Utilization of Random-Mating Population in Sweet Potato Breeding

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Theoretical basis of the breeding method by the use of random-mating population for self-pollinating crops was presented by Hanson in 1959, and the application of this method to sweet potato breeding was proposed by Jones in 1965. The present author considered that this method can be a useful way to have a leap in breeding efficiency of sweet potato, by breaking the *status quo* that the development of excellent varieties has become more and more difficult by usual crossings of existing varieties and lines, including native varieties. Therefore, the author attempted to verify and improve the method proposed by Jones. This study was originally initiated by Kobayashi at the Chugoku National Agricultural Experiment Station in 1968, and succeeded by the present author in 1970. Since then, the study was continued by 1976, with a result of completed procedure of the method, which may offer a guidline in developing sweet potato breeding.

Breeding by the use of random-mating population

This method is to estimate theoretically the gene recombination occurring by repeated intercrossings among individuals of a given population, and apply it to breeding. The actual procedure is to include 4 generations of randomly intermating population without selection into the breeding process. After the completion of the generations without selection, the population is exposed to selections.

At first, 4–30 parental plants are selected. When the number of the parental plants is few, artificial crossing is done to make genes of each parental plant contained equally in the F_1 population. When the number of the parental plants is large, seeds produced by natural crossing are collected in an equal amount from each plant separately and mixed together to grow F_1 population. After the F_1 generation, the population is treated as a randomly intermating population by insect pollination under an isolated condition to proceed its generation. Namely, seeds collected in an equal number from individual plants of the population are mixed, and a part of the mixture is randomly taken to grow the next generation's population consisting of about same number of plants as the preceeding generation. At least up to the 4th generation any selection is not applied in order to break relatively long linkage blocks, so that selection is started at the 5th generation. The population of the 5th and later generations is either transferred as a whole to usual breeding work and exposed to selection, or divided into two groups, the majority and small group, and the majority is transferred to usual breeding work as the material for selection, while the small group is treated as before without selection. However, when promising plants appear in any generation they can be transferred to the customary breeding work.

When no promising plants are found out in several generations after the start of selection, a definite improvement is given to the population after the start of selection (after the 5th generation) according to the breeding objectives. By doing this, the possibility of appearing plants with target characters in later generations becomes higher than the population which proceeded its generation with no improvement. As seeds are produced in a large amount in each generation, a part of the seeds is stored for the use when genetic drift or failure of seed collection may occur in later generations.

