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Seven-Year Evaluation of Geneva® and Polish Rootstocks with 'Golden Delicious Reinders' Apple in Poland

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Abstract

A field study of dwarf apple (*Malus* × *domestica* Borkh.) rootstock performance using 'Golden Delicious Reinders' as the scion cultivar was conducted in Poland from 2001-2007. The study included 6 rootstocks from the Cornell-Geneva rootstock breeding program (Geneva® 11, Geneva® 16, Geneva® 41, Geneva® 202, CG.3007 and CG.4013), 4 rootstocks from the Polish rootstock breeding program (P 14, P 16, P 59 and P 60) and 3 Malling rootstocks as controls (M.9 T337, M.9 Pajam2 and M.26). Over the seven years of the study, no trees were lost on any rootstock due to damage from frost or diseases including fire blight (*Erwinia amylovora* Burr. Winsl.) infestation on the rootstock. Trees growing on P 59 and P 16 had the weakest growth while the strongest growing trees were on P 14, P 60, M.26, CG.4013 and G.202. The size of the trees on G.11, G.16, G.41 and M.9 Pajam2 were similar to that of the trees growing on the standard dwarfing rootstock M.9 T337. The trees started bearing fruit on all rootstocks in the second year after planting. The cumulative yield varied from 31.9 kg with P 59 to 92.7 kg with CG.4013. High yields were also obtained from trees on G.41, P 14, G.202 and M.26. Cumulative yield efficiency expressed as yield per cm^2 of trunk cross-sectional area was highest for trees on P 16, M.9 Pajam2, G.41 and G.11 and lowest for vigorously growing trees on P 60, P 14 and M.26. In 2007, a year of heavy cropping, the mean fruit weight varied from 141 g on P 59 to 232 g on M.9 T337. Fruit size from trees on P 60, P 14, G.41, G.11 G.202 and M.26 was statistically similar to trees on M.9 T337. We conclude that the rootstocks G.11 and G.41, which are highly resistant to fire blight, can be recommended for growing 'Golden Delicious Reinders' apple in the Polish climate, as are the non-resistant rootstocks M.9 T337, P 16 and M.9 Pajam2. For orchards located on light soils CG.4013, G.202, P 14 and P 60 are also promising.

Poland has become one of the largest apple producing countries in the European Union. Polish apple growers must deal with a shorter growing season and colder winters than southern European countries. In recent decades, Polish apple growers have heavily planted trees on M.9 rootstock, yet its susceptibility to fire blight (*Erwinia amylovora* Burr. Winsl.) and to cold winters is of concern. Improved rootstocks with better winter hardiness and fire blight resistance are a priority for Polish growers. The Geneva® or "G" series of rootstocks (designated "G" if released or "CG" if not released) form Cornell University (New York, USA) has been shown to have a high level of resistance to fire blight (2, 6, 18) while the Polish bred "P" series of rootstocks have a high level of winter hardiness (9, 10).

Notable warming of the climate in Poland in recent years has led to planting more trees of the cultivar 'Golden Delicious Reinders'. Of the many known mutants of 'Golden Delicious', 'Golden Delicious Reinders' is becoming the most popular in Poland because the apples are free from russeting (14). Several studies of 'Golden Delicious' in the Polish climate have been conducted (3, 8, 11, 26).

The aim of this experiment was to determine the adaptability and horticultural performance of the fire blight resistant Geneva® rootstocks and the hardy Polish rootstocks when compared to the common Malling rootstocks M.9 and M.26 for growing 'Golden Delicious Reinders' trees on a podsolic soil in the climate of Poland.

