

Geneva® Rootstocks for Weak Growing Scion Cultivars Like ‘Honeycrisp’

Terence Robinson¹, Gennaro Fazio² Steve Hoying³, Mario Miranda⁴ and Kevin Iungerman⁵

¹Dept. of Horticulture, NYSAES, Cornell University, Geneva, NY 14456

²Plant Genetics Resources Unit, USDA-ARS, Geneva, NY 14456

³Dept. of Horticulture, NYSAES, Cornell University, Highland, NY 12528

⁴Cornell Cooperative Extension, Newark, NY 14513

⁵Cornell Cooperative Extension, Balston Spa, NY 12020

This project was partially funded by the NY Apple Research and Development Program

Duplicate field trials with ‘Honeycrisp’ apple on 22 rootstocks conducted for 9 years at Geneva, NY (in Western NY State) and Peru, NY (in Northern NY State), showed that two dwarf Geneva® stocks (G.41 and G.11) had good tree survival, superior yield performance to M.9, similar fruit size as M.9 and less bienniality than M.9. A third stock, G.935, which was similar in size to M.26 was also superior in yield to M.9 but was not less biennial.

For many apple growers in North America, the bacterial disease fire blight is a serious threat to dwarf apple orchards. M.9 and M.26, the most common dwarfing apple rootstocks, are very susceptible to this disease and in some locations this disease limits the planting of dwarfing rootstocks. Outbreaks of the disease in the eastern USA have decimated many dwarf apple orchards.

A number of new apple rootstocks from the Cornell/USDA apple rootstock breeding project, located at Geneva NY which are resistant to the bacterial disease fire blight (*Erwinia amylovora*) are rapidly becoming available. Some elite rootstock genotypes from this program have been tested in second and third level trials within NY state (Robinson and Hoying, 2005) and national trials in the US, and Canada, (Robinson, et al., 2003), France (Masseron and Simard, 2002) and New Zealand (personal communication from Stuart Tustin) with ‘Gala’, ‘Golden Delicious’, ‘Jonagold’ and ‘Empire’. However, the popularity of several weak-growing cultivars requires a re-evaluation of promising rootstocks when the scion cultivar is not vigorous. In this paper, we report on the field performance of elite Geneva® rootstocks from 3 trials in New York State with the weak-growing scion cultivar ‘Honeycrisp’.

Materials and Methods

In 2002, duplicate replicated field trials of 7 Geneva® named and un-named elite rootstocks and 3 Malling rootstocks (M.27, M.9 and M.26), B.9, P.22, Supporter 4 and Ottawa 3 as controls were planted at Geneva, NY (Western part of State) and Peru, NY (Northern part of State) using ‘Honeycrisp’ as the scion cultivar. Two clones of B.9 were compared (European clone and USA clone). Seven clones of M.9 were compared (original, T337, EMLA, Nic8, Nic29, Pajam1 and Pajam2). One Geneva® rootstock (CG.6210) was planted only at Geneva. The plots were laid out as randomized complete block experiment with 10 replications and with each block containing 1 individual tree of each rootstock. All of the plant material was grown in a common nursery in Geneva, NY. The trees were planted as unbranched whips at a spacing of (8 ft X 15 ft) and were headed at 40 inches after planting. Trees were managed with the vertical axis system and fertilized annually with nitrogen and potassium according to local recommendations. Trees were supported with a single wire trellis and a metal tube tree stake.

In 2004, a third replicated field trial of 47 Geneva® named and un-named elite rootstocks and 3 Malling rootstocks (M.9, M.7 and MM.106) and 1 Budgovsky stock (B.9) as controls was planted at Hilton, NY (Western part of state) using 'Honeycrisp' as the scion cultivar. The plot was laid out as randomized complete block experiment with 5 replications and with each block containing 2 individual trees of each rootstock. All of the plant material was grown in a common nursery in Geneva, NY. The trees were planted as unbranched whips at a spacing of (8 ft X 16 ft) and were headed at 40 inches after planting. Trees were managed with the vertical axis system and fertilized annually with nitrogen and potassium according to local recommendations. Trees were supported with a single wire trellis and a metal tube tree stake.

With all three trials, tree survival, number of root suckers and trunk circumference at 1 ft above the graft union were measured annually in November. Fruit number and yield were recorded annually at harvest and fruit size was calculated as the ratio of fruit yield/tree (g) divided by the number of fruit per tree. Cumulative yield efficiency was calculated by dividing cumulative yield by final trunk cross-sectional area. The biennial bearing tendency of each rootstock was assessed by calculating an alternate bearing index for each two years of yield data using the formula: ABI = Absolute Value of (Fruit Number Year 2-Fruit Number Year 1) divided by the Sum of (Fruit Number Year 2+Fruit Number Year 1). This index gives values ranging from 0 to 1 with 0=no biennial bearing and 1=complete biennial bearing. Data were analyzed by ANOVA using SAS statistical analysis software (SAS Institute, Cary, NC, USA). Crop load was used as covariate to compare fruit sizes independent of crop load. Significant differences among means were determined by Least Significant Difference test.

Results

2002 Duplicate Trials at Geneva and Peru, NY. In the Western part of NY State (Geneva), all of the rootstocks had high tree survival except P.22, M.27 and CG.4013 which had from 15-22% tree death over 9 years (data not presented). In the Northern part of NY State (Peru) all rootstocks had high tree survival except CG.4013 which had 17% tree death.

Tree size at the end of 9 years at Geneva, NY fell into three vigor classes, super dwarf, dwarf and semi-dwarf. In the super dwarf group the smallest trees were on P.22 followed by G.65, B.9 and M.27 (Fig 1). There was no significant difference in tree size between the two clones of B.9 (Europe and USA). In the dwarf group the smallest trees were on G.11 followed by CG.3007, G.41, G.935, G.16, CG.4013, the various clones of M.9, Supporter 4 Ottawa 3 and M26. Among the 7 clones of M.9 only Pajam2 was significantly larger than M.9 or M.9T337. The other clones were intermediate in vigor. Only CG.6210 was categorized as a semi-dwarf stock and was much larger than any of the dwarf stocks. At Peru, NY there was a continuum of tree sizes from P.22 which was the most dwarfing to G.935 which was the most vigorous. A comparison of tree growth at Geneva and at Peru showed that on average trees at Peru grew significantly less than at Geneva (only 68% as large as Geneva trees) (Table 1). Stocks that had the least suppression in growth at Peru were G.935, G.16, G.41, CG.3007, G.11, both B.9 clones, and M.26. Stocks which had the greatest suppression of growth at Peru were all of the M.9 clones followed by CG.4013 and M.27.

The highest yield at Geneva was with CG.6210 followed by G.935 and G.41 (Fig. 2). This top group was followed by a large group consisting of all of the M.9 clones, M.26, O.3, G.11, G.16, CG.4013 and CG.3007 which had similar yields. The lowest yielding group were the super-dwarfs, M.27, B.9, B.65 and P.22. At Peru, NY cumulative yield generally reflected tree size with G.935 having the highest yield followed by G.41 and M.9Pajam2 (Fig. 2). This group was

followed by M.26, G.16, G.11, O.3 and M.9Nic8. The weaker clones of M.9 (original, EMLA Pajam1 and T337) had lower yields than the more vigorous M.9 clones. The lowest yielding group was the super-dwarf stocks, P.22, G.65, M.9 and M.27). A comparison of yield at Geneva and at Peru showed that on average trees at Peru yielded only 38% as much as trees at Geneva (Table 1). Stocks that had the least suppression in yield at Peru were G.16, G.41, M.9Pajam2, M.26, G.11, G.935, B.9USA, O.3 and Supporter 4. Stocks which had the greatest suppression of yield at Peru were P.22 followed by G.65, the M.9 clones, CG.4013 and M.27.

