# Effect of dwarfing and semi dwarfing apple rootstocks on growth and productivity of selected apple cultivars

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**Abstract**

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Fourteen clonal apple rootstocks (M.9, M.26, M.27, MM.106, J-TE-E, J-TE-F, J-TE-G, J-TE-H, J-OH-A, Jork 9, Pajam 1, Pajam 2, Burgmer M.9-751, and Burgmer M.9-984) were tested in two experimental orchards established in the Research and Breeding Institute of Pomology Holovousy using scion cultivars Golden Delicious, Melrose, Jonagold, Rubin, and Florina. Following characteristics were recorded: yield, trunk circumference, suckering. Rootstocks Jork 9, Pajam 1, Pajam 2, M.9-751, and M.9-984 produced better results than original rootstock M.9. Clone J-TE-E favourably affected fruit-bearing of the Rubin cultivar. The growth vigour of trees grafted on Pajam 2, M.9-751, and M.9-984 was somewhat larger than those on M.9. Rootstock J-TE-H was semi-vigorous and grafted trees had low yield efficiency. Clone Pajam 1 had the similar growth vigour as M.9. Trees on Jork 9 grew significantly weakly in comparison with M.9. The rootstocks J-OH-A and J-TE-F produced a lot of suckers. The following rootstocks were recommended for growing in commercial plantations: Jork 9, Pajam 1, Pajam 2, M.9-751, and M.9-984.

**Keywords**: apple; rootstock; growth vigour; yield efficiency; suckering

The rootstock is one of the most important factors influencing the profitability of fruit growing. It offers flexible and often the cheapest method of tree vigour control (Webster 1993). A mistake made in selecting the rootstock may adversely affect productivity throughout the lifetime of the orchard. Most modern commercial orchards are planted on dwarfing and semi-dwarfing rootstocks. In many countries, M.9 has become the dominant rootstock for apple because of its suitability for high-density plantings (Wertheim 1997). Nevertheless this rootstock has certain shortcomings such as poor propagation in stoolbed, bad anchorage in soil, brittle roots and susceptibility to fire blight, crown gall, and winter cold injury. These negative characteristics of M.9 became the challenge for the breeders and nurserymen to find clones having better quality traits than the standard M.9. Difficulties in propagating the original Malling selections of M.9, including the virus-free EMLA clone, prompted nurserymen in several European countries to reselect within the existing M.9 populations for subclones exhibiting improved propagation on the stoolbed. There are now many M.9 subclones originating in the Netherlands (NAKB 337-340 and Fleuron 56), Belgium (Nicolai 29), Germany (Burgmer), and France (Pajam 1 and 2) as well as the well-known EMLA subclone (Webster et al. 2000). At present more than 25 sub-clones of M.9 are bred in Europe. These clones have been tested in different climatic and soil conditions. The results of their evaluation are not clear and tests should continue (Warmund 2001; Ladner et al. 2003; Stehr 2005; Dierend, Bier-Kamotzke 2009). This study was

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Table 1. Tree size, yield, and suckering of Golden Delicious (Trial 1)

| Rootstock | Cumulative yield 1991–2009 (kg/tree) | Trunk cross-section area in 2007 (cm$^2$) | Yield efficiency (kg/cm$^2$) | Suckering Σ (1993–2009) (pcs./tree) |
|---|---|---|---|---|
| Pajam 1 | 605.0$^{ab}$ | 125.2$^{ab}$ | 4.8$^{b}$ | 6.8$^{a}$ |
| Pajam 2 | 626.0$^{a}$ | 136.8$^{a}$ | 4.6$^{b}$ | 7.6$^{a}$ |
| Jork 9 | 609.6$^{ab}$ | 98.4$^{c}$ | 6.2$^{a}$ | 7.9$^{a}$ |
| M.9 | 559.0$^{b}$ | 126.8$^{ab}$ | 4.4$^{b}$ | 3.9$^{a}$ |

The means followed by the same letter in each column are not significantly different at $P \leq 0.05$ by Duncan's multiple range test

conducted in order to test selected sub-clones of M.9 in the conditions of the Czech Republic and compare them with domestic rootstocks.

## MATERIAL AND METHODS

Two trial orchards were established in Research and Breeding Institute of Pomology Holovousy. The first orchard (Trial 1) was planted in the spring of 1990. The following rootstocks were used: Jork 9 (originating in Germany), Pajam 1, Pajam 2 (originating in France), J-TE-E, J-TE-F, J-TE-G, J-TE-H, J-OH-A (all bred in the Czech Republic), M.9, and M.27. The rootstocks were tested using the scion cultivars Golden Delicious, Gloster, Melrose, and Jonagold.

