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Field Evaluation of AVG and 1-MCP for Managing Pre-Harvest Drop and Fruit Quality in ‘Gala’ Apples

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Introduction

Pre-harvest fruit drop (PFD) significantly threatens apple production, particularly in sensitive varieties such as 'Gala'. This issue leads to considerable economic losses, as dropped fruits often cannot be marketed as fresh produce, dramatically impacting orchard profitability. Ethylene, a naturally occurring hormone that accelerates ripening, is the primary driver of fruit drop (Greene, 2005). As apple fruits approach maturity, ethylene production escalates, initiating physiological changes such as starch degradation, color change, and increased susceptibility to dropping (Yuan and Carbaugh, 2007). Thus, effectively managing ethylene synthesis or action is essential to extend the harvest window, reduce losses, and maintain fruit quality during storage and marketing.

Two principal plant growth regulators (PGRs) commonly utilized by growers are Aminoethoxyvinylglycine (AVG) and 1-Methylcyclopropene (1-MCP). AVG, commercially known as "ReTain" (Valent BioSciences), inhibits ethylene biosynthesis by blocking the enzyme ACC synthase, thereby slowing fruit ripening and abscission. 1-MCP, commercially available as "Harvista" (AgroFresh Inc.), binds to ethylene receptors, inhibiting ethylene action in fruits (Byers et al., 2005). Both products require precise timing and concentration management to maximize effectiveness and minimize negative side effects like delayed fruit coloration and uneven ripening (Liu et al., 2022).

Field Trials

Between 2018 and 2021, four distinct field experiments were conducted across Virginia to assess the effects of AVG (ReTain), 1-MCP (Harvista), and gibberellin (GA_{4+7}; ProVide) on pre-harvest fruit drop and fruit quality in various 'Gala' strains grafted on different rootstocks.

Experiment 1 (2018): Conducted in Middletown, VA (39.027, −78.280), this trial used 6-year-old ‘Brookfield Gala’ trees grafted on G.16 rootstock. AVG was applied at half-rate (166 g/acre) or full-rate (333 g/acre), either 3 or 1 weeks before anticipated harvest (WBAH), or at both timings. Each application included Silwet-77 surfactant (0.1% v/v) and was delivered with a pressurized sprayer. Fruit drop was monitored weekly from 1 WBAH through 2 weeks after harvest. Fruit quality was evaluated both at harvest and again after 3 months of cold storage.

Experiment 2 (2019): Repeated in the same Middletown orchard with the same ‘Brookfield Gala’/G.16 trees, this experiment compared AVG at full-rate (333 g/acre) and double-rate (666 g/acre) applied at 3 or 1 WBAH; 1-MCP (120 fl oz/acre) applied at starch pattern index (SPI) 2; and 1-MCP (120 fl oz/acre) applied at SPI 1.5 and 3. Internal ethylene concentration (IEC) was measured at harvest in addition to other fruit quality parameters.

Experiment 3 (2021): Conducted in Timberville, VA (38.639, −78.773) on 8-year-old ‘Buckeye Gala’ trees on Nic29 rootstock. Six treatments were evaluated in this experiment. In the first two treatments, trees received either AVG alone at 333 g/acre, or a combination of AVG (333 g/acre) and GA_{4+7} (6.75 fl oz/acre). In the next two treatments, trees were treated with AVG at 166 g/acre combined with either a single application of 1-MCP (120 fl oz/acre) at SPI 1.5 or two applications of 1-MCP applied at SPI values of 1.5 and 3. The final two treatments included 1-MCP (120 fl oz/acre) applied either once (at SPI 1.5) or twice (at SPI 1.5 and 3) without AVG. Fruit quality traits were assessed both at harvest and after cold storage. Stem-

end splitting (SES) was evaluated two weeks after harvest.

Experiment 4 (2021): Performed at the Alson H. Smith Jr. AREC in Winchester, VA (39.185, −78.163), this study used 11-year-old 'Crimson Gala' trees grafted on M.9 rootstock. Treatments included AVG at full-rate (333 g/acre) alone, and AVG at full rate in combination with one or three applications of GA_{4+7} (6.75 fl oz/acre each). The same protocol was followed for drop monitoring and quality assessments as in previous trials.

Across all experiments, standard practices were used for tagging fruit, tracking fruit drop, and evaluating quality traits such as firmness, starch index, fruit weight, DA meter readings, Brix, titratable acidity, and IEC. Stem-end splitting evaluations were performed in Experiments 3 and 4.

