NOTE

Performance of new apple rootstocks for Gala variety in Southern Brazil

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Crop Breeding and Applied Biotechnology
16: 147-152, 2016
Brazilian Society of Plant Breeding.
Printed in Brazil
http://dx.doi.org/10.1590/1984-70332016v16n2n22

Abstract: *The objective of this study was to evaluate the performance of Geneva® apple rootstocks for 'Gala'. The experiment was set in a complete randomized block design with four replications of tree plants per plot. It was used ten Geneva® rootstocks and M.9EMLA and M.7EMLA as controls. It was evaluated plant vigor, annual yield, cumulative yield, cumulative yield efficiency and fruit weight. For 'Gala' vigor control, G.10 and G.757 were more efficient than M.9EMLA; CG.2022 was equivalent and the other rootstocks were less efficient. 'G.24', 'G.969', 'G.30' and 'G.210' presented vigor equivalent to 'M.7EMLA'. 'G.896' was the most vigorous. Among dwarfing rootstocks, G.213 and G.757 were the most efficient on cumulative yield, the last showing the highest cumulative yield efficiency. Among semi-dwarfing, G.210 showed the highest cumulative yield and the highest cumulative yield efficiency. 'G.896' induced higher cumulative yield than 'M.7EMLA'. The greatest 'Gala' fruit weight was on 'G.213' and 'CG.2022'.*

Key words: Malus x domestica *Borkh., geneva series, cumulative yield, cumulative yield efficiency, mean fruit weight.*

INTRODUCTION

The use of rootstocks to grow deciduous fruits is a millenary practice (Webster and Wertheim 2003). Formerly, rootstocks were used to propagate different scion cultivars due to difficulties of propagation by cuttings. Nowadays, apple rootstocks must have good performance in scion vigor control, precocity of bearing, high yield, good fruit quality and resistance to soil-borne diseases and pests (Webster 2002). These parameters have been largely taken into account in apple rootstocks breeding research worldwide. The equilibrium of crop efficiency and fruit quality with an easier plant management and lower production costs may also be achieved with the correct choice of the rootstock (Webster and Wertheim 2003).

Although most of the present studies on apple rootstocks consider many traits of high agronomic value, it is necessary to solve limiting local factors, such as those related to soil, climate and diseases problems (Webster and Wertheim 2003). The prevalent temperature and rainfall pattern in the apple growing region of Southern Brazil subjects the trees to soil diseases and pests, such as root rot (*Phythophtora cactorum*) and woolly apple aphid (*Eriosoma lanigerum*) (Boneti et al. 1999), demanding local research to overcome these problems. Although most researches carried out worldwide to get new apple rootstocks is related to diseases resistance, only a few rootstocks breeding programs included simultaneously resistances to diseases and insects (Cummins

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Received: 27 August 2014
Accepted: 11 December 2015

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and Aldwinckle 1983a). For the South Hemisphere, woolly apple aphid seems to be a limiting pest (Webster et al. 2000). However, the works on apple rootstocks breeding are mainly concentrated in the North Hemisphere (Cummins and Aldwinckle 1983b), where this pest is not important.

Rootstocks of the American Geneva® series (Johnson 2000, Robinson et al. 2006) seem to be those which better satisfy the spectrum of agronomic traits required for growing apples in Southern Brazil. Most of the 20 traits described for the Geneva® series by Cummins and Aldwinckle (1983b) fully satisfy the Brazilian needs. The emphasis is on scion vigor control, on high capacity to induce precocity of bearing and ability to induce trees for high and constant yields of good fruit quality. The simultaneous resistance to root rot disease and woolly apple aphid, the easy propagation by conventional methods, the absence of suckers and burrknots, the graft union compatibility, and the scion free standing are important additional traits of the Geneva® Apples Rootstock Breeding Program. Most of the Geneva® apple rootstocks also have good tolerance to apple replant disease - ARD (White and Tustin 2000, Tustin et al. 2003), an essential trait for renewing apple orchards, which nowadays are very common in Southern Brazil. Some of them induce better lateral branching to the scion under mild winters (Denardi et al. 2013), and some of them have the ability to induce better branch angle to the scion (Fazio and Robinson 2008), which are traits that reduces costs for artificial breaking dormancy and trees training. Identification of new rootstocks for apple has been an urgent demand by apple growers in Southern Brazil. The objective of this study was to compare the performance of different apple rootstocks of the Geneva® series, which has been previously proven to be resistant to root rot and to woolly apple aphid.

