COLLECTION AND CHARACTERIZATION OF LOCAL CASSAVA GERMPLASM FROM THE BRONG AHAFO REGION

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CERTIFICATION

I certify that the work presented in this thesis was carried out at the Regional Agriculture Station at Wenchi in the Brong-Ahafo Region by Mr Ebenezer Boampong of the Crop Science Department, Faculty of Agriculture, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana.

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Dedication

This book is dedicated to my wife Victoria, my children, Asantewaa, Serwaa, Boadi, Obilie and Ofori.

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TABLE OF CONTENTS

	Page
Dedication	ii
Acknowledgement	iii
Abstract	vii
Chapter One	1
Introduction	1
Chapter Two	8
Literature	8
2.1 Germplasm Collection	8
2.2 Characterization	9
2.2.1 Morphological Characterization	10
2.2.2 Biochemical Characterization	12
Chapter Three	20
Materials and Method	20
3.1 Germplasm Collection	20
3.2 Morphological Characterization	24
3.3 Data Analysis	32
Chapter Four	37
Results	37
4.1 Leaf and Stem Characters	37
4.2 Floral Characters	49
4.3 Storage Root Characters	52
Cluster Analysis	70
Molecular Characterisation	75
Chapter Five	84
Discussion	84
5.1 Vegetative Characters	85
5.2 Floral Characters	87
5.3 Storage Root Characters	87
5.4 Resistance to Pest and Disease	90
5.5 Clusters Analysis	91
5.6 Molecular Characterization	92
Ethno-Botanic Information	97
Chapter Six	104
Conclusion	104
Reference	105
Appendix	110

LIST OF TABLES

Page

1. Table 4.1: Frequency of leaf colour (LC) distribution in germplasm 38
2. Table 4.2: Frequency of petiole colour (PC) types in germplasm 38
3. Table 4.3: Frequency of anthocyanine distribution (Petiole) (ADP) in germplasm 41
4. Table 4.4: Frequency of leaf vein colour (LVC) distribution in germplasm 41
5. Table 4.5: Frequency of antheocyanine distribution (Vein) (ADV) in germplasm 43
6. Table 4.6: Frequency distribution of colour of first fully expanded leaf (FELI) in germplasm 43
7. Table 4.7: Frequency distribution of stem colour (SC) in germplasm 44
8. Table 4.8: Frequency of branching (B) distribution in germplasm 44
9. Table 4.9: Frequency distribution of number of levels of branching (BNO) in germplasm 46
10. Table 4.10: Frequency of angle of branching (AB) distribution in germplasm 46
11. Table 4.11: Frequency of colour of sepal (COS) distribution in germplasm ... 51
12. Table 4.12: Frequency of colour of disc (COD) distribution in germplasm ... 51
13. Table 4.13: Frequency of colour of ovary (CO) distribution in germplasm ... 53
14. Table 4.14: Frequency of colour of anthers (COA) distribution in germplasm 53
15. Table 4.15: Root stalk (RS) groupings of germplasm 55

Table 4.16: Position of root (POR) frequency distribution in germplasm 55

17. Table 4.17: Storage root constriction (SRC) distribution in germplasm 57
18. Table 4.18: Frequency distribution of colour of outer surface of Cortex (CODSCOC) in germplasm 57
19. Table 4.19: Frequency of storage root surface texture (SRST) distribution in germplasm 59
20. Table 4.20: Frequency distribution of mealiness in germplasm 59

Table 4.21: Frequency of ACMV score distribution in germplasm 60

22. Table 4.22: Root-tuber yield ranking and corresponding harvest index of cassava accessions 62
23. Table 4.23: Predominant traits associated with the five clusters 74
24. Table 4.24: List of the 50 cassava accessions studied using RAPD technique 76

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KUMASI-GHANA

LIST OF FIGURES

Page

1. Figure 1: Fig. 1: Map of Ghana showing Brong Ahafo Region. Collections were made in the 4 shaded districts 21

2. Figure 2: Dendrogram showing the relationship between the accessions. (No. of accessions in each group are indicated) 71

3. Figure 3: Dendrogram of percentage similarity (below axis) among 50 cassava accessions studied based on the Jaccard similarity index and analysed by UPGMA 83

ABSTRACT

About 200 local cassava germplasm were collected from four districts viz. Asunafo, Wenchi, Nkoranza and Dormaa in the Brong Ahafo region of Ghana.

The germplasm were assembled at Wenchi in the same region and characterized based on a number of morphological and agronomic characteristics.

A cluster analysis was undertaken to ascertain the relationship between the accessions. Molecular characterization using Rapid Amplified Polymorphic DNAs (RAPDs) was applied to further characterise a representative sample of 50 accessions from the different clusters.

The results indicated that certain characters were predominant which gave the indication that over the years, farmers have selected their varieties based on certain important criteria which included the following.

(i) For vegetative characters, farmers had selected varieties with purple petiole colours.

(ii) To suit their intercropping farming systems, farmers had selected for types that had only two or three levels of branching.

(iii) The root characteristics that appeared to have been selected for by farmers included: Cultivars that spread their tubers horizontally just beneath the soil surface and possessed root stalk or "neck", root tubers with pink colour of outer surface of root cortex, smooth rather than constricted root tubers with acceptable cooking quality.

(iv) Disease resistance did not appear to have been seriously considered in the selection process by farmers.

The cluster analysis produced five clear and easily identifiable groups at the first stage of classification based on the morphological data.

There were some relationship between the clusters and the geographical distribution of the germplasm.

Accessions collected from the forest ecozone (Dormaa and Asunafo districts) dominated in Clusters III, IV and V, while those from the forest-savanna transition ecozone dominated in Cluster I.

A phylogenetic tree (dendrogram) generated using UPGMA hierarchical cluster based on the genetic similarity estimates produced six clusters at the 67% Jaccard similarity coefficient level from the molecular characterisation. Accessions from the forest ecozone dominated in Cluster II, III and V. Clusters I, IV and VI consisted of one accession each. With the exception of AFISIAFI, all the other three remaining IITA improved varieties including the mutant TEKBANKYE, which also has IITA background

appeared again in the same cluster (ie. Cluster II) at the second level of classification. ABASAFITAA, and TEKBANKYE were in sub-group b^1, GBLEMODUADE in sub-group b^2 of Cluster II, while AFISIAFI was the only variety that constituted Cluster V.

This study has shown that germplasm collection and characterization, firstly, leads to identification of promising cultivars farmers have selected for over the years. Secondly, it reveals farmers' selection indices which assist breeders in designing future breeding programmes to address the needs of farmers.

The study has also indicated the benefit of characterising germplasm at the morphological level before proceeding to further characterise at the molecular level.

CHAPTER ONE

INTRODUCTION

Cassava (Manihot esculenta, crantz), belongs to the family Euphorbiacea. It is purported to have originated in Latin America from where it was introduced to Africa by the Portuguese during the latter half of the 16th Century (Nweke et al, 1994). The genus Manihot has many wild species which are distributed over several countries in the Americas. These are receiving increasing attention due to their potential as sources of useful traits for cassava improvement. (Kawano, 1992)

Perry (1996) estimated 150–160 species, while G. Mafla et al (1992) reported that 397 genotypes of wild Manihot species are being maintained in vitro. Wild Manihot species include M. glaziovii, M. epruinosa, M. chlorosticta, M. leptophylla, M. tristis, M. tripatita, M. stricta, M. anomala, M. gracilis, M. catingae, M. pohill, M. brachandra, and M. neusana (Asiedu et al, 1992).

In Ghana, cassava, yam, plantain and cocoyams occupy an important strategic niche in Ghanaian agriculture, accounting for about 59% of Ghana's Agricultural Gross Domestic Product (AGDP) of which cassava alone contributes 19% (Dapaah, 1991). In the coastal regions of West Africa, from Cote D'Ivoire to Cameroon, cassava is as important as yam, and farther along the West African coast it is the most important staple after rice (Nweke et al, 1994)

Cassava is easily adapted to relatively marginal soils and erratic rainfall conditions, and has a high productivity per unit of land and labour. Cassava is a basic component

of the farming system in many areas of Africa due to the fact that it produces roots even under the most adverse conditions and maintains continuous supply of tuberous roots throughout the year. These facts clearly indicate that cassava has a very high potential to bridge the food gap in Africa (Nweke, 1996).

The nutritional value of the storage roots of cassava is primarily caloric. The yield of cassava in terms of Kcal/ha significantly outweighs those of rice, maize and sweetpotato (Grubben, 1977). Cassava leaves contain about 30% protein by dry weight and they are eaten in some parts of Africa notably Zaire and Sierra Leone as vegetable.

Cassava also serves as a source of raw material for many industrial products. Its starch is used in the production of industrial alcohol, paper, cosmetic, pharmaceuticals, and in the textile industry (IITA, 1990).

To a limited extent cassava is used as a livestock feed, particularly in non-ruminant diets. Ruminants can be fed on cassava tuberous root, foliage, peel and residue obtained after processing cassava for fufu, gari, flour and starch. The foliage is rich in nitrogen, fiber and ash and so serves as a source of nitrogen and roughage for ruminants (Smith, 1998).

Cassava cultivation in Africa is concentrated in the humid tropical regions. Africa produces 48 million tonnes of cassava annually (Nweke, 1996). The crop is cultivated in almost all the six agroecological zones of Ghana;, mostly by peasant farmers, and is usually grown as an intercrop in association with such crops as maize

(Zea mays), sorghum (Sorghum bicolor), millet (Pennisetum americana), cowpea (Vigna unguiculata), plantain and cocoyam (Boateng, 1991).

The most common sequence of intercropping are: maize-cassava, maize-cassava-cowpea, and maize-cassava-cocoyam in the forest zone; maize-cassava, groundnut-cassava-maize and maize-cassava-cocoyam in the transitional zone; and maize-cassava and cassava-cowpea-maize in the coastal zone (Annor-Frimpong, 1991).

Cassava production in Ghana faces many constraints the major ones of which include the following: use of low yielding varieties which are susceptible to major pests and diseases like African Cassava Mosiac Disease (ACMD), Cassava Green Mite (CGM), Mealybug and anthrascnose; poor soils; poor management; weed infestation; poor markets; perishability of products; cassava varieties failing to meet farmers taste; genotypes of unstable cooking quality (Ajayi and Dixon, 1996).

Cassava farmers are continuously adopting new cultivars with desirable attributes into their cropping systems. With the introduction of new genotypes existing cultivars that may lack the desired traits are abandoned. Farmers therefore continue searching for cultivars with desirable traits irrespective of whether they are local or breeders clones. Traits that farmers look for in new cassava cultivars include the following; early bulking, high root yield, weed suppression, pest/disease tolerance, good processing quality, branching, low HCN potential and good cooking qualities (Nweke, et al, 1994). Variability studies of cassava morphological characters have been facilitated by characterization and growth performance evaluation of cassava germplasm. A great amount of variability occurs in cassava with reference to vegetative, storage root

and inflorescence characters, the basic standard for cassava characterization. Cassava cultivars or genotypes have therefore been grouped under characters which include the following which are found to be variable: taste of boiled roots, branching system, pubescence, leaf shape, colour of young shoot, petiole colour, inner skin colour of root, colour of root flesh (Nweke et al, 1994).

Germplasm collection leads to assembling of genetic diversity in a species. It serves two purposes. Firstly, it helps to prevent genetic erosion of some genes. Secondly, it becomes the source material from which genotypes with desirable characters can be identified and selected for breeding programmes.

The next stage after germplasm collection is characterization and evaluation which serve two functions. Firstly, many accessions have diagnostic value and will assist genebank curators to keep track of an accession and check its genetic integrity over years. The second function is related to the use of the material in breeding programmes (Ramanatha and Riley, 1994).

Some of these characters which are of agronomic and economic importance are normally under polygenic control and are strongly influenced by environment. Therefore the use of morphological markers for genotypic characterization has advantages and disadvantages. The multilocus nature of most of these characters provide information that is extremely useful to breeders. However, complex inheritance makes prediction of breeding behaviour difficult (Ramanatha and Riley, 1994).

This problem has been solved partly by the use of gene products (proteins, peptides) and metabolites (terpenes and flavonoids etc). The most reliable technique is molecular characterization which uses Isozyme analysis or DNA finger-printing to distinguish germplasm into groups of same genotypes and thus eliminate closely related entries.

Morphological and agronomic evaluation of population variability may be supplemented and generally surpassed by more direct study of the genome by means of the analysis of biochemical markers. These markers, in particular isozymes, have been extremely useful in genetic composition of population studies and for determining the magnitude of various evolutionary forces involved in moulding the genetic architecture of plant population (Perez de la Vega et al, 1991).

The molecular approach has several advantages including the following:

(1) absence of environmental influence,

(2) any plant part from any growth stage can be used

(3) numbers for analysis have no limit,

(4) it requires only small amounts of material,

(5) DNA is highly stable, even dry samples can be used (Beese, 1992)

However, molecular characterization has some practical disadvantages: It is not very suitable for large scale screening because of cost. Rapid progress in recent years has resulted in the development of a number of methods for detecting genetic variability. These include: (1) Restricted fragment length polymorphism (RFLP), (2) Random Amplified polymorphic DNA (RAPD).

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The RAPD technique makes use of Polymerase Chain Reaction (PCR) technology. Basically it is simple and quick and requires no radioactivity and is suitable for large samples. RAPDs segregate in Mendelian fashion and are useful in population genetic studies, for locating and manipulating genes of interest, for identifying somatic hybrids at an early stage, for monitoring the levels of genetic diversity between and within populations and for 'finger-printing' individual accessions.

(3) Variable Number of Tandem Repeats (VNTRs), (4) Polymerase Chain Reaction (PCR/Sequencing). (5) Alle-Specific Polymerase Chain Reaction (ASPCR).

At IITA, African Landraces of cassava germplasm have been identified and incorporated into a breeding programme (Dixon, 1997).

In Ghana local cassava germplasm have been collected from parts of Ashanti, Eastern, Volta, Greater Accra, Western and Central regions under NARP Root and Tuber Crops Research Programme. These accessions are being characterized at Crop Research Institute, Fumesua; Plant Genetic Resources Centre, Bunso; and Department of Crop Science, University of Cape Coast. Preliminary results indicate there is a lot of diversity within these local cassava accessions. There was therefore the need to collect, characterize and evaluate local cassava germplasm from Brong Ahafo region where collection had not been made.

The objectives of the project were:

(1) to collect and characterize local cassava germplasm from the Brong Ahafo region

(2) to identify the extent of both phenotypic and genotypic variability within the cassava germplasm collected;

(3) to identify cassava accessions which have desirable trait;

(4) to conserve the local cassava germplasm collected so as to ensure their continued availability for both present and future breeding programmes; and

(5) to collect ethno-botanic information on local cassava germplasm.

CHAPTER TWO

LITERATURE REVIEW

2.1 GERMPLASM COLLECTION

The first stage of any breeding programme is germplasm collection, evaluation and selection. The germplasm materials may come from either local or exotic sources (Dixon et al, 1992).

It is therefore important that at the beginning of any breeding programme an extensive and complete collection of local germplasm is made.

In Africa, local cassava clones yield less than improved clones but they usually carry genes of adaptation to the local conditions especially to drought and resistant to diseases and insects (Dixon, et al, 1992) because the native varieties have been selected by local farmers over a long period for adaptability and palatability.

The conservation of the genetic resources of cassava involves the gathering of representative samples of all the diversity and ensuring its long-term availability with low risk of loss, contamination by pests or pathogens, or genetic modification. Germplasm conservation activities include acquisition, maintenance, description, documentation and implementation of appropriate conditions and facilities for long term storage.

There is an international effort in the conservation of cassava germplasm. The group includes Consultative Group on International Agricultural Research (CGIAR) Institute and National Agricultural Research Systems (NARS). For example at CIAT, there is a core collection which provides the genetic base for their cassava improvement. This material is shared through frequent requests for genotypes with certain characteristics or adaptation for use in the national breeding programmes, genebanks and advanced laboratories (Iglesis et al, 1993).

Similarly, at IITA, a collection of 22 Manihot species is used to broaden the gene pool available to the cassava breeding unit to improve the productivity, pest resistance and adaptability of cassava genotypes made available to NARS (Bia et al, 1992).

The next stage after germplasm collection is evaluation which includes characterization of the materials to avoid or minimize duplication.

2.2 CHARACTERIZATION

Characterization helps to document the genetic variability of a population. This is an important task since genetic diversity within populations and within species determines the rate of adaptive evolution and extent of response in traditional crop improvement (Perez de la Vega, 1993).

Characterization therefore serves two main function. Firstly, some of the accessions may possess diagnostic value which assist genebank curators to keep track of an accession and thus check its genetic integrity. The second function is related to the use of the material in breeding programmes (Ramanatha and Rilley, 1994).

Two major methods can be used in characterization of germplasm. The first and most important method is the use of morphological markers; and the second, the molecular approach which involves the analysis of biochemical markers.

2.2.1 MORPHOLOGICAL CHARACTERIZATION

Morphological characters are important diagnostic features for distinguishing among genotypes. They serve as genetic markers, which facilitate and also speed up selection in crop improvement programmes. The presence of some morphological features may be indicative of some important traits (Ofori and Bennett-Lartey, 1995).

Such morphological characters which are often qualitative in nature include (a) Leaf and stem characters; (b) Floral characters; (c) Storage root characters.

Quantitative characters which are of agronomic and economic importance are normally under polygenic control and are therefore strongly influenced by environment which makes prediction of breeding behaviour and use in morphological characterization difficult. (Perez de la Vega, 1993)

The usual approach to characterization and evaluation of populations involves cultivation of subsamples and their morphological and agronomic description (Perez de la Vega, 1993).

