Effects of dwarfing and semi-dwarfing apple rootstocks on the growth and yield of Gala, Fuji and York apples

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Abstract

A field trial consisting of three apple cultivars ('Red Yorking', 'Rising Sun Fuji', and 'Buckeye Gala') grown on eight to ten dwarfing and semi-dwarfing rootstocks (G.16, G.41, G.935, G.11, G.30, B. 9, M.9 Nic 29, M.26, M.7 and/or MM.111) was established on a research farm (AHS, Jr. AREC, Winchester, VA, USA) in 2011. This trial investigated the effects of rootstocks on tree growth [e.g. trunk cross sectional area (cm^2), TCSA], fruit drop, cumulative yield (2013-2017), and cumulative yield efficiency of the scion varieties. Trees were planted in a 3.6 X 6.7m tree spacing and distributed in four randomized blocks (with two trees per experimental unit) for each cultivar. Analysis of the seven-year dataset showed significant differences among rootstocks, particularly on tree vigor; with B.9 and G.41 exhibiting the lowest TCSA values; whereas MM.111 and M.26 show the highest TCSA values. Because of their dwarfing effects on the grafted scions, both B.9 and G.41 resulted in the highest cumulative yield efficiency for all three scion varieties. However, in terms of the cumulative yield, B.9 showed the lowest values (55.0 and 87.9 kg/tree) for Gala and Fuji, respectively. The highest cumulative yield for Gala and Fuji (167.8 and 203.1 kg/tree) was obtained when trees were on G.30 and M.26, respectively. For York, values of the cumulative yield were not significant between dwarfing (e.g. B.9 and G.41 and more-vigorous (e.g. M.7 and MM.111) rootstocks. Fuji and Gala trees on G.935 also showed high cumulative yields comparable to those on G.30, but were less vigorous. Taking into consideration the suitability for high-density planting systems, cumulative yield, and reported resistance to fire blight, our results would recommend G.41, B.9 or G.30 for 'Red Yorking'; and G.41, G.935 or G.30 for 'Rising Sun Fuji', and 'Buckeye Gala'.

Keywords: apple, tree vigor, yield efficiency, GENEVA® rootstocks, fruit drop

INTRODUCTION

Modern apple production systems that take advantage of high-density production principles and dwarfing rootstocks to plant larger numbers of smaller trees into each hectare of ground. Some of the benefits associated with high-density systems include the ability to produce early crops of high-quality fruit, greater spray application efficiency, and capacity to train, prune, and harvest from the ground. Transitioning to uniform, high-density orchards would also put growers in the best possible position from which they can take advantage of new labor-reducing technologies as they are developed. The higher profitability of high-density systems over the lower-density systems have been demonstrated in several economic studies in the USA (Robinson et al., 2007). However, the cost of establishing high-density orchards is several-fold higher per land area than lower-density systems; as such, the economic risk associated with high-density orchards is relatively high (Robinson et al., 2007). This risk can be escalated if the selection of rootstocks is done without considering the climatic, soil and growing conditions that may affect their performance. Most of the high-density production recommendations in the eastern USA come from research conducted in more northern regions such as New York and Michigan, which have distinctively different growing conditions than Virginia. In particular, Virginia has a longer growing season, and more fertile soils. These factors may interfere with the physiological, biochemical and molecular pathways underlying the dwarfing phenotypes in apple.

At the genetic level, the dwarfing phenotype in apple is controlled by two major quantitative trait loci, namely Dw1 and Dw2 (Fazio et al., 2014; Foster et al., 2015). Most of the known dwarfing rootstocks contain markers associated with one or both of these loci (Foster et al., 2015). However, rootstock-induced dwarfing is also affected by environmental conditions. For instance, the primary axis of 'Royal Gala' on M.9 was found to be shorter and had fewer nodes and fewer sylleptic shoots than vigorous rootstocks when grown under the humid climate of Manawatu, NZ; whereas the same rootstock/scion combinations showed no difference when grown under the warmer and drier conditions of Hawke's Bay, NZ (Seleznyova et al., 2003; van Hooijdonk et al., 2006, 2010). In a similar study examining the effect of three different rootstocks (M.9, M.27 and M.793) on the growth and architectural development of 'Royal Gala' apple trees grown under three different locations of NZ, it was found that nearly a quarter (24.7%) of variations among rootstock/scion combinations can be explained by a principle component (PC) comprised of wind, growing degree days (GDDs) and diurnal temperature variations (Foster et al., 2016). The effect of location on the size-controlling effects of rootstocks has been also confirmed through several studies and rootstock evaluation trials in North America (Autio et al., 2008; Marini et al., 2006).

