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Status of persimmon breeding at the National Institute of Fruit Tree Science, Japan

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SUMMARY – Persimmon breeding at the National Institute of Fruit Tree Science of Japan was summarized focusing on offspring populations yielded by crossings made in the last two decades. The objectives of the breeding program were to release new cultivars with the following characteristics: pollination constant and non-astringent (PCNA), early fruit ripening, fruit free of cracks, desirable taste and high productivity. The percentage of early-ripening offspring had increased until in the mid-1990's as a result of a few cycles of selection. Simultaneously, the percentage of offspring free from cracking habits increased. However, repeated crossings within PCNA cultivars/selections led to severe inbreeding depression of traits such as fruit weight and tree vigour. In the offspring populations from 1982 and 1988, the percentage of offspring with fruit weighing >250 g was 9% and 8%, respectively. Therefore, crosses with low inbreeding coefficients were made among PCNA cultivars/selections as frequently as possible, and the percentage increased to 21% in 1994. At the same time, an effort was made to use cultivars/selections with soft and juicy flesh and a high sugar content as cross-parents. The percentage of offspring with very juicy fruit increased from 22% (1982 offspring population) to 53% (1994). During the breeding process, one early-ripening, one early-to-mid-ripening, and three mid- or late-ripening PCNA cultivars were released. To avoid inbreeding depression, crosses were made among parents with broad genetic variability.

Key words: Astringency, breeding, cracking, early ripening, persimmon.

RESUME – *"Etat actuel de l'amélioration génétique du plaqueminier à l'Institut National de la Science des Arbres Fruitiers, Japon". L'amélioration génétique du plaqueminier à l'Institut National de la Science des Arbres Fruitiers du Japon est résumée en se focalisant sur les populations descendantes de croisements réalisés pendant les deux dernières décennies. Les objectifs du programme d'amélioration étaient de mettre au point de nouveaux cultivars ayant les caractéristiques suivantes : pollinisation constante et non astringent (PCNA), maturation précoce du fruit, fruit sans crevasses, bon goût et forte productivité. Le pourcentage de descendance à maturation précoce a augmenté jusqu'à la moitié des années 1990 comme résultat de quelques cycles de sélection. Simultanément, on a augmenté le pourcentage de descendance ne se crevassant pas. Cependant, des croisements répétés intra cultivars/sélections PCNA ont mené à une sévère dépression par consanguinité de caractères tels que le poids des fruits et la vigueur des arbres. Chez les descendants des populations 1982 et 1988, le pourcentage de descendants donnant des fruits pesant >250 g était de 9% et 8%, respectivement. Donc, des croisements avec faibles coefficients de consanguinité ont été réalisés parmi des cultivars/sélections PCNA aussi fréquemment que possible, et le pourcentage a augmenté à 21% en 1994. En même temps, un effort a été fait pour utiliser des cultivars/sélections ayant une chair tendre et juteuse et une forte teneur en sucre comme parents de croisement. Le pourcentage de descendants ayant des fruits très juteux a augmenté depuis 22% (descendants des populations 1982) à 53% (1994). Pendant le processus d'amélioration génétique on a développé un cultivar à maturation précoce, un autre à maturation de précoce à moyenne, et trois cultivars PCNA à maturation moyenne ou tardive. Afin d'éviter la dépression par consanguinité, des croisements ont été faits parmi les parents ayant une forte variabilité génétique.*

Mots-clés : *Astringence, amélioration génétique, crevasses, maturation précoce, plaqueminier.*

Introduction

The oriental persimmon (*Diospyros kaki* Thunb.) has astringent and non-astringent cultivars (Yonemori *et al.*, 2000). Non-astringent cultivars, whose fruit are consumed while firm and fresh, have a great advantage because there is no need for a post-harvest treatment, such as with carbon dioxide or ethanol, to remove astringency.

Each type is further classified into two sub-types, pollination variant and constant, depending on the relationship between the presence of seeds and flesh colour (Yonemori *et al.*, 2000). The flesh colour of

the variant type is influenced by pollination. Thus, cultivars are commonly classified into four groups: pollination variant non-astringent (PVNA), pollination constant non-astringent (PCNA), pollination variant astringent (PVA) and pollination constant astringent (PCA). The PVNA fruit are completely non-astringent only when they have a sufficient number of seeds, and the quality of the fruit is not usually good for eating because of the coarse flesh that results from many large brown specks in the flesh. In contrast, the fruit of the PCNA cultivars are not astringent at maturity, whether seeded or not, and have a few brown specks.

The National Institute of Fruit Tree Science (NIFTS), Japan, has continued persimmon crossbreeding since 1938. The main breeding objective has been to develop new cultivars that are commercially acceptable and PCNA.

The natural loss of astringency in the PCNA-type is a trait that is qualitatively inherited (Ikeda *et al*., 1985). The PCNA-type is recessive to the other three non-PCNA types (PVNA, PVA and PCA). No PCNA offspring were yielded in crossings between PCNA and non-PCNA cultivars of Japanese origin. The backcross (PCNA × non-PCNA) × PCNA yielded only around 15% PCNA offspring. Therefore, crossings had been made mostly among PCNA cultivars/selections, which yielded only PCNA offspring.

