

Mutation in Citrus

MASAO NISHIURA

Chief, 1st Laboratory of Fruit Tree, Okitsu Branch,
Horticultural Research Station

Most of the present commercial citrus varieties cultivated in the world are said to have arisen through some kind of natural mutation. Methods of artificial vegetative propagation, such as grafting, cutting and layering, which are popularly used in fruit trees, facilitate the conservation and accumulation of mutation, particularly such a mutation followed by sterility, as it must be destined to be eliminated under sexual reproduction.

Moreover, nucellar embryony—extra embryos, derived not from the egg cell but from somatic cells of the nucellus, are developed in the ovules in most varieties of *Citrus*, and also in *Fortunella* and *Poncirus*. This phenomenon is considered to have been of great advantage in maintaining natural mutation, since early mankind had no technique of vegetative propagation.

In ancient times, *Citrus* may have secured the character of poly-embryony, and this phenomenon in *Citrus* poses particularly interesting problems which deserve consideration, for the discussion of the evolutionary pattern in citrus and the utilization of natural and artificial mutations.

In *Citrus*, visible variations arise in the body or somatic tissues of the plant rather frequently, and genetical differences called "bud variation" may be small or great but they are visible, measurable and consistent. In the appearance of the variation, there are two cases in which the tree was affected. The exact point of origin is not known but the differences are visible or measurable from parent clone, and the differences are visible and affecting only on a branch or a limb. The latter is called "limb sport" or "bud sport". There is much information

concerning bud variations, and as a matter of course, the more the *Citrus* variety is widely planted, the more variations are found in it.

In addition, certain chromosomal changes were observed in some citrus. In this paper, the bud variations found in Satsuma mandarin, sweet orange, grapefruit, Natsudaidai and other varieties will be mentioned in the main.

Natural Gene Mutation

1) Variation in Satsuma mandarin

Unshu-mikan or Satsuma mandarin replaced the older varieties about 100 years ago, because of its early ripening character, superior quality and seedlessness. As Satsuma culture increased, growers soon began to distinguish differences between Satsumas grown in various localities. Pomological studies of the various Satsuma types by Dr. T. TANAKA in 1918 confirmed the existence of at least five varieties: "Zairai", "Ikeda", "Ikiriki", "Owari", and "Wase."

The Zairai has large, flattened, coarse, inferior quality and late-maturing fruit. The Ikeda has small spherical fruit of excellent quality which matures later than the Zairai. The Ikiriki has very large fruits of excellent quality and has a rather dwarf growth habit.

The Owari has large, flattened fruit of good quality and is early maturing. The Wase has a thin rind, earlier maturing fruit, and has a dwarf growth habit when compared with the Owari.

Old trees of the Zairai, Ikeda, and Ikiriki varieties still exist but they are no longer propagated and are not recommended for commercial planting.

The Owari variety is the most commonly

grown variety. The Aoe-Wase was first found around 1895 as a limb sport on a tree of the common Satsuma in Oita Prefecture. This discovery of the Wase as a bud mutation was an epochal finding in the citrus industry of Japan. Search for limb sports has attracted citrus researchers' and growers' attention and many new bud variations were discovered among all of the Satsuma varieties. Through the years, many strains of Satsuma have developed through limb sports or bud variations and the superior ones have become the main source of Japanese citriculture today.

In these selections from natural mutation, a very wide range of variations including a range of early to late maturing types have been obtained; namely, Wase Satsumas ripen in early October, several Satsuma strains ripen in early to middle November, and common Satsumas

mature from late November to middle December. Many bud variations of Wase character were found in trees of the Owari and Zairai varieties. Among them, the "Miyagawa-Wase" appeared as a limb sport from the Zairai Satsuma in 1915 and was introduced by Dr. T. Tanaka in 1923. It was the best strain of the early Satsumas until recently.

A large number of limb sports from the Owari variety were found and have given rise to selections superior to the original Owari. Among the best are the "Sugiyama" and "Hayashi". At present, each citrus producing prefecture recommends superior strains for commercial planting. This situation is shown in Table 1. More recently, several limb sports of Owari have been selected for cold hardiness and are being tested.

