NEW YORK
FRUIT QUARTERLY

Editorial

Let's "Grow Sales and Create a Trend"

"Grow Sales!"[1] Two simple words and everyone's goal in today's business world. That, of course is the bottom line, the ultimate purpose, the reason we exist, right? In the produce business, of course it is. The term best fits the produce business, as we *grow* food to *grow* sales.

Many factors weigh on our marketing decisions to grow sales – factors like supplies, quality, demand, and trends. Perhaps a major emerging factor in our industry today is trends. Who would have thought that one man's diet could have such an impact on the way people eat? Impact may not be the right word when you consider the changes being made daily at the fast food chains across the country. It's more of a revolution. Two years ago, a bun-less burger or sliced apples in a Happy Meal would have been a joke. Fortunately, most of the produce industry can benefit from this trend. High fiber with carbs can be justified and built upon. The apple industry has a similar case to make as it relates to carbs as well, but also needs to build upon the vast number of other nutritional attributes of fresh apples. The low carb trend is not going to go away, and it's growing sales in many categories. It's fun to be a chicken farmer or egg producer these days, and despite a list of mad reasons why not to eat red meat, the beef industry is getting fatter. At the same time, bread makers are closing and the wheat silos are bulging.

We continue to have opportunities in the produce business to grow sales or increase markets and at the same time we are tempted to only absorb market share. We make choices about how to increase our business by either replacing a competitor or by finding new consumers. Often the easy road is taken: buying your way into the market. While this may capture more sales at a predictably lower price, it does nothing to increase the market and to address the consumer trend. Trends are very powerful decision-makers for consumers. In many cases, a customer on a mission, or buying with a conviction, will only look for the product, and will not be deterred by price. Fresh produce that has been listed as "Atkins friendly" or identified as a sure way to allow consumers to "look good on the beach" can grow sales at a price that will certainly please the producers. Marketers should make every effort to increase the markets and increase the consumption of these products, without trying to carve up the market or weaken it. Take advantage of the trend to find new customers and to educate your consumers of the benefits of your products.

A greater challenge may lie ahead for fresh produce that isn't awarded the "friendly" status, and innovative marketing and consumer education will be necessary to grow sales. The future must include this approach, instead of the temptation to offer deep discounts to move the product. Consumer confidence in the value of these produce items, other than just a low carbohydrate classification, must be built. Our industries will have to continue to invest in this message and create a full spectrum, healthy approach to sensible dieting that includes fresh fruits and vegetables even if they are above the magical 25-carb rate. All produce, from apples to zucchini, has a good, healthy and nutritious message to convey. The more our industries focus on growing sales and increasing markets and consumption, the faster the trend will kick in.

Jim Allan
President of the New York Apple Association

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[1] Mr. Lee Peters, VP of Marketing, Fowler Farms, Wolcott, NY, as quoted at the U.S. Apple Board of Trustees' Meeting, Washington, DC

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NEW YORK
FRUIT QUARTERLY
VOLUME 12 • NUMBER 3 • AUTUMN 2004

This publication is a joint effort of the New York State Horticultural Society, Cornell University's New York State Agricultural Experiment Station at Geneva, and the New York State Apple Research and Development Program.

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SmartFresh™ (1-MCP) – The Good and Bad as We Head Into the 2004 Season!

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This work was funded in part by the New York Apple Research and Development Program.

1-Methylcyclopropene (1-MCP), sold under the commercial name of SmartFresh™, needs little introduction to storage operators in New York. 1-MCP has quickly become a major component of our industry. Its effects on delaying apple ripening, and especially on maintaining the texture quality of fruit, continue to amaze, and 1-MCP is impacting sales both domestically and internationally. We receive telephone calls from retailers wanting to know how 1-MCP works because they cannot believe the quality of Empire apples that they are selling. The UK market has also responded very positively to the beneficial effects of 1-MCP on fruit quality. The advantage that 1-MCP confers on apple fruit is that it helps maintain the fruit's firmness throughout the entire marketing chain, in contrast to air and CA storage alone where fruit can deteriorate and quickly soften after leaving the packing house.

However, there are positives and negatives to the 1-MCP story, some of which can be addressed by research. Others, such as the effects of 1-MCP on consumer expectations for certain varieties, are ultimately ones that the industry must resolve. We are doing as much as we can with the available resources to understand the strengths and weaknesses of 1-MCP, but rapid uptake of the technology by the New York apple industry means that problems are being identified more quickly than solutions are found. In the case of the last major breakthrough in storage technology, controlled atmosphere (CA) storage, implementation took place over many years, and, even today, problems are still common. With 1-MCP, we as an industry are fast-tracking adoption of a new technology that still has many unknowns.

In this article, some of the major issues that are facing users of 1-MCP are outlined as we approach the 2004 harvest season. We do not have all the answers and some of the opinions below must be regarded as speculative.

Effects of Variety

There are two aspects that are important when considering varietal responses to 1-MCP.

First, what are the inherent qualities that the consumer expects from a particular variety, and will 1-MCP increase or decrease these qualities? In low-aroma apple varieties, such as Empire and Delicious, the most important attributes for consumers appear to be texture and the sugar/acid balance. Consumer responses to such varieties treated with 1-MCP are usually overwhelmingly positive. Exceptions can occur because consumers do expect apples to soften to at least an edible texture, and there have been occasional reports of 1-MCP-treated apples of some varieties being too hard

The situation with high-aroma varieties, such as McIntosh, may be more complex. Inhibition of ethylene production by 1-MCP can inhibit production of aroma volatiles. Therefore, consumer expectations for a soft, aromatic and flavorful fruit may not be met. On the other hand, the market segment for soft apples is declining and it is possible that a less flavorful but firmer McIntosh may create new market opportunities for the industry. Market expectations for a variety must be considered as part of the decision making process regarding 1-MCP use.

SmartFresh (1-MCP) has quickly become a major component of the NY apple industry. Its effects on delaying apple ripening, and softening, continue to amaze, and it is positively impacting sales both domestically and internationally. However, there are also some areas of concern. One of these in particular, has been internal browning disorders. We are doing as much as we can with the available resources to understand the strengths and weaknesses of 1-MCP.

The second aspect is the variability among, and within, varieties in responsiveness to 1-MCP. In theory, every apple variety can respond to 1-MCP, but, in practice, this response is affected by fruit ethylene production. Our research shows that there are few examples of absolutely no response to 1-MCP, but rather that there are degrees of response. The effects of 1-MCP can be long- or short-lived depending on many pre- and post-harvest factors that affect ethylene production by the fruit.

To understand the reason for this it is important to remember that apples are natural producers of ethylene, the compound responsible for softening, red color development, and other ripening processes. Ethylene production can occur in fruit while on the tree as well as after harvest, and occurs autocatalytically, i.e.

a small amount of ethylene in the fruit results in increasingly greater amounts over time. Fruit with high rates of ethylene production cannot respond as well to 1-MCP as those fruit with low rates of ethylene production. Typically, varieties that have lower ethylene production rates during the normal harvest window such as Gala, Empire, Delicious and Jonagold respond strongly to 1-MCP. In contrast, varieties with high ethylene production during the normal harvest period respond much less favorably. For example, we find that effects of 1-MCP on Macoun are limited, as is often the case for McIntosh. Use of Ethrel and other pre-harvest factors that induce ethylene production markedly reduce the effectiveness of 1-MCP. (We suspect that NAA used to prevent preharvest drop may also decrease effectiveness of 1-MCP because it can stimulate ethylene production by the fruit, but we have not been successful in obtaining conclusive data). Also, as described below in the section about delays between harvest and 1-MCP treatment, pre- and post-harvest factors are closely linked.

The bottom line is that variety responses to 1-MCP are affected greatly by ethylene production during the harvest period. Different varieties have different ethylene production rates and timing of this production relative to their normal harvest period. Moreover, pre-harvest treatments can affect the timing of autocatalytic ethylene production. The temptation to harvest fruit earlier to improve the response to 1-MCP must be avoided, however, as fruit harvested prematurely will never develop the flavor and quality characteristics desired by the consumer.

A further complication in considering varieties and 1-MCP is that ethylene production varies from region to region, not only in the timing of its autocatalytic increase, but also in actual rates of production. In general, fruit grown in warmer climates have more rapid ethylene production. In varieties such as McIntosh, growers fight a constant battle between obtaining sufficient red coloration and pre-harvest fruit drop, and the relationship between the two factors is affected by region. The best "home" for 1-MCP useage for McIntosh appears to be the Champlain region where good color development usually precedes ethylene production. Therefore, it is possible to harvest high quality fruit and obtain uniform responses to 1-MCP. Elsewhere in the state, the situation is more problematic. Obtaining adequate color development before ethylene increases (often evidenced by preharvest drop) can be difficult, and even worse, affected seasonally. Therefore, 1-MCP is more likely to have inconsistent benefits on texture and other ripening attributes from year to year. A scenario that is not impossible to imagine in Western New York is that for three years in a row we have good coloring weather, allowing for early harvest of fruit and thus good 1-MCP effects. This is then followed by a late coloring year with little response to 1-MCP, and therefore, an inability to provide the market with product that it has come to expect.

The particular variety and when it is harvested provides the base product for 1-MCP treatment. Although maturity guidelines of starch indices and firmness are provided by AgroFresh (the commercial suppliers of 1-MCP), the most reliable guide to responsiveness of fruit to 1-MCP is ethylene production or internal ethylene concentration (IEC). Thus, when one considers the diversity of orchard microclimates and management decisions that exist in the field, the process of determining potential effects of 1-MCP remains relatively crude.