For more precise and accurate identification of genotypes, and for uniformity, International Board for Plant Genetic Resources (IBPGR) has developed descriptors for quantitative as well as qualitative characters. (Chavez, 1990)

By means of cluster analysis accessions are placed into major groups with distinct morphological and agronomic traits. Cluster analysis, however, does not distinguish the germplasm into genotypic groups.

According to Nweke et al, (1994) Cassava cultivars or genotypes have often been grouped under characters which include the following: taste of boiled roots, branching system, pubescence, petiole colour, inner skin colour of roots and colour of root flesh.

Ofori and Bennett-Lartey, (1995) in their study involving a collection of indigenous cowpea landraces visually characterized and classified them using morphological features to distinguish among genotypes.

However, the effectiveness of using morphological and agronomic characterization to estimate genetic diversity has been questioned by several workers (Gottlieb, 1977;) due to the masking effect of some traits by the environment; and the long generation time of most perennial crops also indicate that many of the morphological descriptors can only be assessed at maturity. (Bernatzky and Tanksley, 1989).

Morphological and agronomic variability may therefore be supplemented and generally surpassed by more direct study of the genome by means of the analysis of the biochemical markers. This is especially important for those traits where screening of large samples of genotypes remain difficult (Lynam, 1992).

2.2.2 BIOCHEMICAL CHARACTERIZATION

Biochemical characterization is far more efficient than morphological characterization in germplasm evaluation because, (1) molecular and biochemical markers are not

subject to environmental influences and provide an opportunity to examine more precisely the genetic relationship between accessions (Bernatzky and Tanksley, 1989); (2) any plant part irrespective of stage of growth may be used; (3) it requires small amounts of material; (4) the stability of DNA makes the use of dry samples possible (Beese, 1992), and (5) the techniques can yield not only qualitative but also quantitative data, which is very important when toxic and other substances are analysed (Perez de la Vega, 1993).

However, biochemical characterization can only be supplementary to other methods since it is not very suitable for screening large samples, because high purity and expensive solvents are required. The techniques are also arduous and time consuming. (Perez de la Vega, 1993)

Biochemical characterization may involve the analysis of isozymes or the use of techniques which examine DNA polymorphism, which refers to different-sized DNA fragments.

Marker and Moller (1959) introduced the term 'isozyme' to define each one of the possible many multiple molecular forms of an enzyme, which are coded by different alleles of the same locus, called allozymes. Therefore the term 'isozyme' is reserved for enzyme forms which catalyse the same reaction but are coded by more than one locus. Isozymes have been used as markers in formal genetic studies, genetic mapping, population and evolutionary studies, identification of cultivars and varieties and in breeding. (Asiedu, 1992)

Confirmation of the authenticity of hybrids can be difficult in the absence of reliable markers. Isozyme markers have been used effectively for this purpose (Asiedu and Mujeebkazi, 1987).

Alien Chromosome segments carrying loci of important traits have been traced through large populations of breeding material using isozyme markers, at a pace that would be difficult to match using other techniques. (Asiedu, 1992)

The basic steps in isozyme analysis involve the extraction of enzymes from plant tissue, electrophoretic separation, enzyme activity staining, and the interpretation of the observed patterns. The efficiency of the extraction of enzymes and maintenance of their integrity before and during electrophoresis are important to isozyme analysis (Asiedu, 1992).

A limiting characteristic of isozyme systems in population studies is the relatively low number which can actually be observed by gel electrophoresis and specific staining. Of the more than 3,000 enzymes known in plants, only about 60 have been assayed for isozyme polymorphism (Vallejos, 1983).

MOLECULAR MARKERS

Presently, more efficient forms of molecular genetic markers for detecting genetic variability and germplasm discrimination include (1) Restriction Fragment Length Polymorphisms (RFLPs), and (2) Random Amplified Polymorphic DNAs (RAPDs) – a polymerase chain reaction (PCR) – based marker. (Perez de la Vega et al, 1991)

RFLPs have been the most effective DNA techniques in identifying populations or varieties, although there is an increasing use of RAPDs these days (Perez de la Vega, 1993).

The Polymerase Chain Reaction (PCR) is an in vitro method for producing large amount of specific DNA fragment of defined length and sequence from small amounts of a complex template (Saiki et al, 1988).

To amplify a DNA molecule with the PCR, four materials are required:

(1) the target DNA isolated from an individual – a few leaves or even a piece of a leaf is usually enough; short strands of known "primer" DNA that will tag and identify the segment to be copied and provide a foundation for beginning the replication process; thermostable taq DNA polymerase, which avoids the need to add new polymerase after each cycle of heat denaturation of the template; and (4) a mixture of nucleotides, the nucleic acid building blocks from which new DNA will be formed. (Saiki, et al, 1988)

PCR involves three major steps, all performed over and over again in a highly automated PCR machine.

Step I - The target DNA is heated to break the bonds that hold the two strands and unwind the molecule.

Step II - The temperature is reduced, the primer molecules bind to and flank the target DNA, thus bracketing and identifying the area to be copied. The primers are the "start" and "stop" signals in the copying.

Step III - DNA polymerase catalyses the formation of single – stranded DNA molecules using the target DNA strands as templates. The synthesis begins at the spot marked the primer DNA. As the enzyme moves along the strand it reads the sequence chemical bases, using it as a template for building a complementary strand and a new nucleotide chain (the 'chain reaction'). The DNA polymerase employed is a special heat tolerant enzyme (called Taq Polymerase) which makes it possible for the use of the same enzyme throughout the process.

At the conclusion of Step III, four DNA strands exist where there was originally one. As the process continues, the PCR is repeated 30 – 60 times, each cycle beginning with a reheating of the mixture (Step I). A cycle takes 1 – 2 minutes and each new DNA segment acts as a template for many additional copies. Thus, the number of copies of DNA increases geometrically.

RESTRICTION FRAGMENT LENGTH POLYMORPHISMS (RFLPs)

This technique determines the differences in length of DNA segments and the loss or gain of target points for a given restriction enzyme. (Bernatzky and Tanksley, 1989). A particular stretch of DNA can occur in fragments of various sizes. The fragments are called polymorphisms. RFLP technique determines the differences in length of DNA segments. Changes in the electrophoretic mobility of DNA fragment due to insertion, deletions or genome rearrangements (Perez de la Vega, 1993) in an

individual, thus causing variations in the distribution of restriction sites which can be used to discriminate among germplasm.

RFLP technique is outlined as follows:

Step I – Total genome DNA is extracted from different individuals of populations. A few leaves or even a piece of a leaf is usually enough to provide sufficient amount of DNA, thus the technique is non-destructive and plants can be saved.

Step II – DNA samples are digested with a restriction enzyme; small portions of the DNA of each plant can be digested by different endonucleases and electrophoresis separately.

Step III – The fragments obtained are separated by electrophoresis in an agarose gel, where samples are located in a row of small wells near one end of the gel and then electrophoresed for several hours.

Step IV – After electrophoresis, the DNA fragments are denatured and blotted (south blotting) to a support membrane where they are firmly placed in the same order as in a gel.

Step V – Gels are then photographed under UV light with polaroid film. The autoradiogram produced reveals a band where the labelled probe has bound a region homologous to the sequence on the restricted DNA.. When the size of the hybridising fragments are different in different individuals, this represents a polymorphism = RFLPs. RFLPs are caused by variations in the distribution of restriction sites.

Data Analysis

All bands are scored for the presence (1) or absence (0) of fragments from amplification of DNA fragments on a score sheet. The data are then analysed with the appropriate software package to obtain a pairwise comparisons between accessions. For example, by using Jaccard's similarity coefficient, a phylogenetic tree (dendrongram) is constructed to show the relatedness of the germplasm.

Even though RFLPs give much higher degree of polymorphism and stability, the disadvantages make its use unattractive. These are (1) the laborious procedure involved, (2) the relatively high costs, and (3) the use of radioisotopes.

As an alternative, the RAPD (random amplified polymorphic DNA) technique developed by Williams et al (1990) provides a faster and easier approach for exploring genetic polymorphism, and also requires very small amounts of DNA.

RANDOM AMPLIFIED POLYMORPHIC DNAs (RAPDs)

RAPDs is a PCR based DNA amplification technique. The main distinction between RFLPs and RAPDs is that, while the former uses Restriction Enzyme among other things, the latter employs a single primer (10-mer) to amplify under low stringency, any genomic region that happens to be flanked by a pair of 10-base priming sites in opposite orientation within 5000 bp of each other.

Primers are random 10-mers with G+C (nucleotides) content of 60-70% with no self-complementary ends (William et al, 1990). RAPD products reveal 1-18 bands; each band represents a locus and bands are dominant. The presence of a DNA fragment in

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one individual and the absence of the same fragment in another gives rise to a polymorphism.

The unique fragment constitutes a genetic marker and RAPD markers are inherited in a Mandelian fashion. Williams et al, (1990), and Welsh and McClellan (1990) proposed the use of single short random primers in a PCR as a method of generating polymorphic markers (RAPDs). DNA polymorphisms result either from differences in the DNA sequence at primer binding sites or by chromosome changes affecting the amplified regions.

After electrophoresis, the amplified fragments can be visualized by fluorescence and the resulting pattern of bands can be interpreted genetically.

As in the case of RFLP, the bands produced by RAPD technique are scored on a score sheet for the presence (1) or absence (0) of fragments from amplification of DNA fragments. The resulting data are thereafter analysed with the appropriate software package to draw a dendrogram which will depict the relationship between the accessions.

RAPD markers have some advantages over RFLPs. First, the process is simple and faster, since after DNA extraction only two relatively rapid operations (4-6) are involved: DNA amplification and electrophoretic separation.

Second, the method requires relatively less investment in laboratory equipment, is less labour intensive and is safer since radioactivity is not necessary. Third, it requires small amounts of genomic DNA.

RAPD markers have proven useful for cultivar identification (HU and Quiros, 1991) and the development of genome-specific markers (Quiros et al, 1991). While important restrictions to the use of RAPDs derive from their dominant mode of inheritance, these markers are for many other reasons a major advancement in marker research, and an important step forward to the increase utility of markers in practical plant breeding (Perez de la Vega, 1993).

Santalla et al, (1998) using the DNA level with RAPD procedure studied the genetic diversity of 19 landraces of the cultivated mung bean, Vigna radiata, and three weedy and wild relatives including V. mungo, V. luteola and V. radiata var. sublobata.

The accessions studied were separated into three main clusters, which included V. radiata landraces, V. mungo and V. luteola respectively.

It was observed that the genetic distance of V. mungo and V. luteola varies considerably from the accession V. radiata.

Despite the advantages assigned to biochemical characterization, the use of DNA markers in germplasm and population studies is, as earlier expressed, limited by cost and the relatively high level of technical equipment required.

CHAPTER THREE

MATERIALS AND METHODS

Site of Experiment:

This study was carried out at the Regional Agricultural Station at Wenchi which is located in the Brong Ahafo region of Ghana. The Station lies within latitude 7° 44'N and longitude 2° 7′ W and has a transitional agroecological vegetation. It has a bimodal rainfall pattern with mean annual rainfall of 1,279.5 mm.

3.1 Germplasm Collection:

Local cassava germplasm collection was carried out in June/July, 1998, from four districts in the Brong Ahafo Region viz.

WENCHI DISTRICT, which is located at the northern part of the region and within the transitional vegetation zone; ASUNAFO DISTRICT, at the southern part of the region with forest vegetation, DORMAA DISTRICT, lying at the western part of the region and which shares common boundary with Cote d'Ivoire and having a forest vegetation; and NKORANZA DISTRICT located at the eastern part of the region and having transitional vegetation type. The selection of the districts was based on their agroecological zone. (See Map of Ghana showing Brong Ahafo Region (Fig). Collections were made in the 4 shaded districts).

Collections were made in collaboration with Ministry of Food and Agriculture staff in the selected districts, comprising, the District Directors of Agriculture (DDAs), District Development Officers (DDOs) and Agricultural Extension Agents (AEAs).

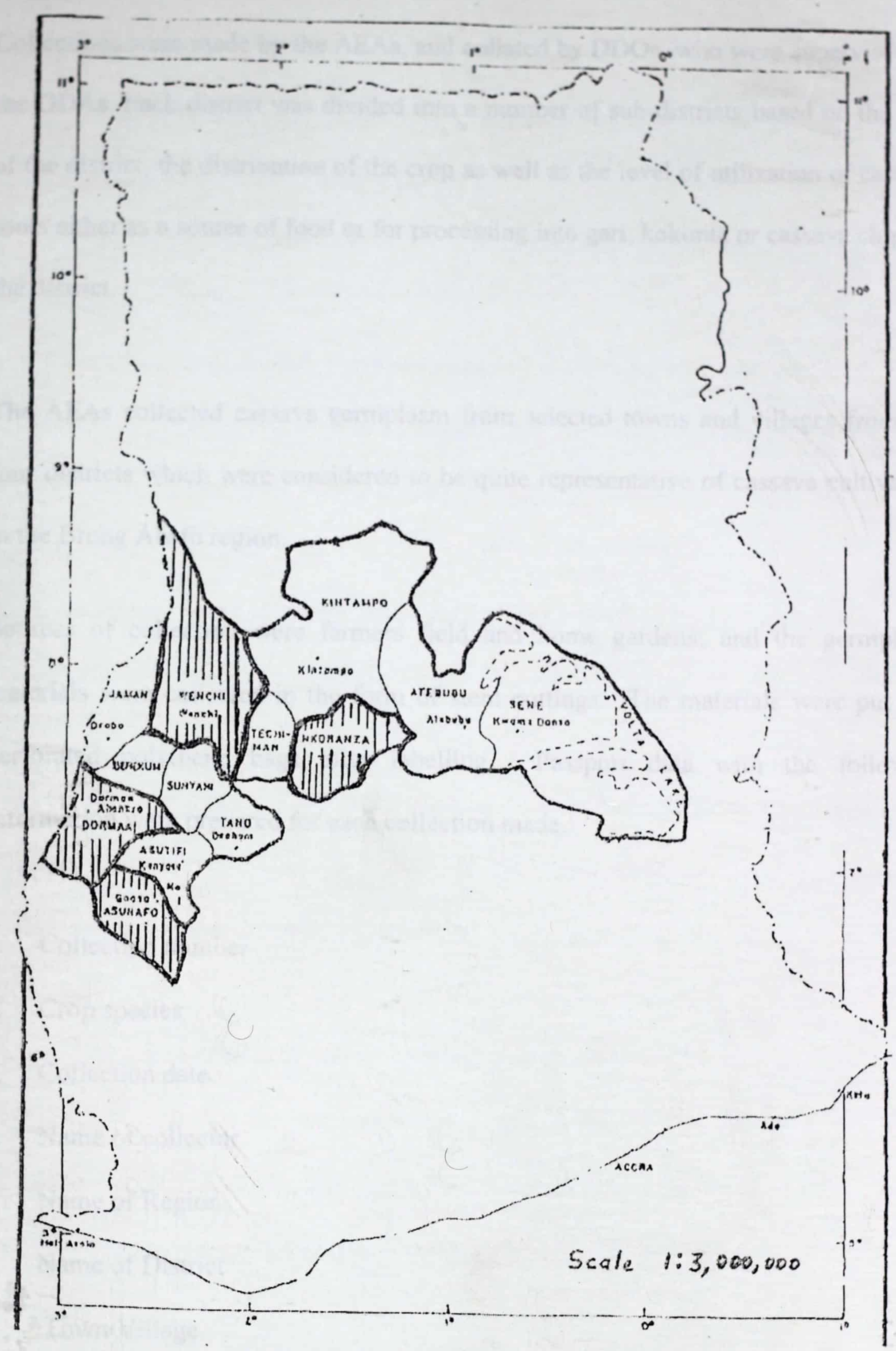

Fig 1 Map of Ghana showing Brong-Ahafo Region. Collections were made in the 4 shaded districts

Collections were made by the AEAs, and collated by DDOs, who were supervised by the DDAs. Each district was divided into a number of sub-districts based on the size of the district, the distribution of the crop as well as the level of utilization of cassava roots either as a source of food or for processing into gari, kokonte or cassava chips in the district.

The AEAs collected cassava germplasm from selected towns and villages from the four districts which were considered to be quite representative of cassava cultivation in the Brong Ahafo region.

Sources of collection were farmers field and home gardens; and the germplasm materials were collected in the form of stem cuttings. The materials were put into perforated polythene bags after labelling. Passport data with the following information were prepared for each collection made.

1. Collection number
2. Crop species
3. Collection date
4. Name of collector
5. Name of Region
6. Name of District
7. Town/Village
8. Precise location of farm
9. Local name of cultivar and the meaning of the name
10. Donor's Name
11. Ethnicity group of Donor

Added Instructions

1. Every polybag with cassava germplasm cuttings was to be perforated.
2. To collect 10 cuttings of each accession.
3. To prepare passport data as above for each collection and placed in the bigger perforated polybag.
4. A duplicate passport data was to be recorded in the field notebook provided. This was to guard against complete loss of information on germplasm collected.
5. Any mistake in writing was to be cancelled cleanly and re-written and not TRACED.
6. Collections were not to include any of the four improved cassava varieties, namely, Gblemoduade, Afisiafi, Tekbankye and Abasafitaa.

Collections were made in June-July, 1998 and all collections were assembled at the Regional Agricultural Station at Wenchi in the Brong Ahafo Region, registered and given accession number described below:

(i) Dormaa district collections, were designated as DMA – 001 etc

(ii) Wenchi district collections, were designated as WCH – 001 etc

(iii) Asunafo district collections, were designated as ASF – 001 etc

(iv) Nkoranza district collections, were designated as NKZ – 001 etc

Establishment and Maintenance

The land which had previously been used for a tomato varietal trial was slashed, double ploughed and harrowed by the middle of June, 1998. Planting was effected when collections were received and grown in one-row plots.

