Protected Cultivation of Fruit Trees in Japan

Ву **FUKUYA KAMOTA**

Division of Pomology, Fruit Tree Research Station (Tsukuba, Ibaraki, 305 Japan)

Recently, protected cultivation of fruit trees has developed remarkably in Japan and the area of this type of cultivation increased very rapidly in the last ten years³⁾. However, this type of cultivation is not at all new, but it has been developed since 1886 in Okavama Prefecture, where grape (Muscat of Alexandria) was cultivated in glasshouses. Development of protected cultivation of fruit trees was very much delayed as compared with that of vegetable cultivation in greenhouses. The reason for the delayed development was that most fruit trees were regarded as unsuitable for protected cultivation because they are perennial crops which grow tall, and many orchards are located on sloping land. Therefore, the house construction for fruit trees is not easy and costs more as compared with that for vegetables. However, such circumstances have changed rapidly in the last several years. Protected cultivation of fruit trees was accelerated by many improvements made on construction materials, training practice for shrub and dwarf type and environmental control in plastic houses.

The term "protected cultivation of fruit trees" used in this paper refers to fruit tree cultivation under glasshouses, plastic houses (vinyl, polyethylene, acryl houses etc.), big size rain shelters and tunnel houses, except net houses¹).

Area of protected cultivation of fruit trees

Fig. 1 shows annual increase of the protected cultivation area for fruit trees, vegetables, and flower crops in the last ten years. The area for fruit trees increased 3.6 times while that for vegetables increased only 1.6 times. The former increased at the rate of 16% per year.

Table 1 shows the total area of protected cultivation of fruit trees (A), the total area of fruit-bearing mature trees in open field orchards (B), and their ratio (A/B) in August 1986^{4,5)}. The total area of protected cultivation is 8,514 ha, out of which 8,315 ha or 98% accounts for plastic houses.

Among the fruit trees in Table 1, grape shows the largest area of protected cultivation (6,200 ha; ca. 73% of the total area), followed by satsuma mandarin (803 ha; 9.5%), others citrus (570 ha; 6.7%), sweet cherry (431 ha; 5.1%), Japanese pear (218 ha; 2.6\%) and loquat (64 ha; 0.8%).

The ratio A/B shows the highest value for grape 23.5%, followed by sweet cherry (18.4%), fig (5.4%), loquat (2.8%), and Japanese pear (1.2%). The percentage of the total area of fruit's greenhouse to the total area of mature bearing area is 2.9%.

Fig. 2 shows geographic distribution of the protected cultivation area of fruit trees. Prefectures which hold the largest area of protected cultivation are Yamagata and Okayama, each showing the area over 1,000 ha. Prefectures showing the area from 300 to 500 ha are Yamanashi, Kagawa, Shimane,



Fig. 1. Annual increase of protected cultivation area for fruit trees, vegetables and flower crops Area in 1975 is taken as 100.

Crops	Area of protected cultivation(ha): A	Ratio (%)	Area of mature bearing trees in open field orchards(ha): B	Ratio A/B(%)
Grape	6, 200. 5	72.96	26.400	23.49
Satsuma mandarin	803.0	9.45	106.900	0.75
Midseason and late maturing citrus	546.6	6.46	36.288	1.51
Sweet cherry	431.4	5.08	2.340	18.44
Japanese pear	218.1	2.57	18.800	1.16
Loquat	64.2	0.76	2.270	2.83
Fig	53.8	0.63	1.004	5.36
Peach	24.3	0.29	13.900	0.17
Japanese plum	14.3	0.17	2.980	0.48
Persimmon	10.7	0.13	26.900	0.04
Apple	1.7	0.02	47.800	0.00
Others**	145.5	1.50		—
Total	8, 514. 1 (8, 368. 6)*	100.0	(285. 582)*	(2.93)*

Table 1.	The area of protected	cultivation and that of mature	bearing trees
	in open field orchards	and their ratio (A/B) (August	1986)

* Numerals in parentheses: The total excluding others.

