Gamma Field Symposia

Number 21

BREEDING OF VARIETIES
BY USE OF RADIATIONS

1982

INSTITUTE OF RADIATION BREEDING
NIAR MAFF
Ohmiya-machi, Ibaraki-ken
Japan
BREEDING OF VARIETIES
BY USE OF RADIATIONS

Report of Symposium
held on
July 22-23, 1982

Institute of Radiation Breeding
NIAR MAFF
Ohmiya-machi, Ibaraki-ken
Japan
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Nanto Seed Co., Ltd
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Faculty of Agriculture, University of Tokyo
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FOREWORD

During the past two decades, many important and interesting findings on radiation breeding have been obtained and they have been reported and discussed at this Symposium every year. Following general reviewing at the 20th Anniversary Symposium, another reviewing of successful cases in radiation breeding was planned for the 21st Symposium to share knowledge, to learn practical methods and to discuss for future development of crop improvement by induced mutation.

The program covered many important crop plants from rice, barley, legume and vegetables to vegetatively propagated crops like ornamental plants, root crop, mat rush and apple. Irradiation services at IRB were also reviewed, intending to help discussions on more effective mutation breeding procedures.

To accommodate ever increasing participants, the Symposium was held again at Gozenyama. The Committee hopes that the Symposium will be of help to breeders as well as to scientists in the relevant field. The Committee also wishes to express its hearty thanks to the contributors and to all others who labored for the Symposium.

The Symposium Committee

Yoshio WATANABE, Chairman
Keishi FUJII
Taro FUJII
Takane MATSUO
Tetsuo NAKAJIMA
Toranosuke SHICHIJO
Hirotada YAMAGATA
Hikoyuki YAMAGUCHI
Etsuo AMANO
Hisashi KUKIMURA
Yasuo UKAI
PROGRAM

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Chairman: K. Kushibuchi
Since Reimei: Its use for rice breeding ...................... H. Sato
The breeding of four new mutant varieties by gamma-rays in rice .......... M. Toda
Mutation breeding in malting barley ........................ M. Hiraki

Session II
Chairman: K. Yamakawa
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Mutation breeding in vegetable crops ....................... T. Yamaguchi

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Mutation breedings in ornamental plants — Technique used for
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Induction and use of artificial mutants in sweet potato .............. S. Marumine

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Breeding of Setonami, a new variety of mat rush .................. M. Sadahira
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SINCE REIMEI: ITS USE FOR RICE BREEDING

Hisao Sato

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496 Izumi, Chikugo-shi, Fukuoka-ken, 〒833

In rice, mutation breeding contributed to the development of three commercial cultivars “Reimei” (released in 1966), “Miyamanishiki” (in 1978) and “Miyukimochi” (in 1979). Reimei has once been grown in the wide area of the northern part of Japan for several years. Since then, Reimei has been used as a cross parent due to its advantages of such better characteristics as lodging resistance and high yielding ability to bear nine prominent descendants (Table 1). Mutsuhonami, Hanahikari, Akihikari, Hayanishiki and Hohai inherited the short-stature plant type, lodging resistance and high yielding ability directly from Reimei, and other fours Niigatawase, Mutsukomachi, Mutsukaori and Musashikogane did indirectly from it. These Reimei-descendants shared the big acreage in farmers’ field after their release. For example, Akihikari was planted to 120,000 ha in 1979, the fourth year after release, and ranked fourth or fifth on the list of planted acreage in Japan since then. Niigatawase and Musashikogane are also increasing their planted area year after year (Table 3). The others were grown widely

Table 1. Rice cultivars developed by the use of Reimei and its descendants

<table>
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<tr>
<th>Cultivar</th>
<th>Year released</th>
<th>Line</th>
<th>Breeding station</th>
<th>Cross combination</th>
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<tr>
<td>Mutsuhonami</td>
<td>1973</td>
<td>Fukei 90</td>
<td>Fujisaka</td>
<td>Wakakusa/Reimei*</td>
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<tr>
<td>Hanahikari</td>
<td>1974</td>
<td>Bikei 84</td>
<td>Obanazawa</td>
<td>Stirpe 136/Dewaminori//Dewaminori/3/Reimei*</td>
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<tr>
<td>Akihikari</td>
<td>1976</td>
<td>Fukei 104</td>
<td>Fujisaka</td>
<td>Toyonishiki/Reimei*</td>
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<td>Hayahikari</td>
<td>1976</td>
<td>Ouu 282</td>
<td>Tohoku</td>
<td>Reimei*/Toyonishiki</td>
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<td>Hohai</td>
<td>1976</td>
<td>Aokei 77</td>
<td>Aomori</td>
<td>Kojyonishiki/Reimei*</td>
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<tr>
<td>Niigatawase</td>
<td>1979</td>
<td>Niigata 16</td>
<td>Niigata</td>
<td>Fukei 91*/Naga 60</td>
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<tr>
<td>Mutsukomachi</td>
<td>1981</td>
<td>Aokei 84</td>
<td>Aomori</td>
<td>Mutsunishiki/Akihikari*</td>
</tr>
<tr>
<td>Mutsukaori</td>
<td>1981</td>
<td>Aokei 85</td>
<td>Aomori</td>
<td>Mutsunishiki/Akihikari*</td>
</tr>
<tr>
<td>Musashikogane</td>
<td>1981</td>
<td>Tamakei 67</td>
<td>Saitama</td>
<td>Tamakei 56*/Aichi 21</td>
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* Reimei or its descendant line.
Table 2. Rice cultivars developed by the use of mutants other than Reimei

<table>
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<tr>
<th>Cultivar</th>
<th>Year released</th>
<th>Breeding station</th>
<th>Parental mutant (Original variety)</th>
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<tr>
<td>Hyokeisake 18</td>
<td>1972</td>
<td>Hyogo</td>
<td>IM 106 (Norin 8)</td>
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<tr>
<td>Kagahikari</td>
<td>1973</td>
<td>Ishikawa</td>
<td>R 6-1 (Koshihikari)</td>
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<tr>
<td>Fujihikari</td>
<td>1977</td>
<td>Chugoku</td>
<td>R 151 (Koshihikari), Fupei 71 (Fujiminori)</td>
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<tr>
<td>Nadahikari</td>
<td>1977</td>
<td>Hyogo</td>
<td>Hyokeisake 18-IM 106 (Norin 8)</td>
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<td>Sachiminori</td>
<td>1978</td>
<td>Hokuriku</td>
<td>R 4-B (Pi. No. 4)</td>
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<td>Katsurawase</td>
<td>1978</td>
<td>Kagoshima</td>
<td>Fupei 71 (Fujiminori)</td>
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<td>Miyanishiki</td>
<td>1978</td>
<td>Miyazaki</td>
<td>Kanto 77 (Koshihikari)</td>
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<tr>
<td>Mineasahi</td>
<td>1980</td>
<td>Aichi-sankan</td>
<td>Kanto 77 (Koshihikari)</td>
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also due to their excellent traits.

Reimei had a unique history before and after its development. The original cultivar “Fujiminori” had a long culm, but was relatively resistant to lodging and secured high yield even under the heavy fertilizer application. It carried the high level of resistance to blast disease and low temperature, and the wide adaptability to various environments. For three years from 1967 through 1969, Fujiminori was proud of the first rank of the wide growing area. It was planted to 210,000 ha in 1968. Although Fujiminori had many advantageous characteristics, mutation breeding suggested more promisingly that the shortening in culm length of Fujiminori would enhance the lodging resistance and the yielding ability. After the seed irradiation of Fujiminori with 20 kR of γ-ray, several short-culmed and lodging resistant mutants were selected and one of the elite lines was named Reimei.

Reimei was 15 cm shorter in culm length and much more strongly resistant to lodging than Fujiminori, and maintained almost similar levels for other favorable traits of Fujiminori (Table 4). Substantially, Reimei outyielded Fujiminori in many experiment plots under heavier fertilizer inputs because of its superiority for every trait. Soon after the release of Reimei, farmers replaced Fujiminori and other cultivars by Reimei in their paddy fields to be planted, and Reimei’s planted area increased to 141,000 ha (5.0% of the total area 2,825,000 ha) in 1969.

Since that time, the surplus of rice production over commercial demand caused the change of breeding objectives to be focused on the more excellent grain and eating quality. Reimei had been continuously grown in wide acreage because of its high productivity, and breeders extensively used Reimei as for a cross parent to transmit the short-stature and lodging resistance from Reimei to those cultivars with better grain and
Table 3. Maximum planted acreage of cultivars

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>Area planted in ha (Year)</th>
<th>Prefecture</th>
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<tbody>
<tr>
<td>Mutsuhonami</td>
<td>9,769 (1975)</td>
<td>Aomori</td>
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<td>Hanahikari</td>
<td>11,782 (1977)</td>
<td>Yamagata</td>
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<td>Akihikari</td>
<td>119,944 (1979)</td>
<td>Aomori and others</td>
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<td>Hayahikari</td>
<td>6,345 (1978)</td>
<td>Chiba</td>
</tr>
<tr>
<td>Hohai</td>
<td>43 (1980)</td>
<td>Aomori</td>
</tr>
<tr>
<td>Niigatawase</td>
<td>18,930 (1981)</td>
<td>Niigata</td>
</tr>
<tr>
<td>Mutsukaori</td>
<td>3,678 (1981)</td>
<td>Aomori</td>
</tr>
<tr>
<td>Musashikogane</td>
<td>201 (1981)</td>
<td>Saitama</td>
</tr>
<tr>
<td>Hyokeisake 18</td>
<td>80 (1972)</td>
<td>Hyogo</td>
</tr>
<tr>
<td>Kagahikari</td>
<td>11,333 (1977)</td>
<td>Ishikawa</td>
</tr>
<tr>
<td>Fujihikari</td>
<td>151 (1978)</td>
<td>Shizuoka</td>
</tr>
<tr>
<td>Nadahikari</td>
<td>30 (1977)</td>
<td>Hyogo</td>
</tr>
<tr>
<td>Sachiminori</td>
<td>1,398 (1981)</td>
<td>Wakayama</td>
</tr>
<tr>
<td>Katsurawase</td>
<td>991 (1981)</td>
<td>Kochi</td>
</tr>
<tr>
<td>Miyanishiki</td>
<td>74 (1978)</td>
<td>Miyazaki</td>
</tr>
</tbody>
</table>

eating quality. The attempts of varietal improvement succeeded as shown in Table 1.

The research works revealed that recessive mutation of a single major gene and a few minor genes (modifiers) for culm length occurred in Fujiminori and resulted in the short stature of Reimei, 15 cm shorter than the original Fujiminori. Reimei's short stature gene is considered possibly to be allelic to the semidwarf gene in Dee-geo-woo-

Table 4. Several characteristics of Reimei, Fujiminori and the descendants of Reimei

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>Heading date</th>
<th>Culm length in cm</th>
<th>Panicle length in cm</th>
<th>Panicle number per m²</th>
<th>Yield in kg per 10a</th>
<th>Grain quality</th>
<th>Resistance to blast</th>
<th>Resistance to low temp.</th>
<th>Resistance to lodging</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fujiminori</td>
<td>Aug. 4</td>
<td>89</td>
<td>19.2</td>
<td>205</td>
<td>593</td>
<td>4</td>
<td>2</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Reimei</td>
<td>Aug. 5</td>
<td>73</td>
<td>18.8</td>
<td>329</td>
<td>572</td>
<td>4</td>
<td>2</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Mutsuhonami</td>
<td>Aug. 6</td>
<td>76</td>
<td>17.6</td>
<td>377</td>
<td>582</td>
<td>3</td>
<td>4</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Akihikari</td>
<td>Aug. 5</td>
<td>76</td>
<td>17.2</td>
<td>346</td>
<td>614</td>
<td>2</td>
<td>3</td>
<td>2</td>
<td>2</td>
</tr>
</tbody>
</table>

Grade: Grain quality: 1 (excellent) - - - 9 (bad)
Resistance: 1 (resistant) - - - 9 (susceptible)
and other semidwarf varieties. The simple inheritance of the short stature of Reimei supported the relative easiness of transferring the short, stiff culm and the high yielding ability from Reimei to other genetic materials. These Reimei's favorable characteristics seemed to be comparatively difficult to combine with better grain and eating quality which are controlled by complicated genetic systems. However, the breeding efforts showed the fruitful results of combining those favorable characteristics into new cultivars such as Mutsuonami, Hanahikari, Akihikari, Hayanishiki and so on (Table 1)

Table 5. Local elite lines developed by the use of mutants

<table>
<thead>
<tr>
<th>Breeding station</th>
<th>Number of elite lines</th>
<th>Mutant other than Reimei</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Direct use</td>
<td>Indirect use</td>
</tr>
<tr>
<td>National</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fujisaka</td>
<td>19 (19)*</td>
<td>13 (13)</td>
</tr>
<tr>
<td>Tohoku</td>
<td>8 ( 7)</td>
<td>11 (11)</td>
</tr>
<tr>
<td>Furukawa</td>
<td>2 ( 2)</td>
<td>2 ( 2)</td>
</tr>
<tr>
<td>Hokuriku</td>
<td>5 ( 2)</td>
<td>4 ( 1)</td>
</tr>
<tr>
<td>Fukui</td>
<td>3 ( 3)</td>
<td>3 ( 3)</td>
</tr>
<tr>
<td>Aichi-sankan</td>
<td>3 ( 0)</td>
<td>4 ( 0)</td>
</tr>
<tr>
<td>Chugoku</td>
<td>4 ( 0)</td>
<td>6 ( 3)</td>
</tr>
<tr>
<td>Kagoshima</td>
<td>2 ( 1)</td>
<td>6 ( 1)</td>
</tr>
<tr>
<td>Prefectural</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aomori</td>
<td>5 ( 5)</td>
<td>12 (12)</td>
</tr>
<tr>
<td>Obanazawa</td>
<td>6 ( 6)</td>
<td>12 (12)</td>
</tr>
<tr>
<td>Shonai</td>
<td>3 ( 3)</td>
<td>4 ( 3)</td>
</tr>
<tr>
<td>Niigata</td>
<td>1 ( 1)</td>
<td>1 ( 1)</td>
</tr>
<tr>
<td>Ishikawa</td>
<td>4 ( 2)</td>
<td>5 ( 0)</td>
</tr>
<tr>
<td>Saitama</td>
<td>2 ( 2)</td>
<td>4 ( 4)</td>
</tr>
<tr>
<td>Nagano</td>
<td>7 ( 6)</td>
<td>9 ( 5)</td>
</tr>
<tr>
<td>Shizuoka</td>
<td>3 ( 0)</td>
<td>3 ( 0)</td>
</tr>
<tr>
<td>Gifu</td>
<td>14 (14)</td>
<td>0 ( 0)</td>
</tr>
<tr>
<td>Aichi</td>
<td>0 ( 0)</td>
<td>4 ( 1)</td>
</tr>
<tr>
<td>Hyogo</td>
<td>3 ( 0)</td>
<td>2 ( 0)</td>
</tr>
<tr>
<td>Miyazaki</td>
<td>5 ( 2)</td>
<td>2 ( 1)</td>
</tr>
<tr>
<td>Total</td>
<td>99 (75)</td>
<td>107 (73)</td>
</tr>
</tbody>
</table>

* Number of lines developed by the use of Reimei and its descendants.
and Table 4).

Since Reimei was released for growing in 1966 as the first mutation breeding cultivar in Japan, the direction of indirect mutation breeding that aimed at shorter culm, characteristic trait of Reimei, successfully resulted in developing nine cultivars by the use of Reimei (Table 1) and also of eight cultivars by the use of other mutants (Table 2). Breeding stations in recent years intensified their breeding efforts of using the short-stature plant type to develop new elite lines. Local elite lines and cultivars which were developed since 1970 numbered 206, of which 148 lines were resulted from the breeding efforts either by direct use of Reimei itself or by indirect use of Reimei's descendants as a cross parent. The proportion of this class amounted to as high as 72% of the total number. Especially breeding stations in the northern cool area of Japan intensively used Reimei and its descendants as breeding materials for high yield. These stations intently used them because Reimei and its many descendants were well adaptive to that area and surpassed in raising favorable progenies for breeders selection. Reimei's plant type will surely be inherited to a number of elite lines and cultivars in the future.

Eight cultivars were released from mutation breeding in which mutants other than Reimei were used as a breeding materials for short culm (Table 2). Such varieties as Koshihikari, Norin 8 and Pi. No. 4 which have excellent grain and eating quality, were easy to lodge under the heavy fertilizer levels to get high yield. Short-culm mutants were selected from those varieties expecting to transmit favorable plant type with

<table>
<thead>
<tr>
<th>Year</th>
<th>Number of cultivars registered</th>
<th>Number of cultivars developed by the use of mutants</th>
</tr>
</thead>
<tbody>
<tr>
<td>1973</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>1974</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td>1975</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>1976</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>1977</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>1978</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>1979</td>
<td>8</td>
<td>0</td>
</tr>
<tr>
<td>1980</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>1981</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>1982</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>39</td>
<td>7 (17.9%)</td>
</tr>
</tbody>
</table>
better grain and eating quality to progenies, and were proved to be effective as shown in Table 2. Those varietal improvement proved the possible usefulness of the short stature of not only Reimei but also of those mutants. As the results, seven cultivars which were developed by the indirect use of mutants in breeding shared 18% in the total number of cultivars released by the Japanese Ministry of Agriculture, Forestry and Fisheries during recent ten years. This number also suggests the significance of induced mutants including Reimei and others, in the present and future rice breeding. Hereafter, mutation breeding should focus its efforts on the indirect use of mutated traits such as short stature which were already incorporated in varieties or elite lines, as well as the direct use, i.e., selection of useful mutants from the mutagen-treated materials.
THE BREEDING OF FOUR NEW MUTANT VARIETIES BY GAMMA–RAYS IN RICE

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Introduction

In a recent decade, we were able to obtain many mutant strains by the irradiation of gamma-rays in rice (Toda 1979).

This report deals with the principal procedures of breeding of four new mutant varieties, the important characteristics of these mutant varieties, and the discussions of some practical problems on radiation breeding.

Materials and Methods

1) Varieties used

Original varieties “TOYONISHIKI”, “TAKANENISHIKI”, “REIMEI” and “TOYONISHIKI” again were adopted to breed new mutant varieties “MIYUKI-MOCHI”, “MIYAMANISHIKI”, “SHIRAKABANISHIKI” and “SHINANOSAKIGAKE” respectively.

2) Quantity of seed irradiated

100 gram of dry seed of each of the original variety was prepared for an irradiation.

3) Dose used

An original variety “TAKANENISHIKI” was irradiated with the exposure of 30 kR of gamma-rays, the others with the exposure of 20 kR. We trusted the irradiation to “Institute of Radiation Breeding, NIAS, MAFF”.

4) Transplanting of young seedling or direct sowing of seed

In only $M_2$ of breeding “MIYAMANISHIKI”, seeds were sown directly into the field with 30 cm × 2 cm sowing space. In the other cases, the method of transplanting young seedling was used. In $M_1$, the seedlings transplanted as two plants to a hill, with 30 cm × 10 cm planting space. In $M_2$ and following generations, they were transplanted as one plant to a hill, 30 cm × 15 cm planting space.

5) Raising and selection of each generation

(1) $M_1$

In the case of breeding “MIYUKI-MOCHI”, the panicle carrying waxy grains
among all of \( M_1 \) panicles was already sought for. In the other cases, seeds for next generation were obtained in accordance with the method of collecting a grain from a panicle.

(2) \( M_2 \)

In the breeding of “MIYUKI-MOCHI”, \( M_2 \) strains were raised by the panicle-to-row method and selected by the method of pedigree selection. In the breeding of the others, \( M_2 \) plants were raised and screened by the method of plant selection.

(3) \( M_3 \) and following generations

The conventional pedigree method was adopted.

6) Detection of mutation

(1) The method of finding out waxy panicle

In order to enhance the efficiency of finding out of mutated panicles, about 350 \( M_1 \) panicles from 50 plants were collected and tied up in a bundle. A bundle may scarcely include two mutated panicles, because of the very low frequency. Grains of each of the bundle were threshed in bulk, and waxy grains were sought for. The few waxy grains obtained from a bundle is considered to be governed by a homo-recessive mutated gene.

(2) The method of finding out plant with superior white-core grain

Grains of each of \( M_2 \) plant were threshed. The hulled rices obtained were investigated on characters such as white-coreness and size of grain.

(3) The method of finding out plant with large grain

Grains of each of \( M_2 \) plant were threshed. The hulled rices obtained were investigated for size of grain.

Results and Discussions

1) Breeding of waxy variety “MIYUKI-MOCHI”

Waxy nature is an endosperm character which is visible and easily distinguishable. Furthermore, an expression of waxy character is hardly influenced by environments. Accordingly, screening of waxy grains from grains produced by \( M_1 \) population could be very easily done. If an excellent non-waxy variety in a given region is converted to a waxy variety, without changes of important agronomic characters, the induced mutant waxy variety is expected to have the surpassing feature in the region.

The procedures of breeding of a new waxy variety “MIYUKI-MOCHI” are shown in Table 1. Dry seed of an original non-waxy variety “TOYONISHIKI” was irradiated with the exposure of 20 kR of gamma-rays. All the panicles, about 20,000 in number, produced on about 3,000 \( M_1 \) plants were investigated. Two \( M_1 \) panicles carrying waxy
FOUR NEW MUTANT VARIETIES IN RICE

Table 1. Procedures of breeding of the new waxy mutant variety “MIYUKI-MOCHI”

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Original var.</td>
<td>“TOYONISHIKI”</td>
</tr>
<tr>
<td>Irradiation</td>
<td>20 kR to 3,800 seeds in May 1973</td>
</tr>
<tr>
<td>M1</td>
<td>2,940 transplanted plants (1,470 transplanted hills)</td>
</tr>
<tr>
<td></td>
<td>19,698 harvested panicles</td>
</tr>
<tr>
<td></td>
<td>2 selected panicles</td>
</tr>
<tr>
<td>M2</td>
<td>2 raised strains (panicle-to-row method)</td>
</tr>
<tr>
<td>M3</td>
<td>Preliminary yielding test as strain no. 15-1</td>
</tr>
<tr>
<td>M4, M5 and M6</td>
<td>Yielding test as strain name “Shinho-Mochi No. 3”</td>
</tr>
<tr>
<td>Register</td>
<td>Commercial variety “MIYUKI-MOCHI” in Feb. 1979</td>
</tr>
</tbody>
</table>

grains were found among them. The handling of materials in M2 and following generations was conducted in accordance with the ordinary panicle of plant-to-row method.

Agronomic characteristics of the new waxy variety are presented in Table 2. The new waxy variety possesses the three excellent characteristics which are a good adaptability to wide area, high resistance to rice blast, and high resistance to lodging, all derived from the original non-waxy variety. However, yield of the new variety was reduced by 8% in comparison with the original variety. The decrease of yield was caused by the decrease of 1,000 grain weight which was 91% of that of the original variety. The other characteristics were almost the same as those of the original variety.

The frequency of M1 panicles carrying waxy grains was 1 per 10,000 panicles (Table 1). Accordingly, the detection of mutated panicles in M1 would have been very difficult if every single panicle had been investigated. But our surveying method was extremely efficient. On the other hand, the preliminary yielding test was able to conduct already in M3. And characteristics of the new variety were almost the same as those of the original variety, except for the decrease of yield due to the decrease

Table 2. Agronomic characteristics of the new waxy mutant variety “MIYUKI-MOCHI” and its original non-waxy variety “TOYONISHIKI” (1976-1978)

<table>
<thead>
<tr>
<th></th>
<th>Date of heading</th>
<th>Length of culm cm</th>
<th>Length of panicle cm</th>
<th>No. of panicles per m²</th>
<th>Yield per kg</th>
<th>Weight of 1,000 grains</th>
<th>Resistance to lodging</th>
<th>Resistance to blast</th>
</tr>
</thead>
<tbody>
<tr>
<td>Original var.</td>
<td>7 Aug.</td>
<td>85</td>
<td>20.2</td>
<td>353</td>
<td>66</td>
<td>21.5</td>
<td>high</td>
<td>high</td>
</tr>
<tr>
<td>New var.</td>
<td>7 Aug.</td>
<td>84</td>
<td>20.4</td>
<td>338</td>
<td>61</td>
<td>19.6</td>
<td>high</td>
<td>high</td>
</tr>
</tbody>
</table>
of 1,000 grain weight. Thus, the mutation breeding of waxy variety by inducing mutation in non-waxy variety is thought to be more efficient than the hybrid breeding in which labour, time and experimental field are greatly required. However, there is a trouble in that the new waxy variety is not distinguishable externally from the original non-waxy one, because of the morphological homogeneity between the two varieties.

It has been reported that an increase of the mutation frequency was significantly greater than the power 1 of the dose (Gaul 1961, Yamashita 1976). On the other hand, Survival, growth and fertility in M₁ are also very important for the program of practical breeding. The dose of 20 kR of gamma-rays is seemed to be enough as a minimum dose, because of bringing high survival, good growth, medium fertility and suitable mutation frequency.

The waxy grains sown in M₂ were hulled rice from which a glumes were removed. In this breeding, the hulled rice of a strain out of two strains did not germinated. The new method for stable germination of the hulled rice is immediately necessary.

The raising of M₁ plant was conducted with close spacing, based on a working hypothesis on diplontic selection (Gaul 1961). Studies on relationship between tiller and mutation in rice plant will be necessary for the increase of mutation efficiency.

2) Breeding of “SAKA-MAI” variety “MIYAMANISHIKI”

“SAKA-MAI” is a group of rice varieties especially suitable for “SAKE” brewing. Grain for “SAKE” brewing is generally required to possess the following three characteristics, firstly, large grain as large as possible, secondly, high frequency of white-core grains up to nearly 100%, thirdly, optimum white-core size between 60% and 70% of whole grain. An original variety “TAKANENISHIKI” possesses small grain and low frequency of grains with good white-core.

The procedures of breeding of a new “SAKA-MAI” variety “MIYAMANISHIKI” are shown in Table 3. Dry seed of an original “SAKA-MAI” variety “TAKANENISHIKI” was irradiated with the exposure of 30 kR of gamma-rays. All of the about 6,000 panicles from 850 M₁ plants were harvested. Then, 3,746 grains, one grain from each of fertile panicles were collected for M₂ screening. These grains were sown directly into the field, and all the 2,562 plants were harvested. 30 plants with good white-coreness were taken, and 5 strains out of these 30 ones raised in M₃ were promising. 1 strain was selected in the following generations.

Table 4 shows characteristics of the new variety. Yield was measured as weight of grains after sieving by the screen with slit of 1.7 mm and 2 mm respectively. 1.7 mm-yield was almost the same in both the new variety and the original one. Because, the increase of size of grain in the new variety was unfavorably accompanied with the decrease of number of panicle per m². However, relative 2 mm-yield of the new variety to the original one was 114%, and 1,000 grain weight of the new variety was
Table 3. Procedures of breeding of the new “SAKA-MAI” mutant variety “MIYAMANISHIKI”

<table>
<thead>
<tr>
<th>Original var.</th>
<th>“TAKANENISHIKI”</th>
</tr>
</thead>
<tbody>
<tr>
<td>Irradiation</td>
<td>30 kR to 3,500 seeds in Apr. 1972</td>
</tr>
<tr>
<td>M₁</td>
<td>1,500 transplanted plants</td>
</tr>
<tr>
<td></td>
<td>850 harvested plants (6,290 harvested panicles)</td>
</tr>
<tr>
<td></td>
<td>3,746 collected seeds (one grain from each panicle)</td>
</tr>
<tr>
<td>M₂</td>
<td>3,746 sown seeds</td>
</tr>
<tr>
<td></td>
<td>2,562 harvested plants</td>
</tr>
<tr>
<td></td>
<td>30 selected plants</td>
</tr>
<tr>
<td>M₃</td>
<td>30 raised strains (plant-to-row method)</td>
</tr>
<tr>
<td></td>
<td>5 selected strains</td>
</tr>
<tr>
<td>M₄ and M₅</td>
<td>Preliminary yielding test as strain no. 11-30</td>
</tr>
<tr>
<td>Register</td>
<td>Yielding test as strain name “Shinho-Sake No. 1”</td>
</tr>
<tr>
<td></td>
<td>Commercial variety “MIYAMANISHIKI” in May 1978</td>
</tr>
</tbody>
</table>

Table 4. Agronomic characteristics of the new “SAKA-MAI” mutant variety “MIYAMANISHIKI” and its original “SAKA-MAI” variety “TAKANENISHIKI” (1975-1977)

<table>
<thead>
<tr>
<th></th>
<th>Date of heading</th>
<th>Length of culm cm</th>
<th>Length of panicle cm</th>
<th>No. of panicles per m²</th>
<th>Yield per are kg</th>
<th>Weight of 1,000 grains g</th>
<th>Frequency of white-core grains %</th>
<th>Size of white-core %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Original var.</td>
<td>1 Aug. 94</td>
<td>21.9</td>
<td>335</td>
<td>50</td>
<td>23.4</td>
<td>47</td>
<td>48</td>
<td></td>
</tr>
<tr>
<td>New var.</td>
<td>1 Aug. 94</td>
<td>21.6</td>
<td>299</td>
<td>57</td>
<td>25.7</td>
<td>69</td>
<td>61</td>
<td></td>
</tr>
</tbody>
</table>

heavier by 10% than of the original one. Therefore, the increase of 2 mm-yield might be mainly due to increase of 1,000 grain weight. Frequency of grain with white-core and size of white-core were 1.5 times and 1.3 times as large as those of the original variety respectively. The other characteristics are seemed to be almost the same as those of the original variety.

In M₁, the frequency of germination, raised seedling and harvested plant were about 50%, 40% and 25% respectively (from Table 3). The results suggest that the exposure of 30 kR would be too much in practical breeding, if the raising of seedling and the management of the field were not very well.

In M₂, grains obtained from M₁ panicle sown directly into field. Frequency of harvested plant was 70% (Table 3). The result indicated that the direct sowing might
not be convenient for radiation breeding, because of inferior germination.

3) Breeding of “SAKA-MAI” variety “SHIRAKABANISHIKI”

For purpose of breeding of good “SAKA-MAI” variety in the cold region of NAGANO-KEN, dry seed of an original non-“SAKA-MAI” variety “REIMEI” with short culm and high resistance to cold was irradiated with exposure of 20 kR of gamma-rays. Table 5 shows the procedures of breeding of a new “SAKA-MAI” variety “SHIRAKABANISHIKI”. About 20,000 panicles from 3,170 M₁ plants were harvested. And about 16,000 grains, one grain from each of fertile panicle, were collected. 6,000 grains out of the grains thus collected from M₁ plants were sown into the nursery. 5,394 M₂ plants were transplanted and harvested. 3 plants showing long culm, large grain and good white-coreness were selected. 3 strains in M₃ were raised following the ordinary pedigree method, and 1 strain was selected.

Table 6 shows agronomic characteristics of the new variety. In comparison with

<table>
<thead>
<tr>
<th>Date of heading</th>
<th>Length of culm cm</th>
<th>Length of panicle cm</th>
<th>No. of panicles per m²</th>
<th>Yield per kg</th>
<th>Weight of 1,000 grains g</th>
<th>Frequency of white-core grains %</th>
<th>Size of white-core %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Original var.</td>
<td>31 Jul.</td>
<td>76</td>
<td>21.8</td>
<td>17.5</td>
<td>67</td>
<td>22.0</td>
<td>6</td>
</tr>
<tr>
<td>New var.</td>
<td>30 Jul.</td>
<td>84</td>
<td>25.2</td>
<td>18.3</td>
<td>74</td>
<td>25.7</td>
<td>49</td>
</tr>
</tbody>
</table>

Table 5. Procedures of breeding of the new “SAKA-MAI” mutant variety “SHIRAKABANISHIKI”

| Original var.   | “REIMEI”          |
| Irradiation     | 20 kR to 3,800 seeds in May 1973 |
| M₁              | 3,170 transplanted plants (1,585 transplanted hills) |
|                 | 19,654 harvested panicles |
|                 | 15,958 collected seeds (one grain from each panicle) |
| M₂              | 6,000 sown seeds |
|                 | 5,394 transplanted and harvested plants |
|                 | 3 selected plants |
| M₃              | 3 raised strains (plant-to-row method) |
|                 | Preliminary yielding test as strain no. 16-76 |
| M₄ – M₁₀        | Yielding test as strain name “Shinho-Sake No. 4” |
| Register        | Commercial variety “SHIRAKABANISHIKI” in Feb. 1983 |
the original variety, the new variety was longer in length of culm and panicle, superior in white-coreness and yield, larger in size of grain. Thus the new variety was seemed to be suitable as material for “SAKE” brewing.

In this breeding, the screening on white-coreness was conducted by the investigation of each of 5,394 plants in M₂. Labour for the examination was too much. White-core grain could be already expected to be detected in M₁, because white-coreness is an endosperm character. Thus, the method of seeking white-core grain in M₁ panicles seems to be more efficient than the method of this breeding.

4) Breeding of a variety for use as feed for domestic animals “SHINANOSAKIGAKE”

A rice variety for use as feed for domestic animals is required, firstly, to be extremely high in yield, to be clearly distinguishable and exactly identified from the original variety in size, shape, softness and color of grain, because the rice production and marketing for human consumption are under the governmental control.

Table 7 shows the procedures of breeding of a new variety “SHINANOSAKIGAKE”. Dry seed of an original variety “TOYONISHIKI” was irradiated with the exposure of 20 kR of gamma-rays. About 20,000 panicles from 2,940 M₁ plants were harvested. And about 17,000 grains, one grain from each of fertile panicle were collected. 6,000 grains out of these grains collected from M₁ plants were sown into the nursery. 5,452 M₂ plants were transplanted and harvested. 10 plants having large grains were screened. 10 strains in M₃ were raised following the ordinary pedigree method, and 3 strains were selected. 1 strain out of the strains became a new variety later.