The second orchard (Trial 2) was planted in the spring of 1992 and tested rootstocks were Burgmer M.9-751, Burgmer M.9-984 (originating in Germany), J-TE-E, J-TE-F, J-TE-G, J-TE-H, J-OH-A, M.9, M.26, and MM.106. Following scion cultivars were used: Rubin, Melrose, Jonagold, and Florina.

Trees were planted in a spacing of 4.5 × 2.3 m and trained as a central leader system. Weed-free strips (1.5 m wide) were maintained under the trees with herbicide applications. The grassed alleys were mowed frequently. Pest and disease management was carried out according to rules for integrated plant production. The experiment was set in a randomised block design with four replications and 3 trees per a plot. The following characteristics were recorded in the trial plantations: yield (kg/tree), trunk circumference (at a height of 50 cm above the graft union), number of suckers (per tree). Root suckers were removed after counting. Using these data, the following characteristics were calculated: trunk cross-section area (TCSA, cm$^2$), cumulative yield per tree, and yield efficiency (YE, kg/cm$^2$). Statistical analysis of data was conducted using the analysis of variance.

## RESULTS AND DISCUSSION

The results of Trial 1 are shown in Tables 1–4. Results of Trial 2 are stated in Tables 5–8.

Table 2. Tree size, yield, and suckering of Gloster (Trial 1)

| Rootstock | Cumulative yield 1991–2009 (kg/tree) | Trunk cross-section area in 2007 (cm$^2$) | Yield efficiency (kg/cm$^2$) | Suckering Σ (1993–2009) (pcs./tree) |
|---|---|---|---|---|
| Pajam 1 | 714.8$^{ab}$ | 124.3$^{b}$ | 5.8$^{b}$ | 2.8$^{b}$ |
| Pajam 2 | 734.2$^{ab}$ | 121.9$^{b}$ | 6.0$^{b}$ | 4.0$^{b}$ |
| Jork 9 | 860.8$^{a}$ | 99.3$^{c}$ | 8.7$^{a}$ | 4.9$^{b}$ |
| M.9 | 766.2$^{ab}$ | 121.9$^{b}$ | 6.3$^{b}$ | 4.9$^{b}$ |
| J-TE-E | 671.6$^{b}$ | 103.4$^{bc}$ | 6.5$^{b}$ | 6.5$^{b}$ |
| J-TE-H | 648.2$^{b}$ | 181.8$^{a}$ | 3.6$^{c}$ | 0.2$^{b}$ |
| J-OH-A | 725.2$^{ab}$ | 111.2$^{bc}$ | 6.5$^{b}$ | 46.6$^{a}$ |

The means followed by the same letter in each column are not significantly different at $P \leq 0.05$ by Duncan's multiple range test

Table 3. Tree size, yield, and suckering of Melrose (Trial 1)

| Rootstock | Cumulative yield 1991–2009 (kg/tree) | Trunk cross-section area in 2007 ($cm^2$) | Yield efficiency ($kg/cm^2$) | Suckering Σ (1993–2009) (pcs./tree) |
|---|---|---|---|---|
| Pajam 1 | 712.1[ab] | 122.3[bc] | 5.8[c] | 19.7[ef] |
| Pajam 2 | 745.4[ab] | 134.7[b] | 5.6[c] | 52.1[cd] |
| Jork 9 | 762.1[a] | 107.1[cde] | 7.1[b] | 17.6[ef] |
| M.9 | 678.3[bc] | 112.5[cd] | 6.2[c] | 54.4[c] |
| M.27 | 474.2[f] | 60.3[g] | 7.9[ab] | 6.2[f] |
| J-TE-E | 630.4[cd] | 90.2[ef] | 7.0[b] | 49.8[cd] |
| J-TE-F | 520.5[ef] | 75.1[fg] | 7.0[b] | 111.2[b] |
| J-TE-G | 537.1[ef] | 62.6[g] | 8.6[a] | 3.1[f] |
| J-TE-H | 597.9[de] | 166.6[a] | 3.6[d] | 26.5[de] |
| J-OH-A | 526.5[ef] | 95.2[de] | 5.6[c] | 147.9[a] |

The means followed by the same letter in each column are not significantly different at $P \leq 0.05$ by Duncan's multiple range test

