ASSESSMENT OF GENETIC DIVERSITY IN A COLLECTION OF GHANAIAN OKRA GERMPLASM *(Abelmoschus spp L.)* USING MORPHOLOGICAL MARKERS.

A thesis submitted in partial fulfillment of the requirements for the award of a MASTER OF SCIENCE degree in CROP SCIENCE, AGRONOMY (PLANT BREEDING) at the Kwame Nkrumah University of Science and Technology, Kumasi, Ghana.

DANIEL OPPONG-SEKYERE (BSc. Agric)

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DECLARATION

I hereby declare that, except for references to works of other researchers which have been duly acknowledged, this work 'Assessment of genetic diversity in a collection of Ghanaian okra germplasm (*Abelmoschus spp.* L.) using morphological markers' is my own original research and that neither part nor whole has been presented elsewhere for the award of a degree.

Daniel Oppong-Sekyere …… ……
Signature Date
(Student)

We declare that we have supervised the student in undertaking the research submitted herein and confirm that the student has our permission to present it for assessment.

Certified by:

Prof. R. Akromah …… ……..
(Supervisor) Signature Date

Prof. R. Akromah …… ……..
(Head of Department) Signature Date

DEDICATION

This project is dedicated to my Uncle, Mr. Samuel Asare-Bawuah and the OppongSekyere family.

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LIST OF ABBREVIATIONS

OLCV --- Okra Leaf Curl Virus

OMV --- Okra Mosaic Virus

CIAT --- Centro Internationale De Agriculture Tropicale

DNA --- Deoxyribonucleic Acid

IBPGR --- International Board for Plant Genetic Resources

CRI --- Crops Research Institute

CSIR --- Council for Scientific and Industrial Research

RAPD --- Random Amplified Polymorphic DNA

RFLP --- Restriction fragment length Polymorphism

SSR --- Simple Sequence Repeat

PGRRI --- Plant Genetic Resources Research Institute.

UEW-M ---- University of Education Winneba-Mampong.

ABSTRACT

A total of 25 accessions of okra collected in Ghana were evaluated for phenotypic identity, diversity and quality based on morphological characterisation. Nineteen quantitative and seventeen qualitative characters were measured on the genotypes in field experiments using randomized complete block design with four replications, and phenotypic characters scored as specified by the standard international crop descriptor for okra (IBPGR, 1991). A dendrogram (cluster diagram) was generated for morphological data based on the Simple Matching Coefficient and four cluster groups were observed. The distribution of the accessions into the groups, based on the morphological traits had no unique geographical relationship. The results of the matrix of similarity among the 25 accessions performed using the NTsys pc programme placed two accessions in a tie, suggesting they were identical. Eight (8) accessions were placed at over 80% similarity, meaning the accession pairs were closely related, and three accessions were 50% similar, which means they matched at half the characters neasured. Six pairs of accessions measured were somewhat diverse, which can be exploited by plant breeders for further improvement. The genetic affinity between the accessions from different regions and ethnic groups could however be due to the selection and exchange of okra between farmers from different regions and ethnic groups. This shows that similar names might not suggest a means for identifying duplicates in the okra germplasm. Further research at the molecular level will be required to confirm duplicate accessions to enhance this work.

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CHAPTER ONE INTRODUCTION

1.1 BACKGROUND

Vegetables are indispensable ingredient in the daily diets of humans as they offer numerous nutritional benefits. They are normally eaten fresh and in sauces and are used by the growing fast-food, hotel, and restaurant industry (Tyler *et al*., 1989). They are consumed almost daily and are traded by a broad range of market participants.

There are a wide range of vegetables in the world including okra, garden eggs, radish, tomatoes, pepper and carrot (IBPGR, 1990; Gulsen *et al*., 2007). The world annual vegetable production, for processing alone, is estimated at 40 to 45 million tons with total production reaching almost 700 million metric tons in 2001 (Ganry, 2009).

Okra, (*Abelmoschus esculentus* L.) can be found in nearly every market in Africa. In Ghana, it is the fourth most popular vegetable after tomatoes, pepper, and garden eggs (Sinnadurai, 1973). There are about 2,283 reported accessions of okra in the world (Hammon and Van Slotten, 1989); 2,029 of these are from the African continent; 1,769 of same are from West Africa (Hammon and Van Slotten, 1989). Okra, therefore, is far more heavily represented in West Africa than what obtains in any other parts of the world (Omonhinmin and Osawaru, 2005).

Okra is a member of the *Malvaceae* (mallow) family. The crop is native to Africa (Kochhar, 1986). The crop was taken to other parts of the world by the Portuguese (Sinnadurai, 1992).

The world okra production, as of 2007, was estimated at 4.8 million tons with India leading the production by 70% followed by Nigeria (15%), Pakistan (2%), Ghana (2%), Egypt (1.7%) and Iraq (1.7%) (Gulsen *et al*., 2007).

In Ghana, Brong Ahafo, Ashanti, Northern, Volta, Greater Accra and Central regions are the bulk producers (in terms of tonnage) (NARP, 1993). About 10 - 15 t /ha of yield can be obtained under good management (NARP, 1993).

The okra provides an important source of vitamins and minerals (Norman, 1992; Lamont, 1999). Hamon and Charrier (1997) have also reported significant levels of carbohydrate, potassium and magnesium. The seeds of okra are reported to contain between 15% and 26% protein and over 14% edible oil content (NARP, 1993).

The young immature green fruits and fresh leaves are primarily used as vegetables, consumed cooked or fried. Dried fruits of okra are ground into powder, stored and used in stews and soups (Siemonsma, 1982a). Okra seeds are reportedly used as substitutes or additives in feed compounds (Purseglove, 1974), in the preparation of okra seed meal and a number of baked products (Martin and Roberts, 1990) and in blood plasma replacement (Vickery and Vickery, 1979).

Okra is a vegetable which one finds in a fresh state in almost all markets in Ghana, during the rainy season and in a dehydrated form during the dry season, particularly in Northern

Ghana due to its strong commercial value for poor women farmers and its vital importance as food diet among the inhabitants of the cities and villages.

Notwithstanding the potential of the crop, there are no improved varieties for cultivation by okra farmers in Ghana. Moreso, there has not yet been any previous reported attempt by breeders at improving the vegetable in terms of developing core collections for higher yield and quality. The accessions under cultivation, over the years, in the various regions across the country are landraces. Nevertheless, these landraces are associated with challenges such as high susceptibility to diseases, pests and nematode (Sinnadurai, 1992).

In addition, these landraces have long maturity periods yet short harvesting duration. They are of poor nutritional quality, non-standard in shape, colour and size, making them unfit for the Ghanaian okra vegetable export market. This has a consequential effect of causing a reduction in the per capita income of the nation.

It is therefore important that plant breeders developed improved varieties of the okra vegetable, which seems to be the last concern in their research programmes for adoption by Ghanaian vegetable farmers and for the export market. Varieties that are perennial in growth habit and at the same time combine higher yields and early maturity with longer harvest duration and more so resistant to diseases and pests, would be ideal to the okra vegetable industry in Ghana. Improved varieties in terms of fruit size, shape and colour are also very much desired in the Ghanaian okra export market. It is against this backdrop that this characterization and genetic diversity study was necessitated as an important first

step, among others, to the improvement of the crop in Ghana thereby providing the foundation on which to enhance their potential use.

Identification and description of the genetic variability available in germplasm collections are the basis of improved plans designed to control genetic erosion; they are also a preliminary requirement for the exploitation of useful traits in plant breeding (Oka, 1991).

Characterization of crops is a very essential first step in any crop improvement programme (De Vicente *et al*, 2005). Characterization of genetic resources therefore refers to the process by which accessions are identified, differentiated or distinguished according to their character or quality (traits) (Merriam-Webster, 1991). In genetic terms, however, characterization refers to the detection of variation as a result of differences in either DNA sequences or specific genes or modifying factors (IPGRI/CIP, 2003).

Characterization provides information on diversity within and between crop collections. This enables the identification of unique accessions essential for curators of gene banks (Ren *et al*., 1995). Moreover, information obtained on genetic relatedness among genetic resources of crop plants is useful, both for breeding and for the purposes of germplasm conservation (Brown *et al.,* 1990).

According to Sawadogo *et al*. (2006), okra is characterized by diversity based on form and colour of fruits and stems. Omonhinmin and Osawaru (2005) have reported wide

morphological variation among accessions of okra, particularly in *A. caillei* (West African) types.

There are reports of diversity studies in okra that used morphological markers (Karp *et al.*, 1997; Martinello *et al*., 2001; Sawadogo and Balma, 2003; Sawadogo *et al*., 2006). Morphological markers are known as 'the traditional marker'. The level of analysis of these markers is phenotype.

Morphological markers come with the following disadvantages; they are influenced by environmental growth conditions, they are labour intensive and require large populations of plants in performing breeding experiments. Moreover, they need large plots of land and/or greenhouse space in which to be grown; but they have remained useful till now as a highly recommended first step that should be undertaken before more in-depth biochemical or molecular studies are attempted (Smith & Smith, 1992). The main advantages of conducting morphological characterization are that published descriptor lists are readily available for most major crop species including okra. It can be carried out *in situ* (on-farm). It is relatively inexpensive. It is relatively easy to carry out (Hoogendijk and Williams, 2001).

Evaluation of such morphological traits therefore requires growing the plants to full maturity before any proper identification can be done (Karp *et al.*, 1997; Stuber *et al*., 1999; Chawla, 2000).

It was therefore necessary to undertake this characterization and diversity study, more importantly, in the Ghanaian ecotypes. This study would afford us the opportunity to assess qualitative and quantitative variations among collections of the Ghanaian okra landraces through morphological evaluation and thus exploit such variations in breeding programmes to develop improved, high yielding varieties. Core collections identified would be exploited for their improvement and consequently provide the foundation on which to enhance their use.

1.2 RESEARCH OBJECTIVES

The objectives of the study were to;

- Undertake morphological characterization of Ghanaian okra germplasm.
- Assess the genetic distinctiveness and relatedness among accessions of okra using qualitative and quantitative markers.
- Identify duplicates in the collection and sort them out to select a core collection for varietal improvement.

CHAPTER TWO LITERATURE REVIEW

2.1 ORIGIN AND BOTANY OF OKRA

Okra, (*Abelmoschus esculentus* L.) has its origin in West Africa (Joshi *et al*., 1974; Kochhar, (1986). It is currently grown on a large scale in Africa, especially in the Sudan, Egypt and Nigeria (Joshi *et al*., 1974). It is also very important in other tropical areas

including Asia, Central and South Americas. Okra is a warm-season annual herbaceous vegetable crop grown primarily for immature fruits used in soups and stews. The Nile Basin seems to have been the route by which this plant spread through North Africa, the Eastern Mediterranean, Asia Minor 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 according to Hamon *et al*., (1990) and Bish *et al*., (1995).

There are a number of varieties, both wild and cultivated. Some of these are *A. esculentus, A. caillei, A. moschatus, A. manihot, A. ficulneus* and *A. tetraphyllus*. Two species in the genus *Abelmoschus* are cultivated; A. *manihot* L. and A. *moschatus* L.
(Stevels, 1988; Siemonsma, 1991).

Okra is an amphidiploid-having a complete diploid set of chromosomes derived from each parent form (Siemonsma, 1982a) with varieties displaying a tremendous variation in plant size, shape, fruit type and color. Okra seed is also similar in size to soybeans and can be handled with most of the same equipment (Martin, 1982). Okra plant is a semi woody, fibrous herbaceous annual with an indeterminate growth habit (Nonnecke, 1989). The plants form a deeply penetrating taproot with dense shallow feeder roots reaching out in all direction in the upper 45cm of the soil. The seeds are dicotyledonous and they vary in shape; roundness, kidney or spherical with epigeal germination (Hamon *et al.,* 1991; Ariyo, 1993).

The monoic flowers of okra are self-compatible (Martin, 1983; Hamon *et al*., 1990). About 35-60 days after emergence, the plant begins to flower; the flower remains open for a day. It is mainly self-fertilized; however, insects such as bumble bees can crosspollinate. Immature fruits of 8-9 cm long are ready for harvest 4-6 days after anthesis. Harvesting is recommended at least every other day for size and quality (Ramu, 1976). About 35-40 days are required from anthesis to seed maturity. If fruits are allowed to mature, plant growth declines and few flowers develop, but with continuous harvesting, the plant continues to set fruit (Purewal and Rhandhawa, 1947). Fruits are harvested 4 to 7 days after the flower has opened, and the fruits are not fibrous (fruits 2 to 4 inches. long). Mature fruits should be removed and discarded as they reduce the plant growth and decrease yield (Purewal and Rhandhawa, 1947; Ramu, 1976).

The rate of allogamy differs according to varieties and ecological conditions (Hamon *et al*., 1991).

Okra has alternate palmate broad leaves and the flowers have five large yellow petals with a large purple area covering the base. The fruit, which is harvested immature, are pale green, green, or purplish fruits and in many cultivars are ridged (Hamon *et al*., 1990). When mature, they are dark brown dehiscent or indehiscent capsules. Fruit shapes range from round to ridged and short to long (Siemonsma, 1982a). The plant and fruits may have small spines on them that create allergies in some people (Ariyo, 1993; Düzyaman, (1997).

Plate 2.1: Typical Okra Plants

2.2 ENVIRONMENTAL REQUIREMENTS OF OKRA

Okra is a warm season crop, growing best between the minimum and maximum mean temperatures of 18 °C (65 °F) and 35 °C (95 °F), respectively (Martin, 1982). In recent years there has been interest in growing it as a protected crop in heated greenhouses in Northern Europe (Buchholz *et al.*, 2006).

Optimum temperature requirements range from 21° to 30°C (Martin, 1982). It can be grown in a wide range of soil types provided the drainage is good. It is intolerant of wet and poorly drained and acidic soils (Incalcaterra and Curatolo, 1997). Okra does not do well in tight, water logged soils, but will tolerate a soil pH range from 6.0 to 7.5 (Incalcaterra and Curatolo, 1997). The addition of lime or dolomite may be necessary

during soil preparation to bring the pH to about 6.0 to 6.5 (Incalcaterra and Curatolo, 1997).

Optimum soil temperature for seed germination is 24°C-32°C (75° - 90°F) (Martin, 1982). Germination is poor at 20°C (68°F). Short day length stimulates flowering of most cultivars (Martin, 1982). Flowering begins at a very early stage of growth at day lengths of less than 11 hr; under long days, the flower buds tend to abort (Chauhan, 1972). Germination will take 5-14 days (Hamon *et al*., 1991). Okra is best eaten just after it is picked but it can be stored for several days. Okra will keep for 7-10 days if kept at 45°C-50°C with a relative humidity of 90%-95% (Martin, 1982).

Okra is very sensitive to ethylene gas, therefore not recommended to be stored with vegetables and fruits that give off ethylene gas such as apples and pears (Lutz and Hardenburg, 1966).

2.3 OKRA NUTRITIONAL INFORMATION

2.3.1 Nutritional Value & Health Benefits

Okra is a repository of valuable nutrients (Tables 2.1 and 2.2) (Grubben *et al*., 1977; Candlish *et al*., 1987). Nearly half of which is soluble fiber in the form of gums and pectins. Soluble fiber helps to lower serum cholesterol, reducing the risk of heart disease (Brown *et al*., 1999). The other half is insoluble fiber which helps to keep the intestinal tract healthy, decreasing the risk of some forms of cancer, especially colorectal cancer

(Schneeman, 1998). Nearly 10% of the recommended levels of vitamin B6 and folic acid are also present in a half cup of cooked okra (Hamon and Charrier., 1997).

Table 2.1: Nutritive value of okra fruit

Variable	Content (%)
Dry matter	10.4
Moisture	85.5 1.8
Protein	0.52 0.98
Starch	0.52
Cellulose	0.09
Lignin	0.001
Calcium	0.0001
Iron	0.00007
Carotene	0.00008
Thiamin	0.0008
Riboflavin Niacin	0.18
Vitamin C	

Source; (Grubben *et al*., 1977; Candlish *et al*., 1987).

Table 2.2: Nutritive value of okra/100g edible portion

Nutrient	Fruit	Leaves
Dry matter (g)	10.4	10
Energy (kcal)	31	33
Protein (mg)	1.8	2.0 Calcium
(mg)	90	70
Phosphorous (mg)*	56	-
Magnesium (mg) *	43	-
Iron (mg)	1.0	1.0
Carotene (mg)	0.1	0.99
Thiamine (mg)	0.07	0.10
Riboflavin (mg)	0.08	0.10

Niacin (mg)	0.8	1.0
Vitamin C (mg)	18	25

Source: Grubben *et al*. (1977) **NB: *** from Hamon and Charrier (1997).