Intra-row as well as inter-row spacing were one metre (1 m) intervals. A total of 212 accessions were collected, but by the time of harvest 38 accessions had been lost so data could be taken on 174 accessions. Loss of planting material was due to a number of factors including poor materials collected, desiccation, destruction by termites, choking of less vigorous ones and severe ACMV attack.

Weeding was initially by hoeing but later was by slashing when the plants closed canopy and was done when it became necessary up to the stage of harvesting in August, 1999.

3.2 MORPHOLOGICAL CHARACTERIZATION

Characterization of the germplasm was carried out using a modified version of the descriptor published by IBPGR. This is based on (1) Leaf and stem characters, (2) Floral characters, (3) Storage roots characters, (4) Pests and diseases, and (5) Biochemical characters.

Leaf and Stem Characters

1.1 Leaf colour/score

- Deep green - 1
- Light green - 3
- Deep purple - 5
- Light purple - 7

1.2 Petiole colour/score

- Deep green - 1
- Light green - 3
- Green purple - 5
- Deep purple - 7
- Light purple - 9

1.3 Anthocyanine distribution (Petiole)

- Upper - 1
- Middle - 3
- Lower - 5
- Entire - 7
- Upper & Lower - 9

1.4 Leaf vein colour

- Deep green - 1
- Light green - 3
- Light purple - 5
- Deep purple - 7

1.5 Anthocyanine distribution (Vein)

- Absent - 0
- Lower part - 1
- Entire - 2

1.6 Colour of first fully expanded Leaf

- Deep green - 1
- Light green - 3
- Deep purple - 5
- Light purple - 7

1.7 Stem Colour

- Light green - 1
- Silver green - 3
- Deep green - 5
- Light purple green - 6
- Deep brown - 7
- Light brown - 9

1.8 Branching

- Absent - 0
- Present - 1

1.9 Number of Levels of Branching [ ]

1.10 Angle of Branching

15° – 39° - 1

40° – 69° - 3

70°– 90° - 5

1.11 Time of Branching from Planting (days) [ ]

1.12 Average height of first apical Branch [cm]

1.13 Height of Plant (average of 5) …. [ ]

Floral Characters

2.1 Colour of sepal

- Orange - 1
- White - 3
- Pink - 5
- Purple - 7

2.2 Colour of disc

- Cream - 1
- White - 3
- Pink - 5
- Purple - 7

2.3 Colour of Ovary

- Green - 1
- Cream - 3
- White - 5
- Orange - 7
- Purple - 9

2.4 Colour of Anthers

- Orange/yellow - 1
- Cream - 3
- White - 5

Storage Root Characters

3.1 Root stalk (neck)

- Absent - 0
- Present - 1

3.2 Storage Root Constriction

- Absent - 1
- Present - 3

3.3 Position of Roots

- Horizontal - 1
- Vertical - 3

3.4 Root surface colour

- Brown - 1
- Light-brown - 3

3.5 Colour of outer surface of root cortex

- Yellow - 1
- Pink - 3
- Cream - 7
- White - 9

3.6 Colour of root pulp

- Yellow - 1
- White - 2
- Cream - 3

3.7 Storage root surface texture

- Smooth - 1
- Rough - 3

3.8 Storage Root diameter (2 roots per plant) [cm]

3.9 Number of storage roots per plant [ ]

3.10 Total fresh weight per plant [kg]

3.11 Total fresh weight of foliage and stem per plant (kg) [kg]

3.12 Percent Dry Matter [ ]

3.13 Mealiness

- Not good - 1
- Good - 2
- Very good - 3
- Excellent - 4

Pest and Diseases

4.1 African Cassava Mosaic Virus (ACMV)

- None (Resistant) - 1
- Minor (Tolerant) - 2
- Susceptible - 3
- Highly susceptible - 4

4.2 Cassava Green Mite (CGM)

- None (Resistant) - 1
- Minor infection (Tolerant) - 2
- Susceptible - 3
- Highly susceptible - 4

4.3 Cassava Bacterial Blight (CBB)

- None (Resistant) - 1
- Minor (Tolerant) - 2
- Susceptible - 3
- Highly susceptible - 4

4.4 Anthracnose

- None (Resistant) - 1
- Minor (Tolerant) - 2
- Susceptible - 3
- Highly susceptible - 4

SENSORY EVALUATION

Mealiness was determined by boiling a piece of fresh root in boiling water for 20 minutes. The boiled roots were assessed by a panel comprising of the project supervisor, the student and the technical staff of Wenchi Agricultural Station.

3.3 DATA ANALYSIS

1.0 CLUSTER ANALYSIS

Cluster analysis using SPSS/PC statistical software package related the accessions into clusters or groups with similar morphological characters.

2.0 MOLECULAR CHARACTERIZATION

Molecular characterization via DNA analysis using leaf extracts was carried out at Crop Science Department, University of Ghana, Legon to distinguish between the accessions into groups of same genotypes.

Due to the cost involved in the analysis only 50 promising accessions were selected from the five (5) major clusters (Table 4.24) obtained after morphological analyses and using the cluster analysis technique, (Figure 2 and Appendix 1).

Using stem cuttings, the plants were raised in polybags at Wenchi Agricultural Station, labelled and later transported to Crop Science Department, University of Ghana, Legon.

Two methods were used in DNA extraction. Twenty-five (25) primers synthesized by Operon Technologies were screened and four of them (OPK-01, OPR-02, OPR-09 and OPJ-04) which produced consistent profile and revealed good polymorphism were used for DNA amplification.

DNA EXTRACTION

The Doyle and Doyle (1990) method with modifications was first used for DNA extraction. DNA was extracted from one gram of young leaves harvested on ice and the frozen leaf tissue were ground in liquid nitrogen using mortar and pestle kept at -20°C. The samples were then transferred in eppendorf tubes (about half full) and 500µl of prewarmed (60°C) CTAB containing 0.3% B-mecaptoethanol was added, mixed thoroughly and incubated in waterbath at 65°C with occasional swirling. Equal volumes of chloroform isoamyl alcohol was added and mixed several times by gentle

inversion. It was then spinned at 10000 RPM for 10 minutes. The supernatant was collected into a new tube and equal volumes of phenol sevag was added and then spinned 10000 RPM for 10 minutes and the supernatant was collected.

Equal volumes of isopropanol plus 1/10 volume NaOAc was added and kept at -20°C for 1 hour, and then spinned at 13000 RPM for 30 minutes. The propanol was removed and the pellets were washed with 70% ethanol, spinned at 13000 for 10 minutes, drained off the ethanol with tissue paper and allowed the pellet to dry. The sample was then dissolved in 200µl Tris, 15µl 10% SDS and equal volumes of phenol-chloroform was added and spinned 13000 RPM for 10 minutes and the supernatant collected. Equal volumes of isopropanol plus 1/10 volume of NaOAc were added and incubated at -20°C overnight and spinned at 13000 RPM. The pellets were washed with 70% EtOH and allowed to dry on a bench. It was then dissolved in 1xTE overnight. Five microlitre (5µl) of TE/Rnase was added to 400µl and incubated for 37°C for 30 minutes. It was extracted twice with phenol-chloroform and centrifuged at 13000 RPM for 25 minutes. Precipitation was done with 0.8 volume of propanol and 1/10 volume of NaOAc overnight and spinned at 13000 for 30 minutes. It was washed and allowed to dry at room temperature and then dissolved in 100µl ITE overnight.

PCR Amplification

PCR amplification were carried out using 4 primers mentioned above. The 30µl PCR reaction mixture contained: 10mM Tris-HCI, 10mM KCI pH 8.3m, 3.5mM $MgCI_2$, 0.17mM each of dATP, dCTP, dGTP and dTTP, 0.5 µM primer, 25mg genomic DNA, and 1.6 U Taq polymerase, Stoffel fragment (Pharmacia). PCR was carried out in a progene Thermo-cycler with heated lid to reduce evaporation. The cycling

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programme involved an initial denaturing at 94°C for1 minute followed by 45 cycles at 94°C for 30 seconds, 37°C for 30 seconds, 72°C for 1 minute, and then a final 5 minutes of 72°C extension. The RAPD-PCR products were electrophoresed in 2% agarose (Sigma, St. Louis, MO) gels in TAE (Tris 1.6 M, acetic acid 0.8 M, EDTA 40mM) at 40 volts for 5 hours. The agarose gel was stained in ethidium bromide, visualized under UV and photographed using a Polaroid MP4 camera. 1000bp DNA from Gibco BRL (New York, USA) was used as standard.

The Dneasy Plant Mini Kit Protocol

The Dneasy Plant Kit protocol for the isolation of DNA from plant tissues (Dneasy Plant Mini Kit Handbook 11/99) was the second method used. Plant tissue was ground under liquid nitrogen to a fine powder using a mortar and pestle. The tissue powder with liquid nitrogen were transferred to a tube and the liquid nitrogen allowed to evaporate.

Four hundred microlitres (400µl) of buffer API and 4µl of Rnase A stock solution (100 mg/ml) were added to a maximum of 100 mg of ground plant tissue and vortexed. The mixture was incubated 10 minutes at 65°C and mixed 3 times during incubation by inverting the tube. One hundred and thirty microlitres (130 µl) of Buffer AP2 was added to the lysate, mixed and incubated for 5 minutes on ice. The lysate was applied to the QIAshredder spin column sitting in a 2 ml collection tube and centrifuged for 2 minutes at maximum speed. The flow through fraction (as above) was transferred to a new tube without disturbing the cell-debris pellet. Half a volume of Buffer AP3 and 1 volume of ethanol (96 – 100%) were added to the cleared lysate and mixed by pipetting. Six hundred and fifty microlitres (650 µl) of the mixture was applied to the Dneasy mini spin column sitting in a 2 ml collection

tube and centrifuged for 1 minute at >6000xg. Five hundred microlitres (500 µl) of buffer AW was added to the Dneasy column and centrifuged for 2 minutes at maximum speed to dry the membrane. The Dneasy column was transferred to a 1.5 ml microcentrifuge tube and pipetted 100 µl of preheated (65°C). Buffer AE directly onto the Dneasy membrane. It was then incubated for 5 minutes at room temperature and then centrifuged for 1 minute at >6000xg to elute. The elution was repeated.

Statistical Analysis

From the whole set of reproducible RAPD bands generated in the 50 cassava accessions by the different primers, band positions for each cassava accession and primer combination were scored from photographic prints of gels as either present (1) or absent (0). The scores were entered into a database program (Microsoft Excel) and compiled in a binary matrix for phenetic analysis using NTSYS-pc (Numerical Taxonomy & Multivariate Analysis) System version 2.0 by Exeter Software. The SIMQUAL program was used to calculate Jaccard's similarity coefficient and a graphic phenogram (dendrogram) of the genetic relatedness among the 50 accessions was produced by means of the unweighted pair group method with arithmetic average (UPGMA) analysis (Sneath and Sokal, 1973.

CHAPTER FOUR

RESULTS

Phenotypic data on thirty qualitative and quantitative variables or characters were used for cultivar identification using an IITA - modified version of IBPGR descriptor for cassava. The results of the characterization are presented below.

4.1 LEAF AND STEM CHARACTERS

4.1.1 LEAF COLOUR (L C)

The descriptor gave the following categories of leaf colour: Deep Green ..... 1, Light Green ..... 3, Deep Purple ..... 5, and Light Purple ..... 7.

Leaf colour distribution in the accessions is shown in Table 4.1. The results indicate that 77.6% of the germplasm had Deep Green lamina, 19.8% Light Green, while 2.6% had Deep Purple leaves.

The distribution of these colours and sites of collection or districts is also shown in Table 4.1. Accessions from Asunafo district had 63.9% Deep Green leaves and 36.1% Light Green; Wenchi collections had 88.2% Deep Green and 11.8% Light Green lamina; Nkoranza district cultivars gave 83.9% and 16.1% Deep Green and Light Green leaves respectively, while germplasm from Dormaa district had 74.3% Deep Green, 18.6% Light Green and 2.6% Deep Purple leaves.

4.1.2 PETIOLE COLOUR (P C)

Five categories of petiole colour described in the descriptor were Deep Green ...1, Light Green .... 3, Green Purple .... 5, Deep Purple .... 7, and Light Purple .... 9.

Table 4.1 LEAF COLOUR FREQUENCY DISTRIBUTION IN GERMPLASM

	1	3	5	7	
ASF	63.9%	36.1%	-	-	
WCH	88.2%	11.8%	-	-	
NKZ	83.9%	16.1%	-	-	
DMA	74.3%	18.6%	7.1%	-	
TOTAL	**77.6%**	**19.8%**	**2.6%**		

Deep Green .... 1; Light Green ....3; Deep Purple .... 5; Light Purple .... 7.

ASF = Collections from ASUNAFO district
WCH = " " WENCHI "
NKZ = " " NKORANZA "
DMA = " " DORMAA "

Table 4.2 FREQUENCY OF PETIOLE COLOUR (P C) TYPES IN GERMPLASM

	1	3	5	7	9
ASF	-	-	41.7%	58.3%	-
WCH		2.9%	79.4%	14.7%	2.9%
NKZ		12.5%	62.5%	21.4%	3.6%
DMA		-	40.0%	47.1%	12.9%
TOTAL	**-**	**4.1%**	**53.6%**	**36.2%**	**6.1%**

Deep Green .... 1; Light Green .... 3; Green Purple .... 5; Deep Purple 7;

Light Purple .... 9.

ASF = Collections from ASUNAFO district
WCH = " " WENCHI "
NKZ = " " NKORANZA "
DMA = " " DORMAA "

The distribution of these petiole colour groupings as observed in the germplasm is shown in Table 4.2.

The predominant colours were green purple (53.6%) and deep purple (36.2%). Others were light purple (6.1%) and light green (4.1%).

The distribution of the colours within districts showed that 58.3% from Asunafo had deep purple petiole colour, 79.4% from Wenchi had petioles which were green purple. Others were, Nkoranza which had 62.5% of the germplasm with green purple petioles and 47.1% of Dormaa collections had deep purple petiole colouration (Table 4.2).

4.1.3 ANTHOCYANINE DISTRIBUTION ON THE PETIOLE (ADP)

The pigment anthocyanine is variously distributed on the petiole of the cassava leaf. The descriptor provided the following five distributions: Upper .... 1, Middle ... 3, Lower .... 5, Entire ....7, and Upper & Lower ....9.

Table 4.3 show the distribution of petiole anthocyanine among the germplasm: 57.7% had anthocyanine at both Upper and Lower parts of the petiole, while 41.3% of them had anthocyanine covering the entire petiole.

Accessions with anthocyanine at either the upper or lower parts of the petiole amounted to only 0.5% in each case.

Within district collections, the distribution was as follows: Asunafo germplasm had 58.3% with anthocyanine covering the entire petiole and 41.7% at Upper & Lower; accessions from Wenchi district indicated 79.4% and 20.6% having anthocyanine at upper & lower and entire respectively; for Nkoranza, upper & lower amounted to

69.6% and entire 30.4%. Dormaa collections exhibited much variability for the trait. Entire was 51.4%, Upper Lower 45.7%, while Upper and Lower each had 1.4% (Table 4.3).

4.1.4 LEAF VEIN COLOUR (L V C)

The colour of the leaf vein as seen in the lamina also varied.

Four categories of colours are given in the descriptor: Deep Green .... 1, Light Green .... 3, Light Purple .... 5, and Deep Purple ....7.

The frequency distribution of leaf vein colour is shown in Table 4.4.

The predominant leaf vein colours were light green (60.2%) and light purple (32.7%). Deep purple and deep green formed 6.1% and 1.0% respectively.

Light green was also the predominant leaf vein colour for each of the district collections: Asunafo (41.7%), Wenchi (79.4%), Nkoranza (71.4%) and Dormaa (51.4%) (Table 4.4).

4.1.5 ANTHOCYANINE DISTRIBUTION ON LEAF VEIN (ADV)

The distribution of the pigment anthocyanine, if present, on the leaf vein differs with different cultivars. The descriptor grouped this variable as: Absent .... O, Lower part .... 1, and Entire .... 2.

The frequency distribution of the anthocyanine distribution on leaf vein observed among the germplasm showed that 50% had anthocyanine at the Lower part, 34.2% entire and 15.8% did not have anthocyanine at all (Table 4.5).

Table 4.3 FREQUENCY OF ANTHOCYANINE DISTRIBUTION (PETIOLE) (ADP) IN GERMPLASM

	1	3	5	7	9
ASF	-	-	-	58.3%	41.7%
WCH	-	-	-	20.6%	79.4%
NKZ	-	-	-	30.4%	69.6%
DMA	1.4%	-	1.4%	51.4%	45.7%
TOTAL	**0.5%**	-	**0.5%**	**41.3%**	**57.7%**

Upper .... 1; Middle .... 3; Lower .... 5; Entire .... 7; Upper Lower 9

Table 4.4 FREQUENCY OF LEAF VEIN COLOUR (L V C) DISTRIBUTION IN GERMPLASM

	1	3	5	7	
ASF	2.8%	41.7%	36.1%	19.4%	
WCH	-	79.4%	20.6%	-	
NKZ		71.4%	25.0%	3.6%	
DMA	1.4%	51.4%	42.9%	4.3%	
TOTAL	**1.0%**	**60.2%**	**32.7%**	**6.1%**	

Deep Green .... 1; Light Green .... 3; Light Purple .... 5; Deep Purple 7

The predominant leaf vein anthocyanine distribution within district collections were; Asunafo, Entire (52.8%); Wenchi, Lower part (76.5%); Nkoranza, Lower part (50.0%) and that for Dormaa district was also Lower part (47.1%) (Table 4.5).

