The Grow New York Project: 1-MCP Effects on Apples (The 2000 Harvest Season)

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The Grow New York Grant Program allowed us to fast-track commercial application information for this potentially important and valuable material.

The inhibitor of ethylene binding, 1-methylcyclopropane (1-MCP), is being researched actively because it maintains fruit quality during storage, and its impact for the marketplace may be huge. At the Ithaca laboratory, we are studying the effects of factors that may influence the effectiveness of 1-MCP, such as variety, temperature of application, and delays between harvest and application. However, these types of experiments cannot replicate many issues that may influence the efficacy of 1-MCP under commercial conditions. Lack of registration for 1-MCP means that any tested fruit must be destroyed and therefore testing of the compound under commercial storage volumes of fruit is prohibitively expensive.

In 2000, the State of New York introduced the Grow New York Grant Program. The aims of this program include funding of projects that involve application of new technologies with the potential for near term commercial application. In conjunction with matching funding from the New York Apple Association and Cornell University, the Grow New York Grant Program has allowed us to develop a unique approach to fast-track the gaining of valuable commercial information.

Objective of the Grow New York Project

To identify the effects of current operating procedures in the New York industry on the efficacy of 1-MCP to control apple fruit ripening and permit successful exploitation of its potential to maintain and increase industry competitiveness.

Procedures

The project was carried out at four storage sites in New York State, with most emphasis being on Western New York because of its focus on long-term CA storage. Air storage regimens were included to ensure that information obtained in these trials would also be applicable to smaller volume operators who are less focused on CA storage. The cooperators were:

1. Chazy Orchards, Champlain Valley
2. Lake Ontario Fruit, Inc., Orleans County
3. Fowler Brothers Inc., Wayne County
4. K.M. Davies, Wayne County

At each site, fruit were sampled off trucks arriving at the storage facility, or in the case of the Champlain, collected from blocks being harvested on that day. Depending on the storage facility, three to six individual fruit orchards, or orchard blocks within an orchard were used. The varieties used were typical of those being harvested commercially during the experimental period. Each sample consisted of 250 apples. Fruit maturity / quality was assessed immediately on 10 fruit, using firmness and starch. At Lake Ontario, internal ethylene readings were also taken. Of the remaining fruit, 160 were designated for the CA storage, and 80 for regular storage.

Basic Protocols

1-MCP treatment

The trials were designed to determine if it would be necessary to treat fruit warm on the day of harvest, or if fruit could accumulate while storage rooms were filled before treatment, as would occur under commercial conditions. All 1-MCP concentrations were 1ppm and applied in sealed plastic containers either warm or cold for a minimum of 16 hours. There were four comparisons:

1. Warm fruit, no treatment on the day of harvest, and then coolstored.
2. Warm fruit, 1-MCP treated on the day of harvest, and then coolstored.
3. Cooled fruit, coolstored on the day of harvest, and no treatment applied.
4. Cooled fruit, coolstored on the day of harvest, and 1-MCP treated cold according to the timing of the CA storage sealing in the facility used.

For CA storage, 80 were designated for warm treatment. For each 80 fruit sample, 40 were treated with 1-MCP, the others serving as untreated controls. The warm 1-MCP treatment consisted of treating all orchard samples at the end of the day in airtight containers. The remaining 80 apples for the CA treatment were placed in cold storage immediately after arriving at the storage facility. They remained in cold storage until all samples were treated at the same time one-day prior to closing the CA room.

For air storage, 20 fruit were used for warm 1-MCP treatment, and 20 as controls. Fruit were treated at the end of the day, held overnight at ambient temperature and put in air storage the next day. For 1-MCP-treatment of cold samples, fruit were collected as described above on a daily basis and placed in regular air storage. They remained in cold storage until all samples were treated at the same time one-day prior to closing the CA room, but were kept in air storage.

After treatment, control and 1-MCP-

treated fruit were stored in air for four months, or in CA until each room was opened for marketing.

Regional differences

1. Champlain - fruit were treated warm with 1-MCP at ambient temperatures on each day of receipt, or treated cold the day before the CA room was sealed. Fruit stored in air were treated at the same time as the CA-stored fruit. The number of samples that accumulated were a function of the number of days that fruit were harvested to fill a room, and therefore varied from two to four days of harvest.
2. Western New York – fruit were treated with 1-MCP as described for the Champlain except that a standard protocol of fruit collection was followed. Fruit were collected and treated at ambient temperatures daily throughout the week. All cold samples were treated on the Friday of each week. Fruit that were stored under CA conditions were placed in the next CA room to be sealed.