Table 1. Varietal differentiation in Unshu-mikan through natural mutation

Name of variety and strain		Season of maturity
Original Unshu-mikan in Kagoshima Prefecture	Zairai (in Fukuoka Prefecture)	
	Ikeda (in Osaka Prefecture)	
	Miyagawa-Wase	Okitsu-Wase (N. S.) E. Oct. Miho-Wase (N. S.) E. Oct. Mochimaru-Wase E. Oct.
		Matsuyama-Wase E. Oct. Tachima-Wase E. Oct. Yonezawa-Unshu E. M. Nov. Nagahashi-Unshu E. M. Nov. Nankan No. 20 E. M. Nov. Shigeta-Unshu E. M. Nov.
	Ikiriki (in Nagasaki Prefecture)	
	Owari (in Aichi Prefecture)	Sugiyama-Unshu L. Nov. Silver-hill (N. S.) L. Nov. Tanikawa-Unshu (N. S.) L. Nov. Nankan No. 4 L. Nov. Tomono-Unshu L. Nov. Hayashi-Unshu E. Dec. Ooiwa No. 5 E. Dec. Ishikawa-Unshu M. Dec. Juman-Unshu M. Dec.

Abbreviations: N. S. = Nucellar seedling

E. = Early, M. = Middle, L. = Late

On the other hand, systematic citrus breeding was projected and conducted at the Horticultural Experiment Station, Okitsu (present Okitsu Branch, Horticultural Research Station, Ministry of Agriculture and Forestry) since 1937. In our breeding program, it is emphasized that selection work among nucellar seedling lines has been conducted on a large scale for improving strains of Satsuma by Dr. M. Kajura. And the effectiveness of breeding through nucellar seedling selection, being obtained from such superior strains as "Okitsu-Wase" and "Miho-Wase", was already mentioned in this periodical (cf. JARQ Vol. 2, No. 1, 1967).

2) Variation in sweet orange

At present, there are many different varieties or strains of sweet orange in the world, however, they are said to have derived from natural mutations through asexual propagation, regardless of gene recombination through hybridization. Though the sweet orange has an ultimate origin in India, it may have been introduced into China for a long time ago, and also was imported into Europe around the 15th century, where many varieties originated from natural mutations. For example, the Shamouti, a famous Palestine orange, originated probably as a bud sport from the Belladi, the ordinary or common orange of Palestine.

The blood oranges such as Maltese blood orange which have anthocyanins in the rind,

septa, and juice vesicles, were arisen in the Mediterranean region. The Washington Navel orange was found in Brazil as a limb sport from "Laranja Selecta" of ordinary sweet orange type.

Within the Washington Navel and Valencia which are the most world-wide varieties at present, many different strains are selected from its bud variation or limb sport, respectively.

Recently, in our country, three strains such as Ukumori, Tange and Suzuki originating as limb sports from Washington Navel were selected and patented. These strains are rather productive even in our unfavourable climatic conditions and are promising.

The Trovita orange was believed to have originated from nucellar seedling of Washington Navel orange in California, and it is non-navel orange which has viable pollen and a few seeds. It was introduced into Japan in 1935 and is promising for trial in our citrus regions where the Washington Navel often fails to set a crop.

3) Variation in Grapefruit

The grapefruit was introduced into Florida in 1823. At present, Florida has the largest production of grapefruit, but the world output of this kind is only about one-sixth the production of sweet oranges. Since the Duncan variety was a seedling of the original tree introduced into Florida in 1823, all other varieties of today may be considered to have arisen from

Table 2. Seedless and flesh color mutations in grapefruit

		Flesh color		
		White	Pink	Red
Seedy (Rind color)	Duncan	→ Walters (white)	→ Foster (red)	→ Hudson (red)
Seedless (Rind color)		↘ Marsh (white)	→ Thompson (white)	→ Rudy (red)
			↘	Webb Red Blush (red)

it by natural mutations. The Duncan has yellow rind at maturity, flesh of pale ivory-yellow, usually spoken of as white, and has from 30 to 50 seeds. The seedless condition has arisen in later days, however, in this case not by bud mutation but by seed mutation. Namely, the Marsh seedless may originate from seedy Duncan through nucellar seedling. And at least three instances, including Marsh, are known of seeds from normal seedy grapefruit producing trees with seedless fruits. The color mutation is quite independent of mutation for seedless condition, and pink and red forms are grown of both seedy and seedless types.

