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Evaluation of ACC and AVG Combination as a New Tool for Managing Pre-Harvest Fruit Drop and Improving Red Color in 'Honeycrisp' Apples

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Introduction

Pre-harvest fruit drop (PFD) poses a major challenge in apple production, often leading to significant yield losses. This phenomenon is closely associated with the fruit's ripening process, during which the phytohormone ethylene plays a critical role by promoting cell wall breakdown, ultimately leading to fruit detachment (Tipu and Sherif, 2024). At the same time, achieving adequate red peel coloration— primarily due to anthocyanin accumulation— is essential for marketability, especially in bi-colored cultivars like 'Honeycrisp'. Ethylene also plays a central role in regulating this color development. This dual role creates a fundamental dilemma: while ethylene is essential for desirable coloration, it simultaneously increases the risk of fruit drop (Tipu et al., 2025).

To combat PFD, growers often apply aminoethoxyvinylglycine (AVG), commercially known as "ReTain" (Valent BioSciences), which effectively reduces drop by inhibiting ethylene biosynthesis (Liu et al., 2022). However, the major drawback of using AVG is that by reducing ethylene, it also hinders the development of red color (Miah and Farcuh, 2024), resulting in fruit that may stay on the tree but fail to meet market color standards, creating a difficult trade-off between preventing yield loss and achieving desired quality.

Addressing this challenge requires alternative strategies that can balance drop control with optimal coloration. This publication highlights the potential benefits of combining AVG with 1-aminocyclopropane-1-carboxylic acid (ACC), the immediate precursor of ethylene. Emerging evidence suggests that ACC may have signaling functions independent of its conversion to ethylene (Polko and Kieber, 2019). The core concept— that an AVG-ACC combination can help reduce pre-harvest fruit drop without compromising color— was detailed with physiological, biochemical, and molecular evidence in a peer-reviewed article by Tipu et al. (2025). This current report presents a grower-focused summary, distilling the key messages from that work and offering a practical solution to the ongoing challenge of balancing fruit retention and coloration.

Trial Characteristics

Two field trials were conducted in 2023 and 2024 at the Alson H. Smith Jr. Agricultural Research and Extension Center (AREC) in Winchester, VA, using 8-year-old 'Honeycrisp' apple trees grafted onto 'Budagovsky 9' (B.9) rootstock. The study included six treatments: Accede (ACC; 380 g/acre), Motivate (ethephon; 750 g/acre), ReTain (AVG; 333 g/acre), ReTain + Accede, ReTain + Motivate, and an untreated control. Treatments were applied either alone or in combination using a Gator-driven tank sprayer, with a nonionic surfactant (Regulaid at 2 pt/acre) added to all applications.

PGR sprays were applied at 3, 2, and 1 weeks before the anticipated harvest, except for ReTain, which was applied only once— 3 weeks prior to harvest. All trees, including the untreated control, received identical orchard and disease management practices throughout the season.

For fruit drop assessment, trees were tagged with initial counts taken at 4 weeks before harvest and subsequent counts conducted weekly from 1 week before to 2 weeks after harvest to calculate the percentage of fruit drop based on retention relative to the initial count.

Fruit background color was assessed on both blushed and unblushed sides of each fruit using a hand-held Delta Absorbance (DA) meter, which measures peel chlorophyll content and provides results as the index of absorbance difference (I_{AD}).Fruit color intensity was measured according to the CIE 1976 system (McGuire, 1992), utilizing L*, a*, and b* values to calculate the hue angle (h°), which represents the color nuance (e.g., red-purple: 0°; yellow: 90°; bluish green: 180°; blue: 180°).

Anthocyanin content was determined by the pH differential method using fruit peel tissue collected from 3 to 5 fruits per replicate 24 hours after each spray application, with sampling conducted at 3, 2, and 1 weeks before anticipated harvest in 2023, and additionally at harvest and 2 weeks after harvest in 2024.

Fruit quality traits that include flesh firmness, fruit weight, fruit diameter, brix (%) and starch index were assessed both at harvest and 2 weeks after harvest (2WAHD).

Trial Results

Fruit Drop:

- In 2023, Motivate-treated trees exhibited the highest fruit drop at both harvest and two weeks after harvest date (2WAHD) compared to the untreated control. In 2024, Accede resulted in the highest fruit drop at harvest, while Motivate again caused the greatest drop at 2WAHD (Figure 1).
- ReTain-treated trees consistently showed the lowest fruit drop percentages across all assessment periods in both 2023 and 2024, with differences being statistically significant.
- The ReTain + Accede combination effectively reduced fruit drop, resulting in significantly lower drop percentages at harvest (2024) and at 2WAH (2023 and 2024) compared to the untreated control, demonstrating consistent performance across both years.

