

EUFRIIN apple rootstock trials: first results across Europe

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Abstract

In 2017, two multi-location apple rootstock trials were established at 16 sites in 12 European countries. The evaluations are performed by members of the EUFRIN (European Fruit Research Institute Network) Apple & Pear Variety & Rootstock Testing Working Group. Two separate trials were arranged, grouping rootstocks into dwarf and semi-dwarf rootstocks according to the expected vigour; 'Galaval' was used as scion cultivar. The trial of dwarf rootstocks includes 'G.11' and 'G.41' (US), 'EM_02', 'EM_03', 'EM_04', 'EM_05' and 'EM_06' (UK), '62-396-B10®' (Russia), 'P 67' (Poland), 'PFR4' and 'PFR5' (New Zealand) and 'Cepiland-Pajam®2' as control. The trial of semi-dwarf rootstocks includes 'G.202' and 'G.935' (US), 'PFR1' and 'PFR3' (New Zealand), 'EM_01' (UK) and 'G.11' as a control for both trials. Part of the rootstocks (from dwarf and semi-dwarf rootstock trials) was planted in replanting conditions to test their tolerance to apple replant disease. All test trees came from the same nursery, and a common standardised evaluation protocol was used. Based on preliminary results averaged across sites, dwarf rootstocks can be ranked in terms of vigour in the following order: 'EM_04' < 'EM_03', 'EM_05' < '62-396-B10®', 'P 67', 'EM_02', 'G.11' < 'G.41', 'Cepiland-Pajam®2' < 'EM_06', 'PFR4' < 'PFR5'. On average, semi-dwarf rootstocks can be ranked in terms of vigour in the following order: 'G11' < 'G.935', 'G.202' < 'PFR3', 'EM_01' < 'PFR1'. The highest cumulative yield in the young orchard was registered for trees on 'PFR5', 'PFR4', 'G.11', 'G.41', 'Cepiland-Pajam®2' and 'EM_02', while the lowest production was found for trees on 'EM_04'. In the group of semi-dwarf rootstocks, the highest yield was on 'PFR3', 'G.935' and 'PFR1'. Rootstocks also had a significant effect on fruit weight and fruit quality parameters. Results from the young orchards revealed interactions between sites and rootstock, potentially leading to site-specific rootstock choice based on the combination of rootstock, soil conditions and climate.

Keywords: fruit quality, *Malus × domestica* Borkh., multi-site experiment, yield, vegetative growth

INTRODUCTION

There is a growing interest in new apple rootstocks on a global level. In addition to precocity, productivity and optimal tree growth control, which have always been the main required features, rootstocks with increased resistance to pests and diseases and better adaptation to various climatic and soil conditions are in great demand.

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Apple rootstock breeding programmes, different from apple cultivar breeding programmes, are carried out only in a few research organisations in the world. New rootstocks have been bred along with the highly productive Cornell Geneva program (Fazio et al., 2015; Robinson et al., 2015) and the traditionally strong NIAB EMR (Webster and Tobutt, 2001) in Poland, Russia, New Zealand, Czech Republic and some other countries.

Despite the relatively high number of new apple rootstocks delivered in recent years, long-term evaluation trials are costly and not frequently established at research institutions. Limited information is available about newly released NIAB EMR rootstocks (Atkinson et al., 1998), and only one scientific publication has focused on apple rootstock selections from New Zealand (Tustin et al., 2014).

Multi-site trials performed in different locations under various climatic conditions deliver the most comprehensive results in the shortest time. In addition to NC 140 rootstock trials in North America (Marini et al., 2014), similar multi-site trials have been started in Europe and are carried out by the EUFRIN (European Fruit Research Institute Network), Apple & Pear Variety & Rootstock Testing Working Group (Kviklys, 2011). This paper will present the first results of European apple rootstock trials.

Here, we evaluated the impacts of new apple rootstocks on tree growth and productivity in a young orchard and determined their adaptiveness to various growing conditions across Europe.

