Rootstock affects fruit nutrient profile and bitter pit incidence of apple

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Abstract

We evaluated fruit bitter pit incidence of 'Honeycrisp' apple as affected by rootstock and then related it to the nutrient levels and ratios of nutrients. Two field experiments were evaluated: one at Geneva NY planted in 2007 with 20 rootstocks and the second plot planted in 2008 at Peru, NY with 41 rootstocks. Fruit yield, fruit size and peel nutrient concentration were measured from 2016 to 2020 at harvest. Bitter pit incidence was evaluated on 50 fruits from each tree after three months in regular atmosphere storage. Significant differences in bitter pit incidence and peel nutrient concentrations were observed among rootstocks. The ratios of K/Ca and N/Ca were evaluated and were well correlated with bitter pit incidence. There were rootstocks that consistently had greater peel nutrient concentrations indicating that differences among rootstocks are stable across years. Among rootstocks, B.9, G.65, G.214 and M.9T337 had the lowest bitter pit incidence, while G.210, M.7, G.814, B.118 and G.41 had high bitter pit incidence. Other rootstocks had intermediate levels of bitter pit and included G.30, G.935, G.4202, M.9Pajam2, G.11, G.16, CG.4210, CG.5046, CG.5202 and M.26.

Keywords: *Malus × domestica,* K/Ca ratio, N/Ca ratio

INTRODUCTION

'Honeycrisp' apple has become one of the most popular cultivars in the USA apple market. It is preferred by consumers because of its crunchiness and excellent flavor. However, it is difficult to grow because of its strong biennial bearing habit and high incidence of bitter pit and other fruit quality disorders after storage (Robinson and Watkins, 2003). Our previous work and other studies have shown that rootstock affects scion fruit nutrient profile and bitter pit incidence (Fazio et al. 2013, 2020; Lordan et al., 2020; Neilsen and Hampson, 2014; Reig et al., 2018). We have shown that the ratio of K/Ca in the fruit peel was correlated positively with bitter pit incidence. Based on our earlier work we have suggested a target ratio of fruit peel K/Ca of <25 to achieve <5% bitter pit. We have also shown that N or N/Ca ratio is positively associated with bitter pit (Robinson and Lopez, 2012).

The objective of this work was to assess rootstock influence on fruit nutrient profiles, bitter pit incidence and economic crop value with a more diverse set of rootstocks over multiple years.

MATERIALS AND METHODS

We evaluated fruit bitter pit incidence as affected by rootstock from 2016 to 2020 in two field plots: 1) A plot planted in 2008 at Peru, NY (northern New York State) with 41 rootstocks and 2) A plot planted at Geneva NY in 2007 with 19 rootstocks.

In the Northern New York State plot the experimental design was a randomized complete block design with 5 block and with 2 trees of each rootstock per block. Fruit yield, and average fruit weight were recorded in 2016 and 2018. A 50 fruit sample from each tree was stored in regular atmosphere storage and after three months bitter pit incidence was evaluated for each tree. Peel samples from a sub-sample of 10 apples were analyzed for concentrations of nitrogen, potassium, calcium, and magnesium in 2018.

In the Geneva NY plot the experimental design was a randomized complete block design with 5 blocks and with 1 tree of each rootstock per block. Fruit yield, and average fruit weight were recorded from 2008 to 2020. In 2018 a 50 fruit sample from each tree was stored in regular atmosphere storage and after three months bitter pit incidence was evaluated for each tree. Cumulative yield and bitter pit incidence were used to estimate yield of bitter pit free fruit which was used in conjunction with fruit size and fresh market prices for each fruit size class to estimate economic value of the crop for each rootstock.

Data were analyzed by analysis of variance using mixed linear models with the SAS statistical program (Cary, NC, USA). Differences among means were evaluated using LSD P≤0.05.