The highest cumulative yield efficiencies at Geneva were with G.935, G.41, B.9, P.22 and G.11 (Fig. 1). M.27 and CG.3007 had intermediate yield efficiency while all of the M.9 clones, G.16, CG.4013, Supporter 4, O.3 M.26 and CG.621 had significantly lower yield efficiency. At Peru, the highest cumulative yield efficiencies were with G.11, M.9T337 and G.41. This group was followed by B.9, M.27, CG.4013, the rest of the M.9 clones, CG.4013, Supporter 4, O.3, G.16 and M.26. CG.3007, G.65 and P.22 had the lowest yield efficiencies. A comparison of yield efficiencies at Geneva and at Peru showed that on average trees at Peru were only 59% as efficient as trees at Geneva (Table 1). Stocks that had the least suppression in yield efficiency at Peru were all of the M.9 clones, CG.4013, M.26, G.11 and M.27. Stocks which had the greatest suppression of yield efficiency at Peru were P.22, followed by G.65, CG.3007, G.935, B.9, O.3 and G.41.

The largest fruit size at Geneva was with M.9Pajam1 followed by G.41, CG.6210, M.9EMLA, M.9T337, M.9Pajam2, M.27, G.11, Supporter 4, M.26 and M.9 (Fig. 3). Stocks with slightly smaller fruit size were B.9, G.935 and M.9Nic29. The rootstocks with the smallest fruit size were P.22, G.65, CG.3007, G.16 and CG.4013. At Peru, NY, the largest fruit size was with M.27 followed by M.9EMLA, M.9T337, Supporter 4, M.9Pajam1, G.41 and M.9Nic8, M.9Pajam2, M.9Nic29, M.9 and G.11. Intermediate fruit sizes were produced with B.9 and O.3 while M.26, G.16, G.935 and G.65 had smaller size. The smallest fruit size was with P.22, CG.4013 and CG.3007. A comparison of fruit sizes at Geneva and at Peru showed that on average trees at Peru produced fruits of almost the same size (91%) as at Geneva with no large differences among stocks (Table 1).

The effect of rootstock on biennial bearing was evaluated by calculating an alternate bearing index (ABI) with a scale of 0=no alternate bearing, to 1=complete biennial bearing. At Geneva, the rootstocks which had the lowest biennial bearing tendency were G.41 followed by G.65, CG.6210, B.9, G.11, G.935, G.16, O.3 and M.26 (Fig. 4). The clones of M.9, P.22, CG.3007 and Supporter 4 were intermediate in biennial bearing tendency while M.27 and CG.4013 had the greatest biennial bearing tendency. At Peru, the rootstocks with the lowest biennial bearing tendency were B.9Europe, CG.3007, M.26, G.41 and P.22. Stocks with intermediate ABI were G.65, M.27, B.9USA, CG.4013, the weaker clones of M.9, G.11, Supporter 4, O.3 and G.16. Stocks with the highest ABI were M.9Nic8, M.9Pajam2, G.935 and M.9Pajam1. A comparison of biennial bearing at Geneva and at Peru showed that on average trees at Peru were had slightly greater alternate bearing (105%) than trees at Geneva (Table 1). Stocks that had less biennial bearing at Peru than at Geneva were CG.4013, CG.3007, M.27, Supporter 4, M.9EMLA, M.9Nic29, M.26, P.22, B.9Europe, M.9T337 and B.9USA. Stocks with greater biennial bearing at Peru than Geneva were G.935, M.9Nic8, M.9Pajam1, G.65, G.11, M.9Pajam2, G.41 and G.16.

Root suckers at Geneva were significantly higher than at Peru where there were almost no root suckers (data not shown). At Geneva the rootstocks with the least root suckers were G.11, G.41, G.16, P.22 CG.3007, M.26 and G.65 while all of the other stocks had between 14 and 33 goatsuckers.

2004 Trial After 7 years all of the rootstocks had high (>90%) tree survival but CG. 2034, and 4088 (data not presented). Tree vigor ranged from super dwarfing (<10 cm² TCA) to vigorous (>60 cm² TCA) with a continuum between the extremes (Fig 5). Super-dwarfing trees which were smaller than B.9 were CG.4291, 4088, 4021, 2406, 2034, 4202, 4003, 4210, 4288, and G.11. Trees similar to B.9 were G.11, 2006, 4019, 5757 and 2022. Trees similar to M.9 were CG.4214, 4292, G.16, CG.6874, 4814, 6143, 5030, and 4001. The trees which were in the dwarfing class but intermediate in size between M.9 and M.7 were CG.6969, 4011, G.935, 6006, G.30, 4004, 5202, 5257, 5012. A group slightly larger categorized as semi-dwarfing but smaller than M.7 were, CG.7480, 8189 4049 6879 and 5890. Trees similar in size to M.7 were MM.106, CG.6001 and 6253. Eight stocks were significantly more vigorous than M.7 or MM.106 with several stocks almost twice the size of MM.106.

As expected, cumulative yield generally reflected tree size (Fig. 6); however, there were several notable exceptions. Among the super-dwarfs, CG4210 had the highest yield, while among stocks similar to B.9, CG.5757 had the highest yield. Among stocks similar to M.9, CG.4001 had the highest yield. Among dwarf trees slightly larger than M.9, CG.4004 had the highest yield. Among semi-dwarf trees smaller than M.7, CG.5890 and 7480 had the highest yield while among trees larger than M.7 or MM.106, CG.6001 and 6024 had the highest yield.

Cumulative yield efficiency which normalizes yield with tree size (TCA) was generally inversely related to tree size (Fig 5). Among the super-dwarf rootstocks smaller than B.9 which had higher yield efficiency than M.9 were CG.4021, 4210, 4003, 2406, and 4291. Among stocks similar to B.9, CG.5757 and B.9 had higher yield efficiency than M.9. Among the group of stocks similar in size to M.9 which had higher yield efficiency than M.9 were CG.4214 and 4814. Among dwarfing stocks slightly larger than M.9 which had high yield efficiency were CG.6969, 4004, 4011, G.935, 6006, 5046, G.30 and 5257. Among semi-dwarfing stocks slightly smaller than CG.7480 and 5890 had higher yield efficiency than M.9. No stock similar or larger than M.7 had yield efficiencies as high as M.9; however, the highest yield efficiency was with CG.6001 which was significantly higher than M.7.

Fruit size varied significantly among rootstocks (Fig. 7). M.9 had the largest fruit size but not significantly greater than the semi-dwarf stocks CG.4004 and 7480 or the vigorous stock CG6001. Rootstocks with the smallest fruit size were the super-dwarfs, CG.4291, 2406, 2034, 4003 and 4288; the dwarfs CG.2006, 4019, 4292, and 6874; and the vigorous stocks CG.6253, 4002, 5463 and 6024. All other stocks had intermediate fruit size.

