Dwarfing Rootstocks of Apple

By SHICHIRO TSUCHIYA

Division of Fruit Breeding, Fruit Tree Research Station

Since the first introduction of apple to Japan in 1872, various plants of Rosaceae had been examined for the usefulness as rootstocks of apple. Among them, those which were selected for practical use were exclusively *Malus* species, particularly those native to Japan from old time, such as *M. prunifolia* var. *ringo* Asami, *M. Sieboldii* Rehd., *M. Sieboldii* var. *arborescens* Rehd., *M. baccata* var. *mandshrica* Schneid., etc. Of them, *M. prunifolia* var. *ringo* Asami has been used quite frequently, and it accounts for the majority of rootstocks for the apple at the full productive stage at present, because of its easy cutting propagation, wide adaptability to soils[8,9] with resistance to drought and excessive soil moisture, resistance to woolly apple aphid and collar rot, and its characters to induce early fruiting and high productivity, although it is relatively vigorating. In addition, a clone[5] which is regarded as a somatic mutant of *M. prunifolia* var. *ringo* Asami is used for more than 90% of nursery apple trees recently being produced. As compared with the former, this clone is easier in propagation and it has a tendency of dwarfing to some extent.

Apple trees on rootstock of *M. prunifolia* reach 6—7 m in tree height when grown freely with a modified leader type training. However, in actual practice, tree height is suppressed to 4—4.5 m at the planting density of 10—18 trees/10a. By this method, fruit production of 4—5 tons/10a is obtained at the full productive stage. However, it takes at least 10—12 years to reach the full productive stage, and

Table 1. Tree growth of four apple cultivars on several rootstocks at 12 year old

Cultivar	Rootstock	Trunk girth	Tree crown		Weight of pruned branches	
			Height	Spread	12-year-old	Total(1-12)
		cm	m	m	kg	kg
Jonathan	M 7	40.5(76)	4.4(90)	4.8(73)	4.3(49)	26.0(46)
	M 9	23.2(44)	2.6(53)	2.8(43)	1.0(11)	6.8(12)
	M 26	34.4(65)	3.6(73)	3.8(58)	4.7(53)	16.1(29)
	MM 106	46.7(88)	4.6(94)	5.6(86)	6.9(78)	44.9(80)
	M. prunifolia	53.0(100)	4.9(100)	6.5(100)	8.8(100)	56.0(100)
Starking Delicious	M 7	40.5(69)	4.4(94)	5.0(71)	4.3(16)	44.2(33)
	M 9	25.2(43)	3.5(74)	3.6(51)	2.5(9)	9.2(7)
	M 26	44.5(76)	4.9(104)	5.4(77)	11.4(42)	37.2(28)
	MM 106	48.3(82)	5.4(115)	6.5(92)	14.3(52)	59.3(44)
	M. prunifolia	58.8(100)	4.7(100)	7.0(100)	27.4(100)	133.7(100)
Golden Delicious	M 7	47.3(80)	5.0(104)	5.8(88)	10.1(49)	47.4(51)
	M 9	29.3(49)	3.4(71)	3.4(52)	2.0(10)	11.2(12)
	M 26	43.0(73)	4.6(96)	4.8(73)	7.0(34)	24.8(27)
	MM 106	54.3(92)	4.9(102)	6.1(92)	9.1(44)	56.5(60)
	M. prunifolia	59.3(100)	4.8(100)	6.6(100)	20.5(100)	93.5(100)
Fuji	M 9	26.7(41)	2.8(56)	3.2(44)	1.4(5)	8.5(6)
	M 26	53.0(82)	4.7(94)	6.0(83)	12.9(42)	53.9(36)
	MM 106	59.0(91)	4.6(92)	6.0(83)	9.9(33)	62.9(42)
	M. prunifolia	64.8(100)	5.0(100)	7.2(100)	29.9(100)	148.3(100)

it requires 240—340 hrs of labor/10a.