The procedure of this method is illustrated in

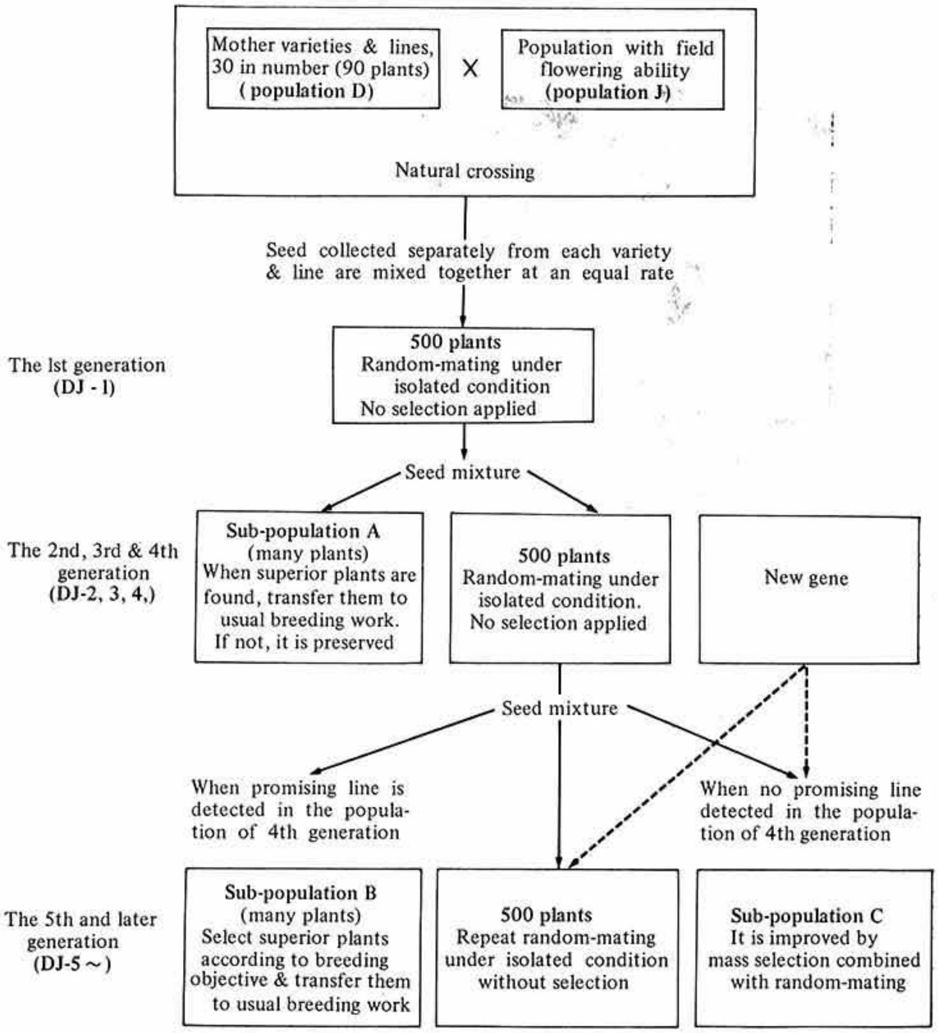

Fig. 1. Sweet potato breeding procedure by the use of random-mating population, developed by the author (1973)

Fig. 1, and a view of random-mating population is shown in Plate 1.

Production of random-mating population

For the production of random-mating population, varieties or lines to be incorporated into the population have to be selected at first. It is an essential pre-requisite that they have genes corresponding to the breeding objectives, and also it is necessary to widen variations, prevent inbreeding depression, and maintain kinds and number of cross-incompatibility specific to sweet potato. The main varieties and lines of Japan are characterized by no flowering in the field under the climatic conditions of Japan. Therefore, it is most important to make the flowering and random-mating in the field condition by insect pollination possible, namely to introduce genetically the "flowering ability in the field (field flowering ability)" into random-mating populations.

The method of genetic introduction of the field flowering ability into the breeding material is as follows. The plants (breeding material) are grafted on a kind of morning glory (Kidachi-

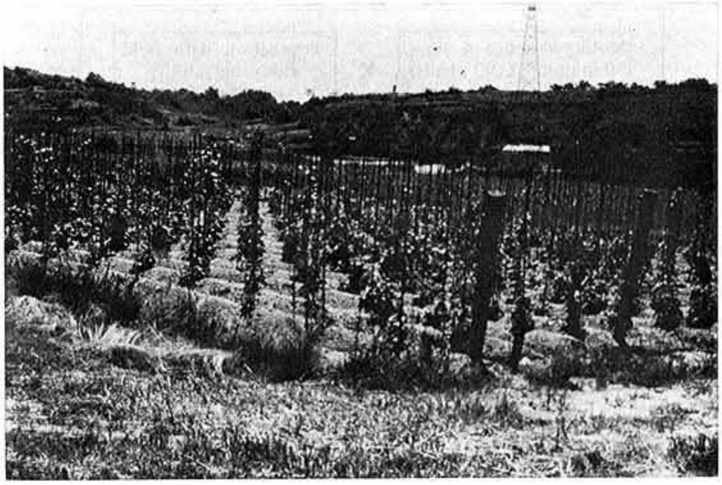

Plate 1. A field of random-mating population

asagao), because the grafting can induce field flowering. Then, the grafted plants are grown between rows of a particular variety which has field flowering ability to make natural crossing by insect pollination between the grafted plants and the field flowering plants. From each variety or line of the breeding material, seeds are collected separately in an equal amount and mixed to form a population. Most of the plants grown from that seeds have the ability to flower and ripen in field conditions.

Thus, the genetic introduction of flowering ability is relatively easy. In general, the extent of the introduction and expression of flowering genes in F_1 was considerably different with varieties or lines, but the flowering ability increased to a high level in the 2nd generation showing no problem practically. In many cases, the flowering ability increased markedly with plants which showed low flowering ability in F_1.

Characteristics of random-mating population

Sweet potato breeding is characterized by F_1-breeding and vegetative propagation: F_1-hybrids directly become varieties. Therefore, it is important in breeding excellent varieties to have wide variations of useful characters in a population. Comparison of variances of main characters between random-mating population at 4 successive generations and corresponding F_1 populations obtained by single crossings of the same parental material as used in the random-mating population showed that the former has greater variances and hence higher possibility of getting promising lines than the latter.

Correlation coefficients among main characters observed at each of the successive generations of the random-mating population were smaller than those of the F_1 populations of single crosses between varieties.

