THE ECONOMIC ASPECTS OF THE PACIFIC SWEET POTATO COLLECTION

— *by* —

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The collection of sweet potato varieties from the Pacific Islands was begun in 1957 with its objective being mainly ethnological in interest (Yen, 1963a). The plant, *Ipomoea batatas* (L.) Lam., first identified specifically by the botanists with James Cook has offered an enigma in the general topic of the peopling of the Pacific, for the debated American origin assigned to the plant forced the recognition of the possibility of prehistoric contacts with the New World (Dixon, 1932). The scope of collection was extended to America and Asia in the light of the unsettled issue of origin, since the evidence of Vavilov (1931: 1949/50) for South American or Mexican provenance has not been defined. The live collection, grown in New Zealand as it was gradually accumulated from successive field trips, demonstrated the comparative variability of varietal populations from the broad geographical areas, and indicated that the ultimate source of the Polynesian, Melanesian and Asian material was America. A report on the incomplete material (Yen, 1963b) showed that the area of provenance for the whole Pacific material could have been identified as South America.

The full collection of 580 varieties was grown for the final comparison in the 1963/1964 season. Cytological investigation has produced little that could differentiate the populations (Wheeler and Yen, *manuscript*), but the addition of varieties from areas previously unrepresented has allowed some further interpretations of the manner of distribution of the plant. While this is not the subject under discussion, the extension of the measurements of variation in its pursuance since 1963 has encompassed some plant characters which are considered to be of economic value. These, then, comprise the focus of this paper. Further, the information gained in the course of fieldwork on the adaptation of the plant into indigenous environments is considered in conjunction with the economic characters in the plant's variability.

The possible contributions of this collection in plant improvement are seen as two-fold:

1. The variation displayed within the species of the characters measured shows that further assessments in depth for as many economic characters as possible may reveal genetic material for the improvement of the plant in modern horticulture.

2. Some selection directions for native cultivation may be somewhat divergent; the definitions of the problems or limitations to production and the selection of parental genetic material of the modern approach to plant improvement may be combined with the selective processes of the cultivators in the multifarious environments under which the plants are grown.

SOME ECONOMIC CHARACTERS FOR MODERN HORTICULTURE

The variations that have been recorded in the sweet potato may be described as extremely wide in character. While the data on the individual morphological traits may suggest that some grouping of these may occur to give at least some sub-specific taxonomic classification, the attempts to achieve this in this collection have resulted in the concept that the species is a highly variable one, with free gene interchange, compatible with the hypothesis of its allopolyploid parentage (Ting and Kehr, 1953), with interference to evolution by the human agency of vegetative propagation (Yen, 1961a).

Since the fuller data is to be published elsewhere, this discussion is restricted to the description of information relevant to the possible implications to plant improvement.

The general indications of the wider range of variability of the American material over the remainder of the populations held good in the expanded material, and over a greater number of plant characters than were included in the preliminary report (Yen, 1963b). At one end of the ranges in four characters, however, the American variability was exceeded with: near glabrous reproductive parts of the flower in some Thai, Philippine and New Guinea varieties; the greater degree of dissection of leaves in some New Guinea varieties; the presence of a mauve rather than white stigma in some New Guinea and Philippine varieties and the lowest specific gravity of edible roots recorded in the collection in one Marquesas Island variety. In 37 other plant characters, the American varieties covered the widest range exhibited in the collection. Thus it is the American portion of the collection which must be expected to yield the highest potential as a gene source for modern plant breeding. Some of the characters assessed in this work of such value may now be described.

The problem of sweet potato production on which many breeders are concentrating are those caused by disease pathogens. As a source of resistance to black rot caused by *Ceratocystis fimbriata* Ell. & Halst, and scurf by *Monilochaetes infuscans* Ell. & Halst., the collection seems to hold considerable promise, for in tests of root inoculation with the two organisms, some varieties exhibit resistance, or at least high tolerance to the diseases (Nielsen and Yen, 1966). The six most resistant varieties to black rot are from Peru (5) and Ecuador, and to scurf from Peru, Ecuador (1), Colombia (1) and the Ryukyu Islands (1). In connection with the previous comment on the free segregating nature of the species, it should be noted that in no case, has one variety scored highly for resistance to both organisms.