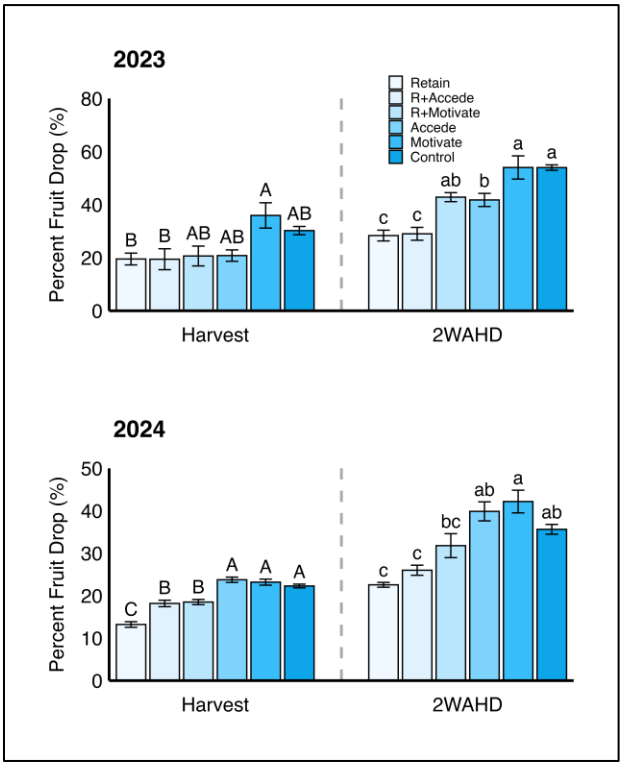

Figure 1. Percentage of fruit drop of 'Honeycrisp' apple treated with ReTain (R), R+Accede, R+Motivate, Accede, Motivate, and an untreated control at harvest and 2WAHD in 2023 (top) and 2024 (bottom). Data represent the mean ± SE (n = 3). Letters indicate significant differences among treatments at P ≤ 0.05, using ANOVA.

Fruit Color:

- Accede and Motivate treatments consistently enhanced fruit peel coloration in both 2023 and 2024 compared to the untreated control (Figure 2), as evidenced by greater chlorophyll degradation (lower I_{AD} values) and increased red color intensity (lower hue angle values) (Figure 3).
- In contrast, ReTain negatively affected the transition from green to red coloration at both harvest and 2WAHD, consistently resulting in the highest I_{AD} and hue angle values across both years.

- The ReTain + Accede combination produced improved red peel coloration, showing lower I_{AD} values in both 2023 and 2024 and intermediate hue angle values in 2024, at both harvest and 2WAHD (Figures 2 & 3).

