# Use of Rootstocks in Solanaceous Fruit-Vegetable Production in Japan

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The utilization of grafts is one of the characteristics in vegetable production in Japan. *Cucurbita* species and *Lagenaria siceraria* as the rootstocks of watermelon began about 1930 to circumvent the disease, Fusarium wilt. In Solanaceous vegetables, use of *Solanum integrifolium* as the eggplant rootstock has intiated since 1955 to protect from Fusarium wilt. Recently, soilborne diseases have made it mandatory to use resistant rootstock in the tomato. Oka (1980) reported that 20 to 23% of the eggplants and 7–9% of the tomatoes grown commercially are grafted. In sweet pepper grafts are not used commercially, but experimental use of rootstocks resistant to *Phytophthora capsici* is presently being investigated.

## Kind of rootstocks

*1) Tomato*

Rootstock cultivars of tomato and their disease resistance are listed in Table 1. Among many soilborne diseases of tomato, bacterial wilt and brown root rot cause severe damage, difficult to control and no resistant cultivars are available against them. Cultivars resistant to bacterial wilt such as Saturn and Venus were introduced from the United States and checked, but their resistance did not hold up in heavily infested soils in Japan. Against other diseases such as Fusarium wilt and Verticillium wilt, resistant cultivars are available. Climatic conditions suitable for bacterial wilt and brown root rot are quite different, i.e., the former favors higher temperatures and is prevalent in the summer while the latter prefers lower temperatures and can only be seen in protected cultures during the cool seasons. Therefore, each of the rootstock cultivars is not resistant to both of the diseases. Thus, most of the rootstock cultivars listed in Table 1 are grouped into either bacterial wilt or brown root rot resistance. Four bacterial wilt resistant rootstocks originated from materials obtained from the United States. BF Okitsu 101 was selected from a breeding line NC 1953-64 N introduced from North Carolina Agricultural Experiment Station. LS 89 has been introduced from Hawaii Agricultural Experiment Station as a line Hawaii 7998, PFN and PFNT were bred using similar materials.

Four of the rootstocks showing resistance to brown root rot resulted from interspecific hybrids between *Lycopersicon hirsutum* and *L. esculentum*; resistance to brown root rot is from the former. They are resistant to Fusarium crown and root rot too. There are no resistant cultivars of tomato to the disease. KNVF and KNVF Tm Signaal were imported from Netherlands. Taibyo Shinko No. 1 and KCFT were bred in Japan using similar parental combinations.

*2) Eggplants*

Rootstock cultivars and its resistance are listed in Table 2. There are four soilborne diseases and pest serious in Japan, i.e., bacterial wilt, Fusarium wilt, Verticillium wilt and root knot nematode. Among them bacterial wilt and Verticillium wilt have the highest priority. Fusarium wilt can be protected by using any rootstocks except those of *S. melongena* to which cultivated eggplants belong. Root knot

**Table 1. Disease resistance of rootstocks for tomato**

| | Rootstock | Bacterial wilt | Brown root rot | Fusarium wilt | Fusarium crown and root rot | Verticillium wilt | Root knot nematode | TMV |
|---|---|---|---|---|---|---|---|---|
| mainly for bacterial wilt | BF Okitsu 101 | ○ | × | ○ | × | × | × | × |
| | LS 89 | ○ | × | ○ | × | × | × | × |
| | PFN | ○ | × | ○ | × | × | ○ | × |
| | PFNT | ○ | × | ○ | × | × | ○ | ○ |
| mainly for brown root rot | KNVF Taibyo Shinko No. 1 | × | ○ | ○ | ○ | ○ | ○ | ○ |
| | KNVF Tm Signaal | × | ○ | ○ | ○ | ○ | ○ | ○ |
| | KCFT | × | ○ | ○ | ○ | × | × | ○ |
| | Kurogane | × | × | ○ | × | ○ | ○ | × |