MATERIALS AND METHODS

In 2017 two multi-location apple rootstock trials were established at 16 sites in 12 European countries: IRTA Fruitcenter Lleida (ES-L) and IRTA Mas Badia (ES-MB), Spain, CTIFL Balandran (FR-B) and CTIFL Lanxade (FR-L), France, Laimburg Research Centre (IT-L), University of Bologna (IT-B) and Edmund Mach Foundation (IT-F), Italy, Agroscope, Switzerland (CH), Unit Fruit Growing & Viticulture Haidegg, Austria (AT), Fruit Research Centre, Jork, Germany (DE), PcFruit, Belgium (BE), InHort, Poland (PL), Research and Breeding Institute of Pomology, Holovousy, Czech Republic (CZ), LAMMC, Lithuania (LT), Nibio, Norway (NO) and NIAB EMR, UK (GB).

The evaluations were performed by the members of the EUFRIN (European Fruit Research Institute Network) Apple & Pear Variety & Rootstock Testing Working Group.

The trial of dwarf rootstocks included 'G.11' and 'G.41' (US), 'EM_02', 'EM_03', 'EM_04', 'EM_05' and 'EM_06' (UK), '62-396-B10®' (Russia), 'P 67' (Poland), 'PFR4' and 'PFR5' (New Zealand) and 'Cepiland-Pajam®2' as control. The trial of semi-dwarf rootstocks included 'G.202' and 'G.935' (US), 'PFR1' and 'PFR3' (New Zealand), 'EM_01' (UK) and 'G.11' as control for both trials. 'Galaval' was used as scion cultivar. The planting material was propagated as 1-year-old-trees by the Dalival nursery, France.

Planting distances depended on the soil properties in each site and varied from 3×0.8 to 4×1.5 m for the dwarf rootstock trial and from 3×1 to 4×1.5 m for the semi-dwarf rootstock trial. According to the planting distances, trees were trained as slender or super spindles.

Each rootstock was replicated four times, with three trees per plot.

A common standardised protocol was used for the evaluations. Tree growth was assessed annually by measuring the trunk diameter at 20 cm above the graft union in autumn. Trunk diameter (d) was used to calculate the trunk cross sectional area (TCSA), using the formula $TCSA = \pi \cdot (d/2)^2$.

The yield (kg tree⁻¹) was measured yearly and presented as accumulated yield for the trial period.

Average fruit weight (g) was calculated based on 50 fruits per sample per replicate, and the yearly average was presented.

Data were analyzed by general analysis of variance (ANOVA) for randomized complete block designs using the statistical program Minitab®16 (Minitab Ltd., UK).

RESULTS AND DISCUSSION

'M.9' size rootstock trial

The tree trunk sectional area (TCSA) measured at the end of the third year revealed differences in rootstock-induced tree vigour (Figure 1). The growth rate of '62-396-B10[®]', 'G.11', 'G.41' is similar to that established in the 2010 NC-140 'Honeycrisp' trial (Autio et al., 2017a). Similar, tree vigour was observed on 'P 67' and 'EM_02'. NIAB EMR rootstocks were extremely dwarfing (32-47% lower than 'Cepiland-Pajam[®]2'), especially 'EM_04', which could be classified in the 'M.27' size class. All rootstocks mentioned above were significantly more dwarfing than 'Cepiland-Pajam[®]2'. Significantly stronger (15-20% compared with 'Cepiland-Pajam[®]2') apple trees grew on 'EM_06' and 'PFR4' and, especially, on 'PFR5' (35%), which could be classified in the 'M.26' size class.

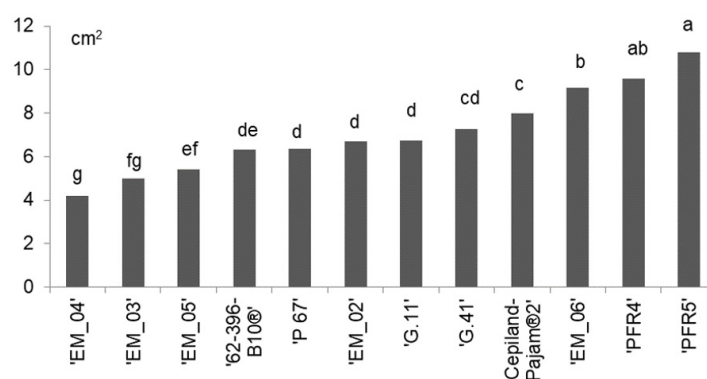


Figure 1. Rootstock effect on tree vigour (cm² TCSA), average of 16 sites, 2019. Values that do not share the same letter are significantly different.

