. Days to 50% flowering had shown to be the best character to select for in this study because it exhibited outstanding significant values for general combining abilities, specific combining abilities, heritability and genetic advance.There was close correlation between SCA and the *per se* performance of some crosses suggesting that the *per se* performance could be used to select the best cross combination for this characters and the best cross combinations in terms of SCA effect involve one or both parents as good general combiners. The significant positive genotypic correlations in general were higher than corresponding significant positive phenotypic correlations for most of the characters in this study suggest very strong inherent association between various characters at genetic level. Correlation studies had indicated that pod width and number of pods were reliable characters to select for when breeding for high yielding okra varieties as they show positive correlation with yield at genotypic level. Path coefficient revealed that establishment, number of leaves at 50% flowering, number of branches per plant and plant height were reliable characters to select for since they had shown highly significant direct effects on yield and had indirect effects through which other yield factors influence yield. Further research is needed to confirm some of the findings over more locations and years.

Keywords

Abelmoschus esculentum, genetic components, path coefficient, additive gene effects, none-additive gene effects

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CHAPTER ONE

INTRODUCTION

Okra (*Abelmoschus esculentum* (L) Moench) also known as ladies 'fingers' are valued for its edible green seed pods (fruits). It is one of the widely grown vegetables in the world especially Nigeria. There exist two major classes of okra in West Africa: the Conventional, *Abelmonschus esculentus*, a native of Asia and the unconventional, the *Abelmonschus callei* a native of Africa which grows naturally in many parts of West Africa especially in the marginal lands (roadsides, backyard farms and wastelands), Martin *et al*. (1981) and Ojo *et al.* (2012)

Okra plant is believed to have originated in South Asia, Ethiopia or West Africa especially Nigeria, (Joshi *et al*., 1974). It is now cultivated in the tropical, subtropical and warm temperate regions of the world. About 9.641 million metric tonnes of okra are produced annually with India topping the list of producers with 6.003 million metric tonnes followed by Nigeria with 2.060 million metric tonnes, (Faostat, 2018).

Okra pods (fruits) are mucilaginous, resulting into the characteristic slime when cooked. The mucilage contains a usable form of soluble fibre. In West Africa, the plant is cultivated as a vegetable crop and the leaves, buds and flowers are often eaten. The leaves and fruit produce a mucilaginous substance, which makes most African delicacies especially soup, slimy and thick, thereby making consumption of bulky foods such as eba, and pounded yam (fufu) easy, (Nwangburuka *et al*., 2012). The leaves are sometimes used as cattle feed. Okra is a popular health food due to its fibre, vitamin C, folate content, a good source of calcium and potassium. It is also known for being high in antioxidants.

Okra production plays a significant role in the economy as other annual crops, and the selection of high yielding cultivars for the edible fruits becomes necessary. Therefore, there is need to evaluate the nature of genetic variability, heritability and character association of some quantitative character in cultivated varieties of okra for possible improvement in quality of yield and yield components. This to enhance productivity and subsequently improve income generation to the local producers, Alegbejo, *et al.* (2008) and Nosiru, *et al. (*2012).

Poor yielding genotypes are among the production challenges confronting okra production in Nigeria. Production level and yield of this important crop is not meeting its demand. There is growing need for increased okra production in Nigeria as demand is also increasing rapidly. Okra production plays a significant role in the economy and more attention should be accorded to the selection of high yielding cultivars and variation for seed and edible fruits. Present cultivars of okra have shown high variability in several characters including yield, Ojo *et al.* (2012). But the yields of these cultivars per unit area of land and per unit of time are very low because of their very low yield capacity. Genetic variability is a very important component of plant breeding which is a major tool for the crop improvement so as to cope with the ever-increasing pressure of an expanding world population. Crop improvement through successful selection programme is only achieved using valid information about the genetic variability of traits of interest knowing full well that improvement in any crop is dependent on the amount of genetic variability in the population. Therefore, there is need to evaluate the amount of genetic variability, heritability and character association of some quantitative traits in cultivated varieties of okra for possible improvement in quality of yield and yield components, Nwangburuka *et al.* (2012).

Increasing the genetic variability by way of crossing of some quantitative traits in cultivated varieties of okra for possible improvement in quality of yield and yield components will enhance the productivity and subsequently improve income generation to the local producers.

Objectives of the Study

The objectives of the study were to:

(i) estimate the general and specific combining ability variances in the okra cultivars.

(ii) estimate the general and specific combining ability effects of okra parents and hybrids generated from them respectively.

(iii) estimate phenotypic and genotypic coefficients of correlation

(iv) determine the path coefficient analysis between yield and its components in okra.

(v) estimate the narrow sense heritability in okra ands

(vi) estimate genetic advance in okra.

CHAPTER TWO
LITERATURE REVIEW

2.1 Okra Plant

2.1.1 Origin and Distribution of Okra

Okra *(Abelmoschus esculentus)* is found all around the world from Mediterranean to equatorial areas as may be seen from the geographical distribution of cultivated and wild species. Cultivated and wild species clearly show overlapping in Southeast Asia, which is considered as the centre of diversity. The spread of the other species is the result of their introduction to America and Africa. There are two hypotheses concerning the geographical origin of *A. esculentus*. Some authors argue that one putative ancestor (*A. tuberculatus*) is native to Uttar Pradesh in northern India, suggesting that the species originated from this geographic area. Others, on the basis of ancient cultivation in East Africa and the presence of the other putative ancestor (*A. ficulneus*), suggest that the area of domestication is north Egypt or Ethiopia, but no definitive proof is available today. For *A. caillei*, only found in West Africa, it is difficult to suggest an origin outside it, Kumar *et al*. (2014).

The geographical origin of okra is disputed, with supporters of South Asian, Ethiopian and West African origins. It was cultivated by the ancient Egyptians by the 12th century BC. Its cultivation spread throughout Middle East and North Africa. The Nile Basin seems to have been the route by which this crop spread through North Africa, the Eastern Mediterranean, Asia, and to India. Okra reached the new world by the way of Brazil and Dutch Guinea. African slaves brought okra to North America by way of New Orleans. This crop is suitable for cultivation as a garden crop as well as on large commercial farms. It is grown commercially in India, Turkey, Iran, Western Africa, Yugoslavia, Bangladesh, Afghanistan, Pakistan, Burma, Japan, Malayasia, Brazil, Ghana, Ethiopian, Cyprus and the Southern United States, Kumar *et al.* 2014. It is grown on a large scale in Africa, especially in Nigeria, Egypt, Ghana and Sudan, Kumar *et al.* (2011).

Knowledge of genetic diversity of a species has an important impact on the improvement of crop productivity as well as the conservation of genetic resources. In recent years more attention has been given to the genetic analysis of diverse genotype sets, which are particularly attractive for association analysis of qualitative traits such as disease resistance or special quality characteristics (Salameh and Kasrawi, 2011)

Martin *et al*. (1981) distinguished two major classes of okra in West Africa. The unconventional, the *Abelmonschus callei* [194 chromsomes: Singh and Bhatnagar (1975)], a native of Africa which grows naturally in many parts of West Africa especially in the marginal lands (roadsides, backyard farms and wastelands). Adeniji *et al.* (2007) described *Abelmonschus callei* to be bigger, higher yielding, hardier, erect with numerous cultivars varying in maturity, degree of branching, plant height pigmentation, pod shape and sizes than the conventional type. The second, as stated by Joshi *et al.* (1953); Joshi *et al*. (1974); and Singh and Bhatnagar, (1975) is the Conventional, *Abelmonschus esculentus* [130 chromosomes, a native of Asia, In the African context, okra has been called as “a perfect villager’s vegetable” because of its robust nature, dietary fibers and distinct seed protein balanced in both lysine and tryptophan amino acids (unlike the proteins of cereals and pulses) it provides to diet, (TAP, 2006). However, okra has been considered a minor crop and until recently no attention was paid to its improvement in the international research program (Duzyaman, 1997).

Major classes of okra in West Africa according to Joshi *et al.*, (1953), Joshi *et al*., (1974), and Singh and Bhatnagar, (1975) and their chromosome numbers are:

i. A *esculentus* (common okra) 95% cultivated area of okra production. Its cytogenetic Amphidiploid number is ($2n$=130-140). It is characterised by Poor adaptation in humid zone, more susceptible to biotic stresses, less vigorous, short life cycle (suitable for short rainy season areas), usually day neutral, cultivated in both rainy (rain fed) and dry (irrigated) seasons.

ii, A. caillei (West African okra) 5% cultivated Area of okra production. It is characterized by better adaptation in humid zone, tolerant/ resistant to biotic stresses, more vigorous, longer life cycle, mostly photoperiod sensitive, cultivated mainly in dry season Its cytogenetic Amphidiploid number is Amphipolyploid ($2n$ = 196- 200): *A. esculentus* ($2n$=130-140) and *A. manihot* ($2n$ = 60-68).

2.1.2 Chromosome number

Very little information is available about cytogenetics and reproductive biology of this very important vegetable crop. Phenotypic variation has been studied by several studies [Salameh, N. and M. Kasrawi, 2011, Salameh, and Kasrawi, 2007, Bello, *et al* 2006. Düzyaman, 2006. Ghai, *et al* 2005. Rawashdeh, L., 1999 Ariyo, 1987]. Salameh, (2014) found that the genome size of okra varied from 3.98 pg 2°C in Jordanian landrace to 17.67pg 2C in Turkish based on Flow Cytometry Analysis. Without a broad base of heterogeneous plant material, it is impossible for plant breeders to produce cultivars that meet the changing needs regarding adaptation to growing conditions, resistance to biotic and a biotic stresses product yield or specific quality requirements (Friedt, 2007). Therefore, the most efficient way to farther improve the performance of crop varieties is to access to large diverse pool of genetic diversity. There are significant variations in the chromosome numbers and ploidy levels of different sepceis in the genus Abelmoschus. The lowest number reported is 2n=56 for A. angulosus, Ford (1938). Whereas the highest chromosome number reported are close to 200 for A. manihot var. caillei [Singh and Bhatnagar (1975), Siemonsma (1982a) and Siemonsmo (1982b)]. The chromosome number within A. esculentus, s 2n = 72, 108, 120, 132 and 144 are in regular series of polyploids with n = 12, Datta and Naug (1968).

Okra was earlier included in genus *Hibiscus,* section *Abelmoschus* in the family Malvaceae. The section *Abelmoschus* was subsequently proposed to be raised to the rank of distinct genus. The wider use of *Abelmoschus* was subsequently accepted in the taxonomic and contemporary literature. This genus is distinguished from the genus *Hibiscus* by the characteristics of the calyx, spathulate, with five short teeth, connate to the corolla and caduceus after flowering, (Chauhan, 1972 and Kundu and Biswas, 1973). There are significant variations in the chromosome numbers and ploidy levels of different species in the genus *Abelmoschus*. The lowest number reported is 2n=56 for *A. angulosus* whereas the highest chromosome number reported are close to 200 for A. manihot var. caillei, Purewal and Randhawa. (1947). The chromosome number and ploidy levels of different species are:

i **A.** esculentus **Chromosome umbers (2n)** comprises of +66, 106, 118**,** 120, 122, 124, 126-134 and **130**

ii. **A.** *caillei* 194

2.1.3. **The okra plant**

Okra is an upright annual, herbaceous 0.6 – 1.5 m tall plant with a hibiscus-like flower. It is a tropical direct sown vegetable with a duration of 90-100 days. Iwena, (2002) and Katung, (2007) had described the botanical features of okra as indicated below:

i. Root: Okra plant has a deep taproot.

ii. Stem: Its stem is semi woody and sometimes pigmented with a green or reddish tinges color. It is erect, variable in branching, with many short branches that are attached to thick semi woody stem. The stem attains heights from 0.4 m in dwarf varieties to 0.6 – 1.5 m in others.

iii. Leaves: The woody stems bear leaves that are lobed and are generally hairy, some reaching up to 12 inches in length. Leaves are cordate (heart-shaped), simple, usually palmately 3-7 lobed and veined. Leaves are subtended by a pair of narrow stipules. The okra leaf is dark green in color and resembles a maple leaf.

iv. Flowers:

The flowers are borne vertically only on the orthotropic axis every two or three days. The flower is axillary and solitary, borne on a peduncle 2.0 – 2.5 cm long. The flowers are large around 2 inches in diameter, with five white to yellow petals with a red or purple spot at the base of each petal and flower will last only for a day. Each blossom develops a small green pod. The flowers are almost always bisexual and actinomorphic. The perianth consists of 5 valvate, distinct or basally connate sepals and 5 distinct petals that are usually basally adnate to the androecium. The androecium consists of numerous monadelphous stamens with apically divergent filaments bearing 1-celled anthers. The gynoecium is a single compound pistil of 2-many carpels, an equal number of styles or style branches, and a superior ovary with 2-many locules, each bearing 1-numerous ovules. The calyx is completely fused to form a protective case for the floral bud and spilts into lobes when the bud opens. The calyx, corolla and stamens are fused together at the base and fall off as one piece after anthesis. The erect sexual parts consist of a five to nine part style, each part with a capitate stigma, surrounded by the staminal tube bearing numerous filaments. The petals wilt in the afternoon and usually fall the following day.

Okra has perfect flowers (male and female reproductive parts in the same flower) and is self-pollinating. Okra flower structure combines both hermophrodism and self-compatibility (Serge and Jean, 1991). They found out that anthesis takes place at the end of the night and the flower opens at dawn and closes mid-afternoon. Three - ten (3-10) undeveloped flowers appear on the crown depending on the period of profuseness. A flower bud takes about 22-26 days from initiation to full bloom. The style is surrounded by a staminal column which may bear more than 100 anthers. The pollen may come in contact with the stigmas through a lengthening of the staminal column or through insect foraging, **(**Tnau Agrictech Portal 2014)**.** The lower most flower bud open into flower. Only one flower appears on a single stem at a time. Temperature and humidity influence flower initiation, flowering, anthesis and stigma receptivity, Venkataramini, (1952). Flower bud initiation, flowering, anthesis and stigma receptivity are influenced by genotype and climatic factors like temperature and humidity. Flower buds are initiated at 22-26 days and the first flower opened 41-48 days after sowing. Once, initiated flowering continues for 40-60 days. Anthesis occur between 6 a.m and 10 a.m. Anthers dehisce before flower opening, and hence self-pollination may occur at anthesis. The dehiscence of anthers is transverse and complete dehiscence occurs in 5-10 minutes. Pollen fertility is maximum in the period between an hour before and an hour after opening of the flower. Pollen stored at 24 hours at room temperature (27 C) and 88% relative humidity was not viable. The stigma was most receptive on the day of flowering (90-100%). Stigma receptivity was also observed the day before flowering (50-70%) and the day after (1-15%). Flowers open only once in the morning and close after pollination on the same day. The following morning the corolla withers. Okra has perfect flowers (male and female reproductive parts in the same flower) and is self-pollinating. If okra flowers are bagged to exclude pollinators, 100% of the flowers will set seed. It has been found experimentally that there is no significant difference in fruit set under open-pollinated, self-pollinated (by bagging alone) and self-pollinated (hand pollination of bagged flowers), indicating that it is potentially a self-pollinated crop.

v. Fruit:

The fruit is an elongated, conical capsule, comprising for the most part, five cavities containg ovules. The fruit is actually long pod is generally ribbed, developing in the leaf axil and spinelesss in cultivated kinds. The fruit is normally yellowish green to green, but is sometimes purple or white. Depending on the vaiety, the pods are the edible portion, are harvested while still tender and immature. They grow rapidly into long (10-30 cm) and narrow (1-4 cm) pod with a tip that is either pointed like a beak or blunt.

vi. Seeds

The okra fruit contains numerous oval, smooth, striated and dark green to dark brown seeds

vii. Growth habit:

Different genotypes have different growth habits, as a result of selection or a natural adaptation mechanism Okra requires a temperature of 18^0C – 30^0C and a rainfall of 100mm – 150mm per annum and long-day length for optimum growth and development, (Iwena, 2002) and Oyolu, (1977) recorded a critical day length of 12½ hours for flower initiation and fruit yield. Uniform day and night temperature levels are preferred by okra, wide difference between day and night temperatures reduces the yield considerably. Katung, (2007) reported that the wet season conditions were most favourable for increased growth, leaf formation and fruit yield, as compared with the dry season environment which resulted in less vegetative and reproductive growth.

The commonest growth habit among all the landraces is indeterminate growth habit with erect general growth appearance. Erect plant type is advantageous to okra production, since it allows maximum and uniform exposure or distribution of all leaves and other vegetative parts for better interception of sunlight, and would also result in an increase in dry matter production and a subsequent increase in yield. Moreover, there is less chance of fruits touching the ground or soil thereby causing fruit rot (Oppong-Sekyere *et al.*, 2011).

The indeterminate nature of the okra landraces is a character which might have been selected for over the years by researchers and farmers because it allows for longer and continuous fruit harvest. This is an advantage when prices of the vegetable fluctuate. Farmers do not want these plants to produce long branches and would rather opt for more plants per area unit. Previous studies in tomatoes by Hanson, (1956) suggested this to be advantageous because it allows the combination of large numbers of fruit with many plants per unit space, which is an indicator of high yield

Cultivation

The plant is cultivated in tropical, subtropical and warm temperate regions around the world, National Research Council (2008). Okra can be grown on wide range of soils, but well drained fertile soils with adequate organic matter result to high yield Akinyele and Temikotan (2007). The crop is widely cultivated throughout the year in the tropics. Okra is a nutritious vegetable which plays important role to meet the demand of vegetable are scanty in the market Ahmed *et al* (2007). It is among the most heat and drought tolerant vegetable species in the world and will tolerate soils with heavy clay and intermittent moisture but frost can damage the pods. In cultivation, the seeds are soaked overnight prior to planting to a depth of 12 cm. Germination occurs between six days (soaked seeds) and three weeks. Seedlings require ample water. The seed pods rapidly become fibrous and woody, and to be edible, must be harvested within a week of the fruit having been pollinated. The fruits are harvested when immature and eaten as a vegetable, Priya et al, (2014).