RESULTS

2008 plot at Peru NY

The incidence of fruit bitter pit was higher in 2016 than in 2018 (Figure 1). Both years had similar crop loads but 2016 was very dry while 2018 had ample rainfall. There was no irrigation in this plot. In general rootstocks with low bitter pit in 2016 also had low bitter pit in 2018. However, not all stocks with high bitter pit in 2016 had high bitter pit in 2018. Stocks with the highest incidence of bitter pit in 2016 were: CG.6879 followed by MM.111, G.935, CG.8189, CG.6143, CG.6001, CG.5087, M.7 CG,5008, G.210 and G.814 (all of which had more than 20% bitter pit). Stocks with the lowest incidence of bitter pit were CG.5030 and CG.5046, followed by CG.3007, CG.4003, CG.5179, CG.6006, G.214, CG.6874, CG.7480, G.65 and V.1 (all of them had less than 5% bitter pit). Other stocks with less than 10% bitter pit were B.9, CG.5012, CG.6024, CG.6253, CG.7230, G.11, G.16, M.9Nic29, O.3 and P.22.

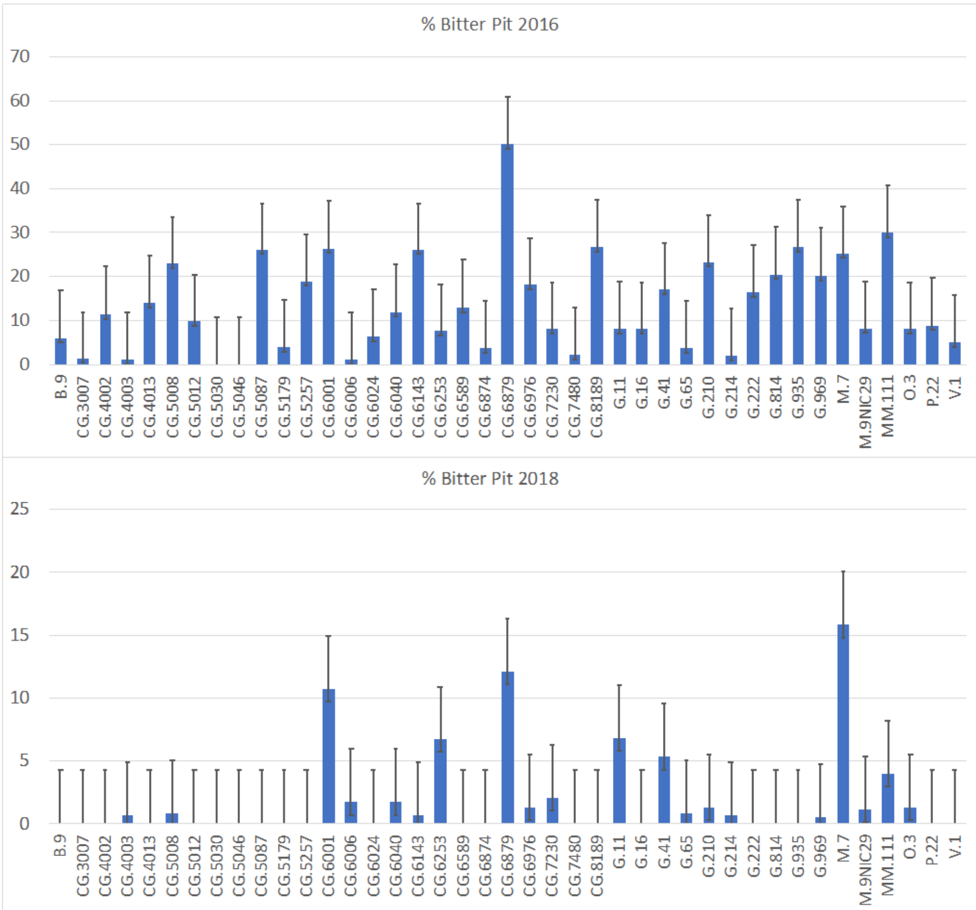

Figure 1. Incidence of bitter pit with mature 'Honeycrisp' apple trees on 41 rootstocks in 2016 (top) and 2018 (bottom) when grown in Peru, New York (northern NY State).

In 2018, stocks with the highest incidence of bitter pit were: M.7, CG.6879, CG.6001, CG.6253, G.11 and G.41(all of which had more than 5% bitter pit) (Figure 1). All other stocks had less than 5% bitter pit.