Cumulative yield in the young orchard depended on the rootstock and tree vigour. A high positive correlation (0.81) was established between yield and TCSA. Yields similar to those of 'Cepiland-Pajam[®]2' were obtained for 'PFR4' and 'PFR5', 'G.41', 'EM_02', 'G.11' and 'EM_06' (Figure 2). The lowest yield (statistically significant) was harvested from trees on the most significantly dwarfing 'EM_04'. A low cumulative yield was obtained for '62-396-B10[®]' and 'P 67'. The lower productivity of 'P 67' was mentioned only once in earlier performed trials (Bielicki and Paśko, 2018). In other trials, 'P 67' (Kviklys et al., 2013) and '62-396-B10[®]' (Fazio et al., 2013; Lordan et al., 2018) were some of the most productive rootstocks.

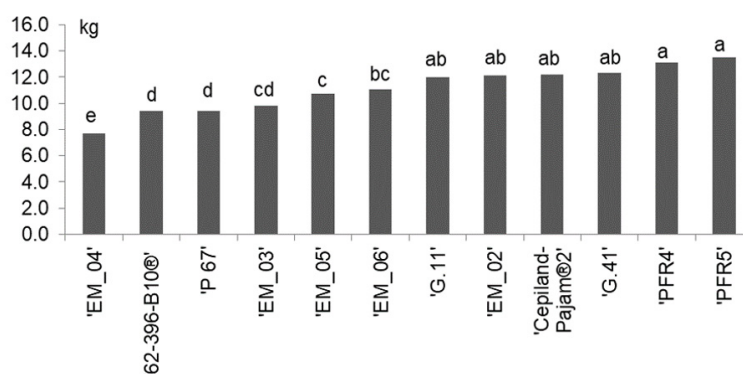


Figure 2. Rootstock effect on cumulative yield (kg tree⁻¹), average of 16 sites, 2018-2019. Values that do not share the same letter are significantly different.

Average fruit weight varied from 149 to 179 g (Figure 3). However, there were no significant differences for any rootstock compared with 'Cepiland-Pajam®2'. Significant differences were established only between 'PFR4' and 'PFR5' with the highest fruit weight and 'EM_03', '62-396-B10®', 'EM_05' and 'EM_02' with the smallest fruits. There was a positive correlation (0.69) between TCSA and average fruit weight.

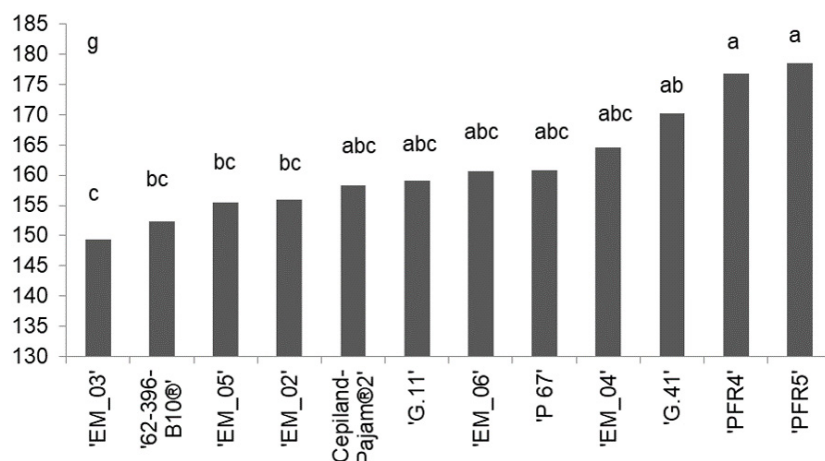


Figure 3. Rootstock effect on average fruit weight (g), average of 16 sites, 2018-2019. Values that do not share the same letter are significantly different.