Okra requires a long, warm and humid growing period. It can be successfully grown in hot humid areas. It is sensitive to frost and extremely low temperatures. For normal growth and development a temperature between 24°C and 28°C is preferred. At 24°C the first flower bud may appear in the third leaf axil while at 28°C it may appear in sixth leaf axil. This higher position is not necessarily accompanied with a delay in time because at higher temperatures the plants grow faster and the higher position is reached earlier. For faster plant growth still higher temperature helps though it delays the fruiting. But at higher temperatures beyond 40°–42°C, flowers may desiccate and drop, causing yield losses.

For seed germination, optimum soil moisture and a temperature between 25°C and 35°C is needed with fastest germination observed at 35°C. Beyond this range the germination will be delayed and weak seeds may not even germinate.

Okra is mainly propagated by seeds and has duration of 90-100 days. It is generally an annual plant. Its stem is robust, erect, and variable in branching and varying from 0.5 to 4.0 metres in height. Leaves are alternate and usually palmately five lobed, whereas the flower is axillary and solitary.

Okra plants are characterized by indeterminate growth. Flowering is continuous but highly dependent upon biotic and abiotic stress. The plant usually bears its first flower one to two months after sowing. The fruit is a capsule and grows quickly after flowering. The greatest increase in fruit length, height and diameter occurs during 4th to 6th day after pollination. It is at this stage that fruit is most often plucked for consumption. The okra pods are harvested when immature and high in mucilage, but before becoming highly fibrous. Generally the fibre production in the fruit starts from 6th day onwards of fruit formation and a sudden increase in fibre content from 9th day is observed (Nath, 1976). Okra plants continue to flower and to fruit for an indefinite time, depending upon the variety, the season and soil moisture and fertility. Infact the regular harvesting stimulates continued fruiting, so much that it may be necessary to harvest every day in climates where growth is especially vigorous.

Being a warm season crop it is susceptible to cold and frost. It thrives well during warm, moist season although it grows fairly well in the hottest summer. The seeds do not germinate below 17°C. Okra flowers drop at 42°C day temperature (Chauhan, 1972). Uniform day and night temperature levels is preferred by okra, wide difference between day and night temperatures reduces the seed yield considerably. Well drained sandy to clay soils supplied with enough organic matter are good for okra cultivation. However, loose, friable and well-manured loam soils having the pH range between 6.0 - 6.8 are the best, Nosiru *et al*. (2012). Land should be thoroughly prepared by deep ploughing, harrowing, laddering.

Manures and fertilizers are applied at the rate of 15 ton compost, 150 kg Urea, 100 kg and 100 kg per hectare. The entire amount of compost, and half of urea are applied during land preparation while the rest of the urea are applied at three equal instalments at 30,45 and 60 days after sowing, Nosiru *et al.* (2012) and Rashid and Singh, (2000).

Seed should be sown during mid-June-Mid July in the Guinea Savannah and Mid February-mid March in the Rainforest. Soil temperatures between 27-30°C help in quick and better seedling emergence. Seeds will not germinate below soil temperatures of 17°C. Seeds should be soaked in clean water for 24 hours before sowing. Seeds which will not absorb water during imbibition should be discarded. Seeds are to be sown in lines and in small hills. Spacing of 60 cm between rows and 30 cm between within rows are to be maintained. Two to three seeds should be sown per hill, Rashid and Singh, (2000).

Floral Biology of Okra

The okra flowers are 4-8 cm in diameter, with five white to yellow petals, often with a red or purple spot at the base of each petal and the flower withers within one day. The flower structure combines hermaphroditism and self-compatibility. Flower bud appears in the axil of each leaf, above 6th to 8th leaf depending upon the cultivar. The crown of the stem at this time bears 3-4 underdeveloped flowers but later on during the period of profuse flowering of the plant there may be as many as 10 undeveloped flowers on a single crown. As the stem elongates, the lower most flower buds open into flowers. There may be a period of 2, 3 or more days between the times of development of each flower but never does more than one flower appear on a single stem. A flower bud takes about 22-26 days from initiation to full bloom. The style is surrounded by a staminal column which may bear more than 100 anthers. The pollen may come in contact with the stigmas through a lengthening of the staminal column or through insect foraging (Thakur and Arora, 1986). Thus the flowers of okra are self-fertile. The pollen grain is large with many pores, and every pore is a potential tube source; therefore, many tubes can develop from one pollen grain (Purewal and Randhawa, 1947).

Pollination and Fertilization

Flower bud initiation, flowering, anthesis and stigma receptivity are influenced by genotype and climatic factors like temperature and humidity (Venkatramini, 1952). From studies made on six okra varieties, Sulikeri and Swamy Rao, 1972 concluded that flower buds are initiated at 22-26 days and the first flower opened 41-48 days after sowing. Once initiated, flowering continues for

40-60 days. Anthesis was observed between 6 a.m and 10 a.m. Anthers dehisce before flower opening and hence self-pollination may occur at anthesis. The dehiscence of anthers is transverse and complete dehiscence occurs in 5-10 minutes (Purewal and Randhawa, 1947). Pollen fertility is maximum in the period between an hour before and an hour after opening of the flower (Srivastava, 1964). Pollen stored for 24 hours at room temperature (27° C) and 88% relative humidity was not viable. The stigma was most receptive on the day of flowering (90-100%). Stigma receptivity was also observed the day before flowering (50-70%) and the day after (1-15%). Flowers open only once in the morning and close after pollination on the same day. The following morning the corolla withers.

Okra has perfect flowers (male and female reproductive parts in the same flower) and is self-pollinating. If okra flowers are bagged to exclude pollinators, 100% of the flowers will set seed. It has been found experimentally that there is no significant difference in fruit set under open-pollinated, self-pollinated (by bagging alone) and self-pollinated (hand pollination of bagged flowers), indicating that it is potentially a self-pollinated crop (Purewal and Randhawa, 1947). The inbreeding depression well pronounced in cross-pollinated crops has not been reported in this crop (Duranti, 1964). Although insects are unnecessary for pollination and fertilization in case of okra, the flowers are very attractive to bees and the plants are cross-pollinated. The cross pollination upto the extent of 4-19% (Purewal and Randhawa, 1947; Choudhury et al., 1970; Shalaby, 1972) with maximum of 42.2% (Mitidieri and Vencovsky, 1974) has been reported. The extent of cross-pollination in a particular place will depend upon the cultivar, competitive flora, insect population and season.

The okra flowers are 4-8 cm diameter, with five white to yellow petals, often with a red or purple spot at the base of each petal and flower lasts only one day. A flower bud appears in the axil of each leaf above 6th to 8th leaf depending upon the cultivar. The crown of the stem at this time bears 3-4 underdeveloped flowers but later on during the period of profuse flowering of the plant there may be as many as 10 undeveloped flowers on a single crown. As the stem elongates, the lower most flower buds open into flowers, (Tnau Agrictech Portal (2014). Okra fruit is an elongated structure, 10-25 cm long, 1.5-3cm diameter, tapering to a blunt point. The fruit is found in its fresh state or dehydrated form in all markets all year round in Nigeria.

Pithiya *et al.* (2017) observed that unlike many other members of pod vegetable group, okra is not strictly season-bound and hence can be gown twice a year. Being a warm season crop, it can be grown under irrigation as well as rainy season crop in major agro-ecological zones. It fits well in sequential cropping systems due to its quick growing habit, medium duration and tolerance to drought, heat and wide variation in rainfall.

Okra is a high yielding crop under a good cropping system, with yield varying from 4,480 to 5,500 kg/ha of green pods, (Ayodele, 1993). Its usefulness has enhanced world production, (Siemonsma and Kouame, 2004). They however asserted that, the yield potential of okra has been grossly affected by poor cropping system, use of crude implement, poor soil, pests and diseases. Okra is cultivated for its fibrous fruits or pods containing round, white seeds. The fruits are harvested when immature and eaten as a vegetable. Okra fruit can be cooked in a variety of ways. The roots and stems of okra are used for cleaning the cane juice from which gur or brown sugar is prepared, (Chauhan, 1972). Its ripe seeds are roasted, ground and used as a substitute for coffee in some countries. Mature fruits and stems containing crude fiber are used in the paper industry. Extracts from the seeds of the okra is viewed as alternative source for edible oil. The greenish yellow edible oil has a pleasant taste and odor, and is high in unsaturated fats such as oleic acid and linoleic acid. The oil content of the seed is quite high at about 40%. Okra is a mucilaginous (when cooked) edible fruit. It is an important source of iron, vitamins A and C, Calcium, thiamine and riboflavin. It has been found to be anti-ulcer, anti-oxidant and a nutritional healing in diabetes. Its mucilage is a suspending agent used as a pharmaceutical adjuvant, (Tindal, 1983, and Christo and Onuh, (2005), Naser and Mahmoud, (2007) and Oppong-Sekyere *et al*. (2011).

viii. Nutritional potential**:** Fresh okra fruit contains 2.1 g protein, 0.2 g fat, 8 g carbohydrate, 36 calories, 1.7 g fiber, 175.2 mg minerals, and 88 mL of water per 100 g of edible portion (Tindall, 1983; Berry *et al*., 1988). Its edible leaf per 100 g contains about 81 ml water, 56 calories, 11 g carbohydrate and 4.4 g protein.

Okra seed oil has potential hypocholesterolemic effect, Rao *et al* (1991). The potential for wide cultivation of okra for edible oil as well as for cake is very high. Okra seed flour could also be used to fortify cereal flour Adelakun *et al*. (2008),For example, supplementing maize ogi with okra meal increases protein, ash, oil and fiber content) Akingbala *et al* (2008). Okra seed flour has been used to supplement corn flour for a very long time in countries like Egypt to make better quality dough Taha, (1947). Its ripe seeds are roasted, ground and used as a substitute for coffee in some countries

Moekchantuk. and Kumar, (2004). Mature fruits and stems containing crude fibre are used in the paper industry Greenish-yellow edible okra oil is pressed from okra seeds; it has a pleasant taste and odor, and is high in unsaturated fats such as oleic acid and linoleic acid. The oil content of some varieties of the seed can be quite high, about 40%. Oil yields from okra crops are also high. A 2009 study found okra oil suitable for use as a biofuel Farooq *et al.*, (2010). The roots and stems of okra are used for clarification of sugarcane juice from which gur or brown sugar is prepared.

Sanjeet et al., (2010) had reported that K, Na, Mg and Ca are the principal elements in pods, which contain about 17% seeds. They also reported that presence of Fe, Zn, Mn and Ni also has been reported. Fresh pods are low in calories (20 per 100 g), practically no fat, high in fiber, and have several valuable nutrients, including about 30% of the recommended levels of vitamin C (16 to 29 mg), 10 to 20% of folate (46 to 88 mg) and about 5% of vitamin A (14 to 20 RAE). Both pod skin (mesocarp) and seeds are excellent source of zinc (80 mg/g), (Glew *et al.*, 1997; Cook *et al.*, 2000). Okra seed is mainly composed of oligomeric catechins (2.5 mg/g of seeds) and flavonol derivatives (3.4 mg/g of seeds), while the mesocarp is mainly composed of hydroxycinnamic and quercetin derivatives (0.2 and 0.3 mg/g of skins). Pods and seeds are rich in phenolic compounds with important biological properties like quartering derivatives, catechin oligomers and hydroxycinnamic derivatives (Arapitsas, 2008). These properties, along with the high content of carbohydrates, proteins, glycol-protein, and other dietary elements enhance the importance of this foodstuff in the human diet. Dried okra sauce (pods mixed with other ingredients and regularly consumed in West Africa) does not provide any beta carotene (vitamin A) or retinol as sun drying denature these elements, (Avallone *et al.*, 2008). However, fresh okra pods are the most important vegetable source of viscous fiber, an important dietary component to lower cholesterol. Seven-days-old fresh okra pods have the highest concentration of nutrients.

Medicinal Properties of Okra

Its medicinal value has also been reported in curing ulcers and relief from hemorrhoids [65]. Unspecified parts of the plant were reported in 1898 to possess diuretic properties. This is referenced in numerous sources associated with herbal and traditional medicine. Okra has found medical application as a plasma replacement or blood volume expander, Lengsfeld *et sl.*, (2004). Adetuyi *et al.,* (2008). Kumar et al (2010). It is also good source of iodine which is useful in the treatment of simple goiter and source of other medically useful compound. It is very useful genitourinary disorders, spermatorrhoea and chronic dysentery. Tests conducted in China suggest that an alcohol extract of okra leaves can eliminate oxygen free radicals, alleviate renal tubular interstitial diseases, reduce protein urea, and improve renal function Liu *et al*., (2005) and Kumar et al., (2009). Unspecified parts of the plant were reported in 1898 to possess diuretic properties Rashid *et al*., (2002) this is referenced in numerous sources associated with herbal and traditional medicine. Some studies are being developed targeting okra extract as remedy to manage diabetes

Insect Pest on Okra Plant

Incidence of insect pests is one of the prime factors in production of okra. The crop is attacked by several insect pests among which shoot and fruit borer, Earias vittella (Fabricius) and Earias Insulana are most serious as it take upper hand by causing direct damage to tender fruits. 88 to 100 percent damage to fruits by fruit borer. The normal seeds per fruit were reduced by 16.47 per cent with increase in stained seeds by 200 per cent and damaged seeds by 18.70 percent infested okra fruits when compared with healthy. The incidence of fruits borers' usually occurring humid condition after the rainfall. The adults' female lays eggs individually on leaves, floral buds on tender fruits. Small brown caterpillars bore into the top shoot and feeds inside the shoot before fruits formation. Later on, developed and bore into the fruits and feed within the fruits. Affected fruits become unfit for consumption purposes. Leafhopper, Amrasca biguttula biguttula (Ishida) and shoot and fruit borer, Earias spp. is a major concern and cause havoc damage. Leafhopper alone had caused 32.06%–40.84% Singh and Brar (1994). Shoot and fruit borer caused 50% reduction in fruit yield, Brar et al (1994). Larvae of fruit and shoot borer bore into shoots during the vegetative growth stage and later in flowers and fruits, rendering fruit unfit for human consumption. Various strategies recommended controlling the pests, the use of insecticide has resulted immediate relief to crop and apparently benefited formers. For same reason the use of chemical is increasing rapidly and will continue in days to come until some reliable alternative control measures are developed. 95% populations of Asian countries are used insecticides.

Insect pest infestation is one of the most limiting factors for accelerating yield potential of okra. The crop is prone to damage by various insects, fungi, nematodes and viruses, although there are wide variability in their degree of infestation. Some of the important insects are fruit and shoot borer, aphids, white flies, ants, etc.

Diseases of Okra Plant

The okra is also subjected to the attack of many diseases affecting leaves, flowers and fruits. The most serious diseases of okra are caused by viruses especially yellow vein mosaic virus (YVMV). Fusarium wilts are some of the more serious diseases attacking okra. Root knot nematodes may also reduce yields. Crop rotation is one method to control many of the plant diseases. In the rainy seasons, rotting of blossoms and pods can be a problem when there are dense canopies. Removal of the lower leaves will allow better air circulation and reduce problems with blossom and pod rot.

The okra plant has the following diseases associated with it.

Yellow Vein Mosaic Virus (YVMV) Causative agent: Yellow Vein Mosaic Virus This is the most important and destructive viral disease in okra that infects crops at all the stages growth. The fruits of the infected plants become pale yellow to white in color, deformed, small and tough in texture. The disease causes 50-100% loss in yield and quality if the plants get infected within 20 days after germination, Sastry and Singh (1974), Givord and Denboer (1980) and Rashid *et al* (2002). Cercospora Leaf Spot Causative agent Cercospora abelmoschi, C. malayensis, C. hibisci In India, three species of Cercospora produce leaf spots in okra C. malayensis causes brown, irregular spots and C. abelmoschi causes sooty black, angular spots .The affected leaves roll, wilt and fall. The leaf spots cause severe defoliation and are common during humid seasons Moekchantuk and Kumar (2004). Fusarium Wilt Causative agent: Fusarium oxysporum f. sp. Vasinfectum Fursarium wilt, a serious disease, found wherever okra is grown intensively. The fungus invades the roots, colonizes the vascular system and thereby restrict water translocation. The disease is soil borne and spread through interculture operation.

Powdery Mildew Causative agent: Erysiphe cichoracearum, Sphaerotheca fuliginea, Powdery mildew is caused by Erysiphe cichoracearum and Sphaerotheca fuliginea. The disease caused by the former is most common in okra growing areas where as the latter has been reported from Bangalore lately Kumar *et al* (2010). Damping Off Causative agent Pythium spp., Rhizoctonia spp. Damping off disease may kill seedlings before or soon after they emerge. Infection before seedling emergence results in poor germination due to decay of seeds in soil. Cool, cloudy weather, high humidity, wet soils, compacted soil, and overcrowding especially favour development of damping-off Ek-Amnuay, (2010).

Steve and Katayama, (2013) had reported that okra pods should be harvested while still tender, which is usually five to six days after flowering. Pods between 20.5 and 30.5 cm in length are preferred by most consumers. Okra should be harvested two to three times a week. Regular picking of fruits increases yield. Mature pods left on the plant will reduce flowering and fruit set. Pods may be cut from the plant with a knife or snapped off by hand. Pods with tips that will bend between the fingers without breaking are too tough for use as a fresh vegetable. They are of the view that when harvested, okra pods rapidly lose moisture. This causes the loss of pod quality. It is recommended that harvesting be conducted in the cooler parts of the day, mornings or evenings, and the harvested okra be kept as cool as possible. Avoid leaving the harvested okra in the sun for long periods of time. Shaded storage areas will help maintain good pod quality. Harvested okra should be stored in ventilated containers. Pods kept in non-ventilated containers will lose colour rapidly due to bleaching, and there can be a build-up of heat due to respiration of the okra.