The number of root suckers varied significantly among rootstocks. M.9 had ~5 root suckers/tree over the 7 years of the trial (data not shown). Those rootstocks which had significantly more root suckers than M.9 were M.7 (which had the most=22) followed by CG.5046, 6143, 5030, 6001, 4214, 6879 and 6024.

Discussion

The duplicate rootstock trials planted at Geneva (Western, NY) and Peru (Northern, NY) revealed a significant difference in performance of each rootstock genotype between Geneva and Peru. Such location effects on rootstock performance have been seen in most national NC140 rootstock trials (Autio, et al., 2005, 2008, Marini, et al., 2006a,b, 2009). This indicates that local recommendations of rootstock should be based on local field performance trials. In this study, G.41 which had the best overall performance at both Geneva and Peru was smaller than all seven M.9 clones at Geneva but larger than all M.9 clones except Pajam2 at Peru. Similarly G.11 which had the second best overall performance at both locations was significantly smaller than

all M.9 clones at Geneva but was similar to M.9EMLA in size at Peru. G.935 which had the third best overall performance was as dwarf as G.41 at Geneva but at Peru it was more vigorous than M.9Pajam2. It appears that all M.9 clones were more severely negatively affected by the climate and soils at Peru than either G.41, G.11 or G.935. G.16 also performed well at both locations and was less affected by the climate in Peru than the M.9 clones but G.16 was inferior to G.41, G.11 and G.935 in yield efficiency and was similar the M.9 clones. These positive results with G.41, G.11 and G.935 are similar to results of other studies (Autio, 2005, 2008; Czynczyk et al., 2010; Marini 2009; Masseron and Simard, 2002; Robinson and Hoying, 2005; Robinson et al., 2003).

The results of fruit size indicate that G.41 and G.11 produce similar fruit size to M.9 even when fruit size is calculated independent of crop load. However, our results show that G.935 produces slightly smaller fruit size than M.9 with fruit size similar to M.26. Our results also show that four Geneva rootstocks (G.65, G.16, CG.3007 and 4013) produce significantly smaller fruit size than M.9. The latter two stocks will be discarded due to this characteristic. Our data also show that P.22 produces small fruit size. The results show that fruit size of B.9 was numerically smaller at both locations than M.9 but the difference was not significant.

The duplicate trials showed that there is a range of vigor among the seven M.9 clones with M.9Pajam2 having the greatest vigor (similar vigor as M.26) and being significantly more vigorous than M.9T337 especially at Peru, NY. The Pajam2 clone was followed by Nic8, Nic29, EMLA, Pajam1, T337 and the original M.9 which was the least vigorous.

Our data show that there is no significant difference in vigor between the European clone of B.9 and the USA clone but at both locations the USA clone was numerically larger than the European clone. There was no significant difference in fruit size or biennial bearing tendency between the two clones of B.9. Although the two clones have different growth characteristics in the stoolbed (trailing vs. erect growth) there is no significant difference in orchard performance. This result is consistent with our earlier results of similar fire blight susceptibility (Russo et al., 2007, 2008).

Through the 2004 field trial of 51 rootstocks we have identified several new dwarfing stocks which may have potential. They include the super-dwarfs CG.4021, 4088 and 4210; the dwarfs, CG.4214, 5757 and 4001. From this group CG.4214 was released in 2010. It was named Geneva® 214. It has excellent stoolbed propagation characteristics which may make it easier to introduce quickly.

New semi-dwarfing stocks which may have potential include: CG.6969, 4011, 6006, 5046, 4004, and 5257. From this group CG.6969 was released in 2010 and named Geneva® 969. It has excellent stoolbed propagation characteristics which may make it easier to introduce quickly. It performs well in northern climates and is free standing. It may be an excellent stock for weak growing cultivars in northern climates like Honeycrisp and MN1914 (Robinson et al. 2010).

New semi-vigorous stocks which may have potential include: CG.7480 and 5890. Among this group CG.5890 were released in 2010 and named Geneva® 890. It has excellent stoolbed propagation characteristic, is free standing, precocious and productive. It is intended for the processing orchards of NY, PA, VA, NC and MI. Among stocks larger than MM.106 those with higher yield efficiency than MM.106 this project identified CG.6001 which may have potential in areas of the world with poor soil resources and where high density orchards are not yet common.

Overall our data have show that over a broad range of climates, that 2 Geneva® stocks, G.11, and G.41 are very similar in dwarfing to M.9 and offer substantial benefits to US growers compared to M.9. They are being commercialized rapidly. Geneva® 11 which is fire blight

resistant but is not immune. It also has good resistance to *Phytophthora* root rot, but it is not resistant to woolly apple aphids or apple replant disease. G.11 has good layerbed and nursery characteristics. It is proving to be an excellent replacement for M.9. Its production in 2010 was about 175,000 liners. Substantial new stoolbeds have been planted which should increase production to 300,000 liners in 2011 and 800,000 liners in 2012.

G.41 is the most efficient and top performer dwarf rootstock in our trials. It has excellent fruit size and induces wide branch angles. It is highly resistant to fire blight (Russo et al, 2007) and is also resistant to *Phytophthora* and woolly apple aphids. It appears to have some tolerance of apple replant disease (Auvil, 2011, Robinson et al., 2011) and has good winter hardiness and appears to have less tendency for biennial bearing with Honeycrisp than other stocks. In the stoolbed, G.41 is a shy rooter and requires specialized rooting techniques including tissue cultured stoolbed mother plants to improve its rooting (Adams, 2010). It has brittle roots and a brittle graft union similar in strength to M.9 and must be handled with care. Its stellar orchard performance in both eastern and western North America indicate that it will be a good alternative to M.9 in high fire blight prone areas, in replant disease areas and in woolly aphid prone areas. Its production in 2010 was only 10,000 liners. Substantial new stoolbeds have been planted which should increase production to 100,000 liners in 2011 and 300,000 liners in 2012.

G.935 is similar in size to M.26 but is more productive. It has induces wide branch angles, is highly resistant to fire blight and *Phytophthora*, and appears to have some tolerance of apple replant disease. It also appears to be very winter hardy, but its not resistant to woolly apple aphid. Fruit size has been slightly smaller than M.9. It is an excellent new rootstock for weak growing cultivars like spur-type ‘Delicious’, ‘Honeycrisp’ ‘Sweet Tango’ or ‘NY1’ (Robinson et al., 2010). Its production in 2010 was only 30,000 liners. Substantial new stoolbeds have been planted which should increase production to 100,000 liners in 2011 and 300,000 liners in 2012.

Other Geneva® rootstocks not evaluated in these trials are G.202 and G.30. G.202 which produces a tree slightly larger than M.26, has a high level of resistance to fire blight, good resistance to *Phytophthora*, apple replant disease and to woolly apple aphid which is an important pest in many climates. It has had higher yield efficiency than M.26, and will be a useful alternative to M.26 in climates that have problems with woolly apple aphid. Its production in 2010 was only 15,000 liners but substantial new stoolbeds have been planted. Geneva® 30 is slightly more vigorous than M.26 and is proving to be useful in northern growing areas where it shows wide soil adaptation good winter hardiness and high yields. It is resistant to fire blight, crown rot and has very high yield efficiency It is difficult to handle in the stoolbed and nursery due to excessive production of sharp spines. This has limited its production for the last 5 years has been about 70,000 liners per year.