The objective of this work was to evaluate the performance of eight to ten dwarfing and semi-dwarfing rootstocks under Virginia's production conditions. These rootstocks originated from four breeding programs in the USA and Europe. The Malling rootstocks, generally referred to as M (i.e. M.7, M.9, and M.26), were selected at the East Malling Research Station, Kent, England). Malling Merton, referred to as MM (i.e. MM.111) and resulted from a collaboration between the Malling station and the John Innes Horticultural Institution, at Morton, England. The Geneva® series of rootstocks, referred to as G. (i.e. G.11, G.16, G.30, G.41, and G.935) has been developed by the Geneva Apple Rootstock Breeding Program, a joint venture between Cornell University and the United States Department of Agriculture (USDA). Budagovsky rootstocks, referred to as Bud or B. (i.e. B.9) have been developed in the Soviet Union from crossing M.8 x Red Standard (Krasnij Standart). In the present study, these rootstocks were evaluated for their effects on the growth and yield parameters of two fresh-market apples, 'Rising Sun Fuji', and 'Buckeye Gala', and a processing cultivar 'Red Yorking', widely grown in Virginia.

MATERIALS AND METHODS

In March 2011, a replicated field trial consisting of three cultivars, ('Buckeye Gala,' 'Rising Sun Fuji', and 'Red Yorking') grown on eight to ten rootstocks (G.16, G.41, G.935, G.11, G.30, B.9, M.9 Nic 29, M.26, M.7 and/or MM.111) was established on the research farm of the AHS Jr. AREC, Winchester, VA. The goal of this trial was to determine the performance of different rootstock-scion combinations under the soil and growing conditions of Virginia.

All rootstocks, except MM.111 were obtained from the same nursery (Mackintosh Fruit Farm, Berryville, VA) and were bud-grafted in August-September 2009 using virus-tested wood. Trees on MM.111 were purchased from Boyer Nursery, Biglerville, PA. Trees were planted in 3.6 X 6.7 m tree spacing (414 tree/ha), and randomly distributed in four double-tree replicated blocks. The experiment was designed to consider statistical comparisons of rootstocks within a given cultivar, but not to compare among cultivars. All trees were trained as a vertical-axe with conduit posts and a double-wire trellis to support the trees. The trees were hand watered as needed in the dry summer of 2011, and a drip irrigation system was installed in 2012. A weed-free strip was maintained under the trees during the growing season. Similar amounts of macro and micro nutrients were applied to all trees according to local recommendations. Chemical sprays to protect against damaging diseases and insects were applied to all trees at the rates and times recommended for Virginia (2018 Spray Bulletin Commercial Tree Fruit Growers, 2018). Crop loads in bearing years were managed by commercial chemical thinning practices.

The effect of rootstocks on tree vigor was assessed by determining the trunk cross-sectional area (TCSA, cm^2) and canopy spread (cm) for each rootstock-scion combination. Trunk circumference (cm) was measured in October at 10 cm above the graft union and was used to calculate TCSA. Canopy spread (cm) was measured based on the average of longest spread and longest cross-spread. Harvest yield (kg/tree) data were collected in the third year (2013), with including or excluding fruit drops. The cumulative yield was calculated for the five growing seasons (2013-2017). The cumulative yield efficiency (kg/ cm^2 TCSA) was calculated by dividing the cumulative yield, by the TCSA of the last year of this trial (2017). Analysis of variance (ANOVA) was performed for all the acquired data using the MIXED procedures of SAS statistical software (release 9; SAS Institute, Cary, NC, USA). All parameters were tested for normality prior to analysis of variance. The Tukey-Kramer HSD test was used to compare means.