1-MCP is classified as a plant growth regulator. We have previously outlined how 1-MCP works to prevent ethylene action (Watkins and Nock, 2000), and a summary of our experiences with 1-MCP is available in the proceedings of the 2003 Cornell Storage Workshop (Watkins and Nock, 2003). Further information about the registration of 1-MCP, including safety profiles, is available at: http://www.epa.gov/pesticides/biopesticides/ingredients/fr_notices/frnotices_224459.htm

Air Compared with CA Storage

We do not advocate the use of 1-MCP as an alternative to CA storage for medium to long term periods. With increasing storage periods, the two technologies are always more effective when used in combination. Use of CA as a supplement to 1-MCP is also more critical with longer storage times, especially if there are bins of fruit that do not respond to the treatment.

1-MCP can be an excellent replacement for CA storage for short term storage, especially to meet the December/January market when storage quality begins to decline. The potential for 1-MCP usage has already been recognized by New York growers who own retail operations which lack CA facilities. It is important to realize, however, that variety responses to 1-MCP also differ greatly even for shorter term storage periods. Apples such as McIntosh can lose their responses to 1-MCP much more quickly than varieties such as Empire, especially during air storage (Figure 1).

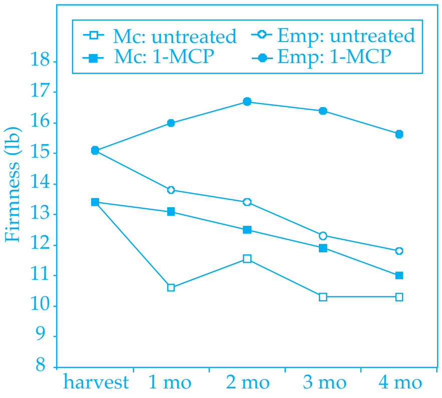

Figure 1. Firmness (lb) of McIntosh and Empire apples treated with 1ppm 1-MCP and stored in air for up to 4 months. Fruit were removed from storage at monthly intervals and firmness measured after 7 days at 68°F.

Delays Between Harvest and 1-MCP Treatment

The New York apple industry is diverse, ranging from small retail operations to large volume cooperatives. While the latter type of operation is able to organize fast harvest and rapid CA storage, many smaller operations are not able to do so due to limitations of scale. The AgroFresh guidelines call for a seven day maximum between harvest and treatment with 1-MCP for most varieties with a smaller harvest window of three days for McIntosh. We have carried out extensive studies with several varieties, and the results of these trials are available in Watkins and Nock (2003). Here, we have selected a few results that illustrate the importance of the time between harvest and treatment as a factor in 1-MCP success.

Harvest date interacts with the need to treat fruit with 1-MCP quickly after

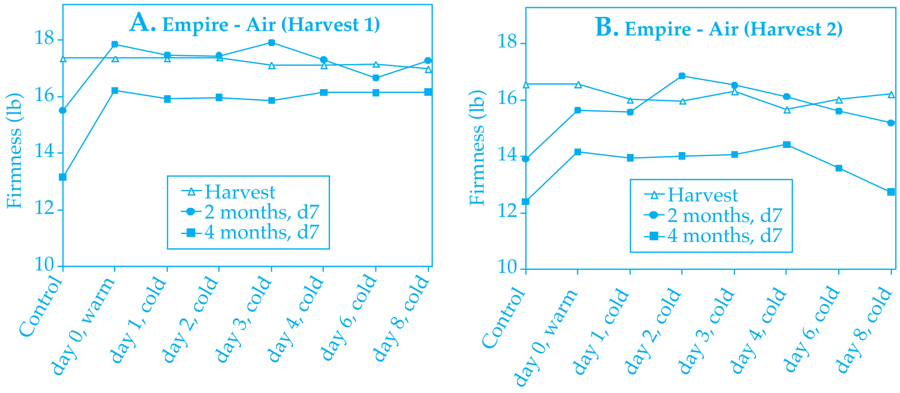

Figure 2. Firmness of Empire apples from two harvest dates (A) Sept. 28, 2000, when the internal ethylene concentrations were 0.39ppm, and (B) October 12, 2000, when the internal ethylene concentrations were 32ppm. Fruit were treated with 1-MCP at harvest (warm) or after 1, 2, 3, 4, 6 or 8 days of cold storage. Fruit were stored in air at 33 °F for 2 or 4 months and assessed after 7 days at 68 °F.

harvest. Figure 2 A and B shows the effect of 1-MCP applied on the day of harvest (warm) or after being placed in cold air storage for 1, 2, 3, 4, 6 and 8 days for early and late harvested Empire apples. For fruit harvested at the start of the optimum harvest window for CA storage, negligible softening occurred after two months plus a seven day shelf life (Figure 2 A). There was little difference among 1-MCP treatments, i.e., warm or cold from one to eight days after harvest. After four months of cold storage, fruit had softened about a pound, but there was still no effect of treatment delays. For fruit harvested later, firmness was maintained for two months, and again softening occurred by the four month evaluation, although to a greater extent than for fruit from the first harvest (Figure 2 B). However, fruit had to be treated within a four day time frame to obtain benefits from 1-MCP. For fruit from this late harvest, treatment within three days was necessary to maintain the firmness of CA-stored fruit for eight months (results not shown).

Because it is common for smaller New York storages to have fewer CA rooms and longer periods of accumulations of fruit, and often different varieties, we also tested the effect of delays of up to 21 days before application of 1-MCP. Jonagold fruit are used as an example of why the response to 1-MCP is affected by time. After harvest, the IEC of fruit initially declined but started to increase by day seven (Figure 3). Our expectation was that this increase would coincide with the declining effectiveness of 1-MCP, and this was illustrated by fruit firmness after five months of CA storage (Figure 4). Fruit treated with 1-MCP either warm, or cold after one or seven days were markedly firmer than fruit that were untreated. However, the effectiveness of 1-MCP declined markedly in fruit that were treated after 14 or 21 days.

These types of data form the basis of current recommendations for maximum delays between harvest and 1-MCP application. It is important to recognize, however, that there are degrees of response to 1-MCP that are affected by both pre- and post-harvest handling interactions. The times between harvest and 1-MCP treatment to obtain optimum responses may be shorter than the industry recommendations, and a good rule of thumb is that the longer the storage period, the more important is rapid 1-MCP application.

Physiological Disorders

1. Carbon dioxide injury. An early concern about 1-MCP was that it appeared to increase fruit susceptibility to external carbon dioxide injury (Figure 5). The varieties that we were most concerned about were McIntosh, Cortland and Empire. (We have not examined the effects of 1-MCP on internal carbon dioxide injury). The mechanism of carbon dioxide injury is not well known, but greener, less mature tissues appear to be more susceptible. 1-MCP may increase susceptibility to injury by maintaining fruit in a younger physiological state during storage. Some of our previous research determined that delays between harvest and exposure to high carbon dioxide concentrations, or application of diphenylamine (DPA) used for control of superficial scald, decreased or eliminated external carbon dioxide injury. Also, the critical time for exposure of fruit to carbon dioxide was in the first month or so of storage.

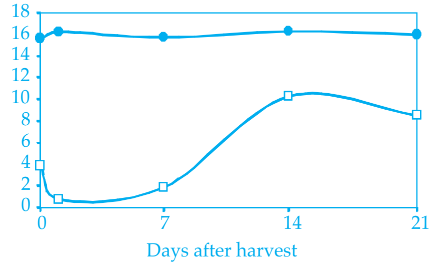

Figure 3. Firmness (lb) and internal ethylene concentration (ppm) changes that occurred in Jonagold apples over a 21 day period in cold storage (33°F) after harvest.

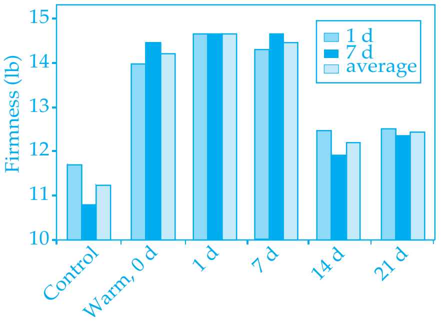

Figure 4. The firmness of Jonagold apples after storage in CA conditions for 5 months, when either untreated, or treated with 1-MCP on the day of harvest (warm), or after 1, 7, 14 or 21 days of cold storage.

We have suggested three possible solutions to avoid carbon dioxide injury (Watkins and Nock, 2003):

1a. Treat all carbon dioxide injury susceptible varieties with DPA. No external carbon dioxide injury has been observed in DPA-treated fruit. Therefore, DPA drenching remains the most straightforward solution to the problem of carbon dioxide injury when used according to the label to prevent scald. However,

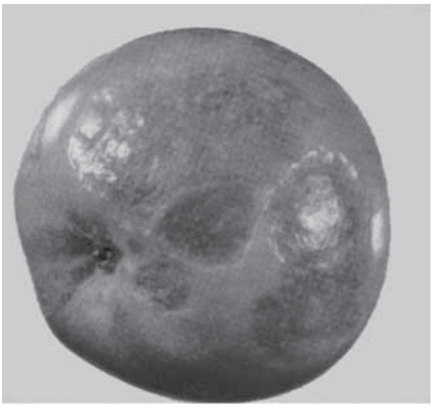

Figure 5. Severe carbon dioxide injury. In some instances, injury is barely perceptible, especially on Empire apples.

many storage operators are reluctant to use DPA because of the chemical and handling costs necessary for treatment. Handling costs are much greater, especially for smaller operations that are not able to utilize truck drenching operations that are typically practiced in Western New York. Also, some operators have found that decay of fruit in bins is higher when fruit are drenched. Finally, regions such as the Champlain that do not use DPA for McIntosh because of a lower scald risk than elsewhere in the state, are understandably reluctant to incorporate its use into their handling operations.