** Others: Prune, raspberry, apricot, etc.-5.9 ha,

Lemon, Yuzu, Kabosu, Sudachi, mango, etc.-121.4 ha.



Fig. 2. Geographic distribution of the area of protected cultivation of fruit trees

Fukuoka, Saga, Oita, and Miyazaki. On the other hand, prefectures holding very small area (below 10 ha) are Miyagi, Tokyo, Kanagawa and Toyama.

Kinds of fruit trees grown by protected cultivation

The kinds of fruit trees cultivated in greenhouses are as many as 35, composed of 12 kinds of deciduous trees and 23 kinds of evergreen trees⁴⁾. Among them, grape is distributed in all of 47 prefectures followed by Japanese pear in 24, fig in 20, satsuma mandarin in 19, peach in 14, persimmon and navel orange in 13 prefectures. On the other hand, each of the following kinds is grown in one prefecture: raspberry, lime, Sudachi, Kabosu, mango and guava. The number of kinds of fruit trees grown by protected cultivation in a prefecture is the greatest in Wakayama (18 kinds), followed by 17 in Saga, 15 in Ehime, 14 in Miyazaki, 13 in Kumamoto, 12 in Kochi and Oita, and 11 in Aichi Prefecture. Only few prefectures grow only one kind per prefecture.

Table 2 shows main cultivars used for protected cultivation. As fruit trees are perennial, selection and renovation of cultivars for protected cultivation are quite difficult as compared with vegetables.

The selection of cultivars should be made carefully by taking the following important factors into consideration:

1) Selection must be made with trees which are already bearing fruit.

2) Cultivars of early or medium maturing type are selected.

3) Improvement of fruit quality and in-

Crops	Cultivars		
Deciduous fruit tree			
Grape	Muscat of Alexandria, Kyohou, Delaware, Pione, Neo Muscat, Muscat Bailey A		
Persimmon	Nishimura-wase, Tone-wase, Maekawa-Jiro, Hiratanenashi, Izu		
Apple	Tsugaru, Raritan		
Sweet cherry	Satonishiki, Takasago, Napoleon Bigarreau		
Japanese pear	Shinsui, Kosui, Hosui, Choju, Nijisseiki		
Peach	Takei-Hakuho, Yahata-Hakuho, Azuma-wase, Nunome, Sunago-wase		
Fig	Masui-Dauphine		
Japanese plum	Ooishi-wase-sumomo, Santa-Rosa, Sordum, Methley		
Apricot	Shinshiu-omi, Heiwa		
Ever green fruit tree			
Satsuma mandarin	Okitsu-wase, Miyagawa-wase, Miyamoto-wase		
Loguat	Mogi, Nagasaki-wase, Morio-wase		
Lemon	Lisbon		
Midseason and late maturing citrus	Murcott, Sminole, Iyo, Kiyomi, Navel orange, Kara, Hassaku, Hyuganatsu Tankan, Encore, Nova, Sanzu		
Other citrus	Sudachi, Kabosu, Yuzu		
Mango	Irwin		

Table 2. The main cultivars of fruit trees in use for protected cultivation

creased harvest should be expected by the adoption of protected cultivation.

4) Kinds or cultivars which offer higher market price of fruit are preferable.

Main grape cultivars used for protected cultivation are Muscat of Alexandria in glasshouses, and Delaware, Pione and Kyohou in simple plastic houses or under rain shelters. Grape cultivars with purple and large-sized fruit, recently attracting attention, are especially regarded to need protected cultivation. In persimmon, Nishimura-wase and Tonewase are used. Sweet cherry is grown by protected cultivation mostly in Yamagata and Yamanashi, where Satonishiki, Takasago or Napoleon is used. Fig grown in greenhouses is almost entirely Masui-Dauphine. Satsuma mandarin cultivars in use are Okitsu-wase, Miyagawa-wase and Miyamoto-wase etc. All of them are early maturing. Loquat (Japanese medlar) cultivars, Nagasaki-wase, Moriowase and Mogi are grown in plastic houses. Most citrus (excluding satsuma mandarin) grown in plastic houses are navel orange, sweet orange, Sudachi, Kabosu, Yuzu, Iyo, lemon and Tankan etc. Mango which is cultivated only Okinawa is Irwin.