2.2 **Genetic Variability in Okra**

Vijaya *et al.* (2013) and Vrunda *et al.* (2018) had observed that creation and utilization of variability using proper breeding procedure is a pre-requisite for the genetic improvement of any crop. Generally, amount of variability is more in the early segregating generations as compared to later generations. The phenotypic expression of the plant character is mainly controlled by the genetic makeup of the plant and the environment in which it is growing. Therefore, it becomes necessary to partition the observed phenotypic variability into its heritable components with suitable parameters such as phenotypic and genotypic coefficient of variation, heritability and genetic advance. Simon *et al.* (2013) also stated that genetic improvement can only be achieved when genetic information about any particular genetic materials is readily available, which the plant breeder can utilize and exploit to achieve fast genetic improvement. Genetic variability provides information on diversity within and between species. Ariyo, (1990) and Jindal *et al.* (2010) had reported that genetic variability study is a very important component of plant breeding which is a major tool being used to cope with the ever-increasing pressure of an expanding world population on food. According to Raje and Rao, (2000), genetic variability is essential in order to realize response to selection pressure. The estimates of genetic parameters of variation are specific for a particular population and the phenotypic expression of the quantitative character may be altered by environmental stress that affects plant growth and development. Information on genetic variability of different characters of a crop and about the useful genes in each cultivar need be properly evaluated to identify the potential cultivars prior to breeding programme for improvement in any crop, (AdeOluwa and Kehinde, 2011).

Bello *et al.* (2015) had also stated that genetic diversity plays a major role in crop improvement for identification of distinctive accessions vital for the curators of gene banks. In any diversity studies, morphological characterization is been recommended as the first step to be taken before in–depth molecular and biochemical analyses are employed. Several researchers also observed high degree of morphological variation among the West African okra accessions, (Adeniji, *et al.*, 2007 and AdeOluwa and Kehinde, 2011). The success of any progress in a breeding programme however, is dependent not only on the magnitude of genetic variability present in that population, but also on the extent to which its desirable characters are heritable. The variability available in a population can be partitioned into heritable and non-heritable components with aid of genetic parameters, such as, genotypic coefficient of variation, heritability and genetic advance, which also serve as a basis for selection, (Muluken *et al*., 2016).

Progress in crop production depends largely on the ability of the breeders to select high yielding varieties. Considerable effort is currently being made in a number of okra breeding program to improve yield attributes such as seed yield, number of pods per plant, pod length and pod width. These characters are particularly important in the breeding program of okra. The vegetative characters are also an important measure of yield and should be considered; number of pods per plant, days to flowering and plant height are some of the most variable quantitative characters of okra, (Alam and Hossain, 2008). Variation is a necessary condition for selection programme aimed at improving some desirable characters. The basic key to bring about the genetic upgrading to a plant is to utilize the available or created genetic variability. If the variability in the population is largely due to genetic cause with least environmental effect, the probability of a superior genotype is much higher for the expression of desired characters.

The local cultivars of okra under cultivation over the years in Nigeria are landraces which are highly susceptible to diseases, long maturity periods yet short harvesting duration, poor nutritional value, and above all non-standard and in shape, colour and sizes (Oppong-Sekyere, 2011). Developing improved varieties that are perennial in growth, higher yield, early maturing with longer harvesting duration as well as standard fruit sizes, shapes, and colour are highly desirable.

Generally, the success of any crop improvement programme depends on the magnitude of genetic variability, genetic advance, character association and the direct and indirect effects on yield and yield attributes in a crop, (Magar and Madrap, 2009 and Nwangburuka *et al*., 2012). Earlier, Somashekhar *et al*. (2011) had stated that gain from selection in a breeding programme is dependent on the amount of variability for the economic characters in the population. Selection of those characters that have high heritability values coupled with high genetic advance helps in this gain. Burton, (1952) had suggested the use of variability and heritability to assess the maximum and accurate effect of selection in okra. Selection of traits with medium to high heritability brings about relatively rapid rate of improvement in breeding programme (Hazem *et al.,* 2013). Snowder *et al.* (2005) had indicated that the higher the heritability, the greater will be the superiority of the individual trait selected for breeding. It was found by Akinyele and Oseikita, (2006) and Duzyama, (2006) that the pubescence and pigmentation of the various plant parts in okra as well as fruit characteristics of the qualitative traits proved to be most significant in the analysis of variability that contributed significantly to the total variation.

Variability in okra species has been investigated by many plant breeders including Bish *et al*. (1995); Akinleye and Osekita, (2006); Duzyaman, (2006); Naser and Mahmoud (2007); Omonhinmin and Osawaru (2005); Osekita and Akinleye, (2008); Alam and Hossein, (2008); AdeOluwa and Kehinde, (2011) and Nwangburuka *et al*. (2012). They established that West African okra is believed to have wide morphological variation which is attributed to the preponderance of out crossing among different accessions though okra is essentially autogamous. Ariyo, (1990) working on genetic diversity among 30 (thirty) accessions of West African Okra observed a large genetic variability among the accessions. The large amount of genetic variability observed supports the opinion that this okra type constitutes a separate species. Within species variation among 30 African genotypes was found to be considerably large based on phenotypic assessment. Pigmentation and fruit characteristics were important components of the genetic variability among the accessions; the number of pods per plant, pod weight, length of peduncle, petiole length and days to maturity were found to be most effective, AdeOluwa and Kehinde, (2011),.

AdeOluwa and Kehinde, (2011), Adeniji *et al.* (2007) and Omonhinmin and Osawaru, (2005) reported that phenotypic variances were greater than genotypic variances, suggesting the role of environmental factor in the genotypic expression of the various okra varieties which give rise to the variability they observed for all the traits they studied. Based on this, Siemonsma and Kouame, (2004) and Nwangburuka *et al.* (2012) suggested the use of phenotypic variance together with genetic advance to determine possible genetic progress.

2.3 **Line by Tester Mating Design Use in Okra**

The line × tester is the most widely used mating design for hybrid development. Line × tester analysis which involves ‘*l*’ lines and‘t’ testers is an extension of the analysis of two factor factorial experiment introduced by Fisher and Yates. In this design, full-sib progenies are generated through crossing '*l*' lines to't' testers. Then, developed progenies as well as parents, are evaluated in developed field trials, Tyagi and Lal, (2005) and Singh and Chaudhary, (1985). The combining ability in line × tester design is estimated using a formula suggested by Singh and Chaudhary, (1985). Line by tester is a mating design in which several testers are mated to a number of lines thereby producing F_1 generations, (Kempthorne, 1957). A tester is a genotype that is used to identify superior germplasm in accordance with breeding objectives in a hybrid-oriented program. A tester line is the one that have simplicity in use, provide information that classifies relative performance of lines into heterotic groups or heterotic patterns, and maximize the expected mean yield, Fasahat *et al.* (2016). Seemingly in coining a definition for a tester, researchers have been influenced by their quest to find the best or most convenient tester for use in hybrid programs. Hallauer and Miranda, (1988) a line or a population with low frequency of favourable alleles in testcrosses can be employed as a tester to find lines with large frequency of favourable alleles. Such testers would be crucial when dominance gene action for the characters of interest is envisaged.

Line by tester design developed by Kempthorne 1957, is a powerful tool commonly used for estimation of GCA and SCA effects involving a large number of genotypes, (Mandan *et al.*, 2007). The design provides information about the general and specific combining abilities of parents and at the same time it is helpful in estimating various types of gene effects (Singh and Chaudhary, 1977). Line by tester has been used by many workers to study some factors in okra. Patil and Patil, (1988) used line by tester to undertake preliminary studies on combiners and combinations for quality character in tomato. Dhaliwal *et al.*, (2009) also used line by tester to study the worth of male-sterile lines of okra in combination with already identified superior performing male parents. Nandan *et al*. (2007) using Line x Tester study found that *gca* variances was greater than *sca* variances for fruit yield per plant indicating preponderance of additive gene action for this trait in okra. They stated that the results are indicative of the fact that hybrid okra has great potentialities of maximizing fruit yield. But Sateesh *et al.* (2013) also using Line x Tester study indicated the presence of the predominance of non-additive gene action for all the characters suggesting the effect of environmental factor of gene action in okra.

Line by tester has the singular advantage over other designs because it estimates the genetic parameters on more parental materials than would have been possible with other designs.

Its main disadvantage is the restriction of the lines to specific testers, thereby limiting the genetic recombination to a narrow genetic base, Dhaliwal *et al.* (2009).

2.4 Combining Ability in Okra

The concept of combining ability has significant practical importance as it is a powerful tool to predict good as well as poor combiners enabling to study comparative performance of lines in a hybridization programme and selection of appropriate parents. Analysis of combining ability provides guidelines for an early assessment of the relative breeding worth of the parent material there by choosing the best general combining parents as well as specific cross combinations for further exploitation, Biel and Atkins, (1967) and Hallauer and Miranda, (1988).

Sprague and Tatum, (1942) defined GCA as the average performance of a genotype in a series of hybrid combinations. They defined SCA as those cases in which certain hybrid combinations perform better or poorer than would be expected on the basis of the average performance of the parental inbred lines. Parents showing a high average combining ability in crosses are considered to have good GCA while if their potential to combine well is bounded to a particular cross, they are considered to have good SCA.

To form a sound bases for any breeding programme aimed at achieving good characteristics, one must have genetic information on the nature of combining ability of the parents and their performance in hybrid combinations, Shivogamasudari *et al*. (1992). The concept of combining ability has been used to obtain information on the inheritance and the types of gene actions in the expression of characters and the selection of parents for hybridization (Yahaya, 2004). Hannan *et al*. (2007) stated that combining ability estimates are important and vital parameter to mould the genetic makeup of a crop and that this information could prove an essential strategy to breeders in the screening of better parental combinations for further improvement.
Rojas and Sprague, (1952) compared estimates of the variances of general combining ability and specific combining ability for yield and their interaction with locations and years. They stressed that the variance of specific combining ability includes not only the non-additive deviations due to dominance and epistasis but also a considerable portion of the genotype × environment interaction.

Means squares for GCA and SCA for genotypes (parents and hybrids) had been reported to be positively significant for all characters in okra. This indicated the presence of considerable amount of genetic variation among the genotypes of okra. Hazem *et al.* (2013), Sateesh *et al.*

(2013) and Mandan *et al.* (2007). They had also reported significant SCA variance exhibited by hybrids for all characters studied. However, Hannan *et al.* (2007) also found some high SCA for fruit weight per plant in a combination of one good combiner and one average or poor combiner as was reported by Jinks, (1983) and Salimath and Bahl, (1986).

The ratio of combining ability variance components (predictability ratio) determines the type of gene action involved in the expression of traits and allows inferences about optimum allocation of resources in hybrid breeding: ð^{2}gca and ð^{2}gca in which σ^2gca refers to general combining ability variance and σ^2sca refers to specific combining ability variance. Singh and Chaudhary. (1985) had reported that the closer this ratio is to one, the greater the prediction of GCA alone, whereas a ratio with a value less than 1 shows SCA action. However, Vijay and Manohar, (1990) and Fasahat *et al.* (2016) were of the view that because in many cases only a few parents are used in crosses, the magnitude of GCA and SCA has been evaluated using the ratio of their sum of squares to total sum of squares for crosses.

Hannan *et al.* (2007) showed that relatively large general and specific combining abilities (GCA/SCA) ratio indicate the existence of additive genes controlling a particular character. While relatively low GCA/SCA ratio indicates the existence of dominant and/or epistatic gene effects. Griffings, (1956) and Hannan *et al.* (2007 stated that the high GCA variance was related to additive and additive + additive interaction and that this represents fixable components of genetic variance.

2.4.1 General combining ability (GCA)

Can *et al.* (1997) and Chadha *et al.* (2001) stated that general combining ability (GCA) refers to the average performance of a line in a series of crosses in which that line has been a common parent. The genetic potential of the parents is expressed in terms of combining ability. Among the parents involved in a large number of crosses, only few exhibits superiority and such parents producing a good hybrid are considered as good general combiners. The general combining ability in respect of a character is the manifestation of additive gene action. The general combining ability is the measure of additive genetic factor whereas specific combining ability is due to non-additive genetic factor. Chadha *et al.* (2001) stated that combining ability of the parents is becoming increasingly important in plant breeding, especially in hybrid production. It is useful in connection with the testing procedures in which it is desired to study and compare the performance of the lines in hybrid combinations. General combining ability (GCA)' is the average performance of the parents in hydroids combination and due to additive gene effect. Parmar *et al.* (2012)

reported that a low GCA value, positive or negative, shows that the mean of a parent in crossing with the other does not vary largely from the general mean of the crosses. In contrast, Franco *et al*. (2001) opened that a high GCA value shows that the parental mean is superior or inferior to the general mean. This indicates a potent evidence of desirable gene flow from parents to offspring at high intensity and represents information regarding the concentration of predominantly additive genes. A high GCA estimate indicates higher heritability and less environmental effects. It may also result in less gene interactions and higher achievement in selection. One of the main features of the elite parent with high GCA effect is its large adaptability, Hallauer and Miranda, (1988).

Ehab *et al.* (2013) stated that the potentiality of any line to be used as a parent in hybridization depends on it's per se performance and the performance of F_1 hybrid derived from it and its own GCA effect. It is also possible that the cross showing high SCA effect also has parents showing high GCA effects, in which case both additive and non-additive gene actions can be utilized.

GCA is an effective tool used in selection of parents based on performance of their progenies, usually the F_1 but it has also been used in F_2 and later generations (Fn). A low GCA value, positive or negative, shows that the mean of a parent in crossing with another does not vary largely from the general mean of crosses. In contrast, Franco *et al.* (2001) had stated that a high GCA value shows that the parental mean is superior or inferior to the general mean. This indicate a potent evidence of desirable gen flow from parents to offspring at high intensity and represents information regarding the concentration of predominately additive genes. A high GCA estimate indicates higher heritability and les environmental effects. It may also results in less gene interactions and higher achievement in selection. One of the main features of the elite parent with high GCA effect is its large adaptability. Shukla and Pandey, (2008), Pawan and Rajeev, (2014) and Tyagi and Lal, (2005) showed that a parent good in *per se* performance may not necessarily produce better hybrids when used in hybridization. Concurrently, it also indicated that one parent of the worst combination could make the best combination if the other parent was selected properly, Oakey *et al.* (2006).

2.4.2 Specific combining ability in Okra (SCA)

Can *et al.* (1997) and Chadha *et al.* (2001) stated that specific combining ability (SCA) refers to a better or worse performance of a cross combination that is expected on the basis of any two lines involved in the cross. It is a cross combination that do relatively better or worse than would be expected and is consequences of dominance and epistasis.

Combining ability or productivity in crosses is defined as the cultivars or parents ability to combine among each other during hybridization process such that desirable genes or characters are transmitted to their progenies. In another definition, combining ability is an estimation of the value of genotypes on the basis of their offspring performance in some definite mating design.

Dey et al (2014) reported that high SCA effects resulting from crosses where both parents are good general combiners (i.e., good GCA × good GCA) may be ascribed to additive × additive gene action The high SCA effects derived from crosses including good × poor general combiner parents may be attributed to favourable additive effects of the good general combiner parent and epistatic effects of poor general combiner, which fulfils the favourable plant attribute. High SCA effects manifested by low × low crosses may be due to dominance × dominance type of non-allelic gene interaction producing over dominance thus being non-fixable. Romeo, (1990) had reported that these fixable genetic components could be used through backcrossing method of selection to transfer enough of these genes to improve other genotypes.

Observations of performance of different cross patterns on the basis of SCA have been used to make inferences on gene action at play. High SCA effects resulting from crosses where both parents are good general combiners (i.e., good GCA × good GCA) may be ascribed to additive × additive gene action, Dey et al. (2014). They further stated that the high SCA effects derived from crosses including good × poor general combiner parents may be attributed to favourable additive effects of the good general combiner parent and epistatic effects of poor general combiner, which fulfils the favourable plant attribute. Dey *et al.* (2014) stated that high SCA effects manifested by low × low crosses may be due to dominance × dominance type of non-allelic gene interaction producing over dominance thus being non-fixable and that predominance of non-additive effects has been reported for inheritance of pod yield and related traits in groundnut under salinity stress in which there were cross combinations with high SCA effects arising from parents with high and low GCA, and another set of crosses with high SCA effects arising from both parents with good GCA effects.

2.5 Heritability and Genetic Advance in Okra

Arun, (2019**)** stated that crop improvement depends on the magnitude of genetic variability present in the base population. The expected improvement in yield components primarily depends on the nature and magnitude of heritable portion of total variation. Selection based on a single character may not always be effective. On the other hand, it is very cumbersome process for a breeder to consider a large number of component characters simultaneously in selection procedure. The presence of genetic variability is of utmost importance for any breeding programme and due to this reason, the plant breeders have emphasized the evaluation of germplasm for the improvement of crop yield as well as for utilization in further breeding programmes. Absolute variability in different characters cannot be the decisive factor in deciding which character is showing the highest degree of variability. Furthermore, relative values of phenotypic and genotypic coefficients of variation give a reliable idea about the magnitude of variability present in a population. In this way, it is indispensable to split the overall variation into genetic and non-genetic components and to standardize this by obtaining the coefficients of phenotypic and genotypic variability. Therefore, this present study was undertaken to discover the potential of okra genotypes based on morphological character.

Johnson *et al.* (1955) stated that heritability estimates together with genetic advance are more important than heritability alone to predict the resulting effect of selecting the best individuals. Hamdi *et al., (*2003) reported that genetic advance is also of considerable importance because it indicates the magnitude of the expected genetic gain from one cycle of selection to another. Therefore, both heritability and genetic advance must be estimated together to obtain reliable selection pressure in a breeding programme. High genetic advance with high heritability estimates offer the most effective condition for selection, (Larik *et al*., 2000). As Demelie *et al.* (2016) observed that both heritability and genetic advance values were high for tender fruit yield, fruit length and fruit weight and other yield related characters in okra. Swati *et al.,* (2014) reported high narrow sense heritability for weight of fruit per plant followed by plant height and that plant height was highly potential character for selection in Okra.

Ehab *et al.* (2013) observed that moderately high heritability estimate for peduncle length which also has moderately high phenotypic and genotypic coefficient of correlation with the difference relatively low, was not followed by high genetic advance. The low genetic advance could mainly be due to non-fixable (non – additive) gene effects i.e. dominance and epistatic effect of genes. It is suggested that such traits can be improved by method of recurrent selection.