RESULTS AND DISCUSSION

Tree Vigor

B.9 rootstock resulted in the smallest 'Gala' trees, based on canopy spread (cm) and TCSA (cm^2) measurements. Trees on G.41 were similar in size to those on B.9, G.11, M.26 and G.935, but smaller than M.9 Nic29 and G.16. Trees on M.7, G.30 and MM.111 had the highest TCSA values and were similar in size (Table 1). These data are similar to those reported in the 2002 NC-140 rootstock trial, where 'Gala' trees on B.9 were significantly smaller than those on M.29 Nic29 or M.26 (Autio et al., 2011).

Fuji trees with the smallest TCSAs were on B.9 and G.41. Trees on G.16, M.9 and G.935 were statistically similar in size (Table 3). Unlike 'Gala', 'Fuji' trees on M.26 came in a different size class than G.41 or M.9 Nic29 and were statistically comparable to more vigorous rootstocks, i.e. MM.111 and G.30. Similar observations were reported for Fuji trees grown under NY conditions (Reig et al., 2017).

York is of a particular importance to apple growers of Virginia, as one of the prominent processing cultivars. In the present trial, M.7 and MM.111 resulted in the largest 'York' trees (Table 5). Trees on B.9 and G.41 were significantly the smallest trees. 'York' on G.935, G.16 and M.26 also produced reasonably small trees that are statistically similar in size to G.41.

Yield and yield efficiency

For 'Buckeye Gala', the greatest cumulative yield, excluding drops, was obtained from trees on G.30 and G.935 (Table 2). Trees on G.935 rootstock showed similar yield and yield efficiency to M.9 and M.26, but they are more resistant to fire blight (Robinson et al., 2008). In addition, G.935 rootstock is resistant to *Phytophthora*, has tolerance to apple replant disease and is tolerant to cold damage (Robinson et al., 2008). Gala trees on G.41, G.11 and G.16 have also shown high cumulative yield and yield efficiency (Table 2). These rootstocks have good resistance to fire blight and *Phytophthora* root rot. However, it has previously been reported that G.16 is highly sensitive to latent viruses (Robinson et al., 2008). This was not an issue in this trial because the trees were propagated using virus-tested wood. The lowest 'Gala' yields were harvested from trees on B.9. Similar to other rootstock trials, the cumulative yield efficiency of 'Buckeye Gala' on B.9 (2.71 kg/ cm^2 TCSA) was higher than those reported for several M.9 strains, including M.9 Nic 29 (Table 2), M.9 Burgmer 756, and M.9 NAKBT337 (Autio et al., 2008; Perry and Byler, 2000).

For 'Rising Sun Fuji', crops harvested from trees on M.26 and G.30 had the highest cumulative yield values and were statistically similar to those on M.9, G.935 and G.16 (Table 4). Fuji trees on B.9 and G.16 showed the highest cumulative yield efficiency values (3.81 and 3.12 kg/cm^2 TCSA, respectively); whereas those on MM.111 showed the lowest value (1.39 kg/cm^2 TCSA). No significant differences were found among trees on G.41, G.935, G.30, M.9 and M.26. However, given the reported resistance of Geneva rootstocks to fire blight and *Phytophthora*, our results suggest that Geneva, not Malling or Malling Morton series would be a better choice for 'Fuji'.

Among the nine rootstocks evaluated in this study for 'Red Yorking', the greatest cumulative yield was harvested from trees on G.30; whereas the lowest cumulative yield was obtained from trees on M.26, G.935 and G.16 (Table 6). Interestingly, 'York' trees on B.9 or G.41 produced a cumulative yield that is statistically similar to trees on vigorous rootstocks, i.e. M.7 and MM.111. The highest cumulative yield efficiency was recorded for trees on B.9 (3.3 kg/ cm^2 TCSA), followed by G.41 (1.56 kg/cm^2 TCSA). Similarly, in the 1990 NC-140 trial, 'York' on B.9 showed the highest yield efficiency (4.87 kg/cm^2 TCSA) in VA, compared to M.9 EMLA, Mark, O.3 and M.26 EMLA (Hirst et al., 2001). The resistance of B.9 to rootstock blight was found to be comparable to that of Geneva rootstocks in several field trials (LoGiudice et al., 2004). Furthermore, B.9 produces a similar, or even smaller tree than M.9, shows resistant to collar rot and is cold-hardy, together making it a good fit for 'York' under the high-density systems.

