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Performance of Geneva® series apple rootstocks grafted with 'Gala Select' in four different replanting soil at Southern Brazil

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Abstract: The objective of this study was to evaluate the agronomic performance of the Geneva® series apple rootstocks G.202, G.213, G.210 and G.814. The rootstock G.202 and G.213 proved to be the less vigorous, being considered dwarfs. For replanting soil, 'G.210' was considered an efficient alternative. The 'G.213' was the most efficient, in a general point of view, demonstrating that it does not change its yield efficiency and stability characteristics, even under replanting conditions. All rootstocks reached the goal of 120 accumulated tons.ha^{-1} in Caxias do Sul-RS, highlighting the faster financial return to the growers. 'G.213' has higher soluble solids content, indicating the possibility of an earlier harvesting. It is concluded that the G.210 and G. 213 rootstocks are good options for the areas evaluated, under replanting conditions, mainly G.213 for more dense systems and G.210 for areas under extreme replanting conditions.

Index terms: Yield; Yield Efficiency; Precocity; 'G.213' and 'G. 210'.

Desempenho de porta-enxertos de macieira da série Geneva® enxertados com 'Gala Select' em quatro diferentes solos de replantio no Sul do Brasil

Resumo: Neste estudo, objetivou-se avaliar o desempenho agronômico dos porta enxertos de macieira da série Geneva® G.202, G.213, G.210 e G.814. Os porta-enxertos G.202 e G.213 demonstraram ser os menos vigorosos, sendo considerados 'anões'. Para áreas de replantio, o 'G.210' pode ser considerado uma alternativa eficiente. O porta-enxerto G.213 foi o mais eficiente em termos gerais, demonstrando que, mesmo mediante condições de replantio, não altera suas características de eficiência e de estabilidade produtivas. A meta de 120 ton.ha^{-1} foi atingida por to-

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dos os porta-enxertos em Caxias do Sul-RS, destacando o retorno financeiro mais rápido ao produtor. 'G.213' apresenta maiores teores de sólidos solúveis, indicando a possibilidade de antecipação na colheita. Conclui-se que os porta-enxertos G.210 e G.213 são opções para solos de replantio, principalmente o G.213 para os sistemas mais adensados e o G.210 para solos em condições de replantio extremas.

Termos para indexação: Produtividade; Eficiência Produtiva; Precocidade; 'G.213' e 'G. 210'.

Introduction

Apple trees currently occupy around 32,468 hectares of planted area in Brazil (IBGE, 2020), highlighting their economic importance.

In recent years, apple orchards have been remodeled to improve land and water use, aiming to increase productivity and profitability (LORDAN et al., 2018). One of the alternatives is the increasing planting density by increasing the number of plants per area (GREGORY et al., 2013).

A higher planting density increases commercial yields since the second and third years from planting. It helps the producer to pay the high investment cost and improve the initial profitability of the orchard (REIG et al., 2020). Furthermore, according to Hampson et al. (2002), regardless of the high cost of planting, a higher plant density results on advantages to growers by increasing productivity, anticipating initial production, and augmenting quality.

One of the main factors to be considered for correctly growing these high-density systems is the correct choice of the rootstock. The so-called dwarfing or semi-dwarfing rootstocks have been efficient for these systems, as they reduce plant growth (REIG et al., 2019).

The M.9 rootstock has been widely used in high-density orchards in southern Brazil (MACEDO et al., 2021). This rootstock presents good resistance to collar root, is highly efficient on inducing to the scion precocity of fruiting, high yield and high fruit quality (GREGORY et al., 2013; DENARDI et al., 2020). However, it is susceptible to the woolly apple aphid, induces weak branching to the scion, and has poor soil anchorage (ROBINSON et al., 2011; DENARDI et al., 2013). Nevertheless, it is a rootstock that does not develop well in replanting soils. Replanting soils is already urgent for cultivating apple trees in many areas at South of Brazil due to the already low availability of virgin soils. However, this practice can result on serious problems due to the so called "apple replanting disease" (ARD) (DENARDI et al., 2018).

One way to circumvent this condition without losing the characteristics of the 'M.9' was to combine it with the vigorous Marubakaido rootstock, using the M.9 as an interstem. This combination has satisfactorily served the grower's sector on maintaining similar fruit quality of 'M.9', even on virgin soil (MACEDO et al., 2021), and also to obtain early production and high productivity attributed of 'M.9' (DENARDI et al., 2020). However, 'Marubakaido' presents strong suckering on the collar of plants and the 'M.9' develops burrknotts along the stem (DENARDI et al., 2018). On the other side, 'Marubakaido' is excessively vigorous, making orchard management complex (MACEDO et al., 2021).