1b. Maintain carbon dioxide levels lower than 1 percent for the first 4 to 6 weeks of CA storage. Several storage operators have used this method during the last two years. Anecdotal evidence has shown that carbon dioxide injury has usually not been eliminated but was reduced to minimal levels, certainly lower than those due to decay where DPA has been used. However, major losses have been suffered by some storage operators even when carbon dioxide levels have been less than 1%. The reasons why some storages were affected more than others are not known. In addition there are many unknowns related to loading and cooling time and effects of elevated carbon dioxide during this time in relation to injury.

For this season we are altering this recommendation for Empire to "maintain carbon dioxide levels less than 0.5 percent for the first 4 to 6 weeks of CA storage." McIntosh appears less sensitive to carbon dioxide injury but we don't have a recommendation for carbon dioxide levels at this time. Lack of a recommendation for McIntosh only affects the Champlain region as DPA is used in all other New York growing regions.

The other consideration about maintaining low carbon dioxide levels in storage is that Empire and McIntosh require high carbon dioxide levels in the storage atmosphere to maintain fruit firmness. Figure 6 shows that carbon dioxide levels close to 2.5 percent are better for maintaining firmness in fruit that have not been treated with 1-MCP. This requirement is reduced in 1-MCP-treated fruit, but Drs. DeEll and Murr in Ontario have found that the absence of carbon dioxide can result in greater losses of firmness than we have observed. Therefore, we recommend allowing carbon dioxide levels to increase after the initial low period.

1c. Delayed application of CA storage after treatment of fruit with 1-MCP. If fruit respond to 1-MCP, their metabolism is slowed down. Therefore, it should be possible to treat with 1-MCP, but not apply CA storage regimes for a week or two. No commercial testing of this recommendation has been carried out to our knowledge for control of carbon dioxide injury, although treatment of smaller fruit volumes on a daily basis and later closing of rooms is becoming more common. In the 2003 harvest season we tested delays of 7 and 14 days on fruit treated with 1-MCP at harvest. McIntosh from the Champlain (Rogers) and Western New York (Marshall), and Empire from the Hudson Valley and Western New York, were harvested from three orchard blocks in each region.

Both McIntosh and Empire fruit responded to 1-MCP in typical fashion (Tables 1 and 2); fruit were firmer than untreated fruit and the softening during the shelf life period at 68°F was reduced or prevented. Treating fruit at the time of harvest, but not applying CA for up to 14 days did not result in softer fruit.

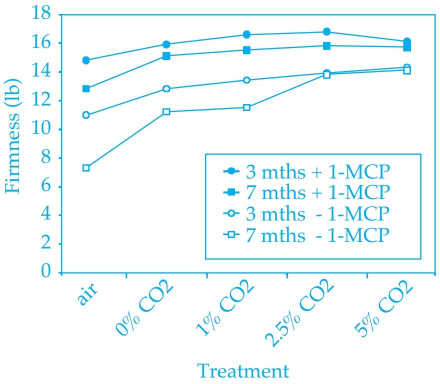

Figure 6. Firmness (lb) of Empire apples either untreated or 1-MCP treated at harvest and stored in air or in 0, 1, 2.5 or 5% carbon dioxide (in 2% oxygen) for 3 and 7 months. The 1-MCP-treated fruit (closed symbols) maintained firmness irrespective of carbon dioxide concentration, whereas the firmness of untreated fruit declined with carbon dioxide of less than 2.5%.

However, the objective of this method was to reduce carbon dioxide injury. For McIntosh, injury was found only on Champlain fruit and for Empire only from Western New York grown fruit. Injury was detected only on 1-MCP-treated fruit

TABLE 1

Firmness (lb) of McIntosh apples from Champlain and Western New York orchards harvested on 24 and 22 September, 2003, (internal ethylene concentrations averaged 15 and 42 ppm) respectively. Fruit were treated with 1ppm 1-MCP after overnight cooling and placed under CA (2% carbon dioxide. 2% oxygen) conditions 2, 7 or 14 days after harvest. Firmness was measured after 6 months of storage plus 1 or 7 days at 68°F.

	Champlain				Western New York			
	No 1-MCP		1-MCP		No 1-MCP		1-MCP	
Delay	1 d	7 d	1 d	7 d	1 d	7 d	1 d	7 d
2 d	14.2	11.7	14.5	14.2	12.6	11.8	13.4	13.1
7 d	12.1	10.3	14.5	13.6	12.2	11.6	13.8	13.9
14 d	11.6	10.5	14.7	13.8	11.7	11.3	13.2	12.9

TABLE 2

Firmness (lb) of Empire fruit from the Hudson Valley and Western New York orchards harvested on 6 and 7 October, 2003, (internal ethylene concentrations averaged less than 1 ppm) respectively. Fruit were treated with 1ppm 1-MCP after overnight cooling and placed under CA (2% carbon dioxide. 2% oxygen) conditions 2, 7 or 14 days after harvest. Firmness was measured after 6 months of storage plus 1 or 7 days at 68°F.

	Hudson Valley				Western New York			
	No 1-MCP		1-MCP		No 1-MCP		1-MCP	
Delay	1 d	7 d	1 d	7 d	1 d	7 d	1 d	7 d
2 d	15.3	14.4	15.5	15.5	16.6	16.4	17.1	16.9
7 d	14.6	13.7	15.7	15.7	16.2	15.0	17.3	17.0
14 d	15.1	13.8	15.9	15.5	16.1	14.9	17.1	17.1

from two of three growers, the maximum being 5 percent for one grower. A delay of seven days did not reduce injury, but less than 1 percent was detected after a 14 day delay. However, in Empire, injury was increased by 1-MCP, but not affected by the 14 day delay.

Other disorders were found in these experiments. In Champlain McIntosh, senescent breakdown in untreated fruit increased with delays before CA storage. Depending on the grower lot, 1-MCP decreased but did not prevent development of breakdown. In Marshall McIntosh, the incidence of breakdown was affected by grower but not by 1-MCP or delays.

For Empire, flesh browning was not affected by 1-MCP in fruit from either region. Core browning and decay in fruit from the Hudson Valley was low and not affected by 1-MCP. However, in the Western New York fruit, core browning was usually reduced by 1-MCP. Decay incidence increased with delays between 1-MCP treatment and CA storage, but was affected by grower, and was usually reduced by 1-MCP. The greatest concern about this technique is that if fruit in the room are not responsive to 1-MCP, then their quality will be worse than if the room was sealed more rapidly after harvest. Therefore, we do not recommend this method to reduce carbon dioxide injury, especially as susceptibility to other disorders may be enhanced.

2. Superficial scald. Development of superficial scald has not been a problem for storage operators who have relied on 1-MCP instead of DPA. More information about scald control and 1-MCP is available in Watkins and Nock (2003). We continue to believe that if applied appropriately, 1-MCP will control superficial scald for many varieties, especially Delicious, but that under New York conditions control is often incomplete for Cortland. In general, if the effects of 1-MCP are beginning to wear off as indicated by fruit softening, then the risk of scald developing in susceptible varieties will increase dramatically.

3. Chilling injury and internal browning disorders. The 2003 storage season has been a difficult one for the industry, with the appearance of browning type disorders. These have fallen into two types – chilling injury and internal breakdown.

TABLE 3

Storage disorders of Empire apples harvested from the Hudson Valley (Oct.3, 2002) and Western New York (Oct. 4, 2002), treated with 1ppm 1-MCP and stored at 33 or 38°F in CA (2% carbon dioxide/2% oxygen) for 9 months and assessed after 7 days at 68 °F. Means are the average of fruit from three orchard blocks.

Growing region	Temperature (°F)	1-MCP	Decay (%)	Senescent breakdown (%)	Flesh browning (%)	Core browning (%)	Ext. carbon Dioxide injury (%)
Hudson Valley	33	-	10	0	6	4	0
		+	10	0	2	14	0
	38	-	38	30	0	26	0
		+	38	0	54	21	0
Western NY	33	-	5	0	12	12	1
		+	6	0	14	16	0
	38	-	20	0	21	29	6
		+	21	0	41	35	4

The most common disorder that was noticed by the industry this year is chilling injury as shown in Figure 7. This injury first appears as a very slight browning discoloration of the flesh, sometimes, but not always accompanied by core browning. To the untrained eye this discoloration can be barely visible and the fruit marketable as no off-flavors are detectable. However, the disorder progresses quickly to the point where fruit become unmarketable. Chilling injury susceptibility is a feature of Empire in particular, and the reason why storage temperature recommendations for this variety are 35-36°F, especially if fruit are stored beyond May when the risk increases substantially. Risk is typically higher in years when July and August temperatures are below the 30 year average. Last season, temperatures were not particularly low, but the weather was cloudier and fruit generally had lower soluble solids contents than normal. Thus the risk was higher than normal and many storage operators responded by increasing storage temperatures. It is uncertain if 1-MCP increased the risk of chilling injury development, especially as there are few examples of the same fruit not being treated with the chemical and being stored under identical conditions.

The second problem has been fruit breakdown and attendant softening that has been associated with use of 1-MCP. This has tended to show up in later harvested fruit, but we do not know what the exact causes are. In some cases, as described below, the browning is diffuse and similar in appearance to chilling injury, but in others, the breakdown is much more extensive.

Figure 7. Chilling injury symptoms on Empire apples.

