KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY, KUMASI

COLLEGE OF AGRICULTURE AND NATURAL RESOURCES

FACULTY OF AGRICULTURE
DEPARTMENT OF CROP AND SOIL SCIENCES

THE EFFECT OF TYPE OF MOTHER YAM AND BOTANICAL EXTRACTS ON THE PERFORMANCE OF THE YAM MINISETT

BY

KWADWO OSEI-SARPONG

MAY, 2009.

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A Thesis submitted to the School of Graduate Studies, Kwame Nkrumah University of Science and Technology, Kumasi, in partial fulfillment of the requirements for the Award of MSc. Agronomy (Plant Breeding option) degree.

KWADWO OSEI-SARPONG

MAY, 2009.

CERTIFICATION

This is to certify that this research work presented in this thesis was carried out by Mr. Kwadwo Osei-Sarpong, Department of Crop and Soil Sciences, Faculty of Agriculture, College of Agriculture and Natural Resources, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana and has not been submitted to any other University for a degree. It is entirely the candidate's own account of research except for the references cited.

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ABSTRACT

The objective of the study was to investigate various modifications of the minisett techniques including the type of mother yam used, age of mother yam and the effect of leaf extracts of *Croton aromaticus* and *Averrhoea bilimbii* on the sprouting of minisetts from the two rotundata yam varieties.

In experiment 1, 5% leaf extracts from *Croton aromaticus* and *Averrhoea bilimbii* was used to treat minisetts from the anterior, middle and posterior portions of *Pona* and *Laribak*o. The minisetts were nursed in baskets and on seed bed and were observed for sprouting and rot for six weeks.

In a second experiment, different ages of *Pona* and *laribako* white yams (ware, milked and regenerated mother yams) were compared with water yam in terms of sprouting capabilities. All the different varieties with the different ages were cut into setts between 80gm - 100gm, treated with insecticide,fungicide and woodash. Air dried overnight, nursed in the seed boxes and watered as and when needed. Data on sprouts or rots were recorded every two weeks.

Results from the experiment1 showed that *Croton aromaticus and Averrhoa bilimbii* leaf extracts influenced sprouting in a varied pattern for the different parts of the varieties used. Sprouting had significant increase, insignificant difference or no response due to rot.

In experiment 2, Milked and regenerated mother yams gave higher sprouts than ware mother yams. The regenerated yam compared favourably with the control, *D. alata* in terms of their sprouting ability. Younger regenerated and milked yams had more buds concentrated on the head, middle and tail regions in that descending order as against the ware yam. In terms of variety there were differences in terms of bud count and sprouting.

Laribako and *D. alata* had the highest number of buds and sprouts more and early than *pona*.

Finally, a partial budget analysis of the improved minisett technology compared to the farmers' practice showed that, improved minisett technique was more profitable.

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DEDICATION

This thesis is dedicated to the Almighty God, Alpha and Omega, Jehova- Overdo who has brought me this far and to my dear and lovely wife, Mrs. Agnes Owusu Sarpong who stood solidly behind me through thick and thin during my studies.

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CHAPTER ONE

1.0 INTRODUCTION

Yam (*Discorea spp*.) is a major staple in West Africa, where it provides food for over 60 million people (Nweke *et al.,* 1991). The West Africa yam belt, which stretches from west of Cameroun mountains to the Bandama river in central Cote D'Ivoire (Coursey, 1967; Hahn *et al.,* 1987) produces 95% of the annual world output of 33 million metric tonnes. In terms of magnitude of production, yam ranks second only to cassava among root and tuber crops. Of the edible yams known, the most popular and preferred yams in order of importance in West Africa are *D. rotundata, D. alata, D. cayensis, D. dumentorium, D. bulbifera and D. esculenta* (Annuebunwa *et al.,* 1998). The white yam, *D. rotundata*, is by far the most preferred in Ghana.

However, yam production is cost intensive compared to other root and tuber crops. According to Annuebunwa *et al.* (1998), seed yams alone constitute 30-50% of the total production cost. Acquah and Evange (1994) identified the high cost of "Pona" seed yam as one of the factors militating against increased production of "Pona" ware yams.

Therefore Gebremeskel and Oyewole (1987) concluded from their work on planting material production that improving planting material production and reducing damage by pests and diseases could increase future production of yam.

Despite the role of yams as a staple in the African continent, Asiedu *et al.* (1998) reported that yam production has received less research attention than it is appropriate for a staple crop. This was attributed to several factors including the following;

- Bulkiness and perishability of tubers. This is due to the fact that planting materials for production of ware yams are derived from the edible portion of the tuber which

is expensive and bulky to transport.

- Low multiplication rates. The multiplication ratio in the field is very low (1: 10) compared, for instance, to some cereals (1:300). These propagules could also serve as sources of virus diseases, nematodes, and fungi unless appropriate measures are taken.
- Long dormancy period (with respect to cropping cycles)
- Phytosanitary restrictions limiting germplasm exchange

The main obstacles encountered in sexual hybridization of yam for genetic improvement include the scarcity of flowering, poor synchronization of male and female flower phases and lack of pollination mechanisms.

Advances have been made in studies of reproductive biology of yam, especially at the Central Tuber Crops Research Institute (CTCRI), Trivandrum, India, and IITA, Ibadan, Nigeria (Abraham and Nair, 1990; Akoroda, 1983, 1985a; Sadik and Okereke, 1975). However, further work is needed to ensure that the genetic diversity locked up in non-flowering desirable genotypes is exploited. Flowering genotypes like *D.* alata, *D. bulbifera, D. cayensis* and *D. rotundata* are genetically dioecious: female flowers tend to be more limited than male, especially for *D. alata* (Martin, 1976) and sterility is quite common. The few yam breeding programmes reported in literature have relied on selections from landraces, and hybridization of desired genotypes within and between species (Abraham *et al.*, 1986; Doku, 1985), without the benefit of the predictive value of knowing the genetics of the characteristics being sought from species that are predominantly complex polyploids.

Therefore the development of the minisett technique by NRCRI,Umudike Nigeria, and popularized by IITA in 1983 was a major breakthrough to some of the problem of the seed-yam. The minisett technique has the following economic potentials:

- It increases net returns by increasing the number of sett to seed yam ratio by about ten times compared with the traditional method (IITA, 1982).
- It is often a quick method of multiplying elite varieties through tissue culture.
- It is also a quick way of multiplying elite varieties generated from breeding programmes.
- It offers the opportunity of optimizing sett sizes to produce predetermined sizes of ware yams for export.

Despite these advantages, farmers adopted the technique only to a small extent, below 40% (Ogbodu, 1995). This was due to:

i. The differential sprouting of the yam tuber and the drudgery associated with the technique (Ndzana *et al.*, 1999).
ii. Some *D. rotundata* spp (Kpuna and Laribako) which are mostly preferred in Ghana and therefore a delicacy to all consumers who use them as "ampesi" do not respond normally to the minisett technique.

This therefore makes the technique commercially non-viable due to the wide variations in time and sprouting rates along the different portions (head, middle, tail) of the tuber, that is sprouting along the tuber is not uniform (Okoli and Igwilo, 1988).

The Root and Tuber Improvement Programme (RTIP) also dealing with resource- poor farmers has shown concern for the low adoption of the yam minisett technique and has

requested for some improvement of the technique for easy adoption.

Traditionally farmers obtain planting materials for yam by pricking or carefully removing partially matured yam (referred to as milking) and leaving the plant to grow for about a month or two to produce an amorphous structure before harvesting. They may also cut the smaller ware yams to plant or whole tubers are cut into pieces and planted. The question one may ask is "could the use of the amorphous structure (regenerated yam) produced after "milking" give an enhanced response and therefore easy and ready adoption to the minisett technique?". If yes, what characteristics of it could be responsible? Could it be because it has more buds, light periderm to encourage easy sprouting or some hormonal influence on the head? These questions need to be investigated.

A number of investigations by scientists working to improve *D. rotundata's* response to the minisett technique have attempted the following methods:

The use of growth regulators (Benzylaminopurine [BAP], Indole acetic acid [IAA], Naphthalene acetic acid [NAA]) to induce sprouting and rooting in yams. The effects of the medium of growth and other agronomic practices on the sprouting of yam have also been successfully investigated (Okwor and Asiedu, 1977).

Averrhoa bilimbii and *Croton aromaticus* leaves, which are common floricultural plants, are believed to release ethylene and can therefore be used to induce sprouting in yam (Bakar *et al.*, 1999). However, a question that needs to be answered is "can the resource-poor farmer access or afford the practice of using expensive growth regulators and thus adopt the tedious agronomic practices involved?

Regenerated yam is used in Benin as yam setts by farmers (Personal communication with

Maroya, GTZ Scientist, 2002). Ghanaian farmers also use the same regenerated yam and/or the ware yam as seed yam. However, the various factors that may influence the efficacy of the type of mother yam used have not been investigated.

This work was undertaken to investigate into various modifications of the minisett technique including the type of mother yam used, the level of maturity of the mother yam and the effect of leaf extracts on the sprouting of the minisetts.

Investigation into the profitability of various methods (Traditional and Improved) of yam planting material production was also undertaken.

The specific objectives of the study were to:

1. Determine the effect of leaf extracts of *Croton aromaticus* and *Averrhoea billimbi* on the sprouting ability of yam minisetts.
2. Determine the effect of bud structure and numbers on sprouting of minisetts.
3. Compare ware yam and regenerated yam for the production of minisetts.
4. Compare the economics of the Traditional and the improved systems of yam production.

CHAPTER TWO

2.0 LITERATURE REVIEW

2. 1 Origin and distribution

Yams are members of the genus *Dioscorea*, which produce edible tubers. They are monocots, despite occasional evidence of a second cotyledon (Lawton and Lawton, 1969). Various species of food yams are cultivated in the tropics and sub-tropics (IITA, 1992). The six most economically important species grown as staple foods in Africa are *D. rotundata* Poir (white guinea yam), *D. cayenensis* Lam (yellow yam), *D. alata* L (water yam), D. *dumentorum* (Kunth) Pax (bitter yam) *D. bulbifera* L (aerial yam) and *D. esculenta* (Chinese yam) (Onwueme, 1978). These six species constitute over 90% of the food yams produced in the tropics (Hahn *et al*. 1987).

In West Africa, man began to gather yams for domestic use as early as 5000 BC, i.e. during the Paleolithic era (Davies 1967). Agricultural archaeologists estimate that true yam-based agriculture started in West Africa approximately 3000 BC, the same time it started in South East Asia (Alexander and Coursey, 1969; Coursey, 1967; Davies, 1967). The earliest domesticated yams in West and Central Africa included *D. rotundata*, *D. cayenensis*, and *D. dumentorum* whilst in South East Asia, *D. alata* was the first species cultivated (Coursey 1967, Onwueme 1978). The occurrence of large number of cultivars of *D. rotundata* arising from thousands of years of domestication and culture of this species in eastern Nigeria (Uzozie 1971, Coursey 1976), lends support to the belief that *D. rotundata* is native to Nigeria, with its most probable place of origin at the eastern banks of the River Niger where it is the most preferred food crop (Hahn et al 1987, Orkwor 1992).

D. esculenta (Chinese yam) has its origin in Indo-china. Chinese farmers have the longest production culture, dating back eighteen centuries. It is an important food in South East Asia, Indonesia, the Philippines and in the South Pacific Islands down to New Guinea.

The aerial yam *D. bulbifera* originated both in Africa and Asia and spread to the other parts of the world. Nigeria alone accounts for 69% of world yam acreage and 78% of world production (Onwueme, 1977).

The spread of yam, particularly *D. alata* from South-East Asia to Africa (Hahn et al 1987) is believed to have occurred by the intervention of early agriculturalists and more recently by Portuguese and Spanish seafarers (east-west movement).

Although there is an extensive cultivation and use of *D. alata* in the West Indies, these cultivars appear to have arrived in the West Indies from Africa. The African species, *D. rotundata* and *D. cayenensis* were taken westward to America and have now become important food crops in South and Central America and the Caribbean (Hahn et al 1987).

The Niger and Benue river belts in Nigeria have the largest genetic base in cultivated *D. rotundata*. The *D. rotundata* is however cultivated in the West Africa zone/belt which stretches from west of the Cameroon mountains to the Bandama river in central Cote d'Ivoire (Coursey 1967, 1976, Hahn et al 1987). This yam zone comprising Nigeria, the Republic of Benin, Togo, Ghana, Cameroon and Cote d'Ivoire produces about 95% of the total world yam production estimated at 30.2 million metric tonnes in 1997 (Table 1) (FAO, 1998).Currently the Asiatic yams, especially *D. alata* and *D. esculenta* are distributed widely in Africa. *D. alata* is now a major staple food in Cote d'Ivoire where it constitutes 65% of the yams grown in the country (IITA 1995). In Nigeria *D. alata* comes second to *D. rotundata* in production and consumption. In West Indies, Papua New Guinea

and New Caledonia, *D. alata* is the major food yam grown and consumed by the people. Similarly African food yams *D. rotundata* and *D. cayenensis* are widely grown in the Caribbean (Hahn et al, 1987).

