# ROOT AND TUBER PHYSIOLOGY WITH EMPHASIS ON YAM IMPROVEMENT

by

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The majority of the contributions and discussions of this meeting are concerned with cereal and legume crops which is somewhat indicative of the relatively poor state of our knowledge of the physiology of tuber crops. Most of the information on sweet potato has arisen from Japan and the USA whilst cassava contributions have in the main been derived from research in Malaysia, India and more recently from CIAT. Our objectives have been to identify the important problems in these crops where physiology may have immediate impact.

Our work in cassava has been concerned with the problems of the cyanoglucoside content and from over 100,000 lines screened only 90 could be considered as having a low leaf cyanide content. These are being incorporated into the breeding program. Investigation of genetic variability in growth and production are severely hampered by high incidence of leaf diseases.

In sweet potato,we have investigated possible differences in photosynthetic efficiency using the Moss chamber with rooted leaf cuttings. Genetic differences were found in the ability of certain lines to survive low $CO_2$ and a simpler system of screening with leaf discs in a small container using KOH to absorb $CO_2$ has been successfully developed which gives good agreement with the Moss technique and overcomes some of the disadvantages of a large chamber with maize as a '$CO_2$-scrubber'.

Although yam is the staple food for millions of people in developing tropical and some subtropical countries, with an estimated global production of 20 million metric tons, progress in improving its yield's quantity and quality has not been substantial to date. This basically stems from lack of hybridization, the continuous vegetative propagation and, consequently, the narrow spectrum of genetical diversity available for selection and improvement by breeders. Therefore, selection based on field performance has been the breeders' major, if not the only, method of improvement. Although some progress has been accomplished through such selection schemes, no major improvement occurred or could be forseen by such methods. It has long been recognized that in order to achieve progress in white yam improvement, the present day limited germplasm collections have to be expanded by hybridization. The number of cultivars in existence in West Africa, according to my estimates, does not exceed 300 cultivars which is a low number for serious selection especially in a crop that has been propagated vegetatively from time immemorial. This points out that in addition to the excellent work that is being conducted on yam improvement in many parts of the world, more attention should be devoted to expanding our limited germplasm collections through hybridization.

Why was it difficult to hybridize yam? There are many reasons and the following are the most important:

1. <u>Flowering</u>: In yam populations propagated vegetatively in West Africa, we seldom obtain more than 50% of the population to flower, and among those plants that flower, there is a high male to female ratio, estimates of which range from 40 male to 1 female plant by Waitt to 5 male to 1 male plant by Sadik and Okereke.

2. <u>Pollination and Fertilization</u>: Because of the dioecious and unisexual nature of yam, pollination between male and female can not be readily accomplished. Because of the sticky nature of pollen grains, their strong adherence to the anthers and the small opening of male and female flowers, wind pollination is not possible. Our work, as well as that of Coursey, supports the hypothesis that pollination is done primarily by small insects such as thrips or flying insects that can insert their long slender proboscises through the flower's small opening. Two years ago we collected thrips from yam flowers and they were later identified by Pitken and classified in a new genus and species, <u>Larothrips</u> <u>dentipes</u>.

In addition to the physical difficulty of pollen transfer from male to female flowers, it has been found that the viability of pollen grains is poor. In addition, there appears to be a certain degree of incompatibility that results in poor embryo development and the production of inviable seeds.

Inspite of all these problems, a small number of fruits with fertile seeds can be found occasionally on female plants.

The next problem limiting the possibility for hybridization is seed germination. Many attempts over the years to germinate yam seed for the production of plants with greater genetical diversity were unsuccessful and were later abandoned because of the common belief that yam seeds are not viable. Following several years of investigation, two major limiting factors for seed germination were identified in our laboratory in 1973. First, a large number of seeds were found to lack embryos or endosperms perhaps as a result of poor pollination and/or fertilization, and secondly, seeds were found to have a dormancy period of about 3 months following harvest. Following the identification of these two factors, nondormant seeds that appeared to be filled, readily germinated in three weeks with a final germination rate from 80 to 90%. During 1973, some 600 plants were grown from seeds to maturity in the greenhouse and the harvested tubers were planted in the field in 1974. In 1974, some 3000 plants originating from seeds collected from several regions of Nigeria were also grown in the field.