As shown in Table 2, seedy Walters of normal type was selected from Duncan through a nucellar seedling, and the Foster originated as a limb sport from it in 1906. The Foster has flushed pink rind, pink flesh and contains seeds. The Hudson, red and seedy grapefruit, was discovered as a limb sport on a Foster tree in the mid 1930's at San Benito, Texas. In the seedless varieties the sequence is clearly established.

The Thompson originated as a pink-fleshed bud sport of a Marsh tree in 1913. It is seedless, just as Marsh is, and of the same external appearance, for no pink shows on the rind. The Ruby is the first grapefruit with deep red flesh arisen as a limb sport of the Thompson at Texas in 1926. It is also seedless and the rind is crimson blush.

Lycopene and associated carotenes are the coloring compounds present in the sports. From about 1935 there was the vogue for planting pink, seedless grapefruit, followed about 1945 with similar heavy planting of red, seedless forms in Florida. It is a quite interesting phenomenon that the color mutations occurred in parallel in both of the seedy and seedless groups.

4) Variation in Natsudaïdai and other citrus fruits of Japan

Natsudaïdai: The Natsudaïdai is the second most popular citrus fruit in Japan and is the most common late-maturing (May to June) variety at present. In Natsudaïdai, search for limb sports has been continued extensively,

and many selections have been obtained. Among them, the "Kawano Natsudaïdai" was found as a limb sport about 60 years ago in Oita Prefecture and was patented in 1950. This selection is early-ripening (March to April) and is much less acid than the standard Natsudaïdai. More recently, the "Tajima Natsudaïdai" was found as a limb sport. It is a late strain, ripens in midsummer and is very juicy. In addition, two seedless mutants have been found from common Natsudaïdai.

Iyo: The Iyo originated as a chance seedling in Yamaguchi Prefecture and was introduced in 1886. It is judged to be a tanger and ripens in January to February. Recently, a limb sport of the Iyo was found that ripened earlier than the parent variety and was seedless. It was patented in 1966.

Hyuganatsu: The Hyuganatsu originated as a chance seedling about 1820 in Miyazaki Prefecture, and is valuable as a late maturing variety with excellent aroma, tender flesh and very juicy for use as fresh fruit. But the severe fruit drop in cold winters reduces its value for commercial planting generally. It ripens in May to June and has a tendency for regreening. Recently, a limb sport of this variety was found that had a deeper color in rind than the parent Hyuganatsu and had excellent quality in later season. It was patented in 1965.

References

- 1) Iwasaki, T., Nishiura, M., Shichijo, T., Okudai, N., and Zaizen, T.: Studies on the Strains of Early Satsuma Orange (2nd Rep.). Bull. Hort. Res. Sta., Japan, Ser. B, No. 1, 37-47 (1962) (in Japanese with English summary)
- 2) Nishiura, M.: Citrus Breeding and Bud Selection in Japan. Proc. Fla. State Hort. Soc., 77, 79-83 (1964)
- 3) Nishiura, M.: Natural Mutation and Its Utilization in the Selection of Citrus Fruits. Gamma Field Symposia, No. 4, 27-42 (1965)
- 4) Nishiura, M.: Citrus Breeding Through Nucellar Seedling Selection. JARQ, Vol. 2, No. 1, 15-19 (1967)
- 5) Nishiura, M., Shichijo, T., Iwasaki, T., Jozukuri, A., and Kihara, T.: Studies on the Strains of

- Satsuma Orange (3rd report). Bull. Hort. Res. Sta., Japan, Ser. B, No. 3, 11-26 (1964) (in Japanese with English summary)
- 6) Tanaka, T.: A Monograph of the Satsuma Orange, With Special Reference to the Occurrence of New Varieties Through Bud Variation. Mem. Fac. Sci. & Agr. Taihoku Imp. Univ., Vol. 4 (1932)
- 7) Webber, H. J. and Batchelor, L. D.: The Citrus Industry. Vol. 1, Univ. of Calif. Press (1948)
- 8) Ziegler, L. W. and Wolfe, H. S.: Citrus Growing in Florida. Univ. of Fla. Press (1961)