<table>
<thead>
<tr>
<th>Original var.</th>
<th>“TOYONISHIKI”</th>
</tr>
</thead>
<tbody>
<tr>
<td>Irradiation</td>
<td>20 kR to 3,800 grains in May 1973</td>
</tr>
<tr>
<td>M₁</td>
<td>2,940 transplanted plants (1,470 transplanted hills)</td>
</tr>
<tr>
<td></td>
<td>19,698 harvested panicles</td>
</tr>
<tr>
<td></td>
<td>16,861 collected seeds (one grain from each panicle)</td>
</tr>
<tr>
<td>M₂</td>
<td>6,000 sown seeds</td>
</tr>
<tr>
<td></td>
<td>5,452 transplanted and harvested plants</td>
</tr>
<tr>
<td></td>
<td>10 selected plants</td>
</tr>
<tr>
<td>M₃</td>
<td>10 raised strains (plant-to-row method)</td>
</tr>
<tr>
<td></td>
<td>3 selected strains</td>
</tr>
<tr>
<td></td>
<td>Preliminary yielding test as strain no. 15-37</td>
</tr>
<tr>
<td>M₄ – M₉</td>
<td>Yielding test as strain name “Shinho No. 38”</td>
</tr>
<tr>
<td>Register</td>
<td>Recognized variety “SHINANOSAKIGAKE” in Feb. 1983 by Ministry of Agriculture, Forestry and Fisheries</td>
</tr>
</tbody>
</table>
Table 8. Agronomic characteristics of the new mutant variety used as feed for domestic animals “SHINANOSAKIGAKE” and its original variety “TOYONISHIKI” (1977-1981)

<table>
<thead>
<tr>
<th></th>
<th>Date of heading</th>
<th>Length of culm cm</th>
<th>Length of panicle cm</th>
<th>No. of panicles per m²</th>
<th>Yield per kg</th>
<th>Weight of 1,000 grains g</th>
<th>Frequency of white-belly grains</th>
</tr>
</thead>
<tbody>
<tr>
<td>Original var.</td>
<td>3 Aug.</td>
<td>88</td>
<td>20.0</td>
<td>459</td>
<td>72</td>
<td>21.3</td>
<td>low</td>
</tr>
<tr>
<td>New var.</td>
<td>4 Aug.</td>
<td>89</td>
<td>19.8</td>
<td>390</td>
<td>73</td>
<td>26.0</td>
<td>high</td>
</tr>
</tbody>
</table>

Table 8 gives agronomic characteristics of the new variety. In comparison with the original variety, the new variety was less in number of panicle per m², larger in size of grain, higher in frequency of white-belly grain, and slightly higher in yield. That is to say, the new variety was satisfactory in size and softness of grain, and in yield.

Summary

1. Breeding of waxy variety “MIYUKI-MOCHI”
   
   Dry seed of an original non-waxy variety “TOYONISHIKI” was irradiated with the exposure of 20 kR. M₁ panicles carrying waxy grains were seeked for using our finding method. The frequency of M₁ panicles carrying waxy grains was 1 per 10,000 panicles. In comparison with the original variety, the new variety was less in yield and 1,000 grain weight, but was almost the same in the other characteristics. The mutation breeding of waxy variety by inducing waxy mutation in non-waxy variety is thought to be more efficient than the hybrid breeding in which labour, time and experimental field are greatly required.

2. Breeding of “SAKA-MAI” variety “MIYAMANISHIKI”

   Dry seed of an original “SAKA-MAI” variety possessing small grain and low frequency of grains with good white-core was irradiated with the exposure of 30 kR. Plants showing good white-coreness were screened in M₂. In comparison with the original variety, the new variety was higher in yield, 1,000 grain weight and frequency of grain with good white-core, was almost the same in the other characteristics.

3. Breeding of “SAKA-MAI” variety “SHIRAKABANISHIKI”

   Dry seed of an original non-“SAKA-MAI” variety “REIMEI” with short culm and resistance to cold was irradiated with the exposure of 20 kR. Plants showing long culm, large grain and good white-coreness were screened in M₂. In comparison with
the original variety, the new variety was longer in length of culm and panicle, superior in white-coreness and yield, larger in size of grain.

4. **Breeding of variety for use as feed for domestic animals “SHINANOSAKIGAKE”**

Dry seed of an original variety “TOYONISHIKI” was irradiated with the exposure of 20 kR. Plants having large grain were screened in M2. In comparison with the original variety, the new variety was larger in size of grain, higher in frequency of grain with white-belly and slightly higher in yield.

5. **Some practical problems on radiation breeding were briefly discussed.**

References


ガンマー線による稲の四新品種の育成

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〒382 長野県須坂市小河原

最近、筆者らはガンマー線によって、もち新品種１、酒米新品種２、えさ米新品種１、合計４品種を育成した。

1. もち新品種「みゆきもち」の育成

もち形質は胚乳形質の一つであり、かつ形質発現が環境に支配されるためで、すでにM₁において、もち遺伝子に関してホモ化を確実に得ることができよう。原品種「トヨシキ」の種子100 gに20 kRのガンマー線を照射し、約3,000のM₁個体を養成した。得られた約20,000のM₁種を調査し、2の突然変異種を得た。この調査に当たって、1穂ごとの調査では労力と時間を要するので、50個体（約350穂）を一束にして脱穂、脱粒し、得られた玄米の中からもち粒をさがす方法がとられた。そして一束から得られたもち玄米は1突然変異種に由来するものとして取扱った。なぜなら突然変異種は1万穂当たり1穂であり、一束内に2の突然変異種を含む確率はほとんどないからである。2のM₁突然変異種をM₂で系統栽培し、1系統を選抜した。

新品種は原品種の特性をよく保持していたが、千粒重がやや軽く、その分だけ低収であった。収量は原品種のそれの92%であった。

育種がすすんでいるうち品種の諸特性を変えることなく、単にもち化する方法は、育種年限や労力の面からきわめて有益と思われる。しかし新品種と原品種の植物体の外観はほとんど同一であり、両者を区別しがたいから、農家の栽培では互いを混入させない注意が必要であろう。

2. 酒米新品種「美山錦」の育成

酒米としての条件はできる限り大粒であること、心白粒率が100%に近いこと、心白の大きさが60〜70%であることである。原品種「たかね錦」は酒米としては小粒であり心白特性もすぐれない。「たかね錦」の種子100 gに30 kRのガンマー線を照射した。850のR₁個体（約60,000のM₁穂）を養成し、一穂一粒法によって3,746粒を採種した。この種子を播き2,562のM₂個体を得た。粒の大きさと心白特性についてM₂個体選抜を行ない、30個体を得た。これらの個体を系統栽培し、M₃で5系統、M₄で3系統、M₅で1系統を選んだ。

1.7 mmで篩別された収量は新品種と原品種で同じであった。これは新品種が大粒になった代わりに総数を減じたからである。しかし2 mm収量は新品種の方が原品種より14%も高かった。これは新品種の千粒重が原品種のそれよりも10%高かったからである。なお心白粒率および心白の大きさは新品種の方が原品種よりはるかにすぐれていた。新品種
は酒造米として好適しよう。

3. 酒米新品种「しゃかば錦」の育成

本県の高冷地では酒米品種がないので、その育成をはかった。原種品として耐冷性の強い「レイメイ」を選び、100 g の種子に 20 kR のガンマ線を照射した。M₁を養成し、一粒一粒法によって 6,000 粒を採取した。この種子を播き 5,394 の R₂ 個体を育てた。M₂ 個体選抜により長株、大粒で米白特性のよい個体を選んだ。M₃で 1 系統を選抜した。

新品種は原種品にくらべて、稈長、穂長が長く、米白性と収量性にすぐれ、大粒でもあった。新品種は酒造米として好適しよう。

4. えさ米新品种「しなのさきがけ」の育成

えさ米としての条件は超多収性と一般米からの識別性がすぐれていることとされている。栽培面積が多くかつ栽培特性がすぐれている「トヨノシキ」を原品種として選び、100 g の種子に 20 kR のガンマ線を照射した。M₁を養成し、一粒一粒法により 6,000 粒を採種した。5,452 の M₂ 個体を養成し、大粒な 10 個体を選抜した。M₃で 3 系統、M₄で 1 系統を選抜した。

新品種は原種品にくらべて、粒が大きくかつ腹白粒となったが、収量はわずかな増収にとどまった。新品種は当面のえさ米として好適しよう。

5. 論 議

稲種子への照射線量は 20〜30kR の範囲がよいこと、放射線育種では玄米を安全に発芽させる技術が必要であること、直播栽培は適当であること、胚乳形質は R₄ で突然変異を発見する方がより効率的であること、単なる大粒化では多収性が得られがたいこと、分けつと突然変異との関係を一層研究すべきことが述べられた。

質 疑 応 答

奥野：メクラモチを支配する遺伝子は第 6 染色体の wx 遺伝子と同一座にあるのでしょうか？

戸田：モチの遺伝子は一個しかないと考えておりますので、一遺伝子内の微細構造の変化だと解釈しています。

奥野：アミロース含量を低下させる遺伝子として wx 遺伝子の他に du （dull）遺伝子が知られており、これは他の染色体にのっていることが解っていますが。

戸田：そうなると解釈が違ってくるかも知れません。
MUTATION BREEDING IN MALTING BARLEY

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Introduction

It was planned in 1956 that we should start to employ the mutation breeding in the improvement of malting barley variety. During the same period, Dr. Tsuchiya of Kihara Biological Institute also started the fundamental experiment on radiation breeding as a research entrusted from the Brewing Society. Since then, we have continued our mutation breeding under the guidance of Dr. Yamaguchi of the University of Tokyo.

Several leading varieties including Kirin Choku 1, which was one of the recommended varieties at that time, were selected for the first trial of radiation treatment to air-dried barley seeds. Since the optimum dose, mutant frequency, selection method, etc of malting barley were not well known, we did trial and error. However, Kirin Choku 1 was late and tall so that a lot of early and/or short mutants were easily selected from this variety with valuable information. Hence the artificial mutation was found quite useful in malting barley breeding and four varieties were bred by this method by 1974.

The mutation breeding has been employed mainly in the partial improvement of agronomic characteristics since the selection for malting quality was very complicated due to many qualitative component concerned and due to lack of adequate testing procedures for evaluating malting quality of small samples of grain for most breeders.

Review of Mutation Breeding

1) Mutagen
We used radiation such as γ-rays, X-rays and neutron during the period from 1956 to 1965, and then some chemical mutagens such as dES, BUdR, EMS and NaN₃ with or without γ-rays since 1966 (Table 1).

2) Selection procedure
Grains were sown in seedbeds on the following day of mutagen treatment. These M₁ plants were transplanted into the field in early spring, usually three months after
Table 1. Mutagens used

<table>
<thead>
<tr>
<th>Mutagen</th>
<th>Treatments</th>
</tr>
</thead>
<tbody>
<tr>
<td>γ-rays</td>
<td>$5 \sim 20 \text{ kR}$, $^{60}\text{Co or }^{137}\text{Cs}$, dry-aired seeds</td>
</tr>
<tr>
<td>X-rays</td>
<td>$5 \sim 20 \text{ kR}$, dry-aired seeds</td>
</tr>
<tr>
<td>Neutron</td>
<td>$2.5 \sim 7.5 \times 10^{12} \text{ Nth/cm}^2$, dry-aired seeds</td>
</tr>
<tr>
<td>dES</td>
<td>Saturated solution, 30 min, $17 \sim 25 \degree \text{C}$</td>
</tr>
<tr>
<td>BUdR (+ γ-rays)</td>
<td>$10^{-3} \text{ M}, (0.5 \sim 1 \text{ kR})$</td>
</tr>
<tr>
<td>NMU</td>
<td>$0.8 \text{ mM}, 30 \text{ min}, 25 \degree \text{C}$</td>
</tr>
<tr>
<td>NMh</td>
<td>$3 \text{ mM}, 30 \text{ min}, 25 \degree \text{C}$</td>
</tr>
<tr>
<td>EDTA (+ γ-rays)</td>
<td>$5 \times 10^{-3} \text{ M}, 5 \text{ hr}$</td>
</tr>
<tr>
<td>Caffeine</td>
<td>$5 \times 10^{-3} \text{ M}, 5 \text{ hr}$</td>
</tr>
<tr>
<td>EMS (+ γ-rays)</td>
<td>$(10, 15, 20 \text{ kR})$</td>
</tr>
<tr>
<td>NaN$_3$</td>
<td>$10^{-3} \text{ M}, 4 \text{ hr}$</td>
</tr>
</tbody>
</table>

Three ears were collected from each plant surviving at harvest time. 12 grains from each ear were sown in the ear-to-row method. In the $M_2$ generation, chlorophyll and morphological mutants in the early growth stage and early heading mutants were marked. Finally in the ripening stage, practical mutants with short and stiff straw, early maturity, long ear, plump kernel, etc. were selected. In the $M_3$ generation, in which selected $M_2$ progenies were grown in plant rows, mutants were confirmed and selected from the viewpoint of practical use. Segregations within lines were also examined. Yield trial and evaluation of malting quality were started in the $M_4$ generation (Fig. 1).

In normal scale of experiment, 500 grains were treated with mutagen and survival rate in $M_1$ was between 70 and 90%. $M_2$ ear-row lines between 1,300 and 1,600, or the total $M_2$ plants, between 16,000 and 20,000, were planted. Mutation frequency of ear-row line up to the young panicle formation stage was from 3 to 5 percent. The

![Diagram](image_url)

Fig. 1. Selection procedure for practical mutant lines.
number of selected M₂ plants was about 150 which was reduced to about 50 lines after selection in M₃ by grain appearance.

It has been found so far that the high dose of radiation induced high mutant frequency in M₂, low survival rate in M₁ and low selection rate of practical mutants, i.e. high frequency of abnormal mutants. It was also found that in the case of chemical mutagen, high concentration made the mutant frequency in M₂ high while low concentration made it easier to select practical mutants.

3) Released varieties bred by mutation breeding

Four varieties shown in Table 2 were almost equivalent to original varieties in terms of malting quality. Therefore both the new varieties by mutation and the original variety could be cultivated in the same area without any problem on later malt production. Since malting barley is a raw material for industrial use, it ought to be as uniform in quality as possible. It was also possible for farmers to harvest at different times if two cultivars differed in maturity. From these points of view, induced mutation was an efficient tool in malting barley breeding.

Table 2. Varieties developed through mutation breeding at Kirin Brewery

<table>
<thead>
<tr>
<th>Variety</th>
<th>Year of Release</th>
<th>Original Variety</th>
<th>Mutagen</th>
<th>Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gamma 4</td>
<td>1962</td>
<td>Kirin Choku 1</td>
<td>γ-rays</td>
<td>Short culm, Early maturity</td>
</tr>
<tr>
<td>Nirasaki Nijo 8</td>
<td>1967</td>
<td>Kirin Choku 1</td>
<td>Cross between 2 mutants</td>
<td>Change of Gamma 4 toward short culm and early maturity</td>
</tr>
<tr>
<td>Amagi Nijo 1</td>
<td>1971</td>
<td>Fuji Nijo</td>
<td>X-rays</td>
<td>Short culm, Early maturity</td>
</tr>
<tr>
<td>Fuji Nijo II</td>
<td>1974</td>
<td>Fuji Nijo</td>
<td>BUdR + γ-rays</td>
<td>Short and stiff culm</td>
</tr>
</tbody>
</table>

4) Outline of Fuji Nijo II

Of four varieties released through mutation breeding, Fuji Nijo II is outlined as a successful example as follows. The original variety, Fuji Nijo, was bred from the cross between Plumage-Archer and Nirasaki Wase No.1 in 1956. Although this variety had good malting potential, its lodging resistance was poor. Therefore we tried to improve the agronomic characteristics, especially the lodging resistance, by induced mutation without any change in malting quality.

(1) Treatment conditions and Survival in M₁ (Table 3)

The 10.5 hr- or 13 hr-presoaked 300 grains were steeped in 1 mM BUdR solution for 1 hr at either G₁ or S-stage of cell cycle. At 16 hr from the start of soaking, grains were irradiated with 1 kR of γ-rays from a ¹³⁷Co source, at a dose rate of 500 R/min.
1. Materials
"Fuji Nijo" harvested at Nirasaki Barley Experimental Farm in 1967
2. Mutagen
(1) S-bromodeoxyuridine (Concentration: 1mM BUdR in 0.5M Tris-buffer solution of pH6.5, treatment: 1hr, 25°C)
(2) γ-rays (source: Cs, Exposure: 1kR, intensity: 500R/min, temperature: 25°C)
3. Treatments and Survival (M₁)

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Stage of treatment of BUdR (Time after start of soaking)</th>
<th>Period of irradiation</th>
<th>No. of grains treated</th>
<th>Germination</th>
<th>Survival</th>
</tr>
</thead>
<tbody>
<tr>
<td>BUdR(G₁)</td>
<td>G₁-stage (10.5 hr)</td>
<td>–</td>
<td>300</td>
<td>261 (87.0)</td>
<td>202 (67.3)</td>
</tr>
<tr>
<td>BUdR(S)</td>
<td>S-stage (13 hr)</td>
<td>–</td>
<td>300</td>
<td>271 (90.3)</td>
<td>208 (69.3)</td>
</tr>
<tr>
<td>γ-rays</td>
<td>–</td>
<td>16 hr after start of soaking</td>
<td>300</td>
<td>259 (86.3)</td>
<td>213 (71.0)</td>
</tr>
<tr>
<td>BUdR(G₁) + γ-rays</td>
<td>G₁-stage (10.5 hr)</td>
<td>16 hr after start of soaking</td>
<td>300</td>
<td>234 (78.0)</td>
<td>154 (51.3)</td>
</tr>
<tr>
<td>BUdR(S) + γ-rays</td>
<td>S-stage (13 hr)</td>
<td>16 hr after start of soaking</td>
<td>300</td>
<td>232 (77.3)</td>
<td>175 (58.3)</td>
</tr>
<tr>
<td>None</td>
<td>–</td>
<td>–</td>
<td>300</td>
<td>252 (84.0)</td>
<td>217 (72.3)</td>
</tr>
</tbody>
</table>

4. Date and place of treatments
Date: Nov. 20, 1967
Place: Laboratory of Radiation Genetics, Faculty of Agriculture, University of Tokyo

all these treatments were carried out at 25 °C.
Survivals were affected in all treatments, especially BUdR + γ-rays treatment. Its lower ratio was probably due to the climatic conditions.
(2) Chlorophyll and morphological mutations in M₂ (Table 4)
The mutation ratio was higher in the G₁ stage than in the S stage and higher by BUdR + γ-rays treatment than by BUdR treatment only, indicating a combined effect of the two agents. Among the chlorophyll mutants, 54% were Xantha mutants.
(3) Practical mutations in M₂ and M₃ (Table 5)
There was no significant difference between the ratios of practical mutations in five treatments: short culm accounted for 56% of the total, short culm with early maturity for 17% and early maturity for 12% in M₂.
Only four lines were selected from 261 M₃ lines planted. One of the four lines was selected because of its early maturity combined with short and stiff straw. This mutant line was obtained from BUdR(G₁) + γ-rays treatment and named "Fuji Niji II" in 1974.
### Table 4. Chlorophyll and Morphological Mutations in M₂

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Number of ear lines planted</th>
<th>Albino</th>
<th>Xantha</th>
<th>Cholina</th>
<th>Striata</th>
<th>Slender</th>
<th>Dwarf</th>
<th>Others</th>
<th>Total</th>
<th>Ratio of mutation</th>
</tr>
</thead>
<tbody>
<tr>
<td>BUdR(G₁)</td>
<td>480</td>
<td>2</td>
<td>12</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td></td>
<td></td>
<td>19</td>
<td>4.0%</td>
</tr>
<tr>
<td>BUdR(S)</td>
<td>504</td>
<td></td>
<td>7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>10</td>
<td>2.0%</td>
</tr>
<tr>
<td>γ-rays</td>
<td>480</td>
<td>4</td>
<td>14</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>5</td>
<td>30</td>
<td>6.3%</td>
</tr>
<tr>
<td>BUdR(G₁) + γ-rays</td>
<td>420</td>
<td>4</td>
<td>15</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>27</td>
<td>6.4%</td>
</tr>
<tr>
<td>BUdR(S) + γ-rays</td>
<td>402</td>
<td>8</td>
<td>2</td>
<td>1</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>17</td>
<td></td>
<td>4.2%</td>
</tr>
<tr>
<td>Total</td>
<td>2286</td>
<td>10</td>
<td>56</td>
<td>7</td>
<td>2</td>
<td>5</td>
<td>8</td>
<td>15</td>
<td>103</td>
<td>4.5%</td>
</tr>
</tbody>
</table>

### Table 5. Practical Mutations in M₂ and M₃

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Number of ear lines planted</th>
<th>Number of variants selected in M₂</th>
<th>Ratio of mutation</th>
<th>Number of lines selected in M₃</th>
<th>Ratio of mutation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Short culm</td>
<td>Early maturity</td>
<td>Short culm with early maturity</td>
<td>Plump grain</td>
<td>Long ear</td>
</tr>
<tr>
<td>BUdR(G₁)</td>
<td>480</td>
<td>27</td>
<td>9</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>BUdR(S)</td>
<td>504</td>
<td>30</td>
<td>11</td>
<td>10</td>
<td>1</td>
</tr>
<tr>
<td>γ-rays</td>
<td>480</td>
<td>33</td>
<td>7</td>
<td>10</td>
<td>11</td>
</tr>
<tr>
<td>BUdR(G₁) + γ-rays</td>
<td>420</td>
<td>25</td>
<td>3</td>
<td>10</td>
<td>9</td>
</tr>
<tr>
<td>BUdR(S) + γ-rays</td>
<td>402</td>
<td>28</td>
<td>10</td>
<td>1</td>
<td>7</td>
</tr>
<tr>
<td>Total</td>
<td>2286</td>
<td>143</td>
<td>30</td>
<td>44</td>
<td>2</td>
</tr>
</tbody>
</table>

Note: * Others include early maturity with long culm, short culm with late maturity, waxless, etc.
(4) Agronomic and malting quality characteristics (Table 6)

Fuji Nijo II matured at almost the same time as the original variety, but it showed greater lodging tolerance and its culm was shorter during the four years tested. The malting quality of this variety was found to be similar to that of the original variety over 3 years.

(5) Culm bending test and shattering resistance test

In order to survey what morphological characters contribute to the lodging tolerance of Fuji Nijo II, culm bending test, of which idea derived from the chain method (Futsuhara 1969), and shattering resistance test were conducted (Fig. 2).

It was shown in Table 7 and 8 that Fuji Nijo II was more tolerant to bending

<table>
<thead>
<tr>
<th>Table 6. Agronomic and malting quality characteristics of Fuji Nijo II</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Agronomic characteristics</strong></td>
</tr>
<tr>
<td><strong>Item</strong></td>
</tr>
<tr>
<td>----------</td>
</tr>
<tr>
<td>Date of Heading</td>
</tr>
<tr>
<td>Date of Maturing</td>
</tr>
<tr>
<td>Degree of Lodging</td>
</tr>
<tr>
<td>Cult Length (cm)</td>
</tr>
<tr>
<td>Ear Length (cm)</td>
</tr>
<tr>
<td>Number of ears per m²</td>
</tr>
<tr>
<td>Yield per are (kg)</td>
</tr>
<tr>
<td>Relative Yield (%)</td>
</tr>
<tr>
<td>Thousand corn weight (g, d.m.)</td>
</tr>
<tr>
<td>Plumpness (over 2.5 mm, %)</td>
</tr>
</tbody>
</table>

Note: Data is the average of 4 years (1971 ~ 1974) at Nirasaki, Yamanashi

<table>
<thead>
<tr>
<th>Malting Quality characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Item</strong></td>
</tr>
<tr>
<td>----------</td>
</tr>
<tr>
<td>Extract (%, d.m.)</td>
</tr>
<tr>
<td>Total nitrogen (%, d.m.)</td>
</tr>
<tr>
<td>Soluble nitrogen (%, d.m.)</td>
</tr>
<tr>
<td>Kolbach index</td>
</tr>
<tr>
<td>Diastatic power (°WK/TN)</td>
</tr>
<tr>
<td>Extract yield (%, d.m.)</td>
</tr>
<tr>
<td>Apparent attenuation limit</td>
</tr>
<tr>
<td>Colour (EBC unit)</td>
</tr>
</tbody>
</table>

Note: Data is the average of 3 years (1971 ~ 1973) pilot malting
Fig. 2. Methods of culm bending test and shattering resistance test.

Table 7. Bending Degree

<table>
<thead>
<tr>
<th>Bending degree</th>
<th>Weight 3g</th>
<th>Weight 5g</th>
<th>Weight 7g</th>
</tr>
</thead>
<tbody>
<tr>
<td>I Fuji Nijo II</td>
<td>0.98</td>
<td>0.89</td>
<td>0.71</td>
</tr>
<tr>
<td>Fuji Nijo</td>
<td>0.95</td>
<td>0.80</td>
<td>0.69</td>
</tr>
<tr>
<td>Difference</td>
<td>0.03*</td>
<td>0.09*</td>
<td>0.02</td>
</tr>
<tr>
<td>II Fuji Nijo II</td>
<td>74.9</td>
<td>53.0</td>
<td>23.0</td>
</tr>
<tr>
<td>Fuji Nijo</td>
<td>59.6</td>
<td>32.3</td>
<td>7.8</td>
</tr>
<tr>
<td>Difference</td>
<td>15.3*</td>
<td>20.7**</td>
<td>15.2*</td>
</tr>
</tbody>
</table>

Note: ** and *, difference significant at levels of 1% and 5%, respectively.

Table 8. Shattering Resistance

<table>
<thead>
<tr>
<th>Part measured</th>
<th>Fuji Nijo II</th>
<th>Fuji Nijo</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st internode Neck ~ Flag leaf</td>
<td>40 g</td>
<td>21 g</td>
<td>19* g</td>
</tr>
<tr>
<td>Flag leaf ~ 1st node</td>
<td>78</td>
<td>62</td>
<td>16</td>
</tr>
<tr>
<td>2nd internode</td>
<td>164</td>
<td>125</td>
<td>39**</td>
</tr>
<tr>
<td>3rd internode</td>
<td>291</td>
<td>239</td>
<td>52*</td>
</tr>
</tbody>
</table>

Note: ** and *, difference significant at levels of 1% and 5%, respectively
Table 9. Morphological Observations

<table>
<thead>
<tr>
<th>Item</th>
<th>Place</th>
<th>Fuji Nijo II</th>
<th>Fuji Nijo</th>
<th>Difference</th>
<th>Increased ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outer diameter of culm (mm)</td>
<td>2nd internode</td>
<td>5.52</td>
<td>4.96</td>
<td>0.56**</td>
<td>11.3%</td>
</tr>
<tr>
<td></td>
<td>3rd internode</td>
<td>5.99</td>
<td>5.15</td>
<td>0.84**</td>
<td>16.3</td>
</tr>
<tr>
<td>Thickness of culm tissue (mm)</td>
<td>2nd internode</td>
<td>1.13</td>
<td>0.91</td>
<td>0.22**</td>
<td>24.2</td>
</tr>
<tr>
<td></td>
<td>3rd internode</td>
<td>1.12</td>
<td>0.90</td>
<td>0.22**</td>
<td>24.4</td>
</tr>
<tr>
<td>Number of vascular bundles</td>
<td>2nd internode</td>
<td>24.8</td>
<td>23.6</td>
<td>1.2</td>
<td>5.1</td>
</tr>
<tr>
<td></td>
<td>3rd internode</td>
<td>29.8</td>
<td>27.4</td>
<td>2.4*</td>
<td>8.8</td>
</tr>
</tbody>
</table>

Note: ** and *, difference significant at levels of 1% and 5%, respectively

and more resistant to shattering than the original variety. Morphological observations showed that outer diameter, thickness of culm and number of vascular bundles were increased in Fuji Nijo II as compared with the original variety (Table 9).

5) **Indirect use of induced mutations**

Indirect use of induced mutations has also been made in the cross breeding involving induced mutants as crossing parents. The typical example of this method is Nirasaki Nijo 8 mentioned earlier, which was derived from the cross of two mutants of Kirin Choku 1, i.e. Gamma 4 and 34 γ-127. This variety was earlier and shorter than either parent (Table 10). The rate of indirect use of induced mutations have been quite high as shown in Table 11.

Table 10. Agronomic characteristics of Nirasaki Nijo 8

<table>
<thead>
<tr>
<th>Item</th>
<th>Kirin Choku 1 (Original variety)</th>
<th>Gamma 4 (A)</th>
<th>34γ-127 (B)</th>
<th>Nirasaki Nijo 8 (A × B)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Date of heading</td>
<td>May 17</td>
<td>May 15</td>
<td>May 13</td>
<td>May 11</td>
</tr>
<tr>
<td>Date of maturing</td>
<td>June 16</td>
<td>June 15</td>
<td>June 13</td>
<td>June 11</td>
</tr>
<tr>
<td>Culm length (cm)</td>
<td>117</td>
<td>102</td>
<td>115</td>
<td>92</td>
</tr>
<tr>
<td>Number of grains per ear</td>
<td>31.8</td>
<td>30.6</td>
<td>31.4</td>
<td>31.2</td>
</tr>
<tr>
<td>Number of ears per m²</td>
<td>366</td>
<td>449</td>
<td>433</td>
<td>377</td>
</tr>
<tr>
<td>Yield per are (kg)</td>
<td>30.0</td>
<td>30.0</td>
<td>36.1</td>
<td>29.6</td>
</tr>
<tr>
<td>Thousand corn weight (g, d.m.)</td>
<td>40.7</td>
<td>40.4</td>
<td>41.5</td>
<td>39.8</td>
</tr>
<tr>
<td>Plumpness (over 2.5 mm, %)</td>
<td>89.3</td>
<td>93.7</td>
<td>90.0</td>
<td>89.0</td>
</tr>
</tbody>
</table>

Note: Data is the average of 2 years (1962 ~ 1963) at Nirasaki, Yamanashi
Table 11. Rate of indirect use of induced mutations in cross breeding (1981)

<table>
<thead>
<tr>
<th>Generation</th>
<th>16</th>
<th>15</th>
<th>14</th>
<th>13</th>
<th>12</th>
<th>11</th>
<th>10</th>
<th>9</th>
<th>8</th>
<th>7</th>
<th>6</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>F_1</td>
<td>0.9</td>
<td>3.4</td>
<td>1.7</td>
<td>20.7</td>
<td>0.9</td>
<td>13.8</td>
<td>0.9</td>
<td>5.2</td>
<td>2.6</td>
<td>50.9</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>F_2</td>
<td>-</td>
<td>3.3</td>
<td>1.1</td>
<td>4.4</td>
<td>1.1</td>
<td>12.1</td>
<td>-</td>
<td>7.7</td>
<td>1.1</td>
<td>44.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>F_3</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>5.0</td>
<td>5.0</td>
<td>25.0</td>
<td>10.0</td>
<td>45.0</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>F_4</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1.6</td>
<td>1.6</td>
<td>19.0</td>
<td>19.0</td>
<td>41.3</td>
<td></td>
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<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>F_5</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1.7</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>15.5</td>
<td>5.2</td>
<td>22.4</td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>F_6</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>4.3</td>
<td>-</td>
<td>-</td>
<td>15.2</td>
<td>2.2</td>
<td>30.4</td>
<td></td>
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<td></td>
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</tr>
<tr>
<td>F_7</td>
<td>-</td>
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<td>-</td>
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<td>7.6</td>
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<td>7.6</td>
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<tr>
<td>F_9</td>
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<td>-</td>
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<td>22.2</td>
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<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>22.2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>F_10</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>16.7</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>16.7</td>
<td></td>
</tr>
</tbody>
</table>

Note: Each figure stands for the rate of the number of crosses using induced mutations to the total number of crosses in each generation. (unit: %)

Conclusion

1) Mutation breeding is an efficient tool in the breeding of malting barley as an industrial material.
2) Not only direct use but also indirect use of induced mutations are effective.
3) Mutation breeding is currently applied to produce Barley Yellow Mosaic Virus resistant mutants in our breeding programme. As a result of intensive selection in the infected field, a promising mutant* has been found from Amagi Nijo, the current leading variety.

Summary

The released varieties of malting barley through mutation breeding is more than ten in number, including foreign varieties. In Japan four varieties has been released so far.

We started mutation breeding in 1956 together with cross breeding that we employed before. Until now, Gamma 4, Amagi Nijo I and Fuji Nijo II have been produced from the direct use of induced mutations and Nirasaki Nijo 8 from the indirect use of them.

*: “Amagi Nijo R”
Mutation breeding has been used mainly in the partial improvement of agronomic characteristics since the selection for malting quality was very complicated.

As the variety bred by induced mutation is usually equivalent to the original variety in malting quality, both this new variety and the original one could be cultivated in the same area without any problem on later malt production. Particularly when one farmer cultivates barley in an extensive acreage, he can harvest at the best time according to the different maturing time of each variety. From these points of view, mutation breeding is an efficient tool in malting barley breeding.

Mutagens we have used so far are X-rays, γ-rays, neutron and chemicals such as dES. From our experience in selection, the low dose of radiation and chemical mutagens are more effective in selection of point mutation than the high dose of radiation which tends to produce many abnormal but few practical mutants.

Acknowledgements

The author is grateful to Dr. H. Yamaguchi of Laboratory of Radiation Genetics, Faculty of Agriculture, University of Tokyo, for his valuable suggestions and encouragement during the course of this work.