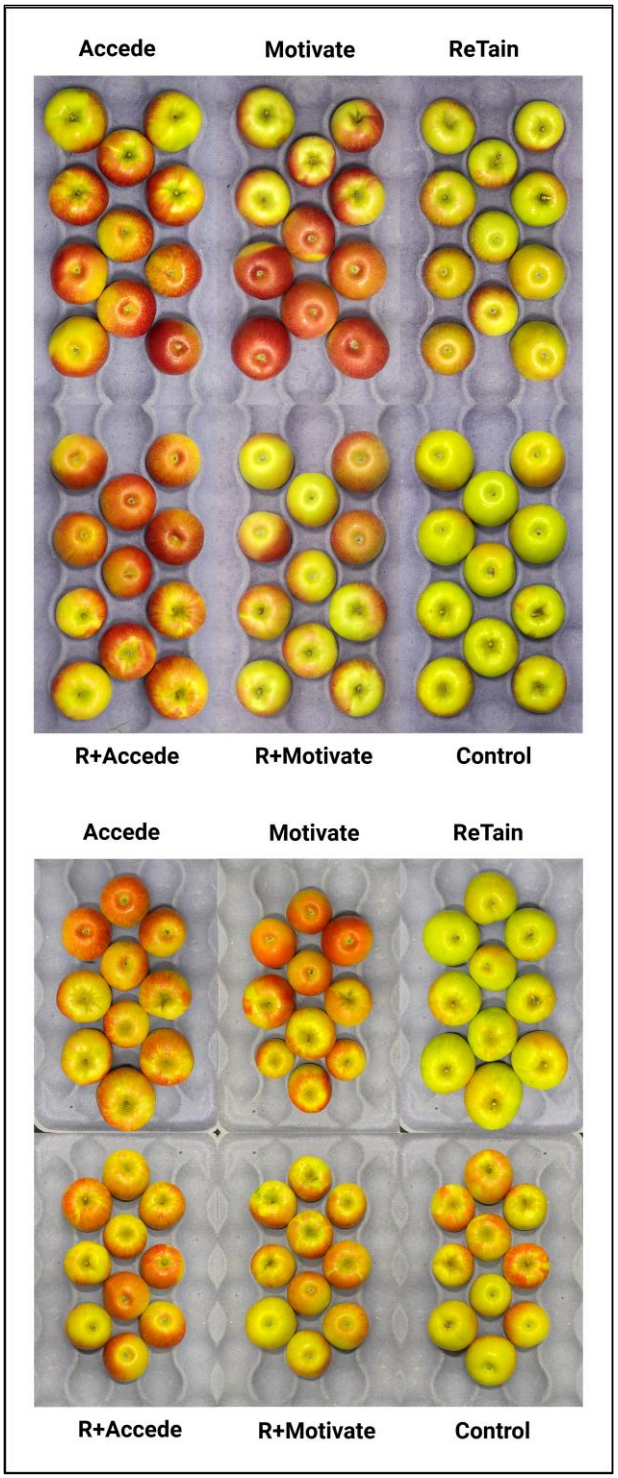

Figure 2. Effect of different PGR treatments on 'Honeycrisp' apple coloration at harvest in 2023 (top) and 2024 (bottom).

- ReTain alone reduced anthocyanin content, but when combined with Accede, the treatment significantly increased anthocyanin levels compared to the untreated control, demonstrating the advantage of using ReTain + Accede combination over ReTain alone (Figure 3).

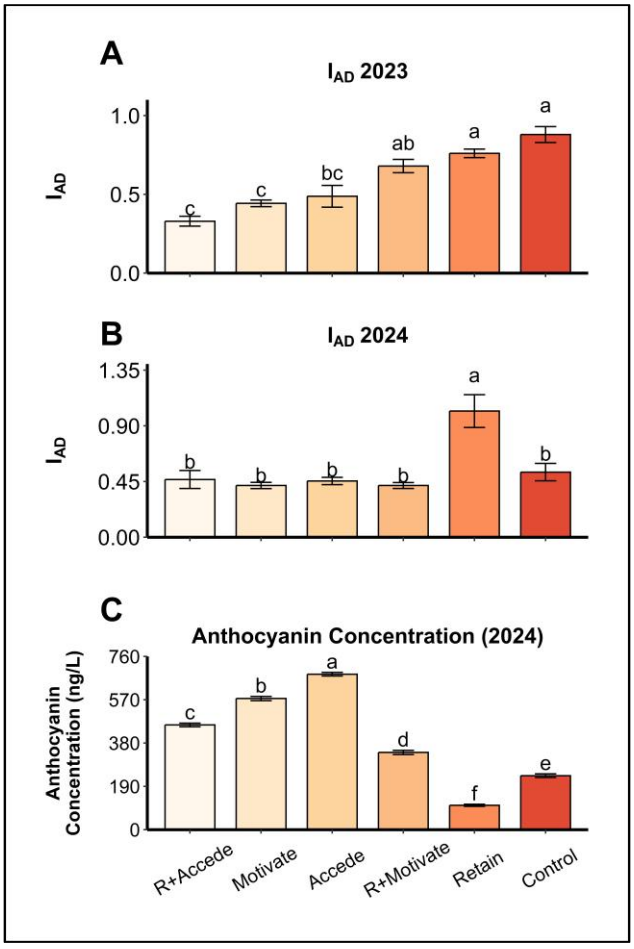

Figure 3. Effect of ReTain (R), R+Accede, Motivate, Accede, R+Motivate, and an untreated control on chlorophyll degradation (I_{AD}) and anthocyanin contents of 'Honeycrisp' apple at harvest. Data represent the mean ± SE (n = 3). Letters indicate significant differences among treatments at $P \leq 0.05$, using ANOVA.