In view of the recent demand for labor-saving, high yield, and good quality, i.e. the demand for developing cultural systems for markedly higher labor- and land-productivities, the dwarfing cultivation has come to be studied mostly by the use of dwarfing rootstocks like M and MM clones which are already in practical use in Europe and U.S.A., etc.

In this paper, effects of dwarfing and semi-dwarfing rootstocks will be presented, from the comparative studies on *M. prunifolia*, M and MM rootstocks, carried out in Morioka Branch of the Fruit Tree Research Station.

Table 2. Fresh weight of Fuji tree on M 9 and *M. prunifolia* at 12 year old

Portion		Rootstock		Weight index of M 9 to *M. prunifolia* (100)
		M 9	*M. prunifolia*	
Top	Shoot	1.7 kg	10.4 kg	16
	2-year-old branches	1.9	9.0	21
	3-year-old branches	1.8	6.6	27
	4-year-old branchns	1.1	5.4	20
	Over 5-year-old limb	16.6	74.4	22
	Trunk	13.3	30.1	44
	Total	36.4	135.9	27
Root crown		5.8	16.2	36
Root[a)]	Diameter 2 mm>	1.4	1.3	108
	2–5 mm	1.2	1.7	70
	5–10 mm	0.8	2.0	40
	10–30 mm	2.3	9.0	26
	30 mm<	6.0	17.2	35
	Total	11.7	31.2	38

a) Root system was examined in the cylindrical soil block of 4 m (diameter) × 2.1 m (depth).

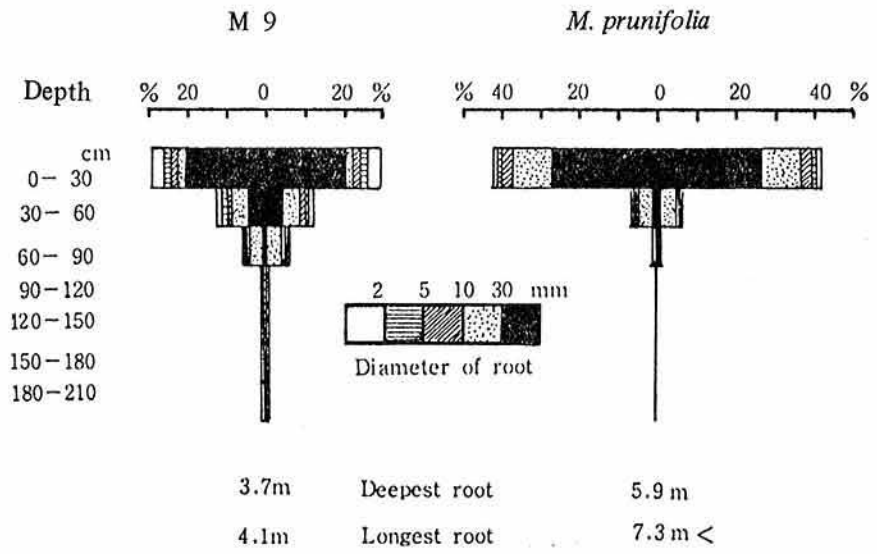

Fig. 1. Root distribution ratio of 12 year-old Fuji tree on M 9 and *M. prunifolia* in the cylindrical soil block of 4 m (diameter) × 2.1 m (depth)

Effect of dwarfing rootstocks on growth of apple trees

Effect of various rootstocks on tree growth is shown in Table 1. Trunk girth, tree height and spread of cultivars on M9 rootstock were only 50% of those of trees on *M. prunifolia* at the tree age of 12 years. Weight of pruned branches in the former was only 10% of the latter, either in a single year or in the total of 12 years. This tendency was more apparently expressed by the result of tree component study (Table 2) with a cultivar Fuji on M9 or *M. prunifolia* rootstock, indicating that dwarfing effect of M9 is much greater than *M. prunifolia*. Distributions of their root system are shown in Fig. 1.

