Evaluation of Dwarfing Rootstocks in Washington Apple Replant Sites

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Abstract

Apple replant disorder is an increasingly significant factor challenging apple (*Malus* × *domestica*) orchard establishment and consistent production. Standard fumigation practices using Telone or Vapam offer effective control, but must be applied correctly and safely, are expensive, subject to restrictive regulation, and not acceptable in organic systems. Dwarfing rootstocks with resistance or tolerance to apple replant disorder offer a clear alternative to producers in tree fruit production areas of the Pacific Northwest of the USA, as long as their genotypes are suitably adapted to the diverse production conditions of the region. In collaboration with the USDA-ARS/Cornell University National Apple Rootstock Breeding Program in Geneva, NY, the Washington Tree Fruit Research Commission (WTFRC) has conducted eight rootstock trials in commercial Washington orchards since 2003. These trials collectively included 65 rootstocks and three scion cultivars ('Gala', 'Fuji' and 'Honeycrisp') planted in modern, high density systems in known replant sites. They featured 46 Geneva® (G.) series selections, as well as 19 other genotypes. Trials were designed as split block (fumigated vs. non-fumigated) randomized complete blocks with a minimum of four replications and typically five or more trees per plot. Most Geneva® rootstocks outperformed the industry standards of Budagovski (B.) 9, Malling (M.) 9 Pajam 2, and M.26 for yield, trunk cross sectional area, and fruit size. Supporter 1, Supporter 2, and Supporter 3 have performed similarly to M.9 clones and have shown no advantage over standard commercial rootstocks. Several Geneva® selections G.41 (tested as CG.3041), G.935 (tested as CG.5935), CG.4214, CG.4814 have performed well in non-fumigated treatments across sites. Trees with G.41 and G.11 rootstocks have shown less vigor than trees on G.935, CG.4214, G.202, and CG.4814. Many of the Geneva® series also show significant improvement over currently available rootstocks for other traits including wooly apple aphid resistance, fire blight resistance, ease of propagation. Our collaborative trials under commercial conditions clearly indicate the potential of improved genotypes for apple production in the Pacific Northwest of the USA.

INTRODUCTION

Plantings of high density apple orchards utilizing dwarfing rootstocks are increasingly significantly in Washington State, USA. Innovative producers are planting more trees per hectare and choosing less vigorous and more precocious dwarfing rootstocks (Robinson et al., 2007). Establishing new orchard requires high capital investment which is threatened by changing markets and global supplies, but also by diseases that kill trees and disorders that impair orchard establishment. Fireblight is one of the first diseases addressed by the Geneva® apple rootstock breeding program. Most of the current rootstock cultivars planted are very susceptible to fireblight. The most common rootstocks now used are from the M.9 family which is very susceptible to fireblight. In combination, susceptible scions and susceptible rootstocks create a risk for large tree losses, especially in favorable environments for fireblight. The biggest losses however, occur from replant disorders where trees do not grow a canopy large enough to provide economically viable yields. Several candidates from the Geneva® rootstock breeding program are being evaluated for horticultural traits and disease resistance (Russo et al., 2007).

As virgin soil becomes scarcer and old orchards decline economically, interest in replanting old sites is increasing. Replanting of old orchard sites in Washington State historically has resulted in unevenly development of the canopies and unacceptable economic performance. Consecutive plantings of deciduous fruit trees in the same soil can create replant disorder and soil fumigation is generally recommended (Washington State University Extension, 2008).

Peak economic performance is achieved when orchards establish their canopies within two seasons, with commercial production of 40 t/ha in the third or fourth leaf and full production of 70 t/ha in the seventh season. Replant susceptible rootstocks, inadequate site preparation, often in combination with an outdated irrigation design results in inconsistent tree growth. Disease resistant rootstocks show promise of increased productivity and reduced risk of replanting on old tree fruit orchard sites.

