Breeding Seedless Watermelon by Using Induced Chromosome Translocation

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Parthenocarpic or seedless fruits are desirable and are popular with consumers, for the development of ovary to a fruit germination of pollen grains on the stigma is necessary to supply growth hormones to stimulate the ovary for further development. Artificial production of seedless fruit is possible by the application of synthetic hormones or by genetic manipulation of sterility barriers.

In Japan seedless watermelon was bred by the utilization of triploidy as sterility barrier (Kihara and Nishiyama 1947, Kihara 1958). Triploid hybrid seeds were obtained from diploid (male) and their autotetraploid (female) as parents. The parthenocarpic fruits were produced by pollination of triploid with pollen grains of diploid plant. Triploid watermelon seeds are commercially produced in Japan and the fruits are popular with the consumers.

However, there are some disadvantages like low yield of F_1 seeds for commercial production, difficulty of germination and nursing F_1 seedlings. Growth period is prolonged in triploid plant with delayed maturity of fruits which is undesirable under Japanese conditions. Sometimes there are developmental defects of hollow heart and colored empty seeds in the fruit.

These defects are mainly due to the nature of polyploidy of parents and the F_1 plants. If the sterility can be induced with structural changes in the chromosomes without change in the chromosome number maintaining diploid level, it may be possible to avoid low production of F_1 seeds, germination difficulty and the other defects of triploid breeding program of seedless watermelon.

Moreover, in this method prior knowledge of varieties and their combining abilities can be used for the selection of proper combinations and to utilize chromosome translocation in any variety unlike in triploid breeding procedure. In this paper an outline of work to utilize chromosome translocation is presented with particular reference to breeding seedless watermelon.

Chromosome translocation and sterility

Chromosome translocation may occur spontaneously or in response to physical and chemi-

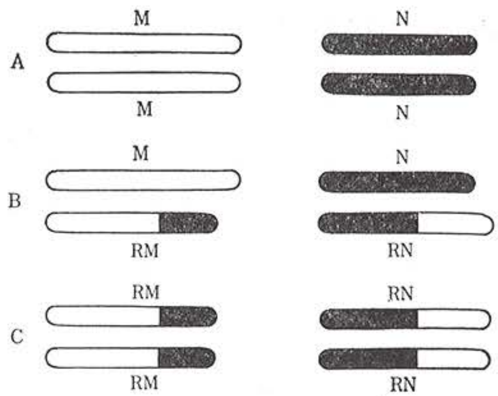


Fig. 1. Diagram of chromosome translocation
A: Normal pairs of original chromosomes.
B: Translocation heterozygote.
C: Translocation homozygote.

cal mutagenic agents. In the present study X-ray was used to induce chromosome aberrations. Translocation may be heterozygote or homozygote in constitution of chromosome pairs. A case of simple reciprocal translocation is presented in Fig. 1. Fig. 1A shows two pairs of normal chromosomes, Fig. 1B shows interchange, part of chromosome between non-homologous chromosomes M and N (translocation heterozygote) and Fig. 1C translocation homozygote.

A translocation homozygote with a few or many interchanges, in the absence of position effects does not differ from normal plant in the phenotypic expression since the total dose of genes per cell remains the same. The chromosome behaviour at meiosis is normal without causing sterility.

From complex translocation heterozygote, homozygote with many viable interchanges are built up by repeated selfing, intercrossing followed by selection. The true breeding homozygous translocated line is intercrossed with normal plant and in F_1 hybrid plant disturbances are caused at the time of meiosis causing abortive gamete formation.

Chromosomes at the meiosis stage show formation of rings of four, six, eight or more chromosomes depending on the number of times of translocation of the homozygous parent stock. Plenty of abortive gametes result from such abnormal division of cell; thereby, the seed setting is limited to a few or none in the fruit. The extent of abortive gamete formation is proportional to the number of times of chromosome interchanges in the original homozygote translocated parent stock.

Experimental results and program for breeding seedless watermelon

Main principles about the use of translocation for breeding seedless fruits are mentioned above.

Use of hybrid seed of watermelon is popular in commercial cultivation because of the hybrid vigour of the plant in bearing fruits and other agronomic advantages. Experiments were carried out in order to test the practical utility of translocation technique in the production of seedless watermelon fruits from the year 1957 to 1961 (Nishimura and Sakaguchi 1960, Sakaguchi 1962).

Asahi-yamato, a popular variety used as a parent in hybrid seed production, was irradiated by 6 kr of X-ray. Plants with translocation were screened from the population. Some of the translocation heterozygotes were intercrossed for building up more translocations. Plants were studied for chromosome associations. Pollen fertility and seed setting were observed.