References

ビール大麦の突然変異育種

開　誠, 真田松吉

麒麟麦酒株式会社
〒150 東京都渋谷区神宮前6丁目26番1号

突然変異育種により実用化されたビール大麦品種は、国内外を合わせて数品種に及んでいる。わが国では「ガンマー４号」を初めとして４品種が実用化されビール大麦の育種に役立っている。

当社では、1956年（昭和31年）から、従来実施してきた交雑育種に併行して突然変異育種を開始した。現在までに直接法により「ガンマー４号」「あまぎ二条１条」及び「ふじ二条Ⅱ」、間接法により「にらさき二条８号」を育成、実用栽培に供してきた。

ビール大麦の場合、品質面での選抜項目が多く、その選抜は複雑である。そこで、当社では、品質面の改良は交雑育種法に頼り、突然変異育種法は導入当初より栽培性の一部改良にその主眼を置いてきた。

突然変異育種法により育成した品種は、品質は原品種と同等の場合が多いので、こうして栽培性のみが改良された品種は、たとえ新品種と原品種が同一地区に同時に栽培され、収穫物が混ざったとしても麦芽製造上、なんらの不都合も生じない。特に一耕作が広い面積の栽培を行う場合には、同一品種では望めない収穫物の分散とこれに伴う作業労力の配分が容易となり、常に適期収穫が出来て穀物を損なう恐れもない。以上のような点からも突然変異育種はビール大麦育種に有効であると考えている。

現在までに当社で用いてきた突然変異源は、X線・γ線・中性子及び1966年（昭和41年）からはdES等の化学薬品も用いてきた。選抜実感としては、放射線量が高い場合、奇形的な変異が多く実用的なものは得にくい傾向にある。その点、低線量照射や化学薬品の方がポイントMutationの選抜には有利である。

質疑応答

山県：M2で強樎を圃場で手さわいで採されたということですが、それが、遺伝的変異であった確率（変異の伝達性）はどの程度だったでしょうか？

開：この時ははっきり強樎性で実用的だと云えたのはこれで10個体でした。形はおかしくても樎は相当強いと思われたのは10個体程度でしたので27,000個体のうち10位です。硬いと云うのも、モノカームみたいなものも含めてです。

山県：そう言うのも確実に樎と言えるのですか？

開：はいそうです。
A NEW AZUKI BEAN VARIETY, BENI–NANBU

Tadao SATOH, Yasutoshi TAKAHASHI, Nobuaki KAMATA,
Kunitoshi SASAKI, Fumio FURUSAWA, Yoshinori KAMIYAMA,
Yasuo OHNO, Kenji SASAKI, Nobuo TAKAHASHI and Syusaku MAITA

Iwate-ken Agricultural Experiment Station
Takisawa-mura, Iwate-gun, Iwate-ken, 〒020-01

Introduction

Azuki bean cultivation area in Iwate-prefecture is about 2,650 ha, next to Hokkaido which has the largest Azuki bean cultivation in Japan. In this prefecture, Azuki bean production has shown only slight decline, while other upland crops have shown a drastic decrease. However, the yield average of Azuki bean in Iwate-prefecture remains in the lowest rank throughout Japan. Some of the reasons of this low yield might be the emergence damage by bird and insect attack, and the others might be virus disease infection and low rate of seed renewal. To cope with the latter, the development of improved varieties is a prerequisite for the high level production of good quality Azuki bean.

Since 1966, Iwate Agricultural Experiment Station has started an Azuki bean breeding project to develop high quality and high yielding cultivars, and to promote Azuki bean production and improve its marketability. In the course of our breeding effort, we succeeded in a release of Iwate-Dainagon by pure line selection from one native cultivar in 1970. We attempted to apply the mutation breeding method through irradiation, and have succeeded in a release of Beni-Nanbu in 1978. In this paper, we report the breeding procedure and the characteristics of Beni-Nanbu.

Pedigree and Breeding Procedure

In 1969, we asked the Institute of Radiation Breeding, NIAS, to give 10 kR dose of gamma ray ($^{60}$Co) irradiation to seeds of the Azuki bean cultivar Monbetsu 26, a recommended cultivar in Miyagi prefecture. Since Monbetsu 26, the original cultivar, has a very large seeds, excellent grain color, uniformity of grain size and grain luster, we intended to make its stem short and to make its maturity early by mutation breeding.

In 1969, we obtained about 1,700 plants, sowing irradiated 2,500 seeds. We ob-
Table 1. Planted and selected number of group of line, line and individual plant

<table>
<thead>
<tr>
<th>Generation</th>
<th>M₁</th>
<th>M₂</th>
<th>M₃</th>
<th>M₄</th>
<th>M₅</th>
<th>M₆</th>
<th>M₇</th>
<th>M₈</th>
<th>M₉</th>
<th>M₁₀</th>
</tr>
</thead>
<tbody>
<tr>
<td>Planted</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group of lines</td>
<td>7</td>
<td>5</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Line</td>
<td>(280)</td>
<td>240</td>
<td>36</td>
<td>28</td>
<td>20</td>
<td>10</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Individual plants</td>
<td>1,700</td>
<td>2,800</td>
<td>2,400</td>
<td>900</td>
<td>700</td>
<td>400</td>
<td>200</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
</tbody>
</table>

| Selected            |    |    |    |    |    |    |    |    |    |     |
|---------------------|    |    |    |    |    |    |    |    |    |     |
| Group of line       | 3  | 2  | 1  | 1  | 1  | 1  | 1  |    |    |     |
| Line                | 10 | 7  | 5  | 2  | 1  | 1  | 1  | 1  | 1  |     |
| Individual plants   | 240 | 36 | 28 | 20 | 10 | 5  | 5  | 5  | 5  |     |

...tained 5~15 seeds from 280 plants, excluding too late plants, too tall ones, deformed ones, and virus-infected ones.

In 1970, sowing mixed seeds of the M₁ plants, we obtained about 2,800 M₂ plants. We selected 240 mutants of early maturity and short stem. If we applied the one-plant-one-grain method to this material, we could have selected a larger number of promising mutants. We applied the line breeding method in M₃ and later on, and in M₇ generation, we were able to get a very promising mutant line and named it Gankai 2. We put it into a performance test. In 1978, this line was named Beni-Nanbu and released to farmers in Iwate prefecture.

Characteristics of Beni-Nanbu

1) General characteristics

Beni-Nanbu has a determinate plant type, with round leaves, slightly-green and thinly pubescent stems, and slightly-yellow flowers. Those characteristics are as same as the original Monbetsu 26. The new cultivar flowers about 13 days earlier and matures more than 10 days earlier than the original one. The maturity belongs to the intermediate to late group. Beni-Nanbu has a good plant type, its plant height being about 20 cm shorter than the original one. It shows only a little liability of excessive vine growth and lodging. It has a closed plant type, in spite of a large number of branches. It bears many pods with dark tawny color. Grain size is medium, being 20% smaller than the original cultivar. However, Beni-Nanbu is excellent in the color and luster of seed coat and uniformity of grain size.

2) Yielding ability and agronomic traits

Data on growth and yield are shown in Table 2 from 1975 to 1978. The yield-
Table 2. Growth and yield of Beni-Nanbu and its original cultivar

<table>
<thead>
<tr>
<th>Variety</th>
<th>Year</th>
<th>Flowering date</th>
<th>Maturity data</th>
<th>Stem length (cm)</th>
<th>No. of branches</th>
<th>No. of pods</th>
<th>Top D.W. at maturity (kg/a)</th>
<th>Yield (kg/a)</th>
<th>100 grains weight (g)</th>
<th>Lodging</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beni-Nanbu</td>
<td>1975</td>
<td>July 30</td>
<td>Oct. 4</td>
<td>74</td>
<td>4.1</td>
<td>33</td>
<td>64.5</td>
<td>24.6</td>
<td>13.3</td>
<td>Medium</td>
</tr>
<tr>
<td></td>
<td>1976</td>
<td>Aug. 10</td>
<td>Oct. 6</td>
<td>71</td>
<td>4.7</td>
<td>32</td>
<td>53.4</td>
<td>23.6</td>
<td>14.6</td>
<td>Slight</td>
</tr>
<tr>
<td></td>
<td>1977</td>
<td>Aug. 1</td>
<td>Sept. 27</td>
<td>76</td>
<td>2.9</td>
<td>34</td>
<td>52.8</td>
<td>23.1</td>
<td>12.3</td>
<td>Medium</td>
</tr>
<tr>
<td></td>
<td>1978</td>
<td>July 25</td>
<td>Sept. 20</td>
<td>62</td>
<td>3.6</td>
<td>33</td>
<td>53.8</td>
<td>25.9</td>
<td>12.5</td>
<td>No</td>
</tr>
<tr>
<td>Mean</td>
<td>Aug. 1</td>
<td>Sept. 29</td>
<td>71</td>
<td>3.8</td>
<td>33</td>
<td>56.0</td>
<td>24.3</td>
<td>13.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Monbetsu 26</td>
<td>1975</td>
<td>Aug. 18</td>
<td>--</td>
<td>84</td>
<td>3.8</td>
<td>22</td>
<td>60.3</td>
<td>24.1</td>
<td>15.7</td>
<td>Severe</td>
</tr>
<tr>
<td></td>
<td>1976</td>
<td>Aug. 15</td>
<td>--</td>
<td>87</td>
<td>5.1</td>
<td>29</td>
<td>61.5</td>
<td>23.4</td>
<td>18.9</td>
<td>Severe</td>
</tr>
<tr>
<td></td>
<td>1977</td>
<td>Aug. 15</td>
<td>Oct. 8</td>
<td>105</td>
<td>3.7</td>
<td>39</td>
<td>53.1</td>
<td>23.7</td>
<td>14.8</td>
<td>Severe</td>
</tr>
<tr>
<td></td>
<td>1978</td>
<td>Aug. 6</td>
<td>Sept. 30</td>
<td>95</td>
<td>4.6</td>
<td>30</td>
<td>67.1</td>
<td>25.6</td>
<td>15.4</td>
<td>Medium</td>
</tr>
<tr>
<td>Mean</td>
<td>Aug. 14</td>
<td>Sept. 29</td>
<td>93</td>
<td>4.3</td>
<td>30</td>
<td>60.5</td>
<td>24.2</td>
<td>16.2</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The growth ability of Beni-Nanbu is significantly superior to Iwate-Dainagon and slightly to Monbetsu 26, the original cultivar. Yearly variation of characters in Beni-Nanbu is less than that of the original cultivar, probably due to early maturity, resulting in the improvement of grain quality. The adaptability to mechanized cultivation was improved by shortening of main stems and branches. It has a medium resistance to virus diseases in the field, as same as the original cultivar, being more resistant than Iwate-Dainagon.

Summary

In January of 1979, a new Azuki bean cultivar, which was developed by the mutation breeding, was named Beni-Nanbu and released to farmers in Iwate-prefecture. Beni-Nanbu, which was developed by Iwate Agricultural Experiment Station, was derived from seeds irradiated by gamma rays (\(^{60}\)Co), 10 kR dose, at the Institute of

Table 3. General characters and grain quality

<table>
<thead>
<tr>
<th>Variety</th>
<th>Leaf shape</th>
<th>Vine growth</th>
<th>Pod color</th>
<th>Grain shape</th>
<th>Grain colour</th>
<th>Uniformity of grain color</th>
<th>Luster of grain</th>
<th>Uniformity of grain</th>
<th>Grain quality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beni-Nanbu</td>
<td>round</td>
<td>no - slight</td>
<td>dark brown</td>
<td>cylindrical</td>
<td>GBr**</td>
<td>good</td>
<td>good</td>
<td>good</td>
<td>good</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>GBr</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Monbetsu-26</td>
<td>round</td>
<td>medium - severe</td>
<td>dark brown</td>
<td>cylindrical</td>
<td>d.GBr***</td>
<td>good - medium</td>
<td>good</td>
<td>good</td>
<td>good - medium</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* eboshi = A headgear worn by nobles in court dress

** GBr = Garnet Brown, *** d.GBr = dark Garnet Brown
Radiation Breeding, NIAS, MAFF.

The original cultivar, Monbetsu 26, is very late maturing with long stem which often causes lodging and yield reduction, although it is resistant to virus disease and has good grain quality. Therefore, this breeding project was set to get short statued and early maturing mutants. The number of the original Monbetsu 26 seeds given irradiation was about 2,500.

Beni-Nanbu is about 13 days earlier in flowering, and about 10 days in maturing than the original Monbetsu 26, being the medium-late group in Iwate-prefecture. Stem is about 20 cm shortened, reducing excessive vine growth and lodging. Beni-Nanbu has a determinate and closed plant type, with abundant branches and dark brown pods. Grain quality is excellent in seed color, luster, and grain size uniformity. Grain yield is stable, less affected by climate and farming practice. Beni-Nanbu outyields Iwate-Dainagon and Odate 2 by 18% and 9%, respectively. It has a medium resistance to virus disease, similar to the original cultivar, superior to Iwate-Dainagon.

Acknowledgements

This work is supported by the Nihon Mamerui Kikin Kyokai. We wish to thank the staffs of Institute of Radiation Breeding and Tohoku National Agricultural Experiment Station, MAFF, for their helpful advice.
小豆新品種「紅南部」の育成について

佐藤 忠士，高橋 康利，鎌田 信昭，佐々木 邦年
古沢 典夫，神山 芳典，大野 康雄，佐々木 健治

岩手県立農業試験場
〒020-01 岩手県岩手郡亀沢村砂浜

1979年1月，放射線育種による小豆新品種が育成され，紅南部と命名した。
「紅南部」は宮城県の変良品種である紋別26号に，60Coによるガンマ線10KR照射を農林水産省放射線育種場に依頼し，1969年から岩手県農試で選抜育成をはかったものである。

原品種紋別26号は，極早生で収穫が年によって不安定となり，長茎で変色倒伏が著しかったが，ウイルス病にはやや強く，極大粒で粒色，粒栄，光沢ともよく，品質がすぐれていたので，短茎，早熟化することを目標に放射線処理をした。処理されたおよそ2,500粒を栽培し，その中から選抜されたものが紅南部である。

「紅南部」の特性は，原品種「紋別26号」より開花は約13日，熟期は10日以上早まり，岩手県では中生の晩に属する。茎長は約20cm短縮し，草姿良く，変色，倒伏は少ない。分枝は多いが短縮型。茸つき良く，熟成色は黒褐色，子実は中粒で原品種より小さくなかったが，鮮紅色を呈し，粒栄，色沢よく，極めて良質である。年次，栽培条件による品質のふれが少ない。収量は岩手大納言より18％，大納2号より9％多収を示し，年次変動が少ない。ウイルス病については原品種と同じく中程度であり，岩手大納言より強いが，岩手県南部のウイルス多発地帯には不向きである。

謝辞
本品種の育成は，日本豆類基金協会のご援助と放射線育種場，東北農試の御指導によるものである。ここに深甚なる謝意を表したい。

質疑応答

松尾：突然変異で粒が少し小さくなったと云うことだそうですが，小豆の粒の大小は商品としての値段に関係するのですか？

鎌田：この場合若いマイナスの面があります。

松尾：早生になっているんで小さくなったのでしょうか。

鎌田：そう云うことだと思う。元の品種より早生化の度合が大きい程小粒と云う傾向を，選抜の途中で感じました。

松尾：紅南部と同じ早生で大粒の品種を育成する計画はおもちですか？
鎌田：この品種の内ではやっていませんが、他の照射した材料でそう云うことをしております。北海道の小豆の中で、早生で大粒のものがありますので、放射線育種でどうかと云う自信はないとですが、そう云うものを作りたいと思っております。
MUTATION BREEDING IN VEGETABLE CROPS

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Introduction

In the field of vegetable production, many complicated and urgent requests have been imposed on vegetable breeders. It is derived partly from abundance of botanical species, which belong not only to autogamous or allogamous seed propagating plants, but also to vegetatively propagating one. In the former case, almost all the main vegetable seeds are sold in the form of F1 hybrid, and the organs used in the latter case differ with species.

On the other hand, a lot of growing types, such as all season culture, continuous cropping, specialized monoculture and cultivation under glass or plastic houses for year round production, developed extensively with the sosio-economic demands and the changes of consumers needs. Under these circumstances, breeding objectives and breeding methods become more remarkably complicated than the other main crops. And their complexity will be intensified keeping pace with the times.

In Japan, the breeding problems in vegetable crops are generally considered to be divided into three categories. The time-consuming problems, such as fundamental breeding technique and breeding for disease and pest resistance are included in the first one and mainly carried out by national research stations. The prefectural experiment stations share the second one for example, application technique or breeding of the prefectural special products and the private corporations or nurseries take part of the third one like practical breeding for seed and seedling marketing. In this way, the vegetable breeding has been efficiently progressed in cooperation with each other.

Mutation breeding in vegetable crops has not yet become a familiar way like cross breeding and line separation. But it is significant to sum up here the registered cultivars bred up by mutation breeding in the world and to check up on them.

* Presently NIAR (Nat'l Inst. Agrobiological Resources)
In this paper, an outline of the registered cultivars will be given in the first section to understand the whole aspect, and some breeding processes carried out in Japan will be described in the following sections for a practical information.

Registered Vegetable Cultivars Bred up by Mutation Breeding

1) Outline of Registered Cultivars

Thirty eight cultivars of vegetables or their relatives have been registered up to 1981 as seen in Table 1. Among them, nine snap bean or kidney bean cultivars (*Phaseolus vulgaris* L.) were released in USA, Federal Republic of Germany, CSSR and Egypt, and large part of them are improved in disease resistance such as anthracnose (*Colletotrichum lindemuthianum*), bacterial diseases, rust, and bean common mosaic virus, besides the induction of early maturity, short season type, high yield and protein content, upright bushy type, suitability of mechanical harvest, white seed colour, and good cooking quality. And especially, it is notable that many disease resistant cultivars have been bred up in this crops, by artificial induction which is thought to be very difficult in other crops. One haricot bean cultivar which belong to *P. lunatus* L. was also released in USSR.

Eight cultivars of pea or garden pea (*Pisum sativus* L.) were bred up in northern europe and Italy. Their main induced characteristics are high yield, early or late flowering, vigorous development, large seed size, high protein content, tendril leaf-type, lodging resistance and suitability of mechanical harvest. In this crop, it is, however, contrastive to snap beans that disease resistant cultivar was not yet bred up by mutation breeding.

Although mustard (*Brassica Juncea* Czern. et Coss.) is used as spice or oil crop, it is also used as a leaf vegetable in asian countries. Five cultivars were registered but main improved traits were high yield, high oil content, early or late maturity, bold grain size, shattering resistance and less erucic acid content. As above mentioned, the mutation breeding of mustard has made great progress as a oil crop, but it remains to be a future problem as a leaf vegetable.

In tomato (*Lycopersicon esculentum* Mill.), four cultivars were registered totally, including two in India and one each in USSR and Japan. Main improved characteristics are earliness, uniform fruit ripening, high yield and dwarf growth type. Moreover, in Japan, TMV and Fusarium crown and root rot resistance were unilaterally introduced to tomato by crossing of wild tomato pollen grains (*L. peruvianum*) which were chronically γ-irradiated during their pollen formation. The detail of the last case will be explained in other section as a unique technique to control cross incompatibility.
Table 1. Vegetable cultivars bred up by mutation breeding

<table>
<thead>
<tr>
<th>Crop</th>
<th>Cultivar</th>
<th>Original C.V.</th>
<th>Year</th>
<th>Mutagen</th>
<th>Country</th>
<th>Main improved character</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lettuce</td>
<td>Evergreen</td>
<td>Wayahead</td>
<td>1966</td>
<td>$^{32}$P $\beta + \gamma$-rays</td>
<td>Japan</td>
<td>Late bolting, Heat tolerance, Many leaved type</td>
</tr>
<tr>
<td>Lactuca sativa L.</td>
<td>Giantgreen</td>
<td>wayahead</td>
<td>1966</td>
<td>$^{32}$P $\beta$-rays</td>
<td>Japan</td>
<td>Late bolting, Heat tolerance, Heavy leaved type</td>
</tr>
<tr>
<td>Edible burdock</td>
<td>Kobarutogokuwase</td>
<td>Yanagawa-nakate</td>
<td>1978</td>
<td>$\gamma$-rays 10 kR</td>
<td>Japan</td>
<td>Very early, Short-rooted type</td>
</tr>
<tr>
<td>Arctium lappa L.</td>
<td>Kobarutowase</td>
<td>Yanagawa-riso</td>
<td>1978</td>
<td>$\gamma$-rays 10 kR</td>
<td>Japan</td>
<td>Early, High yielding</td>
</tr>
<tr>
<td></td>
<td>Kobarutookute</td>
<td>Yanagawa-nakate</td>
<td>1978</td>
<td>$\gamma$-rays 10 kR</td>
<td>Japan</td>
<td>Late, High yielding</td>
</tr>
<tr>
<td>Tomato</td>
<td>Luc 1 S.12</td>
<td>Pushkinsky</td>
<td>1965</td>
<td>$\gamma$-rays</td>
<td>USSR</td>
<td>Early, High yielding</td>
</tr>
<tr>
<td>Lycopersicon esculentum Mill.</td>
<td>Pusa Mal</td>
<td>Sioux</td>
<td>1965</td>
<td>$\gamma$-rays 30 kR</td>
<td>India</td>
<td>Dwarf, 30% more yield than Sioux</td>
</tr>
<tr>
<td></td>
<td>Meeruti</td>
<td>Meureru</td>
<td>1969</td>
<td>$\gamma$-rays 30 kR</td>
<td>India</td>
<td>Uniform fruit ripening, High yielding</td>
</tr>
<tr>
<td></td>
<td>Kyoroyokureiko</td>
<td>IRB 301-30</td>
<td>1974</td>
<td>$\gamma$-rays chronic rad. (1967)</td>
<td>Japan</td>
<td>Good fruit colour, TMV and Fusarium wilt(J3) resistance</td>
</tr>
<tr>
<td>Onion</td>
<td>Compas</td>
<td>Grobol</td>
<td>1970</td>
<td>X-rays 15 kR (1960)</td>
<td>Netherlands</td>
<td>Very firm, Long-keeping, Globe type with brownish yellow skin, suitable for mechanical handling (thick outer scale)</td>
</tr>
<tr>
<td>Allium cepa L.</td>
<td>Brunette</td>
<td>Grobol</td>
<td>1973</td>
<td>X-rays 15 kR (1960)</td>
<td>Netherlands</td>
<td>Very early, High yielding, Good quality</td>
</tr>
<tr>
<td>Spinach</td>
<td>Früremeona</td>
<td>Remona</td>
<td>1969</td>
<td>X-rays + EMS</td>
<td>Germany</td>
<td>Uniform, High yielding</td>
</tr>
<tr>
<td>Spinacia oleracea L.</td>
<td>Krichimskyran</td>
<td>Pasardjishka kapia</td>
<td>1972</td>
<td>X-rays (1965)</td>
<td>Bulgaria</td>
<td>Hybrid variety using induced male sterility, High yielding, Early, Good fruit quality</td>
</tr>
<tr>
<td>Pepper</td>
<td>Albena</td>
<td>Zlsten medal</td>
<td>1976</td>
<td>$\gamma$-rays 13.5 kR</td>
<td>Bulgaria</td>
<td>Attractive fruit, Better flavour, Lack of anthocyanine</td>
</tr>
<tr>
<td>Capsicum annuum L.</td>
<td>M D U. I.</td>
<td>K. I.</td>
<td>1976</td>
<td>$\gamma$-rays (1969-70)</td>
<td>India</td>
<td>Compact plant type, High yielding and capsicine content</td>
</tr>
<tr>
<td>Crop</td>
<td>Cultivar</td>
<td>Original C.V.</td>
<td>Year</td>
<td>Mutagen</td>
<td>Country</td>
<td>Main improved character</td>
</tr>
<tr>
<td>------------------------</td>
<td>---------------------------------</td>
<td>--------------------------------</td>
<td>--------</td>
<td>------------------</td>
<td>----------</td>
<td>------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Mustard</td>
<td>Svalöf's Primex</td>
<td>Svalöf's white mustard</td>
<td>1950</td>
<td>X-rays 35 kR (1941)</td>
<td>Sweden</td>
<td>High yielding and high percent oil</td>
</tr>
<tr>
<td></td>
<td>Seco</td>
<td>Rumanian white mustard</td>
<td>1961</td>
<td>(X-rays)</td>
<td>Sweden</td>
<td>Early maturity, Stalk stiffness, High yield and crude fat content, Resistance to shattering</td>
</tr>
<tr>
<td></td>
<td>Trico</td>
<td>Selection from Primex</td>
<td>1967</td>
<td>X-rays</td>
<td>Sweden</td>
<td>High yield and oil content over Primex</td>
</tr>
<tr>
<td></td>
<td>R.L M 198</td>
<td>R L 18</td>
<td>1975</td>
<td>γ-rays</td>
<td>India</td>
<td>Increased oil content and yield, Later maturity than RL 18</td>
</tr>
<tr>
<td></td>
<td>R.L M 514</td>
<td>R L 18</td>
<td>1980</td>
<td>γ-rays 200 kR (1699)</td>
<td>India</td>
<td>Higher yield, Bold grain size, Early maturity, High oil content, Shattering resistance, Less erucic acid Vigorous development, Higher yield, High regenerative capacity Larger grain, Higher protein content</td>
</tr>
<tr>
<td>Pea or Garden pea</td>
<td>Strål ärt</td>
<td>Kloster</td>
<td>1954</td>
<td>X-rays 10 kR (1941)</td>
<td>Sweden</td>
<td>Higher yield</td>
</tr>
<tr>
<td></td>
<td>Moskovsky 73</td>
<td>Nemochinovsky 766</td>
<td>1974</td>
<td>DES 0.03% (1967)</td>
<td>USSR</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Hans</td>
<td>P 1163</td>
<td>1979</td>
<td>E1 (1967)</td>
<td>India</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Wasata</td>
<td>Line S/2</td>
<td>1979</td>
<td>γ-rays 50 k rad</td>
<td>Poland</td>
<td>Tendril leaflet, Early maturity, High yield, Lodging resistance, Suitable for combine harvest, Fodder pea Shorter plant type, Large seed, High yield, edible pea</td>
</tr>
<tr>
<td></td>
<td>Sum</td>
<td>Cross Porta X Wasata</td>
<td>1979</td>
<td>(γ-rays)</td>
<td>Poland</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Esedra</td>
<td>Sprinter</td>
<td>1980</td>
<td>X-rays 750 rad pollen (1971)</td>
<td>Italy</td>
<td>4 days later flowering, Increased yield, Contemorary pod setting, Better mechanical harvest</td>
</tr>
<tr>
<td></td>
<td>Novana</td>
<td>Sprinter</td>
<td>1980</td>
<td>X-rays 750 rad pollen (1971)</td>
<td>Italy</td>
<td>1 week later flowering, Reduced plant height, Contemorary pod setting, Longer period for canning</td>
</tr>
<tr>
<td></td>
<td>Hamil</td>
<td>Cross (Waseta X 1.6L/78) X Porta</td>
<td>1981</td>
<td>(γ-rays)</td>
<td>Poland</td>
<td>Tendril leaflet, Early maturity, High yield, Lodging resistance, Suitable for combine harvest</td>
</tr>
</tbody>
</table>
### Table 1. (continued 2)

<table>
<thead>
<tr>
<th>Crop</th>
<th>Cultivar</th>
<th>Original C.V.</th>
<th>Year</th>
<th>Mutagen</th>
<th>Country</th>
<th>Main improved character</th>
</tr>
</thead>
<tbody>
<tr>
<td>Snap bean or kidney bean <em>Phaseolus vulgaris</em> L.</td>
<td>Universal</td>
<td>Granda</td>
<td>1950</td>
<td>X-rays 300 R (1938)</td>
<td>Germany</td>
<td>Early maturity, Higher yield, Resistance to <em>Colletotrichum lindemuthianum</em></td>
</tr>
<tr>
<td></td>
<td>Sanilac</td>
<td>Michelite</td>
<td>1956</td>
<td>X-rays (1938)</td>
<td>USA</td>
<td>Bush type, Early maturity, Resistance to <em>Colletotrichum lindemuthianum</em> and bean common mosaic virus, Tolerance to <em>Sclerotinia sclerotiorum</em></td>
</tr>
<tr>
<td></td>
<td>Unima</td>
<td>Cross Granda X Universal</td>
<td>1957</td>
<td>(X-rays) (1938)</td>
<td>Germany</td>
<td>Immune to <em>Colletotrichum lindemuthianum</em>, Resistance to <em>Pseudomonas phaseolicola</em></td>
</tr>
<tr>
<td></td>
<td>Seaway</td>
<td>Michelite</td>
<td>1960</td>
<td>(X-rays) (1938)</td>
<td>USA</td>
<td>Short season, Upright bush type, Resistance to common mosaic virus 1, 15, 123</td>
</tr>
<tr>
<td></td>
<td>Grariot</td>
<td>Michelite Selection from topcross</td>
<td>1962</td>
<td>(X-rays) (1938)</td>
<td>USA</td>
<td>Same as for Sanilac except Stiffer straw, Higher protein content, Resistance to common mosaic virus 15</td>
</tr>
<tr>
<td></td>
<td>Seafare</td>
<td>Michelite</td>
<td>1967</td>
<td>X-rays (1938)</td>
<td>USA</td>
<td>Very early maturity, Bush type, Resistance to α, β, γ races of <em>Colletotrichum lindemuthianum</em> and bean common mosaic virus 1, 15, 123</td>
</tr>
<tr>
<td>Pusa Paruvali</td>
<td>Wax Podd</td>
<td>1970</td>
<td>X-rays (1959)</td>
<td>India</td>
<td>Early, Bush type, Attractive round meaty, Light green pods, 40-45 days maturity, Higher yield</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Alfa</td>
<td>Black Bean</td>
<td>1972</td>
<td>EMS 0.2% (1966)</td>
<td>CSSR</td>
<td>High speed and protein yield, Resistance to <em>Colletotrichum lindemuthianum</em>, Good cooking quality, White seed colour</td>
</tr>
<tr>
<td></td>
<td>Giza 80</td>
<td>Finde</td>
<td>1980</td>
<td>γ-rays 10 kR (1973)</td>
<td>Egypt</td>
<td>Rust resistance, High yield and Protein content, White seedcoat</td>
</tr>
<tr>
<td>Haricot bean <em>P. lunatus</em> L.</td>
<td>Sarpke 75</td>
<td>Tzanava-3</td>
<td>1967</td>
<td>γ-rays 7 kR (1958)</td>
<td>USSR</td>
<td>Higher green pod yield, Resistance to bacterial diseases, Suitable for mechanical harvest</td>
</tr>
</tbody>
</table>
Three cultivars of pepper (*Capsicum annuum* L.) were bred up in Bulgaria and India, including one hybrid variety by means of induced male sterility. Their main improved traits are high yield, earliness, compact plant type, good fruit quality, better flavour, lack of anthocyanine and high capsicaine content.

Of edible burdock (*Arctium lappa* L.) which is a popular root vegetable in Japan, three cultivars were released and their improved traits were of maturity like very early, early and late, besides high yield and short rooted type. The detailed explanation will be given in other section as an example of air-dried seed irradiation of autogamous seed propagating vegetable.

Two cultivars of onion (*Allium cepa* L.) are registered in Netherland and their main traits are very firm long keeping capacity, globe type with brownish-yellow skin, suitability for mechanical harvest, earliness, high yield and good quality.

Two cultivars of lettuce (*Lactuce sativa* L.) were released including one treated simply by internal radiation of $^{32}\text{P}$ and the other compoundly treated by internal $\beta$-rays irradiation of $^{32}\text{P}$ and outer $\gamma$-rays irradiation of $^{60}\text{Co}$. Main improved traits of them are late bolting, heat tolerance and leaf growing habit. More detailed explanation will be given in other section.

In spinach (*Spinacia oleracea* L.), only one cultivar was bred up by compound treatment of X-rays irradiation and EMS seed soaking. And its main improved traits are uniformity and high yield.

Beyond the above-mentioned cultivars, ‘Baical No.9’ of fall-growing chiness cabbage (*Brassica pekinensis* Rupr.: pekinensis group) is said to be bred up by mutation breeding in People’s Republic of China. The main improved traits are cold tolerance, growth period of 65 days, higher yield and better storage quality than local varieties.

2) **Classification of Induced Mutants**

As mentioned above, main improved characteristics of vegetable cultivars bred up by mutation breeding can be classified as follows. The number of cultivars is shown correspondingly in parenthesis.

