Utilization of Rootstocks in Cucurbits Production in Japan

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In Japan, vegetable production by the use of grafting (hereafter referred as graft culture) is widely practiced. Particularly, the graft culture of Cucurbits covers a large area (Table 1). The first grafting was made in about 1930, by using *Cucurbita* species or *Lagenaria siceraria* as a rootstock for watermelon. Then, the grafting in melon and cucumber was begun in about 1955 and 1965, respectively.

Grafting of Cucurbits was originally initiated as a preventive measure against a soil borne disease, Fusarium wilt (*Fusarium oxysporum* f. sp.). Since it was known later that the grafting on selected rootstocks is useful for increasing cultural efficiency and crop yields, as it promotes crop growth and enhances environmental adaptability, the grafting has widely spread.

Kinds of rootstock

1) Rootstocks for watermelon

A survey in 1981 showed that *Lagenaria siceraria* is most frequently used, accounting for 64% of the total number of grafting. It is followed by *Cucurbita* species (26%), *Benincasa hispida* (7%), and watermelon varieties resistant to Fusarium wilt (1%).

Lagenaria siceraria has a high graft com-

Table 1. Grafting culture area of fruit vegetables (1980)

Crop	Protection	Total area	Graft area	Graft/Total
		ha	ha	%
Watermelon	Open field	24,993	23,812	95
	Plastic house	3,244	3,213	99
	Total	28,237	27,025	96
Cucumber	Open field	14,765	4,575	31
	Plastic house	7,044	6,003	85
	Total	21,809	10,578	49
Melon (Earl's Favourite)	Glass house	1,005	481	48
	Plastic house	197	48	24
	Total	1,202	529	44
Melon (Except Earl's Favourite)	Open field	6,284	4,065	65
	Plastic house	3,751	2,262	60
	Total	10,035	6,327	63
Tomato	Open field	6,888	355	5
	Plastic house	5,108	821	16
	Total	11,996	1,176	10
Eggplant	Open field	13,352	2,673	20
	Plastic house	1,694	1,634	96
	Total	15,046	4,307	29

Open field: including small tunnel

patibility with watermelon, and is highly resistant to Fusarium wilt of Cucurbits except that of itself. Grafting of watermelon on *Lagenaria siceraria* causes an increased growth ability at low temperature, and better development, without adverse effects on fruit quality. As Indian varieties are generally prominent in growth ability at low temperature and drought tolerance, the Indian varieties or hybrids between Indian and Japanese varieties are used for rootstocks.

Graft compatibility of *Cucurbita* sp. to watermelon varies with varieties. *C. moschata*, *C. pepo*, and an interspecific hybrid (*C. maxima* × *C. moschata*) have generally a high compatibility, while *C. maxima* has a low compatibility. However, the compatibility differs with varieties even in the same species. *Cucurbita* sp. has the highest resistance to Fusarium wilt and the highest growth ability at low temperature among rootstocks for watermelon. Watermelon grafted on *Cucurbita* sp. is apt to grow too vigorously, resulting in unstable fruit bearing and poor fruit quality. Therefore, *C. moschata*, which does not induce too much vegetative growth, is mostly used, while interspecific hybrid *Cucurbita* sp. and *C. pepo* are also used for rootstocks.

Benincasa hispida has a high graft compatibility with watermelon, and is resistant to Fusarium wilt. It gives watermelon a better growth, without affecting fruit quality. However, due to its poor growth ability at low temperature, it is not suitable for the culture in a cold period.

Watermelon resistant to Fusarium wilt shows an extremely high graft compatibility with watermelon, and it gives better fruit quality than other rootstocks do. As it has a slender hypocotyl, skill is needed for grafting operation.

2) Rootstocks for cucumber

Cucurbita sp. is generally used, though *Sicyos angulatus* is used only in few cases. As hybrid *Cucurbita* sp. is vigorous in growth, it is used throughout the year. During the period of low temperature, *Cucurbita ficifolia*, which has a high growth ability at low temperature, is mainly used. For out-door culture, *C. moschata*, which has a high tolerance to excess water, is partly used together with interspecific hybrid *Cucurbita* sp.. Although graft compatibility and Fusarium wilt resistance vary by cultivars, Shintosa-group (*Cucurbita maxima* × *C. moschata*), *C. ficifolia*, and Sirokikuza (*C. moschata*), which are currently being used, have practically sufficient graft compatibility and Fusarium wilt resistance.