Measurement of fruit quality

Firmness was used as the primary guide of fruit quality. Air stored fruit were kept at room temperature and analyzed after one and seven days. CA-stored fruit were evaluated whenever the rooms are opened and therefore provided a wide range of storage periods ranging from two to seven months. After the room was opened, samples were evaluated at one and seven days at room temperature. The remaining fruit were kept in regular storage for one more month, to replicate marketing periods, and evaluated again at one and seven days.

Results

The results of this project are extensive. To provide an overview of the study, we have presented the Champlain and one of the Western New York sites.

Champlain

Only McIntosh apples were evaluated in the Champlain. The McIntosh types were predominantly old strains on seedling rootstocks, or Rogers on seedling or 111, and to a lesser extent Spur on 111 and RedMax on M26. Six CA storage rooms were used, and fruit were stored from 2 to 8 months, depending on the harvest dates (Table 1). Harvest ranged from September 18 to October 6, fruit from the later harvests being predominantly ReTain-treated.

The results of storing fruit for four months in air are shown in Table 2. Data for evaluation day, that is day 1 versus day 7 of shelf life period, were often similar, and therefore were combined for ease of presentation. However, in one storage room, fruit treated warm with 1-MCP did not soften during the shelf-life period, while all other fruit did. Data for each harvest date are also combined as no effects of this factor could be detected.

Overall, the firmness of air-stored McIntosh was maintained about 0.9 to 1.4lb if fruit were treated warm with 1-MCP on the day of harvest. The only ex

TABLE 1

Flesh firmness and starch indices of McIntosh fruit in orchard blocks at harvest, and CA storage periods, for the Champlain 1-MCP experiments.

Room number	Harvest dates	Firmness (lb)	Starch (1-8)	CA room sealed (2000)	CA room opened	Storage time (approx. months)
1	9/13 - 9/17	18.0	4.0	9/19	5/14/01	8
2	9/19 – 9/20	17.9	5.4	9/21	4/16/01	7
3	9/21 – 9/22	17.4	4.7	9/23	3/1/01	6
4*	9/24 – 9/26	17.6	4.6	9/27	2/1/01	5
5*	9/27 – 9/30	17.2	4.5	10/1	1/10/01	3
6*	10/1 – 10/5	16.4	5.5	10/6	12/12/00	2

*mostly ReTain-treated fruit

TABLE 2

Firmness (lb) of Champlain-grown McIntosh after removal from air storage after 4 months. Fruit were evaluated after 1 and 7 days at room temperature. The data for all harvest dates and for both shelf life periods have been combined.

Room number	Harvest dates (2000)	Treatment			
		Warm fruit		Cold fruit	
		Control	1-MCP	Control	1-MCP
1	9/13 - 9/17	11.2	12.6	11.1	11.8
2	9/19 – 9/20	10.6	11.6	10.4	10.9
3	9/21 – 9/22	10.2	11.2	10.2	10.2
4	9/24 – 9/26	10.5	11.4	10.5	10.6
5	9/27 – 9/30	10.7	11.6	10.5	10.4
6	10/1 – 10/5	10.7	10.9	10.7	10.5
Grand mean		**10.7**	**11.6**	**10.6**	**10.7**

Notes: Effects of treatment significant in all cases except room #4

TABLE 3

Firmness (lb) of Champlain grown McIntosh after removal from CA storage after various periods with and without an additional 1 month in air storage. Fruit were evaluated after 1 and 7 days at room temperature. The data for all harvest dates and for both shelf life periods have been combined.

CA storage

Room number	Harvest dates (2000)	Treatment			
		Warm fruit		Cold fruit	
		Control	1-MCP	Control	1-MCP
1	9/13 - 9/17	12.2	15.9	12.1	14.1
2	9/19 – 9/20	13.4	16.4	13.5	15.7
3	9/21 – 9/22	13.3	16.1	13.3	14.3
4	9/24 – 9/26	12.5	15.7	12.8	14.2
5	9/27 – 9/30	12.6	15.8	12.9	14.4
6	10/1 – 10/5	11.7	13.9	12.0	12.2
Grand mean		**12.6**	**15.6**	**12.8**	**14.2**

CA plus 1 month in air

1	9/13 - 9/17	12.4	15.6	12.4	14.3
2	9/19 – 9/20	12.6	15.6	12.9	14.5
3	9/21 – 9/22	13.2	15.9	13.1	14.1
4	9/24 – 9/26	12.3	15.7	12.7	14.2
5	9/27 – 9/30	12.4	15.4	13.0	14.1
6	10/1 – 10/5	10.9	12.8	11.1	11.0
Grand mean		**12.3**	**15.2**	**12.5**	**13.7**

ception occurred in the late harvested fruit in room 6. Fruit from the earliest harvest showed the greatest response to 1-MCP treatment. Treatment of cooled fruit with 1-MCP generally did not slow softening, except in the first two harvests. Greater differences may have been detectable earlier in storage, four months being too long a storage period in air.