Field Trial Results

Experiment 1:

- Full-rate AVG (333 g/acre) applied 3 WBAH reduced pre-harvest drop by 50% compared to control.
- AVG applied at 1 WBAH had modest effects on ripening and drop suppression but was consistently less effective than the earlier 3 WBAH application.
- A single half-rate AVG application was not sufficient to significantly reduce fruit drop.
- Two half-rate applications of AVG (at 3 and 1 WBAH) were as effective as a single full-rate application in reducing fruit drop.
- AVG-treated fruit retained higher firmness and starch index at harvest and after storage.
- A negative effect on fruit color was observed with early or high-rate AVG applications.

Experiment 2:

- The overall fruit drop rate in 2019 was lower than in the 2018 trial and remained nearly unchanged during the first two weeks after harvest
- Both full- and double-rate AVG applications reduced fruit drop numerically compared to the control, with no significant difference between the two.
- 1-MCP also reduced fruit drop numerically, with double applications required to approach the level of drop control observed with a single AVG application.
- A single application of 1-MCP maintained red color similar to the control, whereas a double application of 1-MCP and a single application of ReTain applied 3 WBAH both reduced fruit color compared to the control.

Experiment 3:

- Trees treated with AVG (full-rate) at 3 WBAH and those treated with 1-MCP (SPI 1.5 and 3) exhibited the lowest fruit drop percentage (Figure 1).
- Combining AVG (half-rate) with 1-MCP did not improve drop control beyond AVG alone.
- Combining AVG (full-rate) with GA_{4+7} did not significantly improve fruit drop or quality beyond AVG alone.
- Stem-end splitting was significantly reduced by AVG-containing treatments compared to the control (Figure 2).
- 1-MCP required two applications to achieve similar SES suppression as a single AVG spray.

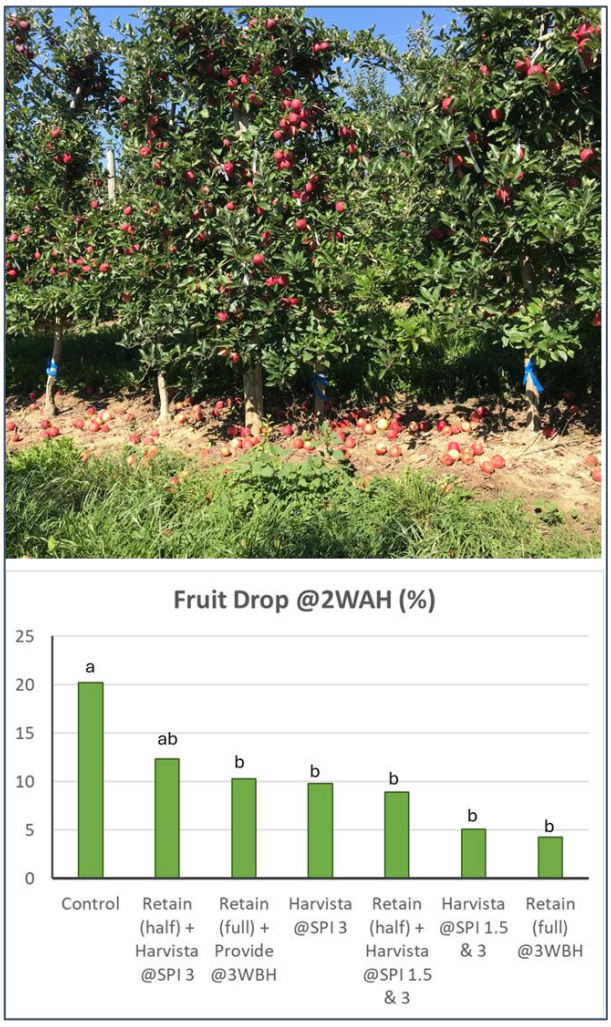

Figure 1. Pre-harvest fruit drop in 'Gala' apples (top image), and percent fruit drop measured two weeks after the normal harvest date (bottom chart) under

different treatment conditions. Bars sharing the same letter(s) are not significantly different (p > 0.05).