○; resistant ×; susceptible

**Table 2. Disease resistance of rootstocks for eggplant**

| Rootstock | Bacterial wilt | Fusarium wilt | Verticillum wilt | Root knot nematode |
|---|---|---|---|---|
| Okitsu No. 1 Taiwan Naga | ○ | × | × | × |
| Taibyo VF | × | ◉ | ○ | × |
| Kurogane No. 1 | × | ◉ | × | × |
| *Solanum integrifolinm, S. gilo* | × | ◉ | × | × |
| *S. mammosum* | △ | ◉ | × | × |
| Shiko No. 1[1)] | ○ | ◉ | × | × |
| *S. torvum* | ○ | ◉ | ○ | ○ |

1) Fukuoka Horticultural Experiment Station

◉; complete resistant ○; high resistant △; the resistance is sometimes negated by the occurence of pathogenic races. ×; susceptible

nematode, although the damage is common, does not wilt eggplants completely. *Solanum integrifolium* has been used generally since 1955 due to its resistance to Fusarium wilt and since it induces high productivity of the scion plants. Earlier it was reported to show some resistance to bacterial wilt, however no clear resistance can be seen at present.

Okitsu No. 1 originated from Taiwan naga is *S. melongena*. Although the resistance of Okitsu No. 1 and Taiwan naga to bacterial wilt is not very high, it is race nonspecific. In contrast to this, *S. mammosum* is highly resistant in many fields but is susceptible in some fields, due to the difference of the pathogen isolates. *S. torvum* has the higher resistance than Taiwan naga and Okitsu No. 1 and the resistance has not been affected so far by pathogen isolates.

Verticillium wilt resistant Taibyo VF (Takii Seed Co.) is an interspecific hybrid between a selected line from Puerto Rican native long-fruited eggplant and *S. integrifolium*, and is resistant to Fusarium wilt, too. Recent experiments have shown that *S. torvum* has a higher degree of resistance to Verticillium wilt than Taibyo VF. *S. torvum* is also resistant to Fusarium wilt and root knot nematode. Thus, *S. torvum* is resistant to all of the four diseases and pest. Furthermore, it also induces higher vigor and productivity of the scion eggplants, and seems very promising as the rootstock of eggplants, although it has not been released for public use.

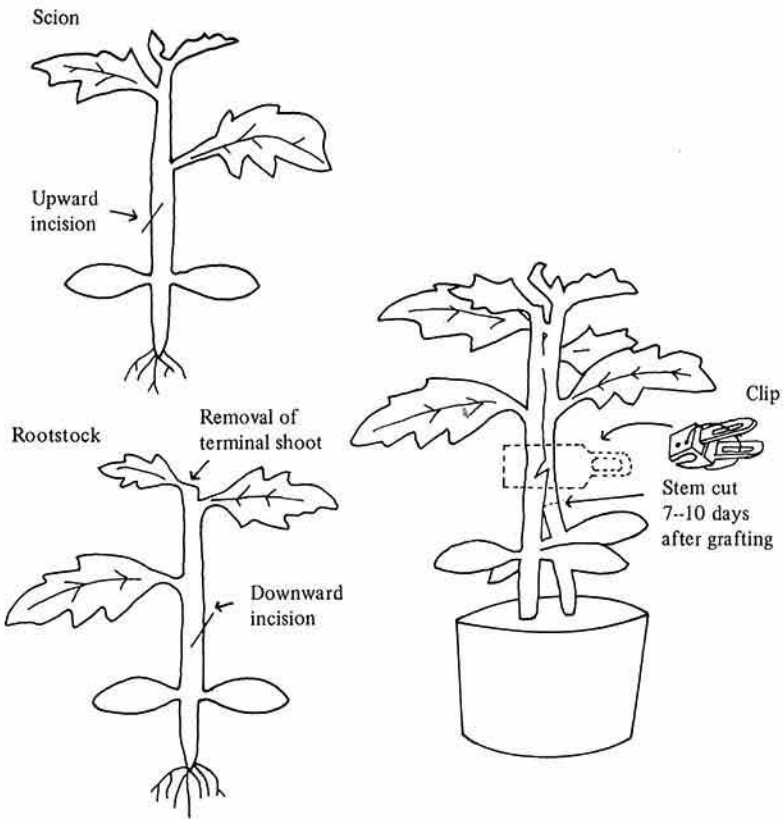


Fig. 1. Approach graft of tomato

## Methods of grafting

There are several types of grafts, however the approach graft and cleft graft are most commonly used in Japan. While both methods are used for the tomato, only the latter is used in eggplants.