2.4 OVERVIEW OF GERMPLASM

Germplasm entails a collection of genetic resources for an organism. This is normally used for the purposes of conservation and management of genetic diversity for use by farmers, breeders and researchers for crop improvement programmes, among others. Germplasm could be for plants, in which the seeds are stored as a collection. For trees, conservation may be done in a nursery (Rubenstein and Heisey, 2003; De Vicente *et al*., 2005).

2.4.1 Standards, Protocols, Descriptor lists

In order to increase international exchange of material, a certain amount of uniformity in data collecting, recording, storage and retrieval is critical (Rubenstein Heisey, 2003). Developing standards for documentation and protocols for exchanging information is essential for ensuring that bridges can be built between myriad information sources. Descriptor lists are a central part of this process (Engels and Visser, 2003; De Vicente, 2005; Rubenstein and Heisey, 2003. Coping with the vast amount of data on crop species and varieties and making it available requires adequate database design and information management systems (Engels and Visser, 2003; De Vicente, 2005; Rubenstein and Heisey, 2003).

2.4.2 Passport data

The documentation of crop diversity collections begins with recording important data when scientists first collect the plant material (De Vicente, 2005). This 'passport data' includes basic information on where, when, and what was collected. Descriptor lists provide a standard language for recording this information (De Vicente, 2005). All of this data must be easily accessible, and ideally stored on computer databases and incorporated into genebank management systems.This is particularly important for planning future collecting missions, determining gaps and duplications in collections (De Vicente, 2005). This information is also very valuable for diversity analysis such as for species distribution maps (Rubenstein and Heisey, 2003).

2.4.3 Characterization

Characterization of each sample involves a careful description of the special characteristics that are inherited, easy to score, and expressed consistently in all environments (Rubenstein and Heisey, 2003). Since most of the traits recorded during characterization are those that can be seen, the person responsible for managing the germplasm material is best placed to carry out the work of documenting these characteristics (De Vicente *et al*., 2005). Many of the characteristics that are recorded on individual accessions can serve as diagnostic descriptors for the accessions (Rubenstein and Heisey, 2003). Such diagnostic characters help genebank curators keep track of an accession and check for the genetic integrity over a number of years of conservation (Rubenstein and Heisey, 2003). Again, descriptors lists are a vital tool for ensuring that

those who are documenting the characteristics of conserved species are using the same language and standards (De Vicente *et al*., 2005; Rubenstein and Heisey, 2003).

2.4.4 Evaluation

Evaluation goes deeper than characterization. It may require special biochemical techniques and usually include agronomic performance, yield and biotic and abiotic stresses, such as drought or pest. These traits are important to plant breeders and researchers in crop improvement. Such evaluation may also use DNA-based methods to analyze a plant's genetic diversity (De Vicente *et al*., 2005; Rubenstein and Heisey, 2003).

The evaluation descriptors, although contributing to some extent to identifying an accession, are more interesting than characterization descriptors because of their value in crop improvement. In general, effective evaluation is possible when there is close institutional and personal interaction between curators and breeders or other crop improvement scientists, and where breeding objectives are reflected in evaluation programmes (De Vicente *et al*., 2005; Rubenstein and Heisey, 2003). Evaluation is primarily carried out by users, in multidisciplinary teams that include breeders, entomologists, pathologists and agronomists (De Vicente, 2005). The potential value of the germplasm depends on the efficiency of the techniques designed to differentiate among accessions (Engels and Visser, 2003; De Vicente, 2005; Rubenstein and Heisey, 2003). Because the farmers are the ultimate users of the product of any crop improvement programme and possess valuable traditional knowledge, due consideration must be given

to involve farmers' views and expectations at some point during any evaluation programme day (Rubenstein and Heisey, 2003).

2.5 CROP DESCRIPTORS AND CROP DESCRIPTOR LISTS

A crop descriptor is made up of a name, an identifying number, a definition, a descriptor state or values or a range of values. E.g. IBPGR, 1991, AVRDC, 2001. Descriptors are tools used to describe or provide information on accessions (Charrier *et al*., 1997). They could be a permanent part of the system (and cannot be changed) or are created and modified (Charrier, 1984; Hamon and Nairot, 1991). Examples include leaf shape, flower color, plant habit, seed color and chromosome number, plant height, days to maturity, protein percent, disease resistance and yield.

A crop descriptor list, however, is a grouping of characterization/evaluation descriptors by crop or group of related species. Each descriptor list contains one or more crop descriptor(s). Some examples of crop descriptor lists include okra, wheat, pepper and maize. Each species should be part of only one descriptor list (IBPGR, 1991; Engels and Visser, 2003).

2.6 THE CONCEPT OF GENETIC DIVERSITY

Information on genetic variation and relationship between accessions or genotypes is important to understand the genetic variations available and its potential use in breeding programmes. More so, to estimate any possible loss of genetic diversity, offer evidence

of the evolutionary forces shaping the genotype diversities, and to choose the genotypes to be given priority for the purposes of conservation (Thormann *et al*., 1994).

2.6.1 Genetic Diversity Studies

The objectives of every morphological characterization include but not limited to the following; to identify distinct genotypes and eliminate obvious duplicates from the germplasm and to select core collection of accessions for conservation and for future work.

Genetic diversity and analysis therefore involve three basic steps:

1. Description of variation within and between populations, regions or area.
2. Assessment of the relationships between individuals, regions, areas and the
3. Expression of relationship between results obtained from different sets of characters.

2.6.2 Measurement of Diversity

There are 4 methods for measuring genetic diversity;

1. Farmers perception & folk
2. Morphological characterization
3. Biochemical characterization and
4. Molecular characterization

(Hoogendijk and Williams, 2001; Zannou, 2006).

The main advantage of conducting morphological characterization, among others is that published descriptor lists are readily available for most major crop species including okra (Hoogendijk and Williams 2001). The application of morphological descriptor lists is the simplest of the formal, standardized repeatable methods of measuring crop genetic diversity (Smith and Smith, 1992; Hoogendijk and Williams, 2001).

Morphological characterization is therefore a highly recommended first step that should be undertaken before more in-depth biochemical or molecular studies are employed in any diversity studies. Tatineni *et al*. (1996) proposed that a large number of polymorphic markers are required to measure genetic relationships and genetic diversity in a reliable manner, which are relatively adequate in okra (*Abelmoschus* spp.) (Hoogendijk and Williams, 2001).

2.7 CORE COLLECTION OF CROP PLANTS

2.7.1 The Concept of Core Collection

Core collection was first defined as 'a limited set of accessions which represented, with a minimum of repetitiveness, the general diversity of a crop species and its wild relatives' (Frankel, 1984).

This was later modified as 'a limited set of accessions derived from an existing germplasm collections, chosen to represent the genetic spectrum in the whole collection, and including as much as possible of its genetic diversity' (Brown, 1995).

Core collection is also defined as ‘a germplasm collection optimally representing specific genetic diversity’, implying that size, type and origin of a core collection depends on the requirements of the compiler (Van Hintum, 1996).

A core collection can be based on a single existing collection or on several existing collections. It can also be a newly created entity. It can represent the diversity in a complete genus, including wild species, or the diversity, in a small part of the gene pool. It can contain as much diversity as possible, but can also give higher priority to certain type of material, reducing the total amount of diversity captured (Van Hintum, 1996). Examples of core collection of plants species are local maize populations with a good combining ability (Radovic and Jelovac, 1994) and *Pisum satium* germplasm with diseases resistance (Matthews & Ambrose, 1994).

2.7.2 Objectives of Core Collection

The objectives of every core collection venture are to;

a. have a manageable collection scaled down to the convenience of the breeder and/or other users
b. to include the widest possible range of variability (Hamon and Van Sloten, 1989).

In an effort to select a representative sample of a collection, a number of approaches have been adopted; random selection (random core), sequential set selection and equivalent core (selection of accessions with accession numbers ending with a five or zero).

2.7.3 The General Procedure for Creating a Core Collection

Core collections of crop plants are created through the following processes;

Definition of the material that should be represented; that is, the domain of the core collection e.g. crop and its wild relatives.

Division of the domain into types, which should be genetically as distinct as possible.

Choosing the number of entries in the core, and allocate them over the types based on the relative importance of, and diversity in the types.

Selection of the entries from each type that are to be included in the core. This selection can be made randomly, or if additional data are available, on the basis of these data.

The objective should be to best represent the diversity in the groups. Practical considerations such as the availability of the seeds, reliability and quality of data on the accessions could play a role in this choice.

Core collections were invented to increase the accessibility of germplasm collection; If there is low accessibility it also implies low utilization and therefore difficult management. A core collection therefore offers a good starting point for searching for new traits, and can be used for in-depth evaluation increasing the knowledge of the entire collection (Van Hintum, 1996).

In summary, the concept of core collection is relevant in germplasm managements as it was first proposed.

2.8 CLUSTERING

2.8.1 Clustering Method

Cluster analysis, also called segmentation analysis or taxonomy analysis is a group of multivariate techniques used to group objects (subjects, respondents, products etc) based on the characteristics they possess. Each object within the cluster will be similar to everyone other object and different from objects in other clusters. In other words, homogeneity and heterogeneity is maximized between them. Each cluster thus describes, in terms of the data collected, the class to which its members belong and this description may be abstracted through use from the particular to the general class or type. It is therefore a multivariate procedure for detecting natural groupings in data.

Clustering is the process of grouping (or clustering) objects in categories based on their common attributes or relationships. Cluster analysis is therefore very useful because it allows one to visualize similarities among taxa by the levels at which they are grouped together (Crawford, 1990).

To measure distance among clusters, a number of methods are available and varies according to the way in which "closest" is defined at each stage of merging groups. The following are some examples;

1. Single link (nearest neighbour)
2. Complete link (farthest neighbour)
3. Average link (UPGMA)

(Aldenderfer and Blashfield, 1984).

2.8.2 Hierarchical Clustering

Is a way to investigate grouping in one's data simultaneously over a variety of scales, by creating a cluster tree. The tree is not a single set of clusters but rather a multi-level hierarchy where clusters at one level are joined to clusters at the next higher level. This allows one to decide what level or scale of clustering is most appropriate in an application. (Hastie *et al*, 2009).

2.8.3 Non-Hierarchical Clustering

These methods generally operate on units by variates matrix and seek to partition the units into a specified number of groups to optimize some criterion. The most common criterion used is maximizing the between groups sun of squares which is equivalent to minimizing the within group sum of square. This method assigns each individual to a unique group by comparing it with the initial classes so that its positioning is the most appropriate.

2.8.4 Objectives for Clustering

Clustering comes with the following objectives;

a. to find natural groupings (as in taxonomy)
b. to simplify data (data reduction)
c. to understand the data better than producing a distribution as a whole (relationship identification).

2.8.5 Types of Data for Clustering

2.8.5.1 Binary data

This data is in a form of presence (1) and absence (0). Similarity coefficients are calculated by either simple matching or Jaccard's method

For the simple matching procedure, similarly coefficient $= \frac{\text{Similar}}{\text{Similar} + \text{dissimilar}}$

Jaccard's suggests that if a scoring in neither accession does not contribute to inter-site similarity, then similarity coefficient = $\frac{\text{only positive similar}}{\text{similar} + \text{dissimilar}}$

2.8.5.2 Qualitative data

This kind of data is extremely varied in nature. It includes any information that can be captured that is not numerical in nature. They refer to characters or qualities, and are either **binary** (taking only two values: present (1) or absent (absent) or **categorical** (taking a value among many possibilities); and are either **Ordinal** (categories that have an order) or **Nominal** (categories that are unrelated) (Aldenderfer and Blashfield, 1984).

2.8.5.3 Quantitative data

Here, distances rather than similarities are considered. The common measure here is the Euclidian distance (Aldenderfer and Blashfield, 1984).

2.8.6 Qualitative Descriptors for Okra

Qualitative descriptors for okra are grouped into three main types; colour, shape and other features. The specific descriptors are the colour of the main stem, the petal base, the leaf petiole, the veins, the lamina and the fruit (unripe): and the position of the fruits on the main stem. These descriptors tend to be highly subjective (Hamon and Van Sloten, 1989).

2.8.7 Quantitative Descriptors

Quantitative descriptors for okra involve plant morphology and development characterized by plant height, number of internodes, stem diameter and branching (Hamon and Van Sloten, 1989).

2.9 CORRELATION AMONG TRAITS

Correlation is a measure of the mutual association between two variables. More so, correlation coefficient measures the mutual association between a pair of variables independent of other variables to be considered (Fakorede and Opeke, 1985).

The correlation between two traits moreover refers to a situation where the two traits vary with each other, either positively or negatively, within a breeding population. Correlation could be due to genetic or environmental causes. The result of correlation is of great value in determining the most effective procedures for selection of superior genotypes for improvement. Knowledge of the correlation among traits serves as a guide to prevent the elimination of some useful traits at the expense of other desirable traits during selection. For example, where desirable traits are known to be negatively correlated, caution during

selection would be needed to ensure a good balance of desirable traits in improved cultivars.

Knowledge of the correlation among traits in a breeding population moreover serves in facilitating indirect selection for fruit yield through selection for yield components. To evaluate relationships, correlation analyses are used such that the values of two characters are analyzed on a paired basis, results of which may be either positive or negative. Many reports show that correlations are common among traits in crop populations including okra (Fakorede and Opeke, 1985).

According to Fakorede and Opeke, (1985), when more than two variables are involved, the correlations per se do not give the complete picture of their interrelationships. Singh *et al*, 1974; Singh and Singh, 1977; Kaul *et al*., 1978 and Ariyo, 1989, have established that in developing a variety, it would be difficult to exercise simultaneous selection for major yield characters when these characters are negatively correlated, but when they are positively associated, component breeding would be very effective.

CHAPTER THREE MATERIALS AND METHODS

3.1 SOURCE OF GENETIC MATERIALS

Twenty-five genotypes of okra were used for the study. Twelve were obtained from the Plant Genetic Resources Research Institute (PGRRI) of the Council for Scientific and Industrial Research (CSIR), Bunso, Eastern Region, twelve from the University of Education Winneba-Mampong; College of Agricultural Science and one from the Department of Horticulture, Kwame Nkrumah University of Science and Technology (KNUST)-Kumasi.

3.2 EXPERIMENTAL SITE AND FIELD OPERATIONS

The experiment was conducted at the Department of Crop and Soil Sciences experimental field, KNUST, between May and November, 2008. The land, which had been allowed to lie uncultivated for one year after a previous harvest of groundnut, was slashed, ploughed and harrowed to a fine tilth for the experiment. The experimental design used was Randomized Complete Block Design (RCBD) with 4 replications. The total experimental area was 14 m x 83 m.

Sowing was by direct seeding on the field at the rate of 2 seeds per hill. Seedlings were thinned to one plant per stand two weeks after germination. There were a total of 100 plots with each plot measuring 2.4 m by 1.8 m. Each plot had sixteen plants with a spacing of 60 cm by 45 cm. Data was taken from four plants within each plot.

All cultural practices including thinning, weed control, watering, fertilizer application (N.P.K. 15:15:15 + 2MgO + 3Zn) and urea, at a rate of 250 kg/ha and 125 kg/ha respectively, were applied to the plants at 30 days after sowing. Plants were also sprayed

against insect pests and diseases using Pyrical 480EC at a rate of 20 ml/15litres of water which was later substituted with kombat 2.5EC (Lambda Cyhalothrin) at a rate of 36 ml/15litres of water (after diseases and pests incidence had been scored for). Weeding was done with a hoe at 2 and 4 weeks after emergence and at early flowering respectively and when necessary.

The soil at the experimental site was sandy-loam (Kumasi series) with pH between 6.4 and 6.8 for the depth 0-15 cm. Total rainfall amount recorded for the experimental period was 1050.5 mm and a total mean sunshine duration figure of 30.4 hrs was also recorded. Minimum and maximum mean temperature figures of 21.9˚C and 31.1˚C respectively were also recorded for the period. The experimental area lies between latitude 06, 43˚ North and longitude 01, 36˚ West.

3.3 PARAMETERS MEASURED

3.3.1 Quantitative Parameters:

Germination percentage (number of days from sowing to 50 % seedling emergence), first flowering (number of days from sowing to 50% full bloom flowering), number of epicalyx segments, fruit length at maturity, number of fruit ridge(s), total number of fruit(s) per plant, peduncle length, epicalyx number, epicalyx length, epicalyx width, 100 seed weight, number of segments from the stigma, plant height, number of internodes, leaf length, leaf width, first flowering node, node(s) producing fruits on main stem, position of fruit on the main stem were measured.

