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Cultivation of Satsuma Mandarin in Vinyl-Greenhouses in Japan

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Abstract

A main objective of growing satsuma mandarin (Citrus unshiu Marc.) in a vinyl-greenhouse is to secure competitiveness of the products in the markets by early shipping of high quality fruits. For early shipping of the products from the vinyl-greenhouses, heating starts in early December and fruits art harvested before the end of July. Although this type of cultivation is profitable under adequate managements, it has a problem caused by unreliability of flowering, which is related to completion of dormancy. To estimate the degree of dormancy completion, a simple method has been employed by the growers to determine contests of carbohydrate. In addition, a benzylamine purine treatment has been developed to promote growth of sprouts and stimulate flower-bud emergence. Further improvements art required to ensure profitability of the cultivation in a vinyl-greenhouse, including reduction of production costs and quality improvement. It costs ¥70 to 100 million to build a one-hectare vinyl-greenhouse, including heating, ventilation and irrigation systems. The fuel required for one season operation is 250 kl, or ¥7.5 million equivalent per ha for the early shipping type. Cost reduction is vital for the future development of this cultivation system.

Discipline: Horticulture
Additional key words: benzylamino purine, dormancy, flower-bud differentiation, Wase satsuma

The acreage of satsuma mandarin (*Citrus unshiu* Marc.) (refer to satsuma m., hereafter) in Japan is about 80,000 ha as of 1990. In the last decade, it has been decreasing from the highest record of 173,000 ha in 1973. The rapid decrease in acreage and production of satsuma m. is regarded as a result of the considerable increase in importation of citrus fruits from overseas, and in addition, the competition with strawberries, melons and many kinds of juices and drinks[3].

The culture of Wase satsuma (*Citrus unshiu* Marc. var. *praecox* Tanaka) under heating in vinyl-greenhouses started in Japan in 1970. A main objective of growing it in a vinyl-greenhouse is to secure competitiveness of the products in the markets by early shipping of high quality fruits. The system has been developed under trial and error by active growers with technical assistance of research scientists concerned[7].

The area and production of Wase satsuma under vinyl-greenhouses in Japan have been steadily increasing in recent years from 25,816 t/463 ha in 1980 to 47,441 t/876 ha in 1988 (Table 1). Although the vinyl-greenhouse satsuma m. corresponds only to 1.6% in the total satsuma m. growing area in 1990, its production amounts to more than 3.0% because the productivity of vinyl-greenhouse culture is two times higher than that of conventional outdoor cultivation. More importantly, since the prices of vinyl-greenhouse satsuma m. are generally about 5 times as high as those of outdoor satsuma m., the contributions attained by the former to the economy of citrus growers have been highly appreciated.

Types and methods of vinyl-greenhouse culture

Very early satsuma was derived from Wase satsuma mandarin as an early ripening mutant. Both cultivars of Wase satsuma and Very early satsuma are employed for the cultivation in a vinyl-greenhouse. Miyagawa wase, one of the most popular strains of Wase satsuma is a leading strain at present,

because its growth can be easily managed under vinyl-greenhouse conditions as compared with that of other strains.

There are two main types in growing satsuma m. in vinyl-greenhouses: one is an early shipping type, and the other is a late shipping type. For the early shipping type, heating commences in early December and fruits are harvested before the end of July. Trees are pruned immediately after harvesting and the summer-cycle shoots which sprout after pruning bear fruits in the next season. This type is also called an early heating type or summer fruiting shoot type; in other words, a type of fruiting on summer-cycle shoot. For the late shipping type, heating starts in January and fruits are harvested during the period August to early October. Pruning is made immediately before vinyl covering or heating in the following season (January). The spring-cycle vegitative shoots which sprout after heating bear fruits in the next season. This type is also called a standard heating type or spring fruiting shoot type.