4.1.6 COLOUR OF FIRST FULLY EXPANDED LEAF (FELI)

In cassava, the colour of the unexpanded or the leaf initials usually differs from the mature leaves. This is a qualitative trait and the following colours and their corresponding scores are described in the descriptor: Deep Green .... 1, Light Green .... 3, Deep Purple .... 5, Light Purple .... 7.

The frequency distribution is shown in Table 4.6. The predominant colours of this variable were light green (75.5%), light purple (16.8%), deep purple (6.1%) and deep green (1.5%). For the districts, the predominant colours were light green: Asunafo (52.8%), Wenchi (97.1%), Nkoranza (78.6%), and Dormaa (74.3%) (Table 4.6).

4.1.7 STEM COLOUR (S C)

There was much variability in this trait among the accessions as all the colours described in the descriptor were represented (Table 4.7). Colours presented in the descriptor were: Light Green .... 1, Silver Green .... 3, Deep Green .... 5, Light Purple Green .... 6, Deep Brown .... 7, and Light Brown .... 9.

Accessions with light green stem colour formed 21.4%, silver green, 9.7%, Deep green, 16.3%, Light purple green, 23%, Deep Brown, 16.3% and Light Brown, 13.3% (Table 4.7). The frequency distribution of stem colour among the accessions from each of the four districts is shown in Table 4.7.

Table 4.5 FREQUENCY OF ANTHOCYANINE DISTRIBUTION (VEIN) (ADV) IN GERMPLASM

	0	1	2
ASF	16.6%	30.6%	52.8%
WCH	5.9%	76.5%	17.6%
NKZ	21.4%	50.0%	28.6%
DMA	15.8%	47.1%	37.1%
TOTAL	**15.8%**	**50.0%**	**34.2%**

Absent ....0; Lower Part .... 1; Entire 2

Table 4.6 FREQUENCY DISTRIBUTION OF COLOUR OF FIRST FULLY EXPANDED LEAF (FELI) IN GERMPLASM

	1	3	5	7
ASF	-	52.8%	11.1%	36.1%
WCH	-	97.1%	2.9%	-
NKZ	-	78.6%	1.8%	19.6%
DMA	4.2%	74.3%	8.6%	12.9%
TOTAL	**1.6%**	**75.5%**	**6.1%**	**16.8%**

Deep Green .... 1; Light Green ....3; Deep Purple .... 5; Light Purple 7

Table 4.7 FREQUENCY DISTRIBUTION OF STEM COLOUR (S C) IN GERMPLASM

	1	3	5	6	7	9
ASF	13.9%	19.4%	11.1%	-	25.0%	30.6%
WCH	20.6%	29.4%	26.5%	-	11.7%	11.8%
NKZ	17.9%	1.8%	26.8%	30.4%	8.9%	14.2%
DMA	28.6%	1.4%	5.7%	40.0%	20.0%	4.3%
TOTAL	**21.4%**	**9.7%**	**16.3%**	**23.0%**	**16.3%**	**13.3%**

Light Green ... 1; Silver Green … 3; Deep Green . 5; Light Purple Green …. 6;

Deep Brown …. 7; Light Brown ….9

Table 4.8 FREQUENCY OF BRANCHING AND NON-BRANCHING TYPES IN GERMPLASM

	0	1
ASF	5.6%	94.4%
WCH	-	100.0%
NKZ	1.8%	98.2%
DMA	5.7%	94.3%
TOTAL	**3.6%**	**96.4%**

Absent …. 0; Present …. 1

The predominant stem colour for each of the districts were:- Asunafo, Light brown (30.6%), Wenchi, Silver green (29.4%), Nkoranza, Light purple green (30.4%), and Dormaa, Light purple green (40.0%).

4.1.8 BRANCHING (B)

The descriptor grouped cassava into Branching types (1) and Non-Branching types (O). Table 4.8 provides the percentage distribution of this trait in the accessions.

Branching types amounted to 96.4% and the non-branching types only 3.6%.

The trend was the same for the district collections. All the collections from Wenchi were branching types, Asunafo, 94.4%, Nkoranza, 98.2% and Dormaa, 94.3% (Table 4.8).

4.1.9 NUMBER OF LEVELS OF BRANCHING (B N O)

The frequency distribution of the number of levels of branching among the germplasm is shown in Table 4.9.

The results show that among the cassava germplasm, 1.5% were non-branching types, 7.2% had one level of branching, 25.1% had two levels of branching, 39.5% had three levels, 24.1% had four levels, while only 2.6% had five levels of branching.

The distribution within district did not follow the same trend. Accessions with three levels of branching predominated in all the districts except in Wenchi where two and four levels predominated.

Table 4.9 FREQUENCY DISTRIBUTION OF NUMBER OF LEVELS OF BRANCHING (B N O) IN GERMPLASM

	0	1	2	3	4	5
ASF	5.5%	2.8%	13.9%	41.7%	30.6%	5.5%
WCH	-	11.8%	29.4%	26.5%	29.4%	2.9%
NKZ	-	9.1%	21.8%	38.2%	29.1%	1.8%
DMA	1.4%	5.7%	31.4%	45.8%	14.3%	1.4%
TOTAL	**1.5%**	**7.2%**	**25.1%**	**39.5%**	**24.1%**	**2.6%**

Table 4.10 FREQUENCY DISTRIBUTION OF ANGLE OF BRANCHING TYPES IN GERMPLASM

	1	3	5
ASF	13.9%	36.1%	50.0%
WCH	11.8%	61.8%	26.4%
NKZ	12.4%	55.4%	32.2%
DMA	11.4%	57.2%	31.4%
TOTAL	**11.0%**	**55.0%**	**34.0%**

15° – 39° .... 1; 40° – 69° .... 3; 70° – 90° 5

4.1.10 ANGLE OF BRANCHING (A B)

There are two types of branching pattern in most cassava varieties. These are the forking and lateral branching types. Variations of these two types determine the kind of angle formed.

The descriptor gave the range as: 15° - 39° .... 1, 40° - 69° .... 3, and 70° - 90° .... 5.

The results show that 55% of the cultivars that branched had moderate angle (40°-69°), 34% had wide angle (70° - 90°), while 11% had branches that formed acute angle (15° - 39°) (Table 4.10).

Within districts, the variation was the same except in the Asunafo collections that the wider angle types (70° – 90°) formed 50%, followed by accessions with moderate angle (40° – 69°), 36.1% and those with acute angle of branching (15° - 39°) constituting 13.9% (Table 4.10).

4.1.11 TIME OF FIRST BRANCHING (TOBFP)

Out of the 212 accessions, about 85% had branched by the 12th Week After Planting (WAP), with the rest branching between 13-21 WAP. First branching was recorded seven weeks after planting among 32 accessions which constituted 16%.

4.1.12 AVERAGE HEIGHT OF FIRST APICAL BRANCH (AVE. AB)

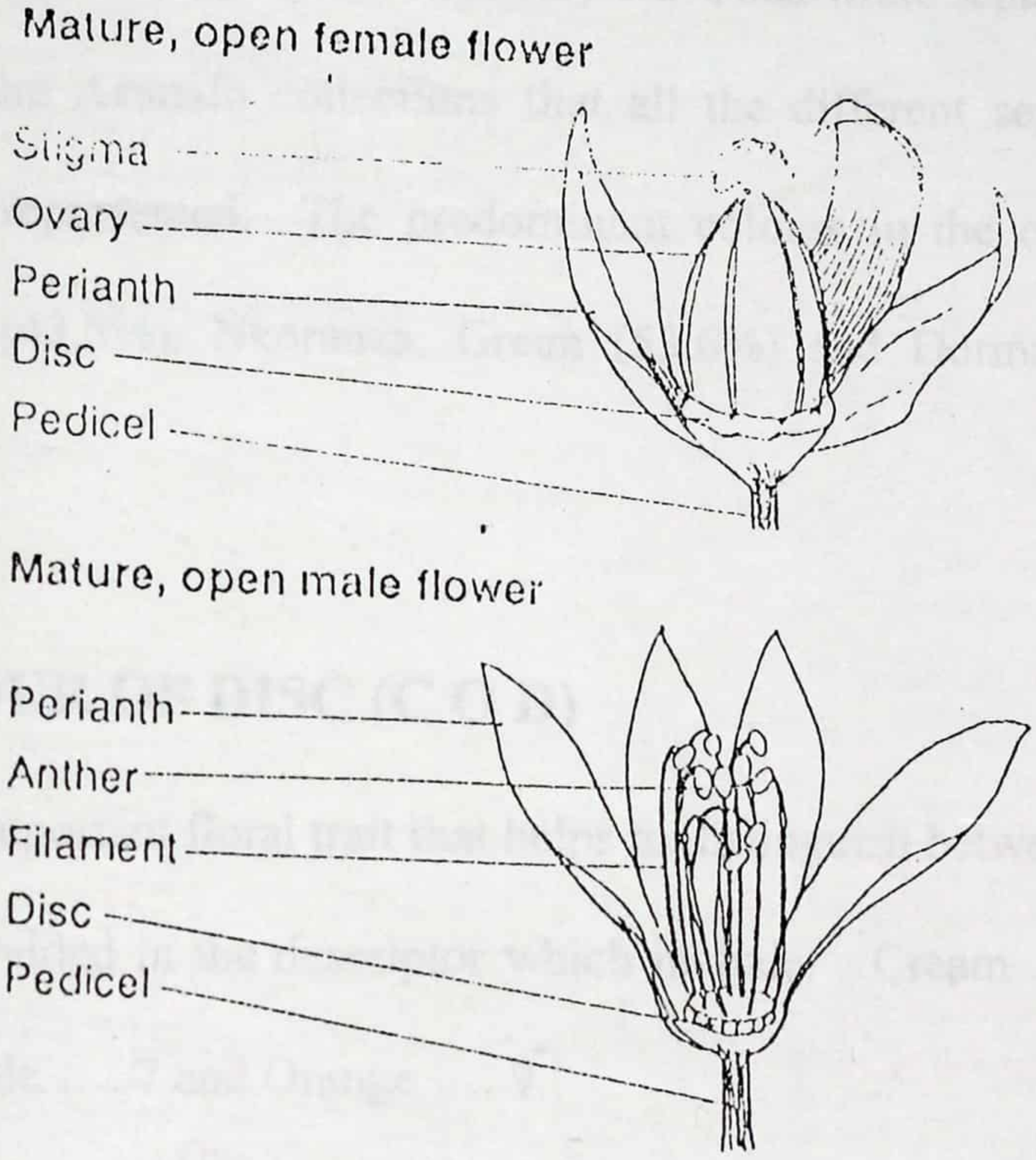
There was much variability in the average height of the first apical branch among the germplasm. For the majority of the collection, the first apical branches appeared when the plants were 50 – 100 cm tall. They constituted 54% of the total collection. Those whose average height of the first apical branches fell below 50 cm amounted to 23% (ie. 46 accessions), while 18% (ie. 35 accessions) had theirs within 100-150 cm, and 5% (ie. 10 accessions) were beyond 150 cm.

4.1.13 PLANT HEIGHT AT HARVEST

Plant height varied a great deal among the germplasm. The minimum was 80 cm, maximum was 374 cm, and the mean was 223 cm. Accessions which were less than 1 metre in height formed 5%, those between one and two metres amounted to 26%, while those greater than 2 metres but less than 3 metres constituted 69.5%. Only 4% were greater than 3 metres in height of the accessions.

4.2 FLORAL CHARACTERS

The floral characters used in the descriptor are based mainly on the colour of sepals, colour of the disc, colour of the ovary and the colour of anther as shown in Fig 4.2 below.



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4.2.1 COLOUR OF SEPALS (COS) FOR BOTH MALE & FEMALE FLOWERS

Much diversity was observed in sepal colour among the cultivars. Orange .... 1, Cream .... 3, White ....5, Purple .... 7, and Green ....9 were the categories of colours indicated in the descriptor.

The results in Table 4.11 show that 39.1% of the accessions had cream sepals, 37.6% Green, 18% Orange, 4.5% purple, while only 0.8% had white sepals.

It was only in the Asunafo collections that all the different sepal colours in the descriptor were represented. The predominant colours in the other districts were: Wenchi, Green (43.5%), Nkoranza, Green (53.6%) and Dormaa, Cream (60.4%) (Table 4.11).

4.2.2 COLOUR OF DISC (C O D)

This is another important floral trait that helps to distinguish between genotypes. Five colours were provided in the descriptor which include: Cream .... 1, White .... 3, Pink .... 5, Purple .... 7 and Orange .... 9.

Nearly 52% of the germplasm possessed purple discs, 24% were Orange, 17% Pink, 6% Cream and 1% had discs with white colouration. (Table 4.12)

Only Asunafo collections had all the colours in the descriptor represented with purple being the dominant colour (44%). The predominant colour of the disc observed in the remaining districts included: Wenchi, 60.9% being purple, Nkoranza, 56.1% purple, and Dormaa, 46.5% purple. (Table 4.12)

Table 4.11 FREQUENCY DISTRIBUTION OF SEPAL COLOUR TYPES IN GERMPLASM

	1	3	5	7	9
ASF	29.9%	34.6%	3.8%	3.9%	30.8%
WCH	34.8%	21.7%	-	-	43.5%
NKZ	17.1%	29.3%	-	-	53.6%
DMA	4.7%	60.4%	-	11.6%	23.3%
TOTAL	**18.0%**	**39.1%**	**0.8%**	**4.5%**	**37.6%**

Orange …. 1; Cream …. 3; White ….. 5; Purple …. 7; Green …. 9

Table 4.12 FREQUENCY DISTRIBUTION OF DISC COLOUR TYPES IN GERMPLASM

	1	3	5	7	9
ASF	12.0%	4.0%	20.0%	44.0%	20.0%
WCH	4.3%	-	26.1%	60.9%	8.7%
NKZ	7.3%	-	22.0%	56.1%	14.6%
DMA	2.3%	-	7.0%	46.5%	44.2%
TOTAL	**6.1%**	**0.8%**	**17.4%**	**51.5%**	**24.2%**

Cream …. 1; White …. 3; Pink …. 5; Purple …. 7; Orange …. 9

4.2.3 COLOUR OF OVARY (C O)

Table 4.13 shows frequency distribution of the colour of the ovary in the local cassava germplasm collected from Brong Ahafo Region. The descriptor describes the following categories of colours: Green ...1, Cream ...3, White ....5, Orange ....7 and Purple :...9. The results showed that 56.4% of the accessions studied had ovaries with orange colouration, 31.3% had green colour, 10.7% were purple, while cream and white ovaries constituted only 0.8% in each case. Within the districts the predominant colours were: Asunafo, green, amounting to 58.3%, Wenchi, orange (65.2%), Nkoranza, orange (73.1%) and Dormaa, also green (48.8%) (Table 4.13).

4.2.4 COLOUR OF ANTHER (C O A)

The descriptor gives three colours for this variable: Orange/Yellow .... 1, Cream .... 3, White .... 5.

There was virtually no variation in Anther colour among the cultivars. From Table 4.14, 98.4% possessed Orange/Yellow anthers, while Cream and White each amounted to 0.8%. Similar trend was observed within the districts where all Asunafo and Dormaa accessions had orange/yellow anthers, Wenchi, 95.7% orange/yellow and Nkoranza, 97.6%, also orange/yellow.

4.3 STORAGE ROOT CHARACTERS

Root tuber yield and its characteristics are ultimately the most important consideration in the choice of a variety. Twelve of these characters were studied, nine of which may be considered as qualitative traits and the rest as quantitative traits.

The results are presented below.

Table 4.13 FREQUENCY DISTRIBUTION OF OVARY COLOUR TYPES IN GERMPLASM

	1	3	5	7	9
ASF	58.3%	-	4.2%	33.3%	4.2%
WCH	17.4%	4.3%	-	65.2%	13.1%
NKZ	22.0%	-	-	73.1%	4.9%
DMA	32.6%	-	-	48.8%	18.6%
TOTAL	**31.3%**	**0.8%**	**0.8%**	**56.4%**	**10.7%**

Green .... 1; Cream .... 3; White .... 5; Orange .... 7; Purple 9

Table 4.14 FREQUENCY DISTRIBUTION OF ANTHER COLOUR TYPES IN GERMPLASM

	1	3	5
ASF	100.0%	-	-
WCH	95.7%	-	4.3%
NKZ	97.6%	2.4%	-
DMA	100.0%	-	-

Orange/Yellow....1; Cream.....3; White.....5

4.3.1 ROOT STALK (R S)

The Root Stalk refers to an extended portion of the cassava root that separates the tuber from the stump. Root stalk may be present or absent and when present may be of variable length.

The descriptor however considered only the presence – (1) or absence – (0) of root stalk or 'neck' of the root tuber. Table 4.15 shows the frequency distribution of this trait among the cultivars collected. Almost 56% of them had root tubers with 'neck' while about 44% produced 'neckless' root tubers. The trend was the same with the district distribution except in Wenchi where 51.5% of the germplasm produced 'neckless' root tubers (Table 4.15)

4.3.2 POSITION OF ROOT (P O R)

The orientation of cassava tubers in the soil is a varietal characteristic which showed a great deal of variation in the cultivars. While some spread their tubers horizontally just beneath the soil surface, in others, the tubers grow vertically into the soil.

The orientation was described as Horizontal – (1) or Vertical – (3) in the descriptor. Results represented in Table 4.16 show that 90.5% of the germplasm positioned their root tubers horizontally in the soil, while 9.5% produced theirs vertically into the soil. A similar trend was observed for the within districts distribution (Table 4.16).

4.3.3 STORAGE ROOT CONSTRICTION (S R C)

Storage root constriction is another qualitative character describing the smoothness or otherwise of the root tubers. The descriptor gave two categories of this character: Absent .... (0), and Present .... (1).

