Institute of Radiation Breeding

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Location

Ômiya-machi, Naka County, Ibaraki Prefecture.

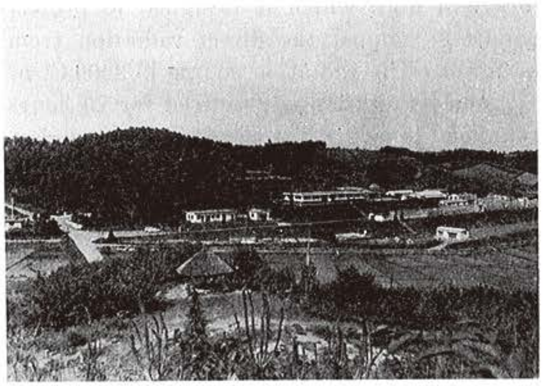

Fig. 1. General view of the Institute

Fig. 2. General view of gamma field

History

The fact that mutation can be induced in living things by irradiation was first published in 1927. In Japan the study of mutation by X-ray irradiation started in 1934, and studies were carried out on the internal radiation of β-ray in plant seeds by the absorption of ^{32}P in 1950.

Gamma rooms using ^{60}Co as radiation source were successively established in some laboratories, as the National Institute of Genetics in 1956 and the National Institute of Agricultural Sciences in 1957 followed by the Forestry Experiment Station, etc.

In addition, a neutron radiation room was set up in the National Institute of Genetics in 1956, and the first atomic reactor for research in Japan was established in the Tokai laboratory, Japan Atomic Energy Research Institute in 1957. Since then all these facilities have been utilized for studies on the induction of mutation in plants.

But gamma rooms are not suitable for irradiating large individuals and for a long-term irradiation. And a demand for the establishment of a gamma field where plants can be irradiated under natural conditions of growth became so strong that its establishment on a three years' program in 1959 was decided following an investigation conducted by the Ministry of Agriculture and Forestry.

The gamma field was planned to be used by national and public research institues, universities and also private researchers as well as the Ministry of Agriculture and Forestry under the administration of the Ministry of Agriculture.

In this way the Institute of Radiation Breeding with a gamma field was inaugurated on April 16, 1960 by a ministerial ordinance as an organization attached to the Ministry of Agriculture and Forestry. The business of the institute includes studies on the method of irradiation for the improvement of crops and forest trees as well as the practice of irradiation by the request of other organizations.

At first importance was attached to the latter work and the institute was so small in scale that it had only two sections—irradiation and research. It has been expanded, however, with the progress of researches and from necessity since and there are 3 laboratories, irradiation, 1st radiation breeding (for annual and biennial plants) and 2nd radiation breeding (for perennial plants), as well as a general affairs section and a business subsection in the institute at present. In addition, some staff members of Tokyo University always stay in the institute to promote research works requested by universities under the wing of the Ministry of Education.

Fig. 3. Laboratories

Fig. 4. Laboratories

Installations and scale

The ground of the institute extends over an area of about 60 ha, most of which is covered with a forest and about 9 ha by a cultivated area. The gamma field has a round shape with the radius of 100 m and an irradiation tower at the center. The irradiating installation is of a suspended type and is supported with 4 legs. The field is surrounded by an earthwork 8 m high which is designed to protect completely against the direct radiation from the tower. The radiation source is 3000 Ci of ^{60}Co, and irradiation is practised for 20 hours from noon to next morning (8 a.m.) every day.

The field is enclosed with an iron fence erected on a circle with its center at the radiation source and with a radius of about 270 m to show off limits, and the area within the radius of 465 m of the radiation source is a restricted area for residence.

A gamma room, gamma hothouse and a gamma phytotron are found in the institute in addition to the gamma field, and all of them are off limits for safety's sake. Office rooms and laboratories are arranged together with the installations and machines necessary for researches outside the restricted area for residence.