### Growth vigour

**Trial 1**: The highest growth vigour of Golden Delicious was found on Pajam 2. The least vigorous trees were on Jork 9. Trees on M.9 and Pajam 1 grew similar. The Gloster cultivar had strong growth on rootstock J-TE-H. On all other rootstocks this cultivar grew significantly less. Trees grafted on Pajam 1 and Pajam 2 had a growth vigour between J-TE-H and M.9, but they did not differ significantly from M.9. The weakest growth was observed on clones J-OH-A, J-TE-E, and Jork 9. The largest trees of Melrose were on rootstocks J-TE-H and Pajam 2. Weaker growth of this cultivar was registered on Pajam 1, M.9, and Jork 9. The smallest trees were on J-TE-F, J-TE-G, and M.27. Piestrzeniewicz et al. (2009) noted similar growth parameters of J-TE-G and M.27. The Jonagold cultivar grew strong on Pajam 2. Trees on Jork 9 and M.27 were significantly weaker than on M.9.

**Trial 2**: The scion cultivar Rubin had the largest trees on M.26 and MM.106. The combinations of these two rootstocks with this cultivar are unsuitable for high density orchards. Trees on J-TE-H and M.9-751 grew more strongly than on M.9. The similar growth vigour as M.9 was observed on M.9-984 and Pajam 1. The weakest trees were grafted on J-TE-G and J-TE-F. J-TE-H with scion cultivar Melrose grew most strongly among tested rootstocks. Clones M.9-751 and M.9-984 influenced stronger growth in comparison with M.9. Combinations with J-TE-E, J-TE-F, and J-TE-G had weaker trees than with M.9, but the differences were not significant. With the Melrose cultivar, the differences among these J-TE rootstocks and M.9 were smaller than with Rubin. On the tested rootstocks, the growth parameters of Jonagold and

Table 4. Tree size, yield, and suckering of Jonagold (Trial 1)

| Rootstock | Cumulative yield 1991–2009 (kg/tree) | Trunk cross-section area in 2007 ($cm^2$) | Yield efficiency ($kg/cm^2$) | Suckering Σ (1993–2009) (pcs./tree) |
|---|---|---|---|---|
| Pajam 2 | 696.7[a] | 191.4[a] | 3.7[b] | 3.6[a] |
| Jork 9 | 621.3[a] | 113.9[b] | 5.5[a] | 2.3[a] |
| M.9 | 658.4[a] | 175.0[a] | 3.8[b] | 17.0[a] |
| M.27 | 471.5[b] | 88.4[b] | 5.4[a] | 1.3[a] |

The means followed by the same letter in each column are not significantly different at $P \leq 0.05$ by Duncan's multiple range test

Table 5. Tree size, yield, and suckering of Rubin (Trial 2)

| Rootstock | Cumulative yield 1993–2009 (kg/tree) | Trunk cross-section area in 2007 ($cm^2$) | Yield efficiency ($kg/cm^2$) | Suckering Σ (1993–2009) (pcs./tree) |
|---|---|---|---|---|
| M.9-751 | $563.3^{abc}$ | $180.4^{bc}$ | $3.1^{bc}$ | $1.4^{f}$ |
| M.9-984 | $639.9^{a}$ | $156.4^{cd}$ | $4.1^{b}$ | $2.9^{ef}$ |
| Pajam 1 | $554.4^{abc}$ | $136.1^{de}$ | $4.1^{b}$ | $7.2^{cdef}$ |
| M.9 | $503.3^{bcd}$ | $145.8^{cd}$ | $3.5^{b}$ | $12.9^{bcd}$ |
| M.26 | $515.3^{bcd}$ | $307.1^{a}$ | $1.7^{d}$ | $15.6^{bc}$ |
| MM.106 | $449.4^{d}$ | $272.9^{a}$ | $1.6^{d}$ | $5.4^{def}$ |
| J-TE-E | $573.2^{ab}$ | $94.4^{f}$ | $6.1^{a}$ | $19.1^{ab}$ |
| J-TE-F | $461.9^{cd}$ | $65.5^{f}$ | $7.1^{a}$ | $26.0^{a}$ |
| J-TE-G | $472.7^{bcd}$ | $74.2^{f}$ | $6.4^{a}$ | $2.9^{ef}$ |
| J-TE-H | $512.5^{bcd}$ | $202.9^{b}$ | $2.5^{cd}$ | $15.1^{bcd}$ |

The means followed by the same letter in each column are not significantly different at $P \leq 0.05$ by Duncan's multiple range test

