Breeding of Sweet Potato Varieties for High Starch Content and High Yield

Satoshi Sakamoto
Plant Breeder, Kyushu
National Agriculture
Experiment Station
Japan

Abstract

The breeding process of sweet potato varieties for high starch content and high yield involved the selection of parental materials, test of combining ability, cross and seed production, selection of dry matter content in the early stage and selection of starch content and tuberous yield in the late stage. Two varieties were developed for raw material of starch using the above method. One variety used is an introduced variety and the other was developed by the use of wild relatives as parent.

In the future, it is necessary to improve such factors as the ability of sweet potato to photosynthesize, its form for light interception and the rate of distribution from the view point of matter production to get higher yield.

Introduction

After the introduction of sweet potato in Japan about 370 years ago, the cultivated area had spread to major portions of the country in a span of two centuries. The cultivated area of about 150,000 ha in 1880 increased to 440,000 ha in 1949. Although the acreage decreased since 1950, over 300,000 ha were still cultivated for the raw material of starch up to 1965. Because of the low price of sweet potato due to the liberalization of imports, the acreage has been decreasing about 10% per year and eventually becoming 62,000 ha in 1978.

The average yield of tuberous root/ha had been about 12 tons before the 2nd World War and increased to 20 tons at present by the extension of improved varieties and the improvement of cultivation methods.

The main use of sweet potato before the 2nd World War was as food for farmers. While the consumption for food decreased due to the dissolution of the food shortage in 1950, it was mainly used as raw material for starch production at the rate of about 50% in 1963. It began to decrease in 1968, due to the import liberalization of sugar and other raw materials for starch. At present, industrial use of sweet potato starch is about 20% of total production. The trend of consumption is shown in Fig. 1.

The prospects of sweet potato in Japan may seem hopeless, but it is still the main crop for upland fields in the southern part of the country because of its tolerance to typhoon and drought, easy cultivation and suitability for cropping system.

The biggest barrier of sweet potato cultivation in Japan is its competition with the price of imported raw materials for starch such as corn. To stabilize the livelihood of the sweet potato farmer it may be effective to extend to these cultivated areas, sweet potato varieties of high starch content and high yield.

Breeding methods

The starch content of sweet potato is controlled by the additive effects of genes, and the accumulation of high starch genes is considered effective to increase the starch content. In order to succeed in breeding high starch containing varieties, it is necessary to use varieties or strains with high starch content as parents (Sakai, 1964). There is a positive high correlation (+0.848) between dry matter content and starch content (Sakai et al., 1960). It is easy to measure the dry matter content of individuals or strains instead of starch content in the case of selection.

The yield of tuberous roots is controlled by non-additive effects, mainly heterosis effects (Sakai, 1964). It is important to choose the crosses which show high combining ability.

In consideration of the two characters mentioned above, the breeding process of varieties for raw material is described as follows:

1) Selection of parental materials which possess high starch content, good storage ability and resistance to pests and diseases.
2) Test of combining ability for root yield among parental materials.
3) Cross and seed production of promising combinations for practical selection.
4) Selection of dry matter content in the early stage of breeding (1-2 years after seedling).
5) Selection of starch content and yield of tuberous root in the late stage (3-5 years after seedling).

Formerly, only indigenous varieties were used as parents for crosses, but the gene sources of these varieties are limited. Recently, the breeding efficacy has decreased due to the possession of common genes between parental varieties, though it was remarkably high in the early period. Table 1 shows inbreeding coefficient of the improved varieties. The new varieties are higher than the varieties released before 1952.

Accompanied with the change of consumption for food to raw material for starch, many crosses were made from 1957, by the breeding method mentioned before. Among crosses between indigenous varieties that attempt to accumulate the genes of high starch content, the average dry matter of seedling generation became less than that of the leading variety, Norin 2. The starch content of strains selected from the above crosses after self-crossing or sibcrossing are several percent higher than that of the parental varieties. There are many promising strains with high starch content but it is necessary to recover frequently the inbreeding depression of yielding ability by heterosis effects.

On the other hand, introduced foreign varieties and wild relatives were used as gene sources to introduce new superior genes and extend the variation of offspring plant. The introduced varieties and wild relatives have played important roles in the breeding of recent sweet potato varieties.

Whenever wild relatives are used, sweet potato should be used as the recurrent parent in backcrossing to eliminate undesirable characters of wild relatives and accumulate the yielding ability of the sweet potato cultivar. As to the number of backcrosses, one-time backcross seems not enough to transfer the yielding ability of sweet potato varieties, and two-time backcross appear to be good for this purpose. The strains which were backcrossed two times did not exhibit twining slender stems, and their morphological characters were almost similar to those of sweet potato (Sakamoto, 1970, 1976; Kobayashi, 1978). From this result, it is recommended that two-time backcross of sweet potato to wild relatives is necessary to breed economical varieties.