West Africa is believed to be the home of yams due to the fact that more yams are produced and consumed in this sub-region especially Nigeria. Clearly yams are produced and eaten in three continents: Africa, Asia and South America especially North Eastern parts of Brazil and the Caribbean Islands and South Pacific.

In Ghana, the yam-growing belt is very narrowly delimited within the derived savannah area. The most important areas where yams are grown commercially are Berekum-Wenchi districts, covering Banda, Techiman, Kintampo, Nkoranza and Atebubu districts in Brong-Ahafo region; Northern Ashanti (Mampong and Ejura districts); Gonja and Dagomba districts; Bimbila in the Northern region; Mankessim and Bawjiase in the Central region; Asesewa in the Eastern region and Karachi, Kpando in the Volta region (Owusu and Ofori, 1969).

Cultivars grown in Ghana

Species predominantly grown Ghana are the white yams *D. rotundata*, Bulbil bearing yams (*D. bulbifera*), yellow yam (*D. cayenensis* and *D. alata* (Irving 1969).

The cultivars grown have significant differences that separate them into varieties. These cultivars have local names in northern Ghana, some of which are “Laribakor” “Pona” “Dundubanza” “Chenchito” “Sola” and “Tantapurika” (Kuma *et al*, 1979). In southern Ghana, these same varieties are called “Bayere fufuo” (Twi); “Yele” (Ga) ; “Ete” (Ewe); and “Etwo” (Fante).

Ecological areas and characteristics of varieties grown

D. rotundata is specially suited to the environmental conditions of northern Ghana, characterized by light sandy soils in the transitional or derived savannah vegetation zones. The plant takes about eight months to mature. The stems and leaves are hairless. The skin of tuber is smooth and brown, while the flesh is usually white and firm.

The cultivar, *D. alata,* which is more fibrous, coarser and poorer in quality than the white and yellow yams, produces large late maturing tubers. These tubers are not poundable into fufu because of its high water content. The tubers appear soft, and drops of water appear on the surface when cut, hence the name "water yam" (Irving, 1969). This species which is locally known as "Afasew" (Twi) matures in about eight to ten months (Doku, 1966).

The yellow yam, *D. cayenensis*, in many respects, is similar to the white yam except that it produces yellow flesh tubers which are poorer in quality than the white yams and do not store well. The yellow colour of its flesh gives it its common name, "yellow yam" although variants, which are almost white in colour, do occur. This yellow colour is due to the presence of carotenoids (Onwueme, 1982). The tuber skin is firmer and less extensively grooved than that of *D. rotundata*. The corm at the head of the tuber is also massive. Physiologically, *D. cayenensis* differs from *D. rotundata* in having a shorter period of dormancy and a longer growing season. Thus it can only be grown in areas where the rainy season is slightly longer than the minimum required for *D. rotundata*. It takes about twelve months to grow and mature. This species of yam will grow for as long as three years if they are continually milked. Yellow yam is locally known by different names such as "Afunu" (Twi); "Esiem" (Fante); "Nkani" (Akuapem). (Akoto and Safo Kantanka, 1987).

2. 2 Importance of yams

The heart of yams importance is in the excellent eating quality of the tubers. Food prepared from yam is always preferred at social gatherings.

Yams are excellent sources of carbohydrate energy. They provide 200 dietary calories per day to over 60 million people. They are also relatively nutritious, providing some vitamins (including vitamin C), minerals and dietary protein (Bradbury and Holloway, 1988), (refer Table 3). Virtually, all of the world's yam production is used as food in contrast to other root crops e.g. cassava and sweet potato, which are also used for livestock feed.

A consequence of the popularity of yam as food is that farmers always have considerable confidence that cash income can be obtained from yams, in addition to direct use by the family. Additionally, yams play a significant role in African socio-cultural traditions.

This role is not unique to West Africa. In various parts of Oceania, similar ceremonies and customs involving yams are an integral part of yam production. Notable in West Africa is that, the commercial importance of the crop has not eroded its traditional status. This co-existence of traditional food security and food business with respect to yam production illustrates that the strength of the long-standing tradition does not impede the realisation of changes that relate to the crop's commercial value. An example is the widespread marketing of ware yam tubers which are easy to handle, transport, and sell because price per tuber suites a wider range of potential buyers. Along side this; the production of very large tubers for ceremonial purposes continues (Quin, 1998).

2. 3. 0 Uses of yam

The importance of yams in the West Africa yam zone is due to the fact that for several decades, before the introduction of maize and cassava, yam was probably the main sustenance for the people (Onwueme, 1978; Coursey, 1976). The greatest competitor to yams has been cassava, which was introduced into the yam growing zone in the 16th century from South America (Carter *et al.*, 1992); Mankind has therefore been using the yam for food since time immemorial and is still used extensively. It is an important staple food. It is also considered as a man's crop as it has ritual and socio-cultural significance. It is the food of choice at many ceremonies and festivals, and an indispensable part of bride price (Hahn *et al.*, 1987).

The uses of yams can be categorised into alimentary; non-alimentary and industrial uses.

2. 3. 1 *Alimentary uses*

The food value is based on the carbohydrate, protein, amino acids, vitamin and mineral content of the tuber (Degras, 1993).

Based on this, different food preparations are prepared in combination with other foods.

In Guyana, cultivars whose tubers contain anthocyanin are used to prepare beer (Grenand, 1980). In the Philippines, the most popular preparation is ice cream made with purple *D. alata* in addition to "guinatan" jellies and yam based candies (Brown, 1951). In their wild state, the *Dioscorea* are part of the diet of omnivorous and vegetarian burrowers of the humid tropics. Yam peels are more commonly used today to feed livestock on family-run farms. Yam can also be processed into flour, crisp, chips or cubes and flakes in addition to common "ampesi" and "fufu", a traditional preparation of elastic, jellified, very dense paste that is obtained using pestle and mortar (Onyia *et al.*, 1987). There are some species

with high productivity but whose use may sometimes be problematic due to the presence of toxic substances in the tubers. For example, Sulit, (1967) proposed the detoxification of *D. hispida* using brine or alcohol followed by processing into starch paste.

2. 3. 2 ***Non-alimentary uses***:

The direct role of the yam as food is paradoxically completed by the use of its toxic products for hunting (Coursey, 1967). Wild species like *D. dragena, D. rupicola* and *D. piscatorum* are used for arrow poisoning and bait. The alkaloids, saponins that they contain have convulsive, paralysing or haemolytic effects. Certain yams are also used in human toxicology, such as an ordeal poison in criminal poisoning. Chevalier (1936), mentions *D. latifolia var contralatrones* as a type of repellent in plots of edible homomorphic cultivars. The toxicological properties of some yams used as insecticides for example are comparable to those of rotenone. For example *D. piscatorum* is used to protect rice in Malaysia and *D. deltoidea* is used for producing anti-lice shampoos in India (Coursey, 1967). Yam contains hormone diosgenin and has therefore become the predominant source for birth control pills (Crabbe, 1979).

2.4.0. **Seed yam production techniques**

Seed yam refers to the planting material derived from the tuber. It could be a small whole tuber with weight ranging from 15g to 95g (mini tuber); a tuber ranging from 150 to 250g (normal seed yam) or a tuber 500g to 1000g (large seed yam for the production of ceremonial large tubers (5 -10kg and above) or even cut setts of whole tubers.

A major constraint in yam production has been the requirement of large quantities of planting materials on a per hectare basis. As many as 10,000 normal seed yams are

required to plant one hectare, in order to produce an economic quantity of ware yams. The scarcity and high cost of purchasing seed yams aggravates this problem.

2. 4. 1 Traditional methods of seed yam production

Traditionally, the farmer sets aside as much as 30% of the harvest, usually small sized tubers (200g to 1000g) as seed yams for the next cropping season. It has been estimated that planting materials constitutes over 33% of the cost out-lay in yam production. This limits the size of yam farms under the traditional cropping methods. Another method involves cutting up an average sized seed yam into setts of about 80g to 100g (Orkwor, Asiedu and Ekanayake, 1998).

2. 4. 2. Improved methods of seed yam production.

2. 4. 2. 1 *Partial sectioning technique*

Nwosu (1975) introduced this partial sectioning technique at National Root Crops Research Institute (NRCRI), Umudike, Nigeria. An average sized seed yam of 300g to 400g is selected and decapitated to remove the apical dominance. The tuber is sectioned into partially cut setts using incisions that are 1cm deep to mark out sett areas of 3cmx3cm on the tuber. The sectioning is first done longitudinally and then horizontally.

The sectioned tuber is buried whole in a fertile soil, compost mixture or moist sawdust. The incision parts will sprout with vigorous roots arising from the base of the sprouting points. The sprouted sections are cut out from the sprouted body and planted in the field. The unsprouted sections are reburied until they sprout. Though tedious, this technique

doubles the multiplication rate to 1:10 over the traditional rate of 1: 5. This technique is labour intensive since it requires considerable manpower for the repeated examining and digging out of tubers to excise sprouted sections for transplanting in the field. The seedlings thus sprouted are delicate and require careful handling, a method best suited for research stations.

2. 4. 2. 2 *Minisett and microsett techniques*

The National Root Crop Research Institute, (NRCRI) Umudike successfully developed the yam minisett technology for rapid, high volume seed yam production (Okoli *et al.*, 1982). It involves the use of 25gm sett sizes and it is an appropriation of the Anambra state traditional farmers sett production method. Accompanying this technology was the development of a yam minisett dust, made up of fungicide, nematicide and insecticides for treating cut setts before planting to protect them from soil borne diseases.

This technology has not only increased the multiplication ratio in seed yam production to 1:30, but has reduced the cost of seed yam production. The minisett technology has been found to be economically viable (Ezeh, 1991) and is being widely adopted across the yam belt of West Africa. According to Okwor and Asiedu (1998), this technique has also spread to the West Indies.

The microsett technique, which is a modification of the minisett technique and introduced by Alvarez and Halm at IITA, (1982) involves the use of 2 - 10g setts, comprising two setts classes (2 - 5g and 5 - 10g). As reported by many workers the minisetts and microsetts are pre-sprouted (a recommendation from IITA) prior to field transplanting.

Otoo, (1984) reported the minisett technique as a method for seed yam production which exploits the fact that yam tubers produce sprouts from almost any point on the yam surface.

Other efforts at producing seed yams in large quantities and cheaply include the use of vine cuttings (Njoku, 1963), milking (Okigbo and Ibe, 1973), segmentation (Okoli, 1978), use of true seeds (Sadik and Okereke, 1975), the Anambra state method (Bachman and Winch, 1979), leaf cutting method (Nwosu, 1975).

2. 4. 2. 3 *Vine cuttings*

Njoku (1963) reported a method of producing yams using vegetative vine cuttings. This method exploits the use of vine cuttings planted in a suitable media. He stated that the method is however suitable for cleaning yams of tuber borne diseases such as nematodes. (Nwosu, 1975), reported that previous experimentation in Nigeria had established conclusively that stem cuttings of edible *Dioscorea spp*. could be rooted, but the experiments were not carried beyond that stage until recently.

Mantell *et al*, (1979) in their attempt to find rapid propagation systems for yam, described the rooting vine cuttings of *D. alata* and *D. rotundata* under mist or in water. However they stated that not all rooted cuttings produce new shoot growth, which is required for satisfactory level of tuber production.

2. 4. 2. 4 *Leaf cutting method*

Nwosu, (1975) reported another development in stem propagation of yam, which was the leaf cutting method. He stated clearly that the procedure is as in vine propagation method except that here the vine is cut up into pieces 2.5 - 3.0cm long, each bearing a pair of mature leaves and buds. He further stated that this exploratory experiment was done

merely to establish possibilities.

2.4. 2.5 *Use of vine cuttings*

Njoku in 1963 had shown that small tubers of white yam could be obtained by planting vines of yam in a suitable media. This method was used in NRCRI to produce small tubers weighing 5-15g in the green house and without the use of growth hormones. Larger tubers of up to 3kg were obtained when these small tubers were planted. This method was constrained by the number of branch vines of the yam plant that could be chipped for rooting early enough in the season without adversely affecting the growth of the mother plant. It is also tedious and produces small tubers.

Although this method is yet to be perfected, it seems promising. Akoroda and Okonmah (1982) showed that parent plants could be set aside from which vine cuttings could be repeatedly obtained.

2.4.2.6 *Sprouted tuber segment method*

Okoli et al (1982) developed the segmentation method in NRCRI to obtain several planting materials from one tuber of yam. Up to 64 segments were obtained from one tuber and up to 28 sprouts appeared at one time on one segment tuber. When sprout-bearing segments were carved out and transplanted and the tuber replaced in the sprouting medium, sprouts emerged from the remaining segments on the tuber. Each of the transplanted segments had thick vigorous vine while on the main tuber, the reverse become true when it is detached from the mother apparently due to reduce quantity of food resources.