MATERIALS AND METHODS

Sites were prepared by disking and deep ripping, followed by shanking of 335 L of Telone C17 per hectare or spraying 748 L per treated hectare with Metam Sodium through a sprinkler system or fixed boom with the irrigation system in operation. While fall fumigation is recognized as standard industry practice, spring fumigation was utilized for these trials to accommodate late modifications to trial protocols and planting designs. Trees were typically planted in late May or early June after a standard four week waiting period following fumigant application. The finished trees provided by the USDA-ARS/Cornell University National Apple Rootstock Breeding Program in Geneva, NY were planted 0.91 m between trees in the row with tall spindle architecture. Row spacing varied from 2.5 m to 4.9 m, giving a range of planting densities from 2,240-3,586 trees per ha. All trees were managed to fit a 2.5 to 3 m row center. The planting a Vantage, NY utilized plant-in-place bench grafts and featured an angled canopy with a spacing of 3.7×0.5 m with 5,977 trees/ha. Newly planted trees were pruned by removing all branches and heading the central leader at 75 cm above the ground. Trials were designed as split block (fumigated vs. non-fumigated) randomized complete blocks with a minimum of four replications and five to seven trees of the same rootstock in each plot. This permitted appropriate statistical analysis while allowing producers to examine multiple tree plots in relevant commercial settings. Data collected included trunk cross sectional area, fruit number per tree, fruit weight per tree, and tree survival.

All trials were managed by commercial growers following standard horticultural practices. Trial locations and the number of genotypes in test are presented in Table 1. Trials were designed for eight seasons of data collection, including three seasons of canopy establishment and five seasons of full commercial production, after which time the blocks were turned over to grower cooperators.

RESULTS AND DISCUSSION

In Washington State, USA a definition of success for new plantings is to produce a cumulative yield of 120 t/ha or more, by the end of the fifth season with fruit size above 200g. Since yield is the primary economic driver for successful orchards, it is used as a key assessment tool for WTFRC trials. Fumigation enhanced yield of all rootstocks in the Wapato replant site (Fig. 1). G.41 (testes as CG.4041), G.935 (tested as CG.5935), and CG.4214 in particular had promising yields in both fumigated and non-fumigated trials. G.11 is very productive with fumigation and is better than M.9 Nic29 or M.9 Pajam 2. B.9 at the 0.91 m in-row tree spacing did not fill the space and is judged as not successful.

The Chelan and Wapato sites show two very different growth rates (Figs. 2 and 3). The Chelan site is a very difficult replant site, where the Geneva® rootstocks show a significant and improved growth difference in both fumigated and non-fumigated trials over the other rootstocks. In Wapato, most rootstocks grew acceptably in fumigated and non-fumigated soil with M.26 being the largest tree. In this one trial, M.26 grew well, but did not have yields competitive with the Geneva® rootstocks, especially in then non-fumigated trials. In most other replant trials, M.26 did not exceed growth of vigorous clones of M.9. G.11 while similar in size to B.9 but had much better yield than B.9. In nearly all trials, B.9 has disappointing yield and tree growth.

Fazio (Washington Tree Fruit Research Commission, 2008) points out that tree growth, as measured by TCSA, was greatest in the first season and became much less thereafter. The Chelan data (Fig. 3) supports this observation, for most trees had little growth the first season. G.16, G.41 and G.935 rootstocks continued to outgrow other rootstocks in both fumigated and non-fumigated trials. The rate of growth of these three rootstocks was similar in fumigated and non-fumigated trials. This highlights the difference between chemical control, which is short lived, versus genetic control which is present for the life of the tree.

Supporter 1, Supporter 2, and Supporter 3 rootstocks were similar in tree size and yield to M.9 rootstocks in Washington State, but do not offer disease resistance or significant replant disorder tolerance. Supporter 2 may be more replant sensitive than the other Supporter rootstocks (Figs. 1, 2, and 3).

Using benchgrafts or sleeping eyes instead of finished trees is becoming a common practice for growers in Washington State using precise high density canopy management practices. These small plants have less and shorter transplant shock and can grow up to 15 cm per week. A highly formalized training system takes advantage of the vigor provided by benchgrafts over feathered nursery trees. Branching can be reliably obtained at each wire when the terminal has passed a wire by 10 cm with timely management practices. Only two branches per wire are kept. In contrast, most finished trees are severely pruned to obtain the small amount of tree to start a two dimensional fruiting wall. Success of benchgrafts or sleeping eyes depends on several cultural practices including selection of plant material, drip irrigation, fertigation through the drip, weed management, trellis construction and timely horticultural management. Mark rootstock has been used successfully by the Auvil Fruit Company at their orchard in Vantage, Washington. In our rootstock trial at Vantage using 'Fuji', Mark rootstock demonstrated high graft take and consistency of initiating growth (Table 2). In contrast, high mortality and lack of growth were seen with G.16 CG.5046 and CG.4019. These symptoms are consistent with virus hyper-sensitivity induced by infected scion wood. Other Geneva® rootstocks, G.41, G.935, G.11, CG.2034 CG.4214, and CG.4004 developed their canopies at a similar rate as Mark. CG.5257, CG.5463, CG.3001 and G.30 were more vigorous than Mark and may be too vigorous in this production system, as trees on these rootstocks persist in growing unwanted shoots that are pinched off or treated chemically.