CA stored fruit responded dramatically to 1-MCP (Table 3). These responses were consistent even when fruit were kept in air cold storage for a month after removal from CA storage. Overall, fruit treated warm with 1-MCP were about 3lb firmer than the untreated control fruit. The benefit of 1-MCP on firmness of cold-treated fruit was approximately 50% of that of the warm-treated fruit, although fruit still averaged 14.2lb. The maintenance of firmness in 1-MCP-treated fruit was consistently greater with earlier harvest date, even though these fruit were stored for the longer periods. Effects of harvest date within a storage lot of fruit were sometimes significant, but no consistent pattern was detectable. This indicates that time after harvest before treatment was not important, and differences probably resulted from effects of orchard block on fruit storability.

TABLE 4

Flesh firmness (lb) and starch indices of fruit varieties at harvest, and CA storage periods, for the Western New York 1-MCP experiments.

Variety	Harvest dates (2000)	Internal ethylene (ppm)	Firmness (lb)	Starch (1-8)	CA room sealed (2000)	CA room opened (2001)	Storage time (approx. months)
McIntosh (Marshall)	9/12 - 9/14	110	15.4	6.4	9/16	2/20	5
McIntosh (standard)	9/18 – 9/21	52	15.2	6.1	9/22	1/22	4
Cortland	9/18 – 9/21	1	16.0	2.3	9/22	1/22	4
Empire	9/25 – 9/28	3	17.8	4.8	9/30	5/30	8
Empire	10/2 – 10/5	14	18.0	5.5	10/7	3/18	5
Delicious	10/9 – 10/12	21	17.4	3.4	10/24	4/3	5

TABLE 5

Firmness (lb) of Western New York-grown varieties after removal from air storage after 4 months. Fruit were evaluated after 1 and 7 days at room temperature. The data for all harvest dates and for both shelf life periods have been combined.

Variety	Harvest dates (2000)	Treatment			
		Warm fruit		Cold fruit	
		Control	1-MCP	Control	1-MCP
McIntosh (Marshall)	9/12 - 9/14	10.1	11.6	10.3	10.3
McIntosh (standard)	9/18 – 9/21	10.4	12.2	10.5	11.2
Cortland	9/18 – 9/21	10.4	13.2	10.4	11.7
Empire	9/25 – 9/28	12.6	15.3	12.5	13.8
Empire	10/2 – 10/5	12.8	15.6	13.1	13.9
Delicious	10/9 – 10/12	14.1	15.9	14.1	15.4

TABLE 6

Firmness (lb) of Western New York-grown varieties after removal from CA storage after various periods with and without an additional 1 month in air storage. Fruit were evaluated after 1 and 7 days at room temperature. The data for all harvest dates and for both shelf life periods have been combined.

Variety	Harvest dates (2000)	Treatment			
		Warm fruit		Cold fruit	
		Control	1-MCP	Control	1-MCP
CA storage					
McIntosh (Marshall)	9/12 - 9/14	10.9	13.4	10.8	12.6
McIntosh (standard)	9/18 – 9/21	11.3	13.5	11.4	12.4
Cortland	9/18 – 9/21	11.0	13.9	11.2	13.4
Empire	9/25 – 9/28	14.6	16.1	14.7	15.3
Empire	10/2 – 10/5	14.7	16.2	14.8	16.0
Delicious	10/9 – 10/12	14.9	16.1	15.0	15.9
CA plus 1 month in air					
McIntosh (Marshall)	9/12 - 9/14	10.8	13.1	10.9	12.1
McIntosh (standard)	9/18 – 9/21	11.4	13.6	11.6	12.3
Cortland	9/18 – 9/21	11.3	14.1	11.0	13.2
Empire	9/25 – 9/28	13.2	15.3	13.3	14.1
Empire	10/2 – 10/5	14.3	16.0	14.3	15.4
Delicious	10/9 – 10/12	14.5	16.0	14.5	15.8

Western New York

In the Western New York storage, six CA rooms were also used (Table 4). The Marshall McIntosh and standard McIntosh (Pioneer, standard, Acey, Rogers, RedMax, Buhr) require different CA regimes. Cortland included Red Cortland as well as the standard Cortland. Empire included Royal as well as the standard strain. The two Empire rooms represented an early harvest destined for eight months storage, and a later harvest for medium term CA storage. Fruit of both Marshall and standard McIntosh strains, the second harvest of Empire, and Delicious, were climacteric at harvest.

