Studies on High Density Planting of Apple in Japan

By HIROYUKI FUKUDA

Morioka Branch, Fruit Tree Research Station
(Shimokuriyagawa, Morioka, 020-01 Japan)

A medium vigor clonal rootstock, Pendulous Maruba (*Malus prunifolia* var. ringo Asami), has been mainly used for apples in Japan since World War II. Apple trees using this rootstock have proven to be productive in the Japanese climate condition. Also, this rootstock can easily develop roots from its hard wood cutting in the open field.

Apple trees on this rootstock are trained in an open center shape, approx. 4 m high, with 2 or 3 scaffold branches in planting spaces from 7.4 m × 7.4 m to 8 m × 8 m, i.e., 156 to 180 trees/ha. The tree height (4 m) is determined by the height of a person's hand stretching upwards on the top of a 2 m high picking ladder. Ladders higher than 2 m are too heavy to handle in the orchard.

Studies on high density planting using dwarfing rootstocks such as M. 26 and M. 9 commenced in Japan around 1965, and, since its merits, such as early cropping and high color development of the fruit, were recognised, high density planting has been increasing in the main apple growing areas, replacing the medium density planting with Maruba rootstock. In 1986, approx. 20% of the apple orchards adopted the high density planting with dwarfing rootstocks.

More than 90% of the dwarfing rootstock used in Japan is M. 26. The use of M. 9, the most popular rootstock in Europe, was considered to be too weak to grow under Japanese conditions. In some orchards, trees grafted on M. 9 tended to loose their vigor before they reached full production.

Trees on M. 26 are planted at a density of 1.5 m × 4 m to 2 m × 5 m, i.e., 1000 to 1666 trees/ha. Trees are trained in a central leader shape, 3.5 m to 4 m high (Plate 1). The trees are higher than those in Europe, but many of growers believe that the higher the tree, the higher the yield. Some experimental results[5] have shown that higher trees tended to increase the yield.

Over 90% of the apple growers in Japan have less than 2 hectares of orchard. It was, therefore, necessary to raise the yield so that they might earn their living. But the situation is changing now. Growers are more concerned with raising larger and high-colored

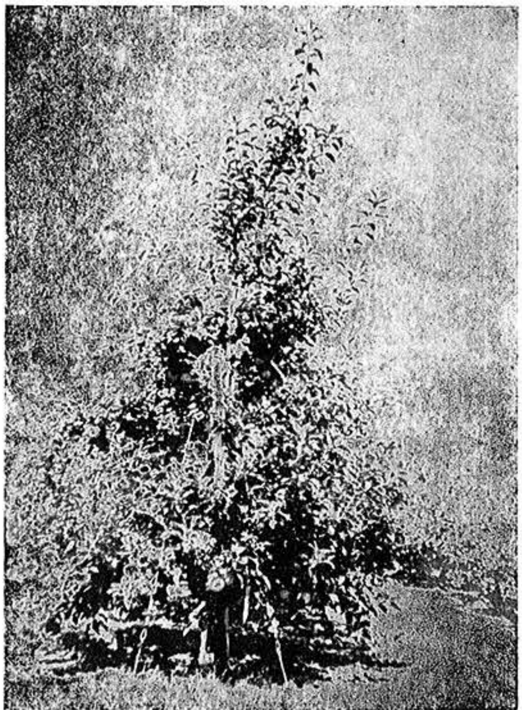

Plate 1. A Fuji/M. 26 tree trained in a central leader shape, approx. 4 m high

fruit rather than with the total yield.

Propagation of rootstocks

After World War II, a pendulous type Maruba clone was found in Nagano Prefecture. Dormant shoots of this clone had a tendency to root easily in hard wood cuttings in the open field. Since the propagation was very easy, it became the most popular rootstock in Japan. Today, more than 70% of apple trees are grafted on this rootstock.

In contrast, dwarfing rootstocks, M. 26 and M. 9 can not be propagative as easily as Maruba. Roots do not emerge from hard wood cuttings before rotting in the open field. Consequently, we propagate these dwarfing rootstocks by grafting on Maruba cuttings.