The late shipping type is regarded as a standard pattern of cultivation in heated vinyl-greenhouses in the country. It was initiated from the onset of protected cultivation of Wase satsuma mandarin. Early maturing in Wase satsuma could be achieved rather

Table 1. Production of Wase satsuma grown in vinyl-greenhouses in Japan

(Unit: ton)

Prefecture	1980	1985	1986	1987	1988
Aichi	4,400	6,280	6,000	6,000	6,500
Tokushima	3,050	3,215	3,300	3,540	3,700
Ehime	6,597	6,900	6,408	6,600	6,628
Saga	1,647	6,479	6,582	7,400	7,800
Nagasaki	730	2,500	2,570	3,400	3,900
Others	9,392	16,124	15,734	17,812	18,913
Total	25,816	41,498	40,594	44,752	47,441

Source: Japan Fruit Growers Cooperative Association.

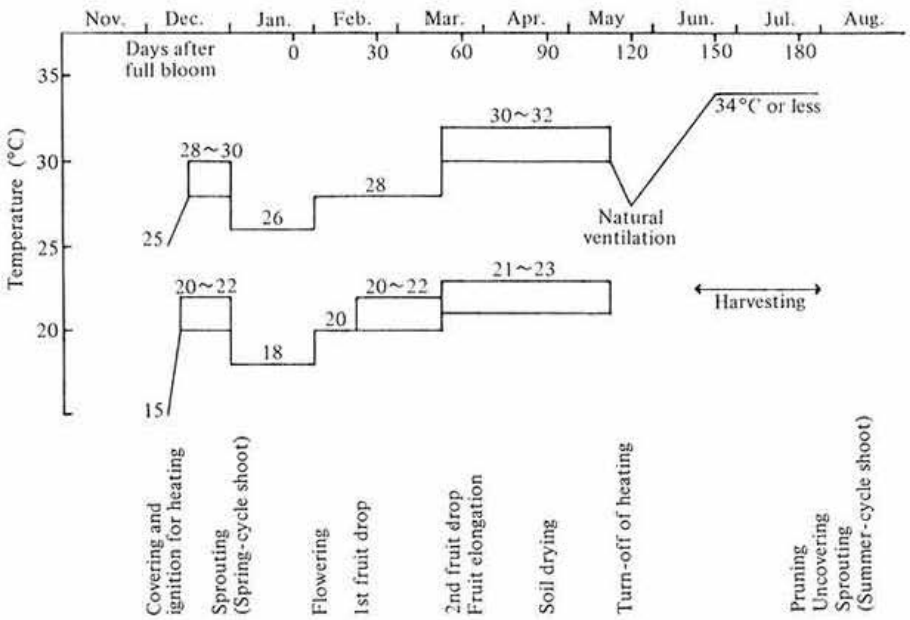

Fig. 1. Temperature regime for an early shipping type in producing Wase satsuma mandarin in a vinyl-greenhouse
Upper line: Daytime, Lower line: Night.

easily by this method. Under the early shipping type, however, Wase satsuma is subjected to heavier physiological stress than the late type, which might be caused possibly by earlier covering and heating. The mandarin plants face some physiological problems, in particular unreliable flowerings which are very likely to relate to the incompletion of dormancy. In stabilizing fruit production under the early shipping type, further technical improvements are to be achieved yet. The present paper summarizes the technical pattern of the early shipping type, and discusses the status of research activities in Japan in this respect (Plates 1 & 2).

Cultivation system of the early shipping type

In the early shipping type, trees are covered by a vinyl film in early December and the room temperature is gradually raised in several days to the levels of 28–30°C in the daytime and 20–22°C during the night. Sprouting starts in approximately 10 days and full bloom comes in 45 days after heating. During the period of about one month before and after flowreing, the room temperature has to be kept slightly lower with the purposes of ensuring the complete development of ovaries, minimizing the fuit shedding, caused by physiological disturbance, and preventing the malformation of fruits. In about 90 days after heating, when the fruit shedding discontinues, the day temperature is raised again to 30°C for fruit development. In mid May when the night temperature in open air comes up to 15–17°C, heating is turned off and the day temperature in the house should be maintained at less than 30°C (Fig. 1).

In regard to the soil water management, sufficient amount of irrigated water is required during the period before heating. High humidity in soil and air is maintained during the sprouting period under continuous irrigation. Overhead watering is generally employed. During the flowering time, limited irrigation is provided and air humidity is kept low to control botrytis fruit ridging (*Botrytis cinerea*) on flowers and young fruits. Continuous watering is needed in the period after petal fall until fruit elongation time.