Outline of Researches

The operation of the gamma field was begun in summer, 1961, and regular experiments started in 1962. Though the institute has a history of only less than 10 years after that, fairly good results have been obtained there positively gathering information from various foreign countries.

The kinds of plants now under treatment amount to dozens in number, including important forest trees, ordinary crops, vegetables, fruits, mulberry trees and tea plants, etc., and studies are being continued on the methods of breeding, how irradiation induces mutation

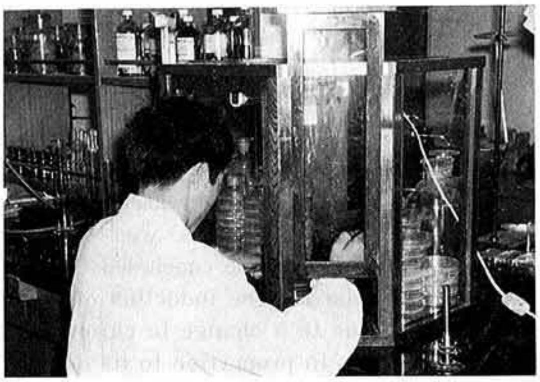

Fig. 5. Experiment of tissue culture

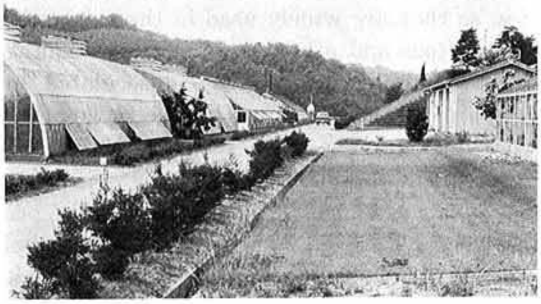

Fig. 6. Greenhouses

and how to test and select the mutants obtained. In recent years various kinds of chemical substances have come into use as mutagens besides radiations, so these substances are also being investigated in comparison with radiation at the institute.

Studies at the institute started from the examination of the dose of radiation, duration of treatment and growing conditions suitable to induce mutation using visible characters as indicators and gave rough ideas about them in a fairly large number of plants.

The studies have extended now to various problems of invisible characters, as the induction of mutation concerning chemical components or resistance to diseases, the mechanism of the heredity of various mutant characters, the effect of radiation on germ cells and the utilization of irradiated pollen to the breeding by crossing.

Several examples of the results recently obtained are topically mentioned below.

1) High-protein mutation in the rice

Japanese waterfield rice generally contains a low percentage of protein and the Norin No. 8 variety is especially so. But when Norin No. 8 was irradiated and the progeny was examined for protein content, it was found that the progeny was made up of various individuals different in the content from less than 80 per cent to about 250 per cent of the value (about 6.5%) in the original variety.

Rice is a staple food of the Japanese, who depend on it for the supply of one-third the amount of protein intake which is originally not sufficient from a nutritional viewpoint.

Therefore, an increase in protein content of rice may be effective for improving the physique of the Japanese. Fortunately, rice protein is of the best quality among the vegetable proteins and is a good nutrient source equal to meat if we can increase the percentage of lysine and a few other amino acids in it. These subjects are now under investigation in cooperation with the National Food Research Institute using the above mentioned irradiated line as material.

The protein content of rice has a tendency to increase with the ripening character of varieties and the small size of rice grains, and is influenced by genetical factors. There is no clue how to change the amino acid composition of rice protein at present. Whether the protein content has relation to the taste of rice or not is unknown.

2) Semi-dwarf bud mutation in the apple

Apple trees are desirable at present not to be too tall for the reason of labor-saving for management and harvesting, and dwarf stocks are introduced in some apple-growing regions.

Dwarf stocks, however, are difficult to be in wide use in apple growing because to use them for making orchards costs very much. Therefore the induction of semi-dwarf bud mutation was attempted by radiation as in the U.S. and Canada and succeeded in obtaining some mutants in such varieties as Iwai, Ralls Janet and Delicious, and their fruits are now under examination. Though these mutants seemed to bear fruits a little smaller in size as compared with the original varieties, the size was within the normal limit and it is probable that such a result is due to overproduction of fruits per area, which indicates that there is a hope for breeding semi-dwarf mutant varieties.

