MICROSETT AND SLIP PROPAGATION OF DIOSCOREA ROTUNDATA SEED YAM

by

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DEDICATION

This thesis is dedicated to

"P E R S E V E R A N C E"

D E C L A R A T I O N

I hereby declare that the work herein submitted as a dissertation for the Doctor of Philosophy degree of the University of Ghana is the result of my own investigation.

.....

Charles Easmon Gyansa-Ameyaw

CERTIFICATION

We certify that the work presented in this thesis was carried out by Charles Easmon Gyansa-Ameyaw of the Department of Crop Science, University of Ghana at the International Institute of Tropical Agriculture, (IITA), Ibadan, Nigeria.

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TERMINOLOGIES

1. Cormous structure (corm) - degenerate rhizome at the head of the tuber, bearing an apical bud at harvest.

2. Lesser seed yam - whole yam tuber weighing less than 200 g.

3. Morphogenetic efficiency - ratio of the dry matter content of the presprouted and unpresprouted slips, expressed as a percentage.

4. Mother seed yam - parent tuber from which microsetts are derived.

5. Seed yam - whole yam tuber weighing between 200-1000 g.

6. Slip - the leafless sprout that arises from the tuber after dormancy-release, comprising a shoot and corm that bears adventitious roots.

7. Ware yam - whole yam tuber weighing more than 1000 g.

ACRONYMS, FORMULAE AND SYMBOLS

ACC	= 1 - aminocyclopropane - 1 - carboxylic acid.
a.i.	= Active ingredient.
ATP	= Adenosine triphosphate.
CIAT	= International Centre for Tropical Agriculture.
CRD	= Completely randomised design.
CP	= Crude protein.
DAH	= Days after harvesting.
DAP	= Days after planting.
F.A.O.	= Food and Agriculture Organisation.
$FeSO_4$	= Ferrous Sulphate.
$\geqslant$	= Greater than or equal to.
IITA	= International Institute of Tropical Agriculture.
IPC	= International Potato Centre.
IRRI	= International Rice Research Institute.
l	= Litres.
LSD	= Least Significant Difference.
$\leqslant$	= Less than or equal to.
MAP	= Months after planting.

MAT = Months after transplanting.

ME = Morphogenetic efficiency.

$Na_2S_2O_3$ = Sodium Thiosulphate.

$(NH_4)_2SO_4$ = Ammonium Sulphate.

ppm = Parts per million.

pers. comm. = Personal communication.

NRCRI = National Root Crop Research Institute.

r = Correlation coefficient.

SAM = S-adenosylmethionine.

St. = Station.

Techn. = Technology.

TP I = Transitional Phase I.

TP II = Transitional Phase II.

U.S.D.A. = United States Department of Agriculture.

VP I = Vegetative Phase I.

VP II = Vegetative Phase II.

WAH = Weeks after harvesting.

WAP = Weeks after planting.

WAT = Weeks after transplanting.

WOT(s) = Week old tuber(s).

χ^2 = Chi-square.

$\approx$ = Approximately.

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SUMMARY

The microsett technique involves the use of 2-10g setts comprising two size-ranges: a lower 2-5g and an upper 5.01-10g.

Preliminary experiments were undertaken to determine the ideal presprouting medium, moisture regime of the latter, presprouting environment, and sett size of the microsetts derived from the white yam variety, TDr 131.

The upper 5.01-10g sett-class presprouted in open-air, raised beds covered with low palm-frond shade, using fresh sawdust at an initial moisture content of 76%, i.e. 1000g of dry sawdust mixed with 3l of water was ideal.

The acceleration and synchronisation of sprouting of the microsetts in the nursery prior to transplanting, by means of mineral nutrients were also investigated. The most practically feasible method of accelerating the sprouting of the microsetts was the tail removal technique. This involved plucking off the cormous structure bearing an apical bud from the head region of the tuber and separating the distal-1/3 region or tail from the head and middle portions of the tuber,

herein also referred to as "head" at 3 weeks-after-harvest (WAH). The resultant tuber parts were soaked in a nutrient mixture of 1500 parts per million (ppm) Urea, 50ppm Florel (ethephon) and 10ppm Ferrous sulphate. The nutrient mixture elicited highly significant sprouting compared to the control such that at 17, 18 and 21 WAH there were no real differences between the heads and tails.

The objective was to accelerate the sprouting of the tails so as to synchronize it with the heads. Consequently, microsetts from the tails could behave as heads when presprouted.

The nutrient mixture application and the tail removal operation were undertaken at 3 WAH, i.e during TP I, on the bases of studies on changes in some macro- and micro-nutrient levels in the tuber with time-after-harvest.

The trends in percent total nitrogen (% TN) were most spectacular : there was a decline between the 3rd and 5th weeks and a rise thereafter in the peripheral 1.6-1.9cm portion of the tuber. The % TN values in the head and tail region microsetts were similar, whilst those of the middle

were markedly low. These suggested a bipolar internal redistribution within the tuber. The head and tail regions of the the tuber were largely sinks, whilst the middle was largely a source.

Furthermore, movement of total nitrogen was probably directed out of the peripheral 1.6 - 1.9 cm tissues into the inner ground tissues from 3 - 5 WAH and towards the periphery from the 5 WAH onwards.

The nutrient mixture was thus supplied at 3 WAH on the assumption that the greatest demand for nitrogen must be at this period.

The trends in % TN and hence crude protein, potassium and iron were similar.

On the strength of this suggested nutrient redistribution, the tuber dormancy stage of yam ontogeny was considered as comprising a "true dormancy" sub-phase, followed by a "biochemically non-dormant tuber" sub-phase. The latter stage was assumedly indicated by the rise in % TN at 5 WAH. Consequently, the reported progressive development of the

meristematic layer probably starts at 5 WAH and continues till the bud on the cormous structure at the head of the tuber, becomes visibly active: the external indication that dormancy is naturally over.

The slip propagation technique entails the use of the cormous structure at the head of the tuber and the associated shoot that arises from it after natural tuber dormancy release. The non-green, achlorophyllised slips derived from tubers of the white yam variety, TDr 603, stored in the dark, showed high morphogenetic ability. This was attributed to probably phytochrome-mediated responses. The direct field planting of the freshly plucked non-green slips is agronomically ideal.

A seed yam production package based on microsetts and non-green slips is proposed.

CHAPTER I

INTRODUCTION

The edible yams, Dioscorea spp. constitute a major starchy staple in the lowland humid tropics, with the West African sub-region producing about two-thirds of the total world production (Hahn and Hozyo, 1983). The prominent cultivated species in this region are Dioscorea rotundata (White Guinea yam), Dioscorea cayenensis (Yellow Guinea yam), Dioscorea alata (Water yam) and Dioscorea dumetorum (Trifoliate yam).

The edible yam is vegetatively propagated by means of small, whole tubers, called "seed yams" or pieces of tubers known as "setts" (Coursey and Booth, 1977). The seed yams range between 100-1500 g in size (Okoli et al., 1982) and it is from these that farmers obtain the large marketable ware yams.

The seed yams or setts are in short supply since production methods are inefficient. Hence, at harvest, the farmer has to decide on what proportions of his crop he should sell as ware yams, use for his home subsistence and store for the next season's planting.

Akoroda and Okonmah (1982) asserted that 10-30% of the

previous crop yield is used as setts for the next season's planting. This may be as high as 40%, representing about 60% of the total production cost of yam (NRCRI, 1981).

According to Coursey (1984) there has been a gradual recession in yam production over the years in West Africa although FAO statistics up to 1977 revealed that world yam output has marginally increased.

A major contributing factor to this declining trend is the short supply of good quality seed yams (Nwosu, 1975).

There is, therefore, the need for the development of a simple but appropriate rapid multiplication technology for seed yam production.

Traditional farmers, produce their own seed yams by undertaking double-harvesting or "milking" or planting small setts of size-range, 70-100 g at close spacing known as the "Anambra System" (Okonmah, 1980). These methods are, however, very inefficient with low multiplication ratios ranging from 1:4 to 1:8 (Alvarez and Hahn, 1984).

The need for a more efficient seed yam production technology is not of major concern to the traditional farmer alone but also the yam researcher. The yam breeder and his team need to rapidly multiply their test materials at the initial stages of an improvement programme. Superior

enotypes selected at the end of the latter, should also be ultiplied for distribution to farmers and other researchers.

The acute shortage of planting material has hitherto everely hampered varietal and agronomic improvement rogrammes. Wilson (1982) reported that it takes three years fter hybridization to obtain enough planting materials to stablish a complete breeding population.

Research efforts geared at evolving a better ultiplication system have resulted in the following echniques: rooted vine-cutting (Njoku, 1963), sprouted tuber egments and excised plantlets methods (Nwosu, 1975), new ropagation method (Okigbo and Ibe, 1973) as well as the inisett (Okoli et al., 1982) and the microsett (Alvarez and ahn, 1984). The latter two are, by all standards, the most racticable and hold much promise in removing the planting aterial bottleneck in yam production. The mini- and icrosett techniques are improvements of the traditional armer's Anambra system and utilize 25 g and 3-5 g sett sizes espectively. The microsetts are characterised by a high ultiplication ratio of 1:90 (Alvarez and Hahn, op. cit.) and hus could constitute an efficient seed yam production echnology if developed.

The edible yam tubers normally go through a post-harvest, dormancy period - the duration of which depends on the species as well as the variety, after which they sprout from the head region. White yam (Dioscorea rotundata), water yam (Dioscorea alata) and chinese yam (Dioscorea esculenta) tubers exhibit dormancy periods of over three months (Passam, 1982), whilst those of yellow yam (Dioscorea cayenensis) are dormant for 1-2 months.

These new sprouts depend upon the storage reserves in the tuber for growth (Coursey, 1961) and thus rendering it less healthy as planting material for the next season.

The amount of storage reserves in the seed yam determine the field establishment, vigour and ultimate tuber yield. The longer the sprouted tubers are kept in storage, the greater the depletion of their reserve food. Sprouting has been reported to result in about 50% loss in weight of stored tubers (NRCRI, 1978).

Farmers periodically inspect these tubers to remove the sprouts, but only to throw them away. Little or no use is made of them.

Thus, for any seed yam production technology to be efficient, it should entail the use of not only the tuber but the leafless sprouts as well.

It is in this light that these studies seek to:

1). identify by means of nursery and/or field experiments, with regard to the microsetts, the ideal

i). presprouting medium

ii). moisture regime of the presprouting medium

iii). presprouting nursery design

iv). sett size

2). investigate means of accelerating and synchronizing sprouting of the microsetts in the nursery.

3). investigate the pre-plant management of the leafless sprouts or "slips".

The ultimate objective of these, is to attempt the development of a more efficient technology for the production of seed yams of white yam (Dioscorea rotundata Poir) using the microsetts and slips.

CHAPTER II

LITERATURE REVIEW

1. Introduction

The edible yams are grown for their tubers (Pans, 1978) and comprise about 50 species. They are monocotyledons (Ayensu, 1972) belonging to the family Dioscoreaceae, although the presence of a second cotyledon has been reported (Lawton and Lawton, 1967).

The economically important food-crop types include Dioscorea rotundata (L) Poir (White Guinea yam), Dioscorea cayenensis Lam. (Yellow Guinea yam), Dioscorea alata L. (Water yam), Dioscorea dumetorum (Kunth) (Trifoliate yam), Dioscorea esculenta (Lour) Burk. (Lesser or Chinese yam) and Dioscorea bulbifera (Potato or Aerial yam) (Kay, 1973).

The white, yellow and water yams, which belong to the section Enantiophyllum (Martin and Sadik, 1977) as well as the trifoliate yam belonging to the section Lasiophyton, are the most economically important species in Africa (essentially West Africa). In this part of the tropics, much ethnocultural symbolism is associated with the production and utilization of the yam (Onwueme, 1978).

2. The Edible Yam Tuber

The yam tuber serves the dual functions of a carbohydrate sink as well as a vegetative propagule (Leon, 1977). Although, Burkill (1960) attributed tuber formation to plagiotropic lobes developed on a degenerate rhizome, thereby providing the phylogenetic requirement of a food reserve for subsequent sprouting; the recent position is that it is neither a stem nor root structure, but rather it originates form the hypocotyl region (Martin and Ortiz, 1963; Lawton and Lawton, 1969). The latter conclusion is based on the absence of buds, scale leaves and a terminal bud on the tuber. Onwueme (1984) reported that the corm attached to the tuber, described as the yam "head" by Burkill (op. cit.) has buds on it at harvest.

As mentioned earlier on (page 4) the tuber becomes dormant after harvest, the duration of which depends on the species as well as the variety. According to Ayensu (1972), a transverse section of the dormant enantiophyllum tubers portrays a less easily identifiable epidermis, an inner cork layer made up of irregularly arranged suberized cells and a secondary cork layer, comprising suberized cells arranged in radial rows.

There is then an inner layer of ground tissue consisting of thick-walled storage parenchyma.

When the dormancy of the enantiophyllum yams is over, new shoots originate from the cormous structure only (Wickham et al., 1981). However, when this cormous structure is removed sprouting occurs by de novo bud formation in tuber-pieces derived from budless, mother tubers (Onwueme, 1979). This is due to the renewed activity of a primary thickening meristem. Shoot formation, according to Wickham et al. (op. cit.), is initiated in the primary thickening meristem of Dioscorea rotundata. The activity of this meristem results in a tuber germination meristem, from which according to Wickham et al., (op. cit.), the shoot apical meristem is organized. A shoot is initially developed during sprouting of most Dioscorea spp. (Burkill, op. cit.) followed by roots from its highly modified basal node(s). The latter is termed primary nodal complex (PNC). Wickham et al. (op. cit.) asserted that the PNC is associated with the shoot apical meristem and is charateristic of both sexual and vegetative propagules. The PNC is characterised by a meristematic layer which gives rise to long, thick roots, PNC-roots, that serve for the provision of

support as well as for water and nutrient uptake (Ferguson, 1973; Ferguson and Gumbs, 1976 cited by Wickham et al., op. cit).

The thin, short-lived, tuber-roots that are found on the body of the tuber are formed by the activity of the primary thickening meristem (Wickham et al., op. cit.). These roots, according to Passam (1977), are normally formed prior to the appearance of the shoots and the PNC-roots usually in response to high humidities.

3. Vegetative Propagation Techniques

i. Traditional Methods

a). Double Harvesting

This entails the removal of the developing tuber for food relatively early in the season (Nwosu, 1975) whereby the parent plant is left to form a new tuber. The latter is stored as seed. The first harvesting is normally undertaken 4-5 months (Onwueme, 1984) after planting.

Onwueme (op. cit.) reported that the second-harvest tubers have certain unique characteristics, such as the fusion of the corm with the rest of the tuber. The corm possesses well-developed buds, which render these tubers as ideal sources of seed yams. The periderm is well-lignified and

hence post-harvest deterioration is much reduced. The double-harvesting operation is very laborious and time-consuming, requiring a lot of skill. Consequently, it is an inefficient seed yam production method.

b). The Anambra State Sett Production System

This is a specialised seed yam production technique developed by farmers in Anambra State, Nigeria.

Small setts of size range 70-100 g (Okonmah, 1980) are planted closely at a spacing of 100 cm x 50 cm, if ridges were used, to produce 228-456 g seed yams (Nwosu, 1975). This technique is very lucrative.

ii. Improved Seed Yam Production Methods

a). Rooted Vine-Cutting

Correl et al. (1955) first reported the use of vine-cuttings for yam propagation. They observed root development on one-node cuttings of non-edible, sapogenin-bearing Dioscorea spp. in sand after 14-21 days at a light intensity of 200 foot-candles. These cuttings produced small, leaf-axillary-borne tubers.

The edible yam: D. rotundata, D. alata and D. dumetorum

can also be propagated by vine-cuttings (Njoku, 1963; IITA, 1974; Martin and Sadik, 1977).

Njoku (op. cit.) and Ferguson (1971) were of the view that vine-cutting propagation may not be of commercial significance, because of the rather poor vigour of the plantlets. This technique is, however, suitable for obtaining nematode-free tubers (Okoli et al., 1982).

b). Sprouted Tuber Segments

The proximal head and distal tail portions of the mother tuber are removed to destroy apical dominance and the remaining portion is presprouted in moist, fermented sawdust or coarse sand medium (Nwosu, 1975). 10 g segments are then carefully removed from the parent tuber together with an associated small plantlet. The plantlets are nursed in soil-filled polyethylene bags for 3-4 weeks prior to field transplanting. This technique requires a lot of skill and may be rather more suitable as a research tool.

c). Excised Plantlets

This, according to Nwosu (op. cit.), is a further improvement of the sprouted tuber segments method.

The sprouts are allowed to develop to a greater extent prior to excision and no tuber segments are attached to them upon removal. The excised plantlets are nursed in soil-compost mixture in polyethylene bags for 2-4 weeks prior to field transplanting. According to Nwosu (op. cit.) the multiplication ratio in this instance is greater than that of the tuber segments method. The plantlets require very careful handling and management, rendering this technique more suitable as a research-tool than as a commercial undertaking.

d). New Propagation Method

Okigbo and Ibe (1973) reported a technique which they described as "new method of yam propagation", involving the rooting of setts in the field, which are then carefully removed leaving a new plant that comprises a new shoot and roots. The mother-sett is replanted and subsequently removed after the establishment of the new plantlet. They asserted that 2 or 3 sequential sett removals and replantings were enough.

Using this method, one could establish more than a stand with the same sett and thereby increase the multiplication ratio. This technique, which is a modification of the

traditional farmer's "milking", is cumbersome and requires a lot of skill and extra care so as not to damage the roots.

e). Tissue Culture

Tissue and plant cell culture methods have recently gained prominence in the multiplication of vegetatively propagated crops especially ornamentals like the orchids.

Mantell et al. (1978) reported a rapid multiplication system for the edible yams using tissue culture. They claimed that one could obtain 65,000 plants from single nodal segments pre-conditioned under long days in 6 months.

Ng (1984) reported that besides nodal cultures, plantlets could also be produced by culturing shoot-tips as well as tuber explants in artificial media.

Tissue culture is, however, an impracticable seed yam production technique and is purely a research-tool in the rapid propagation of disease-free planting materials for distribution.

f). Minisett Propagation Technique

The "minisetts" which Okoli et al. (1982) described as being 25 g or less are either planted directly or presprouted

prior to field transplanting.

The use of the minisett technique and plastic-strip mulch could enhance seed yam production at the farm-level (Alvarez and Hahn, 1984). According to the latter, the plastic-strip mulch, besides effectively minimising weed growth, without adversely affecting the yam plants, also maintained uniform soil moisture level throughout the crop duration. The moisture level under the plastic-strip mulch was significantly higher (4.7%) than the unmulched soil. Presprouted white yam minisetts under plasticulture mature in 5-6 months after transplanting depending on the variety. The minisett technique is a very practicable and appropriate seed yam rapid multiplication technology, much within the scope of the smallholder farmer.

MICROSETT PROPAGATION

SECTION A

NURSERY EXPERIMENTS

CHAPTER III

EFFECTS OF PRESPROUTING MEDIUM, SAWDUST MOISTURE REGIME, NURSERY DESIGN AND SETT SIZE ON SPROUTING IN THE NURSERY

1. Introduction

Alvarez and Hahn (1984) reported that 3-5 g setts, which they termed "microsetts" (Fig. 1) could be used for yam production. According to them, a multiplication ratio of 1:90 is derivable from using the microsetts. This rather high multiplication ratio indicated a great potential in the utilization of the microsetts for seed yam production. The relatively small sizes of the microsetts, however, necessitated their being presprouted prior to field transplanting so as to prevent losses due to dehydration and rotting and thereby obtain uniform field establishment. Nursery management involves the optimisation of the plant responses to environmental factors such as moisture (Hartmann and Kester, 1983). The mobilisation of sugar and other food reserves depends on the imbibition of enough water during the initial stages of germination (Heydecker and Gibbons, 1978).

Fig. 1: 3-5 g Sett-Pieces or "Microsetts" of White Guinea Yam (From Alvarez and Hahn, 1984).

According to Hartmann and Kester (op. cit.), the nursery environment could be controlled by the kind of physical structures, if properly handled. The growth of the propagules could, therefore, be accelerated and the duration of the presprouting operation shortened.

Sett size determines the rapidity of sprouting of the edible yams (Onwueme, 1984). Larger setts produce more vigorous sprouts, which emerge quickly (Onwueme, 1972, 1973).

Okoli et al. (1982) put the size described the minisett as 25 g or less. They, however, did not specify the lowest utilizable size-limit. Alvarez and Hahn (1984) in reporting the possibility of using 3-5g setts for seed yam production, also made no reference to the optimal size.

In the light of the above, experiments were undertaken in the presprouting nursery to identify the ideal presprouting medium, its moisture regime, nursery design and sett size for the microsetts.

2. Materials and Methods

i. Determination of the Ideal Presprouting Medium

About 5 g setts were derived from 200-600 g mother seed yam tubers by laying them horizontally on a clean table and

cutting them up into short cylinders of about 1.8 cm thickness, with a sharp clean knife (see Fig. 22, page 162).

The tubers were washed in tap water to remove any soil particles prior to being cut-up. The cut-surfaces were suberized for a period of twenty-four hours by exposing them to diffused sunlight under light palm-frond shade. They were placed on a transparent polyethylene sheet in a propagation bed, constructed with cement-blocks, with their cut-surfaces upwards. A second polyethylene sheet was used to cover them up, the loose-ends of which were held together with the lower one, using wooden-planks and cement-blocks to create a humid and warm atmosphere for the suberization to proceed.

Prior to covering the setts, they were sprayed with a fungicide mixture comprising 5 g Captan 80 (a.i.w/w 80% Captan) and 2 g "Tecto" (Thiabendazole) in five litres of solution. The lower polyethylene sheet was perforated to facilitate the drainage of the fungicide mixture. The morning (1035-1055 Hours) and afternoon (1345 Hours) temperatures between the polyethylene sheets, were 33^{o} and $31.3^{o}C$ respectively. There was an overcast for most of the afternoon.

The objective of the suberization was to facilitate wound-healing. The latter, according to Passam et al. (1976) involves the desiccation of the parenchyma cells at the wound-or cut-surface, with the deposition of suberin in the adjacent cells beneath the desiccated layer, leading to the formation of a wound-cork or periderm layer. Passam et al. (op. cit.) were of the view that high temperature and humidity facilitate wound-healing.

The presprouting was undertaken in containerized polystyrene trays measuring 60.8 cm x 30.4 cm x 6.3 cm. Each comprised 128 trapezoidally-shaped chambers. The trays were placed on asbestos sheets supported by iron-frames in a propagation house. The latter was basically a translucent-sheeting-roofed mesh-work, superimposed on a cement-block structure.

The presprouting medium treatments were:

a). unwashed but heat-sterilized river sand.

b). fresh sawdust.

c). vermiculite (heat-expanded, mica material).

d). 1:1:1 v/v mixture of the above.

The completely randomised design in three replications was used. There were 128 setts per treatment.

The bulk density and mechanical impedance of each presprouting medium was measured by filling three rows each of one polystyrene tray with the media under consideration. They were watered and left overnight to drain completely.

In calculating the bulk density, the volume of a chamber of the containerized tray was measured by sealing up the basal drainage-hole with a finger and filling it up fully with tap-water. The water was then released into a measuring cylinder, giving the volume as 42.0 cm^3. Two chambers of each medium in the tray mentioned above were emptied into moisture-cans and their fresh weights determined. They were oven-dried at 105^oC for twenty-four hours and weighed. The bulk density of each sample was then determined as the quotient: oven dry weight(g)/42.0 cm^3.

The mechanical impedance was measured by means of an unconfined strength, CL-700 pocket penetrometer. The readings of the latter were taken when its edge or tip penetrated the media surface to a depth of about 6 mm as indicated by the calibration on it. Two readings were taken for each medium and the mean found.

The bulk density and mechanical impedance measurements

were undertaken on the same medium samples from randomly selected chambers.

At 21, 28 and 35 DAP, counts were made of rotted, sprouted and unsprouted setts, using random samples of twenty.

ii. Determination of the Ideal Sawdust Moisture Regime

The fresh sawdust medium was outstandingly the most ideal. Consequently, the following experiment was undertaken to determine its most appropriate moisture regime.

Fresh sawdust was, thinly spread over a polyethylene sheet in the open-air and sun-dried between 0900 - 1500 Hours daily for three days (3 June - 5 June, 1984). The mean air temperature during this period was 26.5^{o}C (IITA, 1984). Two subsamples were collected after the third day and oven-dried to constant weight in moisture-cans using an electric oven at 65^{o}C for forty-eight hours to determine their sun-dried moisture contents.

Four sawdust moisture regimes were obtained by thoroughly hand-mixing 1000 g batches of the sun-dried sawdust with 1,2,3 and 4 litres of water to give 1000g/1, 1000g/2l, 1000g/3l and 1000g/4l treatments respectively. Perforated wooden boxes of dimensions: 60 cm x 30 cm x6 cm were filled with these differentially moistened sawdust to a depth of 2,5 cm using a

completely randomised design in three replications. The unmoistened sun-dried sawdust was used as the control and there was one moisture-regime treatment to a box.

The cut-surfaces of about 5 g and 25 g micro- and minisetts respectively were treated with a suspension of wood ash, Aldrex 'T' - a fungicide/insecticide and Demosan, a fungicide with Chloroneb as the active ingredient, at a rate of 24 g Demosan, 6 g (2 satchets) Aldrex 'T' and about three-quarters, 1 litre cup-full of wood ash in 4 litres of solution. The setts were soaked in this suspension for 2-3 minutes. They were immediately planted in boxes on 6 June, 1984 and covered to about 1.0 cm thickness with the respective sawdust-moisture-regime treatment.

The boxes were left in the propagation house for the first eight days to ensure that rain did not interfere with the experiment during the initial stages. Furthermore, it has been observed that if the sawdust was not watered during the first three to five days after planting, sett rot was minimal. Subsequently the boxes were taken out into the open-air and hand-watered as necessary or by rain.

Two sub-samples each of the 1000 g/11, 1000 g/21, 1000 g/31 and 1000 g/41 treatments were taken on the first day after setting up the experiment. Their moisture contents were determined by oven-drying them at 65°C for forty-eight hours.

Counts were made of rotted, sprouted and unsprouted setts at 5, 8 and 33 DAP. However, those of the microsetts at the 33 DAP were discarded due to miscounting.

iii. Determination of the Ideal Presprouting Nursery Design

About 5g microsetts, the cut-surfaces of which were treated with the wood ash-Aldrex 'T'-Demosan suspension as described in Experiment (ii) were presprouted in fresh sawdust in the following environments:

(a). open air, covered bed (OCB): open-air, 5 m x 1 m, cement-block beds, with low palm-frond shade, about 30 cm high.

(b). open-air, uncovered bed (OUB): open-air, cement-block-beds, without palm-frond shade.

(c). open-air, polystyrene trays (OPT): containerized polystyrene trays, placed under low palm-frond shade in the open-air.

(d). propagation house, polystyrene trays (PPT): containerized polystyrene trays, placed on asbestos sheets supported by iron-frames in the propagation house.

The open-air, propagation beds were filled with moist sawdust to a depth of 1.5-2.0 cm.

The setts were laid in the beds with their cut-surfaces upwards and were separated from each other by a distance of about 1.0 cm. They were covered with the same moist sawdust to a thickness of about 1.0 to 1.5 cm. It has been observed that too thick an upper sawdust layer tended to absorb water and caused the setts to rot, whilst an upper layer of the just-mentioned thickness maintained the integrity of the setts by facilitating further suberization of the cut-surfaces in the beds by means of improved aeration.

Four replications of thirty-two setts were used per environment. Counts of rotted, sprouted and unsprouted setts were made at 21 and 28 DAP.

iv. Determination of Optimal Sett Size

About 100-700g sprouted mother seed yams which have been in the traditional yam barn storage for over a period of six months after harvest, were washed clean of dirt in tap-water

and cut into six weight classes, viz 2-5, 5.01-10, 10.01-20, 20.01-30, 30.01-40 and 40.01-50 g with a clean knife as described in Experiment (i).

Although the microsetts were initially considered as being 3-5 g in size (Alvarez and Hahn, 1984), it was decided to regardredfine them as 2-10 g, thereby splitting them into two size-classes: an upper 5.01-10 g and a lower, 2-5 g.

The cut-surfaces were treated with the wood ash-Aldrex 'T'-Demosan suspension at the rates and times described in Experiment (ii).

Twenty-five setts of each size-class were immediately laid in fresh sawdust in an open-air, propagation bed as described in Experiment (iii), using the completely randomised design in four replications. Each experimental unit was separated from the other by short bamboo stakes.

Counts were made of rotted and sprouted setts at ten-day intervals for four consecutive times.

Data Management and Statistical Analysis

The counts were expressed as percentages. "Total" sprouting was considered as the sum of four shoot developmental stages (page 84). Shoot stages 6b, 6c, and 6d (page 84) were collectively considered as the "leafy and

leafless" sprouting stage with regard to Experiments (iii) and (iv).

Although the counts were repeated over time, each set of records was analysed as a one way classification, disregarding time as a factor.

The ideal presprouting environment experiment was analysed as a completely randomised design (CRD).

The percentage moisture contents of the various sawdust moisture regime treatments in Experiment (ii) using the two sub-samples in each case were also analysed with the CRD option.

The variates were analysed with the Genstat Mark V programme. Those which showed skewed distribution as well as non-significant variance-ratios were angularly transformed and re-analysed. Furthermore, variates which otherwise were not skewed but had general mean values of less than 30% were also transformed angularly (Little, 1985).

The Least Significant Difference (LSD) test was used to compare pairs of treatment means of variates for which the variance-ratio was significant.

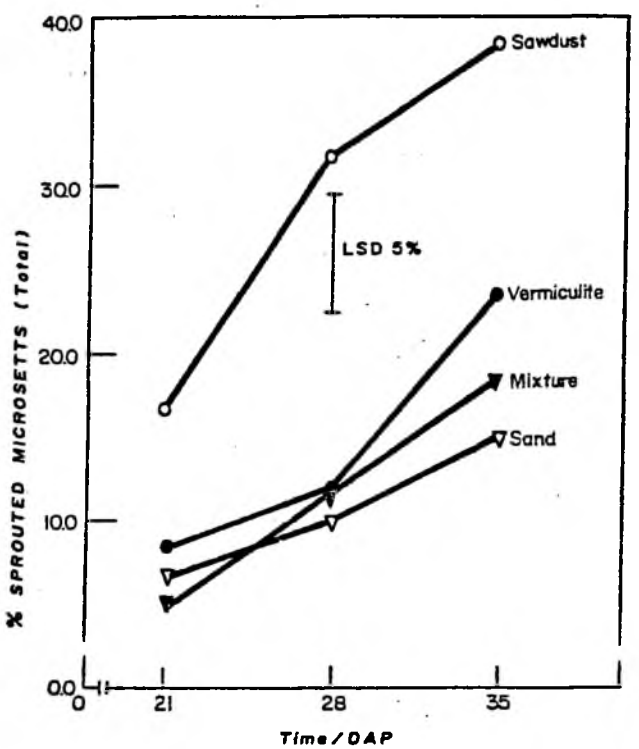


Fig. 2: Effects of Presprouting Media on the Sprouting of Microsetts.

3. Results and Discussion

1. Determination of the Ideal Presprouting Medium

Sprouting in the sawdust was statistically higher than in the vermiculite, mixture and sand media, at 28 DAP (Fig. 2), with the latter three media being statistically similar. However, the sprouting values were generally very low, with the sawdust producing only a non-significant 38.3% total sprouting on the thirty-fifth day. Besides the rather significantly higher rotting losses in the vermiculite and mixture as compared to the sawdust over the five-week period (Table 1), the observed slow sprouting of the setts was due to premature tuberization in the various media.

TABLE 1: Effects of Presprouting Medium on the Rotting of Microsetts over a Five-Week Period.

Medium	% Rotted Microsetts
Sand	30.6
Sawdust	22.8
Vermiculite	37.8
Mixture	47.8
LSD	14.4

This phenomenon was due to the rather advanced age, about 36 WAH, of the mother seed yams. This behaviour, according to Caesar (1979) is an indication of terminal physiological ageing.

Considering the physical properties of the media, the sawdust had relatively higher moisture-holding capacity, with a 32.7% moisture content after a 24h free-drainage as compared to the 8.7% and 12.2% for the sand and mixture media respectively (Table 2). This could necessitate frequent watering for the latter two media thereby creating anaerobic conditions and thus predispose the setts to rotting agents.