Seed tubers weighing up to 500g were produced out of this method. This method was once thought to solve the scarcity of planting materials of yams but the careful excision of segments and the need to return tubers to the sprouting medium to allow more sprouts to

develop restricted the practical use of the segmentation method for producing seed tubers. This was recently confirmed by a team of investigators sponsored by National Agricultural Research Project (NARP) in 1998, (Anuebunwa *et al*, 1998) whose findings showed that farmers preferred cropping larger setts than the recommended 25g. NARP became concerned about this feedback and asked NRCRI to modify the yam minisett technique so as to enhance farmer adoption. Root and Tuber Improvement Programme (RTIP) dealing with Resource poor Farmers in year 2000 also showed concern and asked for the same improvement on the technique. Work started in 2000 to modify the yam minisett technology and the focus this time was finding the type of mother yam to enhance the minisett technology.

2. 5. 0 Sprouting process

Sprouting is a very active and energy demanding physiological process. The sprouted tuber loses a lot of dry matter moisture and continues to deteriorate as the vine grows. Therefore long shelf life of healthy yam tubers could be achieved if sprouting process could be delayed by prolonging dormancy, (Orkwor and Ekanayake, 1998).

A yam tuber if cut into setts is capable of sprouting from many points of the peel of the tuber starting from the head region followed by the tail. Sprouting from fleshy tissue is usually delayed, due to the time required for new bud formation (IITA, 1971). Sprouting in most cultivated clones of *D. rotundata* and *D. cayensis* starts through the growth of single bud at the apex due to apical dominance. The middle section comes third in order of sprouting ability (Miege, 1957; Coursey, 1967).

The process of sprouting in budless tuber pieces of yam begins with active cell division by

meristematic cell just beneath the tuber surface. This mass of cells soon becomes organized and a shoot apex becomes differentiated within it, which pushes through the tuber skin to form a vine. The point of sprout is normally whitish and delicate after which a purplish or whitish or cream colour, depending on the cultivar, appears on the young vine. This also grows a curved scale-leaf that eventually develops into a protective structure. The scale-leaf stimulates the sequence of events involved in the formation of subsequent leaves. This whole process occurs within 1 - 2wks (Onwueme, 1973).

2. 5. 1 Factors affecting the sprouting of yam tubers

2. 5. 1.1 *Physiological age*:

Onwueme, (1975) stated that the readiness with which a yam tuber sprouts and for that matter a minisett sprouts depends on the physiological age of the tuber. In other words, it depends on how long the tuber has stayed in the soil or harvested. Tubers harvested at the same time and planted at different times would have the earlier plantings requiring a very long time to sprout, while progressively later plantings would require relatively shorter time to sprout.

2. 5. 1. 2 *Quality of tuber*

Any bruises or cut on the tuber at harvest may render the tuber liable to infestation by microorganisms such as fungi and bacteria which can cause wet or dry rot. Nematodes (*Scutellonema spp*. and *Melodogyne spp*.) which infest tubers in the field before harvest and can subsequently affect sprouting (Otoo, 1984).

2. 5. 1. 3 *Temperature*

Temperature is known to affect sprouting in yam. The optimum temperature for tuber sprouting is between 25°C and 30°C. Any appreciable change more than 5°C below or above this range delays sprouting (Onwueme, 1975). This explains the significance of mulching the mounds or ridges after sowing or planting during hot season.

2. 5. 1. 4 *Dormancy*

This is physiological resting period of yam during which sprouting is suppressed (Coursey, 1967). Tuber dormancy is important in cultivation. When the yam tuber is dormant it becomes resistant to pathogen attack, and if undamaged, will survive through the dry season. Dormancy also ensures continued food supply. But once dormancy has ended, tubers become more susceptible to pathogen attack (Passam and Noon 1977), and nutrients in the tuber are mobilized for vine growth, reducing quality of the tuber as a food source. The ability to break yam dormancy early and to provide uniform sprouting times would enable farmers to grow two crops of early maturing varieties a year in environments with long growing seasons. Dormancy is not unusual in plants but in yam it is unusual in its duration from 28 days to 180 days depending on the species, and the average duration being 75-100 days. *D. cayenensis,* a species of the West African forest zone where the dry season is very short, has almost continuous vegetative growth.

D. elephantiphes, at the other extreme, spends most of the year dormant, as it is a native of the semi-desert regions. *D. alata* and *D. rotundata*, the principal cropped species are between these extremes with considerable differences between species (Aseidu *et al*., 1999).

Yam after harvest has high respiration rates throughout the tuber especially at the tail since

it is the most recently formed tissue. The respiration rate falls rapidly and immediately before dormancy break. The head region has the highest rate during dormancy. Dry matter is lost due to respiratory activity and respiratory rates decreases with temperature (Passam *et al*, 1978; Passam and Noon 1977). However temperatures below 13°C result in chilling injury (Coursey, 1967).

Moisture loss also occurs during dormancy, perhaps around 10% (Revindram and Wanasundera 1992). These authors also showed that in 150 days, storage at 24-28°C and at 70-90% relative humidity, crude protein and starch levels fell, as did the vitamin C content.

2. 5. 1. 5 *Soil moisture*

Lack of soil moisture does not affect the rate of bud formation or sprout on the tuber but the subsequent elongation of the bud is slowed by moisture stress. Tubers have long been known to sprout while in storage or on the shelf. Onwueme (1976) reported also that setts planted in dry sawdust, dry soil and on dry paper sprouted as readily as moistened setts. However, setts that sprouted under dry conditions tended to produce several more sprouting loci than those sprouted in moist media. Onwueme's work also indicated that the buds produced by sets under dry conditions remained relatively un-elongated, unless moisture was supplied. Apparently the yam tuber, with its high moisture content requires no further hydration for sprouting to occur. Moisture needed for the process is supplied endogenously as reported by Onwueme, (1976).

2. 5 .1. 6 *Soil drainage*

Onwueme (1982) reported that yams cannot tolerate water logging to any appreciable extent and it is therefore imperative that soil be well drained. Poorly drained soils and the resultant water logging cause the roots to be poorly aerated and may result in tuber rot.

2. 5. 1. 7 *Oxygen*

Onwueme, (1982) reported that sprouting of yam setts require ample supply of oxygen. Mayer and Poljakoff (1995) showed that germination (sprouting) was a process related to living cells and required an expenditure of energy by these cells by the process of oxidation. It involves an exchange of gases – output of carbon dioxide and also the uptake of oxygen for respiration. Lack of oxygen results in anaerobic respiration and metabolic processes will be depressed (Amoyaw as cited by Osei-Akoto and Sarfo- Kantanka (1987).

2. 5. 1. 8 *Portion of yam planted*

Yam tuber, if cut into setts, is capable of sprouting from many points of the peel of the body starting from the head region, followed by the tail. Sprouting from the immature tissue is usually delayed, due to the time required for new bud formation (IITA, 1971). Setts from the middle section of the tuber come third in order of sprouting ability (Miege 1957, Coursey 1967).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Experimental site

The field experiments were conducted at the MOFA Regional Agricultural Station, Mampong in the Ashanti Region of Ghana. The station falls within the semi deciduous rain forest agro-ecological zone. The original vegetation has been degraded to Savannah vegetation due to repeated farming. The station experiences an annual mean rainfall of about 1300mm, which falls within two rainy seasons (double maxima). The major rains come in April to July followed by a short dry spell in August in most years. The minor rainy season is between September and October. Temperatures are mostly high but uniform with a monthly mean of about 25.4ºC.

3.2 EXPERIMENT 1: Effect of leaf extracts on sprouting of minisetts.

3.2a Collection and Extraction of leaf extracts

This experiment was to find out the effect of leaf extracts on sprouting of yam minisetts. Four hundred grams (400 g) each of *Croton aromaticus* and *Averrhoa bilimbii* leaves were collected from the Horticulture Department of Kwame Nkrumah University of Science and Technology. Each of these were washed with distilled water, blended and subsequently washed with 2.6 litres of hydrogen peroxide. Without any previous work reported in literature, the quantity used in this study served as a preliminary volume to ascertain the efficacy of the crude plant extract-hydrogen peroxide mixture which was to be diluted with distilled water at three different concentrations. Each level of dilution was to be made up to a litre. Hence the 2.6 litres hydrogen peroxide was mixed with 400 ml of the crude plant extract to make it up to 3 litres. The crude extract was then sieved with *osaga* (sieve) into plastic containers. Five (5) parts of the crude extract were taken and diluted with 95 parts

of distilled water to give a concentration of 5%.

3.2b Treatment and nursing of minisetts.

Clean, healthy and disease-free mature tubers of Pona, Laribako and Dente were selected from the newly produced tubers which had broken dormancy. The selected tubers were cut into head, middle and tail sections. These sections were further cut into minisetts sizes ranging from 25-30 grammes. An average sized tuber gave between 20-40 minisetts.

Thirty (30) freshly cut minisetts from each of the various sections were put in small cane baskets and dipped in a suspension of "Funguran", a fungicide with copper hydroxide 50 WP as the active ingredient, and Dursban, an insecticide with 480 g/l chlorpyrifos as the active ingredient, wood ash and either *Averrhoa bilimbii* or *Croton aromaticus* extract (which contains ethylene as an active ingredient to induce sprouting) for two minutes. The suspension was prepared by mixing 25g of the Funguran, 10ml of Dursban and 50g wood ash all in four litres of water. The wood ash was to help suberise the wounded periderm. The minisetts were treated and dried for a day before nursing. The nursing was done in baskets filled with saw-dust as a medium and also on seed bed. Fifteen cut and treated minisetts each from each section were nursed either in baskets or on seed beds with three replicates each. Data on percent sprout and rot of minisetts after nursing were collected. This experiment was terminated after five (5) weeks due to slow rate of sprouting.

3.3 EXPERIMENT II: Comparison between ware yam of different ages and their corresponding regenerated yams for storage/shelf life

3.3.1 Collection and Production of Mother Yams

Four hundred (400) tubers of regenerated yam of Pona and Laribako were bought from

farms in Salaga District with the help of experts from Savanna Agricultural Research Institute, (SARI) Nyankpala. These were stored till dormancy broke and were planted at the station. Dormancy break was judged by the sprout initiation at the head end of the tuber. The setts were treated with a mixture of "Funguran" (fungicide + bactericide), Dursban, an insecticide and wood ash a day before planting on mounds. Agronomic practices, such as weeding, re-mounding were done as and when necessary. Staking was done two weeks after sprouting. Pricking (i.e. careful removal of the mature tuber without damaging the roots) begun 4 months after sprouting (4 MAS) and subsequently at, 5 MAS. The regenerated tubers from fifty pricked mounds were all harvested at 2 and 1 month(s) respectively after pricking (MAP) when the field experiment was terminated.

All the harvested mother yams were stored in the station's yam barn under good hygienic and free air flow conditions. Therefore the materials used for the preparation of the minisetts and their period of storage were as are shown in Table 1a and 1b.

Table 1a: **Different ages of Ware Yams used in Minisett preparation**

Variety	**Type of mother yam**	**Age of mother yam (months)**	**Length of storage before minisett preparation (months)**
Pona k	Ware yam	4	6
Laribakor L	Ware yam	4	6
Pona	Ware yam	5	5
Laribakor	Ware yam	5	5
Pona	Ware yam	6	4
Labarikor	Ware yam	6	4
Pona	Full grown ware yam	7	3
Laribakor	Full grown ware yam	7	3

Table 1b: Different ages of regenerated Yam used in Minisett preparation

Variety	Type of Mother yam	Months after pricking	Length of storage before dormancy break (months)
Pona	Regenerated yam 2 months old	2	3
Laribakor	Regenerated yam 2 months old	2	3
Pona	Regenerated yam 1 month old	1	3
Laribakor	Regenerated yam 1month old	1	3
Pona	Regenerated yam 1month old	1	2
Laribakor	Regenerated yam 1 month old	1	2

3.3.2 Nursing of Minisetts:

Sterilization of Medium

Sawdust was collected from a local sawmill. They were stuck in jute sacks and put into a barrel with one quarter full of water. A perforated lid separated the water from the sacks. The water was boiled and the saw dust steam sterilized for 24 hours. The temperature in the sacks ranged from 80-90ºC. Seed boxes measuring 40cm ×50cm × 40cm were filled to three quarter full with the sterilized sawdust. These boxes were arranged in a room with eleven boxes per row.

3.3.3 *Preparation of Minisett*

Clean healthy and disease-free mother yams of all ages (6, 5, 4) and, (2 and 1) months after sprouting and pricking respectively, (MAS) (MAP) were selected. These were cut into setts ranging from 80-100 grammes.Normal minisett size ranges between 25g-30g but 80-100g was used, based upon the recommendation by NARP to NRCRI to increase sett size for adoption. An average size regenerated mother yam gave between 8-20 setts. The freshly cut minisetts were put in small cane baskets and dipped in a suspension of Funguran (fungicide and bactericide) and Dursban an insecticide and wood ash for about two minutes. The suspension was prepared by mixing 25g of funguran, 10mls of dursban and two handful of wood ash in 4 litres of water. The wood ash was to help suberise the wounded periderm. The minisetts were treated a day before planting. This method was used to treat all minisetts in all the experiments.