Our results from previous trials are confusing. In 2002 we harvested fruit from three orchard blocks in the Hudson Valley and Western New York and stored untreated and 1-MCP treated fruit under CA conditions at 33 °F and 38 °F for 9 months. The disorder results (Table 3) show that:

3a. Decay was greater in fruit stored at 38 °F than at 33 °F, regardless of region, and there was no effect of 1-MCP on decay.

3b. Senescent breakdown occurred only in untreated fruit from the Hudson Valley that were stored at 38 °F. As we have found elsewhere, senescent disorders were markedly reduced by 1-MCP application.

3c. Flesh browning, which was diffuse, and easily confused with chilling injury, was more prevalent in fruit stored at 38 °F compared with 33 °F, and was much more so in fruit that were treated with 1-MCP.

3d. Core browning was more common at higher storage temperatures but not affected greatly by 1-MCP application.

3e. External carbon dioxide injury was not detected in fruit from the Hudson

Valley, while in Western New York it was worse at 38 °F than at 33 °F, but was not affected by 1-MCP application.

We are also re-examining disorder results from other trials. One for example, was described above where we treated Empire fruit with 1-MCP at harvest or after delays of up to eight days. In the experiment where we stored fruit for four and eight months under CA conditions there was 27 percent flesh browning in fruit from the first harvest, but 83 percent in fruit from the second harvest. The fruit from the second harvest also had high incidences of core browning and water-soaked areas. However, 1-MCP did not affect the amounts of these disorders relative to the untreated controls.

These results are confusing. We have suggested previously that a response to chilling-type disorders could be to use higher storage temperatures, especially since 1-MCP should control ripening and therefore reduce the requirement to use as low as storage temperatures as possible. This recommendation is tempered by the observations that other problems may be much more severe at the higher temperature of 38 °F. Understanding how this problem can be solved is a priority for research during the 2004 harvest season. In the meantime, the industry should assume that there are limits to the use of 1-MCP-treated Empire to extend CA storage periods. Anecdotal evidence is that the problems are associated most with extended storage beyond May/June.

Conclusions

1. The vast majority of apple varieties respond well to 1-MCP, but some, e.g. Macoun, have poor responses probably because of high ethylene production at harvest.
2. 1-MCP can maintain quality of fruit in air for several months, but its effectiveness is affected by variety. Best responses of fruit to 1-MCP occur in combination with CA and we believe that it is unlikely to be a substitute for CA storage. For some varieties, 1-MCP has the potential to greatly improve quality of air-stored fruit marketed during December and January, especially where it is not feasible to hold that fruit in short-term CA storage.
3. Even for responsive varieties, degrees of response to 1-MCP occur. Response to 1-MCP depends on harvest maturity, storage type, length of storage, handling protocols prior to 1-MCP application, and interactions among all of these factors. These interactions are most likely associated with ethylene production of the fruit at harvest and the effectiveness of postharvest handling treatments on slowing down ethylene production by the fruit.
4. Fruit must not be harvested too early to get better responses to 1-MCP however, as these fruit may never develop marketable quality characteristics.
5. Minimizing the time between harvest and 1-MCP treatment becomes increasingly important as the desired storage period increases.
6. 1-MCP can increase risk of carbon dioxide injuries but strategies that can reduce this risk have been identified.
7. 1-MCP can reduce the risk of superficial scald developing, and for many, but not all varieties, can eliminate the requirement for DPA drenching.
8. 1-MCP may increase the risk of chilling injury development, but solutions to the problem have not been identified.

Acknowledgements

This research was supported by the Cornell University Agricultural Experiment Station federal formula funds, Project No. NE-1018, received from the Cooperative State Research, Education and Extension Service, U.S. Department of Agriculture. Any opinions, findings, conclusions, or recommendations expressed in this publication are those of the authors and do not necessarily reflect the view of the U.S. Department of Agriculture.

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Carbon Dioxide Control in Apple CA Storages Using Hydrated Lime

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> The use of SmartFresh (1-MCP) has made the control of carbon dioxide levels in CA storage rooms more critical than ever. 1-MCP appears to increase fruit susceptibility to external carbon dioxide injury. The critical time for exposure of fruit to high carbon dioxide is in the first month or so of storage.

Freshly hydrated, high calcium lime ($Ca(OH)_2$) may be utilized to remove carbon dioxide from CA storage rooms. Bags of hydrated lime placed inside the room will supplement existing scrubbing methods or a dedicated lime scrubber may be used for CO_2 regulation during the storage period.

The amount of lime needed depends on the length of the storage period, the apple variety, storage temperature, atmosphere composition and use of Nitrogen generators, etc. In the past, lime use was based on a half pound of lime per bushel of apples for a three-month storage period. This works out to be 10 fifty-pound bags per 1,000 bushels of fruit. The exact amount needed for a specific set of storage conditions will need to be determined from experience.

Either "chemical" or "agricultural" hydrated lime can be used. Each type is suitable if it is fresh, high in calcium, and of adequate fineness. Particle size is indicated on the bag; at least 95 percent should pass a 100-mesh sieve. Chemical grade is usually finer and more expensive than agricultural grade.

"High calcium" hydrate is more reactive than lime containing large amounts of magnesium. The calcium and magnesium content is stated on the bag in terms of percent calcium oxide (CaO) and magnesium oxide (MgO) contained in the original limestone. For efficient CO_2 removal, the assay should show "70% to 75% CaO" and "less than 2% MgO."

Only fresh hydrated lime is effective in removing carbon dioxide, and lime will gradually loose its freshness over time because it continuously absorbs CO_2 from the air. The 50-pound bags of hydrated lime will weigh approximately 68 pounds when they have absorbed the maximum quantity of carbon dioxide. If the new bags of hydrated lime weigh more than 55 pounds at the time of delivery, reject the shipment and order new lime. The bags may have plastic liners that must be punctured before the lime inside is effective for rapid CO_2 uptake. A board with several nails driven through it can be used to punch a number of holes in the side and ends of each bag as it sits on a shipping pallet.

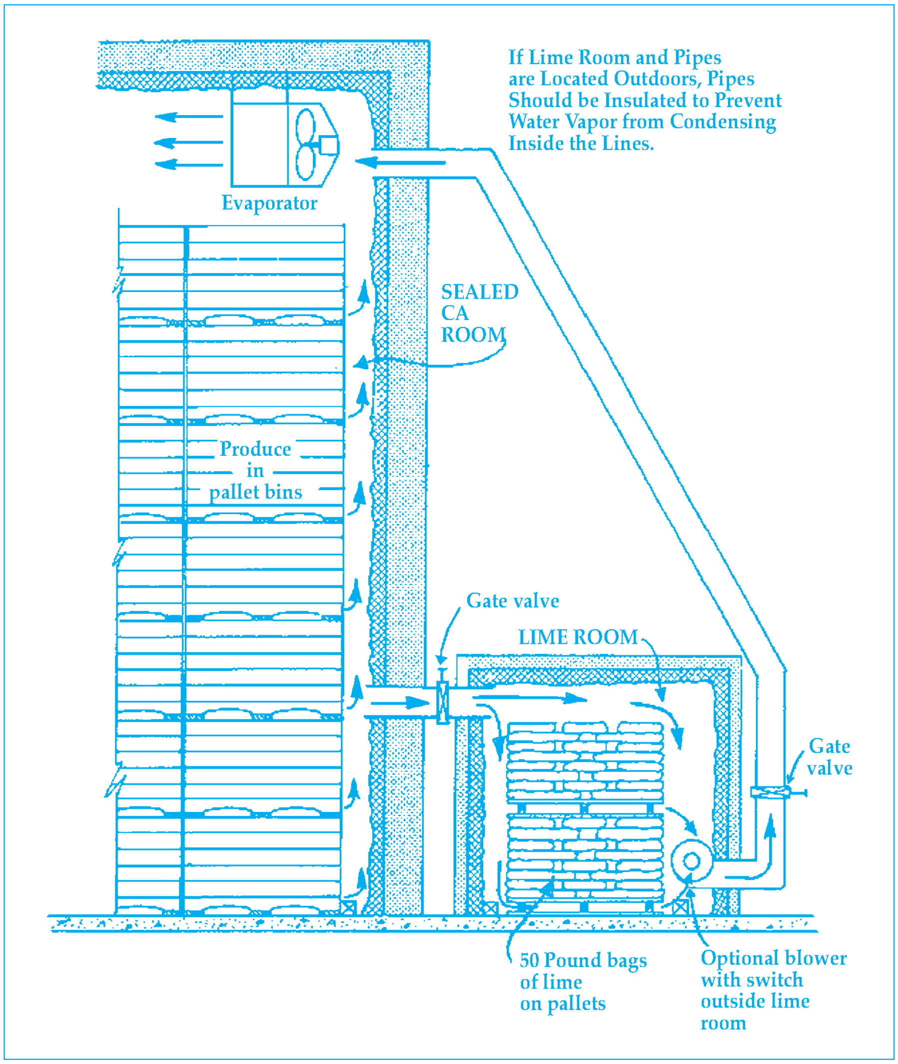

Figure 1. Lime Box Schematic.

If hydrated lime is used to supplement other scrubbing methods, it may be placed directly in the CA room under the evaporator, inside the door, or on a pallet on top of a stack of bins where it does not disrupt the atmosphere circulation in the room. Some heat will be given off as the lime absorbs carbon dioxide, so locate the lime in an area with good air movement away from the room thermometer and refrigeration thermostat sensors.