3.3.2 Qualitative Parameters;

Type (form) of fruit, growth habit (general appearance), ramification (branching out), stem pubescence, stem colour, leaf colour, epicalyx segment persistence, petal color, red colouration at petal base, immature/cotyledon leaf color, fruit pubescence, leaf shape, inflorescence characteristics, epicalyx segments shape, fruit colour, fruit shape, branching position were measured.

3.4 DATA COLLECTION

A standardized crop descriptor for okra (IBPGR, 1991) was used to measure the various parameters studied.

3.5 STATISTICAL ANALYSIS

Averages, range, standard deviation and coefficient of variation were computed for the measurement data.

All qualitative data were converted to binary form: present (1), absent (0). Quantitative data was subjected to analysis of variance (ANOVA) using GenStat discovery edition 3.0 (GenStat 5 Committee, 2000). Means were separated by Least Significant Difference at 5%. Cluster analysis was performed for the morphological characters using The Numerical Taxonomy and Multivariate Analysis System (NTSYS version 2.11s; Rohlf, 2005) and Similarity coefficients calculated by Simple Matching produced by UPGMA (Rohlf, 2005).

Pearson's Correlation analyses between pairs of quantitative parameters were also performed using SPSS version 16.0, with reference to yield parameters.

CHAPTER FOUR RESULTS

4.1 QUALITATIVE MORPHOLOGICAL CHARACTERISTICS OF OKRA GENOTYPES

4.1.1 Seed Colour (SC), Seed Shape (SSh) and Seed Size (SS)

Seed colour, size and shape showed significant variation among the treatments. Seed colour ranged from black to whitish-to-dark. Black colour dominated the population by a little under one-third (32%), similar to those with whitish-to-dark colour. Seed shape ranged from round to spherical. Round seed shape types were the least (24%) in the population. Spherical seed shape was highest (40%). Kidney seed shape was appreciably high among the okra genotypes (36%) (Appendix A, Tables 1 and Table 4.1).

Table 4.1: Qualitative traits that varied among okra collection studied

No	Accession	SC	SSh	SS	BPMS	MLC	LSh	LBr (cm)	LRC	PtC	PC	CDR	StC	NES	FSp	NSfS	FC	FP	FSh	NR/F	PFMS
1	GH 4487 Muomi	1 2	1 2	3	1	1 2	2 1 2	0	1 2	1 2	1 1	1	1	1 1	1	9	1	1	2	1	1
2	GH 4482 Muomi	3	1	2	1	1	2	0	1	2	1	1	2	1	1	9	1	1	2	1	1
3	GH 4499 Fetri	3	1	2	1	2	2 7 7 2 1	0	2	2	1	1	1	1	1	12	1	1	8	2	1
4	GH 1169 Fetri	2 4	2 1	3	1	2 2	1 2 2 3 3	0	2 2	2 3	2 1	1	2	2 3	1	7	1	1	8	2	1
5	GH 4376 Atuogya	3 3 2 2 2	3 2 2 2 3	2	1	2 1 2 2 2	3	0	2 1 1 1 2	3 1 2 2 1	1 1 1 2 1	1	1	1 1 1 2 1	1	9	1	1	2	2	2
6	GH 4490 Fetri	3 4 3 4	3 3 3 1	1	1	1 1 1 2	2	0	1 2 2 2	1 2 1 2	1 2 2 1	1	3	1 2 1 1	1	6	1	1	8	2	1
7	GH 3801 Pora	4	3	1	1	2		0	1	1	1	1	3	1	1	9	5	2	3	2	3
8	GH 6102 Fetri			1	1			0				1	1		1	6	1	1	8	2	1
9	GH 4964 Muomi			2	1			0				1	2		1	6	1	1	2	1	1
10	GH 5793 Gyeabatan			1	1			0				1	3		2	5	2	2	4	2	1
11	GH 5787 Asontem			2	1			0				1	1		1	9	1	2	8	2	4
12	GH 3736 Fetri			1	1			0				1	1		1	5	1	2	8	2	1
13	Atuogya-tiatia			1	3			1				1	1		2	6	2	2	4	2	3
14	DA/08/001Wun mana			2	2			0				2	2		2	9	3	3	6	2	1
15	DA/08/02Sheo mana			1	3			0				2	1		1	5	1	2	14	2	1
16	DA/08/02 Ason-Wen			1	1			0				1	1		1	7	1	1	8	2	1
17	Atuogya-Asante	2 4	2 3	2	2	2 1	3 4	1	1 1	1 1	2 1	1	2	2 2	2	10	1	2	1	2	1
18	Asontem	2	2	1	1	1	2	0	2	1	2	1	1	2	1	9	1	1	8	2	4
19	DA/08/04Wun mana	3 2	3 2	2	2	1 1 1 1 1	4 2	1	2 2	2 2	2 2 2 1 2	2	2	1 2 1 1 1	2	9	3	3	15	2	3
20	DA/08/004 Agbodro	3 4 1 1	3 1 2 3	2	2	1	2 2 2 2	1	1 1 1 1	3 1 1 1	1	1	2	1	2	5	1	1	7	1	5
21	Gbodro-wild			2	2			0				1	2		2	9	4	2	3	3	1
22	DA/08/02Dikaba			1	3			0				1	1		1	6	1	1	13	2	4
23	DA/08/03Sheo mana			1	3			1				3	1		1	10	4	3	15	2	4
24	Atuogya-tenten			3	3			0				2	1		2	5	1	2	1	3	1
25	KNUST/SL1/07Nkrumahene			1	1			0				1	1		1	9	1	1	2	2	4

SC: Seed colour, SSh:Seed shape, SS:Seed size, BPMS: Branching position at main stem, MLC:Mature leaf colour, LSh:Leaf shape, LBr: Length of branches, LRC: Leaf rib colour, PtC: Petiole colour, PC: Petal colour, CDR: Colour of the darkest ridges, StC: Stem colour, NES: Number of epicalyx segments, FSp:Flowering span, NSfS: Number of spines from the stigma, FC: Fruit colour, FP: Fruit pubescence, FSh:Fruit shape, NR/F: Number of ridges per fruit, PFMS: Position of fruit from the main stem, LFP: Lenth of fruit peduncle, SI: Susceptibility to insects, Sdi: Susceptibility to diseases.

From the graph (Figure 4.1), seed size ranged from small, medium to large. Small seed size genotypes were the highest of 48%, which represented about half of the okra population studied. Large seed size was the least among the accessions recording 12%, while medium seed size was 40% high.

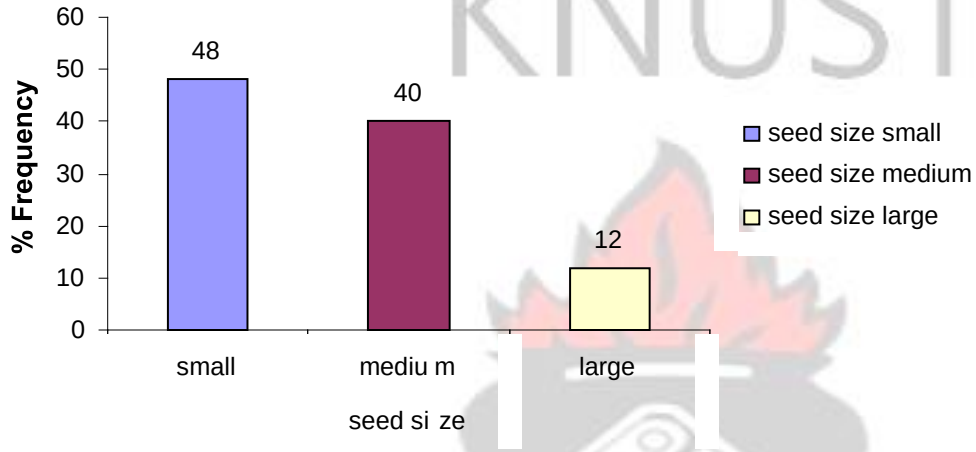

Figure 4.1: Variations in seed size

4.1.2 Growth Characteristics Observed

4.1.2.1 Plant growth habit, general appearance and branching position at-mainstem

From Figure 4.2a, branching position-at-main-stem (general growth appearance) of the okra accessions were 60% in occurrence for Unique Orthotrop Axis (UOA). Densely Branched all Over (DBO) and Densely Branched Base (DBB) characters were 20% in frequency respectively.

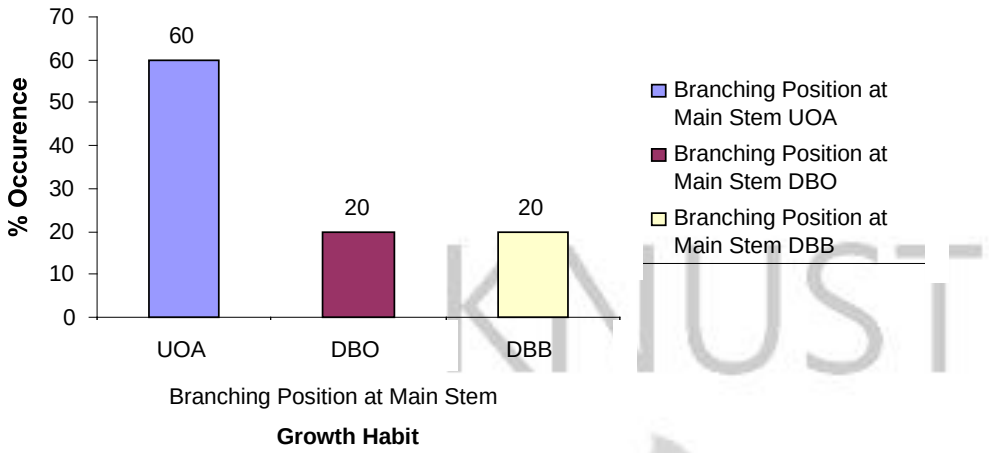

Figure 4.2a: Variations in growth habit

DBB **UOA** **DBO Figure 4.2b: Variations in growth habit**

4.1.2.2 Immature (cotyledon) leaf colour and mature leaf colour

The results of the study showed two distinct leaf colours, green and green-with-red veins. In all, 56% of the okra accessions showed green leaves while 44% had green with red veins (Appendix A, Table 1 and Table 4.1).

4.1.2.3 Leaf shape (form)

From the graph (Figure 4.3a), it can be said that of all the accessions, 16% produced leaves with the shape scored as '1' and '3' respectively, according to the descriptor (IBPGR, 1991; Plate 4.1); 14% produced leaves with the shape scored as '2', 4% had leaves with the shape score of '4'and 2% of the accessions had leaves scored '7' showing five distinct leaf shape types among the okra accessions. This is a very wide variation that generally included 3-, 5- or 7- alternate broad palmate-lobbed leaf shapes (palmate 7, palmate 9 and palmate 10) and 'heart' shape (heart 2, heart 3 and heart 4).

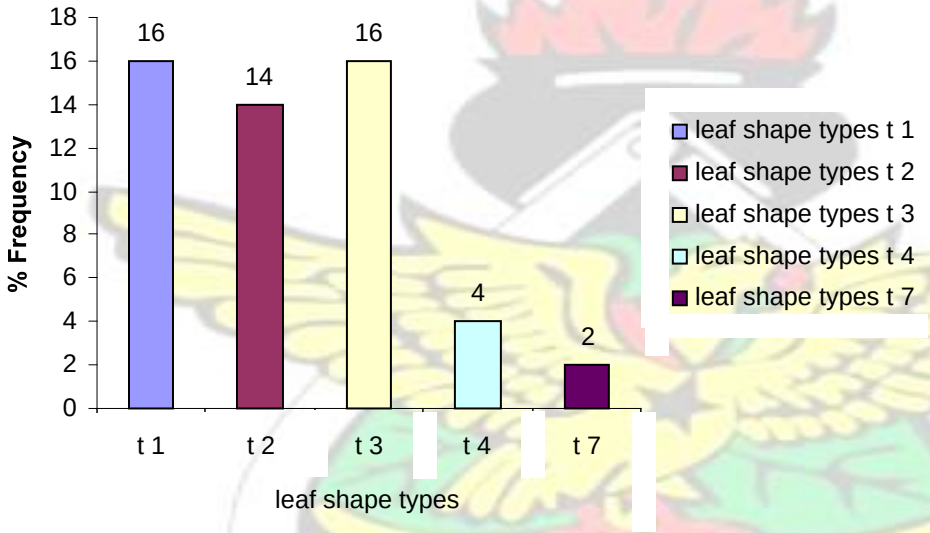

Figure 4.3a: Variation in leaf shape

Alternate broad palmate-lobbed okra leaf

'Heart' shaped okra leaf

Figure 4.3b Variation in leaf shape

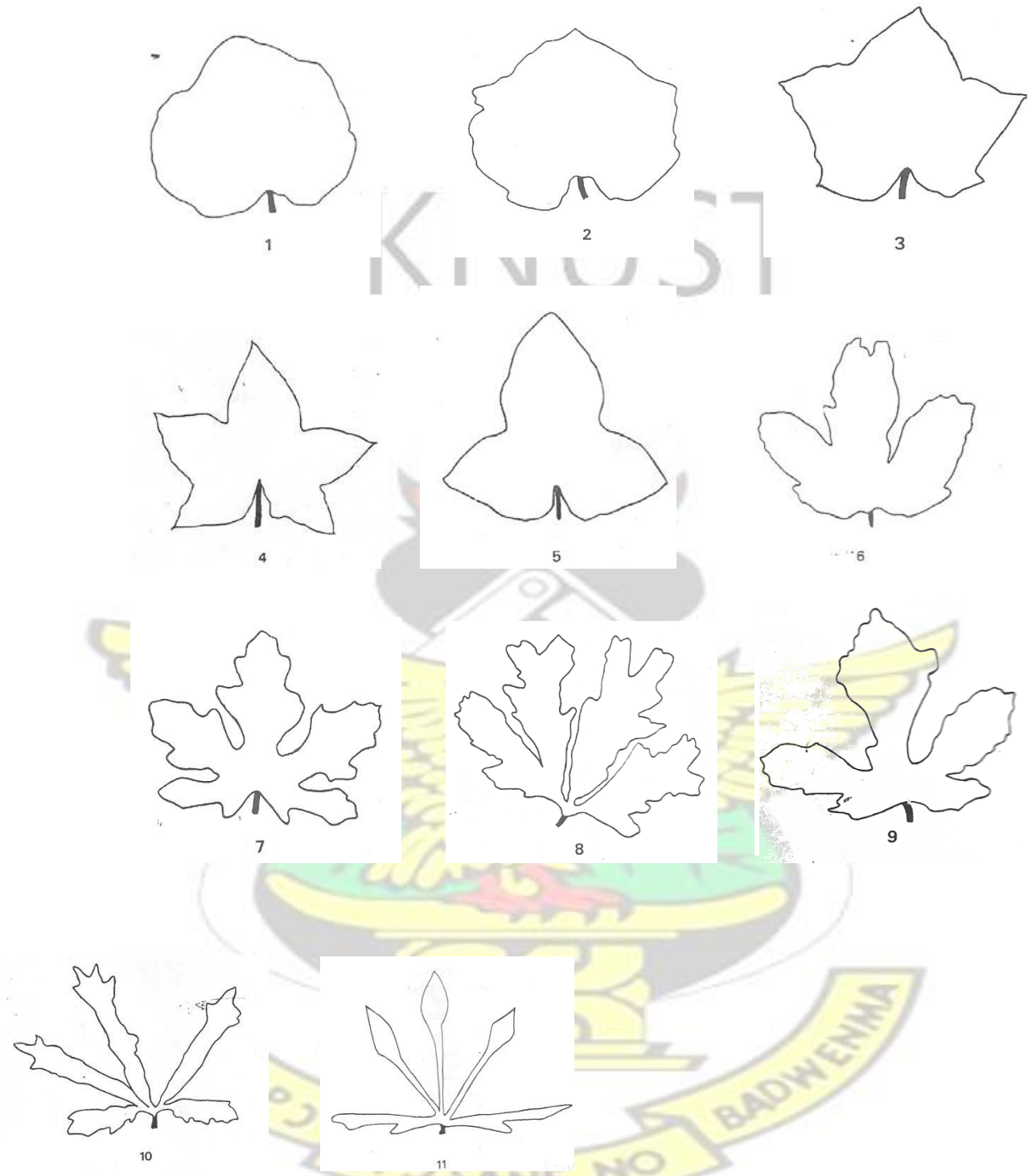

Plate 4.1: Different leaf shapes/forms within okra accessions (IBPGR, 1991)

4.1.2.4 Length of branches

As high as 80% of the okra accessions recorded no branches while the remaining 20%, which had branch lengths between 1cm to 10cm (but not greater than 10) was recorded by accessions DA/08/03 Sheo mana, Atuogya-Asante, DA/08/04 Wun mana, DA/08/004Agbodro, Atuogya-tiatia (Appendix A, Table 1 and Table 4.1).