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Material and Methods

A field experiment was established in the late spring of 2001 (June 10) at the Pomological Orchard of the Institute of Pomology and Floriculture in Skierniewice, Poland (52°N, 20°E). One-year-old feathered maiden trees of 'Golden Delicious Reinders' grafted on 6 rootstock clones of the Geneva® rootstock series (G.11, G.16, G.41, G.202, CG.3007 and CG.4013), 4 rootstock clones from the Polish rootstock breeding program (P 14, P 16, P 59 and P 60) and 3 Malling rootstock clones as controls (M.9 T337, M.9 Pajam2 and M.26), were planted at a spacing of 1.5 m x 3.75 m (1,778 trees/ha). The height of the bud union above the soil level varied from 8 to 10 cm. All of the rootstocks we tested have been previously described (2, 10, 12, 20, 22, 27). The trees on the Geneva® rootstocks, and those on M.9 T337, M.9 Pajam2 and P 16 were produced by Johan Nicolai nursery in Sint-Truiden, Belgium. The trees on P 14, P 59, P 60 and M.26 were produced in a Polish nursery at the Center for Elite Nursery Stock in Prusy, near Skierniewice, Poland. The soil was a deep sandy-loam podsolic soil, pH 5.5 overlaying light clay. Soil was drained at the depth 100 cm. The experimental orchard was planted on a site where various species of fruit trees had been grown for over 70 years. One year before planting, a green manure crop of mustard was grown. The soil was not fumigated prior to planting.

The experimental design was a randomized, complete block design, with the blocks based on the initial trunk circumference, with seven replicates and a single tree per plot. The trees were trained in the form of a slender spindle using minimal pruning in years 1-4, and were drip-irrigated. Soil cultivation, fertilization, orchard protection and weed control procedures were applied according to the recommendations for commercial orchards in Poland (19). The alley-ways between rows were seeded with a mixture of 40 kg of grass seed per/ha (25% *Poa trivialis* L., 25% *Festuca rubra* L. and 50% *Lolium perenne* L.). The grass alleyway was mowed 3-4 times a year. The herbicide strips under the trees were 120 cm wide. Each year the fruitlets were hand-thinned, leaving one fruit per cluster and a spacing of 18 cm between fruits. Annually tree trunk circumference was measured at 30 cm above ground level and converted to trunk cross-sectional area (TCA). The height and spread of tree canopies were measured in late autumn (October) before pruning, from the lowest branches, to the top of tree. The spread of the tree was measured along the row and perpendicular to the row. Fruit yield per tree was recorded each year.

'Golden Delicious Reinders' apples are usually picked in Poland in the first days of October (14). Mean fruit weight of all picked apples was recorded for the last three years, by using an electronic sorting machine manufactured by Greefa (4190 CA Geldermalsen, Holland). In 2007, 28 fruits from each rootstock (4 fruits from each tree which were larger than 70 mm) were randomly collected after grading and were analyzed for red color (% of red blush area), firmness, total soluble solids concentration (TSS) and total titratable acidity (TA). After harvest fruits were kept in cold storage for 5 days at 2.0°C after which fruits were analyzed (October 5). The red blush area was measured visually by estimation. Internal ethylene concentration was measured by extracting a 1ml gas samples from the apple core and injecting it into a HP 5892 II gas chromatograph equipped with alumina packed glass column (Hewlett Packard, Germany). The results were expressed in $\mu l \cdot L^{-1}$. Fruit firmness was measured by and EPT 1R penetrometer (Kelowna, BC Canada) equipped with 11.1 mm standard Magness Taylor tip. The results were expressed in kg of force. TSS and TA were measured in freshly prepared juice. TSS was determined using a digital refractometer ATAGO 101 (Japan) and expressed as a percentage. TA was determined by titration of juice with 0.1 N NaOH to the end point pH = 8.1 using an automatic titrator DL 50 Graphix (Mettler Toledo, Switzerland). The results were expressed as a % malic acid. The data were subjected to an analysis of vari-

ance (R.A. Fisher Statistica ver.7.1 STATS , (Tulsa OK 74104 USA) with the differences between the means evaluated by Duncan's t-test at P≤0.05. Rootstock was considered a fixed effect and block (rep) was considered a random effect. Simple regression analyses were done with the same program.