Though soil water is needed for fruit enlargement on one hand, restricted water supply is also necessary for sugar accumulation in fruits. To produce fruits containing sugar of more than 10 degrees in Brix, soil water should be restricted from the very early stage of fruit growth. Amount of irrigated water should be radically reduced when the fruit diameter becomes about 30 mm in mid April and the soils are kept dry for 40–45 days. To raise the Brix up to 8 degrees at the growth stage of fruits with 40 mm diameter is another important point in growing satsuma m. in a vinyl-greenhouse. Careful irrigation or overhead watering is needed during the period late May to early June. In order to get high Brix in fruits, irrigation is stopped again 20 days before the initiation of harvesting.

Some technical factors affecting flower-bud formation

1) Time to start heating

Differentiation of flower-buds of satsuma m. can be identified morphologically in the period January to March. However, physiological movements for those differentiations take place well in advance to that time. Therefore, the growth of flower-buds could be promoted if the heating starts before the beginning of December.

In order to identify relationships between air-temperature in a greenhouse and flower-bud formation, Okitsu wase trees having fully grown spring flushes were placed under the three air-temperature conditions of 15, 20 and 25°C in phytotron for several months. They were then moved to a 25°C chamber to investigate flower-bud formation. Flower buds were observed in 2.5 and 2.0 months with those trees placed under 20 and 15°C, respectively, but no flower buds were initiated with the trees under 25°C[1]. A method for calculating effective accumulated temperature for flower-bud differentiation was developed after Inoue[1], by adding up those temperatures below 25°C. To estimate an accumulated temperature needed for breaking plant dormancy, the following equation was formulated:

(25°C − monthly average temperature)
× number of days a month.

In adopting this formula in practice, it is presumed in connection with the plant dormancy that the satsuma m. trees in question are ready for heat treatment when the accumulated temperature since September based on the above equation has reached

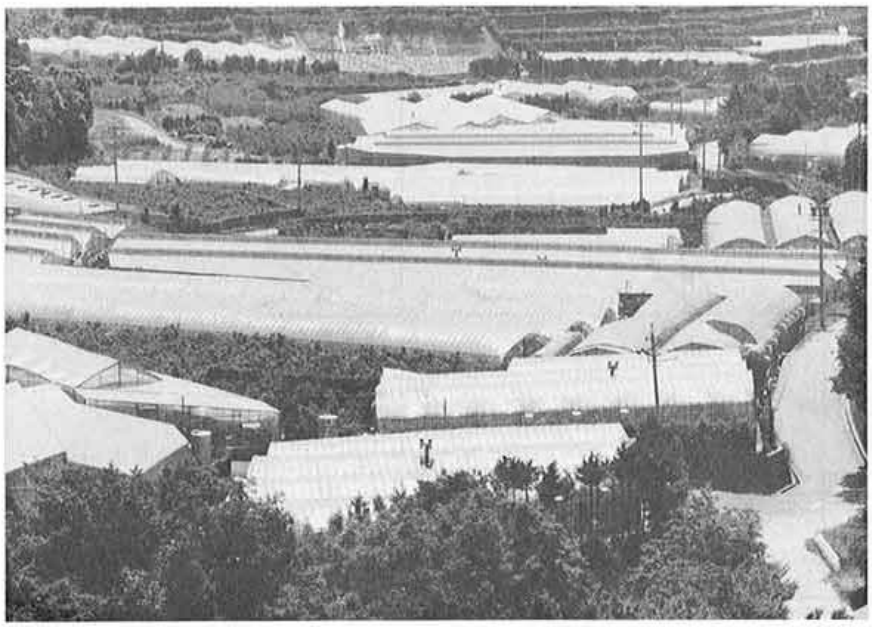

Plate 1. Vinyl-greenhouses for growing Wase satsuma in Gamagori, Aichi Prefecture, Japan

Plate 2. Wase satsuma in a vinyl-greenhouse
Fruits are supported with strings.