Growers must seek new technologies for their orchards to mitigate these current problems. One of the new alternatives that have been highlighted is the Geneva® series apple rootstocks. These rootstocks have important agronomic characteristics for use in southern Brazil (DENARDI et al., 2015). Among these characteristics, it can be highlighted the efficiency in vigor control, induction of high precocity of yield, tolerance to replanting diseases (MACEDO et al., 2021), resistance to important diseases such as collar root rot (*Phytophthora* spp), fire blight (*Erwinia amylovora*) and to the insect wolly apple aphid (*Eriosoma lanigera*) (ROBINSON et al., 2014). In addition, some induce to the scion better branching (DENARDI et al., 2013), opening branch-angle and increasing productivity (FAZIO et al., 2013).

However, studies are still needed to understand the behavior in the edaphoclimatic conditions for replanting in Southern Brazil. Therefore, the objective of this work was to evaluate the agronomic performance of four apple rootstocks from the Geneva® series grafted with cv. Gala Select in apple replanting soils in four locations at Southern Brazil.

Material and Methods

The experiments were implemented and evaluated in four regions at Southern Brazil, with different climates and soil, to explore the performance of these rootstocks in different edaphoclimatic conditions.

The experiments consisted of the apple cultivar Gala Select as scion, grafted onto the Geneva® series apple rootstocks G.202, G.213, G.210 and G.814, all installed in 2017.

Based on a previous study carried out by Macedo et al. (2021), where the authors evaluated the G.213 rootstock compared to M.9 and Marubakaido with interstem of M.9 for a period of nine years, they concluded that ‘G.213’ was superior to the others, presenting low vigor, high productivity and high production efficiency. This rootstock was thus adopted as a standard in the subsequent experiments, choosing new rootstocks from the series for comparison. The rootstocks for this experiment were obtained according to the availability of imports from the Universidade do Estado de Santa Catarina (UDESC).

The first experiment was implemented in the municipality of Painel, State of Santa Catarina (SC) at the Hiroyasu Hiragami company. The climate in this area is humid mesothermal with mild summers, Cfb in the Köppen classification (KÖPPEN, 1948). Average annual precipitation ranges from 1,200 to 1,900 mm, with rainfall well distributed throughout the year. The average annual temperature recorded is 15°C to 16°C, and snow and frost may occur at low temperatures (HIGUCHI et al., 2013). The soils fall into the Humic Cambisol, Litholic Neosol, and Haplic Nitosol classes, developed from rhyodacite and basalt rocks (EMBRAPA, 2004). The soil preparation and the orchard planting were done one year after the removal of the old apple orchard.

The second experiment was installed in Caxias do Sul, State of Rio Grande do Sul (RS), at the Frutalle grower. The climate in the area is humid subtropical, with hot summers and cold, rainy winters, being classified as Cfa type, according to Köppen (KÖPPEN, 1948). The annual temperature is approximately 19.4°C, with the highest average in January (24.5°C) and the lowests in July (14.3°C). The average annual rainfall is 1,324 mm. The predominant soil is Neosol, according to the Brazilian Soil Classification System. Before the installation of the orchard, maize had been cultivated in the area for five years after the eradication of an old apple orchard.

The third experiment was implemented in the region of Vacaria (RS), in the Schio Ltda Agricultural Company. According to the Köppen classification, the climate in Vacaria is Cfb - subtropical with mild summers (KÖPPEN, 1948). The average monthly temperature ranges from 11.4°C to 20.6°C and the average year rainfall ranges from 1,212 mm to 2,088 mm (PEREIRA et al., 2009). The soils in the region is classified as Latosol Bruno, with smooth to wavy relief, with high clay and aluminum contents (EMBRAPA, 2004). The orchard was established four months after the removal of an old apple orchard in the area.

The fourth experiment was implemented in Fischer Fraiburgo Agrícola Ltda Company, in Fraiburgo (SC). The climate is classified as humid mesothermal with cool summers and severe winters, Cfb type, according to Koppen (KÖPPEN, 1948). Rainfall is evenly distributed of around 1,600 mm per year. The average annual temperature varies from 14 °C to 18°C, and the relative humidity varies from

75% to 85% (CAVALAZZI et al., 2007). The soils are classified as Latosol, Bruno, Humic, and Dystrophic (DENARDI et al., 2001). After the removal of the old orchard, the area was left fallow for two years, previously to install this experiment.