Results

By the breeding method using introduced varieties, high starch content and high yield strains were selected from offsprings of many crosses. "Koganesengan" is a new variety developed from the cross between local variety and an introduced one in 1966. This variety possesses high yielding ability from early stage of growth till late stage and higher starch content than Norin 2, which had been a leading variety for industrial use in the southwestern part of the country. "Koganesengan" shows superior combining ability and will be useful as a parent material.

The collection of wild species related to sweet potato had started in 1955, and quite a lot of species and strains had been tested for crossability with sweet potato and specific characters. Apparently, all wild relatives show non-tuberization and have no economic values by themselves. Therefore, agronomic characters such as yield and quality must be transferred from sweet potato and accumulated in the form of backcross using sweet potato as the recurrent parent. Other characters such as resistance to diseases or pests, tolerance to drought and particular growth habits are introduced from wild relatives. A new cultivar, "Minamiyutaka" was a B2 generation released in 1975 as the first variety developed by using wild relatives in Japan. The breeding process of this variety is shown in Table 2. The starch content of this variety is higher than Norin 2 but a little less than "Koganesengan". The yield is higher than "Koganesengan" in the southern part but not in the northern part. Such difference is considered due to the varietal difference in the response to temperature and this variety needs a higher temperature than "Koganesengan" to get high yield.

The efficacy of high starch content and high yield breeding is shown in Fig. 2 using the materials of performance test in 1957, 1966 and 1976. For a comparison of tuberous yield and starch content, Norin 2 was used as the standard variety. Change of consumption from food to raw material became an important problem in 1957. Yield of the materials of this year was about 20% higher than Norin 2 but starch content was almost similar to Norin 2.

On the other hand, "Koganesengan", high starch content and high yield variety was developed in 1966 and its starch content this year was 3-5% higher than Norin 2 due to its breeding efficacy, but its yield was almost the same as that of Norin 2.

"Minamiyutaka" was released in 1975. Its yield in 1976 increased much and remarkably was higher than that of Norin 2. It is the strain with the highest starch content which is 7% higher than Norin 2, and this fact shows excellent breeding result.

In the future, as it is considered that the strains with higher starch content and higher yield will be desired by both the cultivator and the industry, it is necessary to continue to enlarge gene sources and improve the selection method furthermore.

Breeding for dry matter content

The plant type and form for light-interception should affect the growth of plant and tuberous yield. The construction of community of sweet potato is plain compared with the upright plants, besides, excessive top growth weakens light intensity within the community in the late stage of growth and results in low yield of tuberous root. Direct relationship is not observed between top growth and tuberous root production, but this subject is scarcely discussed from the view point of breeding.

The following experiment using the breeding materials shows the relationship between the top characters at the early stage of growth and root yield at harvest. The materials consisted of 647 strains from 37 crosses in one year after seedling. Plant type, growth habit and growth increment of 50 days after planting were divided visually into bush, prostrate and protractile, weak and strong, bad and good, respectively. Distinct relationship were not observed between plant type and root yield, plant habit and root yield, but there was a positive relation between growth increment and root yield (Yamakawa and Sakamoto, 1978). (Fig. 3)

From the result of this experiment, it can be said that the selection of strains which have a vigorous growth increment in the early stage is effective to breed with high yielding varieties. Besides this selection, it is recommended to select the strains which are of numerous tuber type because a plant of this type is able to increase the tuberous yield easily under desirable conditions and strains which maintain a high ability of tuberization from the early stage of growth till the late stage.

Currently, the breeding method of high yielding varieties mainly puts emphasis on the selection of tuberous yield. The tuberous yield may be affected by three factors, i.e., photosynthesis, respiration and distribution of product to the root. It is difficult to evaluate the role of each factor on the tuberous yield, but it is important to measure easily the yielding ability of many breeding materials. To breed up high yielding varieties, it is necessary to improve the ability of photosynthesis, the form for light-interception and the rate of distribution one by one. When these improved factors are accumulated in one plant, it will become the highest yielding variety. Then, our task of sweet potato breeding will have been completed.

