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Review Article.

A Review of Investigations on the Breeding of the Sweet Potato *Ipomoea batatus* Lamk *
Part I

by
V. N. MADHAVA RAO,
Agricultural College and Research Institute, Coimbatore.

The earliest record of the production of sweet potato from seed, according to Thompson (1925), is a report of work done at the St. Helena Penal colony in Queensland in 1901. Since then similar work on a small scale has been done in some of the experiment stations of the West Indies. Over 40 years ago, the Florida Experiment Station is reported (Stout, 1924) to have produced seedlings from seed obtained from the West Indies but the work was discontinued before definite results were obtained. In Japan, Hirama (1941) conducted experiments as early as 1922 which were carried through 1937, resulting in the release of improved strains. About the same time, breeding work was begun at the Virgin Islands Expriment Station by Thompson (1925) who grew approximately 240 varieties through three consecutive years. In India, the first work in sweet potato is reported to have been recorded by Funicane in 1886 (Richharia, 1945) from Bengal. This and the subsequent items of work in India by the Imperial Council of Agricultural Research (now Indian Council of Agricultural Research) were primarily concerned with the study of varieties. Sampath and Bhanumurthy (1948) have recorded some preliminary observations on hybridization and seed setting based on studies made at Benares, Coimbatore and Bapatla. Abraham (1951) conducted studies on inter-varietal and inter-specific hybridization in the University of Trivandrum. Investigations on the floral biology were conducted by Chatterjee and Nagbiswas (1952). Richharia and Ghosh (1954) carried out breeding investigations in Bihar with varieties obtained from different sources including the U. S. A.

Early problems: (i) *Flowering and seed setting:* One of the serious limitations to progress in the early attempts at breeding in this crop was the non-blooming habit and the low fertility of the

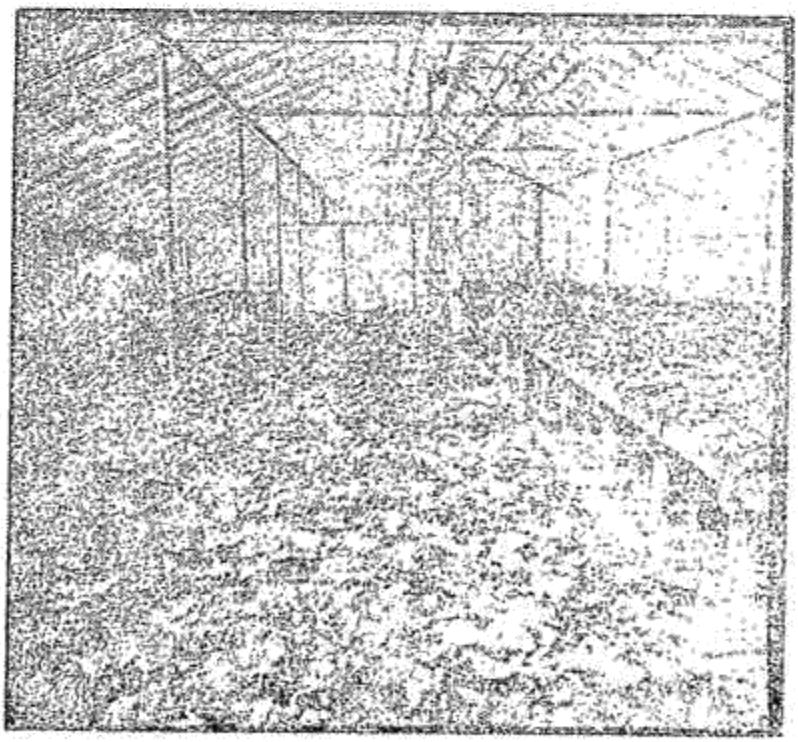
* Summary of a review presented by the author at the Louisiana State University Horticulture Research Department, Baton Rouge, Louisiana, U. S. A. (1958—'59).

blossoms once formed. Though being able to produce commercial crops of roots under most conditions, it flowers best under tropical and subtropical conditions. In general experience, the sweet potato has been so decidedly barren that the Standard Cyclopedia of Horticulture (1917) says of it, "flowers and fruits are rarely seen". A still more recent volume says, "occasionally a small ball or morning glory shaped bloom with a purple throat and white margin may be noticed in commercial fields and the mature seed may be produced if the growing period is prolonged by the use of artificial means".