Construction design and its characteristics

Construction design of plastic houses for fruit trees contrasts in many aspects with that for vegetables. The characteristics of the former are as follows:

1) Plastic houses for fruit trees are generally big and tall, with the ridge as high as 6-7 m.

2) For orchards on sloping land, plastic houses such as terrace-shaped houses have to be constructed on the slope.

3) The shape of greenhouse ground is often irregular, because it depends upon the irregular shape of orchard ground.

As a matter of fact, the shape of plastic houses for fruit trees varies very much. The biggest houses are found for growing sweet cherry, persimmon and peach.

Terrace-shaped houses for growing satsuma mandarin of sloping orchards are named 'Tier type'. In addition, there are the tunnel-shaped roof type and the sloping flat roof type (Plate 1).

For fruit trees receiving shrub type training or dwarf trees, the low roof ridge is



Plate 1. Rain shelter cultivation on sloping grape orchard (Hiroshima Pref.) Polyethylene film is used as covering material of the tunnel-shaped shelter (height: 1 m, width: 1.5 m).



Plate 2. Cultivation of Japanese pear in a greenhouse The ridge of the greenhouse is about 4 m in height and polyvinyl chloride film is used as covering material.

enough; for instance, fig trees cultivated by the training of Ichimonji (like a cordon type training), the height of roof ridge is less than 3 m. The height of roof ridge is also relatively small in case of trellis training of grape vine and Japanese pear, and that of loquat and plums but it is greater than that of vegetable's greenhouses (Plate 2). In addition, a number of simple covering facilities are used for protected cultivation of fruit trees. They are simple vinyl-roofings, umbrella houses, rain shelters and net coverings. There are a lot of kinds and given names of vinyl houses. They are divided into pipe houses (iron, aluminum-iron and woodiron pipe houses etc.) and tunnel houses. They are named by the shape of roof: arch style, wave style and even span style.

The distinction between rain shelters and tunnel houses is very obscure. Umbrella houses that are used as a cover for sweet cherry are separated large structures. Structures used for trellis training (grape and Japanese pear) are very simple.

Growth response of fruit trees in greenhouses

Growth response of fruit trees in greenhouses varies greatly with different covering materials and environment control in the houses. As a typical instance, responses of grape cultivated in a greenhouse will be shown here. Harvesting duration of the grape cultivated in a greenhouse was able to be controlled from the beginning of April to the end of August, whereas the harvest time of grape in an open-field orchard was only at the middle or the end of August^{2,3)}.

The environment management to control the harvesting time is composed of early heating, normal heating, few heating, nonheating, non-covering of house side and open field cropping.

Fig. 3 shows fruit yield (weight) and sugar content of several kinds of fruit trees grown in the greenhouses as compared to those obtained from field orchards. It shows clearly that: the protected cultivation increased the fruit yield in most of the fruit trees examined, except Japanese pear. The yieldincreasing effect was remarkable with navel orange, satsuma mandarin, and lemon. The response of fruit sugar content to the protected cultivation was negative with Japanese pear, but apparently positive with satsuma mandarin. Other kinds of fruit trees ex-





Lemon

Other citrus

amined did not show definite response. Both increase and decrease occurred, or the response was not clearly shown.

The comparison of growth response of fruit trees between greenhouse cultivation and open field cultivation showed many differences between them, such as difference in flowering habit, fruit growth, harvesting time, and fruit qualities⁴⁾. Therefore, although accurate comparison on each characteristic is difficult, the general trend of the growth response is needed to be understood.

There is few investigations on photosynthesis and respiration compared between greenhouse cultivation and open field cultivation. It was found with Japanese pear and grape that photosynthetic rate was relatively lower in a greenhouse than that of open field cultivation. Optimum temperature for photosynthesis was higher in the greenhouse than that of open field cultivation.