Conclusions

Our data have shown that over a broad range of climates and soils, that 2 dwarfing Geneva® stocks, G.11 and G.41 have performed better than M.9 while G.935 which is similar in vigor to M.26 has performed similar to M.9. Previous studies have shown their significant fire blight resistance is an advantage over M.9 and offers substantial benefits to North American apple growers (Russo et al., 2007). Other studies have shown that G.41 also has significant resistance to replant disease (Robinson et al., 2011). We have also identified several new elite rootstocks which may have potential for processing growers who want a free standing tree. These stocks are semi-dwarfing fire blight resistant stocks with high yield efficiency and good precocity. It is likely that these will be free-standing trees.

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Terence Robinson is a research and extension professor at Cornell's Geneva Experiment Station who leads Cornell's program in high-density orchard systems, rootstocks and plant growth regulators. Gennaro Fazio is a research scientist who leads the Cornell/USDA apple rootstock breeding program at Geneva, NY. Steve Hoying is a senior extension associate at Cornell's Hudson Valley Lab who specializes in orchard management and growth regulators. Mario Miranda is a regional extension educator in Western NY specializing in orchard management. Kevin Iungerman is a regional extension educator in Northern NY.

Table 1. Performance of 21 apple rootstocks with ‘Honeycrisp’ as the scion cultivar at Peru, NY as a percentage of their performance at Geneva, NY over 9 years.

(Performance at Peru, NY as a % of Performance at Geneva, NY)							
Rootstock	Tree Survival	Trunk Cross-sectional area	Cumulative Yield	Average Fruit Size	Cumulative Yield Efficiency	Alternate Bearing Index	Cumulative Root Suckers
P.22	112.8	60.9	16.0	89.3	29.3	96.8	0.0
G.65	100.0	71.4	25.9	97.2	35.3	122.9	0.9
B.9Europe	100.0	78.2	38.2	94.0	48.7	97.3	0.0
B.9USA	100.0	80.4	41.0	93.0	50.7	106.3	0.0
M.27	116.3	51.2	34.0	92.3	60.1	82.9	0.5
G.11	100.0	79.9	49.0	91.9	61.4	121.9	0.0
CG.3007	112.4	81.3	36.4	88.5	44.5	81.6	0.0
G.41	100.0	84.6	49.4	89.4	57.7	116.4	0.0
G.935	100.0	105.6	47.7	88.1	45.3	130.2	0.5
G.16	100.0	87.2	50.5	92.0	58.3	112.1	0.0
CG.4013	103.8	46.4	32.1	88.4	69.1	81.1	1.5
M.9	100.0	48.8	29.8	91.1	65.8	103.9	0.0
M.9T337	100.0	48.0	38.8	91.0	84.9	99.4	0.6
Supporter 4	88.0	69.5	40.1	92.2	59.1	89.5	0.0
M.9Pajam1	100.0	46.1	29.8	89.4	66.3	122.9	0.7
M.9EMLA	100.0	51.1	34.6	91.6	74.9	90.5	2.3
M.9Nic29	100.0	59.7	37.4	93.8	62.7	93.2	0.0
M.9Nic8	100.0	61.4	37.5	91.7	63.1	126.8	0.0
Ottawa 3	100.0	72.1	40.9	91.5	56.1	114.9	0.0
M.26	100.0	75.0	49.1	87.7	63.7	96.9	0.0
M.9Pajam2	100.0	61.9	49.1	90.2	79.6	116.6	0.0
Mean Peru vs. Geneva	101.6	67.6	38.4	91.2	58.9	104.9	0.3

^zRootstocks ranked by increasing trunk x-sectional area.

^yMean separation by LSD $p \leq 0.05$.

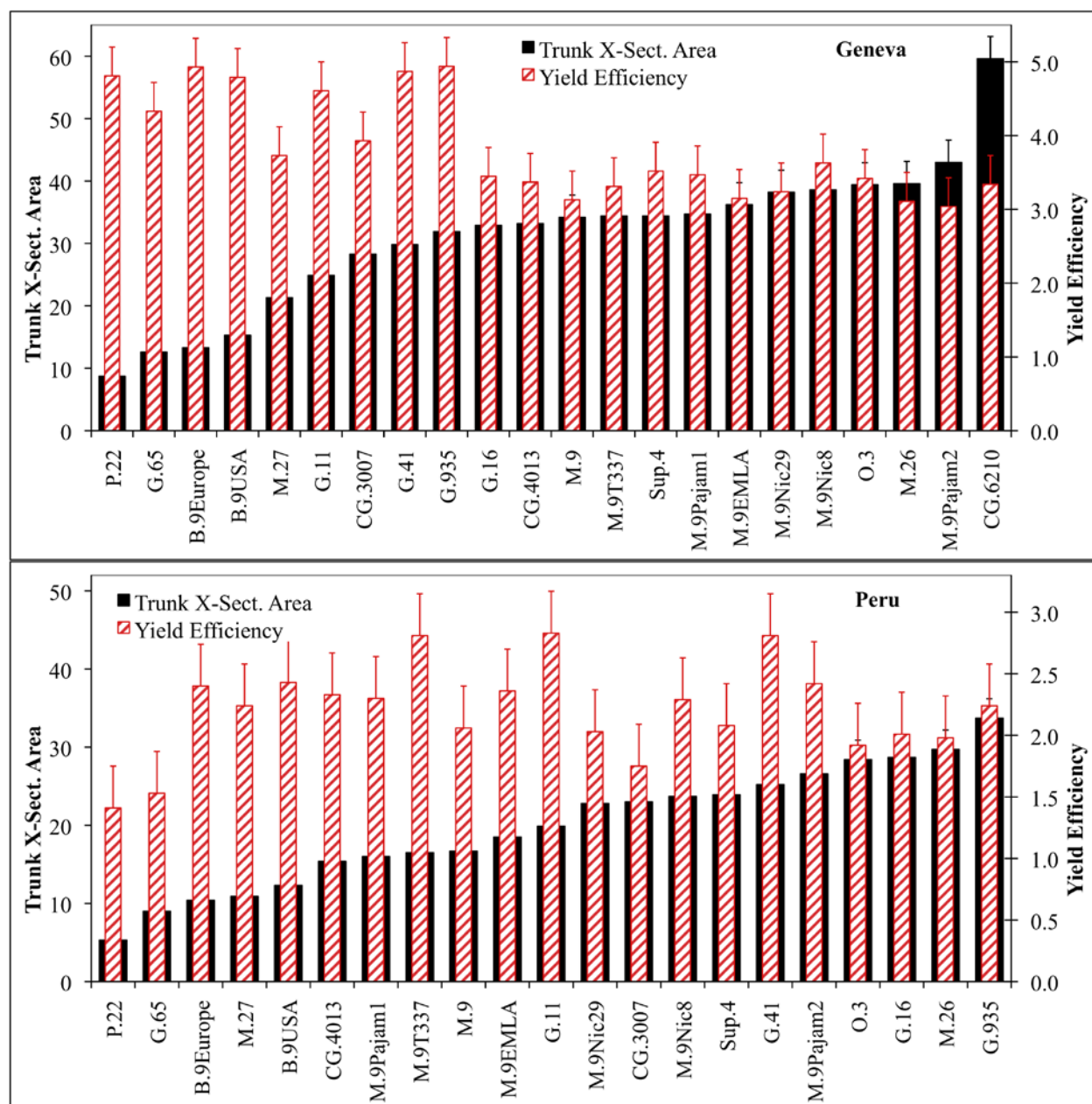


Figure 1. Final tree size (cm^2 trunk cross-sectional area) and cumulative yield efficiency ($\text{kg fruit}/\text{cm}^2$ TCA) of ‘Honeycrisp’ apple trees when grown on 22 rootstocks at Geneva, NY (top) and Peru, NY (bottom) after 9 years.