A rootstock with dwarfing effect next to M9 is M26. This root stock gives, in general, vigorous initial growth, and the growth in several years after planted was close to that on MM106[12,13]. However, the tree vigor declined gradually as fruiting began and production increased, and as a result trunk girth, tree height and spread at the age of 12 years showed 60—75%, and weight of pruned branches about 50% of the case of *M. prunifolia*, respectively. Accordingly, it is considered that the final growth of trees on M26 becomes close to that on M9. This was proved[4,6] almost sufficiently by experiments conducted in each prefectural experiment station, in which early fruit bearing was attempted by training of branches.

Dwarfing effect of M7 and MM106 was less than that of M9 and M26, showing an approximately intermediate one between M9, M26 and *M. prunifolia*, but M7 is considered more effective than MM106[4,6,7,12]. Based on the above results, it is suggested that the dwarfed tree cultivation with 2.5 m tree height and 125—150 trees/10a, and that with 2.5—3 m tree height and 100—125 trees/10a are made possible by using M9 and M26, respectively.

Effect of dwarfing rootstocks on fruit bearing

Effect of rootstocks in accelerating fruit bearing was not apparent for cultivars which have originally early fruiting habit, such as

Table 3. Productivity of four apple cultivars on several rootstocks at 12-year-old

Cultivar	Rootstock	Crop per tree at 12-year-old	Total crop (1—12 years)	Productivity at 12-year-old	
				Crop per 1 cm² of cross section of trunk	Crop per 1 m² of tree spread
		kg	kg	g	g
Jonathan	M 7	51.7(48)	176.0(48)	395.9(83)	2856.4(88)
	M 9	21.8(20)	106.3(29)	507.9(107)	3516.1(110)
	M 26	34.0(32)	179.7(49)	357.9(75)	3008.8(94)
	MM 106	76.2(71)	237.1(65)	437.2(92)	3097.6(96)
	M. prunifolia	106.6(100)	365.3(100)	475.5(100)	3210.8(100)
Starking Delicious	M 7	55.5(164)	123.6(53)	425.0(345)	2831.6(323)
	M 9	26.4(78)	111.8(48)	525.9(427)	2588.2(295)
	M 26	44.5(132)	153.0(66)	281.1(228)	1943.2(221)
	MM 106	56.8(160)	117.8(51)	305.0(248)	1710.8(195)
	M. prunifolia	33.8(100)	232.9(100)	123.1(100)	877.9(100)
Golden Delicious	M 7	119.4(67)	318.2(62)	667.0(105)	4522.7(87)
	M 9	56.0(32)	206.5(40)	824.7(130)	6153.8(119)
	M 26	85.1(48)	313.4(61)	577.7(91)	4701.7(91)
	MM 106	126.8(71)	339.1(66)	539.8(85)	4342.5(84)
	M. prunifolia	177.5(100)	511.7(100)	633.0(100)	5190.1(100)
Fuji	M 9	33.6(20)	151.9(33)	592.6(118)	4200.0(102)
	M 26	93.3(56)	330.6(72)	416.1(83)	3296.8(80)
	MM 106	94.6(57)	280.7(61)	340.9(68)	3342.8(81)
	M. prunifolia	167.4(100)	459.4(100)	502.6(100)	4113.0(100)

Jonathan and Golden Delicious, but the acceleration by 1—2 years was recognized with late fruiting cultivars like Starking Delicious. A tendency that the more the dwarfing effect the more is the acceleration was shown[10,11,12,13]

On the other hand, trees on dwarfing rootstocks like M9 and M26 reached the full productive stage within a relatively short period after the beginning of fruit bearing, but due to small tree spreads the yield per tree did not attain to the yield of large tree spreads caused by *M. prunifolia* or MM106 rootstocks. However, the yield expressed per 1 cm^2 of trunk cross section or 1 m^2 of tree spread area was highest with M9. Particularly this tendency was conspicuous for Starking Delicious (Table 3). Therefore, it can be considered that high yields per unit land area caused by using dwarfing rootstocks are attained by dense planting of trees with higher efficiency of fruit production in spite of smaller tree size.