The ratio of K/Ca in 2018, none of the stocks had a nutrient ratio greater than 20 which is consistent with the low level of bitter pit observed in 2018 (Figure 2). Stocks with the highest ratio of K/Ca were G.41, CG.6879, CG.7230, CG.6001, G.210, O.3, MM.111, CG.5008, CG.5012, CG.5179, CG.5257, CG.6024, CG.6143, CG.6253. The ratio of N/Ca also varied among rootstocks (data not presented).

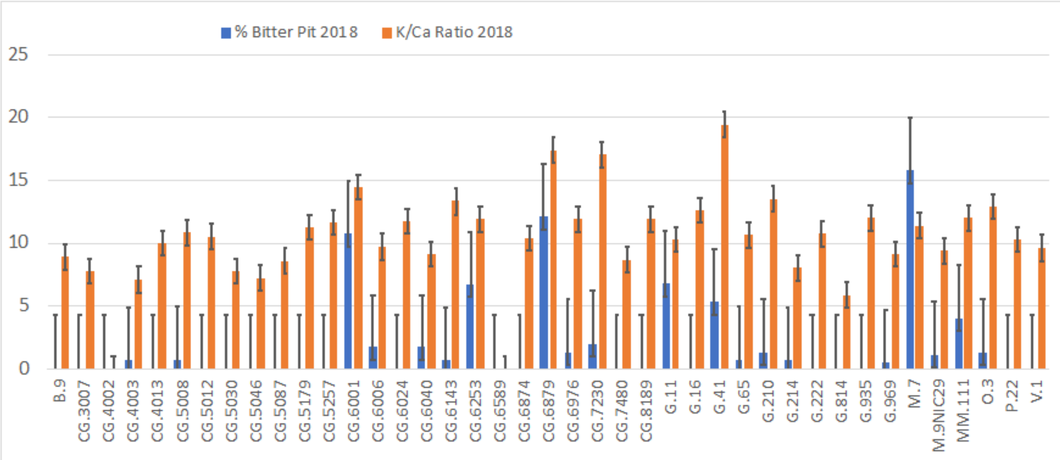

Figure 2. Ratio of K/Ca concentrations in the peel and incidence of bitter pit of mature 'Honeycrisp' apple trees on 41 rootstocks in 2018 when grown in Peru, New York (northern NY State).

2006 plot at Geneva NY

The incidence of bitter pit in 2018 varied significantly among rootstocks with B.9, B.65 and G.214 having less than 5% bitter pit (Figure 3) G.210 had to greatest incidence of bitter pit (40%) followed by M.7, G.814, B.118 and G.41 which all had more than 20% bitter pit. G.11, G.16 G.30, G.935, G.4202, G.4210, G.5046, G.5202, M.26 and M.9T337 and M.9Pajam2 all had between 5 and 15% bitter pit.

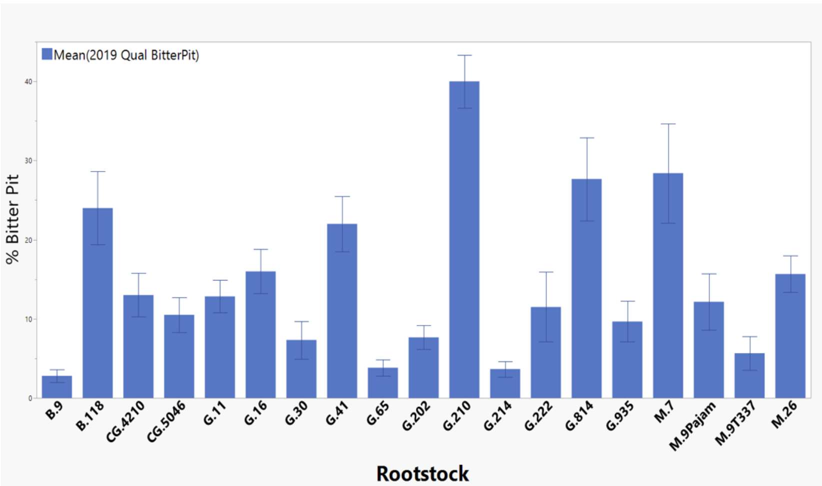

Figure 3. Incidence of bitter pit with mature 'Honeycrisp' apple trees on 19 rootstocks in 2019 when grown in Geneva, New York.