If lime is used as the only method to remove CO_2 it is usually placed in an airtight box or "scrubber" outside the CA room, adjacent to the wall where the evaporator is located (Figure 1). The lime box may be constructed of plywood or metal, fitted with an airtight door and insulated with urethane foam. Size the scrubber to hold 10 bags of lime per 1,000 bushels of fruit and allow approximately 3.5 cubic feet of internal volume for each 50 pounds of lime. Make sure the box is large enough to provide clearance space for atmosphere circulation around and across bags stacked on a shipping pallet. The lime box door should be large enough to permit loading and removal of pallets of lime with a forklift.

Replace the lime when the CO_2 level in the room can no longer be held to the desired level. Spent lime (calcium carbonate, $CaCO_3$) will be a solid lump, but still good for soil application if it is broken up and spread on fields.

Use a 4-6 inch diameter PVC pipe to connect the lime box to the CA room as shown in Figure 1. Connect a similar size pipe to the base of the lime box and extend it overhead and through the wall of the CA room in the vicinity of the evaporator fan intake. The low pressure developed by the evaporator fans is usually sufficient to draw the room atmosphere into the top of the lime box, downward through the stacks of lime where CO_2 is removed, and back into the storeroom. If circulation is not adequate, or if smaller diameter scrubber lines are used, install a small externally controlled centrifugal blower inside the lime room to assist with circulation. Gate valves in the scrubber lines are necessary to regulate scrubbing action or isolate the lime box when lime is changed. If the lime room is located outdoors, it may be necessary to insulate the lines or place the vertical pipe inside the CA room to prevent condensation or ice buildup inside the pipe in winter. The lime box should be leak tested each time the CA room is leak tested.

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Apple Arthropod Management Using Reduced-Risk Pesticide Programs

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Efforts to reduce the use of broad spectrum insecticides like organophosphates, carbamates and pyrethroids have begun and will continue as the Food Quality Protection Act of 1996 is fully implemented. Large scale evaluations of alternative insect control programs based on reduced-risk pesticides were begun in several states in 2002. The NY project is being conducted at 14 sites on growers' farms in the three major apple producing areas of the state.

Fresh and processed apple products constitute a major component in the diets of infants and children. Implementation of the Food Quality Protection Act of 1996 has begun and will continue to limit reliance on broad-spectrum insecticides, which have been the foundation of pest management programs for these crops in New York State for the past 40 years.

New York is a participant in a multistate USDA-RAMP (Risk Avoidance and Mitigation Program) project that is examining pest control programs that use only selective reduced-risk pest control tactics on multiple farms throughout the state over a four year period. The goal of this project is to design pest management systems that will greatly reduce residues and worker exposure to organophosphate, carbamate, and pyrethroid insecticides and to evaluate, on a regional scale, reduced-risk tactics that previous research and experience indicate will be effective, sustainable, economically viable, and compatible with biological control. Among the approaches being used in these programs, which are designed for fresh market apple production, are selective (reduced-risk) insecticides, mating disruption, conservation of natural enemies, and cultural practices. These tactics are being integrated into specific pest management programs designed to be most appropriate for each major production region within the state. This article reports the results after the second year of the study (2003).

The RAMP Project in NY

Research sites were set up in all the major apple growing areas of New York: Western NY (Appleton, Oak Orchard, Lyndonville, Waterport, Sodus, Phelps); Central NY (Lafayette); Hudson Valley (Milton, Stone Ridge, Gardiner); Capital District (Burnt Hills, Granville); and Champlain Valley (Chazy, Valcour). Each research site was a "split-plot design" in which the entire block received a program of reduced-risk insecticides, and a five-acre portion of the block was additionally treated with pheromones for mating disruption of the later summer generations of codling moth (CM), oriental fruit moth (OFM), and lesser appleworm (LAW). Pheromone traps for all species were hung in all plots, and pheromone ties were deployed for CM and OFM; traps were checked weekly. Fruits were inspected for disease and insect damage at harvest. A grower standard comparison block, which had the same varieties and planting style, was also monitored at each site. These blocks all contained at least one fresh fruit variety such as 'Empire' that might be selected for marketing in Europe or some other market outlet that could eventually require IPM protocols for market access.

Private crop consultants played a leading role in the interactions with growers within a region, and were responsible for general communication with cooperating growers, and in ensuring that recommended insecticide sprays were applied to the plots in a timely manner. In growing areas where there were insufficient numbers of private crop consultants, the leading role for appropriate seasonal interactions was undertaken by Cornell faculty or field extension personnel. Materials used in the reduced-risk pesticide program included: Apollo or dormant oil plus Pyramite or Acramite (as needed in summer) for mites, Actara for early season pests (including rosy apple aphid, spotted tentiform leafminer, plum curculio and tarnished plant bug), Avaunt for post-petal fall pests such as plum curculio, internal Lepidoptera and apple maggot, plus Confirm and SpinTor for leafrollers. All sprays were applied by the grower.

From April 22–May 2, Trècè Pherocon IIB pheromone traps were hung in all three plots at each commercial orchard site as follows: one CM, OFM, and LAW trap group was placed at head height and arranged around the canopy of each of three trees in a middle row (one at each end and one in the center) of the Reduced-Risk Pesticides plot, Pheromone+Reduced-Risk Pesticides plot, and Grower Standard plots at each site. All traps were checked and cleaned weekly until late August; CM lures were changed every four weeks, and OFM and LAW lures were changed during the middle two weeks of July. From June 16–July 1, polyethylene pheromone tie dispensers were hung in the Pheromone+Reduced-Risk Pesticides plots at each site, using different products to disrupt three separate moth species: codling moth were disrupted by Isomate CTT ("twin-tube") at 200 ties/acre, and oriental fruit moth and lesser appleworm were disrupted by Isomate M-100 at 100 ties/acre. All OFM ties were hung at head height by hand; CM ties were hung in the upper 1/3 of the tree canopy by hand for dwarf trees, and using a pole+hoop applicator for trees taller than 7 ft. Average time requirements for deploying the pheromone ties were as follows:

Hand-applied: 1.27 hr/acre/person (or 0.79 acre/hr/person); 236 ties/hr/person

Pole+hoop: 1.24 hr/acre/person (or 0.81 acre/hr/person); 242 ties/hr/person

All plots were sampled for representative arthropod pests throughout the season. Ten blossom terminals from each of 10 trees were inspected during the bloom-to-petal fall period for obliquebanded leafroller infestations; 20 fruits on each of 30 trees were examined for plum curculio damage after petal fall; apple aphid infestations (and predator incidence) were assessed on 10 terminals per each of 10 trees several times during the summer months; and leafminer mines were counted on 10 terminal leaves from each of 10 trees in late summer. Mite populations were assessed three to four times during the summer by collecting four 25-leaf samples from each block and brushing them in the lab to count motile forms of phytophagous and predacious mites. Also, from July 21–31, fruit was examined for internal larval feeding damage in each plot by inspecting 20 random fruits on each of 30 trees along the edges and near hedgerows where pressure from immigrating moths was expected to be most severe. Shortly before the respective harvest date in each orchard, 20 fruits were picked from each of 35 trees in each plot: six trees grouped in the center of the plot, 12 trees from the mid-interior region (a few rows in from each of the four edges) and 12 trees from the outside edges + 5 extra along one edge designated as being at high risk for apple maggot injury (700 fruits total per plot). In cases where the Reduced-Risk Pesticides plot was separate from the Pheromones+Reduced-Risk Pesticides plot, a total of 16 trees along the 'apple maggot edge' were sampled in each plot (860 fruits total per plot). All fruits were inspected for damage caused by diseases and insects, including the three internal Lepidoptera species.

TABLE 1

RAMP plots 2003, summary of mean % fruit damage at harvest, across all sites.

Treatment	Int. Lep stings	Int. Lep entries	Apple Maggot	Plum Curc	TarnPl. Bug	Rosy Apple Aphid
Pheromones + Red.-Risk Pstcs	0.15	0.20	0.02	0.29	0.85	0.00
Reduced-risk Pesticides	0.35	0.40	0.13	0.33	0.81	0.00
Grower Std	0.19	0.11	0.06	0.33	0.94	0.02

Treatment	EuroApple Sawfly	Early OBLR	Late OBLR	San Jose Scale	Fruit Scab	Summer Diseases	% Clean*
Pheromones + Red.-Risk Pstcs	0.04	0.13	2.28	0.19	5.28	3.71	95.85
Reduced-risk Pesticides	0.00	0.06	2.20	0.05	5.97	2.89	95.67
Grower Std	0.03	0.08	2.18	0.08	5.81	4.45	95.98

* Results not significantly different (P = 0.05, Fisher's Protected lsd test; disease incidence not considered.)

Results

Pheromone trap catches from around the state revealed codling moth levels were fairly low to moderate throughout the season in all the blocks, with catches rarely exceeding 10 moths per trap per week, and in many cases considerably fewer than five per trap. Abundance of the remaining two species was highly variable, depending on location. In the most western sites, lesser appleworm levels tended to be modest, but oriental fruit moth pressure was sometimes severe, with numbers exceeding 125 per trap per week in one instance. In the eastern orchards, the opposite trend was seen, with OFM scarcely present, particularly during the latter half of the season, and LAW at reasonably high levels (as much as 15–30 per trap per week) in most of these blocks, particularly towards the end of the season and beyond harvest. In all cases, the pheromone ties suppressed trap catches of not only the two target species (CM and OFM), but also LAW, at levels at or near zero. Interestingly, these low or zero-catch patterns were also seen in the pheromone-disrupted plots even during the first flight of these species; i.e., before the application of this season's pheromone tie dispensers. Because a normal number of moths were being caught in the adjacent non-disrupted plots, it must be assumed that either sufficient pheromone was still present from the previous year's ties to affect continued trap shutdown into the spring of this season, or else the previous year's pheromone treatment had a locally suppressive effect on populations within the plot and few moths were migrating in from other plantings. The suppression of LAW is presumed to be due to the similarity of its pheromone blend (98:2 of Z:E-8 12-OAc) to that of OFM (92:8 of Z:E-8 12-OAc).