As *M. prunifolia* gives very high productive efficiency as compared with other M and M.M rootstocks which belong to vigorating or semi-vigorating rootstocks[12], the latter ones may have no use in Japan.

Effect of rootstocks on size, coloration and quality of fruit

Results obtained from studies in 12 years are summarized as follows: Dwarfing rootstocks like M9 and M26 tends to cause, in general, bigger fruit with better coloration and quality than *M. Prunifolia*[10,11,12]. Particularly the former causes 1—1.5% higher sugar contents than the latter. This effect was recognized in other experiments too[4,6,7]. It is obvious that these dwarfing rootstocks are quite suitable for producing good quality fruit. Moreover, it was observed that M9 and M26 rootstocks accelerate fruiting by 10—14 days[6,11,12].

Usefulness of dwarfing rootstocks and future problems

As shown above, the dwarfing rootstocks are evidently useful for securring labor-saving, higher yield, and better quality of fruit. It is quite likely that dwarfed tree cultivation will become predominant in apple production in Japan. At present, the dwarfed tree cultivation by the use of M9 and M26 is being actually practiced (Plate 1).

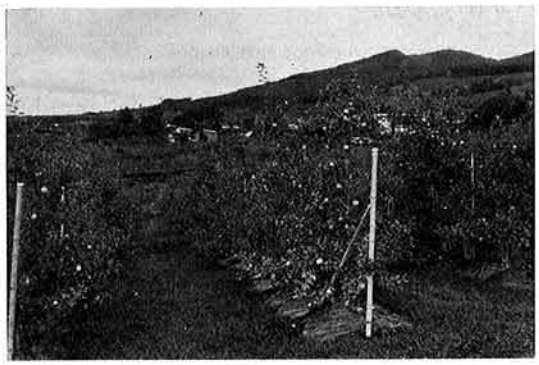

Plate 1. Commercial orchard of dwarfed apple trees on M 26 in Nagano Prefecture (1978).

However, rootstock plants have their own characteristics, of which adaptability to environments and resistance to diseases and insect pests are critical factors in selecting rootstocks. In view of this, M9 and M26, etc., have some problems in the resistance to woolly apple aphid and collar rot, and that to drought, excessive soil moisture, low temperature and frost. It is also known that rootstock clones which exert higher dwarfing effect have higher bark-wood ratio of roots, which are more fragile[1,2]. Therefore, strong, permanent supports are needed in planting trees on dwarfing rootstocks, and an additional cost for that is expected to become a considerable burden to orchard management. Furthermore, in view of small holdings in Japan, duration of productive stage is a great concern. This problem is now under study at many places, and its whole picture is being disclosed. At the same time, attention is directed to establish cultural systems using dwarfing rootstocks.

At present, M and MM dwarfing rootstocks are widely used in many countries of the world, contributing to the development of apple industry. However, they are all rootstocks selected and bred under the environmental

Table 4. Cross compatibility at diallel cross of five rootstock varieties in apple rootstock breeding program

♀ \ ♂	M 9	M 26	M 27	*M. prunifolia*	*M. Sieboldii*
M 9	1.0	63.2	100.0	28.9	75.3
M 26	96.4	0.6	91.7	36.8	95.4
M 27	—*	—	—	—	—
M. prunifolia	99.2	24.5	34.8	8.1	37.2
M. Sieboldii	76.6	72.4	86.2	10.8	11.3

* cross were not carried out

condition of England[13]. Therefore, breeding of good rootstocks adapted to the environment of each country is now in progress. Already, CG clones and MAC clones were released in U.S.A., Ottawa clones in Canada, and Budagovsky clones in Soviet Union.[3]