Results and Discussion

Tree growth. During the 7 yr period of the experiment, no trees were lost due to frost or disease damage to the root system or the scion, neither were any trees lost to infection by fire blight (Table 1). All the trees of 'Golden Delicious Reinders' survived very well the severe winter of 2005/2006, when the temperature dropped to -31.6°C. Before that winter, the trees had naturally hardened off very well.

Based on TCA after 7 yr, 'Golden Delicious Reinders' apple trees growing on P 59 and P 16 were significantly smaller than the trees grafted on the standard dwarfing rootstock M.9 T337 (Table 1). The size of three of the Geneva® rootstocks (G.11, G.16 and G.41) was very similar to that of trees grown on M.9 T337 and M.9 Pajam2. The trees grown on CG.3007, G.202 and CG.4013 were significantly larger than the trees grafted on M.9 T337 and were similar to the trees on M.26.

The size of the trees grown on the Geneva® rootstocks in Poland corresponded well with the results presented by Musacchi et al. (17), and Sansavini et al. (24) from Italy, and Robinson et at. (20, 21, 22, 23), and Johnson et al. (13) from the USA. The strongest growing trees were on P 14, P 60 and M.26. The trees grafted on those three rootstocks were significantly larger than the trees grown on the standard M.9 T337 rootstock and P.14 was also larger than M.26.

Table 1. Survival, tree size, number of root suckers and burr knots of 'Golden Delicious Reinders' apple trees grown on Geneva® and Polish rootstocks throughout seven growing seasons (2001-2007).

Rootstock[z]	Tree survival rate (%)	Truck cross-sectional area 2007 (cm^2)	Tree height 2007 (m)	Tree width 2007 (m)	Cum. no. root suckers 2001-07	Mean area of burr knots 2007 (cm^2)
P 59	100	10.7 a[y]	1.61 a	1.42 a	0	4.3 bc
P 16	100	13.1 a	1.79 ab	1.64 b	0	1.0 abc
M.9 Pajam2	100	19.6 b	2.06 bc	1.76 bcd	0	1.3 abc
G.11	100	21.2 b	2.23 cde	1.83 cde	0	1.3 abc
G.16	100	22.7 b	2.03 bc	1.70 bc	0	0.0 a
M.9 T337	100	23.1 b	2.20 cd	1.86 cde	0	4.7 c
G.41	100	24.9 bc	2.17 cd	1.91 de	0	0.0 a
CG.3007	100	28.7 cd	2.30 cdef	1.95 ef	0	0.9 abc
G.202	100	29.0 cd	2.49 defg	1.93 def	0	0.0 a
CG.4013	100	29.7 cd	2.69 g	1.99 ef	0	0.4 ab
M.26	100	33.3 de	2.40 defg	1.94 def	0	1.3 abc
P 60	100	36.7 e	2.60 fg	2.10 f	0	4.4 bc
P 14	100	42.9 f	2.54 efg	2.11 f	0	3.4 abc

[z] Rootstocks ranked by trunk cross-sectional area

[y] Means within a column followed by the same letter are not significantly different (Duncan's multiple range test P ≤ 0.05).

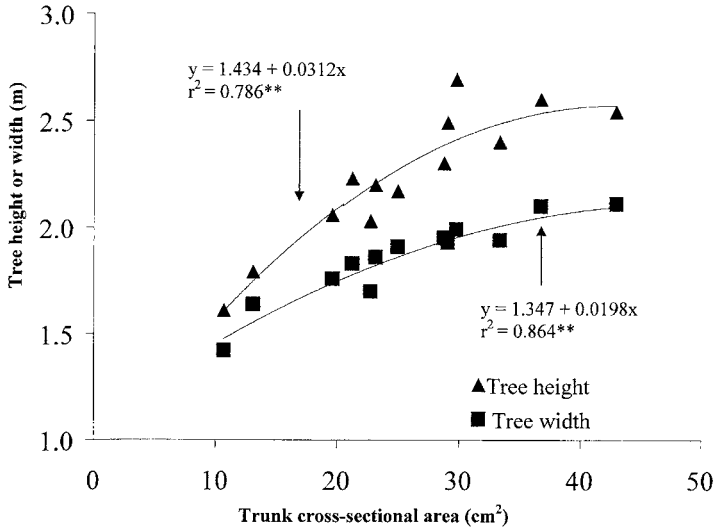

Fig. 1. Relationship between tree height or tree width with trunk cross-sectional area of 13 rootstocks after 7 years in Poland.