The minisetts were then planted in forty-four wooden boxes of size 40cm × 50cm filled with the sterilized sawdust. Fifteen minisetts (15) were carefully arranged in a box to ensure that they did not touch each other to avoid transfer of disease and pests in the box.

Each box was mulched with sterilized dry grass leaves. The treatments were randomized four times in a room. Enough water was applied at intervals depending on how quickly the saw dust dried up. Sprouted minisetts were counted every week up to 10 weeks after nursing (10 WAN) when the experiment was terminated. Minisetts were said to have sprouted when the leafless vines emerged from the bud and grew to about 5cm.Percent sprout development was determined by dividing the total number of nursed setts by number of sprouted setts and multiplied by 100.

3.3.4. *Field Establishment*

The field was ploughed twice, harrowed and ridges made. Sprouted yam setts were planted at a spacing of 1m × 0.5m. Good cultural practices including staking, weeding and remounding were carried out. Percentage establishment data were then collected.this was done by dividing the total number of planted setts by the total number of sprouted setts and multiplied by 100.

3.3.5 *Field Data Collection*

Data collected during pricking for milked yam were weight and number of tubers for the three varieties. The resultant regenerated yam which was either one or two months old were also counted and weighed and the data recorded after harvesting.

3.4 EXPERIMENT III: Bud Counts and Microscopic Study of the Yam bud

This was carried out at the Botany Laboratory of the Department of Biological Sciences of Kwame Nkrumah University of Science and Technology (KNUST).

The objective was to find out whether there were differences in the number of buds on the different species and whether differences existed in the morphology of these buds between the *Rotunda* and *alata* species.To count buds on the Ware and Regenerated yams, 2cm² areas were marked on both types. The number of buds in the marked area were counted and recorded in all the different yam species.

Six months old *laribakor* (1) *pona* (2) and *D. alata* (3) which had broken dormancy were selected. Buds from the head and tail ends of each selected tuber were removed with the aid of a dissecting device. The scale leaves were removed until the apical dome remained. Sections were made from a bud from head (B) and a bud from the bottom (A) end of each variety. Each bud had both longitudinal (l) and transverse (T) sections taken.

All these sections were put in formalin alcohol and acetic acid (FAA) to rinse for 24 hours. They were then put in Resin (LR white resin) for waxing and then cut with an ultra cut microtome to a size of 2µm. Each section was put on a glass slide then in distilled water and heated to a temperature of 60ºC to fix sections. Mixture of Borax and Toluene blue was added to stain. Slide cover was then put on each stained section.

Photomicroscope pictures were finally taken for the various sections.

3.5 EXPERIMENT IV: Investigation into the periderm size or thickness of three yam varieties.

This experiment was carried out to evaluate the periderm thickness of *Rotunda* and *alata* species at K.N.U.S.T Biotech Laboratory. This was to investigate the difference in ease of sprouting for *pona*, *alata* and *laribako*. Periderm of each of the varieties was removed with a pair of forceps and measured with vernier calipers for three selected sections of cut tubers of each variety.

3.6 EXPERIMENT V: Profitability analysis of Seed yam production using the improved minisetts technique and farmers' practice.

This investigation was done in order to compare the profit margins of using three (3) different methods of producing yam setts. The methods were; (1) Farmers' practice of producing ware yam using the head or other part of tuber to plant, (2) farmers' practice of producing regenerated yams for planting and(3) The improved method of producing minisetts from regenerated yam.

To facilitate the determination of the profitability of these methods, the data on total variable input cost which includes cost of land preparation, slashing, mounding, chemicals, mulch, planting material (yam), labour for planting material preparation, weed control, re-mounding and re-ridging of mounds/ridges were collated. In addition, at harvest, the gross farm gate benefits were also determined for each method. The parameters determined included the average yield of milked yam (Ton/ha), average yield of regenerated yam, adjusted yield of milked yam, adjusted yield of regenerated yam, farm gate price of a hectare of milked yam, farm gate price of a hectare of regenerated yam, gross farm gate

price of milked yam, gross farm gate price of regenerated yam and the total gross farm gate benefit. The profitability was determined as the difference between the gross farm gate benefit and the total variable cost (i.e. the cost of all the agronomic practices until harvesting is over)

CHAPTER FOUR

4.0 RESULTS

4.1. Experiment I: The effect of leaf extracts on sprouting of minisetts

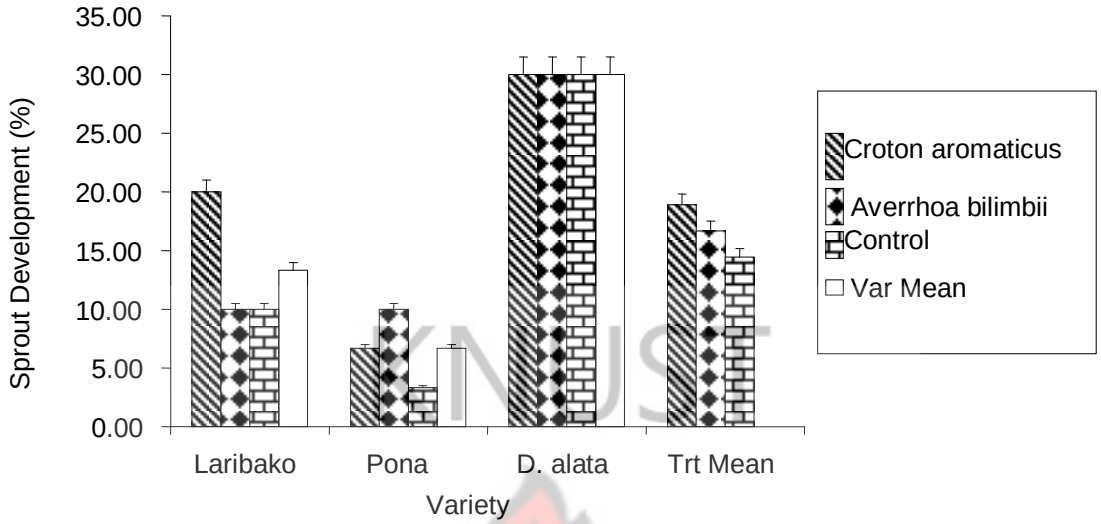
The experiment was set up to study the hormonal effect of the leaf extracts, *Croton aromaticus*, and *Averrhoa bilimbii* on the sprouting of *D. alata and Pona*, and *Laribako* varieties of *D. rotundata*.

As a preliminary study, the 5% concentration crude leaf extract was used to test their efficacy.

4.1.1 Effect of leaf extract on sprouting of the head section on seed bed

The effect of leaf extract on sprouting of minisetts from the head section nursed on seed beds is depicted in Fig. 1a. The leaf extracts did not have any effect on the sprouting of *D. alata*, confirming the fact that sprouting of minisetts of *D. alata* is not a problem. There were significant differences between the responses of *Pona* and *laribako. Croton aromaticus* extract brought about greater improvement in sprouting of *laribako* than in *Pona*, but there was no difference between the two varieties with respect to *averrhoa*. In *laribako*, the control was the same as the treated minisetts, but in *pona*, *averrhoa* brought about significant improvement.

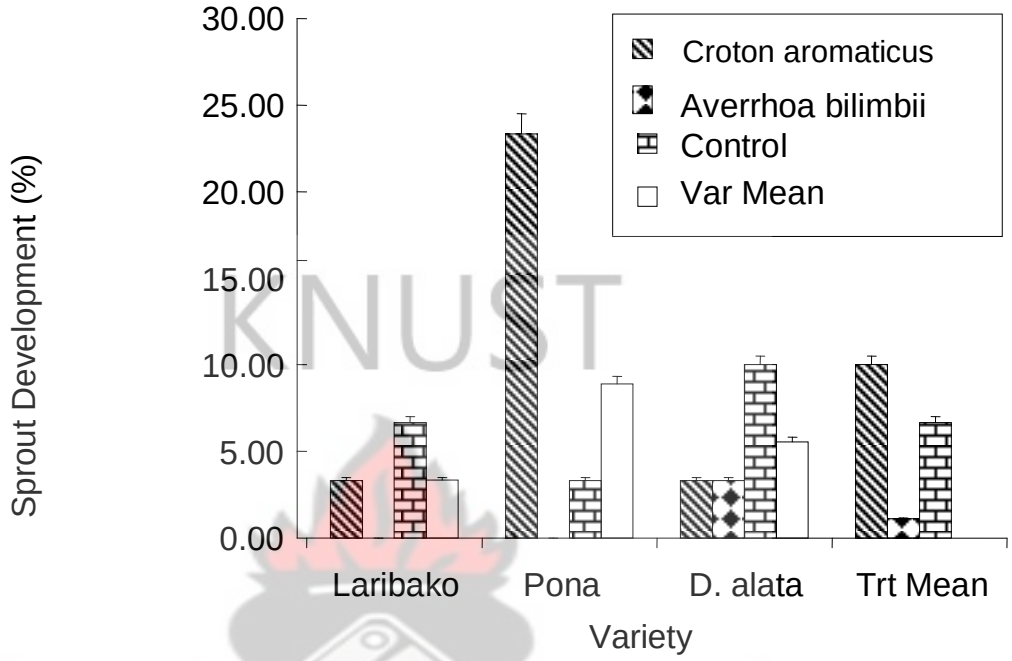
FIG. 1a. EFFECT OF LEAF EXTRACT ON SPROUTING OF HEAD PORTION ON SEED BED



4.1.2 Effect of leaf extract on sprouting of head portion in basket

The effect of leaf extract on sprouting percentages of the head section in basket is shown in the *Fig 1b.* The leaf extracts did not cause any significant improvement in the sprouting percentages of *D. alata* in the basket as it was in the field. *Pona* on the other hand, received a boost from the leaf extract of *Croton aromaticus* whereas sprouting was very much reduced in *laribako.*

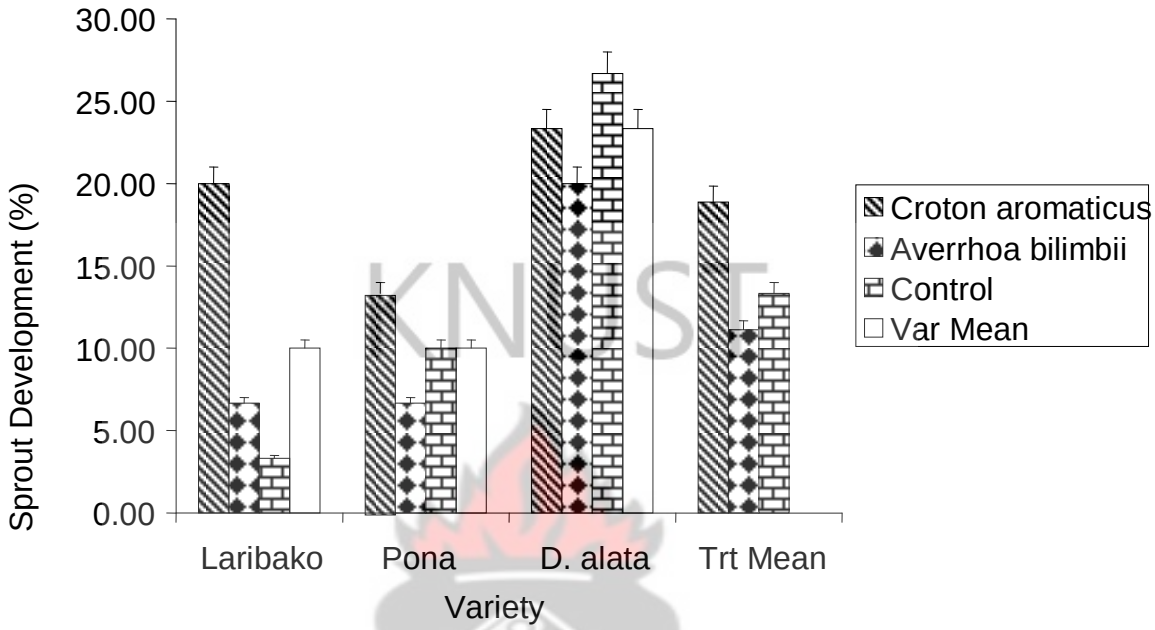
FIG. 1b. EFFECT OF LEAF EXTRACT ON SPROUTING OF HEAD PORTION IN BASKET



4.1.3 Effect of Leaf Extract on Sprouting of Middle portion on seed bed

Croton aromaticus produced significant increase in the sprouting of *laribako* but the increase was not that great in *Pona*. *Averrhoa bilimbii* extract brought no differences in the sprouting percentages of *Pona* and *laribako*. *Laribako* and *Pona* gave sprout percentages lower than that of *D. alata* under all the given treatments. While the response of *laribako* and *Pona* to *Croton aromaticus* were higher than the control,suggesting some suppressive effect of the treatment on sprouting in *D. alata* (See Fig. 2a for the results).