The results in Table 4.17 show that nearly 83% of the cultivars produced root tubers without constrictions, while only 17% of them did produce constricted root tubers. The district distribution produced similar results except in Wenchi where the cultivars that produced smooth root tubers amounted to just 53% (Table 4.17)

Table 4.15 ROOT STALK (R S) GROUPINGS OF GERMPLASM

	0	1
ASF	35.5%	64.5%
WCH	51.5%	48.5%
NKZ	45.8%	54.2%
DMA	41.8%	58.2%
TOTAL	**43.6%**	**56.4%**

Absent …. 0; Present …. 1

Table 4.16 POSITION OF ROOT TYPES IN GERMPLASM

	1	3
ASF	93.5%	6.5%
WCH	90.9%	9.1%
NKZ	89.6%	10.4%
DMA	89.6%	10.4%
TOTAL	**90.5%**	**9.5%**

Horizontal …. 1; Vertical …. 3

The district distribution produced similar results except in Wenchi where the cultivars that produced smooth root tubers amounted to just 53% (Table 4.17).

4.3.4 COLOUR OF OUTER SURFACE OF ROOT CORTEX (CODSOC)

The colour of outer surface of root cortex, which is a qualitative character, is a very important trait since farmers associate it with mealiness. Colours presented in the descriptor were: Yellow .... 1, Pink .... 3, Cream ... 7 and White .... 9. Pink was the predominant colour of root tuber cortex found among the germplasm. From Table 4.18, Pink root tuber cortex formed 61.4%, followed by cream which was 33%, while 3.9% and 1.7% were recorded for white and yellow respectively.

Within the districts, the predominant colours of the root tuber cortex were: Asunafo, Cream (64.5%); Wenchi, Pink (75.8%), Nkoranza, Pink (77%) and Dormaa, also pink (56.7%) (Table 4.18).

4.3.5 STORAGE ROOT SURFACE TEXTURE (SRST)

The descriptor grouped the cassava into types that produce root tubers with Smooth – (1) or Rough – (3) surface texture.

Approximately 85% of the accessions had root tubers with rough surface texture as against only 15% of them with smooth texture (Table 4.19).

A similar trend was observed for the within districts distribution where Asunafo recorded 74.2% for rough texture, Wenchi, 87.9%, Nkoranza, 83.3% and Dormaa, 89.6% (Table 4.19).

Table 4.17 STORAGE ROOT CONSTRICTION (S R C) DISTRIBUTION IN GERMPLASM

	0	1
ASF	80.0%	20.0%
WCH	53.1%	46.9%
NKZ	83.0%	17.0%
DMA	98.5%	1.5%
TOTAL	**82.8%**	**17.2%**

Absent …. 0; Present …. 1

Table 4.18 FREQUENCY DISTRIBUTION OF COLOUR OF OUTER SURFACE OF CORTEX (CODSOC) IN GERMPLASM

	1	3	7	9
ASF	3.2%	32.3%	64.5%	-
WCH	-	75.8%	21.2%	3.0%
NKZ	2.1%	77.0%	14.6%	6.3%
DMA	1.5%	56.7%	37.3%	4.5%
TOTAL	**1.7%**	**61.4%**	**33.0%**	**3.9%**

Yellow …. 1; Pink …. 3; Cream …. 7; White …. 9

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4.3.6 ROOT TUBER YIELD PER PLANT (RTYPP)

Root tuber yield is probably the most important consideration in the choice of a cassava variety, but yield is a quantitative trait which is influenced by many environmental factors including soil fertility, soil moisture regime, pests and diseases and management practices.

Yield results are presented in Table 4.22 in a ranking order.

It was observed that 37 accessions out of the 177 yielded more than Gblemoduade which is the most high yielding variety among the four released improved cassava varieties which include Gblemoduade, Tekbankye, Afisiafi and Abasafitaa; 43 of the germplasm outyielded Tekbankye and 61 and 103 accessions outyielded Afisiafi and Abasafitaa respectively.

4.3.7 MEALINESS

The most important factor that influences farmers choice of cassava varieties for cultivation in most parts of Ghana is whether it is mealy (or poundable) or not.

Four categories of mealiness designated in the descriptor were; Not Good – (1), Good – (2), Very Good – (3), and Excellent – (4).

Table 4.20 depicts mealiness frequency distribution among the cassava accessions from Brong Ahafo region. About 95% of the germplasm produced mealy tubers when cooked, while 5% were found to be unpoundable. Out of the 95% accessions that gave mealy root tubers, 40.5% could be classified as Excellent, 37.5% fell under Very Good and 17% Good.

Table 4.19 FREQUENCY DISTRIBUTION OF STORAGE ROOT SURFACE TEXTURE (SRST) TYPES IN GERMPLASM

	1	3
ASF	25.8%	74.2%
WCH	12.1%	87.9%
NKZ	16.7%	83.3%
DMA	10.4%	89.6%
TOTAL	**15.1%**	**84.9%**

Smooth .... 1; Rough 3

Table 4.20 FREQUENCY DISTRIBUTION OF MEALINESS IN GERMPLASM

	1	2	3	4
ASF	9.6%	19.4%	25.8%	45.2%
WCH	6.0%	18.2%	39.4%	36.4%
NKZ	2.1%	12.5%	37.5%	47.9%
DMA	4.5%	16.4%	44.8%	34.3%
TOTAL	**5.0%**	**17.0%**	**37.5%**	**40.5%**

Not Good ... 1; Good .... 2; Very Good .... 3; Excellent 4

Table 4.21 FREQUENCY DISTRIBUTION OF ACMVD SCORE IN GERMPLASM

	1	2	3	4	5
ASF	2.8%	2.8%	22.2%	30.6%	41.6%
WCH	3.0%	2.9%	11.8%	14.7%	67.6%
NKZ	0.1%	3.6%	5.4%	10.7%	80.4%
DMA	2.9%	8.6%	14.3%	47.1%	27.1%
TOTAL	**2.0%**	**5.1%**	**12.8%**	**28.1%**	**52.0%**

None (Resistance) .... 1; Minor infection (Tolerance) .... 2; Moderate infection (susceptible) .... 3; High infection (very susceptible) .... 4; Very High infection (Highly susceptible) .... 5.

Within the districts, 45.2% of germplasm from Asunafo produced excellent mealy tubers, 39.4% from Wenchi were Very Good, 47.9% from Nkoranza were Excellent, while 44.8% from Dormaa were Very Good (Table 4.20)

4.3.8 AFRICA CASSAVA MOSAIC VIRUS DISEASE (ACMVD) SCORE

Africa Cassava Mosaic Virus Disease (ACMVD) is probably one of the most common and easily perceived disease of Cassava. The descriptor provided the following categories of ACMV Score: None (Resistance) .... 1, Minor infection (Tolerance) .... 2, Moderate infection (susceptible) .... 3, High infection (Very susceptible) . 4, Very High infection (Highly susceptible) .... 5. The data on ACMVD score distribution is shown in Table 4.21

The results indicated that 52% of the germplasm were highly susceptible to ACMV, 28.1% were very susceptible, 12.8% had moderate infection, 5.1% had minor infection, while only 2% had no infection or resistant to the disease.

Within districts, the results gave a similar trend with 41.6% of Asunafo, 67.6% of Wenchi and 80.4% of Nkoranza accessions being highly susceptible (5 on the 1 – 5 scale), while 47.1% of Dormaa cultivars were very susceptible (4 on the 1 – 5 scale).

Table 4.22

ROOT-TUBER YIELD RANKING AND CORRESPONDING HARVEST INDEX OF CASSAVA ACCESSIONS.

ACCESSION	ROOT TUBER YIELD PER PLANT (kg)	RANKING	HARVEST INDEX
1. * WCH – 009	21.3	1	0.54
2. ASF – 029	20.5	2	0.39
3. * NKZ – 009	15.4	3	0.41
4. DMA – 055	14.3	4	0.54
5. DMA – 063	13.8	5	0.62
6. WCH – 012	13.4	6	0.42
7. NKZ – 051	13.4	6	0.51
8. DMA – 042	13.0	7	0.60
9. ASF – 036	12.5	8	0.60
10. * NKZ – 015	12.4	9	0.34
11. DMA – 008	11.6	10	0.56
12. * WCH – 037	10.9	11	0.47
13. * DMA – 002	10.4	12	0.63
14. WCH – 002	10.0	13	0.57
15. ASF – 033	9.7	14	0.55
16. DMA – 054	9.6	15	0.47
17. WCH – 040	9.3	16	0.50
18. WCH – 024	8.8	17	0.51
19. NKZ – 025	8.6	18	0.47

ACCESSION	ROOT TUBER YIELD PER PLANT (kg)	RANKING	HARVEST INDEX
20. WCH – 019	8.4	19	0.62
21. DMA – 003	8.2	20	0.56
22. DMA – 071	7.9	21	0.57
23. WCH – 020	7.8	22	0.63
24. DMA – 035	7.6	23	0.69
25. NKZ – 003	7.6	23	0.54
26. NKZ – 059	7.5	24	0.56
27. ASF – 011	7.4	25	0.54
28. DMA - 064	7.3	26	0.55
29. ASF – 035	7.3	26	0.54
30. DMA – 070	7.0	27	0.55
31. NKZ – 058	6.9	28	0.48
32. NKZ – 057	6.8	29	0.49
33. WCH – 023	6.8	29	0.47
34. DMA – 018	6.7	30	0.46
35. NKZ – 012	6.7	30	0.47
36. NKZ – 020	6.7	30	0.48
37. NKZ – 052	6.7	30	0.63
38. ** GBLEMO – DUADE	6.7	30	0.37
39. ASF – 005	6.6	31	0.37
40. DMA - 043	6.6	31	0.46
41. WCH – 036	6.5	32	0.50

ACCESSION	ROOT TUBER YIELD PER PLANT (kg)	RANKING	HARVEST INDEX
42. DMA – 031	6.4	33	0.54
43. ASF – 027	6.4	33	0.59
44. NKZ – 053	6.4	33	0.52
45. ** TEKBANKYE	6.1	34	0.54
46. ASF – 004	6.0	35	0.50
47. WCH – 029	6.0	35	0.51
48. DMA – 067	5.9	36	0.46
49. ASF – 028	5.8	37	0.46
50. DMA – 036	5.6	38	0.49
51. DMA – 041	5.6	38	0.49
52. ASF – 016	5.6	38	0.20
53. ASF – 022	5.6	38	0.41
54. ASF – 009	5.6	38	0.65
55. ASF – 006	5.5	39	0.52
56. ASF – 014	5.4	40	0.52
57. NKZ – 038	5.4	40	0.60
58. WCH – 004	5.3	41	0.43
59. NKZ – 030	5.3	41	0.50
60. DMA – 060	5.2	42	0.52
61. NKZ – 031	5.2	42	0.31
62. DMA – 014	5.0	43	0.38
63. NKZ – 006	5.0	43	0.41

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ACCESSION	ROOT TUBER YIELD PER PLANT (kg)	RANKING	HARVEST INDEX
64. ** AFISIAFI	5.0	43	0.45
65. ASF – 003	4.9	44	0.49
66. NKZ – 016	4.9	44	0.46
67. DMA – 040	4.7	45	0.47
68. DMA – 010	4.6	46	0.42
69. WCH – 031	4.6	46	0.59
70. WCH – 044	4.6	46	0.49
71. NKZ – 040	4.6	46	0.47
72. DMA – 059	4.5	47	0.44
73. WCH – 023	4.5	47	0.53
74. ASF – 034	4.4	48	0.59
75. DMA – 004	4.3	49	0.50
76. ASF – 007	4.3	49	0.44
77. NKZ – 014	4.2	50	0.49
78. NKZ – 056	4.2	50	0.46
79. DMA – 012	4.0	51	0.83
80. DMA – 066	4.0	51	0.51
81. DMA – 023	4.0	51	0.65
82. DMA – 052	4.0	51	0.53
83. NKZ – 033	4.0	51	0.43
84. NKZ – 041	4.0	51	0.51
85. ASF – 026	3.8	52	0.52
86. NKZ – 021	3.8	52	0.45
87. WCH – 027	3.7	53	0.55

ACCESSION	ROOT TUBER YIELD PER PLANT (kg)	RANKING	HARVEST INDEX
88. DMA – 029	3.6	54	0.53
89. DMA – 068	3.6	54	0.60
90. WCH – 041	3.6	54	0.64
91. NKZ – 010	3.6	54	0.60
92. DMA – 048	3.5	55	0.64
93. WCH – 021	3.5	55	0.47
94. WCH – 034	3.5	55	0.48
95. DMA – 047	3.4	56	0.55
96. NKZ – 001	3.4	56	0.49
97. NKZ – 022	3.4	56	0.40
98. DMA – 016	3.3	57	0.42
99. ASF – 008	3.3	57	0.70
100. ASF – 015	3.3	57	0.38
101. ASF – 021	3.3	57	0.41
102. ASF – 024	3.3	57	0.43
103. WCH – 026	3.3	57	0.60
104. NKZ – 037	3.3	57	0.47
105. DMA – 027	3.2	58	0.52
106. NKZ – 044	3.2	58	0.53
107.** ABASAFITAA	3.1	59	0.54
108. DMA – 024	3.0	60	0.56
109. DMA – 045	3.0	60	0.50
110. DMA – 026	3.0	60	0.22

	ACCESSION	ROOT TUBER YIELD PER PLANT (kg)	RANKING	HARVEST INDEX
111.	DMA – 025	3.0	60	0.44
112.	ASF – 012	3.0	60	0.45
113.	ASF – 018	3.0	60	0.50
114.	NKZ – 024	3.0	60	0.56
115.	DMA – 038	2.8	61	0.31
116.	DMA – 053	2.8	61	0.62
117.	WCH – 030	2.8	61	0.58
118.	DMA – 013	2.6	62	0.39
119.	ASF – 020	2.6	62	0.48
120.	WCH – 042	2.6	62	0.51
121.	NKZ – 035	2.6	62	0.29
122.	NKZ – 026	2.6	62	0.41
123.	DMA – 037	2.5	63	0.42
124.	WCH – 001	2.4	64	0.41
125.	NKZ – 039	2.4	64	0.46
126.	DMA – 017	2.3	65	0.51
127.	ASF – 031	2.3	65	0.29
128.	NKZ – 013	2.3	65	0.37
129.	WCH – 006	2.2	66	0.41
130.	WCH – 025	2.1	67	0.41
131.	WCH – 032	2.1	67	0.37
132.	DMA – 056	2.0	68	0.50
133.	DMA – 015	1.9	69	0.40
134.	DMA – 010	1.9	69	0.46

ACCESSION	ROOT TUBER YIELD PER PLANT (kg)	RANKING	HARVEST INDEX
135. DMA – 065	1.8	70	0.58
136. WCH – 011	1.8	70	0.45
137. DMA – 062	1.7	71	0.34
138. DMA – 049	1.7	71	0.46
139. DMA – 014	1.7	71	0.52
140. NKZ – 028	1.7	71	0.46
141. ASF – 025	1.6	72	0.22
142. WCH – 01	1.6	72	0.33
143. WCH – 01	1.6	72	0.50
144. DMA – 06	1.5	73	0.43
145. DMA – 044	1.4	74	0.20
146. NKZ – 029	1.4	74	0.28
147. DMA – 069	1.3	75	0.35
148. DMA – 020	1.3	75	0.48
149. WCH – 043	1.3	75	0.39
150. NKZ – 043	1.3	75	0.39
151. NKZ – 045	1.3	75	0.43
152. NKZ – 034	1.3	75	0.39
153. NKZ – 055	1.3	75	0.45
154. ASF – 032	1.3	75	0.29
155. DMA – 021	1.2	76	0.27
156. NKZ – 004	1.2	76	0.30
157. DMA – 009	1.1	77	0.21

ACCESSION	ROOT TUBER YIELD PER PLANT (kg)	RANKING	HARVEST INDEX
158. DMA – 019	1.1	77	0.44
159. WCH – 016	1.1	77	0.48
160. NKZ – 048	1.0	78	0.50
161. DMA – 022	1.0	78	0.33
162. DMA – 011	0.9	79	0.90
163. NKZ – 011	0.8	80	0.36
164. DMA – 033	0.8	80	0.33
165. ASF – 023	0.7	81	0.19
166. ASF – 030	0.7	81	0.33
167. WCH – 013	0.7	81	0.20
168. DMA – 058	0.6	82	0.23
169. DMA – 057	0.5	83	0.29
170. DMA – 032	0.5	83	0.38
171. DMA – 050	0.5	83	0.38
172. WCH – 022	0.5	83	0.20
173. NKZ – 047	0.5	83	0.17
174. NKZ – 018	0.5	83	0.09
175. NKZ – 042	0.5	83	0.42
176. DMA – 039	0.4	84	0.22
177. DMA – 034	0.3	85	0.23

* Accessions selected for Adaptive Research based on Yield Potential, cooking quality and Tolerance to ACMV.

** Released varieties.

4.3.9 CLUSTER ANALYSIS

The data on the morphological characters were subjected to cluster analysis using the SPSS/PC software. This resulted in grouping the cultivars into major clusters as shown in the dendrogram (Fig 2) and Appendix 1.

Five major clusters and some sub-groupings within the clusters were identified and these are described below.

CLUSTER I

It contained 73 accessions of which 65% came from the forest-savanna transition ecozone (Wenchi and Nkoranza districts). There were five closely related subgroups within this cluster.

The genotypes of cluster I, on the average, possessed deep green mature leaves, light green leaf vein, green purple petioles and deep green stems. Other predominant traits associated with this cluster were: early and low branching habit, mean plant height of about 2.4 metres at maturity, pink root tuber cortex and majority of the cultivars produced root tubers which were mealy (Table 4.23) All the IITA improved varieties including the mutant Tekbankye which also originated from IITA appeared in Cluster I.