MATERIAL AND METHODS

The experiment was set in 1996 in Fraiburgo, in the State of Santa Catarina (lat 27° 00' 12.8" S, long 50° 54' 52.0" W, alt 1,050 m asl), in a complete randomized block design - CRB, with four replications and three plants per plot. Treatments were the Geneva® series apple rootstocks G.10, CG.2022, G.24, G.30, CG.58, G.210, G.213, G.757, G.896 and G.969, and the controls were M.9EMLA (dwarfing) and M.7EMLA (semi-dwarfing), all of them were grafted with Gala as scion variety. These rootstocks were previously selected for resistance to root rot and to woolly apple aphid, and for some other agronomic traits also suitable for the needs of Southern Brazil region.

The experimental orchard was established in 1996 at 1,050 m above sea level, under 1,226 accumulated Chilling Units, according to a modified North Carolina model (Ebert et al. 1986). Evaluations were carried out from 1998/1999 to 2003/2004 seasons. Fertilizers and limestone were applied to improve soil fertility according to the recommendations for apple cultivation in Southern Brazil. The orchard had Gala as main variety and Fuji as pollinator variety, which were planted in 4m x 2m spacing. Plants were thinned in order to leave one fruit per cluster in the lateral buds and two to tree fruits per cluster in terminal buds.

The evaluated variables were: trunk cross sectional area - calculated by the equation TCSA = $\pi d^2/4$ (cm^2), according to the methodology of Czynczyk and Bielicki (2012), where d is the diameter of the stem taken at 5 cm above the graft union; annual yield (kg $tree^{-1}$); cumulative yield during the evaluated period (kg $tree^{-1}$); mean fruit weight (g); and cumulative yield efficiency (CYE), obtained by the ratio between the cumulative yield and the TCSA (kg of fruit per cm^{-2} of TCSA).

Data were subjected to the SISVAR statistical program (Ferreira 2011) for analysis of variance, in order to evaluate the significance of the interactions and the effects of the rootstocks on performance of Gala variety. Mean values were compared using the Scott-Knott test ($P < 0.05$).

RESULTS AND DISCUSSION

For annual mean yield (kg $tree^{-1}$), it was observed significant effect for rootstock x year interaction. However, there was no significant effect for this interaction for mean fruit weight.

According to Webster (1995), the measure of the trunk diameter is the most common variable used to estimate apple tree size. Based on this criteria, the Geneva® apple rootstocks G.10 and G.757 were the most efficient in controlling the vigor of the canopy measured by the TCSA, being significantly more efficient than M.9EMLA for the canopy of 'Gala' (Table 1). However, 'Gala' grafted on 'G.757' developed stem and branches thinner and longer than on the other rootstocks (data not shown), suggesting that G.757 has no more dwarfing effect than 'M.9EMLA' in controlling the development of 'Gala'. 'CG.2022' presented dwarfing effect similar to 'M.9EMLA'. 'G.213' and 'CG.58' showed efficiency in controlling the vigor of 'Gala' intermediate between the controls 'M.9EMLA' and 'M.7EMLA'. The rootstocks G.24, G.969, G.30 and G.210 were all equivalent in controlling the vigor of 'Gala', being similar to the control M.7EMLA. The most vigorous rootstock evaluated was G.896, showing TCSA significantly higher than M.7EMLA. Robinson and Hoying (2004) and Robinson et al. (2011), studying the performance of apple varieties on different rootstocks, observed that the vigor of the trees grafted on the rootstocks G.30 and G.210 was in between the dwarfing M.26 and the semi-dwarfing M.7. When grafted on 'G.969', the vigor of 'Gala' was in between that induced by 'M.9EMLA' and 'M.7EMLA', and it was estimated to be similar to that obtained with 'M.26EMLA'. In the present study, 'G.969' had TCSA equivalent to that of the rootstock M.7EMLA.