TABLE 2: Some Physical Properties of Various Microsett Presprouting Media

Medium	% Moisture Content (after 24 h free-drainage)	Bulk Density ($g\ cm^{-3}$)	Mechanical Impedance ($kg\ cm^{-2}$)
Sand	8.7	1.29	0.70
Sawdust	32.7	0.13	0.25
Vermiculite	25.5	0.10	0.25
Mixture	12.2	0.58	0.25

A high moisture-retention capacity is desirable, as a highly significant correlation coefficient (r= +0.93**) was obtained between % moisture retention and total sprouting at the fifth-week period (Table 3). The ideal medium, thus, appears to be one that is able to maintain a high moisture content after a single watering than one which has to be regularly watered at short intervals.

Furthermore, a highly significant negative correlation coefficient (r= -0.75**) was also observed between bulk density and total sprouting at the fifth week (Table 3). Consequently, sand which had the highest bulk density of 1.29 g cm-3 (Table 2) elicited the lowest sprouting value (Fig. 2). This could be due to its porosity and thus its low moisture-holding capacity. Likewise, mechanical impedance was negatively related to total sprouting, producing a correlation coefficient, r, of -0.57* (Table 3).

ii. Determination of the Ideal Sawdust Moisture Regime

a). Total Sprouting

Total sprouting generally increased with increased sawdust moisture regime for the 5 g and 25 g setts over all the sampling periods (Table 4).

TABLE 3: Correlation Coefficients Between Presprouting Medium Moisture Content, Bulk Density, Mechanical Impedance and % Microsett Total Sprouting At 5 WAP.

	% Total Sprouted Microsetts
% Moisture Content	0.93**
Bulk Density	-0.73**
Mechanical Impedance	-0.57*

* Significant at P = 0.05; n = 4.

** Significant at P = 0.01; n = 4.

TABLE 4: Effects of Sawdust Moisture Regime on Sprouting in the Nursery over Time

Moisture Regime (Gram Sawdust /litres of water)	% Total Sprouted Microsetts				
	Sett Size/g				
	5		25		
	Time (DAP)		Time (DAP)		
	5	8	5	8	33
1000/0	0.0	0.0	0.0	0.0	25.0
1000/1	1.4	1.4	8.3	15.3	63.9
1000/2	29.2	37.5	19.5	27.8	79.2
1000/3	52.8	61.1	48.6	50.0	79.2
1000/4	55.6	62.5	56.9	72.2	80.6
LSD 5%	20.6	10.0	19.2	18.9	15.4

Considering the 5 g setts at 5 DAP, although no real differences were observed between the control (1000 g/01) and 1000 g/11 treatments, as well as between the higher moisture regime treatments: 1000 g/31 and 1000 g/41, the 1000 g/21 treatment significantly promoted total sprouting in comparison to the 1000 g/11 and 1000 g/01 treatments (Table 4); nonetheless, this was significantly lower than those at the higher moisture regimes. Similar trends were observed at the eighth day.

The higher moisture regimes, 1000 g/31 and 1000 g/41 produced statistically superior sprouting values in relation to the other treatments at 5 and 8 DAP with regard to the 25 g setts (Table 4). The 1000 g/21 treatment significantly promoted sprouting than the control, but its effect was however not really different from that of the 1000 g/11 treatment.

At 33 DAP (under open-air conditions), whereby all the experimental units were uniformly hand-watered as necessary or by rain, there were no real differences between the 1000 g/11, 1000 g/21 and 1000 g/31 treatments (Table 4). The 1000 g/41 treatment produced statistically superior total sprouting compared to the 1000 g/11 treatment. The control treatment was, however, significantly inferior to all the other moisture

regime treatments, producing only 25.0% total sprouting at this period (Table 4).

b). Leafy-and-Leafless-Shoots

There were no real differences among the moisture regime treatments with regard to the development of microsetts with "leafy and leafless" shoots for the 5 g setts (Table 5). The 1000 g/2l and 1000 g/3l treatments produced only marginal numerical values of 2.8% at 5 and 8 DAP respectively.

Thus, the total sprouting values observed for the 5 g setts (Table 4) at these times were predominantly those of the microsetts at the unemerged shoot developmental stage characterised by the formation of whitish callus-like protuberances.

Whilst there were no statistical differences between the control and the 1000 g/1l treatments for the 25 g setts, the remaining treatments produced significantly superior sprouting than the control at 5 DAP (Table 5). Similar trends were observed at the eighth day, but for the fact that the 1000 g/1l treatment was really more effective than the control.

However, at the thirty-third day, the 1000 g/4l and 1000 g/1l treatments, produced statistically similar leafy-and-leafless-shoot sprouting values, although the effect of the

TABLE 5: Effects of Sawdust Moisture Regime on the Development of the Leafy-And-Leafless-Shoots* Stage in the Nursery over Time

Moisture Regime (Gram Sawdust /litres of water)	% Sprouted Setts				
	Sett Size/g				
	5		25		
	Time (DAP)		Time (DAP)		
	5	8	5	8	33
1000/0	0.0	0.0	0.0	0.0	18.1
1000/1	1.4	1.4	5.6	9.7	56.9
1000/2	2.8	2.8	9.7	15.3	72.2
1000/3	0.0	2.8	9.7	16.7	73.6
1000/4	0.0	0.0	15.3	22.2	76.4
LSD 5%	N.S	N.S	7.8	8.6	20.0

* Leafless Shoots : see Figs. 6b and 6c (page 84)
Leafy Shoots : see Fig. 6d (page 84)

1000 g/4l was numerically superior to that of the 1000 g/1l (Table 5). The control treatment, 1000 g/0l, was significantly inferior to the rest.

As reported by Currier (1967), water is a major constituent of metabolically active tissue and all physiological processes, sprouting inclusive, depend on it as a reactant and solute translocatory medium. Thus, increasing

the sawdust moisture content probably increased the rate of solute mobilization and transport as well as metabolism. McIntyre (1984) reported that high humidity as well as the supply of water through the cut - end of the potato tuber markedly promoted sprouting. Furthermore, Onwueme (1976) reported that bud elongation in the yams is accelerated in moist media.

By 8 DAP no re-watering had been undertaken yet. Thus, the similarity in the sprouting trends for the 25 g setts (Table 5) at the fifth and eighth days (propagation house) with those at the thirty-third day (open-air), especially with regard to the 1000 g/2l, 1000 g/3l and 1000 g/4l treatments, imply that the initial moisture content of the sawdust medium is of prime importance. Infact, a very highly significant association, r=+0.99*** (P=0.001), was observed between the % sprouted setts values for the fifth and thirty-third days, as regards the 25g setts.

c). Sett Dehydration/Rotting

The 5 g setts, being smaller in size, were relatively more prone to dehydration losses than the 25 g ones (Table 6). This was evidenced by the 100% sett dehydration at 8 DAP for the 5 g setts but 9.7% for the 25 g setts, with respect to the control treatment.

TABLE 6: Effects of Sawdust Moisture Regime on the Sett Rot or Dehydration Losses in the Nursery over Time

Moisture Regime (Gram Sawdust /litres of water)	% Rotted Or Dehydrated Setts				
	Sett Size/g				
	5		25		
	Time (DAP)		Time (DAP)		
	5	8	5	8	33
1000/0	98.6	100.0	5.6	9.7	55.6
1000/1	5.6	15.3	1.4	1.4	12.5
1000/2	0.0	0.0	0.0	0.0	2.8
1000/3	0.0	0.0	0.0	0.0	5.6
1000/4	4.2	4.2	0.0	0.0	5.6
LSD 5%	6.5	7.8	N.S	7.3	14.1

Apart from 5 DAP, dehydration or rotting losses at 8 and 33 DAP for the control treatment of the 25 g setts were significantly greater than those at the higher moisture treatments (Table 6). Furthermore, there were no real differences among the other moisture regime treatments, besides the control. Consequently, the observed sprouting responses could be largely attributed to moisture effects.

One could, thus, employ the sprouting observations at 5 DAP (Table 4 and 5) to adjudge the ideal moisture regime.

TABLE 7: % Moisture Content of the Sawdust Moisture Regime Treatments

Sawdust Moisture Regime (Grams sawdust /litres of water)	% Moisture Content (Fresh weight basis)
1000/0	7.3
1000/1	53.1
1000/2	68.7
1000/3	76.0
1000/4	80.0
LSD 5%	3.3

Hence, the 1000 g/3l treatment, representing a moisture content of 76.0% (Table 7) was apparently the ideal sawdust moisture regime for presprouting the microsetts and minisetts.

This is due to the fact that, considering the total sprouting trends for both the 5 g and 25 g setts (Table 4), there were no real differences between the 1000 g/3l and 1000 g/4l treatments, but these two treatments were significantly superior to the 1000 g/2l and the lower moisture regimes.

Although there were no significant differences between the 1000 g/2l, 1000 g/3l and 1000 g/4l treatments, especially for the 25 g with regard to the development of the

leafy-and-leafless-shoot stage at 33 DAP (Table 5), 1000 g/31 is recommended. This is because one may not need to re-water the setts again or water sparingly the uppermost layer if the multi-layered planting method using perforated wooden boxes or baskets (page 195) is used.

iii. Determination of the Ideal Presprouting Nursery Design

The open-air beds, covered with low palm-frond shade (OCB) elicited significantly superior total sprouting than the rest (Table 8). Furthermore, it significantly promoted the development of the leafless-shoot-stage of the microsetts at 21 and 28 DAP. (Table 9).

The open-air, uncovered bed treatment (OUB) exhibited non-significant sprouting responses in comparison to those of the polystyrene trays in the propagation house (OPT) (Table 8 and 9).

The sprouting of the microsetts under the open-air, polystyrene-tray-treatment (OPT) was significantly lower than those of the PPT and OUB treatments at 21 DAP (Table 8 and 9), but evened out with the OUB as regards

TABLE 8: Effects of Presprouting Nursery Design on the Sprouting of Microsetts

Presprouting Nursery Design	Total Sprouted Microsetts (%)	
	Time (DAP)	
	21	28
Propagation House/ Polystyrene Trays	57.7	69.8
Open-air/Polystyrene Trays (Shaded)	25.0	46.9
Open-air/Uncovered Bed	44.8	54.2
Open-air/Covered Bed	82.8	85.9
LSD 5%	13.6	15.7

TABLE 9: Effects of Presprouting Nursery Design on the Development of Microsetts at the Leafless-Shoot-Stage

Presprouting Nursery Design	% Sprouted Microsetts (leafless-shoot-stage)	
	Time (DAP)	
	21	28
Propagation House/ Polystyrene Trays	7.3	25.0
Open-air/Polystyrene Trays (Shaded)	3.1	7.8
Open-air/Uncovered Bed	10.4	21.9
Open-air/Covered Bed	43.8	73.4
LSD 5%	9.3	15.9

total sprouting at 28 DAP (Table 8). It was, however, significantly inferior to the PPT treatments with respect to both total sprouting (Table 8) and the leafless-shoot- stage at 28 DAP (Table 9).

Sprouting under the OPT treatment was significantly confounded by rot in comparison to the other three design treatments (Table 10). This situation was largely due to the rather very humid conditions observed under this design.

TABLE 10: Effects of Presprouting Nursery Design on the Rot Incidence of Microsetts

Presprouting Nursery Design	% Rotted Microsetts — Time (DAP) 21	28
Propagation House/ Polystyrene Trays	7.3	7.3
Open-air/Polystyrene Trays (Shaded)	31.3	31.3
Open-air/Uncovered Bed	11.5	11.5
Open-air/Covered Bed	3.1	3.1
LSD 5%	14.7	14.7

Afternoon temperatures, recorded during the 1st week after planting between 1500 - 1600 Hours showed a striking similarity in the sawdust temperatures for the PPT and OPT treatments (Table 11). The sawdust temperature for the OUB treatment was similar to that of the air: 34.5°C.

Since the palm-frond shade modified the air-temperature, resulting in a sawdust temperature of 31.1°C for OCB treatment, it could be suggested that the significantly lower sprouting values of the microsetts under the OUB treatment as compared to the OCB (Table 8 and 9) could be due to faster moisture depletion of the sawdust as a result of the relatively higher temperatures.

Onwueme (1973) reported that the initiation of sprouting buds is promoted by dry conditions but the subsequent elongation of these is dependent on moisture availability.

Preston and Haun (1963) observed that exposure of Dioscorea spiculiflora setts to continuously high temperatures above 26.7°C stimulated sprout initiation, whilst an additional two more weeks at 32.2°C promoted sprout elongation. They concluded that such high

temperatures combined with high moisture levels, among others, would stimulate rapid vegetative growth.

The sawdust under the OCB design treatment was moist throughout the experimental period, being watered by the rain or hand as necessary. Consequently, the combination of such moist conditions along with the high temperatures (Table 11) might have created ideal condition for sprouting to proceed, rendering the OCB design as the ideal for presprouting the microsetts.

TABLE 11: Afternoon Temperatures in Sawdust-Based, Presprouting Nursery Designs of Microsetts

Presprouting Nursery Design	Temperature/^{o}C		
	Air	Below Palm Fronds	Sawdust
Propagation House/ Polystyrene Trays	32.4	-	31.4
Open-air/Polystyrene Trays (Shaded)	34.5	33.8	30.9
Open-air/Uncovered Bed	34.5	-	35.9
Open-air/Covered Bed	34.5	34.3	31.1
Open-Air	34.5	-	-

iv. Determination of the Optimal Sett Size

Sprouting was generally observed to increase with sett size (Tables 12 and 13); nonetheless, there was marked natural groupings of the setts with regard to the leafless-and-leafy-shoot-stage (emerged shoots) (Table 12 and Fig. 3).

This natural grouping of the sprouting behaviour of the sett-classes was evident from the 17 DAP and became more pronounced at the 26 DAP, whereby three natural groups were apparent on the basis of the lack of real differences within them:

a). Group I ... 20.01-30 g, 30.01-40 g and 40.01-50 g

b). Group II ... 5.01-10 g and 10.01-20 g

c). Group III ... 2-5 g.

The significant superiority of the Group I setts over the others, in this instance, could be attributed to the relatively greater amounts of remobilizable food reserves with increasing sett size. Onwueme (1972, 1973) reported that larger setts produce more vigorous shoots which rapidly emerge.

Although one could partially attribute the behaviour of the 2-5g setts (Group III) to a confounding effect of rot (Table 14) probably due to their small

TABLE 12: Effects of Sett Size on the Development of the Leafy-and-Leafless-Shoots in the Nursery Over Time

Sett Size Class/g	% Sprouted Setts (leafy-and-leafless-shoots) Time (DAP)				LSD 5%
	10	17	26	33	
2 - 5	1.0	3.0	16.0	33.0	10.1
5.01-10	1.0	8.0	42.0	55.0	9.5
10.01-20	4.0	20.0	49.0	57.0	9.7
20.01-30	3.0	39.0	86.0	95.0	16.0
30.01-40	12.0	53.0	87.0	92.0	10.9
40.01-50	8.0	51.0	84.0	94.0	16.5
LSD 5%	4.1	12.6	13.6	12.8	

TABLE 13: Effects of Sett Size on Sprouting in the Nursery Over Time

Sett Size Class/g	% Sprouted Setts (Total) Time (DAP)				LSD 5%
	10	17	26	33	
2 - 5	34.0	62.0	63.0	65.0	12.8
5.01-10	71.0	82.0	82.0	84.0	N.S.
10.01-20	71.5	91.0	90.0	87.0	10.8
20.01-30	88.0	100.0	100.0	100.0	4.4
30.01-40	83.0	96.0	99.0	100.0	7.0
40.01-50	89.0	97.0	99.0	100.0	N.S.
LSD 5%	13.8	7.9	7.2	8.8	

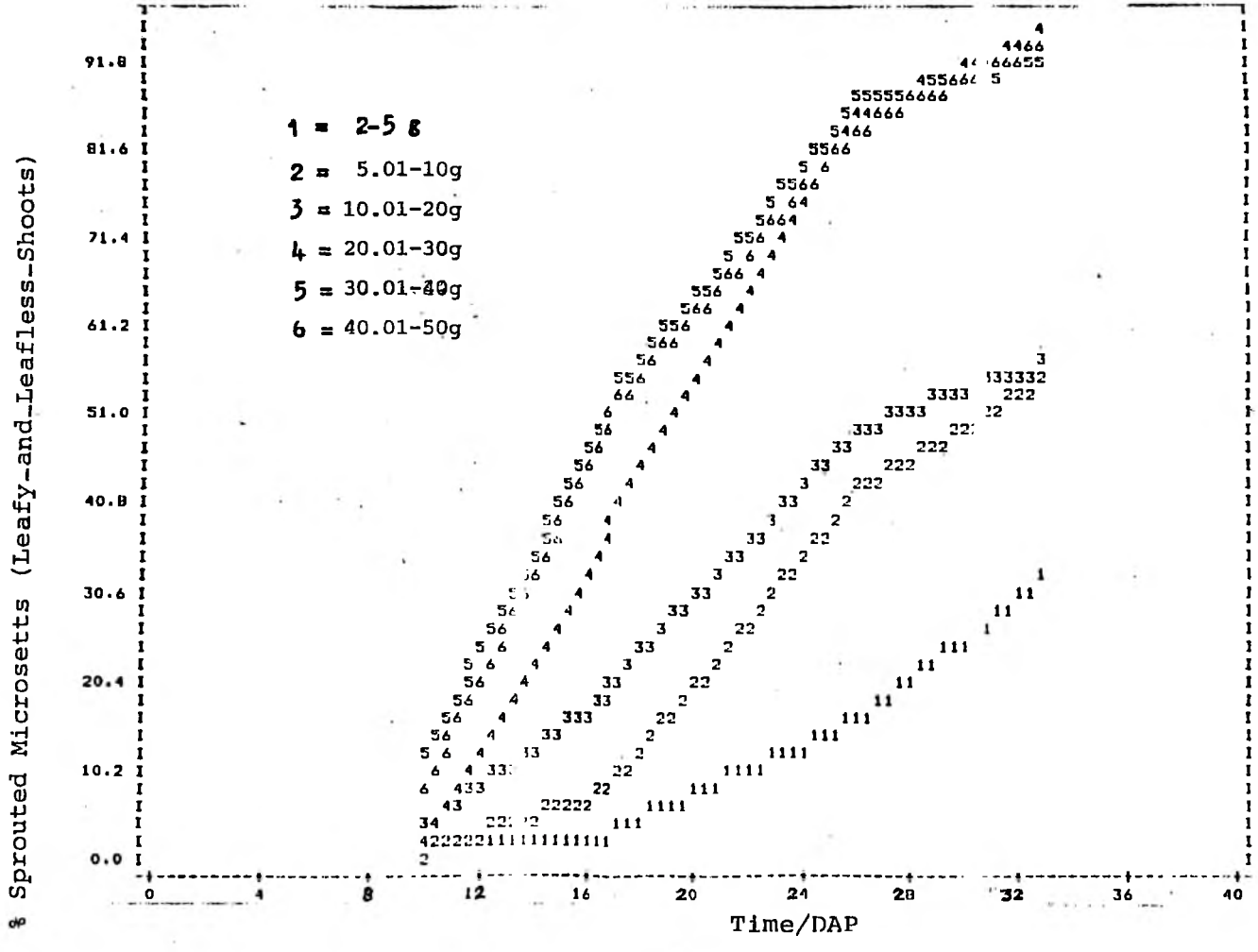


Fig. 3: Effects of Sett Size on Sprouting Over Time in the Nursery.

TABLE 14: Effects of Sett Size on Rotting in the Nursery Over Time

Sett Size Class/g	% Rot				LSD 5%
	Time (DAP)				
	10	17	26	33	
2 - 5	23.0	28.0	32.0	35.0	N.S.
5.01-10	8.0	11.0	14.0	16.0	N.S.
10.01-20	0.0	3.0	4.0	9.0	N.S.
20.01-30	0.0	0.0	0.0	0.0	-
30.01-40	0.0	0.0	0.0	0.0	-
40.01-50	0.0	0.0	0.0	0.0	-
LSD 5%	5.7	6.8	8.3	8.1	

sizes, the decrease in rotting with increasing sett size was an indication that the observed natural groupings in Fig. 3 were more of a physiological nature.

Furthermore, the sprouting trends (Fig. 3) could be assigned to the various phases of the sigmoid curve. The latter according to Moore (1979), represented the changing size of a growing cell, population of cells, tissue, organ or organism. He considered the sigmoid growth curve as follows:

i). An initial accelerating phase of slow growth

rate characterized by an exponential change in size, known as the logarithmic phase of growth.

ii). Linear phase of growth during which growth is almost linear with time.

iii). A phase of declining growth.

Moore (op. cit.) asserted that the linear phase may be absent, being replaced by a point of inflection.

The curve for the Group III setts could be regarded as representing the initial logarithmic phase of the sigmoid growth curve. Those of Group II can be considered as having very short linear phases of growth, whilst the 20.01-30 g subcomponent of Group I is largely exhibiting the linear phase. The resemblance of these sprouting trends to the various phases of the sigmoid curve implies that, whilst the Group I sett-classes could be presprouted "unaided", in terms of external stimulation possibly by means of nutrient application, those of Groups II and III would require external stimulatory sources to accelerate their sprouting.

It, therefore, appears that the 5.01-10 g size-class of the microsetts (a subcomponent of Group II), is the ideal.

SECTION B

FIELD EXPERIMENT

CHAPTER IV

EFFECTS OF SETT SIZE ON THE FIELD ESTABLISHMENT, GROWTH, FRESH TUBER YIELD AND YIELD-RELATED ATTRIBUTES.

1. Introduction

Subsequent to the nursery experiments, a field investigation was undertaken to ascertain the performance of the optimal size-class of the microsetts, determined earlier on in the nursery on the basis of its sprouting responses.

2. Materials and Methods

Sprouted propagules of the six size-classes enumerated in Experiment iv, Section A (page 27) were transplanted in the field using a randomised complete block design in four replications.

The soil type was of a sandy loam texture and quite gravelly, belonging to the Ibadan soils which has been classified as an Oxic Paleustalf or Ferric Luvisol by the U.S.D.A. and F.A.O. respectively (Moorman et al., 1975). The physical and chemical properties of these soils are shown in Tables 15a and 15b respectively.

The transplanting was done on ridges through plastic-strip mulch at a spacing of 1.25 m x 0.30 m and a depth of about 5 cm. The planting holes were made with sharpened wooden-splinters. Total plot size was 7.2 m x 1.25 m.

Twenty-five plantlets were used per experimental unit. One transplanting row was used per ridge and the experimental plants were bordered by other yam plants growing under plastic mulch.

Table 15a: Physical Characteristics of the Ibadan Soils

Depth cm	Gravel %	Mechanical Analysis %			Penetro-Meter Readings kg cm-2	Bulk Density g cm-3	
		Sand	Silt	Clay		Overall	Fine Earth
0 - 25	9	71.0	11.7	17.3	0.50	1.48	1.46
25 - 50	44	71.6	11.1	17.3	2.25	1.45	1.25
50 - 62	60	80.6	6.1	13.3	4.50	1.65	1.32
62 - 72	50	76.6	7.1	16.3	4.50	1.66	1.08
72 - 115	35	58.2	5.4	36.4	4.10	1.65	1.45
115- 155	14	49.2	13.4	37.4	3.90	1.70	1.61

Source: Moorman *et al*. (1975)

TABLE 15b: Chemical Properties of the Ibadan Soils.

Depth cm	pH		Exchangeable Cations me/100g						C E C me/ 100g	Organic C %	Total N %	Bray P1 ppm P
	H_2O	KCl	Ca	Mg	K	Na	Mn	Al				
0 - 25	6.5	5.8	3.7	1.0	0.17	0.08	0.01	0.13	5.68	1.34	0.102	5.4
25 - 50	6.5	5.9	2.12	0.5	0.1	0.07	0.05	nd*	3.34	0.44	0.033	3.6
50 - 62	6.3	5.6	1.15	0.25	0.04	0.04	0.02	0.01	2.00	0.19	0.017	4.2
62 - 72	6.3	5.5	1.45	0.33	0.05	0.05	0.02	nd	2.50	0.22	0.017	5.8
72 - 115	6.3	5.3	2.32	0.54	0.05	0.05	0.01	0.02	3.47	0.30	0.025	2.3
115 - 155	6.3	5.3	2.35	0.58	0.04	0.04	nd	0.01	3.52	0.13	0.025	2.5

*nd - not detectable; Source: Moorman et al. (1975).

The plastic mulch, which had a thickness of 0.048 mm, was greyish-white on one side and black on the other. It was laid over the ridges prior to transplanting after a heavy downpour, with the greyish side uppermost. As mentioned earlier on, Alvarez and Hahn (1984) reported that the use of the plastic mulch with regard to the minisetts effectively controlled weed growth and maintained a relatively higher soil moisture content, even at harvest. The plant were not staked.

About 3 MAT, three whole plants were randomly sampled from each plot for Growth Analysis determination. It was observed that a necrotic leaf disease attacked the plants towards the end of the growing season, resulting in premature senescence of some. Consequently, counts were made of plants with totally senesced shoots for all the treatments at 4 MAT. The tubers were harvested at 5 MAT by means of iron-diggers, using effective plot sizes of 5.7 m x 1.25 m.

iii. Data Management

a). Growth

The following attributes were derived:

1). Harvest Index (HI) .... ratio of the tuber dry

weight to that of the whole plant.

2). Relative shoot dry matter (Rsdm).... ratio of the shoot dry weight to that of the whole plant.

3). % Leaf dry matter content .... ratio of leaf dry weight to its fresh weight, expressed as a percentage.

b). Harvest

1). Counts of senesced plants at 4 MAT and surviving plants at harvest (Psh) were expressed as percentages. Other attributes considered were:

2). Average tuber size (As) ... quotient of the total fresh tuber yield and the total number of tubers.

3). Average tuber size: sett size ratio (S) .... quotient of the average tuber size harvested and the average sett size planted.

4). Number of tubers per plant (Tnp) and per hectare (Tnh).

5). Total fresh tuber yield (Ty) was expressed in Tonnes (t) per hectare (ha).

iv. Statistical Analysis

All the variates were analysed with the Genstat Mark V programme to obtain the analysis of variance tables. The LSD

test was used to compare pairs of treatment means of variates for which the variance-ratio was significant.

3. Results and Discussion

a). Growth

There was a marked inverse relationship between the shoot relative dry matter, Rsdm, and Harvest Index, HI (Table 16) resulting in a correlation coefficient, r, of -1.0.

TABLE 16: Effects of Sett Size on the Growth of White Yam: 3 MAT

Sett Size Class (g)	Number of Leaves Per Plant	Leaf Dry Matter (%)	Relative Shoot Dry Matter (%)	Harvest Index
2 - 5	204	18.1	65	0.35
5.01-10	123	18.7	65	0.35
10.01-20	147	16.7	57	0.43
20.01-30	196	18.8	30	0.70
30.01-40	171	19.7	34	0.66
40.01-50	223	25.6	39	0.61
LSD 5%	N.S.	5.0	14.0	0.14

Whilst Rsdm decreased with increasing sett size (Table 16) with a minimum value of 30% at the 20.01-30 g sett class, the HI increased with sett size, peaking at the 20.01-30 g (Table 16).

Besides the trends described above, two significantly dissimilar groups for both Rsdm and HI were evident (Table 16). Group I comprised the 20.01-30 g, 30.01-40 g and 40.01-50 g sett classes, whilst Group II comprised those of 2-5 g, 5.01-10 g and 10.01-20 g.

Within these broad groups, the Rsdm and HI were not really different. The subcomponents of Group II produced significantly lower HI values than those of Group I, whereas the Rsdm values of the former were, significantly greater than those of the Group I (Table 16). This increase in tuber bulking ability (HI) with sett size could be attributed to earlier tuber initiation by the larger setts (Ferguson et al., 1984). Furthermore, according to Onwueme (1972, 1973), larger setts produce more vigorous sprouts, leading to greater photosynthetic activity. It is evident from Table 16 that the 40.01-50 g setts had significantly greater leaf dry matter content than all the rest, possibly a reflection of the relatively higher photosynthetic activity. However, the

retention of assimilates in the shoots of the plants derived from these setts is lower, as shown by the Rsdm value of 39.0%, which was really lower than those of the Group II setts.

There were no real differences among the treatments in number of leaves per plant (Table 16). Moreover, with the similarity in leaf dry matter values among the sett classes, besides that of the 40.01-50 g, it is suggestive that the intra-shoot competition for assimilates was probably less intense.

Consequently, the lack of differences between the 2-5 g and 10.01-20 g sett-classes, despite the significant difference in sprouting between them in the nursery (Experiment iv, Section A, page 46) could be attributed to an inherent readjustment mechanism. This might set in, with decreasing sett size to ensure the production of adequate storable reserves in order to maintain a vigorous, competitively and naturally-fit, next-generation.

However, the existence of differences between Group I and II setts, in HI, implies that this growth readjustment mechanism could operate within certain limits of sett sizes. This indicates a sort of step-wise response.

b). Total Fresh Tuber Yield and Related Attributes

Plant survival at harvest (Psh), number of tubers per plant (Tnp) and total fresh tuber yield (Ty) generally increased with sett size (Table 17). There were no real differences among the sett classes with regard to Psh.

It was observed that the number of sprouts per sett increased with sett size and this might account for the significantly greater tnp values obtained from the group i setts (page 57), besides the 30.01-40 g sett class.

BLE 17: Effects of Sett Size on Field Performance, Fresh Tuber Yield, Yield Components and Related Attributes: 5 MAT

tt ze ass g)	Average Sett Size (g)	Plant Survival at Harvest (%)	Number of Tubers /plant	Total Fresh Tuber Yield (t/ha)	Number of Tubers /ha	Average Tuber Size (g)	Average Tuber Size: Sett Size Ratio
- 5	3.5	80.64	1.0	1.4	21505	65.1	18.6
01-10	7.5	82.82	1.0	3.6	22086	163.0	21.7
.01-20	15.0	81.94	1.07	6.5	23381	278.0	18.5
.01-30	25.0	87.77	1.17	11.2	27384	409.0	16.4
.01-40	35.0	88.38	1.14	11.5	26869	428.0	12.2
.01-50	45.0	89.91	1.18	11.6	28293	410.0	9.1
) 5%	-	N.S.	0.079	4.1	N.S.	111.9	8.1

The Group I setts also produced significantly greater Ty values than the Group II. Within the Group II, the 10.01-20 g sett class produced a significantly higher Ty value than the 2-5 g. The Ty obtained from the 5.01-10 g was however, statistically similar to those of the 2-5 g and 10.01-20 g sett classes.

These trends in total fresh tuber yield, Ty, could be due to differences in Harvest Index at 3 MAT as earlier explained (page 57).

However, the significant Ty difference between the 2-5 g and 10.01-20 g sett classes could be due to the premature foliar senescence: 96.4% at 4 MAT (Table 18), associated with the observed leaf necrotic disease (page 54).

TABLE 18: Foliar Senescence of White Yam Derived from Various Sett Sizes: 4 MAT.

Sett Size (g)	% Plants with Totally Senesced Shoots
2 - 5	96.4
5.01-10	19.9
10.01-20	28.7
20.01-30	16.8
30.01-40	26.7
40.01-50	11.0
LSD 5%	26.5

Tuber yields have been reported to increase with sett size (Ferguson et al., 1984). Nonetheless, the existence of such natural groupings of tuber yield within a range of sett-classes could imply that one could use the lowest sett-class within a given group, without really reducing tuber yield.

Average tuber size, (As), generally increased with sett size (Table 17). Three significantly distinct groups were observed for As. Group I comprised the 20.01-30 g, 30.01-40 g and 40.01-50 g sett-classes, Group II being the 10.01-20 g, whilst Group III involved the 2-5 g and 5.01-10 g.

The trends in the natural groupings for As, could be attributed to reasons given for the HI (page 57); the confounding effect of the premature foliar senescence at 4 MAT might account for any deviations in this respect.

The rather very low tuber size: sett size ratio, S, values (Table 17) could be due to the premature foliar senescence observed at 4 MAT (Table 18). By 5 MAT, all the shoots had virtually senesced, necessitating the harvesting of the tubers.

Nonetheless, the lack of real differences between the S values for the 2-5 g, 5.01-10 g and 20.01-30 g sett-classes implies that the microsetts could be a very economical seed

yam production technology. The 2-5 g and 5.01-10 g sett-classes are the lower and upper size-ranges of the microsetts respectively, whilst the minisett size of 25 g reported by Okoli et al. (1982) lies within the 20.01-30 g.