The size of the tree canopy (tree height and tree width) was well correlated with the TCA in a curvilinear manner (Fig 1). Trees on CG.4013 tended to be taller than expected from their TCA while trees on G.16, G.41, CG.3007 and M.26 tended to be shorter than expected from their TCA. Tree width was more highly correlated to TCA than tree height. Only G.16 and M.26 tended to have narrower canopies than expected from their TCA.

In Poland, rootstocks that are more vigorous than M.9 are recommended for orchards planted on light soils (9). From this trial, CG.3007, G.202 CG.4013, P.60, P.14 and M.26 can be recommended for orchards planted on light soils in Poland. It is worth noting that P 14 was significantly more vigorous than M.26 over the 7 years of this trial but in our experience, young trees on P.14 usually grow more vigorously than they do when mature and producing full crops (7, 9, 10).

Roots suckers and burr knots. None of the trees in this experiment produced any root suckers. The production of root suckers is known to be influenced by climate (16) and in many climates M.9 produces significant numbers of root suckers. Thus, our data do not allow any conclusions about the suckering potential of the new Geneva® or Polish stocks. The area of the rootstock shank covered by burr knots differed significantly among rootstocks (Table 1). The largest mean size of burr knots was found on the rootstock shanks of M.9 T337, P 60, P 59 and P 14. The trees on G.41, G.16, G.202 had no burr knots. The strong tendency of M.9 rootstock and its related clones to be susceptible to producing burr knots is well-documented in the literature (10, 17, 27).

Yield. The trees of 'Golden Delicious Reinders' started bearing fruits on all rootstocks in the second year after planting. The effect of the rootstock on cumulative yield in the first four years of cropping (2002-2005) varied significantly among the rootstocks (Table 2). The trees on P 59 and P 16 had the lowest yields over the first four cropping years. The trees on M.9 T337 were intermediate in early yield. Trees on most of the Geneva® rootstocks yielded similarly to the trees on M.9 T337. Trees on P 14, M.26 and CG.4013 were in the group with the highest yield. In the last two-year period of the experiment (2006-

2007), the highest yield was obtained from trees on G.41, followed by CG.4013, G.202, M.9 Pajam 2 and P 16, while the lowest yield was from trees on P 59 (Table 2). The yields from all the remaining trees grafted on the Geneva® rootstocks and the Polish rootstocks were similar to the yields obtained from trees on M.9 T337. The cumulative yield for the seven-year period after planting was highest from trees on CG.4013 followed by G.41, P 14, G.202, and M.26 (Table 2). The lowest cumulative yield was obtained from trees grown on P 59. The cumulative yields from the trees grown on the remaining Geneva® and Polish rootstocks were similar to the yields obtained from the trees on M.9 T337. In general the cumulative yields from our trial would have been higher if we had not thinned aggressively to achieve large-sized fruits (>7.5 cm in diameter and weighing over 192 g). In most years, fruitlets were thinned to a distance of about 18 cm between fruits. Thus, the cumulative yields obtained in Poland from trees on the standard dwarfing rootstocks M.9 T337 and M.9 Pajam2 were lower than yields obtained from trees of the same age in Italy or Spain (4, 17). Nevertheless the yield data from this study show the high yielding potential of 'Golden Delicious Reinders' trees in Poland and are comparable with data obtained by previous studies in Poland (3, 5, 11, 26).