For the annual mean yield (kg tree^{-1}), it was observed that the low crop load in 1998/99 was related to the first commercial crop of the orchard. The low crop load observed in the 2000/01 and 2002/03 growing seasons (Table 2) may have been due to a deficient thinning carried out in each of the previous years, causing biennial bearing in 'Gala' (Camilo et al. 1991).

For the performance of 'Gala' on the dwarfing rootstocks, (Table 2), the highest annual mean yields were obtained on G.213 rootstock during the five years of evaluation, showing to be the one with the most regular performance among the dwarfing rootstocks in this trait along the five growing seasons. Even though 'G.757' showed higher annual mean yield for 'Gala' than 'M.9EMLA' in most of the seasons, it was observed more yield regularity of 'Gala' on 'G.213'. G.10

Table 1. Trunk cross sectional area (TCSA), cumulative yield (CY), cumulative yield efficiency (CYE) and fruit weight of 'Gala' grafted on different apple rootstocks, Fraiburgo/SC – growing seasons from 1998/1999 to 2003/2004

Rootstock [1]	TCSA (cm^2)	Cumulative yield (kg tree^{-1})	Cumulative yield efficiency (kg of fruits/cm^{-2} of TCSA)	Mean fruit weight (g)
G.10	11.45 e	19.03 g	1.66 c	122.00 b
G.757	15.02 e	65.18 e	4.34 a	124.12 b
M.9 EMLA	22.03 d	53.36 f	2.42 b	123.77 b
CG.2022	22.64 d	60.76 e	2.68 b	133.62 a
G.213	28.02 c	85.67 c	3.06 b	136.89 a
CG.58	28.51 c	49.04 f	1.72 c	110.61 d
G.24	32.23 b	79.75 d	2.47 b	119.72 c
G.969	34.55 b	92.85 b	2.69 b	118.13 c
M.7 EMLA	37.01 b	65.24 e	1.76 c	116.73 c
G.30	39.08 b	92.40 b	2.36 b	124.36 b
G.210	39.66 b	98.98 a	2.50 b	125.86 b
G.896	50.88 a	94.02 b	1.85 c	119.74 c

[1] Means followed by the same letter in the column do not differ significantly (P > 0.05) by the Scott-Knott test.

Table 2. Mean annual yield of Gala apple grafted on different rootstocks, Fraiburgo/SC – growing seasons from 1998/1999 to 2003/2004

Rootstock[1]	Annual mean yield (kg tree^{-1})				
	1998/99	1999/00	2000/01	2001/02	2002/03
G.10	1.51 Bd	6.90 Af	1.62 Bd	7.78 Af	1.22 Bg
G.757	8.71 Ca	17.90 Bd	8.31 Cb	23.51 Ad	6.74 Ce
M.9 EMLA	6.83 Cb	14.10 Be	7.52 Cb	20.40 Ae	4.51 Df
CG.2022	5.51 Cc	15.30 Be	7.09 Cb	18.86 Ae	14.01 Bc
G.213	8.73 Ca	24.02 Ac	8.33 Cb	24.24 Ad	20.34 Ba
CG.58	3.92 Cc	15.30 Be	5.74 Cc	19.51 Ae	4.57 Cf
G.24	6.46 Cb	26.40 Ab	7.89 Cb	27.31 Ac	11.69 Bd
G.969	10.45 Da	24.10 Bc	12.06 Db	31.80 Ab	14.44 Cc
M.7 EMLA	5.22 Dc	18.80 Bd	5.30 Dc	28.40 Ac	7.82 Ce
G.30	6.83 Db	26.20 Bb	8.84 Db	32.21 Ab	18.33 Cb
G.210	7.25 Eb	25.50 Bb	9.55 Db	34.63 Aa	22.04 Ca
G.896	10.62 Ca	28.70 Ba	12.30 Ca	34.01 Aa	8.39 De