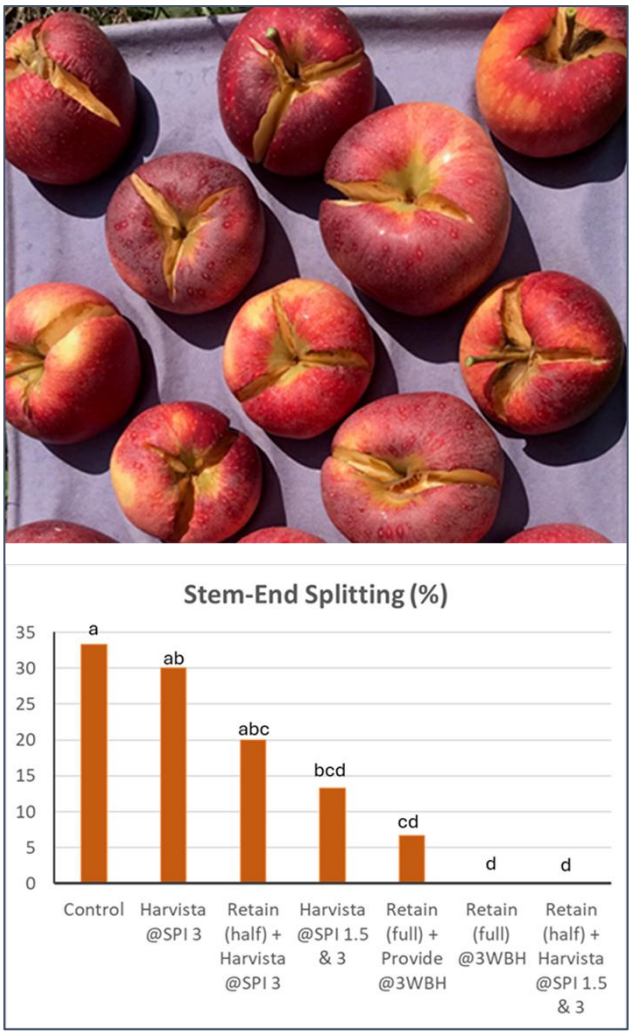

Figure 2. Stem-end splitting in 'Gala' apples (top image), and percentage of fruit exhibiting stem-end splitting measured two weeks after the normal harvest date (bottom chart) under different treatment conditions. Bars sharing the same letter(s) are not significantly different (p > 0.05).

Experiment 4:

- AVG alone and in combination with GA_{4+7} effectively reduced fruit drop.
- No clear additive benefit of GA_{4+7} over AVG alone was observed.
- Fruit treated with AVG alone maintained firmness and exhibited less stem-end splitting.
- Fruit color was slightly compromised by AVG applications, regardless of GA_{4+7} inclusion.

Summary and Conclusion

Fruit Drop Control:

- A single full-rate application of ReTain (333 g/acre) applied three weeks before harvest consistently reduced fruit drop by 39% to 80%, as measured two weeks after the normal harvest date, compared to untreated controls.

This full rate was more effective than a half-rate (166 g/acre), though not significantly different from a double rate (666 g/acre).

- ReTain's efficacy in reducing fruit drop was statistically comparable to both single and double applications of Harvista, suggesting it is a cost-effective alternative with fewer applications required.
- Harvista showed better drop control with two applications than one, although this improvement was not statistically significant.

Fruit Quality:

- ReTain, whether applied alone or in combination with ProVide or Harvista, delayed ripening and negatively impacted fruit coloration (Figure 3). Although the delay in ripening helped maintain higher firmness and extended the harvest window, it also reduced skin coloration and delayed sugar accumulation, as indicated by lower Brix values at harvest.
- Harvista, in contrast, preserved fruit firmness without adversely affecting color or sugar content when used in single applications (Figure 3), making it a suitable choice for markets requiring earlier and better-colored fruit.
- Neither ReTain nor Harvista significantly affected fruit size or weight.

Stem-End Splitting:

- ReTain alone is more effective than Harvista or ProVide in reducing fruit cracking in Gala apples.
- The addition of ProVide in combined treatments did not provide additional benefits beyond those achieved by ReTain alone.
- A double application of Harvista was required to match the stem-end splitting control achieved by a single ReTain spray, underscoring ReTain's superior efficacy and potential cost-effectiveness for controlling this particular physiological disorder.

Figure 3. ‘Gala’ fruit coloration at harvest as influenced by different treatments. A single application of ReTain and a double application of Harvista significantly reduced red color development, while a single Harvista application had minimal impact compared to the untreated control.

References

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