In Japan, M9 and M26, which are regarded as most suitable among M and MM clones, will be utilized for the time being, but the breeding of good rootstocks well adapted to the environmental condition specific to Japan is desired basically. At present, a breeding program for dwarfing rootstocks, which possess such characteristics as easy cutting propagation, high resistance to woolly aphid, collar rot, drought, excessive soil moisture, and low temperature, and which show grafting affinity, early fruit bearing habit, and high productivity is in progress at Morioka Branch of the Fruit Tree Research Station (Table 4). Although it may not be in the near future that really excellent rootstocks can be obtained from that breeding program, it is hoped to get them as early as possible, because the breeding of excellent rootstocks is very important along with the breeding of excellent cultivars for the development of apple industry.

References

1) Aoki, N. & Okuse, K.: The structure of the roots of two main domestic apple rootstocks and some own-rooted apple trees, and the correlation of structure to vigor. *Bull. Faculty Agr., Hirosaki Univ.*, **8**, 8–12 (1962) [In Japanese with English summary].
2) Beakbane, A. B., & Thompson, E. C.: Anatomical studies of stem and roots of hardy rootstocks. II. The internal structure of the roots of some vigorous and some dwarfing apple rootstocks and correlation of structure with vigour. *J. Pomol. Hort. Sci.*, **17**, 141–149 (1939).
3) Cummins, J. N.: Breeding apple rootstocks for Northern America. Transaction of the Illinois State Hort. Soc. and the Illinois fruit council for the year 1976, 13–23 (1977).
4) Hosogai, S. et al.: Studies on dwarfing apple. rootstocks. 5. Autumn meeting of the Jap. Soc. Hort. Sci., 78–80 (1976) [Abstr. In Japanese].
5) Koike, H. et al.: Studies on *M. prunifolia sp.* 2. Autumn meeting of Jap. Soc. Hort. Sci., 56–57 (1973) [Abstr. In Japanese].
6) Koike, H. et al.: Studies on high density planting of apple trees. 2. Spring meeting of Jap. Soc. Hort. Sci., 26–27 (1977) [Abstr. In Japanese].
7) Mikami, T. et al.: Studies on dwarfing apple rootstocks. 2. Autumn meeting of Jap. Soc. Hort. Sci., 54–55 (1973) [Abstr. In Japanese].
8) Sadamori, S. et al.: Studies on root-stocks of apple. I. Effects of soil moisture on the growth of several *Malus* seedlings. *J. Jap., Soc. Hort. Sci.*, **21**(2), 107–112 (1952) [In Japanese with English summary].
9) Sadamori, S. et al.: Studies on root-stocks of apple. II. Comparison of domestic apple and *Malus Sieboldii* seedlings as apple rootstocks under nursery and orchard conditions. *J. Jap. Soc. Hort. Sci.*, **24**(2), 49–53 (1955) [In Japanese with English summary].
10) Tsuchiya, S. et al.: Apple rootstock studies. I. The influence of EM IX, *M. prunifolia*, and apple seedling rootstocks on growth and cropping of three apple varieties. *Bull. Hort. Res. Sta. Japan*, **C**, No. 6, 11–20 (1970) [In Japanese with English summary].
11) Tsuchiya, S. et al.: Apple rootstock studies. II. Twelve years' results on growth, cropping, and fruit quality with three varieties on M 9, *M. prunifolia*, and apple seedling rootstocks. *Bull. Fruit Tree Res. Sta. Japan*, **C**, No. 2, 13–41 (1975) [In Japanese with English summary].
12) Tsuchiya, S. et al.: Apple rootstock studies. III. The influence of Malling and Malling—Merton rootstocks on growth, cropping, and fruit quality of several apple varieties. *Bull. Fruit Tree Res. Sta. Japan*, **C**, No. 3, 1–49 (1976) [In Japanese with English summary].
13) Tukey, H. B.: Dwarfed fruit trees, The Macmillan Company, N.Y. (1964).