3) Entire-leafed mutation in mulberry

An entire-leafed bud mutation has been obtained from an irradiated tree of the Ichinose variety which is a representative mulberry cultivated in Japan and has lobed leaves. This mutant was heavier in the dry weight of leaves than the original variety, and silkworms fed on its leaves seemed to produce cocoons a little heavier than those with leaves of Ichinose in a preliminary experiment. The mutant, however, appeared to be a little inferior to Ichinose in the growth of shoots for summer or autumn rearing when branches were pruned after the end of spring rearing, showing that further investigations are necessary for its practical use.

4) Bud mutation in rose

In many cases mutants induced in perennial plants are obtained in the form of chimera, and the question arises whether the cutting-back of a chimera branch is suitable or not for obtaining a complete mutant. This question has been settled by a study carried out in roses, and many ornamentally interesting mutants, as high centered pointed and pure yellow lines of the Peace variety with several other lines have been selected from among the mutants obtained in the course of the study.

5) Mutation in chrysanthemum

Many flower color mutants were obtained by irradiating Delaware, a red-flowered foreign chrysanthemum variety, and yellow Delaware, a yellow-flowered natural mutant of Delaware, showing an interesting fact that the changes in these color mutations were in the direction of red—yellow or from both red and yellow to an intermediate without exception as seen in natural mutation. This is noticeable from a viewpoint investigating the mechanism of mutation.

In this study it was also found that the more the dose of radiation was increased, the more the number of chromosomes was changed. From this result it can be concluded that the effect of radiation for the induction of mutation which is due to a change in chromosome number increases in proportion to its dose.

6) Male sterility in tomato

F_1-plants are more vigorous in growth and resistant to diseases than the parental varieties, so they are widely used in the cultivation of tomatoes and other vegtables. The mother plants, however, need to be emasculated for obtaining F_1-hybrids, and this is a laborious work which makes the seeds expensive. If male sterile lines are bred, they will make emasculation unnecessary and benefit the production of F_1-seeds. Therefore, the breeding of male sterile tomato lines was attempted by using radiation.

Tomato plants were irradiated with about 10 KR of γ-rays in divided doses of 1–2 KR a day at about the time when the first flower clusters appear. From among the buds which regenerated from leaf axils about a month after the irradiation vigorous ones are selected for growth and flowerage.

Seeds are collected from these flowers and sowed to grow the progeny, from among which individuals producing no normal pollen are selected and pollinated with the pollen of normal plants to obtain the seeds.

Male sterile lines giving normal and sterile plants in a ratio of 1:1 in the progeny can be bred in this way and maintained by pollinating sterile individuals with pollen of normal plants every generation. Five male sterile lines of three tomato varieties are maintained at the institute at present. In the same way, 70 lines of a wheat variety, two lines of a snapdragon variety and a rape line have been bred as male sterile ones.

7) Interspecific crossing in tomato

Though the interspecific crossing between the cultivated tomato (*Lycopersicum esculentum*) and the wild tomato (*L. peruvianum*) is expected to be effective for increasing the resistance of the former to diseases, hybrid seeds are hardly obtainable because of the cross-incompatibility between the two species. The difficulty, however, could be overcome by the use of radiation. That is, a fairly large number of fertile seeds were obtained when cultivated tomato plants were pollinated with pollen of wild tomatoes irradiated at the time of the formation of the pollen mother cell. Back cross was made in the same way. And the progeny is now undergoing line selection and disease-resistance tests. Some lines thus obtained are nearly immune from virus diseases and closely resemble cultivated tomatoes in appearance.

It is of deep significance that cross-incompatibility which greatly hindered breeding by crossing has been overcome by using radiation.