Selected Yam Varieties for the Tropics

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This 8-year program for selecting better yam (*Dioscorea*) varieties for the tropics includes: a worldwide collection of varieties of the principal species; the development of techniques to evaluate varieties agronomically, and for culinary and processing characteristics; the selection and testing of varieties; and the distribution of selected varieties throughout the tropics. In addition, composition with respect to proteins and starch was

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determined, and the nature of the yellow pigments and the bitter substances was elucidated. Taxonomic relations were clarified by numerical computerized techniques. *Dioscorea alata* was judged the most flexible and useful species, and 17 selected varieties were obtained. *Dioscorea esculenta* was found to be much more variable than expected, and 8 varieties were selected for their high potential. On the other hand, persistent problems with viruses prevented the distribution of *Dioscorea rotundata – D. cayenensis*. In addition, this species complex appears to be narrowly adapted.

The edible yams of the tropics, of which there are 50 or more species, have hardly left their original homes to serve mankind. To be sure, edible yams are found in every part of the tropics where they can be grown. Nevertheless, distribution has been accomplished haphazardly. The cultivars present in any particular region are often inferior to the better ones known elsewhere. Furthermore, the introduction of better cultivars has been impeded by a lack of published information. The result has been that yams are not as widely utilized as their potential merits.

To remedy this situation the U.S. Agency for International Development suggested a program of collection and distribution of yam varieties. Collections were begun in 1969 at the Mayaguez Institute of Tropical Agriculture. It became evident at that time that varieties easily available in the Caribbean were not representative of the full range of germ plasm, and that progress could only be made by collecting yams extensively on an international basis. It was also evident that we did not know enough about yams to define a good variety. Therefore, while USAID funded the collection and distribution phases of the program, MITA funded supplementary investigations as necessary.

The collection of yams was made over a period of several years through correspondence and through collecting trips. A visit to West Africa was financed by FAO, and one to Southeast Asia was financed by USAID. During these trips about 800 accessions of yams were acquired. I am indebted to many persons throughout the tropics for help in obtaining new varieties. Without qualified professional help in each location, the collecting expeditions would have been unsuccessful.

In Puerto Rico, newly introduced varieties were grown for a year or more in isolation from the principal collection, and were observed for pests and diseases. A system of evaluation based on morphological, agronomic, physiological, culinary, and processing characteristics was developed, and was adapted to the different species. Criteria for selection were developed. Preliminary selections were tested for yields in replicated field trials.

This paper represents a summary of activities and findings, and includes plans up to the expected closing of the program in June 1977.

D. alata

Of the various species of *Dioscorea* collected, the greater yam (*Dioscorea alata*) quickly became our favorite. Under the conditions where we have seen *D. alata* grown in Puerto Rico, it is the most dependable species, although some of its varieties are unreliable due to their susceptibility to *Colleotrichum*, *Cercosporum*, and other foliar diseases. *D. alata* often yields exceptionally well. Its tubers, if kept free of damage at harvest, can be stored about 5 months. We have stored tubers for 8 months or more by regularly eliminating shoots.

All varieties of the greater yam have certain traits in common. Their growing season is long (8–10 months). All require support for the vines. All can be established easily from any piece of the tuber. Regardless of planting time, all mature about the same time, with no more than a month of difference between the earliest and the latest varieties. I believe all are susceptible to virus disease, but the majority can be maintained symptom free by rogueing and planting only from superior tubers.

During the study of the greater yam we found some unexpected differences. Yellow fleshed varieties were shown to contain nutritionally valuable amounts of carotene. Unusual varieties from Papua New Guinea showed the most fascinating shapes, consisting of a series of intersecting vertical planes. Varieties were found that were almost free of wings on stems and petioles, and in some cases leaves were principally alternate rather than opposite. Tuber characteristics were highly variable. Varieties that had reverted to the wild were found in Africa and in the West Indies. These were propagated exclusively from aerial tubers. Very few varieties flowered, and fertile seeds were never produced during the 7-year study period.

The within-species relationships of the varieties were studied by numerical taxonomic techniques. About 235 of the 350 varieties we collected were used for this study, and 100 characteristics were noted. It was possible to classify varieties into 13 groups that were defined on the basis of character means. These groups were related to, but not identical with, certain geographical areas. Based on the amount and nature of variation seen, we concluded that Papua New Guinea was a centre of variation, and possibly the centre of origin of the species. The sympatric species *Dioscorea nummularia* resembles some of the *D. alata* cultivars found there. An unexpected finding was that the Caribbean and African varieties are somewhat related to each other, and that their affinities in Southeast Asia were not traceable with our materials.

Tubers of *D. alata* were found especially useful for processed products, including fries, chips, instant flakes, and flour. They were not suitable for the production of fufu. The tubers were usually rich in protein compared to roots and tubers of other species, and some exceptionally rich varieties were found. The proteins contained sufficient lysine but were always short of methionine.