Cumulative yield from the Geneva plot from 2008 to 2020 was greatest for G.935 followed by G.210, G.214, G.11, G.30, G.41, G.5046, G.202 (Figure 4) The lowest cumulative yield was with G.65 followed by B.118, G.814, B.9 and M.7. When the percent bitter pit from the 2018 crop year was applied to the cumulative yield the greatest calculated bitter pit free yield was with G.214 (810 t ha^{-1}) followed by G.935, G.11, G.30, G.5046, G.16, G.202, M.9T337, M.9Pajam2 and G.202 which all had more than 600 t ha^{-1} cumulative yield of bitter pit free fruit.

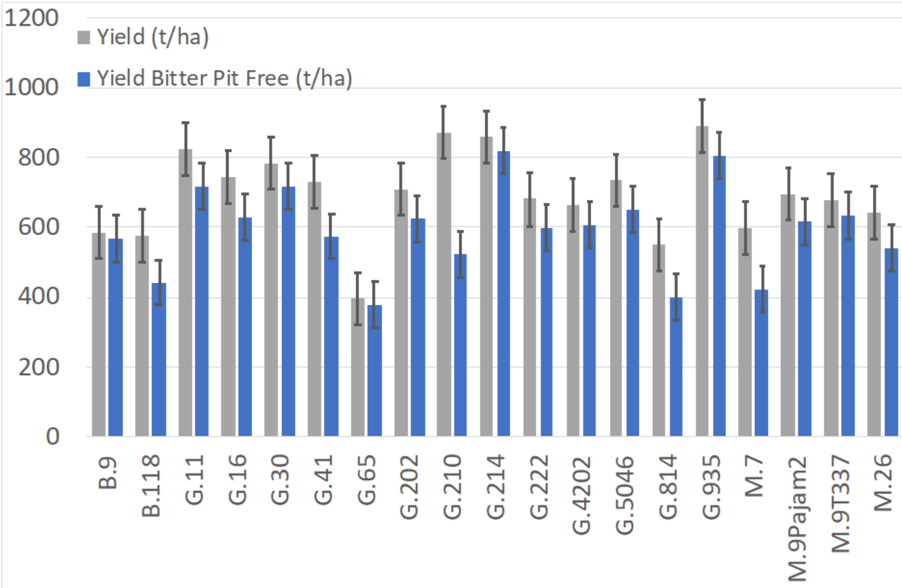

Figure 4. Cumulative total yield and yield of bitter pit free fruit of 'Honeycrisp' apple trees on 19 rootstocks from 2008 to 2020 when grown in Geneva, New York.

Cumulative crop value from 2008 to 2020 was greatest for G.214 ($ 1.3 million ha^{-1}) followed by G.935, G.11, G.30, M.9T337, G.202, M.9Pajam2, CG.5046 and CG.4202 which all had cumulative crop values of more than $ 1 million ha^{-1} (Figure 5). The lowest cumulative crop value was with G.65 followed by G.814, M.7, G.118, M.26, G.210 and B.9.

