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Development of the Sweet Potato for Increased Usage in the Caribbean

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Inexpensive, efficient food crops that are attractive, tasty, nutritious, and versatile are needed in the Caribbean. The sweet potato has the advantage that it can be produced and harvested throughout the year. Usage of the sweet potato can be increased by breeding better varieties, especially those with little or no sweetness and bland flavors, and by better methods of preparation. A diffusion process was developed, which improves the acceptability even of the worst sweet potatoes. A household type process for making flour was developed; flours can be used in partial substitution for wheat flour. Insect resistance and stress tolerances are needed. Progress has been rapid, using mass selection as a tool. Varieties with new characteristics are available and need regional testing. Progress is being made in developing improved horticultural techniques and short cuts for testing adaptability.

"Our daily bread" is a beautiful fragment of a prayer which expresses a truth: most people in this world tend to fill a great part of their food needs with a single staple food. Staple foods are great foods. If you begin to enumerate the great foods of the world, the list, in order of importance, would be wheat, rice, corn, potatoes, barley, and tied in sixth and seventh places, cassava and sweet potatoes. Note that four of these crops are cereal grains, and three are roots or tubers. This paper concerns the sweet potato. Two-thirds of the world's sweet potatoes are grown in China where sweet potato is a great food. In very few other places in the world, however, can sweet potato be said to be "Our daily bread."

The sweet potato is a crop of the Caribbean. While its origin is somewhere in the American tropics, we cannot be sure how it originated and spread. But a significant fact is clear: sweet potato was in the Caribbean before Columbus arrived. It was carried from place to place by the original peoples, and it is highly probable that it continued to evolve in the Caribbean. It is still an important food, and still represented by hundreds of ancient varieties.

For just a moment let us contrast the sweet potato to other starchy crops which are its rivals in the tropics (Table 1). Its season is quite short, just a little longer than that of potatoes, and it can be planted or harvested any time of the year. The propagating material is the stem, useful as feed but not as food, and thus the principal edible portion is not sacrificed when a new crop is planted. Its level of culture is relatively simple, and it can be produced in anyone's backyard. But the crop can also be mechanized. Its food value (chiefly in terms of calories, vitamin C, and in yellow-fleshed types, vitamin A) is medium to high, sometimes a little better, sometimes a little less than other root crops. Finally, all parts of the sweet potato plant can be used as feed for animals. It appears that the combination of favorable characteristics of the sweet potatoes give it an appreciable edge over other crops that

TABLE 1. Principal starchy crops of the tropics (excluding grains) and some of their characteristics.

CROP	MINIMUM TIME TO PRODUCE (MONTHS)	PROPAGATING MATERIAL	RELATIVE EASE OF CULTURE	NUTRITIONAL VALUE	RESIDUES AS FEED
SWEET POTATO	4	STEM	EASY	MEDIUM-HIGH	YES
POTATO	3	EDIBLE PORTION	DIFFICULT	MEDIUM-HIGH	NO
CASSAVA	10	STEM	EASY	LOW	LIMITED
YAM	8	EDIBLE PORTION	MEDIUM	MEDIUM	NO
TARO	10	VARIOUS PARTS	MEDIUM	MEDIUM	LIMITED
TANIER	10	VARIOUS PARTS	MEDIUM	MEDIUM	LIMITED
BANANA	10	RHIZOME	EASY	LOW-MEDIUM	LIMITED
PLANTAIN	12	RHIZOME	MEDIUM	LOW-MEDIUM	LIMITED

TABLE 2. Current and potential use of sweet potato in tropics.

USE	RELATIVE POTENTIAL
FARINACEOUS VEGETABLE FOR BOILING, EVERYDAY USE	VERY HIGH
COMMERCIAL SOURCE OF CHIPS AND FRENCH FRIES	HIGH
FLOUR TO SUBSTITUTE IN PART FOR WHEAT FLOUR	HIGH
FRESH, CANNED OR DRIED PRODUCT TO MAKE DESERTS (ICE CREAM, MILK SHAKES, PIE)	MEDIUM
SWEET, MOIST ROOT TO MAKE DESERT-LIKE VEGETABLE	MEDIUM
ANIMAL FEED	MEDIUM
LEAFY VEGETABLE	LOW
SOURCE OF STARCH	LOW
SOURCE OF ALCOHOL	UNKNOWN

TABLE 3. TARS sweet potato breeding program.