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4.1.3 Pigmentation Characteristics among the Okra Accessions

4.1.3.1 Leaf rib colour

Leaf rib colour among the okra accessions showed two distinct colours, green and green-with-red veins. Fifty-two percent (52%) of the okra population recorded green leaf-rib colour while the remaining 48% displayed green with red-veined rib colour (Appendix A, Table 1 and Table 4.1).

4.1.3.2 Petiole colour

The okra recorded purple, green and green-with-red veins petiole colours representing 48%, 44% and 8% respectively among the okra accessions. This is a wide variation. Among the okra accessions, GH 3801 Pora and DA/08/02Dikaba exhibited a unique purple petiole colours while KNUST/SL1/07Nkrumahene, Asontem, GH 3736 Fetri, GH 4964 Muomi, GH 6102 Fetri and GH 4487 Muomi as well as GH 4964 Muomi, GH 4490 Fetri, GH 1169 Fetri, GH 4482 Muomi had their petioles tinged green and greenwith-red veins, respectively (Appendix A, Table 1 and Table 4.1).

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4.1.3.3 Petal (flower) colour

The graph in Figure 4.4a showed a variation in colour of flowers displayed by the okra accessions. Flower colour in the accessions ranged from golden yellow to yellow. From Figure 4.4a, 60%, which represents more than half of the okra bore golden yellowcoloured petals while the remaining 40% bore yellow-coloured petals.

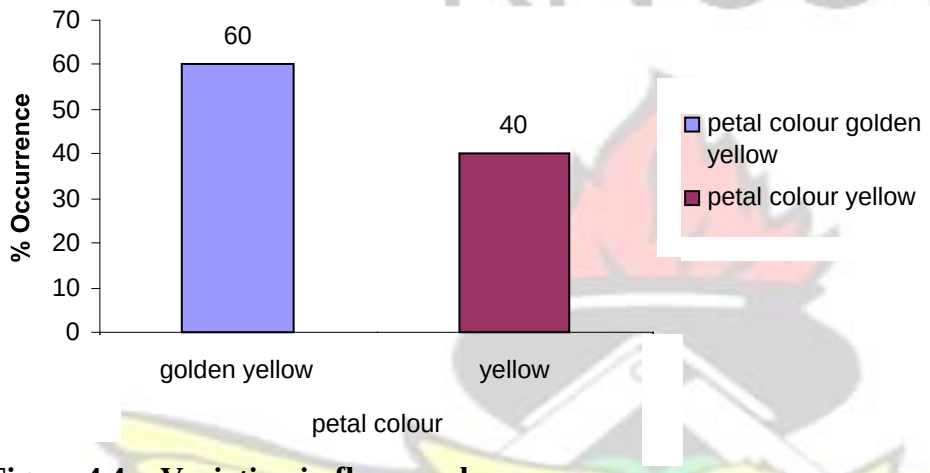

Figure 4.4a: Variation in flower colour

Plate 4.4b Variation in flower colour

4.1.3.4 Colour of the darkest ridges of fruits

Colour of fruit ridges of the okra landraces displayed wide variation. In all, eighty percent (80%) of the okra accessions depicted 'light' ridge fruit colour while dark ridge and light-to-dark ridge colours recorded 16% and 4% respectively. DA/08/03Sheo mana stood differently by showing light-to-dark coloured rigdes (Appendix A, Table 1 and Table 4.1).

4.1.3.5 Stem colouration

The results shown by Figure 4.5 depicted three distinct stem colours; green, green-withpurple tinge to completely purple. In all, 56% of the accessions had their stems tinged green, 36% of them had green stems with red veins and a small 10% of the accessions were tinged purple. Varieties GH3801 Pora and GH5793 Gyeabatan had a unique purple-tinged stems. Stem colour showed a wide varitation.

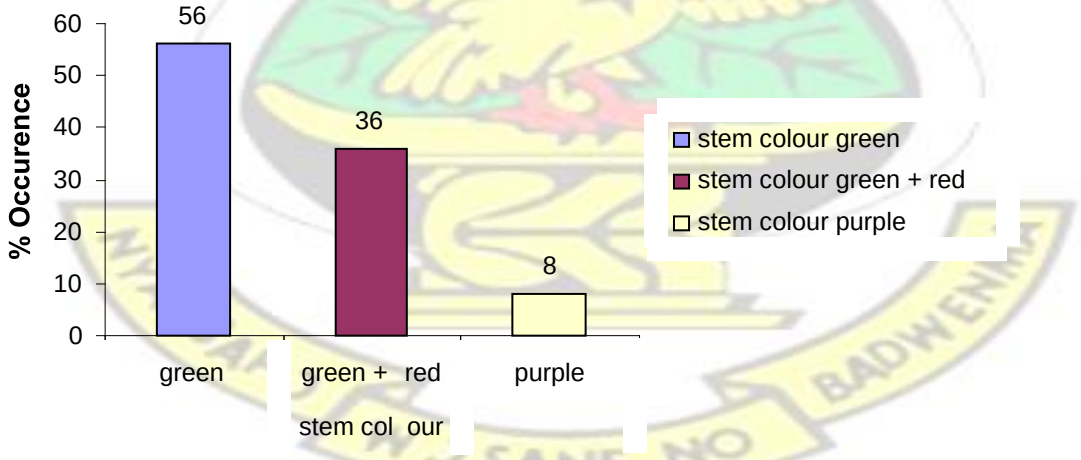

Figure 4.5: Variation in stem colour

4.1.4 Effect of Okra Varieties on Diseases and Pests Susceptibility

4.1.4.1 Susceptibility to viral (OMV and OLCV) diseases, insects and pests Okra Mosaic Virus (OMV) and Okra Leaf Curl virus (OLC) diseases were the two main diseases observed among the okra. Pests (fruit and stem borers-flea beetles; *Podagrica* spp., jassids; *Empoasca* spp., Aphids*; Aphis gossipii*, Cotton stainer *(Dysdercus* spp.) were among the insects identified mostly just before harvest.

Out of the 25 okra entries, accession GH3801Pora was highly susceptible to OLCV but moderately susceptible to OMV. Atuogya-tenten, GH 3736 Fetri, Atuogya-tiatia, Atuogya-Asante and GH 4376 Atuogya showed high tolerance to OLCV/OMV and pests. KNUST/SL1/07Nkrumahene, DA/08/02Dikaba, DA/08/03Sheo mana, DA/08/004Agbodro, DA/08/02Asontem, DA/08/02Sheo mana, DA/08/001Wun mana, GH 5787Asontem did not show any signs of viral infestation but showed few cases of insects and pests attack particulary at harvest (Appendix A, Table 1 and Table 4.1).

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Plate 4.5a: Okra leaf curl virus b. Okra mosaic virus c. Pests/insect-infested leaves

4.1.5 Flowering Characteristics among the Okra Genotypes

4.1.5.1 Number of epicalyx segments, shape and persistence

Number of epicalyx segments (NES) of all entries ranged from 5 to 10, showing an appreciable amount of variation among the okra varieties. Variety GH4490 Fetri recorded NES greater than ten (>10) segments. Nonetheless, NES within the range 8 to10 represented 68% of the okra varieties; close to two-thirds of the okra population studied. Epicalyx segment shape was lanceolate and showed partial persistence among all the okra genotypes (Appendix A, Table 1 and Table 4.1).

4.1.5.2 Flowering span

Flowering span showed either single flowering or grouped flowering. Single flowering dominated the okra population by 68%. The remaining 32% of the okra were of the grouped flowering type (Appendix A, Table 1 and Table 4.1).

4.1.5.3 Number of segments of the stigma

Number of segments of the stigma among the okra accessions varied between five and twelve. About 40% of the okra accessions formed 9 segments from the stigma while only 4% developed 12 segments from the stigma (Appendix A, Table 1 and Table 4.1).

4.1.6 Fruit Characteristics among Okra Accessions Studied

4.1.6.1 Fruit colour

The results in Figure 4.6a showed that fruit colour displayed five distinct colours that ranged from common green, green with red spots, dark green to black, green-to-yellow to completely

purple. In total, 72% of the accessions produced green fruits while 8% displayed green-with-red-spotted fruits, dark green to black fruits and green to yellowfruits respectively. A small 4% of the accessions had fruits tinged purple. Variety GH3801 Pora had a unique purplish pigmented fruit colour.

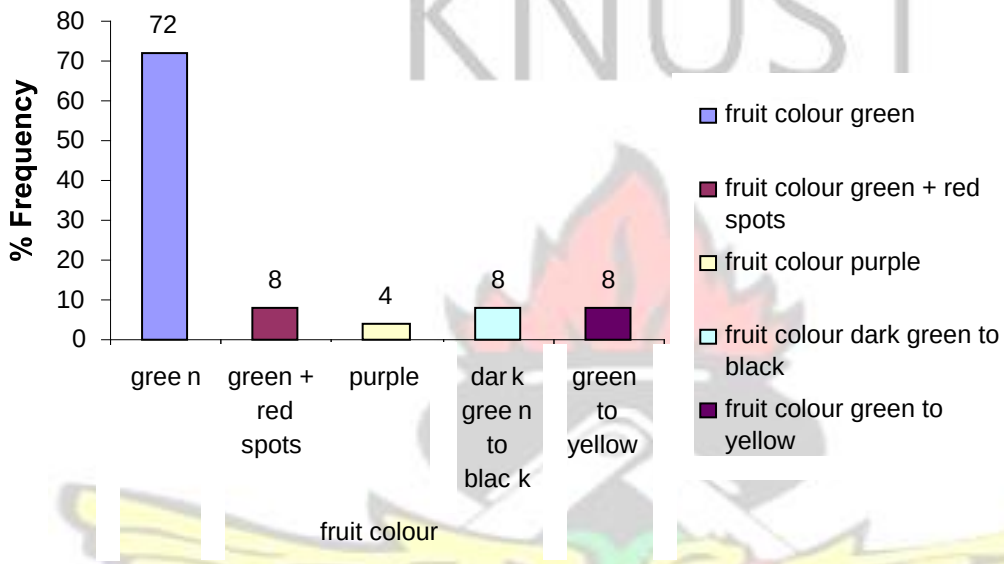

Figure 4.6a: Variation in fruit colour

Yellowish-green okra fruits

Purple (GH3801 Pora) okra fruit

Okra with green fruits

Plate 4.6b: Variation in fruit colour

4.1.6.2 Fruit pubescence

Fruit pubescence showed wide variation among the okra accessions. From the results in Figure 4.7, sixty-four percent of the okra genotypes showed fruits with no hairs on them while the rest had rough, downy or little hairs on their fruits representing 4%, 12% and 20% occurrences respectively. This character showed wide variation in this study.

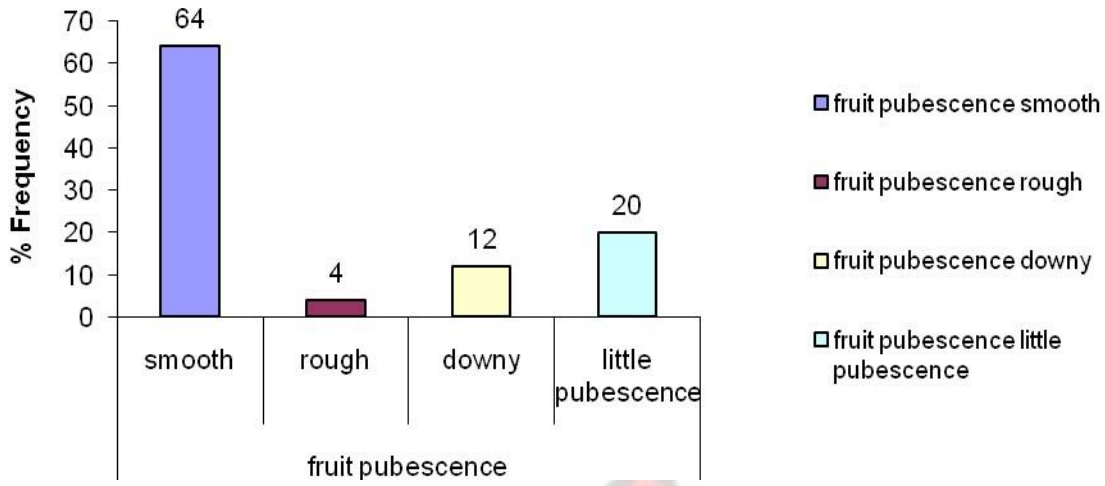

Figure 4.7: Variation in fruit pubescence

4.1.6.3 Fruit shape (form)

Fruit shape among the okra accessions showed the greatest diversity; from short and triangular to long straight or long curved. From the results in Figure 4.8a, 8% of the accessions bore fruits with shape scores of '1', '3', '4', and '15'respectively, according to the descriptor (IBPGR, 1991; Plate 4.5). Twenty percent (20%) of the accessions bore fruits with shape score '2' while 4% bore fruit with shape scores '6', '7', '13 and '14'respectively. Fruit shape scores '5', '9', '10' '11' and '12' did not show any occurrence (zero percentages) while shape score of type '8' recorded the highest occurrence of 32% of the okra accessions.

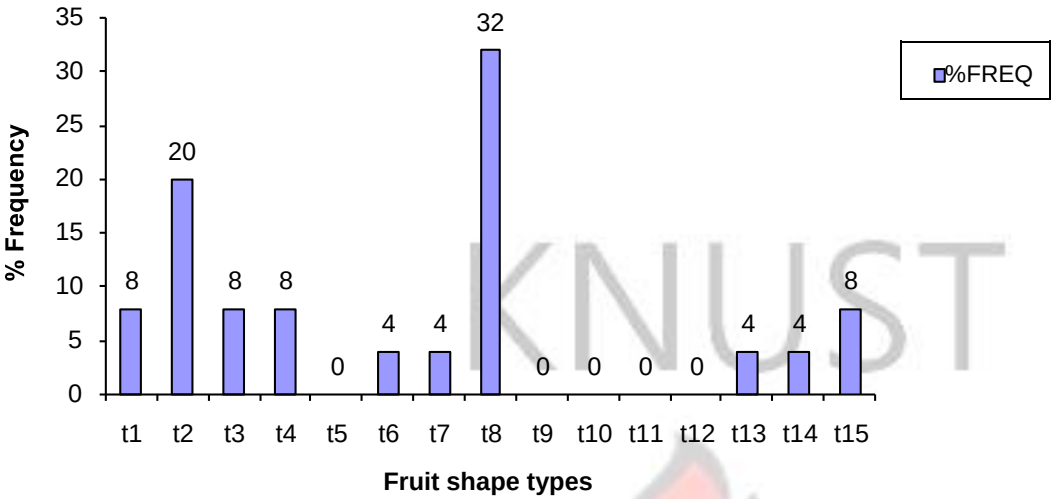

Figure 4.8a: Variation in fruit shape or form

Agbodro

Wun mana

Sheo mana

Gyeabatan

Atuogya Asante

KNUST Nkrumahene

Plate 4.4b: Variation in fruit shapes (forms)