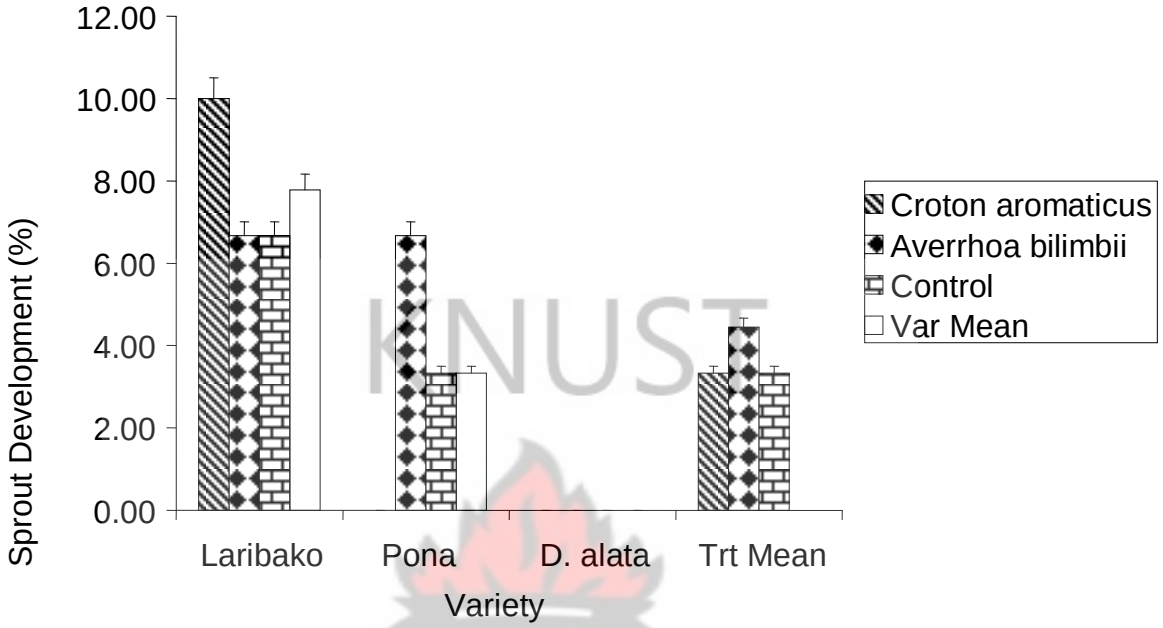
FIG. 2a. EFFECT OF LEAF EXTRACT ON SPROUTING OF MIDDLE PORTION ON SEED BED



4.1.4 Effect of leaf extract on sprouting of Middle Portion in basket

Croton aromaticus significantly improved sprouting in *laribako*, but not in *Pona* as the effect was not different from the control. *D. alata* did not show response to any of the leaf extracts. The results are as shown in Fig.2b.

FIG. 2b. EFFECT OF LEAF EXTRACT ON SPROUTING OF MIDDLE PORTION IN BASKET

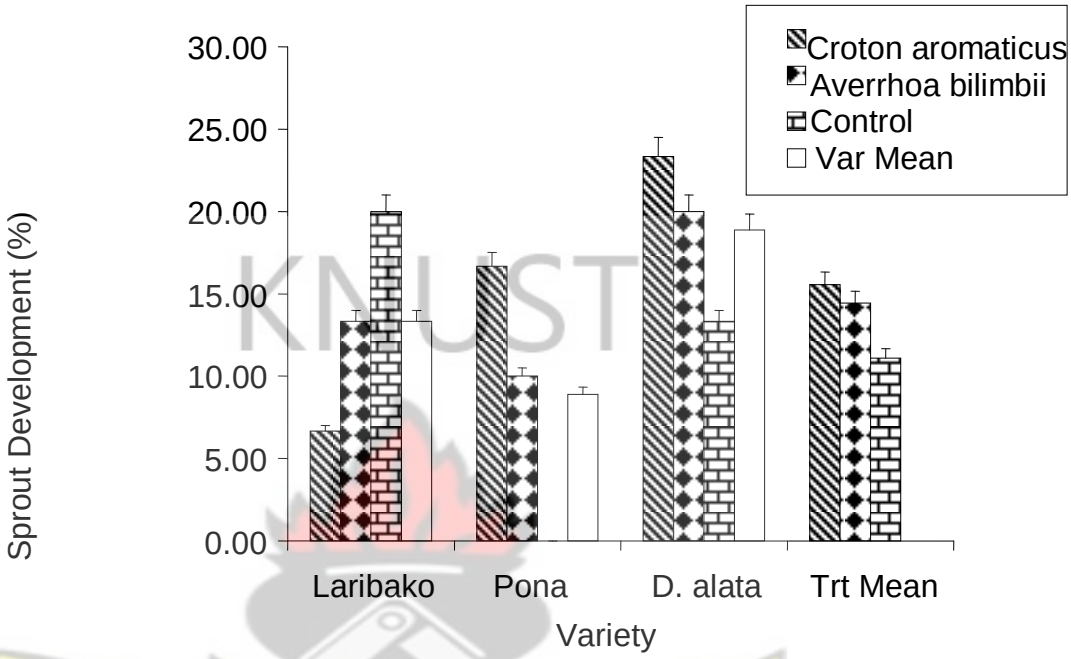


NB. D. Alata recorded no sprouts

4.1.5 Effect of Leaf Extract on Sprouting of Minisetts from Tail Portion of Tuber on seed bed

Croton aromaticus extract increased sprouting in *D. alata* and Pona but not as much in *laribako*. *Averrhoa bilimbii* extract rather gave increased sprouting in *D. alata* and *laribako* but not as much in *Pona*. For the control, *laribako* recorded the highest sprout percentage followed by *D. Alata*. Pona did not respond to any of the three plant extracts. (See Fig. 3a)

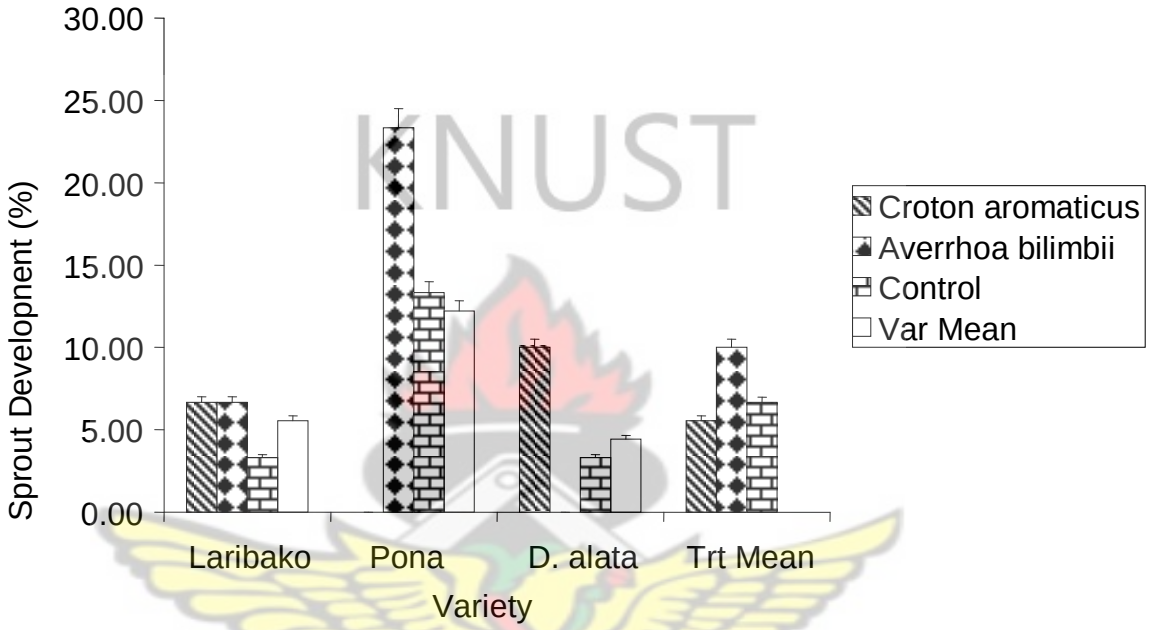
FIG. 3a. EFFECT OF LEAF EXTRACT ON SPROUTING OF TAIL PORTION ON SEED BED



4.1.6 Effect of Leaf Extract on Sprouting of Minisetts from Tail Portion of Tuber in basket

Pona did not respond to *Croton aromaticus* leaf extract while *laribako* and *D. alata* did. On the other hand, *Averrhoa bilimbii* extract enhanced sprouting in *Pona* but had very little influence on the sprouting of *laribako*. *Laribako* responded to all the leaf extracts (refer to Fig 3b).

FIG.3b. EFFECT OF LEAF EXTRACT ON SPROUTING OF TAIL PORTION IN BASKET



4.2. Experiment II.

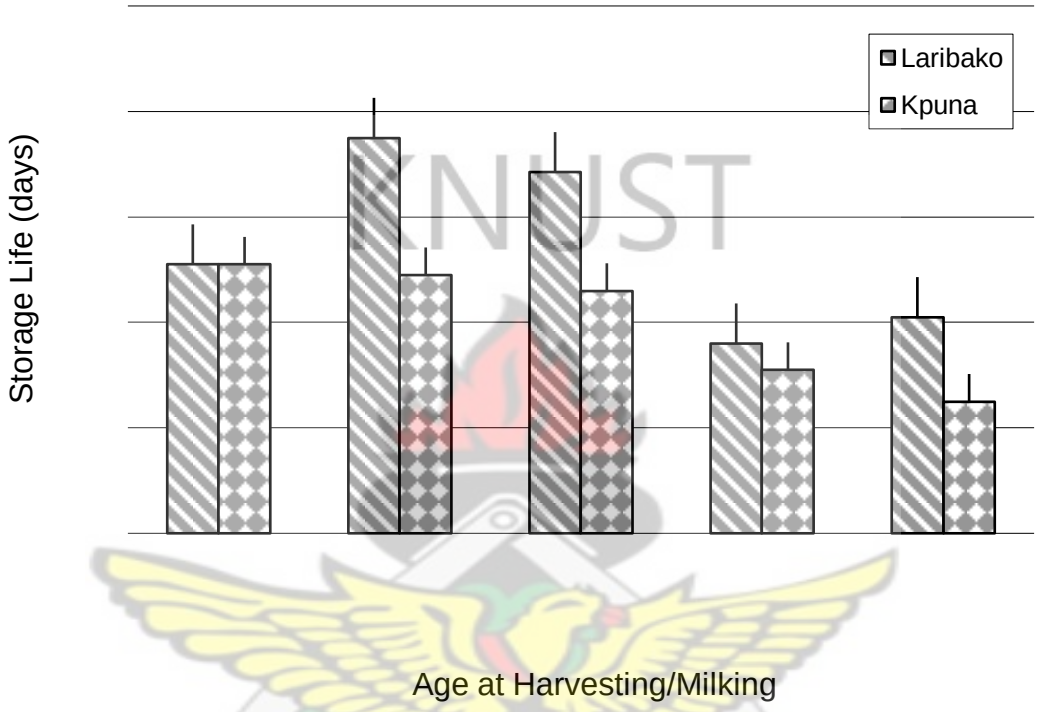
4.2. 1.Comparison between ware yam at different ages and their corresponding regenerating yams, for shelf / storage life.

Significant differences were established between the varieties as shown if fig. 4.

Storage life generally increased with age from 1 month but declined after 5 months.

The shortest (41 days) and longest (75 days) values for *laribako* for the 1 and 5 months old tubers respectively. The storage life for *Pona* was at different ages not significantly different from six months. Similar observation was made between 5 and 4 months for *laribako*. Storage life was longer for *laribako* than *Pona* in all ages except at 6 months indicating interaction between age and variety.

Fig. 4. Comparison between ware yam of different ages and their corresponding regenerated yams for shelf /storage life



4.2.2 Comparison between ware yam of different ages and their corresponding regenerated yams, for 50 % dormancy break.

No significant difference was established between the varieties; however the number of days to 50% dormancy break was significantly influenced by age.

Four (4) month old milked tubers took significantly higher number of days (180) to break

dormancy followed by five (5) month old tubers which took 150 days. No significant differences were established between full season ware yam (6 months) and 2 and 1 month regenerated tubers. These results are shown in fig. 5.