Means followed by the same uppercase letter in the line and by the same lowercase letter in the column do not differ significantly (P > 0.05) by the Scott-Knott test.

was the worst rootstock evaluated in this study, inducing the lowest annual mean yield to 'Gala' in all growing seasons (Table 2). For the most vigorous rootstocks, it was shown that G.896 and G.210 induced 'Gala' to express the highest yield, both more efficient than M.7EMLA (Table 2), mainly G.210, which induced 'Gala' to express higher yields all over the five growing seasons. 'G.896' performed better than 'G.210' during the first three growing seasons, but it was less efficient in the last growing season. 'G.969' induced 'Gala' to express higher yields than 'M.7EMLA', and presented less biennial bearing along the years, when compared to the two controls 'M.9EMLA' and 'M.7EMLA'. For the rootstocks similar to M.7EMLA in ability to control the vigor of 'Gala', G.969 presented the best regularity for yield during the five evaluated growing seasons. However, this rootstock induced 'Gala' to present yield less than 'G.210', in the last growing season.

The greatest cumulative yield (CY) of 'Gala' grafted on the most dwarfing rootstocks was obtained on G.213 (Table 1). CY of 'G.213' was more than twice that of the control 'M.9EMLA'. The rootstocks CG.2022 and G.757 also performed better than M.9EMLA. The lowest CY was obtained with the rootstocks G.10 and CG.58, even though CG.58 did not differ significantly from M.9EMLA (Table 1). Both 'G.10' and 'CG.58' are also susceptible to burrknots (Kvitschal et al. 2013), which are abnormalities that affect the plant in some aspects, such as stunting of tree vigor development and court for woolly apple aphid establishment. These burrknots must induce production of smaller fruits (Cummins and Aldwinckle 1983a). Among the rootstocks with ability to control the vigor similarly to M.7EMLA, all of them showed CY higher than that of M.7EMLA, with emphasis to G.210. For the 10 rootstocks of the Geneva® series evaluated in this study, G.30 and G.24 are susceptible to wooly apple aphid (Johnson 2000). Also, according to Robinson and Hoying (2004), 'Gala' grafted on 'G.30' has shown problems of stem rupture at the graft union in the USA. Observations carried out in the State of Santa Catarina, Brazil (data not presented), showed that 'G.30' has the tendency to emit lateral branches and spines in the nursery, which increases the need of labor hand at grafting for removing them. This fact was also observed by Robinson et al. (2011) in the USA.

The cumulative yield efficiency (CYE), which represents the yield potential of a tree regarding to its TCSA, is largely used in studies for contrasting results in rootstocks trials (Robinson et al. 2006, Robinson et al. 2011). It simplifies the interpretation of the results when rootstocks of different vigor standard are planted in the same spacing. On the other hand, according to Embree et al. (1993), TCSA has good correlation with the apple canopy size. Among the dwarfing rootstocks, it was observed that G.757, G.213 and CG.2022 were the most efficient rootstocks, with emphasis to G.757, which had CYE significantly higher than all of the other evaluated rootstocks, including the dwarfing control M.9EMLA (Table 1). For the rootstocks with vigor similar to or higher than 'M.7EMLA', all of them presented CYE higher than this semi-dwarfing control.

The rootstocks that induced 'Gala' to express the lowest CYE were G.10, CG.58, G.896, and the control M.7EMLA (Table 1). According to Robinson et al. (2011), generally the yield efficiency of a rootstock is inversely related to its vigor. This was the case for 'G.896' and 'M7.EMLA, but the same was not observed for the dwarfing 'G.10', since it induced 'Gala' to express CYE inferior to the dwarfing, but more vigorous control 'M.9EMLA'. For the rootstocks with vigor similar to that of M.7EMLA, G.210, G.30, G.969 and G.24 showed higher CYE. 'G.896', even being more vigorous than the control 'M.7EMLA', showed similar CYE. 'G.969', 'G.210', 'G.24' and 'G.30' (more vigorous) had CYE equivalent to 'G.213', 'CG.2022' and 'M.9EMLA' (less vigorous). Robinson et al. (2006) also observed that 'G.210' and 'G.30' had higher yield efficiency than 'M.7'. Czynczyk and Bielicki (2012) observed negative correlation between the index of yield efficiency and TCSA in Poland. Although the results of the present study also show an overall tendency of inverse relation between vigor and yield efficiency, it was observed both contradictory facts: the rootstock G.10, even less vigorous than the M.9EMLA, induced lower CYE, and the semi vigorous rootstock G.896, which is a more vigorous rootstock than M.7EMLA, induced similar CYE in 'Gala'.