Besides the S, there were no real differences between the 2-5 g and 5.01-10 g sett-classes Psh, Ty, As and Tnp with both sett-classes occuring in the same natural group. Consequently, one is apt to regard the lower, 2-5 g sett-class as ideal.

The sprouting behaviour of the 2-5 g setts in the presprouting nursery was however slow. This was exhibited by the significantly lower (34 and 64%) total sprouting values at 10 and 33 DAP respectively (Table 13, page 46) as compared to the 71 and 84% values produced by the 5.01-10 g sett-class at the respective time-periods under consideration. The 5.01-10 g sett-class is thus more appropriate - at least until methods of accelerating sprouting are perfected.

SECTION C

SYNCHRONISATION AND ACCELERATION OF SPROUTING

CHAPTER V

1. Introduction

i). Background

As indicated in Experiment i, Section A, it was envisaged that in view of their rather small sizes, directly planting the microsetts in the field could lead to dehydration as well as rot losses and thus reduce field establishment. Consequently, it was decided to presprout them.

However, the major bottle-neck encountered during the presprouting operation in the nursery was the rather slow and uneven sprouting of the setts. This was evidenced by the results of Experiment i, Section A, (Fig. 2), whereby it took five weeks to obtain a peak sprouting of 38.3% for the sawdust medium.

These results were confounded by the fact that the microsetts were derived from physiologically old tubers, which in turn produced tubers in the media. However, this observation provided an insight into the general sprouting behaviour of the microsetts which was apparent from the results of Experiments iv, Section A, Fig. 3.

Miege (1957), on dividing the tubers of Dioscorea alata

and Dioscorea cayenensis into five regions, found that setts derived from the proximal "head" - near the corm, dominated those from the distal regions.

Coursey (1967) reported that farmers either plant whole seed tubers or cut them up into three portions: "heads", "middles" and "tails" and that the order of preference was heads, tails and middles.

Although Coursey (op. cit.) attributed the differential superiority of the heads to the presence of buds on the associated cormous structure, the persistence of this phenomenon in setts devoid of the corm as reported by Miege (op. cit.) implies that the physiological condition of the mother tuber is of utmost significance.

Furthemore, cells situated along the longitudinal axis of the tuber differ in their time of formation: cells in the head region are relatively older due to the fact that they are formed during the early stages of tuberization.

The slow and uneven sprouting of the microsetts was therefore attributed not only to their relatively small sizes, but also their physiological age differences (Fig. 4).

Thus the need to explore possibilities of accelerating and synchronizing sprouting in the nursery, prior to field transplanting, became evident.

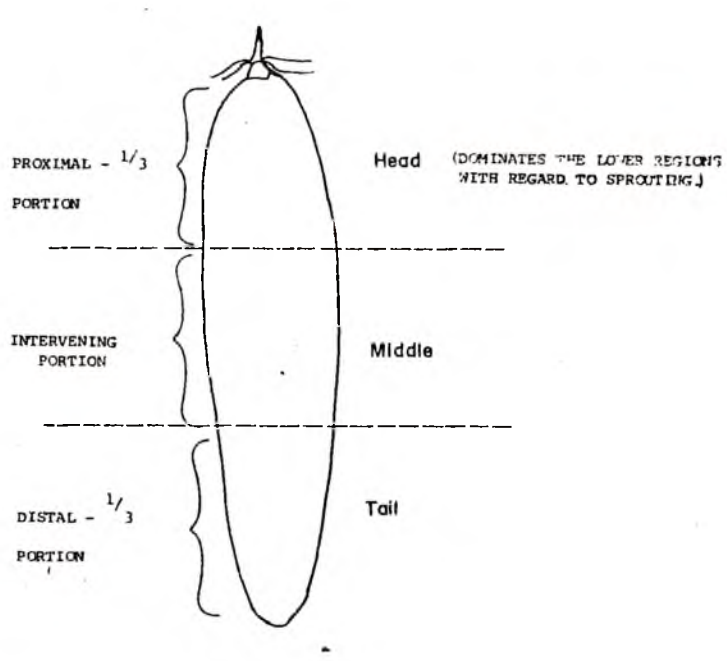


Fig. 4: Physiological Age-Zones of the Yam Tuber

To this end, physiological studies were initiated in an attempt to find simple and practical solutions to the fore-mentioned constraint.

ii). Physiological Ontogeny of the Edible Yam Tuber: Conceptual Basis

According to Coursey (1967) the growth of the yam is closely linked with the seasonal cycle: the lush-green, aerial shoot formed during the wet season senesces at the start of the dry season, throughout which the tuber remains underground as dormant organ.

Dormancy (Levins, 1969) is an adaptive strategy to survive unpredictable environments; hence, the development of underground tubers, among others, is the morphological expression of this evolutionary phenomenon (Coursey, op. cit.; Wareing, 1969; Pate and Dixon, 1982).

The dormancy mechanism in edible yams has not been elucidated, although an endogenous inhibiting principle has been implicated (Okagami and Tanno, 1977).

The intra- and inter-specific variation in the duration of the dormant period is a reflection of their adaptation to the respective ecological niches (Passam, 1982) where they evolved. Thus Dioscorea rotundata which is adapted to the

drier savanna agro-ecological region, characterized by a mono-modal rainfall pattern of about 7 months duration (Martin and Sadik, 1977), exhibits a tuber dormancy period of 2-3 months. However, Dioscorea cayenensis, although taxonomically related to D. rotundata (Leon, 1977) but adapted to the rain-forest region, where the rainy season is longer and bimodal, shows an almost continuous vegetative growth with a very short dormancy period of 1-2 months. Burkill (1951) cited by Coursey (1967) reported that the elephant foot yam, Dioscorea elephantipes, which is adapted to hot, semi-arid regions remains as dormant underground organ, for most part of the year.

It is, thus, inferable that the tuber dormancy stage is merely a hypogeous extension of the earlier epigeous vegetative growth and could, therefore, be considered as constituting a vegetative growth phase. Okoli (1980) had earlier expressed a similar view that "yam tuber-shoot growth is a continuum, whether the tuber is in the field or in storage".

Passam (1982) provided evidence indicating that the tuber respires, although in a supressed state during the dormancy period. This implies that the tuber is physiologically active and thus living.

Furthermore, the various phases of bud dormancy (Kramer and Kozlowski, 1979) are characterised by considerable metabolic and meristematic activity.

Growth in eukaryotes, according to Wareing (1970), could take the form of that of the shoot, root or cambium, entailing basically meristematic activity in all instances.

Hence the kind of growth that occurs during the dormant tuber stage needs to be clarified. Moore (1979) defined growth as an "irreversible increase in size, which is commonly, but not necessarily (e.g. growth of an etiolated seedling) accompanied by an increase in dry weight and in the amount of protoplasm". He continued, "alternatively, it may be viewed as an increase in volume or length of a plant or part ... growth includes cell division as well as enlargement".

However, tuber size has not been observed to increase in storage and thus it could be argued that growth does not occur.

Nonetheless, Sachs (1961) reported that whilst growth at the tissue, organ and organism levels of organization could be considered as increase in volume; growth at the cellular level is separable into two subcomponents: cell division (increase in number) and cell expansion (increase in volume).

Cellular growth (Steward et al., 1964) could occur either

by enlargement of preformed cells with minimum cell division or rapid cell division, with virtually no cell enlargement.

Furthermore, callus development from any tissue involves three basic stages: induction, division and differentiation (Aitchison et al., 1973). The induction phase, entails the preparatory activities that precede cell division and is characterized by increased metabolic rates and constant cell size. They were of the opinion that tissue growth occurs throughout both the differentiation and division phases.

Onwueme (1973) reported that when tuber dormancy is naturally over, shoot formation (sprouting) occurs by de novo budding from a meristematic layer, 1-2 mm to the surface of the tuber. He illustrated the progressive pattern of development of this meristem, from an initial thin, discontinuous band from which the shoot bud is differentiated.

Cell differentiation (Nover, 1977) is the assumption of distinct roles by cells, through unequal gene expression. Using the catalase gene-system in maize as a model, Scandalios (1977) revealed that differentiation and development follow a phased sequence, whereby the regulating gene-expression processes are temporally and spatially programmed. Shoot bud formation in the edible yam, occurs just before sprouting (Onwueme, 1979).

It could, therefore, be argued in the light of the available information on the mechanism of plant growth and development that the de novo budding at the end of the dormancy period of the edible yam tuber is the culmination of the earlier, sequentially modulated chain of interacting events.

It is thus proposable that these sequential and phase-dependent aspects of the morpho-genetic processes (signalling and triggering of the inductive phase; the cellular growth phase comprising cell division, elongation and differentiation) as well as their intrinsic temporal programming component could be considered as the bases for the "continuity in growth" of the tuber during the dormancy stage.

This growth stage in the ontogeny of the edible yam is referred to as Vegetative Phase I, VP I (Fig. 5). The appearance of visible sprouting buds on the corm, was assumed to be the agronomic "marker", signalling the end of VP I (Dormancy). At this stage, the tuber is assumed to be physiologically mature. This assumption contradicts that of Caesar (1979) that maturity of the tuber coincides with harvest. Presumably, he might have considered shoot senescence as the indicator of tuber maturity.

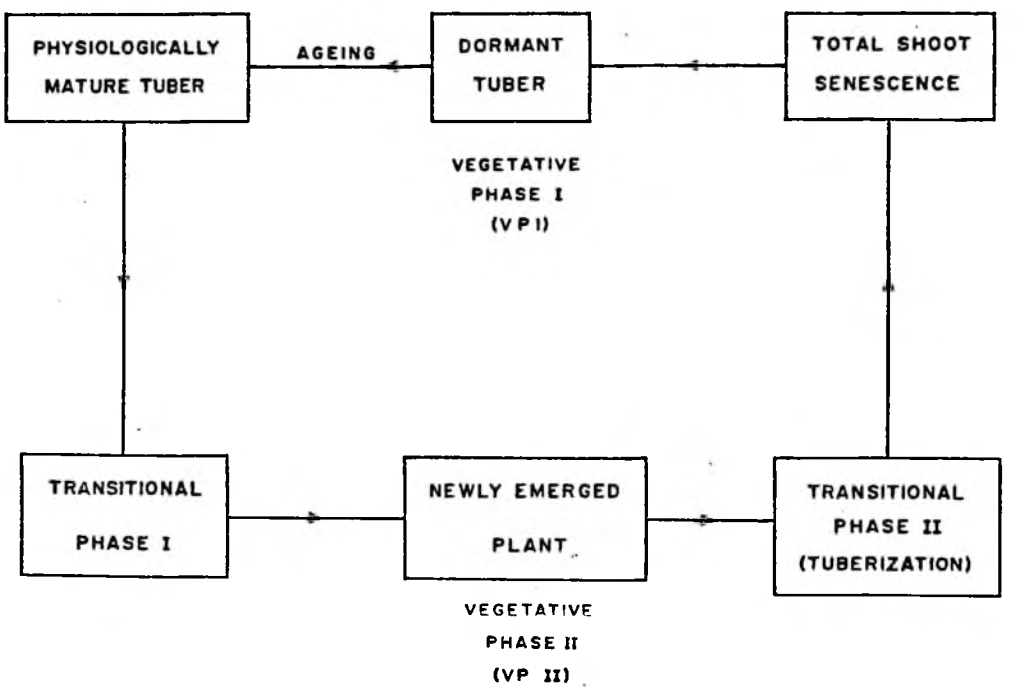


Fig. 5: Physiological Ontogeny of White Yam (D. rotundata)

The yam tuber, at harvest, cannot be considered as being physiologically mature, although agronomically so, as it has not yet attained the capacity to form adventitious buds which is attained after the dormant period is over (Onwueme, 1973, 1979). Thus, tuber maturity does not physiologically precede dormancy, but rather marks the end of the latter.

The phenomenon of premature tuber formation (observed in Experiment i, Section A) is, according to Caesar (1979), an indication of terminal physiological ageing.

Ageing, as defined by Leopold (1980) refers to "processes of accruing maturity with the passage of time", such as the change of a seedling into a juvenile and finally into a mature plant.

According to Kramer and Kozlowski (1979), ageing follows maturation in woody plants and is more of a progressively degradative nature.

This maturation to ageing sequence could also be applicable to the edible yam tuber in view of its perennating nature; but the ageing process in this context is rather of a transitional nature as exemplified above by Leopold (op. cit). This is because the formation of a new tuber from the microsett as in Experiment i, Section A (Page 30) and the development of a shoot from this new tuber only involves a

change in developmental phase, with the old giving rise to the new.

Thus, if the mother tuber from which the microsetts are derived were not physiologically too old, the transformation of the sprouted propagules into new, autotrophic plants would occur without any premature tuber formation.

This ageing phenomenon implies, therefore, that a transition phase exists and this is assumed to be the period between the attainment of physiological maturity of the tuber, as indicated by the appearance of sprouting buds on the corm and the field establishment of a new, independent plant. This is termed Transitional Phase I, TP I (Fig. 5).

TP I is assumed to be the stage in the ontogeny of the yam tuber which can be actively manipulated by man - the researcher, extension-worker, seed yam farmer, in sett preparation - minisetts, microsetts and so on.

It is considered as the most important ontogenetical phase, with respect to seed yam production. It was, furthermore, presumed that TP I is the most physiologically plastic in the ontogeny of the yam tuber, during which the latter could respond to a wide range of environmental conditions.

Muller (1975) cited by Caesar (1979) suggested a similar behaviour for the potato tuber, whereby he elucidated a "phase of physiological readjustment during the transition from 'physiological maturity' to dormancy". He inferred that during this readjustment period, the tuber is most vulnerable to all forms of environmental influences.

Whilst the suggestion of a physiological readjustment phase is plausible, it must be reasserted that the other working-model of "physiological maturity marking the end of tuber dormancy" is more acceptable - at least, with regard to the edible yam. It was, hence, proposed that by modifying the environment ambient to the physiological mature tuber or microsetts derived from it one could shorten the duration of TP I.

Tuberization is an age-related change in the ontogeny of the yam, as evidenced by the premature tuber formation, on the microsetts mentioned earlier on. Consequently, it was regarded as a transitional phase in the growth cycle: Transitional Phase II (TP II). The end of TP II and the epigeous vegetative growth phase (Vegetative Phase II, VP II) was assumed to be indicated by total shoot senescence.

Leopold (op. cit.) defined senescence as the deteriorative changes that occur in the living organism that ultimately leads to its death as contrasted with ageing, which according to him, concerns "processes of accruing maturity with the passage of time". Ageing, thus does not ultimately lead to death, but results in a transition from one stage to another. The yam tuber, therefore, ages whilst the aerial shoot senesces. Shoot senescence was assumed to be the agronomic indicator for the harvest of the tubers from the field, but by no means the indicator of tuber maturity.

On the basis of these assumptions underlying the morpho-physiological model (Fig. 5) the following studies were undertaken in the pursuit of practically solving the problem of the slow and uneven sprouting of the microsetts.

CHAPTER VI

EFFECTS OF NITROGEN AND SULPHUR SOURCES ON THE SPROUTING OF MICROSETTS.

1. Introduction

Sobulo (1972) studied macro-nutrient changes in tubers of growing white yam plants in the field and observed an initial peak, followed by downward and oscillating trends in nitrogen and phosphorus. The potassium levels generally decreased with time. It was, thus, presumed that levels of nutrients in the dormant tuber might be sub-optimal.

Mengel and Kirkby (1982) reported that ample nitrogen supply highly stimulated the growth rate of plants during the vegetative phase.

On the strength of the above presumption, together with those underlying the physiological ontogeny of the tuber (Section C, Chapter IV), it was argued that growth of the tuber during VP I or TP I (Fig. 4) would most likely respond to exogenous nutrient supply.

This argument was validated by an exploratory trial, in which microsetts derived from dormant tubers were dipped for

an hour in 5, 10, 50 and 100 ppm of ammonium sulphate ($(NH_4)_2SO_4$) as well as of urea with distilled water as control and presprouted in moist sawdust. Whilst sprouting generally increased with concentration of $(NH_4)_2SO_4$ at 4 and 10 WAP, it was suppressed by urea except at the 5 ppm concentration.

Kefeli and Kadyrov (1971) emphasized the role of phytohormones in controlling growth and developmental processes along with the natural inhibitors.

According to Wittwer and Bukovac (1958), gibberellin application promoted early and uniform sprouting of Katahdin potatoes. Martin (1977) found that the response of water yam (Dioscorea alata) tubers to exogenous gibberellic acid (GA_3) application was rather inconsistent. When applied to terminally dormant tubers, GA_3 either promoted sprouting or was non-effective. However, according to Martin (op. cit.), it prolonged dormancy when applied to freshly harvested tubers and re-induced dormancy in sprouted tubers. This implied that the time of application, in terms of the age of the tuber (that is, time-after-harvest), is of utmost importance and was emphasized by Martin (op. cit.).

Passam (1977) reported that post-harvest GA_3 application

did not extend the dormant period of D. rotundata tubers. Nonetheless, it was not surprising that dipping microsetts derived from freshly harvested tubers in various concentrations of GA_3 and benzyladenine, a cytokinin (Ameyaw, unpublished), rather prolonged dormancy in the case of the GA_3 and was not effective with respect to the benzyladenine. The application times could have been inappropriate in these instances.

Most of the phytohormones are expensive and water-insoluble. Their handling, therefore, could be very cumbersome for the farmer. Nonetheless, Addicot (1969) was of the view that soluble nutrients serve as substrates for hormone biosynthesis. This was reiterated by Marschner (1982) who asserted that endogenous phytohormone levels can be directly modulated by mineral nutrition.

Many thiourea and urea derivatives are known to possess cytokinin activity (Bruce et al., 1965 cited by Thomas, 1977). Cibes and Adsuar (1966) reported that thiourea- chlorethanol combinations stimulated the sprouting of water yam tubers, whilst according to Samarawira (1983), 2% thiourea solution alone promoted the sprouting of dormant white yam tubers.

These stimulatory effects of thiourea as well as its combination with chlorethanol could, thus, be attributed

largely to a change in the endogenous phytohormonal balance due most probably to the induction of cytokinin activity.

Skoog and Miller (1975), in propounding the "hormone-balance" concept, reported that organogenesis in plants depends on the auxin: cytokinin ratio, whereby a high endogenous cytokinin level favours shoot formation, which in the context of the yam is sprouting.

Consequently, the observed promotory effects of $(NH_4)_2SO_4$ and urea (5 ppm) on sprouting, as regards the afore-mentioned exploratory trial, was presumed to be due to the modulation of internal phytohormone biosynthesis (Addicot, op. cit.; Marschner, op. cit.). Furthermore, it was proposed that the sulphur atom in the $(NH_4)_2SO_4$, might be accountable for the relative effectiveness of the latter over urea, and hence might be of prime importance in the light of the promotory influences of thiourea reported by Cibes and Adsuar (op. cit.).

Structurally, thiourea is a substituted urea in which the oxygen atom is replaced by a sulphur.

The following experiment was therefore undertaken to investigate the effects of nitrogen and sulphur sources on the acceleration and synchronisation of sprouting of microsetts derived from the TP I stage of growth in the nursery.

2. Materials and Methods

Sprouted mother seed yams which had been stored in the traditional yam barn for about 20 weeks after harvest (WAH) were cut into heads, middles and tails.

The heads referred to the upper 1/3 portion proximal to the corm, the distal 1/3 being the tail, whilst the intervening portion was considered as the middle (Fig 4).

The upper size-range of the microsetts, 5.01-10 g, was considered ideal (Figs. 3 and 22) and thus was used for these experiments.

Setts were derived from each of the three tuber portions and separately soaked for an hour in 5, 10, 50 and 100 ppm solutions of the following nutrients, with de-ionised water as the control:

i. ammonium sulphate ..... inorganic source of nitrogen and sulphur.

ii. adenine sulphate ..... organic nitrogen and inorganic sulphur source.

iii. urea ..... organic nitrogen source.

iv. sodium thiosulphate ..... inorganic sulphur source.

Since the macro-nutrients of interest were nitrogen and sulphur compounds of these elements containing phosphorus and

potassium were avoided.

The sodium thiosulphate ($Na_2S_2O_3$) was chosen on the assumption that the sodium ion may be non-beneficial (Marschner, 1983) as well as non-harmful.

The setts were treated with the wood ash-Aldrex 'T'-Demosan suspension at the rates and times described in Experiment iv, Section A (page 24).

They were then planted in fresh, moist sawdust in open-air, propagation beds as described in Experiment ii, Section A.

Each nutrient was handled as a 3 x 5 mixed factorial experiment involving three tuber portions and five nutrient levels, laid out as a completely randomised design in three replications. Twenty setts were used per treatment combination.

The experiment was repeated using 28-week-old tubers (WOTs). Planting, in this instance, was undertaken in polystyrene trays, using fresh moist sawdust, as the presprouting medium. The trays were placed on asbestos sheets on iron-frames in the propagation house. Between 3 and 4 WAP, in both cases, counts were made of rotten, sprouted and unsprouted setts. The sprouted setts were categorized as follows:

i. Sprouted Type I ..... Those with non-emergent shoots characterised by a whitish mass of callus-like tissue (Fig. 6a).

ii. Sprouted Type II ..... Those with non-green, leafless-shoots (Fig. 6b).

iii. Sprouted Type III ..... Those with green, leafless-shoots (Pin shoots; Fig. 6c).

Data Management and Statistical Analysis

The counts were expressed as percentages.

Sprouted Types II and III were considered as plantlets with "emergent, but leafless shoots".

"Total" sprouting was regarded as sum of Sprouted Types I, II, and III.

The variates were analysed with the Genstat Mark V programme. Those exhibiting skewed distribution as well as non-significant variance-ratios were angularly transformed and re-analyzed.

The results of the two experiments were pooled for analysis as scorings were made after the same WAP.

Separate control (de-ionised water) treatments were set up for each nutrient for both the 20- and 28 WOTs.

Fig. 6a: Unemerged-shoot-stage.

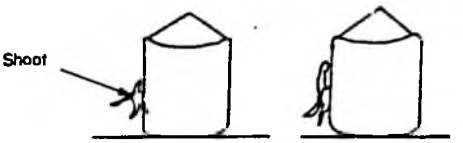


Fig. 6b: Emerged, non-green, leafless-shoots-stage.

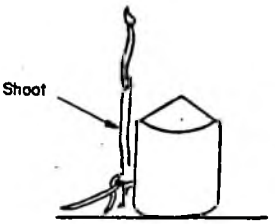


Fig. 6c: Emerged, green, leafless - - shoot-stage.

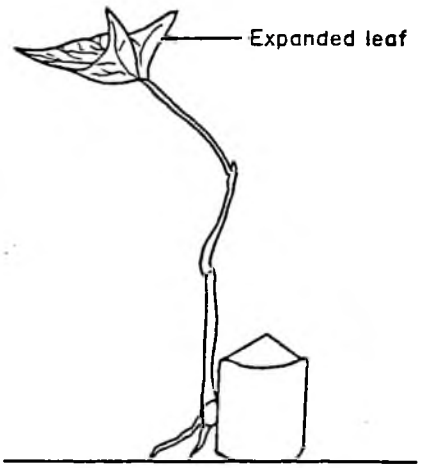


Fig. 6d: Leafy-shoot-stage.

Fig. 6 : Shoot developmental stages of presprouted microsetts.

However, prior to analysis, a mean control value for each variate was derived for $(NH_4)_2SO_4$ and $Na_2S_2O_3$ as well as for urea and adenine sulphate with respect to the 20-week-old tubers. This was necessitated by a higher sett degeneration observed with regard to the latter two nutrients, emanating from an earlier lapse in the sawdust moisture regime. This was fore-stalled during the second experiment concerning the 28 WOTs and thus an average control value was obtained for the variates, as regards all the four nutrients.

The Least Significant Difference (LSD) test was used to compare pairs of treatment means of variates for which the variance-ratio was significant.

3. Results and Discussion

i). Pooled Analysis: 20- and 28-week-old-tubers (WOTs) Over All Nutrients

Sodium thiosulphate ($Na_2S_2O_3$) significantly promoted sprouting of the microsetts compared to the other nutrients and the control (Table 19).

There were no real differences among the ammonium sulphate, adenine sulphate and control (Table 19), with the control being really more effective than urea.

TABLE 19: Pooled Response of Microsetts Derived from 20- and 28-WOTs to Nitrogen and Sulphur Sources: 3-4 WAP

Nutrient	Total Sprouted Microsetts (%)
Ammonium Sulphate	61.7
Sodium Thiosulphate	79.4
Urea	52.5
Adenine Sulphate	67.6
De-Ionised Water	61.2
LSD 5%	6.7

These results confirmed the earlier proposition that the superiority of ($(NH_4)_2SO_4$) over urea (page 80) could be attributed to the sulphate radical ($SO_4^=$) in the $(NH_4)_2SO_4$.

Plants can metabolize inorganic sulphur solely as the highly oxidized form of $SO_4^=$ (Peck Jr., 1970; Schiff and Hodson, 1973). Consequently, all other forms of sulphur such as thiosulphate, $S_2O_3^=$ (Peck Jr., op. cit.) must be oxidized to sulphate or reduced to sulphide, which according to Thompson et al. (1970) is the most reduced state of inorganic sulphur in plants, before entering the metabolic pathways. No

work has so far been done on the mechanism of sulphate metabolism in the edible yams.

Nonetheless, Thompson et al. (op. cit.) reported that the amino acid, methionine, is normally formed from the $SO_4^=$ radical in plants; it is then activated to S-adenosylmethionine, SAM (Murr and Yang, 1975) which upon being converted to 1-aminocyclopropane-1-carboxylic acid (ACC), serves as the precursor of ethylene (Adams and Yang, 1979).

Martin and Cabanillas (1976) and Passam (1977) reported that exogenous ethylene-generators promote the sprouting of the edible yam tubers. Thus the rather significant effect of $Na_2S_2O_3$, in this instance, could be ascribed to the enhancement of endogenous ethylene production along the $S_2O_3^=$ ---> $SO_4^=$ ---> SAM ---> ACC ---> ethylene pathway.

Tuber Age, Portion and Nutrient Concentration

i). Sodium Thiosulphate

Total sprouting generally increased with concentration of $Na_2S_2O_3$ for the 20 WOT setts, with 5 and 100 ppm being significantly promotory compared to the control (Table 20).

However, sprouting generally decreased with respect to the 28 WOT setts (Table 21) - the 10 ppm concentration produced a significantly inferior value of 80.6%, representing a drop of 10.8% compared to that of the control.

This implied that the tuber ages and thus the time of microsett preparation after natural tuber dormancy breakage is a critical determinant of the sprouting response.

The sprouting of vegetative propagules involves the conversion of the non-structural carbohydrates into monosaccharide derivatives, which are then used up in sucrose synthesis, to be utilized by the meristematic cells (Goodwin and Mercer, 1983).

Caesar (1979) reported that during storage, the level of sucrose in potato tubers increase with time and attributed this to physiological ageing.

Thus, compared to the 20 WOT, the physiologically older 28 WOT setts (occuring in the advanced stages of TP I) might have contained higher levels of remobilizable reserves which rendered them unresponsive to external sources.

The response of the physiologically dissimilar microsetts (i.e. setts derived from different regions of the tuber (Fig. 4) to sodium thiosulphate differed markedly. Sprouting, generally, increased with concentration for the head-region-derived setts from the 20 WOTs (Table 21), but

TABLE 20: Sprouting Response of Microsetts Derived from 20 WOTs to Sodium Thiosulphate

Concentration /ppm	Total Sprouted Microsetts (%)			
	Tuber Region			Average Concentration Effect
	Head	Middle	Tail	
0	64.3	57.1	52.0	57.8
5	75.0	78.9	79.6	77.8
10	70.0	66.3	78.6	71.6
50	88.4	52.5	51.7	64.2
100	88.3	84.6	50.0	74.3
LSD 5%	N.S.	N.S.	16.6	11.3

TABLE 21: Sprouting Response of Microsetts Derived from 28 WOTs to Sodium Thiosulphate

Concentration /ppm	Total Sprouted Microsetts (%)			
	Tuber Portion			Average Concentration Effect
	Head	Middle	Tail	
0	95.0	94.2	85.0	91.4
5	86.4	88.3	85.0	86.6
10	81.7	80.0	80.0	80.6
50	93.3	91.7	93.3	92.8
100	80.0	93.3	83.3	85.6
LSD 5%	N.S.	8.6	N.S.	7.9

for the middle and tail setts, it peaked at 5 ppm and thereafter declined (Table 21); nonetheless, as regards the middle setts, it rose again to a significant 84.6% at 100 ppm.

These clearly-demonstrated-opposite responses to the nutrient with respect to the origin of the sett on the tuber, indicating that there are peculiar characteristics of the different regions of the tuber (Fig. 4) that determine the sprouting performance of setts derived from them.

The differential physiological age of the respective regions of the tuber could be attributed to the variation that exists along the tuber axis with regard to the time of formation of the cells during the ontogenetical development of the tuber in the field as described in Chapter V.

This variation could be in the form of different pH levels and thus differences in the rates of enzyme activities. Ugochukwu and Anosike (1985) reported that pH increases from the tail to the head-region of the white yam tuber and Davies (1972) cited by Ugochukwu and Anosike (op. cit.) was of the view that the role of the pH variation in different parts of the tuber might be to control the rate of enzymatic reactions.

Plant morphogenesis, according to Tran Thanh Van (1980) as well as Yeoman and Forsche (1980) is characterized by a quantitative equilibrium involving several factors, which are

primarily determined by the physiological stage of the mother plant; notably the intercellular and inter-tissue correlations at the time of explant excision.

Differences in the sprouting of the setts from the various regions of the tuber were not significantly affected by the concentration of $Na_2S_2O_3$ for the 28 WOT (Table 21). This could be attributed to physiological ageing, on "whole-tuber" basis, indicating that all the parts of the tuber were mature enough to sprout without the aid of nutrients.

According to Oluoha and Ugochukwu (1984) cited by Ugochukwu and Anosike (op. cit.), freshly harvested white yam tubers have lower pH levels than those that have been stored for several months. Thus, as the tuber ages in storage, their enzyme activities also change along with the changes in pH.

Consequently, the endogenous levels of carbon skeletons, mineral nutrients and thus the phytohormonal balance (Addicot, 1969; Marschner, 1982) would vary for the three physiologically dissimilar tuber parts culminating in the observed differential sprouting responses.

ii. Ammonium Sulphate

The concentration main effects and the response of the

physiologically dissimilar setts to the $(NH_4)_2SO_4$ were non-significant and also inconsistent (Tables 22 and 23).

The ineffectiveness of the $(NH_4)_2SO_4$ could be attributed to the acidifying effects of the ammonium ion (Barker et al., 1966). According to the latter, a remarkable increase in solution acidity occurs when roots of higher plants are nourished from nutrient solutions containing ammonium-nitrogen. Barker et al. (op. cit.) were of the view that this situation results from the relatively more rapid absorption of ammonium ion (NH_4^+) compared to that of the associated anions.

Furthermore, the ages of the mother tubers at which the nutrient was applied - 20 and 28 WAH, might not have been ideal.

iii. Adenine Sulphate

The setts from the 20 WOTs responded to the adenine sulphate whilst those from the 28 WOTs did not.

The various concentrations of adenine sulphate did not elicit real differences in total sprouting with regard to the head setts (Tables 24 and 25).

However, total sprouting generally increased with concentration regarding the tail- and middle-region-derived setts for the 20 WOTs (Table 24), whilst those of the 28 WOTs

TABLE 22: Sprouting Response of Microsetts Derived from 20 WOTs to Ammonium Sulphate

Concentration /ppm	Total Sprouted Microsetts (%)			
	Tuber Region			Average Concentration Effect
	Head	Middle	Tail	
0	64.3	57.1	52.0	57.8
5	66.4	48.8	59.7	58.3
10	51.0	52.7	53.3	52.3
50	60.0	53.3	72.5	61.9
100	70.8	50.0	55.1	58.6
LSD 5%	N.S.	N.S.	N.S.	N.S.

TABLE 23: Sprouting Response of Microsetts Derived from 28 WOTs to Ammonium Sulphate

Concentration /ppm	Total Sprouted Microsetts (%)			
	Tuber Region			Average Concentration Effect
	Head	Middle	Tail	
0	68.0	65.8	40.0	58.0
5	84.8	68.3	55.0	69.4
10	76.7	72.7	51.7	67.0
50	65.0	66.7	46.7	59.4
100	71.7	63.3	60.0	65.0
LSD 5%	N.S.	N.S.	N.S.	N.S.

