

Rootstocks for Organic Apple Orchards

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New organic apple orchards, like conventional orchards, depend on rapidly filling the allotted space with canopy to achieve early fruiting, to pay back the initial investment of planting the orchard (Gonzalez et al., 2023). Using a planting density of ~1300 trees/acre and a rootstock that performs well in an organic system will result in the trees filling the allocated space by the end of the third year (Lordan et al., 2019). Such intensive orchards are not common among organic growers, which limits their profitability. In addition, almost all previous organic apple management research in the Eastern US has been done with more traditionally spaced orchards (Garcia et al., 2013).

One of the major challenges faced by organic orchardists is to provide proper nutrition to apple trees to achieve high productivity, particularly with greater weed competition and the use of organic fertilizers. Apple rootstocks have been shown to influence the mineral nutrient composition of leaf and fruit tissue in orchards under conventional management; however, there is little information about their nutrient use efficiency under organic management.

Conventional dwarfing apple rootstock genotypes are susceptible to fire blight bacterial disease and apple replant disease and are vulnerable to cold injury which are major problems in organic systems. This has limited their use in organic apple production in the Eastern US. The new Geneva® apple rootstocks have high potential to improve orchard performance by impacting soil health and nutrient status, plant-associated soil microbial communities, tree growth, and fruit yields (Fazio, 2014; Robinson et al., 2014).

The first U.S. organic field trial with the Geneva® rootstocks was performed in Chelan, WA (Auvil et al., 2011) and showed how impactful the new rootstocks could be by increasing yields by 20-65% when compared to traditional rootstocks M.9, M.26 or B.9. Similar results have been observed with similar Geneva® rootstocks in Europe where they are providing novel solutions to organic apple growers (Spornberger et al., 2020; Wurm, 2018). In addition to improvement in productivity and tree survival, some Geneva® rootstocks impact mineral nutrient uptake and utilization in apple in diverse ways that are linked to improved fruit quality, tree growth, and perhaps return bloom (Fazio et al., 2018a; Fazio et al., 2018c; Robinson and Fazio, 2022). Traditional rootstocks have shown drastic deficiencies with regards to nutrient uptake which are then translated into poor tree growth followed by lower yields of lower quality fruit (Garcia et al., 2013; Lanauskas et al., 2014; Racsko et al., 2008; Weibel et al., 2008). Given the paucity of information on how some of the newer rootstocks perform under organic management with regards to nutrient uptake we set a goal to understand this subject by interrogating nutrient content in several field trials under organic management.

Material and methods

Plant Materials: The research featured two dedicated organic apple research plots at Cornell's Experimental fields in Geneva, NY

(GEN) and Ithaca, NY (ITH) and another one established on a grower field in Albion, NY (ALB).

The experiments at the GEN and ITH locations are a 0.5 acre plots, planted in May 2015 and compare 11 Geneva® disease resistant rootstocks with one conventional rootstock. Stocks include M.9T-337, G.16, G.222, G.214, G.969, G.30, G.11, G.935, G.41 G.202 and G.890. The scion variety was 'Modi' which is resistant to apple scab and perhaps cedar apple rust cultivar (Agnello et al., 2017). The trees were spaced at 3' x 12', giving a planting density of 1210 trees/acre. Trees were trained to the Tall Spindle system, creating a slender fruiting wall. The field was under organic management 5 years prior to planting. The experiment utilized a randomized complete block experimental design with 10 single-tree replications.

The experiment on the organic grower farm at the ALB location features a 0.7 acre plot planted in 2012 on the shores of Lake Ontario and combines 20 commercial and experimental rootstocks including B.9, CG.2006, CG.3001, CG.4003, CG.4013, G.213, G.214, CG.4288, CG.4294, CG.5030, CG.5202, G.484, G.257, G.890 G.202TC, G.41, G.41TC, G.935, G.935TC, and M9-T337. Trees were grafted with 'Autumn Crisp' scion cultivar. The field was under certified USDA Organic management since planting. There were three replications with each elemental plot composed of three to five trees per rootstock.