The averages of the 2019/2020-2020/2021 harvests and the 2021/2022 harvest were evaluated.

All orchard management tasks such as planting layout, pruning, training and fruit thinning, were carried out according to growers' preference in each area. The planting layout adopted for the areas of Painel-SC, Caxias do Sul-RS, and Fraiburgo-SC was 0.90 m between plants and 3.5 m between rows, totaling a density of 3,174 plants per hectare. In the Vacaria-RS region, the spacing was 0.90m between plants and 4.0m between rows, totaling 2,777 plants per hectare.

The variables evaluated were trunk cross-sectional area (TCSA) (cm^2), productivity ($ton.ha^{-1}$), yield efficiency ($kg.cm^2$), fruit diameter (mm), polp firmness (N) and soluble solids content (SSC) (Brix°).

- The Trunk cross sectional area (TCSA) was obtained by the average of the longitudinal and transversal measurements of the stem diameter at 10 cm above the grafting point. To transform the diameter values into TCSA, the equation A = (πd 2)/4 was used, where d = trunk diameter;

- The productivity ($ton.ha^{-1}$) was calculate, by using the fruit mass per plant and the number of plants per hectare multiplied as a function of the spacing used. Only the five central plants of each plot were harvested. The accumulated productivity was obtained by the sum of the productivity of each year;

- The yield efficiency (YE) ($kg.cm^2$) was calculated by the ratio of the average weight of fruits per plant ($kg. plant^{-1}$) by the TCSA of the scion (cm^{-2}), expressed in kg of fruits produced per centimeter square (cm^{-2}) of TCSA. The accumulated yield efficiency was obtained by the sum of the productivity of each year;

- The average fruit diameter (mm) was determined with 20 fruits placed on a graduated wooden ruler, adapted in an "L" shape. The total value visualized on the ruler was divided by the 20 fruits to obtain the average diameter.

- The pulp firmness was measured with a digital texturometer, TA.XTexpress/TA.XT2icon Texture Analyzer, with an 11 mm tip. The reading was performed in the equatorial zone of the fruit. A superficial cut of two epidermis discs of about 1 cm in diameter was made on opposite sides, with greater and lesser exposure to the sun to perform the reading. The results were expressed in Newtons.

- The soluble solids content (SSC) (Brix°) was determined with the juice extracted from a slice of each of 10 fruits in the sample. A digital sugar refractometer model ITREFD-45 was used.

The experimental design for each cultivation site was in randomized blocks with four replications, with each repetition composed of ten plants, from them only the five central plants were evaluated. Statistical analysis was performed using the Scott-Knott test at 5% probability in the SISVAR program (FERREIRA, 2011).

Results and Discussion

According to Czynczyk and Bielicki (2012), the TCSA measure is the most used variable to estimate plant vigor. As shown in Table 1, when analyzing the TCSA in the four regions, there were significant differences among rootstocks, where G.213 and G.202 have lower TCSA values, as compared to the other two rootstocks in all areas. In Painel-SC, these two rootstocks showed a TCSA around 25% lower when compared to G.814 and G.210. In Caxias do Sul-RS and Vacaria-RS, these dwarfing rootstocks are ~45% less vigorous than G.210 and G.814. Based on these results, it is possible to separate the genotypes into two groups, of which G.213 and G.202 can be described as dwarfing rootstocks and G.814 and G.210 as semi-dwarfing. A rootstock can be called dwarf when it has a low TCSA and, consequently, induced to the scion a low vigor (DENARDI et al., 2015). Our results corroborate those described by Denardi et al. (2016).

According to Habibi et al. (2022), dwarf rootstocks are precocious and fruit earlier in relation to the more vigorous rootstocks. This study confirmed this condition for 'G.213' in two areas when evaluated the averages of the 2020/2021 harvests. In the Painel-SC region it had 37.08% more production than 'G.814' (Table 1). When evaluating the Caxias do Sul-RS experiment, this rootstock was the most productive (64.70 tons.ha^{-1}) (Table 1). This is a satisfactory result for these regions due to the conciliation of lower plants vigor with high productivity. Presently, one of the most critical changes in the apple sector is the planting density. According to Pasa et al. (2016), the use of high plant densities associated with vigorous rootstocks is the cause of low yields in apple orchards.