CONCLUSIONS

Geneva rootstocks evaluated during the course of this study, G.41, G.935, G.11, G.16 and G.30 produce tree size, cumulative yield and yield efficiency that are comparable, if not better than, the widely-grown dwarfing. M.9, and semi-dwarfing rootstocks, M.26 and M.7. However, due to their reported resistance to fire blight, Geneva series show a great potential as alternatives to Malling series in Virginia and other Mid-Atlantic states, where rainy and humid spring weather can lead to severe rootstocks blights that become hardly preventable if the rootstock is not inherently resistant.

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Table 1. Growth and yield parameters of 7th leaf 'Buckeye Gala' trees grown on ten rootstocks in Winchester, VA.

Rootstock	Trunk cross-sectional area (TCSA, cm^2)[1]							2017			Yield Efficiency (fruit wt., kg/TCSA)	
	2011	2012	2013	2014	2015	2016	2017	Canopy spread (cm)	Yield incl. drops (kg/tree)	Fruit drop (by wt., kg) (%)	Drops excluded	Drops included
B.9	1.7 de	2.0 d-f	5.8 f	10.3 e	17.0 d	18.2 e	20.5 e	237 c	14.2 c	15.3 ab	0.58 a-c	0.69 ab
G.41	1.3 e	1.7 f	6.7 fg	13.3 de	28.2 cd	33.9 d	38.2 de	328 ab	32.8 ab	16.2 ab	0.69 a	0.84 a
G.11	2.1 cd	2.6 c-e	8.0 d-f	14.7 cd	32.3 c	37.1 cd	41.5 cd	308 b	25.5 bc	17.0 ab	0.49 a-d	0.61 a-c
M.26	0.8 f	1.2 f	7.3 e-g	16.1 cd	34.9 c	38.6 cd	48.1 cd	306 b	21.8 bc	22.1 a	0.34 cd	0.44 bc
G.935	2.1 bc	2.7 cd	9.3 c-e	18.2 bc	37.4 bc	45.1 cd	52.2 b-d	346 ab	32.6 ab	16.1 ab	0.50 a-d	0.62 a-c
G.16	2.6 b	3.2 bc	10.7 bc	18.5 bc	38.5 bc	49.6 bc	58.5 bc	343 ab	34.9 ab	11.1 b	0.52 a-d	0.60 a-c
M.9 Nic 29	1.4 e	1.9 ef	6.9 fg	14.9 cd	41.5 a-c	50.3 bc	58.8 bc	358 ab	29.2 bc	10.0 b	0.44 a-d	0.49 bc
M.7	3.7 a	4.2 a	14.6 a	29.1 a	53.7 a	63.3 ab	69.6 ab	339 ab	24.2 bc	15.0 ab	0.27 d	0.32 c
G.30	3.3 a	4.0 ab	12.0 b	22.1 b	50.8 ab	61.0 ab	70.9 ab	354 ab	49.8 a	7.0 b	0.65 ab	0.71 ab
MM.111	1.3 c	2.5 c-e	10.1 b-d	21.0 b	54.5 a	71.1 a	84.2 a	373 a	34.0 ab	7.3 b	0.38 b-d	0.41 bc

[1]Trunk and canopy measurements 24 and 25 Oct 2017. Full bloom 12 Apr 2017. Harvest, 10 Oct, 2017. Mean separation within column by Tukey's HSD Test (p=0.05).

Table 2. The effect of ten rootstocks on the cumulative yield (2013-17) of 'Buckeye Gala' trees grown in Winchester,