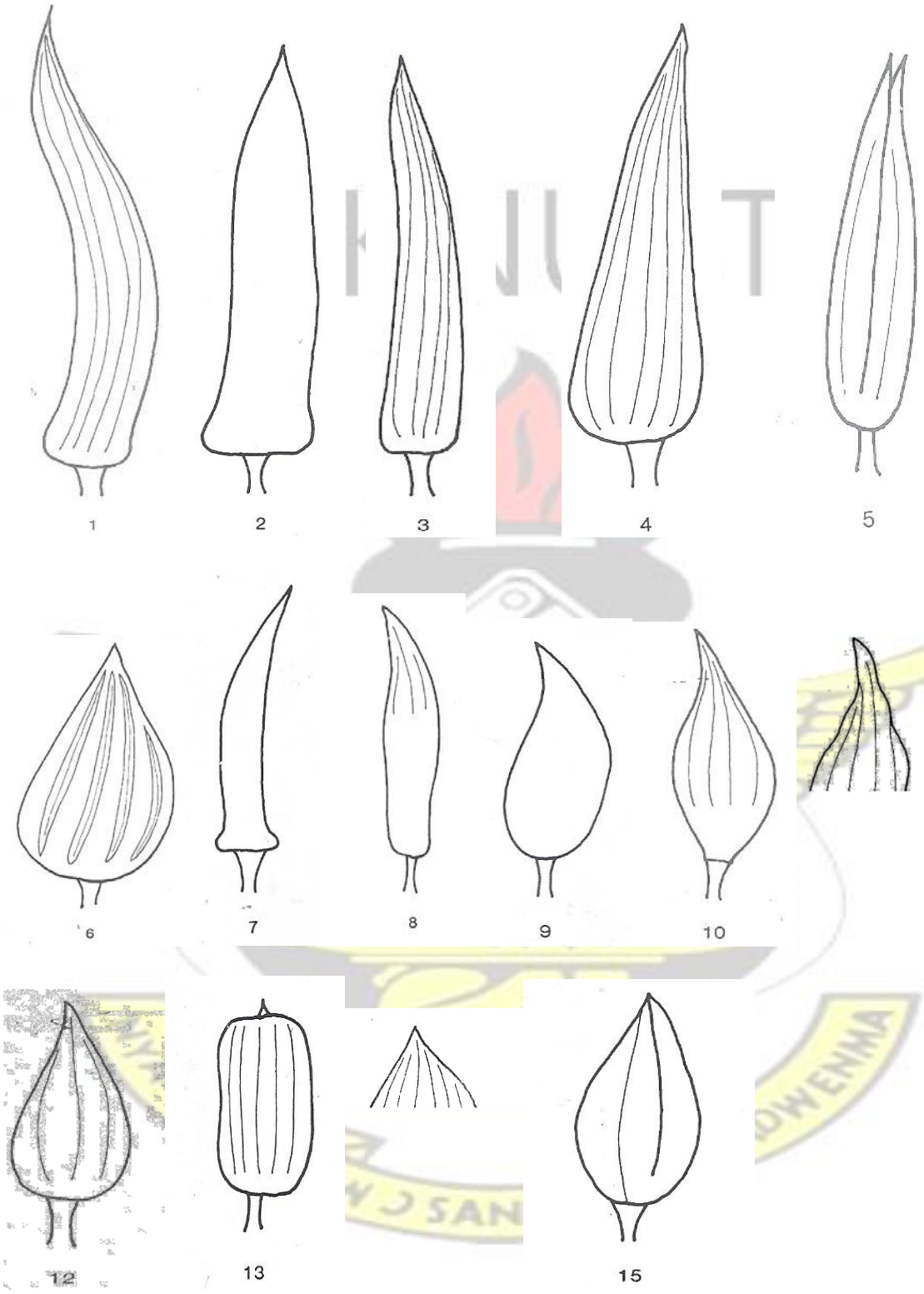
1
2
3
4
5
6
7
8
9
10
12
13
15

Plate 4.5: Variation in fruit shapes (IBPGR, 1991)

4.1.6.4 Number of fruit ridges

Number of fruit ridges and position of fruits on main stem are useful only for cultivated forms of okra. The number of ridges per fruit of the 25 entries ranged from 0-12 ridges (Plate 4.6). Accessions DA/08/004 Agbodro, GH 4964 Muomi, GH 4482 Muomi, GH 4487 Muomi recorded no well-marked ridges on their fruits while Gbodro and Atuogyatenten had ridges of up to 5 counts on their fruits. The rest of the okra accessions, representing about 80% had very conspicuous ridges per fruit at between 8 and 12 ridges (Appendix A, Table 1 and Table 4.1).

Plate 4.6: Variation in fruit ridges (spines)

4.1.7 Fruit Characteristics in Relation to Plant Growth

4.1.7.1 Fruit position on the stem

The position of fruits on the main stem of the accessions showed five distinct variations; erect, intermediate, slightly falling, horizontal and drooping positions. The results in Figure 4.9 showed that, 60% of the accessions had fruits that were intermediate on the stem, which means they were half upright on the stem, 20% of the accessions bore fruits which were in erect (upright) position, 12% of the okra accessions bore fruits which were

positioned horizontally on the stem while only 4% bore fruits which were slightly falling and drooping respectively (fruits in an almost upside down position).

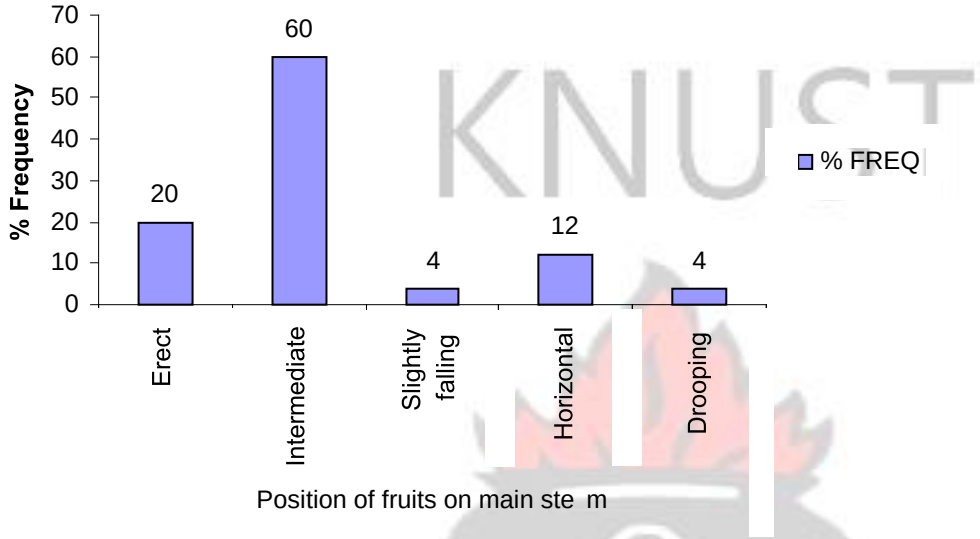

Figure 4.9: Variation in fruit shape or form

4.1.7.2 Length of fruit peduncle of the 25 okra genotypes

All okra accessions showed significance in fruit peduncle length ranging from 1 to 3 cm to >3 cm. Sixty-four percent of the okra had fruit peduncle length ranging between 1 and 3cm while the remaining 36% had peduncle length greater than 3cm (Appendix A, Table 1 and Table 4.1).

4.1.8 Days to First Flowering (DFF)

Generally, all the okra accessions recorded high germination percentages. Earliness in okra is determined by the number of days from sowing to 50% full-bloom. This character recorded a wide variation among the okra accessions studied. These variations are as shown in Figure 4.10;

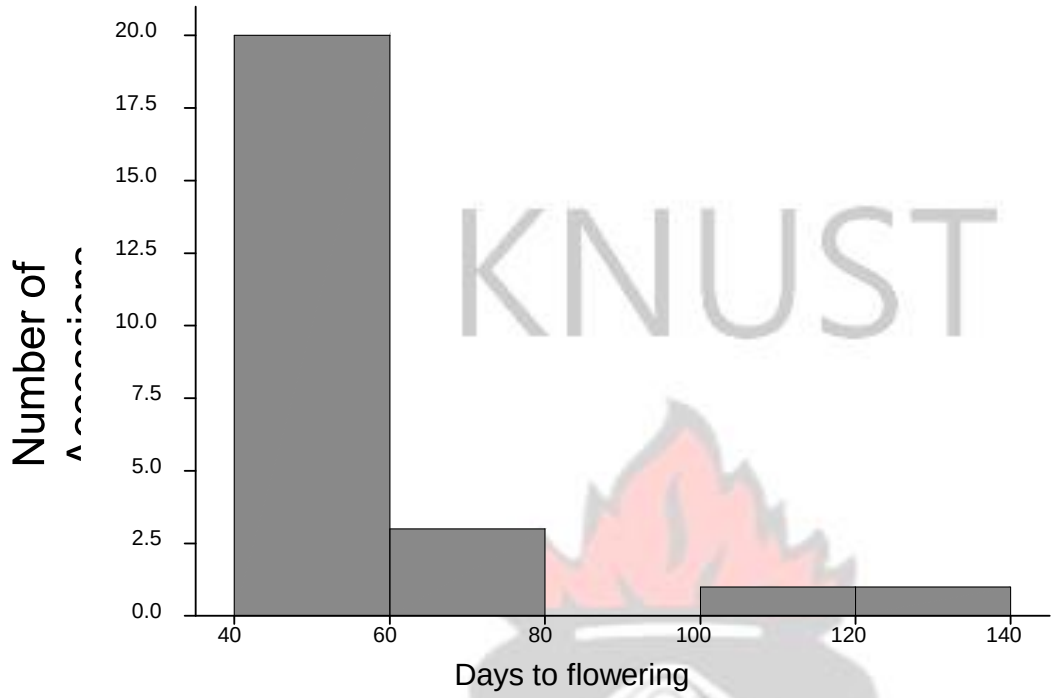

Figure 4.10: Variation in the number of days to flowering

Okra accession Atuogya-Asante recorded the longest number of days to flowering of up to 128 days. Shorter number of days to flowering was recorded in accessions KNUST/SL1/07Nkrumahene, DA/08/02Dikaba, GH5787Asontem, GH6102 Fetri and Asontem, recording as early as between 44 and 48 days (Table 4.2). This is a character that breeders are interested in and will exploit to improve yield. For instance, early maturing plant types could be selected for areas with short rainy seasons in the rain fed ecologies. Such genotypes will also be suitable in areas where farmers grow a second crop to take advantage of residual water after harvesting the early crop.

Table 4.2: Assesion means for quantitative characters that showed variation in okra

N0.	Accession	NS/F	MPH (cm)	DFF	FFN	NTF/P	FF-PN	FFrtWt(g)	SDYLD	$SW_{100\ (g)}$ (Kg/plot)
1	GH4487 Muomi	95.50	68.00	58.50	7.00	59.80	7.75	5.45	8.94	3.86
2	GH4482 Muomi	71.20	57.00	52.25	6.50	51.00	6.00	6.60	8.13	3.51
3	GH4499 Fetri	8.00	39.60	49.00	7.50	16.80	8.00	5.64	7.75	3.35
4	GH1169 Fetri	63.00	116.00	55.75	6.75	79.20	5.25	5.92	7.76	3.35
5	GH4376 Atuogya	72.20	55.80	52.25	8.00	91.20	8.50	6.67	8.86	3.83
6	GH4490 Fetri	77.00	54.80	51.75	7.75	76.20	7.00	7.01	7.15	3.09
7	GH3801 Pora	68.50	65.20	45.25	6.50	58.00	7.00	3.53	7.37	3.19
8	GH6102 Fetri	63.00	60.50	47.25	5.75	56.50	5.50	6.42	8.30	3.59
9	GH4964 Muomi	84.00	54.20	43.25	8.00	69.00	8.25	6.86	6.66	2.88
10	GH5793 Gyeabatan	74.80	71.10	70.00	7.50	112.20	7.75	12.40	7.52	3.25
11	GH5787 Asontem	78.50	127.50	44.00	6.25	142.00	6.50	7.29	7.26	3.14
12	GH3736 Fetri	83.80	63.20	50.25	7.75	58.80	7.75	6.85	7.70	3.33
13	Atuogya-tiatia	72.50	43.20	54.25	3.75	144.00	4.50	7.27	6.66	2.88
14	DA/08/001 Wun mana	84.00	26.80	74.25	10.75	67.80	9.25	14.22	14.79	6.39
15	DA/08/02 Sheo mana	85.20	28.20	48.50	6.25	73.20	6.00	12.26	7.30	3.16
16	DA/08/02 Asontem	70.20	61.70	41.75	6.75	69.20	7.00	11.57	7.99	3.45
17	Atuogya-Asante	76.00	63.50	128.25	7.75	52.50	7.25	12.40	8.51	3.68
18	Asontem	73.00	71.00	51.25	6.25	62.00	5.50	8.58	7.07	3.06
19	DA/08/04 Wun mana	73.00	42.70	50.25	6.00	69.80	7.00	13.43	7.04	3.04
20	DA/08/004 Agbodro	84.20	49.50	68.25	7.75	29.00	7.25	6.76	7.95	3.44
21	GBODRO-wild	74.20	48.50	50.25	7.75	76.00	7.75	8.68	8.14	3.52
22	DA/08/02 Dikaba	72.50	64.90	48.00	6.25	68.00	6.00	12.01	7.83	3.38
23	DA/08/03 Sheo mana	82.80	71.20	53.25	8.00	54.30	8.25	13.08	7.35	3.18
24	Atuogya-tenten	73.00	40.20	50.00	7.00	58.00	6.50	9.21	7.87	3.40
25	KNUST/SL1/07Nkrumahene	105.50	69.20	46.75	6.50	70.20	6.25	9.42	4.71	2.04

NS/F: Number of seeds per fruit, MPH: Maximum plant height, DFF: Days to first flowering, FFN: First floweing node, NTF/P: Number of total fruits per plant, FF-PN: First fruit –producing node, FFrtWt (g): Fresh fruit weight, SDYLD: Seed yield, $SW_{100\ (g)}$: 100 seed weight.

4.1.9 Maximum Plant Height, MPH

The height of plants in this study varied significantly among the okra accessions studied (Table 4.2). The tallest plant with the height of 127.5 cm occurred among GH 5787Asontem followed by GH1169Fetri with 116.0 cm. On the other hand, accession DA/08/001Wun mana recorded the shortest plant height of 26.80 cm. Height at flowering and fruiting (final height) are of particular interest for breeding programmes because tall, thin stems increase logding near harvesting time and this could result in loss of dry matter and a subsequent decrease in fruit yield.

4.1.10 Yield

Number of matured green fruits per plant (NTF/P) for the okra genotype varied significantly. The highest yield of 144 fruits was observed for Atuogya-tiatia followed by GH5787 Asontem with 142 fruits and accession GH5793 Gyeabatan producing 112 fruits. Accession number GH4499 Fetri had the least number of fruits of 16.8 (Table 4.2). Yield was significantly affected by environmental factors leading to flower drop and low yield.

4.1.11 Susceptibility to Viral Diseases (OLCV, OMV)

Atuogya, Wun mana and Sheo mana types of okra exhibited high resistance to the diseases (viral) and pests/insects.

Siemonsma, 1992(a)(b) had indicated that, Okra mosaic virus (OMV), transmitted by flea beetles (*Podagrica*), is widespread in Africa but damage is much less important than that caused by okra leaf curl disease (OLCV), transmitted by whitefly (*Bemisia tabaci*). Differences in diseases/insects/pests susceptibility observed among the okra genotypes,

particularly the Atuogya types, might be due to the inherent genetic potential of the different okra landraces (differences in cultivar types) to resist environmental stresses including diseases/pests/insect. Research findings of Stevels, (1988) are in support of this result. This resistance by the Atuogya accessions could be used as a genetic base to improve other susceptible varieties such as GH3801 Pora.

4.2 CORRELATION ANALYSIS

A correlation of the characters with the total fruit production showed that the following characters (Table 4.9) showed positive correlation, which generally means that they influenced fruit production or yield.,The highest significant ($p< 0.01$) correlation was recorded between first flowering node and first fruiting node (0.736).

The correlation results revealed a positive and a highly significant association between maximum plant height and number of internodes (0.467, $p < 0.01$) and fruit length at maturity (0.502). Maximum plant height again recorded significant positive correlation between first flowering node (0.246, $p < 0.05$) and first fruit-producing node (0.213).

Correlations between first flowering node and first fruit producing node, and fruit length at maturity were significantly high and positive (0.736, $p < 0.01$); (0.253, $p <$ 0.05). Correlation results between days to first flowering and first flowering node ($r =$ 0.252), fresh fruit weight (0.291), seed yield (0.282) and 100 seed weight (0.282) were also positive and significant ($p < 0.05$).

Number of total fruits per plant revealed significantly high and positive correlation ($p < 0.01$) with first flowering node (0.258), first fruit-producing node (0.308), fruit length at maturity (0.557) and maximum plant height (0.435) but negative correlation with fruit width (-0.020). Highly significant association was revealed between seed yield and days to first flowering as well as between 100 seed weight and days to first flowering (0.282, $p < 0.01$) but a negative yet non-significant association was recorded between either of the two and number of seeds per fruit (-0.013) (Table 4.9).