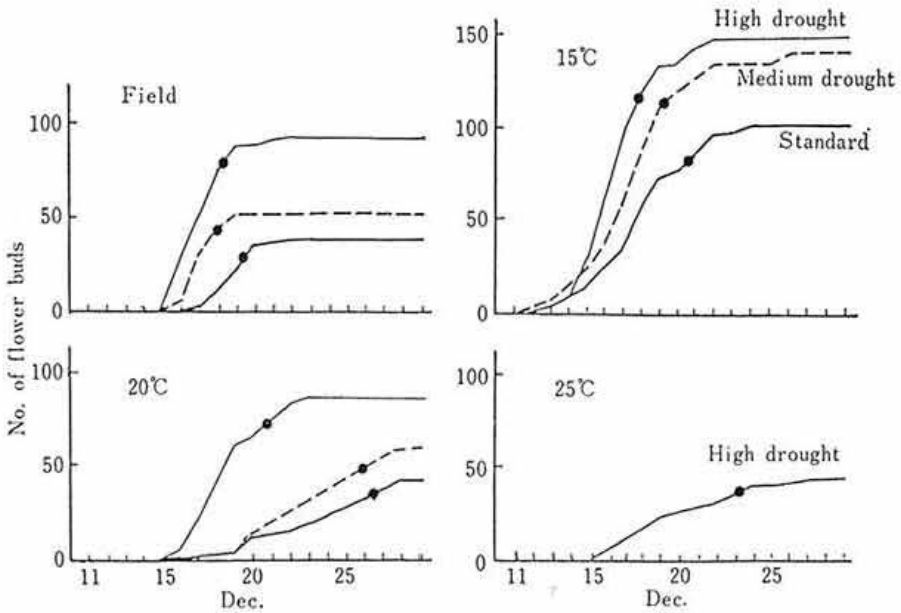

Fig. 2. Number of flower-buds coming out after the trees are transferred to a 25°C room in mid December
●: 80% appearance of total flower buds.
Source: Inoue (1989)[2].

750°C. It is recognized that the degree of dormancy in satsuma m. is not high, compared with other deciduous fruit trees; it continues for about two months in case where temperatures are maintained below 25°C.

Apart from air-temperature, a low level of soil moisture is another factor which promotes flower-bud differentiation. In the tropics, yearly mean temperature is approximately 27°C and the fluctuation of monthly temperatures is small: however, citrus trees in that region differentiate flower-buds even under such a temperature condition. It is very likely that the differentiation in the tropics depends mainly on a low level of soil moisture in the dry season (Fig. 2).

In addition, day length and girdling may also be associated with flower-bud differentiation as an environmental and physiological stimulation factor, respectively.

The growers' experiences indicate that a greater profit could be earned from earlier heating, providing that the mandarin trees in a vinyl-greenhouse are fully ready for that heat treatment. It is therefore quite natural for mandarin growers to prefer to begin heating rather early, i.e. just before or after the estimated completion of physiological differentiation of flower-buds. Such an early heating, however, occasionally causes problems of unstable flowering and fluctuated fruit production. Therefore, an appropriate method to estimate flower formation is urgently needed.

2) Estimation of flowering

(1) Fruiting shoot test[4]

With the purpose of identifying the flowering as early as possible, fruiting shoots (summer-cycle shoots) under normal growth were collected 20 days before the planned heating. They were placed in a growth chamber, which was under 28°C and 90% relative humidity with lighting. The summer cycle shoots were cut in 15 cm length in advance; leaves of which were removed. Those shoots sprouted and had flowers within 5 days.

There was a positive correlation in the number of flowers between the result of the fruiting shoot test undertaken and the actual flowering in a heated vinyl-greenhouse. The correlation coefficient obtained is not satisfactorily high at present. However

the above-stated method is presently recommended as a tentative measure.

(2) A simplified method for estimating carbohydrate contents[4)]

There is a close relationship between carbohydrate or C–N ratio in the fruiting shoots and flower-bud differentiation. It was found that the trees with a higher carbohydrate concentration or a higher C–N ratio bore more flowers. For practical use of this relationship in estimating flower formation, a simplified method for determining carbohydrate contents is necessary, because a great number of samples have to be investigated within a limited time. A dried ground-shoot tissue was subjected to measurement of color reaction of the contained starch and iodine to estimate a starch level in the shoot. The measurements were taken by eye or by a color meter (Fig. 3). It was felt however that further studies would be required to develop a convenient device to estimate flower-bud initiation more effectively and efficiently.