CONCLUSIONS

Disease resistant rootstocks G.41, CG.4214 and G.935 can maintain growth after the first leaf and significantly out grow industry standards in tough replant conditions. G.11, G.41, G.935, and CG.4214 have had greater yields than M.9 in most trials. When good management is combined with fumigation, disease resistant dwarfing rootstocks, drip irrigation and fertigation, replanted orchards will exceed performance of orchards planted on virgin ground using clones of M.9.

Fumigation has a strong effect on yield which continues past the first year. There is significant site to site variability of fumigation effect and also rootstock performance, especially with the industry standards such as M.26 and M.9 Nic29. The Geneva rootstocks, especially G.11, G.41, G.935, and CG.4214 have not exhibited measurable site to site variance. These rootstocks have considerable promise for the Washington State apple industry.

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<u>Tables</u>

Table 1. Locations and details of rootstock trials in Washington State in cooperation with USDA/ARS/Cornell University.

Trial duration	Location	Trial type	Cultivar	Number of genotypes
2003 – 2011	Royal City	Rootstock	Honeycrisp	24
2003 – 2011	Chelan	Rootstock	Honeycrisp	24
2004 – 2012	Naches	Replant	Honeycrisp	16
2004 – 2012	Chelan	Replant	Gala	12
2004 – 2012	Wapato	Replant	Gala	12
2006 – 2014	Wapato	Replant	Gala	34
2006 – 2014	Brewster	Replant	Fuji	24
2006 – 2014	Vantage	Plant in Place	Fuji	28

Table 2. Survival, growth and flowering of 'Fuji' apple trees on 28 rootstocks at Vantage, WA over 3 years ^{z}.

Rootstock	Survival (%)	Tree height 2007 (m)	Branches per tree	Trunk cross-sectional area 2007 (cm^2)	Flower number 2008
CG.2034	96 a ^{z}	10.7 abcd	11.3 abcde	3.7 cdef	48.7 a
CG.2406	82 ab	8.9 def	8.9 defgh	2.7 f	19.3 fgh
CG.3001	100 a	11.3 ab	12.4 abc	5.3 ab	36.2 bcde
CG.3007	96 a	9.5 bcdef	9.3 bcdefgh	3.0 ef	20.2 fgh
G.41	96 a	10.9 abc	12.0 abcd	4.8 abcd	36.5 abcd
CG.4002	25 cd	3.9 g	1.4 i	0.9 h	6.6 i
CG.4004	96 a	11.1 abc	12.1 abcd	4.6 abcd	16.5 ghi
CG.4011	96 a	11.3 ab	12.3 abc	4.7 abcd	36.9 abcd
CG.4013	55 bc	8.2 f	7.2 gh	3.6 def	20.1 fgh
CG.4019	6 d	-	-	-	-
CG.4172	96 a	8.4 ef	7.5 fgh	5.6 fg	41.0 abc
CG.4202	100 a	10.9 abc	11.8 abcd	4.3 abcde	23.8 efg
CG.4210	100 a	9.4 cdef	9.2 bcdefgh	2.7 fg	39.7 abc
CG.4214	96 a	11.0 abc	11.1 abcde	3.9 bcdef	44.5 ab
CG.4288	92 a	9.3 cdef	9.1 cdefgh	3.3 def	35.3 bcde
CG.4814	100 a	9.4 cdef	8.3 efgh	3.0 ef	22.0 fgh
CG.5046	8 d	4.9 g	1.5 i	-	-
CG.5087	91 a	10.3 abcde	10.4 abcdefg	3.7 cdef	25.1 defg
CG.5179	100 a	10.6 abcd	10.9 abcde	2.9 ef	44.7 ab
CG.5202	88 ab	10.4 abcd	10.8 abcdef	4.8 abcd	21.1 fgh
CG.5257	100 a	11.5 a	12.7 a	5.7 a	29.6 cdef
CG.5463	91 a	11.3 ab	12.4 ab	5.9 a	9.8 hi
G.935	92 a	11.4 a	12.3 abc	4.7 abcd	29.8 cdef
G.11	100 a	11.2 abc	12.0 abcd	3.7 cdef	38.8 abc
G.30	100 a	11.5 a	12.8 a	5.5 a	35.9 bcde
Mark	100 a	11.2 abc	12.4 ab	5.2 abc	35.2 bcde
Sup.4	94 a	9.3 cdef	9.2 bcdefgh	3.3 def	17.8 fghi
G.16	0 d	-	-	-	-

^{z}Orchard was established utilizing bench grafting and plant-in-place techniques in 2006.
^{y}Mean separation by Tukey's test (p<0.1) (n = 4). Values with the same letter do not differ significantly.