2.5.1 Heritability (Narrow sense)

Heritability is defined as the proportion of phenotypic variance among individuals in a population that is due to heritable genetic effects, also known as heritability in the narrow sense while heritability in the broad sense is defined as the proportion of phenotypic variance that is attributable to an effect for the whole genotype, comprising the sum of additive, dominance, and epistatic effects (Hans-Peter and Jens, 2007). Dudley and Mol, (1969), Rafi and Nath (2004) and Ivy *et al.* (2007) had reported that heritability estimates provide authentic information about a particular genetic attribute which will be transmitted to the successive generations. A broad-sense heritability estimate provides information on the relative magnitude of genetic and environmental variation in the population and help breeders to determine the possible extent for improvement through selection. Again the heritable portion of the total variation might not be always due to additive gene action. Bruce, (2010) observed that heritability determines the degree of resemblance between parents and offspring, which in turn determines the response to selection. He further stated that heritability is a function of both the genetic and environmental variances.

A more useful form of heritability for plant breeder as used in this study is the narrow sense heritability (h^2 ns), which is the ratio of additive genetic variance (VA) to total phenotypic variance (VP). This is because using broad sense heritability results in: the degree of heterozygosity within segregating population will be related to the number of selfing generation. Maximum heterozygosity will be found in the F_1 family, and will be reduced by half in each subsequent selfed progeny. Similarly the dominance genetic variance will be dependent on the degree of heterozygosity in the population and will differ between filial generations, Sharma (2002) and Singh, (2012).

Heritability indicates how much of the phenotypic variability has a genetic origin, and gives objective information for the genetic selection process (Falconer, 1981). For any planned breeding programmes aimed to improve yield potentials of crops, it is necessary to obtain adequate information on the magnitude and type of genetic variability and their corresponding heritability. This is because selection of superior genotypes is proportional to the amount of genetic variability present and the extent to which the characters are inherited. Heritability for example, is used to indicate the relative degree to which a character is transmitted from parent to offspring. The magnitude of such estimates also suggests the extent to which improvement is possible through selection, (Nechifor *et al.* 2011).

Bruce, (2010) and Singh, (2012) had reported that heritability is the proportion of total variance that is attributable to the average effects of genes and this is what determines between relatives the degree of resemblance between relatives and that it expresses the reliability of the phenotypic value as a guide to the breeding value. Only the phenotypic value of the individual can be directly measured, but it is the breeding value that determines their influence on the next generation. If heritability of a character is very high e.g., 0.8 or more, selection for the character should be fairly easy because there would be a close correspondence between genotype and phenotype. But for a character with low heritability, say less than 0.4, selection may be considerably difficult or virtually impractical due to the confusing effect of the environment. Heritability estimates are used to predict the gain from selection (genetic advance).

Singh, (2012) and Fasahat, (2016) had observed that quantitatively inherited characters differ in heritability. A character such as yield is greatly influenced by environment. Characters not influenced by environment are usually having high heritability. They may influence the choice of the breeding procedure used by the plant breeder. Selection is effective in F_2 if the characters are highly heritable. Singh, (2012) and Fasahat, (2016) had also observed that selection for a character with low heritability may be made more effectively if based on F_2 progeny performance. The net gain from selection depends upon the combined effect of the heritability, the amount of genetic variation present, the selection intensity and the cycle length (season per cycle).

Pradip *et al.* (2010) had stated that a character with high heritability in association with high genetic advance is an indication of expression of additive gene action. Characters without such combination appear generally because of non-additive gene action. Therefore, it may be stated that among the characters under study, plant height, number of fruiting nodes, fruit yield per plant, inter nodal distance and number of fruits per plant are likely to be operated by additive genes. Improvement in these characters would be effective by selection on the basis of phenotype.

Heritability studies have been done in a wide range of okra cultivars in breeding programmes. Nwangburuka *et al.* (2012) and Simon *et al.* (2013.), reported high percentage broad-sense heritability in plant height, fresh pod length, fresh pod width, mature pod length, branching per plant and pod weight per plant in okra suggesting the effect of additive genes effect and reliability of selection based on phenotype of these traits for okra improvement. Sibsankar *et al.* (2012) and Nwangburuka *et al.* (2012) reported that high narrow sense heritability in okra indicating that most genetic variations in characters in okra were due to additive gene effects.

Pawan and Rajeev, (2014) also reported heritability over mean being higher for first fruiting node, days of first picking number of branches per plant, plant height, number of fruits per plant and yield per plant in okra which might be indicative of likely effectiveness of selection for such characters. Udengwu, (2008) reported Martin *et al.* (1981) that in their review of variation in okra varieties, a surprisingly large number of characteristics are inherited in a simple fashion and have high narrow sense heritabilities, which suggested that they are controlled by relatively few genes.

Simon *et al.* (2013) had found out that heritability estimates gave moderate values of for number of plants per plot and for Internodes distance to higher values for pod yield and for number of branches per plant. This findings they observed was in line with the higher Phenotypic Coefficient of Variation recorded generally in the experiment, suggesting that genotype-environmental interaction affects the yield and yield components of the okra cultivars studied. Therefore, selection could be effective if done based on phenotypic performance of the traits. High heritability estimates is very important in determining superior genotype when selection for improvement is required. When the heritability of a character is medium to high, selection based on the individual level of performance allows relatively rapid rate of improvement. The higher the heritability of a character, the greater will be superiority of the individual (or character) selected for breeding. Arun *et al.* (2019) stated that the heritability estimate provide the information on the magnitude of inheritance of quantitative characters but does not indicate the magnitude of genetic gain obtained by selection of best individual from the best population.

2.5.2 Genetic advance

Genetic advance is the increase in the level of a quantitative variable that results from selection. This is also referred to as the response to selection being the difference between the mean phenotypic value of the offspring of the selected parents and the whole of the parental generation before selection (Johnson *et al.*, 1955). Genetic advance is an important selection parameter that aids breeder in a selection programme (Substrata *et al*., 2004). But Arun *et al.* (2019) stated that the heritability estimate provide the information on the magnitude of inheritance of quantitative characters but does not indicate the magnitude of genetic gain obtained by selection of best individual from the best population. So, heritability along with genetic advance is more useful than the heritability alone. In their study of okra they found high genetic advance coupled with high heritability was observed for pod yield and plant height, (Arun *et al.,* 2019). It indicated that additive gene action was more important for these characters.

Idahosa *et al.* (2010) reported that the expected genetic advance as percentage of population mean (GA%) was relatively high for pod length, pod weight, seeds per pod and 100-seed weight characters and these genotypes could be exploited through improvement and selection programmes. Manal, (2009) had also found great magnitude of genetic advance in some traits in okra and that these parameters were under the control of additive genetic effects. Swati *et al.* (2014) and Kumar *et al.* (2011) reported high percentage of genetic advance for weight of fruit per plant and plant height which indicated more numbers of additive factors for this character for which improvement is feasible through selection based on phenotypic observations; this could lead to fast genetic improvement of the material.

2.6 Correlation Analysis in Okra

In genetic studies, it is necessary to distinguish between two causes of correlation between characters, these are genetic and environmental. The genetic course is chiefly pleiotropic, though linkage may cause transient correlation particularly in populations derived from divergent strains, (Falconer, 1981). Pawan and Rageev, (2014); Sibsankar *et al.* (2012); Simon *et al.* (2013) and Alam and Husain, (2008) reported the presence of genetic variability in okra characters and that the values of PCV were greater than GCV suggesting the influence of environmental effect on the inheritance of these characters.

Pithiya *et al.* (2017) observed that optimizing pod yield is one of the most important goals for most okra growers and, consequently, most okra breeding programs. For improving this crop through conventional breeding and selection, adequate knowledge of association that exists between yield and yield related characters is essential for the identification of selection procedure, Paroda and Joshi, (1969) and Frageria and Kokli, (1997) had also reported that yield is the main objective of a breeder, so it is important to know the relationship between various characters that have direct and indirect effect on yield. The degree of relationship or association of these characters with yield can be ascertained by correlation studies and path analysis. The degree of relationship between characters of economic importance is valuable in making decisions in plant breeding especially for selection purposes. A better understanding of the contribution of each character in building the genetic makeup of the crop may be obtained through association studies (Sibsankar *et al.,* 2012 and Semashekhar *et al*., 2011). Sibsankar *et al.* (2012) showed that correlation analysis indicated priority for selection base on number of fruits per plant and fruit weight for yield improvement in okra. Characters such as time of flowering, time to set fruit, number of fruits per plant, fruit size and weight are functions of fruit yield in okra. These characters are found to be positively and significantly correlated with yield.

Vrunda *et al.* (2019) stated that yield is a complex character resulting from multiplicative interactions of various yield components. Therefore, correlation studies between yield and other traits will be of interest to breeders in planning the hybridization programme and evaluating the individual plants in segregating populations. A study of correlation between different quantitative characters provides an idea of association that could be effectively exploited to formulate selection strategies for improving yield components. For any effective selection programme, it would be desirable to consider the relative magnitude of association of various characters with yield. Dattijo *et al.* (2016) had also observed that the efficiency of selection in any breeding programme mainly depends upon the knowledge of association of the characters. The suitable knowledge of such associations between yield and its related characters could appreciably enhance the efficiency of the crop improvement through the utilization of the appropriate selection indices. The correlation coefficient that indicates an association between two characters is useful as a basis for indirect selection for further crop improvement. It does not only assist in the formation of selection indices but it also permits the prediction of correlated response. They observed that selection of parents based on yield alone could be misleading.

Ibrahim and Hussein, (2006) stated that for inter-character association estimates to be repeatable such character must have both significant genotypic and phenotypic correlations and any selection based on this is reliable. Higher genotypic correlation coefficient over phenotypic correlation coefficient suggests very strong inherent association between various characters at genetic level. Ibrahim and Hussein, (2006) working on roselle (*Hibiscus sabdariffa*) found positive and significant phenotypic and genotypic correlation between plant height at maturity, seeds per pod and pods per plant, days to flowering and branches per plant with seed weight per plant and pod weight per plant, across environments is a strong indication that these characters are major factors in relation to seed yield per plant and pod yield per plant. This suggests that selection directed towards these characters will be effective in ensuring seed and pod yield in okra. Somashekhar *et al.* (2011*)* found out that results they obtained showed genotypic coefficient of correlation showed more significant relationship between the pairs of characters, meaning that, these characters are more related genotypically and selection strategy for yield improvement should rely on average fruit weight, number of fruits per plant, 100 seed weight, number of branches per plant, during selection process in segregating populations is very effective, as these characters exhibited positive significant association with fruit yield per plant.

Izge *et al.* (2006) had earlier, working on millet reported that correlation coefficients for most of the pairs of characters revealed the presence of strong positive genotypic association between yield/ha with number of tillers/plant, number of leaves/plant, plant height, panicle length, number of seed/panicle and yield/plant. Strong and positive phenotypic association also exist between yields/ha, with number of tillers/plant, number of leaves/plant, plant height, panicle length, number of seeds/panicle and yield/plant. Observed that even though, both the types of correlations are comparable in magnitude; the genotypic correlations are of higher magnitude than their corresponding phenotypic correlations, indicating a strong inherent relationship among the characters studied.

Izge *et al.* (2006) had stated that the correlation studies taken alone are often misleading and the actual dependence of grain yield on the correlated yield component characters needs confirmation, which can easily be untangled and unravelled by path coefficient analysis. Pithiya *et al.* (2017) also observed that correlation measures the mutual relationship between different traits of a plant, it helps to determine the yield contributing components Correlation itself does not reflect the cause of association between two variables. To understand the actual relationship between the dependent traits and various independent traits, it is advisable to partition the correlation coefficient into direct and indirect effects, which was facilitated by path coefficient analysis. These biometrical techniques help in selection of superior plant genotype for future breeding programme.

2.7 Path Analysis in Okra

Pithiya *et al.* (2017) observed that correlation measures the mutual relationship between different traits of a plant, it helps to determine the yield contributing components but does not reflect the cause of association between two variables. To understand the actual relationship between the dependent traits and various independent traits, it is advisable to partition the correlation coefficient into direct and indirect effects, which was facilitated by path coefficient analysis. These biometrical techniques help in selection of superior plant genotype for future breeding programme.

Yield is known to be the function (effects) of many characters (cause) in okra. The cause contributes directly to the realization of the yield (the end product). Guddadamath *et al.* (2011) had stated that path coefficient analysis is a powerful tool, which enables portioning of the given relationships in its further components. In other words, it takes into account not only the relationship of component characters with the dependent character, but simultaneously takes care of its relationship with other component too. Thus, it helps in understanding the causal system in a better way because it enables portioning the total correlations coefficient into direct and indirect effects of various characters.

Thulasiram *et al.* (2017) observed that the overall correlation observed between two attributes is a function of a series of direct and indirect association between the component characters. In order to know these specific forces in building up the total correlation, which is simply a standardized partial regression coefficient and measures the direct influence of one component on the other and permits the partitioning of the total correlation coefficient into its components of direct and indirect effects.

Vrunda *et al*. (2019) stated that the complexity of character relationships among themselves and with fruit yield became evident from the discussion alone but did not provide a comprehensive picture of relative importance of direct and indirect influences of each of the characters to the fruit yield, as these traits were the resultant product of combined effects of various factors complementing or counter- acting. The path co-efficient analyses provides an effective means of untangling direct and indirect causes of association and permits a critical examination of the specific forces acting to produce a given co-relation. Thulasiram *et al*. (2017) also observed that the character like yield is dependent character and it is the resultant effect of number of component characters, but direct selection for yield is essential to bring a rational improvement in the desirable traits. Correlation coefficient analysis measures the mutual relationship between various plant characters on which selection can be based for improvement in yield, Sabtrata *et al*., (2004).

The path coefficient analysis involves a method of partitioning correlation coefficient into direct and indirect effects through alternate pathway. Path analysis indicated priority for selection base on number of fruits per plant and fruit weight for yield improvement in okra. Characters such as time of flowering, time to set fruit, number of fruits per plant, fruit size and weight are functions of fruit yield in okra. Guddadamath *et al.* (2011) reported that path coefficient analysis of fruit yield and its components revealed that number of fruits per plant, fresh fruit weight, fruit length, first fruiting node, plant height, number of branches per plant, length of internode were the most important traits contributing towards fruit yield per plant.

Dattijo *et al.* (2016) had observed that number of pods per plant had the greatest direct influence on pod yield followed by fresh weight per pod which had positive genotypic association with pod yield. Path coefficient analysis showing positive and high direct effects on fruit yield indicates their importance as reliable selection criteria for the improvement of yield in okra. Thulasiram *et al.* (2017) had also reported that the characters exhibiting significant positive phenotypic correlation with yield per plant were found to be correlated with plant height, number of leaves per plant, number of primary branches per plant, number of nodes per plant and number of fruits per plant and these characters were also positively interlinked among themselves which indicated the importance of these characters while selection.

CHAPTER THREE
MATERIALS AND METHODS

3.1 Plant Materials

Some okra cultivars were obtained locally for this work from different locations in the North–East of Nigeria. The cultivars were divergent in their characteristics as shown in Table 1.

3.2 Experimental Sites

The crossing nursery was conducted at College of Education, Hong. The hybrids and their parents were evaluated across two locations: College of Education, Hong and the Teaching and Research farm of the Modibbo Adama University of Technology, Yola in 2017. Hong is located on latitude 10^{o} 15" North and 13^{o} 20" East. It has an average rainfall of 1016 mm per annum and a temperature between 26.5 – 30.0^{o}c on altitude 246m above sea level in the Northern Guinea Savannah ecological zone, Izge and Garba, (2012). The teaching and research farm of the Modibbo Adama University of Technology, Yola, located within longitude 120 ^{o} 35'E and latitude 90 ^{o} 10'N, (Adebayo and Tukur, 1999) in the savannah agro- ecological zone of Nigeria during the 2017 cropping seasons. The soil of these areas is characteristically sandy loam.

3.3 Crossing Nursery.

This was established at the College of Education, Hong in Adamawa State during the 2016 rainy season. After normal land preparation, two rows of 6 beds of 2m x 2m each were constructed. Each bed was sown with 18 stands of okra at 30cm x 60cm, figure 1.

It has to be noted that anthers dehisce before flower opening, and hence self-pollination may occur at anthesis in okra. The dehiscence of anthers is transverse and complete dehiscence occurs in 5-10 minutes. Pollen fertility is maximum in the period between an hour before and an hour after opening of the flower. Pollen stored at 24 hours at room temperature (27 C) and 88% relative humidity was found not viable, pollens may not be stored and immediate use is recommended. The stigma was most receptive on the day of flowering (90-100%). Stigma receptivity was also observed the day before flowering (50-70%) and the day after (1-15%). Flowers open only once in the morning and close after pollination on the same day. The following morning the corolla withers. Okra has perfect flowers (male and female reproductive parts in the same flower) and is self-pollinating.