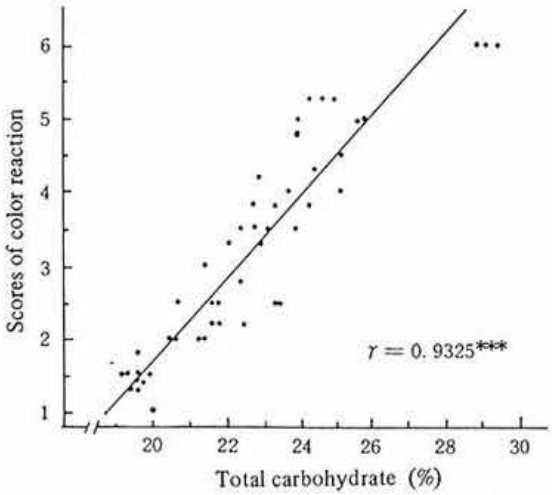

Fig. 3. Relationship between starch-iodine color reaction and total carbohydrate in satsuma mandarin shoots
Source: Kawano (1987)[4)].

3) Stimulation of sprouting and flowering by benzylamino purine[5)]

It is already reported that benzylamino purine (BA) activates shoot sprouting of satsuma m. A cultivar Imamura of one-year-old under sprays of 25, 50, 100 ppm BA, showed more flushes sprouted than the nonsprayed materials. The higher concentration of BA produced more flushes. Stimulation of sprouting with BA took place from the nodes not only of the shoot tips but also of the basal part of shoots[5)] (Fig. 4).

It is generally observed that a BA treatment on shoot also stimulates the flower-bud emergence. It is therefore concluded that the BA treatment is highly effective to ensure the flowering of satsuma m. for

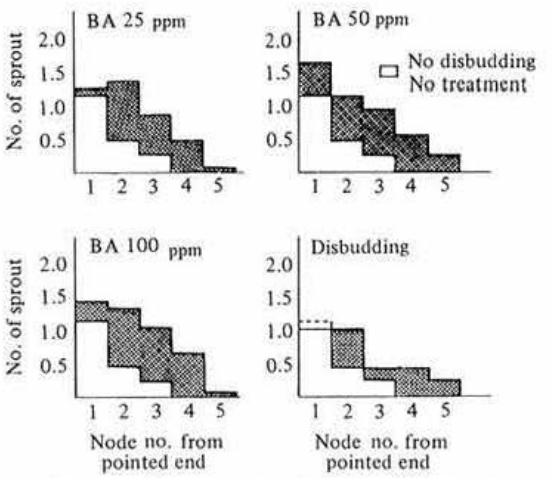

Fig. 4. Influence of benzylamino purine on the sprouting of satsuma mandarin Imamura
Source: Takahara et al. (1987)[5)].

Table 2. Standard application of benzylamino purine (BA 3% liquid) for satsuma mandarin

Objective of application	Environmental condition	Application time*	Method of application
Sprouting	Outdoor or heated vinyl-greenhouse	Immediately before and during sprouting (after harvesting in a heated vinyl-greenhouse)	Spraying on greenwood
Flower-bud emergence	Heated vinyl-greenhouse (early shipping type)	Immediately after heating	Spraying on trees

* One application of 150–300 ppm a year.

