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Field Performance of Rootstocks for Bitter Pit Reduction in 'Honeycrisp' Apples

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Introduction

'Honeycrisp' apples are among the most profitable cultivars in the U.S., ranking third in production after 'Gala' and 'Red Delicious' (Donahue et al., 2021). Their high market value is driven by strong consumer demand for their unique texture, juiciness, and flavor. However, the variety is notoriously prone to bitter pit (BP), a physiological disorder that continues to challenge growers and packers. On average, BP accounts for about 20% crop loss annually, but in some years, losses can reach 80%, resulting in substantial economic damage (Cheng and Sazo, 2018).

BP typically appears as sunken, dark spots on the fruit surface, often with brown, oxidized tissue underneath. While BP has long been associated with low calcium (Ca^{2+}) levels, studies have shown that total Ca^{2+} concentration in fruit does not consistently predict the disorder's occurrence (de Freitas et al., 2010; Falchi et al., 2017). This is because the physiological mechanisms behind BP involve more complex interactions—such as imbalances in the partitioning of Ca^{2+} within fruit tissues and competition with other nutrients like potassium (K^{+}), magnesium (Mg^{2+}), and nitrogen (N). For example, excessive Mg^{2+} can outcompete Ca^{2+} for cell wall binding sites, while high nitrogen promotes vegetative growth, pulling Ca^{2+} away from developing fruit (Lim et al., 2005). As a result, nutrient ratios like K^{+}/Ca^{2+}, Mg^{2+}/Ca^{2+}, and N/Ca^{2+} are considered more reliable indicators of BP risk than total Ca^{2+} levels alone (de Freitas et al., 2010; Fazio et al., 2020).

Rootstocks also play a critical role in BP incidence by influencing tree vigor, nutrient uptake, and fruit mineral balance. For instance, some rootstocks have been shown to alter Ca^{2+} accumulation in the fruit or increase unfavorable Mg^{2+}/Ca^{2+} ratios, leading to higher susceptibility (Fazio et al., 2020; Donahue et al., 2021).

The current study evaluated the performance of 14 different rootstocks in relation to BP development in 'Honeycrisp' apples over four consecutive seasons (2018–2021).

While this publication focuses on BP incidence, the effects of the same set of rootstocks on tree growth and yield characteristics were previously reported in a multi-location trial (Cline et al., 2021) and summarized in an earlier extension publication (Sherif, 2022). This current report provides a condensed, grower-oriented summary of a more detailed peer-reviewed article published by Islam et al. (2021), which offers additional technical insights into the underlying physiology.

Field Trial Overview

This study was conducted at a commercial orchard in Piney River, Virginia, using 'Honeycrisp' apple trees grafted on 14 different rootstocks. The trees were planted in 2014 as part of a larger USDA-funded, multi-state rootstock evaluation project (NC-140). The trial included rootstocks from four breeding programs: Budagovsky (B.10), Geneva (G.11, G.202, G.214, G.30, G.41, G.935, G.969), Malling (M.9-T337, M.26 EMLA), and Vineland (V.1, V.5, V.6, V.7). All trees were trained to a tall spindle system and spaced at 4 feet within the row and 12 feet between rows (approximately 906 trees per acre). The orchard was managed according to standard commercial practices, including irrigation, fertilization, hand thinning, pest control, and disease management.

Each rootstock was replicated with 10 trees in a completely randomized layout. Fruits were first harvested in 2016, and data on BP incidence and fruit quality were collected from 2018 to 2021. BP was assessed both at harvest and after three months of cold storage. Fruit quality traits—including weight, size, firmness, and sugar content—were measured at harvest each year. In addition to fruit quality and BP assessments, skin tissues from 'Honeycrisp' apples on three different rootstocks (B.10, G.41, and V.6) were collected after two months of storage to analyze key mineral nutrients: calcium, magnesium, and potassium.

Field Trial Results

Rootstock Influences on Bitter Pit Incidence

Bitter pit incidence in 'Honeycrisp' apples varied widely depending on the rootstock used. Over a four-year period (2018–2021), trees on B.10 consistently showed the lowest levels of BP at harvest and after three months of cold storage. In contrast, trees grafted on V.6 and V.7 had the highest BP incidence. Moderate BP levels were observed in trees on several other rootstocks, including G.11, G.41, G.202, G.214, G.935, G.969, M.26 EMLA, M.9-T337, V.1, and V.5. The rankings were largely consistent whether fruit was evaluated fresh or after storage (Figure 1).