A. **Morphological characteristics (Total 27)**
   a. Dwarf, Compact growth habit or suitability for machine harvesting (Total 13: pea 5, snap bean 4, tomato 2, pepper 1, onion 1)
   b. Leaf shape or leaf number (Total 4: lettuce 2, spinach 1, pea 1)
   c. Stalk stiffness or lodging resistance (Total 4: pea 2, snap bean 1, mustard 1)
   d. Grain size (Total 2: pea 1, mustard 1)
   e. Fruit shape (Total 1: pepper 1)
   f. Male sterility (Total 1: pepper 1)
   g. Resistance to shattering (Total 1: mustard 1)
   h. Short root (Total 1: edible burdock 1)
B. Physiological and ecological characteristics (Total 62)
   a. High yield (Total 25: pea 6, snap bean 5, mustard 5, tomato 3, edible burdock 2, pepper 2, spinach 1, onion 1)
   b. Bolting, flowering and maturing habit (Total 21: snap bean 5, pea 4, mustard 3, edible burdock 3, tomato 2, lettuce 2, onion 1, pepper 1)
   c. Colour (Total 6: snap bean 3, tomato 1, onion 1, pepper 1)
   d. Good quality (Total 4: pepper 2, onion 1, snap bean 1)
   e. Vigorous development or regenerating ability (Total 2: pea 2)
   f. Keeping or canning ability (Total 2: onion 1, pea 1)
   g. Heat tolerance (Total 2: lettuce 2)
C. Disease resistance (Total 10: snap bean 9, tomato 1)
D. Increased content of constituent (Total 12: mustard 6, snap bean 4, pepper 1, pea 1)

3) Mutagens and Applied Methods

Registered cultivars can be assorted into two categories i.e. direct and indirect use of induced mutants. Among thirty eight registered cultivars, six cultivars (16% of registered ones) were indirectly bred up by cross breeding, using induced mutants as parents. Other thirty two cultivars (84% of registered ones) were directly induced and selected ones. In these cases, thirty cultivars (94% of the latter) were bred up by single use of mutagens which consist of both physical agents (90%) like γ-rays (50%), X-rays (37%) and β-rays (3%), and chemical reagents (10%), like EMS, EI, and DES (about 3% respectively). The other two cultivars were bred up by compound use of mutagens, like \(^{32}\)P β-rays + γ-rays and X-rays + EMS.

Therefore, physical mutagens occupied an overwhelming portion in comparison with chemical ones. Among physical mutagens, X-rays was applied before 1960 (year of registration), but its application did not so increased. On the other hand, γ-rays was never applied before 1960, but its application had remarkably increased thereafter. And it can be pointed out that there is no vegetable cultivar bred up by the use of fast or thermal neutrons.

On the methods of application, air-dried seeds were acutely irradiated with γ-rays or X-rays in almost all cases. Pollen irradiation with X-rays can be seen in *Pisum sativus* (two cultivars). In a special case to get viable inter-specific hybrid seeds between *Lycopersicon esculentum* × *L. peruvianum*, pollen mother plants were chronically irradiated from pollen mother cell differenciation to dehiscence. As an example of internal irradiation with β-rays, yound floral buds of *Lactuca sativa* were smeared with \(^{32}\)P solution and also the solution was poured into rooting zone. In chemical mutagenesis, seed soakings in EMS, EI and DES solutions were applied in *Pisum sativus* (two cultivars) and *Phaseolus vulgaris* (one cultivar) respectively.
Breeding Process of Kobaruto Trio in Edible Burdock

Wild plant of edible burdock (*Arctium lappa* L.) distributes widely in Europe, Siberia and northern part of China, but its utilization as a root vegetable is limited only in Japan. This composite plant is practically regarded as autogamous one, because stigma are covered with their own pollen grains at dehiscence and natural crossing rate remains at low level. On breeding method of this crop, line separation had only been applied for long time, because effective breeding system had never been established up to that time.

Yanagawa SaiShu Kenkyukai (Yanagawa Seed Corporation) collected local strains from Saitama, Chiba, Tokyo, Nagano and Aichi prefectures in 1948 and registered 'Yanagawa Riso' in 1966 after successive line separation from Saitama strain. In the

<table>
<thead>
<tr>
<th>Year</th>
<th>Month</th>
<th>Item</th>
</tr>
</thead>
<tbody>
<tr>
<td>1969</td>
<td>Apr.</td>
<td>Air-dried seeds of three leading varieties (Yanagawa riso, Yanagawa nakate and Yamada wase) were radiated acutely with γ-rays (60Co) at doses of 10, 20 and 30 kR.</td>
</tr>
<tr>
<td></td>
<td>May</td>
<td>Sowing of irradiated seeds. Viable and good germination at 10 kR, partially germinated and followed to death at 20 kR, not germinated at 30 kR.</td>
</tr>
<tr>
<td></td>
<td>Nov.</td>
<td>Digging out M1 plants irradiated only at 10 kR and transplanted in Dec.</td>
</tr>
<tr>
<td>1971</td>
<td>May</td>
<td>About 216 thousands M2 seeds (average 1249/plant) sown and 140 thousands M2 plants grown in 40 a field.</td>
</tr>
<tr>
<td></td>
<td>Oct.</td>
<td>Digging out. Selected and transplanted 83 M2 plants (Short-rooted type 64, long- and thick-rooted 11 long- and slim-rooted 8), but remarkably excellent plants could not find. M2 plants from Yamada wase were discarded at this time.</td>
</tr>
<tr>
<td>1974</td>
<td>Aug.</td>
<td>M4 seeds from 110 plants harvested.</td>
</tr>
<tr>
<td>1975</td>
<td>May</td>
<td>M4 seeds sown at a rate of 30-50 seeds/plants.</td>
</tr>
<tr>
<td>1977</td>
<td></td>
<td>Performance tests and surveys of characteristics were carried out.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Reached to practical fixation of characters. Released and Registered.</td>
</tr>
<tr>
<td>1978</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
same year, a similar strain 'Yanagawa-nakate' of medium maturity and somewhat longer root was also bred up as a new cultivar. These cultivars and 'Yamada-wase' which registered by Mr. Yamada in 1955, were the leading varieties at that time when Yanagawa Seed Corporation started mutation breeding.

Breeding process of Kobaruto Trio 'Kobaruto-gokuwase', 'Kobaruto-wase' and 'Kobaruto-okute' which literally mean Cobalt very early, Cobalt early and Cobalt late is shown in Table 2. 'Kobaruto' was named after the irradiation source of $^{60}$Co at IRB (Institute of Radiation Breeding, NIAS, MAFF) where the seeds were treated.

The main remarkable points in the process can be picked up as follows: (1) Leading varieties were used in plural (2) Irradiation was carried out at three different exposure doses (3) Breed-objectives were simplified to some important characters like root shape with good quality and maturity without early bolting. (4) Large $M_2$ population estimated to be 140 thousands was used for selection (5) Suitable selection method like autumn sowing to discard early bolting plants was especially applied in $M_3$ generation, in addition to the routine selections (6) Breeder's tenacious eagerness to breed up new cultivars tided over a crisis when they could not find any excellent plants in $M_2$ generation and many persons doubted of the fruitful future.

Without these factors, Kobaruto Trio could not be released successfully. The small number of $M_1$ plants, however, should be pointed out, regarding the bottle-neck effect from $M_1$ to $M_2$ generation. So it can be recommended to increase $M_1$ plants and to decrease $M_2$ seeds per $M_1$ plants.

Main improved characteristics of Kobaruto Trio is shown in Table 3. Since these

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>Main characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kobaruto-gokuwase</td>
<td>Very early maturity (growing period of 100 days from sowing to harvest. Very short root (45-50 cm long, 2 cm diameter) with fine whitish skin, cylindrical shape, crackless and lack of pithiness. Adaptable to shallow soil and spring sowing. Vigorous upright growth habit with less leaves.</td>
</tr>
<tr>
<td>Kobaruto-wase</td>
<td>Early maturity (120 days), about 80 cm long root, 2.5 cm diameter, with fine whitish skin, crackless, cylindrical to bottom end. Soft texture and less pithiness. Resistant to bolting. Adaptable to both spring and autumn sowing. Vigorous upright growth habit with 5 to 6 leaves and high yielding.</td>
</tr>
<tr>
<td>Kobaruto-okute</td>
<td>Late maturity (180-200 days). Very high yield, Suitable for long keeping with good cooking quality. Lack of pithiness. Vigorous growth habit with long green leaves.</td>
</tr>
</tbody>
</table>
cultivars had released, a new category including very early, early and late maturities was introduced, besides the ordinary medium maturity which had never been divided until that time. The short rooted cultivar like ‘Kobaruto-gokuwase’ is also a quite new one with labour-saving shape for digging out and it will establish a stabilized cropping of spring sowing.

Beyond the success of Kobaruto Trio, it is eagerly expected to breed up the remarkably shorter rooted cultivars with more stabilized character manifestation and the more resistant cultivars against replant failure, and to develop breeding counter-measures to control inbreeding depression.

Disease Resistant Breeding in Tomato by Means of Radiation

It has well known that Lycopersicon peruvianum is one of the most promising species as a gene source for disease resistant breeding in tomato. The inter specific hybridization between L. esculentum and L. peruvianum has long been tried since 1915. Fruits set well only when L. esculentum is used as the pistilate parent, but hybrid embryos abort at very early stage even in this case. The application of embryo-culture technique had been attempted, but the efficiency was very low because it is difficult to get the sufficient-sized embryos for culturing.

Yamakawa (1971) tried to overcome this severe cross-incompatibility, using chronic gamma irradiation of male gametophytes and obtained some inter-specific hybrids. In 1978, he also reported the behaviour of self- and cross-compatibility and disease resistance in their progenies. The outline of breeding process of IRB 301-30, -31 and -32 released as disease resistant breeding stock from the Institute of Radiation Breeding can be seen in Fig. 1.

Two male sterile line which were bred up by his inner disbudding method and controlled respectively by a single recessive gene (ms-a, and ms-b), were used as female parents. Both pollen parents (No. 9-1, -2) of L. peruvianum (P.I. 126944) had been vegetatively propagated from the same accession and irradiated with gamma rays for ca.30 days before anthesis at exposure rate of 78 R/day and the pollen was crossed to the above-mentioned male sterile lines in 1967.

In the case of IRB 301-30 and 301-31, the F₁ plant (No. 14) derived from the cross of ‘Shugyoku’ (ms-a) X P.I.126944 (No. 9-2) was backcrossed to ‘Shugyoku’ (ms-a). The B₁F₁ plant (No. 14) was selected by the screening tests in B₁F₂ generation for six kinds of diseases: TMV, CMV, Leaf mold, Fusarium wilt race 1, Fusarium crown and root rot (Fusarium wilt race J3), and Bacterial canker. The B₁F₂ plants (No. C4-5 and C4-9) were backcrossed respectively to ‘Ponderosa’ and ‘Yozu’. After
Fig. 1. Pedigrees of IRB 301-30, 31 and 32 (Yamakawa et al., 1978).

1), 2) Both male sterile plants are radiation-induced mutants.
3), 4) Both plants of *L. peruvianum* had been irradiated with gamma radiation for ca. 30 days before anthesis at 78 R/day, and the pollen was transferred onto *L. esculentum*.

successive selfings and screening tests, these lines were released at the B2F6 generation as disease resistant breeding stocks in 1972. In the case of IRB 301-32, the F1 plant (No. 1) from the cross of 'Shugyoku' (ms-b) × P.I. 126944 (No. 9-1) was backcrossed to 'Shugyoku' (ms-a). The B1F1 plant (No. 23) was selected by the above-mentioned method. The B1F3 (No. V-1) was backcrossed to Okitsu No. 9. After successive selfings and screening tests, IRB 301-32 was released at the B2F4 generation in 1972.

Results of inoculation test of these lines and their F2 plants from the crosses of GCR lines (Glasshouse Crops Research Institute, England, possessing known alleles of TMV-resistant genes) with the known strains of TMV revealed that these lines possessed the Tm-2 gene. IRB 301-30 and 301-31 were also found to possess the resistance to Fusarium crown and root rot which was very severe in winter culture of green- or plastic-houses in Japan. These lines had been used as the breeding stocks by breeders
of regional experiment stations and seed companies.

In 1974, Musasi Plant Breeding Farm LTD released a commercial variety ‘Kyoryoku reiko’ using IRB 301-30 as a breeding stock. This variety is considered to have a combined disease-resistance to TMV, Fusarium crown and root rot, Fusarium wilt, Leaf mold, Early blight and Leaf spot. And another new variety ‘Kyoryoku ogata reiko’ was released as an ameliorated variety of large fruit with good skin colour and resistance to internal browning.

Breeding Process of ‘Ever green’ and ‘Giant green’ in Lettuce

Hyogo Prefectural Agricultural Experiment Station started mutation breeding, using ‘Waya head’ which belong to ‘Butter head’ type lettuce and released two cultivars ‘Ever green’ and ‘Giant green’ in 1966. The outline of their breeding process can be seen in Table 4.

Table 4. Breeding process of ‘Ever green’ and ‘Giant green’ in lettuce

<table>
<thead>
<tr>
<th>Year</th>
<th>‘Ever green’</th>
<th>‘Giant green’</th>
</tr>
</thead>
<tbody>
<tr>
<td>1959</td>
<td>Young buds of ‘Waya head’ at the early bolting stage were smeared with 2 ml solution of $^{32}$P 50 µci/ml. And 2 ml solution of 105 µci/ml was also poured to rooting zone. And seeds were harvested from four treated plants.</td>
<td>About 1800 plants were grown. Nine gigantic plants were found. They bolted late and were heat tolerant and disease resistant. One plants (No. 5) was selected. Frequency rate of these plants and rate of selection were $5 \times 10^{-3}$ and $6 \times 10^{-4}$ respectively.</td>
</tr>
<tr>
<td>1960</td>
<td>Air-dried seeds harvested in the previous year were irradiated with γ-rays (4.2 kR). Sown after harvesting. A very late bolting plant with similar growth habit to original parent was selected from 1200 plants. Selection rate was $8 \times 10^{-4}$.</td>
<td>Similar to that of ‘Ever green’.</td>
</tr>
<tr>
<td>1961</td>
<td>Successive selfings and selections were carried out. Remarkable segregation was not observed.</td>
<td>Character of the selected line reached to the practical level of fixation and no inbreeding depression was observed.</td>
</tr>
<tr>
<td>1963</td>
<td>Character of the selected line reached to almost complete level of fixation and no inbreeding depression was observed.</td>
<td></td>
</tr>
<tr>
<td>1964</td>
<td>Final selection and survey of characters was made.</td>
<td>Same as that of ‘Ever green’.</td>
</tr>
</tbody>
</table>

From Sohno et al. (1966).
In 1959, the cluster of young buds of four 'Waya head' plants were smeared with 2 ml solution of $^{32}$P 50 $\mu$Ci/ml, and 2 ml of 105 $\mu$Ci/ml was also poured to rooting zone, at the early stage of bolting. This internal radiation method with $\beta$-rays was applied commonly to both cultivars.

In the case of 'Ever green', however, air-dried seeds from the previously treated plants with $^{32}$P, were also irradiated with $\gamma$-rays at the exposure dose of 4.2 kR. And a very late bolting plant with the similar growth habit to original cultivar was selected from 1200 plants and the rate of selection was ca. $8 \times 10^{-4}$. After successive selfings and selections, a new cultivar 'Ever green' was released in 1966.

In the case of 'Giant green', nine gigantic plants were found out of 1800 plants which were grown from seeds harvested from the internally irradiated plants. Among these late-bolting plants with heat-tolerance and disease resistance, one plant was selected at the selection rate of ca. $6 \times 10^{-4}$. After successive selfings and selections, another new cultivar 'Giant green' was released in the same year.

This is the first and the sole case of breeding by means of internal radiation with $\beta$-rays. The starting generation, however, is now considered too early in spite of the lucky success at that time. And another problem at present is that the application of internal radiation is more severely restricted by the Law concerning Prevention from Radiation Hazards due to Radio-isotopes, Etc. than at that time.

Their main traits are shown in Table 5. The floral differentiation and bolting

<table>
<thead>
<tr>
<th>Table 5. Main characteristics of 'Ever green' and 'Giant green'</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>'Ever green'</strong></td>
</tr>
<tr>
<td>A. Summer cropping</td>
</tr>
<tr>
<td>Late bolting more than three weeks and two weeks respectively compared with 'Kuroba waya head' and 'Waya head'. Leaf colour is intermediate of them. Grade of leaf crinkle and growth habit are medium. Long term harvestability of more than fifty days.</td>
</tr>
<tr>
<td>B. Winter cropping</td>
</tr>
<tr>
<td>Medium growth habit and leaf weight type. Suitable for winter cropping. Excellent quality with good taste and external appearance.</td>
</tr>
</tbody>
</table>

From Fujisawa et al. (1966).
in lettuce are accelerated by high air-temperature. Therefore, heat tolerance of lettuce has been eagerly expected in order to secure the well cropping from early bolting and heat damage in warmer climate. These new cultivars possess heat tolerance and late bolting habits. ‘Ever green’ has also long term harvesting ability and suitability to winter cropping with the excellent quality.

Conclusion

Mutation breeding in this field has not yet become a familiar way like cross breeding or line separation. But the vegetable or the relative cultivars bred up by mutation breeding until 1981 could be listed up to be thirty eight as already mentioned. This is not so small share comparing to ca. 520 crop cultivars bred up by mutation breeding in the world. The number of species to which these cultivars belong is too small. This suggests the shortage of the species which had been used as the targets of mutation breeding and does not mean the unfruitful future of this method. The abundance of botanical species and the intricated requests in this field should be rather regarded as the touch-stone for the future success in other vegetables.

The improved traits were different from species to species but the spectrum as already classified were similar in almost all cases to other crops. These induced mutants and the new cultivars will be the prominent mile stone for the other vegetables.

As for the mutagens and the application methods, acute irradiation of air-dried seeds with γ-rays or X-rays occupied the overwhelming part and the rest consisted of β-rays internal radiation or γ-rays chronic irradiation of plants, seed soakings in EMS, EI and DES solution, and their compound treatments. It is, however, regrettable that we have no examples of the exposure to fast or thermal neutrons, no utilization of tissue culture or micropropagation and no vegetatively propagating vegetables among them. These problems are now in progress or should be tested in the future.

Some breeding processes or procedures carried out in Japan were also reviewed and they will be suggestive for the breeding in other vegetables.

Acknowledgements

The author would like to express sincere thanks to Mr. Y. Yanagizawa and Mr. K. Miyamoto of Yanagawa Seed Corporation, to Mr. S. Sohno and Mr. T. Fujiwara at Hyogo Prefectural Experiment Station and to Dr. K. Yamakawa at Vegetable and Ornamental Crops Research Station for the kind supplies of their valuable data.
MUTATION BREEDING IN VEGETABLE CROPS

References


野菜類における突然変異育種

山口 隆*

農業技術研究所放射線育種場

野菜は、種子（自殖・他殖性）並びに栄養体（利用器官を異なる）繁殖の作物を含み、その種類が多い。主要野菜では社会経済的並び栽培上の諸条件に適合した、作型の分化・専門化・生産出荷の周年化がみられ、果菜類を中心に施設化が進め、販売種子はほぼ一部雑種になっている。一方では、特殊な立地条件を解明を持つ特産野菜も存在する。このような特殊事情を反映して、育種に対する要請も多様で、かつ特徴的であり、突然変異育種の適用場面が多いと考えられる。

野菜類の突然変異育種の現況は、まだ軌道に乗っているとは言えないが、世界で約40の育成品種が公表されている。誘導変異または放射線利用によって導入された形質には、形態的なものとして、矮性・コンパクトな草型、収穫適性、茎葉の形態・性質、耐倒伏性、良種型など収穫物のサイズ・形状と偏性、雄性不稔などがあり、生理生態的なものとして、早熟性、耐寒性、熟期の均一性、多収性、強健性、耐病性、耐暑性、耐寒性、良質、含有成分・色素の改良などが挙げられる。

使用された突然変異源は、単用の場合、γ線が最も多く、X線がこれに次ぎ、両者のいずれかがほとんどの育成品種に使われ、β線と化学的突然変異源は各1例ずつに留まった。併用では、β線とγ線、X線とEMSが各1例ずつ挙げられる。使用法は、気乾種子の急照射（γ線・X線）が圧倒的に多く、緩照射（γ線、植物体、交雑不和性の破壊）、内照射（β線、32Pの幼芽培養及び根部から）である。EMS・EI・DESの種子浸漬が各1例ずつ上記の併用が2例であった。

国内で得られた実績では、自殖性作物のγ線種子照射の例としてコボウを、種間交雑胚の種得に放射線を利用した例としてトマトを、β線内部照射の例としてレタスなどの果実を紹介した。

手掛けられた野菜の種類は多くないが、育成品種数は全作物の突然変異育種品種中かなりのシェアを占めており、野菜類においても突然変異育種は、期待に十分答えると考えられる。また、栄養繁殖性野菜類では、これまでに突然変異育種による品種が公表されていない。これには、組織・細胞培養法の利用を含めて今後に期待される点が大きい。

野菜は、栽培管理が集約的に行う必要があるため、要請される特性が変更しやすく、短期的な評価にとらわれやすいためか、少数個体を含む東京初期の世代で選抜を終結させる場合が多いが、成功した事例では、かなり多くの個体を用いており、妥当な世代で選抜を行なっていることを、改めて指摘する必要があるものと考えられる。

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質 疑 応 答

平野：ゴボウ「コバルト早生」の育成経過中1970年8月に311万株とありますが、これをどう扱ったかを説明して頂けませんでしょうか？

山口：逆算方式で、ひとつのがに70〜80、普通の採種をしたものとして推定値としてのせております。

平野：311万粒を全部40aに全部まいたと解釈して良いのですか？

山口：はい、そうです。

平野：そんなにまかけるんですか？もしそうならどんな選抜過程をとったのですか？

山口：柳川種苗の方補足して下さい。

柳川：播種粒数の推定は311万粒ですが、検定した個体数ははっきりいたしません。

座長：311万株検定したかと云うことですが、それ程できなかったと思います。

山口：播くだけはよかったと云うことで、検定した数はもっと少ないと思います。
MUTATION BREEDINGS IN ORNAMENTAL PLANTS
– TECHNIQUE USED FOR RADIATION INDUCED
MUTANT IN BEGONIA, CHRYSANTHEMUM,
ABERIA AND WINTER DAPHNE –

Hisao Matsubara

Tokyo Metropolitan Isotope Research Center
Fukazawa-machi, Setagaya-ku, Tokyo, 〒158

Introduction

In practical uses of ornamental plants, difficult problems have existed due to the facts that the utility are decided by market value and fashion with scarcity and tastes of consumers respectively. Therefore, it is necessary by careful examination to select the breeding objects of ornamental plants.

At present, it is well known that radiation induced mutants in ornamental plants are seen mostly in the varieties of chrysanthemum, begonia and dahlia as reported in IAEA reports (Mutation breeding newsletter No. 1-20, IAEA, 1972-1982; Sigurbjörnsson and Micke, 1974). In Japan, it is reported that radiation induced mutants of ornamental plants are shown in chrysanthemum, rose, begonia, azalea and aberia (Nakajima, 1965; Nakajima and Kawara, 1967; Sigurbjörnsson and Micke, 1974).

On the other hand, the propagation of many ornamental plants are made by in vitro culture of organs and tissues (Arora and Nakao 1970; Hartsema, 1962; 1962; Holdgate, 1977; Kehr, 1975; Wakasa, 1981). In plant breeding of the cloning plants, therefore, it has been observed that radiation induced somatic mutants were obtained from combinations of tissue culture, pruning and irradiation techniques to adventitious buds or latent buds, and pruning techniques (Matsubara, Shigematsu, Suda and Hashimoto, 1971; Matsubara et al., 1974; Shigematsu and Matsubara, 1972). Many changes in irradiated plants have been observed after irradiation to buds consisted of a few or a single cell, at the time (Sparrow, Sparrow and Schairer, 1960). When buds of a single apical cell type were irradiated, wholly somatic mutant could have been obtained. But, most of the mutants induced in irradiated plants were observed as sectorial chimera.

In this paper, author describes the practical methods of the application of in vitro
culture and pruning for the isolation and fixation to solid somatic mutant from small sectorial somatic mutation induced by gamma irradiation in our laboratory.

Materials and Methods

The procedure of the experiments were designed from the previous reports in our laboratory, as shown in Table 1 (Matsubara et al., 1971, 1972, 1974; Matsubara 1975; Shigematsu and Matsubara, 1972; Shigematsu and Hashimoto, 1977; Suda, Matsubara and Kudo, 1980; Suda and Matsubara, 1982). The examples and programs are shown as follows.

Table 1. Development process of the radiation breeding by combination of in vitro culture and repeat pruning technique described in this report.

<table>
<thead>
<tr>
<th>First step:</th>
<th>Discussion of effects on various stages of the flower development by irradiation on tulip bulbs, as reported by Matsubara, H. (1975)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Results... (1)</td>
<td>Distribution size and shapes of the radiation induced red spots were variably observed.</td>
</tr>
<tr>
<td>(2)</td>
<td>Radiation induced red spots and stripes were not observed at the stages after completion of whole epidermis of flower petal.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Second step:</th>
<th>Application of the combination of in vitro culture and pruning technique.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Point... (1)</td>
<td>Induction methods of adventitious bud or latent bud by in vitro culture and pruning technique.</td>
</tr>
<tr>
<td>(2)</td>
<td>Determination of the bud size for the irradiation.</td>
</tr>
<tr>
<td>(3)</td>
<td>Application of in vitro culture and repeated pruning for the increasing of mutated sector size or for isolation and fixation of mutant.</td>
</tr>
<tr>
<td>Explant...</td>
<td>bebonia, chrysanthemum</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Third step:</th>
<th>Development of in vitro culture (Simplified in vitro culture)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Point...</td>
<td>(1) Japanese Kanuma soil + charcoal instead of agar.</td>
</tr>
<tr>
<td>(2)</td>
<td>Application of air bubbling water culture to induce adventitious buds.</td>
</tr>
<tr>
<td>Explant...</td>
<td>begonia, aberia</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Explant...</td>
<td>garden and woody plants *</td>
</tr>
</tbody>
</table>

[Note] *: experiment plants... Japanese Zelkova, common cameria, winter daphne, sweet-scented oleander.
1) Plant materials

Potted plants of Begonia rex, var. "Winter Queen"; Begonia masoniana, var. "Iron Cross"; Chrysanthemum morifolium, var. "Blue Rige" and Japanese Kogiku group were used. And cuttings of garden trees, Aberia grandiflora, var. "Hana-Tsukubane-Utsugi" and Daphne odora with red flowers were used.

2) Methods of irradiation

The leaves and stems of matured stock plants were cut into small pieces (about 0.3 cm × 0.3 cm~0.5 cm × 0.5 cm in size). The cuttings were cut into small pieces about 5-10 cm length. These pieces were cultured in pot or in vitro on the agar or Japanese Kanuma soil bed, and in aerating solution to make the adventitious buds or latent buds (Matsubara and Suda, 1971; Suda and Matsubara, 1978). The pieces with induced small buds were placed in gamma irradiation room and exposed at acute irradiation in our laboratory (3 kCi 60Co). The exposure doses and dose rates were

Table 2. LD50 value of survival in ornamental plants (gamma-irradiation)

<table>
<thead>
<tr>
<th>Name of plant</th>
<th>Specis</th>
<th>Conditions at irradiation time</th>
<th>LD50, kR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Begonia</td>
<td>Begonia masoniana</td>
<td>1 week after leaf cutting</td>
<td>0.4—0.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(cutting in Jan.)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>12 weeks after leaf cutting</td>
<td>9—10</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(cutting in Jan.)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>10 weeks after leaf cutting</td>
<td>1—2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(cutting in Mar.)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>5 weeks after leaf cutting</td>
<td>0.5—0.6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(cutting in Jun.)</td>
<td></td>
</tr>
<tr>
<td>Winter daphne</td>
<td>Daphne odora</td>
<td>2 months after cutting</td>
<td>1—2</td>
</tr>
<tr>
<td>Abelia</td>
<td>Abelia grandiflora</td>
<td>6 months after cutting</td>
<td>3—5</td>
</tr>
</tbody>
</table>

[ Note ] Methods used to estimation of the irradiation dose ranges in the mutation breedings.

1) From the experiments of 50% survival dose (this table).
2) Seedling: From relation between 50% survival dose (LD50) and 50% dry matter percentage (RD50), as reported by Yamaguchi (1981).
3) Cutting: From relation between 50% plant height and 50% vice bulb yield+ (explant; tulip, gladiolus et al.) or 50% flowering++, (Matsubara et al., unpublished; Suda et al., unpublished).

The correlation coefficient \( \gamma^+ = 0.9437^{**} \)

\( \gamma^{++} = 0.9891^{***} \).
decided according to previous reports on LD_{50} of germination, growth and survival, as shown in Table 2 (Matsubara et al., unpublished; Suda and Matsubara, 1971; Suda and Matsubara, 1981; Yamaguchi, 1981).

3) Isolation and fixation technique for solid mutants

After the irradiation, the following treatments were applied for the *in vitro* or potted culture to induce somatic mutation.

a) The *in vitro* culture for isolation and fixation of a parts of small sectorial somatic mutation area induced on leaves and other organs were attempted to make up solid somatic mutants (Fig. 1, 2). The materials used in this experiments were *Begonia rex*, *Begonia masoniana* and *Chrysanthemum morifolium* (Shigematsu and Matsubara, 1972; Shigematsu and Hashimoto, 1977).

b) The combination with pruning and *in vitro* culture were examined to develop the induced potential mutation into mutation, as reported by Matsubara et al. (1971). After the treatments, *in vitro* culture and repeated pruning were to increase mutated sector size, to isolate and to fix the induced sectorial somatic mutation as mutant (Matsubara, Shigematsu and Suda, 1974; Suda, Matsubara and Kudo, 1980; Suda and Matsubara, 1982). *Begonia masoniana*, *Begonia rex*, and *Daphne odora* were used throughout in these experiments (Fig. 1 and 3).

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**Fig. 1.** Scheme showing the procedure of the isolation and fixation of the somatic mutant plant induced by irradiation (begonia).
Fig. 2. Schematic representation for the production of the somatic mutant induced by irradiation (chrysanthemum).

Fig. 3. Scheme showing the procedure of the isolation and fixation of the somatic mutant plant induced by irradiation (garden and woody plant).
c) The combination of repeated pruning for development of mutant from latent buds or cells, and in vitro culture for rapid propagation of mutant tissues were examined. In this experiment, Abergia grandiflora was employed (Fig. 3).

4) Confirmation of the solid somatic mutant

After irradiation treatment, in vitro culture was used for selection of somatic mutants with peripheral chimera or non-peripheral chimera plant, and for quick propagation of somatic mutant plants. The methods were used for most of the explants in the present experiments. Fig. 1 ~ 3 summarized experimental procedures mentioned above.

Table 3. Main improved characters of the somatic mutants obtained in this experiment (Begonia rex. variety "Winter Queen")

<table>
<thead>
<tr>
<th>Solid somatic mutant type No.</th>
<th>Irradiation dose, kR</th>
<th>Main improved or changed characters</th>
<th>Name of new variety</th>
<th>Breeding Process</th>
</tr>
</thead>
<tbody>
<tr>
<td>γ-1-A</td>
<td>10</td>
<td>Changed wholly to green in ground color with numbers of silver-white spots (550-700 spots per leaf), standard leaf shape</td>
<td></td>
<td>Fig. 1. B-C-D-G</td>
</tr>
<tr>
<td>γ-1-B</td>
<td>10</td>
<td>The same as above on leaf color and shape; but numbers of silver-white spots (400-500 spots per leaf)</td>
<td>&quot;Gin-Sei&quot;</td>
<td>Fig. 1. B-C-D-G</td>
</tr>
<tr>
<td>γ-2</td>
<td>10</td>
<td>The same as above on leaf color; but numbers of silver-white spots (300-350 spots per leaf) and diamond leaf shape</td>
<td></td>
<td></td>
</tr>
<tr>
<td>γ-3-A</td>
<td>10</td>
<td>The same as above on leaf color; but numbers of silver-white spots (150-250 spots per leaf) and spiral leaf shape, and oxidant sensitive</td>
<td>&quot;Ryoku-Ha&quot;</td>
<td>Fig. 1. B-C-F-G</td>
</tr>
<tr>
<td>γ-3-B</td>
<td>10</td>
<td>The same as above on leaf color; but numbers of silver-white spots (50-100 spots per leaf) and over lapped leaf shape</td>
<td></td>
<td>Fig. 1. B-C-F-G</td>
</tr>
<tr>
<td>γ-3-C</td>
<td>10</td>
<td>Wholly to green leaf color and over lapped leaf shape</td>
<td></td>
<td>Fig. 1. B-C-F-G</td>
</tr>
</tbody>
</table>

2) At a glance, the mutants are much alike to the original form, but by close examination, the mutants differ in detailed characters.

2) Chimeric mutants: Begonia masoniana, "Mini-Mini-Iron", "Orange-Iron".
Results and Discussion

Radiation induced somatic mutants and characters are summarized as follows.

1) Somatic mutants of *Begonia rex*

Table 3 shows culture methods used and ornamental characters of somatic mutant strains some of which became to be new varieties thus obtained. From irradiated “Winter Queen”, six kinds of fully changed mutant could be obtained by the method used (Fig. 1-B-C-D-G and Fig. 1-B-C-F-G). Among *in vitro* culture plantlets on agar beds, three healthy plants were transplanted to flower pots in green house. After transplantation, two of the three plants grew to mature (“Gin-Sei”, Fig. 1-B-C-D-G). In another case, all of the mutant plantlets on Japanese Kanuma soil beds grew to mature plants (“Ryoku-Ha” and others). The forms and colors of leaves of new mutant plants were markedly changed (Matsubara et al., 1974; Matsubara and Suda, 1978). The leaf color of mutants were changed entirely from green to green with many small white-silver spots. The number of spots per leaf differed by strain. Strain with 550-700 spots, 400-500 spots, 300-350 spots, 150-250 spots and 50-100 spots were observed respectively. New variety “Gin-Sei” was the strain with about 400-500 small spots per leaf, and “Ryoku-Ha” was the strain with about 150-250 spots per leaf (“Ryoku-Ha”, Fig. 1-B-C-F-G, Fig. 4).