'M.26' size rootstock trial

Five rootstocks predicted to be semi-dwarfing were tested in nine sites in seven European countries. Both Geneva rootstocks 'G.935' and 'G.202' had greater TCSA values than trees on the control rootstock 'G.11', by 26 and 31%, respectively, and could be classified in the 'M.26' size class (Figure 4). This is in agreement with Fazio et al. (2013) but contradicts other trials where 'G.935' was classified in the same class as 'M.9' (Marini et al., 2014), and the growth of 'G.202' was similar to that of 'Cepiland-Pajam®2' (Autio et al., 2017b).

'PFR1' is a strong-growing rootstock and could be classified in the 'MM.106' size class. 'PFR3' and 'EM_01' took an intermediate position between these two classes, with significantly different vigour.

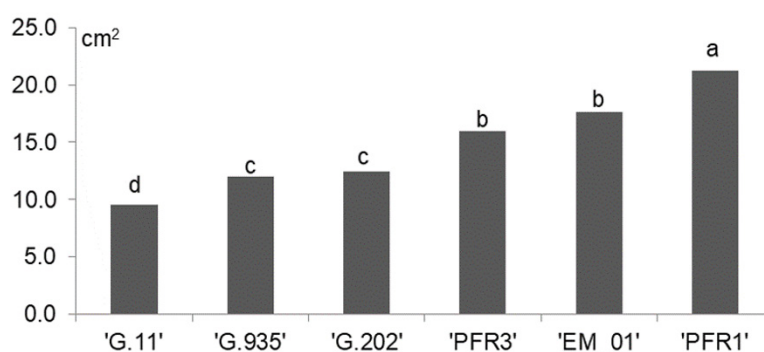


Figure 4. Rootstock effect on tree vigour (TCSA, cm²), average of 9 sites, 2019. Values that do not share the same letter are significantly different.

The highest yearly yields were obtained from the trees on 'PFR3' and 'G.935' (Figure 5). The high yielding capacity of 'G.935' has been reported in numerous trials (Autio et al., 2017a, b; Marini et al., 2014). 'PFR1' had a similar yield but did not differ from 'G.11'. Rootstocks

'EM_01' and 'G.202' gave the lowest cumulative yield among the tested rootstocks.

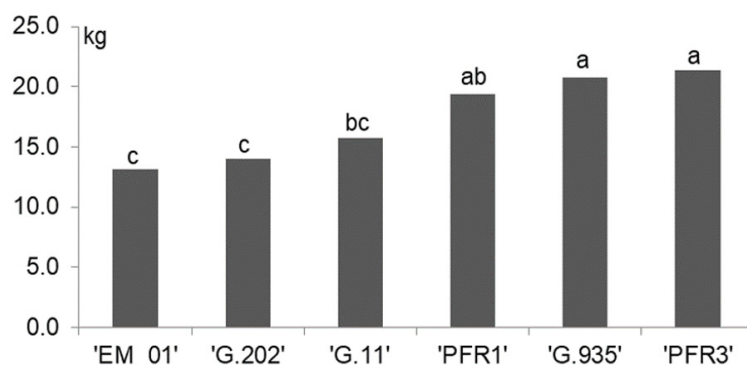


Figure 5. Rootstock effect on cumulative yield (kg tree⁻¹), average of 9 sites, 2018-2019. Values that do not share the same letter are significantly different.

Average fruit weight varied from 164 to 176 g. Despite the differences among the rootstocks in vigour and yield, no significant differences were found in fruit weight.

Location effect on tree growth and yield

Planting distances varied among trial locations, depending on soil properties, soil history and orchard management practices. In some locations, rootstock trials were established at replanting conditions without soil disinfection/fumigation; fresh soil was used in other trials. These are the main reasons for significant differences in apple tree growth and yield among the trial sites (Figures 6 and 7). Tree growth during the first years differed almost by a factor of 3 compared to FR-B and GB sites. The most significant tree growth was recorded in all sites in France and Spain, followed by PL. Modest tree growth was reported for GB and NO, though there were no significant differences to BE, IT, B and CH.