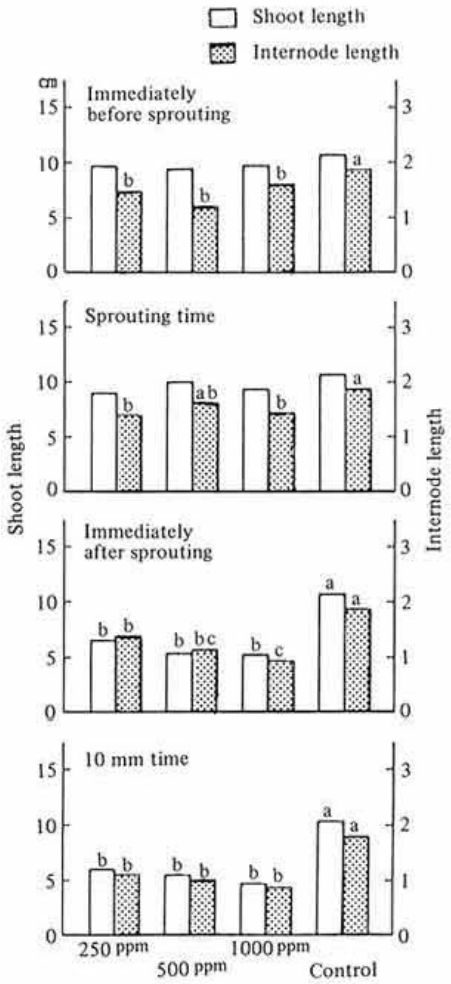

Fig. 5. Influence of paclobutrazol on the growth of satsuma mandarin Imamura
a, b, c: Duncan's multiple range test, 5% level.
Source: Takahara et al. (1987)[6].

the early shipping type under vinyl-greenhouse culture (Table 2).

4) Control of out-of-season sprouting[6]

In the early shipping type, mandarin trees are generally pruned immediately after harvesting in July. The summer-cycle shoots after pruning are used for fruiting in the next season. After summer-cycle shoots have matured, autumn-cycle shoots appear occasionally. However, the autumn-cycle shoots are not suitable for fruiting, since they are subjected to cool weather in the winter season before full maturation. It is confirmed that choline salts of maleic hydrauzide (C-MH) and triazol compounds such as paclobutrazol and uniconazole are effective in controlling sprouting of the autumn-cycle shoots (Fig. 5).

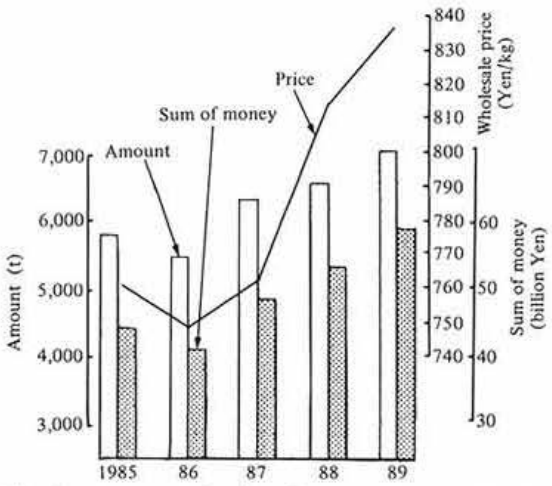

Fig. 6. Amount and price of house satsuma dealt with by the Tokyo Metropolitan Wholesale Market
Source: The Japan Agricultural Press (Nihon Nogyo Shinbun).

Issues and problems for further development

Cultivation of satsuma m. in vinyl-greenhouses plays an important role, as mentioned earlier, in the Japanese citrus industry. The average acreage of citrus orchards in a farm household in Japan is less than 1 ha and most of the citrus growers are engaged in off-farm employments as a second job. However, for the full-time growers, who are generally leaders in the growers' communities, use of vinyl-greenhouses is essential in their farming management.

The amount of satsuma m. from vinyl-greenhouses is increasing in the Tokyo Metropolitan Wholesale Market year after year. In accordance with the increase of consumption, wholesale prices have also been rising (Fig. 6). It may be said that the satsuma m. production in a vinyl-greenhouse is attractive for the citrus growers. However, it has some problems to be solved. The first is a high production cost. It costs ¥70 to 100 million (or US$520,000–740,000) to build a one-ha vinyl-greenhouse, including heating, ventilation and irrigation systems. The fuel

required in a season is estimated at 250 k*l*, or ¥7.5 million (or US$56,000) per ha for the early shipping type. Therefore, cost reduction is vitally important. The second is a fruit quality. Improved techniques are required to accelerate fruit coloring and control rind puffing. The third problem relates to unstable fruit production due to close planting and excessive soil drying. In addition to these problems, the satsuma m. growers will also have to take into account a great competition among the producers, which may possibly take place in future.

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