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Performance of 'Rakuraku Fuji' Apple Trees on JM.7 and M.9Nagano Rootstocks, and M.9 Nagano/Marubakaido Interstem Combination in Japan.

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Abstract

Trees of 'Rakuraku Fuji' apple (*Malus X domestica* Borkh.) on JM.7, M.9Nagano rootstocks and M.9Nagano/Marubakaido (*Malus prunifolia* Bork. *var. ringo* Asami) interstem combination were evaluated for growth and productivity in a high density orchard situation on a deep volcanic ash soil in Azumi, Nagano, Japan. By the 5th leaf, trees on JM.7 and M.9Nagano/Marubakaido exceeded the alloted space (2 x 4m), and every other tree in the rows was removed following harvest. After 8 growing seasons, trees on JM.7 and M.9Nagano/Marubakaido had a similar trunk cross-sectional area (TCA) and were larger than trees on M.9Nagano. Trees on M.9Nagano had a greater cumulative yield efficiency through the 6th year. In the 8th year, trees on M.9Nagano/Marubakaido had a greater cumulative yield efficiency than trees on JM.7 and M.9Nagano. Calculated yields per ha based on 2 x 4m spacing (1250 trees per ha) of trees on M.9Nagano/Marubakaido and JM.7 were greater than those on M.9Nagano through the 5th year after which trees were thinned to 625 per ha. In years 6 through 8, trees on M.9Nagano had the highest calculated yield per ha. Trees on JM.7 and M.9Nagano/Marubakaido were too vigorous for high density planting with less than 2 x 4 m spacing on the deep volcanic ash soils found in Nagano.

Introduction

The trend of worldwide apple production has been to higher density orchards that provide economic advantages through earlier production, and reduced cultural expenses associated with handling smaller trees. Barritt (1) points out that the definition of "high density" varies with apple growing region - it is 600 to 1000 trees per acre (1482 to 2470 trees/ha) in the USA where land is more available, and from 1000 to 1500 trees per acre (2470 to 3705 trees/ha) in Europe where land is limited.

M.9 is the most commonly planted dwarfing rootstock in high density orchards worldwide. However, problems associated with the use of M.9 rootstock include poor anchorage (2, 14), poor rooting ability (2,14), susceptibility to low temperature injury (2, 14) and crown gall disease (6). In Japan, the interstock system, grafting dwarfing rootstocks on rooted cuttings of apple chlorotic leaf spot virus (ACLSV) -sensitive Marubakaido, has been adopted for the propagation of dwarfing rootstocks due to ease of rooting. Instead of a virus infected M.9, M.26 has been propagated by the interstock system as a main dwarfing rootstock in Japan (7, 9).

M.9Nagano, an ACLSV-free clone (called M.9 minus), was developed by heat-treatment (3) of original M.9 at the Nagano Fruit Tree Experiment Station (8). JM series rootstocks are newly released, dwarf to semi-dwarf apple rootstocks developed from a cross of Marubakaido x M.9, JM.5 (very dwarfing), JM.1, JM.7, JM.8 (dwarfing similar to M.9EMLA), and JM.2 (semi-dwarfing) were released from the Apple Research Center, NIFTS in 1996 and 1997 (13). JM.7 has been attracting growers' attention because of its excellent rooting ability by hardwood cuttings, resistance to crown rot (*Phytophthora* sp.), wooly apple aphid, apple stem pitting virus, and apple stem grooving virus (13).

The objective of this study was to evaluate the performance of 'Rakuraku Fuji'

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apple trees on JM.7 and M.9Nagano rootstocks, and M.9Nagano/Marubakaido combination under a 2 x 4 m high density orchard condition on a deep volcanic ash soil in Azumi, Nagano, Japan.

Materials and Methods

In March, 1993, 'Rakurakau Fuji' trees on M.9Nagano (30 cm length)/Marubakaido were planted at 2 x 4 m spacing in volcanic ash soil at a commercial orchard in Azumi, Nagano, Japan. These trees were planted with 15 cm of interstem exposed above the soil surface to enhance rooting from the interstem. In April, 1994, Marubakaido understocks of these interstem trees were removed by cutting them with pruning shears under ground from holes dug beside the rootstocks. These trees were grown as trees with M.9Nagano rootstocks. In April, 1994, one-year-old trees on JM.7 and M.9Nagano (30cm length)/Marubakaido were planted to compare with the growth of trees on M.9Nagano rootstocks.

Three replications of five trees per rootstock were planted at a 2 x 4 m spacing in a randomized complete block design. Trees were planted with 15 cm of interstock or rootstock above the soil surface and were supported with a trellis. Trees were trained as the spindle bush without controlling tree height and tree spread to fit their allotted space (12, 15). Flowers of trees were thinned by spraying lime-sulfur (22%; 33 to 40 liters/4000 liters of water /ha) at full bloom and the remaining fruits were thinned by hand until 60th day after full bloom for adjusting crop load to 50 to 60 leaves per fruit, considered the ideal leaf-fruit ratio for producing 300 to 350 g 'Fuji' apples (9). Pest control, irrigation and other cultural practices were based on local recommendations.

By the 5th growing season, trees on JM.7 and M.9Nagano/Marubakaido had exceeded their allotted space. After harvest, trees on these rootstocks were thinned by removing alternate trees in the rows.

Data collected annually included tree height, spread, trunk circumference at 20 cm above the graft union, and yield. TCA was calculated from trunk circumference measurements. The means were separated by Duncan's multiple range test.

Results and Discussion

No trees were lost after eight growing seasons. It was observed that trees on JM.7 and M.9Nagano rootstocks produced few suckers, while trees on M.9 Nagano/Marubakaido produced many suckers (data not shown).