![Fig. 4. Photograph showing original plant (“Winter Queen”, at left) and solid somatic mutant plant (“Ryoku-Ha”, at right) separated by the repeated pruning techniques (Fig. 1.) from the mutation sector induced by irradiation.](image-url)
2) Somatic mutants of *Begonia masoniana*

In this experiment, the mutants were originated from adventitious bud irradiated on Japanese Kanuma soil culture bed as prepared in *in vitro* culture (Fig. 1-A-C-E-G or 1-A-C-F-G, Fig. 5). It is very important that new mutants with differently characterized habits have been induced by irradiation, and that similar characters could be obtained frequently from one species, or one variety in this case. The high frequency might be due to numbers of adventitious bud per piece of leaf cut from limited area and cultured *in vitro*, and simplified culture (Matsubara and Suda, 1971; Suda and Matsubara, 1978).

3) Somatic mutants of *Chrysanthemum morifolium*

The young plant pinched at shoot tip were irradiated. After irradiation, these plants were cultivated in ordinary field conditions. In variety “Brue Rige”, one of the flowers on sub-shoot of irradiated plant showed, at flowering time, white color in chimeric form which was different from original pink color. The flower buds with mutated white flower color were collected and cut into small pieces. The pieces were cultured *in vitro* to develop into fully mutated plants with white flower color (Fig. 2-A-B-D-E). This mutant plant with white flowers was only different in color from

![Fig. 5. Advantitious plantlets obtained by *in vitro* culture using small leaf piece. Photograph of approximately 3 months after incubation *in vitro* (explant: *Begonia masoniana*). A: plantlet developing from adventitious bud. B: small leaf piece. C: Japanese Kanuma Soil + charcoal. D: adventitious root. E: capped test tube.](image-url)
original pink flower (Matsubara, Shigematsu, Suda and Hashimoto, 1971). According to these results, we applied repeated pruning method instead of \textit{in vitro} culture to "kogiku" groups of many branching type. Many solid somatic mutants are obtained from "kogiku" as reported by Matsubara, Suda and Hashimoto, 1972 (Fig. 2-A-B-C-E).

From the results, it is important that somatic mutants induced on a part of flower organ were fixed to whole and solid mutant plants by \textit{in vitro} culture or by repeated pruning.

4) Somatic mutants of woody plants

Small rooted cuttings were irradiated with various doses. In \textit{Aberia} grandiflora, although somatic mutations of five type which altered plant size and leaf color were found, one of them was remarkably changed to dwarf type with more variegated leaves of deep green having brighter yellow color on leaf margin, than other mutants or original plants (Tokyo Metrop. Isot. Res. Center, 1977). The mutant was considered to be valuable as garden shrub or as hedge.

In \textit{Daphne odora}, somatic mutations of various type which altered flower color, flower number per branch, and the number of flowers per cluster were investigated. One of them was remarkably mutated as illustrated in Fig. 6, and reported by Suda and Matsubara, 1982.

Among the radiation induced somatic mutants, two varieties of \textit{Begonia rex} and four varieties of \textit{Begonia masoniana} have been reviewed in "Begonias" (1981) by Ashizawa et al., and in "The Japan Begonia Society news letter" (1977) by Misono of The Japan Begonia Society. Also, a variety of \textit{Abelia grandiflora} has been reviewed in "Variegated Plants" (1978) ed. by Yokoi and Hirose.

![Fig. 6. Photograph showing original plant (Daphne odora, at left) and radiation induced solid somatic mutant "Daphne-γ-3" (at right). The size of flower cluster of "Daphne-γ-3" is twice the size of original plant.](image-url)
Previous reports suggested that in vitro cultures technique are becoming more and more important, not only for rapid propagation and virus free multiplication, but also for use in mutation breeding (Broertjes et al. 1976; Devreux 1973; Broertjes 1978).

Combination of in vitro culture and pruning treatment used in the present experiments had been developed and previously reported, by such as Bauer 1957 and others. From these experiments, it is suggested that appropriate combination of various pruning techniques and in vitro cultures can be useful in the radiation breeding of ornamental crops, which are propagated vegetatively.

Summary

Several methods of obtaining somatic mutant plants by γ-ray irradiation on pieces of tissues as in vitro adventitious bud technique or small cutting methods with repeated pruning are described.

1) The irradiation to the adventitious buds in the small pieces of organ cultured in vitro and to the small cuttings are employed. Culture beds of agar or of Japanese Kanuma soil were used in vitro culture. In these experiments, Japanese Kanuma soil bed in in vitro culture worked well for root development and transplant of the induced mutants.

2) Combination with in vitro culture and repeated pruning technique were used for isolation and fixation of solid somatic mutant from small sectorial mutation induced by irradiation. This method was successful for begonia, chrysanthemum, aberia and winter daphne.

3) These data indicates that most of the induced mutant plants were non-chimeric, while a few others were chimeric. Among the new varieties, ‘Gin-Sei’, ‘Ryoku-Ha’, ‘Big-Cross’, ‘Kaede-Iron’, ‘Mei-Fu-Hana-Tsukubane-Utsugi’ and ‘Daphne-γ-3’ are non-chimeric, and “Mini-Mini-Iron” and “Orange-Iron” are chimeric. Moreover, these new varieties have remarkably differed in size and in color pattern from original variety.

From the experimental results of somatic mutation, it is indicated that plant tissue culture have enormous potential in radiation breeding and in rapid propagation of the somatic mutant.

Acknowledgements

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Station. I wish to express my thanks to Dr. Mituru Oka, President of Tokyo Metropolitan Isotope Research Center, for advice and to cooperation researchers, for useful discussions. I also wish to thank the persons concerned of Tokyo Metro. Agri. Forest. Fisher. Division, University of Tokyo, Chiba University, Tokyo University of Agriculture and Technology and Japan Begonia Society, for valuable suggestions.

References


観賞植物における突然変異育種
——ベゴニア，キク，アベリア，ジンチョウゲの
突然変異育種に利用した技術——

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ガンマ線照射で，体細胞突然変異の出現を行うための，組織培養の方法や反覆せん定の
技術の組合せ利用について示す。
1. 器官小切片の培養や切り返しによる方法で誘導される不定芽に対して照射を行った。
組織培養床として，寒天と鹿沼土とを用いた。鹿沼土の利用は，育成植物の根の発育
と移植の面で成果を得た。
2. 照射により誘発される，セクター状の突然変異部分の拡大と，体細胞突然変異の分離
・安定をするために，組織培養と反覆せん定との組合せ技術を開発した。この技術は，
ベゴニア，キク，アベリア，ジンチョウゲの放射線育種で有効であった。
3. この方法で得られた体細胞突然変異の多くは，安定した非キメラの植物であった。実
際には，育成した新品種中，「銀星」，「緑波」，「ビッグ・クロス」，「カエデ・アイ
アン」，「明駆ハナツツキバネツキ」，「ジンチョウゲ－3号」は非キメラであり，
「ミニ・ミニ・アイアン」，「オレンジ・アイアン」はキメラ植物であった。
これらの新品種は，いずれも，大きさ，色調の点で原品種と顕著に違った形質をもった
ものである。
これらの実験事実は，組織培養技術が放射線育種や体細胞突然変異植物の急速増殖に，
より有益な効果をもたらすことを示している。
INDUCTION AND USE OF ARTIFICIAL MUTANTS IN SWEET POTATO

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Introduction

Intentional breeding programs of sweet potato (*Ipomoea batatas* (L.) Lam.) started in 1926 in Japan. At the beginning stage, the efficacy of breeding was remarkable and outstanding varieties like Okinawa 100, Gokoku-imo, Norin 1 and Norin 2 were bred up and these varieties became the leading varieties of sweet potato cultivation.

The efficacy gone down due to inbreeding depression as increase the chance of inbreeding, because the parental materials of these cultivars were limited only Japanese local varieties. In these cases, breeding progresses were observed on the characters determined mainly by additive effect of polygenes such as starch content but characters of non-additive type such as tuber weight showed tendency to decrease the effect of breeding.

As a result, for breeding toward high starch content and high yield, it was necessary to introduce new genes from foreign cultivars, from wild relatives. Mutation breeding were employed to extend the variation of genes, and experiment of mutagenesis were began from 1957.

Besides these, red skin color is prefered for table cooking and white or yellow for raw materials in industries. For this purpose, induction of skin color mutants is one of the important objectives.

Materials and Methods

X-ray, ethylene imine, $^{32}$P and $^{60}$Co were used as the mutagen. Tubers were subjected to X-ray irradiation in 1957, cuttings to ethylene imine treatment in 1968, cuttings and tubers to $^{32}$P irradiation in 1960 and 1969 and tubers to $^{60}$Co irradiation in 1969, respectively, with a different doses. Treatment of $^{32}$P was done with a method
to pour a diluted solution into the hole of about 2 cm³ in a tuber, and irradiation was done from the inside of tuber. The cuttings from treated tuber were planted on the field and observation of the characters of plant was made. On MV₂ generation, one tuber was treated as one line and observation of tuber weight and dry matter content of selected lines were carried on from MV₄ to MV₆ generation.

Results

1) Mutagenic effects

All mutagens used in these experiments induced visible mutants and mutagenic effects were observed (Table 1). Visible mutants of top were slender vine, short vine and stem color mutants and skin color mutants as a root. Mutation rate of tuber skin color induced by ⁶⁰Co irradiation is between 4~60% based on tuber and 0.5~1.3% based on plant (Table 2).

In the MV₂ generation of ³²P irradiation, the variance of stem length, tuber yield

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Variation</th>
<th>Mutagen</th>
<th>Year of treatment</th>
<th>Year of mutant appearance</th>
<th>Name of treated varieties</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vine</td>
<td>Thick</td>
<td>Slender</td>
<td>X-ray</td>
<td>1958</td>
<td>1958</td>
</tr>
<tr>
<td></td>
<td>do</td>
<td>do</td>
<td>³²P</td>
<td>1960,1963</td>
<td>1964</td>
</tr>
<tr>
<td></td>
<td>do</td>
<td>do</td>
<td>Ethylene imine</td>
<td>1969</td>
<td>1969</td>
</tr>
<tr>
<td>Skin color</td>
<td>Brown</td>
<td>Green color</td>
<td>⁶⁰Co</td>
<td>1972</td>
<td>1972</td>
</tr>
<tr>
<td>of tuber</td>
<td>Red</td>
<td>Yellow white</td>
<td>³²P</td>
<td>1979</td>
<td>1979</td>
</tr>
<tr>
<td></td>
<td>do</td>
<td>Red brown</td>
<td>³²P</td>
<td>1979</td>
<td>1979</td>
</tr>
<tr>
<td></td>
<td>do</td>
<td>Light red brown</td>
<td>³²P</td>
<td>1979</td>
<td>1979</td>
</tr>
<tr>
<td>Light crimson</td>
<td>Yellow</td>
<td>White</td>
<td>³²P</td>
<td>1970</td>
<td>1970</td>
</tr>
<tr>
<td></td>
<td>do</td>
<td>Crimson</td>
<td>³²P</td>
<td>1970</td>
<td>1970</td>
</tr>
<tr>
<td>Red brown</td>
<td>Red</td>
<td>White</td>
<td>³²P</td>
<td>1978</td>
<td>1978</td>
</tr>
<tr>
<td></td>
<td>do</td>
<td>Yellow</td>
<td>³²P</td>
<td>1978</td>
<td>1978</td>
</tr>
<tr>
<td></td>
<td>do</td>
<td>Yellow brown</td>
<td>⁶⁰Co</td>
<td>1978</td>
<td>1978</td>
</tr>
<tr>
<td></td>
<td>do</td>
<td>Yellow</td>
<td>³²P</td>
<td>1978</td>
<td>1978</td>
</tr>
<tr>
<td></td>
<td>do</td>
<td>Yellow brown</td>
<td>Ethylene imine</td>
<td>1979</td>
<td>1979</td>
</tr>
<tr>
<td>Light yellow</td>
<td>Yellow</td>
<td>White</td>
<td>³²P</td>
<td>1966</td>
<td>1967</td>
</tr>
<tr>
<td>brown</td>
<td>do</td>
<td>Red</td>
<td>³²P</td>
<td>1967</td>
<td>1968</td>
</tr>
</tbody>
</table>
and dry matter contents varied wider than non-treated plant, respectively (Table 3). MV2 and MV3 generation of skin color mutant lines induced by 60Co irradiation

Table 2. Mutation rate of tuber skin color induced by 60Co irradiation

<table>
<thead>
<tr>
<th>Name of variety (Year of irradiation)</th>
<th>No. of layed tuber</th>
<th>No. of sprouted tuber (A)</th>
<th>No. of planted cutting (B)</th>
<th>No. of skin color mutant</th>
<th>Mutation rate</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>No. of plant (C)</td>
<td>C/A</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>No. of tuber (D)</td>
<td></td>
</tr>
<tr>
<td>Kyushu 66 (1972)</td>
<td>74</td>
<td>74</td>
<td>560</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Kyushu 78 (1978)</td>
<td>26</td>
<td>24</td>
<td>1100</td>
<td>15</td>
<td>52</td>
</tr>
<tr>
<td>Kyushu 79 (1979)</td>
<td>28</td>
<td>24</td>
<td>1100</td>
<td>15</td>
<td>23</td>
</tr>
</tbody>
</table>

a) dose of irradiation were 15 kR.

Table 3. Variance and heritability of individuals in MV2 generation

<table>
<thead>
<tr>
<th>Name of variety (Year of irradiation)</th>
<th>No. of individuals</th>
<th>Max. length of stem</th>
<th>Total length of stem</th>
<th>Tuber weight</th>
<th>Dry matter content</th>
<th>No. of tubers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Okinawa 100 (1965)</td>
<td>V1 a) 731</td>
<td>213.3</td>
<td>1609.1</td>
<td>69664.3</td>
<td>4.13</td>
<td>–</td>
</tr>
<tr>
<td></td>
<td>V2 b) 174</td>
<td>161.9</td>
<td>1039.3</td>
<td>77089.5</td>
<td>3.06</td>
<td>–</td>
</tr>
<tr>
<td></td>
<td>H2 c)</td>
<td>0.569</td>
<td>0.607</td>
<td>0.475</td>
<td>0.574</td>
<td>–</td>
</tr>
<tr>
<td>Kuokei 38 (1965)</td>
<td>V1 a) 500</td>
<td>66.66</td>
<td>1854.0</td>
<td>22159.3</td>
<td>4.77</td>
<td>–</td>
</tr>
<tr>
<td></td>
<td>V2 b) 114</td>
<td>42.61</td>
<td>883.0</td>
<td>17654.4</td>
<td>7.24</td>
<td>–</td>
</tr>
<tr>
<td></td>
<td>H2 c)</td>
<td>0.614</td>
<td>0.675</td>
<td>0.557</td>
<td>0.397</td>
<td>–</td>
</tr>
<tr>
<td>Kyuokei 15-2120 (1966)</td>
<td>V1 a) 279–289</td>
<td>697.3</td>
<td>6109.1</td>
<td>20093.1</td>
<td>1.69</td>
<td>1.81</td>
</tr>
<tr>
<td></td>
<td>V2 b) 283–291</td>
<td>100.4</td>
<td>2538.3</td>
<td>26649.0</td>
<td>1.60</td>
<td>1.82</td>
</tr>
<tr>
<td></td>
<td>H2 c)</td>
<td>0.874</td>
<td>0.407</td>
<td>0.310</td>
<td>0.513</td>
<td>0.500</td>
</tr>
<tr>
<td>Satsuma-aka (1966)</td>
<td>V1 a) 180–188</td>
<td>111.6</td>
<td>1050.6</td>
<td>16801.3</td>
<td>1.87</td>
<td>1.53</td>
</tr>
<tr>
<td></td>
<td>V2 b) 179–186</td>
<td>107.3</td>
<td>768.5</td>
<td>14087.3</td>
<td>2.91</td>
<td>0.93</td>
</tr>
<tr>
<td></td>
<td>H2 c)</td>
<td>0.510</td>
<td>0.577</td>
<td>0.554</td>
<td>0.392</td>
<td>0.621</td>
</tr>
</tbody>
</table>

Table 4. Variation of characters in skin color mutant

<table>
<thead>
<tr>
<th>Original line</th>
<th>Generation</th>
<th>Character</th>
<th>No. of plant</th>
<th>Average</th>
<th>C.V.</th>
<th>Maximum</th>
<th>Minimum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kyushu 78</td>
<td>MV3</td>
<td>tuber weight per plant</td>
<td>53</td>
<td>471g</td>
<td>23.3%</td>
<td>675g</td>
<td>274g</td>
</tr>
<tr>
<td></td>
<td></td>
<td>dry matter content</td>
<td>53</td>
<td>37.4%</td>
<td>4.4%</td>
<td>40.4%</td>
<td>33.0%</td>
</tr>
<tr>
<td></td>
<td>Non-treated original line</td>
<td>tuber weight per plant</td>
<td>21</td>
<td>523g</td>
<td>12.8%</td>
<td>672g</td>
<td>419g</td>
</tr>
<tr>
<td></td>
<td></td>
<td>dry matter content</td>
<td>21</td>
<td>39.0%</td>
<td>2.6%</td>
<td>41.4%</td>
<td>37.1%</td>
</tr>
<tr>
<td>Kyushu 79</td>
<td>MV2</td>
<td>tuber weight per plant</td>
<td>17</td>
<td>616g</td>
<td>35.8%</td>
<td>983g</td>
<td>250g</td>
</tr>
<tr>
<td></td>
<td></td>
<td>dry matter content</td>
<td>17</td>
<td>36.5%</td>
<td>6.0%</td>
<td>41.5%</td>
<td>33.2%</td>
</tr>
<tr>
<td></td>
<td>Non-treated original line</td>
<td>tuber weight per plant</td>
<td>13</td>
<td>717g</td>
<td>21.7%</td>
<td>950g</td>
<td>508g</td>
</tr>
<tr>
<td></td>
<td></td>
<td>dry matter content</td>
<td>13</td>
<td>36.7%</td>
<td>4.3%</td>
<td>39.4%</td>
<td>33.6%</td>
</tr>
</tbody>
</table>

showed higher coefficient of variation on tuberous yield and dry matter content than non-treated original lines (Table 4). There are many inferior lines of MV3 generation on tuberous yield and dry matter content than original line and some lines almost same as original line (Kyushu 78). In the case of Kyushu 79, some mutated lines show lower tuberous yield but higher dry matter content than original line.

2) Effect of dose

Doses of $^{32}$P treatment in this experiment were up to 330 $\mu$ci per cutting

Table 5. Effect of irradiation on heritability in MV2 generation of Koganesengan

<table>
<thead>
<tr>
<th>Characters</th>
<th>Year</th>
<th>Dose per cutting ($\mu$Ci)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>Tuber weight</td>
<td>1967</td>
<td>21.4%</td>
</tr>
<tr>
<td></td>
<td>1968</td>
<td>45.0%</td>
</tr>
<tr>
<td>Dry matter content</td>
<td>1967</td>
<td>&lt; 0</td>
</tr>
<tr>
<td></td>
<td>1968</td>
<td>&lt; 0</td>
</tr>
</tbody>
</table>
Table 6. Relationship between dose and sprouting obstruction of tuber (1970)

<table>
<thead>
<tr>
<th>Name of variety</th>
<th>No. of treated tubers A</th>
<th>Average tuber weight</th>
<th>Total dose a)</th>
<th>No. and ratio of rotted tuber B(B/A×100)</th>
<th>No. and ratio of sprouted tuber C(C/A×100)</th>
<th>No. and ratio of non-sprouted tuber D(D/A×100)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kyushu 58</td>
<td>15</td>
<td>2750g</td>
<td>10kR</td>
<td>3( 20)%</td>
<td>12( 80)%</td>
<td>0(  0)%</td>
</tr>
<tr>
<td></td>
<td>15</td>
<td>2400</td>
<td>20</td>
<td>3( 20)</td>
<td>12( 80)</td>
<td>0(  0)</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>1590</td>
<td>10</td>
<td>1( 10)</td>
<td>9( 90)</td>
<td>0(  0)</td>
</tr>
<tr>
<td>Kyushu 34</td>
<td>10</td>
<td>1350</td>
<td>20</td>
<td>2( 20)</td>
<td>8( 80)</td>
<td>0(  0)</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>1480</td>
<td>30</td>
<td>1( 10)</td>
<td>2( 20)</td>
<td>7( 70)</td>
</tr>
<tr>
<td>Kyukai 15-2120</td>
<td>10</td>
<td>1350</td>
<td>10</td>
<td>5( 50)</td>
<td>5( 50)</td>
<td>0(  0)</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>1450</td>
<td>20</td>
<td>9( 90)</td>
<td>0(  0)</td>
<td>1( 10)</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>1260</td>
<td>30</td>
<td>10(100)</td>
<td>0(  0)</td>
<td>0(  0)</td>
</tr>
<tr>
<td>Kyushu 65</td>
<td>5</td>
<td>580</td>
<td>10</td>
<td>0(  0)</td>
<td>5(100)</td>
<td>0(  0)</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>590</td>
<td>20</td>
<td>0(  0)</td>
<td>0(  0)</td>
<td>5(100)</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>660</td>
<td>30</td>
<td>1( 20)</td>
<td>0(  0)</td>
<td>4( 80)</td>
</tr>
</tbody>
</table>

a) Dose-rate was 200 R/h

Koganesengan and treatment of 330 μci showed LD50. Heritability of tuber weight in MV2 generation of Koganesengan showed higher value between 20~330 μci than non-treated line but the heritability did not increase the value as higher doses. Heritability of dry matter content varied year to year (Table 5).

Tubers were irradiated by 60Co with 10~30 kR doses at 200 R/h dose rate. As a result, a dose of 30 kR gave unsprouted tubers and it was difficult to take cuttings (Table 6). Mutation of stem and skin color were observed in 10~20 kR but visible variation did not increase in 30 kR.

3) Progeny test of mutant

Visible mutant such as diameter of vine, color of vine and skin color of tuber did not change until later generations.

F1 hybrid seeds obtained from combinations used skin color mutant as a parent showed high inheritance of tuber skin color to next generation (Table 7).

Clonal transmission of dry matter content on selected lines for high and low dry matter content and tuber weight on selected lines for high and low tuber weight were shown in Fig. 1. As a result, there was tendency to approach to original line both dry matter content and tuber weight, so it is questionable that the selections for dry
Table 7. Progeny test of skin color mutant derived from Okinawa 100 (1973)

<table>
<thead>
<tr>
<th>Combination</th>
<th>No. of investigated plants</th>
<th>Frequency of $F_1$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Female</td>
<td>Male</td>
</tr>
<tr>
<td>Original variety $^{a)}$ Kyukeli $^{b)}$ 15-2120</td>
<td>37</td>
<td></td>
</tr>
<tr>
<td>Mutant of skin color $^{b)}$</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

a): Skin color was pale pink  
b): Skin color was yellow white.

Dry matter content

![Graph of Okinawa 100](image)

![Graph of Kyushu 38](image)

Tuber weight

![Graph of Okinawa 100](image)

![Graph of Satsuma-aka](image)

Fig. 1. Clonal transmission of characters on selected lines.
Table 8. Progeny test of mutant of low starch content derived from irradiated Okinawa 100 (1973)

<table>
<thead>
<tr>
<th>Female</th>
<th>Combination</th>
<th>No. of investigated plant</th>
<th>Dry matter contend</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Mean</td>
</tr>
<tr>
<td>Original variety</td>
<td>Kyukei 15-2120</td>
<td>36</td>
<td>30.6%</td>
</tr>
<tr>
<td>Mutant of low starch content</td>
<td></td>
<td>66</td>
<td>28.3</td>
</tr>
</tbody>
</table>

matter content and tuber weight in these selected lines were genetic variation. They seemed to be rather environmental. To investigate this, selected low starch content line from irradiated Okinawa 100 was used as parental material to produce hybrid seeds. In this hybrid generation, there were more plants of lower dry matter content than combination using original line as parent of F₁ generation and this result meant the selected line was a genetic variation (Table 8).

4) Use of mutant

Breeding process and scheme for use of mutant were shown in Fig. 2. Kyushu 58 was treated by $^{32}$P with $50\sim100$ μCi per cutting in 1968 and tubers produced from above cuttings were irradiated further with 15 kR of $^{60}$Co gamma rays. Cuttings of shoot from these tubers were planted and skin color mutants were selected from them in 1969. Characteristics of mutants were examined in 1970 and 1971. Starch content of skin color mutant lines were higher than that of original line. This mutant was used as female parent in crossing with Kyushu 66 in 1972. Variation of dry matter content in F₁ generation of above cross was compared with that of F₁ generation using original line as parent. As a result, cross of mutant showed a little higher average dry matter content and higher percentage of high dry matter content (more than 39%) individuals than cross of original line. Individuals of high dry matter content and high tuber weight were selected and one of them named as a new line, Kyushu 78 in 1978. Main characteristics of this line were, as shown in Table 9, higher tuber weight and starch content than Kyushu 58 and Norin 2, slightly less tuber weight but higher starch content and a little higher starch yield than Koganesengan.

High resistance of Kyushu 78 to black rot *Ceratocystis fimbriata* (Ellis et Halsted) J.A. Elliott, root knot nematode *Meloidogyne incognita* Kofoid et White and root
lesion nematode Pratylenchus coffeae Zimmermann might be inherited from Kyushu 58.

Thus, Kyushu 78 was considered excellent variety for raw material of starch with the characters as mentioned above except for red skin color. As yellow or white skin color is preferred for raw material of starch, it is necessary to change the skin color of Kyushu 78 for use in starch industry. Then, it was irradiated by $^{60}$Co with 15 kR dose and skin color mutants have been obtained.
Table 9. Characteristics of Kyushu 78

<table>
<thead>
<tr>
<th>Name of variety</th>
<th>Based on Norin 2</th>
<th>Resistance to disease</th>
<th>remark</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ratio of tuber</td>
<td>ratio of starch</td>
<td>black rot</td>
</tr>
<tr>
<td></td>
<td>weight</td>
<td>content</td>
<td>weight</td>
</tr>
<tr>
<td>Kyushu 78</td>
<td>184%</td>
<td>28.6%</td>
<td>226%</td>
</tr>
<tr>
<td>Norin 2</td>
<td>100</td>
<td>22.1</td>
<td>100</td>
</tr>
<tr>
<td>Koganesengan</td>
<td>193</td>
<td>25.1</td>
<td>205</td>
</tr>
<tr>
<td>Kyushu 58</td>
<td>124</td>
<td>25.2</td>
<td>134</td>
</tr>
<tr>
<td>Norin 2</td>
<td>100</td>
<td>23.4</td>
<td>100</td>
</tr>
</tbody>
</table>

Discussion

Natural mutations were frequently observed in sweet potato and “Tsurunashigenchii” and “Beniaka” were main cultivars of natural mutant before cross breeding. In this paper, it is tried to make clear the mutagenic effects and to find out ways to use mutants as breeding materials directly or indirectly.

All mutagens examined, X-ray, ethylene imine, $^{32}$P and $^{60}$Co induced visible mutant and mutagenic effects of them were confirmed. Though optimum doses vary by characters or the varieties, as a rough estimate, 50～200 μci per cutting or 300～500 μci per tuber for $^{32}$P treatment and 15 kR for $^{60}$Co gamma-irradiation for tuber seem to give favorable results. X-ray irradiation and ethylene imine treatments were examined only for one year, and 8 kR of X-ray irradiation seemed too small in dose for optimum but 0.8% treatment of ethylene imine induced some variations.

Although plant type of sweet potato is prostrate and some varieties stretch the vine more than 5 m, short vine is desirable for the mechanization and light receiving efficiency. $^{32}$P or $^{60}$Co treatment induced many slender vine mutants but short vine mutants were observed only after $^{60}$Co irradiation. Though mutagenic effects of vine shortening were proved, short vine mutants were frequently low tuber yield. As a practical mutation breeding, it is necessary to combine characters of short vine and good growth of early stage to get higher yield. Therefore, it is necessary to treat materials by the mutagen and to select necessary mutant keeping eyes on these characters.

There were many reports on artificially induced skin color mutants (Mashima and Sato, 1959; Kukimura, 1971), and such mutants were also induced in the present experiments. In case of $^{60}$Co irradiation to induce a skin color mutant, it is considered
that more than 50 tubers for irradiation and 1,000 cuttings for planting are necessary. Because definite skin color of tuber is desired for consumption of sweet potato, e.g. red or crimson skin color for table cooking and white or yellow for raw material in starch industry, it is necessary to consider both skin colors of parent and of the mutant use as a parent in ordinary breeding.

An attempt to induce the resistant mutant for root lesion nematode using Koganesengan by $^{60}$Co irradiation was failed but resistant mutation for scurf *Menilochaetes infuscans* Ellis et Halsted ex Harter using Kyushu 34 by $^{60}$Co was successful and a resistant mutant was selected. As a result, it is recognized that mutation frequencies seemed to vary with characters and strength of treatment and method of selection should be modified according to breeding objectives.

To increase the starch yield per unit area, it is necessary to get high tuber weight and to increase the starch content. For this purpose, the possibility to induce the variation of high yield and high starch content by radioisotope irradiation are investigated. In some cases, variance of tuber yield and starch content increased in $MV_2$ generation of $^{32}$P or $^{60}$Co treatment than non-treated line. Selection differentials of both characters in early generation were fairly high but these became low and approached to the original line. As a reason for this, it is considered that the selection was made about phenotype of these characters and environmental variation was included in it. Besides, radiation damage might be occured in progenies of irradiation. To make clear the genetic transmission of the selected traits for tuber weight and starch content of mutant, progeny test was conducted. In $F_1$ generation of crosses in which the low starch content mutants were used as parents, plants of low starch content appeared more than in that of cross use the original line as parent. The results proved that induced low starch content variation were genetical, and this suggested the possibility to induce the mutants of quantitative characters. As starch content is a character controlled mainly by additive effects of polygenes, mutant of high starch content will be useful as the parent of hybridization.

As mentioned above, irradiation by radioisotope induced the genetic variation of quantitative characters, but deteriorative variations occured more than progressive variations. However, in some cases, skin color mutants include same or improved plants on quantitative characters (Table 4). To increase the efficiency of repeated irradiation, it is necessary to select desirable plant before each irradiation.

Though selection of qualitative characters after irradiation could be made visually and did not require so much labor for selection, selection of quantitative characters are fairly laborious as it is measured individually. It is recommendable to establish the simple testing method for quantitative characters. There seems to be a positive relation between tuber yield and top growth of early growth stage (Yamakawa and
Sakamoto, 1978) and it may be a simple testing method to select by the amount of top growth in early growth stage. Instead of selection for starch content and dry matter content of tuber, selection by specific gravity of tuber is a easy and economical method. In tuber of sweet potato, the relation between starch content and specific gravity is less tight than that in tuber of potato due to open space in tissue of tubers but enough to use as preliminary selection instead of dry matter content (Sakai et al. 1960). In future, it is necessary to make further investigation to minimize the environmental variation.

Example of practical breeding using mutant was shown in Fig. 2. Original line Kyushu 58 was treated by $^{32}$P and $^{60}$Co and skin color mutants were selected and some mutants showed higher starch content than original line. In F$_1$ generation of cross using high starch content mutant line as parent, average of dry matter content of population and percentage frequency of high dry matter content plant were higher than that of F$_1$ which used original line as parent. From the above result, it is very likely that genes for starch content functioned as additively. High resistance to diseases and pests of Kyushu 78 were inherited from resistant original line Kyushu 58.

As mentioned above, Kyushu 78 was selected from cross between skin color mutant induced from Kyushu 58 by artificial radioisotope treatment. High yield and high starch content line Kyushu 66 was improved for practical characters of tuber yield and starch content. Induced skin color mutant from Kyushu 78 by $^{60}$Co irradiation show high starch content and high resistance to pests and diseases. They will be useful as a parent to introduce these characters to progeny.

**Summary**

X-ray, ethylene imine, $^{32}$P and $^{60}$Co were used as mutagen for sweet potato mutation breeding and visible variations were observed for all mutagen. In the case of $^{60}$Co irradiation, mutation rate of skin color is 0.5~1.3% based on cutting. Direction and variation of dry matter and tuber yield of mutants which were induced by $^{32}$P and/or $^{60}$Co irradiation showed more deteriorative variation than progressive variation but some induced mutant lines show same or superior characters than original line. In the case of $^{32}$P irradiation to tuber, obstruction is not so much up to dose of 10,000 $\mu$Ci per tuber but treatment of 330 $\mu$Ci per cutting approximate to LD$_{50}$. By tuber treatment with $^{60}$Co gamma rays, suppression of sprouting occurred in dose of 30 kR. Tendency to increase a variation was not observed at higher doses. 50~200 $\mu$Ci per cutting or 300~500 $\mu$Ci per tuber in $^{32}$P treatment and 15 kR in $^{60}$Co gamma-irradiation for tuber seemed to be optimum dosages.
Hybrid seed of mutant selected for dry matter content was compared with that of original line and it was concluded that the variation of selected line was genetic.

Mutant induced by $^{32}$P and $^{60}$Co treatment was used as a parental material and progeny of the cross was selected for practical characters. As a result, a line of higher starch yield with high resistance to pest and disease was selected and this line was used as parental material of further breeding.

Acknowledgements

Present experiments conducted at Sweet Potato Breeding Laboratory, Upland Crop Division, Kyushu National Agricultural Experiment Station from 1957 to 1980. The author wish to thank successive chiefs and members of Laboratory for completion of the works by encouragement and support of them. The author also wishes to express his thanks to Mr. S. Sakamoto of present chief of Laboratory for correcting of the manuscript. Irradiation of X-ray and $^{60}$Co were conducted at National Institute of Agricultural Science and Institute of Radiation Breeding, NIAS. Treatment of $^{32}$P was conducted Radio Isotope Laboratory, Kyushu National Agricultural Experiment Station.

The author is grateful to all staffs of above Institute for support of these experiment.