Sicyos angulatus, a naturalized Cucurbits plant discovered in 1951, has high graft compatibility with cucumber and watermelon and resistance to Fusarium wilt and *Meloidogyne incognita*. Its disadvantages are wide variations in graft compatibility and Fusarium wilt resistance due to different regions of seed collection, lack of germination uniformity caused by hard seeds, and troublesome operation of grafting due to slender hypocotyls.

3) Rootstocks for melon

For the greenhouse culture of melon (Earl's Favourite is exclusively used), Fusarium wilt resistant varieties of melon are used as rootstock, while for the plastic house culture and out-door culture interspecific *Cucurbita* sp. is mainly used, and resistant varieties of melon are partly used.

In the year-round culture of a high grade cultivar, Earl's Favourite, in well-equipped (such as for heating) glasshouses, more emphasis is placed on fruit quality than environmental adaptability, so that Fusarium wilt resistant cultivars of melon, Barnett Hill Favourite, Emerald Gem, or Ooi, are used as the rootstock.

In the plastic house culture or out-door culture of melon, the environmental adaptability is also required along with the Fusarium wilt resistance, so that interspecific hybrid *Cucurbita* sp. is mainly used. However, the use of it induces a risk of poor fruit bearing and poor fruit quality due to excessively vigorous vegetative growth, so that *C. moschata* with less vigorous growth and high graft compatibility with melon has come to be employed recently. In selecting rootstock cultivars of

Cucurbita sp. it must be taken into account that a given rootstock shows varied graft compatibility with different cultivars of scion. Therefore, rootstock cultivars with high graft compatibility specific to each scion cultivar must be selected. There is no such a change in graft compatibility of *Cucurbita* sp. used as rootstocks for watermelon and cucumber.

Methods of grafting

Grafting of Cucurbits is classified into tongue graft, cutting of tongue grafted stock, and approach graft. The graft method differs with kinds of the crop (Table 2).

Table 2. Grafting methods and their ratio to total grafting culture area (1980)

Crop	Tangue graft	Cutting of tongue-grafted stock	Approach graft
	%	%	%
Watermelon	54	37	9
Cucumber	8	5	87
Melon (Earl's Favourite)			100
Melon (Except Earl's F.)	39	2	59

1) Tongue graft

This method is most popularly used for grafting watermelon on the rootstock of *Lagenaria siceraria* or *Cucurbita* sp.. Grafting of the scion with a half-expanded cotyledon to the rootstock with the first true leaf just emerging gives the highest survival rate, and good subsequent growth. As shown in Fig. 1, the stem tip is removed from the rootstock and a slantwise slit is opened on the surface of the hypocotyl starting from a vicinity close to the cotyledon by using a bamboo spatula. Then, a wedge-shaped hypocotyl of the scion is firmly inserted into the slit. Sometimes, a vertical hole is made in the peripheral portion of rootstock hypocotyl, to which scion is inserted. The grafting is made on rootstocks kept planted in pots, or those digged up from pots, which are later planted to pots. In the tongue graft, its success or failure depends more on plant management after the graft than the grafting manner. To avoid wilting on the day and the next day of the graft, a vinylfilm and a reed screen on it are spread on the grafted plants to give humidity and shade. After the 3rd–4th day, plants are exposed to sunlight unless they wilt, and after the 7–8th day, the usual nursing method is applied.