Table 1. Root primordia found in the cortex just above the buds of dormant rootstock shoots (1983)

Rootstock	Total buds investigated	Buds having root primordia
Maruba	15	15
M. 26	15	0
M. 9	15	0

There may be several reasons why M. 26 does not develop roots. We have found that, while the dormant shoots of Maruba have root primordia in the cortex around the bud, those of M. 26 and M. 9 don't (Plate 2 and Table 1)[4].

Roots of Maruba cuttings at first appear from the callus tissue developed on the basal cut surface, but when the cut surface has rotted, roots emerge from just above the bud, where the root primordia are located. In contrast, rooting of M. 26 is limited to only the basal cut surface, and no root emerges from the bud area, even if the tissue has rotted. M. 9 seldom rooted even from the basal cut surface.

The breeding laboratory of our research station is now selecting new dwarfing rootstocks from the cross strains of M. 9 × Maruba, which may be propagated easily by the hard wood cutting method in the open field. Some of the strains, Q9 and Q64, were found to have root primordia in the cortex of 1 year old wood, and some unpublished data showed that the hard wood cuttings of these two strains had a tendency to root.

Development of root primordia in the cuttings may be advantageous for easy rooting,

Plate 2. Root primordium (→) in the cortex just above the bud area of a Maruba dormant shoot (×40)
BS: bud scales, C: cortex, X: xylem.

although many other factors such as biochemical conditions are related to the root emergence of rootstocks.

Productivity of apple trees on dwarfing rootstocks

Apple trees grafted on dwarfing rootstocks reach their full yield stage in 5–6 years after planting, while it takes more than 10 years for trees on Maruba. Early cropping of those trees is related to the high density planting and greater flower bud formation.

With regard to flower formation it appears that apple trees in the central part of Japan tend to have more flowers than those in the northern region. The full production stage yield is 40 to 60 t/ha in the central region, while it is only 30 to 40 t/ha in the northern region. Trees on dwarfing rootstocks, having a decreased tendency for biennial bearing, are also apt to have a higher yield. However, trees in the central region sometimes loose their growth vigor due to overloading.

Dry matter production per leaf (DPL) of Fuji trees calculated from the growth of the fruit, leaf, shoot, and volume increment of the wood (trunk and branches) and root did not differ much between rootstocks (Table 2)[2]. It was within the range of 5.39–6.48 for both

Table 2. Yearly dry weight increment and its distribution in Fuji trees grafted on M. 9 and Maruba (1983)

Rootstock & tree No.		Dry wt. increment (kg) A	Leaf dry wt. (kg) B	DPL A/B	Dry wt. distribution in each part (%)				
					Fruit	Leaf	Shoot	Wood	Root
M. 9	No. 1	8.07	1.35	5.98	59.6	16.7	5.8	6.7	11.1
	No. 2	5.73	0.89	6.44	62.6	15.5	5.2	4.4	12.2
	Average	6.90	1.12	6.21	61.1	16.1	5.5	5.6	11.7
Maruba	No. 1	44.93	8.33	5.39	22.3	18.5	17.6	24.1	17.5
	No. 2	26.23	4.05	6.48	44.6	15.4	7.8	18.9	13.3
	Average	35.58	6.19	5.94	33.5	17.0	12.7	21.5	15.4

Trees on M. 9: 9 year old planted in a space of 1.5 m×4 m.
Trees on Maruba: 14 year old planted in a space of 5 m×5 m.

Table 3. Dry weight of 6 year old Fuji and Tsugaru trees grafted on M. 9 rootstock (1986)

Cultivar	Tree No.	Top weight (g)			Root weight (g)			T/R ratio
		Wood	Shoot	Total	Diameter <2 mm	Diameter >2 mm	Total	
Fuji	1	9772	1165	10937	2218	205	2423	4.51
	2	9410	1449	10859	1990	188	2178	4.99
	3	9126	917	10043	1964	133	2097	4.79
	4	9826	1200	11026	1984	133	2117	5.21
	5	9262	1123	10385	2268	137	2405	4.32
	Average	9479	1171	10650	2085	159	2244	4.75
Tsugaru	1	6003	723	6726	1650	176	1826	3.68
	2	7314	458	7772	2097	197	2294	3.39
	3	4862	512	5374	1719	201	1920	2.80
	4	4019	760	4779	1508	181	1689	2.83
	5	5249	661	5910	1619	152	1771	3.34
	Average	5489	623	6112	1719	181	1900	3.22

M. 9 and Maruba. But there was a difference in the distribution of the dry matter to various parts of trees. At the expense of the wood and shoot, the distribution to the fruit increased in trees on M. 9. These trees sometimes stop growing with the overdistribution of dry matter to the fruit. Some of the stunted trees did not recover their growth for a few years.