Yield efficiency. The trees on P 16 had the highest cumulative yield efficiency followed by M.9 Pajam 2, G.41, G.11, M.9 T337, P 59, CG.4013 , and some, and the lowest yield efficiency was with trees on P 14 and P 60 (Table 2). Yield efficiency was negatively correlated with TCA (Fig. 2). Trees on P.16, M.9 Pajam2 and G.41 had higher than expected yield efficiency from their TCA while P 59, G.16 and CG.3007 had lower yield efficiencies than expected from their TCA.

Fruit size. The effect of rootstock on fruit weight was modest and varied from year to year (Table 2). In 2005, nearly all of the rootstocks had fruit weights similar to that of fruits from trees on M.9 T337, while only the fruit size from trees on P 59 was significantly smaller. In 2006, the fruit size from the trees grown on nearly all rootstocks was similar to that of the fruits obtained from the trees on the standard dwarfing rootstock M.9 T337 except fruits from CG.4013 and P.14 were significantly larger than M.9 Pajam 2 and P.16.

Table 2. Cumulative yield, cumulative yield efficiency (CYE) and fruit size of 'Golden Delicious Reinders' apple trees grown on Geneva® and Polish rootstocks.

	Cumulative yield (kg/tree)			CYE (kg/cm^2	Fruit size (g)		
Rootstock[z]	2002-2005	2006-2007	2002-2007	TCA)	2005	2006	2007
P 16	25.1 a[y]	36.9 cdef	62.1 bc	4.98 e	181 c	199 a	202 bcd
M.9 Pajam2	34.3 b	42.1 def	76.4 cde	4.02 d	160 bc	197 a	195 bcd
G.41	40.4 bcd	49.7 f	90.1 ef	3.71 d	123 abc	221 ab	214 cde
G.11	41.8 bcd	28.1 bc	69.9 bcd	3.43 cd	165 bc	244 ab	207 bcde
M.9 T337	36.6 b	34.8 bcde	71.4 bcd	3.27 bcd	163 bc	227 ab	232 e
P 59	22.4 a	9.5 a	31.9 a	3.19 bcd	116 a	210 ab	141 a
CG.4013	46.0 cde	46.6 ef	92.7 f	3.11 bcd	165 bc	256 b	184 b
G.202	35.9 b	43.7 def	79.7 def	2.77 abc	158 bc	220 ab	215 de
G.16	36.5 b	23.1 b	59.6 b	2.64 abc	181 c	223 ab	180 b
CG.3007	40.6 bcd	28.2 bc	68.9 bcd	2.43 ab	140 abc	211 ab	186 bc
M.26	48.2 de	30.5 bcd	78.8 def	2.42 ab	149 abc	224 ab	208 bcde
P 14	51.1 e	37.1 def	88.2 ef	2.13 a	155 abc	247 b	214 cde
P 60	38.1 bc	34.0 bcde	72.1 bcd	2.00 a	158 bc	233 ab	218 de

[z] Rootstocks ranked by cumulative yield efficiency

[y] Means within a column followed by the same letter are not significantly different (Duncan's multiple range test P ≤ 0.05).

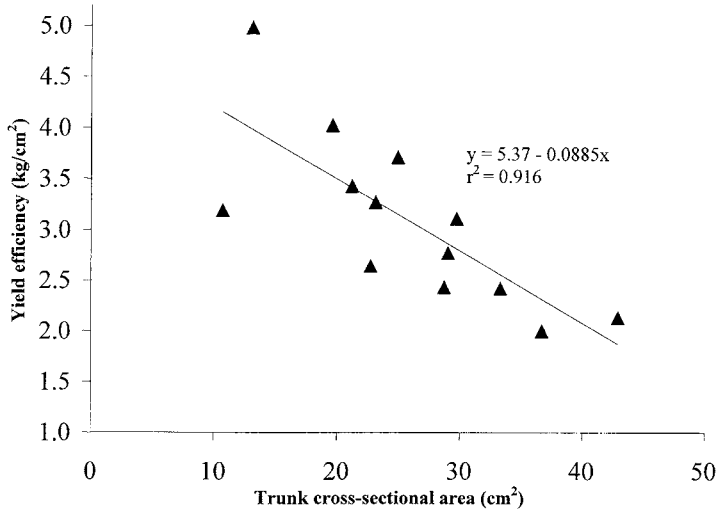

Fig. 2. Relationship between 7-year cumulative yield efficiency and trunk cross-sectional area of 13 rootstocks after 7 years in Poland.