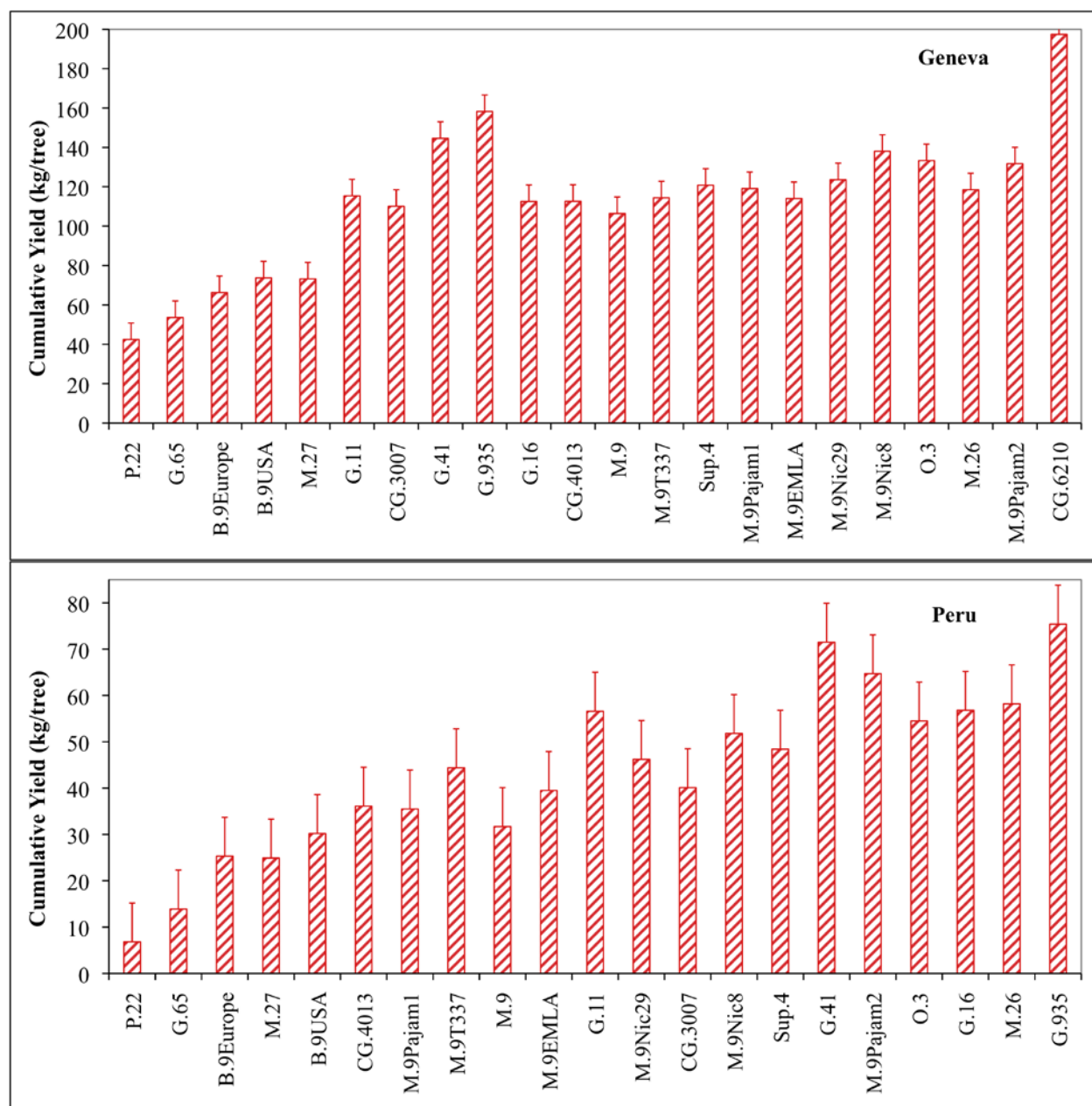


Figure 2. Cumulative yield (kg/tree) of 'Honeycrisp' apple trees when grown on 22 rootstocks at Geneva, NY (top) and Peru, NY (bottom) after 9 years.