Fruit Quality:

- Fruit firmness did not differ significantly among treatments in 2023, but showed significant variation in 2024, with the ReTain + Motivate treatment exhibiting the highest firmness at both harvest and 2WAHD (Table 1).
- Soluble sugar content (brix%) differed significantly at harvest in 2023, with the highest

values observed in the ReTain + Accede treatment. In 2024, significant differences were noted at both harvest and 2WAHD, with Accede producing the highest brix% at harvest and Motivate at 2WAHD.

Table 1. Effects of Different Treatments on Fruit Firmness and Soluble Sugar Contents (Brix%) on 'Honeycrisp' Apples at Harvest in 2023 and 2024.

2023		
Treatment	Firmness (lbf)	Brix%
Accede	17.13 a	11.95 ab
Motivate	16.82 a	10.80 b
ReTain	17.02 a	12.25 ab
ReTain+Accede	17.04 a	12.53 a
ReTain+Motivate	17.39 a	11.77 ab
Control	16.35 a	10.76 b

2024		
Treatment	Firmness (lbf)	Brix%
Accede	16.58 b	12.82 a
Motivate	17.40 ab	12.78 a
ReTain	18.39 a	10.81 c
ReTain+Accede	17.34 ab	12.02 ab
ReTain+Motivate	18.43 a	11.75 b
Control	17.63 ab	12.80 a

Data represent the mean ± SE (n = 3). Letters indicate significant differences among treatments at P ≤ 0.05, using ANOVA.

- At harvest in 2023, Motivate, ReTain + Motivate, and ReTain + Accede treatments resulted in the highest starch index values, indicating earlier ripening compared to the untreated control. In contrast, in 2024, ReTain-treated fruits consistently showed lower starch index values, reflecting reduced starch breakdown and delayed ripening relative to other treatments.
- Fruits treated with Accede or ReTain + Accede did not differ significantly in starch index from the untreated control in either year, suggesting that these treatments had minimal effect on the natural rate of starch degradation.

Summary and Conclusion

- Accede and Motivate individually enhanced fruit coloration and accelerated ripening, but these benefits came at the cost of significantly increased fruit drop, ultimately reducing yield in both years.

- Applying ReTain three weeks before the anticipated harvest effectively reduced fruit drop by inhibiting ethylene production. However, a key drawback was its suppression of red skin coloration, as it delayed chlorophyll degradation and ripening.
- The combined application of ReTain and Accede not only minimized pre-harvest fruit drop but also significantly improved red pigment development and overall peel color compared to the untreated control— offering a clear advantage over using ReTain alone.
- In addition to enhancing color and reducing drop, the ReTain + Accede treatment maintained desirable fruit firmness and did not compromise sugar accumulation, making it a promising strategy to improve overall fruit quality and maximize economic returns.

References

Liu, J., M.T. Islam, and S.M. Sherif. 2022. "Effects of Aminoethoxyvinylglycine (AVG) and 1-Methylcyclopropene (1-MCP) on the pre-harvest drop rate, fruit quality, and stem-end splitting in 'Gala' apples." *Horticulturae* 8: 1100. https://doi.org/10.3390/horticulturae8121100

McGuire, R.G. 1992. "Reporting of objective color measurements." *HortScience* 27: 1254. https://doi.org/10.21273/HORTSCI.27.12.1254

Miah, M.S., and M. Farcuh. 2024. "The expression of key ethylene and anthocyanin biosynthetic genes of 'Honeycrisp' apples subjected to the combined use of reflective groundcovers and Aminoethoxyvinylglycine in the Mid-Atlantic US." *Plants* 13: 1141. https://doi.org/10.3390/plants13081141

Polko, J.K., and J.J. Kieber. 2019. "1-Aminocyclopropane 1-carboxylic acid and its emerging role as an ethylene-independent growth regulator." *Frontiers in Plant Science* 10. https://doi.org/10.3389/fpls.2019.01602

Tipu, M.M.H., K.R. Jahed, and S.M. Sherif. 2025. "Integrated application of ACC and AVG mitigates pre-harvest fruit drop and enhances red coloration in apple." *Plant Growth Regulation*. (In press)

Tipu, M.M.H., and S.M. Sherif. 2024. "Ethylene and its crosstalk with hormonal pathways in fruit ripening: Mechanisms, modulation, and commercial exploitation." *Frontiers in Plant Science* 15. https://doi.org/10.3389/fpls.2024.1475496

2025 SPES-712NP