Table 4.3: Correlation Analysis of Quantitative Characters in Okra Accessions

CHARACTERS	DFF	FFN	FF-PN	FFrtWt(g)	FLM (cm)	FW (cm)	MPH (cm)	NI	NS/F	NTF/P	SD YLD(kg/plot)	SW_{100} (g)	Wt (kg)
DFF	1												
FFN	0.252*	1											
FF-PN	0.144	0.736**	1										
FFrtWt (g)	0.291**	0.026	-0.000	1									
FLM (cm)	0.172	0.253*	0.238*	0.073	1								
FW (cm)	-0.011	0.088	-0.028	-0.033	-0.125	1							
MPH (cm)	0.082	0.246*	0.213*	0.099	0.502**	0.019	1						
NI	-0.033	-0.097	-0.047	0.008	0.194	0.154	0.467**	1					
NS/F	0.069	0.044	0.056	0.022	0.142	-0.075	0.008	0.051	1				
NTF/P	0.023	0.258**	0.308**	0.049	0.557**	-0.020	0.435**	0.127	0.025	1			
SD YLD (kg/plot)	0.282**	0.232*	0.205*	0.210*	0.195	0.105	0.178	0.132	-0.013	0.081	1		
SW_{100} (g)	0.282**	0.232*	0.205*	0.210*	0.195	0.105	0.178	0.132	-0.013	0.081	1.00**	1	

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

***DFF = Days to First Flowering**
***FFN = First Flowering Node**
***FF-PN = First Fruit-Producing Node**

***FFrtWt (g) = Fresh Fruit Weight**
***FLM (cm) = Fruit Length at Maturity**
***FW (cm) = Fruit Width**
***MPH (cm) = Maximum Plant Height**
***NI = Number of Internode**
***NS/F = Number of Seeds per Fruit**
***NTF/P = Number of Total Fruits per Plant**
***SD YLD (kg/plot) =Seed Yield**
***SW_{100} (g) = 100 seed weight**

4.3 CLUSTERING OF OKRA ACCESSIONS

4.3.1 General Clustering of Okra Accessions into Groups

A cluster diagram obtained from the morphological descriptors produced four main subcluster groups of okra accessions at a co-efficient of 0.63. Accessions were put into cluster groups based on certain qualities unique to them. Cluster A recorded the highest number of accessions (16) while cluster B consisted of only one accession.

It was observed that 23 out of the 25 okra accessions studied were distinct accessions. A tie was recorded between accessions GH6102Fetri and GH3736Fetri. Similarity coefficient ranged from 45.8% to 86.5%. There was no unique relationship between the cluster groups and the regions of collection. Accessions with similar quantitative and qualitative morphological characters appeared well grouped in the same cluster. Okra accessions with common local names were also found in the same cluster (Figure 4.8).

4.3.2 Similarity per a Cluster Group

Cluster A comprised 16 accessions, differing from accession in the other clusters by having green fruit colour, golden yellow petal colour. Within cluster A, sub-cluster A_1 produced accessions with green stem colour as against A_2 with green-with-purple tinge stem colour. Within sub-cluster A_2, sub-sub-cluster A_{21}, consisting of accessions GH4482Muomi and GH4964Muomi, produced the same fruit shape (type 12) and leaf shape (type 1).

Okra genotypes, GH3801 Pora and DA/08/02 Sheo mana were singled out of the two unique sub-cluster groups A_1 and A_2 due to the fact that GH3801 Pora formed a unique fruit colour/pigmentation (purple), and leaf shape (type 7) while DA/08/02 Sheo mana had fruits with green colour and leaf shape of type 3.

Cluster B comprised only one okra accession, DA/08/03 Sheo mana, and this differed from accessions in the other clusters mainly in its fruit pubescence or the presence of hairs on its fruits (downy plus hairs), and fruit colour (green to yellow).

Cluster C, the second largest cluster with 6 okra accessions, composed of okra genotypes that were different from the others by their reduced fruit pubescence, yellow petal colour with stem colour having a combination of green with purple tinge. The orientation of fruits on main stem was drooping.

Within cluster C, sub-cluster C_1 formed fruit with shape of type 4, and combined green with red-spotted fruits while sub-cluster C_2 showed fruits with a combination of dark green plus red and dark green-to-black as well as leaf shape of type 2. Sub-cluster C_3 included fruits with dark green-to-black colour only.

Cluster D consisted of 2 okra accessions, Atuogya-tiatia and Atuogya-tenten. These were different from accessions in the other clusters by their branching position-at-mainstem; being densely branched base (DBB) and fruit pubescence being little rough with dark hairs. The orientation of fruits-at-main-stem of these okra varieties was horizontal.

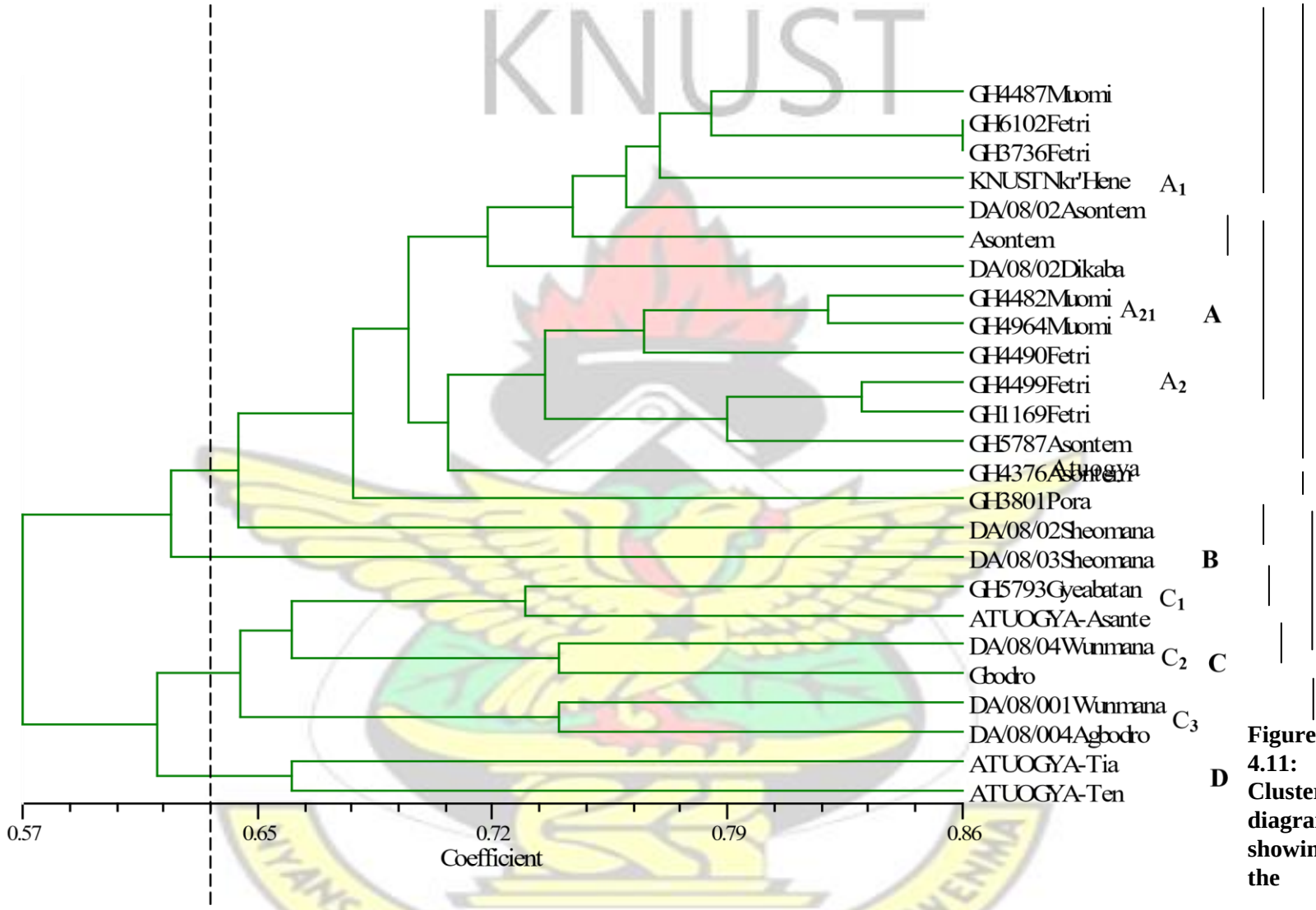

Figure 4.11: Cluster diagram showing the relationship among 25 okra accessions revealed by UPGMA cluster analysis based on morphological characters

4.4 AGRONOMIC PERFORMANCE AMONG OKRA ACCESSIONS

Table 4.4: Means, Standard Error, Range, Coefficient of Variation (CV%), Standard Deviation (SD) and F. Probability at l.s.d. 5% of 25 okra accessions

Traits	N	Mean ± S.E	Range	C.V%	S.D	F. Pro.
NS/F	25	74.60 ±0.48	8.00-105.50	0.70	15.70	<0.001
MPH(cm)	25	59.60 ±1.35	6.80-127.50	3.10	35.40	0.031
DFF	25	55.38 ±1.85	41.75-128.25	2.70	18.48	<0.003
FFN	25	7.04 ± 0.23	3.75-10.75	3.40	1.60	0.003
NTF/P	25	70.60 ±2.65	16.80-144.00	6.00	26.90	<0.001
FF-PN	25	6.95 ± 0.25	4.50-9.25	4.40	1.53	0.024
FFrtWt (g)	25	8.78 ± 0.14	3.53-14.22	1.90	3.12	<0.001
SDYLD(Kg/plot)	25	7.86 ± 0.33	4.71-14.79	0.49	2.30	<0.001
$SW_{100\ (g)}$	25	3.40 ± 0.14	2.04-6.39	4.90	9.90	<0.001

The accession means, standard error, range, coefficient of variation, standard deviation and F. probability for the nine quantitative traits that varied significantly ($p < 0.05$) among the okra collection are shown in Table 4.4.

CHAPTER FIVE DISCUSSION

5.1 EXTENT OF VARIATION IN QUALITATIVE AND QUANTITATIVE MORPHOLOGICAL CHARACTERISTICS

Variation is a necessary condition for selection in breeding programmes (Hazra and Basu, 2000; Omonhinmin and Osawaru, 2005). The morphological descriptors developed and used for characterizing each morphotype in this study are shown at Appendix A, Table 1 as proposed by IBPGR, (1991) descriptor lists for okra.

The okra genotypes characterized in this study showed a broad variation for most traits, which allows for the identification of promising accessions for okra breeding in Ghana and beyond. The variation in leaf shape, leaf rib colour, petal colour, petiole colour, stem colour, fruit colour and pubescence and fruit shape, among others, were easily recognizable with visual appraisal.

Variations observed in this study was apparent for branching position on main stem which was either unique orthotrop axis, densely branched over or densely branched base. Plants with unique orthotrop axis revealed the highest as against the lowest recorded by branched okra accessions. This is because different genotypes have the tendency of exhibiting different growth habits, whether as a result of selection or a natural adaption mechanism. This is similar to a statement made by Hanson, (2005) in studies made in tomato. The most predominant leaf colour was green while green with red veins was leas frequent. Similar observation was found with leaf rib colour. Leaf shape revealed 'heart' and 'palmate' shapes. These results are similar to those found by Myanmar, (1995) in okra studied.

Variations in stem colour among the okra accessions in this study were significant. This revealed the highest for green and the lowest for purple while green with red purple tinge was appreciably high. This observation is in line with the findings of Bish *et al*., (1995).

Petal colour was either golden yellow or yellow with golden yellow flowers recording the highest. This is contrary to observation made by Myanmar, (1995) who found petal colour

to be 100% yellow for all 40 okra accessions examined. Akinyele and Akinlosotu (1991) also found similar results in their okra research.

Differing from results of the present study again, fruit orientation was 100% erect for all accession as reported by Myanmar, (1995) as against a combination of erect, intermediate, slightly falling, horizontal or drooping, in the present study where intermediate fruit position revealed the highest and the lowest recorded by drooping position. Variation revealed in this study for fruit colour was highest for green and appreciably high for green-to-yellow as well as green-to-red spots. This is different from results found by Myanmar, (1995) in which fruit colour was observed to be either green or yellow-to-green though green fruit colour was found to be highest in the okra accessions studied. These results were expected because, Myanmar (1995) might have examined improved okra collections that were more uniform. The okra genotypes used in this study were landraces, and hence more variable or diverse.

Results obtained in this study show that the okra accessions exhibited varying degrees of fruit pubescence including smooth, rough, downy or little hairs on fruits but with the majority having smooth fruits. This result is in sharp contrast to those of Bish *et al*., (1995) and Thomas, (1991) who found downy type of fruit pubescence to be highest, followed by slightly rough while prickly fruits was the least in the okra accessions they studied. This shows that farmers in Ghana have selected the smooth fruit types as their preferred fruit and discarded the hairy types.

Variation in okra species has been investigated by several researchers (Singh *et al*. 1974; Singh and Singh, 1977; Akinyele and Oseikita, 2006; Bish *et al*., 1995; Thomas, 1991 and Duzyaman, 2005). They found that a large number of okra characters such as pigment colour and spines on the fruit surfaces are inherited in a simple fashion, suggesting that these characters are controlled by relatively few genes (monogenically inherited).

Ariyo, (1993) indicated that the pattern of genetic variation observed in characters studied in West African okra suggests a lot of out crossing among the taxon. Wide morphological variation observed in okra characters studied could perhaps, be attributed to the preponderance of outcrossing among different accessions of the okra studied.

Adeniji, (2003) and Lim and Chai (2007) investigated a range of qualitative and quantitative characters of different okra accessions and found great diversity in characters that are again similar to the results found in the present study. Mishra and Chhonkar, (1979) have also reported considerable variation in okra vegetative and fruit characters. They noticed variation in number of branches per plant, fruit yield per plant, number of seeds per fruit, fruit length, plant height at flowering, maximum or final plant height, fruit growth, fruit weight, days to 50% flowering and total number of leaves per plant. These agree with results found in this okra morphological diversity studies.

5.2 ASSOCIATION AMONG MORPHOLOGICAL TRAITS (CORRELATION ANALYSIS)

The association between pairs of quantitative yield traits (Table 4.9) in the okra landraces studied saw flowering and fruiting parameters (fruit size, fruit weight, average number of fruits per plant, first-flowering node, first fruiting node and days to firstflowering), maximum plant height and number of internodes recording significant ($P < 0.01$) positive associations. Findings of several researchers (Singh and Singh, 1977; Kaul *et al*., 1978 and Hazra and Basu, 2000) suggested that component breeding would be very effective when there is positive association of major yield characters, as found in this study.

Earlier findings of Kumar and Reddy (1982) had also revealed that number of total fruits per plant had the highest direct effect on seed yield followed by maximum plant height and days to first flowering. The highly significant correlation ($P < 0.01$) recorded between fruit length at maturity and average number of total fruits per plant in this study indicated the possibility of selecting highly prolific fruit types with longer fruits.
This is supported by the research findings of Akinyele and Oseikita (2006).

The significant positive relationship of days to first flowering, first flowering node with first fruiting node and maximum plant height at flowering observed in the study shows that there is strong relationship between days to flowering and days to fruit or node production and maturity hence, indicative of a strong relationship between the stages of plant growth at which flowering is initiated and final height at which the entire crop life cycle is completed. These results corroborate findings of Akinyele and Oseikita (2006).

The number of total fruit per plant exhibited positive and significant correlation with maximum plant height, according to the result of the correlation analysis. This implies that plant height favoured the performance of the okra plants and should be selected for as a component of yield; the implication being that any improvement in height of okra accessions would indirectly select for or increase fruit yield. Similar results were found by Reddy *et al*. (1985) and Henry and Krishna, (1990).

The positive correlation recorded between days to first flowering and first fruitproducing node indicates that days to flowering can be used as a criterion for selecting lines that have a few numbers of days to maturity, so that production can occur twice in a cropping season. This finding is similar with the report of Ariyo *et al*. (1987) and Oseikita and Akinyele, (2008).

The non-significant negative association between the fruit length and fruit width characters in the present study shows that the two characters could be selected for separately as they are components of seed yield. This is supported by Shukla, (1990) in his earlier finding of correlation and path co-efficient analysis in okra.

Newall and Eberhart (1961); Ariyo *et al*. (1987); Henry and Krishna (1990), noted that characters that exercise negative correlation with one another will be difficult to select for in characterization of desirable traits, and that those with negative association but non-significant correlation will be disregarded in selection for crop variety improvement.

It could therefore be deduced from the associations above, that, any improvement sort that is directed at maximum plant height (height at flowering), days to first flowering and number of internodes, among others, would indirectly result in improvement in (fresh) fruit weight, seed yield and a subsequent increase in total fruit yield, results that is a prerequisite in any breeding programme.

5.3 PATTERN OF VARIATION AND DESCRIPTION OF THE CLUSTER GROUPS

In cluster group A, the cluster analysis generally found accessions GH6102Fetri and GH3736Fetri (from Biakoye and Kpogadzi respectively) in a tie. That is, the two accessions were placed at 100% similarity. These Fetri accession may therefore be identical. Perhaps, they may have been collected by the same farmer and misnamed due to the informal way of germplasm exchange from farmer to farmer, diverse languages or ethnic groups in the areas covered by the collection and marketing, which accounts for the differences in local names.

Within cluster group A are also found other 'Fetri' accessions; GH4490Fetri, GH4499Fetri and GH1169Fetri. These may again be the same accession but picked at different locations and time and named differently due to the informal means of germplasm collection, selection and dissermination by okra farmers. Similar reason could be ascribed to the three accessions of Muomi (GH4487, GH4482, and GH4964 from Bedoku, Prampram and Sutapong, respectively) also found in the same cluster group A.