Data on European red mite and phytoseiid predators were analyzed by first determining the average density of each for the four times samples were collected from each plot. Densities were compared among the reduced-risk strategies and the standard strategy using analysis of variance. There were significantly more phytoseiids in the Reduced-Risk plots (0.15 per leaf) compared with the Standard plots (0.9). There were no differences in European red mite densities between the two treatments. Most phytoseiids identified were *Typhlodromus pyri*; however, there was a difference in species composition between Reduced-Risk plots and the Standards, with *T. vulgaris* and *Amblyseius andersoni* being found at different levels in the two treatments at later sample dates.

Fruit damage at harvest caused by fruit-feeding insects was uniformly low across all blocks and treatments (Table 1), with no statistically significant differences between the Reduced-Risk pesticide blocks, with or without pheromones, and the Grower Standards, similar to the 2002 results. Overall damage by internal-feeding Lepidoptera was somewhat reduced from 2002, however, with only six farms exhibiting any internal worm damage in 2003, compared with eight farms in 2002 (Figure 1). Some distinct differences did occur among the stratified samples taken within respective blocks. For instance, localized damage of up to 13–16 percent was noted along a specific orchard edge in one case.

In no instance were fruit damage readings statistically correlated with the pest management strategy used. However, for damage caused by internal Lepidoptera, which were responsible for an average of 0.24% fruit damage, the data suggest that

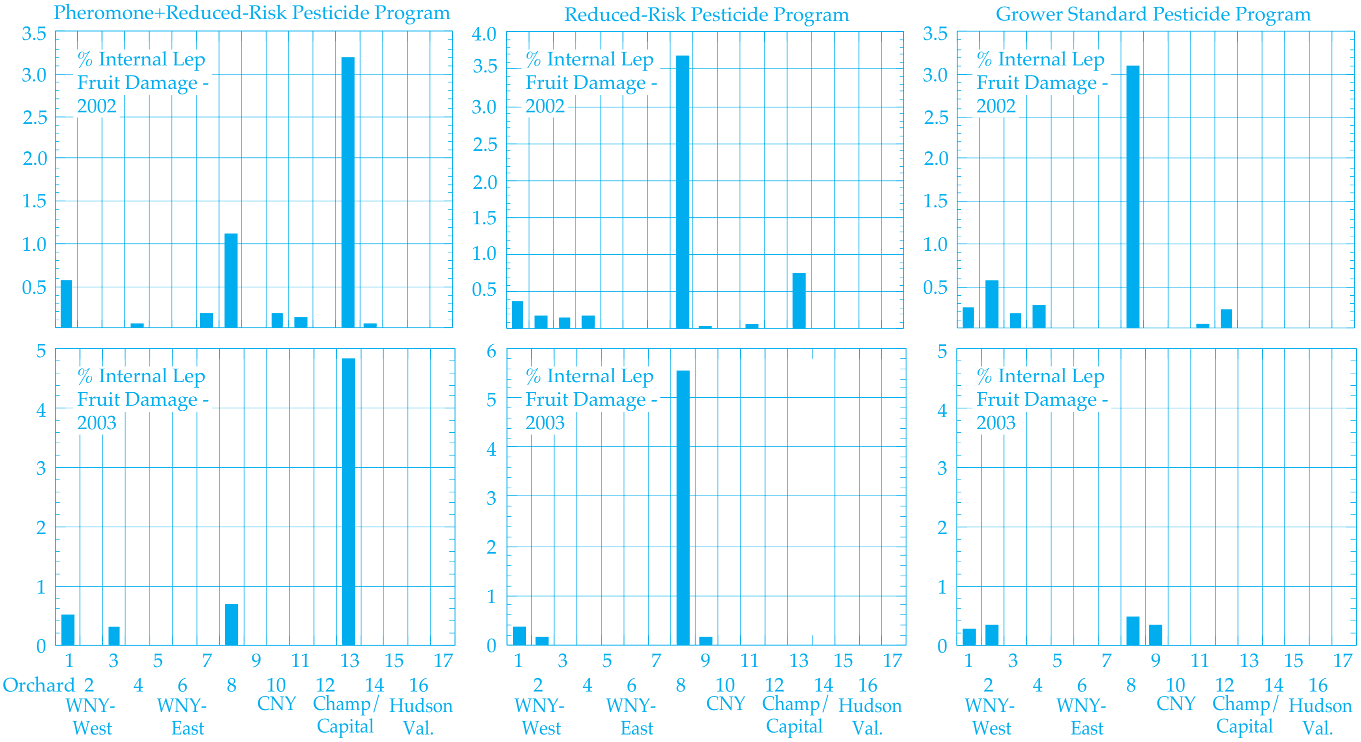

Figure 1. Percent fruit damage at harvest caused by internal-feeding Lepidoptera moth pests (oriental fruit moth, lesser appleworm, and codling moth) in plots receiving a program of pheromones plus reduced-risk pesticides, reduced-risk pesticides only, or under the grower's standard management program, 2002 and 2003 seasons. (WNY, western NY; CNY, central NY; Champ/Capital, Champlain Valley and Capital District)

this damage might be higher in the two reduced-risk programs. In these programs, the six highest incidences of fruit damaged occurred in either the Reduced-Risk or Rheromone+Reduced-Risk treatments. However, all of these six observations came from just three farms. Of the arthropod pests, the greatest experiment-wise incidence of fruit damage was due to the summer generations of OBLR (2.2 percent). The most consistent arthropod pests were plum curculio and tarnished plant bug, although the percent damaged fruit attributable to these pests was quite low. Location in the blocks influenced the proportion of fruit damaged by summer generations of OBLR, plum curculio, tarnished plant bug, and European apple sawfly. In all cases, the highest incidence of damage occurred in the exterior sections of the plots.

Conclusions

Extensive evaluations of insect pest management programs that use organophosphate (OP) insecticides to control plum curculio, CM, OFM and apple maggot have shown their effectiveness. In addition, because some mite and aphid predators have become resistant to OP's, successful biocontrol of pest mites and aphids has been possible. However, because OP insecticides are toxic to other natural enemies in orchards, it has been difficult to obtain biocontrol of foliar pests such as leafhoppers and leafminers. Also, leafrollers, OFM and leafminers that were formerly of minor importance in orchards, have become resistant to OP's and now must be controlled with other classes of insecticides, many of which are toxic to mite predators. Results from small-plot evaluations of the new more selective, reduced-risk insecticides have shown that these compounds are effective against secondary pests such as aphids, leafhoppers, leafminers, and leafrollers. However, fruit damage from CM, OFM, and apple maggot in plots treated with reduced-risk materials has often been slightly higher than that occurring in plots treated with organophosphates. This project will help determine if selective insecticides alone, or integrated with mating disruption, can provide adequate control of direct pests of fruit for which there is no allowable tolerance of damage. It will also help identify potential new pests, as well as natural enemies, that may occur in orchards treated with these new, selective tactics.

Acknowledgments

We wish to acknowledge the cooperation of all the growers (M. Biltonen, W. Blackler, M. Boylan, E. Brown, G. Burnap, S. Datthyn, R. Farrow, M. Fleckenstein, M. Forrence, T. Furber, T. Green, J. Knight, M. Maloney, D. Oakes, S. Reed, P. Russell, R. Schoonmaker, K. Trammel, and D. Wilson), consultants (P. Babcock, J. Eve, J. Misiti, and R. Paddock), and fruit extension agents (D. Breth and K. Iungerman) participating in this trial, without whom this study could not have taken place. We also thank our technical field assistants, Milo Bonacci, Emily Fitzgibbons, Scott Lakso, Rachel Mussack, Josh Burden, Jason Sheehe, Judy Staton, Peter Jentsch and the Hudson Valley crew. We are grateful for support and material received from CBC America Corp., Dow AgroSciences, Dupont, Makhteshim Agan, and Syngenta. This work was supported by a grant from the USDA Risk Avoidance and Mitigation Program.

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Management of Nitrogen and Carbohydrate Reserves to Improve Growth and Yield of Apple Trees

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This work was funded in part by the New York Apple Research and Development Program.

In the fall, trees accumulate carbohydrate and nitrogen reserves. Some of the nitrogen reserves come from the leaves as the tree remobilizes nitrogen from the leaves back into the permanent parts of the tree before leaf fall. The relatively short period of good weather in the fall after harvesting the crop may limit reserve nitrogen and reserve carbohydrate levels of trees in New York. Results from this project show that nitrogen reserves are very important to tree growth and cropping the next year. Management strategies for improving tree nitrogen reserves include fall urea sprays or fall ground fertilization.

Both reserve nitrogen and reserve carbohydrates are essential for the growth and development of apple trees in spring because they provide energy and building blocks for the new growth before photosynthesis and significant root uptake of nitrogen take place. In the fall, trees accumulate carbohydrate and nitrogen reserves. Some of the nitrogen reserves come from the leaves as the tree remobilizes nitrogen from the leaves back into the permanent parts of the tree before leaf fall. Compared with other apple growing regions, there is a very short leaf retention period in the fall after harvesting the crop in New York and the Northeast. This could limit tree performance the following season in our area for two reasons. First, because photosynthesis is often limited after harvest, apple trees may not have enough time to accumulate sufficient reserve carbohydrates. Secondly, the rapid drop of temperature after harvest may significantly reduce mobilization of nitrogen from leaves back to the plants during leaf senescence and decrease root activity for nitrogen uptake from the soil, leading to low reserve nitrogen status.