The importance of these observations do not lie in the identifications of the resistances, for varietal differences of reaction to black rot have been recorded by Cheo (1953) and Martin (1954), and to scurf by Poole (1932) and Kantes and Cox (1958). The variability over a wider range of material than is usually tested, however, indicates that there may be more effective resistances than are presently known; that the seemingly quantitative inheritance of the resistance reactions may allow of a building up of resistance by selection in breeding populations from hybridisations of varieties; that there may be further resistances to other economic diseases within the collection. Using material from the collection, Martin (1966) has investigated the reaction of varieties to soil rot (*Streptomyces ipomoea* Person & Martin). His so-far unpublished results from tests devised by Carlson and Struble (1960), of the correlation of low numbers of layers of non-nucleated periderm root tissue and resistance to this disease indicate the strong possibility of resistance which could be higher than some common American commercial varieties derived from varieties from South America, the Marquesas Islands and New Guinea.

The further distribution of material from the collection to sweet potato breeders working with plant pathologists may well produce more useful resistance characteristics. While this may be considered as the greatest potential for the collection as a source of genetic factors, there are some other interesting plant characters which may be of use in breeding programmes.

One is growth habit of the plant. There are two varieties, one Mexican and one Peruvian which display shorter vine lengths (the product of short internodes and low number of nodes) which extend to only a mean of 15 inches at maturity under New Zealand conditions. These vary from one another however in that the Mexican variety has prostrate stems while the Peruvian is upright. The utility of such characters may be more apparent with the modern agronomic trends toward the minimisation of herbage growth to facilitate bulk harvest methods, and closer planting spacings to produce uniform and somewhat smaller roots.

A further example is one directly concerned with production, and while applicable only to New Zealand conditions, may point to possibilities in other temperate areas. It has been shown (Yen, 1963b) that there is segregation in the species in the ability of individual clones to set swollen storage roots in New Zealand. Of those which do, there is a wide variation exhibited in measurements of production based on per plant figures of number of edible roots, or weight. In the most recent comparative growing for example, the standard New Zealand variety, *Owairaka Red* produced mean figures of 5.2 roots per plant with a weight of 3.7 lbs. These were exceeded, as in previous comparisons, by a number of imported varieties, but despite the further additions to the material, the performances outstanding in these indicants of yield were repeated by two Peruvian varieties, one bearing nearly 18 roots for only 3 lbs weight per plant, but of a size useful in canning, and the other with only four roots but weighing nearly 7 lbs per plant. It is unfortunate, that in other characters, these varieties are unsuited for direct introduction into New Zealand commercial growing, but they are being investigated further in their breeding potential.

The records of specific gravity of roots grown in the experimental plots have shown that the figures of between .95 and 1.09 for the collection exhibit a range of variation in access of that of the *Solanum* potato. The latter, with a range of 1.06 – 1.12 (Schippers, 1963), must be considered a better source of starch, but in tropical climates, the comparative gross production per acre would favour the sweet potato. That there is scope for selection in the species, particularly where solids contents are important as in some forms of processing, may be taken as unquestionable as shown by the variation in this collection. In terms of seeking products from tropical areas for modern use, however, the competitive nature of other starchy root crops, e.g. manioc, has to be taken into account.

ECONOMIC CHARACTERS IN INDIGENOUS CULTIVATIONS

The adaptability of the plant in Pacific native agricultural contexts takes on a rather different identity, for both the environments in which the sweet potato is grown and its cultivation methods are more contrastive with modern horticulture than, for example, the grain cultures of the Middle East and Western Europe. It is well to pause in consideration of these differences, for they have direct bearing on the choice of objectives in plant improvement for the area.