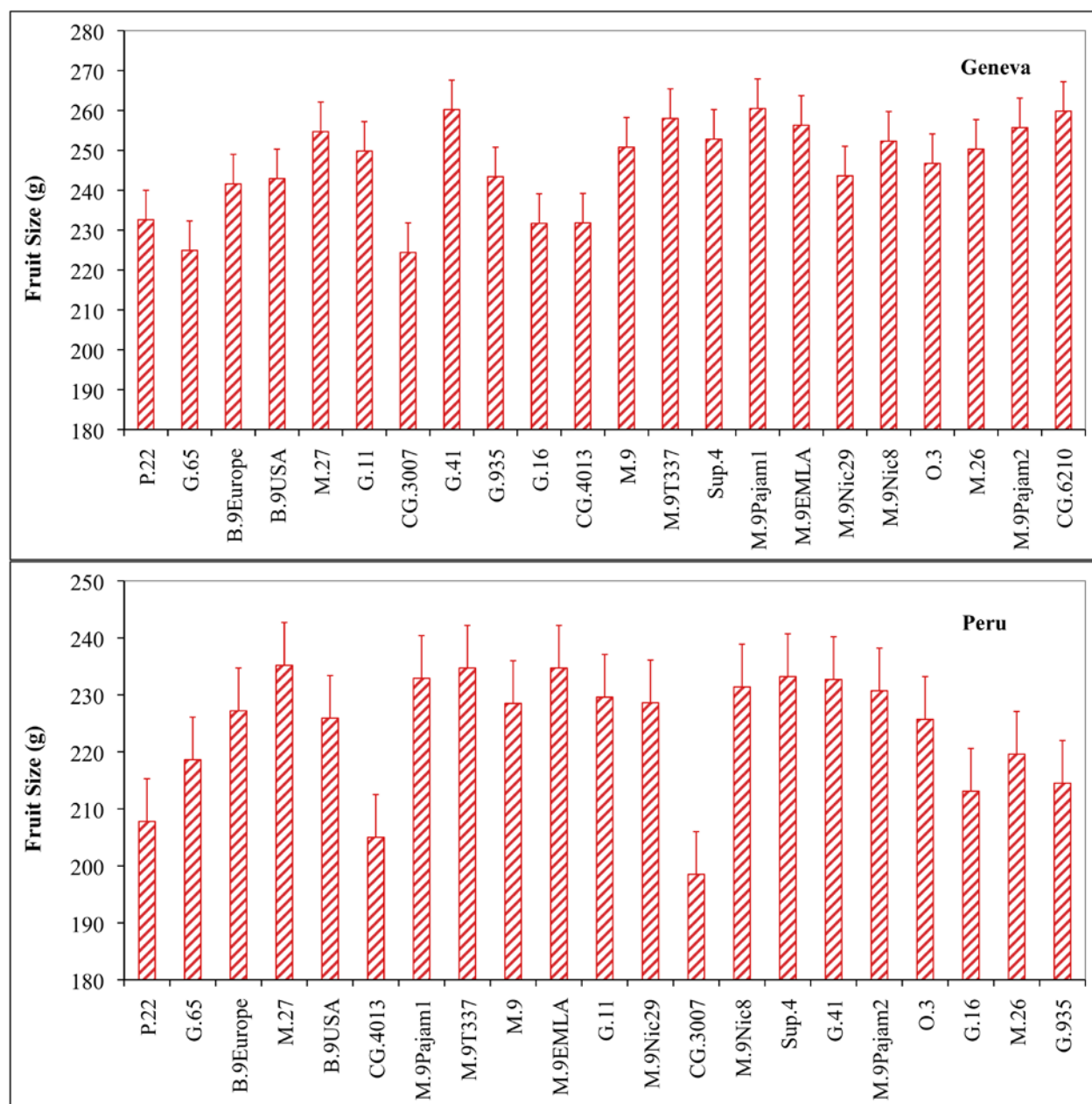


Figure 3. Average fruit size (g/fruit) of 'Honeycrisp' apple trees when grown on 22 rootstocks at Geneva, NY (top) and Peru, NY (bottom) after 9 years.

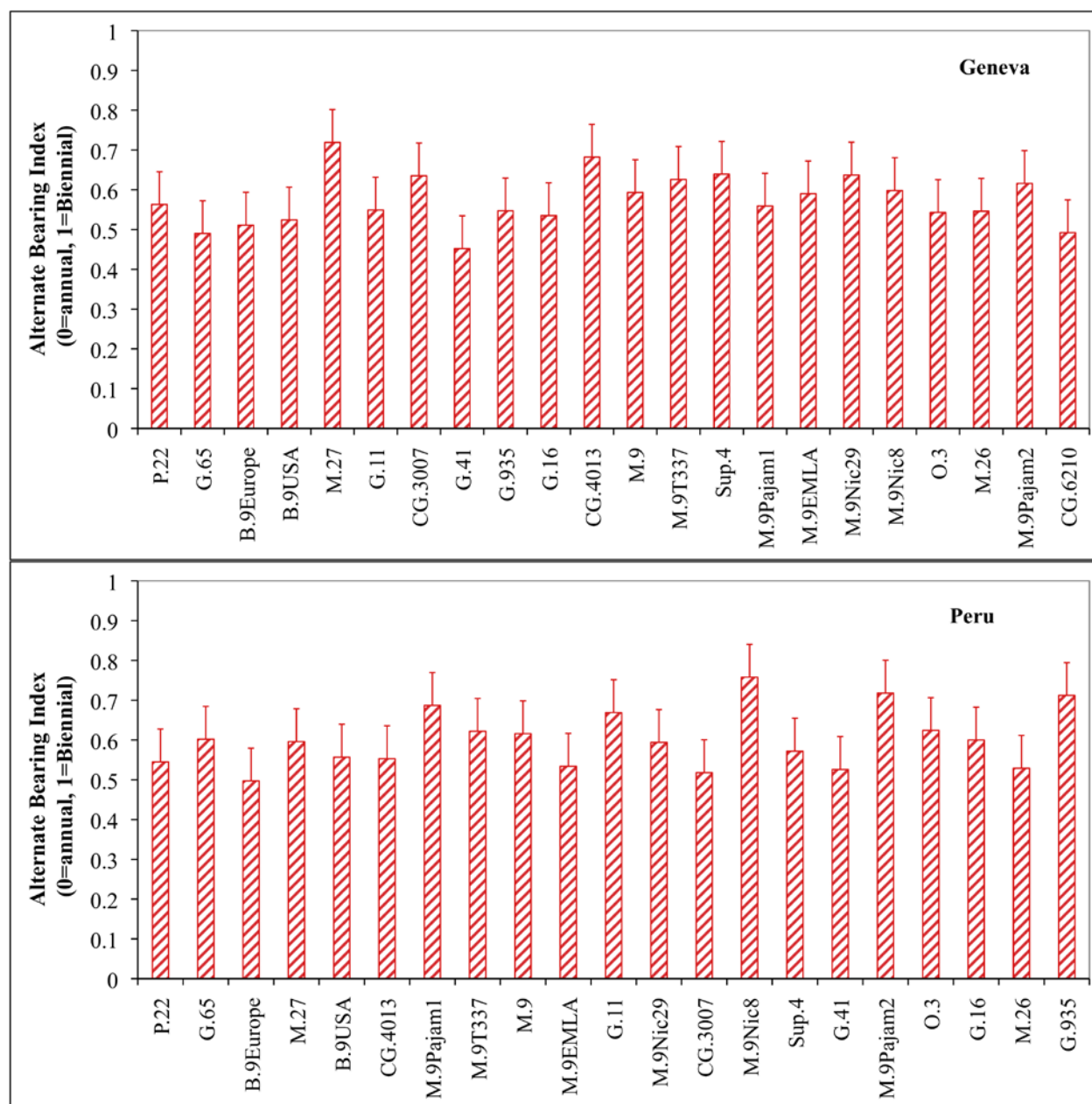


Figure 4. Alternate bearing index (0=annual cropping, 1=biennial cropping) of 'Honeycrisp' apple trees when grown on 22 rootstocks at Geneva, NY (top) and Peru, NY (bottom) after 9 years.