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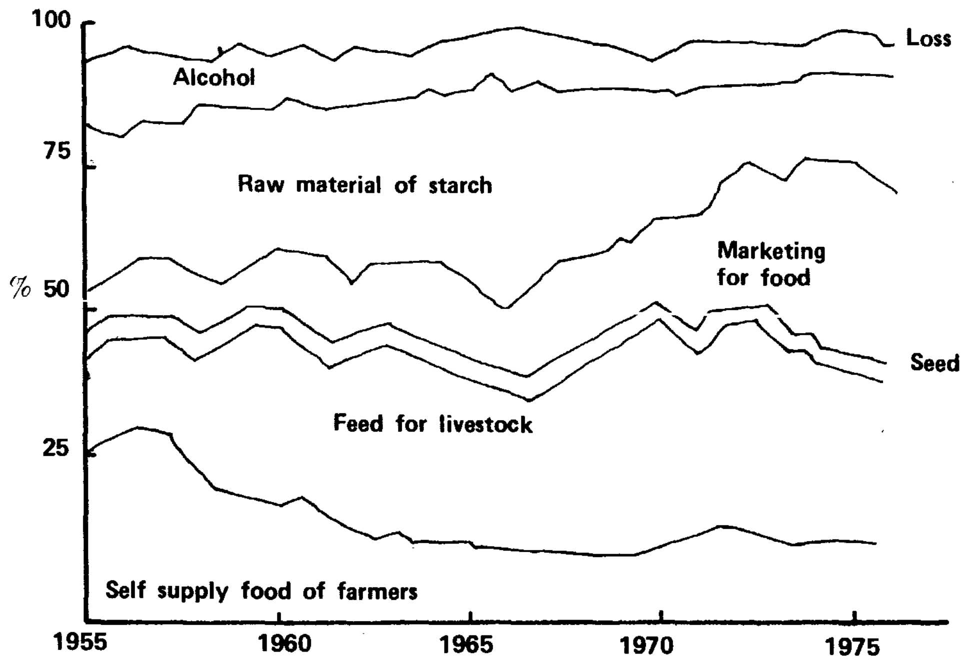

Fig. 1. Trend of consumption of sweet potato in Japan

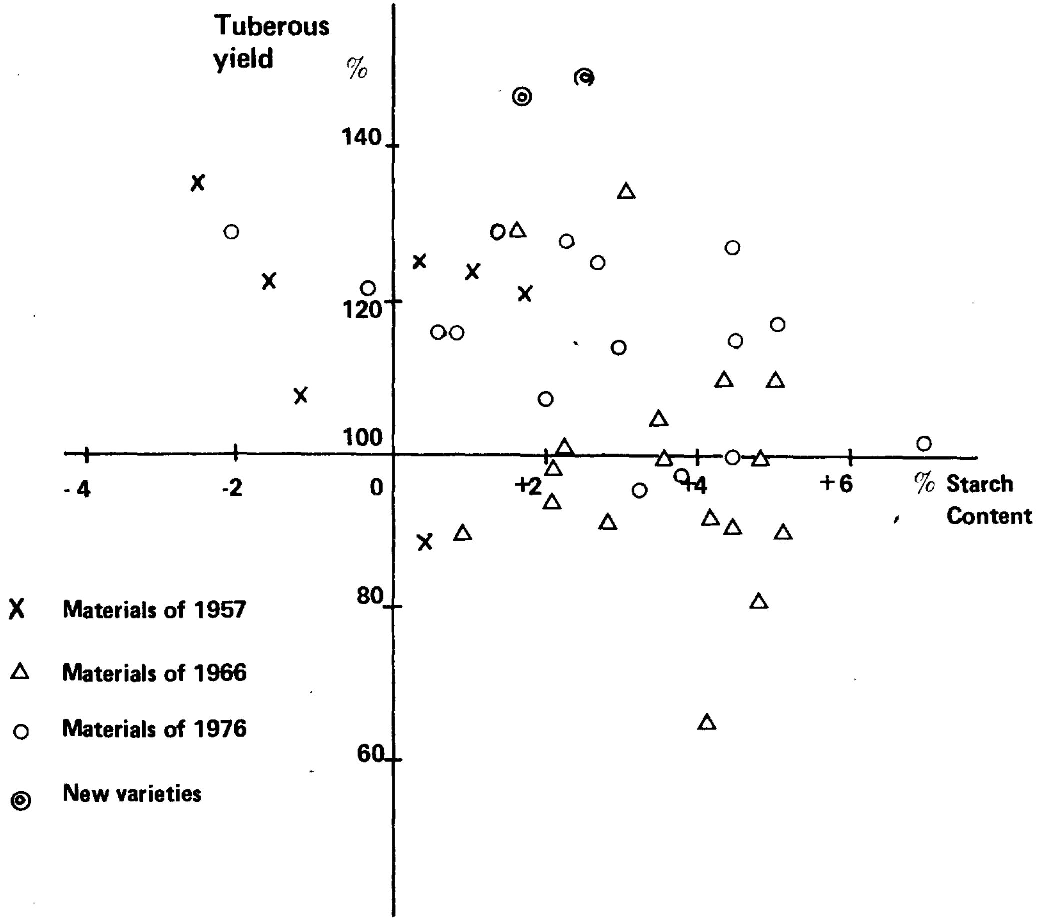

Fig. 2. Comparison of starch content and tuberous yield using the materials of performance test in 1957, 1966 and 1976 with Norin 2