TABLE 24: Sprouting Response of Microsetts Derived from 20 WOTs to Adenine Sulphate

Concentration /ppm	Total Sprouted Microsetts (%)			
	Tuber Region			Average Concentration Effect
	Head	Middle	Tail	
0	45.0	43.3	25.2	37.8
5	61.0	38.3	7.8	35.7
10	60 0	53.3	32.6	48.6
50	36.2	25.4	45.7	35.8
100	36.7	68.3	66.2	57.1
LSD 5%	N.S.	24.8	17.5	14.9

TABLE 25: Sprouting Response of Microsetts Derived from 28 WOTs to Adenine Sulphate.

Concentration /ppm	Total Sprouted Microsetts (%)			
	Tuber Region			Average Concentration Effect
	Head	Middle	Tail	
0	95.0	94.2	85.0	91.4
5	96.7	86.7	96.7	93.3
10	91.7	91.7	81.7	88.3
50	83.3	86.7	84.9	85.0
100	91.7	71.7	100.0	87.8
LSD 5%	N.S.	N.S.	13.4	N.S.

did not respond (Table 25). This was most probably due to ageing effects as mentioned earlier on.

Whereas it required only 5 ppm of $Na_2S_2O_3$ to obtain real differences in total sprouting for the tail setts from the 20 WOTs (Table 20), it took 50-100 ppm of adenine sulphate to elicit really superior effects compared to the control (Table 24) for the tail setts. Furthermore, whilst $Na_2S_2O_3$ suppressed sprouting of the tail setts after the 5 ppm level (Table 20), sprouting increased generally with adenine sulphate concentration for the tails (Table 24).

These responses indicated that the association of the inorganic sulphate radical with the organic nitrogen source might be influencing the metabolism of these nutrients and thus the sprouting.

Working on a suspension culture of Ipomoea spp. (Morning glory), Zink (1984) reported that the nitrogen source in the growth medium affected the synthesis of ATP-sulphurylase, that catalyzes the synthesis of adenosine-5^1 -phosphosulphate, which constitutes the primary step in sulphate metabolism. He iterated that the rate of formation of this enzyme depends on the nitrogen source, with slowly metabolised forms forming lower levels of the enzyme in relation to the rapidly metabolised.

iv. Urea

Total sprouting of the setts derived from the 20 WOTs initially and significantly peaked at 5 ppm, declining at 10 ppm, to rise thereafter to a really different 57.5% at 100 ppm, compared to the control (Table 26). Those derived from the 28 WOTs did not respond to the urea-nitrogen (Table 27) and this could be attributed to ageing effects as described earlier on. Whilst the middle and especially the tail setts from the 28 WOTs showed generally increasing but non-significant responses (Table 27), the middle-and head-setts from the 20 WOTs elicited real differences compared to the control (Table 26).

The head setts produced an initial significant sprouting of 83.3% at 5 ppm (Table 26) compared to the 45.0% at 0 ppm and declined. Sprouting of the middle setts from the 20 WOTs increased generally with concentration, with 100 ppm producing a significantly superior sprouting of 92.0% in relation to the control. The sprouting of the tail setts from the 20 WOTs (Table 26) was confounded by rot.

TABLE 26: Sprouting Response of Microsetts Derived from 20 WOTs to Urea

Concentration /ppm	Total Sprouted Microsetts (%)			
	Tuber Region			Average Concentration Effect
	Head	Middle	Tail	
0	45.0	43.3	25.2	37.8
5	83.3	51.1	26.3	53.6
10	48.7	29.1	28.9	35.6
50	43.8	53.8	15.4	37.6
100	49.9	92.0	30.6	57.5
LSD 5%	21.1	35.8	N.S.	12.1

TABLE 27: Sprouting Response of Microsetts Derived from 28 WOTs to Urea

Concentration /ppm	Total Sprouted Microsetts (%)			
	Tuber Region			Average Concentration Effect
	Head	Middle	Tail	
0	68.0	65.8	40.0	58.0
5	73.0	48.3	36.7	52.7
10	78.3	65.0	46.7	63.3
50	61.7	50.0	48.3	53.3
100	47.5	75.0	55.0	59.2
LSD 5%	N.S.	N.S.	N.S.	N.S.

It could be argued that the head setts being physiologically older would contain higher levels of nitrogen and by virtue of the differences in enzyme levels (Ugochukwu and Anosike, op. cit.) and thus activity, might probably remobilize their stored nitrogen at a relatively faster rate.

The exogenous supply of urea-nitrogen, therefore, could rapidly result in supra-optimal levels after 5 ppm leading to a negative feedback mechanism that represses the assimilatory enzymes and ultimately sprouting.

The middle setts, however, are relatively younger and thus their internal nitrogen levels as well as rate of nitrogen mobilization may be slower, rendering them responsive to external nitrogen supply.

It is suggestible, on the basis of this increasing urea-nitrogen requirement with decreasing physiological age, that urea-nitrogen concentrations greater than 100 ppm would be more effective on the tail setts. Further research is needed in this direction.

The urea might be probably exerting its observed promotory action on the head and middle setts from the 20 WOTs (Table 26) by influencing cytokinin biosynthesis, thereby tilting the auxin-cytokinin ratio (Skoog and Miller, 1957) in favour of shoot production.

Takeuchi (1909) cited by Bollard (1959) reported that many higher plants readily assimilate urea-nitrogen through its conversion to ammonia by the enzyme, urease. Bollard (op. cit.) suggested that plants that lack this enzyme utilize the urea-ornithine pathway.

In any case, the ammonia released, according to Bollard (op. cit.), combines with pyruvic and α-ketoglutaric acids to yield alanine and glutamic acid - both being amino acids.

Wagner and Michael (1971) cited by Mengel and Kirkby (1982) reported that amino acids are required for cytokinin biosynthesis.

CHAPTER VII

EFFECTS OF SHOOT DEVELOPMENTAL STAGE/AGE OF PRESPROUTED MICROSETTS ON FIELD ESTABLISHMENT, FRESH TUBER YIELD AND YIELD-RELATED ATTRIBUTES.

1. Introduction

Total sprouting as considered in Chapter VI was the sum of three shoot developmental stages (Figs. 6a, b and c).

Nonetheless, there was no information on the appropriateness of these sprouted types for field transplanting, with regard to early field establishment, fresh tuber yield and its related attributes.

The following experiment was, thus, undertaken to determine the ideal shoot growth stage for field transplanting, since once the correct stage were determined, one could accelerate its development by external application of mineral nutrients as discussed in Chapter VI.

2. Materials and Methods

Presprouted 5g setts at four different stages of sprouting were transplanted through plastic-strip mulch on

ridges as described in Chapter IV, Section B, in a randomised complete block design in three replications.

The soil type was as described in Chapter IV, Section B. The sprouting stages were:

i. "Tuber-roots, unsprouted" stage ... propagules that have been in the sawdust medium for 3-7 DAP.

ii. "Non-green, emerged" shoot stage ... propagules that have been in the sawdust medium for 3-5 WAP and are about 0.5 - 1.5 cm long.

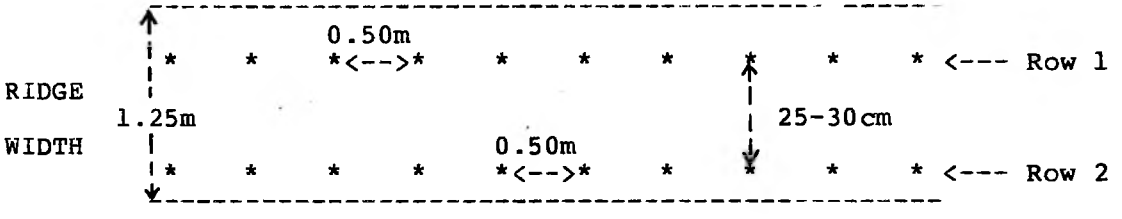
iii. "Green, pin, leafless" shoot stage... propagules that have been in the sawdust medium for 5-7 WAP and are characterised by needle-shaped, leafless shoots, that are about 3-5 cm long.

It must be clarified that these shoots were green because only a single layer of setts was used during planting and were, therefore, exposed. If more than one planting layer had been used, these would have been non-green in appearance.

iv. "Leafy" shoot stage ... propagules that have been in the nursery for over 7 weeks, bearing one or more expanded leaves.

Sprouting stages ii, iii and iv were considered as the "sprouted types". The "unemerged" shoot stage (Fig. 6a) was not considered, since it was more of a transitional nature.

Twenty propagules were used per plot, each of which measured 4.5 m x 1.25 m. The spacing was 0.50 m x 1.25 m, with two rows per ridge, using a ridge-to-row pattern as shown below:



The experimental plot was bordered by white yam plants growing under plastic mulch.

The plants were rain-fed. Weeds were regularly hand-picked: mostly Talinum triangulare and Tridax procumbens which were growing through the planting holes in close association with the crop.

Weeds in the unmulched furrows were early in the growing season sprayed with a mixture of Cotoran and Dual at a rate of 2g a.i/ha, using a spray-hood. Nevertheless, due to high wind-action, there was spray-drift to some of the treatment plants, especially those with expanded leaves.

The herbicide application was thus discontinued and instead hoeing was undertaken.

At 4 WAT, counts were made on single-plant basis of the number of leaves. Counts were also made of senesced and surviving plants at 5 and 5 1/2 MAT respectively. The tubers were harvested with iron-diggers at 5 1/2 MAT, using an effective plot size of 3.5 m x 1.25 m.

Data Management

Counts of established, senesced and surviving plants were expressed as percentages.

The number of tubers as well as their fresh tuber weights were recorded. The total fresh tuber yield (Ty) was thus computed and expressed in Tonnes/ha.

The tuber size: sett size ratio, S, calculated as the quotient: average tuber size(g)/5.0g, was derived.

Statistical Analysis

The variates were analysed with the Genstat programme. The Least Significant Difference (LSD) test was used to compare treatment means for variates with significant variance-ratio.

3. Results and Discussion

i. Plant Establishment, Senescence and Survival

There were no significant differences among the sprouted types with respect to plant establishment at 1 MAT, but that of the unsprouted was significantly poor (Table 28).

However, foliar development was relatively faster with regard to the leafy-shoot-stage, as indicated by the significantly greater number of leaves at 1 MAT (Table 28).

There were no real differences among the treatments in the number of regarding plants with senesced shoots at 5 MAT (Table 28).

TABLE 28: Effects of Stage of Shoot Development of Presprouted Microsetts on Field Performance

Stage of Shoot Development	% Field Establishment (1 MAT)	Number of Leaves/ Plant (1 MAT)	% Plants with Senesced Shoots (5 MAT)	% Plant Survival at Harvest (5 1/2 MAT)
Leafy-Shoots	98.4	10.0	73.2	64.96
Green, Pin-Shoots	93.8	4.5	79.7	77.53
Non-green, Emerged-Shoots	92.1	3.5	58.2	79.62
Rooted, Unsprouted	17.5	0.34	65.5	55.96
LSD 5%	12.3	3.1	N.S.	16.30

Whereas plant survival at harvest (5 1/2) for the pin- and non-green, emerged-shoot-stages were significantly greater than that of the unsprouted (Table 28), the leafy-shoot stage did not significantly differ from the latter. There were, thus, considerable losses as regards the leafy-shoot-derived plants during the growth period.

This is largely attributable to the damage caused by the herbicide-spray drift, fore-mentioned.

ii. Fresh Tuber Yield and Yield-Related Attributes

There were no significant differences among the treatments in the number of tubers per plant (Table 29). The sprouted types elicited significantly greater fresh tuber yield, Ty, average tuber size, As, and average tuber size: sett size ratio, S. values compared to the unsprouted (Table 29)

Nonetheless, the performance of the leafy-shoots, with regard to Ty, was significantly inferior to that of the non-green, emerged-shoot-stage (Table 29) despite its significantly greater number of leaves at 1 MAT (Table 28).

This could be partly attributed to the herbicide-spray-drift damage early during the growth period. However, the leafy shoots produced profuse rooting in the sawdust medium, necessitating the trimming of the extremely long ones.

TABLE 29: Effects of Stage of Shoot Development of Presprouted Microsetts on Fresh Tuber Yield and Yield-Related Attributes

Stage of Shoot Development	Fresh Tuber Yield (t/ha)	Average Tuber Size (g)	Number of Tubers /plant	Number of Tubers /ha	Average Tuber Size: Sett Size Ratio
Leafy-Shoots	3.49	146.9	1.0	23,758	29.4
Green, Pin-Shoots	4.80	169.3	1.0	28,353	33.9
Non-green, Emerged-Shoots	5.55	190.6	1.0	29,119	38.1
Rooted, Unsprouted	1.41	68.9	1.0	20,465	13.8
LSD 5%	1.84	57.8	N.S.	6,282	13.8

According to Ferguson (pers. comm.), the edible yams have poor root regeneration ability and therefore, the root-trimming operation could result in transplanting shock and thereby influence the ultimate tuber yield.

Furthermore, the leafy-shoots, especially those that have started vining prior to field transplanting, normally die-back soon after they have been transplanted leading to shoot regrowth. This, however, retards growth and the new shoot, thus formed, is less vigorous.

There were no real differences among the sprouted types, concerning the number of tubers per hectare, Tnh, (Table 29). However, apart from the leafy-shoots, the pin-and non-green, emerged-shoots produced significantly greater Tnh vaues than the unsprouted. This could be due to the factors discussed earlier on with respect to plant survival at harvest.

It is thus evident that the non-green, emerged-shoot-stage (Fig. 6b) could be the most ideal for transplanting the presprouted microsetts in the field.

iii. Influence of Mineral Nutrition on the Development of the Non-green, Emerged-Shoot-Stage in the Presprouting Nursery

Whilst investigating the effects of nitrogen and sulphur sources on the sprouting of the microsetts (Chapter VI, page 83), the "leafless shoot" stage was considered as the sum of the green, pin-shoot as well as the non-green, emerged-shoot-stages.

The overall analysis of the 20- and 28-WOT-experiments for the four nutrients, disregarding age as a factor, revealed that whilst sodium thiosulphate and adenine sulphate were, on

the average, really superior to the control (de-ionised water) in promoting the development of the leafless-shoot-stage (Table 30), urea and ammonium sulphate were non-stimulatory.

TABLE 30: Influence of Nitrogen and Sulphur Sources on the Development of the Leafless-Shoot-Stage

Nutrient	% Sprouted Microsetts (Leafless-shoot-stage)			
	Tuber Region			Average Nutrient Effect
	Head	Middle	Tail	
Ammonium Sulphate	35.5	24.0	18.4	26.0
Sodium Thiosulphate	51.7	41.0	34.8	42.5
Urea	30.5	24.6	11.1	22.1
Adenine Sulphate	42.3	39.2	38.8	40.1
De-Ionised Water	37.3	34.4	21.2	31.0
LSD 5%	6.2	6.0	5.5	6.2

Adenine sulphate, however, was significantly promotory on only the tail setts, whereas sodium thiosulphate significantly stimulated sprouting, in this context, of the setts from all the three regions.

In the light of these trends, it is evident that one could accelerate the development of the leafless-shoot-stage of the presprouted microsetts by the external application of mineral nutrients. Nonetheless, the sources of these nutrients and their formulation were apparently important.

CHAPTER VIII

EFFECTS OF CONTINUOUS NUTRIENT SUPPLY ON THE SPROUTING OF MICROSETTS IN THE NURSERY.

1. Introduction

The non-green, emerged-shoots-stage, (NGS), on the basis of the results in Chapter VII was adjudged the most ideal for field transplanting. This entails a presprouting period of about 3-5 weeks.

At the end of this period, the propagules are a mixture of predominantly the non-green, emerged-as well as the green, pin-shoot-stages (page 84) which are collectively referred to as the "leafless shoot" stage.

The promotive action of sodium thiosulphate and adenine sulphate on the development of the leafless-shoot-stage (Table 30) indicated the possibility of synchronising the attainment of this developmental stage on setts derived from all parts of the tuber and also shortening the duration of the presprouting period.

Consequently, the objectives of these studies were reformulated to aim at obtaining 50% setts at the leafless-

shoots-stage - primarily, non-green shoots formation, irrespective of the origin of these setts on the mother tuber at 3 WAP. As shown in Table 30, whilst sodium thiosulphate was significanly effective on all the setts, irrespective of their origin on the tuber, adenine sulphate was effective on only the tail setts.

Thus, it could be argued in the light of the stimulatory action of both sodium thiosulphate and adenine sulphate on the tail setts, that the mineral nutrients could be more effective, if applied together.

This reasoning is further supported by the report of Braakhekke (1983) that a balanced supply of nutrients is necessary for optimum plant performance. Furthermore, adenine sulphate produced numerically superior values for the head and middle setts compared to the control (Table 30). The differences in sprouting values for the adenine sulphate and the control, in this instance, were marginally lower than the LSD values at P = 0.05.

It would appear therefore, that if the mode of nutrient application: the 1h-preplant-dip, were modified, one could realize the objectives under consideration.

The supply of sugars is one of the factors that control growth and other metabolic activities (Hawker et al., 1979). Shoot-genesis of tobacco callus-cultures (Thorpe, 1974) depends on the "continuous" supply of free sugars from the growth medium.

It was consequently proposed that a multi-nutrient solution, applied continuously rather than as a single, 1h-dip could be more effective in achieving the 50% NGS formation target at 3 WAP in the nursery. The use of the multi-nutrient solution was also aimed at exploring the possibility of developing a nutrient "concentrate" to boost the sprouting of the microsetts.

2. Theoretical Basis for the Formulation of the Nutrient Solution

The nutrient mixture was formulated as follows:

Adenine Sulphate	0.55 ppm
Ferrous "	" "
Copper "	" "
Manganese "	" "
Potassium biphosphate	" "
Urea	" "
Cobaltous chloride	" "

'Florel' (2-chloroethylphosphonic acid)... 0.055 ppm

Sucrose ..... 667 ppm

The above formulation was primarily, sulphur-based, so as to stimulate endogenous ethylene production, as discussed in Chapter VI (page 87).

Campbell et al. (1962) reported that high tuber dormancy levels of yam tubers were associated with low levels of glutathione and that the concentration of this compound increased as the tuber aged.

Glutathione, is a tripeptide, which according to Kosower and Kosower (1969) maintains cellular membrane integrity. It also influences the enzymatic control of carbohydrate metabolism (Boyer, 1959) - another vital process with regard to sprouting. Sulphur is required for the biosynthesis of glutathione (Coleman, 1966).

Hence, the observed promotion of sprouting by sodium thiosulphate could be attributed not only to increased endogenous ethylene synthesis but also to glutathione.

As mentioned earlier (page 80), Skoog and Miller (1957) in propounding the "hormone-balance" concept of organ-formation, showed that the root and shoot formation processes of tobacco pith tissue were dependent on the auxin-cytokinin ratio with high cytokinin levels enhancing

shoot differentiation and vice-versa.

The cumbersome handling requirements of these phytohormones necessitated the use of the mineral nutrients (Chapter VI, page 79) that reportedly (Addicot, 1969; Marschner, 1982) could serve as substrates for hormone biosynthesis.

Adams and Yang (1977, 1979) reported a cycle for methionine (sulphate) metabolism in relation to ethylene formation involving a postulated pathway for the production of the ethylene precursor, ACC, from SAM. An adenine by-product was formed in the process. Adenine, a purine base, is the precursor of the cytokinins (Leshem, 1973).

It was, therefore, postulated that the external application of an ethylene-generator: an inexpensive, liquid-formulated source, in very low concentration could exert a momentarily negative feedback inhibition effect on the conversion of SAM to ACC.

The alternative pathway of SAM --> 5^{1}-Methylthioribose could thus be stimulated resulting in an adenine (Ade) by-product.

Thomas (1977) citing van Staden et al. (1973) suggested that ethylene most likely acts by stimulating cytokinin biosynthesis in Spergula arvensis seeds. This supports the

reasoning that external ethylene supply could promote internal cytokinin production.

Significant increases in cytokinins were found by Yoshida and Oritani (1972) as a result of nitrogen application. Hence, nitrogen was included in the nutrient-mixture as adenine sulphate and urea. Iron is implicated in protein synthesis (Perur et al., 1961 cited by Mengel and Kirkby, 1982). It was therefore included in the mixture and as ferrous sulphate, since the ferrous form is the most important in plant metabolism (Bowen and Kratky, 1983). Plant growth processes, according to Ohki (1982), are dependent on minute levels of manganese for maximum activity. Alloway and Tills (1984) reported that copper-containing enzymes are involved in cellular defence mechanisms as well as hormonal metabolism. Thimann (1956) cited by Shkolnik (1984) suggested the involvement of cobalt in the stimulation of a step in oxidative metabolism, probably the synthesis of adenosine triphosphate (ATP). Adequate potassium levels facilitate the linkage of amino acids into polypeptides (Helal and Mengel, 1968, cited by Mengel and Kirkby, 1982).

Phosphorus, according to Gauch (1972) is involved in the energy relations of the plant: high-energy-phosphate bonds serve as energy sources for the synthesis of sucrose and proteins. Potassium and phosphorus were, therefore, included in the nutrient mixture as potassium biphosphate.

As mentioned earlier, the sprouting of the vegetatively propagated structures (Goodwin and Mercer, 1983) involves the conversion of the non-structural or storage carbohydrates into monosaccharides, which are then used up in sucrose synthesis. Ketiku and Oyenuga (1973) reported that sucrose constituted the bulk of the total sugars in white yam tubers. It was, therefore, decided to include sucrose in nutrient mixture as a supplementary carbon-source.

3. Materials and Methods

A propagator (Fig. 8) based on the model shown in Fig. 7 was improvised, using containerized polystyrene germinators, cheese-cloth and a plastic-strip mulch film.

Unit 1, being the trough containing the nutrient mixture, was constructed by scooping out the various compartments of a polystyrene germinator of gross dimensions: 67cm x 34cm x 10cm

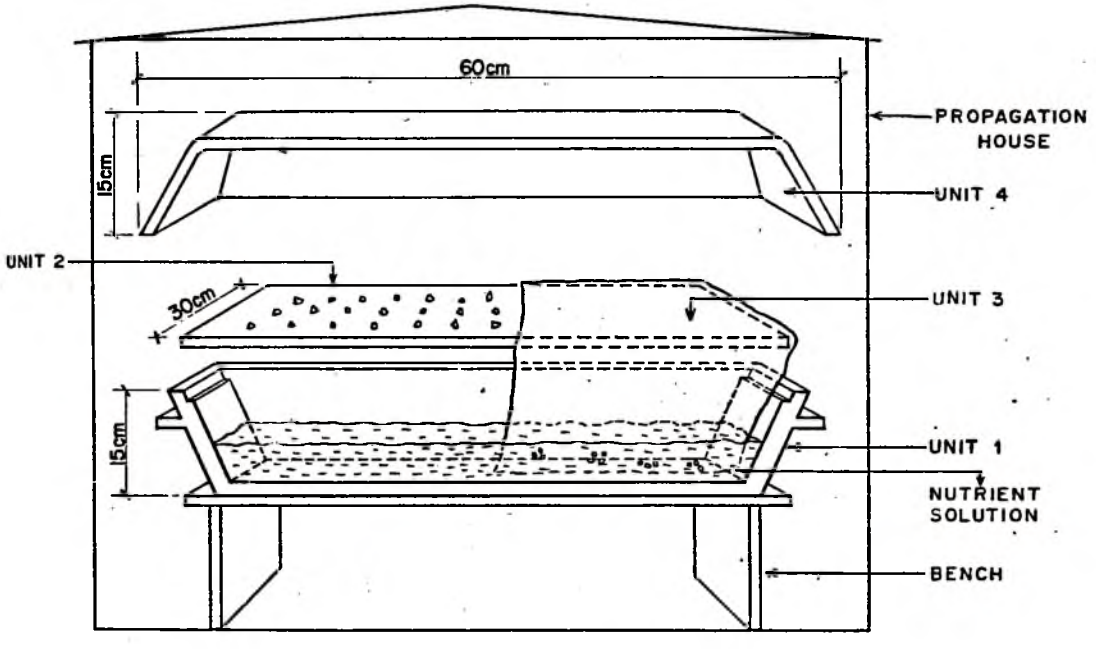


Fig. 7: Diagrammatic Representation of a Microsett Prespouting Set-up Utilizing a Continuous Nutrient Supply.

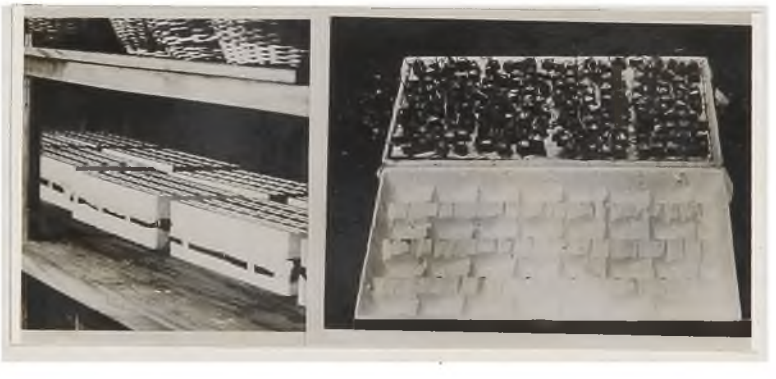


Fig. 8: Improvised Polystyrene, Cheese-Cloth-Based Propagator for Presprouting the Microsetts Using Continuous Nutrient/Moisture Supply.

with a knife. The interior was then lined with the plastic-strip mulch, which was held in place by drawing pins and scotch-masking tape.

Unit 2, was also a polystyrene tray that served as the support for the cheese-cloth, absorbent material (Unit 3).

Unit 4, the polystyrene cover, was constructed as described for Unit 1, except that it was not lined with the plastic-strip mulch film. Unit 4 was designed to create a dark environment for shoot emergence to proceed. It had been observed during an exploratory trial that setts with unemerged shoots (Fig. 6a) go into secondary dormancy when exposed to light. Furthermore, 12 of the original drainage-holes at the base of the cover were left unsealed as vents to facilitate the dissipation of excess humidity as well as enhance ventilation. The other drainage-holes were sealed with scotch-masking tape. These vents of dimensions, 1.0 cm x 1.0 cm, nonetheless, permitted the entry of some light. This was evidenced by the greening of the shoots, just after emergence.

Sprouted tubers were divided into heads, middles and tails as described in Chapter VI (page 81). About 7g setts were derived from these portions and their cut-surfaces

treated by dipping them in 6 g/l suspension of Demosan, a.i. Chloroneb, for 2-3 minutes.

The setts from each of the three tuber portions were kept separately and used in a two-factor experiment. The first factor, being the mode of nutrient application, involved the following levels:

i. continuous nutrient application

ii. 1h nutrient dip, followed by continuous, de-ionised water supply.

iii. continuous de-ionised water supply (control).

The second factor was tuber portion, with three levels: heads, middles and tails.

Four replicate groups of 50 setts were used for each experimental unit. The setts were laid on the cheese-cloth in the propagators with their distal cut ends facing downwards, along the direction of the normal geotropic orientation of the tuber in the field (see Figs. 10 and 12). This was done to simulate the natural pattern of water uptake from the tuber to the epigeous shoots, after absorption by the tuber-roots. Furthermore, it was argued that, direct contact of the un-cut periderm of the setts with the cheese-cloth would create a too-humid- microenvironment in the interface between them.

This could result in anaerobic conditions and thus impair the sprouting process.

About 31 of the nutrient mixture and de-ionised water were used per propagator. This was renewed twice weekly during the experimental period of 30 days. It was ensured that the cheese-cloth was very wet, throughout the experimental period.

The cut-surfaces of the setts were sprayed daily with 6g /l suspension of Demosan by means of a hand-sprayer to control fungal infection.

The experiment was set up in the propagation house, described in Chapter III (page 21).

Counts were made of the rotted, unsprouted and sprouted setts at 20 and 30 DAP. However, the 20 DAP results were discarded due to a miscount.

Data Management and Statistical Analysis

The counts were expressed as percentages. "Total" sprouting was considered as the sum of shoot developmental stages 6a, b and c (Fig. 6). Some of the Stage 6b shoots were even green in colour and thus there was really no clear-cut distinction between the Stages 6b and c. Consequently, the "leafless shoot" sprouting was considered as the sum of Stages

6b and c.

The results were analysed with the Genstat programme, using the completely randomised design option.

The Least Significant Difference test was used to identify real differences among the treatment means.

4. Results and Discussion

i. Development of the Leafless-Shoot-Stage

The effect of the nutrient mixture applied either continuosly or as a 1h-dip was not really superior to the control (Table 31).

ABLE 31: Mode of Nutrient Mixture Application on the Sprouting of Microsetts in a Cheese-Cloth-Based Propagator: 30 DAP.

ode of utrient pplication	% Sprouted Microsetts (Leafless-shoots)				LSD 5% (Mode of Application)
	Tuber Region			Average Mode of Application Effect	
	Head	Middle	Tail		
ontinuous	58.0	59.5	14.0	43.8	14.4
h-Dip	34.1	66.7	28.8	43.2	14.9
e-Ionised ater	57.8	42.7	29.0	43.2	7.8
SD 5%	12.5	9.0	11.6	N.S.	

Thus, the objective of 50% leafless-shoot-stage development at 21 DAP (3 WAP) for setts derived from all the three regions of the tuber was not realized, using the continuously applied nutrient mixture method: only a non-significant 43.8% was obtained even at 30 DAP. There were, however, significant responses with regard to the source of the microsetts on the tuber (Table 31; Fig. 9).

The proximal dominance of the head setts over those from the middle and tail regions of the tuber was significantly maintained with regard to the control. However, the leafless shoot development of the middle setts was really promoted by the 1h-dip and continuous supply methods (Table 31) compared to the control. This represented a relative increase of 56.2% and 39.3% respectively over the control (Fig. 9), which is considered as 0% on the ordinate.

The 1h-dip method significantly suppressed the development of the leafless-shoot-stage for the head setts; on the other hand, the continuous supply method produced numerically similar results relative to the control. The latter observation for the head setts was not confounded by sett rot (Table 32) and thus could be attributed to feedback inhibition due to the accumulation of some intermediary

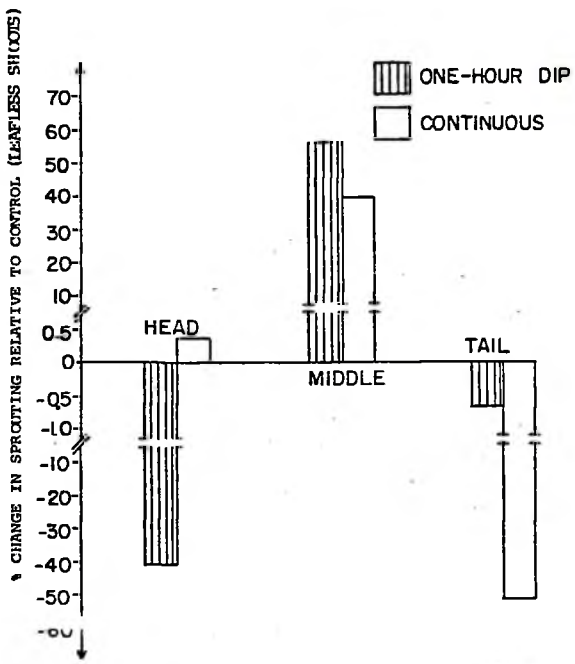


Fig. 9: Relative Effectiveness of Mode of Nutrient Application on the Promotion of Sprouting of Microsetts: 30DAP

metabolites. This may be of competitive nature (Harper, 1975), since the continuous supply method significantly promoted the development of the leafless-shoot- stage in comparison to the 1h-dip.

Hence, despite the fact that there were no significant differences between the sprouting values produced by the continuous supply method and the control, as regards the head setts, the proximal dominance of the heads over the middle setts was removed under the continuous supply, in contrast to the control (Table 31).

TABLE 32: Mode of Nutrient Mixture Application on the Rotting of Microsetts in a Cheese-Cloth-Based Propagator: 30DAP

lode of lutrient pplication	% Rotted Microsetts				LSD 5% (Mode of Application)
	Tuber Region			Average Mode of Application Effect	
	Head	Middle	Tail		
ontinuous	8.0	4.0	22.9	11.7	15.0
h-Dip	16.9	2.0	8.1	9.0	N.S.
e-Ionised ater	7.5	12.2	21.4	13.7	N.S.
SD 5%	N.S.	5.2	N.S.	N.S.	

The sprouting of the head and middle setts was, therefore, synchronous.