Most PCNA cultivars are of Japanese origin and have a narrow genetic diversity that is characterized by late ripening and cracking habits. 'Fuyu' and 'Jiro', the leading PCNA cultivars in Japan, are late ripening, and early bud-sport cultivars derived from them ('Matsumotowase-Fuyu' and 'Maekawa-Jiro'), which are mid-ripening, have been grown since the 1950's. In the early stage of NIFTS breeding, 'Suruga', which is late ripening and has a fruit cracking habit at the calyx end, was released in 1959 (Iikubo *et al*., 1961). Early-ripening PCNA cultivars were lacking, so NIFTS released 'Izu', an early-ripening PCNA cultivar, in 1970 (Hirose *et al*., 1971). 'Izu' has delicious fruit with attractive reddish fruit skin, but its tree is not vigorous and not very productive; furthermore, the fruit does not keep well. Therefore, it was necessary to have more and better early-ripening PCNA cultivars continuously available.

The inheritance of some fruit and flower characteristics, the variation of genetic resources, and NIFTS persimmon breeding have been reviewed (Yamada, 1993; Yonemori *et al*., 2000). In this paper, NIFTS breeding is summarized with a focus on offspring populations yielded by crossings made in the last two decades. This information has not been previously presented.

Breeding system

In NIFTS breeding, persimmon cross-seedlings are top-grafted to mature trees to promote early fruiting. Top-grafting is accomplished with shoots from one-year-old seedlings. Crossing and top-grafting are routinely done every year. First fruiting is usually obtained in the third to fourth year of top-grafting; therefore, four to five years are required after crossing. After an evaluation of several years, offspring that performed well are selected and tested from about 30 locations for a regional trial in Japan. After the second selection, new cultivars are released.

Achievements over the last three decades

In the last three decades, 10,541 seedlings have been raised and top-grafted. A total of 7676 offspring have been discarded, and the rest are being evaluated.

In the 1980's, a breeding target was emphasized that would develop a superior early-ripening PCNA cultivar. Crosses among existing PCNA cultivars, which are mostly late ripening, did not yield offspring that ripen early because the inheritance of the fruit ripening time is quantitative and mostly additive with a narrow range of segregation of offspring within a cross (Yamada *et al*., 1995). However, after a few cycles of selection over 50 years, the fruit ripening time of cultivars/selections that had been used as a cross-parent gradually shifted toward early ripening (Yamada, 1993; Yonemori *et al*., 2000).

Another serious drawback in the breeding was the high frequency of PCNA offspring that were

susceptible to fruit cracking at the calyx and/or stylar end because many PCNA existing cultivars have cracking habits, whose inheritance is quantitative (Yamada *et al*., 1988; Yamada, 1993; Yonemori *et al*., 2000).

Over the last two decades, the percentage of offspring that ripen early increased until the mid-1990's (Fig. 1A), a characteristic that developed over a few cycles of selection. Simultaneously, the percentage of offspring without a cracking habit increased (Fig. 1B). The percentage of PCNA offspring whose fruit traits were evaluated each year was 98% and 90% in 1982 and 1988, respectively.