The procedures for approach graft are illustrated in Fig. 1. Both of a scion plant and rootstock plant with 3.5 to 4.0 true leaves and a stem diameter of 3–4 mm are carefully removed from seedling flat. Upward (scion) and downward (rootstock) incision is made with a razor blade at a position between cotyledon and the first true leaf opposite to the latter. The lips of the incision are placed into each other and clipped. Both plants are potted together. The lower stem of scion plant is cut off ten days after grafting, and clip is removed 1–2 days later. The merit of this method is that success is very high even under undesirable conditions such as high temperatures and low humidities. The disadvantage of this graft is that the union between the scion and rootstock is weak and the plants tend to break off or bent at the union. The cleft graft of tomato (Fig. 2) uses rootstock plants potted and grown until 5–6 true-leaf stage. These plants are decapitated leaving three true leaves. Stems are split 3/4 of the diameter to a depth of 1.5 cm. A wedge shaped terminal of scion with 2–3 true leaves and cotyledons is inserted into the split and clipped. Clip is removed 7–10 days after grafting.

Cleft graft of eggplants as shown in Fig. 3 is similar to that of tomato. For the rootstock, plants with 5–6 true leaves are decapi-

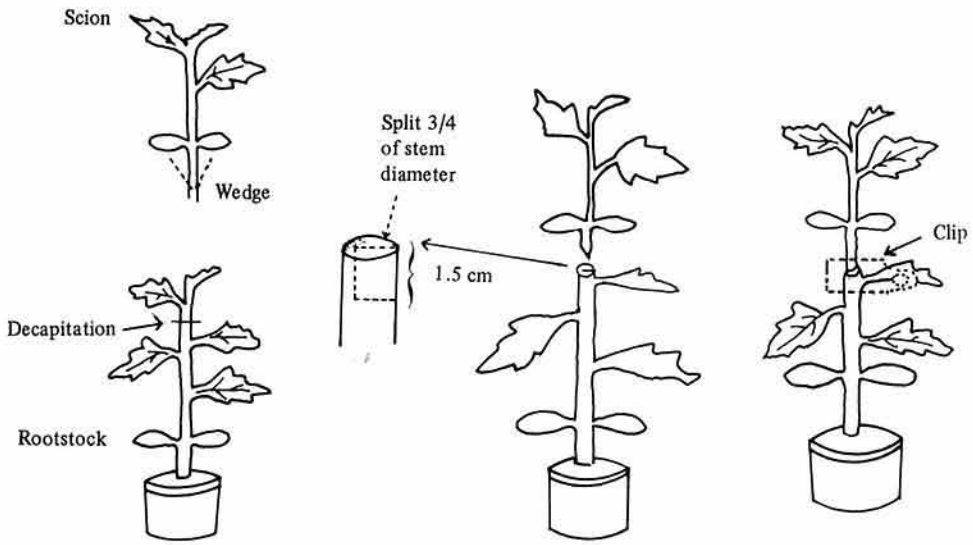


Fig. 2. Cleft graft of tomato

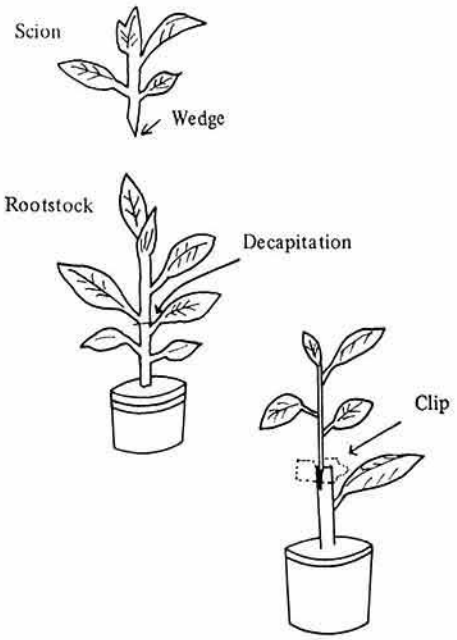


Fig. 3. Cleft graft of eggplants

tated leaving one true leaf. A wedge shaped terminal scion with 3 leaves is taken from 4–5 true leaf seedlings.