Fruit Quality and Its Link to Bitter Pit

From 2018 to 2021, fruit weight, diameter, and firmness were measured at harvest, while sugar content (measured as soluble solids content or SSC) was assessed from 2019 to 2021. Apples from trees on B.10 rootstock were the smallest, averaging 168 grams, while those on V.5 and V.6 were the largest, averaging around 220 grams. Although fruit weight varied by rootstock, there were no significant differences in fruit diameter, firmness, or sugar levels. However, fruit that were larger and heavier tended to have more bitter pit. In fact, both fruit weight and size were positively correlated with bitter pit incidence, with fruit weight showing the strongest link. This suggests that rootstocks producing larger/heavier fruit may carry a higher risk of bitter pit, especially if calcium balance is not carefully managed.

Mineral Composition of the Fruit Peel

To better understand why some rootstocks are more prone to BP, we analyzed the mineral composition of fruit peel after storage, focusing on three contrasting rootstocks: B.10 (low BP), G.41 (moderate BP), and V.6 (high BP) (Figure 2). Apples from B.10 had significantly higher calcium concentrations in the peel—about 60% more than those from G.41 and V.6. In contrast, apples from G.41 and V.6 had higher levels of magnesium and potassium, which are known to compete with calcium and contribute to BP development (Figure 3). These rootstocks also showed elevated Mg^{2+}/Ca^{2+} and K^{+}/Ca^{2+} ratios, which are commonly associated with a higher risk of bitter pit.

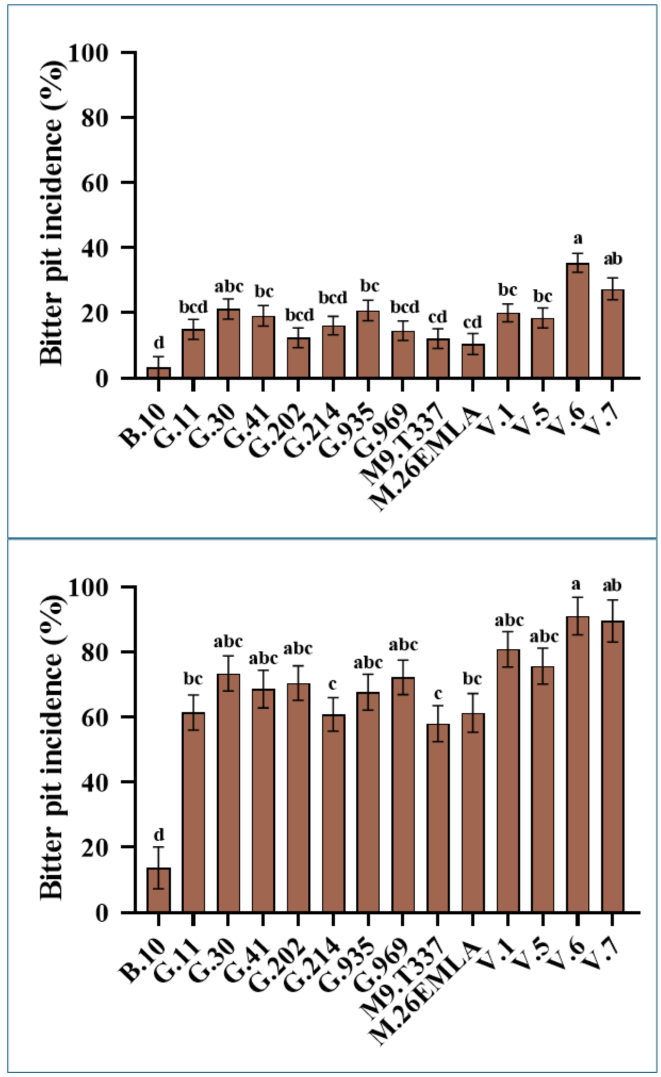

Figure 1. Effect of rootstock on bitter pit incidence in 'Honeycrisp' apples. Average BP incidence at harvest over four growing seasons (upper panel) and after three months of cold storage based on three growing seasons (lower panel). Bars with different letters indicate significant differences at the 5% level based on Tukey's HSD test.

Summary and Conclusions

- This multi-year evaluation underscores the importance of rootstock selection as a practical tool for managing BP in 'Honeycrisp' apples. Rootstocks differed not only in BP susceptibility but also in their effects on fruit mineral composition.
- B.10 consistently showed the lowest BP incidence, while also producing smaller fruit with higher peel calcium and lower magnesium and potassium

levels—a mineral profile commonly associated with reduced BP risk.