In 2007 there were considerable differences in fruit size between rootstocks. Rootstocks with significantly smaller fruit size than M.9 T337 were P 59, G.16, CG.4013, CG.3007, P 16, and M.9 Pajam2. The fruit sizes obtained in the last two years (2006 and 2007) were in line with those reported by Musacchi et al., (17), and Jadczuk et al. (11).

Crop load. Mean fruit density (crop load) over 4 years (calculated as fruit number per cm^2 of TCA) was higher for trees on P 16 than for trees on P 14 and P 60 (Table 3). All other stocks had intermediate crop loads and were similar to M.9 T337. Ranking of the rootstocks by mean crop load was similar to the ranking of rootstock by cumulative yield efficiency. The individual year crop loads show that some rootstocks (P 59, G.11, G.16, CG.3007, M.26, P 60, and P 14) had significant biennial bearing while other rootstocks (P 16, M.9 Pajam2, M.9 T337, G.41, CG.4013 and G.202) had more annual cropping (Table 3).

Fruit quality. In 2007 there were only small differences in fruit flesh firmness among rootstocks. Fruit from trees on M.9 Pajam2, G.202 and P 60 ranked highest for fruit firmness while fruit from trees on CG.3007 ranked lowest for fruit firmness (Table 4). Only M.9 Pajam2 had significantly higher fruit flesh firmness than M.9 T337. Although 'Golden Delicious Reinders' is a green/yellow cultivar, there were significant differences in the area of red blush on the fruit skin among the rootstocks (Table 4). The red blush area was significantly greater on fruits harvested from trees on M.9 T337 and G.202 than from trees grown on CG.4013 and P 16. Stocks with the least amount of red blush area were CG.4013, P 16, P 59, G.16, G.41 and M.9 Pajam 2. The highest internal ethylene concentration was recorded in the fruits from the trees on G.41 followed by M.9 T337, CG.3007, P 59 and P 14 while the lowest internal ethylene concentration was in fruits harvested from trees grafted on P 60 followed by G.202, M.9 Pajam2, G.11 and M.26 (Table 4). Other rootstocks had intermediate internal ethylene concentrations. The lowest fruit TSS was from trees on P 14 followed by P 59, CG.4013, P 16, G.41, CG.3007 and G.11, while fruit from trees on G.16, M.9T337, M.26, M.9Pajam2, G.202 and P 60 had the highest TSS. The TSS from trees on the other rootstocks was similar to fruits from trees on M.9 T337. The highest

Table 3. Crop load of 'Golden Delicious Reinders' apple trees grown on Geneva® and Polish rootstocks throughout four growing seasons (2004-2007).

	Crop load (number of fruits/cm² TCA)				
Rootstock[z]	2004	2005	2006	2007	Mean[y]
P 16	5.6	5.8	8.1	8.1	6.9 b
M.9 Pajam 2	5.2	8.3	6.1	6.5	6.5 ab
P 59[x]	-	11.3	1.1	5.8	6.1 ab
M.9 T.337	5.3	9.1	3.6	4.8	5.7 ab
G.41	5.1	6.7	4.3	6.2	5.6 ab
G.11	3.4	11.8	0.7	5.9	5.4 ab
CG.4013	4.2	7.8	2.5	6.0	5.1 ab
G.16	4.0	10.5	0.8	4.9	5.0 ab
CG.3007	2.8	9.2	0.5	4.9	4.4 ab
G.202	3.5	6.2	3.5	4.4	4.4 ab
M.26[x]	-	8.2	1.0	3.8	4.3 ab
P 60[x]	-	7.4	1.2	3.4	4.0 a
P 14[x]	-	7.3	0.6	3.8	3.9 a

