Effects of a Sprayable Formulation of 1-MCP (Harvista) and Naphthaleneacetic Acid (NAA) on Fruit Set of Pioneer McIntosh When Applied at and Following Bloom

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Ethylene is a naturally occurring plant hormone that regulates many physiological processes within the apple. It is an extremely important hormone in that it can be generated directly by the breakdown of the plant growth regulator ethephon immediately following application. It may also be regulated or modified within the plant by the use of the ethylene inhibitors aminoethoxyvinylglycine (AVG, ReTain) and 1-MCP (SmartFresh, Harvista). ReTain reduces the production of ethylene in the plant by retarding its biosynthesis. The 1-MCP inhibits ethylene responses by irreversibly attaching to ethylene binding sites, thus preventing a plant from responding to ethylene.

The use of ethylene inhibitors has become very important in the apple industry. Commercially, uses are generally related to fruit ripening in the fall. ReTain is applied preharvest to retard preharvest drop and to delay ripening as a labor management technique. SmartFresh is applied as a gas soon after harvest to retard further ripening and senescence of stored fruit.

Minimal work has been done to evaluate the effects of ethylene inhibitors when applied at bloom or during the early postbloom period. This is an important physiological time for apples, since final fruit set is largely determined during this time period. It has been known for many years that ReTain will increase fruit set when applied near petal fall, but this has not been adopted for any practical use. SmartFresh is applied commercially as a gas in an enclosed room, thus little work was done to influence physiological processes in the orchard because of the difficulties associated with application of a gas in the orchard. Recently, a sprayable form of 1-MCP was made available that can be applied to trees in the orchard.

The mode of action of specific thinners has yet to be clearly defined. It has long been known that NAA causes the production of ethylene, and it is suspected that the ethylene production following application may be a major contribution to the thinning response caused by NAA. A way to test the involvement of ethylene in the thinning response is to use an ethylene inhibitor. To date, there are no published reports on the influence 1-MCP may have on the thinning response to NAA application.

This investigation was initiated with two objectives in mind: 1) determine if 1-MCP could influence either initial set or retard June drop by counteracting the abscission-promoting effects of ethylene; and 2) determine if 1-MCP could either modify or negate the effects of the thinning spray, NAA, presumably by counteracting the effects of ethylene that are generated following NAA application.

Materials & Methods

Two experiments were initiated on mature 'Pioneer Mac'/M.9 apples growing at the UMass Cold Spring Orchard Research & Education Center in Belchertown, MA. Normal commercially acceptable pest control and cultural management practices were

Table 1. Effects of 1-methylcyclopropene (1-MCP) application at different physiological stages on fruit set of 'Pioneer McIntosh'/M.9 apples.

1-MCP application[z]		Bloom	Fruit set	
Stage	Date	Blossom clusters per cm^2 LCSA[y]	Fruit per cm^2 LCSA	Percent set
Control	---	9.9 a[x]	11.0 a	109 a
Bloom	10 May	9.9 a	10.1 a	108 a
Petal Fall	17 May	9.9 a	12.3 a	129 a
10 mm	24 May	9.8 a	10.0 a	103 a
Significance				
Treatment		NS	NS	NS

[z]1-MCP was applied with a CO_2 back-pack sprayer at 209 $mg \cdot L^{-1}$ in 1% AFxRD-038 oil and 0.05% Silwet L-77.
[y]LCSA, limb cross-sectional area.
[x] Means within columns not followed by a common letter are significantly different at odds of 19 to 1 (Duncan's New Multiple Range Test, $P = 0.05$).
[NS]Nonsignificant.

used during the course of the experiment.