The tail setts did not respond to the nutrient mixture application (Table 31). The continuous nutrient supply method significantly suppressed sprouting compared to the control and 1h-dip treatments.

ii. Total Sprouting

There were no significant differences between the 1h-dip and the continuous, as well as between the latter and the control treatment with respect to average total sprouting (Table 33)

TABLE 33: Mode of Nutrient Mixture Application on the Sprouting of Microsetts in a Cheese-Cloth-Based Propagator: 30 DAP.

Mode of Nutrient Application	% Sprouted Microsetts (Total)				LSD 5% (Mode of Application)
	Tuber Region			Average Mode of Application	
	Head	Middle	Tail		
Continuous	83.0	92.0	48.3	74.4	18.0
1 h-Dip	79.1	93.6	71.2	81.3	14.6
De-Ionised Water	85.0	69.2	55.3	69.9	5.1
LSD 5%	N.S.	4.4	17.9	7.1	

The 1h-dip, on the other hand, was superior to the control.

The proximal dominance of the head setts over those from the distal regions of the tuber was significantly maintained for the de-ionised water or control (Table 33) as observed for the leafless-shoots (Table 31). This was rather reversed for the 1h-dip and continuous supply methods, with the middle setts exhibiting numerical superiority over the heads (Table 33).

Moreover, the tail setts under the 1 h-dip treatment did not elicit a significantly different total sprouting value compared to the heads, under this treatment. However, the response of the tail setts for the 1 h-dip method was significantly greater than that for the continuous supply. This could be due to supra-optimal nutrient build-up, leading to negative feedback inhibition, most probably of the enzymes involved in the sprouting process.

CHAPTER IX

EFFECTS OF PHYSICAL ORIENTATION ON THE SPROUTING OF MICROSETTS USING THE CHEESE-CLOTH-BASED-PROPAGATOR.

1. Introduction

In Chapter VIII, the microsetts were placed on the cheese-cloth, with their tail cut-surfaces touching it.

Besides the reasons mentioned earlier in Chapter VIII, for this placement method, it was anticipated that by simulating the natural direction of water-flow from the tuber to the shoots under field conditions, one could facilitate nutrient or water absorption through the cheese-cloth in the process.

However, these hypotheses were not based on any "a priori" knowledge. The following investigation was, therefore, undertaken to identify the most appropriate orientation of the microsetts in this consideration.

2. Materials and Methods

About 7g setts derived from the middle region of sprouted tubers were dipped in a 6 g/l suspension of Demosan for 2-3 minutes.

They were laid on the cheese-cloth in the improvised propagator units described in Chapter VIII (page 116), using three different physical-orientation treatments: "conventional", "normal" and "inverted".

These were chosen on the basis of the geotropic orientation of the tuber in the field (Fig. 10). The conventional orientation involved the placement of the un-cut tuber surfaces or periderm in direct contact with the cheese-cloth (Fig. 11). The distal cut-surfaces of the setts were in direct contact with the cheese-cloth with regard to the normal orientation (Fig. 12). In the case of the inverted (Fig. 13), the proximal cut-surfaces were in contact with the cheese-cloth.

Four replicates of 50 setts each, were used for each of the orientation treatments. Only tap-water was continuously supplied through the cheese-cloth.

It was observed during the experiment in Chapter VIII that the cheese-cloth was rather too wet. This was due to the fact that the lower trough/unit was kept very full throughout the experimental period. This affected the vigour of the non-green, emerged-shoots, some of which turned brownish-white.

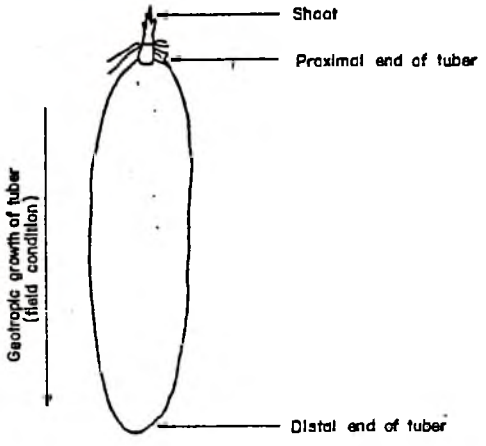


Fig. 10 :- Orientation of the white yam tuber in the field.

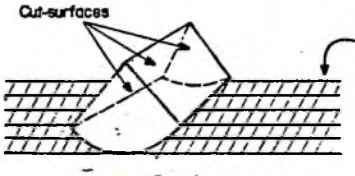


Fig. 11 : Conventional microsett orientation in the propagator

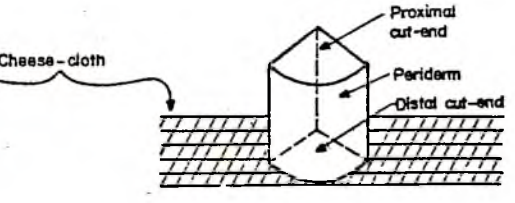


Fig. 12: Normal microsett orientation in the propagator

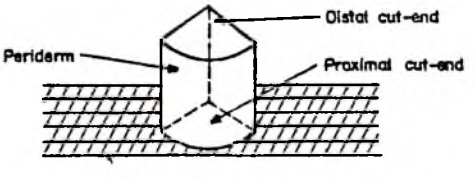


Fig. 13 : Inverted microsett orientation in the propagator

Consequently, the cheese-cloth in this experiment was kept just moist, by supplying only a litre of tap-water at any given time.

In a few cases, it was quite difficult to visually designate the proximal and distal cut-surfaces of the setts. However, it had been observed in an exploratory trial that when the distal cut-surfaces are in contact with the moist cheese-cloth, the setts absorbed water so quickly that their un-cut peridermal surfaces moistened up within a minute. If it were, however, the proximal cut-surfaces that were in contact with the cheese-cloth the respective peridermal surfaces took relatively longer time to moisten up completely.

Hence, about 1-2 minutes after the cheese-cloth has been moistened, the normally-orientated setts were observed closely and those exhibiting partial wetting of their periderms were turned the right way up.

Likewise, the inverted setts were also inspected and those showing complete wetting of the peridermal surfaces within the given time-period were corrected.

At 30 DAP, counts were made of rotten, unsprouted and sprouted setts.

Data Management and Statistical Analysis

The counts were expressed as percentages. They were categorised as reported in Chapter VIII (page 121) and analysed with Genstat programme using the completely randomised design option.

The LSD test was used to identify real differences among the treatment means.

3. Results and Discussion

There were no significant differences between the inverted and normal orientations with regard to sett rot, leafless-shoot-stage development and total sprouting (Table 34). However, the performance of the conventionally

TABLE 34: Effects of Physical Orientation on the Integrity and Sprouting of Microsetts Using the Cheese-Cloth-Based Propagator: 30 DAP

Type of Orientation	% Sprouted Microsetts		Rot Incidence (%)
	Leafless-Shoot-Stage	Total	
Inverted	87.5	96.5	1.0
Normal	91.0	97.0	1.0
Conventional	60.0	65.3	31.3
LSD 5%	10.2	7.1	4.7

orientated setts, in these respects, was significantly poorer (Table 34).

The rather significantly higher rotting of the conventionally orientated microsetts at 30 DAP was of the dry type - characterised by fungal infection of the cut-surfaces. Visually the extent of wound-periderm formation (Passam et al., 1976) on the cut-surfaces, with respect to the conventionally orientated setts was greater than the rest. Loss of moisture-content accompanies wound repair in the yams (Passam et al., op. cit.). This implies that the conventionally orientated setts with their relatively greater exposed cut-surface areas, might probably have lost more water. The latter situation might therefore have increased the rate of wound-healing in a compensatory move to reduce further water loss. However, this might have in the process led to the observed greater volume of wound-periderm (dead) tissue, thereby predisposing the setts to fungal infection.

Sprouting of the conventionally orientated setts might also have been supressed by a rather too-humid-an-interface between the un-cut sett periderm and the cheese-cloth. According to Onwueme (1973), the meristematic layer of the yam tuber is only about 1-2 mm from the surface. Sprouting is an

energy-requiring process. Thus, any high humidity conditions in the cheese-cloth-sett-periderm interface could lead to anaerobiosis, resulting in the accumulation of ethanol (Anosike, 1978, cited by Ikediobi, 1985) and thereby impairing the sprouting process.

The normally and invertedly orientated setts could, thus, be considered as having smaller exposed cut-surface areas and hence relatively minimal water-loss. Consequently, the suggested compensatory wound-healing might have been minimal, leading to a relatively lower amount of wound-periderm tissue. In this vein, any fungal attack was effectively controlled by the regular Demosan spray. Furthermore, it could be argued that setts orientated normally or invertedly take up water rapidly to replace any that is lost through dessication. These setts might also have adequate aerobic conditions around the exposed, un-cut peridermal surfaces and thereby enhancing their sprouting.

CHAPTER X

EFFECTS OF THE REMOVAL OF THE DISTAL -1/3 (TAIL) OF DORMANT TUBERS AND NUTRIENT APPLICATION ON THE SYNCHRONOUS SPROUTING OF THE RESULTANT TUBER PARTS.

1. Introduction

i. Background

The objective of obtaining 50% sprouted microsetts at the leafless-shoot-stage (Chapter VIII) at 21 DAP, using the continuously applied nutrient mixture (Chapter VIII) was not realized, even at 30 DAP. This was attributable to the composition of the nutrient mixture as well as the physiological immaturity of the setts derived from the tail region of the tuber (Fig. 4).

Cobalt was included in the nutrient mixture due to its stimulation of a step in oxidative metabolism (Thimann, 1956 cited by Shkolnik, 1984). Passam (1982) reported that increased respiratory activity is associated with the sprouting of the yam. However, it was later realized that cobalt has been reported to inhibit ethylene synthesis (Abeles, 1973), The promotive action of sodium thiosulphate

in Chapter VI was attributed to the modulation of endogenous ethylene biosynthesis. Furthermore, ethylene released by ethrel or ethephon has been reported to boost sprouting of the edible yams (Martin and Cabanillas, 1976; Passam, 1977).

It was, thus, apparent that the composition of the nutrient mixture needed revision.

There was a significant suppression of the development of the leafless-shoot stage of the tail setts in Chapter VIII. They also responded differentially to sodium thiosulphate and adenine sulphate (Chapters VI and VII). These observations were considered as an affirmation of the importance of the differences in the physiological age of the tuber.

The apparent solutions were:

i). to use different concentrations of the nutrients, either mixed or solely applied to the tail setts, or

ii). to discard the tail setts entirely.

Both of these options are, however, undesirable: in the first instance, the seed yam farmer would find it too cumbersome and time-consuming to measure or weigh different amounts of the same chemical(s). As regards the second alternative, the farmer would prefer, for economic reasons, to cut up the whole tuber into microsetts.

Hence, none of the above propositions are acceptable, in practice.

The following experiment was thus undertaken to investigate means of removing the slow sprouting bottle-neck of the tail region of the tuber and the microsetts derived from it.

ii. Conceptual Basis

It has been observed that when the tail portion of tubers are accidentally broken off during harvesting, they sprout on their own in storage, after the dormant period is over. Moreover, when farmers plant the tail pieces of tubers, they do sprout.

Hence, the distal-1/3 (tail) of sprouted tubers were cut and the wound-surfaces treated with a wood ash-Demosan-Aldrex 'T' suspension at the rates described in Chapter III. They were left on bamboo slats in the open-air, live-tree-shaded, traditional yam barn and protected from the rain by an over-head, translucent, polyethylene sheet, rain-screen.

Eight weeks later, lateral buds were developed all over the un-cut peridermal surface of the tuber (Fig. 14) - has been earlier reported (Giradot, 1956; Miege, 1957; Okoli, 1978) that lateral buds exist in the yams.

Fig. 14: Development of Buds on the Distal 1/3-Portion or Tails of Sprouted Tubers

Consequently, it was surmised that since the tail portion of the tuber was capable of forming such profuse lateral buds when separated from the rest of the tuber, then in such a condition, it could be physiologically considered as a "head" region – likewise all microsetts derived from it.

According to Onwueme (1984), at harvest, the corm attached to the tuber bears an "eye" (bud). The latter elongates after the dormant period is over into a new sprout, the growth of which suppresses the development of others from the distal regions. Thus, it was apparently evident that besides the differences in age between the head, middle and tail regions, the presence of an "eye" on the corm even at harvest is of considerable importance in determining the sprouting behaviour of the microsetts from these regions.

It was, therefore, conceptualized that if the corm were removed and the tail -1/3 portion separated from the head and middle portions - the latter operation herein referred to as "tail removal", the resultant parts could be induced to sprout simultaneously likewise the microsetts derived from them.

However, the questions that had to be answered were:

i). when during the post-harvest period should the dormant tail be removed?

ii). how could one synchronise the sprouting of the resultant portions?

Between October, 1984 and March, 1985, 5 g microsett samples derived from the three physiological age-zones (Fig. 4) of 1, 3, 5, 7, 11, and 20 WOTs were oven-dried at 65°C for 5 days and analyzed for their total nitrogen, potassium, phosphorus, total calcium and iron contents at the IITA Analytical Laboratory. The peripheral 1.6 - 1.9 cm portion of the tuber involving the entire anatomical cross-section: the outer cork layer, cortex, primary thickening meristematic layer and part of the inner ground tissue were analyzed.

The results of these analyses showed a decline between the 3rd and 5th weeks and a rise thereafter in total nitrogen, potassium and iron contents of the tubers (Figs. 15, 16 and 17).

Incidentally, the calcium content peaked at the 5th week, when the potassium and total nitrogen levels were lowest (Figs. 15, 16 and 18).

The phosphorus level remained relatively constant throughout the sampling period (Fig. 19).

These trends, especially the decline in % total nitrogen levels between the 3rd - 5th weeks and the rise thereafter was unexpected and cannot be accounted for.

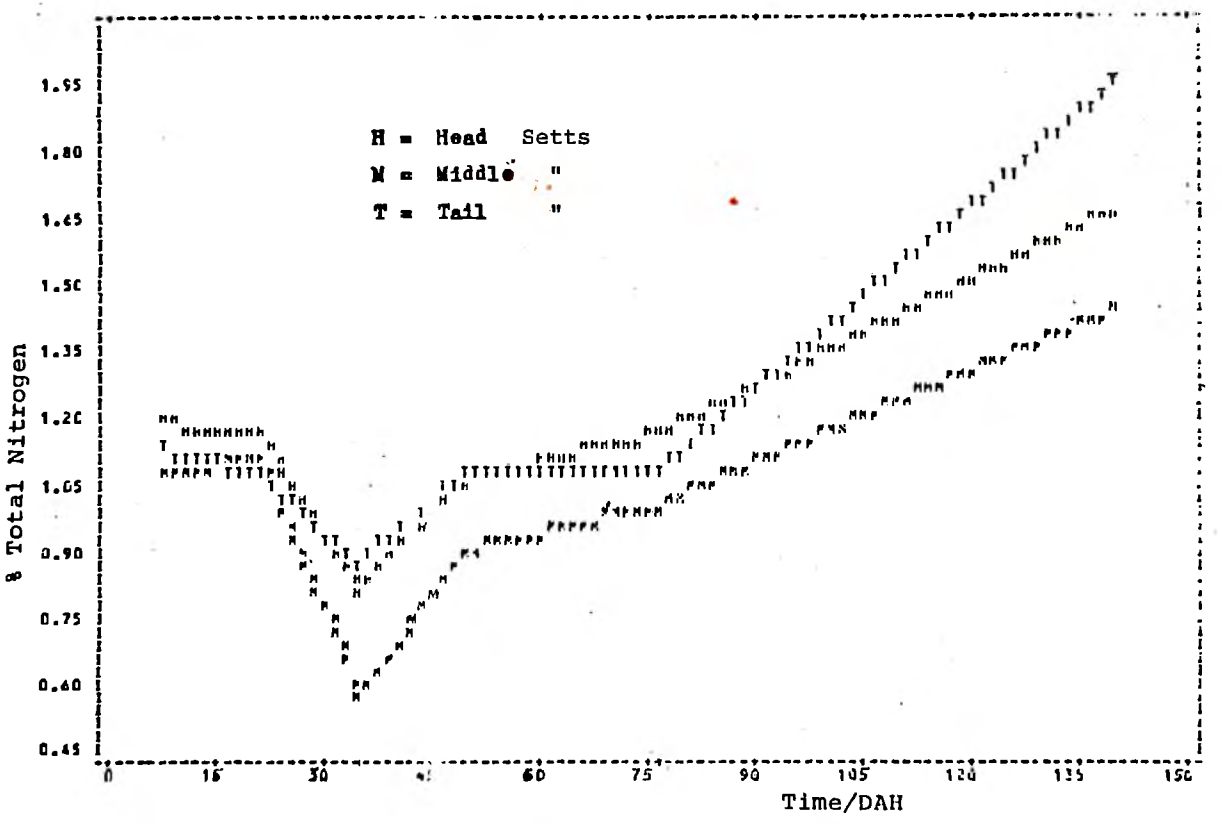


Fig. 15: Post-Harvest Changes with Time in Nitrogen Status of Microsetts Derived from Tubers Stored in the Traditional Barn.

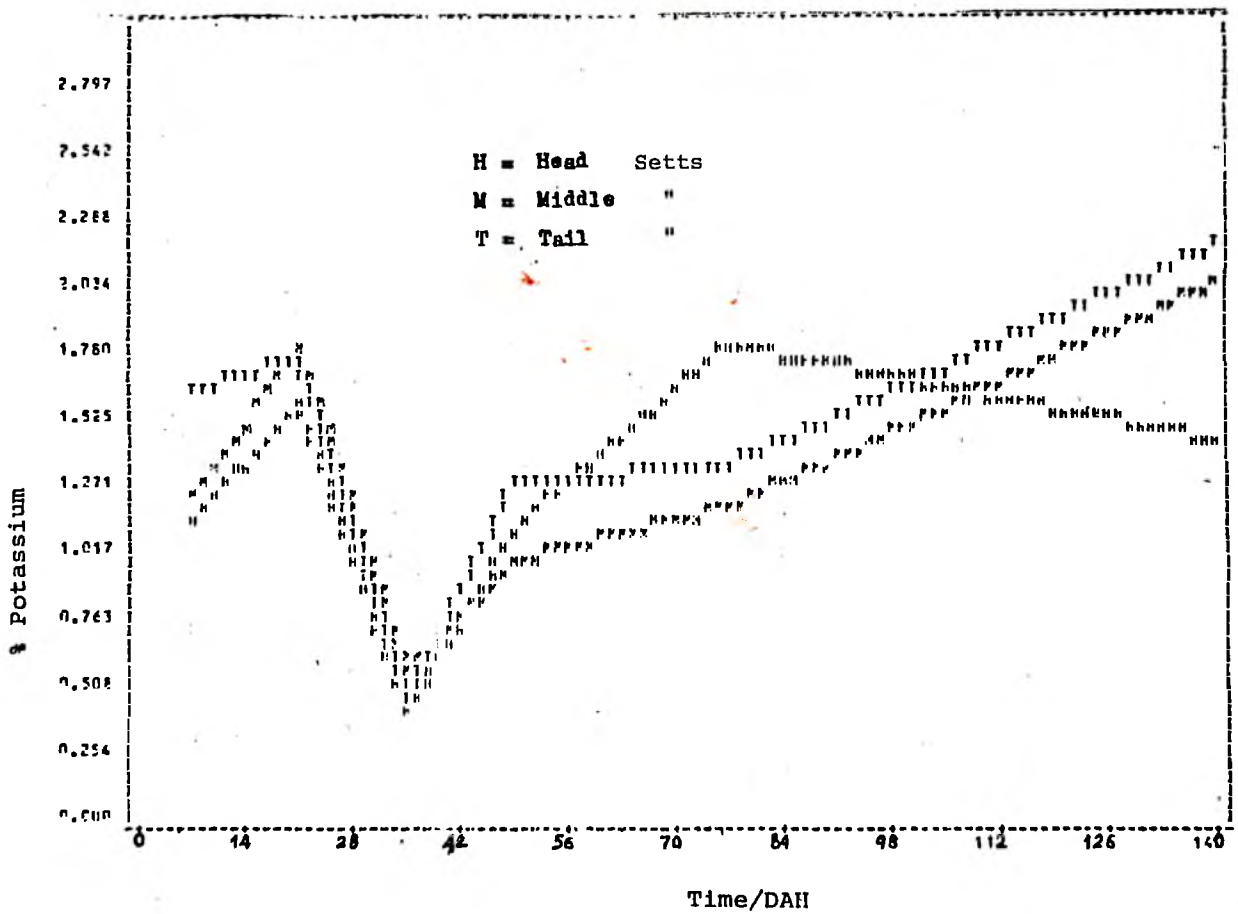


Fig. 16: Post-Harvest Changes with Time in Potassium Status of Microsetts Derived from Tubers Stored in the Traditional Barn.

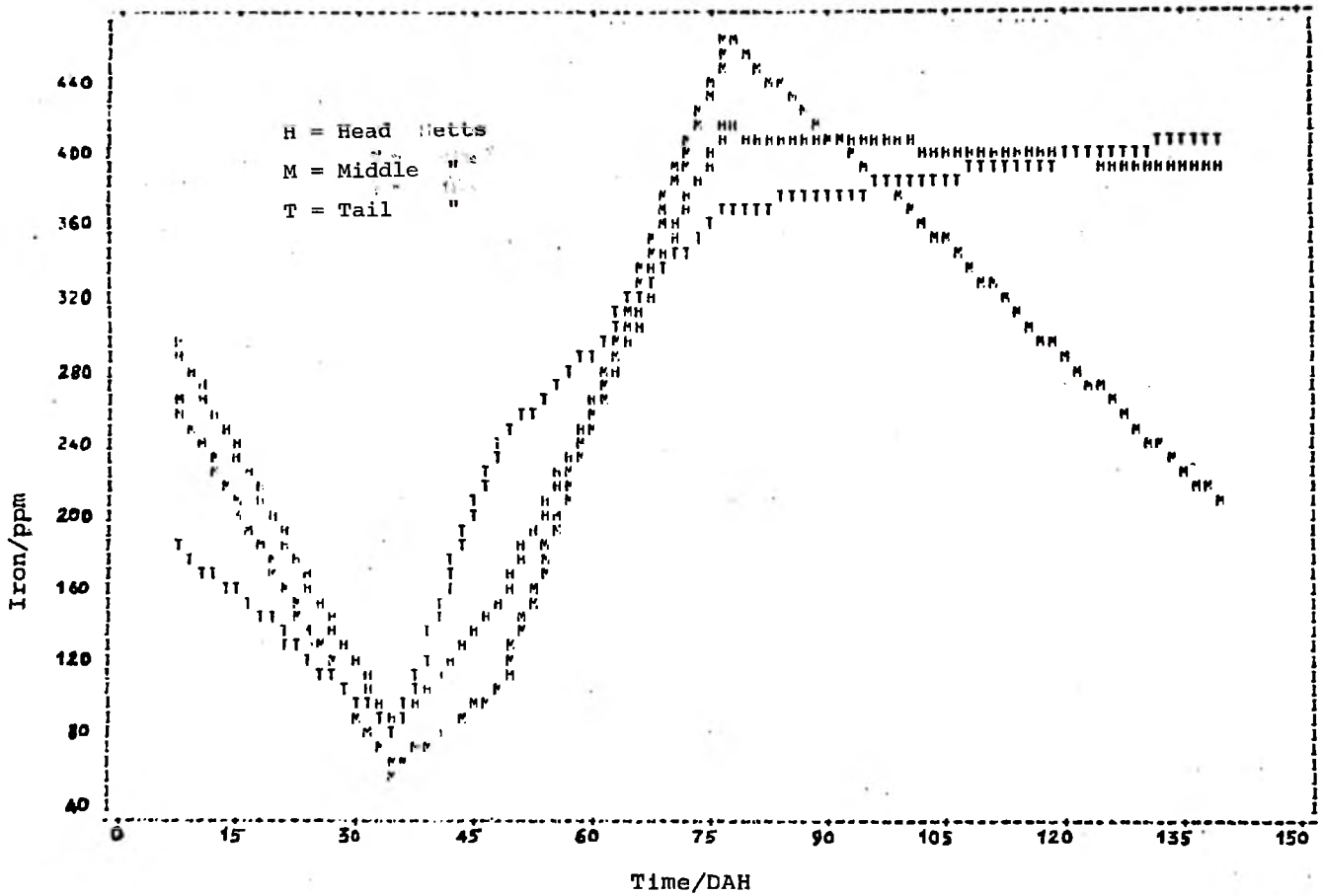


Fig. 17: Post-Harvest Changes with Time in Iron Status of Microsetts Derived from Tubers Stored in the Traditional Barn.

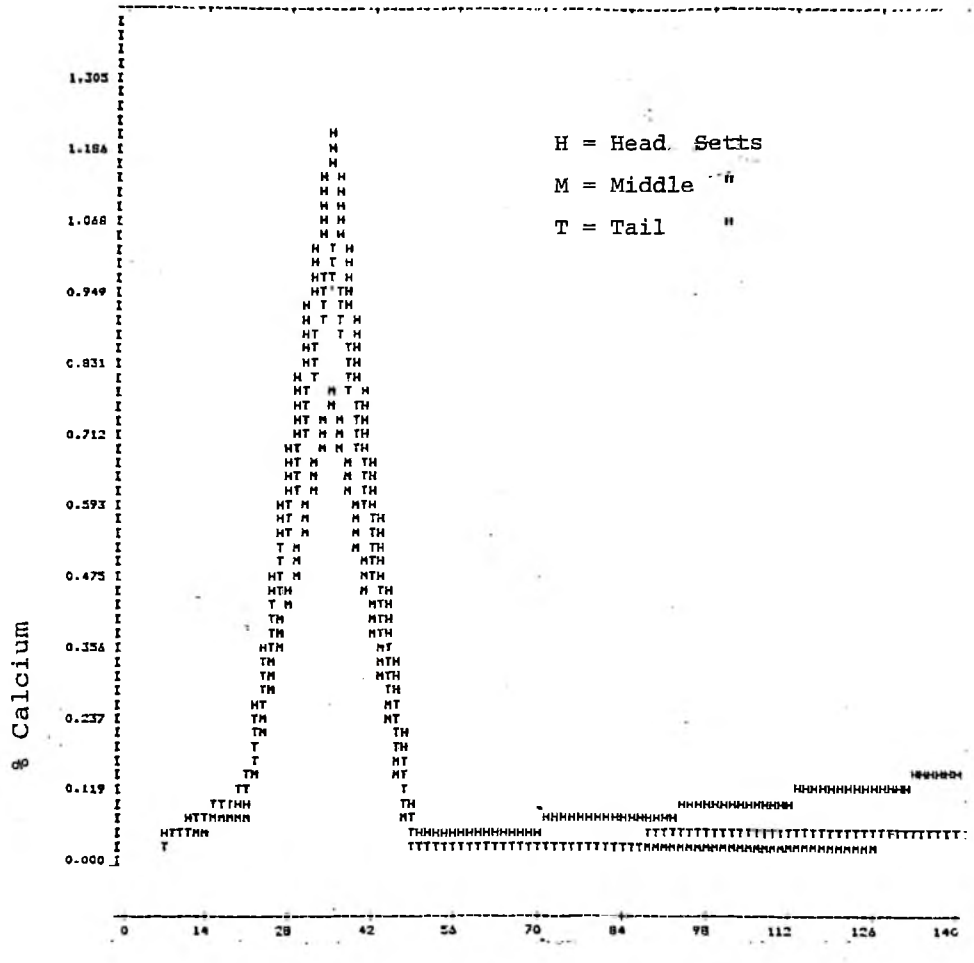


Fig. 18: Post-Harvest Changes with Time in Calcium Status of Microsetts Derived from Tubers Stored in the Traditional Barn.

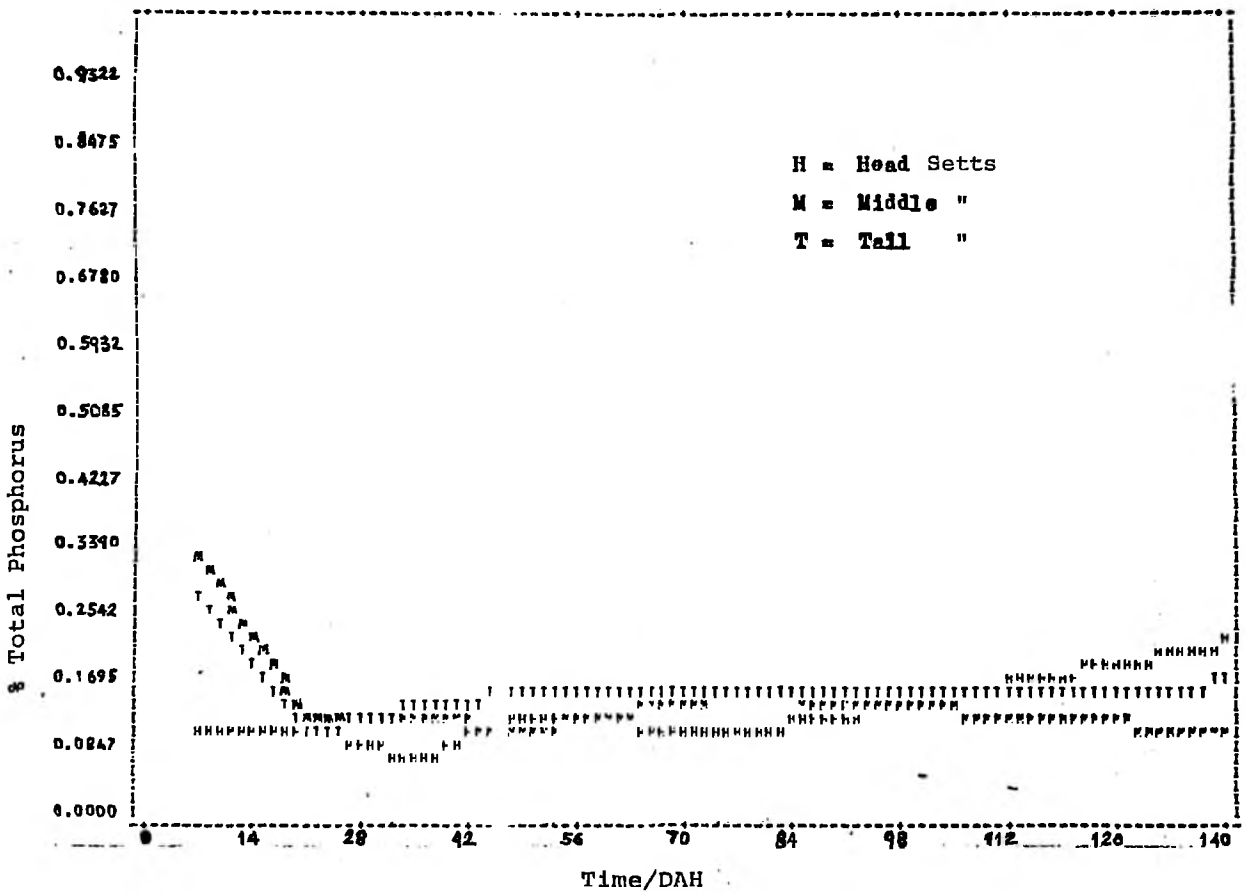


Fig. 19: Post-Harvest Changes with Time in Phosphorus Status of Microsetts Derived from Tubers Stored in the Traditional Barn.

It was, therefore, presumed that a certain peculiar physiological/biochemical mechanism operates during this period, which leads to a decline in % total nitrogen content.

Consequently it was proposed that it would be most appropriate to introduce nitrogen exogenously during this period. One could thereby create a metabolic pool which the meristematic cells could use in dividing, when the dormant period was over. Onwueme (1973) had reported that sprouting of the edible yam tuber occurs by de novo budding due to the activity of a meristematic layer, just beneath the periderm. The 3rd WAH (Transitional Phase I, Fig. 5) was thus considered as ideal for removing the tail and stimulating the synchronous sprouting of the resultant parts by externally supplying a nutrient source.

The above reasonings represented the conceptual basis of the following experiment.

2. Materials and Methods

Seed-yam-sized-tubers harvested at 6 MAT were washed with tap-water and kept on bamboo-slats in the traditional yam barn.

Three weeks later, they were divided into four groups of

fifteen tubers each. The tail portions (Fig. 4) of two of these four groups were removed with a knife.

Thirty of these cut tubers, comprising fifteen tail and fifteen 'head' portions - the latter being the proximal head and intervening middle portions together, were soaked in a nutrient mixture formulated as 1500 ppm Urea, 50 ppm Florel and 10 ppm $FeSO_4$ for an hour. The other batch of thirty cut-tuber portions were similarly soaked in de-ionised water, as control. One of the two remaining batches of whole, un-cut tubers, fifteen in number, was also soaked in the nutrient mixture for an hour. The other batch was soaked in de-ionised water as control.