[z] Rootstocks ranked by mean crop load
[y] Means within a column followed by the some letter are not significantly different (Duncan's multiple range test P ≤ 0.05
[x] Crop load on rootstock P 59, M.26, P 60 and P 14 was measured only for 3 years (2005-2007).

Table 4. Fruit firmness, red blush area, internal ethylene concentration (IEC), total soluble solids (TSS) and total acidity of 'Golden Delicious Reinders' apple trees grown on Geneva® and Polish rootstocks in 2007.

Rootstock[z]	Fruit firmness (kg)	Red blush area (%)	IEC (ppm)	TSS (%)	Total acidity (%)
P 60	6.84 bcd[y]	16.0 abcd	85.1 a	15.3 bcd	0.58 cd
G.202	6.90 cd	23.7 cd	85.4 a	15.3 bcd	0.64 e
M.9 Pajam2	6.95 d	11.0 abcd	97.6 ab	15.4 bcd	0.56 cd
G.11	6.50 ab	14.0 abcd	109.2 abc	14.9 abcd	0.53 bc
M.26	6.64 abcd	19.3 bcd	110.7 abc	15.6 cd	0.65 e
CG.4013	6.60 abc	4.3 a	122.2 bcd	14.5 abc	0.53 bc
P 16	6.69 abcd	6.0 ab	123.4 bcd	14.6 abc	0.54 bc
G.16	6.55 ab	10.7 abcd	124.4 bcde	16.0 d	0.54 bcd
P 14	6.69 abcd	14.3 abcd	135.2 cdef	14.1 a	0.58 cd
P 59	6.54 ab	7.7 abc	146.3 def	14.5 ab	0.45 a
CG.3007	6.35 a	18.0 abcd	148.9 def	14.8 abc	0.49 ab
M.9 T337	6.61 abc	25.3 d	156.7 ef	15.6 bcd	0.60 de
G.41	6.58 abc	11.7 abcd	164.7 f	14.7 abc	0.54 bcd

[z] Rootstocks ranked by internal ethylene concentration
[y] Means followed by the same letter are not significantly different (Duncan's multiple range test P ≤ 0.05).

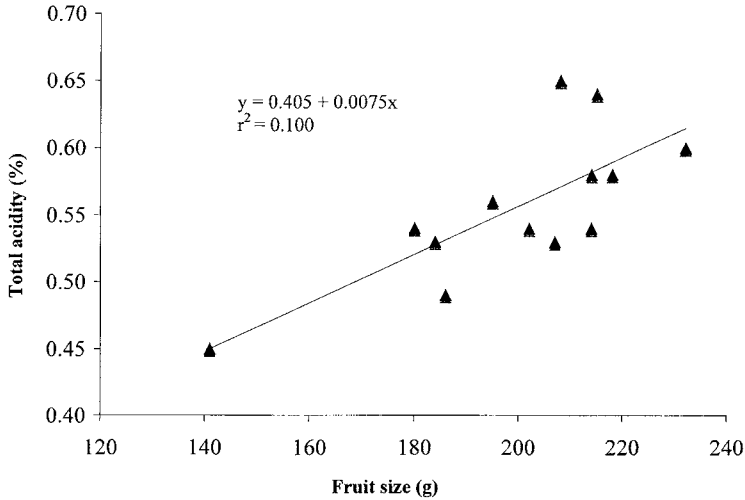

Fig. 3. Relationship between fruit total acidity and fruit size of 13 rootstocks in 2007 in Poland.

TA was from trees grown on M.26, G.202, and M.9 T337 while the lowest TA was from trees on P 59 and CG.3007. Other rootstocks which had significantly lower TA than M.9 T337 were P 16, G.11 and CG.4013.