CLUSTER II

There were 26 cultivars in .Cluster II with four subgroups.

Collections from the two agroecological zones in the region were almost equally represented; 12 were from the forest ecozone and 14 from the forest-savanna transition ecozone. Accessions in Cluster II also had deep green mature leaves with light purple leaf vein and deep purple petiole colouration.

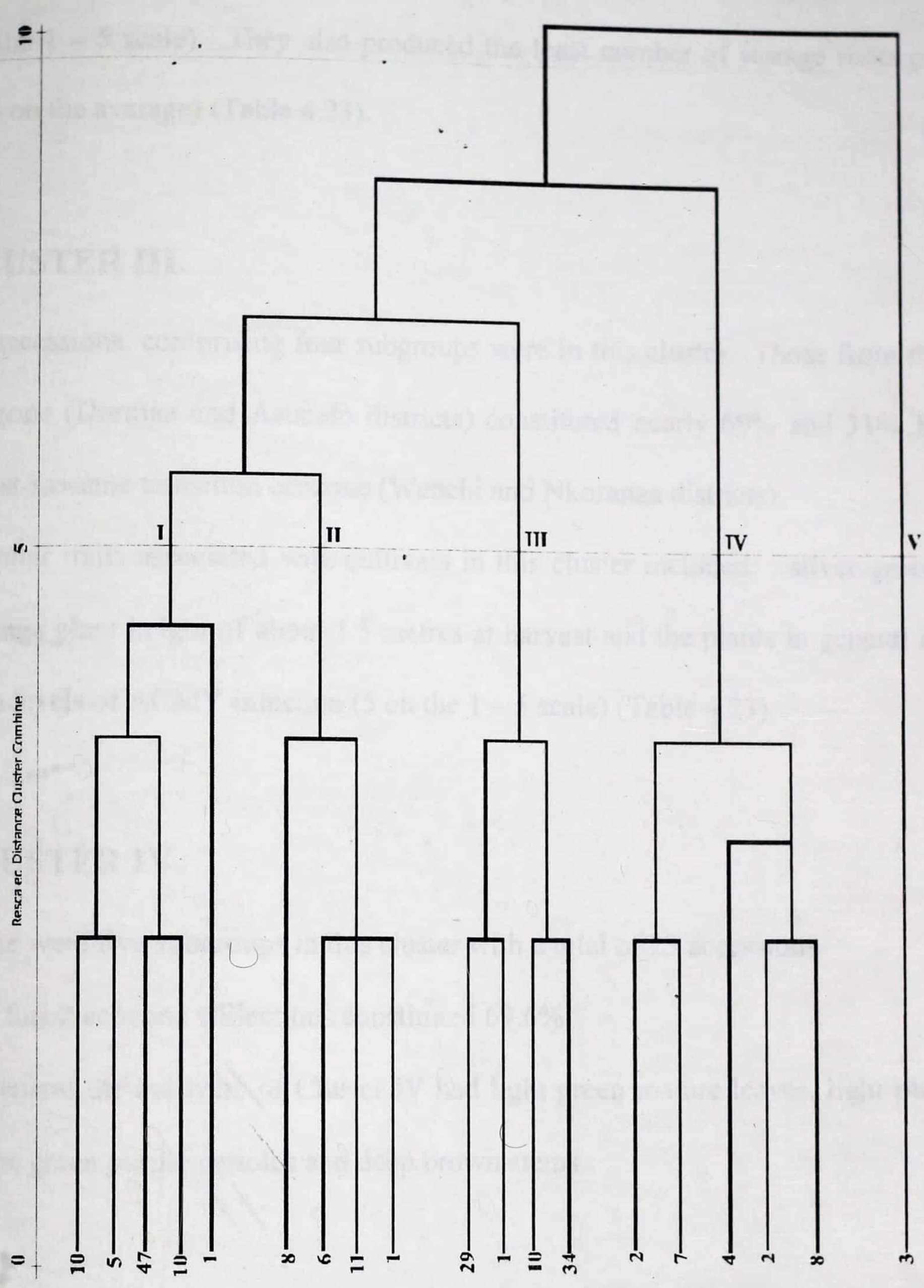

Fig. 2 Dendogram showing the relationships between the accessions. (No. Of accessions in each group are indicated)

Other distinguishing morphological characters associated with Cluster II included: two levels of branching and mealiness score being very good (3 on the 1 – 4 scale); with most of the accessions in the cluster recording high level of ACMV infection (4 on the 1 – 5 scale). They also produced the least number of storage roots per plant (3.4 on the average) (Table 4.23).

CLUSTER III

74 accessions, comprising four subgroups were in this cluster. Those from the forest ecozone (Dormaa and Asunafo districts) constituted nearly 69% and 31% from the forest-savanna transition ecozone (Wenchi and Nkoranza districts).

Peculiar traits associated with cultivars in this cluster included: silver green stems, average plant height of about 1.5 metres at harvest and the plants in general had very high levels of ACMV infection (5 on the 1 – 5 scale) (Table 4.23).

CLUSTER IV

There were five subgroups in this cluster with a total of 23 accessions.

The forest ecozone collections constituted 69.6%.

In general the cultivars of Cluster IV had light green mature leaves, light purple leaf veins, green purple petioles and deep brown stems.

Averagely, most of the cultivars took 66 days to branch at a height of about 103 cm, attaining a height of about 2.5 metres or more at harvest. They produced excellent mealy tubers with white root surface cortex. Cultivars of Cluster IV were far more tolerant to ACMV infection (2 on the 1 – 5 scale) compared to their counterparts in the other clusters (Table 4.23).

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CLUSTER V

It was the smallest grouping comprising only three cultivars which all came from the forest zone. These three cultivars branched early around 47 days after planting, were about 25 cm tall at branching stage and attained mean height of 130 cm at maturity. Their root tubers were very poundable (4 on 1 – 4 mealiness scale) and the root surface cortex had cream colouration.

Table 4.23 Predominant traits* associated with the five clusters

CLUSTER	ACMV	ADP	ADV	AVE-AB	BRANCH	BNO	CO	COA	COD	CODSO	CORP	COS	FELI	HTOFP	LC
1	3	9	1	26	1	4	1	1	9	3	2	9	3	242	1
2	4	7	2	156	1	2	7	1	9	3	2	3	3	246	1
3	5	9	1	83	1	2	1	1	5	3	2	1	3	148	1
4	2	7	2	103	1	4	7	1	5	9	2	3	3	258	3
5	3	9	0	25	1	1	1	1	9	7	2	9	3	130	1

CLUSTER	LVC	MEAL	NO-SRP	NOPH	PC.	POR	RS	RSC	SC	SRC	SRST	TFWOF	RTYPP	TOBFP	AB
1	3	3	7.5	4	5	1	1	1	5	0	3	6	7.25	55	5
2	5	3	3.4	5	7	1	1	1	1	0	3	2.6	2.9	123	3
3	3	3	7.6	5	5	1	1	1	3	0	3	1.02	8.4	123	3
4	5	4	13.4	5	5	1	1	1	7	0	3	24.4	12.46	66	5
5	3	4	4.2	2	5	1	1	1	2	0	3	8	9.7	47	3

* For full name of traits see text

4.4 MOLECULAR CHARACTERIZATION

After subjecting the morphological data to cluster analysis, 50 accessions were selected from the five clusters produced and analysed at the molecular level using the RAPD technique to ascertain their relatedness or discriminate between them. (Table 4.24). Four (4) primers (OPKO1, OPRO2, OPRO9 and OPJ14) out of twenty-five (25) which produced reproducible amplification products were used in the study

The informative oligonucleotide primers gave clear scorable bands and detected polymorphism among the fifty (50) cassava accessions. The typical PCR amplification products are shown in Table 4.4.1 below.

Table 4.4.1. Four DNA Primers used for the RAPD analysis of cassava germplasm showing the amplified (A) and polymorphic (P) fragments.

Serial No.	Primer	Nucleotide Sequence 5' to 3'	No. of Fragments A	Polymorphic
1	OPK01	CATTCGGAGCC	9	7
2	OPR02	CACAGCTGCC	10	10
3	OPR09	CTTCACCCGA	12	8
4	OPJ14	CACCCGATG	10	7
			41	32

A total of 41 RAPD fragments which produced clear and easily scorable bands were amplified by the four primers (Table 4.4.1). The number of bands per primer ranged from 9 to 12. The size of the DNA bands that were produced in the PCR reaction ranged from 300 to 1500 bp (molecular weight in base-pairs), but most of them ranged between 500 – 1000 bp (see DNA Amplification Photographs 1, 2, 3 and 4).

Table 4.24

LIST OF THE 50 CASSAVA ACCESSIONS STUDIED USING RAPID TECHNIQUE.

1.	WCH – 012	26.	NKZ – 030
2.	NKZ -038	27.	DMA – 042
3.	ASF -035	28.	ASF – 001
4.	NKZ – 025	29.	ASF – 025
5.	ASF – 035	30.	WCH – 022
6.	DMA – 029	31.	DMA – 055
7.	WCH – 036	32.	DMA – 060
8.	DMA – 024	33.	TEKBANKYE
9.	DMA – 034	34.	WCH – 040
10.	AFISIAFI	35.	DMA – 069
11.	WCH - 020	36.	DMA – 011
12.	DMA – 009	37.	DMA – 018
13.	DMA – 059	38.	DMA – 036
14.	ASF – 027	39.	ASF – 030
15.	WCH – 024	40.	ASF – 018
16.	NKZ – 009	41.	ASF – 005
17.	ASF – 014	42.	NKZ – 057
18.	DMA – 067	43.	WCH – 037
19.	WCH – 009	44.	GBLEMODUADE
20.	NKZ – 058	45.	DMA - 003
21.	DMA – 030	46.	DMA – 027

22.	ASF – 029	47.	NKZ – 015
23.	DMA – 041	48.	ASF – 002
24.	DMA – 002	49.	ABASAFITAA
25.	.DMA – 014	50.	WCH - 027

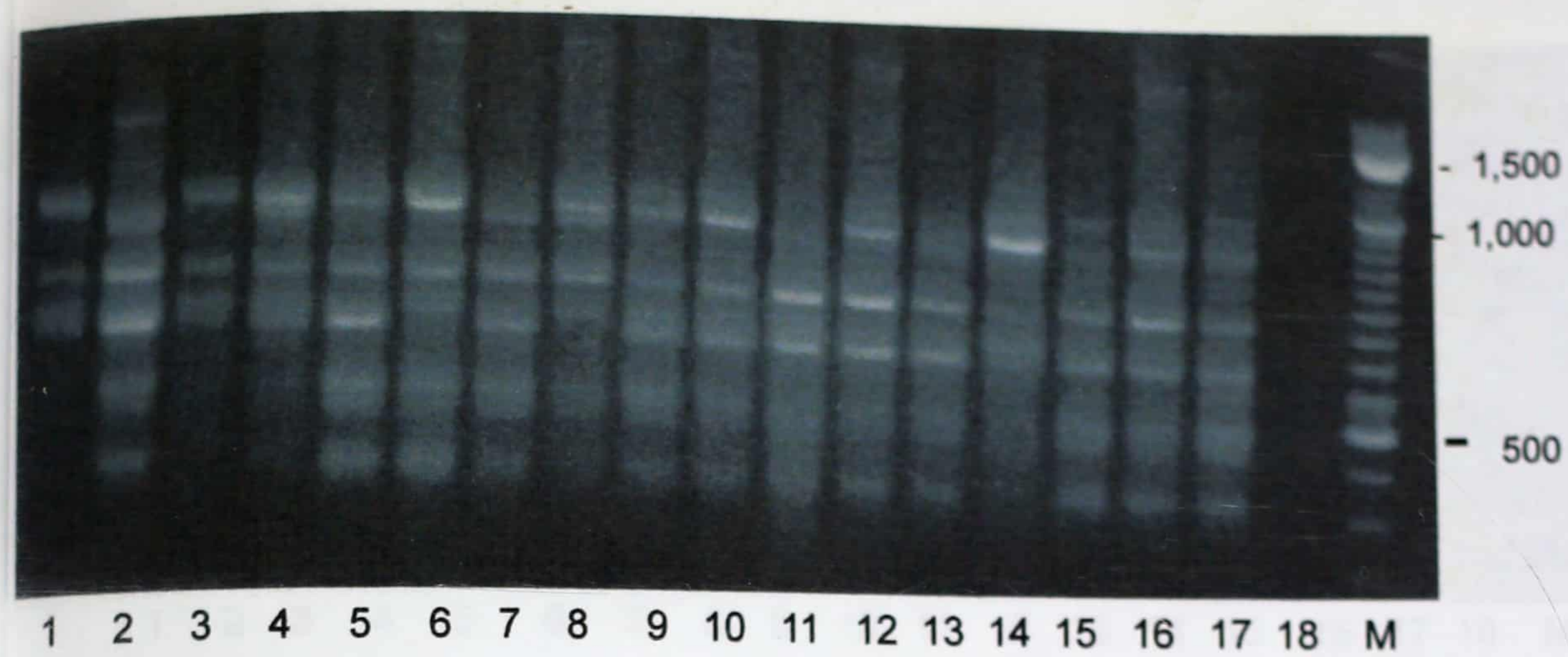


FIGURE 1: RAPD pattern produced from DNA amplification of 18 Cassava accessions using operon primer OPK-01.

M is a marker. Beginninig from lane 1 to 18: DMA-069, ASF-014, NKZ-009, WCH-024, ASF-027, DMA-059, DMA-009, WCH-020, AFISIAFI, DMA-034, DMA-024, WCH-036, DMA-029, ASF-035, NKZ-025, ASF-021, NK2-038, WCH-012

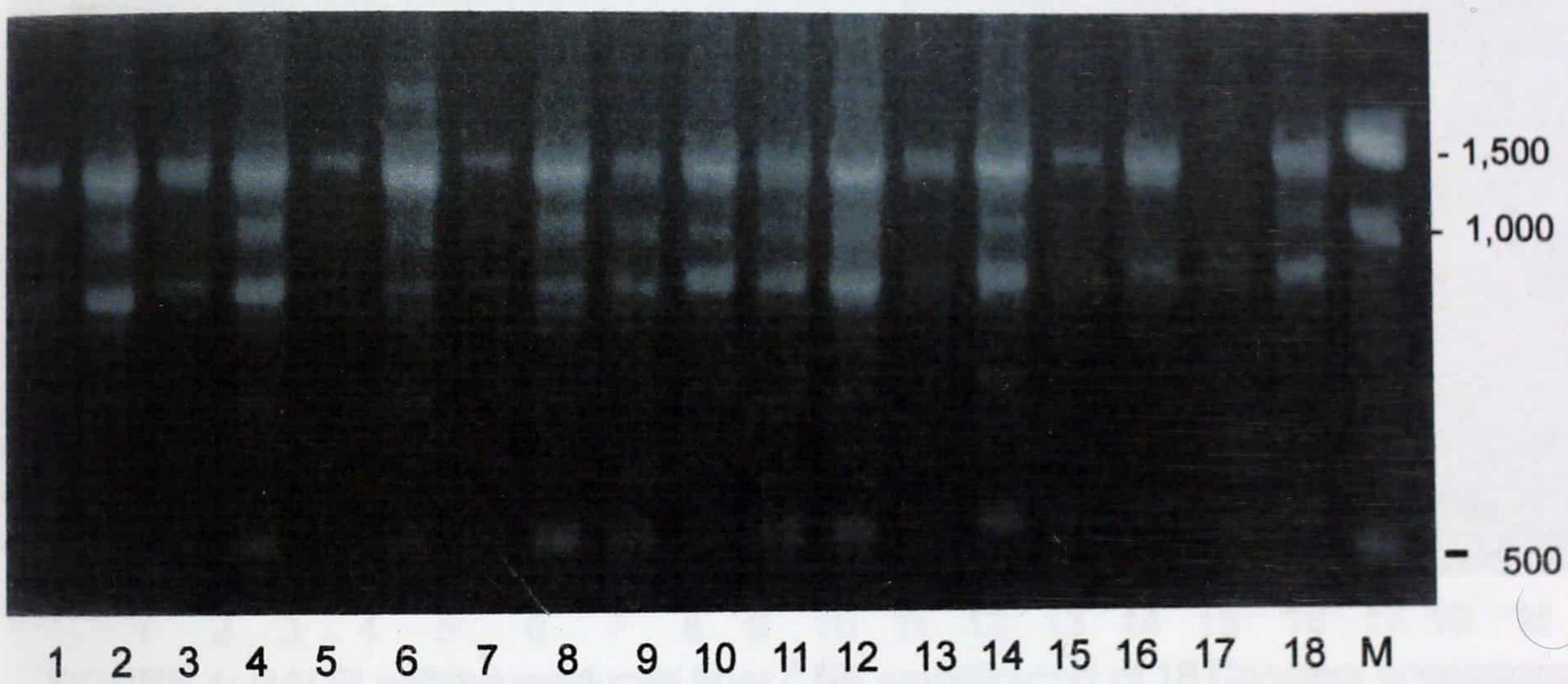


FIGURE 2: RAPD pattern produced from DNA amplification of 18 Cassava accessions using operon primer OPJ14.

M is a marker. Beginninig from lane 1 to 18: DMA-011, DMA-069, WCH-040, TAKBOKYE, DMA-060, DMA-055, WCH-022, ASF-025, ASF-011, DMA-042, NKZ-030, DMA-014, DMA-002, DMA-041, ASF-029, DMA-030, NKZ-058, WCH-009.