Nutrient analysis Nutrient levels were measured by two methods targeting both fruit and leaves. Ten randomly selected fruits and fully developed mid-position leaves distributed throughout the tree canopy were harvested 120 days after bloom on three replicates of each rootstock genotype from each of the 3 field trials (GEN, ITH and ALB). Fruit and leaves from the same trees in ALB were collected in 2014, 2016, 2022 and 2023 where the samples from 2014 and 2016 were oven dried, ground into powder and shipped a third party (A&L Great Lakes Laboratories, Inc. Fort Wayne, IN) for mineral analysis of several macro- and micro-mineral nutrients via inductively coupled plasma optical emission spectrometry. Samples from GEN, ITH and ALB collected in 2022 and 2023 were collected in the same way but nutrient levels (Ca, Cu, K, P, S, Mn, Ni and Fe) were measured using a hand-held X-ray nutrient analyzer instrument (Bruker Tracer 5) where intact fruit were subjected to two reading on opposite sides similar to what has been described in the literature (Kalcsits, 2016) and leaves were ground, pelletized and analyzed in a similar way. Leaf and fruit nutrient levels were tabulated and analyzed with SAS and JMP Pro 17 statistical software packages (Cary, NC); rootstock genotype was treated as the main effect in a randomized complete block analysis. Rootstock genotype means for all nutrients tested were used in a multivariate analysis to gener-

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We compared rootstock performance and nutrient profiles in three organic orchards. Based on overall productivity and nutrient use efficiency, G.890, G.484, G.222, G.41 and perhaps G.935 seem to be well suited for organically managed orchards.

somewhat inconsistent between locations and years in the NC-140 trials. In the Albion organic trial G.484, G.890, G.222, and CG.5030 displayed higher levels of leaf P and S. CG.4003 displayed consistently higher levels of Ca in leaves and fruit.

After 9 growing seasons, G.41, G.484 G.222 and G.935 and are promising rootstocks for organic production in a high-density system. For a medium density system, G.890 has shown good promise. G.484 was not included in the Geneva or Ithaca trials but has shown outstanding performance in other trials (Fazio and Robinson, 2023) (Figure 4). Based on nutrient uptake efficiency, G.890, G.484, G.222, and perhaps G.935 seem to be well suited for organically managed orchards, however, the susceptibility of G.935 to Woolly Apple Aphid make it less desirable in a system with limited insecticides to control this insect.

The knowledge of nutrient uptake potential of apple rootstocks under organic management gained in these experiments combined with other knowledge of productivity, disease and insect resistance can guide the decisions on rootstock choice and fertilizer