Rootstock	Yield (kg/tree) 2013		2014		2015		2016		2017		Total Yield 2013-17		Cumulative yield efficiency	
	incl. drops	excl. drops	incl. drops	excl. drops	incl. drops	excl. drops	incl. drops	excl. drops	incl. drops	excl. drops	incl. drops	excl. drops	incl. drops	excl. drops
Bud.9	4.8 c	4.8 c	7.6 b	7.6 b	19.4 bc	18.2 bc	16.4 c	15.0 c	14.2 c	12.0 c	59.9 d	55.0 c	2.95 ab	2.71 ab
G.41	5.4 c	5.4 c	18.8 a	18.8 a	43.3 a	40.8 a	33.6 b	31.8 bc	32.8 ab	26.9 bc	126.8 a-c	116.7 b	3.31 a	3.04 a
G.11	6.8 bc	6.8 bc	18.4 a	18.4 a	29.1 a-c	28.2 a-c	39.2 b	37.0 b	25.5 bc	20.5 bc	109.7 bc	101.7 b	2.67 a-c	2.47 a-c
M.26	5.0 c	5.0 c	18.5 a	18.5 a	32.0 a-c	31.1 a-c	27.6 bc	25.4 bc	21.8 bc	17.6 bc	92.9 b-d	86.1 bc	1.97 de	1.80 d-f
G.935	6.9 a-c	6.9 a-c	21.7 a	21.7 a	44.3 a	42.6 a	43.5 ab	41.0 ab	32.6 ab	26.9 bc	134.0 ab	125.2 ab	2.72 a-c	2.54 a-c
G.16	7.5 a-c	7.5 a-c	21.0 a	21.0 a	35.2 ab	34.2 ab	33.4 bc	31.8 bc	34.9 ab	30.8 ab	126.7 a-c	120.0 b	2.17 cd	2.05 c-e
M.9 Nic 29	4.8 c	4.8 c	13.4 ab	13.4 ab	18.6 bc	18.3 bc	37.9 b	35.8 b	29.2 bc	26.1 bc	98.9 b-d	93.4 bc	1.75 de	1.65 ef
M.7	9.9 a	9.9 a	16.1 ab	16.1 ab	19.4 bc	18.4 bc	41.6 b	39.2 b	24.2 bc	20.5 bc	92.2 cd	86.2 bc	1.46 e	1.35 f
G.30	9.3 ab	9.3 ab	21.9 a	21.9 a	30.9 a-c	30.3 a-c	59.1 a	57.1 a	49.8 a	45.9 a	167.8 a	161.3 a	2.37 b-d	2.28 b-d
MM.111	4.9 c	4.9 c	15.8 ab	15.8 ab	17.1 c	16.7 c	37.1 b	36.3 b	34.0 ab	31.6 ab	108.8 bc	105.3 b	1.35 e	1.31 f

Mean separation within column by Tukey's HSD Test (p=0.05).

Table 3. Growth and yield parameters of 7th leaf 'Rising Sun Fuji' grown on eight rootstocks, Winchester, VA.

	Trunk cross-sectional area (TCSA, cm^2)[1]							2017			Yield Efficiency (fruit wt., kg/TCSA)	
Rootstock	2011	2012	2013	2014	2015	2016	2017	Canopy spread (cm)	Yield incl. drops (kg/tree)	Fruit drop (by wt., kg) (%)	Drops excluded	Drops included
B.9	1.6 de	2.1 de	7.2 bc	11.2 d	16.8 e	20.4 e	23.0 e	231 c	26.8 d	5.4 b	1.06 a	1.12 a
G.41	1.2 e	1.5 e	6.9 c	15.0 c-d	30.5 de	38.0 de	43.4 de	322 b	38.0 cd	10.5 a	0.86 ab	0.96 ab
G.16	2.4 cd	2.9 b-d	8.7 bc	16.5 b-d	33.1 c-e	45.1 cd	49.9 cd	321 b	54.6 bc	7.6 ab	1.03 a	1.12 a
M.9 Nic 29	3.3 a-c	3.6 a-c	10.3 ab	19.7 a-c	43.3 b-d	56.7 a-d	62.1 b-d	370 a	64.0 ab	7.3 ab	0.97 a	1.05 a
G.935	2.4 de	2.8 cd	10.5 ab	22.6 ab	44.2 b-d	53.7 b-d	62.5 b-d	354 ab	47.7 b-d	10.7 a	0.65 ab	0.74 ab
G.30	4.0 a	4.3 a	13.3 a	26.2 a	49.3 a-c	62.6 a-c	71.2 bc	389 a	72.2 ab	7.7 ab	0.93 ab	1.01 ab
M.26	2.9 bc	3.7 a-c	13.2 a	24.3 a	57.2 ab	74.4 ab	84.5 ab	365 ab	81.0 a	7.7 ab	0.89 ab	0.97 ab
MM.111	3.5 ab	3.9 ab	12.1 a	25.2 a	62.2 a	78.7 a	98.0 a	356 ab	53.2 bc	8.9 ab	0.53 b	0.58 b

[1]Trunk and canopy measurements 24 and 25 Oct 2017. Full bloom 12 Apr 2017, Harvest, 10 Oct, 2017. Mean separation within column by Tukey's HSD Test (p=0.05).