The nutrient mixture formulation was based on the earlier experiments. In Chapter VI, the effective concentration of urea as regards total sprouting, increased from 5 ppm for the head setts to 100 ppm for the middle (Table 26). Although, the sprouting of the tails was confounded by rot in this instance; it was evident from the trends for the tail setts of the 28 WOTS (Table 27) that a concentration of urea greater than 100 ppm could be effective and depending on the time of application, delay sprouting of the physiologically older middle and head portions - thereby synchronising sprouting.

The promotive action of sodium thiosulphate, as mentioned earlier, was attributed to ethylene synthesis. Ethephon (Florel), being a cheap and readily available phytohormone source and as a water-soluble, liquid formulation was included in the nutrient mixture to act as a source of ethylene.

Sulphur is also involved in glutathione synthesis (page 113).

The similarity of the trends in changes in total nitrogen and iron, Fe, contents of the tubers over time (Figs. 15 and 17) suggested an involvement of iron in nitrogen metabolism (protein synthesis).

The corm on the proximal head region of all the tubers was removed prior to the application of the nutrient mixture and de-ionised water treatments.

The wound surfaces of the cut tubers as well as that, which was created as a result of the removal of the corm were smeared with a wood ash-Demosan mixture at a rate of 6 g Demosan to 1 1/2- handfuls of ash.

The tubers were stored on bamboo slats in the open-air, live-tree-shaded, traditional yam barn under a polyethylene sheet rain-screen.

Counts were made of sprouted and unsprouted tubers at 15,

17, 18 and 21 WAH. The sprouted tubers comprised those with emerged and unemerged shoots.

At 32 WAH, random, fresh weight samples of 150 g each from the tubers under consideration - including the whole, un-cut ones, were oven-dried for 5 days at 65°C. Four subsamples were used in each case.

This was undertaken to determine the losses in dry mater of the cut tubers in relation to the whole. The green sprouts were discarded.

Observations

At 5 WAH, peridermal cracks were observed on some of the treated tubers, especially near the proximal ends of the "heads"; bud-like protuberances also appeared on the tubers. Sprouting was observed on the treated tubers at 11 WAH.

Sprouting on tubers with their corms intact which were simultaneously harvested with those used in this experiment was first observed at 15 WAH.

Data Management and Statistical Analysis

i. Sprouting

The counts for each of the four scoring periods were analysed with the chi-square test.

The total chi-square sum of squares was partitioned into its tuber parts and nutrient main effect as well as the tuber-parts x nutrient interaction components as described by Maxwell (1961).

ii. Dry Matter Determination

The results of the tuber dry matter determination were analysed as a 2 x 2 x 2 factorial, using the completely randomised design option of the Genstat programme.

The factors and the respective levels were:

a). type of tuber : 1). whole
2). cut

b). tuber parts : 1). heads
2). tails

c). nutrient : 1). nutrient mixture
2). de-ionised water (control)

The analysis of variance of the derived attribute, % tuber dry matter, calculated as the ratio of the tuber dry weight to its fresh weight expressed as a percentage, was obtained.

The LSD test was used to compare the factor-level combinations that elicited significant variance-ratio.

3. Results and Discussion

i. Sprouting

The sprouting data expressed as counts are shown in Tables 35 to 38.

Whilst the tuber parts (heads and tails) were significantly different at the first scoring date, 15 WAH, they became statistically similar with time (Table 39).

The nutrient main effect was not significant at 15 WAH, when the tuber parts were really different (Table 39; Figs. 20a and b); it was, however, significant from the second scoring date onwards (Table 39).

This response-trend was highly desirable, as too-an-early promotion of sprouting by the nutrient mixture before the onset of the rains, was avoided.

Thus, the objective of accelerating the sprouting of the tails was achieved: this was evidenced by the lack of real differences among the tuber parts for the 17, 18 and 21 WAH scoring times. At the latter date, twenty-two and twenty-one of the heads and tails respectively had sprouted out of a total of twenty-nine in each case (Table 38a). Furthermore, at 17 WAH, the lack of significant differences between the heads and tails (Table 36a; Table 39) could be attributed to the rather highly significant sprouting elicited by the

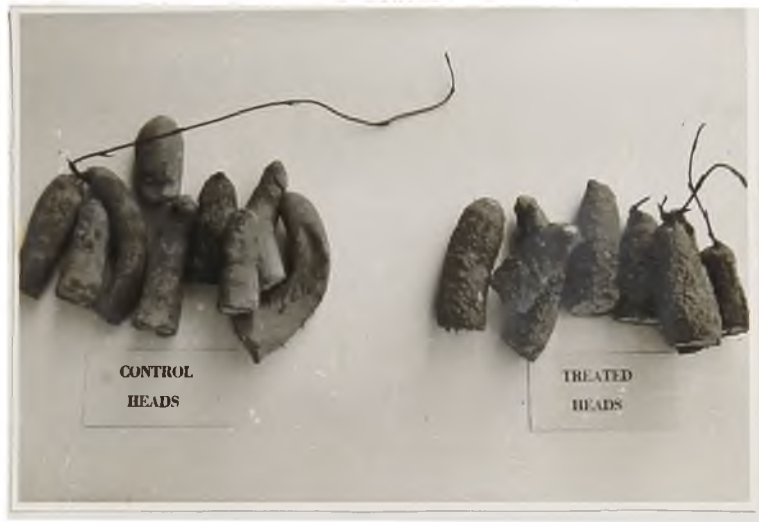


FIG. 20a: EFFECTS OF DORMANT TUBER MANIPULATION AND NUTRIENT APPLICATION ON THE SPROUTING OF THE HEADS: 15 WAH.

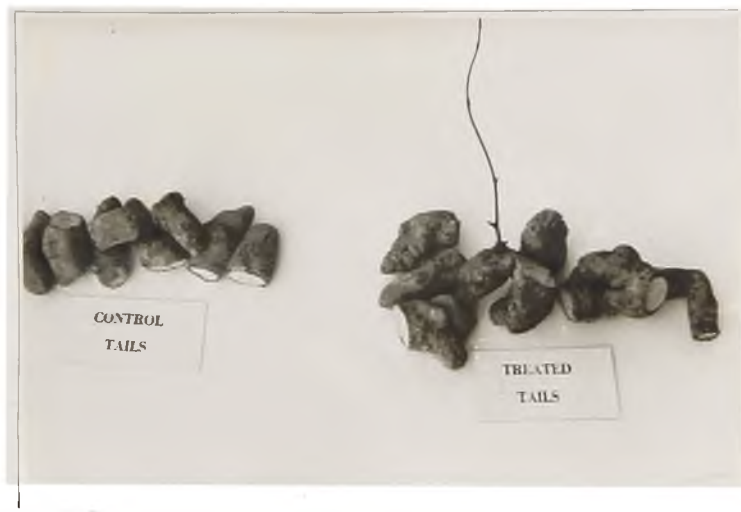


FIG. 20b: EFFECTS OF DORMANT TUBER MANIPULATION AND NUTRIENT APPLICATION ON THE SPROUTING OF THE TAILS: 15 WAH.

TABLE 35: Effects of Dormant-Tuber-Tail Removal and Nutrient Mixture Application on the Sprouting of the Resultant Tuber Parts: 15 WAH

a). Tuber Parts (Heads (H) Vrs Tails (T))

	H	T	Total
No. Sprouted	19	6	25
No. Unsprouted	10	23	33
Total	29	29	58

b). Nutrient (De-Ionised Water (T_o) Vrs. Nutrient Mixture (T_1))

	T_o	T_1	Total
No. Sprouted	9	16	25
No. Unsprouted	20	13	33
Total	29	29	58

c). Tuber-Parts x Nutrient

	HT_o, TT_1	HT_1, TT_o	Total
No. Sprouted	13	12	25
No. Unsprouted	17	16	33
Total	30	28	58

TABLE 36: Effects of Dormant-Tuber-Tail Removal and Nutrient Mixture Application on the Sprouting of the Resultant Tuber Parts: 17 WAH

a). Tuber Parts (Heads (H) Vrs Tails (T))

	H	T	Total
No. Sprouted	21	14	35
No. Unsprouted	8	15	23
Total	29	29	58

b). Nutrient (De-Ionised Water (To) Vrs. Nutrient Mixture (T_1))

	T_o	T_1	Total
No. Sprouted	13	22	35
No. Unsprouted	16	7	23
Total	29	29	58

c). Tuber-Parts x Nutrient

	HT_o,TT_1	HT_1,TT_o	Total
No. Sprouted	17	18	35
No. Unsprouted	13	10	23
Total	30	28	58

TABLE 37: Effects of Dormant-Tuber-Tail Removal and Nutrient Mixture Application on the Sprouting of the Resultant Tuber Parts: 18 WAH

a). Tuber Parts (Heads (H) Vrs Tails (T))

	H	T	Total
No. Sprouted	22	16	38
No. Unsprouted	7	13	20
Total	29	29	58

b). Nutrient (De-Ionised Water (T_o) Vrs. Nutrient Mixture (T_1))

	T_o	T_1	Total
No. Sprouted	15	23	38
No. Unsprouted	14	6	20
Total	29	29	58

c). Tuber-Parts x Nutrient

	HT_o, TT_1	HT_1, TT_o	Total
No. Sprouted	19	19	38
No. Unsprouted	11	9	20
Total	30	28	58

TABLE 38: Effects of Dormant-Tuber-Tail Removal and Nutrient Mixture Application on the Sprouting of the Resultant Tuber Parts: 21 WAH

a). Tuber Parts (Heads (H) Vrs Tails (T))

	H	T	Total
No. Sprouted	22	21	43
No. Unsprouted	7	8	15
Total	29	29	58

b). Nutrient (De-Ionised Water (T_o) Vrs. Nutrient Mixture (T_1))

	T_o	T_1	Total
No. Sprouted	17	26	43
No. Unsprouted	12	3	15
Total	29	29	58

c). Tuber-Parts x Nutrient

	HT_o,TT_1	HT_1,TT_o	Total
No. Sprouted	22	21	43
No. Unsprouted	8	7	15
Total	30	28	58

TABLE 39: Chi-Square (χ^2) Analysis of the Effects of Dormant-Tuber-Tail Removal and Nutrient Mixture Application on the Sprouting of the Resultant Tuber Parts

Time (WAH)	Source of Variation	Degrees of Freedom	χ^2	Significance Level
15	Tuber Parts	1	11.88	P=0.001
	Nutrient	1	3.45	N.S.
	Tuber-Parts x Nutrient	1	0.0013	N.S.
	Total	3	15.33	
17	Tuber Parts	1	3.53	N.S.
	Nutrient	1	5.84	P=0.025
	Tuber-Parts x Nutrient	1	0.35	N.S.
	Total	3	9.72	
18	Tuber Parts	1	2.75	N.S.
	Nutrient	1	4.88	P=0.050
	Tuber-Parts x Nutrient	1	0.09	N.S.
	Total	3	7.72	
21	Tuber Parts	1	0.09	N.S.
	Nutrient	1	7.28	P=0.010
	Tuber-Parts x Nutrient	1	0.02	N.S.
	Total	3	7.39	

nutrient mixture as compared to that of the control (Table 36b; and Table 39).

The effects of the nutrient mixture were even more striking at 18 WAH. Although, there were no real differences between the sprouting values for the head and tails (Table 37a; Table 39), the nutrient mixture significantly promoted sprouting compared to the de-ionised water (control) (Table 37b; Table 39).

It could, therefore, be suggested that the similarity of the tails to the heads is due to the effect of the nutrient mixture.

It is also arguable that the consistent drop in the statistic for the tuber parts with time (Table 39) - an indication of the increasing similarity of the tuber parts, serves as an evidence of the fact that the ethylene generated from the Florel, could be enhancing the ageing of the tails.

The urea-nitrogen could as well be boosting cytokinin and protein synthesis as mentioned in Chapter VI.

ii. Tuber Dry Matter

There were no real differences in % dry matter (DM) content between the cut-heads and the head portions of the un-cut, whole tubers (Table 40).

TABLE 40: Effects of Dormant-Tuber-Tail Removal and Nutrient-Mixture Application on the Tuber Dry Matter Content: 32 WAH

Tuber Type	% Dry Matter			
	Tuber Parts			
	Nutrient		Nutrient	
	De-Ionised Water	Nutrient-Mixture	De-Ionised Water	Nutrient-Mixture
Whole	36.2	36.0	35.3	35.0
Cut	33.0	39.5	38.4	38.7
LSD 5%	N.S.	1.8	N.S.	1.6

Similarly, there were no significant differences between the tail portions of the whole tubers and those of the cut as regards the control treatment: de-ionised water (Table 40).

However, the heads and tails of the cut tubers had significantly greater % DM content than the respective portions of the whole, un-cut tubers. It is quite difficult to adduce reasons for this, but it was observed that the sprouting of the whole tubers was very rapid. Consequently, these tubers might have lost relatively greater amounts of dry matter.

This, therefore, justifies the "tail removal" method as the dry matter loss from the resultant parts is relatively lower.

iii. A Re-appraisal of the Conceptual Basis of the Physiological Ontogeny of the Edible Yam Tuber

The tail removal method was undertaken at 3WAH primarily because of the declining trend in % total nitrogen content (%TN) of the tuber from the 3rd to the 5th week after harvesting as shown in Fig. 15.

Nonetheless, this trend was not well understood at the time of setting up the experiment. It was thus presumed that there could be certain physiological or biochemical factors that determine the pattern of nitrogen distribution in the tuber with time.

However, the observation at 5 WAH of the formation of lateral buds on the treated heads coincides with the rise in % TN content at 5 WAH (Fig. 15). The lateral buds became more pronounced with time (Fig. 21).

Furthermore, considering the mode of preparation of the microsett samples used for the nutrient analysis: 5 g pieces with the outer periderm intact (Fig. 22) were derived from ware yam tubers ($\geq$ 1000 g) produced from minisetts and the

Fig. 21: Development of Buds on the Heads

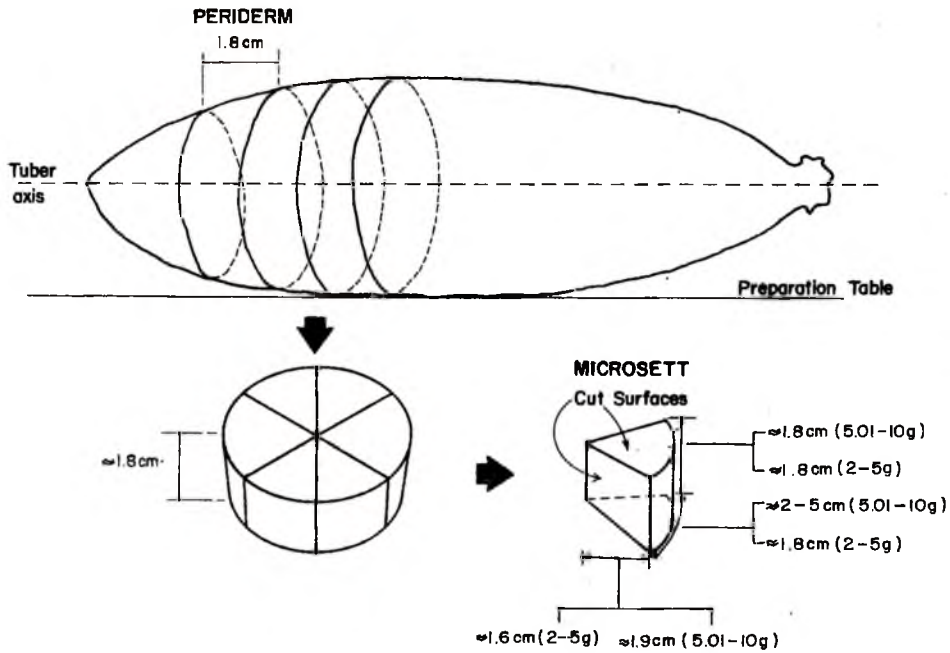


Fig. 23 - MICROSETT LINEAR DIMENSIONS AND MODE OF PREPARATION.

inner storage parenchyma tissue discarded. Thus the observed trends in % TN, could suggestedly be attributed to internal redistribution in the tuber during the post-harvest period (Fig. 23).

According to Arene et al. (1985), the corky periderm, cortex and meristematic layer, which together form the outermost, non-storage tissues of the tuber are only a few millimeters thick; infact, Onwueme (1973) reported that the meristematic layer is only 1-2mm from the tuber surface.

Since the tuber could sprout from any part of it, it means that the meristematic layer is periclinally distributed. The activity of this meristem would, therefore, depend on the supply of mobilized food reserves from the inner ground or storage parenchyma tissues. This supports the proposal that the observed trends in the mineral nutrients could be due to redistribution within the tuber during storage. Further research is required to affirm this.

It could as well be proposed that the tuber initiates meristematic activity at 5 WAH, as evidenced by the consistent rise in % TN (Fig. 15) and hence % crude protein, % CP (Fig. 24) levels after this period. % CP is derived from the relation: % TN x 6.25. Affirmatory histological studies are required in this direction.

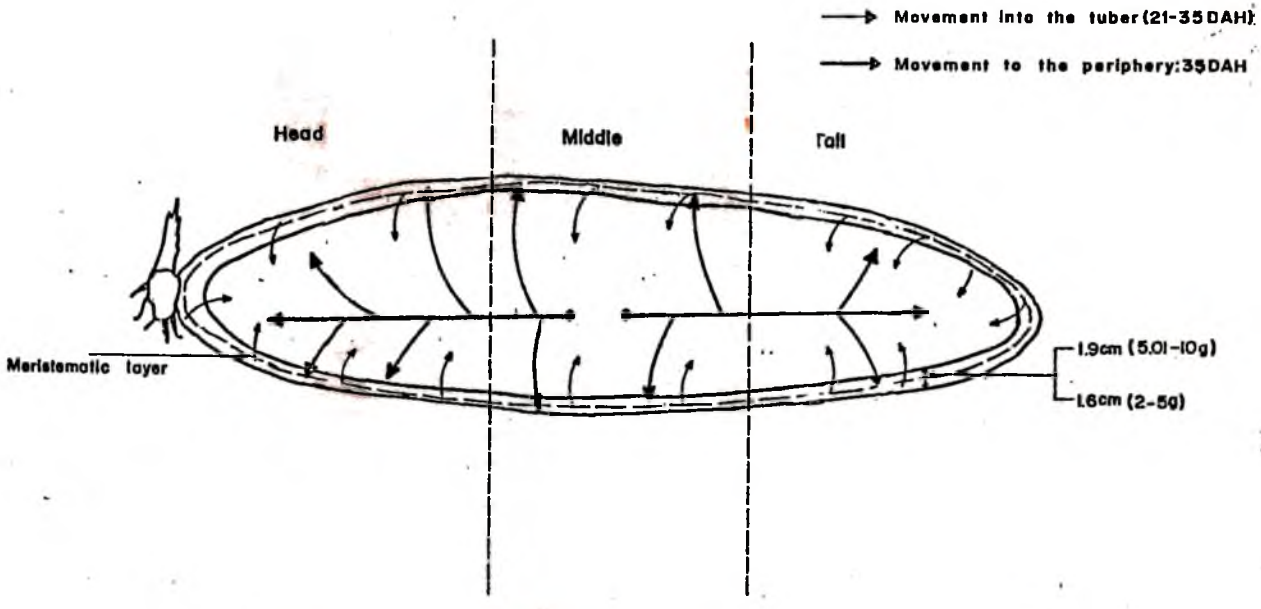


Fig. 23: GENERALISED INTERNAL MOVEMENTS OF NITROGEN IN THE WHITE YAM TUBER AFTER HARVEST.

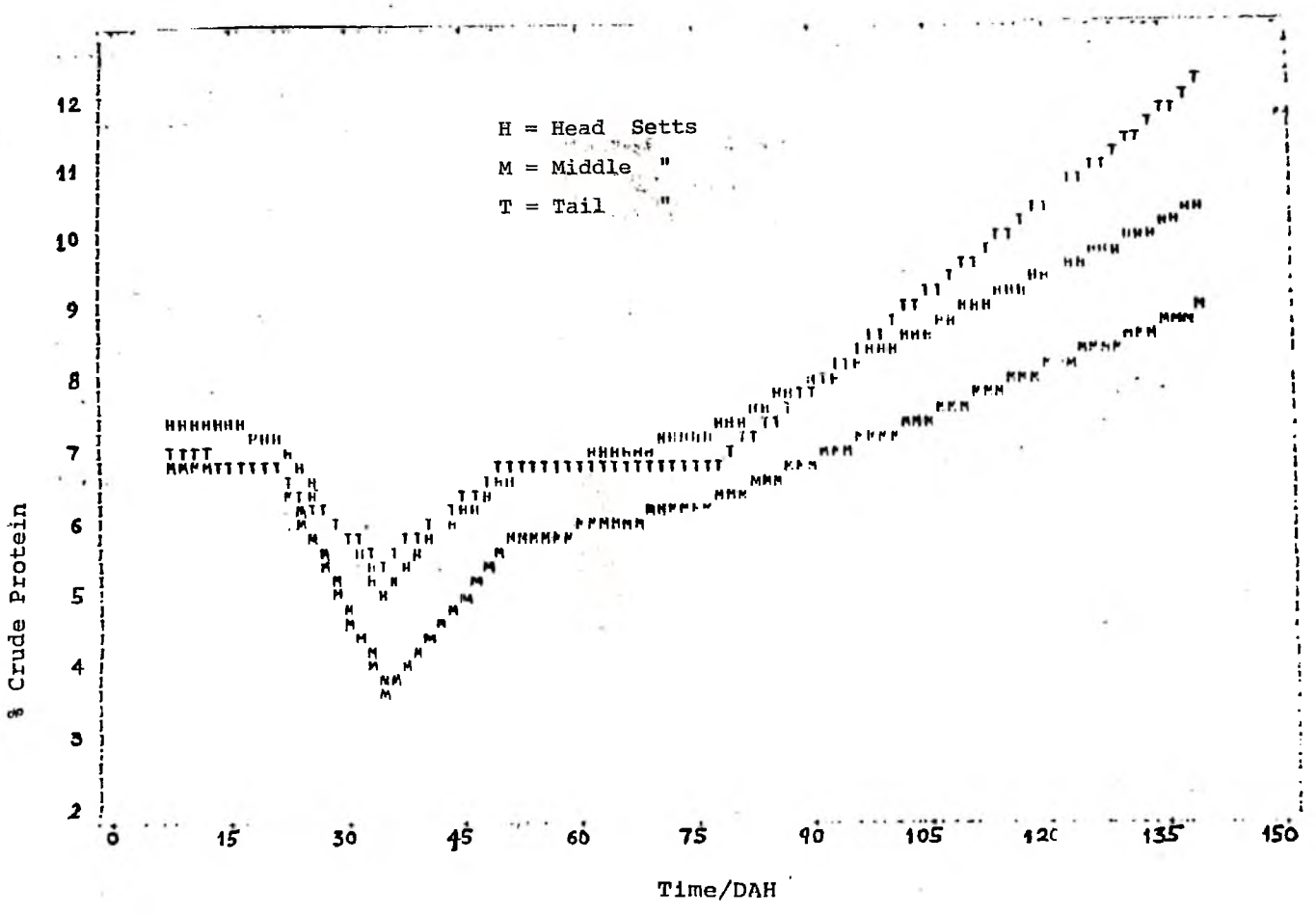


Fig. 24: Post-Harvest Changes with Time in Crude Protein Content of Microsetts Derived from Tubers in the Traditional Barn.

The trends in % total calcium, Ca, and % TN during the first 5 weeks were most remarkable (Figs. 15 and 18). Whilst % TN decreased from the 3rd to the 5th week and increased thereafter, the Ca level increased from the 3rd to the 5th week, peaking at the latter and declining thereafter. These, indicated a negative relationship between % TN, i.e. protein synthesis and the % Ca status.

It appears, therefore, that the calcium ion, Ca^{2+}, suppresses protein synthesis. As the average tuber crude protein level (irrespective of tuber portion) decreased and increased (Table 41) the Ca level increased and decreased respectively, in the periphery of the tuber as depicted for nitrogen (Fig. 23). Steward and Preston (1940, 1941a,b) reported that Ca^{2+} concentration in potato slices suppresses protein synthesis.

Furthermore, Steward and Mott (1970) demostrated that in growing carrot cultures, the diurnal increase in potassium and protein levels peak simultaneously and then fall. A similar trend in protein and potassium levels has been observed in pea root cultures (Sexton and Sutcliffe, 1969). The latter found that the rate of increase peaked at the time of most rapid cell enlargement. Yagi (1972) cited by Sutcliffe (1973) made a similar observation in young developing bean leaves.

TABLE 41: Post-Harvest Changes Over Time in Calcium, Total Nitrogen and Crude Protein Levels of Microsetts Averaged Over the Three Physiological Age-Zones of the Tuber

Time (DAH)	Calcium (%)	Total Nitrogen (%)	Crude Protein (%)
7	0.036	1.136	7.10
21	0.104	1.110	6.94
35	1.003	0.755	4.72
49	0.027	1.019	6.37
77*	0.043	1.080	6.75
140	0.075	1.677	10.48
LSD 5%	0.065	0.110	1.06

* Natural tuber dormancy release.

Similar trends were observed in potassium and crude protein levels (Figs. 16 and 24).

These support the proposition that the increase in % TN and hence crude portein levels in periphery of the tuber could be attributed to initiation of meristematic activity. It is, therefore, inferable that tuber dormancy breaks at the biochemical level at 5 WAH, for the white yam variety, TDr 131.

Calcium is highly immobile and thus its increase between the 3rd - 5th WAH may be due to desequestration from vacuoles in the periphery of the tuber.

Considering the trends in Figs. 15 to 19, it was evident that the middle region was generally lagging behind, especially for % TN (Fig. 15), whilst the heads and tails had almost similar levels.

Thus, the middle region of the tuber probably serves as a "source" for nutrients, whilst the head and tail regions are "sinks", as indicated by the unbranched, bold arrow-heads in Fig. 23.

Sinks, according to Sutcliffe (1976), are growing organs of the plant: meristems, young leaves and so on, to which materials move from sources of supply in the plant.

The tail and head of the tuber are both characterised by apical growing points: that of the tail operates during the geotropic development of the tuber in the field, whilst that of the head is active after tuber dormancy release.

It could, therefore, be argued that the proximal dominance of the head setts over the distal parts is one of differential nutrient levels and hormonal distribution or production. This is affirmed by the suggestion of Sutcliffe (1976) that the growing axis controls the mobilization and

transport of nitrogen by regulating the synthesis of proteolytic enzymes in the aleurone layer in germinating cereal grains.

Thus, by removing the corm on the heads, its suppression of lateral buds on the body of the tuber is removed. This suppression might probably occur by nutrient deprivation as suggested by Goebel (1900) cited by Guern and Usciati (1972) who attributed apical dominance to nutrient deprivation of the axillary buds.

On the basis of these trends and reasonings, one could hypothetically divide the Vegetative Phase I of the physiological ontogeny of the yam tuber (Fig. 5) into the following sub-phases: a true dormancy and biochemically non-dormant tuber (Fig. 25).

The true dormancy sub-phase, involving the first 3 WAH is characterised by a decline in % TN in the meristematic region (Figs. 15 and 23). It might, therefore, be inductive in nature during which meristematic cells prepare to divide (Aitchison et al., 1973).

The nitrogen could be moving into the storage parenchyma tissue (Fig. 23) along phytohormonal gradients, possibly, to be used as substrates for the synthesis of enzymes required for the mobilization of food reserves.

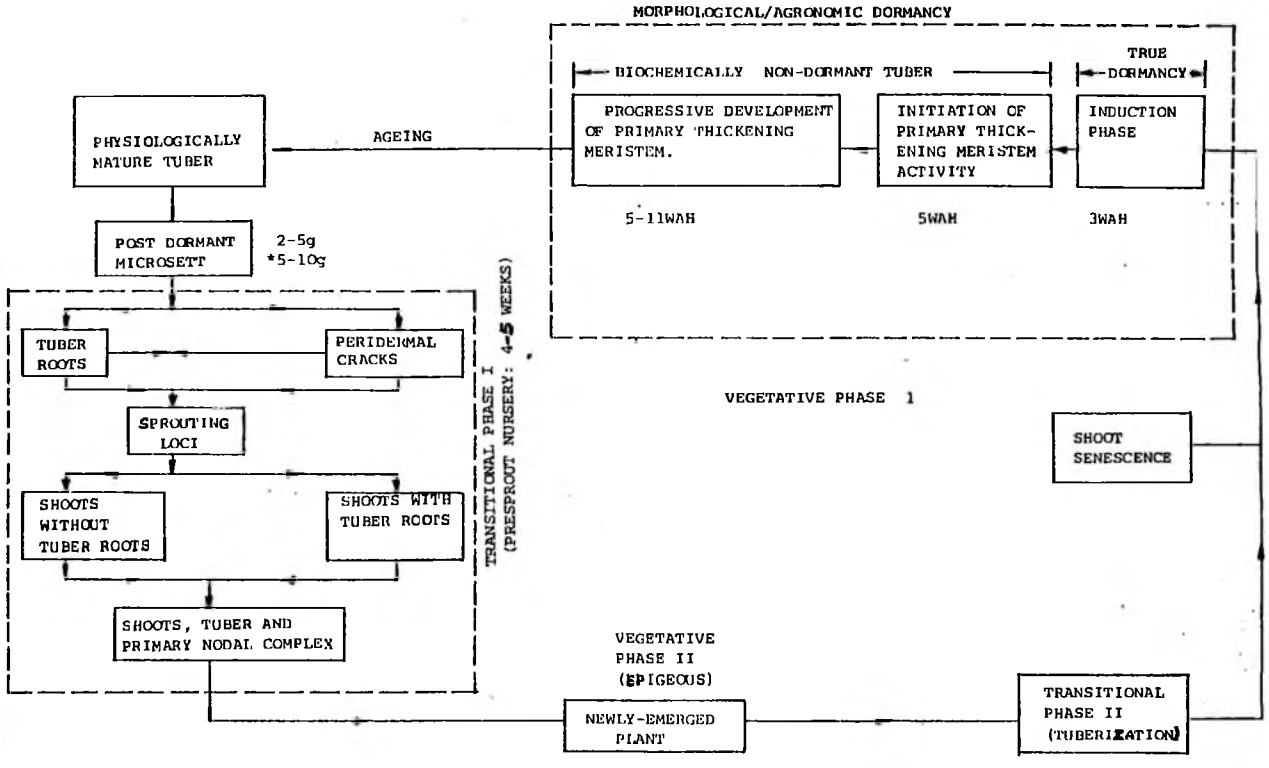


Fig. 25: Microsett-based morpho-physiological ontogeny of white yam.

Thus, the earlier assumption that there is "continuity" in growth of the tuber in the field as well as in storage (page 68) cannot completely hold: a phase of inductive, true dormancy probably exists. Further biochemical and histological studies are required in this direction.

The biochemically non-dormant tuber sub-phase involves the initiation of meristematic activity at 5 WAH and its progressive development. This is indicated by the rise in % TN (Fig. 15) in the peripheral meristematic region (Fig. 23) of the tuber.

In effect, tuber dormancy probably breaks at 5 WAH although it is morphologically evident at 11 WAH, when visible sprouting buds appear on the corm or tuber.

Further studies on this nutrient redistribution as well as histological changes could lead to the breakage of tuber dormancy. In this way, one could undertake year round seed yam production.

SECTION D

SLIP PROPAGATION

CHAPTER XI

EFFECTS OF DARK-STORAGE-DERIVED-SLIP MANAGEMENT ON FIELD ESTABLISHMENT, FRESH TUBER YIELD AND YIELD-RELATED ATTRIBUTES.

1. Introduction

Passam (1982) reported that a rise in tuber respiration is associated with sprouting leading to a depletion of the food reserves.

Sprouting, therefore, reduces the quality of the tubers as sources of planting material. Sprouts are, thus, routinely removed from the tubers in storage, but only to be thrown away. This practice is undesirable since in-storage sprouting involves the transfer of food reserves from the tuber into the new vine, rendering the latter economically important.

The "new propagation method" reported by Okigbo and Ibe (1973), with slight modification however, could provide an avenue for making economic use of the green sprouts that arise from the tubers in the open-air, traditional yam barn.

However, the sprouts that develop under dark-storage conditions are whitish or pale yellow in appearance being devoid of chlorophyll.