The same was not observed for the G.202 dwarf rootstock. On the contrary, this rootstock was inferior to the others in yield in all the evaluated areas, reaching around 10 tons.ha^{-1} less than 'G.213' in Caxias do Sul and also for 'G.210' in Vacaria in the two initial years of evaluation (Table 1). As already

Table 1. Trunk cross-sectional area (TCSA), productivity (Tons.ha^{-1}), and yield efficiency (Kg.cm^{-2}) of Geneva® series apple rootstocks grafted with the cv. 'Gala Select' in four regions, Painel- SC, Caxias do Sul- RS, Vacaria- RS, and Fraiburgo- SC under replanting soil condition, evaluated in the 2019-2020 and 2020-2021 averages an 2021-2022.

Rootstocks	TCSA (cm^{-2})		Productivity (Ton. hectare^{-1})			Yield Efficiency (Kg.cm^{-2})		
	Averages	2021	Averages	2021/2022	Accumulated	Averages	2021/2022	Accumulated
				PAINEL- SC				
G.213	9.38 b	16.19 b	36.12 a	38.89 a	75.00 a	1.14 a	0.76 a	1.90 a
G.202	8.82 b	15.65 b	22.73 c	29.86 b	52.58 b	0.83 b	0.60 b	1.44 b
G.814	11.30 a	21.30 a	26.24 b	35.81 a	62.05 b	0.72 b	0.53 b	1.26 b
G.210	11.56 a	21.93 a	37.64 a	39.86 a	77.51 a	1.00 a	0.56 b	1.57 b
Cv%	**7.90**	**7.82**	**6.64**	**21.15**	**12.71**	**14.49**	**7.96**	**15.24**
				CAXIAS DO SUL- RS				
G.213	9.28 b	13.52 c	64.70 a	64.99 b	129.67 b	2.86 a	1.61 a	4.56 a
G.202	10.10 b	18.80 b	54.70 c	72.39 b	126.83 b	2.39 b	0.99 b	3.38 b
G.814	14.65 a	25.57 a	60.25 b	84.41 a	144.66 a	1.73 a	0.80 b	2.53 c
G.210	13.71 a	23.09 a	61.35 b	78.65 a	140.00 a	1.73 a	0.94 b	2.68 c
Cv%	**5.12**	**7.67**	**1.24**	**13.04**	**6.45**	**2.84**	**19.03**	**6.64**
				VACARIA- RS				
G.213	6.74 c	12.23 b	22.67 b	27.67 c	50.34 d	1.21 a	0.82 b	2.03 a
G.202	7.60 c	14.51 b	18.53 c	45.77 b	64.30 c	0.88 b	0.88 b	1.76 b
G.814	10.26 b	22.00 a	22.44 b	49.36 b	71.80 b	0.83 b	0.81 b	1.64 b
G.210	11.24 a	23.12 a	28.06 a	72.55 a	100.61 a	0.92 b	1.14 a	2.06 a
Cv%	**7.02**	**9.78**	**5.01**	**12.09**	**5.99**	**5.44**	**11.18**	**4.94**
				FRAIBURGO- SC				
G.213	8.18 d	9.70 c	22.67 a	26.90 b	49.58 b	0.85 a	0.87 a	1.72 a
G.202	10.28 c	11.19 b	17.00 b	31.79 b	48.79 b	0.56 d	0.98 a	1.54 b
G.814	12.15 a	13.83 a	26.12 a	41.16 a	67.27 a	0.66 c	0.95 a	1.61 b
G.210	11.45 b	13.88 a	26.62 a	41.93 a	68.56 a	0.74 b	1.05 a	1.79 a
Cv%	**7.26**	**4.74**	**13.24**	**11.71**	**8.75**	**7.10**	**11.76**	**4.22**

The table contains the averages for the 2019-2020 harvests; 2020-2021 and 2021-2022, considering 2021 data for the TCSA for the 2021-2022 harvests.

described by other authors (DENARDI et al., 2015 and 2016), among the dwarfing rootstocks already evaluated, G.213 proves to be the most productive. Even so, this rootstock may be harmed due to the replanting conditions of the areas. According to Rufato et al. (2021), these conditions can delay the development of dwarfing rootstocks and consequently, hinder them to express their full yield potential.