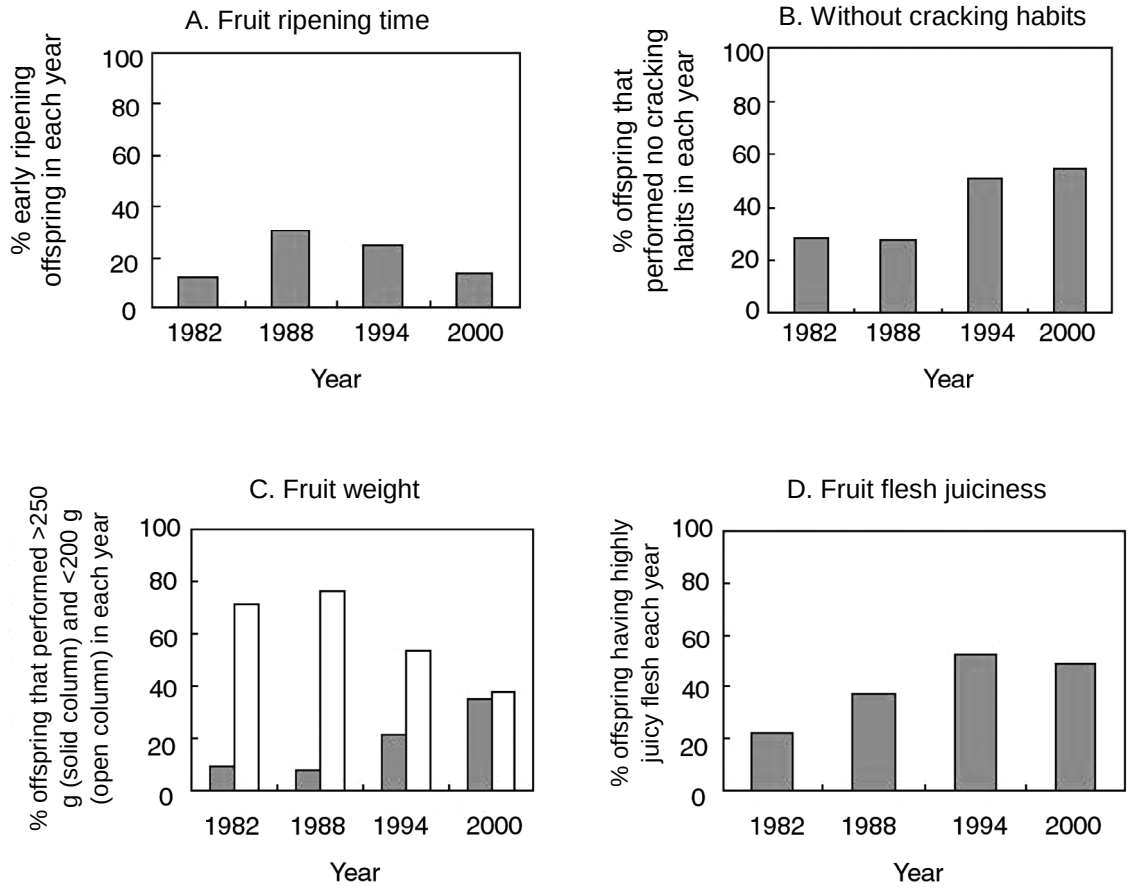

Fig. 1. Offspring frequency in breeding populations from 1982-2000 for fruit ripening time (A), absence of fruit cracking (B), fruit weight (C) and fruit flesh juiciness (D). Each column shows the percentage of offspring evaluated for fruit traits in each year (population size = 697 offspring in 1982, 154 offspring in 1988, 506 offspring in 1994 and 839 offspring in 2000; a small percentage of offspring were not evaluated for some traits).

During the breeding process, three mid- or late-ripening PCNA cultivars ('Youhou', 'Taishu' and 'Yubeni') and one early-to-mid-ripening PCNA cultivar for greenhouse growing ('Shinshu') were released in the 1990's (Yamane *et al*., 1991a,b, 1998a, 2001; Yonemori *et al*., 2000). In addition, two cultivars with bright-red leaf colour in defoliation ('Tanrei' and 'Kinshu') were released for ornamental use in 1993 (Yamane *et al*., 1998b). Those cultivars were selected primarily, and tested in a regional trial in the 1980's.

However, repeated crossings within PCNA cultivars/selections led to severe inbreeding depression of some traits, such as fruit weight and tree vigour (Yamada, 1993; Yamada *et al*., 1994). In the offspring from 1982 and 1988, the percentage of fruit weighing >250 g (more than or nearly the same as 'Fuyu' and 'Jiro') was 9% and 8%, respectively (Fig. 1C). Therefore, crosses with low inbreeding coefficients

were made among PCNA cultivars/selections as frequently as possible, and the percentage increased to 21% in 1994. Simultaneously, we made an effort to use cultivars/selections that were ranked high for eating quality (with soft and juicy flesh and a high sugar content) as cross-parents. The percentage of offspring with very juicy fruit increased from 22% (1982 offspring population) to 53% (1994) (Fig. 1D).

In 2000, 'Soshu' was released, an early-ripening PCNA cultivar with medium-size fruit that crack very little and are juicy (Yamada *et al*., 2001). 'Soshu' was produced from a 1988 cross, and its first fruiting was in 1992. It was tested in a regional trial that began in 1996.

However, the inbreeding depression increased significantly as crossings were made using selections out of the offspring population as parents. We stopped using early-ripening selections as parents, which were produced after several cycles of crossings among PCNA genotypes. To avoid inbreeding depression, the crosses should be made among parents with broad genetic variability, even though this technique yields superior offspring at a low frequency and makes cultivar improvement slower for characteristics on which inbreeding has little influence, such as fruit ripening time.

Since the 1992 crossing, the breeding objectives have shifted to high quality, large fruit, absence of cracking, and high productivity, without emphasizing fruit ripening time.

New approaches to avoid inbreeding depression

Since 1992, a new approach has been used on a small scale in an attempt to avoid inbreeding depression by crossing PCNA cultivars originating in China (Yamada *et al*., 1993) and Japan. The cross segregated 35% offspring with astringent fruit (Ikegami *et al*., 2000). The trait of loss of natural astringency in the Chinese PCNA cultivar seems to be genetically different from that in the Japanese PCNA cultivar.

Another approach is to obtain PCNA offspring from the backcross (PCNA × non-PCNA) × PCNA, which was started in 1992. As a result, the percentage of PCNA offspring in the offspring population whose fruit traits were evaluated each year decreased to 83% and 68% in 1994 and 2000, respectively. So far, 849 and 944 offspring have been obtained from PCNA × non-PCNA and (PCNA × non-PCNA) × PCNA, respectively. The backcross was not effective for obtaining PCNA offspring. However, non-PCNA-linked molecular markers have been recently developed (Kanzaki *et al*., 2001). Using this technique, PCNA offspring in young plants can be identified before they are top-grafted in a selection field. This technique should increase the number of PCNA offspring that are top-grafted in the selection field by seven.

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