The adaptability of the plant over a wide range of environmental conditions is demonstrated in Oceania, for it is found within the agricultural contexts of low-lying coral atolls and the high volcanic islands (Barrau, 1958 ; 1961). The sweet potato has been collected in gardens on the sandy and coral derived soils close to island shores, from drained swamp areas and from hill cultivations up to 5000 feet in elevation. Generally, the plant here is associated in agricultural systems with perennial tree crops like banana, sago, coconut, breadfruit, and other major starch sources such as taro, yam, manioc, often occupying a secondary, supplementary role. At levels of 5000 feet and over on the continental islands the plant assumes a major role. In Luzon, it is the major component in the cropping pattern of the shifting cultivation element of the steep, higher slopes which accompanies the permanent field rice terrace cultivations. In New Guinea, over a million mountain people (the estimate for the Australian central highlands is around one million, Watson, 1964) are largely dependent on the sweet potato for their subsistence. It may be said that among contemporary indigenous societies, that the sweet potato has been adapted in agricultural systems which incorporate the slash-and-burn or milpa methods in slope cultivations. The spatial succession in terms of altitude of crop plant importance has been noted by several authors, e.g., Barrau, 1958; Brookfield, 1964, for New Guinea, and the place of the sweet potato at the maximum levels of agriculture at approximately 8000 feet pointed out. The inferences for the adaptation of the plant lie in two directions — the ability to grow on steep topographies, and some tolerance to the cooler conditions. The pre-historical distribution of the plant as a major agricultural plant in peripheral Polynesia may reflect somewhat this adaptation; for in Hawaii the plant occupied the principal role in *kula* (dryland mountain) cultivation (Handy, 1940); the Easter Islanders relied on the plant since many of the other Polynesian staple plants like coconut, breadfruit grew poorly; in New Zealand, the sweet potato was adapted to the more temperate environment after the invention of the Maoris of underground storage techniques which allowed the plant to be grown as a virtual annual plant (Yen, 1961b).

The adaptation of the plant to the relatively atypical tropical conditions may be seen as the interaction between modification of the environment by cultivators — agricultural methods — and the inherent genetic ability of the plant in its variability to withstand the natural environment. It is the latter aspect on which attention is focussed.

The growth habit of the sweet potato plant, referred to earlier, has been classed into several forms, and those which achieve the fastest growth in terms of ground cover are seen to be the most suited to mountain landscapes. Of all the plants grown as starch staples in the tropics, the sweet potato must be regarded as the best for its soil-containing possibilities. The extremes in the range of variation of growth habit, however, the bush types with agronomic possibilities in modern horticulture, and the very long vined forms with long internodes (over 10 cms. in some Peruvian and Colombian types), with poor branching development, do not provide effective plant density. The intermediate types of rapid growth and profuse branching patterns appear as the most effective.

The testing of 293 varieties from the collection for reaction to cold in New Zealand proved that the species can be segregated into classes of degrees of tolerance. While no varieties withstood sustained low temperatures at or near frost level 32 degrees F.), many, even those derived from lowland tropic regions, exhibited surprising tolerance. It is therefore suggested that in high tropic areas where unpredictable cold conditions can prove disastrous to sweet potato production, and therefore to the food supply levels, e.g., in New Guinea (Meggit, 1958; *South Pacific Post,* 1961), the purposeful selection of cold tolerant genes may be an important stabilising production factor in such economies. Some trends of exploitation of sub-alpine areas about 8000 feet, as described by Bowers (1965), however, may be limited by the demand on the species to withstand further cold conditions, and the substitution of other crops e.g., the *Solanum* potato as suggested by Keleny (1960) may have to be extended if agricultural expansion continues. Comparable heights have not yet been reached in Philippines indigenous agriculture, but should demographic changes owing to improvements in human hygiene and health measures result in upward trends, adjustments in agriculture may occur in the intensification of efforts on the swidden portion rather than the permanent rice field. The limitations to the latter may be seen not only in the additional expenditure of labour to create or elaborate agricultural capital, but also in terms of the adapation of rice to higher altitudes, the amounts of land suited to terracing, and especially, the available supplies of water for irrigation.