Figures

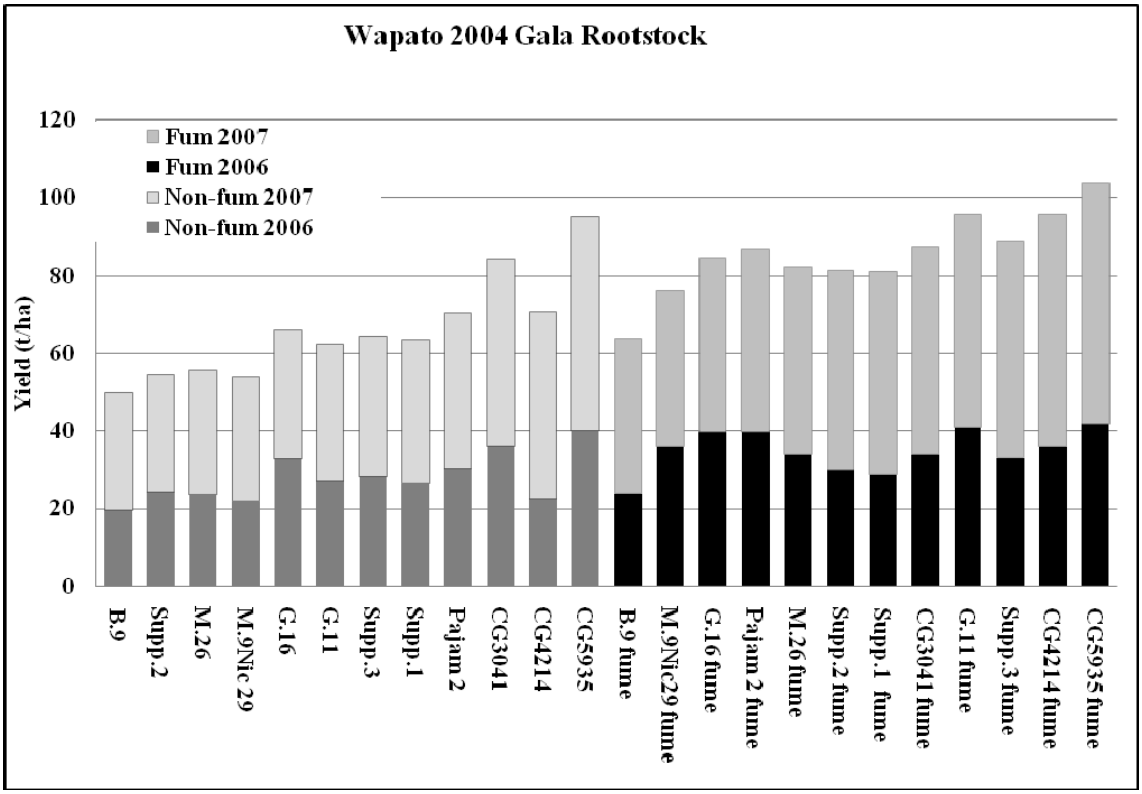

Fig. 1. Cumulative yield over 4 years of 'Gala' apple trees on 12 rootstocks with and without pre-plant fumigation at Wapato, WA. Trial was planted in 2004.