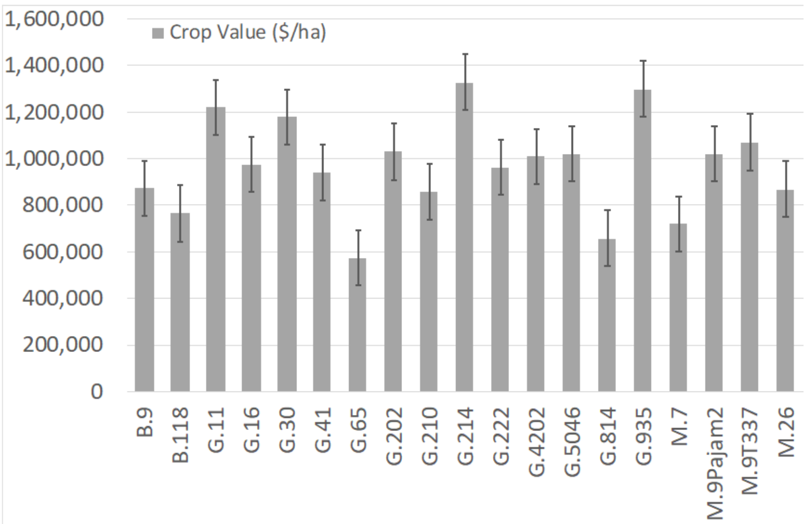

Figure 5. Cumulative crop value of 'Honeycrisp' apple trees on 19 rootstocks from 2008 to 2020 when grown in Geneva, New York.

DISCUSSION

The results of this study support our earlier results that showed rootstock genotype has a large influence on bitter pit incidence and on the fruit nutrient levels of the peel (Fazio et al., 2020). In this study we have confirmed that B.9 in most cases has low bitter pit incidence (Donahue et al., 2021). We have also identified several new Geneva® rootstocks which have low bitter pit incidence (G.214 and G.65) and other rootstocks that have high bitter pit incidence (G.210 and M.7).

The incidence of bitter pit is one factor to consider when selecting a rootstock for a new planting of 'Honeycrisp'. In addition to bitter pit incidence, the total cumulative yield of a rootstock needs to be considered to determine the economic result of different rootstocks (Lordan et al., 2019). Our results from the 2006 Geneva plot indicate that although B.9 had a low incidence of bitter pit, its cumulative yield was significantly lower than other stocks resulting in at least 10 other stocks which had higher cumulative yield of bitter pit free fruit than trees on B.9. When the yield and fruit size data were converted to crop value the best stocks had a 44% greater cumulative crop value than B.9. 'Honeycrisp' has low scion vigor and with B.9 it often does not fill the allotted space. We have suggested that rootstock vigor should allow filling the space in the first 2-3 years and will have high yields of bitter pit free fruit to maximize crop value and income.

We have previously shown that some rootstocks such as G.41 and G.11 have greater uptake of K than other rootstocks such as G.214 and G.969 (Fazio et al., 2020). It appears that bitter pit incidence is greater with rootstocks which are efficient in uptake of K and N while high K uptake is associated with greater fruit size. Greater K and N uptake is often associated with greater rootstock vigor (e.g., M.7) but can also be associated with dwarfing stocks such as G.11. The difference in K uptake of various rootstocks can be used to match rootstock to scion variety in a "designer rootstock" fashion. The best rootstock for a small fruit size cultivar like 'Gala' would be a stock with high K uptake like G.11 or G.41. The best rootstocks for a bitter pit sensitive cultivar like 'Honeycrisp' would be stocks that have sufficient vigor to fill the space but which also have low K uptake. It appears that G.214 has both sufficient vigor to fill the space and low K uptake resulting in low bitter pit incidence. It has been shown that another Geneva® rootstock, G.969, also has low incidence of bitter pit and similar vigor as G.214.

The differences in rootstock nutrient profiles indicate that different soil fertility management programs are needed for each rootstock. For stocks with natural high K uptake much lower fertilizer inputs of K are needed. For stocks with low natural K uptake higher levels of fertilizer inputs of K are needed. In New York State, our recommendations for fertilizer K inputs are based on M.9 rootstock but for G.11 or G.41 new standards need to be developed.

The ratio of fruit peel K/Ca can be used as a prediction of bitter pit incidence (Al Shoffe et al., 2019) and as a guide for fertilization inputs. For orchards on rootstocks that have high K/Ca or high N/Ca ratios in the fruit and therefore high bitter pit incidence there are several mitigation strategies that can be employed such as:

- Increase the quantity of Ca through foliar sprays (Rosenberger et al., 2004; Torres et al., 2017);
- Eliminate annual N applications;
- Eliminate annual K applications;
- Increase lime applications;
- Avoid application of AVG or 1-MCP. Watkins et al. (2021) have reported that applications of these plant growth regulators as preharvest drop control agents exacerbated bitter pit in trees which have high K/Ca ratios.