Stout (1924) collected information on the flowering and seed setting of the sweet potato from 15 States in the U. S., A., the United State Department of Agriculture, and from the Virgin Islands, Puerto Rico, Cuba, Santa Damingo, Barbados and St. Vincent (Trinidad), Hawaii, Cuam, Phillippines, Java, Newzealand and Australia. Thompson *(loc. cit)* says that seed production is restricted rather closely to the tropical regions. Although the plant flowers frequently in South Atlantic, the Gulf States of the U. S. and occasionally as far north as Washington D. C., it is only in exceptional cases that perfect seed matures in the U. S. He is of the opinion that a relatively dry tropical climate apparently is conducive to seed production whereas the more humid areas are less favourable. The information collected by Stout *(loc. cit)* is more or less in agreement with Thompson's observations. Young of Georgia is quoted by Stout *(loc. cit)* thus: "on several occasions, seeds have been produced and seedlings grown in an experimental way though no strain of superior variety has been produced". The reports obtained by Stout from Barbados, Puerto Rico, Philippines and the New York Botanic Garden are that there was profuse bloom but no seed; Calvino in Cuba was, however, successful and obtained 1000 seedlings. But the seedlings so produced reverted largely to types not considered desirable for commercial growing.

In Hawaii, a large number of varieties and hybrids thereof seeded freely, but during the moist seasons the foliage developed most luxuriantly and even seedling varieties were less inclined to seed during the wet season. Raising of seedlings was found difficult in Queensland. A report from Java (Stout, *loc. cit.*) says that self-fertilization is possible even if a large planting is made of one sort isolated from other varieties. Menezes (1953) observed 66 varieties and concluded that all varieties flowered well under the conditions of the State of Paulo in Brazil, fertile pollen was produced but very little seed set under conditions of self-pollination.

Examination of seedlings at an early stage prior to isolation of promissing ones. (Sweet Potato Research Centre, Chase, Louisiana, U. S. A.)



Seedlings of sweet potato in the green house (Sweet Potato Research Centre, Chase, Louisiana, U. S. A.)

Sampath and Bhanumurthy *(loc. cit.)* state that the sweet potato flowers freely at Benares and that the varieties differ in the extent of flowers. At Coimbatore and Bapatla, they state that conditions for flowering and seed setting are optimum during the cool months from December to February and that "even if the vines flower freely, no seed may set as there is a high degree of self incompatibility". In 1950 Richharia and Ghosh *(loc. cit.)* tried over 1600 plants of 25 varieties introduced in Sabour from the Indian Agricultural Research Institute, of which only 36 plants of five varieties flowered. In 1951 they tried 14 American varieties besides five from the Indian Agricultural Research Institute and three local varieties. Two of the American varieties died and of the remaining 12, seven flowered while all the local and Indian Agricultural Research Institute varieties flowered. They attribute the better flowering in 1951 to a more favourable temperature than during the previous year.

Inducing flowering: Tioutine (1935) made unsuccessful attempts to induce flowering in varieties that did not flower naturally by restricting the root system by grafting on another species of *Ipomoea* and by growing the varieties as perennial cultures under glass. He explained that the ability to produce flowers is a varietal characteristic and that fertility in the species is the exception rather than the rule. Thompson's (1925) work showed that plants within the same variety varied in the tendency to produce flower and seed. Mcclellan quoted by Miller (1939) found pronounced effects of varying periods of daylight exposure on the growth and blossoming of sweet potatoes and beans.

The experiments of Miller (1937 and 1938) in the Louisiana State University Agricultural Experiment Station were probably the most comprehensive and also the most successful. Miller tested a number of treatments such as root pruning, vine girdling, growing the vines on trellises, photoperiod adjustments and stimulation of natural flowering and fruiting conditions by temperature adjustments. In one of his experiments, the plants were set to the green house in August. They were trained to a trellis and kept growing under optimum conditions. At that time no flowering occurred. Two pounds of super phosphate were worked into the soil around each plant, watered heavily and kept on what may be considered the wet side of the optimum from November until January 1. During this period the plants developed highly vegetative growth. Begining from January 1 and extending to February 15 the plants were watered lightly or kept on the dry side. Following this period of drying and

desiccation, the plants were again watered heavily for six weeks until they again became rather vegetative. Following this, the plants were maintained in optimum growth. In the later part of this second vegetative growth, the plants bloomed and set seed from selfed, crossed and inter-crossed flowers from four varieties. Among other contributory factors to flowering are mentioned: (i) a day length of 11½ hours increased to 12½ hours, (ii) a relative humidity of 75 to 85 percent and (iii) a temperature varying from 70° to 80°F. The building up of carbohydrate reserves is suggested to be responsible for the flowering.

The plants bloom better when trained to a trellis and thus given plenty of air and sunlight.

Another method is described by Miller in which the vines are trained on an upright trellis and cut from ½ to ⅔ across at the base when they have reached a length of 6 or 7 feet. Under this treatment some varieties flowered as early as July.