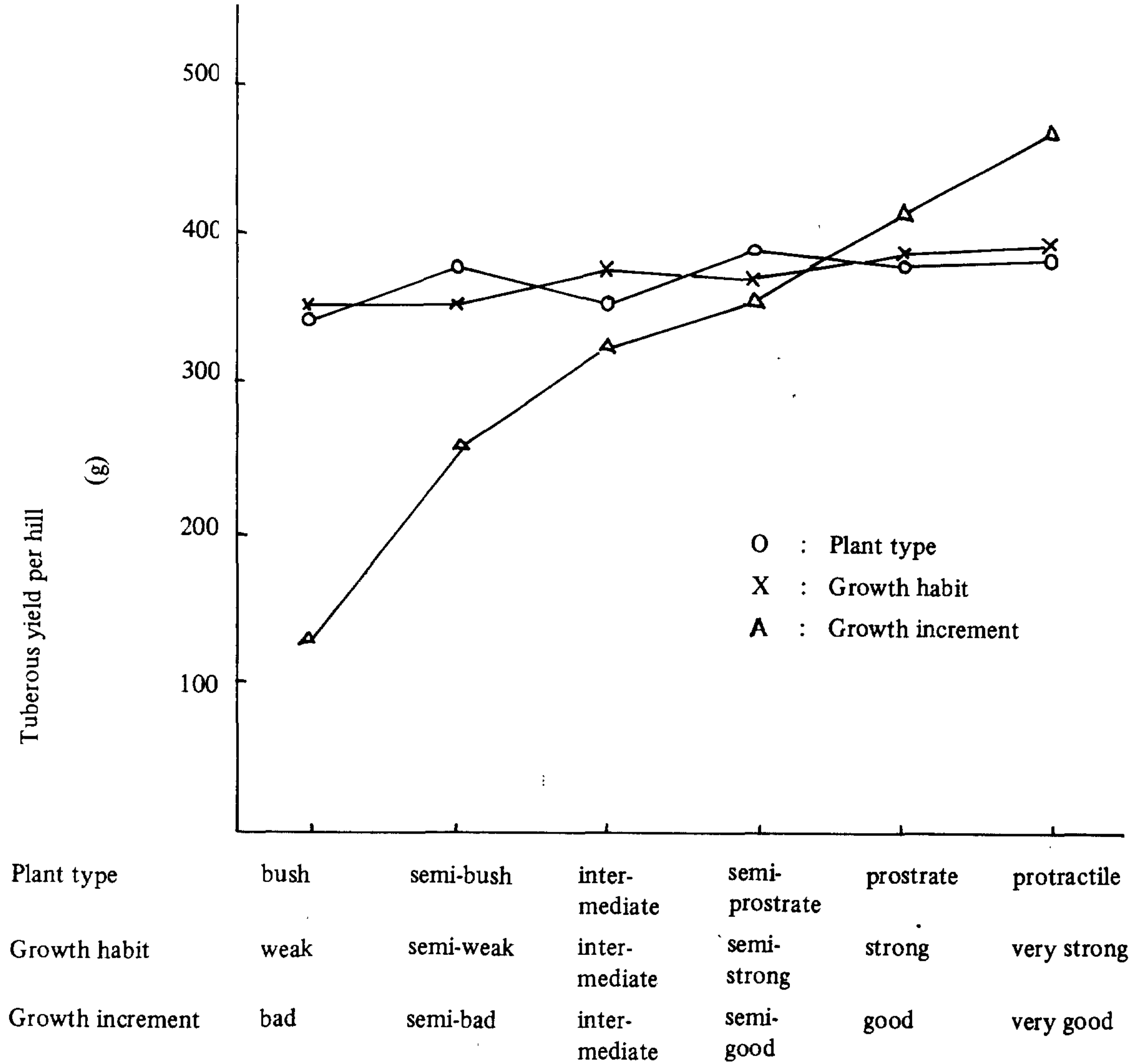

Figure 3. Relationships between top characters at the early growth stage and tuberous yield at the harvest.