A further measure of adaptability is in the occurrence of plant disease disorders caused by pathogens. The ranges of diseases known in the sweet potato of American horticulture have not been identified in native agricultural contexts, but during field work, the incidences of diseases have often been observed on a large scale. In lower altitudinal zones, e.g. below 5000 feet in New Guinea and in hill cultivations not far from the sea, but under 1000 feet in elevation, the leaf disease caused by *Elsinoe* sp. appears to be of considerably more importance as a limiting factor of production than in other areas. In the higher elevations in New Guinea, the disease was not observed. The identification of diseases is a pre-requisite to improvement for such areas, and the possibility of physiological races of organisms over the wide ecology of the Pacific may pose further problematic situations that are not uncommonly encountered by plant breeders.

In the side issue of human adaptation in an area like continental New Guinea, the effect of diseases in agricultural plants in the warm humid zones of coasts and middle altitudes may have to be considered along with other ecological considerations, the prevalence of human diseases and the social pressures on land resources in the story of the expansion of populations into the upland areas. The dependence of these peoples on the sweet potato invests it with the responsibility of not only the main contributor to caloric intake, but the nutritional quality aspect of the diet. The lack of protein is perhaps its most serious defect, especially where alternative sources are poor, e.g. in New Guinea (Bailey, 1963. Oomen *et al* 1961) have pointed out possibilities of selection in this character, for the variability that was encountered suggests similarity to the characters explored in the Pacific collection.

The dual-purpose utilisation of the sweet potato in the Pacific has considerably more emphasis in native agricultures, for the plant provides both leaf and starchy root resources in the diets of humans and animals, and particularly in pig-raising. The social consequences of the sweet potato in terms of its effect on human population (Watson, 1965) in New Guinea may also apply to swine-herd populations, for the role of pigs in economic and ceremonial life is extensive (Vayda *et al,* 1961). The feeding of sweet potato roots may be generally assigned to surplus and discarded production, but two methods of feeding herbage are employed. One is by the cutting of stems and leaves expressly for direct feeding to pigs — sometimes in Asia, they are chopped and boiled with household scraps first; and by "controlled grazing" of fields, generally after the main root harvests. The involuntary breaking-in to cultivations by domestic and the sometimes hunted feral pigs constitutes an indirect, but by no means, infrequent contribution to the food supply. Fortunately, the improvement of this aspect of utilisation by selection is parallel to the requirements of plant type for slope cultivation, for it is the "intermediate" fast-growing types which have the ability to recover after cutting, and perhaps, after controlled grazing. From South China, there is information on utilisation that indicates that selection is practiced towards the glabrous stem and leaf forms on the score of their suitability for both human and animal consumption.

The foregoing may convey that in Pacific indigenous agriculture, there are no plant selective procedures. This impression should be corrected. In a previous paper (Yen, 1967), some of the ecological and social phenomena which render these procedures less apparent have been outlined. The directions of selection appear to be towards some of the characters that have been treated, but it is considered that the assistance of modern breeding methods may accelerate such effects by the concentrating genetic diversity towards the desirable ends of the ranges of variation.

THE POSSIBILITIES OF UTILISATION OF THE COLLECTION

The modern trend in plant breeding is toward the elimination or minimising limiting factors to production, the fitting of the plant to advanced techniques of cultivation and harvest and the improvement of quality for specific ends, e.g. processing, while at least maintaining production level. The exploitation of the Pacific collection, including the important South American array, lies in the search for useful gene contributions to these ends. Apart from indicating this potential, there is little point in further elaboration, for the approach merely represents what has become a classical approach to the improvement of crop plants — the exploration of materials collected from indigenous cultivation contexts. The problems of breeding procedures in the sweet potato, the improvements in techniques and the refinements in the methods of assessments of the various required qualities are to be discussed in this symposium.