- Differences in BP severity among rootstocks appear to involve not just total calcium content, but also how calcium is distributed and utilized within the fruit.
- These results suggest that rootstocks can influence calcium partitioning, offering management options beyond traditional calcium sprays or general nutrient strategies.
- Growers should consider rootstock effects not only on vigor and yield, but also on fruit quality and the development of physiological disorders such as BP.
- In summary, B.10 emerges as a promising rootstock for 'Honeycrisp', combining modest fruit size, improved calcium balance, and significantly lower bitter pit incidence. In addition, our earlier research showed that trees on B.10 perform comparably to those on M.9 in both size and cumulative yield efficiency, making it a suitable option for high-density orchard systems.

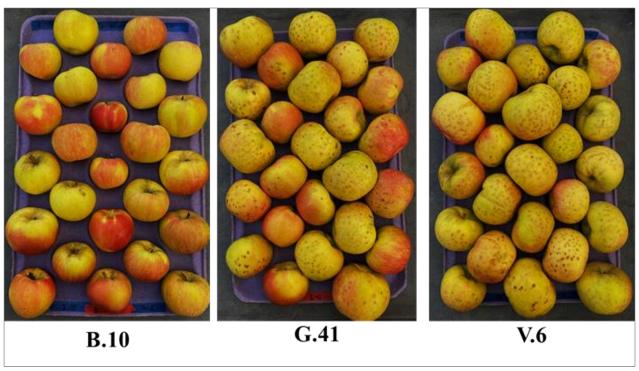

Figure 2. Development of bitter pit symptoms on 'Honeycrisp' apples from B.10, G.41, and V.6 rootstocks after two months of cold storage.

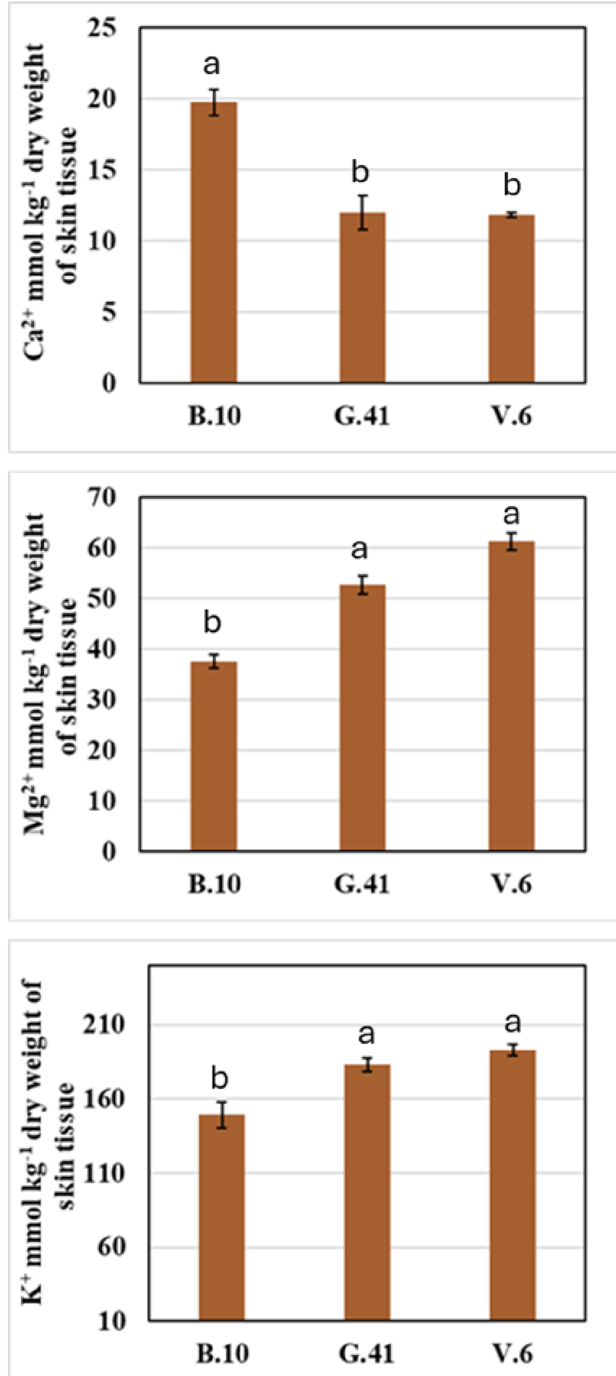

Figure 3. Concentrations of calcium (Ca), magnesium (Mg), and potassium (K) in the skin tissue of 'Honeycrisp' apples from B.10, G.41, and V.6 rootstocks after two months of cold storage. Bars with different letters indicate significant differences at $P < 0.05$ based on Tukey's HSD test.

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