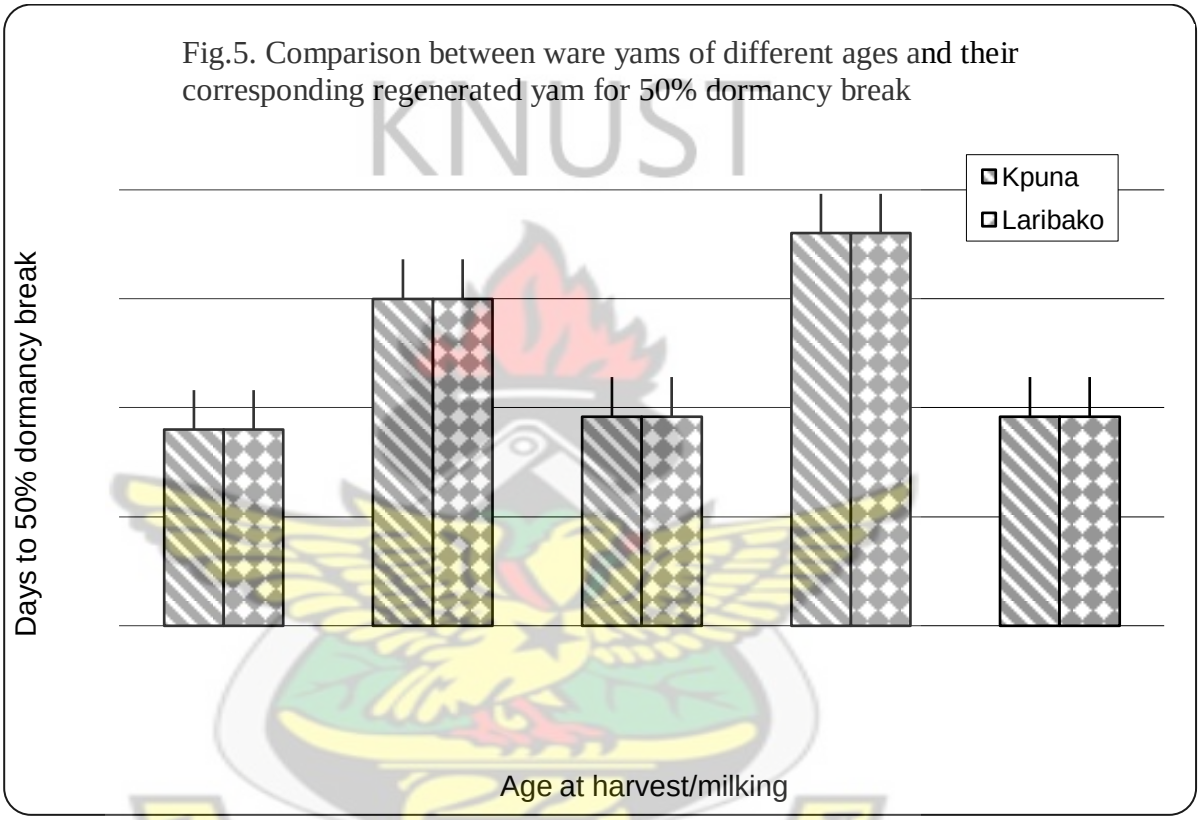


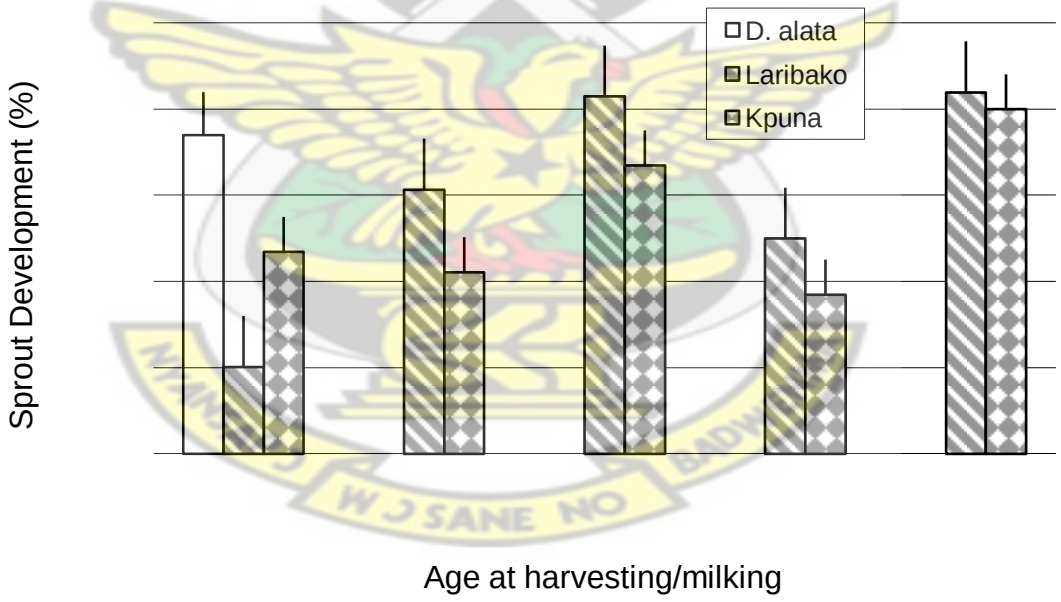
Fig.5. Comparison between ware yams of different ages and their corresponding regenerated yam for 50% dormancy break

4.2.3.1 Comparison between Ware yam of different ages and their corresponding regenerated yams for % Sprout development (2002).

Dormancy break refers to the number of days taken by mother yams to develop sprouts at head end from time of harvest**.**

Varietal differences existed for ages 1 to 5 between *laribako* and *Pona*. Six (6) month old material of *D. alata* had the highest sprouting. In *Pona* the lowest value of 32 was for the 4 months old ware yam but its corresponding two months old regenerated tubers gave the highest percent sprout. Similarly, the values for the 1 month old regenerated tubers were higher than the corresponding 5 month old ware yam. (See fig. 6a)

Fig.6a. Comparison between Ware yams of different ages and their corresponding regenerated yams for % Sprout development (2002).

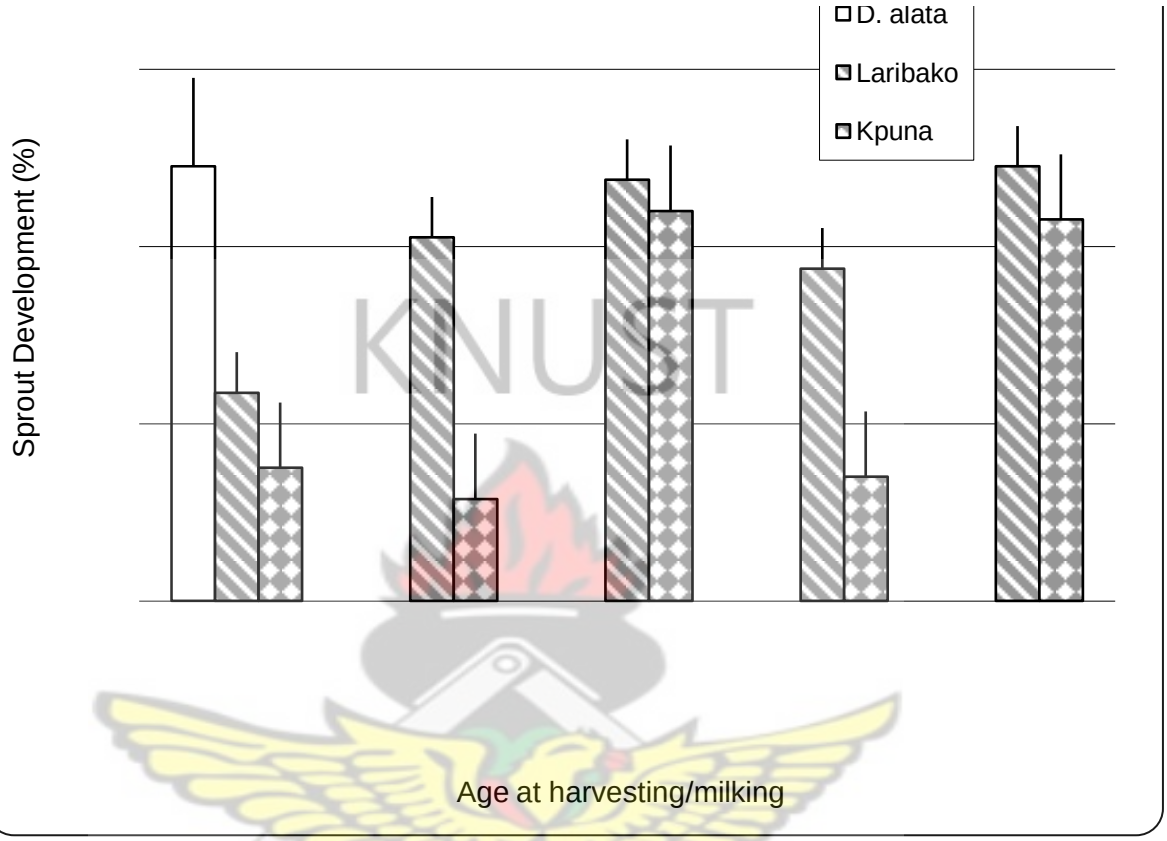


4.2.3.2 Comparison between ware yams of different ages and their corresponding regenerated yam for % sprout development (2003).

Percent sprout development refers to the number of nursed setts which sprouted during nursing divided by the total number of nursed setts multiplied by 100

Significant differences were established between the varieties. *D. alata* gave the highest sprout development than *Pona* except for 1 and 2 months old regenerated *Pona* where no significant differences were established. The lowest and highest sprout development for *laribako* which were 47 % and 98 % were for the full season ware yam and the 2 month old regenerated tubers. In the case of *Pona,* it was 23 and 88 at 5months old ware yam and its corresponding one month old regenerated tubers. Significant interaction was established between age and variety. These results are presented in fig. 6b.

Fig. 6b.Comparison between ware yams of different ages and their corresponding regenerated yam for % sprout development (2003)



4.2.4 Comparison between Ware yams of different ages and their corresponding Regenerated yams for Plant establishment.

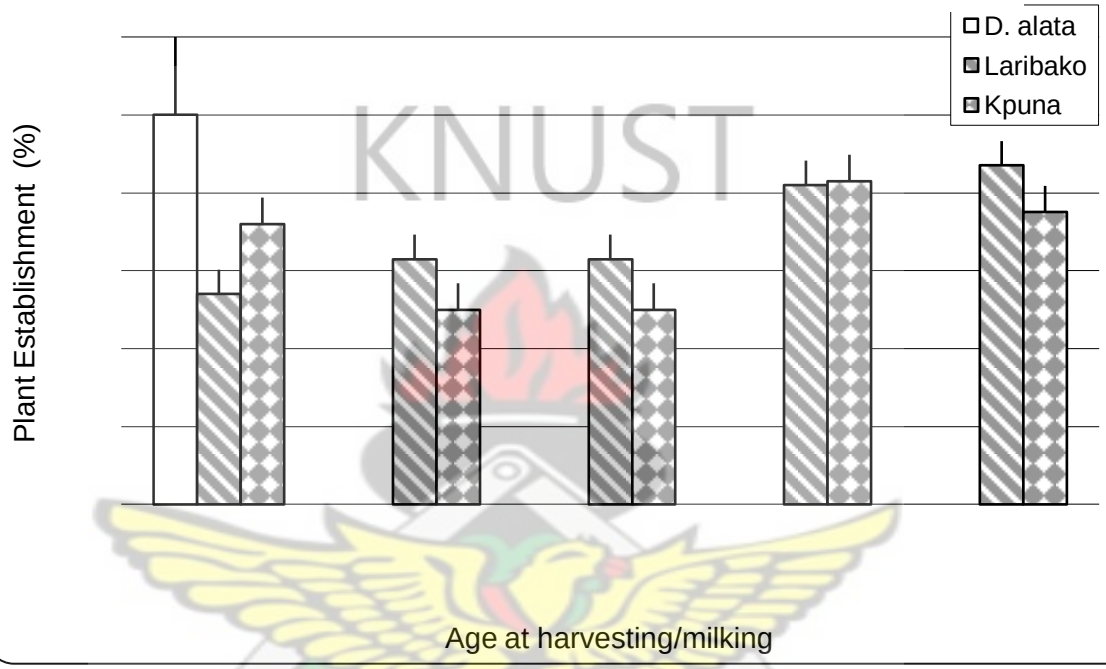
Plant establishment is the number of nursed planted setts which emerged as a seedling

For the full season yams (6 months) *D.alata* (100) was significantly higher than *Pona* (72) and *laribako* (54) at 6 months.

Significant differences were established between *Pona* and *laribako* at all the ages except at 4 months. The highest (87) and lowest (54) values for *laribako* were for the 2 months regenerated and full season (6 months) ware yam while the highest for *Pona* was for the 4

months old ware yam (83) and the lowest for the 5 months old ware yam and its corresponding 1 month old regenerated tubers. Plant establishment was higher for *laribako* than *Pona* at all the other ages. See Fig. 7 for these results.

Fig.7.Comparison between Ware yams of different ages and their corresponding Regenerated yams for Plant establishment.