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Literature cited

Al Shoffe, Y., Nock, J.F., Zhang, Y., Zhu, L., and Watkins, C.B. (2019). Comparisons of mineral and non-mineral prediction methods for bitter pit in 'Honeycrisp' apples. Sci. Hortic. (Amsterdam) *254*, 116–123 https://doi.org/10.1016/j.scienta.2019.04.073.

Donahue, D.J., Reig, G., Rutzke, M., Wallis, A., Basedow, M., and Elone, S.E. (2021). A predictive model for *Malus × pumila* Borkh 'Honeycrisp' to reduce storage risk in Eastern New York State, U.S.A. Acta Hortic. *1314*, 409–418 https://doi.org/10.17660/ActaHortic.2021.1314.51.

Fazio, G., Kviklys, A., Grusak, M.A., and Robinson, T.L. (2013). Phenotypic diversity and QTL mapping of absorption and translocation of nutrients by apple rootstocks. Asp. Appl. Biol. *119*, 37–50.

Fazio, G., Lordan, J., Grusak, M.A., Francescatto, P., and Robinson, T.L. (2020). I. Mineral nutrient profiles and relationships of 'Honeycrisp' grown on a genetically diverse set of rootstocks under Western New York climatic conditions. Sci. Hortic. (Amsterdam) *266*, 108477 https://doi.org/10.1016/j.scienta.2019.05.004.

Lordan, J., Fazio, G., Francescatto, P., and Robinson, T.L. (2019). II. Horticultural performance of 'Honeycrisp' grown on a genetically diverse set of rootstocks under western New York climatic conditions. Sci. Hortic. (Amsterdam) *257*, 108686 https://doi.org/10.1016/j.scienta.2019.108686.

Lordan, J., Francescatto, P., Fazio, G., and Robinson, T.L. (2020). Effects of apple rootstocks on nutrient concentration in 'Honeycrisp' scions. Acta Hortic. *1281*, 97–104 https://doi.org/10.17660/ActaHortic.2020.1281.15.

Neilsen, G., and Hampson, C. (2014). 'Honeycrisp' apple leaf and fruit nutrient concentration is affected by rootstock during establishment. J. Am. Pomol. Soc. *68*, 178–189.

Reig, G., Lordan, J., Fazio, G., Grusak, M.A., Hoying, S., Cheng, L., Francescatto, P., and Robinson, T. (2018). Horticultural performance and elemental nutrient concentrations on 'Fuji' grafted on apple rootstocks under New York State climatic conditions. Sci. Hortic. (Amsterdam) *227*, 22–37 https://doi.org/10.1016/j.scienta.2017.07.002.

Robinson, T., and Lopez, S. (2012). Crop load affects 'Honeycrisp' fruit quality more than nitrogen, potassium, or irrigation. Acta Hortic. *940*, 529–537 https://doi.org/10.17660/ActaHortic.2012.940.76.

Robinson, T.L., and Watkins, C.B. (2003). Crop load of Honeycrisp affects not only fruit size but many quality attributes. New York Fruit Quarterly *11* (*3*), 7–10.

Rosenberger, D., Schupp, J., Hoying, S., Cheng, L., and Watkins, C. (2004). Controlling bitter pit in 'Honeycrisp' apples. Horttechnology *14* (*3*), 342–349 https://doi.org/10.21273/HORTTECH.14.3.0342.

Torres, E., Recasens, I., Lordan, J., and Alegre, S. (2017). Combination of strategies to supply calcium and reduce bitter pit in 'Golden Delicious' apples. Sci. Hortic. (Amsterdam) *217*, 179–188 https://doi.org/10.1016/j.scienta.2017.01.028.

Watkins, C.B., Al Shoffe, Y., Nock, J.F., and Zhangm, Y. (2021). Harvista™ effects on fruit maturity on 'Honeycrisp' apples and susceptibility to physiological storage disorders. Fruit Quarterly *29* (*3*), 4–7.