A good variety of *D. alata* is resistant to leaf spot diseases and viruses, and is not affected adversely by excessive moisture. The tubers are borne in pairs or in threes, are spherical or cylindrical in shape, are not often branched, and have smooth but thickened skin that resists abrasion. The surface may have some fine roots, but the principal roots should be concentrated in the fibrous upper extreme of the tuber. Resistance to insects, diseases, and nematodes is desirable. Yields must be high and dependable, even when the crop is produced without support for the climbing vines.

Some special characteristics related to cooking are desirable. The parenchyma storage flesh should be white or cream coloured, and free of anthocyanin pigments. The "grain" of the tuber caused by starch accumulation around the vascular bundles should be fine, giving a compact and uniform appearance. After being cut or injured, or after prolonged storage, the flesh should not discolour readily by oxidation. The boiling time necessary to reach an acceptable softness may vary, but the better varieties generally reach this stage rapidly. The cooking water should remain free of gray or pink pigments. The flesh of the boiled tuber may be white, cream, or light yellow, appetizing in appearance, and free from gray colour. It should appear to be smooth, and that appearance should be verified when tasted. The cooked tuber should be moist in the mouth; not dry and difficult to swallow. The taste should be rich and distinctive, neither too bitter nor too sweet.

In addition, the variety should produce good yields (20 t/ha or more), the tuber should store well and resist fungi, and the seed pieces should germinate readily when planted.

No varieties were seen that combined all desirable characteristics. Selection of new varieties thus became a matter of compromise.

Seventeen excellent varieties were selected for distribution. I believe that some of these will replace traditional varieties wherever they are grown. These 17 were obtained from widely diverse regions, including Fiji, the Philippines, Java, Malaysia, Papua New Guinea, India, Nigeria, Sierra Leone, and Puerto Rico.

D. cayenensis – D. rotundata Complex

In contrast to *D. alata*, the collection of cultivars of *D. cayenensis* and *D. rotundata* was the most difficult to manage. We started with an excellent group of 220 introductions collected from Sierra Leone to Nigeria as well as local varieties found in the Caribbean. From the beginning many plants showed strong virus-like symptoms. This condition was the same as that called the shoestring disease in West Africa. There was no doubt that introductions showing such symptoms had been collected in all of the principal yam growing regions of Africa, and in the Caribbean. Our experience with this disease in Puerto Rico is that it reduces yields, sometimes drastically. The use of small tubers for replanting results in a more rapid spread of the disease, possibly because such tubers are found more frequently on diseased plants. Plantations grown under optimum conditions and rogued free of symptoms for 2 or 3 years become almost symptom-free. Constant vigilance appears necessary to maintain reasonably healthy materials.

Since most introductions were based on a single small tuber, it is no surprise that virus-like symptoms were often severe. Even in the first planting, symptoms were found in all introductions. In an effort to preserve the germ plasm, all introductions were multiplied for 1 or 2 years before rogueing was begun. Prolonged heat treatment of tubers, sometimes found useful in reducing symptoms in *D. alata*, was not useful in the case of the African species.

When virus symptoms were not eliminated, a program of severe rogueing was begun. During the 2 years of rogueing, the majority of the varieties were eliminated. Furthermore, with time even the more resistant varieties have shown intolerable levels of the disease.

Given the circumstances, we have taken an extremely difficult decision. The African yam collection will not be distributed but will be eliminated. Three varieties that appear to be completely resistant to the virus disease will be tested in isolation for 2 more years, but it is unlikely that these will be used anywhere except on the island of Puerto Rico.

While working with this collection, we have written a production bulletin, analyzed the carotenoid pigments, and identified a bitter substance as leucoanthocyanidin. In addition, we have finished a study of the relationships of 97 cultivars using the techniques of numerical taxonomy. In that study the species complex is divided into nine groups that coalesce to form two principal trunks. One of these represents chiefly yellow tubered cultivars, the other represents chiefly white ones. It is interesting to note that the two trunks anastamose with respect to two groups that show similarities even though they differ in tuber colour. The conclusion from our study is that the two names *D. cayenensis* and *D. rotundata* reflect artificial classification of what is an extremely variable complex.

With respect to the work of the future with this species, we are convinced that, in the Caribbean, *D. alata* is better adapted and more reliable. But in West Africa even the best *D. alata* varieties may not be competitive with the African cultivars. In most parts of the world, these African yams have never had a real try. It appears to us that the breakthrough in seed production achieved at IITA by Sadik and others opens the door for a more extensive use of the African yams throughout the tropics. It would be highly desirable to introduce African yams as seed and to develop varieties for local adaptation. Seedlings that we have established from seeds sent to us by Sadik may not be fully evaluated before our program terminates. Nevertheless, we believe the breeding work will continue at another experiment station in Puerto Rico. Obtaining virus-free varieties will not be enough. If resistance is not found, the job of keeping varieties free of virus will be formidable.