References

かんしょにおける変異体の誘発と利用

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突然変異を誘起し育種に利用する目的で誘発原にＸ線、エチレンイミン、$^{32}$P、$^{60}$Coを用いた。

１）誘発効果

各誘発原とも可視変異が作出され、茎径、茎長、茎色、皮色などの変異が多かった。

塊根に$^{60}$Coを照射した場合の皮色変異の株の出現率は植付株数に対して0.5 〜 1.3 %であった。$^{32}$P及び$^{60}$Coを照射した$vM_2$世代の切干歩合、塊根収量は原系統よりも分散が増大した。照射した後代の切干歩合及び塊根収量の変異方向は負の方向へのものが多い傾向であったが、原系統と同等のもの、上回るものも含まれた。

２）線量効果

$^{32}$Pを切干1株当たり0 〜 330 μCi処理した結果、330 μCiでLD₅₀を示した。塊根照射では塊根当たり10,000 μCiの高線量でも障害は極めて少なかった。$^{60}$Co照射では塊根に10 〜 30 kRを照射した結果、30 kRで不萌芽の塊根が多く障害が大きかった。これら使用した線量の内で、高線量ほど変異が増加する傾向は認められず、したがって$^{32}$P照射では苗当たり50 〜 200 μCi、塊根当たり300 〜 500 μCi、$^{60}$Coの塊根照射では15 kR程度が適当であると考えられた。

３）変異体の後代検定

皮色変異を交配母本にした場合、皮色の伝達力は高いかった。照射した後代の切干歩合及び塊根収量は、$vM_2$世代で選抜差が大きかったが、従時的に差が小さくなる傾向が認められ、突然変異の遺伝性に疑問が抱かれた。このため、照射し低切干歩合で選抜した系統を母本にして交配種子を作成し、後代検定を行った結果、明らかに原系統組合せよりも低切干個体が多く出現し、量的形質についても遺伝的突然変異を誘起できることが認められた。

４）変異体の利用

高でん粉多収性品種の育成を目的に放射線を用いて突然変異の誘起を行い、その突然変異を交配母本に利用して選抜を重ねた結果、原系統の耐病虫抵抗力を受けつき、でん粉歩留り、単位面積当たり塊根収量及びでん粉収量が原系統をはるかに上回る系統を選ぶことができた。この系統は更に$^{60}$Coを照射して皮色突然変異をもっており、交配母本として利用価値が高いと考えられる。

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質 疑 応 答

藤井太：突然変異に再度変異原処理を行い、新しい変異体を誘発する試みをおもちですか？微生物ではかなりやられておりますが、我々のグループの例ですと、窒素固定菌をニトロソグアニジンで処理した後、his(-)がとれたのです。これはNif遺伝子のすぐそばにあるんです。それで、もう一度変異原処理をしてNif(+)をとったという例があるものですから、作物とか観賞植物とかで変異を起させたのですが、何か悪い形質があった時、もう一遍変異原を与えると云う様な方法をとられているかどうかですが。

丸峯：九州78号の場合は交配育種ですが、収量以外の形質、乾燥性や耐病性は相加的な効果がありますので、そう思うものではもう一回やる事によって良い系統が選抜できるかも知れません。
BREEDING OF SETONAMI, A NEW VARIETY OF MAT RUSH BY GAMMA RAY IRRADIATION

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Introduction

Mat rush (*Juncus decipiens* NAKAI) produced in Japan is used in housing life. Ninety to ninety-five percent of it is worked into tatami-facing, and the rest is manufactured into things like a figured mat. The breeding objective of mat rush, therefore, is to improve, in the whole rush growing districts in Japan, favorable varieties for tatami-facing which are of good quality, high yielding, resistant to diseases, adaptable to mechanical cultivation and early and late harvesting. Being good in quality is pre-requisite to anything else, since mat rush is a profitable crop.

In Hiroshima Prefecture, mat rush breeding has been put into practice in a small scale since 1919, and the two methods have been adapted for it: seedling selection and clonal separation.

It was not until 1947, however, that the systematical mat rush breeding started, to which clonal separation was mainly applied. Cross breeding began in 1952, but the four varieties which were registered until now by the Ministry of Agriculture and Forestry were all reared by clonal separation. Mutation breeding by use of radiation started in 1963. Its aim was not only making favorable variations of seedlings and clones out of the varieties hitherto raised and increasing the amount of thus improved variations, but also getting rid of inferior characters of cultivars. The object of this experiment was “Asanagi”, one of the varieties raised in 1962 (Nakano et al. 1968), which has a rather poor yielding ability though its quality in fine. It was irradiated in four treatments by gamma rays and, after that, selections were made in order to get varieties which have high yielding ability and resistant against lodging (Futsuhara 1963, Futsuhara et al. 1967). But, because of the development of netting culture method, which has been popular throughout Japan since 1965, to prevent mat rush from falling down mat rush became more strongly desired to have characters such as good quality, high yielding ability and adaptability to mechanical culture than the resistance for lodging. Consequently, varieties of such characters became the objects
of our selections.

The new variety "Setonami" was raised by this method. Although 19 years have passed since the irradiation of gamma ray, tatami-facing made from Setonami is for better than that made from any other varieties.

The following is the report of its rearing process and its characteristics.

**Rearing Process**

For 187 days from April 18 to December 5 in 1963, plants of Asanagi were irradiated by gamma rays of $^{60}$Co in a gamma field at the Institute of Radiation Breeding (the distance from the source of radiation was 9 meter; the dose rate was 363 R/day; the accumulated dose was 68 kR). Besides these plants, three groups of plants were also irradiated. Irradiated doses were 45 kR, 20 kR and 9 kR respectively as shown in the Table 2. After irradiation, plants were brought to the Tobu Branch of Hiroshima Prefectural Agricultural Experiment Station, separated to about 20 young propagules with 1-3 tillers (the first division, MV$_1$) and transplanted into paddy fields for multiplication. At the first division, 480 individuals were separated from the plants that received the dose of 68 kR. Clonal separation and selections started in December, 1964. They were done as shown in the Table 1. In December, 1969, one of these strains (MV$_7$) were designated as the line number "Seto No.9". Their cuttings were distributed among the prefectures concerned, and their productivity and local adaptability were tested. They were found to be excellent in these tests and registered as "Mat Rush Grass Norin No.5" and named "Setonami" in June 22, 1982.

<table>
<thead>
<tr>
<th>Year</th>
<th>Test</th>
<th>No. of tested Strains</th>
<th>No. of tested Plants</th>
<th>No. of selected Strains</th>
<th>No. of selected Plants</th>
</tr>
</thead>
<tbody>
<tr>
<td>1963</td>
<td>Irradiation of gamma ray</td>
<td>24</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1964</td>
<td>Propagation after division (MV$_1$)</td>
<td>480</td>
<td>467</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1965</td>
<td>Individual selection (MV$_2$)</td>
<td>4,133</td>
<td>100</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1966</td>
<td>Line selection (MV$_3$)</td>
<td>100</td>
<td>13</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1967</td>
<td>Preliminary performance test (MV$_4$)</td>
<td>13</td>
<td>5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1968</td>
<td>Performance test (MV$_5$)</td>
<td>5</td>
<td>5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1969</td>
<td>Performance test (MV$_6$)</td>
<td>5</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1970~</td>
<td>Performance test and local adaptability test</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Results and the Characteristics of SETONAMI

1) Variations as a result of the irradiation and selections

After irradiation of gamma rays, 2.7 percent of the 480 individuals separated at the first division died as shown in the Table 2. Some of them were partly albino, some had extremely thick or slender stems. Thick stems were found more than slender stems. Comparison of the average length of longest stem in each individual revealed that the more the dose of radiation were given, the longer stems were inclined to grow. But, as for the average number of stems per plant, the less the dose of irradiation were given, the more stems the plants produced. In reference to the stem length of

<table>
<thead>
<tr>
<th>Dose (kR)</th>
<th>Dose rate (R/day)</th>
<th>No. of plants tested</th>
<th>No. of plants died</th>
<th>Partial albino</th>
<th>Thick stem</th>
<th>Slender stem</th>
<th>Mean stem length (cm)</th>
<th>Mean stem number</th>
</tr>
</thead>
<tbody>
<tr>
<td>68</td>
<td>363</td>
<td>480</td>
<td>13</td>
<td>2</td>
<td>3</td>
<td>10</td>
<td>121</td>
<td>71</td>
</tr>
<tr>
<td>45</td>
<td>240</td>
<td>512</td>
<td>21</td>
<td>1</td>
<td>3</td>
<td>11</td>
<td>120</td>
<td>82</td>
</tr>
<tr>
<td>20</td>
<td>152</td>
<td>488</td>
<td>12</td>
<td>2</td>
<td>1</td>
<td>10</td>
<td>115</td>
<td>87</td>
</tr>
<tr>
<td>9</td>
<td>52</td>
<td>515</td>
<td>23</td>
<td>1</td>
<td>1</td>
<td>12</td>
<td>118</td>
<td>84</td>
</tr>
<tr>
<td>Cont.</td>
<td></td>
<td>81</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>124</td>
<td>116</td>
</tr>
</tbody>
</table>

Table 3. The distribution of the stem length of the individuals separated once after the irradiation of gamma rays (1964)

<table>
<thead>
<tr>
<th>Dose (kR)</th>
<th>Item</th>
<th>Plant height (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>68</td>
<td>No.</td>
<td>2    3    7    21    137  249  47  1  467</td>
</tr>
<tr>
<td></td>
<td>%</td>
<td>0.4  0.6  1.5  4.5  29.3  53.3  10.1  0.2  100</td>
</tr>
<tr>
<td>45</td>
<td>No.</td>
<td>1    2    3    38    189  215  42  1  491</td>
</tr>
<tr>
<td></td>
<td>%</td>
<td>0.2  0.4  0.6  7.7  38.5  43.8  8.6  0.2  100</td>
</tr>
<tr>
<td>20</td>
<td>No.</td>
<td>2    1    7    76    229  160  1  476</td>
</tr>
<tr>
<td></td>
<td>%</td>
<td>0.4  0.2  1.5  16.0  48.1  33.6  0.2  100</td>
</tr>
<tr>
<td>9</td>
<td>No.</td>
<td>2    5    50   211   206  18  492</td>
</tr>
<tr>
<td></td>
<td>%</td>
<td>0.4  1.0  10.2  42.9  41.9  3.7  100</td>
</tr>
<tr>
<td>Cont.</td>
<td>No.</td>
<td>1    1    19   44    16  81</td>
</tr>
<tr>
<td></td>
<td>%</td>
<td>1.2  1.2  23.5  54.3  19.8  100</td>
</tr>
</tbody>
</table>
Table 4. The distribution of the stems of more than 60cm found in the individuals separated once after the irradiation of gamma rays (1964)

<table>
<thead>
<tr>
<th>Dose (kR)</th>
<th>Item</th>
<th>1--</th>
<th>41--</th>
<th>81--</th>
<th>121--</th>
<th>161--</th>
<th>201--</th>
<th>241--</th>
<th>280</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>68</td>
<td>No.</td>
<td>105</td>
<td>188</td>
<td>123</td>
<td>40</td>
<td>7</td>
<td>3</td>
<td>1</td>
<td></td>
<td>467</td>
</tr>
<tr>
<td></td>
<td>%</td>
<td>22.5</td>
<td>40.3</td>
<td>26.3</td>
<td>8.6</td>
<td>1.5</td>
<td>0.6</td>
<td>0.2</td>
<td></td>
<td>100</td>
</tr>
<tr>
<td>45</td>
<td>No.</td>
<td>76</td>
<td>181</td>
<td>160</td>
<td>60</td>
<td>9</td>
<td>3</td>
<td>2</td>
<td></td>
<td>491</td>
</tr>
<tr>
<td></td>
<td>%</td>
<td>15.5</td>
<td>36.9</td>
<td>32.6</td>
<td>12.2</td>
<td>1.8</td>
<td>0.6</td>
<td>0.4</td>
<td></td>
<td>100</td>
</tr>
<tr>
<td>20</td>
<td>No.</td>
<td>49</td>
<td>176</td>
<td>172</td>
<td>59</td>
<td>16</td>
<td>4</td>
<td></td>
<td></td>
<td>476</td>
</tr>
<tr>
<td></td>
<td>%</td>
<td>10.3</td>
<td>37.0</td>
<td>36.1</td>
<td>12.4</td>
<td>3.4</td>
<td>0.8</td>
<td></td>
<td></td>
<td>100</td>
</tr>
<tr>
<td>9</td>
<td>No.</td>
<td>68</td>
<td>190</td>
<td>147</td>
<td>62</td>
<td>18</td>
<td>6</td>
<td>1</td>
<td></td>
<td>492</td>
</tr>
<tr>
<td></td>
<td>%</td>
<td>13.8</td>
<td>38.6</td>
<td>29.9</td>
<td>12.6</td>
<td>3.7</td>
<td>1.2</td>
<td>0.2</td>
<td></td>
<td>100</td>
</tr>
<tr>
<td>Cont.</td>
<td>No.</td>
<td>8</td>
<td>18</td>
<td>23</td>
<td>13</td>
<td>9</td>
<td>9</td>
<td>1</td>
<td></td>
<td>81</td>
</tr>
<tr>
<td></td>
<td>%</td>
<td>9.9</td>
<td>22.2</td>
<td>28.4</td>
<td>16.4</td>
<td>11.1</td>
<td>11.1</td>
<td>1.2</td>
<td></td>
<td>100</td>
</tr>
</tbody>
</table>

each individual, the more an individual received gamma rays, the longer stems it became to have. Results are shown in Table 3. Table 4 shows that the more an individual was irradiated, the fewer stems it produced.

Inflorescence which appear on stem degrade quality for making. Many individuals

<table>
<thead>
<tr>
<th>Plant height (cm)</th>
<th>Number of inflorescence per hill</th>
</tr>
</thead>
<tbody>
<tr>
<td>76–80</td>
<td>1</td>
</tr>
<tr>
<td>81–85</td>
<td>6 2 11 3 1 1 19 5</td>
</tr>
<tr>
<td>86–90</td>
<td>6 10 21 9 5 1 32 19</td>
</tr>
<tr>
<td>91–95</td>
<td>12 10 21 13 7 1 41 24</td>
</tr>
<tr>
<td>96–100</td>
<td>1 2 2 2 5 2</td>
</tr>
<tr>
<td>101–105</td>
<td>1 1</td>
</tr>
<tr>
<td>Total</td>
<td>25 22 56 27 15 1 3 1 100 50</td>
</tr>
</tbody>
</table>

Note: ( ); Control

Fig. 1. The relation between the plant height and the number of inflorescences per hill separated twice after the irradiation of gamma rays (5 June, 1964).
among 4,133 plants separated twice after the irradiation of gamma rays which amounted to the dose of 68 kR, were found to bear inflorescences. 100 well-grown individuals bearing fewer inflorescences were selected. The relation between their stem length and inflorescences is shown in the Fig. 1. According to observation made in the fifth of June, the individual which was to be called Setonami, later, had stem length of 94 cm, with 51 stems per plant and no flower setting.

These 100 individuals were continually selected by line selection method. These selections were made intending to get line or lines with good growth, but with few inflorescences and slender stems.

Table 5. Characteristics of a new variety “Setonami” as compared to the original variety “Asanagi”

<table>
<thead>
<tr>
<th>Variety</th>
<th>Plant height (cm)</th>
<th>Stem number per hill</th>
<th>Yields (kg/a)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>more than 60 cm</td>
<td>more than 105 cm</td>
<td>more than 60 cm</td>
</tr>
<tr>
<td>Setonami</td>
<td>140</td>
<td>99</td>
<td>54</td>
</tr>
<tr>
<td>Asanagi</td>
<td>136</td>
<td>94</td>
<td>49</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Variety</th>
<th>Percentage of inflorescence setting (%)</th>
<th>Stem thickness (mm)</th>
<th>Weight of stem per 1 meter length (g/100 stems)</th>
<th>Length of leaf sheath (cm)</th>
<th>Tatami facing quality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Setonami</td>
<td>0.4</td>
<td>1.49</td>
<td>34.4</td>
<td>14.5</td>
<td>excellent</td>
</tr>
<tr>
<td>Asanagi</td>
<td>1.4</td>
<td>1.49</td>
<td>35.7</td>
<td>13.7</td>
<td>good</td>
</tr>
</tbody>
</table>

Note: These data are average value of twelve years, 1969 and from 1971 to 1981.

2) The characteristics of a new variety SETONAMI
   (1) Morphological characteristics

Setonami belongs to the intermediate type and its growth form is tiller type. Its stems are longer than Asanagi, the original variety, and it produces more stems than Asanagi. It is notable that Setonami produces many stems longer than 105 cm. It bears very few flowers and its florescence is smaller than Asanagi's. Its mature stems are a little lighter green than Asanagi's, but they are more beautiful than Asanagi's when dried.
The stems of Setonami are rather slender like that of Asanagi, and their thickness is as uniform as that of Asanagi. They are moderately stuffed and pliant.

(2) Ecological characteristics

Setonami's flowering time is the same as Asanagi's. There is little difference between them in regard to the degree of top die. Setonami, however, yield more than Asanagi. Its rate of multiplication by application of manure is high, and its degree of deterioration caused by it is lower than Asanagi.

Setonami seems to be slightly sensitive to Mat Rush Stem Rot (*Rhizoctonia solani* Kühn) than Asanagi, but there is no conspicuous difference when grown by ordinary net culture.

(3) Processing characteristics

As Setonami's stems are slender, the length of a mat woven by the unit number of its long stems is relatively short, but, when field efficiency are considered, length of mat woven by Setonami is longer than by Asanagi, on the basis of an unit planted area. Therefore, Setonami's tatami-facing production per planted area are higher than that of Asanagi. A tatami mat made from Setonami is excellent and beautiful, even superior in quality to that made of Asanagi which has hitherto been reputed as best in quality.
Suitable Regions to Raise SETONAMI and Some Directions for Raising It

1) Suitable regions

Suitable regions to raise Setonami is Setouchi and the north part of Kyushu.

2) Some directions for raising it

(1) Setonami belongs to the tiller type and its stems are slender, which are apt to break easily when they are dug for propagation by cuttings or by separation. For the preparation of sound propagules, dense planting and overgrowth must be avoided.

(2) As the stems are slender, they may fall down at early stage of growth. Set the net early, and, as they grow higher, raise the net higher twice or thrice before the harvest so that may not fall down on the net.

(3) Take preventive measures against Mat Rush Stem Rot according to the standard control measures.

Summary

The new mat rush variety SETONAMI was obtained from ASANAGI by the following procedure. Twenty-four growing plants of Asanagi were irradiated with gamma ray with the accumulated dose of 68 kR (at the distance of 9 meter from $^{60}$Co source, the dose rate of 363 R/day) in a gamma-field at the Institute of Radiation Breeding from April to December, 1963. They were brought back to the Tobu Branch of Hiroshima Prefectural Agricultural Experiment Station in December the same year, divided into 480 individuals and planted in a paddy field. They were then selectively cultivated from December, 1964 by clonal separation.

In December, 1969, one of these strains (MV-7) was named as the line number Seto No.9. Their cuttings were distributed among the prefectures concerned, and their productivity and local adaptability were tested. They were found to be excellent in these tests and registered as “Mat Rush Grass Norin No.5” and named SETONAMI in June 22, 1982.

Although the growth pattern is that of a tiller type, Setonami produces longer stems with a larger number of tillers especially long stems exceeding 105 cm, as compared with Asanagi. It bears very few flowers and its florescence is smaller than Asanagi. The dried stem has more beautiful lustre than Asanagi. The stem is approximately as thick as Asanagi, and also supple. Setonami almost equals Asanagi in the degree of top die. Setonami yields more than Asanagi. Setonami seems to have slightly sensitive to Mat Rush Stem Rot (Rhizoctonia solani Kühn) than Asanagi. There is no conspicuous difference when grown by ordinary net culture.
Tatami-facing production of Setonami per unit planted area is higher than that of Asanagi. A tatami-facing made of Setonami is even superior in quality to that made of Asanagi which has hitherto been reputed as best in quality.

Suitable regions to raise Setonami is Setouchi and the north part of Kyushu.

References

放射線照射によるいぐさ新品種
「せとなみ」の育成

定 平 正 吉

〒720 広島県立農業試験場い草試験地

いぐさの育種目標は、良質多収、耐病性、機械化栽培適性、早・晩期対適応性などを具備する農場用品種を育成することにあるが、なかでも良質であることが最優先される。

いぐさの育種は実生選抜法と栄養系分離法の二方法が行われてきており、これまでに農林登録された4品種は、いずれも栄養系分離法によるものであった。

放射線照射による突然変異育種は、これまでに育成された品種の実生及び栄養体における変異の篭的な向上と量的な拡大を図るとともに、不良性質の除去を行うことを目的として1963年から開始された。

いぐさの新品種「せとなみ」は、1963年4月から12月まで、農林省放射線育種場ガンマー圃場において、生育中の「あさなぎ」24株に総線量68 kR（線源（Co）からの距離9 m、線量率363 R/day）のガンマー線を照射したものの中から育成された。

すなわち、1963年12月照射終了後の株を広島県立農業試験場東部支場（現い草試験地）に持ち帰り、480個体に株分けして水田に植付けを増殖。1964年12月に4,133個体に株分けしてから、栄養系分離法により選抜育成したものである。1969年に「瀬戸9号」の系統名（地方番号）を付し、成績優良なため1982年6月22日いぐさ農林5号に登録、「せとなみ」と命名された。

「せとなみ」は、生育型は分げつ型に属し、あさなぎに比べて茎長は長く、茎数特に、105 cm以上の長茎数が多い。着花は極めて少なく、花序の大きさもあさなぎより小さい。生茎の色はあさなぎよりやや淡緑を呈するが、乾茎の色はあさなぎより美しく光る。茎の太さは中細種に属し、茎の充実は適度でしなやかである。先の程度はあさなぎほど同じである。収量はあさなぎより多い。イグサ紋枯病抵抗性はあさなぎよりもやや弱いようであるが、一般の圃場栽培では顕著な差はみられない。

「せとなみ」は穂が細いため、単位本数当たりの収穫量は短いが、収量が多いため、単位面積当たりの収穫量は多い。収穫の品質は、これまで最良といわれていたあさなぎよりも、さらに良好で美しくある。

「せとなみ」の適地は、瀬戸内及び九州北部地域である。

「せとなみ」を栽培するにあたっては、茎の短く折れやすいため、苗床では過密植にならずにし、本田では倒伏を防ぎ、イグサ紋枯病に対する適確な防除を行う必要がある。
質 疑 応 答

角田：組織培養と突然変異育種をくみ合わせたいとのお話がありましたが、どの様なねらいですか？

定平：現在生長点培養をやっております。それからカルスを作っていますが、充分増えればそれに関放射線をかけたりしたいと思っております。カルスからの再分化については、まだ確立されておりませんが、それができる様になりましたからやってみたいと思っております。
EFFECT OF GAMMA IRRADIATION UPON
THE MUTATION OF SKIN COLOR
OF THE ‘FUJI’ APPLE CULTIVAR

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Shimokuriyagawa, Morioka-city, Iwate-ken, 〒020-01

Introduction

The new apple cultivar ‘Fuji’ was bred at the Morioka Branch, Fruit Tree Research Station in 1958. ‘Fuji’ matures in early or mid-November and has a good texture, good taste and long shelf life as reported by Sadamori et al. (1963).

It is expected that the ‘Fuji’ apple, whose production rate continues to increase, will in the near future replace the Ralls Janet as the leading apple cultivar. The cultivation area of the ‘Fuji’ cultivar occupied about 18,000 ha in 1981 which is over 35% of the total apple growing area in Japan.

Although the quality of the ‘Fuji’ fruit is high, the skin color is not so attractive. In 1963 and 1964 the ‘Fuji’ cultivar was irradiated with gamma rays in the growing tree stage or as dormant scions. Some promising mutants of the color sport mutation were selected. The procedures and results were as follows;

Materials and Method

1) Chronic irradiation to the sapling

In 1963, two year old ‘Fuji’ saplings grafted onto Maruba-kaido (*Malus prunifolia*) were planted in a gamma field of the Institute of Radiation Breeding in Ohmiya-machi, Ibaraki Prefecture which now belongs to the National Institute of Agrobiological Resources.

The dosage per day was different due to the planting distance from the cobalt 60 source, receiving 200 R (R = Röntgen), 100 R, 50 R, 25 R and 12.5 R per day respectively. The saplings were irradiated for 223 days, receiving a total dosage of 44,600 R, 22,300 R, 11,150 R, 5,575 R and 2,788 R respectively.

Irradiated saplings were transplanted in 1964 at the Morioka Branch, Fruit Tree Research Station and were grown without any pruning or cut back of the branches.
2) **Acute irradiation to the dormant scions**

Dormant scions of the 'Fuji' cultivar were sealed up with polyethylene bags and placed at different distances from the cobalt 60 source.

The treatment in 1963 was 6,000 R and 3,000 R each for one day, thus a total dosage in 1963 was 6,000 R and 3,000 R. In 1964, the dosage per day was changed to 6,000 R, 3,000 R, 1,200 R and 600 R and the scions were irradiated for one day, two days, five days and ten days respectively, thus the total dosage in 1964 was 6,000 R in all treatments.

Irradiated scions were sent to the Morioka Branch, Fruit Tree Research Station and grafted onto Maruba-kaido (*M. pumifolia*) rootstock and nursed. Again they were grown without any pruning or cut back of the branches.

**Results**

1) **Chronic irradiation to the sapling**

As shown in Table 1, we selected three color sports from Mori-ho-fu (See footnote in Table 1) No.1, No.2, No.16 and one spur-type tree of Mori-ho-fu No.17 which had a dosage of $50 \times 223$ days, a total dosage of 11,150 R. But all trees which received a total dosage of over 20,000 R died, and trees which received under 5,000 R

<table>
<thead>
<tr>
<th>Dosage per day</th>
<th>Days</th>
<th>Total dosage</th>
<th>No. of trees planted</th>
<th>Survival rate</th>
<th>Mutated tree</th>
<th>Selected strain number</th>
</tr>
</thead>
<tbody>
<tr>
<td>$200^{a} \times 223^{b}$</td>
<td>$= 44,600^{R}$</td>
<td>4</td>
<td>0</td>
<td>0</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>100 $\times 223$</td>
<td>$= 22,300$</td>
<td>9</td>
<td>0</td>
<td>0</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>50 $\times 223$</td>
<td>$= 11,150$</td>
<td>14</td>
<td>8</td>
<td>57.1</td>
<td>4</td>
<td>50.0</td>
</tr>
<tr>
<td>25 $\times 223$</td>
<td>$= 5,575$</td>
<td>19</td>
<td>18</td>
<td>94.7</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>12.5 $\times 223$</td>
<td>$= 2,788$</td>
<td>25</td>
<td>23</td>
<td>92.0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

a R = Röntgen.
b D = Day.
c Mori-ho-fu; 'Mori' means Morioka, 'ho' means irradiated, 'fu' means 'Fuji'. This means that each strain number of the mutated 'Fuji' variety was irradiated and selected at the Morioka Branch, Fruit Tree Research Station.
d Spur-type mutation.
Fig. 1.  Mori-ho-fu\textsuperscript{a} No.1 (The right two are Mori-ho-fu No.1 and left two are the control).
Solid type mutations induced by chronic irradiation of 50 R X 223 days, a total of 11,150 R to saplings of the 'Fuji' cultivar. For color tone of the fruit refer to the original color illustration reported by Yoshida et al. (1981).
\textsuperscript{a}; See foot-note in Table 1.

produced no mutant.

Mori-ho-fu No.1 is a solid color sport, as illustrated in Fig. 1. For color tone of this fruit refer to the original color illustration reported by Yoshida et al. (1981). Two other color sports of Mori-ho-fu, No.2 and No.16, are stripe color sports. Mori-ho-fu No.17 is a spur-type mutation and the fruit size of this sport is very small. Average fruit weight is about 80 g, as illustrated in Fig. 2.

2) Acute irradiation to the dormant scions

Irradiated scions were grafted onto Maruba-kaido at Morioka. After grafting, many abnormal growths occurred, such as rosette, stunt and bifurcate growth as illustrated in Figs. 3, 4, 5. But all these trees returned to normal growth by the following autumn.

As shown in Table 2, in scions receiving 6,000 R (600 R/day X 10 days irradiation), there was no mutation. But five other scions which had received a total dosage of 6,000 R and 3,000 R produced eleven color mutants and two spur-type mutants. All these color sports are of the stripe type. Mori-ho-fu No.3 showed a brilliant red
Fig. 2. Fruit harvested from spur-type mutated tree. Upper center one is control. Left three are Mori-ho-fu\textsuperscript{a} No.18. Middle two are Mori-ho-fu No.17. Right three are Mori-ho-fu No.19. \textsuperscript{a}; See foot-note in Table 1.

Fig. 3. Abnormal growth showing rosette in the 'Fuji' cultivar grafted onto Maruba-kaido (\textit{Malus prunifolia}) rootstock after acute irradiation of 6,000 R to dormant scions.
Fig. 4. Stunted growth in the 'Fuji' cultivar grafted onto Maruba-kaido (*Malus prunifolia*) rootstock after acute irradiation of 3,000 R to dormant scions.

Fig. 5. Bifurcate growth in the 'Fuji' cultivar grafted onto Maruba-kaido (*Malus prunifolia*) rootstock after acute irradiation of 3,000 R to dormant scions.
Table 2. Occurrence of color sport mutation on dormant scions of the ‘Fuji’ variety treated by acute irradiation of gamma rays.

<table>
<thead>
<tr>
<th>Dosage per day × day = total dosage</th>
<th>No. of trees planted</th>
<th>Survival rate</th>
<th>Mutated tree</th>
<th>Selected strain number</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>No.</td>
<td>%</td>
<td>No.</td>
</tr>
<tr>
<td>Irradiation in 1963</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6,000R&lt;sup&gt;a&lt;/sup&gt; × 1&lt;sup&gt;b&lt;/sup&gt; = 6,000R</td>
<td>20</td>
<td>18</td>
<td>90.0</td>
<td>5</td>
</tr>
<tr>
<td>3,000 × 1 = 3,000</td>
<td>29</td>
<td>29</td>
<td>100</td>
<td>4</td>
</tr>
<tr>
<td>Irradiation in 1964</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6,000 × 1 = 6,000</td>
<td>10</td>
<td>9</td>
<td>90.0</td>
<td>1</td>
</tr>
<tr>
<td>3,000 × 2 = 6,000</td>
<td>14</td>
<td>10</td>
<td>71.4</td>
<td>1</td>
</tr>
<tr>
<td>1,200 × 5 = 6,000</td>
<td>21</td>
<td>16</td>
<td>76.2</td>
<td>2</td>
</tr>
<tr>
<td>600 × 10 = 6,000</td>
<td>18</td>
<td>15</td>
<td>83.3</td>
<td>0</td>
</tr>
</tbody>
</table>

<sup>a</sup> R = Röntgen.
<sup>b</sup> D = Day.
<sup>c</sup> Mori-ho-fu; Refer to foot-note in Table 1.
<sup>d</sup> Spur-type mutation.

Fig. 6. Mori-ho-fu<sup>a</sup> No.3 (The right two are Miri-ho-fu No.3 and the left one is the control).
Stripe type mutation induced by acute irradiation of 3,000 R X 1 day, a total of 3,000 R, to dormant scions.
For color tone of the fruit refer to the original color illustration reported by Yoshida et al. (1981).
<sup>a</sup>; See foot-note in Table 1.
color as illustrated in Fig. 6. For color tone of this fruit refer to the original color illustration reported by Yoshida et al. (1981).

Some color sports showed a sector type of coloring like Mori-ho-fu No.2, No.5, No.10, No.11 and No.16 as illustrated in Fig. 7. Mori-ho-fu No.17 and No.18 are spur-type mutations and fruits are very small (cf. Fig. 2).

![Image of apples](image)

**Fig. 7.** Mori-ho-fu\(^a\) No.10. Sector type mutation induced by acute irradiation of 3,000 R X 1 day, a total of 3,000 R, to dormant scions.

For color tone of this fruit refer to the original color illustration reported by Yoshida et al. (1981).\(^a\); See foot-note in Table 1.

**Summary**

We selected fifteen color sports and three spur-type mutations in these experiments. These sports are summarized in Table 3. Although the average size of the fruit looks somewhat lighter than the control ‘Fuji’, the fruit firmness, the refractometer index and malic acid content are not much different from the control. The taste and keeping quality are still the same as the ordinary ‘Fuji’ cultivar.

Among these selected bud sports, Mori-ho-fu No.3 was the best and was considered to be good for practical cultivation. Later we found one other good color sport from Mori-ho-fu No.3 and named it Mori-ho-fu No.3A (cf. Table 3).