In air storage, the responses of both Marshall and standard McIntosh strains (Table 5) were similar to those shown for Champlain-grown fruit. The effect of 1-MCP on firmness of the other varieties was much greater, however, especially for Empire. Cortland and Delicious also responded well, although the untreated control fruit of Delicious maintained good firmness. In all cases, the effect of warm treatment was much greater than cold treatment.

Under CA storage conditions, all varieties responded well to 1-MCP treatment (Table 6). Empire apples exceeded minimum export firmness standards,

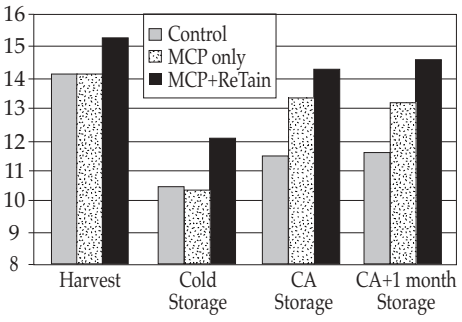

Figure 1. Effect of pre-harvest ReTain on firmness (lb) of control and 1-MCP-treated McIntosh apples. The air and CA storage periods were four and five months respectively. CA stored fruit were either assessed after removal, or after an additional one month in air storage. Apples assessed after one and seven days at room temperature.

even with an additional month in air storage after the CA rooms were opened. The effects of treating cold compared with warm fruit were less evident for Cortland, the second Empire harvest, and Delicious, than for the other varieties.

The effects of harvest date within any storage room were not consistent, suggesting that fruit could be accumulated over at least several days before treatment with 1-MCP and closing of these rooms for application of CA.

Further evaluations

We are still evaluating these data, as collection of information about treated fruit is allowing us to examine the range of management techniques used by the industry. For example, in the Champlain use of ReTain did not seem to prolong the effective application dates for McIntosh. However, in western New York, McIntosh treated with ReTain and 1-MCP were firmer after storage compared to non-ReTain treated fruit with or without 1-MCP (Figure 1). This suggests ReTain has potential to improve the efficacy of 1-MCP by decreasing ethylene production at harvest. Further investigation is warranted on McIntosh as well as other varieties.

Conclusions

1. 1-MCP is a powerful tool to maintain firmness of New York-grown apple varieties, especially under CA storage conditions. The residual effects of 1-MCP on firmness after removal of fruit from CA suggests that 1-MCP will result in improved shelf life, and better quality fruit in the marketplace.
2. 1-MCP is not a substitute for CA storage for some varieties, if air storage is prolonged, e.g. four months, but may be a valuable means of maintaining fruit quality for shorter storage periods.
3. The effectiveness of 1-MCP was affected by fruit temperature when 1-MCP was applied in McIntosh (in air and CA) and Cortland (in CA), and in the first Empire harvest, but to a much lesser extent in the second Empire harvest, and in the case of Delicious. However, in Ithaca-based trials we were not able to find effects of treatment temperature with similar 1-MCP-exposure periods to those used here, and a 16-hour exposure time used in the Grow New York trials may not have been sufficient to get maximal responses.
4. It seems unlikely that the delays between harvest and treatment of fruit with 1-MCP will be a significant factor if procedures similar to those used for rapid CA storage are followed. No consistent differences among harvest date were detected.
5. The effectiveness of 1-MCP lessens with later harvest date, probably because of increasing rates of ethylene production in these fruit. Low ethylene fruit responded better to 1-MCP treatment than did high ethylene fruit, which suggests fruit should be picked early in the harvest window (pre-climacteric) in order to maximize the benefits of 1-MCP.

Photo 1. Firmness measurements were made using an Electronic Pressure Tester. (EPT).

The 2001 Trials

We are continuing this research. During the 2001 harvest season fruit in the Hudson Valley have also been treated, as well as in two Champlain locations and in Western New York. In addition to obtaining further information about responses of fruit under CA storage conditions, we are evaluating shorter-term air storage periods.

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