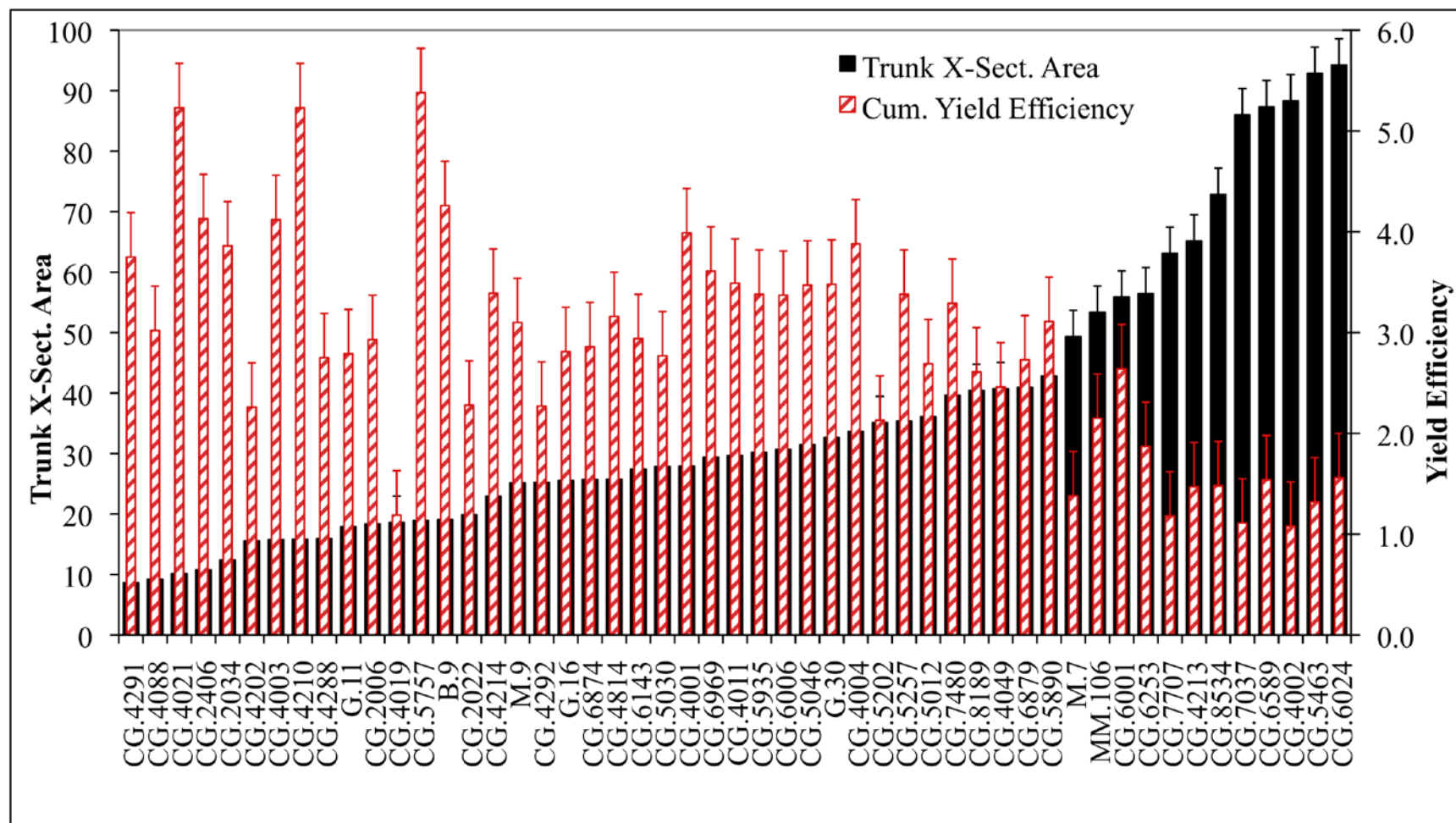


Figure 5. Final tree size (cm² trunk cross-sectional area) and cumulative yield efficiency (kg fruit/cm² TCA) of 'Honeycrisp' apple trees when grown on 51 rootstocks at Hilton, NY after 7 years (Burch Plot).

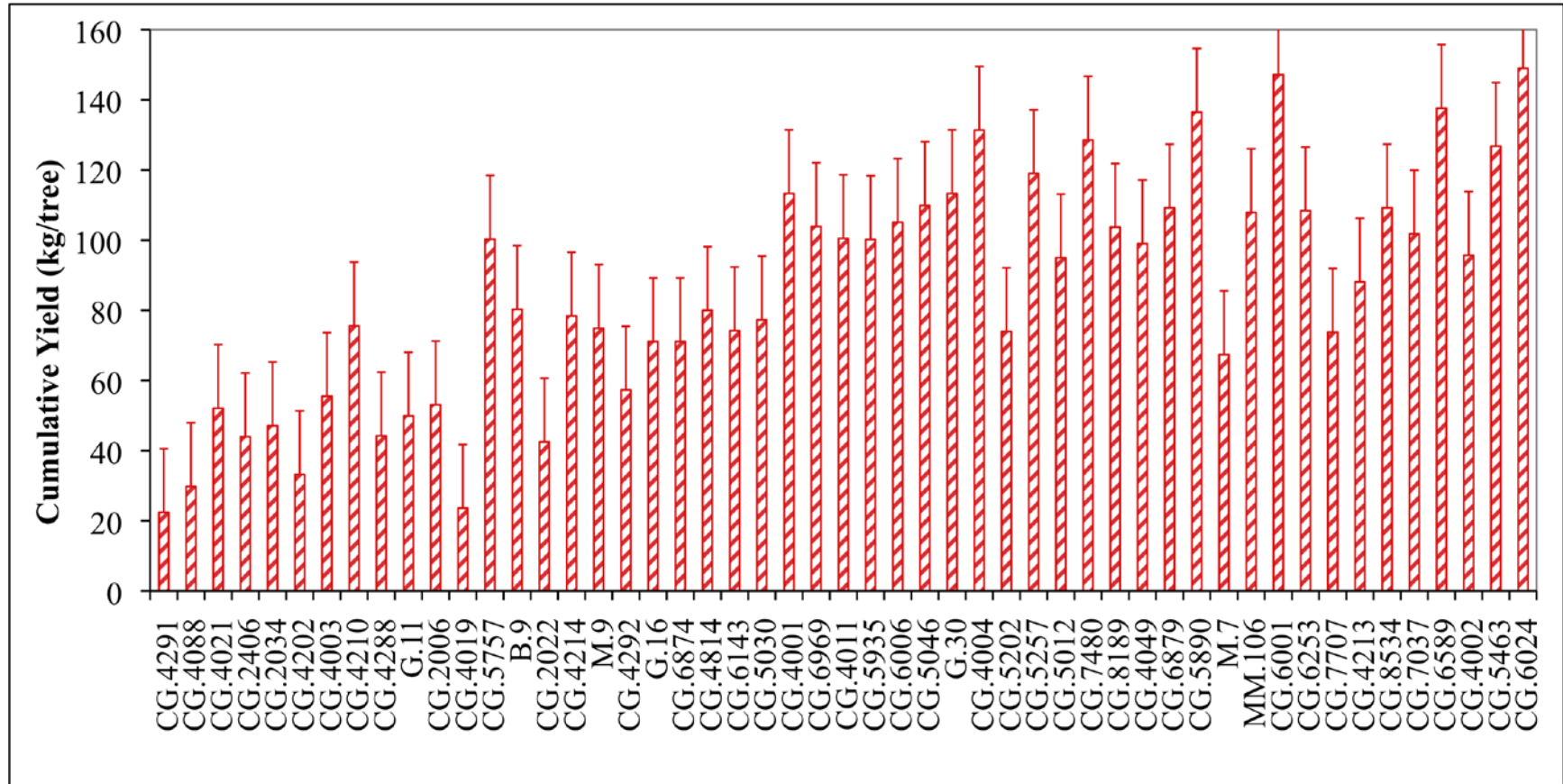


Figure 6. Cumulative yield (kg/tree) of 'Honeycrisp' apple when grown on 51 rootstocks at Hilton, NY after 7 years (Burch Plot).