4.2.5. Comparison between Ware yam of different ages and their corresponding regenerated yams for Yield

At 6 months, *D. alata* gave the highest yield of 5.54t/ha but no significant differences were established between *Pona* (1.09t/ha) and *laribako* (0.91t/ha). The lowest (0.91t/ha) and highest (2.73t/ha) yields for *laribako* were for the full season ware yam and the 2 month old regenerated yam while that of *Pona* were 1.03t/ha and 1.90t/ha were at 4 and 2 months respectively. The yield of *laribako* was significantly higher than *kpuna* at all the other ages except for 1 month old regenerated yam indicating age by variety interactions. These

results are shown in Fig. 8.

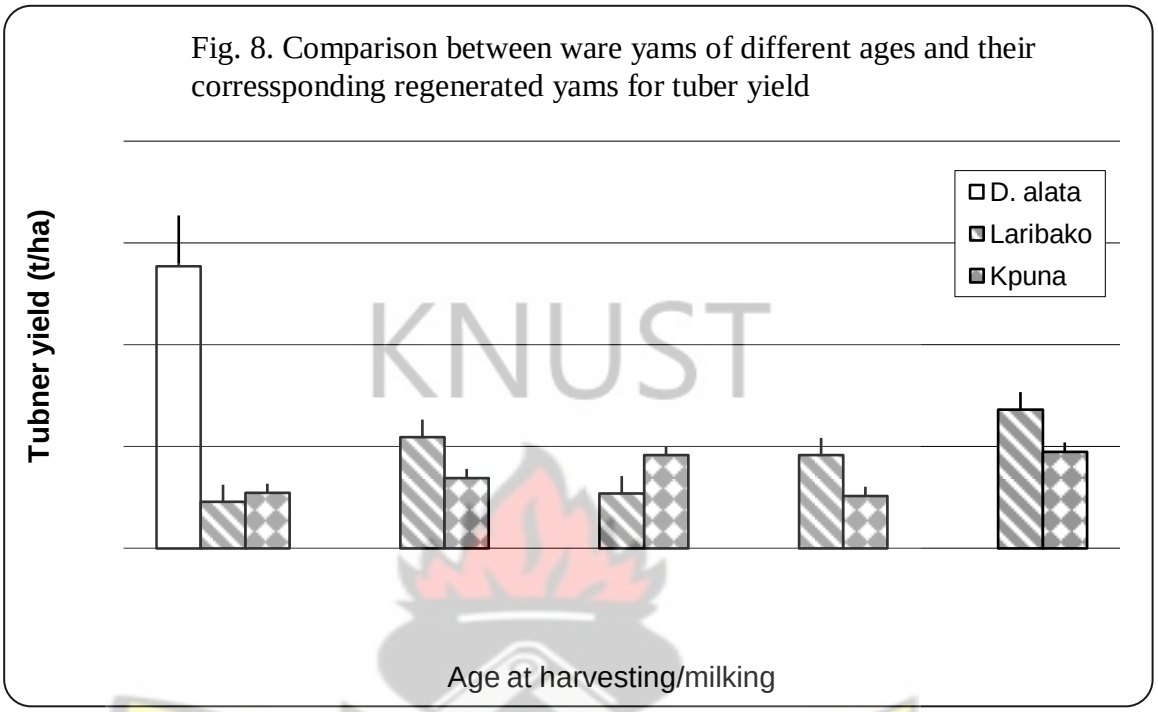


Fig. 8. Comparison between ware yams of different ages and their corressponding regenerated yams for tuber yield

4.2.6 Comparison between Ware yam at different ages and their corresponding Regenerated yam for Bud density

Figure 5a shows the number of active buds observed per $2cm^2$ of tuber surface that have been stored for six months after harvest and have broken dormancy.

Significant differences were established between the varieties as represented in Fig. 5

The number of bud was significantly higher for *laribako* than *Pona* at all ages. However *D. alata* (6) was significantly higher than *Laribako* (4) at 6 months.

The lowest number of buds for *Pona* (3) was at 1 and 6 months whilst the highest (5) was at 2 and 4 months respectively. The lowest (4) and highest (7) number of buds for *laribako* were at 6 and 2 months. No significant interaction was established between age and variety.

Fig. 9a. Comparison between ware yams at different ages and their corresponding regenerated yams for bud density

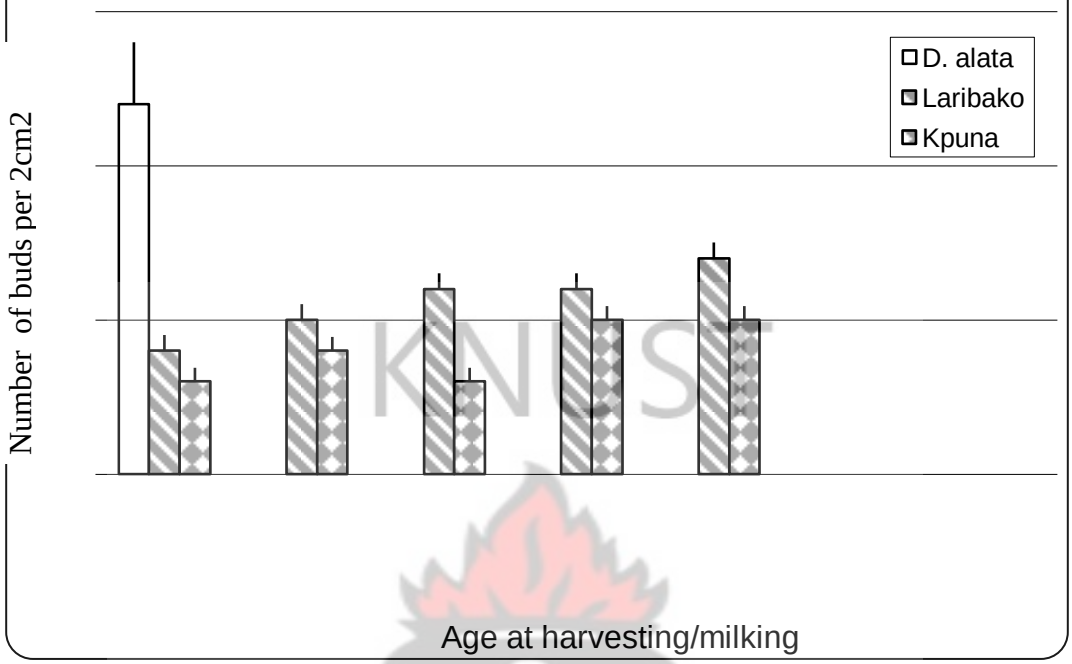


Fig.9b A Photograph of Yam Bud Counts on the Three varieties of Yam

Figure 5b is a photograph of how yam buds were counted on the three yam varieties

4.3 Investigation into periderm thickness of 3 yam varieties.

Results from this investigation showed that, *D. alata* and *laribako* had an average periderm thickness of 0.5mm while *Pona* was 1.0mm.

Table 2: Periderm size / thickness (mm) of the 3 yam varieties

Variety	Replication 1	Replication 2	Replication 3	Average
Pona	1	1	0.95	0.98
Laribako	0.50	0.48	0.60	0.52
D.alata	0.50	0.40	0.60	0.50

Table 3: Profitability of Different Methods of Yam Planting Material Production

ITEM NO	*GROSS FARM GATE BENEFIT*	*FARMERS METHOD OF PRODUCING REGENERATED YAM(¢)*	*IMPROVED MINISETT TECHNIQUE (¢)*	*WARE YAM PRODUCTION (¢)*
1a	Average yield milked yam (Ton/Ha)= 14.4	7,200,000.00	11,213,000.00	7,200,000.00
1b	Average yield regenerated yam (Ton/Ha) = 13.0	6,500,000.00	9,859,000.00	
2a	Adjusted yield (milked yam) 1a x 0.9	6,480,000.00	10,090,000.00	6,480,000.00
2b	Adjusted yield (regenerated yam) 1b x 0.9	5,850,000.00	8,873,000.00	
3a	Farm gate price milked yam (1 ha)	2,000,000.00/ 100 tubers	2,000,000.00/100 tubers	2,000,000.00/100 tubers
3b	Farm gate price regenerated yam (1ha)	3,000,000.00/ 100 tubers	3,000,000.00/100 tubers	
4a	Gross farm gate price milked 2a x 3a)	12,960,000.00	20,180,000.00	12,960,000
4b	Gross farm gate benefit price (2b x 3b)	17,550,000.00 30,510,000.00	26,619,000.00 46,799,000.00	12,960,000

	Total gross farm gate benefit (4a +4b)			
	VARIABLE INPUT COST			
5	Land preparation			
	Slashing labour ¢	500,000	500,000	500,000
	Mounding labour ¢	500,000	-	500,000
	Ridging	-	600,000	-
6	SETT PREPARATION			
	Cost of setts	15,000,000	5,000,000	10,000,000
	Chemicals		100,000	
7	CUTTING-PLANTING	250,000	375,000	250,000
	Labour	250,000	375,000	250,000
	Mulching/capping			
8	WEED CONTROL			
	Labour 3 weeding	1,125,000	1,125,000	1,125,000
	Herbicide		300,000	
	Re-mounding / Re-ridging	375,000	450,000	375,000
9	STAKING			
	Cost of stakes	600,000	300,000	600,000
	Labour	375,000	187,500	375,000
10	Milking/1st harvesting			
	Labour	1,500,000	2,500,000	
11	2ND HARVESTING			
	Labour	1,500,000	2,500,000	1,500,000
12	Transportation of tubers home	600,000	900,000	600,000
13	Total variable input	22,575,000	15,212,500	17,575,000
14	Change in net benefit (4-13)	7,935,000	31,587,000	-4,615,000

Table 4: SUMMARY OF PARTIAL BUDGETING 2002

ITEM NO	*GROSS FARM GATE BENEFIT*	*FARMERS METHOD OF PRODUCING REGENERATED YAM(¢)*	*IMPROVED MINISETT TECHNIQUE (¢)*	*WARE YAM PRODUCTION (¢)*
	Total gross farm gate benefits	30,510,000	46,799,000	12,960,000
	Total variable input	22,575,000	15,212,500	17,575,000
	Change in net benefit	7,935,000	31,587,000,	-4,615,000
		A	B	C

Method B which is the Improved minisetts technique has the highest farm gate benefit (¢46,799,000) followed by A, farmers practices (¢30,510, 000).and C which was the ware yam production method received the least farm gate benefit (¢12,960,000.00).

In-terms of total variable input that is total cost of production, A had the highest (¢22,575,000), f0llowed by C (17,575,000) as against B which had (¢15,212,500.00). Method B had the highest net returns (¢31,587,000) followed by method A which had (¢7,935,000.00). Method C had negative net returns (¢4,615,000.00).

CHAPTER FIVE

5.0 DISCUSSION

5.1 Effect of leaf extracts and sprouting medium on yam minisetts sprouting

Sprouting of minisetts was highly related to both the type of leaf extract and sprouting medium used. .

Croton aromaticus remarkably enhanced sprouting than *Averrhoa bilimbii*.

There is a possibility of variations in their ethylene contents, with higher levels associated with *Croton aromaticus*. It is also likely that other phyto-chemicals which are present in these extracts either promote (as with *Croton aromaticus*) or suppress (as with *Averrhoa biblimbii*) the sprouting process, either singly or in an interactive manner.

Planting on seedbed promoted sprouting than planting in basket filled with sawdust. This might be attributed to rapid rotting of minisetts resulting from frequent watering in the basket. Moisture retention was low in the porous sawdust as a result of increased drainage. The continuous moist environment somehow promoted fungi growth and subsequent rotting of minisetts in the baskets. This observation is in agreement with Onwueme (1982) who emphasized endogenous supply of moisture for the sprouting process and no hydration is required externally.

5.2 Effect of variety and portion of tuber on yam minisetts sprouting

Sprouting of minisetts among the tuber portions and the varieties did not follow any consistent order. For example, the highest sprouting *D. alata* had more sprouts in the head, followed by the tail and the middle. However, in the *D. rotundata* varieties, highest sprouts

were recorded from the tail portion, followed by the head whilst the middle produced the least sprouts. This is in agreement with a report by IITA (1971) that normally, increased sprouting of setts is expected from the head region followed by the tail.The number of sprouts observed in all the experiments were ridiculously low due to the excessive rots experienced during the coduct of the experiment.

5.3 Comparison between Ware yam at different ages and their corresponding Regenerated yam for 50% dormancy break

The ability of the yam tubers to sprout after variable and often prolonged period of dormancy is a vital quality characteristic. Days to dormancy break was found to be dependent on age but not variety of the mother yam. The varieties were within the same species, and for that matter, differences in dormancy periods were not expected to be pronounced as expected between species (Martin and Sadik, 1977; Coursey, 1967). Tuber dormancy was more pronounced in the milked yams than the full-season and regenerated yams. In the full-season yam, the tubers attained physiological maturity and may therefore contain low levels of glutathione (Campbell et al., 1962) and other batatasins (Ireland et al., 1981) which are known to be associated with tuber dormancy. For the regenerated yam however, the short dormancy period could be explained as a result of active morphogenetic and physiological growth process characterized by rapid cell multiplication of the meristematic tissues (Onwueme, 1978; Okonkwo, 1985). It is therefore likely that long dormancy period expressed by the milked yams was due to the harvest tubers and higher contents of a group of growth inhibitors which need much time to breakdown in store. The long dormant period of the milked yams, without loss of viability, is a vital quality

attribute which enables them to be used in propagation where subsequent planting is delayed. On the other hand, where successive plantings are being done immediately after the order, the full – season and regenerated yams would be most ideal.