Studies conducted by Miller in 1929 included a treatment of overwintering the vine cuttings taken in August, transferring them to a greenhouse and planting in spring followed by girdling.

Yet another technique developed by Miller (1939) is the boquet method or the "melting pot technique". Vines bearing flower buds about to open are cut and placed in a nutrient solution of acidified water in a lath house where they develop roots in a few days. They continue to flower and produce seeds and the set is reported to be much higher than in the field. Hawaiian varieties have been induced to flower by this technique.

Probably more significant in its value, particularly in view of the failure of the attempts of Hartman (1947), is the success achieved by Mikell, Miller and Edmond (1948) in inducing flowering in the Jersey type of sweet potato which seldom flowers in the United States. They grafted one of the Jersey varieties, Orange Little Stem on *Ipomoea ruber* and *I. Carnea* rootstocks. The latter do not produce storage organs. The resulting accumulation of carbohydrates is believed to have induced the flowering. Lam and Wadner quoted by Millet (1955) found it possible to induce flowering and seed set in the Jersey type by grafting on morning glory stock, provided they allowed two or more leaves to remain on the stock. If the leaves were removed from the stock, flowering was retarded or inhibited

entirely. They conclude that the leaves develop the hormone 'florigen' which is responsible for flower production. Whittwer quoted by Miller (1955) found that 2, 4-D effectively induced flowering in the Jersey type. Stino and Hassan (1954) working in Egypt found that scions of rarely blooming types produced flowers readily when grafted on to readily blooming types and this has been suggested as indicating a translocation of a flowering stimulus upwards from the stock to the scion. Miller (1937), however, is of the opinion that no such translocation takes place. The flowering, according to him, is due to the accumulation of carbohydrates in the scion and due to the fact that the non-tuber forming rootstock species does not utilise any of the carbohydrates reserves so accumulatec

In Japan, Sigemura *et al* (1938) report of having induced flowering in 27 varieties under artificial short day conditions with a photoperiod of 8-10 hours. Akimoto's experiments (1940) included three methods of accelerating flowering viz. grafting on botanically related tuberous plant, water culture and short day treatments. The water culture treatment is reported to have given the best results. Cross fertilization gave a higher percentage of set than selfing. Sugawara (1940) has reported a similar success with water culture treatment.

Prijampoljskii (1950) obtained some seed at Odessa by treating cuttings with manganese solutions of various concentrations for two to six hours. Edmond and Martin (1946) found length of day most effective in flower and fruit production

Improvement through mutations: Elmer (1938) calls attention to the widespread occurrence of bud mutations in sweet potato varieties and to the consequent need for continued plant selection by the farmer to maintain quality of his stocks. Richard (1939) estimates that on an average one mutation occurs in every 7000 plants. Most of them being retrogressive, he suggests that the skin and flesh colour of all seed potatoes be checked. Miller and Kimbrough (1937) found six mutations in Porto Rico variety, differing mainly in skin and flesh colour. Further rigid selection over a six year period gave rise to a strain known as unit 1 Porto Rico, believed to be the best source of Porto Rico seed available in 1936. About 2000 bushels of this strain were certified in 1936. Carmago (1952) refers to six mutations in Brazil, most of which differ in stem colour while two of them are regarded as distinct improvements on the parents, ranking among the best varieties available for cultivation.

Breeding Investigations: Sampath and Bhanumurthy (1948) conducted preliminary investigations on the hybridization of the sweet potato with six clones differing in the presence or absence of purple colour in the stem, leaves and tubers as well as in the shape of leaves. They obtained four capsules at Coimbatore out of 20 flowers pollinated, and at Bapatla ten capsules out of 180 flowers cross-pollinated. At Bapatla they report that pigmented types gave proportionately more capsules than unpigmented ones. They also noted two lengths of style, one about 14 mm. and the other about 16 mm. and that similar types can be crossed. They verified the heterozygous nature of the parent type by sowing two seeds from one capsule which gave one purple and one green seedling. Because of the high number of chromosomes in this species ($2n = 90$) they doubt if cytogenetical line of improvement will be practicable. Richharia and Ghosh (1954) conducted breeding investigations in Bihar. Detailed studies of seedlings raised showed distinct segregation for incision of lamina, petiole, node and inter-node colour, pubescence on vine, root colour etc. No conclusions have, however, been drawn in view of the limited population.

Work initiated at the Louisiana State University Agricultural Experiment Station by Miller and co-workers had specific aims directed towards not only the improvement of the crop in general but also in increasing the dietetic value in terms of the carotene content and the market value by way of improving the external and internal colour, shape of roots etc.