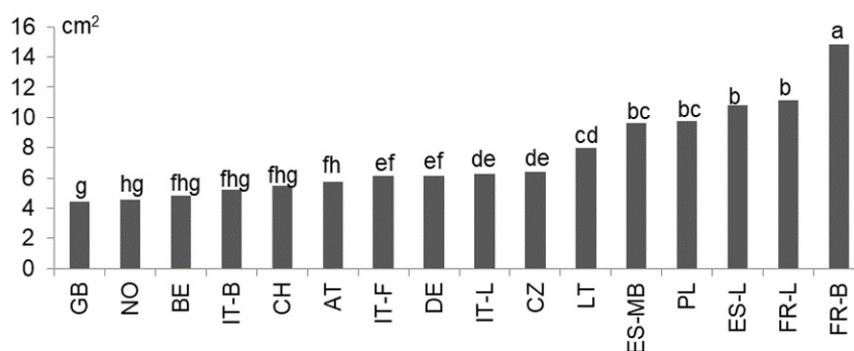


Figure 6. Average apple tree trunk cross sectional area (TCSA, cm²) at different trial sites. Average of 12 rootstocks. Values that do not share the same letter are significantly different.

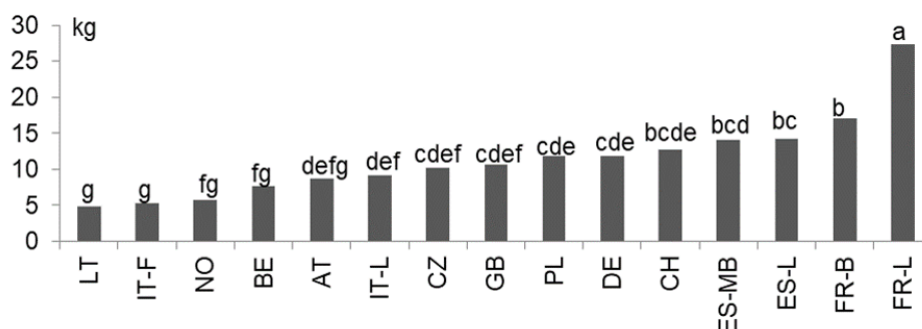


Figure 7. Average cumulative yield (kg tree⁻¹) at different trial sites. Average of 12 rootstocks. Values that do not share the same letter are significantly different.

Differences in tree growth were one of the main reasons for differences in cumulative yield (Figure 7). Again, the most productive trees in the young orchard were located in all sites in France and Spain, exhibiting the strongest growth. Due to spring frosts in some years in some sites during the first two bearing seasons, the evaluation of the location effect on tree productivity could only be preliminary.

Rootstock location interactions are generally recorded for all multi-site experiments (Marini et al., 2008; Kviklys et al., 2013; Marini et al., 2014). In our trial, some interactions were noticed, but long-term experiments are needed to draw a sound conclusion.

CONCLUSIONS

Multi-site apple rootstock trials performed by the members of the EUFRIN (European Fruit Research Institute Network) Apple & Pear Variety & Rootstock Testing Working Group were established at 16 sites in 12 European countries in spring 2017 and included 17 dwarf and semi-dwarf rootstocks.

According to the tree trunk cross sectional area, rootstocks in the 'M.9' size trial can be preliminary ranked, in terms of vigour, in the following order: 'EM_04' < 'EM_03', 'EM_05' < '62-396-B10®', 'P 67', 'EM_02', 'G.11' < 'G.41', 'Cepiland-Pajam®2' < 'EM_06', 'PFR4' < 'PFR5'.

According to the tree trunk cross sectional area, rootstocks in the 'M.26' size trial can be preliminary ranked, in terms of vigour, in the following order: 'G11' < 'G.935', 'G.202' < 'PFR3', 'EM_01' < 'PFR1'.

In the 'M.9' size trial, rootstocks 'PFR5', 'PFR4', 'G.11', 'G.41', 'Cepiland-Pajam®2' and 'EM_02' gave the highest cumulative yield in the young orchard.

In the 'M.26' size trial, rootstocks 'PFR3', 'G.935' and 'PFR1' gave the highest cumulative yield in the young orchard.

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