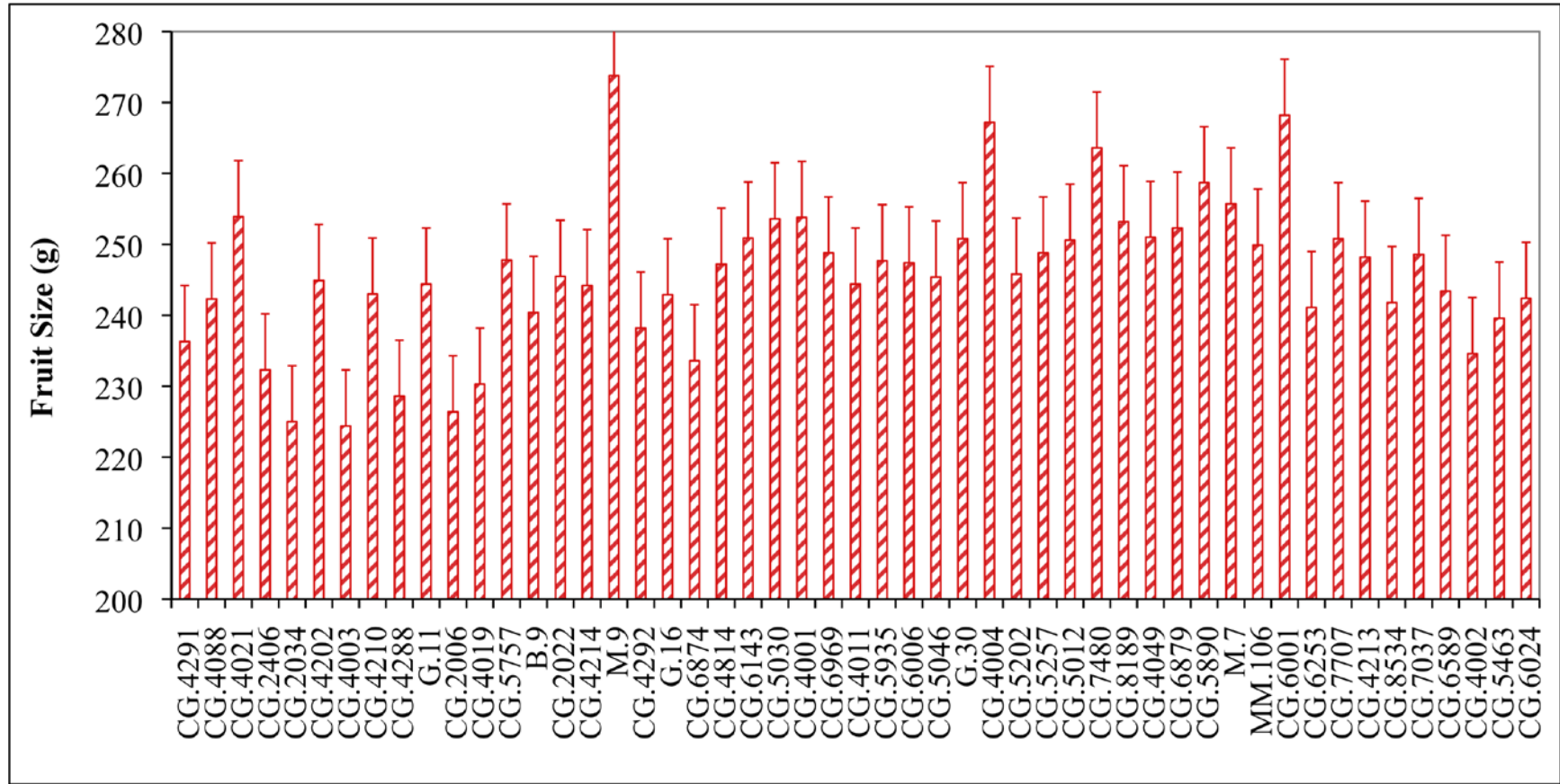


Figure 7. Average fruit size (g) of 'Honeycrisp' apple trees when grown on 51 rootstocks at Hilton, NY after 7 years (Burch Plot).

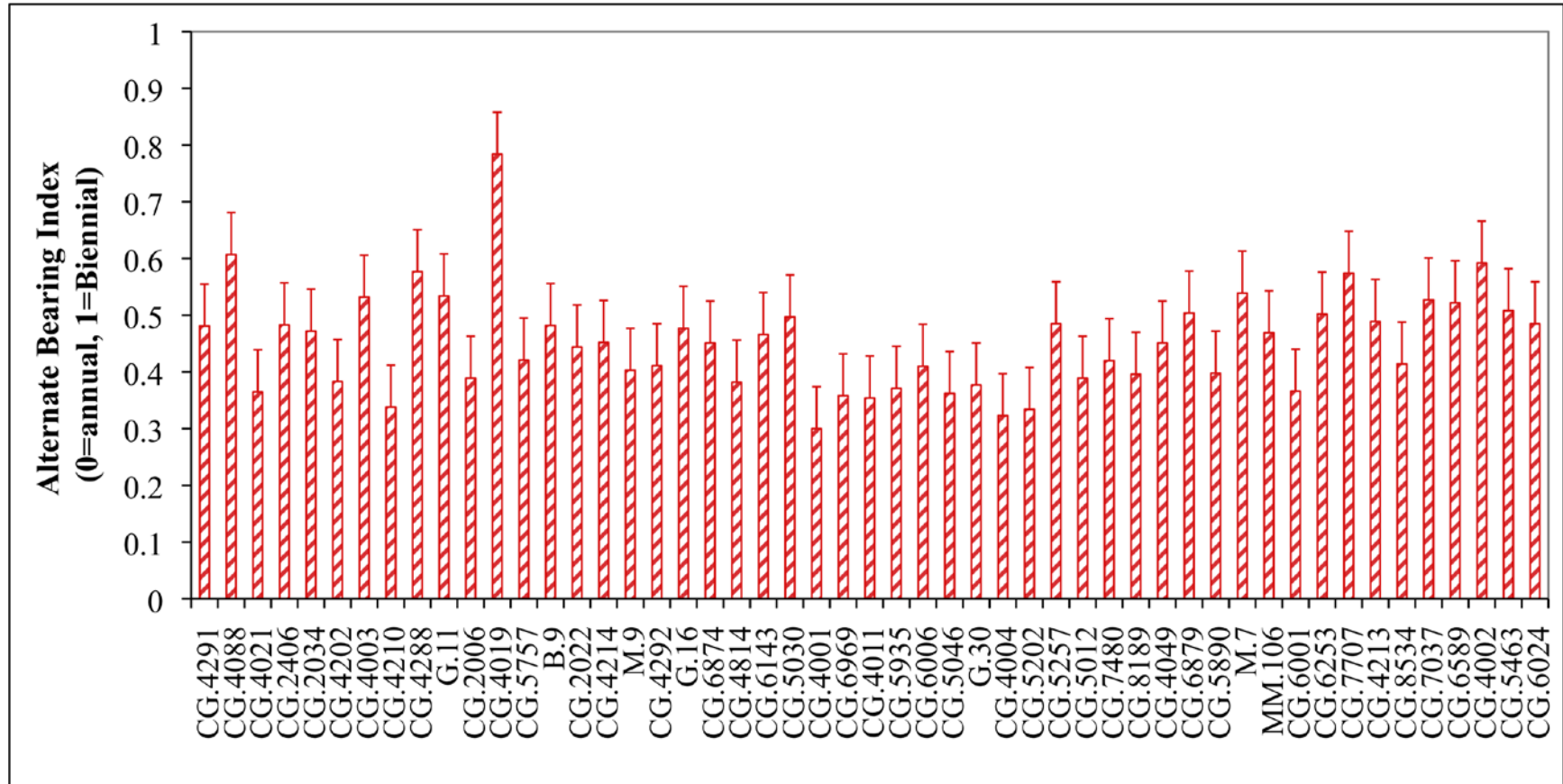


Figure 8. Alternate bearing index (0=annual cropping, 1=biennial cropping) of 'Honeycrisp' apple trees when grown on 51 rootstocks at Hilton, NY after 7 years (Burch Plot).