The morphogenetic potential of these non-green sprouts were, therefore, investigated in an exploratory trial. Seventy-seven of these sprouts were carefully plucked as "slips" from tubers of the white yam variety, TDr 603, which have been in the dark-storage for about 5 weeks.

The tubers were bought from a farmer and thus the actual time of tuber dormancy release was not precisely known.

The slips comprising the leafless shoot and corm, as well as the adventitious roots (Fig. 26) were presprouted in a top-soil-filled bed for about 3 weeks.

Subsequently, the dry matter content of the plantlets was determined using a subsample of twenty-four, after oven-drying them at 65^{o} for 72 h. Similarly, the dry matter content of the unpresprouted, freshly removed slips was also determined.

It was observed that the slips attained a dry matter content of 58.9% at the end of 3 weeks of presprouting in the topsoil, representing a net increase or "morphogenetic efficiency", ME, of 340.3% compared to the unpresprouted. ME was derived as a ratio of the dry matter contents of the presprouted and unpresprouted slips, expressed as a percentage.

This rather high ME of the slips stimulated further interest in them. It was thus proposed that since the

Fig. 26: Non-green Slips Plucked from Tubers in Dark Storage.

non-green slips grew luxuriantly in "topsoil" in the nursery, they could as well as perform similarly under direct field planting conditions provided adequate soil moisture could be assured.

It was in this light that the following experiment was undertaken.

2. Materials and Methods

Three batches of 30-50 cm high, non-green slips were obtained: the first was "presprouted" in topsoil for 3 weeks, the second "pre-rooted" in moist sawdust for 4 days, whilst the third was freshly plucked from the tubers.

The pre-rooted and unpresprouted slips were derived from tubers that had been in dark storage for about 8 weeks. The presprouted were obtained from tubers that had been in storage for about 5 weeks prior to presprouting.

These slips were transplanted or planted on ridges covered with plastic-strip mulch using two rows per ridge (Fig. 27). The intra-row spacing was 0.30 m x 1.25 m.

The depth of planting or transplanting was about 5-7 cm. One slip was used per planting or transplanting hole; however, the multi-shooted slips were not trimmed to one.

A total plot size of 6.0 m x 1.25 m in three replications

Fig. 27: Non-green Slips Growing Under Plastic-strip Mulch in the Field: 2 WAT

each, with forty-two plants per replicate was used. The plots were not laid in any particular experimental design and thus the replicated plots for each of the three batches were close to one another.

The plastic mulch was laid over the ridges soon after a heavy downpour of rain. It was expected to ensure the maintenance of adequate soil moisture conditions for growth.

The soil type was of a sandy loam to sandy clay loam texture belonging to the Iwo soils. This has been classified as an Oxic Paleustalf or Ferric Luvisol by the U.S.D.A. and F.A.O. respectively (Moorman et al., 1975). The physical and chemical properties of these soils are shown in Tables 42a and b.

TABLE 42a: Some Physical Characteristics of the Iwo Soils.

Depth cm	Gravel %	Mechanical Analysis %			Penetrometer Readings kg cm^{-2}	Bulk Density g cm^{-3}	
		Sand	Silt	Clay		Overall	Fine Earth
0 - 25	13	70.4	12.4	17.6	0.58	1.20	1.17
25 - 50	39	54.4	23.0	22.6	0.67	1.36	1.29
50 - 62	41	46.4	12.0	41.6	1.83	1.52	1.37
62 - 72	28	38.4	10.0	51.6	4.33	1.48	1.40
72 - 115	31	22.3	23.4	54.3	4.50	1.49	1.40
115 - 155	16	20.9	24.8	54.3	4.50	1.43	1.38

Source: Moorman et al. (1975)

TABLE 42b: Some Chemical Properties of the Iwo Soils.

Depth cm	pH		Exchangeable Cations me/100g						C E C me/100g	Organic C %	Total N %	Bray P1 ppm P
	H_2O	KCl	Ca	Mg	K	Na	Mn	Al				
0 - 25	6.3	5.8	4.93	1.31	0.23	0.06	0.12	0.06	6.82	1.54	0.154	2.8
25 - 50	6.2	6.0	5.75	1.75	0.27	0.07	0.14	0.06	8.15	1.66	0.181	1.1
50 - 62	6.3	5.5	2.74	0.78	0.22	0.05	0.03	0.12	4.16	0.49	0.046	0.7
62 - 72	6.3	5.9	2.88	0.92	0.32	0.05	0.03	0.12	4.37	0.50	0.048	0.4
72 - 115	6.3	5.2	2.89	0.91	0.32	0.05	0.03	0.10	4.37	0.28	0.035	0.8
115 - 155	6.0	5.1	2.40	1.38	0.24	0.06	0.01	0.13	4.23	0.13	0.019	0.1

Source: Moorman et al. (1975).

At 2 WAT or WAP, the directly planted slips showed marked yellowing on their leaves. Hence, 500 ppm (0.5 g/l) 15:15:15 NPK fertilizer was applied as a foliar spray to all the plots.

The directly planted slips recovered instantly. Moreover, a starter-solution of 500 ppm 15:15:15 NPK was applied at planting. However, it is very likely that the rains might have leached out these nutrients before the plants were established.

Replacements were undertaken for the presprouted slips at 2 WAT due to very poor field establishment. Counts were made of established plants at 2 WAT or WAP.

The tubers were harvested at 5 MAT or MAP, with iron-diggers, using effective plot sizes of 5.4 m x 1.25 m.

Data Management and Statistical Analysis

The counts for established plants at 2 WAT or WAP were expressed as percentages.

At harvest, the variates considered were:

a). Number of surviving plants expressed as a percentage of the number planted.

b). Total fresh tuber yield, expressed as Tonnes per hectare (t/ha).

c). Average tuber size.

d). Number of tubers per plant and,

e). Number of tubers per hectare.

The variates were analyzed with the completely randomised design option of the Genstat Mark V programme.

Real differences among the treatments were compared with the LSD test.

3. Results and Discussion

TABLE 43: Effects of Pre-Plant Management of Dark-Storage-Derived-Slips on Field Performance, Fresh Tuber Yield and Yield Components

Type of Slip	% Plant Establish-ment (2 WAT/WAP)	% Plant Survival at Harvest (5 MAT)	Fresh Tuber Yield (t/ha)	Average Tuber Size (g)	Number of Tubers /plant	Number of Tubers /ha
Directly Planted	88.1	51.24	17.8	363.0	1.7	49,036
Pre-Rooted	45.2	30.74	8.2	206.0	2.3	39,806
Presprouted	15.0	65.12	15.0	186.0	2.2	80,646
LSD 5%	16.9	15.94	5.6	123.1	0.4	15,460

The directly planted slips elicited significantly greater early field establishment at 2 WAP than the pre-rooted and presprouted. Field establishment significantly decreased with

presprouting (Table 43). This was suggestedly considered as an indication of the severe intolerance of the slips to transplanting shock, probably due to poor readjustment to new micro-environments.

Furthermore, the latter situation might have been accentuated by the fact that the pre-rooted and presprouted slips were not transplanted with a ball-of-earth.

The very poor establishment of the presprouted slips necessitated the replacements at 2 WAT.

There were, therefore, no real differences between fresh tuber yield for the presprouted and directly planted slips (Table 43), whilst the pre-rooted produced significantly lower yield in relation to the rest. These tuber yield trends were, however, a reflection of the % plant survival at harvest, which was confounded by the presprouted-slip-replacements at 2 WAT.

The number of tubers per plant significantly increased with presprouting. This was evidenced by the significantly lower number of tubers per plant produced by the directly planted slips as compared with the pre-rooted and presprouted.

There was a compensatory readjustment of tuber size in response to the change in number of tubers per plant: the directly planted slips produced a significantly higher average

tuber size of 363.0 g (Table 43; Fig. 28) vis-a-vis their significantly lower number of tubers per plant in relation to the presprouted and pre-rooted (Table 43).

The presprouted slips produced significantly greater number of tubers per hectare (Tnh) than the pre-rooted (Table 43). This could be attributed to the differences in plant survival at harvest (Table 43). The latter was, however, confounded by the replacements undertaken for the presprouted at 2 WAT.

Similarly, the Tnh value produced by the presprouted slips was significantly greater than that of the directly planted (Table 43). This superiority could be due to the significantly greater number of tubers per plant produced by the presprouted (Table 43). The physiological basis of this phenomenon, however, requires further study.

The morphogenetic ability of the non-green slips might probably be due to the phytochrome-mediated responses. This reasoning is based on the observation that the slips did not grow viny, but exhibited a rather "bushy" canopy architecture.

Moore (1981) reported that the inhibition of stem elongation is one of the photomorphogenetic, phytochrome-mediated responses.

The freshly plucked slips were also observed to rapidly

Fig. 28: Tubers Derived From Directly-Planted Slips: 5 MAP

turn green when exposed to very high intensity light. The greening, in this instance, started from the tip and rapidly moved down towards the base.

It is thus proposable that it might be during this greening process after exposure to light, that the tendency of the shoot to grow viny is lost and the bushy habit acquired. Briggs and Rice (1972) reported that high phytochrome levels are associated with meristematic tissue. The initiation of greening at the tip of the slips could thus be due to high levels of phytochrome - infact (Moore, op. cit.) reported that phytochrome - controlled, photo-responses mediate chloroplast development.

SECTION E

SEED YAM PRODUCTION PACKAGE

CHAPTER XII

MICROSETT- AND SLIP-BASED SEED YAM PRODUCTION TECHNOLOGY

Based on the results obtained from the experiments conducted as well as other pertinent practical observations, the following seed yam production package is proposed (Fig. 29). The recommendations for the microsetts, in this instance, are also applicable to the minisetts (25g sett-pieces).

1. Purchase and Storage of Mother Seed Yam

Depending on the variety, white yam tubers go through a dormancy period of 2 - 3 months after harvest in November-December.

Thus at the start of a seed yam production operation, the farmer would have to purchase mother seed yams (100 - 1500 g tubers) around February - March and store them.

Large, ware yams should be avoided. Some of these have rather too thick a periderma1 layer, the dead tissues of which become soggy when in contact with water; there is also a wastage of the inner ground tissues during sett preparation. Moreover, setts derived from these tubers exhibit a slower

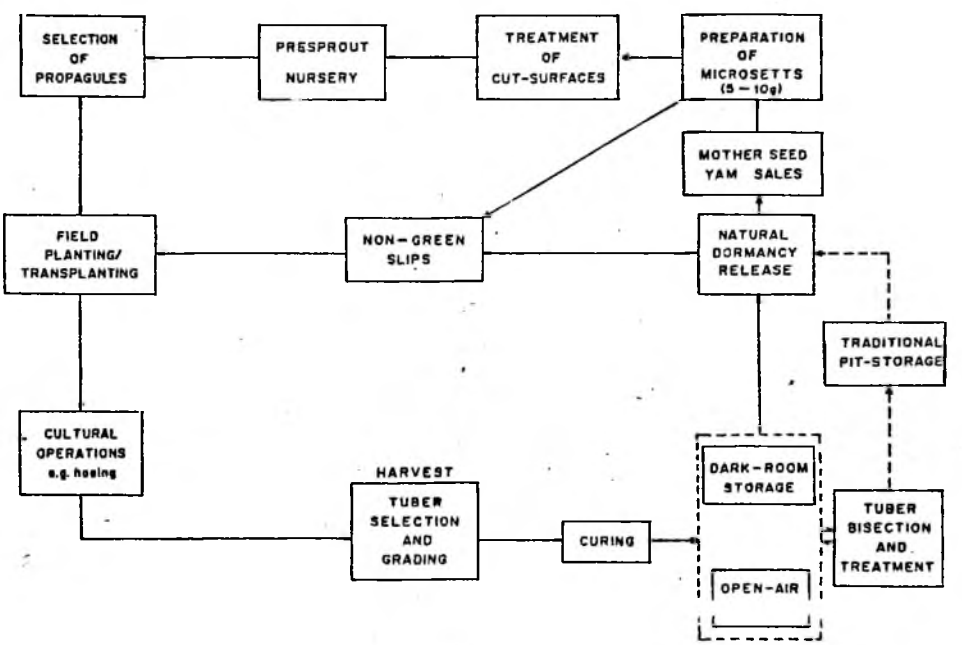


Fig. 29: Schematic Representation of the Proposed Microsett- and Slip-Based Seed Yam Production Technology for White Yam (Dioscorea rotundata)

rate of sprouting than those from the seed-yam-sized-tubers.

The mother seed yams could be stored in a dark but well-ventilated room or in the modified traditional, live-tree-shaded yam barn on horizontal bamboo-slats under an overhead, polyethylene sheet, rain-screen.

2. Preparation of Microsetts

The preparation of the microsetts should be undertaken between the 2nd week of April - 1st week of May.

Healthy and good quality nematode-free tubers, devoid of knobs and a continuous layer of dark, dry-rot tissue on and beneath the periderm respectively, must be selected. The tubers should also be devoid of scale-insects (symptomised as white spots on the periderm or tuber skin) as well as mealybug infestation. These characteristics should be emphasized during the purchase of the mother seed yams.

The upper size-range of the microsetts, 5.01 - 10 g, with a minimum size of 5 g is ideal. These should be obtained by placing the selected, sprouted tubers horizontally on a clean table and slicing them into short cylinders. These are then subdivided into cubes or triangular-like units of dimensions: 1.8 cm x 2 - 5 cm x 1.9 cm (Fig. 22). In practice the short cylinders could be 1.5 - 1.8 cm thick.

The maintenance of high hygienic conditions during sett preparation is imperative, in view of the rather small sizes involved. Consequently, the tubers must be cleansed of dirt in water; the preparation table and knife must also be likewise cleaned.

3. Treatment of Cut-Surfaces

The microsetts should be treated with a fungicide-wood ash-suspension, by dipping them in the latter for 2 – 3 minutes. 24 g of Demosan (a.i. Chloroneb), 6 g (2 satchets) Aldrex 'T' (a fungicide/insecticide) and about one-and-a-half handfuls of wood ash in 4 litres of solution could be used. The Aldrex 'T' is not easily miscible with water and thus should be first mixed with the wood ash.

However, the fungicides cited in this instance are not the absolutely ideal types: Kocide 101 or Dithane M45 if available could also be used at a rate of 6 g/l. The latter is equivalent to 3 teaspoonfuls of the fungicide in 1 medium-sized (450 g)-"Milo" (a cocoa beverage) -tinful of water. Hence, should 4 litres of Dithane M45 and wood ash-suspension be prepared, one should mix 4 medium-sized -Milo-tinfuls of water with 12 teaspoonfuls of the fungicide and one-and-a-half handfuls of wood ash. The just stated

measure of the fungicide is also equivalent to one tomato puree tin, with the top flattened.

During preparation of the suspension, the farmer should wear hand-gloves or cover his hands with a polyethylene bag-wrapper. A short, wooden-splinter could be used to stir the suspension, in order to facilitate the mixing process.

4. Presprouting Medium Preparation

The ideal presprouting medium for white yam microsetts is fresh, undecomposed sawdust of medium-coarse texture.

The initial sawdust moisture regime is very critical: it should be high. Thus, an initial moisture content of 6%, that is, 1000 g of dry, fresh sawdust thoroughly hand-mixed with 3l of water is ideally recommended. At this moisture regime, one may only need to sparingly water the uppermost layer or even not to re-water at all, when the multi-layered planting method (page 195) is used.

There is no need to air-dry the fresh sawdust prior to moistening. Thus, if the sawdust were quite moist at collection, as a result of rain, 2l of water could be mixed with 1000 g of the sawdust.

Hence, an initial moisture regime range of 2 - 3l per 1000 g fresh sawdust could be generally used. This rate is

equivalent to 2 - 3 medium-sized-Milo-tinfuls of water per 2 "American" or "Dinor Oil" tinfuls (flattened-top) of fresh sawdust.

The water should be added gradually to the sawdust in small amounts, with thorough hand-mixing. This operation could be undertaken on a plastic sheet, used fertilizer bags and so on.

For large-scale purposes, the moistening operation could be facilitated by using an oar-like wooden structure with a long handle and a broad, flattened base, spade or shovel. After properly admixing the sawdust and water, any excess water should be permitted to drain away for about 3 minutes by spreading out the sawdust on a perforated plastic sheet or on an inclined surface — under shade. Woven baskets could also be used for this purpose.

5. Seedbeds

The presprouting could be undertaken on raised, open-air nursery beds similar to those used for nursing pepper or tomato seeds. Raised beds are better than the sunken, cement-block-edged ones, as they ensure better aeration, drainage as well as heat dissipation.

The beds could be many metres long, a metre wide and 15 - 20 cm high.

Oil-palm-rachis or raffia baskets and wooden boxes with perforations on the bottom and sides as well, could also be used.

The wooden boxes could ideally be constructed by placing closely together, thin planks of wood. In this way, aeration and drainage of excess water would be enhanced.

Concerning very important breeding or clonal materials, the improvised cheese-cloth-based-wooden-presprouter (Fig. 30) could be utilized. The wooden wedges should be nailed to the basal trough to avoid flotation problems. The upper trough should over-hang the basal one in order to enhance adequate ventilation. Apart from the cheese-cloth, any absorbent cotton material could also be used.

6. Planting of Treated Setts in Seedbeds

The microsetts should be planted in the seedbeds immediately upon removal from the wood ash-fungicide-suspension.

Prior to planting the treated setts, the surfaces of the raised beds or the bottom of the baskets or wooden boxes should be covered with about 1.5 cm thickness of the moistened sawdust.

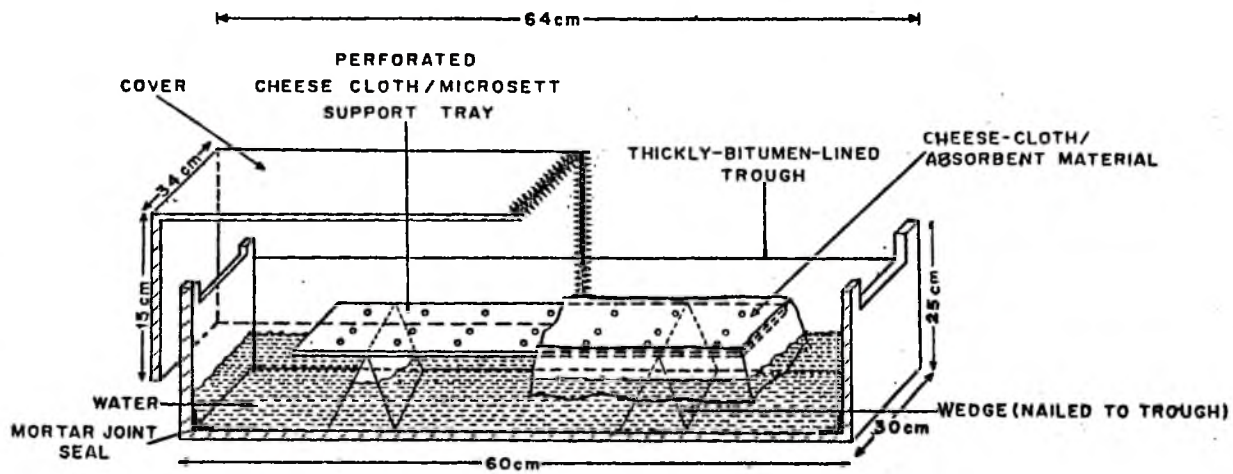


Fig. 30: A Proposed Cheese-Cloth/Absorbent-Material-Based-Wooden-Microsett-Presprouter (For Special Clonal-Materials).

The setts should be orientated on this basal sawdust layer in a random fashion, if more than one layer is to be planted. That is, there is no need to orientate the sett such that the un-cut peridermal surface is in direct contact with the sawdust medium.

A second layer of the microsetts could be planted in the seedbeds by covering the first layer with about 1.0 - 1.5 cm thickness of the moist sawdust, 7 - 8 layers could be used if in boxes or baskets, depending on the height.

The setts should be placed about 1.0 cm away from the sides of the boxes or baskets.

The setts in the top or uppermost layer in the baskets, boxes or raised beds should not however be randomly orientated: the un-cut peridermal surface should be turned downwards, and the cut-surfaces upwards. This operation could be facilitated on raised beds by using a short stick, when large numbers of setts are being handled: one could presprout 40,000 - 80,000 on a single raised bed depending on its length.

The uppermost layer of setts should be covered with about 1.0 cm thickness of the moist sawdust.

With regard to the wooden cheese-cloth-based-presprouter

(Fig. 30) the setts should be either normally or invertedly orientated on the cheese-cloth (Figs. 12 and 13, page 130).

7. Post-Planting Management

A low, palm-frond shade, about 30 cm high should be erected above the open-air, raised beds.

The baskets or boxes should be kept in a shady, well-ventilated area on supports or raised frame-work to enhance free-drainage. The environment should be such that evaporation would be very minimal.

Ideally, re-watering must be avoided during the first 3 - 5 days after planting. Sparingly water the uppermost layer at the end of the stipulated period if necessary.

It is advisable to keep the microsett-filled baskets or boxes under shade throughout the presprouting period. However, with respect to the minisetts, the boxes or baskets could be sent into the open-air and watered as necessary using a very fine-nozzled, watering-can or hand-sprayer or by the rain.

As regards the open-air raised beds, if it rained during the first 3 - 5 days after planting, one could break up the matted surface layer of the sawdust by running the fingers gently through it. This would enhance aeration and the dissipation of excess moisture.

The palm fronds should be removed in the evening and replaced the following morning. Moreover, the palm fronds should also be temporarily removed after a heavy downpour, to be replaced when the sun comes up strongly.

Furthermore, when the rains begin to stabilize, overcast is usually high and the palm fronds may be completely removed in the case of the minisetts. The setts in the uppermost layer tend to be exposed after re-watering the sawdust and thus they should be covered with about 1.0 cm thickness of moist sawdust, when such a situation arises.

Concerning the improvised wooden-presprouter, about 1 litre of water should be initially used. This amount should be renewed twice weekly throughout the presprouting period. It must be ensured that the cheese-cloth or absorbent material is kept just moist.

The exposed cut-sufaces of the setts which are not in contact with the cheese-cloth should be sprayed daily with a 6 g/l suspension of any fungicide such as Dithane M45 by means of a hand-sprayer to control fungal infection.

8. Soils

Sandy loam soils with a little bit of gravel are appropriate for seed yam production.

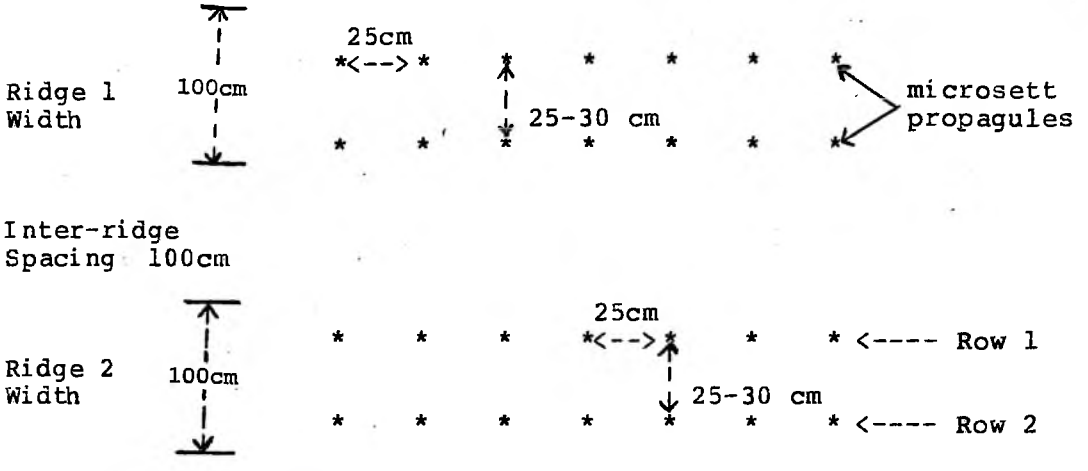
9. Field Transplanting

The minisetts and microsetts should be transplanted in the field at 3 - 4 and 4 - 5 weeks after planting in the nursery respectively. If a farmer utilizes both the micro- and minisett techniques, then one could transplant all the sprouted setts simultaneously at 4 weeks after planting in the nursery.

The best stage of shoot development for transplanting is when the shoot is leafless (Figs. 6b and c). Healthy propagules at the leafless stage of shoot development should therefore be carefully selected. The last field transplanting should be done by the end of the first week of June. The propagules should be kept in moist sawdust during transit from the nursery to the field.

10. Spacing

The selects should be planted on ridges at a spacing of 100 cm x 25 cm, using two transplanting rows per ridge as shown below:



11. Depth of Transplanting

The depth of transplanting should be about 5 - 7 cm. Too deep or shallow microsett propagule placement should be avoided.

The transplanting holes could be made with a sharpened wooden-splinter.

12. Propagule Orientation at Transplanting

It is advisable to place the un-cut periderm from where the shoot emerges (especially with respect to white yam) downwards.

13. Plastic-Strip Mulching

If the plastic-strip mulch were available, the ridges should be covered with this material only after a heavy downpour of rain and should be held in place by clods of earth.

Transplanting is done through the plastic, using sharpened wooden-splinters to make the transplanting holes. Care should be taken not to open the plastic bordering the holes too widely during the transplanting operation.

Ideally, the transplanting should be undertaken in the mornings, before the sun comes up very strongly.

14. Staking

Staking would not be necessary, if the plastic-strip mulch were used (Fig. 31). This is because the plastic mulch breaks the direct contact of the leaves with soil-borne pathogens and also displays the leaves for better light interception. Furthermore, the objective is not to produce ware yams and the ideal seed yam size is about 200g as reported by the Technology Transfer Station (1984).

However, in the absence of the plastic mulch, it is imperative that staking must be undertaken.

The following modified trellis-system is proposed: 2

Fig. 31: Microsett-Derived-Plants Growing in the Field Under Plastic-Strip Mulch

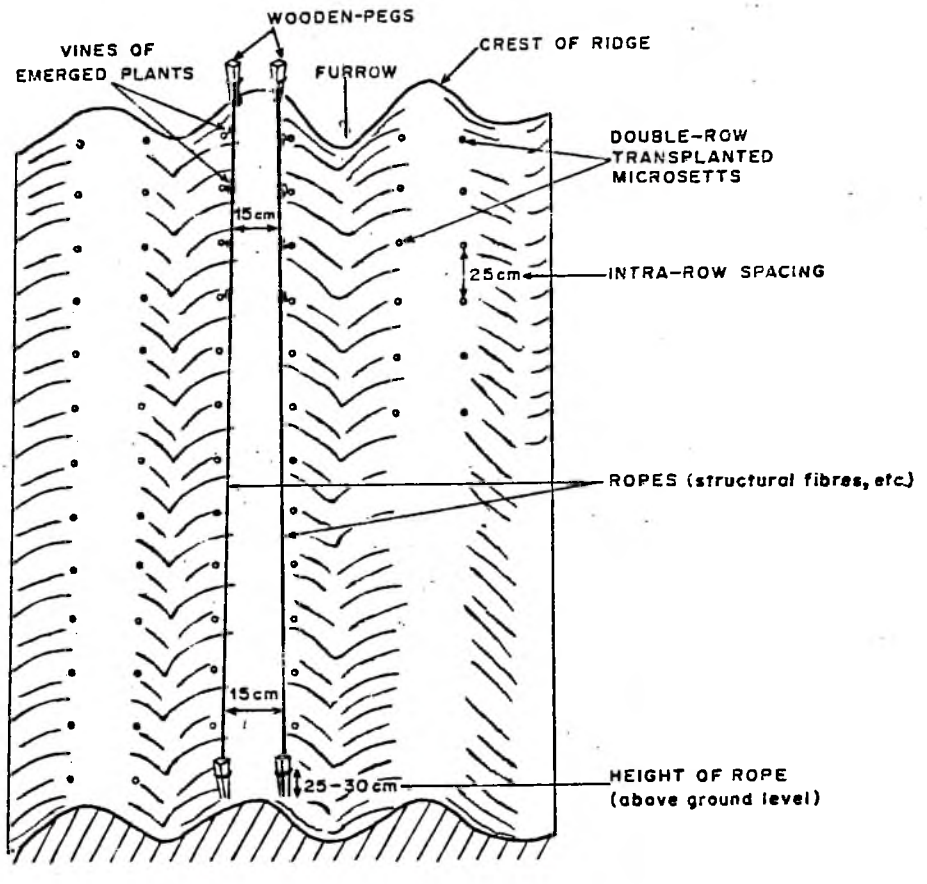


Fig. 32: Proposed Staking System for Double-Row-Transplanted, Microsett-Derived-White-Yam Propagules

parallel ropes, about 15 cm apart and 25 - 30 cm above the ground, suported by wooden pegs, should be run along the crest of the ridges (Fig. 32). They could be constructed at 3 m - intervals. When the shoots emerge and begin to vine, they could be carefully trailed on these ropes.

As reported by Coursey (1967) the use of longer stakes, at least 2 m high, are advantageous in yam production. However, with seed yam production, the objective is not to produce a big tuber: a 200 g seed yam size is minimal for ware yam production (Technology Transfer Station, 1984). Thus, the above-mentioned trellis-height could suffice in this instance.

15. Fertilizers

One may not apply fertilizers to the plants.

16. Weed Control

Hoeing and handpicking of weeds around the growing plants are recommended. The microsett-derived plants are very sensitive to weed competition and thus require extra attention in this regard.

17. Harvesting and Grading

The tubers could be harvested depending on the variety at 5 - 6 MAT with iron-diggers or any other equivalent tool, care

Fig. 33: Seed Yams from 7 g Microsetts

being taken to avoid bruises on the periderm.

The tubers (Fig. 33) should be size-graded as follows:

i. Ware yams ..... ⩾ 1000 g (if available)

ii. Seed yams ..... 200 - 1000 g

iii. Lesser seed yams ..... ⩽ 200 g

For subsequent seed yam production, healthy, good quality mother seed yams within the seed yam size-grade, preferably greater than 300 g should be selected.

18. Curing

The freshly harvested tubers should be cured for a period of 5 - 7 days prior to being stored.

The curing is aimed at inducing extra periderm formation in order to prevent handling damage in storage. Furthermore, wound-healing of damaged portions (during harvest) is enhanced. Consequently, storability is improved.

The curing could be undertaken by placing the tubers on the ground under shade and covering them with palm fronds.

19. Storage

The cured tubers could subsequently be stored in specially constructed dark-rooms: thatched-or aluminium-sheeting-roofed as convenient or in the open-air, live-tree-shaded yam barn described earlier on (page 148).

If a polyethylene sheet rain-screen were not used in the

open-air yam barn, it would be advisable to send the mother seed yams indoors to prevent rotting losses, when the rains begin.

20. Synchronisation and Acceleration of Sprouting of the Microsetts

The tail removal technique showed a great deal of potential, in its simplicity and appropriateness, in solving the slow and synchronous sprouting of the microsetts in the presprouting nursery. It basically involves the removal of the distal - 1/3 portion or tail of the dormant tuber and the cormous structure at the head at 3 WAH.

The resultant 2 parts are then soaked in a nutrient mixture comprising 1500 ppm (1.5 g/litre) Urea-nitrogen, 50 ppm Florel (ethephon) and 10 ppm $FeSO_4$.

The cut-surfaces are treated with the ash-fungicide-mixture described earlier on.

The tuber parts could then be stored in the traditional, open-air, yam barn under a rain-screen or in a dark-room. Under these conditions, protection from the rain is of utmost importance in order to forestall fungal infection through the wound-surfaces.

However, the traditional farmer's "pit storage" method could be ideal for such bisected tubers. It entails burying

the tuber parts immediately after treatment in pits, about 30 - 40 cm deep and covering them with topsoil till the dormancy period is over. It could be done in the open-air.

For practical purposes, it may be better to use mother seed yams bigger than 300 g and dividing them into two, in the middle section.

The tail removal method is yet to be perfected. The chemicals as well as their concentrations are not absolute. Further research is suggested in this direction.

21. Non-green Slip Propagation

The non-green slips, 30 - 50 cm high, derived from sprouted tubers in the dark storage before the rains stabilize, could be directly planted on ridges or mounds in hydromorphic areas, if available, or backyard gardens and regularly watered.

However, when the rains stabilize, the slips could also be directly planted on ridges in the field through the plastic-strip mulch as described for the microsetts. In the absence of the plastic-strip mulch, grass straw should be used. The slips do not require any staking.

A foliar/shoot spray of 0.5 g/l of 15:15:15 NPK fertilizer could be applied at 2 - 4 WAP.

As much as possible, hoeing as a weed control method is recommended.