After 8 growing seasons, the height of trees on M.9Nagano, JM.7 and M.9 Nagano/Marubakaido were not significantly different (Table 1). Trees on JM.7 and M.9Nagano/Marubakaido had greater spread than those on M.9Nagano. After removing every other tree at the fifth year after planting, 'Rakuraku Fuji' trees on JM.7 and M.9Nagano/Marubakaido comfortably filled the 4 m allotted space while trees on M.9Nagano were somewhat overcrowded at the 2 m spacing (Table 1).

TCA correlates well with the weight of the above ground portion of the tree and is commonly used as the index for estimating the tree size (16). The TCA of trees on JM.7 and M.9Nagano/Marubakaido were greater than those on M.9Nagano (Table 1). Trees on M.9Nagano had the smallest canopies and TCA values in years 5 through 8 which are somewhat close to TCA values of ideal trees for a 2 x 4 m spacing as described by Koike (9). TCAs of trees on JM.7 and M.9 Nagano/Marubakaido were similar (Table 1).

According to Mantinger (10), the range of tree spacing of 'Fuji' on M.9 is from 1.0-1.2 x 3-3.2 m for high density apple orchards in South Tyrol, Italy. In Italy, planting of 'Knipboom' trees, (2-year-old feathered nursery trees), was recommended to control vegetative tree growth by promoting the early fruiting (4). In our study, 'Rakuraku Fuji' trees on M.9Nagano proved to be somewhat too vigorous for 2 x 4 spacing. The dwarfing effect of M.9Nagano on the growth of scions seemed to be a little different than the new clones of M.9 which are used in narrower spacings (1.0 -1.2 x 3.0-3.2 m) in higher density planting systems in Europe (5). The cause of the somewhat vigorous

Table 1. Height, spread and trunk-cross-sectional area (TCA) of 8-year-old trees and cumulative yield efficiency of 'Rakuraku Fuji' on JM.7, M.9Nagano and M.9Nagano/Marubakaido.

Rootstock	Height (cm)	Spread (cm)	TCA (cm^2) at following years after planting						Cumulative yield efficiency (kg/cm^2) at following years after planting					
			3	4	5	6	7	8	3	4	5	6	7	8
JM7[Z]	392a[X]	400a	41.2a	58.7a	71.6a	79.6a	89.3a	103.8a	0.31b	0.92b	1.37b	2.10b	2.62a	2.89b
M.9Nagano[Y]	404a	325b	23.6c	33.0c	44.9c	53.5b	68.8b	82.0b	0.70a	1.54a	1.91a	2.52a	2.62a	2.77b
M.9Nagano/ Marubakaido[Z]	414a	458a	30.8b	44.5b	61.2b	77.3a	87.7a	102.6a	0.24b	1.16b	1.59b	2.28b	2.68a	3.06a

[Z]Trees were planted at 2 x 4 m spacing until 5th year and 4 x 4 m from the 6th year by thinning each second tree in the rows.
[Y]Trees were planted and maintained at 2 x 4 m spacing.
[X]Means followed by the same letter within each column are not significantly different using Duncan's multiple range test (p 0.05).

Table 2. Annual yield per tree and calculated yield per hectare of 'Fuji' on JM7, M.9Nagano and M.9Nagano/Marubakaido.

Rootstock	Yield per tree (kg) at following years after planting						Calculated yield (tons/ha) at following years after planting					
	3	4	5	6	7	8	3	4	5	6	7	8
JM7[V]	12.9a[Z]	41.4a	43.7a	69.3a	67.1a	65.5b	16.1a[Y]	51.7a	54.5a	43.6b	42.3b	41.3c
M.9Nagano	16.5a	34.2a	34.9b	49.0b	45.4b	47.1c	20.6a[X]	42.8a	43.6b	61.3a	56.7a	58.8a
M.9Nagano/Marubakaido	7.4b	4.5a	45.6a	69.3a	68.7a	79.2a	9.3b[Y]	55.6a	56.9a	43.7b	43.3b	49.9b

[Z]Means followed by the same letter within each column are not significantly different using Duncan's multiple range test (p 0.05).
[Y]Calculated yield per hectare worked out for 1250 trees until 5th year and calculated for 625 trees from 6th year after planting.
[X]Calculated yield per hectare worked out for 1250 trees until 8th year after planting.

tree growth of 'Rakuraku Fuji' on M.9Nagano shown in this study was probably related to the planting of whip nursery trees with few lateral branches and also to the deep volcanic ash soil.

Usually, cumulative yield efficiency is highest for the more dwarfing rootstocks (11). In this study, the most dwarf trees on M.9Nagano had the highest yield efficiency until the 6th year after planting as compared to vigorous trees on JM.7 and M.9Nagano/Marubakaido (Table 1). The drop in cumulative yield efficiency for trees on M.9Nagano in the 8th year seems to be caused by somewhat overcrowded canopies at the 2 x 4 m spacing.

Yield per tree on both rootstocks and the interstock increased gradually including the years showing little annual increase or a little annual decrease (Table 2). Although calculated yields (1250 trees) per ha of trees on JM.7 and M.9 Nagano/Marubakaido were higher than those of trees on M.9Nagano in years 3 through 5, those changed to lower than those of trees on M.9Nagano in years 6 through 8 after planting. Yields of trees on M.9Nagano increased gradually up to 58.8 tons in years 3 through 8 after planting except for the years showing little annual increase (Table 2).

In conclusion, M.9Nagano, one of the virus-free clones of M.9 developed in Nagano, was suitable for a 2 x 4 m spacing of high density 'Rakuraku Fuji' orchard under the deep volcanic ash soil and climatic conditions of this study. In contrast, 'Rakurakau Fuji' apple trees on M.9/Marubakaido interstock and JM.7 rootstock were vigorous and required a wider in-row spacing by the 5th year after planting.

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