It is very interesting that only one sport from Mori-ho-fu No.1 is a solid color
Table 3. Fruit characteristics of the bud mutated ‘Fuji’ variety induced by gamma rays, both chronic and acute irradiation (1973)

<table>
<thead>
<tr>
<th>Strain number</th>
<th>Average weight per fruit (g)</th>
<th>Fruit firmness (1b)</th>
<th>Index of refractometer (%)</th>
<th>Malic acid content (%)</th>
<th>Color type</th>
<th>Appearance</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mori-ho-fu a No.1</td>
<td>220</td>
<td>16.1</td>
<td>12.5</td>
<td>0.30</td>
<td>Solid</td>
<td>Good</td>
<td></td>
</tr>
<tr>
<td>Mori-ho-fu No.2</td>
<td>308</td>
<td>16.7</td>
<td>13.8</td>
<td>0.32</td>
<td>Stripe</td>
<td>Good</td>
<td>Sector (partial)</td>
</tr>
<tr>
<td>Mori-ho-fu No.3</td>
<td>260</td>
<td>15.7</td>
<td>14.1</td>
<td>0.40</td>
<td>Stripe</td>
<td>Good</td>
<td></td>
</tr>
<tr>
<td>Mori-ho-fu No.3 A b</td>
<td>228</td>
<td>14.6</td>
<td>14.3</td>
<td>0.37</td>
<td>Stripe</td>
<td>Good</td>
<td>Promising</td>
</tr>
<tr>
<td>Mori-ho-fu No.5</td>
<td>248</td>
<td>13.9</td>
<td>12.2</td>
<td>0.32</td>
<td>Stripe</td>
<td>Good</td>
<td>Sector (partial)</td>
</tr>
<tr>
<td>Mori-ho-fu No.6</td>
<td>179</td>
<td>17.8</td>
<td>13.2</td>
<td>0.37</td>
<td>Solid</td>
<td>Good</td>
<td>Chimera</td>
</tr>
<tr>
<td>Mori-ho-fu No.7</td>
<td>188</td>
<td>14.7</td>
<td>11.3</td>
<td>0.31</td>
<td>Stripe</td>
<td>Moderate</td>
<td></td>
</tr>
<tr>
<td>Mori-ho-fu No.8</td>
<td>229</td>
<td>14.1</td>
<td>12.3</td>
<td>0.33</td>
<td>Stripe</td>
<td>Good</td>
<td></td>
</tr>
<tr>
<td>Mori-ho-fu No.9</td>
<td>239</td>
<td>14.3</td>
<td>12.0</td>
<td>0.34</td>
<td>Stripe</td>
<td>Good</td>
<td>Russet lenticels</td>
</tr>
<tr>
<td>Mori-ho-fu No.10</td>
<td>307</td>
<td>15.3</td>
<td>12.8</td>
<td>0.42</td>
<td>Stripe</td>
<td>Good</td>
<td>Sector</td>
</tr>
<tr>
<td>Mori-ho-fu No.11</td>
<td>226</td>
<td>15.7</td>
<td>11.7</td>
<td>0.34</td>
<td>Stripe</td>
<td>Moderate</td>
<td>Sector</td>
</tr>
<tr>
<td>Mori-ho-fu No.12</td>
<td>222</td>
<td>15.6</td>
<td>12.6</td>
<td>0.37</td>
<td>Stripe</td>
<td>Moderate</td>
<td></td>
</tr>
<tr>
<td>Mori-ho-fu No.13</td>
<td>229</td>
<td>15.0</td>
<td>12.4</td>
<td>0.33</td>
<td>Stripe</td>
<td>Moderate</td>
<td></td>
</tr>
<tr>
<td>Mori-ho-fu No.14</td>
<td>194</td>
<td>17.3</td>
<td>13.1</td>
<td>0.28</td>
<td>Stripe</td>
<td>Good</td>
<td></td>
</tr>
<tr>
<td>Mori-ho-fu No.16</td>
<td>257</td>
<td>15.5</td>
<td>14.5</td>
<td>0.42</td>
<td>Stripe</td>
<td>Good</td>
<td>Sector (partial)</td>
</tr>
<tr>
<td>Mori-ho-fu No.17</td>
<td>79</td>
<td>18.8</td>
<td>14.0</td>
<td>0.37</td>
<td>Stripe</td>
<td>Bad</td>
<td>Fruit small</td>
</tr>
<tr>
<td>Mori-ho-fu No.18</td>
<td>78</td>
<td>25.0</td>
<td>14.3</td>
<td>0.49</td>
<td>Stripe</td>
<td>Bad</td>
<td>Spur-type</td>
</tr>
<tr>
<td>Mori-ho-fu No.19</td>
<td>102</td>
<td>22.8</td>
<td>14.0</td>
<td>0.60</td>
<td>Stripe</td>
<td>Moderate</td>
<td>Spur-type</td>
</tr>
<tr>
<td>Control b</td>
<td>259</td>
<td>15.1</td>
<td>13.6</td>
<td>0.38</td>
<td>Stripe</td>
<td>Moderate</td>
<td></td>
</tr>
</tbody>
</table>

a Mori-ho-fu; Refer to foot-note in Table 1.
b Data obtained in 1977.

Type, and the other sports are all stripe type. Therefore it is suggested that Mori-ho-fu No.1 is a homozygous recessive mutant, with regard to fruit color, as reported by Ikeda et al. (1976).

Mori-ho-fu No.6 was selected as a solid color type in the first selection, but later it changed to the stripe type. So this strain must be a chimera in fruit color.

We selected three spur-type sports, but all these spur-type trees bore only small fruit, so they are of no value for commercial use.
Acknowledgement

The author wishes to express thanks to co-workers T. Haniuda, S. Tsuchiya, T. Sanada, T. Nishida and S. Sadamori.

References

放射線照射によるリンゴ‘ふじ’の枝変わり誘起

吉田義雄

〒020－01 農林水産省果樹試験場盛岡支場

栽培上着色に問題のある‘ふじ’の優良着色系枝変わりを求めるため1963年、64年に農林水産省農業技術研究所放射線育種場においてガンマー線照射を実施した。

苗木に対する照射は1963年の生育期間中に1日あたりの線量を200 R（R=Röntgen）、100 R、50 R、25 R、12.5 Rとし、それぞれ223日間照射した。

休眠枝（穂木）に対する急照射は1963年は6,000 Rおよび3,000 Rを各1日、1964年には1日あたりの線量を6,000 R、3,000 R、1,200 R、600 Rの4段階に分けて総線量が合計6,000 Rになるよう、それぞれ1日、2日、5日、10日間照射した。

照射した苗木は果樹試験場盛岡支場に移植し、照射した休眠枝は盛岡支場でマルバカイドウ台に接木して突然変異の発現を調査した。

1）苗木照射で1日あたりの線量が100 R以上で総線量が200 R以上をうけた樹は翌年の春を越えなかったが、すべての成長点で伸長がみられず、3年目には全株枯死した（Table1）。

2）苗木照射で1日あたりの線量が25 R以下で総線量から5 kR以下の樹は生存率が90％以上であったが、変異個体は発現しなかった（Table1）。

3）苗木照射で変異個体を発現したのは1日あたりの線量が50 Rで223日間照射した区で、着色系3個体、スーパータイプ枝変わり1個体を発見した（Table1）。

4）休眠枝照射では3,000～6,000 Rを照射し、マルバカイドウ台に接木した後でFig.3、4、5に示す生育の異常がみられたが、翌年の秋まではすべての樹が正常に復した。

5）休眠枝照射で1日あたりの線量が600 Rで10年照射した区では変異個体は得られなかったが、1日6,000 R区で変異率が27.8％と最も多く、次いで1日3,000 R区で13.8％の変異率が得られた。1日あたりの線量を6,000～1,200 Rとし、照射日数を1～5日と変えた区では10～12.5％の変異率が得られた（Table2）。

6）着色系枝変わりは14系統を選抜した。そのうち全面赤色に着色し、しまが現われない1系（Solid type）は1系統（Fig.1）だけで他はすべてが発達する2系（Stripe type）であった（Table3）。

7）Strip typeにはしまが扇形（sector）状に発現するものがあり、实用上問題がある（Table3、Fig.7）。

8）着色系の果実は一般に小さ目であるが、食味は標準‘ふじ’に比べて劣らない。

9）盛放ふ3は選抜当初はSolid typeであったが、変異した枝の伸長にしたがいStripe typeが増加した。これはキメラと思われ、实用に移す場合に問題がある。

10）盛放ふ3は有望と思われる（Fig.6）が、これよりさらに優良枝変わりが出ており、こ
れを盛放ぶ3 Aとした。
11）スーパータイプの枝変わりは3系統発現したが、果実はいずれも100 g前後と小さく実用に供し得ない（Fig. 2）。

質疑応答

久木村：自然の突然変異ではソリッドな着色とストライプの着色の型はどの様に出てくるのかと云うこと、生体照射と急照射とで突然変異体で小玉になり具合、線量の高いもの低いもので相関の様なもののがみられるかどうかを教えて頂きたいのですが。

吉田：自然の枝変わりは各県でておりますが、殆どがストライプの型です。長ぶの2から長ぶの20いくつか迄20数系統あります全部ストライプ型です。青ぶの13、秋ぶの1山ぶの2、岩ぶの10などありますか、殆どストライプです。実用的に使われたソリッドのものは長ぶの1だけです。それから小玉になる線量率、急照射、緩照射の関係はつかんでおりません。

稲津：実用上問題にならないと思いますが、アントチアンが全然なくなってしまっ変異はありませんでしたか。

吉田：ありませんでした。植物体でも果実でもです。

稲津：アントチアンが増量する方向にだけ変異したと考えてよろしいのでしょうか？

吉田：セクターなどの変異もあったのですから、増量の方向にだけ変異したとはいえません。
IRRADIATION SERVICE AT THE INSTITUTE OF RADIATION BREEDING

Yasuo Ukai

Institute of Radiation Breeding, NIAR* MAFF
Ohmiya-machi, Naka-gun, Ibaraki-ken, 〒319-22

History of Irradiation Service

The Institute of Radiation Breeding (IRB) was established on April 1960 and irradiation at the gamma-field started from June 15 of the year. Shortly after the first irradiation, the prescription for irradiation service activity to be carried out at the institute was announced on August 1. The first request for irradiation was on

Table 1. Number of requests for irradiation of plant materials by laboratories and universities

<table>
<thead>
<tr>
<th>Year</th>
<th>National Inst.</th>
<th>Prefect. Inst.</th>
<th>Cooperat. Use</th>
<th>University</th>
<th>Private</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1961</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1962</td>
<td>2</td>
<td>1</td>
<td>13</td>
<td>16</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1963</td>
<td>3</td>
<td>6</td>
<td>3</td>
<td>12</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1964</td>
<td>1</td>
<td>3</td>
<td>6</td>
<td>10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1965</td>
<td>2</td>
<td>3</td>
<td>20</td>
<td>3</td>
<td>28</td>
<td></td>
</tr>
<tr>
<td>1966</td>
<td>1</td>
<td>6</td>
<td>25</td>
<td>1</td>
<td>3</td>
<td>36</td>
</tr>
<tr>
<td>1967</td>
<td>6</td>
<td>8</td>
<td>26</td>
<td>1</td>
<td>12</td>
<td>53</td>
</tr>
<tr>
<td>1968</td>
<td>8</td>
<td>17</td>
<td>29</td>
<td>4</td>
<td>16</td>
<td>74</td>
</tr>
<tr>
<td>1969</td>
<td>5</td>
<td>15</td>
<td>27</td>
<td>4</td>
<td>16</td>
<td>67</td>
</tr>
<tr>
<td>1970</td>
<td>11</td>
<td>14</td>
<td>26</td>
<td>2</td>
<td>13</td>
<td>66</td>
</tr>
<tr>
<td>1971</td>
<td>4</td>
<td>17</td>
<td>23</td>
<td>1</td>
<td>13</td>
<td>58</td>
</tr>
<tr>
<td>1972</td>
<td>7</td>
<td>10</td>
<td>31</td>
<td>3</td>
<td>10</td>
<td>61</td>
</tr>
<tr>
<td>1973</td>
<td>3</td>
<td>10</td>
<td>26</td>
<td>3</td>
<td>7</td>
<td>49</td>
</tr>
<tr>
<td>1974</td>
<td>7</td>
<td>16</td>
<td>24</td>
<td>3</td>
<td>5</td>
<td>55</td>
</tr>
<tr>
<td>1975</td>
<td>5</td>
<td>12</td>
<td>23</td>
<td>2</td>
<td>7</td>
<td>49</td>
</tr>
<tr>
<td>1976</td>
<td>5</td>
<td>13</td>
<td>21</td>
<td>3</td>
<td>11</td>
<td>53</td>
</tr>
<tr>
<td>1977</td>
<td>7</td>
<td>12</td>
<td>23</td>
<td>7</td>
<td>5</td>
<td>54</td>
</tr>
<tr>
<td>1978</td>
<td>7</td>
<td>8</td>
<td>18</td>
<td>1</td>
<td>13</td>
<td>47</td>
</tr>
<tr>
<td>1979</td>
<td>7</td>
<td>14</td>
<td>20</td>
<td>2</td>
<td>6</td>
<td>49</td>
</tr>
<tr>
<td>1980</td>
<td>2</td>
<td>11</td>
<td>21</td>
<td>7</td>
<td>12</td>
<td>53</td>
</tr>
<tr>
<td>1981</td>
<td>10</td>
<td>13</td>
<td>19</td>
<td>10</td>
<td>14</td>
<td>66</td>
</tr>
<tr>
<td>1982</td>
<td>8</td>
<td>11</td>
<td>20</td>
<td>1</td>
<td>10</td>
<td>50</td>
</tr>
</tbody>
</table>

Total 112 220 422 81 173 1008

* Presently NIAR (Nat'l Inst. Agrobiological Resources)
bulbs of gladiolus, lily and other ornamental plants by Horticultural Department of Chiba University on December 25. However, owing to an unexpected breakdown of the bank surrounding the gamma-field during the rainy season of the year, the regular irradiation i.e. irradiation for 20 hours each day except Sunday and national holidays had not been practiced until April 2 of the next year. Only two requests were received in the first year (Table 1).

The number of requests increased during the subsequent six years. Requests came from national and prefectural agricultural institutes as well as universities. In 1965 the budget was acknowledged for Joint Utilization of the gamma-field by national universities and since then irradiation of twenty or more plant materials were generally requested each year. Increase of request is clear in 1967. This may be partly due to the construction of a gamma-room installed with 1200Ci (44.4TBq) of Cobalt-60 source which enabled the irradiation of seed and seedlings at higher exposure rates in relatively short terms. And it may also come from the fact that a rice variety “Reimei” appeared in 1966 as the first one produced by the direct use of induced mutants and that the variety proved to be high yielding and became one of the leading varieties. 1008 requests were received by the end of 1982. Irradiations for the Joint Utilization group were highest in number, followed by those for prefectural agricultural institutes. Requests from gardeners and companies including seed and brewery companies amounted to 173.

Plant materials which were requested to be irradiated by national and prefectural agricultural institutes were all used as sources for plant improvements. A total of 332 requests were classified into eight groups as follows,

<table>
<thead>
<tr>
<th>Group</th>
<th>Number</th>
<th>Group</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rice</td>
<td>90</td>
<td>Industrial crops</td>
<td>34</td>
</tr>
<tr>
<td>Other cereals</td>
<td>42</td>
<td>Forage crops</td>
<td>19</td>
</tr>
<tr>
<td>Legumes</td>
<td>23</td>
<td>Vegetables, flowers</td>
<td>38</td>
</tr>
<tr>
<td>Tuber crops</td>
<td>22</td>
<td>Fruit trees</td>
<td>64</td>
</tr>
</tbody>
</table>

Total 332

Crop plants irradiated covered different sorts of annual and perennial species. Rice was most frequently irradiated. Requests for other cereals including barley, wheat, oats, buckwheat and sorghum were 42. Among legumes soybean was most, accompanied by peas, kidney bean and azuki-bean. Sweet potato was main among tuber crops. Industrial crops included rush, mint, beat, flax and tobacco. Forage crops such as alfalfa, white clover, orchard-grass and dallisgrass are also irradiated but total number of requests was relatively small. Vegetables such as tomato, welsh onion, persil, pumpkin, asparagus, cucumber and ornamentals such as chrysanthemum, margaret, gladiolus, lily, orchid, croton were irradiated. Apples, cherry, persimmon and loquat were treated.
Letter of Inquiry about the Results of Irradiation

To know if the plant materials irradiated at IRB produced successful results in screening of the aimed mutants in later generations or not, letters of inquiry were sent to the relevant institutes under the name of the director Y. Watanabe. Since the universities and private companies seldom put their direct purpose of irradiation in screening of mutants for releasing of a new variety, sending of letters were confined to the national and prefectural agricultural institutes from which irradiations were requested during 18 years from 1962 to 1979. 277 letters were sent out and 222 were returned with reply by February 10, 1980. Sixteen were excluded from summing up of the results, because they had no direct relation to plant improvements. The replies were classified according to success or failure and reason of failure if they not succeeded, giving the following results,

<table>
<thead>
<tr>
<th>Reason of Failure</th>
<th>Count</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>A new variety was released through the irradiation or a promising mutant was obtained</td>
<td>28</td>
<td>(13.6%)</td>
</tr>
<tr>
<td>The population is under multiplication with expectation for obtaining of a promising mutant</td>
<td>53</td>
<td>(25.7%)</td>
</tr>
<tr>
<td>The population was discarded due to severe irradiation damage in M1</td>
<td>15</td>
<td>(7.3%)</td>
</tr>
<tr>
<td>No mutant to be aimed at was detected in M2 or later generations</td>
<td>80</td>
<td>(38.8%)</td>
</tr>
<tr>
<td>Mutants were obtained but eventually discarded due to sterility or deleterious mutations</td>
<td>20</td>
<td>(9.7%)</td>
</tr>
<tr>
<td>Failure in growing of materials after irradiation or other reasons</td>
<td>10</td>
<td>(4.9%)</td>
</tr>
</tbody>
</table>

Number of plants which were grown in M1 and M2 generations much differed with crop plants treated. In rice the number of plants was larger on the average than in other crops but varied from hundreds to tens of thousands between experiments. A fact of interest was obtained when the relation of the number of M1 and M2 plants to success or failure in attainment of the aim of irradiation was investigated. As shown in Fig. 1, the number of plants grown was larger in M1 than in M2 in some experiments and the reverse was true in other. In either case all but one experiments in which release of a new variety was succeeded or one or more promising mutants were obtained had M1 and/or M2 generations larger than 10,000 plants. Similar results were obtained for barley and soybean. The number of plants to be grown in M1 and M2 generations indeed depend upon the expected frequency of the mutant aimed at, the chance of detection of the mutant and others, but it can be concluded from the results that
Fig. 1. Total number of $M_1$ and $M_2$ plants grown in mutation breeding experiments in rice.

- ☺: Release of a new variety was succeeded,
- ●: One or more promising mutants were obtained,
- △: Mutants were obtained but accompanied by unremovable defects,
- ×: No mutants aimed at were obtained.

A sufficient number of plants is prerequisite for successful screening of mutants in plant breeding.

Varieties Produced by Utilizing the Irradiation Service

Yearly change of the number of requested irradiations and the cumulative number of released varieties by direct use of induced mutants in Japan are shown in Fig. 2. The number of varieties steadily increased since 1961 and reached to 35 by the end of 1983. Among them the number of varieties produced, mainly by national and prefectural agricultural institutes, utilizing irradiation service at IRB is 13. The first variety appeared in 1972, 6 years after the start of increase in the number of requests during 1966-1967. As shown in Fig. 3, six to twelve years were required after irradiation for release of a variety. Roughly speaking, from 241 irradiations carried out at IRB
Fig. 2  Years required for a release of a new variety after mutagenic treatment. Rice: 7, 18, 19, 20, 21, Wheat: 4, 11, Barley: 2, 3, 10, 13, Soybean: 8, 9, 22, Azuki-bean: 14, Rape: 1, Lettuce: 5, 6, Tomato: 12, Burdock: 15, 16, 17
●: Variety derived from irradiation at IRB, ○: Variety derived from irradiation or other mutagenic treatments at other institutes or universities.

Fig. 3. Number of irradiation requested (broken line), cumulative number of varieties released through direct use of mutants in Japan (open column) and cumulative number of released varieties derived from irradiations at IRB (solid column).
Table 2. Released varieties produced by direct or indirect use of induced mutants as of December 1983

<table>
<thead>
<tr>
<th>Mutagens</th>
<th>Japan 1) Crops</th>
<th>Ornaments</th>
<th>Other countries 2)</th>
<th>Crops</th>
<th>Ornaments</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gamma-rays</td>
<td>21</td>
<td>9</td>
<td>75</td>
<td>89</td>
<td></td>
<td>194</td>
</tr>
<tr>
<td>X-rays</td>
<td>1</td>
<td></td>
<td>48</td>
<td>111</td>
<td></td>
<td>160</td>
</tr>
<tr>
<td>Thermal neutrons</td>
<td></td>
<td></td>
<td>15</td>
<td>7</td>
<td></td>
<td>22</td>
</tr>
<tr>
<td>Fast neutrons</td>
<td></td>
<td></td>
<td>7</td>
<td>4</td>
<td></td>
<td>11</td>
</tr>
<tr>
<td>Chemicals</td>
<td>1</td>
<td></td>
<td>21</td>
<td>2</td>
<td></td>
<td>24</td>
</tr>
<tr>
<td>Combined</td>
<td>3</td>
<td></td>
<td>7</td>
<td>8</td>
<td></td>
<td>18</td>
</tr>
<tr>
<td>Indirect use</td>
<td>22</td>
<td></td>
<td>103</td>
<td>9</td>
<td></td>
<td>134</td>
</tr>
<tr>
<td>Unknown</td>
<td></td>
<td></td>
<td>9</td>
<td>9</td>
<td></td>
<td>18</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>48</strong></td>
<td><strong>9</strong></td>
<td><strong>285</strong></td>
<td><strong>239</strong></td>
<td></td>
<td><strong>581</strong></td>
</tr>
</tbody>
</table>

1) Ukai, Y. 1982
2) IAEA, Vienna, 1972-1983

from 1961 to 1976 by request from national and prefectural institutes, 13 varieties were successfully produced, the chance of success being about 6 percent.

According to the author's calculation, 581 varieties have been released by direct or indirect use of mutants in the world by the end of 1983 (Table 2). Sparsely ionizing radiations, namely gamma-rays and X-rays are most frequently utilized mutagens. Out of 429 varieties produced by direct use as much as 354 (82%) were derived from the populations treated with gamma-rays or X-rays. The majority of the directly produced varieties in Japan also derived from gamma-rays. Although it is well known that some sort of chemical mutagens and thermal and fast neutrons generally give much higher frequency of mutants, the released varieties derived from these mutagens are small in number in spite of their high efficiency and/or effectiveness for mutation induction. There are several reasons for it. Facilities are not so easily available and the materials to be treated are very limited in quantity in neutron exposure as compared with gamma-ray and X-ray irradiation. The residual radioactivity of plant materials after neutron exposure give much difficulty in handling and growing of the materials. Treatment with chemical mutagens is laborious if the size or quantity of materials to be treated is large. From these circumstances the superiority of sparsely ionizing radiations to other mutagens in practical mutation breeding may remain unchanged and the irradiation service using gamma-rays as a main mutagen as has been so far carried out at IRB may be useful also in future.

Data obtained after the presentation at the Symposium are also included in this report.
Summary

A total of 1008 plant materials were irradiated at IRB as service during 22 years from 1961 to 1982. Requests came from national and prefectural agricultural institutes, universities, private companies, gardeners and so on. Requests from national universities are the most, followed by those from prefectural institutes. Plant materials treated covered a wide range of annual and perennial species. Rice was most frequently irradiated. Among 222 requests for breeding purpose 13.6% resulted in success. Out of the 35 varieties produced by the direct use of mutants by the end of 1983 in Japan, 13 are related to the irradiation service at IRB.

References

放射線育種場の依頼照射

鵜飼保雄

農業技術研究所放射線育種場

〒319-22 茨城県那珂郡大宮町私書箱3号

1961年6月15日のガンマーフィールドの初照射からまもなく8月15日に放射線育種場の依頼照射規定が告示され、生体照射を主とする依頼照射の受付けが始められた。1982年末までに1008件の依頼照射がおこなわれた。1965年からは全国国立大学による東京大学放射線育種共同利用が始まった。依頼者別では、共同利用が約4割、国の農業機関が1割、指定試験場と県農試が2割、共同利用以外の大学等教育機関が8%、民間が2割弱であった。対象作物は穀類、豆類、豆類、野菜、花、花木、果樹等広範囲にわたった。作物別ではイネが最も多かった。

依頼照射に関するアンケート調査の結果では、育種を目的とする206件の照射中、品種育成または有望突然変異体の選抜に成功したのは28件、今後の選抜を期待して照射集団を維持増殖中が53件、残り125件が不成功であった。照射後の当代（M1）と次代（M2）の栽植個体数は、対象作物や実験者により著しく異なっていた。水稻に限っても、数百から数万まで広い差があった。興味あることに、品種育成または有望系統の選抜に成功したのは1件を除きすべて、M1またはM2を1万個体以上供試した場合に限られることが観察から認められた。

突然変異利用による育成品種の数は、1983年末までに、世界で581、日本で57に達している。わが国における突然変異体の直接利用による35品種中、13品種が放射線育種場における依頼照射に由来している。

質疑応答

天野（放育）：世界の育成品種の中のムギ類について、オオムギとコムギでは品種育成の成果の内訳はどうでしょうか？オオムギの方が多いのでしょうか？2倍体と6倍体ともで難しさが違うと思いますが。

鵜飼：1981年までに103品種ありますが、内訳はオオムギが最も多く59、ついてコムギ24、デュラムコムギ12、エンパク7、ライムギ1になっています。

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IRRADIATION SERVICE FOR THE VEGETATIVELY PROPAGATED CROP BREEDING AT THE INSTITUTE OF RADIATION BREEDING

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Since, the establishment of the Institute of Radiation Breeding in 1962, the total of 200 cases of irradiation service of vegetatively propagated crops has been performed on the request from practical breeders of various fields. Joint works between the Institute and other research institutions with the aim of variety improvement are not included into the irradiation service. Among the 200 cases around 40 cases which could not be traced were the service for commercialized irradiated bulbs from the Japan Atomic Energy Relations Organization (Nippon Genshiryoku Bunka Sinkozaidan). And 50 cases which could not also be traced were for private horticulturists or for teaching materials at school. Finally, 109 cases could be followed up into their results by comprehensive questionnaires to each breeder. The present report deals with them.

1) Kinds of the crop plant

Figure 1 shows the number of cases in each crop among the 109 cases of irradiation services. Herbs and ligneous plants are half-and-half. Less number of cases in mulberry, tea and roses is due to the fact that most of these crops have been involved into coordination research projects between the Institute and other laboratories. There was no need to use the irradiation service system in those crops.

Among the 109 cases, 48% of the total were fruit trees, 22% were root crops, 9% were mat rush (Juncus decipiens NAKAI) and Chinese mat grass (Cyperus malaccensis LAM.). As uncommon plant materials, hosho (A kind of camphor tree utilized for extraction of perfume, Cinnamomum camphoroides HAYATA), Japanese butterbur (Petasites japonicus MAXIM.), senkyu (Cnidium officinale MAKINO) were requested to irradiate. Cultivated Japanese butterbur is a triploid plant and senkyu is an inter-

* Presently NIAR (Nat’l Inst. Agrobiological Resources)
specific hybrid of complete sterility. Both of them can not be improved by conventional cross breeding. It is considered that only the induction of somatic mutations can be the source of genetic variations for improvement.

2) Objectives of improvement

Almost all of the 109 cases of irradiation service aimed to produce new cultivars except of some cases in apple and potato. In apple, inactivation of virus was aimed at and in potato killing effect on potato cyst-nematodes (*Heterodera rostochiensis WALL.*) were undertaken though not successful.

Characters expected to induce are listed in Table 1. High yielding, early maturity and better quality are generally aimed at in every crop. Dwarfism, colour changes in flower, fruit and tuber are very frequently aimed at in fruit trees, ornamentals and root crops. Moreover, characters which are difficult to obtain by conventional breeding methods are nominated. For examples, thornlessness of Citrus, larger size of fruit in grape and cherry, flowering characters of chestnut and grape, non-hardy true seed of sweet potato, non-cavern tuber of potato are enumerated, though they seemed to be very difficult to induce by mutations. In Table 1, double underlined characters are actually found among clonal progenies from irradiated materials. Single underlined
Table 1. Expected characters to recover in the irradiation service of vegetatively propagated crops

<table>
<thead>
<tr>
<th>Character</th>
<th>No. of case (%)</th>
<th>Crop *</th>
</tr>
</thead>
<tbody>
<tr>
<td>Colour of flower, fruit skin and tuber skin</td>
<td>31(27)</td>
<td>Apple, Japanese persimmon, rose Chrysanthemum, sweet potato</td>
</tr>
<tr>
<td>Disease resistance</td>
<td>16(14)</td>
<td>Loquat, potato, sweet potato, Chinese mat grass, elephant foot, senkyu</td>
</tr>
<tr>
<td>High yielding</td>
<td>14(12)</td>
<td>Chesnut, taro(Colocasia), mat rush, Chinese mat grass, Japanese butterbur, senkyu</td>
</tr>
<tr>
<td>Better quality</td>
<td>13(11)</td>
<td>Chesnut, mat rush, Japanese butterbur</td>
</tr>
<tr>
<td>Maturity</td>
<td>12(10)</td>
<td>Grape, potato, taro(Colocasia), elephant foot, mat rush, Japanese butterbur</td>
</tr>
<tr>
<td>Dwarfism</td>
<td>12(10)</td>
<td>Loquat, walnut, sweet potato, Gladiorus</td>
</tr>
<tr>
<td>Floral organ( flowering stage, more flowering)</td>
<td>9( 8)</td>
<td>Grape, mat rush, walnut</td>
</tr>
<tr>
<td>Fruit character(size, seedless)</td>
<td>8( 7)</td>
<td>Grape, cherry, Citrus</td>
</tr>
<tr>
<td>Tuber and root(starch content, dormancy, hairiness, non-caverning)</td>
<td>6(5.5)</td>
<td>Potato, taro(Colocasia)</td>
</tr>
<tr>
<td>Others(cold torelance, drought resist-ance, lodging resistance, non-hardy seed, aneuploidy, sprouting habit)</td>
<td>6(5.5)</td>
<td>Citrus, taro(Colocasia), mat grass, sweet potato, sugar cane Gladiorus</td>
</tr>
</tbody>
</table>

* ... actually found among clonal progenies
   ... feasible to be induced though not clear its transmissibility

ones are highly feasible to induce though it was not clear if they are genetic variation or not. From these results, it can be said that such characters were actually obtained by artificial mutations as clour changes of fruit skin and dwarfism in fruit trees, flower colour changes in rose and Chrysanthemum, shorter vines and colour changes of root tuber in sweet potato, less hairiness of taro tuber, better quality and less flowering in mat rush and Chinese mat grass. Only two cases of disease resistance mutation are reported in the irradiation service, field resistance of sweet potato against sculf (*Monilochaetes infuscans* ELLIS et HALSTED) and loquat canker (*Erwinia eriobotryae* ISHIYAMA et MUKOO). In the latter case, it needs more study to conclude because
the judgement has been done only from a single inoculation test in MV₁ generation, and because of extraordinarily high frequency of resistant plants in MV₁ generation.

3) Applicants for the irradiation service

As shown in Figure 2, 80% of the total 109 applicants were from prefectural agricultural or horticultural experiment stations which include 28% of the designated stations by the national subsidy (Shitei shiken). Applicants from national institutions were 14% only of the total, being mostly with Citrus and sweet potato. Reasons behind of this is that there are several national institutions whereby irradiation facilities are installed somehow.

![Fig. 2. Applicant for the irradiation service.](image)

4) Materials and methods of the irradiation

In the most cases, clonal organs, scions, tubers and cutting were applied to the irradiation service, but a few cases of chronic irradiation to whole plant and acute irradiation to true seed were carried out (refer to Figure 3.). In elephant foot (konnyak, Amorphophacus conjak Makino) and potato, chronic irradiation was carried out during the flower bud development and meiosis with the purpose of amplifying the genetic diversity of the seed.

Through the chronic irradiation of mat rush, promising mutants for practical use were recovered from the derivatives which were multiplicated by suckers from MV₁ plants. One of them was tested for their productivity and quality when processed.
It was released as a registered cultivar of the Ministry of Agriculture, Forestry and Fisheries (please refer to the context p.83). Hybrid seed or seed from open pollination of grape, Citrus, chestnut, tea plant, potato, sweet potato and mat rush were irradiated. In the hybrid F₁ seed from the highly heterozygous parents, Mendelian segregation will take place and it is not clear whether the variation of a given seedling is the result from the recombination of parental genotypes or from the mutation. But, from the practical viewpoint, it is expected to amplify the genetic diversity of breeding materials.

Although the successful cases to release new commercial varieties through the irradiation service were all by chronic irradiation, it is yet premature to conclude the relationship between irradiation method (either acute or chronic irradiation) and sifting of promising mutant clones for new release, since the number of examples is so scarce. But it is expected that higher dosage can be applied to materials with less irradiation hazard by the chronic irradiation and it may result in much higher mutation frequency, though mutated somatic sector size tends to be smaller than by acute irradiation. Some ways to enlarge the mutated sector size when the chronic irradiation was employed, should be investigated.

5) Dealing with materials after the irradiation

Irradiated scions of fruit trees are usually grafted onto pertinent root stocks to each species and detection for somatic mutations on the character of interest is followed. When the characters of fruit is a matter of examination, top grafting are employed
in most cases in order to shorten the time to reach flowering. Pruning after the irradiation are ordinary done as well as the practical procedure in the common orchard.

In case of fruit trees the cutting back method are not usually applied, although it might be useful to arrange the all twigs in same clonal generation.

In sweet potato and mat rush, screening for desirable mutant clones were carried out in MV_{2} and in MV_{3} generations. In true seed irradiation of sweet potato and mat grass, screening were carried out in the first or second clonal generation after the irradiation.

Since higher dosages of radiation were applied to true seed than to vegetative organs like scions or tubers in some crops, it has been very frequently recognized that growth of plants and yielding ability is less superior to the control plants. But it was reported that they were recovered in a few clonal generations later.