The 'G.210' in the Painel region was ~30.29% more productive than 'G.814' (Table 1). In Vacaria it had an average yield of around 28.06 tons.ha^{-1} in the first two years, being the most productive among those evaluated (Table 1). This rootstock had high productivity in all areas, reaching 50 accumulated ton. ha^{-1} more productive than 'G.213' in Vacaria. Since the removal of the old apple orchard and the implantation of the new one took only four months, the conditions for replanting intensified, and thus, 'G.210' proved to be a good alternative for the immediate reconversion of apple orchards within the spacing conditions adopted in this experiment. As described by Rufato et al. (2021), greater vigor under extreme replanting conditions may be involved with better productive performance of apple trees.

It must be stated that a standard spacing was adopted for the experiments to evaluate the performance of the rootstocks under the same conditions. The rootstock G.213 has shown a dwarfing behavior and can be used in smaller spacing, increasing plant density and consequently productivity per hectare. However, under the same spacing conditions, 'G.210' seems to have better performance in replanting areas, as seen in Vacaria-RS.

When analyzing the data from the 2021/22 crop and the accumulated yield, the G.213 dwarfing rootstock did not differ from the more vigorous (Table 1) in the Painel region only, even when facing lower rainfall in the periods that include fruiting, from October to January. The average temperature in this period was not different from the other seasons (19.6°C) (Figure 1A), a fact that could be a factor linked to this condition. Furthermore, the type of soil that this region presents can

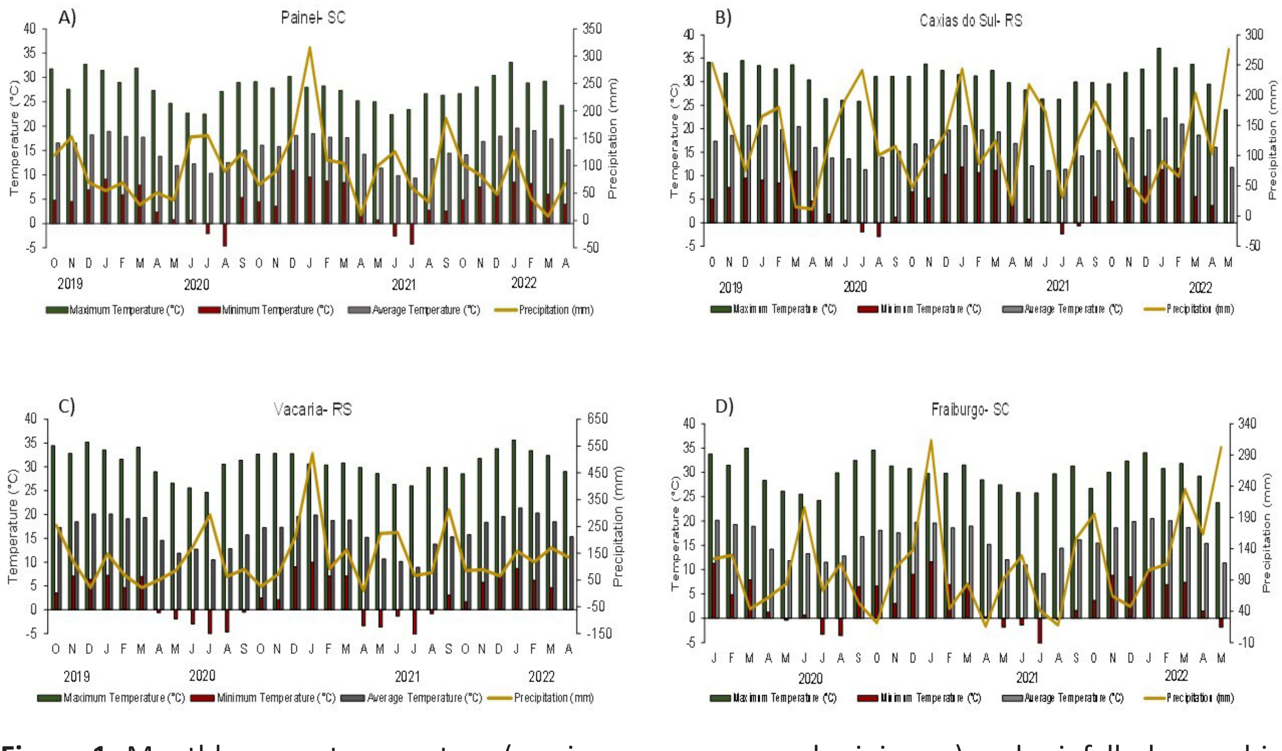

Figure 1. Monthly mean temperature (maximum, average and minimum) and rainfall observed in the municipality of Painel- SC (A), Caxias do Sul- RS (B), Vacaria- RS (C) e Fraiburgo-SC (D) in the 2019/2020; 2020/2021 and 2021/2022 harvests. Data obtained from the Epagri/Ciram meteorological station.

also contribute, as it has a high content of organic matter and thus increases water infiltration and retention (SILVA et al., 2005).