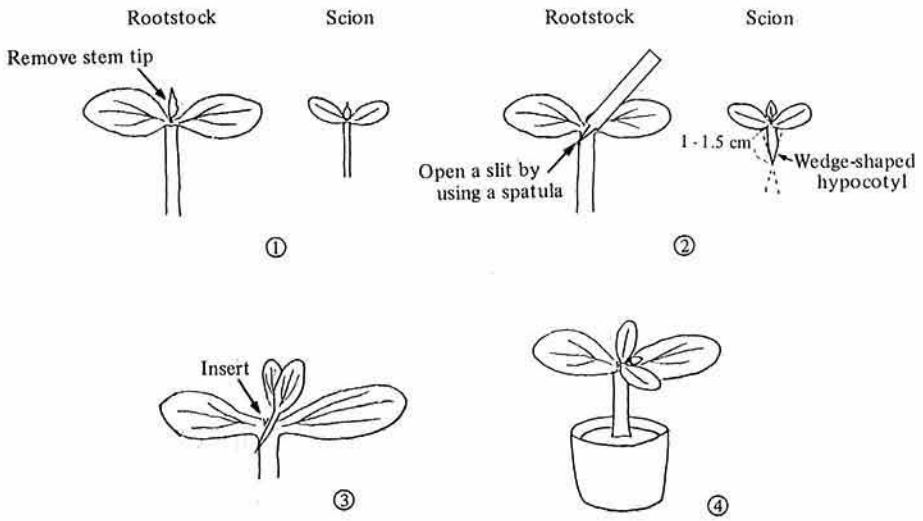

Fig. 1. Tongue graft of watermelon

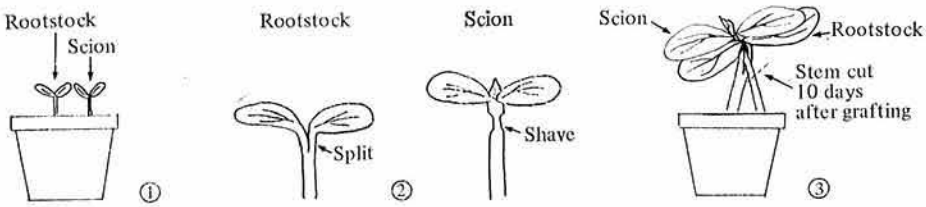

Fig. 3. Approach graft of melon (Earl's Favourite)

a pot at the same time; the former at the center, and the latter 2–3 cm apart from it. The grafting is made when the first true leaf begins to emerge, after the full expansion of cotyledon. A slit of 0.5 cm in depth is opened at the top of the hypocotyl, after the removal of cotyledon of the rootstock. The scion hypocotyl is shaved at its both side at a portion 0.5 cm below the cotyledon. A shallow shaving results in delayed union. The shaved portion of the scion is inserted into the slit of the rootstock, and fixed with a clip. The grafted plants are grown under a usual nursery management, and about 10 days after the graft the scion stem is cut off.

Problems in rootstock utilization

1) Disease resistance[1,3]

In areas when watermelon grafted on *Lagenaria siceraria* is grown continuously for many years, a sudden wilting and die-back symptom frequently occur at and after the beginning of fruit enlargement. Although the cause is not fully revealed yet, *Fusarium oxysporum* f. sp. *Lagenariae* is regard to be the cause for many cases. Varieties of *L. siceraria* resistant to the disease have been developed, but they are not highly resistant, so that *Cucurbita* sp. or *Benincasa hispida*, both do not show the symptom, is taking the place of *L. siceraria* in the affected areas.

In a part of the area of watermelon grafted on *B. hispida*, Fusarium wilt appeared recently. The causal pathogen belongs to *F. oxysporum* f. sp. *niveum*, and it has relatively low pathogenicity to watermelon, while it severely attacks *B. hispida*, so that it is different from the one which severely infested watermelon so far. Varietal difference of *B. hispida* in the resistance to it is reported, but resistant rootstock varieties have not been bred.

Recently, Fusarium wilt of cucumber grafted on *C. ficifolia* is reported. The causal agent, belonging to *F. oxysporum* f. sp. *lagenariae* shows lower pathogenicity to *L. siceraria*, but it infects more severely *C. ficifolia* and *C. moschata*, as compared with *F. oxysporum* f. sp. *lagenariae* so far known. Its incidence is confined to a quite limited area at present, but careful watching is needed for the future spread. Resistance of *C. ficifolia* differs by countries from which it was introduced, but highly resistant ones have not been found out.

It has been made clear recently that *F. oxysporum* f. sp. *melonis* in Japan has two races. In addition, *F. oxysporum* f. sp. *cucumerinum* also attacks melon. Therefore, melon to be used as a rootstock must have the resistance against two races of *F. oxysporum* f. sp. *melonis* and *F. oxysporum* f. sp. *cucumerinum*.