Understanding how growth and fruiting of apple trees are related to reserve nitrogen and reserve carbohydrates has important practical implications for managing nitrogen and carbohydrate reserves to improve growth and yield of apple trees. The conventional view has been that the initial growth and development of apple trees in the spring is largely determined by reserve carbohydrate levels. By differentially altering reserve nitrogen and reserve carbohydrates using foliar urea application in the fall, we have shown that the initial growth of apple nursery trees is mainly determined by reserve nitrogen, not reserve carbohydrates. Conversion of a portion of the reserve carbohydrates to free amino acids and proteins by foliar urea application in the fall significantly improved tree growth. However, this may not be completely applicable to bearing trees in the orchard. Bearing trees not only have vegetative growth, but also have reproductive growth. As a result, the assimilated carbon in bearing trees is not only partitioned to vegetative growth and storage, but also to the fruit. In fact, producing a high quality, consistent crop is the ultimate goal of orchard management. The objective of this work was to determine how growth and fruiting of apple trees are related to reserve nitrogen and reserve carbohydrates and how to optimize the management of these nutrient reserves to improve the productivity of apple trees.

Experimental Procedures

Three experimental approaches have been used to alter the reserve nitrogen and reserve carbohydrate status of apple trees. The first is manual defoliation in combination with or without foliar urea applications in the fall; the second is carbon dioxide enrichment with or without nitrogen application after harvest in the fall; and the third is manipulation of cropload.

Experiment 1. We studied the effects of manual defoliation and foliar urea application in the fall on reserve nitrogen and reserve carbohydrate status, and tree growth and fruiting the following year. This experiment was conducted at a Cornell experimental farm using six-year-old 'Marshall McIntosh'/M.9 trees at a spacing of 6 x 14 feet. Trees received one of the following four treatments after harvest: (1) natural defoliation without foliar urea application (control), (2) manual defoliation on October 12, (3) 3 percent foliar urea sprayed twice in the fall (September 28 and October 5), and (4) 3 percent foliar urea sprayed twice (September 28 and October 5), followed by manual defoliation on October 12. There were five replications for each treatment with four trees in each plot in a completely randomized design. Spur

TABLE 1

Reserve N and reserve carbohydrate concentrations of six-year-old Marshall McIntosh/M.9 apple trees in response to manual defoliation and foliar urea application

Treatments	Spur N(%) (%)	Shoot N(%) (%)	Spur carbohydrates (mg/g)	Shoot carbohydrates(mg/g)
Control	1.37a	0.94a	91.7a	103.9a
Foliar urea (F)	1.47b	1.05b	79.0b	95.3b
Defoliation (D)	1.16c	0.73c	73.0b	94.4b
F + D	1.24c	0.80c	73.6b	93.6b

Different letters within the same column indicate significant level at 0.05%.

TABLE 2

Effects of defoliation and foliar urea applications on fruit yield and quality of six-year-old Marshall McIntosh/M.9 apple trees.

Treatments	Fruit number (#/tree)	Fruit Weight (g)	Yield (kg/tree)	Soluble solids (%)
Control	178.3ab	153.8a	27.30ab	12.46a
Foliar urea (F)	191.8a	159.6ab	30.64a	12.49a
Defoliation (D)	124.6c	171.1b	21.41c	12.09a
F + D	148.9bc	167.1b	24.72bc	12.40a

and extension growth were sampled before budbreak to measure nitrogen and carbohydrates. Test trees did not receive any nitrogen fertilizer during the second growing season. Spur leaf samples were taken on June 1 to determine total spur leaf area, leaf number, leaf nitrogen content. Fruit number, yield, and fruit quality were measured at harvest.

Experiment 2. In this study we enriched the air with carbon dioxide or applied nitrogen in the fall to affect reserve nitrogen and reserve carbohydrates and evaluated tree growth and fruiting the following year. There were two levels of CO_2 concentrations: ambient (360 ppm) and an elevated level (1000 ppm), and two levels of nitrogen supply: no N or 2 liters of 140 ppm N applied to soil twice weekly for five weeks. So there were a total of four treatment combinations with three replications each in a completely randomized design. Second leaf Gala/M.26 trees that grow in sand culture were used in this experiment. The cropload of these trees was adjusted by hand thinning to six fruit per cm^2 TCA at 10 mm king fruit. They were supplied with 150 ppm Peter's 20-10-20 fertilizer with micronutrients every week during the growing season until mid August. A total of 36 uniform trees were selected and each was randomly assigned to one of the four treatments above. Six temperature-controlled plastic chambers were used in the field to provide CO_2 treatment. The CO_2 concentration inside the chamber was controlled by an injection system and monitored by an infrared analyzer. Soil N treatment began at the same time when the trees were moved into the CO_2 chambers. Two liters of 140 ppm N (from ammonium nitrate) were provided to each tree twice weekly for five weeks. After natural leaf fall, pots were covered with woodchips to protect the root system during the winter. Before budbreak the following year, one set of trees from each of the four treatment combinations was destructively sampled to measure dry weight, nitrogen and carbohydrates. The remaining trees were divided into two groups. One group did not receive any nitrogen supply at all while the other group received 140 ppm N supply starting from petal fall until mid August. Fruit was harvested in mid September. Total fruit number, fresh weight, and total leaf area were measured at harvest.

Experiment 3. We imposed different croploads to determine the effect of cropload on tree growth and reserve nitrogen and reserve carbohydrates. We used third leaf 'Honeycrisp'/M.9, 'Jonagold'/M.9 and 'Gala'/M.9 trees. Cropload was adjusted to 0, 3, 6, 9, 12, and 15 fruit/cm^2 trunk cross-sectional area (TCA) at 10-mm king fruit by hand thinning. At harvest, fruit number and yield per tree were recorded. Before budbreak the following spring, spurs, extension growth, and roots were sampled for nitrogen and carbohydrate analysis.

For all the experiments above, nitrogen was determined by the Kjeldahl method. Soluble sugars were extracted with 80% ethanol three times, then separated and quantified by using a Dionex High Performance Liquid Chromatograph (HPLC). Starch was converted to glucose, and then measured by the HPLC. Total non-structural carbohydrates are the sum of starch and soluble sugars. Soluble sugars include sorbitol, sucrose, glucose and fructose.

Results and Discussion

Experiment 1. Reserve nitrogen and carbohydrates. Manual defoliation significantly decreased both reserve nitrogen and reserve carbohydrates in spurs and extension growth (Table 1). Foliar urea application increased nitrogen content, but decreased reserve carbohydrates in both spurs and extension growth. Application of foliar urea followed by manual defoliation tended to increase reserve nitrogen content in both spurs and extension growth compared with manual defoliation alone although this is not statistically significant.

Growth and yield. Manual defoliation in the fall significantly decreased spur leaf number, total leaf area, specific leaf weight, and leaf N content per unit leaf area the following spring. Foliar urea application did not affect spur leaf number, specific leaf weight, and leaf N content, but increased total spur leaf area the following spring. Foliar urea application followed by manual defoliation the following spring increased total spur leaf area, specific leaf weight, and leaf N content compared with

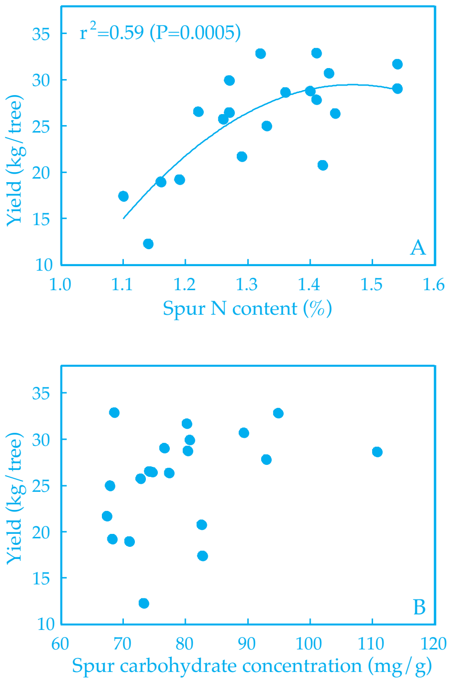

Figure 1. Fruit yield of 6 year-old 'Marshall McIntosh'/M.9 trees in relation to reserve nitrogen content (A) and reserve carbohydrate concentration (B) in spurs.

manual defoliation alone (data not shown). Manual defoliation significantly decreased fruit number and yield per tree the next year (Table 2). Foliar urea application tended to increase fruit number and yield per tree although not statistically significant. Foliar urea application followed by manual defoliation tended to increase fruit number and yield compared to manual defoliation alone. There was no difference in fruit quality except that fruit size was slightly larger in trees with lower fruit number. When regression analysis was used to examine fruit number and yield in relation to reserve nitrogen and reserve carbohydrates, it was found that fruit number and yield were significantly related to reserve nitrogen content in spurs, but not reserve carbohydrates (Figure1).

TABLE 3

Effects of elevated CO_2 and N application in the fall on dry weight and reserve N and reserve carbohydrate status of potted 'Gala'/M.26 apple trees.

Fall Treatments CO_2	 N	DW(g/tree) (g/tree)	N content %	Total N (g/tree)	CHO Conc (mg/g)	Total CHO (g/tree)
360	0	1031.0	0.62	6.39	153.3	158.1
	Soil N	1024.9	0.98	9.99	134.8	138.2
1000	0	1107.2	0.59	6.54	162.1	179.7
	Soil N	1104.8	0.86	9.51	140.4	155.2
Significance						
Fall CO_2		ns	ns	ns	Ns	$P<0.05$
Fall N		ns	$P<0.0001$	$P<0.0001$	$P<0.05$	$P<0.05$

P values indicate the significance level. ns: non significant.