In the other areas, however, this rootstock and 'G.202' were inferior to the most vigorous ones. In Caxias do Sul, 'G.814' had 20% more production than 'G.213' in the 2021/22 crop (Table 1); 'G.210' in Fraiburgo had 15.03 tons.ha^{-1} more than this rootstock (Table 1). It is important to emphasize that in this season, these regions suffered a period of water deficit (drought). In the periods from October to January, the Caxias do Sul region had much less intense rainfall when compared to the averages of the 2019/20 and 2020/21 harvests, reaching 19.1, 74.45, 83.55, and 113.95 mm less rain in the period in question. Temperatures were also high, reaching a maximum of 37.11°C in January 2022 (Figure 1B).

In Fraiburgo, the same situation was observed, where on the period between November and January there was a reduction in precipitation in this crop compared to the 2020/21 crop, receiving 44.4, 90.6, and 207.4 mm less rainfall (Figure 1D). According to Tombesi et al. (2011), the more vigorous rootstocks can reduce the internal water deficit of plants, as they have better hydraulic conductivity, since they have a smaller number of xylem vessels; however, vessels with larger diameters facilitate the translocation of water from the roots to the canopy.

Furthermore, rootstocks with greater vigor configure a root system that has a better ratio between thicker/thinner roots and more active cells at the tips (ATKINSON, 2001). According to Leinfender and Merwin (2006), this better-developed root system, associated with tolerance to harmful agents in apple replanting soil, is another characteristic attributed to vigorous rootstocks that can influence the development of rootstocks in replanting areas.

A significant result was observed on productivity in Caxias do Sul in the 2020/2021 harvests averages, where all rootstocks exceeded 50 tons per hectare (Table 1). According to Reig et al. (2019), yield precocity and capital return, especially for high-density systems, are essential due to the high initial investment cost of these systems. Another crucial data observed in Caxias do Sul was the accumulated yield, where all the evaluated rootstocks reached above 120 tons in the three seasons studied in this experiment (Table 1). According to Macedo et al. (2021), reaching the goal of 150 tons in five harvests is a guarantee to the growers to pay the initial cost of installing the orchard, especially for high-density systems. According to the productivity of the last crop (2022), we can infer that this goal will be reached, benefiting growers in the region of Caxias do Sul-RS.

According to Czynczyk and Bielicki (2012), the yield efficiency, which takes into account the production per plant (kg.plant^{-1}) and the vigor (TCSA), is one of the essential parameters to be evaluated and is the one that most represents the yield potential of a grafted apple plant. Therefore, the cultivar may be the most productive (annual and cumulative yield), but, if it has lower yield efficiency, it will have a lower productive potential, as Denardi et al. (2018) described in a study with the Fuji Suprema and Galaxy apple cultivars.

Among the evaluated rootstocks, the G.213 was the most efficient, with an accumulated yield efficiency of 1.90, 4.47, and 1.72 kg.cm^{-2} in Painel, Caxias do Sul and Fraiburgo, respectively (Table 1). In Vacaria, this rootstock did not differ from G.210, both being more efficient cumulatively in this area (~2.05 kg.cm^{-2}) (Table 1). This demonstrates that even under replanting conditions, the 'G.213' does not change its capacity of yield efficiency and stability (RUFATO et al., 2021). Therefore, Macedo et al. (2019; 2021) consider the G.213 a new efficient and reliable apple rootstock alternative for producing apples in Southern Brazil, regardless of the planting area, both in virgin and replanting soils, and for in high-density systems.

According to Habibi et al. (2022), dwarfing rootstocks tend to induce to the scion larger fruits. These results corroborate the present study in the Fraiburgo area, where 'G.213' induced to the scion larger fruits (Table 2). Another possibility is that in this region, in the 2021/22 harvest, this rootstock, compared to the others, had the lowest production (26.90 ton.ha^{-1}) (Table 1). It is possible that this low production, as a result from a low fruit load, may be related to the diameter of these fruits, since plants with a low load have a facilitated ability to partition assimilates, nutrients and water (YILDIRIM et al., 2016).