Experiment 1. Time of Application of 1-MCP. Twenty 18-year-old 'Pioneer Mac' apple trees were selected in a non-irrigated block in 2007. At the pink stage of flower development, two representative limbs per tree were randomly selected, tagged, and their circumferences measured. After counting all blossom clusters on the selected limbs, blossom cluster density was calculated by dividing the number of blossom clusters by cm^2 limb cross-sectional area. Trees were placed into five groups (replications) based upon similarity in the calculated blossom cluster density. Treatments were randomly assigned among the four trees within each replication. Treatments were sprayable 1-MCP (Rohm and Haas Company, Spring House, PA) applied at three distinct physiological stages: bloom (May 10), petal fall (May 17), and 10-mm diameter fruit (May 24). One tree in each replication was not sprayed and served as the untreated control. The sprayable formulation of 1-MCP was applied as a dilute handgun application using an 3 gal backpack sprayer propelled with CO_2 at 40 lb pressure. In the backpack sprayer, 62.5 g of 1-MCP formulation was placed along with 113.5 mL AFxDR-038 summer oil and 6 mL of Silwet L-77 . This gave a final 1-MCP concentration in the tank of 209 mg per liter with 1% oil and 0.05% Silwet L-77. The sprayable 1-MCP was mixed in the orchard. The sprayer was filled with water, and then Silwet L-77 and summer oil were added and mixed using a portable drill equipped with an attached paint mixer. The previously measured 1-MCP was added to the tank, mixed for 30 seconds, the top placed on the sprayer, and then the tank was pressurized with CO_2. The contents of the tank were sprayed on trees within 10 minutes of mixing. Approximately 0.8 gal of spray was applied to each tree.

On May 17, 20 spurs were randomly selected on the periphery of each tree and tagged. Tagging was done at this time to preclude potential bias when fruit started to enlarge and before fruit size differences within the spur became apparent. The first set count was taken on May 29 when fruit were about 14 mm in diameter and it was possible to get a good indication of initial fruit set. The number of persisting fruit on

each spur was counted on May 29, June 6, June 13, and August 14, and the average number of persisting fruit on each spur was calculated. At the end of June drop, in July, all persisting fruit were counted on the tagged portions of each of the two selected limbs, and final fruit set calculated. At the normal time of harvest on September 10, 30 fruit were harvested from each tree. Fruit were weighed and red color estimated to the nearest 10 percent. A 10-apple subsample representative of the sample was selected. Flesh firmness was assessed on two sides of each fruit using a Lake City Technical Products Inc. EPT-1 Econic pressure tester (Lake City Technical Products Inc., Kelowna, BC, Canada). A juice sample collected while conducting the pressure test was collected and soluble solids determined using a hand-held refractometer. Fruit were then cut at the equator and dipped in an iodine solution for approximately 1 minute. The starch distribution pattern was then judged on a scale of 1-8 (Blanpied and Silsby, 1992).

Experiment 2. Interaction of 1-MCP with NAA. Twenty-four uniform trees were selected in the spring of 2007 in the block described above, and they were similarly tagged, blossom clusters counted, and bloom density calculated. Trees were placed into six groups (replications) based upon similarity of blossom cluster density. Two trees in each replication received a spray of 1-MCP at 209 mg per liter as described above on May 24. One day later, one tree in each replication that was previously unsprayed received a spray containing 6 mg NAA per liter, while a second tree that was previously sprayed with 1-MCP also received a dilute spray of 6 mg NAA per liter, leaving one tree that received a spray of 1-MCP only. Spray applications were done similarly to that described in Experiment 1. One tree per replication was unsprayed and served as the untreated control. At the end of June drop, all persisting fruit on the tagged portion of the two selected limbs per tree were counted and final set calculated. At the normal harvest time in September, a 30-apple sample was randomly harvested from the perimeter of each tree and subjected to the same evaluation that was described previously.

Results

Experiment 1. Time of Application of 1-MCP. Regardless of the application time, 1-MCP did not affect the final fruit set (Table 1). This was true regardless of whether the set was expressed as fruit per cm^2 limb

Table 2. Effect of 1-methylcyclopropene (1-MCP) application at different physiological stages on fruit set of individually tagged spurs on 'Pioneer McIntosh'/M.9 apples.

1-MCP application[z]		Number of fruit per spur			
Stage	Date	29 May	6 June	13 June	14 Aug.
Control	---	3.4 b[y]	2.7 a	1.9 a	1.5 a
Bloom	10 May	3.3 b	2.6 a	1.9 a	1.5 a
Petal Fall	17 May	4.0 a	2.8 a	2.1 a	1.6 a
10 mm	24 May	4.5 a	2.7 a	2.0 a	1.6 a
Significance					
Treatment		**	NS	NS	NS

[z]1-MCP was applied with a CO_2 back-pack sprayer at 209 mg·L^{-1} in 1% AFxRD-038 oil and 0.05% Silwet L-77.
[y]Means within columns not followed by a common letter are significantly different at odds of 19 to 1 (Duncan's New Multiple Range Test, $P = 0.05$).
NS, ** Nonsignificant or significant odds of 99 to 1, respectively.