Among the main cultivars, Tsugaru, Jonagold, Ōrin, Senshū and Mutsu have a greater tendency to loose their growth vigor than Fuji.

One of the reasons is that Fuji has a greater compatibility to dwarfing rootstocks than other cultivars. In one investigation, it was shown that the T-R ratios were higher in Fuji trees than in Tsugaru trees (Table 3). The top part of that cultivar grows with a root relatively smaller than Tsugaru, because the nutrients and water translocate through the graft union rather smoothly.

With Fuji/M. 26 trees, overgrowth would be a problem rather than the loss of growth vigor.

Table 4. Size of Fuji/M. 26 trees in several representative apple orchards (1983 and '84)

Orchard No.	Planting space (m)	Tree age	Tree height (m)	No. of branches/tree
1	1.5×3.5	8	3.49	45
2	1.6×3.8	10	4.51	33
3	1.5×4.0	10	3.75	31
4	1.5×4.0	9	4.23	33
5	1.5×4.0	10	4.16	30
6	2.0×4.0	9	3.75	28
7	2.0×4.0	7	3.95	37
8	2.0×4.0	10	4.70	37
9	2.0×4.0	9	3.95	37
10	2.0×4.0	8	4.00	34
11	2.0×4.8	10	3.95	29
12	2.0×5.0	11	3.73	35
13	2.5×4.0	9	4.10	24
14	2.5×4.0	9	3.25	32
15	2.5×5.0	5	3.08	27
16	3.0×6.0	7—8	3.25	32
Average			3.85	32

Tree shape management

Several central leader shapes are being tested in Japan, not only by growers, but by research persons. At first, when high density planting was introduced, the spindle bush or the slender spindle was referred to as the prototype of the tree shape. But this soon changed to special types. Many growers preferred to grow apple trees more than 3.5 m in height in order to raise the yield.

Table 4 shows the height of apple trees on M. 26 in several representative commercial orchards. The average height of trees investigated was 3.85 m[3]. In some orchards they grow trees more than 4 m, which no longer means 'dwarfed apple trees'.

The use of M. 26 for Fuji was also related to the trend of the trees to grow so high. This cultivar has a greater compatibility to M. 26, and the growth of the trees is too vigorous to keep them within the planting spaces, 1.5 m × 4 m or 2 m × 4 m. A strong pruning to keep them within the space induces overgrowth. Consequently, many growers grew the trees taller to moderate the horizontal growth.

Some growers planted trees with shanks longer than 25 cm to control growth vigor. However, this technique often brought about a 'stunted tree' with the development of