## Problems involved in the use of rootstocks

*1) Environmental adaptability*

The popularity of grafts is not only for disease resistance but also for tolerance to unfavorable environment and for higher productivity. Eggplants grafted onto *S. integrifolium* are more tolerant to heat and humidity and are better yielders. On the contrary, Okitsu No. 1 and other *S. melongena* rootstocks tend to be less vigorous, susceptible to physiological disorders such as Mg deficiency, and consequently less productive.

*2) Fruit quality*

KNVF and other interspecific hybrids are very vigorous, and sometimes cause excessive foliage proliferation. Excessive vegetative growth often results in poor quality fruits

such as malformed fruits, vacant fruits and blotchy ripening as well as poor fruit set. Careful crop managements such as control of plant vigor by withholding water and nutrition are sometimes effective in improving quality, however the selection or the improvement of rootstocks may be the final solution.

*3) Shortage of resistance*

Even resistant rootstocks become diseased except for Fusarium wilt of both of tomato and eggplants. In heavily infested soils and under extremely unfavorable environments, the so-called resistant plants become diseased. Intensive successive croppings of the same rootstock provide the opportunity for the occurrence of new pathogenic types with increased virulence qualitatively or quantitatively.

*4) Movement of pathogen between graft companions*

Another serious problem is damage caused by tomato grafting and TMV infection.

There are two types of resistance against tomato TMV. One is symptomless or tolerant type and another is hypersensitive type. *Tm* gene is the former, *Tm*-2$^a$ is the latter, and *Tm*-2 is intermediate; mostly the latter but to some TMV strains acts as the former. Type of TMV resistance of tomato rootstocks are presented in Table 3. When hypersensitive scion is grafted onto TMV-infected susceptible or symptomless type rootstock, the scion produce severe systemic necrosis presumably due to massive supply of TMV to the scion from the infected rootstock. In contrast, when TMV-infected susceptible or symptomless scion is grafted onto hypersensitive rootstock, root activity of the latter declines causing retarded plant growth, sometimes wilt. These relationship is summarized in Table 4. By knowing the genotype of scion cultivars and rootstocks, dangerous combination can be avoided.

**Table 3. Type of TMV resistance of tomato rootstocks**

| Type of resistance | Rootstock |
|---|---|
| susceptible | BF Okitsu 101, LS 89, PFN, Kurogane |
| resistant Tm type[1)] | KNVF, Taibyo Shinko No. 1 |
| Tm-2 type[2)] | KCFT, PFNT |
| Tm-2$^a$ | KNVF-Tm-Signaal |

1) This type involves Tm gene, gene from P.I. 126445 and possibly other genes.
2) This type involves Tm-2 gene. gene from 'Perou 2', gene from IRB lines and possibly other genes.

**Table 4. Problems associated with combinations of tomato scions and rootstocks with different types of TMV resistance**

| rootstock | Scion: susceptible or Tm type resistance | Scion: Tm-2 type resistance | Scion: Tm-2$^a$ type resistance |
|---|---|---|---|
| susceptible or Tm type | ○ | △[2)] | ×[1)] |
| Tm-2 type resistance | △[4)] | ○ | ○ |
| Tm-2$^a$ type resistance | ×[3)] | ○ | ○ |

○; no problem ×; should not be grafted
△; possible damage

1) When the rootstock is infected with TMV, the scion produce severe systemic necrosis.
2) Symptoms similar to 1) might occur occasionally.
3) Infection of the scion with TMV causes growth retardation and sometimes wilt of entire grafted plants.
4) Symptoms similar to 3) might occur occasionally.

## References

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