Melrose were similar. But the differences in growth vigour between M.9 and J-TE-H and between M.9 and the group of dwarfing clones (J-TE-E, F, and G) were larger. The results of growth vigour with Florina and Jonagold cultivars on the tested rootstocks were very similar. Our evaluation of some rootstocks differs from Loreti et al. (2001), who observed the following order of growth vigour: M.9 EMLA > M.9-751 = M.9-984 = Pajam 1 = M.26 > Jork 9 > Pajam 2. The growth vigour in our trials was as follows: M.26 > MM.106 > J-TE-H > Pajam 2 > M.9-751 > M.9 984 > M.9 = Pajam 1 > J-TE-E > J-TE-F > J-OH-A > J-TE-G = M.27. The reason for different growth vigour of tested rootstocks might have consisted of our specific soil conditions and the use of different scion cultivars.

### Yield and yield efficiency

**Trial 1**: Gloster and Melrose cultivars produced best (concerning cumulative yield; kg/tree) on Jork 9. Callesen (1997) also noted the high productivity of this rootstock. The best yield with Golden Delicious and Jonagold was on Pajam 2. High yielding trees were also on M.9 and Pajam 1. The trees with low growth vigour (M.27, J-TE-G) exhibited the poorest total yields. Clone J-TE-H had strong a growth vigour, but cropping was rather lower. The best YE was on Jork 9 and on dwarfing rootstocks M.27 and J-TE-G. The high YE on J-TE-G was also noted in rootstock trials in Canada, Mexico, and the United States (Marini et al. 2009). Also M.9

Table 6. Tree size, yield, and suckering of Melrose (Trial 2)

| Rootstock | Cumulative yield 1993–2009 (kg/tree) | Trunk cross-section area in 2007 ($cm^2$) | Yield efficiency ($kg/cm^2$) | Suckering Σ (1993–2009) (pcs./tree) |
|---|---|---|---|---|
| M.9-751 | $580.1^{a}$ | $94.3^{b}$ | $6.2^{b}$ | $23.5^{bc}$ |
| M.9-984 | $562.2^{ab}$ | $82.3^{bc}$ | $6.8^{b}$ | $19.8^{bc}$ |
| M.9 | $445.5^{bc}$ | $65.8^{cd}$ | $6.8^{b}$ | $40.2^{b}$ |
| J-TE-E | $470.6^{abc}$ | $60.2^{cd}$ | $7.8^{a}$ | $43.8^{b}$ |
| J-TE-F | $404.1^{c}$ | $59.8^{cd}$ | $6.8^{b}$ | $73.7^{a}$ |
| J-TE-G | $459.6^{abc}$ | $54.0^{d}$ | $8.5^{a}$ | $2.7^{c}$ |
| J-TE-H | $544.7^{ab}$ | $124.8^{a}$ | $4.4^{c}$ | $28.1^{bc}$ |

The means followed by the same letter in each column are not significantly different at $P \leq 0.05$ by Duncan's multiple range test

Table 7. Tree size, yield, and suckering of Jonagold (Trial 2)

| Rootstock | Cumulative yield 1993–2009 (kg/tree) | Trunk cross-section area in 2007 ($cm^2$) | Yield efficiency ($kg/cm^2$) | Suckering Σ (1993–2009) (pcs./tree) |
|---|---|---|---|---|
| M.9-751 | 566.4$^{a}$ | 149.4$^{b}$ | 3.8$^{c}$ | 1.1$^{d}$ |
| M.9-984 | 585.6$^{a}$ | 149.5$^{b}$ | 3.9$^{c}$ | 2.4$^{cd}$ |
| M.9 | 550.8$^{a}$ | 139.9$^{b}$ | 3.9$^{c}$ | 7.4$^{bcd}$ |
| J-TE-E | 525.4$^{a}$ | 108.8$^{c}$ | 4.8$^{b}$ | 13.8$^{bc}$ |
| J-TE-F | 439.6$^{b}$ | 87.5$^{d}$ | 5.0$^{b}$ | 14.8$^{b}$ |
| J-TE-G | 365.3$^{c}$ | 59.8$^{e}$ | 6.1$^{a}$ | 0.7$^{d}$ |
| J-TE-H | 565.0$^{a}$ | 215.1$^{a}$ | 2.6$^{d}$ | 2.9$^{cd}$ |
| J-OH-A | 349.7$^{c}$ | 69.4$^{de}$ | 5.0$^{b}$ | 26.9$^{a}$ |

The means followed by the same letter in each column are not significantly different at $P \leq 0.05$ by Duncan's multiple range test

showed a high level of YE. Czech rootstocks J-TE-E, J-TE-F, J-TE-G, J-TE-H, and J-OH-A did not show better productivity than foreign rootstocks Jork 9, Pajam1, Pajam 2, and M.9. Only J-TE-G and J-TE-E had quite good YE comparable with best clones of M.9.