Table 2. Parameters of fruit quality, diameter (mm), polp firmness (N) and soluble solids content (SSC) (Brix°) of 'Gala Select' on four apple rootstocks of the Geneva® series in four regions under replanting soil conditions Painel-SC, Caxias do Sul- RS, Vacaria- RS and Fraiburgo- SC evaluated only in the 2021-2022 season.

Rootstocks	Diameter (mm)/season 2021/2022	Firmness (N)/season 2021/2022	SSC (Brix°)/season 2021/2022
PAINEL- SC			
G.213	63.96 a	81.76 d	13.55 a
G.202	62.04 a	90.85 b	12.40 b
G.814	62.04 a	86.18 c	11.48 b
G.210	61.42 a	102.38 a	11.30 b
Cv%	**5.84**	**1.73**	**9.67**
CAXIAS- RS			
G.213	60.67 b	61.20 c	13.00 a
G.202	64.00 a	59.50 d	13.06 a
G.814	64.32 a	69.42 b	11.90 b
G.210	66.00 a	75.68 a	12.30 b
Cv%	**2.75**	**0.40**	**3.42**
VACARIA- RS			
G.213	63.50 c	52.86 b	14.20 a
G.202	63.00 c	52.56 b	13.35 b
G.814	64.75 b	73.72 a	13.25 b
G.210	67.50 a	52.62 b	13.25 b
Cv%	**4.17**	**1.55**	**3.90**
FRAIBURGO-SC			
G.213	65.64 a	85.13 a	14.10 a
G.202	62.75 b	65.42 d	13.38 a
G.814	63.25 b	76.60 b	12.42 b
G.210	62.54 b	69.22 c	12.22 b
Cv%	**2.11**	**1.80**	**6.85**

In Caxias do Sul, on the other hand, the 'G.213' had the smallest fruits among the evaluated rootstocks. This rootstock did not differ from the others in terms of production, showing a high fruit load (64.99 ton. ha-^{1}). This factor was associated with the water deficit that occurred in the region, mainly during the period between October and January, where rainfall was only 300 mm (Figure 1B) that may have affected fruit size (MAHHOU et al., 2006). According to Boini et al. (2019), fruit growth is directly correlated with the water potential of the plant stem, and in the face of water stress, this potential decreases, making it difficult to transport water to the fruit and, consequently, reducing its growth.

In table 2 it is shown that the results of pulp firmness were significant different in all areas, where the fruits of the most vigorous rootstocks (G.210 and G.814) were the firmest in Painel, Caxias do Sul and Vacaria. However, in Fraiburgo, the fruit of 'G.213' was the firmest. Regarding soluble solids contend (SSC), the two dwarfing rootstocks showed the highest levels, mainly G.213 (Table 2). According to Habibi et al. (2022), dwarfing rootstocks demonstrate a more remarkable ability to partition carbon to the reproductive areas, thus increasing the SSC in the fruits. Still, the more vigorous rootstocks need to distribute carbohydrates more intensively to the vegetative part, configuring a reserve sink and reducing the levels for the fruits (HARTMANN et al., 1997). When considering parameters such as polp firmness and soluble solids content, our results corroborate those found by Rufato et al. (2021) that they attributed probable anticipation of fruit and consequently harvest anticipation of scions grafted on the G.213 rootstock.

Conclusion

Among the four rootstocks evaluated, G.202 and G.213 have the lowest TCSA, consequently being the most efficient in vigor control of the scion. However, 'G.202' is less productive in all studied areas.

In the Caxias do Sul replanting soil, all the rootstocks anticipate production and reach an accumulated yield similar, reaching the goal of 120 tons, indicating a fast financial return to the growers.

The G.210 is an efficient apple rootstocks alternative for cultivating orchards in replanting soils, at least for the cv. Gala Select.

The 'G.213' proves to heave high and constant yield efficiency, maintaining good stability and being a good alternative for high density apple planting.

In terms of quality, the two dwarfing rootstocks G.202 and G.213 have a higher content of soluble solids and less firmness than G.210 and G.814, indicating an earlier fruit ripening and, consequently earlier hasvesting, mainly for G.213.

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