2) Quality[2]

Cucurbita sp. used as rootstock to watermelon or melon is generally liable to cause a lowering of fruit quality. Water melon grafted on *Cucurbita* sp. shows hard and fibrous flesh, and melon on *Cucurbita* sp. gives fruit skin dotted with depressions and green spots, and easily-fermentable flesh. It is due to the fact that the graft culture by the use of *Cucurbita* sp. rootstock induces excessively vigorous vegetative growth. In such a case,

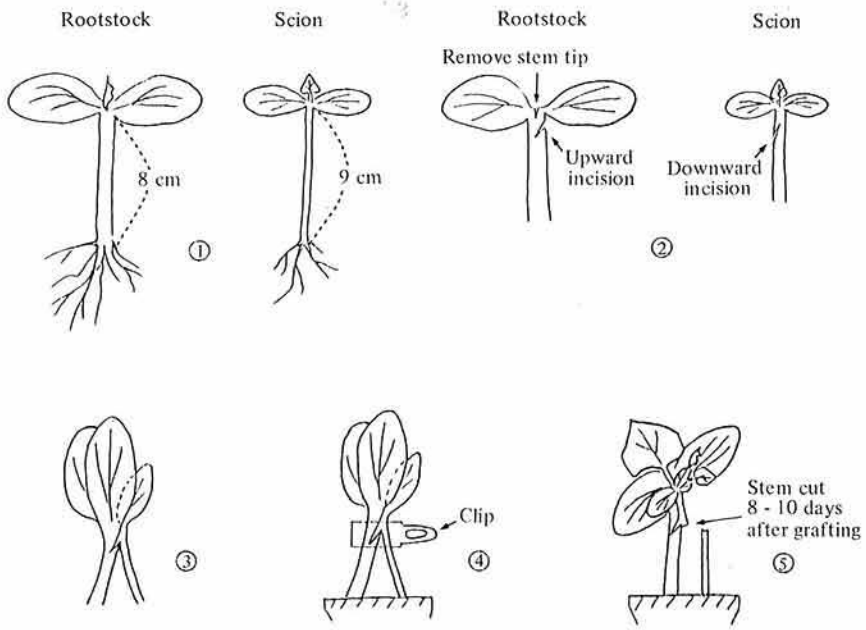

Fig. 2. Approach graft of cucumber

2) Cutting of tongue-grafted stock

A scion is grafted on a cutting of rootstock and the grafted cutting is planted to soil. It aims at increasing both grafting efficiency and root amount due to emergence of adventitious roots and its use to watermelon is increasing yearly. To promote the rooting of grafted nursery plants, soft and porous bed soil with high water- and air-permeability is potted and kept at 25°C. Scions must be grafted before they wilt, but slight wilting of rootstock is permissible. After the grafting, more careful management is needed than that for tongue-graft.

3) Approach graft

It is generally used for grafting cucumber or melon for plastic house culture or open culture on *Cucurbita* sp. rootstocks. Although it is more troublesome than tongue graft in grafting operation, it gives a high rate of success under less intensive management of grafted plants. Rootstocks with their first true leaf just emerged and scions with their first true leaf half-expanded or full-expanded are at the best stage for grafting. As shown in Fig. 2, both rootstocks and scion plants are taken up from the soil. After removing the stem tip from the rootstock, a slantwise (at the angle of 30–40°) incision, which is 0.5–0.7 cm in length and reaching the depth of 1/2–2/3 of the diameter of hypocotyl is made downwards on the hypocotyl immediately below the cotyledon. A slantwise (at the angle of 20–30°) incision of 0.5–0.7 cm in length, reaching the depth of 2/3 of the diameter of hypocotyl is made upwards on the hypocotyl, about 1 cm below the cotyledon, of the scion plant. The both incisions are clutched each other, and squeezed gently with a clip. Then, the both plants are potted with their roots separated each other. They are grown without shading unless they wilt, though shading is given after the graft. When the graft union is established after 8–10 days, the scion hypocotyl is cut immediately below the grafted part.

A special type of approach graft as shown in Fig. 3 is exclusively used for greenhouse melon. A rootstock and a scion are sown in

other rootstocks except *Cucurbita* sp. are used, or when *Cucurbita* sp. is to be used, it is better to use *C. moshata* which has less vigorous growth as rootstock, instead of vigorous interspecific hybrid *Cucurbita* sp. and *C. pepo*. It is also better to reduce the use of fertilizers.

3) Environmental adaptability

There is an example that cucumber grafted on *C. ficifolia* showed Mg-deficiency and hence reduced production. It was induced by antagonistic inhibition of Mg absorption due to excessive accumulation of K and Ca, caused by heavy application of fertilizers.

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