Table 4. The effect of eight rootstocks on the cumulative yield (2013-17) of 'Rising Sun Fuji' trees grown in Winchester, VA.

	Yield (kg/tree)													
	2013		2014		2015		2016		2017		Total Yield 2013-17		Cumulative yield efficiency	
Rootstock	incl. drops	excl. drops	incl. drops	excl. drops	incl. drops	excl. drops	incl. drops	excl. drops	incl. drops	excl. drops	incl. drops	excl. drops	incl. drops	excl. drops
Bud.9	5.7 a-c	5.6 a-c	15.5 c	14.6 c	28.2 a	27.5 a	20.3 c	15.0 b	26.8 d	25.3 e	96.4 c	87.9 c	4.21 a	3.81 a
G.41	3.2 c	3.2 c	24.1 a-c	23.2 a-c	38.6 a	37.6 a	34.1 a-c	27.0 ab	38.0 cd	33.6 de	138.0 bc	124.5 bc	3.26 b	2.94 b
G.16	6.3 a-c	6.2 a-c	24.7 a-c	23.8 a-c	46.5 a	45.2 a	30.2 a-c	26.5 ab	54.6 bc	50.2 b-d	162.3 ab	151.9 ab	3.33 ab	3.12 ab
M.9 Nic 29	8.2 ab	8.0 ab	24.3 a-c	23.2 a-c	49.5 a	48.0 a	23.5 bc	21.2 ab	64.0 ab	59.0 a-c	169.6 ab	159.3 ab	2.76 b	2.59 b
G.935	4.8 bc	4.6 bc	37.7 a	36.0 a	48.6 a	46.4 a	47.1 a	36.9 a	47.7 b-d	41.9 c-e	185.9 ab	165.8 ab	3.03 b	2.69 b
G.30	3.9 bc	3.8 bc	29.9 ab	29.2 ab	46.0 a	45.1 a	39.8 ab	33.3 a	72.2 ab	66.3 ab	216.0 a	200.3 a	3.03 b	2.81 b
M.26	9.7 a	9.5 a	24.7 a-c	24.0 a-c	44.7 a	43.1 a	40.3 ab	36.7 a	81.0 a	74.2 a	179.7 ab	168.3 ab	2.44 b	2.29 b
MM.111	4.5 bc	4.3 bc	18.0 bc	17.2 bc	31.0 a	29.8 a	27.9 bc	24.8 ab	53.2 bc	47.9 b-e	127.9 bc	118.1 bc	1.50 c	1.39 c

Mean separation within column by Tukey's HSD Test (p=0.05).

Table 5. Growth and yield parameters of 7th leaf 'Red Yorking' grown on nine rootstocks in Winchester, VA.