In a normal watermelon plant eleven bivalents of chromosomes are observed in the pollen mother cells at meiosis as shown in Fig. 2A. In some plants a ring of six chromosomes and two rings of four chromosomes were observed as shown in Fig. 2B. Fig. 3 shows microphotographs of pollen grains in normal plant and translocation heterozygote

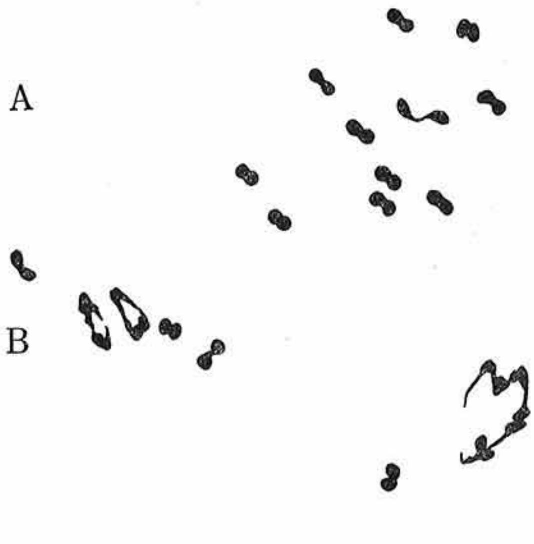


Fig. 2. Association of chromosomes in pollen mother cell at meiosis
A: Eleven bivalents in normal plant.
B: A ring of six chromosomes, two rings of four chromosomes and four bivalents in translocation heterozygote.

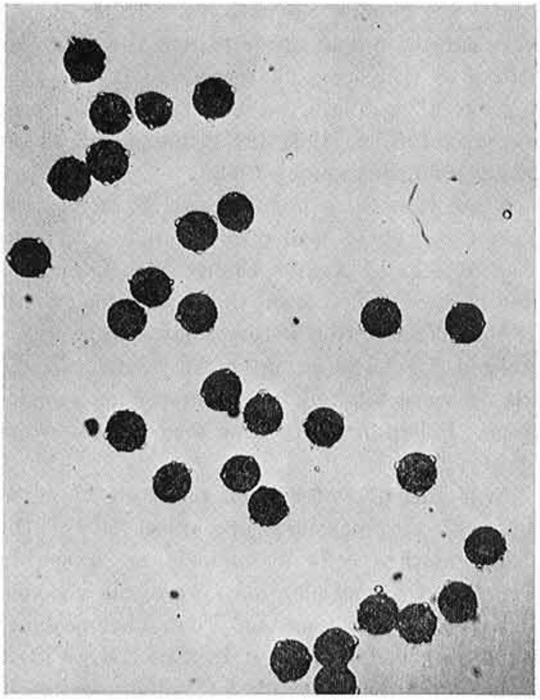
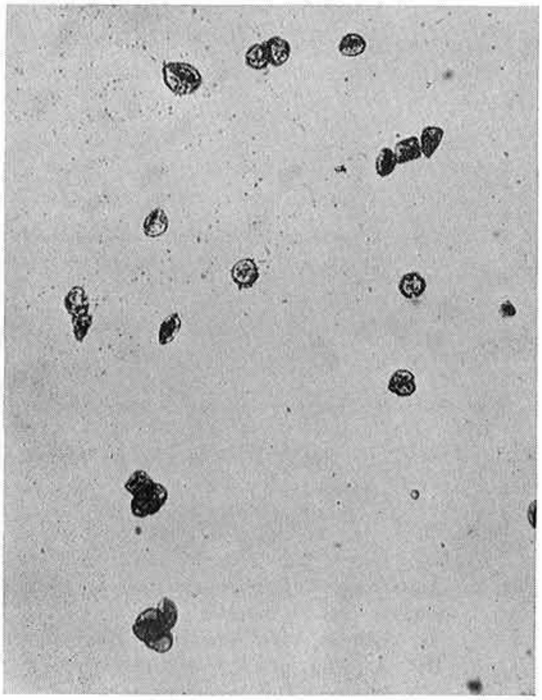


Fig. 3. Microphotographs of pollen grains
A: Normal plant.



B: Abortion in translocation heterozygote.

plant with four times of translocations.