Table 1 Description of the cultivars of okra to be used in the study.

s. no	Genotype	Identifying Characters	MaturityPeriod (day)
Testers			
1.	Gella 1:	average height, brown base and light green top, late profuse and productive branching, divided small leaf span, average flowering time, pod is short and fat.	61
2.	Gella 2:	a short plant, purple base and green top, none branching, small round leaf, early flowering, pod is short and averagely fat.	52
3.	Pukum 1:	a short plant; purple base and green top; branches early, profusely and productive; small round leaf; very early flowering; pod is short and fat.	51
4.	Bature:	a tall plant; stem colour is light green; has late productive branching; leaf is medium size and slightly divided; lately flowering; pod is long and hairless.	57
Lines			
5.	Dirbuni :	an average height plant; stem colour is red; branching is early and from the base; leaf is of average span and slightly divided; it is early relatively flowering; pod is short and fat.	52
6.	Puba:	the stem is very tall; its colour is sported red; branching is late but productive; its leaves are wide; it is late flowering; pods are of average	62
7.	Hong:	the plant is very tall; its stem colour is brownish; it branches lately and at the top though productive; leaves are wide and slightly divided; it is late flowering; pods are tall and fat.	61
8.	Shafa:	a short plant; it is green in colour and none branching; its leaves are very wide; early flowering and pods are very long and fat.	51
9.	Gudumya:	is a tall plant; stem colour is sported brown; it branches very late and has a wide slightly divided leaf; flowers late as	

Table 1 Continues.

		well with medium sized fat pods.	65
10.	Hawul	a short sized plant; it has a brownish base and green top; it branches very late; its leaves are wide and slightly divided; it flowers very early producing very long fat pods.	46
11.	Pukum 2:	a very short plant; it has a brownish base and green top; branches very late but productive; its leaves are very wide and divided; it is very early flowering producing very short fat pods.	51
12.	Marama:	it is of average height; it has a brownish base and light green top; it branches very late but profusely and productive; leaves are small and well divided; very early flowering producing long slim pods.	56

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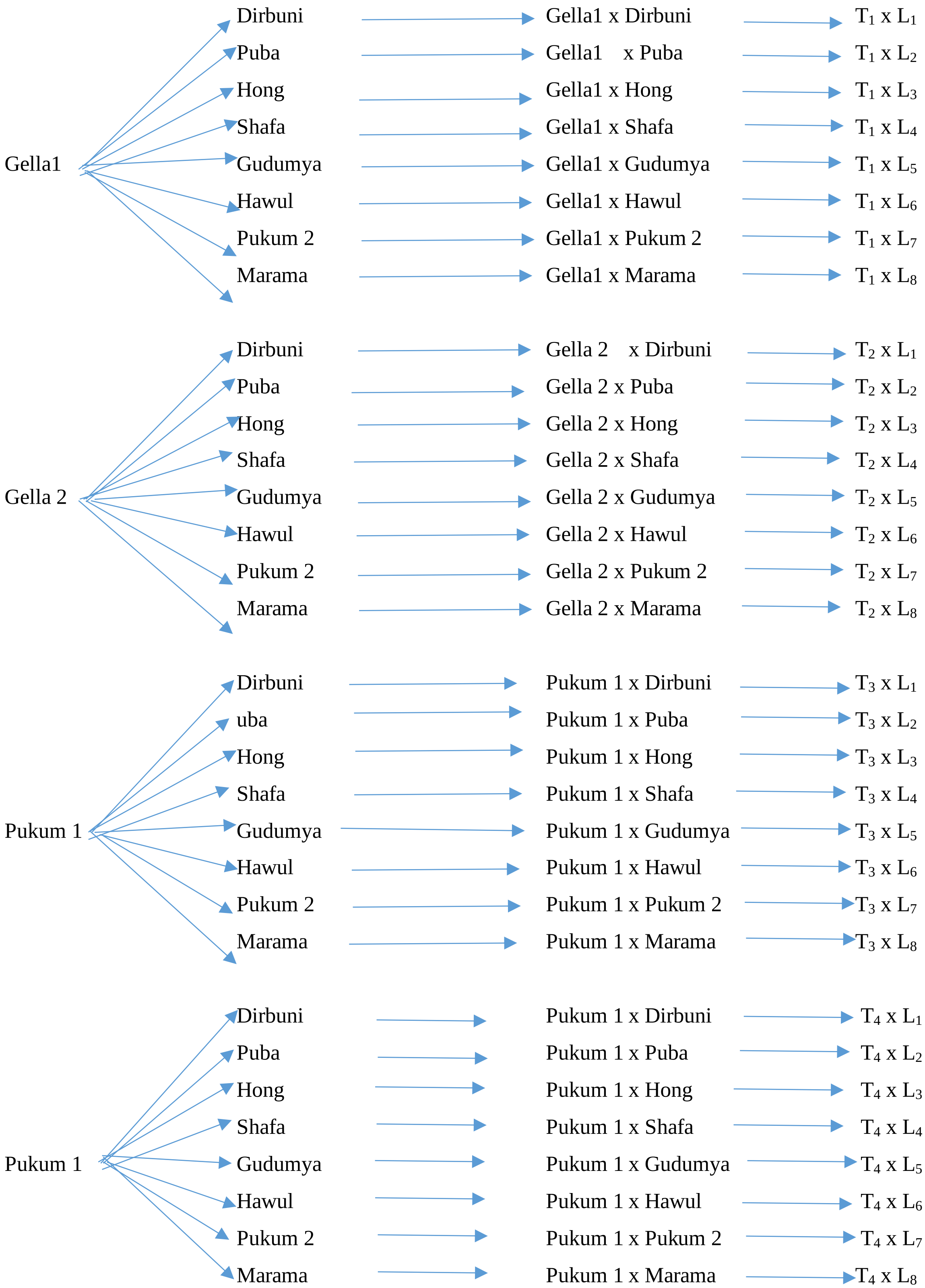

Fig. 1. Crossing Pattern of the 4 testers and 8 Lines

If okra flowers are bagged to exclude pollinators, 100% of the flowers will set seed. It has been found experimentally that there is no significant difference in fruit set under open-pollinated, self-pollinated (by bagging alone) and self-pollinated (hand pollination of bagged flowers), indicating that it is potentially a self-pollinated crop

Crossing was made between the lines and the testers to generate crosses. These crosses were obtained by emasculating the flowers of the females (lines) to remove anthers for each cross. Anthers were carefully removed making sure the stigma and style do not break. Mature pollens were removed from the males (testers) to be dusted on the stigma of females. Each cross was labelled appropriately. Properly dried matured fruits were collected and seeds were removed and stored in marked containers for subsequent evaluation.

3.4 Field Progeny Evaluation.

The resulting F_1 progenies (32) plus the parental cultivars (12) were evaluated in 2018 in a randomised complete block design (RCBD) (Fig.2). There were forty four (44) plots (2m x 3m) per replication replicated three times. This brought up to one hundred and thirty two (132) plots. Plant spacing was 50cm x 60cm (20 plants/plot) bringing up to one hundred and eighty eight plants per replication. This brought up to one thousand, six hundred and forty (1640 plants) in the entire experimental field

The land was prepared using hand hoe and beds of 2m × 3m were made for the 44 treatments. Weeding was done as and when required.

Nematicides called VAPAM at the rate of 1litre/120 litres of water was applied to reduce attack by nematodes and possibly other soil borne insects in the field at planting

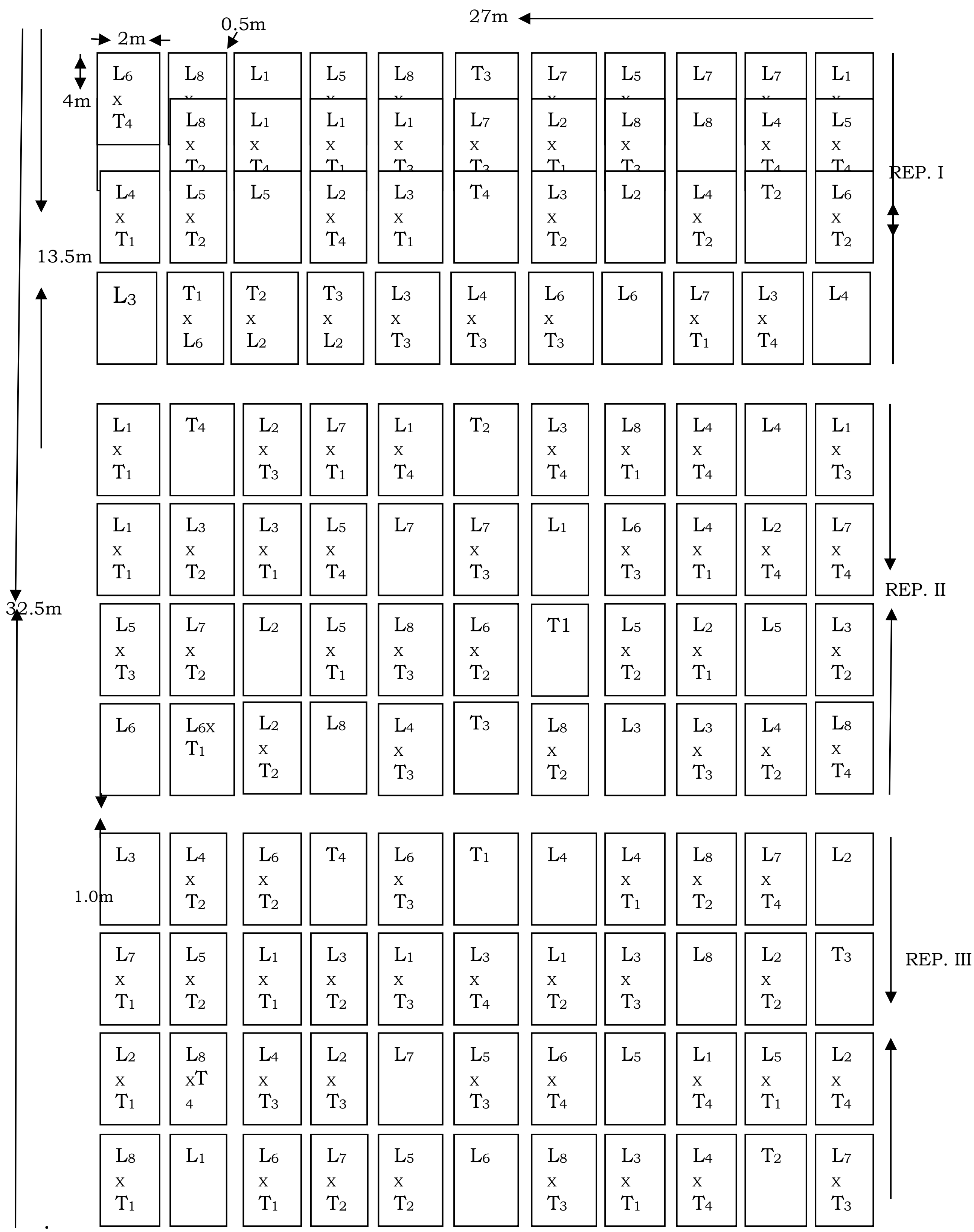

Fig. 2. Field plan 0f the 44 denotypes arranged in R.C.B.D replicated three (3) times (m).

3.5 Data Collection

Six middle plants were randomly sampled for recoded observations in each plot. Data collection was made as and when due for each parameter. The means obtained were used for biometrical analysis.

The parameters measured were as follows:

3.5.1 ***Establishment count*** **-** by counting the number of plants obtained in each bed.

3.5 ***Days to 50% flowering*** - by counting the days taken by 50% of the plants to produce flowers from sowing.

3.5.3 ***The number of leaves at 50% flowering*** - by counting the leaves on the plant when 50% of the plants have produced flowers.

3.5.4 ***Number of fruits (pods)/plant*** - by counting and recording the number of fruits produced by the genotype at each harvest.

3.5.5 ***Pod length*** (cm) - by measuring the length of matured pod (fruit) from the base to the tip of the fruit using tailors tape or ruler in cm.

3.5.6 ***Pod width*** (cm) - by measuring the circumference of the matured pod at the centre using venial clipper in cm.

3.5.7 ***Number of branches/plant*** **-** by counting the number of primary branches produced by the genotype at full growth.

3.5.8 ***Plant height*** (cm) - by measuring the height of the genotype when it stops growth from ground level to the top using tailors tape or ruler in cm.

3.5.9 ***Yield/plant*** (kg) - by finding the average weight of fruits produced by a genotype over the production period.

3.6 Statistical Analysis.

The first step in the line x tester analysis will be to perform the analysis of variance (ANOVA) (Tables 2 and 3) as per design and to test significances among genotypes (Crosses and parents). When the differences are found significant the line x tester analysis was done to estimate combining ability effects according to Singh and Chaudhary (1985). Mean data were used to estimate phenotypic and genetic correlation according to Paroda and Joshi (1970) and path analysis according to Singh and Chaudhary (1985), broad sense heritability according to Hanson *et al.* (1956) and lastly genetic advance according to Johnson *et al* .(1955).

Table 2 Form of Analysis of Variance and Expected Mean Square in A Line X Tester in Individual Location

Source of Variation	Degree of Freedom	EMS
Replication	2	$\delta e^2 + fhmt\delta^2 r$
Treatments	43	$\delta e^2 + fhmr\delta^2 t$
Crosses	31	$\delta e^2 + fmrt\delta^2 h$
Testers (males)	3	$\delta e^2 + fhrt\delta^2 m$
Lines (females)	7	$\delta e^2 + hmrt\delta^2 f$
GCA	5	$\delta e^2 + 1/(n-1)\Sigma sij^2$
SCA	45	$\delta e^2 + 1/n+mf\Sigma sij^2$
Error	90	δe^2
Total	230	

Source: Singh and Chaudhary (1985)

Table.3 Form of Analysis of Variance and Expected Mean Squares in a Line X Tester Combined across Two Locations.

Source Variation	df	MS	EMS
Replications (r)	ly (r − 1)		
Location (l)	l – 1		
Rep / location	L(r -1)	m_1	$\delta^2_e + r\delta^2 lmfy$
Testers (m)	m - 1	m_2	$\delta^2_e + r\delta^2 ymlf + r\delta^2 fy/lm + r\delta^2 yflm$
Line (f)	f – 1	m_3	$\delta^2_e + r\ \delta^2 myl + r\delta^2 fy/lm + r\delta^2 my/lf$
Line x Tester	(l – 1)(m – 1)	m_4	$\delta^2_e + r\delta^2 ymlf + r\delta^2 fy/lm + r\delta^2 my/lf$
Entries (e)	e −1	m_5	$\sigma^2_e + r\sigma^2 gly + rl\sigma^2\ gy + ry\sigma^2 gl + rly\sigma^2$
GCA	(n-1)	m_6	$\delta^2_e + 1/(n-1)\Sigma sij^2$
SCA	(n + mf)-1	m_7	$\delta^2_e + 1/n + mf\Sigma sij^2$
G × l	(g − 1) (l − 1)	m_9	$\sigma^2_e + r\sigma^2 gly + ry\sigma^2 gl$
Error (g × r)	(g − 1) (r − 1)ly	m_{11}	σ^2

3.6.1 The mathematical model equation for line by tester for individual location:

$$Y_{ijk} = \mu + m_i + f_j + (mf)_{ij} + e_{ijk}.$$

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

μ = general mean

m_i = effect of the i^{th} male.

f_j = effect of the j^{th} female

mf = male x female

$e_{ij}k$ = expected random error associated with each observation.

Source: Singh and Chaudhary (1985)

3.6.2 **Estimation of general combining ability effects**

(i) Lines – $g_i = \frac{x_{i...}}{tr} - \frac{x_{...}}{ltr}$

Where, l = no of lines

t = no of testers

r = no of replications

(ii) Testers – GCA (testers) = $gt = \frac{x.j.}{lr} - \frac{x_{...}}{ltr}$

3.6.3 **Estimation of SCA Effects**

$$S_{ij} = \frac{xij}{r} - \frac{x_{i..}}{tr} - \frac{x.j.}{lr} - \frac{x_{...}}{ltr}$$

3.6.4 **Standard errors for combining ability effects**

i) S.E. (GCA for line) = (Me/r x t)½

ii) S.E. (GCA for testers) = (Me/r x l)½

Iii S.E., SCA (effects) = (Me/r) ⅓

1v S.E. (gi - gr) line = (2Me/r x t) ⅓

V S.E. (gi - gr) tester = (2Me/l x r) ⅓

Vi S.E.(Sij - Sxj) ⅓

3.6.5 Estimation of proportional contributions of lines, testers and their interaction to total variance

(a) Lines = $\frac{SS(l) \times 100}{SS\ (crosses)}$

(b) Testers = $\frac{SS(t) \times 100}{SS\ (Crosses)}$

(c) Line x tester = $\frac{SS(l + t) \times 100}{SS\ (crosses)}$

3.6.6 Phenotypic (PCV), genotypic (GCV) and error/environmental (ECV) coefficient of variations

The formulae used to calculate PCV, GCV and ECV were given by Burton and Devane (1952).

Phenotypic coefficient of variation (PCV):

$$PCV\% = \frac{\sigma^2 p \times 100}{X}$$

Where: $\sigma^2 p$ = Phenotypic standard deviation

X = Mean

Genotypic coefficient of variation (GCV):

$$GCV\% = \frac{\sigma^2 g}{X} \times 100$$

Where, $\sigma^2 g$ = Genotypic standard deviation

X = Mean

Environmental coefficient of variation (ECV):

$$ECV\% = \frac{\sigma^2 e}{X} \times 100$$

Where: $\sigma^2 e$ = Error standard deviation

X = Mean

3.6.7 *Narrow sense heritability*

Because the additive component of genetic variance determines the response to selection, the narrow sense heritability estimate is more useful to plant breeders than the broad sense estimate. It is estimated as given by Hanson *et al* (1956):

$$\mathbf{h^2} = \frac{ð^2a}{ð^2p}$$

where: $ð^2_a$ genetic variance

$ð^2_p$ phenotypic variance

3.6.8 *Genetic advance*

It is the improvement in mean genotypic value of selected plants over the parental population will be calculated by using the following formula given by Johnson *et al* (1955).

Expected genetic advance

$$GA = K.\ \sigma ph^2$$

Where: K = Constant selection differential at 5% level intensity

σp = Phenotypic standard deviation

h^2 = Heritability in broad sensse

3.6.9 Genotypic and phenotypic correlation

The expectation of mean squares and mean cross products will be pooled and used to calculate the genotypic and phenotypic correlation between pairs of characters (Table 4) according to Paroda and Joshi (1970).

Table 4 Expectation of Mean Squares and Mean Cross Product for Calculating Genotypic and Phenotypic Correlation.

Analysis of variance			Analysis of covariance	
Source variation	MS	EMS	MCP	EMCP
replication	mr_{11}	$\delta e^2 + r\delta e\ ^2 g_{11}{}^2$	$m\ r\ _{12}$	$\delta e^2{}_{12} + \delta e^2 g_{12}$
treatment	mt_{II}	$\delta^2 eii$	Me_{12}	$\delta e^2{}_{12}$
Error	me_{II}			

Where MS = mean square

EMS = expected mean square

MCP = Mean cross products

EMPC = Expected mean cross products

Mr_{11}, mt_{11}, me_{11} = means squares for replication, treatment (genotypes) and error for character 1.

$\delta^2\ g_{11}$ = phenotypic variance for character s 1and 1

$\delta^2\ e\ _{11}$ = environmental variance for characters 1and 1

mr_{12}, mt_{12}, me_{12} = mean cross products for replications, treatments and error for characters 1 and 2 respectively.