D. esculenta

Of the species of *Dioscorea* we have worked with, perhaps *D. esculenta* is the least known. Nevertheless, we believe that it might have a real potential in the tropics. The habit of producing multiple tubers not unlike potatoes is useful when machine harvest is contemplated. The small tubers are useful at the household level and are easy to handle if replanted. Some varieties, if handled carefully, store well. Furthermore, *D. esculenta* is probably more resistant to viruses than even *D. alata*. The chief disadvantage with respect to *D. esculenta* is that the growing season is long, almost 12 months. I believe that it might be possible to plant and harvest *D. esculenta* at any time of the year in some regions near the equator. Nevertheless, *D. esculenta* is fussy about season. Its period of dormancy is not very flexible, and indeed we have had problems in adjusting varieties from the southern hemisphere to 18°N in Puerto Rico. The wide variation among cultivars of *D. esculenta* has never been described, but has at least been hinted at, in the literature. Varieties from Papua New Guinea, the presumed centre of origin, have been carried to some islands of the Pacific but apparently in a random fashion. Although I was able to collect a wide variety of cultivars from the regions, I have no doubt that much remains to be done to entirely describe this species.

The West African and Caribbean cultivars of *D. esculenta* bear about 20–50 relatively small tubers that range from mere swellings to about 400 g in size. Their flesh is white and their eating qualities are high. In contrast, some varieties of *D. esculenta* in Papua New Guinea bear 6 or 8 tubers up to 2 kg in weight. The largest tuber I have seen was the shape and size of a small watermelon, and weighed about 5 kg. In general the flesh of these large tubers is somewhat coarse and subject to polyphenolic oxidation. Between the extremes there are many interesting varieties that bear intermediate sized tubers of good quality. Some of these have been selected for distribution in January or February of 1977.

In Papua New Guinea one also encounters many primitive varieties, often with small, branched, or irregular tubers. Flesh colour may be white, purple, or yellow. Thorniness of the roots surrounding the crown varies. An unexpected characteristic sometimes seen is the curling of the tuber toward the surface, and at times, the penetration of the surface by the tuber.

The starch grain of *D. esculenta* is fine compared to that of the principal species *D. alata* and *D. rotundata*. The amylose content of the starch is low, and the protein content of the tuber is extremely high in some cultivars.

D. esculenta merits a wider trial throughout the tropics, but only where growing season is long, and rainfall is abundant.

Other Species

During the course of our studies we have had the opportunity to work with six other edible species. While finding some merit in all of them, and realizing that we have not seen all of the germ plasm available, we have rejected some of the species, as follows: *Dioscorea bulbifera*, about 100 collections. The tubers of this species are always bitter; *Dioscorea hispida*, about 15 collections. This species is poisonous and needs special treatment to render it harmless; *Dioscorea dumetorum*, about 12 collections. This is sometimes poisonous, and the tuber is very irregular; *Dioscorea nummularia* and *D. pentaphylla*. Tubers are large, irregular, sometimes multiple, and cooking characteristics are below par; and *Dioscorea trifida*, which is very susceptible to viruses. Yields decline rapidly when the virus appears.

Literature Produced

As part of the research and development program 37 manuscripts were prepared for publication, and a few more are planned. The titles of these manuscripts are appended to this paper. Perhaps the major task was a review of modern production techniques, followed by detailed handbooks on the principal species. Within-species taxonomic relationships were studied in the case of the principal species. Nutritive values, especially protein and amino acid contents, were determined and yams were compared to other roots and tubers with respect to their nutritive values. The composition of the flesh was analyzed with respect to carotenoids, polyphenols that oxidize, and bitter substances. Certain physiological characteristics were studied: the curing period, and how it affects storage life; the extension of storage life with chemical treatment; and the stimulation of sprouting. To develop standards of selection, fried chips, instant flakes, and flours were developed and tested. Superior selections were described. Plans call for a thorough review of written contributions and recommendations before terminating the program.

Reprints and planting pieces are available free to investigators throughout the tropics. Reprints, already in short supply, are sent out at time of request. Tubers are shipped each January or February. Shipments are furnished with phytosanitary certificates. Nevertheless, we recommend that tubers we distribute be quarantined for a year until shown to be disease and insect free.

Manuscripts Concerning Yams

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Martin, F. W. *A collection of West African yams.*

Martin, F. W. *The edible yams.*

Martin, F. W., and Sadik, S. *Tropical yams and their potential. IV. Dioscorea rotundata and D. cayenensis.*

Martin, F. W. *Stimulating the germination of yam tubers with ethephon.*

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Martin, F. W. *The tropical yams, their growth requirements and their potentials.*

Martin, F. W., and Rhodes, A. M. *The relationship of Dioscorea cayenensis and D. rotundata.*