Pollen fertility or seed number is inversely proportional to the number of times of translocation, with increase of every one time of translocation fertility is reduced to nearly half (Fig. 4). In these studies plants with 3.1%

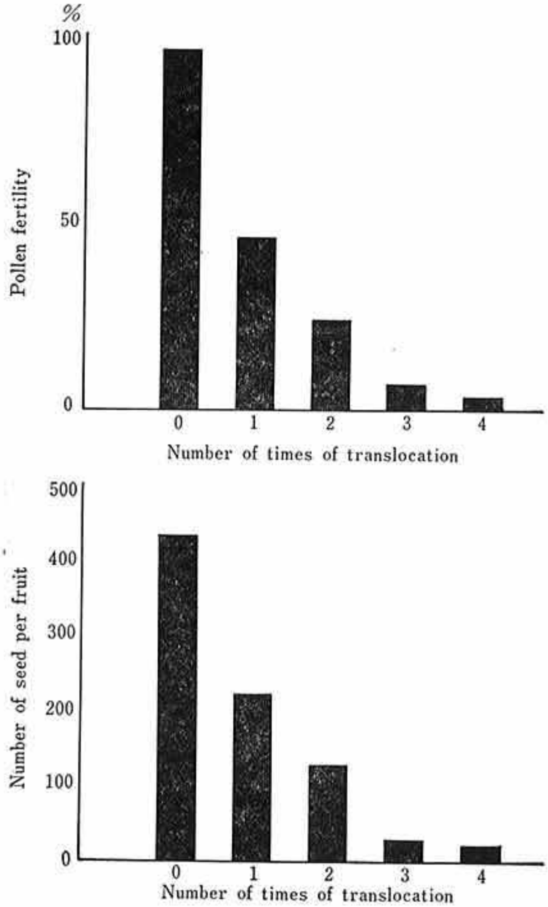


Fig. 4. Relationships between the fertility and the number of times of translocation
A: On the pollen fertility.
B: On the seed setting.

of pollen fertility (percentage of dark stained grain with pigment) with 19.9 seed setting on an average per fruit were observed in heterozygote with four times of translocations. In the normal plant the fertile pollen was 95.3% with 429.2 seeds per fruit.

No differences were observed between normal and hybrid plant in habit, size, taste and texture of fruit and in the agronomic characters except in sterility. Transverse sections of normal watermelon fruit and seedless fruit borne on the plants with chromosome translocations are presented in Fig. 5.

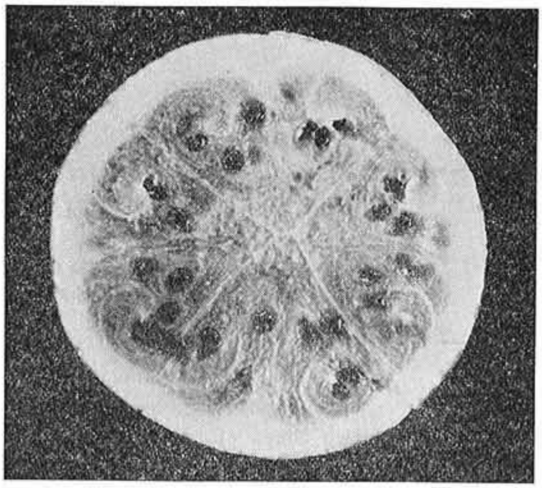
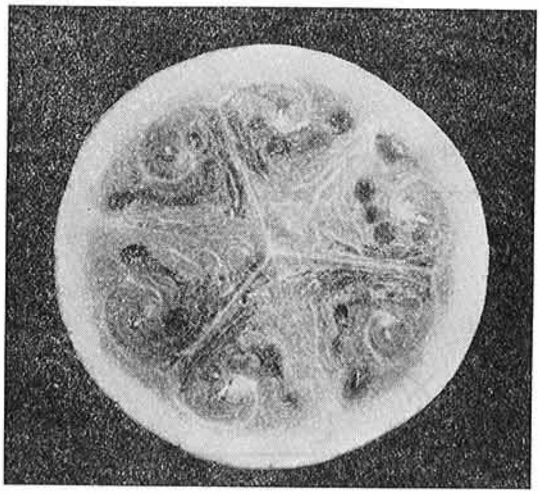


Fig. 5. Transverse section of watermelon fruits
A: Normal fruit.



B: Seedless fruit by the use of chromosome translocation.

Breeding procedures for seedless watermelon are proposed in Fig. 6. In drawing up this program no technical difficulties are assumed to breed complex translocation homozygote with many translocations in one strain to cause complete abortive gamete formation in the F_1 plant. For the purpose synthesizing objective homozygote chromosome translocation complex, combined process of several times irradiation, crossing and selfing may be required.

For bearing fruits in the hybrid plant in field artificial pollination or mixed culture with normal plants is necessary to provide healthy pollen for development of the ovary to produce parthenocarpic fruit.