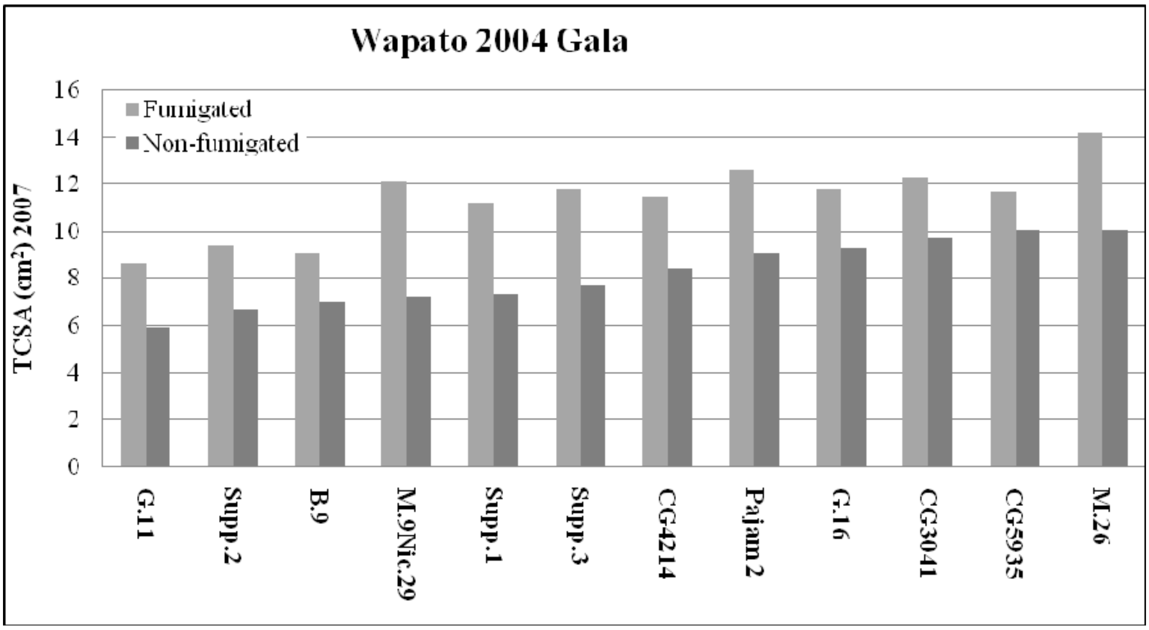

Fig. 2. Trunk cross sectional area after 4 years (2007) of 'Gala' apple trees on 12 rootstocks with and without pre-plant fumigation at Wapato, WA. Trial was planted in 2004.

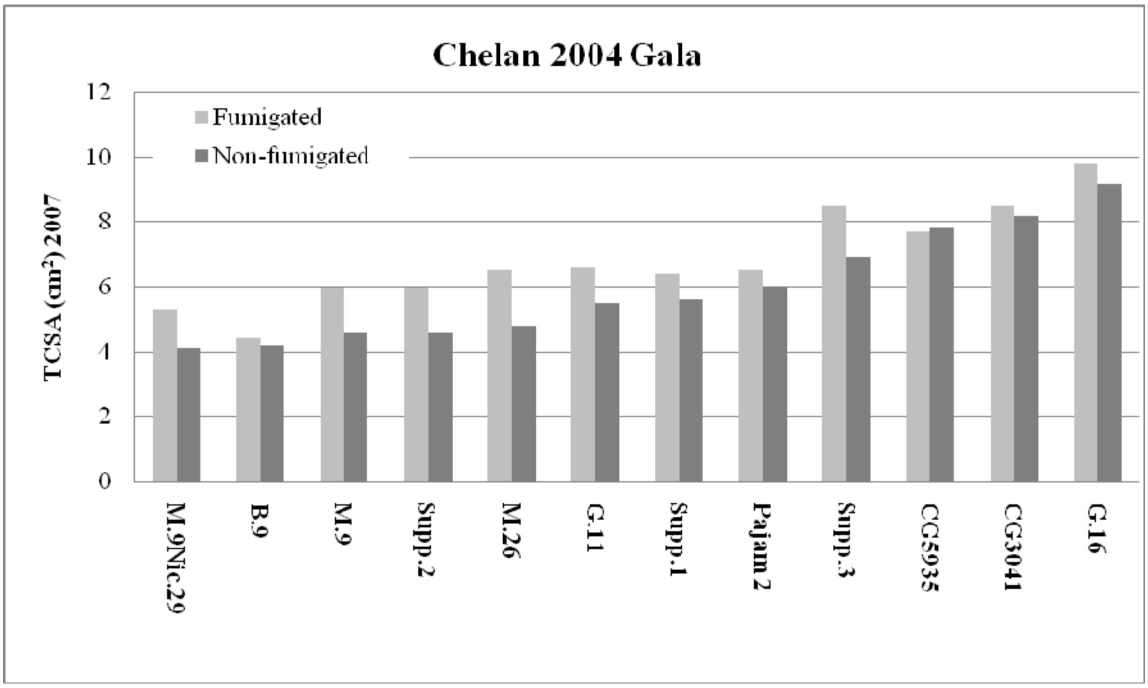

Fig. 3. Trunk cross sectional area after 4 years (2007) of 'Gala' apple trees on 12 rootstocks with and without pre-plant fumigation at Chelan, WA. Trial was planted in 2004.