Okra accessions GH4376Atuogya and Atuogya-Asante were found in cluster groups A and C respectively. One would expect these to be under one cluster group, however, they did not. Perhaps, the traits considered were inadequate or were not sufficiently discriminatory to permit their classification into one group. Similar results can be speculated of accessions such as DA/08/02 Sheo mana and DA/08/03 Sheo mana as well as DA/08/04 Wun mana and DA/08/001 Wun mana, which did not enter into one cluster group but were found in cluster B and sub-clusters C_2 and C_3 respectively.

The great difference in genetic relationship, particulary among the Atuogya, Wun mana, Sheo mana, Muomi and Fetri collections demand further classification of these collections by employing more discriminatory characters or by utilizing molecular markers.

It must be said that most of the okra genotypes found in the same cluster group, such as GH1169Fetri and GH4499Fetri (originally collected from Gabusa and Nyingutu respectively, both in the Northern region), Atuogya-tenten, Atuogya-tiatia, AtuogyaAsante, Asontem and KNUST/SL1/07 Nkrumahene (collected originally in the Ashanti region), DA/08/02 Sheo mana, DA/08/03 Sheo mana, and DA/08/04 Wun mana, DA/08/001 Wun mana (all from Sakogu in the Northern region), and scoring similar similarity indices may be eliminated from the germplasm collection. IBPGR, 1991 report that, repeated regional collections without proper documentation could account for duplication in germplasm collections.

From the analysis of the similarity matrix (Appendix C, Table 6), similarity coefficient ranged from 45.8%, for the most distantly related accession, to 86.5% for those closely related. This is therefore indicative of a higher variability in the okra accessions studied.

From the similarity matrix, two pair of accessions, DA/08/03 Sheo mana and GH4482 Muomi, Atuogya-tiatia and GH4964 Muomi showed the widest variation in the characters measured, scoring 0.458 on the similarity matrix, meaning these okra pairs are 45.8% similar and 54.2% dissimilar in the characters measured.

These variations are what plant breeders are very much interested in and therefore are suitable for further breeding purposes. This results is confirmed by Reid *et al*., (1998), who argued that, genetic diversity of crops in Africa have been naturally preserved for a longer time by virtue of the continent's relative traditional agriculture.

Four pairs of accessions; Atuogya-tiatia and GH4487 Muomi, DA/08/04 Wun mana and GH4487Muomi, DA/08/04 Wun mana and GH4490 Fetri and Atuogya-Asante and GH4499 Fetri showed a similarity matix of 0.49 according to Appendix C, Table 6. This again implies that they were 49% similar. These okra accessions are therefore suitable for exploitation by breeders for further improvement of quality and yield. Mondal (2003) said that genetic diversity is essential to meet the diversified goals of plant breeding which included increase in yield, diseases and pest resistance, wider adaptation and desirable qualities. This demonstrates the level of diversity that exists among selected okra accessions. For instance accession Atuogya-tiatia, originally collected from Ejura in the

Ashanti Region and GH4499 Fetri collected from Nyingutu in the Northern Region were 51% dissimilar and are therefore suitable for exploitation and improvement.

Observation from Appendix C, table 6 placed only three pairs of accessions; DA/08/03 Sheo mana and GH4376 Atuogya, DA/08/001 Wun mana and GH4376 Atuogya and Atuogya-Asante and GH 4490 Fetri at 50% similarity, meaning the two accession pairs matched at half the characters measured.

The similarity matrix again showed that of all the accessions measured, eight (8) accessions gave a matrix score of 0.8 and above. This shows that the pairs are 80% or more similar, according to the similarity matrix.

Studies by Irwin *et al*. (1998) affirmed that closely related accessions are normally located within 80–90% similarity. Crosses between accessions with similarity indices of 80–100% may, therefore, not be desirable; and that the potential for successful crossing of unrelated varieties may generate into an array of genotypes from which useful agronomic types may be selected, a similar observation was made by Gulsen *et al*. (2007). The large size of the accessions from a wide range of geographical areas is very essential for genetic distance estimation (Nei, 1978).

Findings of Singh *et al*. (1974) and Torkpo *et al*. (2006) indicate that the wide range of similarity indices, coupled with the clustering of accessions, suggested useful variability in the okra germplasm collection for genetic preservationists and plant breeders for improvement programmes.

5.3.1 Implication of the Results to Breeding

5.3.1.1 Germplasm selection and exchange

Okra is a very popular vegetable in Ghana and some have been selected by farmers based on characters that best fit their needs. This has generated a large number of traditional varieties (Torkpo *et al*., 2006). In addition, different ethnic groups in the regions have contributed to this selection leading to numerous vernacular names given to the same landraces according to ethnic groups (Gulsen *et al*., 2007).

The accessions; 'Atuogya' tiatia and 'Atuogya' tenten, which clustered under cluster group D and Atuogya-Asante (under sub-cluster C_1), in the Akan language means 'neglected'. These behave like volunteer crops; the seeds remain dormant in the soil for a long time and once forest is cleared, they germinate and grow again. They may adapt to and survive the environmental stresses for up to 3 years, and shrubs can reach 4m or even higher, becoming woody at the base, strongly branched with a main stem of up to 7cm in diameter. These varieties tend to be indeterminate and exhibit annual or perennial characteristics in growth habit (Mondal *et al*, 1989; Siemonsma, 1982a; Sinnadurai, 1992).

This is evident by their relatively longer days to first flowering and fruiting or node formation as well their densely branched characteristics observed in this study. These perennial Atuogya varieties have the advantage of being highly resistant to environmental stresses such as drought and diseases and pests. On the contrary, the accessions

DA/08/02Asontem, Asontem, GH5787Asontem, as well as Fetri and Muomi varieties, which clustered under cluster group A, in the Akan language means ‘early maturing’ or ‘the early one’. These remain the most popular okra cultivars in southern Ghana. These varieties are known to be bi-annual and they usually take about ten weeks to three months from sowing to produce the first fruit. These would produce flowers and fruits on the onset of the rains at both the major and the minor seasons. As shown by the results of this study, the ‘Asontem’ varieties had shorter days from sowing to flower formation and fruiting. They also had unique orthotrop axis in terms of branching position, general appearance and growth habit.

These early maturing but disease susceptible Asontem types of okra could be selected for and incorporated into the highly disease-resistant and drought tolerant as well as high yielding Atuogya varieties that exhibited perenniality, so as to develop promising okra genotypes useful for commercial or export production in Ghana.

5.3.1.2 Growth habit

Different genotypes have different growth habits. The commonest growth habit among all the landraces observed was indeterminate growth habit with erect general growth appearance (Unique orthotrop axis) (Figure 4.2).

Erect plant type is advantageous to okra production since it would allow maximum and uniform exposure or distribution of all leaves and other vegetative parts for better interception of sunlight. This would result in an increase in dry matter production and a

subsequent increase in yield. This is in conformity with the findings of Hanson, (2005). Moreover, there is less chance of fruits touching the ground or soil thereby causing fruit rot.

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, (2005) 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 for high yield. Short branches and internode length with flowers are, however desirable.

Okra genotypes such as 'Wun mana' and 'Sheo mana' types produced dense branches with fruits closer to the soil, yet gave higher total fruit yields. This could be selected for and incorporated into other 'Asontem' varieties which had the typical unique orthropic axis branching (erect) but moderate in plant height, in order to develop elite okra types that are less lodging with higher yields and can therefore pass for commercial production.

5.3.1.3 Fruit Characters and Production

Fruits displayed great diversity in size-shape and length. They ranged from short and triangular to long straight or long curved. Earliness, expressed by the lower leaf axil in which flower buds appear, is partly due to varietal characteristic.

Fruits with characteristics such as smooth, spineless, slender with green (light or dark) skin are very desirable in the Ghanaian local and export markets (Irimerin and Okiy, 1986; Sinnadurai, 1992). Varieties such as KNUST/SL1/07Nkrumahene, DA/08/004 Agbodro and Asontem were among the landraces that displayed such traits. These can therefore be selected for breeding by crossing them with other local materials such as 'Atuogya', 'Sheo mana' or 'Wun mana' accessions which were comparatively high yielding with longer harvest duration and also highly resistant to environmental stresses such as diseases and pests and drought but revealed undesirable fruit shape and colour.

5.4 PERFORMANCE AMONG AGRONOMIC CHARACTERS

Number of seeds per fruit, maximum plant height (cm), days to 50% flowering, fruiting and node formation, number of total fruits per plant, fresh fruit weight, seed yield, 100 seed weight and susceptibility to diseases, insects and pests were among the agronomic characters that exhibited significant variation among the okra accessions studied (Table 4.8).

Progress in crop production depends, to a great extent, on the ability of breeders to select high yielding varieties to improve yield attributes such as seed yield, number of fruits per plant, fruit length and fruit width. The result of the present study indicated that**,** days to 50% flowering, first node of fruiting, weight of fresh fruits, seed yield, final plant height, fruit yield and number of seeds per fruit showed highly significant variation ($p < 0.05$, Table 4.8).

Generally, the significant differences ($p < 0.05$) revealed among the above attributes of yield may be due to environmental influences on the genotypes as well as differences in the genetic potential of the different okra landraces (cultivar types). This corroborate findings of Sing *et al*. (1986) who mentioned the role of environmental factors as well as differences in the genetic make-up of different varieties in yield determination of okra.

5.5 SELECTION OF OKRA CORE COLLECTION

A core collection from the 25 okra landraces studied will include representatives from the cluster, sub-cluster and sub-sub-cluster groups based on genetic distances, superior agronomic performance and unique morphological characteristics; and performance would be kept for future research work.

The following selection has therefore been suggested;

GH4487 Muomi

KNUST/SL1/07 Nkrumahene

DA/08//02 Asontem

Asontem

DA/08/02 Dikaba

GH 4376 Atuogya

DA 3801 Pora

DA/08/02/Sheo mana

DA/08/03 Sheo mana

GH 5793 Gyeabatan

Atuogya-Asante

DA/08/04 Wun mana

Gbodro

DA/08/001 Wun mana

DA/08/004 Agbodro

Atuogya-tiatia and

Atuogya-tenten

CHAPTER SIX CONCLUSION

The pubescence and pigmentation of various plant parts as well as fruit characteristics, among qualitative traits of the okra landraces studied, proved to be most significant in the analysis of variability and contributed significantly to the total variation observed. The genetic variation in the accessions was detected mainly by colour traits and yield characters.

The study has established that, varietal names are often descriptive; 'the early one', 'the late one', 'the dry season type', 'the wet season type'. The genetic affinity between the accessions from different regions observed in this study could however be attributed to the selection and exchange of okra germplasm between farmers from different regions and also between ethnic groups. Migrant farmers often carry seeds from their homes to their new locations, thus creating duplications in the germplasm.

Nevertheless, there are distinct morphotypes in the Ghanaian okra germplasm, depicted by variation in petal colour, pubescence of the leaf and stem, fruit shape, anthocyanin pigmentation and number of days to 50% flowering.

The dendrogram produced from the morphological descriptors demonstrated the efficiency of this descriptor list in grouping different species into different clusters by simultaneous consideration of quantitative and qualitative characters. This capability of identifying a significant qualitative variation within a sub-cluster is an obvious advantage of the unweighted hierarchical clustering technique used in this study. The clustering pattern indicated the presence of diverse forms in collections made from the same location, indicating tremendous opportunity to select the most desirable lines for that eco-geographical location.

Correlation analysis derived between pairs of quantitative yield characters in okra landraces studied demonstrated a strong and a persistent association between flowering and fruiting parameters.

Okra accessions KNUST/SL1/07Nkrumahene, DA/08/02Dikaba, GH5787Asontem, GH6102 Fetri and 'Asontem' recorded the most promising results in terms of days to 50% flowering at between 44.00 and 48.00, first flowering and fruiting nodes at between 5.00th and 6.00th nodes, days to 50% seedling emergence at 8 days, average number of total fruits per plant at between 60 and 145 fruits and fruit colour (green). Moreover, their fruit sizes at maturity, leaf colour, branching position, as well as their susceptibility to diseases and insect and pests were satisfactory.

6.1 RECOMMENDATIONS FOR FUTURE INVESTIGATION

For future research work, it is recommended that the following be considered;

i. The okra accession should be assessed for DNA variations using any of the biochemical molecular markers such as SSR, RAPDs, RFLP to confirm diversity based on morphological characters.

ii. The okra landraces should be analyzed for variations in insect-pest and disease resistance with application of molecular techniques such as SSR, RAPDs and PCR-RFLP for the development of resistant varieties to the most common yet dangerous diseases and pests of okra such as Okra Mosaic Virus (OMV) and Okra Leaf Curl Virus (OLCV).

iii. Development of okra varieties that are perennial in growth habit yet early maturing with longer harvest duration and

iv. Development of standards in terms of fruit size, shape and colour desired particularly for the Ghanaian export market.

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APPENDICES

Appendix A

Table 1: Evaluated characteristic of okra collection. Coding of qualitative characters is according to IBPGR, 1991 descriptors for okra.

Code for character		Parameter measured	Character codes No.
Qualitative			
1	**SC**	Seed colour	1=dark, 2=black, 3=whitish to dark,

			4=purple to black
2	**SSh**	Seed shape	1=Roundness, 2=Kidney, 3=Spherical
3	**SS**	Seed size	1=Small, 2=medium, 3=large
4	**BPMS**	Branching position at main stem	1=UOA-unique orthotrop axis, 2=DBO-densely branched all over, 3=DBB-densely branched base
5	**MLC**	Mature leaf colour	1=Green, 2=Green+red veins
6	**LSh**	Leaf shape	From types 1 to 11
7	**LBr (cm)**	Length of branches	0= no branches, 1= branches rarely > 10cm 8
	LRC	Leaf rib colour	1=Green, 2=Green+red veins
9	**PtC**	Petiole colour	1=Green, 2=Green+red veins, 3=purple
10	**PC**	Petal colour	1=Golden yellow, 2=yellow
11	**CDR**	Colour of the darkest ridges	1=light, 2=dark, 3=light to dark
12	**StC**	Stem colour	1=green, 2=green+purple tinge, 3=purple
13	**NES**	Number of epicalyx segments	1=8 to10, 2=5 to 7, 3=>10
14	**FSp**	Flowering span	1=Single flowering, 2=grouped flowing
15	**NSfS**	Number of segments from the stigma	From 5 to 12 segments
16	**FC**	Fruit colour	1 =Green, 2=green+red spots, 3=dark green to black, 4=green to yellow, 5=purple
17	**FP**	Fruit pubescene	1=Smooth, 2=little rough, 3=downy+hairs
18	**FSh**	Fruit shape	From types 1 to 15
19	**NR/F**	Number of ridges per fruit	1=0, 2=b/n 5 and 12, 3=5ridges
20	**PFMS**	Position of fruit from the main stem	1=intermediate, 2=slightly falling, 3=horizontal, 4=Erect, 5=Drooping
21	**LFP**	Length of fruit peduncle	1=1 to 3cm, 2=>3cm
22	**SI**	Susceptibility to insects	Scale: 1 to 9; (*Podagrica* spp, Aphids, Cotton stainer): NS=0-1,WS=1-3,IS=3-5, HS=6-9
23	**Sdi**	Susceptibility to diseases	Scale: 1 to 9; (OMV, OLCV): NS=0-1, WS=1-3, IS=3-5, HS=6-9

Quantitative

24	**DFF**	Days to First Flowering
25	**FFN**	First Flowering Node
26	**FF-PN**	First Fruit-Producing Node
27	**FFrtWt (g)**	Fresh Fruit Weight
28	**MPH (cm)**	Maximum Plant Height
29	**NS/F**	Number of Seeds per Fruit
30	**NTF/P**	Number of Total Fruits per Plant
31	**SD YLD (kg/plot)**	Seed Yield
32	**SW_{100} (g)**	100 seed weight
33	**50%DE**	50% Days to emergence
34	**CL L (mm)**	Cotyledon leaf length
35	**CLW (mm)**	Cotyledon leaf width
36	**CWR**	Cotyledon width ratio
37	**%G**	Percentage germination
38	**NI**	Number of internodes
39	**EL (cm)**	Epicalyx length
40	**EW (cm)**	Epicalyx width
41	**FLM (cm)**	Fruit length at maturity
42	**FW (cm)**	Fruit width
43	**LL (cm)**	Leaf length
44	**LB (cm)**	Leaf breadth
45	**StD (mm)**	Stem diameter