The greatest mean fruit weight was obtained with 'Gala' grafted on the dwarfing rootstocks G.213 and CG.2022, while the lowest means were observed in CG.58 for this trait (Table 1). It is important to emphasize that 'G.213' and 'CG.2022' induced 'Gala' to produce fruits of higher mean fruit weight, when compared to the dwarfing control 'M.9EMLA', which is considered to be one of the most efficient in inducing large fruits size in apple scion (Webster 2002). Generally, according to Webster and Wertheim (2003), dwarfing rootstocks are more efficient than vigorous ones to induce large fruits size to the scion variety. Nevertheless, in this study 'Gala' grafted on the semi-dwarfing 'G.210' and 'G.30' had mean fruit weight higher than when grafted on the semi-dwarfing control 'M.7EMLA', and even equivalent to that obtained when grafted on the dwarfing 'G.757', 'G.10' and 'M.9EMLA'. The semi-dwarfing Geneva® rootstocks evaluated in this study

(G.24, G.969 and G.896) induced ‘Gala’ to present fruit weight performance similar to the control M.7EMLA (Table 1).

Considering all the traits evaluated for ‘Gala’ grafted on different Geneva® rootstocks, the best ones observed in this study were: the dwarfing G.213 and G.757, the semi-dwarfing G.210, and the semi-vigorous G.896. It is important to emphasize that the best decision on rootstock choice for new ‘Gala’ orchards will depend on many factors, among them the planting density that the grower intends to use, the natural soil fertility, and the soil condition (replant or new areas). All these factors influence plant vigor. For instance, G.896 can be a good option for replanting areas with low soil fertility, and to use low plant densities in the orchard; however, the same does not apply for G.213, which is more adequate for fertile soils on high densities planting.

CONCLUSIONS

According to the ability of controlling the vigor of ‘Gala’, ‘G.10’ and ‘G.757’ are more efficient than ‘M.9EMLA’; ‘CG.2022’ has equivalent effect to ‘M.9EMLA’; ‘G.213’ and ‘CG.58’ induce significantly higher vigor than ‘M.9EMLA’, but less vigor than ‘M.7EMLA’; ‘G.24’, ‘G.969’, ‘G.30’ and ‘G.210’ have similar effect to the semi-vigorous control ‘M.7EMLA’; and ‘G.896’ induces more vigor than ‘M.7EMLA’.

Geneva® G.213 and G.757 are the most promising dwarfing apple rootstocks for ‘Gala’, based on high annual mean yields along the seasons, cumulative yield, cumulative yield efficiency and mean fruit weight, when compared to the other evaluated dwarfing rootstocks .

Among the studied semi-dwarfing Geneva® rootstocks, G.210 is the most promising for ‘Gala’ in terms of yield and fruit size.

The mean yield of ‘Gala’ grafted on the semi-vigorous rootstock G.896 is higher than when grafted on M.7EMLA; however, yield efficiency is the same for both rootstocks.

Among the ten Geneva® apple rootstocks studied, G.213 and CG.2022 induce ‘Gala’ to produce the largest fruits size.

AKNOWLEDGEMENTS

The authors greatly thank Dr. Luiz Carlos Argenta for helping with the tissue culture propagation of the Geneva® rootstocks when they were first introduced to Brazil; the logistic support given by the company Renar Maçãs S.A. to carry out the field experiment. The authors also thank ABPM – Associação Brasileira de Produtores de Maçã - and FAPESC – Fundação de Amparo à Pesquisa do Estado de Santa Catarina – for the financial support for this study.

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