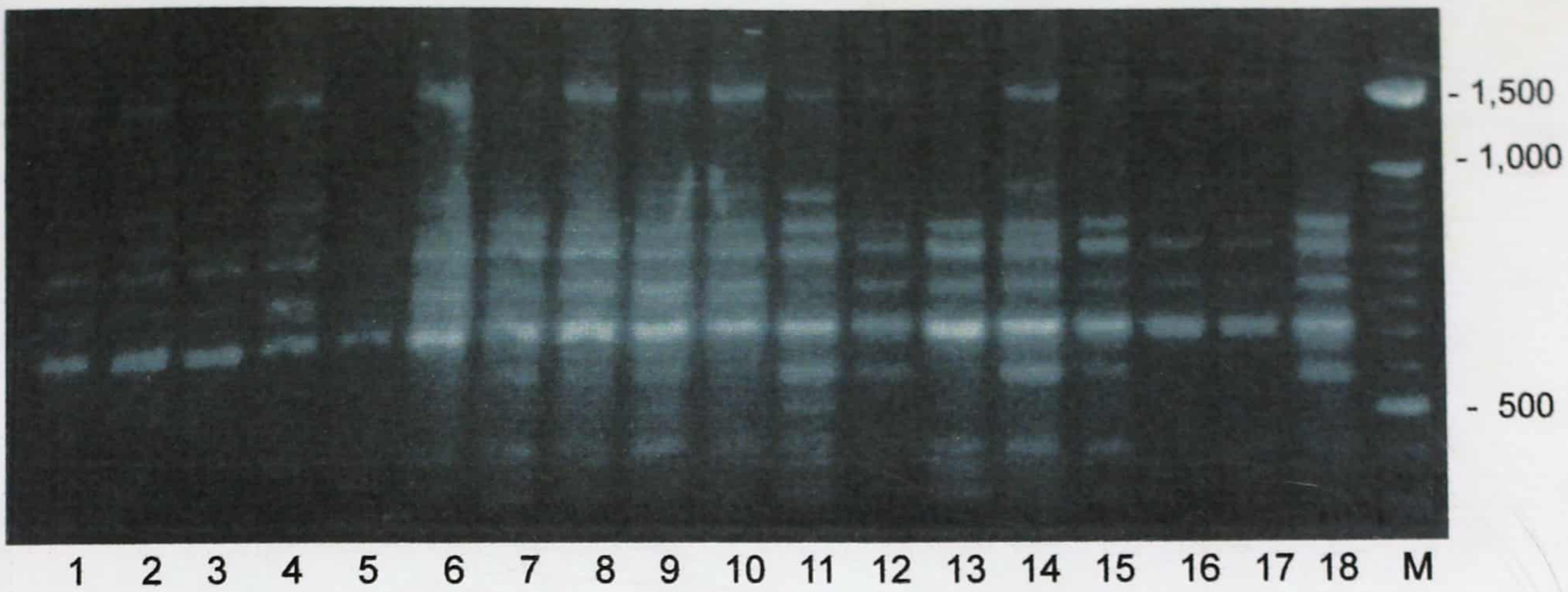


FIGURE 3: RADP pattern produced from DNA amplification of 18 Cassava accessions using Operon primer OPR-02.

M is a marker. Beginning from lane 1 to 18: WCH-040, TAKBOKYE, DMA-060, DMA-055, WCH-022, ASF-025, ASF-011, DMA-042, NKZ-030, DMA-014, DMA-002, DMA-041, ASF-029, DMA-030, NKZ-058, WCH-009, DMA-067, ASF-014

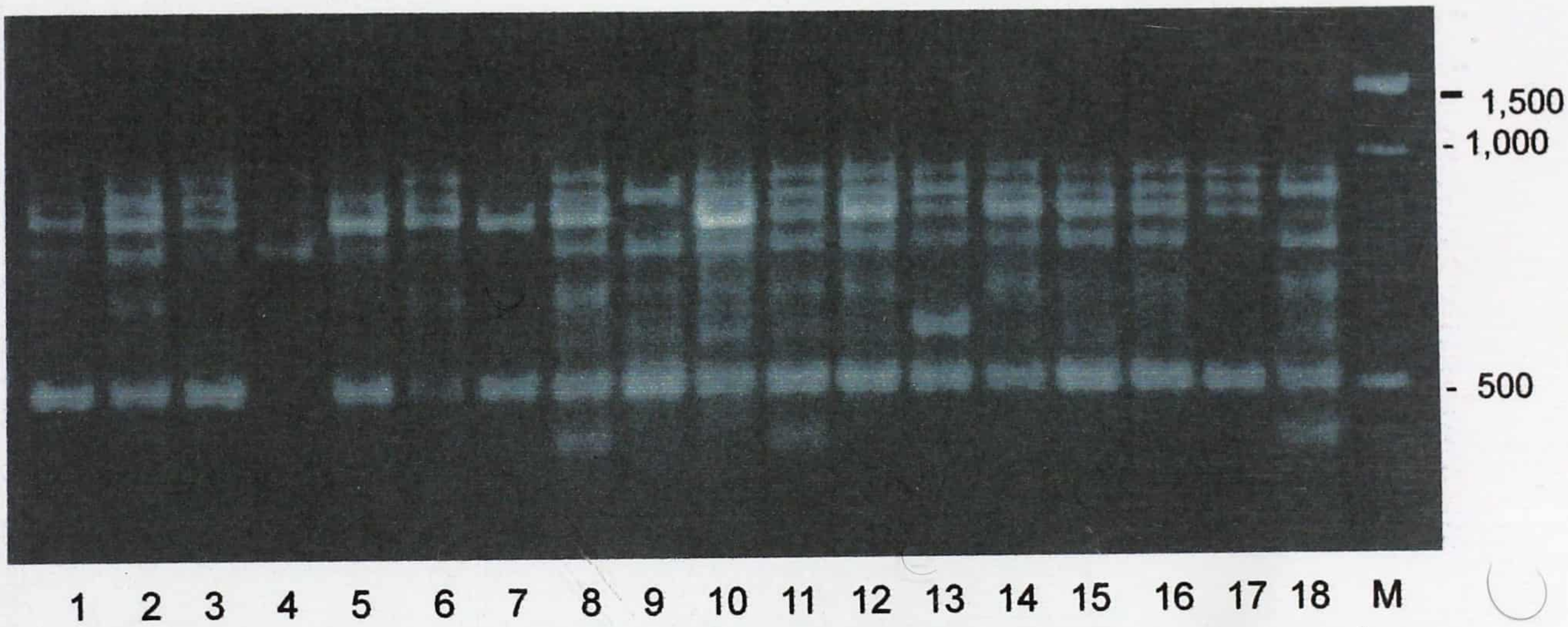


FIGURE 4: RADP pattern produced from DNA amplification of 18 Cassava accessions using Operon primer OPR-09.

M is a marker. Beginning from lane 1 to 18: WCH-040, TAKBOKYE, DMA-060, DMA-055, WCH-022, ASF-025, ASF-011, DMA-042, NKZ-030, DMA-014, DMA-002, DMA-041, ASF-029, DMA-030, NKZ-058, WCH-009, DMA-067, AFISIAFI.

None of the primers was specific for any of the accessions and none of the primers used could provide enough markers to discriminate between all of the 50 accessions. A total of 32 bands were polymorphic.

Data from the scoring of the bands (Pictures) (1, 2, 3 & 4) were subjected to UPGMA analysis using NTSYS – PC version 2.0. The Jaccard's Similarity Coefficient ranged from 93% for the most closely related accessions to approximately 53% for those most distantly related.

A phylogenetic tree (dendrogram) generated using UPGMA hierarchical cluster analysis based on the genetic similarity estimates separated the 50 accessions into six main clusters (Fig 3) with two subgroups each for Cluster II, III and IV at 67% Jaccard's Similarity Coefficient level.

These clusters are described below.

Cluster I

Cluster I consisted of only one accession ie. Accession WCH – 012. (1)

Cluster II

This was the largest group and comprised 37 accessions. There were two main subgroups (a) and (b), and each had two subgroups (a^1 & a^2, b^1 & b^2).

The composition of each subgroup (a & b) and the sub-subgroups (a^1 & a^2, b^1 & b^2) were: subgroup (a) consisted of 14 accessions with 6 accessions in sub-subgroup (a^1) and 8 accessions in sub-subgroup (a^2). Subgroup b had 23 accessions which further sub-divided into two subgroups b^1 & b^2. The compositions were: 10 accessions in sub-subgroup b^1 and 13 accessions in sub-subgroup b^2.

The dendrogram gave the following distribution in Cluster II.

Subgroup a

Sub-Subgroup a¹

1 – NKZ – 038 (2)

2 – NKZ – 009 (16)

3 – DMA – 059 (13)

4 – DMA – 067 (18)

5 – WCH – 009 (19)

6 – WCH – 022 (30)

Sub-Subgroup a²

1- ASF – 035 (3)

2 – WCH – 036 (7)

3 – DMA – 036 (5)

4 – DMA – 034 (9)

5 – WCH – 020 (11)

6 – NKZ – 025 (4)

7 – DMA – 029 (6)

8 – ASF – 027 (14)

Subgroup b

Sub-Subgroup b¹

1 – DMA – 024 (8)

2 – ASF – 018 (40)

3 – ASF – 002} (48)

4 – Abasafitaa} (49)

5 – NKZ – 058 (20)

6 – ASF – 011 (28)

7 – DMA – 002 (24)

8 – ASF – 014 (17)

9 – Tekbankye (33)

10 – WCH – 037 (43)

Sub-Subgroup b²

1 – NKZ – 030 (26)

2 – DMA – 003 (45)

3 – DMA – 042 (27)

4 – DMA – 064} (38)

5 – WCH – 027} (50)

6 - ASF – 025 (29)

7 – DMA – 011 (36)

8 – DMA – 027 (46)

9 – DMA – 069 (35)

10 – ASF – 030 (39)

11 – NKZ – 057 (42)

12 – Gblemoduade (44)

13 – NKZ – 015 (47)

Cluster III

Cluster III consisted of 3 accessions which formed two subgroups. Subgroup (a) had one accession, DMA – 009 (12), while subgroup (b) had 2 accessions VIZ. WCH – 024 (15) and DMA – 018 (37).

Cluster IV

In Cluster IV, two subgroups were also observed. They were composed of 7 accessions. Subgroup (a) comprised DMA – 030 (21), ASF – 029 (22), DMA – 060 (32), and WCH – 040 (34), while DMA – 041 (23), DMA – 014 (25) and DMA – 055 (31) formed subgroup (b).

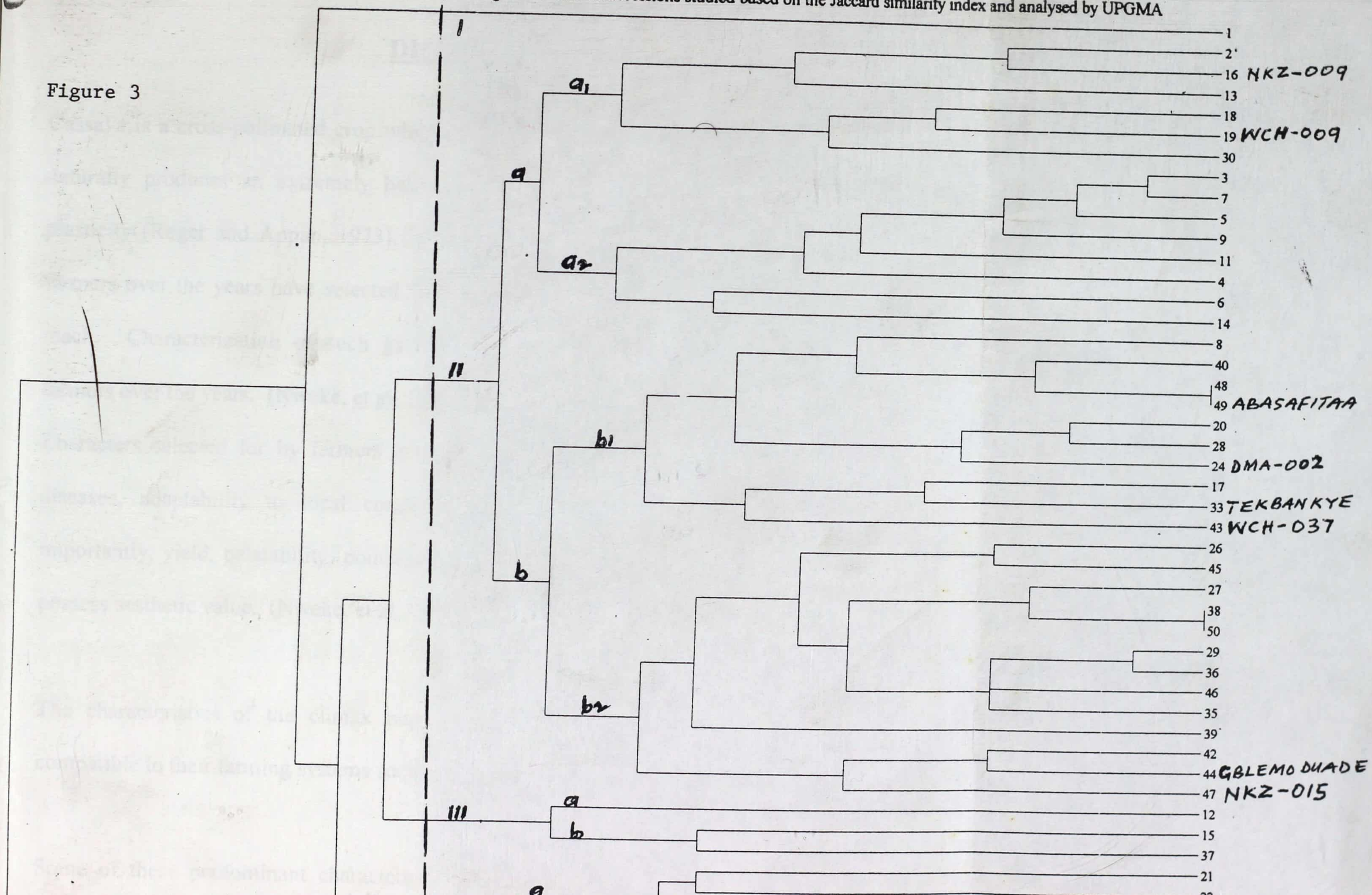
Clusters V and VI

These two clusters together consisted of two accessions, AFISIAFI (10) and ASF – 005 (41) respectively.

Numbers in brackets represent accessions on the dendrogram (Fig. 3) of percentage similarity among the 50 cassava accessions studied based on the Jaccard similarity index and analysed by UPGMA.

Dendrogram of percentage similarities (below axis) among the 50 cassava accessions studied based on the Jaccard similarity index and analysed by UPGMA

Figure 3



CHAPTER FIVE

DISCUSSION

Cassava is a cross-pollinated crop which is both monoecious and protogynous, hence it naturally produces an extremely heterozygous gene pool, allowing great phenotype plasticity (Roger and Appan, 1973). Climax populations represent the best genotypes farmers over the years have selected from the existing natural populations within their reach. Characterization of such germplasm therefore reveals traits selected for by farmers over the years. (Nweke, et al, 1994; Dixon, et al, 1992)

Characters selected for by farmers may include: resistance or tolerance to pest and diseases, adaptability to local conditions especially drought, earliness, and most importantly, yield, palatability, poundability (mealiness), as well as those cultivars that possess aesthetic value. (Nweke, et al, 1994; Dixon, et al. 1992)

The characteristics of the climax population also reveal what farmers consider as compatible to their farming systems such as branching and levels of branching.

Some of these predominant characters and how they fit into the traditional farming systems and farmers expectations of what they consider as "good" cassava varieties are discussed below:

5.1 VEGETATIVE CHARACTERS

The vegetative characters discussed here are: Stem Colour, Petiole Colour, Branching and Levels of branching.

Results on stem colour gave no clear pattern as all the stem colours occurred to have been selected for in all the districts. This is an indication that stem colour may not have been seriously selected for by farmers.

The results showed that about 90% of the germplasm had petioles with purple colour which implied that, this may have been preferred by farmers.

Petiole colour is a qualitative trait with little or no environmental effect. It is therefore a very useful trait to distinguish among accessions.

The implication is that over the years farmers have selected varieties with purple petiole colour and have rejected the other types. The probable reasons are that, aesthetically the purple petiole gives the impression of a healthy looking plant.

Secondly, the purple-petiole is the "Ankra-type", the commonest variety in the country which Ghanaian farmers associate with good cooking quality.

Another important vegetative character is the branching habit of a cassava cultivar which is also very important to a farmer as it relates to the type of farming system he/she may practice.

The results showed that approximately 90% of the cassava germplasm were branching types, an indication of farmers' preference for cultivars with this trait. But, with the type of farming system practised by most farmers in the country where cassava is intercropped with other crops, most commonly maize, one would have thought that farmers would

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select for the non-branching types which will not shade the other crops. The predominance of branching types implies that farmers take other characters into consideration in choosing varieties.

For instance, maize, which is the most common crop intercropped with cassava forms canopy quite early in the season and therefore makes the two crops compatible even if the cassava is a branching type. The other aspect of branching habit is the levels of branching which is a very useful qualitative trait for genotype identification and discrimination, and also greatly influences farmers choice of varieties. (Nweke, et al, 1994)

The data presented in Table 4.9 reveals that varieties with three levels of branching (about 40%) were most common on farmers' fields and that those with two or four levels (25% and 24% respectively) were equally acceptable to farmers, but non-branching (1.5%) or profusely branching types (2.6%) were unacceptable to farmers.

Cultivars that branch profusely are likely to branch at very low heights and would develop a thick and low canopy very early in the season. Even though such varieties would quickly suppress weed growth, they would however not be quite suitable varieties for the usual intercrop farming system practised by the farmers. It is also very difficult to undertake weeding or other cultural practices in such low branching types.