**Trial 2:** All cultivars produced best on clones M.9-984 and M.9-751. The high yield was also found with trees of Rubin grafted on J-TE-E and Pajam 1. The lowest cumulative yield with this cultivar was recorded on dwarfing rootstocks J-TE-G, J-TE-F and on semi vigorous clone MM.106. Trees of Melrose grafted on M.9 yielded less in comparison with clones J-TE-H, J-TE-E, J-TE-F, and J-TE-G. The differences were not significant. The cumulative yield of Jonagold on all Czech rootstocks (except J-TE-H) was worse than on the other tested rootstocks. The same can be said about the Florina cultivar, because all Czech rootstocks had lower cumulative yield than foreign ones. Rootstocks J-TE-E, J-TE-F, J-TE-G caused high YE with all cultivars. On the contrary, the most vigorous scion/rootstock combinations (J-TE-H, M.26, MM.106) had low value of YE. Unlike our results Dierend and Bier-Kamotzke (2009) reported very low YE of trees grafted on rootstocks J-TE-E and J-TE-F.

## Suckering

**Trial 1**: Root suckering was a serious problem with trees grafted on J-TE-F and especially on J-OH-A. Both rootstocks are useless for commercial orchard due to their excessive suckering. Small-

Table 8. Tree size, yield, and suckering of Florina (Trial 2)

| Rootstock | Cumulative yield 1993–2009 (kg/tree) | Trunk cross-section area in 2007 ($cm^2$) | Yield efficiency ($kg/cm^2$) | Suckering Σ (1993–2009) (pcs./tree) |
|---|---|---|---|---|
| M.9-751 | 649.7$^{a}$ | 117.0$^{ab}$ | 5.6$^{b}$ | 1.6$^{bc}$ |
| M.9-984 | 611.6$^{ab}$ | 103.1$^{bc}$ | 5.9$^{b}$ | 0.7$^{bc}$ |
| M.9 | 603.7$^{ab}$ | 91.5$^{cd}$ | 6.6$^{ab}$ | 3.1$^{bc}$ |
| J-TE-E | 491.1$^{bc}$ | 67.9$^{de}$ | 7.2$^{a}$ | 5.3$^{ab}$ |
| J-TE-F | 521.8$^{bc}$ | 78.4$^{de}$ | 6.7$^{ab}$ | 8.4$^{a}$ |
| J-TE-G | 466.9$^{c}$ | 63.3$^{e}$ | 7.4$^{a}$ | 0.1$^{c}$ |
| J-TE-H | 585.5$^{ab}$ | 134.3$^{a}$ | 4.4$^{c}$ | 1.3$^{bc}$ |

The means followed by the same letter in each column are not significantly different at $P \leq 0.05$ by Duncan's multiple range test

er but still abundant suckering was observed with clones J-TE-E and M.9. Clones M.27 and J-TE-G produced small amounts of suckers. Production of suckers may have been affected by the scion cultivar. In our trial, trees of the Melrose cultivar produced more suckers than trees of other evaluated cultivars.

**Trial 2**: The excessive production of suckers was found again with rootstocks J-TE-E, J-TE-F, J-OH-A, and M.9. Very few suckers produced clones J-TE-G, M.9-751, and M.9-984. As well as in Trial 1, there were a lot of suckers with the Melrose cultivar. Very low suckering was noticed with the Florina cultivar.

## CONCLUSION

Rootstocks Jork 9, Pajam 1, Pajam 2, M.9-751, and M.9-984 produced better than original rootstock M.9. Rootstock J-TE-E affected favourably fruit-bearing of cultivar Rubin. The growth vigour of trees grafted on Pajam 2, M.9-751, and M.9-984 was a little larger than on M.9. Rootstock J-TE-H is semi-vigorous and grafted trees have low yield efficiency. Clone Pajam 1 has similar growth vigour as M.9. Trees on Jork 9 grow significantly weaker than on M.9. The rootstocks J-OH-A and J-TE-F produced a lot of suckers in our experiments. The following rootstocks are recommended for growing in commercial plantations: Jork 9, Pajam 1, Pajam 2, M.9-751, M.9-984. Rootstock J-TE-E is acceptable for the Rubin cultivar. Other Czech rootstocks did not exhibit better properties than new foreign rootstocks.

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