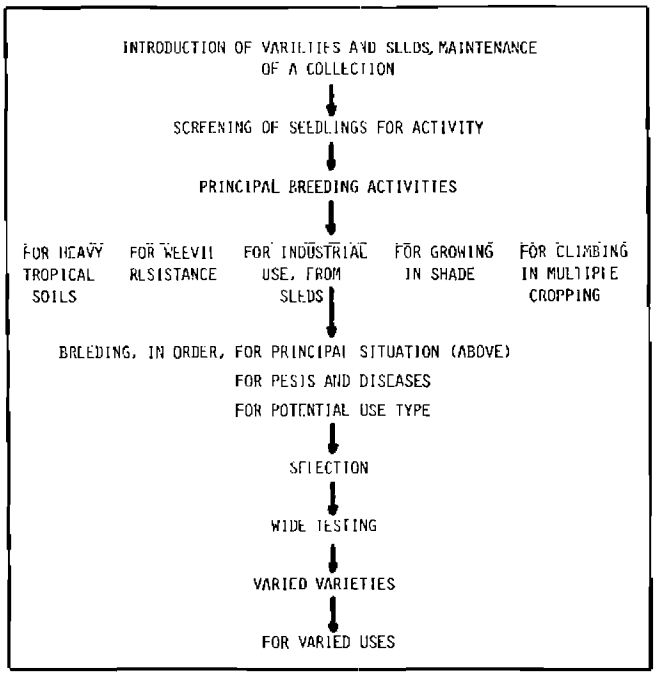

TABLE 4. Four types of sweet potatoes for the tropics.

NAME	COLOR	SWEETNESS	MOUTHFEEL
DESSERT	ORANGE	HIGH	MOIST
TROPICAL	WHITE TO YELLOW	MEDIUM	INTERMEDIATE TO DRY
STAPLE	WHITE	VERY LOW	INTERMEDIATE
HIGH NUTRITION	YELLOW TO ORANGE	VERY LOW	INTERMEDIATE

might substiture for it in the diet. Furthermore, the current and future potentials of the sweet potato far surpass current usage (Table 2).

If the sweet potaro has the advantages thar I have described, why has it not become a more important crop? I believe that the sweet potato is not a more important crop because people do not want to eat it every day. For most of us, a sweet can never be a staple. For many, sweet potato is a good crop for a special dish or a desserr, but a tiresome crop for every day. Yet, it is not just sweetness; not everyone likes the taste of sweet potatoes. Thus, if sweet potaro is going to realize its potential, it will have to be made over to better fit what people want.

The sweet potato must also conform to farmers' needs. An easy crop to grow, the sweet potato has one very serious disadvantage. It is susceptible to the sweet potato weevil (*Cylas formicarius elegantulus*), an insect which tunnels into the storage root, resulting in off-color and bad taste. If this pesr is not controlled the farmer can say goodbye to the sweet potato, for what he harvests will not be fit for man or animal.

Improving the Sweet Potato— The Challenge and the Technique

The sweet potato poses a special challenge to the person who would improve it. While a perennial, propagated vegetatively and thus easy to preserve as a variety, the sweet potato is a difficult crop to breed. It is self-incompatible by nature, and this restriction is complicated by sterility, probably due to hybrid origin. Furthermore, the sweet potato is a hexaploid and rhus has six instead of two sets of chromosomes. Hand pollinations are so unfruitful that they average less than a tenth of a seed per pollinated flower. Sweet potato cross-breeding has traditionally been labor intensive.

A new technique, mass selection, developed and demonstrated in South Carolina by Alfred Jones (Jones et al., 1976) has made sweet potato breeding easier (Table 3). Very effective for weakly expressed characteristics, the technique nevertheless is very simple. For any trait that can be measured or rated accurately, plants are selecred that display rhe highest values seen of the trait. These are planted in an isolated location during the season of shorr days, stimulated to flower by tying the vines ro uprighr poles, and cross-pollinated by bees. The seeds are planted and seedlings are selected again. While any seedling can become a variety, the population itself tends to change wirh each cycle of selection in two ways, towards increased flowering and towards an increased frequency of genes determining the desired charactetisric. The chromosomes containing favorable genes are selecred first, and with time unfavorable linkages are broken, and progress continues.