5.2 FLORAL CHARACTERS

Floral characters studied included the colour of sepals, colour of disc, colour of ovary and colour of anthers. The data collected on all the four variables did not indicate any clear pattern as all the traits for each of the variables were represented.

Since farmers invariably use cuttings or clonal materials for propagation of the crop, the floral characters bear little or no consequence to farmers' choice of varieties.

However, the fact that a large proportion of the germplasm were flowering types (about 90%) is an indication that new varieties could be generated on farmers' fields through cross-pollination.

The non-flowering types, on the other hand, face the danger or possibility of becoming extinct through genetic erosion or in the event of a devastating disease since they are unable to contribute to the creation of variability in the climax population.

5.3 STORAGE ROOT CHARACTERS

Root tuber yield and its characteristics are ultimately the most important goal of cassava breeding and also rank high in the choice of a variety by farmers. But yield is a quantitative trait which is influenced by many environmental factors.

However, there are some qualitative aspects of the root tuber such as the presence or absence of root stalk, orientation of the root tubers, storage root constriction, colour of outer surface of root cortex, storage root surface texture, and mealiness that influence farmers in deciding which variety they keep or throw away.

Thus they serve as important traits which influence farmers choice of cultivars.

5.3.1 POSITION OF ROOT AND ROOT STALK

The orientation of root tubers in the soil relates to the ease of harvesting, and the presence/absence of root stalk or "neck" influences the degree of damage caused to the tubers during severing from the stump at harvest. About 91% of the germplasm were observed to have spread their root tubers horizontally beneath the soil surface and 56% of them possessed root stalk or "neck".

The horizontally-oriented root tubers will be easier to harvest with the farmer's digging machete than those which grow vertically deep into the soil. Cultivars that produce root tubers that are oriented vertically into the soil invariably lack root stalk and are thus vulnerable to bruising during harvesting; whereas those that produce tubers horizontal to the soil surface and have "neck" make harvesting relatively easy and severing leads to little or no damage to the tubers. Such undamaged tubers are likely to generally store relatively longer than those without stalk.

5.3.2 STORAGE ROOT CONSTRICTION

This is an external root character that is used for cultivar characterization.

The results showed that nearly 83% of the cultivars produced smooth tubers rather than constricted ones. Root tubers with surface root constrictions reduce the market value of such tubers.

5.3.3 MEALINESS

The results in Table 4.20 showed that about 95% of the germplasm produced mealy tubers when cooked. Mealiness is the most important factor that determines whether farmers in most parts of Ghana will adopt a cassava variety or not (Nweke et al. 1994; Dixon et al. 1992) as only mealy cassava can be used in their popular traditional 'Fufu' and 'Ampesi' preparations.

It is important therefore that breeders are mindful of this important trait when carrying out research in cassava improvement programmes since acceptance or otherwise of cassava varieties hinges on this trait.

Other root characters that farmers select for are those that positively correlate with mealiness of the tubers when cooked. For example, surface root texture that is rough rather than smooth is often associated with good cooking quality.

Farmers will also keep a cultivar that produces tubers with pink outer surface of the cortex instead of cream or white, because the former is presumed to be mealy.

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5.4 RESISTANCE TO PESTS AND DISEASES

The discussion so far points to the fact that farmers make a conscious effort in selecting varieties based on their suitability for the farming system and cooking quality as the types with mealy cooking qualities and those compatible with the intercropping farming system predominated in the climax populations collected from farmers' fields.

When it comes to diseases particularly ACMVD, the picture is different. The results on ACMVD indicated that about 98% of farmers' cultivars were susceptible to the disease. This may imply that farmers make no conscious effort to select for disease – free planting materials.

The reason for this situation may be farmers' lack of appreciation of the detrimental effect of these diseases on yield. Consequently they may not practice crop hygiene or plant with disease-free planting materials, thus perpetuating the diseases in their farms.

To check this practice, researchers must clearly demonstrate to farmers the effect of diseases on yield before recommending to farmers the need to select for disease-free cuttings.

The other possibility is that farmers may have selected for disease and pest resistance cultivars, but with time these have succumbed to the disease as the disease pathogens accumulate with continued clonal propagation.

A system should therefore be developed to produce disease-free planting materials for distribution to farmers.

5.5 CLUSTER ANALYSIS

Exchange of cultivars among cassava farmers is a very common practice and since cassava is a cross-pollinated crop, new varieties are often generated on farmers' farm. A good cultivar identified by one farmer may soon end up on a different farm and given a different name at the new location.

The cluster analysis therefore serves as the first step in identification of such closely related genotypes leading eventually to the elimination of any duplicates in the germplasm. The dendrogram shown in Fig. 2 and Appendix I clearly showed that five clusters could easily be identified.

Accessions collected from the forest ecozone (ie. Dormaa and Asunafo districts) constituted nearly 70% of genotypes in Cluster III and IV and 100% in Cluster V, while those from the forest-savannah transition ecozone (Wenchi and Nkoranza districts) formed 65% of those in Cluster I.

Accessions from the two ecozones were almost equally represented in Cluster II.

It was interesting to observe also that all the IITA improved varieties including the mutant Tekbankye which also has IITA background appeared in the same cluster even at the first level of classification. This may be due to the possession of similar predominant traits, notably, cream root cortex colour, horizontal orientation of root tubers to the soil surface, non-constricted root tubers and branching habit.

5.6 MOLECULAR CHARACTERIZATION

The use of morphological characters in germplasm identification and discrimination is less reliable compared to molecular markers due to the effect of the environment on some of the traits.

Secondly, the long vegetative phase before attainment of reproductive stage of most perennial crops indicate that many of the morphological descriptors can only be assessed after a considerable number of years.

Molecular markers on the other hand are not subject to environmental influences and provide an opportunity to examine more precisely the genetic relationship between accessions (Bernatzky and Tanksley, 1989) by the use of any plant part irrespective of stage of growth, requires small amount of material and also makes the use of dry samples possible.

However, molecular characterization can only be supplementary to morphological approach since it is not very suitable for screening large samples, because high purity and expensive solvents are required. The techniques are also arduous and time consuming. For these reasons, only 50 accessions out of 177 accessions studied were selected from the five clusters obtained after subjecting the morphological data to cluster analysis (with each cluster adequately represented) were analysed at the molecular level via RAPDS technique.

A phylogenetic tree (dendrogram) generated using UPGMA hierarchical cluster analysis based on the genetic similarity estimates separated the 50 accessions into six main

clusters (Fig 3) with two subgroups each for Clusters II, III and IV at 67% Jaccard similarity coefficient level.

Clusters I, V and VI had one accession each.

Materials from the forest ecozone dominated in Cluster II, III and IV. It formed 62% in Cluster II, 67% in Cluster III and 86% in Cluster IV.

The implication of this observation is that most of the farmers cultivars are more adapted to the forest ecozone of the region. This is not entirely surprising because until recently cassava cultivation was rather restricted more or less to the forest ecozone of Ghana. Thus, the introduction of cassava to the forest-savannah transition ecozone in recent years through exchange of cultivars among cassava farmers from the two different ecozone may have resulted in a number of the cultivars unable to survive or become adapted to the relatively harsh weather conditions and other factors, such as, erratic rainfall, long dry season and annual bushfires in their new environment (ie forest-savannah transition ecozone).

This situation therefore calls for breeding for specific adaptations instead of blanket breeding for all ecologies.

Interestingly, except AFISIAFI, all the remaining IITA improved varieties including the mutant TEKBANKYE which also has IITA background appeared again in the same cluster (ie. Cluster II) at the second level of classification by RAPDs technique.

ABASAFITAA and TEKBANKYE were in sub-subgroup b^1, GBLEMODUADE in sub-subgroup b^2 of Cluster II, while AFISIAFI was the only variety that constituted Cluster V.

This observation, to some extent, is in corroboration with the outcome of the results of the morphological characterization where all the improved varieties were grouped in the same cluster.

However, unlike the first stage of classification in which TEKBANKYE, GBLEMODUADE and AFISIAFI were quite close, classification at the molecular level grouped ABASAFITAA and TEKBANKYE in sub-subgroup b^1, GBLEMODUADE farther down in sub-subgroup b^2 of Cluster II, while AFISIAFI alone formed Cluster V on the phylogenetic tree (dendrogram Fig 3).

This shows that ABASAFITAA and TEKBANKYE were more closely related. Morphologically, they both have light brown stems, brown and smooth storage root surface texture and the outer surface of the root cortex is cream. They also produced smooth or non-constricted root tubers which were oriented horizontally to the soil surface and were mealy when cooked. Another observation was that eventhough the five elite accessions which have been selected for further evaluation were grouped in Cluster II, they fell into different subgroups.

The accessions, NKZ – 009 and WCH – 009 were in sub-subgroup a^1, DMA – 002 and WCH – 037 in sub-subgroup b^1 where ABASAFITAA and TEKBANKYE were grouped, while NKZ – 015 was grouped in sub-subgroup b^2.

The accessions NKZ – 009 and WCH – 009 were therefore closely related.

They both commonly had the following morphological traits: purple petiole colour, light green leaf initials, same branching habit, presence of root stalk and the production of smooth tubers. Others were: horizontal orientation of root tubers in the soil, brown and rough storage root surface texture and poundable (mealy) root tuber.

It was also observed that DMA – 002, WCH – 037, ABASAFITAA and TEKBANKYE were also closely related, indicating that DMA – 002 and WCH – 037 had the same common traits as those listed earlier for ABASAFITAA and TEKBANKYE.

The accessions NKZ – 015 and GBLEMODUADE, on the other hand were found to be more closely related. The morphological traits common to both were: Green purple petioles, same branching habit, non-constricted root tubers, horizontal orientation of tubers in the soil, brown root surface colour and white being the colour of the outer root cortex.

The results from the RAPD analysis carried out on the 50 cassava accessions indicate that the accessions were closely related based on their similarity coefficients. However, the accessions in group I and III are fairly genetically distantly related at Jaccard's similarity

coefficient of 53% and hence could be selected for further breeding programme to maximise variability.

ETHNO – BOTANIC INFORMATION

Exchange of cultivars among cassava farmers is a very common practice. A good cultivar identified by one farmer may soon end up on a different farm and given a different name at the new location. Some of these local names give indication of the special or unique features of the new cultivar in its new location. Such features may refer to (i) morphological characteristics, (ii) the yielding potential of the cultivar, (iii) the tuber characteristics, (iv) the use to which the tuber is put, and (v) the economic importance of the cultivar in its new area.

It was therefore of interest to collect information on the local names of the varieties and their meaning.

A few examples of some of the accessions whose local names provide some ethno-botanic information as were given by the farmers are discussed here.

ACCESSION	LOCAL NAME	TRANSLATION	IMPLICATIONS
(1) DMA – 001	Bankye-Broni	Cassava which is like a 'a whiteman'	It refers to aesthetic value of some morphological parts which may be the stem or petiole colour
(2) DMA – 003	Tu-gyabi - tuntum	Remove some tubers and leave some and the outer surface colour of the tubers/stem is BLACK.	High yielding, so harvesting by periodic removal of tubers is recommended. It also indicates that BLACK is the colour of the outer surface root cortex or the stem
(3) DMA – 007	Tu-gyabi – koko o	Harvest some of the tubers and leave some, and the outer surface of the tubers/stem is RED.	Has the same morphological and agronomic traits as DMA – 003 above except that the colour of the outer surface root cortex or the stem is PINK instead of BLACK.
(4) DMA – 015	Bokentema	Tuber yield of one plant fills a basket	Very high yielding with tubers filling a basket to the brim.
(5) DMA – 016	Nfiemienu – bankye	Two years Cassava	The cultivar takes two years to reach maturity, ie. a late maturity type.

	ACCESSION	LOCAL NAME	TRANSLATION	IMPLICATIONS
(6)	DMA – 019	Kowoka	Settle your debt	High yielding which translates to high income for settling debt.
(7)	DMA – 020	Bankye-fitaa	White – Cassava	Possesses white petioles or stems or "White" is the colour of the outer surface of the root cortex.
(8)	DMA – 023	Bankye-Nkanfoo	Cassava that is like D. dumentorum yam	The root tuber flesh is yellowish or tastes like Dioscorea dumentorum.
(9)	DMA – 033	Bosome Nsia	Six months Cassava	This is in reference to earliness. Harvesting can be effected 6 months after planting
(10)	DMA – 040	Mma-duasa	Thirty children	Yield inclined. Produces many tubers
(11)	DMA – 044	Kronfoo mmpe	The thief does not like it.	Does not attract pilfering. This may be attributed to its high Cyanide content (bitterness), poor cooking quality, or low yield potential
(12)	DMA – 057	Bankye pampro	Cassava that resembles bamboo	Height is most probably the trait being referred to and means that the cultivar is as tall as a bamboo plant.
(13)	DMA – 067	Bankye flowers	Cassava that looks like flower	The local name talks about aesthetic value or the cultivar flowers profusely.

ACCESSION	LOCAL NAME	TRANSLATION	IMPLICATIONS
(14) WCH – 004	Baatia	Short lady	It is referring to the morphology of the plant, which in this case is its "shortness" but also looks as beautiful as a lady.
(15) WCH – 005	Bankye-borodee	Cassava – plantain	This is talking about the tuber flesh colour which it is claimed to be similar to that of the plantain fruit – ie. yellowish.
(16) WCH – 007	Tua-kentema	Fills a basket when harvested	Very high yielding cultivar
(17) WCH – 021	Tete-bankye	Olden days Cassava	The cultivar was introduced into the traditional farming system long ago.
(18) WCH – 023	Kumkom	Kills hunger	Very high yielding and as such prevents famine.
(19) WCH – 027	Hani-bankye	Hunter's cassava	This may refer to the sweetness of the tuber such that it can be consumed raw by the hunter who has no time or place to cook.
(20) WCH – 037	Alata-bankye	Cassava from Nigeria	Meaning it was introduced into the country from Nigeria.
(21) WCH – 038	Bankye-soja	Cassava resembling a soldier	The plant is erect and probably non-branching type.

ACCESSION	LOCAL NAME	TRANSLATION	IMPLICATIONS
(22) WCH – 039	Bankye-nkyim-kyim	Contorted cassava	Two meanings can be read from this; (i) the stem having contorted appearance, or (ii) the root tuber is constricted at many points.
(23) NKZ – 005	Ampe nkyere	Does not like salt	Refers to the sweet taste of the roots and therefore do not require the addition of salt during cooking.
(24) NKZ – 007	Asitrodoo	Very erect cassava	The plant is erect and firm. It is therefore not prone to lodging.
(25) NKZ – 010	Awesewa	Dwarfish	Smallish and beautiful. This may refer to the morphology of the plant structure or the root tubers.
(26) NKZ – 018	Yemma wo	We won't give you	Because the tubers possess excellent cooking qualities, its planting materials (cuttings) are guarded jealously.
(27) NKZ – 020	Mensuhia	Don't complain of poverty	For poverty alleviation because of its high yielding characteristics.
(28) NKZ – 042	Ahenewa	A young Queen or King	This refers to the aesthetic nature of the cultivar.
(29) ASF – 002	Bogyimi	Yields like a fool	The yield is overwhelming

	ACCESSION	LOCAL NAME	TRANSLATION	IMPLICATIONS
(30)	ASF – 007	Dabo-dabo kote	Like a Duck's penis	Produces constricted root tubers.
(31)	ASF – 008	Bankye-nanka	Snake-like cassava resembling the Viper	The tubers are quite long and big.
(32)	ASF – 010	Bankye-Ababaawa	Cassava which is like a beautiful young lady	Plant/tuber very beautiful
(33)	ASF – 014	Bankye-Abrodwomaa	Cassava which is similar to sweetpotato	The tubers taste like sweetpotato
(34)	ASF – 023	Edabowo	Still wearing the old scalf ?	Farmers will keep cultivars with stable cooking qualities.
(35)	ASF – 030	Edasobowo	Are you still wearing the old scalf?	Same as ASF – 023 above. Probably due to its stable cooking quality.
(36)	ASF – 031	Bankye-Hemaa	Cassava whose beauty equals a Queen	It is as beautiful as a Queen. It has an aesthetic value.

1. It can be deduced from the foregoing that the main features that farmers consider in naming cultivars include: (i) Vegetative characters such as the colour of petiole and stem and the structure (height) of the plant; (ii) the storage root characters, namely, the yield, tuber shape, size, smoothness or otherwise of tubers and the colour of the outer surface of root cortex, as well as the taste of the raw or boiled root tubers

   (iii) the economic value of the cultivar in terms of the income derived from the sale of the fresh or processed root; (iv) the aesthetic value of either the shoot or root tuber.

2. The importance of this ethno-botanic information is that it can give a breeder an insight into what to expect in a local germplasm collection. It also assists in the identification of some useful traits that some of the cultivars possess even before subjecting the germplasm to a scientific study.

   It also reveals the selection criteria of the farmers.

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CHAPTER SIX

CONCLUSION

This study has confirmed the fact that germplasm evolution is constantly taking place on farmers' fields and that the climax cultivars seen on farmers' fields are a result of years of selection by farmers.

The study also revealed that Ghanaian farmers do not put much emphasis on selecting for disease and pest resistance, but rather on the suitability of the cultivars for their farming system and meal preparation.

That may explain why they would not accept varieties that are high yielding and resistant to diseases but do not have acceptable cooking quality.

The implication of this observation is that breeders should, from now on, give more attention to cooking quality in any cassava improvement programme.

The study also showed that cluster analysis in germplasm characterization using morphological data can be an effective tool in establishing relationships between cultivars and in eliminating duplicates.

The molecular characterization via RAPDs technique was very effective in showing the relatedness of the accessions and greatly contributed in discriminating among the germplasm and that it should be used as supplementary to morphological characterization.

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