$\delta^2 g_{12}$ = genotypic covariance between characters 1 and 2

$\delta^2 e_{12}$ = environmental covariance between characters 1 and 2

The genotypic correlation coefficient (rg) is calculated as

$$r\rho = \frac{\delta^2\rho_{12}}{\sqrt{\delta^2\rho_{11} \times \delta^2\rho_{22}}}$$

while the Genotypic correlation coefficient (rg) is calculated as

$$rg = \frac{\delta^2 g_{12}}{\sqrt{\delta^2 g_{11} \times \delta^2 g_{22}}}$$

where $\delta^2\rho_{22}$ and $\delta^2 g_{22}$ are phenotypic and genotypic variance for character 1 and

$\delta^2 g_{12}$ = genotypic covariance between characters 1 and 2.

3.6.10 ***Estimation of path analysis***

The path analysis was calculated using the matrix method according to Singh and Chaudhary, (1985). Path coefficient is the ratio of the standard deviation of the effect due to a given cause to the total standard deviation of the effect. Contribution of the causal components to the effect (yield) occurs in either direct or indirect ways.

$$\begin{bmatrix} rx_1Y \\ rx2Y \\ rx_3Y \end{bmatrix} = \begin{bmatrix} rx_1x_1 & rx_1x_2 & rx_1x_3 \\ rx_2x_1 & rx_2x_2 & rx_2x_3 \\ rx_3x_1 & rx_3x_2 & rx_3x_3 \end{bmatrix} \begin{matrix} a \\ b \\ c \end{matrix}$$

Fig.3. Path coefficient represented in a matrix form.

Source: Singh and Chaudhary (1985)

Where y = yield a = path coefficient form x1

x_1 = Yield component 1 b = path coefficient from x_2

x_2 = Yield component 2 c = path coefficient from x_3

x_3 = yield component 3 r = correlation among the components

CHAPTER FOUR

RESULTS

4.1 Analysis of Variance

The mean square values from the analysis of variance in a line x tester for nine characters of okra combined across the two locations (Yola and Hong) are presented in Table 5. The results showed that the mean squares and the interaction between location and entries, crosses and parents were all highly significant except pod width per plant and yield. The observation of significant differences in most characters is an indication that genetic diversity do exist among the varieties, thereby providing basis for selection.

It was also observed that the general combining ability (GCA) variances were not significant while specific combining ability (SCA) mean squares were significantly different for days to 50% flowering per plant, number of leaves at 50% flowering per plant and pod length. The variance ratios ($ð^2$GCA / $ð^2$ SCA) were all positive except establishment count which is negative.

Comparatively, the estimates of specific combining ability (S CA) variances were consistently higher than that of general combining ability (GCA) variances and the $ð^2$GCA / $ð^2$ SCA variance ratios were less than unity.

The estimates of proportional contribution of lines and testers revealed that the lines contribute higher than the testers for all the characters. Their interaction contributed higher than both for all the characters as well.

Pod width per plant and yield per plant did not show any significant mean squares for all the sources of variation studied.

4. 2 Mean Performances of Parents across Locations

The estimates of mean performances of parents for nine characters of okra across locations (Yola and Hong) during the 2017 cropping season are presented in Table 6. The combined mean performance of the 12 okra parents in nine yield related characters in the two environments indicated that there were significant differences with respect to all the characters. The potentiality of any line to be used as a parent in hybridization depends on it's per se performance and the performance of F_1 hybrid derived from it and its own GCA effect.

4. 2. 1 *Establishment count*

The result indicated that all the parents established reasonably well but at average none reached hundred percent (20). Establishment ranged between about 17 (85%) for Gaya and 18 (90%) for Hong wild.

4. 2. 2. *Days to 50% flowering*

Hawul was the earliest genotypes in terms of Days to 50% flowering (about 45 day after sowing) followed by Shafa and Pukum 2. On the other hand Gudumya, and Puba were late flowering genotypes (about 65 and 62 days after sowing). It can be seen that earliest and latest flowering parents were found in the lines.

4. 2. 3. *Number of leaves at 50% flowering*

In terms of number of leaves at 50% flowering, Dirbuni had the highest number of leaves at 50% flowering after sowing followed by Gella 1. Pukum 2 had the least number of leaves at 50% flowering

4.2.4 *Number of pods per plant*

For number of pods. Pukum 1 was the best producer followed by Pukum 2. On the other hand, Gella 2 was the least producer of pods (about 8 in number) followed by Hawul.

4. 2. 5 *Pod length per plant*

Gudumya produced the longest pods (14.803cm) followed by Hong and Shafa. The shortest pod of 4.429 cm was produced by Pukum 1 followed by Dirbuni. It was observed that most of the plants (genotypes) had long pods (ranging from11.723cm to 14.803cm)

4. 2. 6 *Pod width per plant*

The fattest pod of 11.501 cm was produced by Marama followed by Gella 1. The slimiest pod was produced by Shafa (9.613cm) followed by Hawul (genotypes).

4. 2. 7 *Number of branches per plant*

Dirbuni was the most branched genotype (6) followed by Pukum 2 (5.613). The parent with the lowest number of branches was Hong with about one (1). Was observed that the parent with higher number of branches produced the highest number of pods.

4. 2. 8 *Plant Height*

The tallest plant was Gella 1 (160.250cm) followed by Marama (156cm). theshortest plant was Hawul (56.167cm). it was observed that most of the pants (genotypes) were tall (ranging from 102,708cm to 160.250cm).

4. 2. 9 *Pod* ***yield per plant***

The tallest plant was Gella 1 (160.250cm) followed by Marama (156.). The shortest parent was Hawul (56.167cm). It was observed that most of the plants (genotypes) were tall (ranging from 102.708cm to 160.250cm).

Gela 1 had the highest yield of 27.450g followed by Pukum 1(94.500g) and Dirbuni (153.458). The lowest yielder was recorded by Gudumya with 8.900g. It can be observed that the plant with the highest number of pods was not the highest yielder in terms of weight (Pukum1 had the highest number of pods, 33.098).

4. 3 Mean Performance of Crosses

The mean performance of crosses for the nine characters of okra evaluated across locations in 2017 in a line x tester analysis is presented in Table 7.

Mean performance of the 32 okra accessions in nine yield and yield related characters in two environments indicated that there were significant differences among the 32 okra accessions with respect to all the characters at maturity.

4. 3. 1 ***Establishment count***

The result indicated that all the crosses established reasonably well. It ranged between 16 plants per plot for Gella 2x Puba and 19 plants per plot for Gella 1 x Pukum 2. In general the crosses established better than the parents.

4. 3. 2 ***Days to 50% flowering***

The earliest hybrid to flower were Gella 2 x Hawul (41.333 days after sowing) followed by Pukum 1 x Dirbuni (42.667 days after sowing). The latest to produce 50% flowers at days after sowing was Gella 1 x Gudumya (71 days after sowing) followed by Gella 1 x Puba (68 days after sowing).

4. 3. 3 N*umber of leaves at 50% flowering*

In terms of number of leaves at 50% flowering, the highest number of leaves produced was Gella 1 x Dirbuni (93) followed by Pukum 1 x Dirbuni (58). The least number of leaves produced were Bature x Hawul (25.33) and Pukum 1 x Pukum 2 (23.50)

4. 3. 4 Number *of pods*

The highest producer in terms of the number of pods was Pukum 1 x Dirbuni (23.345) and Pukum 1 x Puba (20) followed by Gella 2 x Gudumya and Gella 1 x Pukum 2 (about 19). On the other hand, Bature x Gudumya was the least producer of pod number (about 5).

4. 3. 5 *Pod Length*.

Pukum 1 x Hong produced the longest pods (21.273 cm) followed by Gella 1 x Shafa (20.132). The shortest pod of 5.400cm was recorded for Gella 2 x Hong.

4. 3. 6 *Pod width*

The fattest pod of 13.936 cm was produced by Gella 2 x Hong and Gella 2 x Puba followed closely by Bature x Gudumya (13.000). The slimiest pod was produced by Gella 2 x Pukum 2 (4.283cm).

4. 3. 7 *Number of branches*

Gella 1 x Dirbuni was the most branched genotype (9) followed by Pukum1 x Dirbuni (8). None-branching genotypes were Gella 1 x Hong, Gella 2 x Hong, Bature x Hong, Bature x Gudumya and Bature x $L_{6.}$ It can be seen that the genotypes with higher number of branches produced the highest number of pods.

4. 3. 8 *Plant Height*

The tallest hybrid was Gella 1 x Gudumya (206 cm) followed by Gella 1 x Marama (182.170cm). The shortest height was Pukum 1 x Hawul (57.830 cm) followed by Gella 1 x Shafa (66.670 cm).

4. 3. 9 *Pod yield/plant*

Gella 1 x Shafa had the highest yield of 28.060g/plant followed closely by Pukum1 x Puba (26.987g / plant). The least yielder was Gella 2 x Shafa with 14.050g/plant. It was observed that the plant with the highest number of pods was not the highest yielder Pukum 1 x Pukum 2.

4. 4 Components of Genetic Variances

Components of Genetic Variances of the Nine Characters of Okra Evaluated Across locations in 2017 cropping season in a Line x Tester Genetic Variability Study is presented in Table 8. Expectedly, phenotypic variances were generally higher than the genotypic variances in all the characters studied. The highest phenotypic and genotypic variances in all the characters

considered were recorded in plant height (405.523 and 111.118 respectively). High phenotypic and genotypic variances were also observed in number of leaves at 50% flowering per plant (417.352 and 11.434 respectively). Lowest phenotypic and genotypic variances were observed in days to 50% flowering per plant (0.054 and 0.003 respectively) and yield per plant per plant (0.004 and 0.003 respectively)

Phenotypic coefficient of variation showed higher values than genotypic coefficient of variation for the characters. The highest pairs were observed in plant height (10.600 and 58.368) and number of leaves at 50% flowering per plant (11.441 and 20.436)while least was exhibited by yield followed by days to 50% flowering per plant.

The highest genotypic coefficient of variation was observed in pod width followed by number of leaves at 50% flowering per plant. The lowest genotypic coefficient of variation occurred in days to 50% flowering per plant. As for phenotypic coefficient of variation, the highest was also observed in pod width per plant followed by number of branches per plant. The lowest was also observed in days to 50% of flowering per plant.

Narrow sense heritability (h^2) was observed to be highest for days to 50% flowering per plant (0.644) followed by yield per plant (0.177) and number of branches per plant (0.114). It can be observed that these characters showed greater *per se* performances in the hybrids than in the parents (table 5 and 6 compared). The lowest narrow sense heritability was observed for establishment followed by pod width per plant. These characters had little differences between there hybrid and parental *per se* performances.

Genetic advance (GA) had the highest values in number of number branches per plant (505.107) followed by number of leaves at 50% flowering (50.725) while the least value was observed in yield (0.001) followed by establishment count (0.032). It can also be observed that this character (number of leaves at 50% flowering per plant) show higher value in the *per se* performances in the hybrid than in the parents (table 5 and 6 compared).

Environmental variance had the highest values in number of leaves at 50% flowering per plant followed by plant height while the least were observed in pod width per plant followed by days to 50% flowering per plant and yield per plant.

4. 5 General Combining Ability Effects of Parents

General Combining Effects of the Nine Characters of Okra Evaluated Across locations in 2017 cropping season in a Line x Tester Genetic Variability Study is presented in Table 9.

4. 5. 1 *Establishment count per plant*

Gella 1 was the best male general combiner while Hawul was the best female general combiner. Most of the parents were not general combiner for this characters.

4. 5. 2. *Days to 50% flowering per plant*

Gella 1 was the best male general combiner while Hong was the best female general combiner. Most of the parents were not also good general combiner for this characters.

4. 5. 3. *Number of leaves at 50% flowering per plant*

Dirbuni was the best male general combiner (**13.536****) followed by Gella 1 (**2.536****). Hong was the best female general combiner (**5.453**).**

4.5.4 *Number of pods per plant per plant*

Dirbuni was the best male general combiner (**1.375****) while there was any good general combiner among the female parents for this character.

4. 5. 5 *Pod length per plant*

Pukum 1 was the best male general combiner for this character. Hong was the best female general combiner **(3.299**)** for this character.

4. 5. 6 *Pod width per plant*

There was no any parent (male or female) general combiner for this character.

4. 5. 7 *Number of branches per plant*

Dirbuni was the best male general combiner for this character (**2.187**)** white there was no general combiner among the female parents for this character.

4. 5. 8 *Plant Height per plant*

Marama was the best male general combiner for this character (**11.708***) followed closely by Gella 1 (**10.000***). Hong was the best female general combiner for this character (**13.083***) followed closely by Gudumya (**10.666**^{x}).

4. 5. 9 *Pod* ***yield per plant per plant***

There was no any parent (male or female) general combiner for this character.

Gella 1 was the best general combiner. It showed significant positive GCA effects for establishment count, number of leaves at 50% flowering, days to 50% flowering, number of pods, plant height and number of branches. Dirbuni was also good general combiner as it showed significant positive GCA effects for number of leaves at 50% flowering per plant, days to 50% flowering, number of pods per plant, plant height and number of branches while Hong was also good general combiner as it showed significant positive GCA effects combiner for number of leaves at 50% flowering, days to 50% flowering, pod length, and plant height.

It can be observed that the parental varieties (Gella 1 and Dirbuni) performed very well, (considering *per say* performance for yield and its components) were also the best general combiners for most of the characters.

Bature and Marama were the worst general combiners as they did not show any significant positive GCA effects for all the characters except plant height in case of Marama. Surprisingly both had positive GCA effects for days to 50% flowering showing that they are long season varieties.

It can be observed that the three (3) best combiners (Gella1, Dirbuni and Hong) were general combiners for days to 50% flowering, number of leaves at 50% flowering per plant, plant height and number of branches per plant.

None of the parents showed any significant positive GCA effect for pod width per plant and yield per plant (except Hawul for yield).

4. 6 Specific Combining Ability Effects of Crosses

Specific Combining Ability Effects of Crosses of the Nine Characters of Okra Evaluated Across locations in 2017 cropping season in a Line x Tester Genetic Variability Study is presented in Table 10.

4.6.1 Establishment count per plant

Gella1 x Pukum 2 was having the highest positive SCA effect (**0.973***) Both parents exhibited significant positive SCA effect for number of pods. Gella 2 x Dibuni (**0.765*) and** Gella 2 x Puba (**0.682*)** also showed significant positive SCA effect for establishment count.

4.6.2 Days to 50% flowering per plant

In terms of days to 50% flowering, negativity of SCA effects implies earliness while positivity implies lateness. Pukum x Dirbuni hybrids were observed to have exhibited the highest negative significant SCA effects for days to 50% flowering followed by Bature x Hawul. Gella 2 x Hong exhibited negative significant SCA effect for days to 50% flowering signifies earliness and positive significant SCA effect for number of pods and number of branches. These hybrids are therefore early okra varieties. Almost all these hybrids shows positive significance SCA effect for number of pods. On the other hand, the highest significant positive SCA was observed in Gella 2 x Pukum 2 followed by Bature x Puba and Pukum 1 x Hawul. Positive significant SCA signifies late maturity. Therefore these hybrids are late maturing genotypes which can be used for selection of late maturing okra.

4.6.3 Number of leaves at 50% flowering per plant

I case of number of leaves at 50% flowering, the highest was observed in Gella 2 x Hong followed by Gella 1 x Dirbuni.

4.6.4 Number of pods per plant per plant

The highest estimate of SCA effect for number of pods was Gella 1 x Shafa followed by Gella 2 x Dirbuni and Gella 1 x Puba. All the characters that exhibited high SCA effects also had at least one high general combiner as one of the parents in the cross.

4.6.5 Pod length per plant

12 hybrids where found to exhibit high positive SCA effect for pod length. The highest effect was observed in Gella 2 x Puba followed by Bature x Gudumya, Gella 1 x Pukum 2, Gella 1 x Hawul and Gella 1 x Dirbuni. Some of them (Gella 1 x Pukum 2, Gella 1 x Hawul and Gella 1 x Dirbuni) had one or both parent as general combiners for pod length. In addition some of the hybrids exhibited very low SCA effects for pod width and yield.

4.6.6 Pod width per plant

None of the crosses showed any significant (either positive or negative) SCA effects for pod width per plant.

4.6.7 Number of branches per plant

The highest estimate of number of branches was observed in the cross Gella 1 x Shafa followed by Gella 2 x Hong. Gilla 1 x Shafa hybrid also exhibited negative SCA effect for days to 50% flowering and plant hight (early and dwarf hybrid) and high significant positive effect for number of leaves at 50% flowering, number of pods and pod width. They also exhibited high per say performance in number for branches.

4.6.8 Plant Height per plant

For plant height, Gella 1 x Hawul was having the highest positive SCA effect (43.760) followed by Pukum1 x Dirbuni. Both parents exhibited significant positive SCA effect for number of pods, while Gella 1 x Hawul (significant positive SCA effect) was a late maturing hybrid, Pukum x Dirbuni (significant negative SCA effect) was an early maturing hybrid.

4. 6. 9 *Pod* ***yield per plant per plant***

None of the crosses showed any significant (either positive or negative) SCA effects for yield per plant.

4. 7 Genotypic and Phenotypic Correlation

The Genotypic and Phenotypic Correlation of The Nine Characters of Okra Evaluated across Locations in 2017 cropping season is Presented in Table 11.

4. 7. 1 ***Establishment count per plant***

At the genotypic level, establishment count had significant positive correlation with all other characters except days to 50% flowering and yield which are negative. At the phenotypic level, there was no any correlation with any character.

4. 7. 2. ***Days to 50% flowering per plant***

It had only a single positive correlation with plant height (0.7790**) and negative correlation with number of branches (-0.4832*). At the phenotypic level, there was no correlation with any other character.

4. 7. 3. ***Number of leaves at 50% flowering per plant***

At the genotypic level, it had positive correlation with number of branches per plant (0.4936*) and positive correlation with number of branches per plant at the phenotypic level (0.4785*).

4.7.4 ***Number of pods per plant per plant***

There was no single correlation with any other character at both genotypic and phenotypic levels.

4. 7. 5 ***Pod length per plant***

There was positive correlation with establishment at both genotypic level (0.7900**) and phenotypic (0.5777*) levels.