Several modifications may be necessary to improve this original program from the practical experience. It is still not clear as to the most effective number and size of chromosome ring and on the most efficient method for accumulation of many translocations.

Practical application of the translocation method is actively pursued by many research workers (Oka, Watanabe and Nishiyama 1967, Shimotsuma 1968).

It is hoped that in the near future the new technique is commercially exploited for the production of seedless watermelons.

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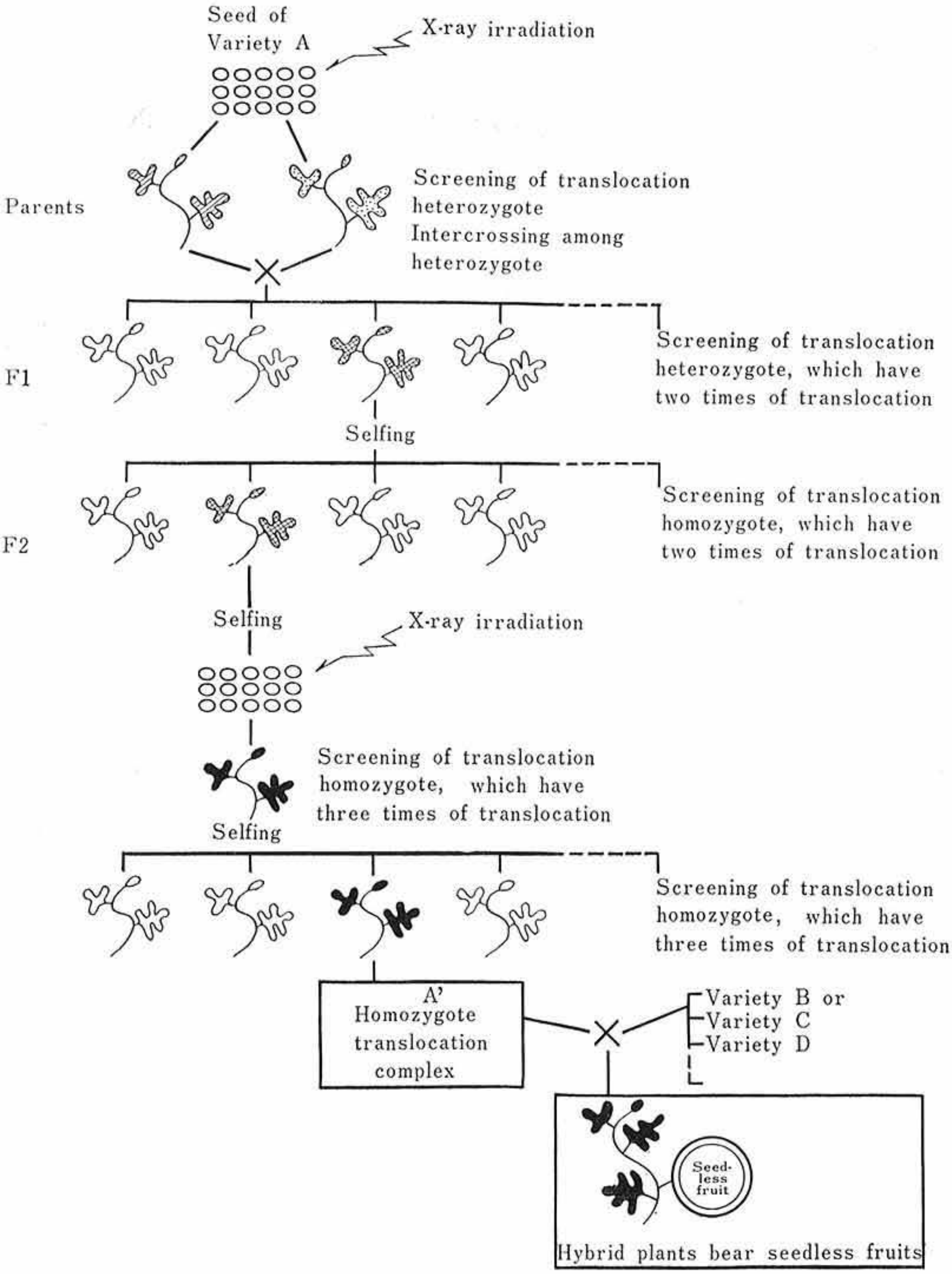

Fig. 6. The plan of breeding procedure of seedless watermelon
An example of breeding of homozygote chromosome translocation complex (three times of translocations are contained) is shown in this diagram. More times of translocations can be obtained by repeating from first step to last step of this figure.