The variations in TA, TSS and internal ethylene concentration were likely connected with the differences in fruit size and the degree of ripening. In this trial, fruit size, was not correlated with TA and fruit firmness, TSS or internal ethylene concentration (Fig. 3). Notable rootstock effects on fruit quality which were in line with the correlation of fruit size and TA were: M.9 T337 had the largest fruit size and high TA and TSS in agreement with Autio et al. (1); P 59 had the smallest fruit size and low TA and TSS in agreement with Skrzyński (25). Rootstocks which had higher than expected TA in relation to their fruit size were G.202 and M.26 while CG.3007 had lower than expected TA for its fruit size. Our results in relation to firmness, TSS and TA are comparable with the data obtained by Musacchi et al. (17),Bonany et al. (4) and Autio et al. (1).

Internal ethylene is probably the best indicator of fruit maturity at harvest and thus those rootstocks inducing higher ethylene concentration in the fruit have more advanced fruit maturity than those rootstocks with low fruit internal ethylene concentration. Our data indicate that G.41 CG.3007, P 59, P 14 and G.16 advance fruit maturity similarly to M.9 T337 while P 60, G.202, and G.11 delay fruit maturity similarly to M.26. Others have not reported on fruit maturity effects of Geneva® and Polish rootstocks but the differences between M.9 and M.26 have been noted before (15). An interesting anomaly is that our data show fruits from M.9 T337 to be more mature than fruits from M.9 Pajam2. Since the 2 rootstocks are clones of M.9 this is unusual.

Conclusions. (1) After 7 yr, trees of 'Golden Delicious Reinders' on G.11, G.16 and G.41 rootstocks were similar in size to those on the standard dwarfing rootstocks M.9 T337 and M.9 Pajam2. Trees on P 16 and P 59 were significantly weaker in comparison with trees on M.9 T337. The strongest growing trees were on P 14, P 60 and M.26. The rootstocks CG.4013, G.202, CG.3007 were intermediate between M.26 and M.9 T337. (2) Cumulative 7 yr yield was highest from trees on CG.4013, G.41, P 14, G.202 and M.26; however, only G.41 was similar in vigor to M.9 T337. Rootstocks with yield similar to M.9T337 were CG.3007, G.11, M.9 Pajam2, P 16 and P 60.

Significantly lower yields were obtained only from trees grafted on P 59. The highest yield efficiencies were with trees on P.16, M.9 Pajam2, G.41 and G.11 while the trees on P 60 and P 14 had the lowest yield efficiencies. (3) The Geneva® series rootstocks and Polish rootstocks with different growth vigor included in this trial had little effect on fruit size, which varied from year to year. Smaller fruit size tended to be produced only by the trees on P 59. In 2007, a heavy cropping year, the largest fruits were from the trees on M.9 T337, G.41, P 60, G.202, M.26, P 14 and G.11. In countries with short growing seasons like Poland where it is very difficult to obtain high quality fruits of 'Golden Delicious Reinders' (over 190 g or diameter over 7.5 cm), rootstocks which produce large fruit size are important. (4) Chemical analyses performed in October 2007 revealed small differences in total acidity, soluble solids, and fruit firmness among the fruits picked from the rootstocks tested. The highest TA was found in fruits from the trees on M.26, G.202, and M.9 T337. The highest TSS was found in the fruits picked from the trees grown on G.16, M.26 followed by M.9 T337 and M.9 Pajam2. (5) The rootstocks G.11 and G.41 are highly suitable in the Polish climate for 'Golden Delicious Reinders' apple trees, as are trees grown on M.9 T337, P 16 and M.9 Pajam2. For orchards located on light soils, the rootstocks CG.4013, G.202 P 14 and P 60 are also promising.

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I certify that the statements made by me above are correct and complete. R.M. Crassweller, Business Manager. December 31, 2009.