Program and Progress at the Tropical Agriculture Research Station

The sweet potato breeding project at the Tropical Agriculture Reseatch Station, named "The Development of Stress-Resistant Sweet Potatoes for the Tropics," was officially begun October 1, 1981, but plans and activities were initiated nine months before that time. Supported by permanently assigned funds from the so-called Section 406 program, the sweet porato project is aimed at the tropics in genetal, yer spin-off is expected to rouch the temperate zone as well. It is staffed by one scientist and thtee technicians, each dedicating two-thirds of his time to this effort. Informally speaking, the objective is to make the sweer potato into the most important farinaceous crop of the tropics. This objective does not depreciate any other crop, but tests on the belief that the sweet potato, and no other ctop, can fill that role. However, in a broader sense, rhe objectives are to develop sweet potatoes that are so atttactive to the palate that people will want to eat them every day, and so toletant of stresses, diseases, and pests that farmers will be able to produce them easily, even on

soils or in ecological conditions that are not today considered favotable for sweet potato. Where feasible, we also wish to improve the production systems, whether in mono- or multiple-cropping, in order to reduce risk to farmers. Finally, the objective is to broaden the use of sweet potatoes so that the impact of the crop is realized.

In order to accomplish these goals we are breeding sweet potato by mass selection. Our mass selection program requires a full year for each cycle. We plant seeds in January to April, transplant them to the field, screen for characteristics desired either in field or greenhouse, and then select plants to be used, together with the best of previous selections, in poly-crosses that will flower and bear seed during the dry season.

Getting a good sample of germplasm was our problem at the beginning. Now, having introduced about 40,000 seeds from the USA, West Africa, the French West Indies, Central America, and the South Pacific, we have all of the germplasm that we need. Please note that the clonal varieties of sweet potato cannot be legally imported into the USA or Puerto Rico, unless they pass through rigid quarantine procedures at Glenn Dale, Maryland. Within the germplasm available there is a broad scope for selection, and new variation is readily produced following hybridization. Germplasm improvement is accomplished through up to 15 poly-crosses each year. We now have seeds to spare for other investigators.

Closely related to the question of introduction of germplasm, is that of the evaluation of germplasm already here in Puerto Rico. In fact, this emphasis cannot be separated from the testing and evaluation of new varieties of our own program In order to evaluate varieties we had to develop standards. We did this for what we consider four types (Table 4). The *dessert* type is that most appreciated in the southern USA, orange, moist and very sweet. The *tropical* type, ranging from white to yellow, from low to high in sweetness, and from intermediate to dry in the mouth, is already found throughout the Caribbean. The *staple* type is what we are now beginning to produce, white, without sweetness, hopefully neither too dry nor too moist, and with a bland flavor suitable for everyday use. The *high nutrition* type, which could contain large amounts of vitamin A in a non-sweet type, is still only a dream, although we have seen prototypes.

We have finished a series of tests for our first ten varietal selections of the tropical and dessert types and have seen that some are well adapted, even to heavy, poorly drained soils and acidic conditions. At this early stage of our breeding program, I already believe we have significant new varieties. However, we have just begun to test a second set of varieties. These are our staple and substaple varieties, and I am confident that they are going to be better than the first set, at least in table quality.

By developing our sweet potatoes in heavy, acidic, poorly drained, infertile soils, we are subjecting them to stresses of several kinds. The Mayaguez soils (Catalina clay, Cialitos clay) are not very well suited to sweet potatoes, but they are representative of the tropics. We have seen that sweet potatoes that produce well in these soils, also tend to produce well in other soils. On the other hand, varieties that are well adapted to, and productive in other soils are not necessarily adapted to Mayaguez soil. Thus, our aim to breed stress-resistant sweet potatoes is met in part by breeding in the Mayaguez soil where the most important stresses seem to be high acidity, root flooding, and low fertility.

However, breeding for stress resistance also involves the use of greenhouse tests where large numbers of plants can be screened in a small space. Since sweet potatoes will produce a small storage root even when cuttings are planted in 3-inch pots, stress factors impeding production can be studied in the greenhouse. The stress tests that we have developed and standardized include root flooding, shading, soil acidity, poor fertility, drought, and competition. With each of these tests, we are finding that seedlings vary in their reaction to stress. We test single cuttings of seedlings and if stress tolerances are found, we test again on a triplicate basis. Stress resistant seedlings then are poly-crossed to produce the next generation.