At harvest, the tubers should be graded, cured and stored as described for those derived from the microsetts.

SECTION F

GENERAL DISCUSSION

AND

SUGGESTIONS

CHAPTER XIII

GENERAL DISCUSSION

The need for a more efficient seed yam production technology for white yam (Dioscorea rotundata Poir) based on the microsetts and the slips necessitated these studies. The results of the various fore-discussed experiments indicate the practical realization of this objective.

1. Fresh sawdust was outstandingly the ideal presprouting medium (Nursery Experiment i, page 30). It was characterized by a relatively higher moisture holding capacity, low mechanical impedance and bulk density.

2. It was evident from the results of Nursery Experiment ii (page 32) that the sprouting observations at 5 DAP could be used to adjudge the ideal moisture regime. This implied that the initial sawdust moisture content is of utmost importance.

3. The natural grouping of sprouting behaviour of the sett sizes depicted in Fig. 3 (Nursery Experiment iv, page 47) is an expression of the nutritional differences that

occur as the sett size decreases. For example, 50% sprouting was obtained for the 20.01-30g setts of Group I at about 18 DAP. However, it took over thirty days for the Group III setts (2-5g) to produce about 40% sprouting (Fig. 3).

4. The slow and non-uniform sprouting attribute of the microsetts was identified as the major constraint. On the basis of an assumption that the yam tuber actively grows even in storage (page 71) attempts were made to accelerate and synchronize the sprouting of the setts (Chapters VI to X) in the nursery.

The tail removal technique was the most practical means of accelerating and synchronizing the sprouting of the microsetts. It constitutes a major contribution of these studies to yam tuber physiology and technology.

5. Morphologically, the yam tuber is bipolar in nature: there is a distal meristem and a proximal bud at the head of the tuber.

The distal bud is active during tuberization in the field whereas the proximal elongates into the new vine after natural tuber dormancy release.

A generalized bi-directional movement of nitrogen within the tuber was apparent: the head and tail regions of the tuber probably serve as major sinks for nitrogen and other nutrients such as iron, potassium and calcium. The middle region was largely a source of these nutrients. Furthermore, there was an apparent movement out of the peripheral 1.6-1.9 cm tissues from 3-5 WAH into the inner ground tissues. A reversed movement occured after 5 WAH. According to Onwueme (1973), the meristematic layer is located only 1-2mm from the periderm. Consequently, nutrient deprivation of the peripherally located meristematic tissue initials and the relative sink strengths for nutrients of the proximal apical bud and the distal meristem could be of prime importance in the induction as well as the release of tuber dormancy. Meristematic activity in the white yam tuber might also probably start by 5 WAH. This is implied from the consistent rise in % total nitrogen levels in the peripheral 1.6-1.9 cm region of the tuber from 5 WAH onwards. Consequently, % crude protein and thus enzyme concentration could also be considered to be on the increase in the peripheral tissues from this time-period. Increase in protein synthesis is associated with increased meristematic activity.

The polarised redistribution of nutrients within the tuber with time after harvest is also a fundamental contribution of these studies to the physiology and technological manipulation of the yam tuber.

CHAPTER XIV

SUGGESTIONS

1. Fresh sawdust, although the ideal presprouting medium, is not readily available in all the yam growing areas. Consequently further work should be undertaken to find alternative medium for such areas.

2. The frequency of re-watering of the sawdust medium was not studied with regard to Nursery Experiment ii (page 32). Further investigations are suggested in this direction.

   The volume of water required during re-watering should also be worked out. In determining this, the number of layers in a seed-bed must be considered. In a multiple - layered planting, the upper-most sawdust layer tends to dry up whilst the innermost layers are still moist. Hence, it may be necessary to apply just enough to keep the topmost layer moist.

3. Besides moisture, the maintenance of optimal temperature conditions in the pre-sprouting medium is imperative for accelerating the sprouting of the microsetts.

Consequently, further investigations should be undertaken to explore the means of achieving this objective.
With regard to the open-air raised beds, one could consider the use of heat-generating electric coils. These could be laid over the beds and partially covered with gravel to prevent direct contact with the basal sawdust layer. The ideal electric voltage that would maintain the optimal temperature should be worked out. The heat generated from these coils could permeate the entire medium. However, the heat-generating current should be correlated with the number of presprouting layers of sawdust. The use of this heating system may not be practically feasible as regards perforated containers such as wooden boxes or baskets.
Consequently, the direct exposure of the mother seed yam tubers to alternating temperatures for specific periods may be undertaken.

4. Further research involving the use of exogenously applied nutrients should be undertaken to bridge the gap between the Group II and III setts (Nursery Experiment iv, page 47) with those of Group I. This nutritionally enhanced sprouting of the setts would be reflected in their field performance.

5. The chemicals and their respective concentrations in the mixture applied to the tuber parts as regards the tail removal technique were not absolute. It is, therefore, suggested that a broad range of concentrations of these chemicals (page 147) as well as other elements like potassium, calcium and so on should be studied.

The ideal time, frequency and mode of application of the chemicals should be worked out. With respect to the mode of application hand-spraying of the tuber parts should be one of the treatments.

The acceleration of sprouting of the tuber parts in this manner could serve as a means of negating the use of fresh sawdust. Top-soil could then the used as a substitute. The superiority of sawdust as the ideal presprouting medium is attributable to it's better physical properties. Chemically, however, it does not contribute anything to enhance sprouting. The microsetts even appear chlorotic and exhibit poor vigour in the field, succumbing easily to leaf necrotic infection when left in the sawdust medium for longer periods - over seven weeks.

6. In these studies on the acceleration and synchronisation of sprouting, reported here, the term "synchronisation" was defined in terms of the equality of the numbers of the sprouted parts at a specific period of time. However, it is suggested that equality in the rates of sprouting must also be considered as an aspect.

7. Further studies should be undertaken on the polarised redistribution of nutrients within the tuber with time after harvest.

8. The bipolar nature of the tuber implies the existence of physiological gradients within it. These could be manifested as those of differential oxygen and osmotic concentrations, enzyme activities, carbohydrate levels, phytohormones and so on. Such gradients should be investigated along both the radial as well as the bipolar, axiate planes of the tuber.
Consideration should also be taken of the dynamic nature of these changes in terms of time. The latter should be initially expressed on the basis of percent shoot senescence rather than time after harvest.
As indicated by Bloch (1965), most polarities in organs are electrical in nature. He was of the view that a

parallel relationship exists between the pattern of electrical potentials and the general structural symmetry. Changes in bio-electric potentials along the radial and longitudinal axiate planes of the tuber could thus be studied over time.

Correlations of these potentials with other physiological gradients such as mineral nutrient, enzyme levels and activity, abscisic acid, gibberellic acid, auxin, and carbohydrate levels could throw more light into the mechanism of tuber dormancy.

9. The morpho-physiological polarity of the tuber was manifested as the superiority of the head setts over those from the distal regions in sprouting behaviour. This implies that a gradation exists along the longitudinal plane of the tuber in the time of initiation of meristematic activity in a proximal ---> distal direction. Hence, histological studies should be undertaken to investigate cellular differentiation in the peripheral 5 mm region of the tuber over time. Setts derived from the three physiological age-zones of the tuber should be utilized.

The histological changes could then be correlated with the bio-electric, mineral nutrient, osmotic concentration, absolute formative material levels and ratios, pH, enzyme levels and activities for each time - period considered. One could thereby obtain a concrete impression about the mechanism of tuber dormancy with regard to it's initiation and release.

As reported by the Technology Transfer Station (1984), the minimum seed yam size is about 200 g. Thus, the performance of the slips, especially the directly planted ones, indicates their potential as an adjunct to the microsett technology.

It is therefore being suggested that further research be carried out on them. The physiological as well as biochemical bases of their "bushy" habit need to be elucidated. It might be possible, in the process, to extract the active principle or synthesize its analogues to be used to induce bushiness in commercial seed yam production. Further research is suggested to make economic use of the green slips.

LIST OF REFERENCES

Abeles, F.B. (1973). Ethylene in Plant Biology. Academic Press. New York and London. 302 pp.

Adams. D.O. and Yang, S.F. (1977). Methionine Metabolism in Apple Tissue. Implication of S-adenosylmethionine as an intermediate in the conversion of methionine to ethylene. Plant Physiol. 60: 892-896.

_____(1979). Ethylene Biosynthesis: Identification of 1-aminocyclopropane - 1 - carboxylic acid as an intermediate in the conversion of methionine to ethylene. Proceedings National Academy of Science, U.S.A. 76 (1): 170-174.

Addicot, F.T. (1969). Ageing, Senescence and Abscission in Plants: Phytogerontology. HortScience 4 (2): 114-116.

Aitchison, P.A., Macleod, A.T. and Yeoman, N.M. (1973). Growth Patterns in Tissue (Callus) Cultures. In: Plant Tissue and Cell Culture. Botanical Monographs. Vol. 11. 2nd Edition, H.E. Street (ed). Blackwell Scientific Publishers. p. 267-306.

Akoroda, M.O. and Okonmah, L.U. (1982). Sett Production and Germplasm Maintenance Through Vine Cuttings in Yams. Trop. Agric. (Trinidad) 59 (4): 311-314.

Alvarez, N.M. and Hahn, S.K. (1984). Seed Yam Production. In: Tropical Root Crops: Production and Uses in Africa. Proceedings of the Second Triennial Symposium of the International Society for Tropical Root Crops, African Branch. Douala, Cameroun, 14-19 August, 1983. E.R. Terry, Doku, E.V., Arene, O.B. and Mahungu, N.M. (eds) p. 129-132.

Alloway, B.T. and Tills, A.R. (1984). Copper Deficiency in World Crops. Outlook in Agriculture. 13 (1): 32-42.

Arene, O.B., Nwankiti, A.O. and Okafor, N. (1985). The Chemical Basis of the Pathology of Yam Tuber. In: Advances in Yam Research: The Biochemistry and Technology of the Tuber. Godson Osuji (ed). Biochemical Society of Nigeria in Collaboration with Anambra State University of Technology. p. 251-258.

Ayensu, E.S. (1972). Anatomy or the Monocotyledons. VI Dioscoreales. Oxford. At the Clarendon Press. 182 pp.

Barker, A.V., Volk, R.J. and Jackson, W.A. (1966). Root Environment Acidity as a Regulatory Factor in Ammonium Assimilation by the Bean Plant. Plant Physiol. 41: 1193.

Bloch, R. (1965). Polarity and Gradients in Plants. A Survey. Encyclopaedia of Plant Physiology Part I. Differentiation and Development. Volume XV. W. Ruhland (ed.). Springer - Verlag Berlin. Heidelberg. New York. p234-274.

Bollard, E.G. (1959). Urease, Urea, and Ureides in Plants. In: Utilization of Nitrogen and its Compounds by Plants. Symposia of the Society for Experimental Biology. Number XIII. H.K. Porter (ed). p. 304-329.

Bowen, J.E. and Kratky, B.A. (1983). Micronutrients. World Farming. 25 (3): 10.

Boyer, P.D. (1959). Sulfhydryl and Disulfide Groups of Enzymes. In: The Enzymes. Vol. 1. P.D. Boyer, H. Lardy and K. Myrback. (ed). Academic Press, Inc. New York. p. 511-588.

Braakhekke, W.G. (1983). A Triaxial Ratio Diagram and Its Use in Comparative Plant Nutrition. In: Genetic Aspects of Plant Nutrition. M.R. Saric and B.C. Loughman (ed). Martinus Nijhoff/Dr. W. Junk Publishers. The Hague/Boston/Lancaster. p. 331-338.

Briggs, W.R. and Rice, H.V. (1972) Phytochrome: Chemical and Physical Properties and Mechanism of Action. Ann. Rev. Plant Physiol. 23: 293-334.

Burkill, I.H. (1960). The Organography and the Evolution of Dioscoreaceae, the Family of the Yams. J. Linn. Soc. (Bot) 56: 319-412.

Caesar, K. (1979). Importance and Implications of the Physiological Age of Seed Materials of Tropical Root Crops. In: Proceedings of the International Symposium of Tropical Root and Tuber Crops. Manila, Philippines, 1979. p.475-481.

Campbell, J.S., Chukwueke, V.O., Teriba, F.A. and Ho-a-Shu, H.V.S. (1962). Some Physiological Investigations into the White Lisbon Yam (Dioscorea alata L.) I. The Breakage of the Rest Period by Chemical Means. Emp. J. Expl. Agric. 30: 232-238.

Cibes, H.R. and Adsuar, J. (1966). Effects of Chlorethanol and Thiourea on the Germination and Relative Yield of the Yam (Dioscorea alata L.). J. Agric. Univ. Puerto Rico. 50 (3): 201-208.

Coleman, R. (1966). The Importance of Sulphur as a Plant Nutrient in World Crop Production. Soil Science 101 (4): 230-239.

Correl, D.S., Schubert, B.G., Gentry, H.S. and Hawley, W.O. (1955). The Search for Plant Precursors of Cortisone. Econ. Bot. 9: 307-375.

Coursey, D.G. (1961). The Magnitude and Origins of Storage Losses in Nigerian Yams. J. Sci. Food Agric. 12 (8):

------- (1967). Yams. An Account of the Nature, Origins, Cultivation and Utilization of the Useful Members of the Dioscoreaceae. Longmans. 230

------ (1984). Potential Utilization of Major Root Crops with Special Emphasis on Human, Animal and Industrial Uses. In: Tropical Root Crops: Production and Uses. Proceedings of the Second Triennial Symposium of the International Society for Tropical Root Crops - Africa Branch, Douala, Cameroun, 14-19 August, 1983, E.R. Terry, E.V. Doku, O.B. Arene and N.M. Mahungu (eds). p.

------ and Booth, R.H. (1977). Root and Tuber Crops. In: Food Crops of the Lowland Tropics. C.L.A. Leakey and J.B. Wills (eds). Oxford Univ. Press. p. 75-100.

Currier, H.B. (1967). Nature of Plant Water. In: Irrigation of Agricultural Lands. Hagan, R.M., Haise, H.H. and Edminster, T.W. (eds). Dinauer, R.C. (Managing ed.). Agronomy Series No. 11. Amer. Soc. of Agron. Madison, Wisconsin, U.S.A. p. 307-319.

Ferguson, T.U. (1971). The Propagation of Dioscorea spp. by Vine-Cuttings - a Critical Review. Tropical Root and Tuber Crops Newsletter 4:

-------, Haynes, P.H. and Spence, J.A. (1984). The Effect of Sett Size, Sett Type and Spacing on Some Aspects of Growth, Development and Yield in White Lisbon Yam (D. alata L.). In: Proceedings of the Sixth Symposium of the International Society for Tropical Root Crops. IPC, Lima, Peru. 21-26 February, 1983. p. 649-655.

Gauch, H.G. (1972). Inorganic Plant Nutrition. Dowden, Hutchinson and Ross, Inc. Stroudsburg Pa. 488 pp.

Giradot, L.V. (1956). Planting and Fertilization Experiments with Yams. Rep. Cent. Agric. Expt. Stn., Suakoko, Liberia.

Goodwin, T.W. and Mercer, E.I. (1983). Introduction to Plant Biochemistry. 2nd Edition, Pergamon Press. Oxford, New York, Toronto, Sydney. 677 pp.

Guern, J. and Usciati, M. (1972). Apical Dominance. In: Hormonal Regulation in Plant Growth and Development. H. Kaldewey and Y. Vardar (eds.). Weinheim: Verlag Chemie p. 383-400.

Hahn, S.K. and Hozyo, Y. (1983). Sweet Potato and Yam. In: Potential Productivity of Field Crops Under

Different Environments. IRRI. Los Banos, Philippines. p. 319-340.

Harper, H.A. (1975). Review of Physiological Chemistry. 15th Edition. Los Altos, California. Lange Medical Publications. 437 pp.

Hartmann, H.T. and Kester, D.E. (1983). Plant Propagation. Principles and Practices. 4th Edition. Prentice-Hall, Inc. Englewood Cliffs, New Jersey, 727 pp.

Hawker, J.S., Marschner, H. and Krauss, K. (1979). Starch Synthesis in Developing Potato Tubers. Physiol. Plant. 46: 25-30.

Heydecker, W. and Gibbons, B.M. (1978). Attempts to Synchronise Seed Germination. Acta Horticulturae 72: 79-92.

Ikediobi, C.O. (1985). Biochemistry and Physiology of Yam Storage. In: Advances in Yam Research. The Biochemistry and Technology of the Tuber. Godson Osuji (ed.). The Biochemical Society of Nigeria in Collaboration with the Anambra State University of Technology. p. 109-141.

I.I.T.A. (1974). Annual Report.

------- (1984) Weather Report.

Kay, D.E. (1973). Root Crops. Crop and Product Digest 2. Tropical Products Institute. London, p. 190-202.

Kefeli, V.I. and Kadyrov, C.S. (1971). Natural Growth Inhibitors, Their Chemical and Physiological Properties. Ann. Rev. Plant Physiol. 22: 185-196.

Ketiku, A.O. and Oyenuga, V.A. (1973). Changes in the Carbohydrate Constituents of Yam Tuber (Dioscorea rotundata Poir) During Growth. J. Sci. Fd. Agric. 24: 367-373.

Kosower, E.M. and Kosower, N.S. (1969). Lest I Forget Thee, Glutathione ..... Nature 224: 117-120.

Kramer, P.J. and Kozlowski, T.T. (1979). Physiology of Woody Plants. Academic Press. New York, San Francisco, London. 811 pp.

Lawton, J.R.S. and Lawton, J.R. (1967). The Morphology of the Dormant Embryo and Young Seedling of Five Species of Dioscorea form Nigeria. Proc. Linn. Soc. Lond. 178: 153-159.

Lawton, J.R. and Lawton, J.R.S. (1969). The Development of the Tuber in Seedlings of Five Species of Dioscorea from Nigeria. Bot. J. Linn. Soc. 62: 223-232.

Leon, J. (1977). Origin, Evolution and Early Dispersal of Root Crops. In: Proceedings of the Fourth Symposium of the International Society for Tropical Root Crops. CIAT, Cali, Colombia. 1-7 August, 1976.

James Cock, Reginald MacIntyre and Michael Graham (eds.). p. 20-36.

Leopold, A.C. (1980). Aging and Senescence in Plant Development. In: Senescence in Plants. K.V. Thimann (ed.). CRC Press. P. 1-12.

Leshem, Y. (1973). The Molecular and Hormonal Basis of Plant Growth Regulation. Pergamon Press Ltd. Headington Hill Hall. Oxford. 156 pp.

Levins, R. (1969). Dormancy as an Adaptive Strategy. In: Dormancy and Survival. Symposia of the Society for Experimental Biology. No. XXIII. H.W. Woolhouse (ed.). p.1-10.

Little, T.M. (1985). Analysis of Percentage and Rating Scale Data. HortScience 20 (4): 642-644.

Mantell, S.H., Haque, S.Q. and Whitehall, A.P. (1978). Clonal Multiplication of Dioscorea alata L. and Dioscorea rotundata Poir. Yams by Tissue Culture. J. Horticultural Science. 53: 95-98.

Marschner, H. (1982). Effects of Mineral Nutrition on Phytohormone Balance in Plants. In: Plant Nutrition. Proceedings of the Ninth International Plant Nutrition Colloquium. Vol. 1. Warwick University, England. August 22-27, 1982. A. Scaife (ed.). p. 354-358.

-------- (1983). General Introduction to the Mineral Nutrition of Plants. In: Inorganic Plant Nutrition. Encyclopaedia of Plant Physiology. New Series. Vol. 15. A.A. Lauchii and R.L. Bieleski (eds.). p. 5-60.

Martin, F.W. (1977). Prolonging the Storage Life of Yams by Removal of Shoots and by Treatment with Gibberellic Acid and Waxes. Tropical Root and Tuber Crops Newsletter. 10: 39-44.

------ and Cabanillas, E. (1976). Stimulating the Sprouting of Yam Tubers with Ethephon. J. Agric. Univ. Puerto Rico. 60 (4): 592-596.

------ and Sadik, S. (1977). Tropical Yams and Their Potential. 4. Dioscorea rotundata and Dioscorea cayenensis. Agriculture Handbook. USDA. No. 502. 36 pp.

------ and Ortiz, S. (1963). Origin and Anatomy of Dioscorea floribunda and D. spiculiflora. Bot. Gaz. 124: 416-421.

Maxwell, A.E. (1961). Analyzing Qualitative Data. Methuen and Co. Ltd. 11 New Fetter Lane, London. EC4. 163 pp.

McIntyre, G.I. and Quick, W.A. (1984). Control of sprout growth in the potato. Effect of humidity and water supply. Can. J. Bot. 62: 2140-2145.

Mengel, K. and Kirkby, E.A. (1982). Principles of Plant Nutrition. 3rd Edition. International Potash Institute. Switzerland. 655 pp.

Miege, J. (1957). Influence de Quelques Caracteres des Tubercules Semences Sur la Levee et le Rendement des Ignames Cultivees. J. Agric. Trop. Bot. Appl. 4 (7-8): 315-342.

Moore, T.C. (1979). Biochemistry and Physiology of Plant Hormones. Springer-Verlag. New York. Heidelberg. Berlin. 274 pp.

------- (1981). Research Experiences in Plant Physiology. A Laboratory Manual. 2nd Edition. Springer-Verlag. New York. Heidelberg. Berlin. 348 pp.

Moorman, F.R., Lal, R. and Juo, A.S.R. (1975). The Soils of IITA. IITA Technical Bulletin No. 3. 48 pp.

Murr, D.P. and Yang, S.F. (1975). Conversion of 5^{1}-Methylthioadenosine to Methionine by Apple Tissue. Phytochemistry 14: 1291-1292.

Ng, S.Y. (1984). The Application of Tissue Culture Techniques in Tuber Crops At IITA. Paper Presented at Central African Regional Root Crop Workshop. Brazzaville. Congo. 11-15 June, 1984.

Nover, L. (1977). Cell Differentiation - a Prerequisite of Life? In: Cell Differentiation in Micro-organisms, Plants and Animals. Proceedings of an International Symposium. L. Nover and Mothes, K. (eds.). North-Holland. p. 22-26.

Njoku, E. (1963). The Propagation of Yams (Dioscorea spp.) by Vine Cuttings. J. West Afri. Sci. Assoc. 8 (1): 29-32.

NRCRI, (1978). Newsletter. July-October. Nos. 12-13, p. 3.

(1981). Newsletter. January-June. No. 17, p. 2.

Nwosu, N.A. (1975). Recent Development in Vegetative Propagation of the Edible Yam (Dioscorea spp.). Paper Presented at the 11th Annual Conference of the Agric. Society of Nigeria, Enugu. 1-5 July, 1975, 16 pp.

Ohki, K. (1982). Soybean Nitrate Reductase Activity and Photosynthesis Related to Manganese Status Determined by Plant Analysis. In: Plant Nutrition. Proceedings of the International Plant Nutrition Colloquium. A. Scaife (ed.). Commonwealth Agricultural Bureaux. Vol. 2, p. 448-453.

Okagami, N. and Tanno, N. (1977). Dormancy in Dioscorea: Generality of Gibberellin - Induced Dormancy in

Asexual Dormant Organs. Pl. Cell Physiol. 18: 309-316.

Okigbo, B.N. and Ibe, D.G. (1973). A New Method of Yam Propagation. In: Proceedings of the Third International Symposium on Tropical Root Crops, IITA, Ibadan, Nigeria. C.L.A. Leaky (ed.). p. 259-262.

Okoli, O.O. (1978). Stimulating Axillary Buds in Yam (Dioscorea spp.). Expl. Agric. 14 (1): 89-92.

(1980). Dry Matter Production and Tuber Sprouting in Yams (Dioscorea spp.). Expl. Agric. 16 (2): 161-167.

------, Igbokwe, M.C., Ene, L.S.O. and Nwokoye, J.V. (1982). Rapid Multiplication of Yam by Minisett Technique. National Root Crops Research Institute, Umudike, Nigeria. Research Bulletin 2: 1-12.

Okonmah, L.U. (1980). Rapid Multiplication of Yams. IITA Manual Series No. 5, 21 pp.

Onwueme, I.C. (1972). Influence of the Planted Tuber on the Vegetative Performance of White Yam (Dioscorea rotundata Poir) Plants. Nig. Agric. J., 9: 170-173.

------ (1973). The Sprouting Process in Yam (Dioscorea spp.) Tuber Pieces. J. Agric, Sci. Camb. 81: 375-379.

------ (1976). Performance of yam (Dioscorea spp.) planted without water. J. agric. Sci. Camb. 87: 413-415.

------ (1978). The Tropical Tuber Crops: Yams, Cassava, Sweet Potato and Cocoyams. John Wiley and Sons. Chichester. 234 pp.

------ (1979). Tuber Physiology in Yams (Dioscorea spp.) and its Agricultural Implications. In: Proceedings of Fifth International Symposium of the International Society for Tropical Root Crops, Manila, Philippines, p. 235-243.

------ (1984). Yam. In: The Physiology of Tropical Field Crops. P.R. Goldsworthy and Fisher, N.M. (eds.) John Wiley and Sons Ltd. p. 569-588.

Pans, (1978). Pest Control in Tropical Root Crops. Centre for Overseas Pest Research. London. Manual No. 4, 235 pp.

Passam, H.C. (1977). Sprouting and Apical Dominance of Yam Tubers. Tropical Science 19 (1): 29-39.

------ (1982). Dormancy of Yams in Relation to Storage. In: Yams. Ignames. J. Miege and Lyonga, S.N. (eds.). Clarendon Press. Oxford. p. 285-293.

------, Read, S.J. and Richard, J.E. (1976). Wound Repair in Yam Tubers: Physiological Processes During Repair. New Phytologist. 77 (2): 325-331.

Pate, J.S. and Dixon, K.W. (1982). Tuberous, Cormous and Bulbous Plants: Biology of an Adaptive Strategy In Western Australia. University of Western Australia Press. 268 pp.

Peck, Jr., H.D. (1970). Sulfur Requirements and Metabolism of Micro-organisms. In: Symposium: Sulfur in Nutrition. Oregon State University, 1969. O.H. Muth (ed.); J.E. Oldfield (Associate ed.). The Avi Publishing Company, Inc. p. 61-79.

Preston, W.H. and Haun, J.R. (1963). Relationships of Temperature and Photo-period to Growth, Flowering, Senescence and Dormancy of Dioscorea spiculiflora. Bot. Gaz.: 346-353.

Sachs, R.M. (1961). Gibberellin, Auxin and Growth Retardant Effects Upon Cell Division and Shoot Histogenesis. Advances in Chemi. Ser. 28: 49-58.

Samarawira, I. (1983). Effect of Thiourea Treatments on the Induction and Development of Buds in White Yam (Dioscorea rotundata Poir) Tubers. Trop. Agric. (Trinidad) 60: (2): 128-130.

Scandalios, J.G. (1977). Regulation of Isozyme Patterns in Plant Cell Differentiation. In: Cell

Differentiation in Micro-organisms, Plants and Animals. Proceedings of an International Symposium. L. Nover and K. Mothes (eds.). North-Holland. p. 467-483.

Schiff, J.A. and Hodson, R.C. (1973). The Metabolism of Sulphate. Annu. Rev. Plant Physiol. 24: 381-414.

Sexton, R. and Sutcliffe, J.F. (1969). Some Observations on the Characteristics and Distribution of Adenosine Triphosphatases in Young Roots of Pisum sativum, Cultivar Alaska. Ann. Bot. 33: 683-694.

Shkolnik, M. Ya. (1984). Trace Elements in Plants. Developments in Crop Science (6). Elsevier. Amsterdam. Oxford. New York. Tokyo. 463 pp.

Skoog, F. and Miller, C.O. (1957). Chemical Regulation of Growth and Organ Formation in Plant Tissues Cultured In Vitro. Symp. Soc. Exp. Biol. 11: 118-131.

Sobulo, R.A. (1972). Studies on White Yam (Dioscorea rotundata). II. Changes in Nutrient Content with Age. Expl. Agric. 8: 107-115.

Steward, F.C. and Preston, C. (1940). Metabolic Processes of Potato Discs Under Conditions Conducive to Salt Accumulation. Pl. Physiol., Lancaster 15: 23-61.

------ and ------ (1941a). The Effect of Salt Concentration Upon the Metabolism of Potato Discs and the Constrasted Effect of Potassium and Calcium Salts which have a Common Ion. Pl. Physiol., Lancaster 16 (1): 85-116.

------ and ------ (1941b). Effects of pH and the Components of Bicarbonate and Phosphate Buffered Solutions on the Metabolism of Potato Discs and their Ability to Absorb Ions. Pl. Physiol., Lancaster 16 (3): 481-519.

------ and Mott, R.L. (1970). Cells, Solutes and Growth: Salt Accumulation in Plants Re-examined. Int. Rev. Cytol. 28: 275-370.

------, Mapes, M.O., Kent, A.E. and Holsten, R.D. (1964). Growth and Development of Cultured Plant Cells. Science 14: 20-21.

Sutcliffe, J.F. (1973). The Role of Protein Synthesis in Ion Transport. In: Ion Transport in Plants. Proceedings of an International Meeting. W.P. Anderson (ed.). p. 399-406.

------ (1976). Regulation in the Whole Plant. In: Transport in Plants II. Part B. Tissues and Organs. Encyclopaedia of Plant Physiology. New Series. Volume 2. V. Luttge and Pitman, M.G. (eds.). Springer-Verlag. p. 394-417.

Technology Transfer Station. (1984). Annual Report. Ubiaja, Nigeria.

Thomas, T.H. (1977). Cytokinins, Cytokinin-active COmpounds and Seed Germination. In: The Physiology and Biochemistry of Seed Dormancy and Germination. A.A. Khan (ed.). Elsevier/North-Holland Biomedical Press. p. 111-144.

Thompson, J.F., Smith, I.K. and Moore, D.P. (1970). Sulfur Requirement and Metabolism in Plants. In: Symposium: Sulfur in Nutrition. Oregon State University. 1969. O.H. Muth (ed.); J.E. Oldfield (Associate ed.). The Avi Publishing Company, Inc. p. 80-96.

Thorpe, T.A. (1974). Carbohydrate Availability and Shoot Formation in Tobacco Callus Cultures. Physiol. Plant. 30:77-81.

Tran Than Van, K. (1980). Control of Morphogenesis by Inherent and Exogenously Applied Factors in Thin Cell Layers. In: Perspectives in Plant Cell and Tissue Culture. Supplement II A. International Review of Cytology. I.K. Vasil (ed.). Academic Press. p. 175-193.

Ugochukwu, E.N. and Anosike, E.O. (1985). Studies on Enzymes of Carbohydrate Metabolism in Yams. In: Advances in Yam Research. The Biochemistry and Technology of the Tuber. Godson Osuji (ed.). The Biochemical Society of Nigeria in Collaboration with the Anambra State University of Technology. p. 91-105.

Wareing, P.F. (1969). The Control of Bud Dormancy in Seed Plants. In: Dormancy and Survival. Symposia of the Society of Experimental Biology. Number XXIII. H.W. Woolhouse. (ed.). Cambridge: At the University Press. p. 241-262.

------ (1970). Growth and Coordination in Trees. In: Physiology of Tree Crops. Proceedings of Second Long Ashton Symposium. University of Bristol. 25-28 March 1969. L.C. Luckwill and Cutting, C.V. (eds.). Academic Press. p. 1-21.

Wickham, L.D., Wilson, L.A. and Passam, H.C. (1981). Tuber Germination and Early Growth in Four Edible Dioscorea Species. Ann. Bot. 47: 87-95.

Wilson, J.E. (1982). Recent Developments in the Propagation of Yam, Dioscorea spp. In: Yam. Ignames. J. Miege and Lyonga, S.N. (eds.). Clarendon Press. Oxford. p. 55-59.

Wittwer, S.H. and Bukovac, M.J. (1958). The Effects of Gibberellin on Economic Crops. Economic Botany. 12 (13): 213-255.

Yeoman, M.M. and Forsche, E. (1980). Cell Proliferation and Growth in Callus Cultures. In: Perspectives in Plant Cell and Tissue Culture. Intl. Rev. of Cytology. Supplement 11 A. I.K. Vasil (ed.). Academic Press. p. 1-21.

Yoshida, R. and Oritani, T. (1972). Cytokinin Glucoside in Roots of the Rice Plant. Plant and Cell Physiol. 13: 337-343.

Zink, M.W. (1984). Regulation of ATP- Sulphurylase by Various Nitrogen and Sulphur Sources in Cultured Ipomoea spp. Can. J. Bot. 62: 2107-2113.