Rootstock	Trunk cross-sectional area (TCSA, cm^2)[1]							2017			Yield Efficiency (fruit wt., kg/TCSA)	
	2011	2012	2013	2014	2015	2016	2017	Canopy spread (cm)	Yield incl. drops (kg/tree)	Fruit drop (by wt., kg) (%)	Drops excluded	Drops included
B.9	1.8 bc	2.0 bc	6.4 d	8.3 c	13.3 d	15.0 d	17.2 d	214 d	18.0 a	18.6 a	0.85 a	1.05 a
G.41	1.7 bc	2.1 bc	8.3 a-d	13.9 bc	26.6 cd	30.4 cd	37.0 cd	315 bc	13.6 a	25.5 a	0.34 b	0.43 b
G.935	1.8 bc	2.1 bc	8.3 a-d	15.9 ab	29.0 bc	32.4 b-d	41.8 bc	304 c	4.6 a	31.1 a	0.07 b	0.12 b
M.26	1.8 bc	2.2 bc	7.1 cd	14.1 bc	32.7 bc	36.1 bc	44.2 bc	298 c	3.7 a	28.2 a	0.06 b	0.09 b
G.16	2.2 ab	2.5 a-c	7.6 b-d	15.0 ab	32.1 bc	36.8 bc	49.2 bc	318 a-c	8.0 a	30.2 a	0.08 b	0.15 b
M.9 Nic 29	1.4 c	1.6 c	6.5 d	13.9 bc	35.0 bc	41.8 bc	52.9 bc	334 a-c	10.2 a	27.7 a	0.13 b	0.20 b
G.30	2.5 a	2.7 ab	10.6 a	19.3 ab	39.7 a-c	45.9 bc	57.1 bc	369 a	15.1 a	27.6 a	0.21 b	0.29 b
M.7	2.1 ab	2.5 a-c	9.7 a-c	20.5 a	41.5 ab	50.6 ab	65.1 ab	345 a-c	15.8 a	16.7 a	0.19 b	0.23 b
MM.111	2.7 a	3.5 a	10.2 ab	18.7 ab	49.4 a	65.1 a	86.2 a	366 ab	14.1 a	22.7 a	0.12 b	0.16 b

[1]Trunk and canopy measurements 24 and 25 Oct 2017. Full bloom 12 Apr 2017. Harvest, 10 Oct, 2017. Mean separation within column by Tukey's HSD Test (p=0.05).

Table 6. The effect of nine rootstocks on the cumulative yield (2013-17) of 'Red Yorking' trees grown in Winchester,

Rootstock	Yield (kg/tree)													
	2013		2014		2015		2016		2017		Total yield 2013-17		Cumulative yield efficiency	
	incl. drops	excl. drops	incl. drops	excl. drops	incl. drops	excl. drops	incl. drops	excl. drops	incl. drops	excl. drops	including drops	excluding drops	including drops	excluding drops
Bud.9	6.5 a	5.0 a	8.6 bc	6.9 b	22.1 a	16.9 a	19.4 b	14.0 a	18.0 a	14.5 a	74.4 b	57.2 ab	4.33 a	3.33 a
G.41	7.1 a	4.7 a	14.2 b	8.5 b	25.0 a	13.7 ab	29.0 b	17.1 a	13.6 a	10.7 a	88.9 ab	54.6 ab	2.53 b	1.56 b
G.935	5.9 a	3.7 a	12.7 bc	8.6 b	19.7 ab	14.4 ab	29.9 ab	15.8 a	4.6 a	2.6 a	72.8 b	45.0 ab	1.77 b-d	1.09 bc
M.26	5.9 a	3.7 a	12.6 bc	9.4 ab	20.1 ab	9.9 ab	27.7 b	17.0 a	3.7 a	2.4 a	59.6 b	36.8 b	1.59 b-d	0.93 bc
G.16	5.9 a	4.7 a	14.9 ab	12.1 ab	12.9 ab	5.9 b	30.0 ab	18.7 a	8.0 a	4.5 a	61.6 b	82.9 a	1.48 cd	0.92 bc
M.9 Nic 29	4.7 a	4.0 a	11.5 bc	8.5 b	14.9 ab	9.3 ab	35.4 ab	26.1 a	10.2 a	6.8 a	76.7 b	54.7 ab	1.47 cd	1.02 bc
G.30	7.9 a	5.9 a	22.7 a	16.7 a	21.1 ab	11.5 ab	49.7 a	34.3 a	15.1 a	10.8 a	116.6 a	79.2 ab	2.09 bc	1.42 bc
M.7	5.5 a	4.7 a	10.6 bc	7.1 b	21.9 a	14.1 ab	38.6 ab	29.2 a	15.8 a	12.7 a	92.4 ab	67.7 ab	1.41 cd	1.02 bc
MM.111	7.1 a	5.7 a	5.8 c	4.7 b	8.3 b	5.8 b	32.5 ab	24.6 a	14.1 a	10.4 a	61.0 b	46.2 ab	0.80 d	0.60 c

Mean separation within column by Tukey's HSD Test (p=0.05).