5.4 Comparison between Ware yam at different ages and their corresponding Regenerated yam for sprout development

From this study, sprouts emerge from buds, hence, sprouting was observed to be highly related to bud formation in contradiction to what Akoroda and Okoli (1995) who reported that there was no relationship between number of buds and sprouting. They observed multiple bud varieties had higher rate of sprouting rates showed thicker periderm.

Sprouting was observed to be more pronounced in *laribako* than *Pona* at all ages except the full season (6 months old) ware yam. . *Laribako* has also a thinner periderm than *Pona* which allows easy penetration of apical dome of the bud cells ,this explains why *laribako* is an early maturing type and therefore produced more scales than buds at six months. The younger regenerated tubers (ie. 2 and 1 month old) behaving like the ware yam heads also produced more sprouts than the 4 – 6 months old ware yams. This might be due to inherent hormonal characteristics present in the regenerated yam which promotes more sprouts than in the ware yams.

5.5 Comparison between Ware yam at different ages and their corresponding Regenerated yam for bud development

Bud development is dependent on the type and age of mother yam used. *Laribako* produced more buds that *Kpuna* at all the age categories, whilst the control, *D. alata*, was superior to all of them. This might be due to he inherent varietal characteristics, which either promotes or suppresses the process of bud formation, such as variations their

hormonal levels that has been shown to influence dormancy and sprouting (Campbell et al., 1962). Similarly, tubers of regenerated yams produced more buds than that of their corresponding ware yams. In the regenerated yams those harvested at two month old developed more buds, followed by the four and one month old tubers. In the same way, the five month old ware yam produced more buds than the six month old ones.

All these observations indicate that the younger tubers have less suberised periderm than the older tubers owing to active cell division of the meristematic cells to form buds. In other words, as the tuber is ageing, the cells become more fibrous, lignified and produces more scales instead of buds, and therefore not dividing.

5.6 Comparison between Ware yam at different ages and their corresponding Regenerated yam for yield at harvest.

Genetic differences comprising both varietal and species variations and the influence of environment on crop age, leaf area duration and resource allocation to the tubers have been observed to influence tuber yields of cultivated yams (Hahn and Hozyo, 1983).

Generally, *Laribako* yielded higher than *Kpuna* except for the yields from one month old regenerated yam. The regenerated yams, particularly the one milked at four month, out-yielded both the full-season and the five month old ware yams.

The differences in yield between *Laribako* and *Kpuna* basically resulted from the differences in their growth duration owing to their genetic differences. The differences in tuber yields between the regenerated and ware yams could also be explained on the basis of their plant architecture and growth rates. The seedlings from regenerated yams were much robust and were growing vigorously than those from the ware yams. Therefore they took full advantage of the favorable climatic conditions to mature earlier, and evaded pest

and disease attacks than the seedlings of the ware yams which expressed slender shoots right from sprouting throughout the growing period. This agrees with similar study by Doku (1985) that growth vigor closely parallels earliness or maturity and increased yield. Another factor which contributed to yield differences in the regenerated yams and the ware yams was the number of tubers produced per hill. Plants raised from regenerated yams produced more and bigger tubers than those obtained from ware yams after six month period.

5.7 Profitability of Different Methods of Yam Planting Material Production

A Cost and benefit analysis of the various methods used in this study for production of yam planting material took the form of partial budgeting. In 2002, a comparative analysis of methods A (farmers' practice of producing regenerated yam), B (Improved minisetts technique) and C (Ware yam production method) were undertaken. Method B turned out to be the most beneficial technology since it gave the highest farm gate benefit of ¢46,799,000.00 followed by A which yielded ¢30,510,000.00 and C, ¢12,960,000.00 respectively. Method B which had the highest farm gate price had the least production cost of¢15,212,500.Method A had production cost of ¢22,575,000.00, whilst method C had ¢17,575,000.00

The Net benefit, which is the difference between the total farm gate price and the total production cost for the three methods were A (¢7935,000.00), B (¢31,587,000) and C (-¢4615,000.00). It is therefore convincing that, application of the improved minisett technology for yam planting materials is a very profitable method

CHAPTER SIX

CONCLUSION AND RECOMMENDATIONS

6.0 CONCLUSIONS:

6.1 *Effect of leaf extract on sprouting of minisett.*

The response of the various parts of yam varieties used to the leaf extracts gave varied sprouting percentages when nursed on seed beds or in baskets. The following findings were made

- *Croton aromaticus* increased sprouting significantly for the **head portion** of *laribako* and *Pona* on seed bed and basket respectively
- For the **middle portion**, *Croton aromaticus* consistently increased sprouting significantly for *laribako* than in *Pona* for seedbeds and baskets while *Averrhoa bilimbii* did not give any significant effect on the sprouting of the two varieties.
- For the **tail portion**, *Croton aromaticus* gave *Pona* significant sprout increase over *laribako* when nursed on seed bed but the reverse was true when baskets were used though low sprouts were observed. *Averrhoa bilimbii* extract significantly increased sprouting of *Kpuna* when nursed in baskets.

6.2 Comparison between ware yams of different ages and their corresponding regenerated yam for 50%dormancy break.

- Younger regenerated yams take significantly lesser days to break dormancy than the older ware and milked yams in all the varieties used.

6.3 Comparison between ware yams of different ages and their corresponding regenerated yam for % sprout development

- When dormancy is fully broken minisetts from milked and regenerated mother yams from *laribako* and *Pona* sprouts higher and uniformly.

6.4 Comparison between ware yams of different ages and their corresponding regenerated yam for yield at harvest.

- *Laribako* sprouts and yields higher than *Pona*. Younger regenerated yams of both *Pona* and *laribako* yields higher than ware yams of both varieties.

6.5 Profitability of different methods of yam planting material production.

- Application of improved minisetts technology for yam planting material production is the most profitable method of seed yam production as shown by the partial budget analysis.

RECOMMENDATIONS

- The use of *Croton aromaticus* and *Averrhoea bilimbii* on sprout induction in yam minisett must be investigated further to ascertain the optimum concentration and the level of maturity required for the minisett technology.
- Regenerated mother yam (between 1 –2 months old), which brings excellent uniformity in sprouting and pricked or milked mother yams (between four and five months old) are the best material for the improved minisett technique.

- The improved minisett technique using the regenerated mother yam proves to be an excellent solution to the poor response of Pona and laribako to the minisett technique.and must be recommended immediately to farmers for adoption.

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APPENDIX 1

CLIMATIC DATA FOR MAMPONG-ASHANTI [1999-2003]

[1999]

YEAR		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC	MEAN
Rainfall (mm)		53.1	36.6	71.4	204.1	128.9	198.9	168.3	104.6	219.4	212.4	49.6	0.0	
Temp ^{0}C	Max	32.2	32.3	33.4	31.7	31.1	30.3	29.0	28.8	28.8	29.1	31.1	31.8	30.8
	Min	21.2	21.3	21.9	21.8	21.7	21.5	21.0	20.5	20.8	20.7	21.2	20.6	21.2
	Mean	26.7	26.8	27.6	26.7	26.4	25.9	25.0	24.6	24.8	24.9	26.1	26.2	26.7

[2000]

YEAR		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC	MEAN
Rainfall (mm)		51.1	9.2	96.9	104.1	157.3	143.9	195.5	90.8	91.7	122.4	28.2	Tr	
Temp ^{0}C	Max	31.8	33.8	34.4	32.6	32.3	30.1	28.2	27.8	28.2	29.5	31.0	31.3	30.8
	Min	21.5	20.4	22.5	22.1	22.1	21.4	20.5	20.5	21.1	221.1	21.7	20.8	39.3
	Mean	26.7	27.1	28.5	27.4	27.2	25.8	24.4	24.2	24.7	125.3	26.4	26.1	

[2001]

YEAR		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC	MEAN
Rainfall (mm)		0.0	38.1	67.7	204.6	34.0	165.3	148.0	32.6	187.8	130.3	59.2	16.1	
Temp ^{0}C	Max	na	na	na	na	na	Na	na	na	na	na	na	na	na
	Min	na	na	na	na	na	Na	na	na	na	na	na	na	na
	Mean	na	na	na	na	na	Na	na	na	na	na	na	na	na

[2002]

YEAR		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC	MEAN
Rainfall (mm)		2.5	58.5	308.3	138.0	273.8	185.9	149.5	112.4	176.2	28.1	26.0	28.2	
Temp ^{0}C	Max	32.1	34.3	32.1	21.8	30.9	29.1	28.2	27.1	28.2	29.3	30.8	30.6	29.6
	Min	20.7	21.6	22.0	21.3	21.3	20.8	21.6	20.7	21.0	21.1	21.4	20.1	21.1
	Mean	26.4	28.0	27.1	21.6	26.1	25.0	24.9	23.9	24.6	25.2	26.1	25.4	

[2003]

YEAR		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC	MEAN
Rainfall (mm)		13.1	29.4	82.1	253.6	104.6	189.6	7.7	61.4	201.0	278.3	133.7	0.8	
Temp ^{0}C	Max	32.2	33.5	33.6	31.3	31.7	29.0	28.4	28.4	29.1	30.1	30.4	30.8	30.7
	Min	21.0	22.4	22.5	21.6	22.2	21.1	20.7	20.9	21.1	21.0	21.1	19.2	21.2
	Mean	26.6	28.0	28.1	26.5	27.0	25.1	24.6	24.7	25.1	25.6	25.8	25.0	

APPENDIX 2

THE WORLD'S LEADING YAM PRODUCERS IN 1990

	Area (1000 ha)	% of World Area	Production (1000 tonnes)	% of World Prod.	Yield (Kg/ha)
World	2928	100	29,447	100	10,057
Nigeria	1,900	64.9	22,000	74.7	11,579
Cote d'lvore	266	9.1	2,528	8.6	9,504
Benim	90	3.1	992	3.4	11,026
Ghana	200	6.8	700	2.4	3,500
Togo	40	1.4	420	1.4	10,500
Zaire	38	1.3	270	0.9	7,200
Africa	2,789	95.3	28,249	95.9	10,127
West Indies	59	2.0	350	1.2	6,122
Oceania	18	0.6	284	1.0	15,818
Asia	15	0.5	198	0.6	12,876

Source: FAO Prod. Yearbook Vol. 44

COMPOSITION OF YAM TUBERS OF VARIOUS SPECIES

[Blank spaces indicate where no figures are available]

	D. rotundata	D. alata	D. cayenesis	D. esculenta	D. dumetorum
Moisture (%)	60-70	70	80	70-80	80
Starch (%)	25-30	28	-	25	-
Sugars (%)	0.32	0.5	-	1-2	-
Fat (%)	0.1	0.1-0.3	0.1	0.1-0.3	0.3
Crude protein (%)	1.1-2.0	1.1-2.8	1.0	1.3-2.1	2.8
Crude Fibre (%)	0.4-0.8	0.6-1.4	0.4	0.2-1.5	0.3
Ash (%)	0.7-2.6	0.7-2.1	0.5	0.5-1.2	0.7
Vitamin C (mg per 100g)		6-1.2		5-2.8	5-820.3-
Vitamin B1 (mg per 100g)		-		0.09	-0.08-
Vitamin B2 (mg per 100g)		-		0.03	-0.02-
Vitamin A (mg per 100g)		0.8		0.018	-0.017-

Culled form Onwueme [Tropical root & Tuber crops 1994]

APPENDIX 3

Table Approximate condensed values of the principal chemical components of tubers of the main yam species (% fresh weight)

SPECIES	MOISTURE	CARBOHYDRATES	CRUDE PROTEIN	LIPIDS	CRUDE CELLULOSE	ASH
D. Alata	65-73	22-29	1.12-2.78	0.03-0.27	0.65-1.40	0.67-2.06
D. rotundata-cayenesis	58-80	15-23	1.09-1.99	0.05-0.12	0.35-0.79	0.68-2.56
D. opposite	70-80	16-29	1.11-3.10	0.06-1.10	0.33-1.00	0.69-1.10
D. esculenta	67-81	17-25	1.29-1.87	0.04-0.29	0.18-1.51	0.50-1.24
D. bulbifera	63-67	27-33	1.12-1.50	0.04	0.70-0.73	1.08-1.51
D. dumetorum	79	17	2.78	0.28	0.30	0.72
D. trifida	69-73 (1)	38	2.54	0.44	-	-
D. nummularia(2)	75	21	1.81	0.15	0.43	0.76
D. transversa (2)	68	29	1.81	0.06	0.49	0.91
D. pentaphylla (2)	86	11	0.94	0.15	1.30	0.50

Data from Coursey (1967) except for (1) personal data: (2) Bourreet [1973, simplified]