Table 2: Accession means for quantitative characters

No.	VARIETY	50% D E		CLL (mm)	CLW (mm)		LWR	%G	NI
1	GH 4487 Muomi	10.00	2.650	2.40	1.077	87.5	12.50		
2	GH 4482 Muomi	8.25	2.475	2.47	1.012	62.5	13.25		
3	GH 4499 Fetri	10.50	2.725	2.52	1.012	81.2	14.75		
4	GH 1169 Fetri	9.75	2.525	2.52	0.960	68.8	11.75		
5	GH 4376 Atuogya	8.50	2.350	2.48	0.922	62.5	15.00		
6	GH 4490 Fetri	9.50	2.300	2.82	0.822	75.0	14.00		
7	GH 3801 Pora	8.50	2.475	2.02	1.082	81.2	13.75		
8	GH 6102 Fetri	7.50	2.325	2.25	1.145	68.8	14.25		
9	GH 4964 Muomi	9.50	2.325	2.67	1.110	68.8	12.25 10	GH 5793 Gyeabatan	7.25	2.305
	2.70 1.337	93.8	13.75						
11	GH 5787 Asontem	8.13	2.720	2.67	1.135	68.8	10.00		
12	GH 3736 Fetri	11.00	2.350	2.62	1.072	87.5	13.75		
13	Atuogya-tiatia	11.25	2.425	2.62	1.075	81.2	10.00		
14	DA/08/001wun maana	9.00	2.400	2.57	0.990	81.2	13.75		
15	DA/08/02sheo maana	10.25	2.325	2.80	3.167	93.8	12.50		
16	DA/08/02 Asontem	8.00	2.450	2.25	1.475	75.0	13.25		
17	Atuogya-Asante	10.50	2.600	2.00	1.210	68.8	12.75		
18	Asontem 7.50	2.555	2.42	1.030	81.2	14.50			
19	DA/08/04Wun maana	8.25	2.525	2.15	1.207	93.8	12.75		
20	DA/08/004 Agbodro	7.50	2.232	2.67	0.952	81.2	14.00		
21	GBODRO-wild	10.00	2.600	2.38	1.140	87.5	14.50		
22	DA/08/02Dikaba	8.11	2.307	2.70	1.072	68.8	11.75		
23	DA/08/03Sheo maana	11.50	2.625	2.50	1.195	75.0	12.75		
24	Atuogya-tentem 9.50 2.550 2.38 1.190 81.2 12.50 25 KNUST/SL1/07Nkrumahene							8.21 2.925 2.85 1.982 68.8 13.75	

50%DE: Days to Emergence, CLL: Cotyledon leaf length, CLW: Cotyledon leaf width, LWR: Leaf width ratio, %G: percentage germination, NI: Number of internodes,

Accession means for quantitative characters continued

No.	VARIETY	EL (cm)	EW (cm)	FLM (cm)	FW (cm)	LL (cm)	LB (cm)	StD (mm)
1	GH 4487 Muomi	2.375	1.15	9.82	3.32	15.50	18.43	6.10
2	GH 4482 Muomi	1.900	3.33	8.75	3.12	19.00	20.00	6.12
3	GH 4499 Fetri 1.925	3.23	6.95	2.50	19.00	19.98	7.43	
4	GH 1169 Fetri 1.825	3.03	9.25	3.10	18.75	19.75	5.75	
5	GH 4376 Atuogya	2.075	2.45	9.00	3.75	17.00	21.25	7.92
6	GH 4490 Fetri 2.325	3.58	11.20	2.40	21.00	20.75	7.33	
7	GH 3801 Pora	2.075	4.85	7.87	3.00	15.50	19.50	6.50
8	GH 6102 Fetri 2.150	5.25	8.12	2.27	14.25	16.00	5.85	
9	GH 4964 Muomi	2.350	2.83	10.02	3.35	18.25	21.75	7.82
10	GH 5793 Gyeabatan	2.475	2.98	10.02	3.40	16.00	21.00	6.28
11	GH 5787 Asontem	1.950	4.53	7.25	3.20	16.50	18.00	4.90
12	GH 3736 Fetri 1.850 4.40 8.05 2.70 16.75 21.25 6.38 13 Atuogya-tiatia 1.700 5.38 8.40 2.95 15.50 18.50 4.95 14 DA/08/001wun maana 2.338 5.88 10.17 2.87 15.00 21.25 5.90							
15	DA/08/02Sheo maana	2.050	5.43	9.80	3.62	18.50	19.75	5.78
16	DA/08/02 Asonten	2.225	6.28	9.30	2.77	18.00	18.75	6.88
17	Atuogya-Asante	2.325	5.03	9.60	2.57	16.25	19.75	6.43 18 Asontem 1.925 3.03 8.72
19	DA/08/04Wun maana	2.075	2.38	8.30	2.87	16.75	20.50	7.70
20	DA/08/004 Agbodro	2.275	1.08	11.62	2.42	17.50	21.25	6.85
21	GBODRO-wild	2.525	1.15	7.07	3.12	17.75	20.25	8.45
22	DA/08/02Dikaba-Wen	2.075	1.10	8.00	2.67	20.50	16.12	3.75
23	DA/08/03Sheo maana	2.550	0.95	8.72	3.25	16.25	17.65	6.60
24	Atuogya-tenten	2.175	1.63	9.17	2.57	18.25	16.00	6.30
25	KNUST/SL1/07 2.375 1.30	11.27	3.22	15.25	18.00	5.98 Nkrumahene		

EL: Epicalyx length, EW: Epicalyx width, FLM: Fruid length at maturity, FW: Fruit Width, LL: Leaf length, LB: Leaf breadth, StD: Stem diameter.

Appendix B Table 3: *Abelmoschus esculentus* (Okra) Germplasm Passport Data

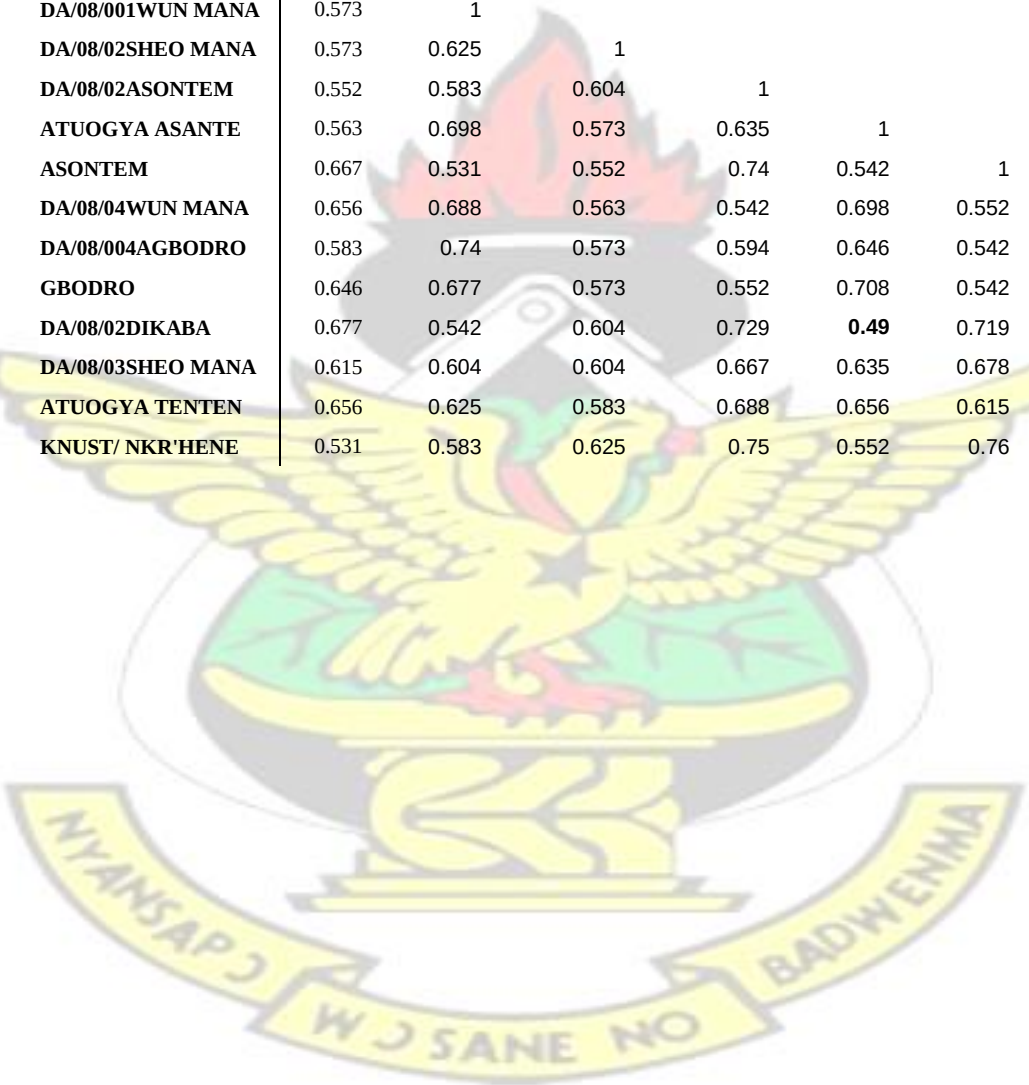
Accession No.	Genus Species	Common Name	Vernacular Name	Collecting Org.	Locality	Country	Source
GH 1169	*Abelesculentus*	Okra	Fetri	P.G.R.R.I	Gabusa village	Ghana-TogoB	Field
GH 3736	,,	,,	,,	,,	Kpogadzi	Ghana	Farm store
GH 3801	,,	,,	Pora	,,	Kalivio	,,	,,
GH 4376	,,	,,	Atuogya	,,	Defense	,,	,,
GH 4482	,,	,,	Muomi	,,	Prampram	,,	Field

GH 4487	,,	,,	,,	,,	Bedoku	,,	Farm store
GH 4499	,,	,,	Fetri	,,	Nyinguto	,,	,,
GH 4964	,,	,,	Muomi	,,	Sutapong	,,	Field
GH 4490	,,	,,	Fetri	,,	Dabala	,,	Farm store
GH 5787	,,	,,	Asontem	,,	Koranten	,,	Field
GH 5793	,,	,,	Gyeabatan	,,	Ketekrachi	,,	Farm store
GH 6102	,,	,,	Fetri	,,	Biakoye	,,	,,
KNUST/SL1/07	,,	,,	Nkrumahene	KNUST	Tek	,,	,,
DA/08/02	,,	,,	Dikaba-Ewe	Mampong Agric.Univ.	Wenchi	,,	Market
DA/08/04	,,	,,	Wum mana (drought okro)	,,	Sakogu E/Mamprusi	,,	Farm store
DA/08/004	,,	,,	Agbodro	,,	Jasikan V/R	,,	,,
DA/08/001	,,	,,	Wum mana	,,	Sakogu E/Mamprusi	,,	,,
DA/08/01	,,	,,	Asontem	,,	Wenchi-Awisah	,,	Market
DA/08/02	,,	,,	Sheo mana	,,	Sakogu E/Mamprusi	,,	Farm store
DA/08/03	,,	,,	,,	,,	Sakogu	,,	,,
Gbodro Wild	,,	,,	Gbodro-wild	,,	Jasikan	,,	Field
Asontem	,,	,,	Asontem	,,	Ejura-Aframso	,,	Farm store
Atuogya--tiatia	,,	,,	Atuogya-tiatia	,,	,,	,,	Field
Atuogya-tenten	,,	,,	Atuogya-tenten	,,	Ejura	,,	Farm store
Atuogya- Asante	,,	,,	Atuogya (Asante)	,,	Kayera-Offinso	,,	,,

Appendix C Table 4: Similarity Coefficient Values for Cluster Diagram

VARIETY	1	2	3	4	5	6	7	8	9	10	11	12
1. GH4487MUOMI	1											
2. GH4482MUOMI	0.719	1										
3. GH4499FETRI	0.781	0.708	1									
4. GH1169FETRI	0.719	0.771	**0.833**	1								
5. GH4376ATUOGYA	0.646	0.74	0.708	0.688	1							
6. GH4490FETRI	0.625	0.76	0.76	0.781	0.74	1						
7. GH3801PORA	0.625	0.656	0.698	0.698	0.656	0.646	1					
8. GH6102FETRI	0.792	**0.81**	**0.802**	0.76	0.74	0.708	0.708	1				
9. GH4964MUOMI	0.729	**0.823**	0.74	0.74	0.635	0.771	0.604	0.688	1			
10. GH5793GYEABATAN	0.583	0.594	0.615	0.615	0.656	0.667	0.646	0.604	0.667	1		
11. GH5787ASONTEM	0.75	0.719	0.76	**0.823**	0.719	0.688	0.708	0.75	0.708	0.604	1	
12. GH3736FETRI	0.781	0.667	**0.854**	0.729	0.69	0.719	0.76	**0.865**	0.698	0.635	0.76	1
13. ATUOGYA TIATIA	**0.49**	0.51	0.51	0.531	0.552	0.542	0.646	0.563	**0.458**	0.604	0.563	0.573
14. DA/08/001WUN MANA	0.552	0.521	0.563	0.542	**0.5**	0.514	0.552	0.552	0.531	0.594	0.51	0.625
15. DA/08/02SHEO MANA	0.594	0.646	0.688	0.75	0.583	0.719	0.656	0.573	0.677	0.635	0.698	0.625
16. DA/08/02ASONTEM	0.719	0.708	0.688	0.688	0.667	0.719	0.677	**0.823**	0.677	0.615	0.698	0.75
17. ATUOGYA ASANTE	0.542	0.531	**0.49**	0.531	0.51	**0.5**	**0.48**	0.563	0.583	0.729	0.521	0.531
18. ASONTEM	0.688	0.615	0.698	0.635	0.656	0.625	0.688	0.771	0.563	0.625	0.75	0.76
19. DA/08/04WUN MANA	**0.49**	0.542	0.563	0.542	0.563	**0.49**	0.552	0.552	0.51	0.531	0.552	0.542
20. DA/08/004AGBODRO	0.604	0.594	0.615	0.53	0.573	0.563	0.583	0.563	0.583	0.604	0.563	0.635
21. GBODRO	0.542	0.594	0.635	0.53	0.656	0.563	0.583	0.583	0.542	0.687	0.563	0.552
22. DA/08/02DIKABA	0.635	0.604	0.688	0.688	0.604	0.573	0.698	0.74	0.594	0.531	0.698	0.75
23. DA/08/03SHEO MANA	0.677	**0.458**	0.646	0.563	**0.5**	0.552	0.594	0.635	0.552	0.573	0.653	0.688
24. ATUOGYA TENTEN	0.698	0.604	0.625	0.604	0.594	0.51	0.531	0.677	0.594	0.635	0.573	0.625
25. KNUST/ NKR'HENE	0.74	0.646	0.688	0.688	0.625	0.677	0.635	0.781	0.677	0.552	0.781	0.792

VARIETY	13	14	15	16	17	18	19	20	21	22	23	24	25
ATUOGYA TIATIA	1												
DA/08/001WUN MANA	0.573	1											
DA/08/02SHEO MANA	0.573	0.625	1										
DA/08/02ASONTEM	0.552	0.583	0.604	1									
ATUOGYA ASANTE	0.563	0.698	0.573	0.635	1								
ASONTEM	0.667	0.531	0.552	0.74	0.542	1							
DA/08/04WUN MANA	0.656	0.688	0.563	0.542	0.698	0.552	1						
DA/08/004AGBODRO	0.583	0.74	0.573	0.594	0.646	0.542	0.573	1					
GBODRO	0.646	0.677	0.573	0.552	0.708	0.542	0.74	0.646	1				
DA/08/02DIKABA	0.677	0.542	0.604	0.729	**0.49**	0.719	0.583	0.551	0.531	1			
DA/08/03SHEO MANA	0.615	0.604	0.604	0.667	0.635	0.678	0.625	0.573	0.594	0.708	1		
ATUOGYA TENTEN	0.656	0.625	0.583	0.688	0.656	0.615	0.604	0.573	0.656	0.688	0.604	1	
KNUST/ NKR'HENE	0.531	0.583	0.625	0.75	0.552	0.76	0.563	0.573	0.51	0.729	0.708	0.646	1



Appendix D Table 5: Mean Climatic Data of Experimental Location during Period of Study

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Month & Year	Temperature (°C) Min.	Max.	Relative Humidity (%)	Rainfall (mm)	Sunshine Hours

May, 2008	22.8	33.0	82	185.8	5.3
June, 2008	22.5	31.4	85	279.8	4.6
July, 2008	22.3	29.8	88	145.0	3.3
August, 2008	20.8	29.5	88	164.5	3.4
September, 2008	21.3	30.0	87	148.9	3.3
October, 2008	21.6	31.3	85	95.8	5.7
November, 2008	22.2	32.7	84.20	30.7	4.8