In breeding sweet potato to be used as industrial material and livestock feed, main target is placed on high starch content and high yield. However, a negative correlation exists between them: selection for high yield results in many lines of low starch content, while selection for high starch content tends to induce many lines of low yield. Thus, it is quite difficult to develop varieties with both high starch content and high yield by customary intervarietal crossings. It was found out, however, that the negative correlation between them was broken by repeated random-mating (Table 1). Correlation coefficient between yield of tuberous roots and starch content of the varieties and lines used in the random-mating population was −0.336, while it was reduced to only −0.049 in the random-mating population at the 6th generation, showing no correlation. This result indicates that the repeated random mating gives a possibility to select out lines of high starch content and high yield.

Table 1. Correlation coefficient between total weight of tuberous roots/plant and starch content

Population	Correlation coefficient
DJ-6: Population after repeated random-mating for 6 generations	−0.049
D: Population of varieties and lines used for the parental material of the above random-mating population	−0.336
DJ-1 (A): F_1 population of Chugoku 28×J-population	−0.344
DJ-1 (B): F_1 population of Wannop×J-population	−0.162

Improvement of random-mating population by mass selection

As appearance and its magnitude of various characters of sweet potato are attributed to recombination of genes and heterosis, superior genes can not be judged by phenotype of parental plants. On the other hand, even when superior genes exist in a parent or parents, the averaged evaluation of intervarietal hybrid population becomes low due to formation of homozygote genotypes or accumulation of inferior genes, and the superior genes are apt to be overlooked. Therefore, it must be an effective method to apply mass selection according to the breeding objectives to the random-mating population after its 4th generation, and continue random-mating in the improved population.

As an example, result of three successive mass selections applied to a random-mating population with regard to the total weight of tuberous roots (heavy roots more than 50 g/each+trash roots 10–50 g/each) per plant is shown in Fig. 2. As evident in this figure, the combination of mass selection and random-mating undertaken to improve the population was very effective, showing the increase of about 160 g in total weight of tuberous roots/plant by the mass selection repeated three times, as compared to the population without mass selection. Frequency distribution of total weight of tuberous roots/plant in both populations is given in Fig. 3.

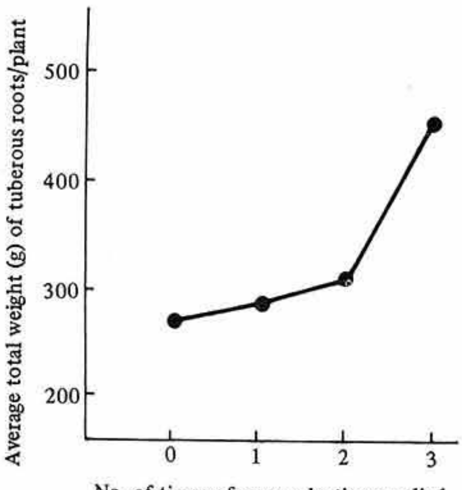

Fig. 2. Effect of repeated mass selection for high yield applied to random-mating population on average total weight of tuberous roots/plant (1976)
Note: Selection rate was 10% each time

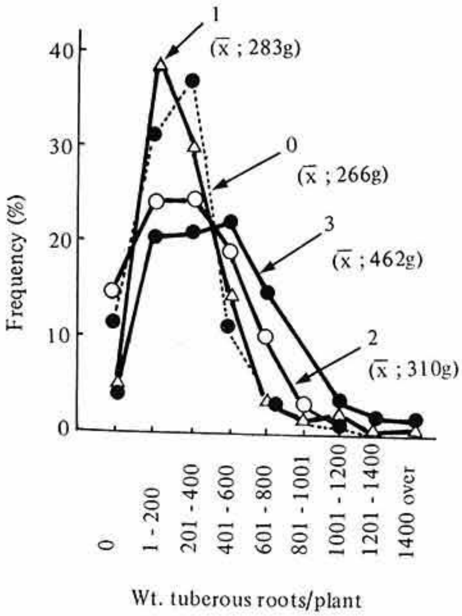

Fig. 3. Effect of repeated mass selection for high yield applied to random-mating population on frequency distribution of total weight of tuberous roots/plant (1976)
Note: Selection rate was 10% each time
0,1,2,3: No. of times of mass selection applied

In the former population, the number of inferior plants not bearing tuberous roots was markedly reduced and that of plants which showed more than 400 g of the total weight of tuberous roots/plant was increased.

Thus, the possibility of appearing superior plants was actually recognized, suggesting that the combination of mass selection and random-mating makes it possible to breed out epochal varieties which can not be expected by the customary inter-varietal crosses.

From the results of this study, it was made clear that this breeding method is very effective in sweet potato breeding. It is expected that the breeding method using random-mating population will further be improved to make it more effective, and contribute to the sweet potato breeding in Japan.

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