4. 7. 6 ***Pod width per plant***

There was single correlation with establishment (0.8100**) at genotypic level but none at phenotypic level.

4. 7. 7 *Number of branches per plant*

Pod length per plant did not have any significant positive correlation with any character at either genotypic or phenotypic levels but had significant negative correlation with establishment count at genotypic level.

Surprisingly, yield did not show any significant positive correlation with any of the characters in this study but had significant negative correlation with establishment count a
plant height at genotypic level. However it showed insignificant positive correlation effect with days to 50% flowering for yield at both genotypic and phenotypic levels.

There was positive correlation establishment (0.7900**) and days to 50% flowering (0.5848*) at both genotypic and phenotypic levels respectively.

4. 7. 8 *Plant Height per plant*

There was positive correlation establishment (0.8300**) and number of leaves at 50% flowering (0.4785*) at both genotypic and phenotypic levels respectively.

4. 7. 9 *Pod* ***yield per plant per plant***

There was single correlation with establishment (0.8100**) at genotypic level but none at phenotypic level.

Genotypic correlation (upper right triangle) showed significant differences for nine (9) pairs of characters while phenotypic correlation (lower left triangle) showed negative significant differences for only three (3) pairs of characters. The genotypic correlation in general was higher than the corresponding phenotypic correlation for most of the characters. It can also be observed that majority of the pairs of characters were not significantly associated with one another for yield at phenotypic level and only few at the genotypic level for correlation coefficient.

At the genotypic level, establishment count had the highest number of characters that it correlates with for yield. It had highly positive correlation coefficient with number of leaves at 50% flowering, number of branches per plant, plant height, number of pods per plant and pod width per plant but not with days to 50% flowering and yield. There were no single characters that it correlates with for yield at the phenotypic level

There was significant positive correlation coefficient between days to 50% flowering with plant height, number of leaves at 50% flowering with number of branches per plant and number of pods per plant with number of branches for yield at both genotypic and phenotypic levels.

Plant height exhibited highly significant positive correlation with establishment count and days to 50% flowering per plant but had none at the phenotypic level. However plant height showed highly significant negative correlation coefficient with days to 50% flowering per plant, pod length per plant and pod width per plant as well as number of pods per plant and establishment count for pod yield. Pod length per plant showed insignificant positive correlation effect with days to 50% flowering for yield at both genotypic and phenotypic levels.

4. 9 Path Analysis

The combined estimates of direct and indirect effects of yield components of okra on yield of pods per plant from path coefficient analysis of the nine characters of okra evaluated across locations in 2017 cropping season in a line x tester analysis is presented in Table 12.

In the table, the diagonal figures indicate the direct effects while the non-diagonals represent the indirect effects.

The path coefficient analysis reveals that number of leaves at 50% flowering and pods width had the highest positive direct effect on yield though, their correlation with yield were low and negative. On the other hand, number of pods per plant, pod length and plant height showed significant negative direct effects on yield and their respective correlations with yield were also negative except plant height (which is positive) and low.

4.9.1 *Indirect effects*

4.9.1.1 ***Establishment count***: It showed no positive indirect effect with any of the characters for yield

4.9.2 *Days to 50% flowering*:

Though its direct effect on yield was positive but low, it had no significant positive indirect effect with any of the characters for yield.

4.9.1.3 ***Number of leaves at 50% flowering***: It had a highly significant positive indirect effect with establishment count and low positive insignificant effect with number of branches, number of pods per plant and pod width per plant.

4.9.1.4 ***Number of branches*****:** Though all the characters had positive insignificant indirect effect on yield except days to 50% flowering, they are low. Its direct effect is low and insignificant

4.9.1.5 ***Plant height per plant*****:** It had positive significant indirect effects with establishment count and insignificant positive indirect effects with number of leaves at 50% flowering, number of pods per plant, pod length per plant and pod width per plant.

4.9.1.6 ***Number of pods per plant*****:** It had highly positive significant indirect effects with days to 50% flowering per plant, pod length per plant and plant height. There was also highly negative significant indirect effects with establishment count.

4.9.1.7 ***Pod length per plant***: It had positive significant indirect effect with number of pod per plant and plant height. It also had highly negative insignificant indirect effects with establishment count and days to 50% flowering.

4.9.1.8 ***Pod width per plant*****:** It had highly positive insignificant indirect effects with establishment count and significant positive indirect effect with number of pods per plant and highly negative insignificant direct effects with plant height.

4.9.1.9 ***Yield per plant*****.** Yield had negative insignificant indirect effect with all the characters except plant height which is low

CHAPTER FIVE
DISCUSSION

5.1 Combined Across Locations

5.1.1 *Analysis of variance*

The result obtained in the analysis of variance for the combined locations indicated that large amount of genetic variability existed between the parents and crosses. It therefore suggests that both the parent population and the hybrids derived from them would most likely respond to selection pressure. This is in consonance with what has been reported earlier by Anwanobong and Ebiamadon, (2015) and Duzyaman and Vural, (2002), where it was demonstrated that such genetic variability existed amongst okra varieties. Differences in flowering periods among the varieties in the current study implied that their maturity periods vary. Depending on the desire of the breeder, appropriate selection can thus be made for either early or late maturing varieties.

The significant variances observed in the SCA (non-additive gene effects) for some of the characters were indicative of the importance of non-additive genetic effects in the inheritance of some of the characters. Jagan *et al.* (2013) had observed that these types of parents may be used for hybridization to produce promising varieties. However, the magnitude of the SCA variances appeared more predominant indicating that the non-additive effect is more important in the control and inheritance of these characters. This reveals the role of environmental factors in the expression of the characters. Nandan *et al.* (2007) using Line x Tester study found that *gca* variances was greater than *sca* variances for fruit yield per plant indicating preponderance of additive gene action for this trait in okra. They stated that the results are indicative of the fact that hybrid okra has great potentialities of maximizing fruit yield. But Sateesh *et al.* (2013) also using Line x Tester study indicated the presence of the predominance of non-additive gene action for all the characters suggesting the effect of environmental factor of gene action in okra, similar to this study.

The non-significant differences observed for pod width per plant and yield per plant indicates that the genetic components of these characters are intact and therefore, any improvement sort must be directed towards these characters. AdeOluwa and Kehinde, (2011) had observed similar occurrence for some characters in okra.

The interaction between location and entries, crosses, lines and testers were significant for most of the characters indicating that the environments in the two locations had influenced the parents, crosses, GCA and SCA to a great deal. This implies that the two locations were probably deferent in most of the environmental factors. AdeOluwa and Kehinde, (2011) had observed similar occurrence in okra for some characters. The GCA variance comprises of fixable portion, while the SCA represents nonfixable genetic variance. Selection is more effective and progress in evolving the economic characters is much faster when genetic variance is primarily due to additive gene action. Selection is therefore, more effective in days to 50% flowering and number of leaves at 50% flowering. In such situation, not only the means of generation remain unchanged but the genetic variance is readily translatable from one generation to another.

Pod width per plant and yield per plant had no significant differences for any of the sources of variation. It shows that these characters were not affected by environmental variation of the two locations.

The estimates of GCA/SCA ratio (variance ratio) indicated that a relatively higher proportion of SCA was responsible for the expression of all the characters. The magnitude of the ratio varied among different characters (Sateesh *et al*., 2013). This in turn indicates the prevalence of non-additive gene action determining these characters.

The contribution of lines x testers interaction to the total variance was higher for all the characters considered in this study. The contribution of lines to the total variance was also higher for all the characters considered in this study than the testers. The high contribution of lines to the total variance indicates the importance of both lines and lines x testers interaction to the total variance. The result is in agreement with the findings of Kachadia *et al.* (2011)

5.1.2 *Mean performance of parents and crosses*

An examination of the mean (*Per se*) performance of parents and hybrids for different characters revealed the superiority of some of the varieties over others. Good potential exist for varieties such as Gella 1 and dirbuni which had outstanding performances for both yield and yield components. Gella 1 was the best general combiner. Similarly, Gella 1 x Puba, Gella 1 x Shafa, Gella 2 x Hawul, and Pukum 1 x Shafa were identified as superior yielding crosses which could be used for further selection to obtain high yielding varieties of okra. Depending on the objective of the breeder, there is a wide range of varieties to choose from for improvement in terms of yield and yield components of okra. As had been observed by Akram and Shah, (2002) if the objective is to produce an early maturing of okra, with high number of pods and pod length the hybridization with Hawul (the earlies variety with high number of pods and pod length) will bring about the desired objective. Alternatively, as Jaiprakashmarayan *et al.* (2013) stated, if it is required to produce high yielding variety due to increased number of leaves, number of pods and pod length, then Gella 1 and Pukum 1 and Dirbuni could be choice for hybridization. Since leaves serve as the sites for photosynthetic activities in any plant, an increase or a decrease in their number may have very serious implications for production of assimilates in the crop. Consequently, a greater number of them in any particular variety would be assumed to produce a better crop yield due to the higher photosynthetic capacity that is brought to bear by an increased leaf area index and a resultant higher intercepted radiation and its utilization efficiency, Ahiakpa *et a*l. (2013)

Similarly, Gella 2 x Hawul was the earliest hybrid, therefore these parental combinations can be used to select for early maturing varieties of okra. If the desire is to produce a high yielding of okra due to increased number of leaves, pod width and height the combinations of Gella and Shafa would probably result into meeting the objective.

Variation was also observed in the number of pods. The highest number of pods was produced by Pukum1 x Dirbuni (23) followed by Pukum1 x Puba (20). Number of pods is a good measure of productivity which may be exploited in breeding progamme to produce high yielding okra varieties.

Pukum 1 x Hong, Gella x Shafa and Gella 1 x Hawul produced the longest pods per plant ranging from 19.880cm – 21.223. Gella 1 x Hong (28.060) and Gella 1(27.450) had the highest yield per plant. The tender green pod is often considered as the most important and economical part of okra production since it is utilized as vegetable. Consequently, fruit length in consonance with pod number and pod weight are the most important determinants of production or yield. Thus, selection based on these characters will be quite beneficial in okra breeding programmes. These results are also in conformity with others reported earlier by Sakar *et al.* (2005) and Shafiquraahan ans Sailesh, (2017).

5.1.3 Components of genetic variances

Genetic parameters for yield and yield contributing characters of okra varieties showed wide variation genotypically and phenotypically. The high significant genotypic and phenotypic variances observed for some of the characters studied (plant height and number of leaves at 50% flowering) indicated that the genotypes utilized are of variable background thereby providing a large scope for selection. As had been observed by Abshishek *et al.*, (2013) phenotypic variances were generally higher than their respective genotypic variances thus revealing the role of environmental factors in altering the expressions of characters. Similar trend of variation was reported by AdeOluwa and Kehinde, (2011) in okra. The preponderance of σ^2sca revealed the predominant role of non-additive gene action governing these characters. These results of the present investigation are in conformity to the findings of Kachhadia *et al*. (2011), Rafi and Nath, (2004) and Kumar *et al*. (2014). Swati, (2014) had also stated that high ðpcv and ðgcv were observed for yield per plot and number of fruit per plant. High heritability values coupled with high genetic advance were recorded for weight of fruit per plant and plant height. They were of the view that the genetic makeup, environmental factor and age of the plant affect the number of fruits and size of the fruits which in turn is responsible for overall yield efficiency.

The environmental influence was considerable for all the characters except pod width and yield which could be observed from the differences between genotypic variance and phenotypic variance and also the differences between genotypic co-efficient of variation and phenotypic co-efficient of variation. The character was highly potential for selection. In pod width and yield, higher genotypic variance compared to phenotypic variance was not found. Genotypic co-efficient of variation were also lower than the corresponding phenotypic one which indicated the larger influence of environment and phenotypic selection would not be effective in these characters. The result of this study agrees with the findings of Alam and Hossain, (*2008*)

Phenotypic coefficient of variation was observed to be higher than the corresponding genotypic coefficient of variation for all the characters studied implied their relative resistance to environmental variation. It also shows that genetic factors were predominantly responsible for expression of these characters and selection could be made effectively on the basis of phenotypic performance. This is vividly observed in plant height and number of leaves indicating less environmental influence on the phenotypic expression of these characters and they are mostly governed by genetic factors. Hence, selection of these characters simply on the phenotypic value may be effective. The finding of Christo and Onuh, (2005) and Sateesh *et al*. (2013) were similar to that of the present findings. AdeOluwa and Kehinde, (2011), Adeniji *et al.* (2007) and Omonhinmin and Osawaru, (2005) reported that phenotypic variances were greater than genotypic variances, suggesting the role of environmental factor in the genotypic expression of the various okra varieties which give rise to the variability they observed for all the traits they studied. Based on this, Siemonsma and Kouame, (2004) and Nwangburuka *et al.* (2012) suggested the use of phenotypic variance together with genetic advance to determine possible genetic progress.

The high value of PCV and GCV observed for number of leaves at 50% flowering per plant and plant height showed less influence of environment on their phenotypic expression while low GCV and PCV value of characters e.g. days to 50% lowering per plant and yield per plant on the other hand suggested the greater environmental impact on these characters thus; selection on account of phenotypic source would not be valuable for the genetic improvement of crops. This is in line with what Bello *et al.* (2015) had earlier observed..

On the contrary, a wide difference between PCV and GCV was observed for number of leaves at 50% flowering, number of pods per plant, pod length per plant, number of branches per plant, number of branches per plant and plant height indicating higher influence of environment on these characters thus, selection on the phenotypic basis would not be effective for the genetic improvement of such characters. Similar results were obtained by), Chaurasia *et al*. (2011) and Das *et al*. (2012).

Chaurasia *et al*. (2011), Vrunda *et al.* (2018) and Bello *et al*. (2015) had reported that when heritability is high for a character, selection is fairly easy for that character and that a very high heritability also indicated high genetic base. A close relationship between the genotype and phenotype is probably based on small environmental effects. Therefore, selection for these characters could lead to appreciable increase in okra pod yield. In this study, days to 50% flowering, yield and number of branches exhibited higher values for narrow sense heritability. In this respect, Kishor *et al.* (2016) reported that the higher values of narrow-sense heritability for a particular character indicated that it is controlled largely by genes acting in an additive effect. Thus, if heritability is high for a character, the plant breeder can go for selection of individuals or group of individuals. In crops like okra high narrow-sense heritability estimates may be helpful for the development of improved varieties as such days to 50% flowering, yield and number of branches can be used for the development of improved varieties of okra. Bello *et al*. (2015) and Muluken *et al*. (2016) had reported moderate heritability value for number of primary branches while low broad sense heritability estimate however, was observed for number of pods per plant. They suggested that these genotypes cannot be improved through direct selection for these characters. These results are also in close conformity with the findings of Da *et al*. (2012); El-Gendy *et al*. (2013) and Jagan *et al*. (2013). Low heritability as observed for most of the characters (establishment count, number of leaves at 50% flowering, number of pods per plant, pod length per plant and pod width per plant) also suggested ineffective direct selection in improving the characters because of masking effect of the environment, Bello *et al.* (2015). On the other hand, a situation where the characters had both low heritability and genetic advance as observed for establishment count and pod with require special techniques including recurrent selection and hybridization should be followed Bozokalfa *et al.* (2010) and Muluken *et al.* (2016).

Similarly, days to 50% flowering, pod width per plant, and number of branches per plant, with high estimates of heritability, GCV and GA, may be good predictors of yield in crops according to Mehta (2006). This agrees with the finding of Ibrahim and Hussein, (2006).

Bello *et al.* (2015) and Pradip *et al.* (2010) stated that the proportion of heritable variation was not sufficient to ascertain the genotypic coefficient of variation alone, but with the assistance of heritability estimates and genetic advance expressed as percentage of mean. Both high heritability in conjunction with genetic advance estimates, not only provide adequate information on each parameter, but also depicted an expression of additive genetic effect as well as genotypic response to selection. Therefore, the high estimates of heritability, GA and GCV recorded in number of branches per plant could be explained by additive gene action, hence its improvement can be done through mass selection (Randhawa and Sharmar, 1972; Ibrahim and Hussein, 2006). Ibrahim and Hussein, (2006) and Pal *et al.* (2010) had observed that, for inter-character association estimates to be repeatable such character must have both significant genotypic and phenotypic correlations and any selection based on this is reliable (Ibrahim and Hussein, 2006).

Johnson *et al.* (1955) stated that heritability estimates together with genetic advance are more important than heritability alone to predict the resulting effect of selecting the best individuals. Hamdi *et al.* (2003) reported that genetic advance is also of considerable importance because it indicates the magnitude of the expected genetic gain from one cycle of selection to another. Therefore, both heritability and genetic advance must be estimated together to obtain reliable selection pressure in a breeding programme. High genetic advance with high heritability estimates offer the most effective condition for selection (Larik *et al.*, 2000).

Number of branches had exhibited high narrow sense heritability with high genetic advance as percentage of mean. Panse, (1957) had concluded that a character with high heritability in association with high genetic advance is an indication of expression of additive gene action. He concluded that characters without such combination appear generally because of non-additive gene action. Demelie *et al.* (2016) observed that both heritability and genetic advance values were high for tender fruit yield, fruit length and fruit weight and other yield related characters in okra. Swati *et al.* (2014) also reported high narrow sense heritability for weight of fruit per plant followed by plant height and that plant height was highly potential character for selection in Okra.

Vrunad *et al.* (2019) had also observed that environmental influence was meagre on expression of characters as evident by narrow gap between genotypic and phenotypic co-efficient of variation. The genotypic and phenotypic co-efficient of variations were high for all the characters except days to 50% of flowering and yield. A high range of variation, genotypic co-efficient of variation, heritability and genetic advance for plant height, number of branches per plant, and fruit yield per plant was recorded. This indicated broad genetic base, less environmental influence and these characters are under control of additive genes, simple and early selection schemes would be effective for improvement of these characters.

Low estimation of heritability was recorded for establishment count, plant height, number of leaves at 50% flowering, number of pods, pod length and pod width. This is indicative of the fact that these characters are rather more influenced by the environment and may not respond much to selection phenotypically.