Methods of Breeding: Edmond and Martin (1946) have given a detailed account of the floral structure of the sweet potato. The flowers open just before, at or immediately after sunrise and close on the same day. The anthers dehisce just before or immediately after the flower opens and the amount of pollen that is shed varies with the seedling or variety. A high humidity is believed to facilitate shedding of the pollen, the stigmatic surface is most receptive between 8-00 A. M. and 10-00 A. M.; the fruit requires a month to attain maturity; most fruits contain one or two seeds and very few contain 3-4 seeds.

Sampath and Bhanumurthi (1948) observe, "All the flowers opened by 8 a. m. with burst anthers and all withered the same day".

Controlled pollination: In selfing and protecting the flowers of the male parent in the crosses, Miller *et al* employed a large paper clip placed on the tip of an "about to open flower" in the late afternoon.

The next morning emasculation of the selected female parent is performed between 5-00 a. m. and crossing between 8-00 and 10-00 a. m. on the same day. In selfed flowers the corolla is closed again with the paper clip. Pill boxes and soda straw have also been used to protect flowers. According to Edmond and Martin (1946) emasculation is done on an "about to open flower" between 2-00 p. m. and 6-00 p. m. Pollination of flowers consists of removing the pill box or straw, applying the pollen, replacing the straw and tagging. Menezes (1953) states that the best time in Brazil to effect emasculation is 16-00 hours, the pollination being performed at the same time on the following day. Richharia and Gosh (1954) emasculated fully developed buds late in the afternoon, covered them with parchment bags and pollinated the following morning between 6 and 10 a. m. They state that the anothers generally burst when the corolla is fully expanded mostly at sunrise. Sampath and Bhanumurthy (1948) have dispensed with emasculation on the grounds that because of self-sterility no emasculation is needed.

Sterility and fertility: Miller (1938) found varietal differences in flowering and setting which he ascribes as due to differences in photoperiodic responses. The earlier part of the optimum time for pollination, namely 7 to 9 a. m. in the spring and 8 to 10 a. m. in the fall seemed to be more conducive to seed setting in selfed flowers. Miller *et al* (1943) evaluated the plants in the nursery as to their fertility level when used as parents. Certain lines were more fertile as female parents than others. Preliminary studies suggested that lack of fertility may be due to the style being deficient in an unknown substance which may initiate pollen germination or it may contain some substance which acts as an inhibitor to pollen germination. They also found considerable difference in plants with regard to ability to produce viable pollen. With the help of this information planned crosses were made using very fertile female and good pollen producing plants as parents, increasing thereby the seed production.

Togari and Kawahara (1942) carried out studies on compatibility relationships in the sweet potato at the Tokyo Agricultural Experiment Station. Approximately 50 varieties were tested and classified into three groups each of which is intrasterile and is fertile in crosses with the other two groups. As shown by the percentage capsule set and seed number per capsule in compatible matings, differences in grade of compatibility were noted in reciprocal crosses between members of the three groups. It is suggested that grades of pollen activity exist among the three groups. The stimulating

action of the pistil upon the pollen also varies; pollen grain germination is almost completely suppressed in selfing, neighbour pollination and intravarietal pollination within each of the varieties designated A, B and C. Germination of pollen grains occurred, however, in the matings A×B, B×C and A×C and their reciprocal crosses. Compatible matings showed variations in the percentage of pollen germination and tube growth, closely corresponding to the variations in the percentage of capsule set and number of seeds per capsule previously observed. In regard to the possibility of inducing pseudo-fertility by means of bud pollination, Togari (1942) observed that since the style of the sweet potato flower does not become receptive until a few hours before anthesis, by which time the pollen fails to germinate bud pollination offers little prospect of overcoming incompatible matings.

In Delhi, Chatterjee and Nagbiswas (1952) found that although the flowers did not set fruit, pollen fertility ranged from 76·5 to 100 percent; the plants appeared to be self-sterile.

Seeds and Sowing: The seeds of selfings and crossings are saved until required for sowing. They are scarified with sulphuric acid and planted in warm moist soil maintained from 75° to 85°F. Richharia and Gosh (1954) report of the failure of germination of seeds soaked in tap water in petri-dishes. Treatment with concentrated sulphuric acid for 15 minutes gave satisfactory germination.

In Louisiana Agricultural Experiment Station about one week after the seedlings appear, they are transplanted in the green house bench or bed. As the seedling grows, cuttings consisting of 3 to 4 nodes are made and planted in the green house or the seedlings allowed to grow and vine cuttings made just before they are set in the field. A single plant thus produces five or six cuttings which will be ready for planting by the third week of May. These in turn produce sufficient seed stock for the production of the plants in the following year.

(To be concluded)