Our method of seedling establishment from seeds can be summarized as follows: The fruits are collected from plants after maturation in November-December. The fruits are split open to release the seeds. The seeds are dewinged and stored at room temperature until April, by which time the dormancy period is over. In April the seeds are treated with fungicides and germinated in Petri dishes over wet filter paper. Germination seedlings are transferred from Petri dishes and transplanted into peat pots and allowed to grow until the development of the second or third leaf. These seedlings are then transplanted to the greenhouse or to the field.

This year we found that this lengthy procedure can be simplified by eliminating many of the intermediate steps. We found that the seeds can be seeded directly in moist peat pots and allowed to germinate and establish and later transplanted to the field. Alternatively, the seeds can be drilled directly in seed beds provided that the seed bed is well mulched and well protected from heavy rains. Seedlings established in the seed beds were easily transferred to the field without significant loss due to poor establishment. Another alternative is to drill seeds on well mulched ridges in their permanent place. With this last method we had some agronomic problems which I will discuss later. Nevertheless, seeds germinated well.

What results have we obtained so far? As I mentioned earlier, we grew 600 plants from seeds in 1973 in the greenhouse mainly because we did not know about their chance of success if they were planted directly in the field. Unfortunately, we planted them in small polyethylene bags because Waitt mentioned in one of his papers that "it would take a seedling up to three years to produce a 400 gm tuber". To our surprise, the polyethylene bags started splitting after 3 months from seedling transplanting as a result of tuber enlargement. The plants when harvested produced tubers, some of which weighed more than 1 kilogram. These tubers were planted in the field in April, 1974.

I would like to summarize some of the observations that we obtained from these plants:

1. <u>Flowering and Fruiting</u>: As I mentioned earlier, yam plants usually flower scarcely and seldom does the percentage of the flowering plants exceed 50%. Of those plants that flower, there is a large number of plants that are males and only a few are females. However, plants that originated from seeds in the previous year flowered better. Almost 80% of the plants flowered and, interestingly enough, the ratio between male and female plants was almost 1:1. In addition to that, 4% of the population produced monoecious plants containing both male and female flowers on the same plant. In addition, there was a tremendous increase in the number

of flowers per plant. Whereas a maximum of 185 flowers are usually produced per plant from tuber cuttings, a maximum of 11,000 female flowers were produced per plant from seeds. In addition to the increased flowering, there was an increase in number of fruits and seeds per plant, presumably because of better pollination and fertilization. On some plants, more than 1000 fruits were produced.

2. Genetical Diversity: Observations made throughout the growing season on plants grown from seed revealed a wide spectrum of genetical variability in respect to the following:

(a) Plant height
(b) Canopy structure
(c) Leaf shape and size
(d) Inflorescence shape and length
(e) Climbing habit
(f) Stem color
(g) Stem thorniness
(h) Date and degree of flowering, fruiting and seed set
(i) Tuber shape and size
(j) Disease susceptibility

## Present activities

Seeds were collected from the best 20% of the plants produced from seeds in 1973. In addition, we collected seeds from 20 of the best producing yam localities in Nigeria. All of these seeds were germinated this year, starting in April, and the seedlings were transplanted to the field in early June. This will result in the production of more than 30,000 new seedlings, each seedling genetically different from every other seedling. Because of the large number of seedlings, they were deliberately planted in the field at a spacing of 1 M between rows and 25 to 50 cm within the row. Each seedling is allowed to climb on a bambo stick to avoid mixing between plants and to facilitate data recording.