6) Problems underlying

In Table 2, it is shown that the number of materials applied for mutagenic treat-

<table>
<thead>
<tr>
<th>Crop</th>
<th>When the irradiation was applied</th>
<th>When the selection was carried out</th>
<th>Character recovered</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Material</td>
<td>No. of individual</td>
<td>Generation</td>
</tr>
<tr>
<td>Apple</td>
<td>Dormant scion</td>
<td>15</td>
<td>?</td>
</tr>
<tr>
<td>Loquat</td>
<td>Dormant scion</td>
<td>140</td>
<td>MV_{1}</td>
</tr>
<tr>
<td>Japanese apricot</td>
<td>Seedling</td>
<td>25</td>
<td>?</td>
</tr>
<tr>
<td>Rose</td>
<td>Seedling</td>
<td>30</td>
<td>?</td>
</tr>
<tr>
<td>Chrisanthemum</td>
<td>Rooted seedling</td>
<td>35</td>
<td>MV_{2}</td>
</tr>
<tr>
<td>Mat rush</td>
<td>Stock</td>
<td>96</td>
<td>MV_{3}</td>
</tr>
<tr>
<td>Chinese mat grass</td>
<td>Stock</td>
<td>28</td>
<td>MV_{2}</td>
</tr>
<tr>
<td>Sweet potato</td>
<td>Root tuber</td>
<td>45</td>
<td>MV_{2}</td>
</tr>
<tr>
<td></td>
<td></td>
<td>30</td>
<td>MV_{1}</td>
</tr>
<tr>
<td></td>
<td></td>
<td>30</td>
<td>MV_{1}</td>
</tr>
<tr>
<td>Taro(Colocasia)</td>
<td>Tuber</td>
<td>240</td>
<td>MV_{2}</td>
</tr>
</tbody>
</table>
ment and number of population which were subjected to the selection for expected characters. In the most of successful cases to obtain desired mutations in vegetatively propagated crops, the screening was made in large scales from larger number of materials in advanced generation where the mutated sector by somatic mutation had enlarged enough.

Very frequent cases of practical breeding procedure in irradiation service are as follows: As many as 10 to 20 scions are acutely irradiated with LD_{30} to LD_{50} dosage of radiation and the scions are grafted onto the pertinent healthy root stocks. Grafted union will be allowed to grow and yield by common cultivation management with ordinary pruning procedure up to about 10 years. During that time detection for expected characters is continued without any success. It must be considered to improve the efficacy of recovery of desired mutations by enlarging mutated sectors to promote mutation frequencies.

Cutting back method can force to sprout lateral and latent buds which are consisted of rather less number of cell at the growing point. Consequently it results in larger mutated sectors and higher rates of apparent mutations.

Application of micro-propagation in vitro to mutation breeding is also recommended to step up the clonal generation in a limited time and also it can save the cost of raising the materials in the field or orchard. It would be possible to carry out the mutation breeding in the laboratory scale, if any proper characters are aimed at to secure. Anyhow one must think out some positive means to promote the efficacy in recovery of desired mutant clones.

It was found in the answers to the questionnaires on irradiation services that the success of grafting of scion or rooting of cutting are relatively few because of the radiation damage onto the root primordia or cambia. It is recommended to shield grafting or rooting part of the materials in order to keep the vitality of tissue and to reduce radiation hazard. In a recent case of irradiation service of grape cuttings, lower half of cutting where rooting may come up were shielded with lead plate during the irradiation. This procedure has led better survival rate of the material.

Todd’s Mitcham, a mint cultivar released through mutation breeding in the United Stated in 1971, took 16 years from the irradiation by thermal neutrons (Murray, 1969). Five years later another release was Murray Mitcham from the same material source. In the latter case it took 21 years !! Also in the United States a Bermuda grass cultivar Tifway-2 was released in 1981, taking 11 years of detection and adaptability test (Burton, 1981; Burton et al., 1982). The new cultivar is a mutant which possesses frost resistance and nematode resistance. In Japan, a mat rush cultivar Setonami has been released from Hiroshima Prefectural Agricultural Experiment Station after 19 years since the first chronic irradiation at the Gamma Field of the Institute of Radiation
Breeding (Sadahira et al., 1982). Shiramogi which is a loquat cultivar released from Nagasaki Prefectural Horticulture Experiment Station is one of seedlings which derived from irradiated true seed by open pollination. It took 20 years until the release from the irradiation treatment. It, indeed, takes a plenty of time to screen useful mutants and to multiplicate promising mutant for the sake of various tests. In vegetatively propagated plants, in general, multiplication takes longer time than seed propagated crops. So, adaptability test, check for disease resistance and field performance trials at the farmer’s field or orchard tend to delay toward the rather later stage after the recovery of the mutant than in the case of seed propagated crops.

It is short sighted philosophy to emphasize that the mutation breeding in vegetatively propagated crops is a quick and easy method where Mendelian segregation of mutant homozygotes cannot be expected.

References

栄養繁殖性作物の依頼照射の現状と問題点

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〒319-22   茨城県那珂郡大宮町私書箱 3号

栄養繁殖性作物についての依頼照射は昭和37年以降現在まで約200件である。その成果について、アンケートなどで追跡できた109件の結果を中心として検討した。

1）作物

照射依頼の作物別件数をみると、木本作物と草本作物とは半々であり、木本作物では果樹が圧倒的である。草本作物では、イモ類が半数以上を占めており、またイグサの件数も多い。珍らしい例ではタキ、薬用植物、サトウキビの培育カルスなどの例がある。これらの内から、実用品種として登録されているものはイグサ1件、ヒチトゥイ1件である。木本作物では有望系統として検討され、惑いは検討中のものはあるが、実用品種となったものはない。

2）育種目標

依頼照射の殆どが品種育成を目的としているが、例外としてウィルスの不活性化、殺虫効果を狙ったものもある。育種目標としては、一般的な早生、多収、耐病性、矮性などが多いが、雌花先熟型、雄性化の回復、非確実性などの特殊なもののが目標としている例があった。

実際に得られた変異としては、果樹での果皮着色性、矮性、バラ、キクでの花色変異、イモ類での短蔓性、皮色変異、ミノ毛の少ない変異、イグサの着花性変異、品質などである。耐病性については、遺伝的かどうかの検討が充分ではないが、ビツで報告例がある。

3）依頼者

依頼者は約8割が公立試験場で、その4割は指定試験の育種センターである。残りの2割は数件の民間が占める他は国立試験機関である。

4）照射材料と照射方法

栄養体の急照射が殆どであるが、果樹類のクルミ・ブドウ・カンキツ、イモ類のカンショ・パライショ、イグサ類のイグサ・シヒトウイでは組合わせ種子、自然授粉種子も材料としている。生体照射（生体照射）はウメ、パライショ、コンニャク、イグサ、シヒトウイなどで行われ、実用品種として登録されたイグサ類の2品種はいずれもこれによるものであった。

5）照射後代の取扱

果樹類などでは、急照射を行った種木を接木、芽接などを行い、以降検定して行くのが

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殆んどあり、果実の変異を目的とする場合は高接をしている。積極的な切戻法を採用する例は少なかった様に思われる。カンジョ、イグサなどではvM₃で選抜を行い、希望の変異を見出している。種子照射の場合は実生1～2年目で検定し、選抜しているが、栄養体照射より高い線量を照射する例が多く対照に比較すると、生育・収量で劣る例が多い。

6) 今後の問題点

希望する変異の型を得ている例では、やはり供試材料の規模が大きく、選抜を適当な世代で行っていることが分る。永年生作物では供試材料の数が限られるので、切戻法、ミクロ繁殖法などを積極的に応用する必要がある。また穂枝・植木の照射では、その後木、発根などの際の悪影響を避ける為に低線量率での照射、遮蔽などを考える必要がある。

アメリカで放射線育種により勝れた品種が育成された例では、ハッカで照射から16年、バミューダー・グラスで11年を経過して初めて登録品種となっている。イグサの例でも照射から農林登録まで19年を要している。栄養繁殖性作物では、少数の材料で短期間に勝れた新品種が育成できると安易に考えるべきではない。
総合討論（座長：山口彦之）

座長：昨日と今日にわたって放射線育種の実用品種育成について話し合って頂きました。大学共同利用の成果についても話ししなければいけないので、ひとつだけつけて加えますと、鹿児島大学の池田さんがサトウキビで品種をひとつ出されましたので報告しておきま。糖分が高くて、収量も多いと云うことでも登録が進められています。
それでは、各講演者から、まず補足して頂くことがありましたらここでお願いしたいと思います。フロアからも質問もお願いします。
佐藤：特にありませんが、イネの突然変異育種については戸田さんがむしろ話題提供されたわけです。突然変異体の直接利用の方では、イネの場合で、フジミノリの様な品種を短縮化、短縮化するのに放射線が本当に使えるかどうかと云う様な所で、育種目標をきちんと決めて試みるべきだと思います。短縮化した場合に、穂長も短かくなりますから、どうか種を確保して多収に結びつけるかと云うことでも頭に入れて、いかに放射線が使えるかを考える事が必要であると考えます。また、母本として突然変異体を使う場合、母本としての利用価値がどこにあるかをはっきり根ずることが必要と思います。昨日お話ししました様にレイメイ以外に実際に母本として使われたもので、それは自身は系統番号も付けられていないで、使われている例もあります。良質のコンビカリを短縮化して母本に使って成功した例がありますが、コンビカリを親にした場合は仲々うまく行かない様な時には、長期的に考えて、交配育種でも放射線育種でも短縮化を計ってから使うと云うことも必要であり、長い目でみれば、放射線育種の利用面があるのではないかと云うことも考えております。

座長：昨日佐藤さんから農業技術研究所の菊池さんの遺伝子分析の結果、レイメイと低脚鳥尖とが同じ短縮の遺伝子だと云う報告がありました。
カリフォルニアでも半短性の放射線育種をやっておりますが、その遺伝子も低脚鳥尖の遺伝子と同じだと云う報告があります。この遺伝子は放射線によって出易い遺伝子ではないかと思われます。これはカリフィルニアのイネの交配母本として盛んに使われておりますし、日本でもアメリカでも非常に有用な遺伝子が放射線によって得られていると結論でできます。次に戸田さんのお話は非常に興味がありましたが、講演要旨の中に放射線育種に対する態度と云うことで3点程あけておられますが、私も同感でありまして、昨日はその御説明がなかったのですが、その辺を中心にして補足して頂きたいのですが。
戸田：しゃべりますと時間が長くなりますので、途中での質問が出ましたらふれたいと思います。

今：ビール麦の中で、外国でやって特徴的な例がありますので御紹介申し上げます。チェコスロバキアでの例ですが、パルビッキーと云う品種から突然変異でデアマンと雲う品種を育成しております。原品種はかなり長桿で、倒れ易いものを極短桿にしましたが熟期も10日
間連させて、倒伏に強く、しかも収量の高いものにしております。現在、それから間接利用で収量が高く倒伏しないものを育成し、現在の主力品種になっております。昨冬と思うのは日本では合いませんが、間接利用の良い面じゃないかと思い、大変参考になっております。

長谷川（大放畑）：2点ばかり質問致します。最初に、非常に多品種の変異原を使っておられ、低線子照射や化学物質の方が点突然変異について有意ではないかと述べられましたが、育種に有効な変異原はどれかと云うことの経験的に或いはデータ的に出されておられるかどうかと云う点、次に、ソディウムアザイドについてですが、これは薬緑素突然変異については高い突然変異率がNilanの所で得られており、一方、実用形質ではあまり出ないとは聞いておりますので、アザイドの変異原としての可能性についてお教え頂きたい。

開：最初の点ですが、これはあまり証拠とかデータを持ちません。私共が使っていての実感と云いますか……。何となくそちらを選び易いと云う。科学的ではないが、そう思うことです。ソディウムアザイドですが、薬緑素抵抗性を得る為に手近にあるものを使ったのでありますし、ストライドでお見せした通りの結果が得られており、つまりオ・ムギの薬緑緑抵抗性だと思われるものが得られました。その点では実際に得られたと云う事です。その中味については私はうまく答えられません。結果的にうまく行ったと云う風に思っております。

錦田：昨日品質について申し落しましたが、製あん特性とか食味に関してはまず原品種なみであると云うことをつけ加えます。

座長：その品種（紅南郎）は現在どれ位栽培されているでしょうか？

錦田：現在2,600 ha の小豆作のうち、およそ1/3です。

山口熱：講演要旨の第1表の所ですが、誘発原もはっきりしていないのですが、ハクサイでパイツアイNo.1 と云う品種が中国で突然変異育種によると云うことで報告されておりますが、方法・材料が不明です。インゲンマメ（Haricot bean）で品種がソ連で育成された例があります。どちらも表に入れるものを忘れていましたので補足致します。総計しますと突然変異による新種品は40位と思われます。放射線育種場でやっております依頼照射についてですが、依頼照射を実施される時は、放射線育種場のスタッフと事前によく打ち合せをして頂く、また途中経過の中でも相互に連絡しあって行ってけら、もう少しキメ細かな育種が進むのではないかと考えます。書類だけで、照射した種子が返って行くだけではなく、相互の情報交換を行うことによってもっと有効な結果が得られるのではないかと思います。それから、御出席の皆様は突然変異研究の御経験者でいらっしゃいますが、関連の所に我々の放射線育種場をよく利用して頂く様 PR に努めて頂く様お願いをしておきたいと思います。

松原：私どもの所にも一般の方達が依頼相談に良く来られるのですが、枝変わりと云うとすくに出る様な感覚での相談が多いのですが、先程久木村さんのお話がありました様に、やはり、ある年数慎重にやる必要がある。そうでないと、仲々出て来ないとかいう事です。私達が登録したものでも、あの様な方法を用いましても5年位はかかっておりますので、その点を補足しておきたいと思います。
丸峯：昨日スライドをお見せする時間がなくてお見せ出来なかったのですが、ここで見て頂きたいと思います。

定平：セトナミが良質であると申しましたが、雑表の品質の評点の1点の差がどの位違うのかを補足しておきます。雑表にしますとイグサは10a当りで400～450枚できます。1枚の価値が、セトナミで3,000円位です。アサナギで2,600～2,700円でありまして10aで12万円の差が生ずることになります。品質と申しますと表現がイグサではだいぶ難しかいのですが、この様になります。

吉田：1点だけ補足します。苗木照射をして或いはまた穂木室照射をして盛岡へ移植、或いは大き接木したもの、すべて切り戻しなど樹形に影響することは一切しませんでした。久木村さんが、問題点として積極的な切り戻しがされていないと指摘されましたが、ここで補足しておきます。私どもは強い切り戻しをやるかどうかを話し合ったのですが、あまり強い切り戻しを行なうと放射線の効果か、切り戻しの効果か、分らなくなると考え、軽い間引き程度ではまず次の次第です。試験としてはそれで良いかも知れませんが、積極的に変異個体を得る為に強い切り戻しを行なった方が良かったのではないかと考えております。

鶴野：依頼照射では、私どもが種子をお預りして、適正な線量を照射してお返ししております。山口さんの云われたことと関連するのですが、放射線育種の効率は照射した時点で突然変異が起きたかどうかの誘発率で決るのではないで、照射後集団をどの様に展開させてゆくか、選抜世代でのいかんな選抜をしたかに大きく関与します。特に、材料が自殖か他殖か、倍数体か2倍体かなどがからんで来ると突然変異の誘発率が高いかと云って突然変異体の出現率が高くなると云うわけには行きません。やはり、何が育種目標でどう云う材料かを私どもに教えて頂ければ、どの様な線量にするか参考になりますし、その後の集団の扱い方で何かのお役に立つと考えています。

生井：鶴野さんの云われた自殖性。他殖性でみた場合には、殆どが自殖性のもので成果が上っていると思うのですが、他殖性で実際に成果がみられたものがあれば、栄養系でなく、種子作物の例をお教え頂けませんか？

鶴野：イタリアンライグラスで他殖性の突然変異体を選抜する方法を考えて来たものですから、かなり文献を探しました。牧草類でいくつかの品種がでているのですが、大半は自殖性の牧草でレスペティザ、サブクローバーなどで、他殖性の牧草では非常に例が少ないわけです。しかも、その少し例でも、他殖性と云うことの選択的に使ったと云うわけではなく、どちらかと云えばたまたま出たと言うことで、他殖性に適した方法を積極的に使ったことがないのを知っていると思います。

久木村：1点だけ補足します。例えば、果樹の稲木を照射して、育種の場に持ち帰られて、接木とか発根苗を作られる場合には、着生や発根に失敗する例が多い様です。その様な部分、つまり生きて行く為に必要な部分は、すっかり遮蔽すると云うことも効率が高まることがになると思います。カキの果実特有をみる為に高接を随分やったが、全部失敗してしまったと云う様な例がありました。

中島：久木村さんのお話の最後の所で、切り戻しとミクロ繁殖法を利用するとありましたが、実際にミクロ繁殖法を利用している例があるのでしょうか？
久木村：実際に応用されている例は聞いておりませんが、例えばリンゴなどを使って、1年足らずの内に yM₂をと行ける。勿論組織培養の手法を使っております。放射線育種場で果樹を扱っている真田さん、何か御知知でしたら紹介して下さい。

真田：具体的にそれを使って成果が出たと云う報告はありません。ミクロ繁殖法で非常に大量に増殖することができますし、腹芽をどんどん出させることがで可能ですので、培養を使う場合には初期選抜を使う事のできる形質であれば具体的に展開できるのではないかと思います。例えば、耐病性とか、発根性の問題とか初期選抜のできる形質でないとメリットがないと思います。

中島：生長点を培養して行きますが、リンゴの場合みたいに、物凄く増やすわけですね。その様な方法で、先程の切り戻しの効果をもっとあげると云う様な培養をして行っている選抜するのでではなく、苗を物凄く増やす。そうすれば突然変異を起こしたものを補え易いと思います。その点では生長点を使って個体数を増やすと云うことが手法として確立して来ていると思います。

座長：一通り補足と質問を終り総合討論に入ります。

先程、少し触れました様に、戸田さんは突然変異育種により組む態度として、第一に強い目的意識、次に確実に希望する変異体が得られると云う信念、それから簡易変異検定法をあげておられます。最初の強い目的意識ですが、これはどの部分を改良するかと云う問題ですが、その形質が突然変異により得られるかをスクリーニングする必要があります。グスタフソンが良く言うのですが、ある作物で突然変異があれば、同じ様な形質の突然変異は他の種でもできる。これを並行突然変異と言います。その意味で目的意識をもつことが重要だと思います。山口隆さんが野菜でどうか形質が改良されたかをまとめられておりますが、ある作物でどうか形質が改良されたと云うことを知ることは他の作物にとっても参考になると考えます。この点を戸田さん補足して下さい。

戸田：私の申し上げる強い目的意識として、育種学的に考えたある特定の形質を改善すると云う意味の目的意識よりも、もう少し高いものです。今はイネを売り込むとう云う時代ですが、単純な目的意識では仲々新品種は生まれません。イグサや他の作物で、登録まで年数がかかった指摘がありました。そうするとイネを取りあげてみる背景、自分の売り込みを含めて今の育種は成立しない時代であります。ですから何年も踏みをしているわけだと思います。私の育種目的意識は県や国の行政をリードしつつ次元での発想が必要であると考えます。高冷地には酒米がない、従ってそう云うに対して酒米を栽培して県の米を売りたいものだと云うのは農業試験場の発想で、そう考えることは現在できないわけですから、形質を変えると云う意味でそれに立ち向う為に突然変異育種が役立つことになるかも知れません。毛の無いイネと云うものも農家のこと考えて、私も考えて育成中であります。メクラモチのお話でしたのが、ウルチにもモチを混ぜて建てて売っております。そんなことなら始めるのが良い、中間モチそのものの、遺伝子の問題を取りあげているわけなくて、売ること目的の為にやっているので、目的意識の対象が違うわけです。それから、日本のイネを2〜3％はどうしてもあげたいものですが、それにはどうするかと云う目的意識。これからは韓国やIRRI系や、草型のものに対し
て突然変異はどういう風に立ち向うべきか、それでも新しい発想だと思います。日本全体、ある県と美しいものをリードし得るものを探し得る強い目的意識を考えて頂ければ有難いと思っております。

角田（東北大）：私のデントライス構想について戸田さんが講演の中で言及されて、ちょっと誤解があるかと思いますので弁解しております。7年前の育種学会の多収性グループの10周年記念でデントライス計画と云うものを提案したのを、もう少し詳細に「農業と経済」という一般誌に書いております。それを読みたくと真実が解けて頂けると思います。デントライス構想とは、粉状の米を造ることを誤解されています。デントライスは飼料作物として改良された品種群ですが、そう思うものをイネで作ろうと思う構想であります。品質としてはデントライスを頭においたものです。全部が粉状じゃないと、外側がもう少し白で中に粉状のものが沢山つまっているものであり、粗碎きでも非常に早く生で消化できるもので、決して全部が粉状ではありません。chalky と云うもの、トウモロコシで云えば粉粒種と云うものを観点におき、イネでやってみるべきだと言っております。デントライス構想自身はトウモロコシのデント型、つまり凹んでると思う意味ですが、凹んでる原因が、外側にもう少し質があって中側に粉状部があって頭に出ていると云う意味です。そう思う形質なんで、戸田さんが育成された信州38はそれに近いものであります。

戸田：粒質を変える場合、千粒重量は収量に関係なく変えるようすれば、腹白が一番であります。その次に小さな心白、これは酒米にも使えませんが、そのものは食味が普通のものと変わりませんから、何らかの識別性をつけなければならない。中位の心白、これは酒米にとどまらずですから、酒米との競合の問題があり、酒米を飼料米で作っていると云う時代になると非常に問題でしょう。それから、大心白、心白部分を大きくすればする程、一般論としては、千粒重が軽くなり、稔実も悪くなり、収量も低下します。限界がりやり所の関心を深くさせ、そこで考えれば、4、5年あれば、その様々な系統はいかほどでしょう。それから、飼料米の識別性で困る必要はありません。国で踏み切る場合は技術は既にありますのでどうぞおやり下さいと云えます。しかし、その迄言うと怒る人がいますから、何ですか、一応、放射線育種で組み込んだ場合は楽ですよ、後で残った問題が困るんですと申しあげたいのです。私は醸造米になると思うのをデントライスと思っておりますので、大変失礼しました。

角田：デントライスがフリント、スイートと異なるのは、識別性でそうなかったのではなく、元々、飼料用として養うものを作ると云う農民の期待に答えた結果であると、アメリカではさんが聞かされました。日本でも長期的な展望では識別性ではなくて、飼料米として最高品質を求めれば、当然飯米と違ってると私は考えます。

座長：富山大学の小林さんはゴマで新数を増やした突然変異体を作っておられますが、新数を増やすと云う事に成功されました。どういう風に発想されましたか？

小林（富山大）：植物の形態学的な細かい観察が大事な要素です。突然変異育種をやる段階でも、そう思う基礎的観察に基づく発見から始まるのではないかと感じています。Capsule は心皮からできていますが、その心皮を増やすにはどうしたらいかと考え
ました。大豆、小豆では同じCapsuleを作り出しても、これは一枚の葉ですが、ゴマは幸いにして数枚の心皮からできており、元々は一枚のものからできているのが原型と考えられます。長期間の栽培の間に自然の中で心皮数を増やすと云う方向にきたと云うこともありりますから、何か適当な処置をやればもっと増やす方法が見つからないかと考えました。つまり、形態学的な観点が大切だと云う実感です。

藤澤：安易な気持ちでやるよりは、植物学の解剖学的と云うか、発生学的と云うか、その様々な点からどうするかが考えられるかと云う勉強を絶えずしておかなければならないと云うことだと思います。

次に、変異原で処理しても、放射線照射をしても、結局は変異をどうやって見つけるかが重要で、やはり茎が短い、早生、色などが主眼になっております。しかしこう云う可視的なものではなく、今後は生理的または品質的な変異の発見方法の開発をしていかなければならないと考えます。この点については何かありませんか？例えば依頼照射で今まで全く異なる形質が着目している例などはいかがですか？

鶴尾：簡単な形質以外で、耐病性が依頼照射の中で一番多いです。短縮、早生、雄性不稔などは数百分の1、数千分の1でできますが、耐病性は数百分の1とかで、1栄養2栄養低くなりますので、個体数を非常に沢山扱わねばならないと云う点で困るところもあります。従って、接木で大量に検定できるとか、トキシンで細胞レベルで選抜するとか、雑種で繰り返し検査するのに、簡単な形質が残ると云うものなら簡単ですが、そうでなければ、生体をひとつの一つ測らねばならないと云うものは変異選択では難しいと思います。

久木村：栄養繁殖性作物の依頼照射で目的とされ、難しい形質と云うのは、やはり生産形質で、イモ類の薬粉防と云った様なものです。やはり、簡易検定法がないとなかなか育種の現場では困難です。例えばパレインでは簡単に比重で薬粉防をチェックできますので、かなり大きな照射後の集団を扱うこともできると思います。簡易な変異検定法の開発が少ない、難しい形質では大変だと思います。

座長：変異の発見は2段階でやるべきだと思います。まず大雑把に選抜する。次に細かい検討をする。それでなければ発見できないのではないか。戸田さん如何ですか？

戸田：2番目に信念と云いましたが、アルビノ、クロロフィール変異などは確率ででます。また形質では突然変異率は、場合によっては育種家自身が作るものと考えます。突然変異を発見する方法の為の検定方法によってスペクトルが変わるわけですから、やはり強い目的意識で、自分なりの最高の知恵を発揮し一番のスペクトルを云うことになりますから、突然変異率は育種家自身が自分作り出すものである、もっと強い云い方をしますと、スペクトルは自分が引きよせるものである、と。それ故の気持ちでないといけないと云うのが私の信念です。モチは1割収量が低いのは当然ですが、それを10割に戻してみせると、スペクトルが変って来ます。人によってうんと違って来ます。信念とやり方の中で決まって来ます。次のような変異発見法についてですが、可視的な形質では私のやった程度が限度だろうと思います。もっとこれからは新しい時代に入って行くと
思いません。突然変異芽種の場合は多数の系統を収量テストしないと駄目だと思いません。植株が5cm短いと云うほどの、色々な形質に関連するため、植株が高いか低いかと云うことは、測定値で単に低いのではなくて、野菜の中で、いつ観察したときに低かった、その次の時も低かった、と云う風に記載して、野菜が真黒になって、最後に書いてみたら短かったと云うことだけではないのであって、刀ってみて、測定したら短かっただけでは仕方がないと思います。種数や菌株説明でも圃場で細かい観察が必要であると考えます。収量は何年やっても正確には揃えられません。それより種数、菌株、登熟歩合、粒重などが必要に重要なことを考えています。千粒重はあまり注目されますが、これは非常に重要な方法であると考えております。原種類を100とした時の千粒重の相対値は年次によるばらつきが殆どなく、2％も違って10％水準で有意差ができます。そう思うものを重要視して、収量調査はそれを裏づけるものとしてみるべきだと思います。たとえ統計処理だけで、手法が正しいならば良いと云うわけではない、圃場で観察し、それを検証するものとして収量を調べるべきだと思います。AとBとではどちらが正しいかを決めたら、ではBとCとではどちらが良いか、そのことを行きつ遅れて検定しないといけないと思います。最後に申しあげておきたいのですが、単純な劣性突然変異ではなく、非常に複雑な現象を扱っているのだと云うことです。パラと変わっただけで、他の形質が変わっていないことをとは殆どないので、そこにまた面白さや可能性があるのであって、劣悪なもののがそんな風に出てきます。そこで何を見るかはそれからの問題であります。新しいイネの品種に立ち向かう、そう思う時代であると思います。普通の可視的な時代は終った、新しいものにどう立ち向かうか、新しい突然変異育種の方法に習うことをポッシュする時だと思います。

飼料：変異の選抜に関じて、雑種育種と直接比較しますと、雑種の場合は変異が連続的になります。そしてその様な分布の一番極端なものを拾えることになると思います。突然変異芽種では、それぞれの遺伝子が単独で変化していますので圃場全体を見渡した時は交雑種よりも円均に見えます。そうすると雑種芽種を長年やって来た人には放射線をかけたが大して変異は出なかったと判断する場合が間々あると思いますが、その点は変異の出方がまるで違うのだと云うことを念頭に置くべきだと思います。突然変異では円均に見える集団でも非常に低い頻度ですが、目的とするものがポッと出ると云う出方でありますので、選抜もそれにあわせたものにする必要があると感じます。

座長：突然変異芽種の成功例は自殖性作物だけで、他殖性作物にはないが、何故でしょうか？その辺を少し。

天野：トウモロコシで永年突然変異をやってきましたが、トウモロコシは自家不和合でなく、自殖がきますので、例として適当かどうかは分かりませんが、強制自殖できるなら突然変異体をとることは難しくありません。ヘテロシスを起しませますので、検定系統と支配すると遺伝子のバックグラウンドがバラバラになってしまいますか、元の親系統の花粉と混ぜる様なことをして、選抜の段階で特別な事を考えますが自殖系での突然変異体をとることも不可能ではない様です。これはテスターとして使える様々な特徴に関する遺伝学的実験で、育種ではないのですが、ですから他殖性の場合でも不可能ではないと思います。
中島薔：質問ですが、山口薔さんの野菜の例の中に、カラシナとかホウレンソウの様な他殖性のものがありました、我々での例はありませんか？どの様に進められているのでしょうか？

山口薔：申し訳ありませんが、原典に遇って調べておりません。完全な他殖性作物でなく、かなりのものが部分他殖で行けるものがあったりしてまして、手法的には自殖に類似した形で進められているのではないかと思います。

座長：トウモロコシの例が出てましたが、トウモロコシは雄花と雌花が異熟のために他殖になっているわけで、他殖の植物で突然変異育種をやる時には他殖自殖の方向にもって行くのもひとつの方法でありましょう。例えばトウモロコシで雄花と雌花と同じにマッチする突然変異体がないかと、そう思う風に考えます。

天野：トウモロコシでは、個体の内部で自殖させるに苦労するのは極く少数の系統で、熟期そのものはほぼ一致しております。すなわち、雄花が早咲く位で、雌花が開いている時にまだ花粉は残っておりますので自殖は可能です。雄花と雌花が着生する場所が違います。種子を照射した場合、雄花と雌花とで突然変異セクターが別になります為に、普通に自殖したのでは突然変異体がとれません。それをもう一世代播いてみるか、または花粉に紫外線照射するとかしますと自殖で突然変異体が拾えます。トウモロコシではセクターを考えないといけませんが、熟期では自家和合ですから突然変異体はとれています。

生井：用語の整理をした方が良いと思います。自殖性、他殖性となっておりますが、本当は自家交配の作物と、自家不和合性のものとした方が良いと思います。他殖性でも自家合合がありますし、それは突然変異育種の可能性があります。本当の意味で自家不和合性のBrassicaでは蕾変粉ができません、カラシナは自家不和合性ですが、部分不稔と云う程度です。本当の意味で自家不和合で自殖のきかない作物で名前を教えて頂きたい。

鶴崎：イタリアンライグラスの方法ですと、自家不和合の場合でも応用がきくと思います。同じ個体からとった稔い枝を次代の系統としてまとめて植えて、その系統の中だけで交雑し、系統間は隔離する様にします。すると普通の自殖性作物の1/4の期待頻度で突然変異体がとれます。いちおうイタリアンライグラスで実証されていますし、他ので自己不和合性のものでもできると思います。個体で交雑すればいく場合もあるのですが、育種規模で考えた時には、それぞれの個体に掛けて種子がとれると云う他殖性は数が少ないと思いますので、やはり自然の集団で自殖か他殖かの分類もそう言う方法を選択する時の判定の規準にするんじゃないかと思います。

座長：もうひとつの問題は、カンショの突然変異育種で、倍数体であり、また栄養繁殖であり、丸峯さんから大難しいとかお話がありました。その点丸峯さん如何でしょうか？

丸峯：カンショでは3～4の目標で始めました。ひとつは皮色、あと是作業能率化のための短づくり、穀粉含量などです。穀粉含量は、在来の「無藤無砂」と言う品種が24.5％程度、今一番高い品種で29.5％です。30～40年間で5％向上したのですが、それ程度高くない。突然変異で真に1％の向上ができれば大きな成果であると考えまして大分力を入れてやりました。変異のみつけ方としては、最終的には個々の穀粉値を測定するのですか、大量の材料を検定する為には、硬度、比重選などをやります。パレイショと違いまし
て、孔隙率が違いますので、品種間では0.4～0.5程度しか相関がありませんが、品種内では0.8以上と高い相関があります。γ線照射後、比重測定を致しましたが10a単位で測定した比重測定との相関がでたのですが、翌年はなくなったと云うことで、それは年次の変異とあまり広い面積のものを使ったため、環境変異も入って来ていたと考えました。もっと小面積で比重測定すれば、澱粉含量についても選抜できるのではないかと考えます。収量性については、変性ですので競合が多く、仲々真の変異をみつけることができません。しかし、地上部の初期生育と収量と相関がありますので、初期生育にも注目して選抜すれば、収量性に関する選抜もできるのではないかと思います。

座長：これで総合討論を終わりますが、まとめとして、突然変異は色々と成果が上っていると考えます。しかし、技術として確立しました後の、どうやって発展させて行くかで、先程から問題になっております様に、やはり目的意識をもってゆくこと、信念、それから変異の発見法の開発だと思います。何事も頭を使って工夫すると云うのが重要で、この御出席の皆様の中で、依頼照射を放射線育種場にされる方は、種子をたすって送って送り返して貰うだけではなく、変異をどうやってみつけるかについて、照射をする前に一度訪問されて、ディスカッションをスタッフの人達として、確実に突然変異を得る様にした方が成功に近づくのではないかと思います。長時間の御討論ありがとうございました。