Photosynthetic rate and yields of satsuma mandarin of greenhouse cultivation were higher than those of open field cultivation. Although leaves of satsuma mandarin tend to become shade leaves in the greenhouse, the protected environment in the greenhouse was effective in keeping relatively high temperature and avoiding leaf injury by wind and rain, resulting in longer duration of photosynthetic activity which increased the total photosynthetic production per year. It may explain the increased fruit yield and increased sugar content of fruit of satsuma mandarin in the greenhouse.

The growth response to the protected cultivation is not limited only to acceleration of flowering, fruit enlargement, and harvesting time, but also makes a difference in flowerbud initiation and development.

Problems in protected cultivation of fruit trees in future

It is expected that the protected cultivation of fruit trees brings about great advantages, such as alleviation of seasonal labor concentration and smooth labor distribution in a year due to diversified cropping season and all weather working days, alleviation of disease and insect pest control and avoidance of meteorological crop disasters. All these advantages cause stabilized high yields, high quality of fruit, early harvest and more income.

However, the protected cultivation requires great investment for production materials and increases production costs. Therefore, higher technology of cultural management becomes essential.

Many problems to be solved are as follows:

1) Development of technology for stabilized production of high quality fruits in greenhouses:

Selection of kinds of crops and cultivars as well as the breeding works is very important. Cultural management of trees and proper control of fruiting are also important. It is necessary to set up the standard of controlling climatic and soil environment in greenhouses in order to give better condition to crops. Adoption of dwarf trees and compact training, and prevention of reduced tree vigor caused by physiological troubles as well as diseases and insect pests are important in future.

In future, not only the use of existing fruitbearing orchards but also a new system by which fruit-bearing trees grown in containers are transferred into greenhouses, must be considered.

2) Reduction of production cost:

Cost of greenhouse construction is apt to increase due to increased size and irregular ground shape of greenhouses and construction on sloping land. The first step to reduce cost of production is to save the cost of construction materials and facilities.

The use of dwarfing rootstocks, compact training, pot culture, and appropriate house structuring have to be promoted.

Secondly, improvement of cropping system, oil saving, and automatic control of temperature and water supply are needed. Studies on these aspects have to be intensified.

3) Strengthening management and sale system:

The optimum operational scale of protected cultivation of fruit trees is not made clear yet, though it must vary depending on different districts or different technical levels of farmers. Economic analysis of cost and income of protected cultivation has not been made satisfactorily. In promoting the protected cultivation, the problem of aggregation of the number of independent greenhouses in a given area has arisen. How to develop marketing system there is another relevant problem. It is expected that the protected cultivation of fruit trees may not be widely adopted in the north-east part of Japan, except Yamagata Prefecture. However, the use of simple facilities like rain shelters will be needed to stabilize yields against low temperature and heavy rain.

To the contrary, in the south-west part (Kyushu, Shikoku and Kinki district) of Japan and Yamanashi Prefecture, the protected cultivation will be actively adopted, aiming at the more effective use of favorable climate there, protection against strong wind and rain, and higher productivity in relatively small orchards there.

It is difficult to estimate the future increase in the acreage of protected cultivation in Japan. However, it will be anticipated that the acreage will increase to a fairly large extent, on the basis of an assumption that the annual rate of increase of the acreage in the past five years, 16% (Fig. 1), will continue for a considerable period.

References

 Fruit Tree Research Station, Div. of Pomology: A survey by questionnaires on protected cultivation of fruit trees. 1-52 (1981) [In Japanese].

- Fruit Tree Research Station, Div. of Pomology: A survey by questionnaires on temperature control practices in fruit's green houses. 1-62 (1984) [In Japanese].
- Kamota, F. & Taniguchi, T.: The existing state and the significance of introduction of protected cultivation of fruit trees. Ienohikari-kyokai, 1-30 (1985) [In Japanese].
- Kamota, F.: Protected cultivation of fruit trees in Japan. J. Agr. Met., 42(4), 391-395 (1987) [In Japanese].
- Ministry of Agriculture, Forestry and Fisheries, Div. of Vegetable Production & Marketing: Statistics on greenhouse horticulture (July 1984–June 1985) (1986) [In Japanese].

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