If the improvement of sweet potato stocks in indigenous cultivations were to follow the orthodox approaches which result in the introduction of the "finished", adapted varieties, the difficulties of such attainment would be considerable. Little organised plant breeding can be done *in situ* under the present conditions of scientific organisation and finance, and any proposal of initial work to be done from outside would still require the selection and testing of breeding material over the wide range of environments which constitute the occupation areas of native cultivators. The different nature of the agricultural systems and the terrains does make difficult the application of normal field plot techniques in both spatial and time perspectives. The following, then, is a suggested modification of procedures which incorporate the modern approaches with the selective procedures of the peoples in question:

1. *The Definitions.* Some of the plant characters that fit the contexts of areas, ecological and utilisational, have been suggested. The necessity for further definitive research, however has been indicated, including issues of plant pathology. The role of pests has not been mentioned, but the presence of both leaf and root predators has been observed in field work over the whole Pacific area. These definitions should be applied to the collection to assess the breeding possibilities over the broad base of requirements in the species. While the South American collection appears to have the most promise, there is sufficient transgression from that variation in some of the other populations to suggest that new genes or at least new combinations may have been evolved due to relative isolation of the populations after initial introduction.

2. *Plant Breeding.* Since most characters in the sweet potato appear to be inherited quantitatively, modern directive breeding techniques should be applied to concentrate gene blocks which contribute to the manifestation of desired characters. The physiological control facilities now available could be put to use in the preliminary laboratory testing of such combinations by growing them in the simulated light and temperature conditions of the areas for which they are intended.

3. *Field Selection.* The introduction of a range of these combinations directly into the hands of indigenous agriculturists may have two expected results: The selection of clones immediately considered desirable, and the testing of these by empirical observation. Horticultural curiosity ensures such observation over the range of environments and agricultural practices that ensue in given communities; the succession of testings under such conditions exposes the clones into the sexual reproductive cycle of the plant, with subsequent contributions into the local gene pool of desirable adventive genetic material. The combination with local adaptations may give enlarged scope for the selective talents of the native selectors.

There is now considerable substantiation of the exploitation of seedling sweet potato varieties in such agricultures. In the earlier phases of this work, the occurrence of true seed led to the suggestion that this provided the sources for the accidental discovery of seedlings (Yen, 1960). That there is cultural awareness of the source of such new varieties, if not the actual mechanics of their production, has been made obvious in subsequent field-work in the Philippines and Oceanic islands, where records of new varieties with descriptions of their seedling leaflets on first discovery. These are lent support by the specific observations of Bulmer (1965) in the western and eastern highlands of New Guinea. The practice of selection is further reflected in the categorisation of varieties by the western highlands informants of Bowers (1965), into those which grow well and those that are never planted in the high altitude gardens of the Kaugel Valley. Two of three varieties cited as examples of those adapted to high level growing proved to be among the most cold -tolerant in the collection in the New Zealand test. This is a small, but significant indication of the functionalism of native selection.

On the other hand, the suggested procedure takes advantage of the asexual propagating method applied universally to the plant, for selection by elimination, with concurrent growing of the local forms, may negate immediately and thoroughly, any mistakes that might be made in new introductions. Were the plant obligately sexual and cross-fertilising in breeding habit, there would be far less room for unpredictable error.

CONCLUSION

The plans for the development of indigenous areas and peoples seldom consider subsistence agriculture as an integral part of a contemporary economic system. Barrau (1958) is one of the few to suggest that some stress be placed on this aspect. In some Pacific islands, the subsistence systems have been virtually replaced by cash and plantation cropping. This replacement has brought with it some problems — in native nutrition; the imbalance of transitional-type economies which provide labour without the increase of capital; the erosion of social institutions, many of which were the cohesive forces for agricultural organisation in earlier times. The conservation of subsistence forms of agriculture, in their internal function of local food supply must be considered an important part of any future designs in guiding the evolution of viable economic systems. "Conservation" as used here has a connotation of progress, for it considers assistance that may be afforded by modern scientific endeavour in folk contexts.

The latter portion of this paper is a minor and indeed, hesitant essay towards a contribution in this direction.

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