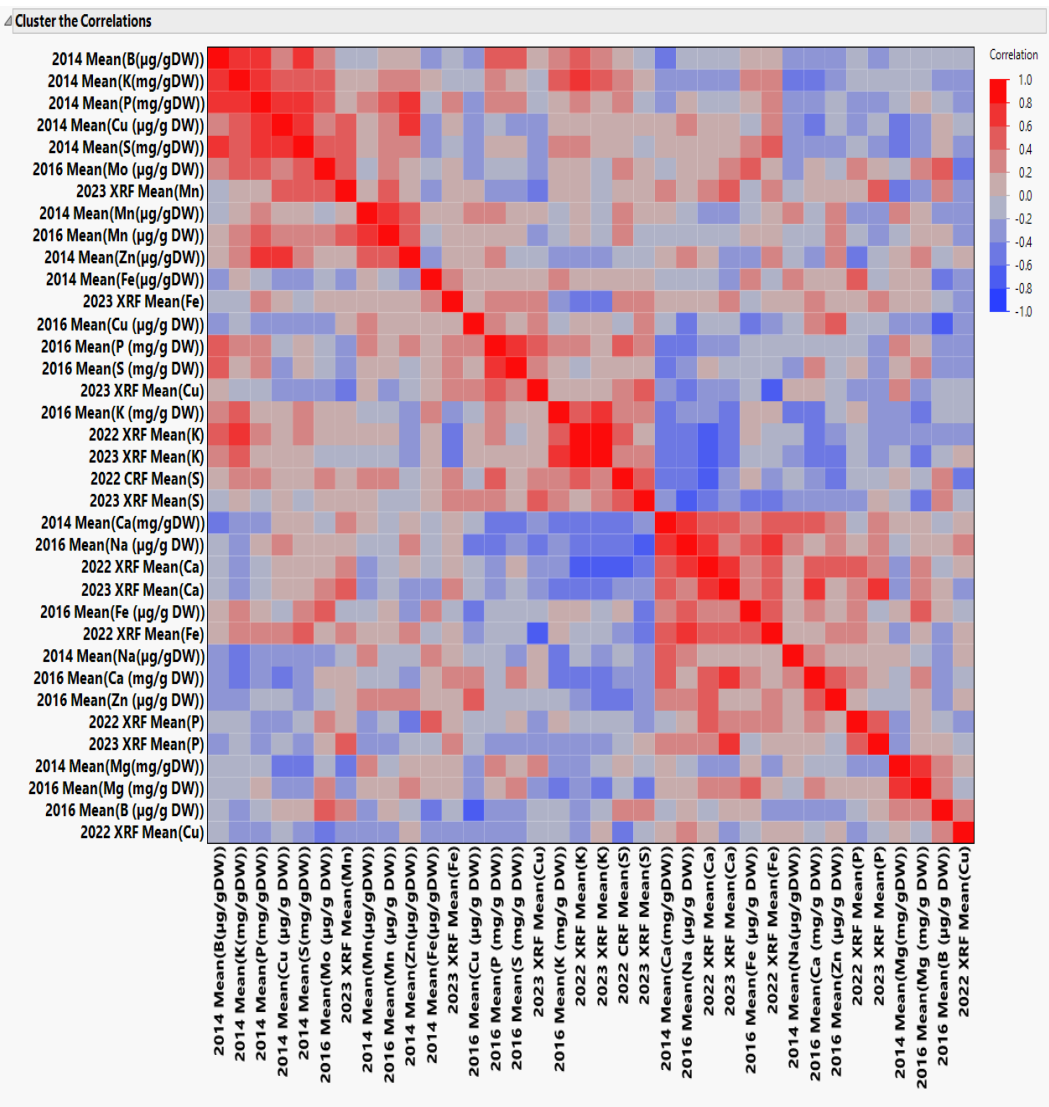


Figure 2. Clustered correlations for ALB 2014, 2016, 2022-23 leaf ICP and XRF data.

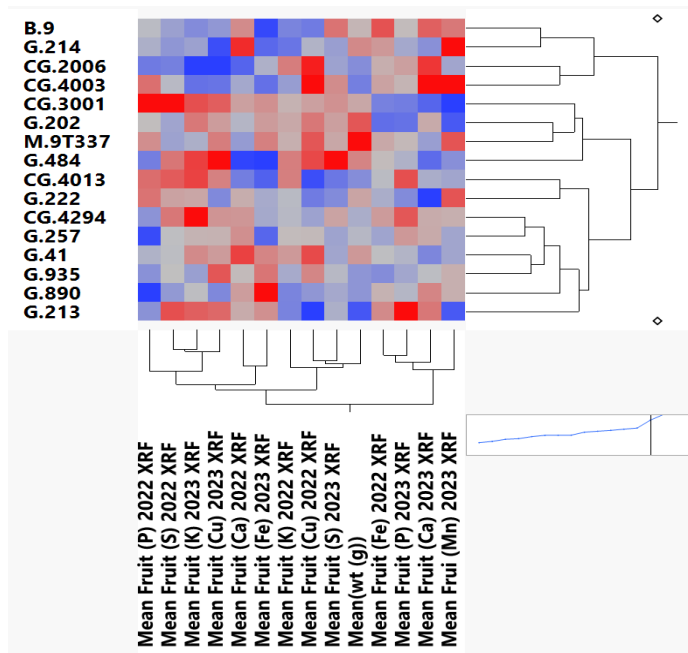


Figure 3. Dual hierarchical clustering (WARD) of 2022-2023 genotypic means for fruit XRF data collected from the ALB location. Red corresponds to high values; blue corresponds to low values and gray to average values.



Figure 4. Four year old apple trees of 'Autumn Crisp' on G.935 (left), G.484 (center) and G.890 (right) rootstocks at the Albion organic rootstock trial.

applications. This is one of the first sets of experiments that has examined rootstock effect on nutrients under organic management. Further, long term research is needed correlate productivity and fruit quality to these rootstock traits.

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