Heritability however, indicates only the effectiveness with which selection of a genotype can be based on phenotypic performance, but fails to indicate the genetic progress. Heritability estimates along with genetic gains found in days to 50% flowering and number of branches per plant are more effective and reliable in predicting the improvement through selection Johnson *et al.* (1955) and Alam and Hossain, (*2008*). Alam and Hossan, (2008) also stated that the estimates of genetic advance helps to predict the extent of improvement that can be achieved for improving the different characters.

High genetic advance observed in number of leaves at 50% flowering and plant height suggest that effective selection based on these character might be effective for increasing pod yield. High heritability with low genetic advance seen for yield revealed that non-additive gene action was involved for expression of this character. The high heritability was exhibited due to the influence of favorable environment rather than genotype and selection for such trait may not be rewarding. This result is also similar with those reported by Abdelmageed, (2010); El-Gendy *et al*. (2013) and Jagan *et al*. (2013).

The low genetic advance observed for establishment, pod width per plant and yield could mainly be due to non-fixable (non – additive) gene effects i.e. dominance and epistatic effect of genes as suggested by AdeOluwa and Kehinde, (2011). They suggested that such characters can be improved by method of recurrent selection.

5.1.4 General combining ability effects of parents

General combining ability (GCA) refers to the average performance of a parent in a series of crosses in which that line has been a common parent. The genetic potential of the parents is expressed in terms of combining ability. Among the parents involved in a large number of crosses, only few exhibits superiority and such parents producing a good hybrid are considered as good general combiners.

Gella 1 was the best general combiner among the testers for most of the characters. It showed highly positive significant effects for plant height, days to 50% flowering and number of leaves at 50% flowering. Height and number of leaves in plant are important. Height in plant is an indication of increased number of flowers and therefore yield, whereas number of leaves signifies high synthetic capacity, therefore increased production. Gella 1 was also observed to have positive significant GCA effect for number of branches, pod length and establishment. Good GCA effect for these characters are also important because they are good indicators of yield in plant.

Dirbuni and Hong were found to be the general combiner among the lines for four characters each. Parental varieties showing good general combining ability may be used in a multiple crossing programme from which high yielding varieties can be obtained.

Gella 1, Dirbuni and Hong showing high GCA value indicates that they show potent evidence of desirable gene flow from parents to offspring at high intensity and represents information regarding the concentration of predominantly additive genes effects. They may also show higher heritability and less environmental effects and also result in less gene interactions and higher achievement in selection. Franco *et al*. (2001) had earlier stated that a high GCA value shows that the parental mean is superior or inferior to the general mean. This indicates a potent evidence of desirable gene flow from parents to offspring at high intensity and represents information regarding the concentration of predominantly additive genes.

It is worth noting that the high GCA effects were obtained from the parents with highest means for a particular character. AdeOluwa and Kehinde, (2011) had reported similar observation.

It can be justified to say that good general combining parents can be predicted from their *per se* performance for each character and not necessarily going into the calculation of the cumbersome GCA effects.

Pod width per plant and yield per plant did not show any significant GCA effect by any of the parent studied. Selection based on these characters will not be viable for improvement of okra since no parent can combine for them. Similar situation was observed in Table 7 where these characters did not show any significant differences. Heritability and genetic advance for these were also found very low (Table 10). The presence of non-additive gene effect had played a great deal in this respect.

5.1.5 Specific combining ability effects of crosses

Specific combining ability effects are usually used to identify the best cross combinations for hybrid production. In this study, there was close correlation between SCA and the *per se* performance of some crosses suggesting that the *per se* performance could be used to select the best cross combination for this characters. It can be seen that the best cross combinations in terms of SCA effect involve one or both parents as good general combiners.

In this study, good number of hybrids had been identified for significant SCA effects for some of the characters observed. The inter-crossing of these okra varieties could generate a population with large gene pool from which superior varieties and hybrids could be produced. AdeOluwa and Kehinde, (2011) had similar observation. Hazem *et al.,* (2013); Sateesh *et al*. (2013) and Mandan et al. (2007) had reported significant SCA effects exhibited by hybrids for all characters studied while Hannan *et al.* (2007) found some high SCA effects for fruit weight per plant in a combination of one good combiner and one average or poor combiner.

Significant number (13) of the hybrids showed significant positive SCA effects for number of leaves at 50% flowering. Great number of leaves in plant is an indication of increased amount of food synthesis and therefore increased yield. Selection for this character can therefore be realized by the use of these hybrids. Similar findings have been reported by several researchers (Divan *et al*., 2013 and Hosana *et al*., 2015).

Many of the hybrids showed negative significant SCA effects for days to 50% flowering (Pukum 1 x Dirbuni, Bature x Hawul, Gella 2x lMarama, Bature x Dirbuni and Pukum 1 x Pukum

2. Negative significant SCA effect implies earliness and therefore these hybrids can be used for selection of early maturing varieties of okra.

5.1.6 Genotypic and phenotypic correlation

Frageria and Kokli, (1997) stated that the degree of relationship or association between various characters with yield can be ascertained by correlation studies. Bhazrdwaj and Sharma (2005) indicated that correlation between characters of economic importance is valuable in making decisions for selection purpose. Kadams, (1999) had reported that the most important association for improvement in plants is the relationship between yield and its components. Sibsankar *et al.* (2012) and Osekita and Ariyo, (2000) showed that correlation analysis indicated priority for selection base on number of fruits per plant and fruit weight for yield improvement in okra. Characters such as time of flowering, time to set fruit, number of fruits per plant, fruit size and weight are functions of fruit yield in okra and that these characters are found to be positively and significantly correlated with yield.

It is obvious that fruit yield is a complex character that depends on many independent yield contributing characters, which are regarded as yield components. Changes in yield due to varying degree of positive and negative associations between yield and its components and among components themselves. Therefore, as Osetika and Akinyele, (2008) and Medagam *et al.* (2013) stated that selection should be based on these component characters after assessing their association with fruit yield per plant.

The significant positive genotypic correlations in general were higher than corresponding significant positive phenotypic correlations for most of the characters in this study suggest very strong inherent association between various characters at genetic level and that the phenotypic effect has a lot of environmental influence. Higher genotypic correlation coefficient over phenotypic correlation coefficient suggests very strong inherent association between various characters at genetic level. This trend was also observed by Manyong *et al.* (2002); Medagam *et al.* (2013); Shafiqurrahaman *et al.* (2017), and Ibrahim and Hussein (2006). More significant genotypic association between the different pairs of characters than the phenotypic correlation means that there is strong association between those characters genetically, but the phenotypic value is lessened by the significant effect of environment. A positive correlation between desirable characters is valuable to the plant breeder because it helps in determining the extent of improvement that could be brought in the characters and also in selecting suitable genotypes.

The results emphasize that selection based on pod length per plant will be essential enough in improving plant yield because their correlation with yield were positive. The results are in line with Rashwan, (2011) an El-Gendy, (2012).

Ibrahim and Hussein, (2006) stated that for inter-character association estimates to be repeatable such character must have both significant genotypic and phenotypic correlations and any selection based on this is reliable. Therefore, the positive and significant phenotypic and genotypic correlation between plant heights with days 50% flowering per plant, number of pods per plant with number of branches per plant, across the environments is a strong indication that these traits are major factors in relation to yield per plant and pod yield per plant. This suggests that selection directed towards these characters will be effective in ensuring pod yield in okra. This also agrees partly to the report of Adeniji and Aremu, (2007).

However, the negative significant correlation at the phenotypic and genotypic levels between days 50% flowering with number of branches suggests that any selection to improve pod yield directed towards the phenotype of these characters will be effective. The negative correlation between yield and the above characters may be due to the direct negative relationship between them and suggests the influence of environmental factors limiting the yield (Ibrahim and Hussein, 2006). This agrees with the report of Malik *et al*. (2000).

Izge *et al.* (2006) had earlier, working on millet reported that correlation coefficients for most of the pairs of characters revealed the presence of strong positive genotypic association between yield/ha with number of tillers/plant, number of leaves/plant, plant height, panicle length, number of seed/panicle and yield/plant. Strong and positive phenoltypic association also existed between yields/ha, with number of tillers/plant, number of leaves/plant, plant height, panicle length, number of seeds/panicle and yield/plant. They observed that even though, both the types of correlations are comparable in magnitude, the genotypic correlations are of higher magnitude than their corresponding phenotypic correlations, indicating a strong inherent relationship among the characters studied.

The negative correlation between days to 50% flowering and yield at the phenotypic level is an indication of earliness which can be exploited for increased yield. Its genotypic correlation with yield was also negative and significant. Simon *et al.* (2013) had observed that selection for early flowering may result in an increased number of pods per plant, ultimately leading to an increased yield.

5.1.7 Path analysis

The path co-efficient analyses developed by Wright (1921) provides an effective means of untangling direct and indirect causes of association and permits a critical examination of the specific forces acting to produce a given co-relation. Medagan *et al.* (2013) had stated that path analysis is a statistical method for determining the magnitude of multiple effects on a complex process. Bhardwaj and Sharma, (2008) and Frageria and Kokli, (1997) had earlier reported that path coefficient partitions correlation coefficient into direct and indirect effects through alternate pathways towards realization of yield. These pathways (characters) contribute to the realization of yield.

The result of this study indicated that number of pods had the highest positive direct effect on yield though its correlation with yield was negative and insignificant. This is so because of the indirect effects of establishment, number of branches and plan height had more than counter balanced its direct effect. Sibsankar *et al.* (2012) had reported similar results.

There was positive direct effect towards yield by the number of leaves at 50% flowering though its genotypic correlation with yield was negative and low because of the high negative effects of number of branches and other negative characters which had more than counter balanced its direct effect. These results are in close harmony with the finding with Saryam *et al.* (2015) and Yadav *et al.* (2002).

Number of branches had the highest negative direct effect on yield and its correlation with yield was also negative and low. This could be attributed due to the abundant negative indirect effects which has more than counter balanced all the other positive indirect effects. Steve and Katayama, (2013) had reported similar finding.

Plant height also showed high negative direct effect on yield and its genotypic correlation with yield was negative and high. This direct effect had more than counter balanced all the other positive indirect effects. Saryam *et al.* (2015) and Sibsankar *et al.* (2012) also found similar results.

Pod width, though had medium negative direct effect on yield its genotypic correlation with yield was positive but low. This had been so because of the more than counter balancing effects number of branches, plant height and all the other positive indirect effects had on the negative direct effect. Gangashetti *et al.* (2013) and Saryam *et al.* (2015) found similar results.

CHAPTER SIX.

6.0 SUMMARY, CONCLUSION AND RECOMMENDATIONS.

6.1 Summary

Okra (*Abelmoschus esculentum* (L) Moench) also known as ladies 'fingers' are valued for its edible green seed pods (fruits) and one of the widely grown vegetables in the world especially Nigeria. Two major classes of okra in West Africa: the Conventional, *Abelmonschus esculentus*, a native of Asia and the unconventional, the *Abelmonschus callei* a native of Africa which grows naturally in many parts of West Africa especially in the marginal lands (roadsides, backyard farms and wastelands.

Okra plant is believed to have originated in South Asia, Ethiopia or West Africa especially Nigeria, now cultivated in the tropical, subtropical and warm temperate regions of the world. Okra leaves and fruits (pods) produce a mucilaginous substance, which makes most African delicacies especially soup, slimy and thick, thereby making consumption of bulky foods such as eba, and pounded yam (fufu). Okra is a popular health food due to its fibre, vitamin C, folate content, a good source of calcium and potassium. It is also known for being high in antioxidants.

Poor yielding genotypes are among the production challenges confronting okra production in Nigeria though its production plays a significant role in the economy. The local cultivars of okra under cultivation over the years in Nigeria are landraces which are highly susceptible to diseases, long maturity periods yet short harvesting duration, poor nutritional value, and above all non-standard and in shape, colour and sizes. Developing improved varieties that are perennial in growth, higher yield, early maturing with longer harvesting duration as well as standard fruit sizes, shapes, and colour are highly desirable. Selection of high yielding cultivars for the edible fruits becomes necessary. Present cultivars of okra in Nigeria have shown high variability in several characters including yield but the yields of these cultivars per unit area of land and per unit of time are very low because of their very low yield capacity. Therefore, there is need to evaluate the amount of genetic variability, heritability and character association of some quantitative characters in cultivated varieties of okra for possible improvement in quality of yield and yield components.

The indeterminate nature of the okra landraces is a character which might have been selected for over the years by researchers and farmers because it allows for longer and continuous fruit harvest. This is an advantage when prices of the vegetable fluctuate. Farmers do not want these plants to produce long branches and would rather opt for more plants per area unit. Previous studies suggested this to be advantageous because it allows the combination of large numbers of fruit with many plants per unit space, which is an indicator of high yield.

The first step in crop improvement is to investigate and establish vital information which would be useful to the breeder in planning breeding programmes. It is for this reason that genetic variability study was undertaken using 12 okra varieties namely Gella 1, Gella 2, Pukum 1, Bature, Dirbuni, Puba, Hong, Shafa, Gudumya, Hawul, Pukum 2, and Marama.

This study was undertaken to examine the general and specific combining ability effects, genetic components, correlation, heritability, genetic advance and path coefficient in forty four (44) okra genotypes (parent and crosses). These were carried out to investigate and establish vital genetic information for identifying promising parents and crosses with good breeding values of important agronomic character for developing high yielding okra varieties.

Line by tester design developed by Kempthorne, (1957) and described by Singh and Chaudhary, (1985) being a powerful tool commonly used for estimation of GCA and SCA effects involving a large number of genotypes which provides information about the general and specific combining abilities of parents and at the same time being helpful in estimating various types of gene actions was used to cross four testers with eight lines. The twelve parents and thirty two cross combinations where evaluated in two locations viz: Hong and Yola in a randomized complete block design (RCBD) with three replications in the 2017 cropping season. These two locations are of differing soil and climatic conditions. The data collected on yield and its components were subjected to biometrical analysis.

The result obtained revealed that the variances for entries, parents and crosses were significant for most of the characters implying that the genotypes used were highly variable and amenable to selection procedures. The GCA and SCA variances were also significant for days to 50% flowering and plant high suggesting that both additive and non-additive gene effects were important in the genetic control of these characters. However, the non-additive gene effect was more predominant going by the ratio ð^{2}GCA / ð^2 SCA which were all less than unity. These further suggest that a breeding strategy most be adopted that would take cognizance of the gene effect simultaneously. Preferably the use of biparental mating followed by selection can be formulated to achieve rapid genetic improvement in this okra population.

Per se performance of parents and crosses indicated that it was possible to identify the best parent and cross combination. Parents such as Gella 1 and Dirbuni were found to be good parents for most of the characters while Gella 1 x Dirbuni, Gella 1 x Gudumya, Gella 1 x Pukum 2 and Pukum 1 x Pukum 2 were also identified as good crosses for most of the characters.

The high significant genotypic and phenotypic variances observed for some of the characters studied (plant height and number of leaves at 50% flowering) indicated that the genotypes utilized are of variable background thereby providing a large scope for selection. Genetic components analysis has revealed that ðpcv was higher than ðgcv for all the characters indicating that environmental influences was low suggesting that selection for these characters can be done based on their phenotypic performances.

Higher values of narrow-sense heritability for a particular character indicated that it is controlled largely by genes acting in an additive effect hence the plant breeder can go for selection of individuals or group of individuals. In crops like okra high narrow-sense heritability estimates may be helpful for the development of improved varieties as such yield and number of branches can be used for the development of improved varieties of okra.

The highest narrow sense heritability was observed in days to 50% flowering. These indicate that this character is controlled by additive gene effect and selection based on these characters would be very promising on phenotypic appearance. Similarly, Gella 1 x Pukum 2 had the highest number of characters with high SCA effects. Gella 1 and Pukum 2 were good general combiners as such at Gella 1 x Pukum 2 was a result of additive + additive gene actions. Selection based on these cross would lead to improvement in okra yield.

High genetic advance observed in number of leaves at 50% flowering and plant height suggest that effective selection based on these character might be effective for increasing pod yield. High heritability with low genetic advance seen for yield revealed that non-additive gene action was involved for expression of this character. The high heritability was exhibited due to the influence of favorable environment rather than genotype and selection for such trait may not be rewarding.

Gella 1, Dirbuni, Puba and Hong showing high GCA values indicate that they show potent evidence of desirable gene flow from parents to offspring at high intensity and represents information regarding the concentration of predominantly additive genes effects. They may also show higher heritability and less environmental effects and also result in less gene interactions and higher achievement in selection.

Significant number of the hybrids showed significant positive SCA effects for number of leaves at 50% flowering. Great number of leaves in plant is an indication of increased amount of food synthesis and therefore increased yield. Many of the hybrids showed negative significant SCA effects for days to 50% flowering. Negative significant SCA effect implies earliness and therefore these hybrids can be used for selection of early maturing varieties of okra.

Results from correlation studies had indicated that pod width and number of pods were reliable characters to select for when breeding for high yielding okra varieties as they show positive correlation with yield at genotypic level.

Pod length, though had medium negative direct effect on yield was the best character to select for because it had contributed the highest to yield as indicated by its positive correlation with yield.

6.2 Conclusion

Vital genetic information was obtained on genetic variability of okra in the study. These information need to be effectively utilized by the breeders in the improvement of okra varieties that would produce high yield for the benefit of commercial and domestic farmers. Phenotypic variances were generally higher than genotypic variances revealing the role of environmental factors influencing the expressions of characters in this study. Gella 1 and Dirbuni (the best general combiners) were good parents that can be used for multiple crossing programmes. Gella 1 x Pukum 2 and Pukum 2 x Dirbuni were good cross combinations that could generate a population with large gene pool from which superior varieties could be produced. Days to 50% flowering had shown to be the best character to select for in this study because it exhibited outstanding significant values for general combining abilities, specific combining abilities, heritability and genetic advance.

6.3 Recommendation

The existence of genetic variability observed among the okra genotypes used indicated great potential for improvement. Further research is needed to confirm some of the findings over more locations and years

6.4 Contribution to Knowledge.

The general and specific combining ability effects, phenotypic and genotypic coefficients of correlation, the path coefficient analysis between yield and its components, the narrow sense heritability and estimate genetic advance in okra had been evaluated for possible improvement of varieties that are perennial in growth, higher yield, early maturing with longer harvesting duration and standard fruit sizes.

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