## Seedbeds and direct field planting

The foregoing research was started, initially, with the major aim of increasing the genetical diversity. However, because of the ease by which seed can be obtained and germinated and because of the ease by which seedlings can be produced and transplanted, our objectives have been expanded to look into the possibility of planting yam from true seeds on a commercial basis. We realize the fact that a yam population produced from seeds is highly diversified and non-uniform and would lead at the harvest of all kind of tuber sizes and shapes; however, one feels that research directed towards such a possibility should be started now so the method can be used when breeders produce more uniform seeds.

Our approach has been to develop a simple and cheap method of seedling production which can be used by the African farmer. Our first approach was to produce seedlings in seed beds, the way farmers produce their own tomato or tobacco seedlings. Seeds were planted 5 cm apart in rows, 10 cm apart and covered lightly with rice husks. The seed bed was protected from heavy rains by building a simple bamboo canopy. The seedling emerged after 4 weeks and were successfully transplanted to the field after the development of the third leaf. Enough planting material for one hectare of land can be produced from a 100 $M^2$ seed bed.

Following our success in the production of yam seedlings in seed beds, we wanted to know if direct seeding on ridges can be accomplished without the need for transplanting. The seeds were drilled on flat ridges 1 M apart and covered with rice straw to protect the seed bed from heavy rains. The seeds germinated but, because of the thick layer of rice straw, the seedlings were badly tangled with the straw when they emerged and, when we attempted to remove the straw to expose the seedlings to the light, most of the seedlings were pulled out in the process and, therefore, the experiment was a catastrophy in a way. However, it proved that seed germination can be accomplished if we can improve on the system agronomically.

The questions that are frequently asked are: What sort of yields do we obtain from yam plants originating from seeds? Can a farmer produce tubers of marketable size in one year through seeds? These questions are difficult to answer at this stage of our research, which is still in the stage of infancy. All plants used in our research have never been given a period of growth longer than four months which is too short for the production of marketable tubers. The reason for this is related to the problem of seed dormancy and seed storability. Because of the length of the dormancy period and because of the unavailability of methods to break the dormancy period, we have been forced to start seed germination after April and, therefore, to plant the seedlings in the field during the first two weeks in June at the earliest. We may have an answer for that next year by using seeds that have been in storage. At that time, we will start seed germination in February so the seedlings can be transplanted in April which is the normal planting date of yam from tubers.

If we discover that it is not possible to produce marketable size tubers within one year, we may have to suggest to farmers, ministries or private enterprises to produce their own seed tubers from seeds for the following year by using the seed bed method described above. If it were to be proven that viruses are not seed borne, obviously the planting material will be free of viruses and his yields could be improved. Transmission of nematodes through tubers can also be eliminated since they can be controlled easier in seed beds.

## Future activities

As we get further in our research, we are automatically finding more problems. Aside from the problems I mentioned earlier, the following are important problems that we are faced with and should be investigated:

1. Understanding the nature of the seed dormancy and finding methods for breaking it to facilitate seed germination at any desired time.

2. Finding effective and inexpensive methods for seed storage.

3. Establishing agronomic research to simplify seed germination and seedling establishment on an economic basis.

4. Finding methods for floral induction to tap the genetical resources in nonflowering plants with the rotundata species and other yam species such as alata ... etc.

5 Identifying yam viral diseases and studying their etiology and mode of transmission. A serious look should be taken, also, to find out whether these diseases are seed borne or not.

6. Study of tuberization mechanism.

## Yam Cooperators' Network

By the end of this year, I will have more than 30,000 yam tubers from plants that we started from seed this year. In addition, we expect to collect more than half a million seeds. Next year the number of seeds will amount to several millions. Frankly, this is more than one person or institute can handle. I would like to propose the establishment of a network for yam cooperators throughout the tropical yam belt. For obvious reasons, we cannot supply the cooperators with vegetative materials, but what we can do is to supply yam seeds instead, which should contain more genetical diversity. We seek the cooperation of many people specialized in certain areas of research such as genetics, biochemistry, physiology agronomy, entomology and pathology.