What we do not yet know is whether the stresses imposed in an artificial situation, the greenhouse, bear any relationship to stresses in the field; yet, we suspect that they do. In our first selection for shade resistance, all 38 selections our yielded all 18 standard varieties in a field plot beneath trees. Furthermore, in a test of 100 seedlings selected at random, subjected to greenhouse tests but also grown in three situations in the field, stress test results, especially for tolerance of acidity, were partially correlated with yield performance in the field. In addition, using only stress test results and selecting the top 15% of the seedlings, we would have been able to select nine out of the top ten yielders in Mayaguez fields.

With this kind of research, we are trying not only to develop new sweet potatoes, but also to determine something about their ability to adapt to other environments different from those of Mayaguez.

As a prominent factor influencing yields, we have identified the stem cutting and its treatment before and after planting as being of crucial importance in yield. For example, healthy-appearing cuttings from old plantings do not produce as well as similar cuttings from younger and more vigorous plantings. The nutritional status of the cutting can range from dismal to promising. Furthermore, the cutting may suffer from distinct levels of virus charge. More exact information on the influence of pre- and post-planting procedures will permit the development of better sweet potato production systems.

In the tropics the sweet potato is frequently produced in multiple cropping systems. Our answer to the special needs these systems require is the development of climbing sweet potatoes to be combined with corn, and development of shade tolerant sweet potatoes to grow under trees such as coconuts. We have rapidly produced climbing varieties using selection and poly-crossing, but these sweet potatoes are different and require much study before they can be released. For example, they have small stems and are difficult to root. They may be more sensitive to photoperiod, and may accumulate virus charge more readily. Thus, breeding has been very successful in producing a new kind of plant, but one which we do not know yet how to handle.

The search for shade tolerance is not difficult, but results so far suggest that the level of tolerance is low. It may take many years of mass selection to develop a truly useful level of shade tolerance.

I would like to be able to report progress with respect to the sweet potato weevil, but like all farmers who know this pest, I have no sweet words. We think we have a good methodology for searching for weevil resistance so that it can be strengthened by mass selection. Now, with almost four years of field experience behind us, we feel that weevil resistance is uncommon and weak, thus hard to find, and harder yet to strengthen. Yet we feel that the search for weevil resistance is very necessary, and that the germplasm under development may as yet be the most important contribution we can make. We urge farmers to use those few controls that can permit reasonable production in spite of weevils.

I have not touched on the subject of processing, but wish to mention two contributions we have made. One is the development of diffusion-processed sweet potato pulp through a simple process that makes any sweet potato taste better. With this process sweet potato could be used as a staple food in any household. The second contribution is the development of a precooked, non-sweet flour from one variety of sweet potato that would permit excess from the harvest to be stored for future use. In order to develop a process suitable for small scale use, we have had to develop technical solutions suitable for the average household. It

appears that sweet potato flour could substitute for a good proportion of the wheat flour now imported in the Caribbean.

Future Prospects, Plans, and Needs

The greatest need for the future is to get people excited about the sweet potato. If others can share our dreams they need not establish rival, duplicative, or competitive programs. In place of this, all comers are welcome to try our plant materials and our processes. Furthermore, we are convinced that our own findings on production techniques, the techniques developed by our sister institutions, and the advances in weevil control developed and tested in AVRDC, Taiwan can make it possible to produce better sweet potatoes.

We especially need serious cooperators who will plant our varieties side-by-side with those already available, and who will help others to understand and to try the new sweet potatoes. This process must be a continuous effort. We expect to be developing and releasing new varieties continuously over a long period of time. Some of our goals will be easily reached, including increased developing tolerances to some common stresses. On the other hand, I am not convinced that we shall succeed in obtaining weevil-resistant varieties.

In order to fulfill the potentials of the sweet potato we need entrepreneurs as well, large and small, who will look to the sweet potato as a source of income. This is difficult since the sweet potato is not a glamorous food, nor is it pushed by large food chains nor supported by a well developed marketing system. Yet, sweet potato can fill new roles, and people now can define these roles.

It is only through an extension of the work already successfully begun that sweet potato can become what its nature suggests, "our daily bread."

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