Table 3. Effect of 1-methylcyclopropene (1-MCP) application alone and in combination with naphthaleneacetic acid (NAA) at the 10 mm stage on fruit set of 'Pioneer McIntosh'/M.9 apples.

	Bloom	Fruit set	
Treatment[z]	Blossom clusters per cm^2 LCSA[y]	Fruit per cm^2 LCSA	Percent
Control	10.2	10.6	108
NAA	10.2	7.3	89
1-MCP	10.2	8.4	89
1-MCP + NAA	9.7	5.6	60
Significance			
1-MCP	NS	*	*
NAA	NS	**	*
1-MCP x NAA	NS	NS	NS

[z]1-MCP was applied on 24 May with a CO_2 back-pack sprayer at 209 mg·L^{-1} in 1% AFxRD-038 oil and 0.05% Silwet L-77. NAA was applied at 6 mg·L^{-1} as a dilute hand-gun spray on 25 May, one day after 1-MCP treatment.
[y]LCSA, limb cross-sectional area.
[NS, **, *]Nonsignificant or significant at odds of 19 to 1 or 99 to 1, respectively.

cross-sectional area (LCSA) or as percent set. Spurs evaluated on May 29 on trees treated with 1-MCP at petal fall (12 days prior) and at the 10-mm stage (5 days prior) had a higher initial fruit set than both the untreated control and spurs treated at bloom (Table 2). However, as June drop proceeded and subsequent counts were made, there was no difference in set among the treatments. Moreover, there were no differences in fruit weight, surface red color, soluble solids, starch rating, or flesh firmness (data not shown).

Experiment 2. Interaction of 1-MCP with NAA. NAA treatments were previously shown to cause ethylene production that was then linked to fruit drop. It is also well documented that 1-MCP interferes with ethylene-dependent processes. Therefore, this experiment was done to test whether 1-MCP would interfere with the abscission induced by NAA. In contrast to the results for Experiment 1 (Table 1), application of 1-MCP alone resulted in a significant reduction in fruit set (Table 3). As expected, NAA at 6 mg per liter also caused significant thinning, expressed as LCSA or percent set, respectively. Although a significant increase in fruit drop was caused by the 1-MCP + NAA treatment, there was no significant interaction between these growth regulators (Table 3). Even though 1-MCP caused some thinning in Experiment 2, most fruit quality characteristics were indistinguishable for control versus 1-MCP-treated fruit, as in Experiment 1 (data not shown).

Discussion

Results for these experiments clearly indicate that 1-MCP does not increase initial fruit set or retard fruit drop during the June drop period. It is known that initial set can be increased by lowering endogenous levels of ethylene in young fruit by the application of the ethylene biosynthesis inhibitor ReTain (AVG). Therefore, it was unexpected to find that application of a competitive inhibitor of ethylene action did not

increase set, and in one instance, reduced set.

An explanation for the lack of response may be found in a parallel and more fundamental study that was conducted by Drs. Zhu, Yuan, and Beers at Virginia Tech. Their study confirmed our finding that 1-MCP does not affect early fruit set or fruit abscission in apple. They also showed using molecular techniques that the lack of effect was attributed to the lack of influence of 1-MCP on enzymes responsible for or involved in fruit abscission.

There are two generally recognized systems involved in ethylene biosynthesis in apple. System 1 acts in vegetative tissue and in this system ethylene inhibits its own biosynthesis. System 2 operates in apples during ripening where ripening fruit evolved large amounts of ethylene which in turn stimulates its own biosynthesis.

NAA caused significant and appropriate thinning in this investigation. Application of 1-MCP on trees treated with NAA did not negate the thinning effect. Ethylene production was not monitored in this investigation. However, in the parallel work done at Virginia Tech it was found that 1-MCP did not retard ethylene production, and in one case actually increased it. This may be one explanation for the reduced fruit set on 1-MCP-treated trees in this study.

Commercial uses and commercial success of 1-MCP in fruit is dependent upon its ability to negate the effects of ethylene that is being produced by ripening fruit in system 2. In addition to its effect on delaying senescence of apples in storage, 1-MCP sprayed on trees as the sprayable formulation Harvista, can dramatically reduce preharvest drop of apples. The preliminary conclusion from this experiment is that altering any vegetative response to ethylene in system 1 by the use of 1-MCP is very unlikely.

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