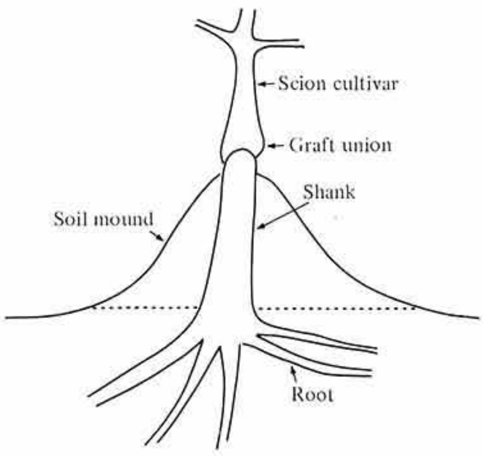

Fig. 1. Soil mounding of a long shank

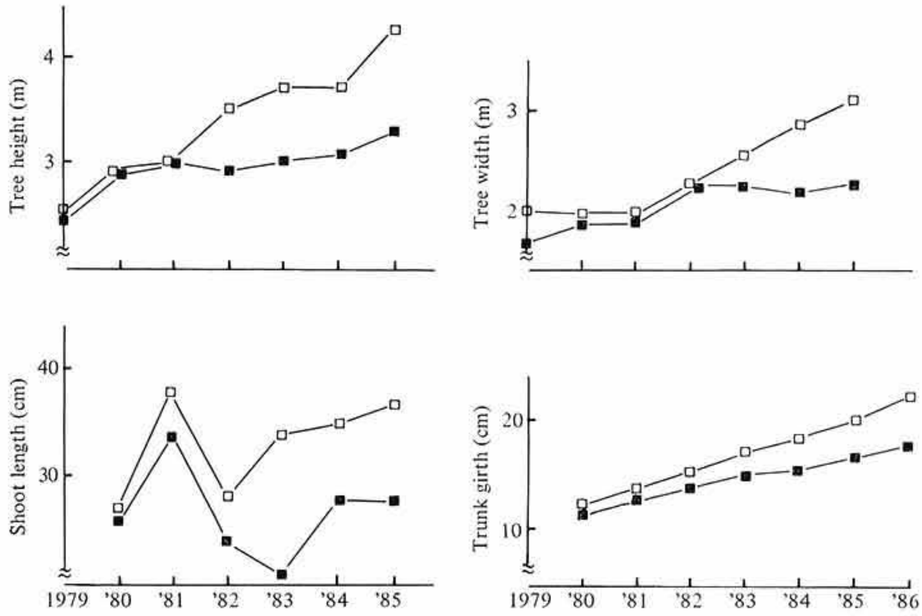

Fig. 2. Effect of soil mounding on the tree growth of Jonathan/M. 26 (1987)
□ Soil mounding was operated in 1979.
■ Control.

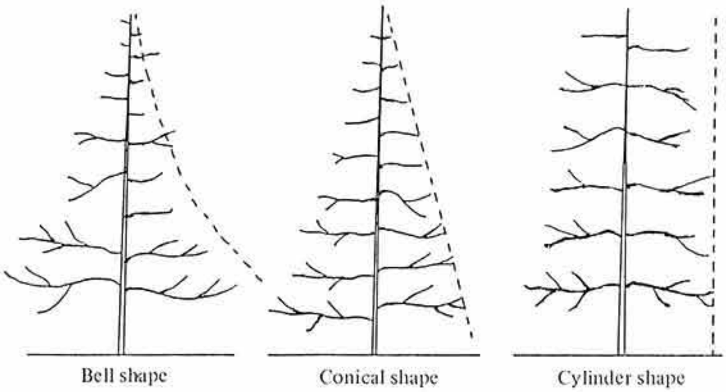

Fig. 3. Apple tree shapes in high density orchards in Japan

burrknots on the shank. Long shank trees did not grow uniformly; some trees became large and others remained small. In order to recover the growth of these trees, soil mounding around the shank was tried (Fig. 1). Soil mounding was proved to be effective for recovering growth vigor due to rooting from the burrknot on the shank (Figs. 1 and 2)[1]. As a result of this experience, trees are now planted with a short shank of 5–10 cm. The less vigorous rootstock, M. 9, will be reevaluated for the Fuji cultivar, since the rootstock free from virus is now available.

Planting space will also be reconsidered. In case of Fuji/M. 26, the tree spaces should be 2.5 m or more with 5 m of row space. Planting in a wider space brought about reduced yield, but better coloring of fruit due to improvement of sun light perception carried a higher income to the growers. It is also probable that the wider planting space makes it possible to reduce the tree height. The tree height was less than 3.5 m in 3 of 4 orchards where tree spaces were 2.5 m or more (Table 4).

With the less vigorous cultivars, Tsugaru, Jonagold, Ōrin Senshū and Mutsu, it was also possible to control the tree size, when planted in a tree space of 2.0 m.

Apple tree shapes in high density orchards are classified into 3 groups; bell, conical, and cylinder shapes (Fig. 3)[3]. Some growers believe the cylinder shaped trees have a higher yield, but it requires a more complicated and time-consuming pruning technique to maintain better sun light perception to the lower branches. Otherwise, these branches weaken and droop.

Conical and bell shapes are more advisable, since they can be pruned easier than the cylindrical type. In these shapes 2–4 scaffold branches are kept in the basal part of the trees. By making lower scaffold branches, branch drooping can be prevented. The bell shape has longer scaffolds than the conical shape in order to improve sun light perception to the lower branches. Consequently, the bell shaped tree requires a wider space than the conical. Wider planting space makes it possible to place somewhat longer, productive lower scaffold branches.

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