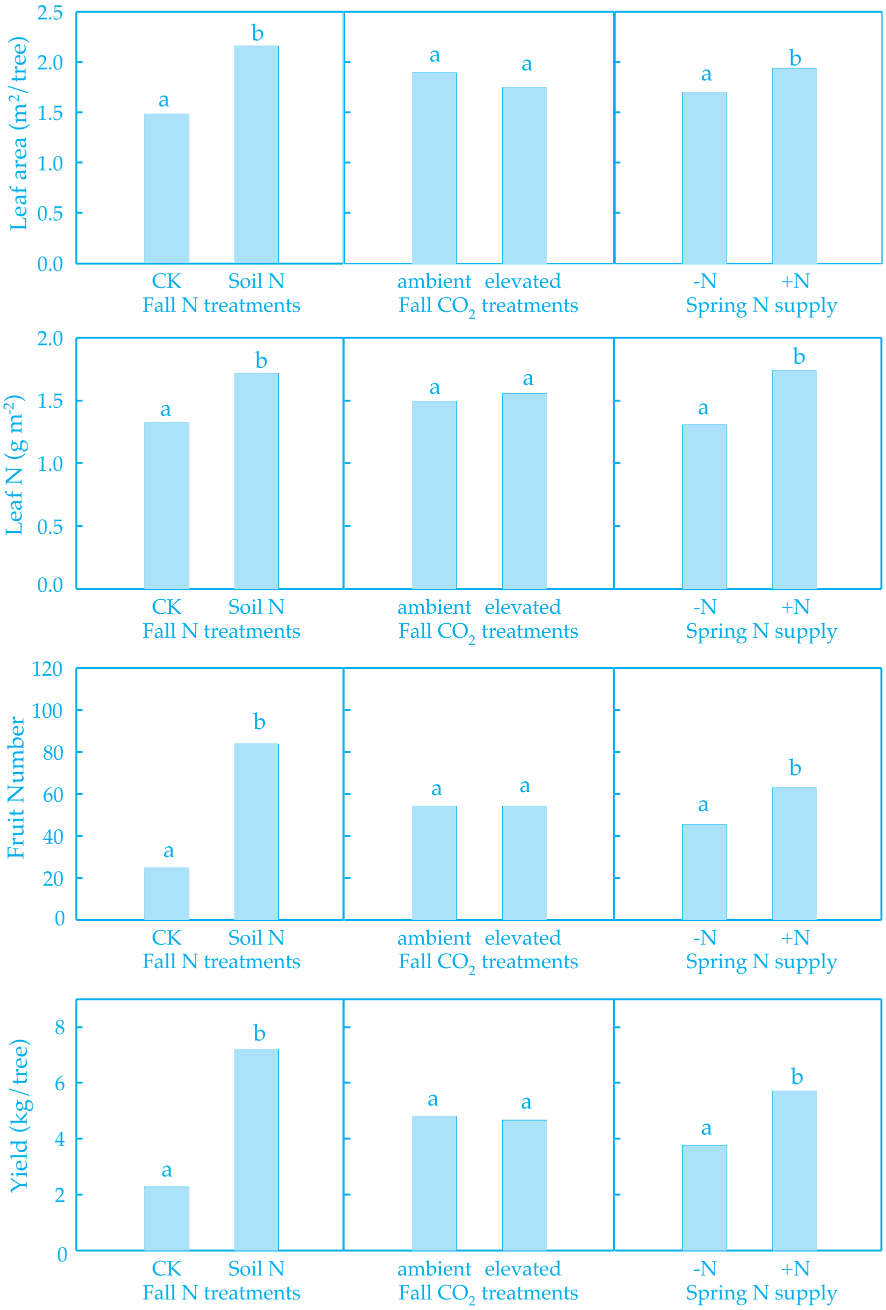

Figure 2. Leaf area, leaf nitrogen content, fruit number and yield of potted 'Gala'/M.26 apple trees in relation to fall CO_2 and N treatments and spring N supply. Different letters indicate significant difference at 5% level.

Experiment 2. Reserve nitrogen and carbohydrates. Fall CO_2 enrichment slightly increased both carbohydrate concentration and total dry matter of the tree, resulting in a significant increase in the total amount of reserve carbohydrates (Table 3). Nitrogen application in the fall significantly increased N content and total amount of N accumulated in the tree, but reduced carbohydrate concentrations.

Growth and yield. Fall CO_2 enrichment increased total amount of reserve carbohydrates, but it did not affect total leaf area, fruit number, or fruit yield the following year (Figure 2). Regardless of spring N supply, trees with high N reserves but low carbohydrate reserves had a larger total leaf area, higher fruit number and total yield than those with low N reserves but high carbohydrate reserves. Spring N supply also significantly increased total leaf area, leaf N content, fruit number, and total yield.

Experiment 3. Over a wide range of cropload (0 to 14 fruit per cm^2 TCA), spur N content or carbohydrate concentration did not change significantly (Fig. 3A, B). However, tree vegetative growth, as measured by the increase of TCA, decreased as cropload increased (Figure3C). This indicates that apple trees are able to maintain their reserve nitrogen and reserve carbohydrate concentrations in response to increasing cropload by reducing vegetative growth. However, this will inevitably lead to a decrease in the total amount of reserves, which may in turn negatively affect growth and fruiting the following season.

Summary

The key findings of this project are:

- Manual defoliation after harvest reduced both reserve nitrogen and carbo-

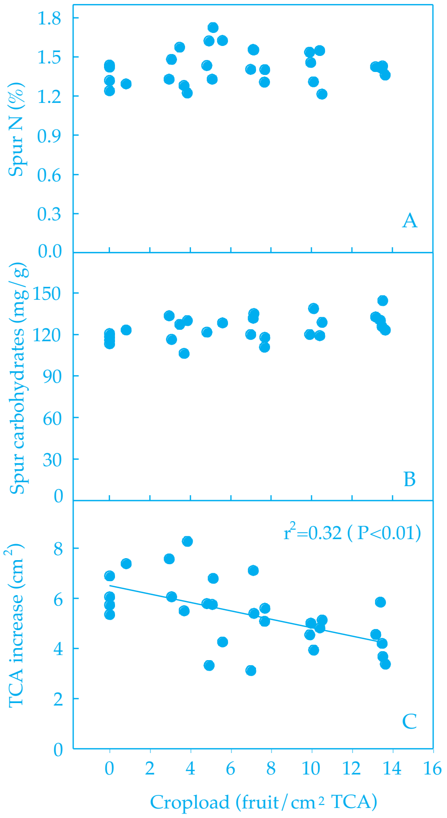

Figure 3. Effects of cropload on spur nitrogen (A), carbohydrates B) and increase of trunk cross-sectional area (C) of 3rd leaf 'Honeycrisp'/M.9 trees.

hydrates. Foliar urea applications in the fall increased reserve nitrogen, but decreased reserve carbohydrates. Apple yield the following year was more related to reserve nitrogen than reserve carbohydrates.

- CO_2 enrichment of bearing trees after harvest increased the total amount of reserve carbohydrates. Fall nitrogen application increased tree total reserve nitrogen, but decreased total reserve carbohydrates. Trees with high nitrogen reserves but low carbohydrate reserves had better vegetative growth and higher fruit set and yield the following season than those with low nitrogen reserves but high carbohydrate reserves.
- Concentrations of reserve nitrogen and reserve carbohydrates were not affected significantly by cropload, but tree growth was decreased by increasing cropload.
- Both foliar urea application and soil N application in the fall enhanced tree nitrogen reserves, and consequently improved tree growth and fruiting the following season.

These findings clearly showed that both vegetative growth and fruiting of bearing apple trees are mainly determined by nitrogen reserves, not carbohydrate reserves. Therefore, how to improve tree reserve nitrogen status should be an important part of orchard management. Cropload must be optimized as it affects tree growth (as well as fruit quality and flower bud initiation) and consequently the total amount of nitrogen and carbon reserves available for the following year. Maintaining healthy foliage in the fall is critical for building up both carbohydrate and nitrogen reserves. Both foliar urea application and soil N application can be used in the fall to enhance tree nitrogen reserves, and consequently improve tree growth and fruiting the following season.

In addition, our nitrogen timing study using ^{15}N-ammonium nitrate showed that mature apple trees took up significant amounts of fertilizer nitrogen between budbreak and the end of spur leaf growth, which contributed about 30 percent to the spur leaf N. So, applying nitrogen between budbreak and bloom provides another route for satisfying early tree N demand for canopy development and fruit growth.

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Reducing Spray Drift From Orchards – A Successful Case Study

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This work was funded in part by the New York Apple Research and Development Program.

Reducing spray drift and improving deposition are increasing concerns for fruit growers. Drift results in damage to susceptible off target crops, environmental contamination to watercourses and an unintentionally reduced rate of application to the target crop, thus reducing pesticide effectiveness. Pesticide drift also affects neighboring properties, often leading to public outcry and conflict. For many dwarf-tree apple orchards we have found that reducing fan speed by 25 percent provides a simple, inexpensive method of reducing drift.

The application of pesticides has been of concern for many years, particularly in relation to methods of reducing drift and improving deposition. Many growers still use older airblast sprayers with hollow cone or air-shear nozzles which provide a large amount of air to penetrate traditional large fruit tree canopies. During recent years many growers have removed traditional tree plantings and replaced them with dwarf and semi-dwarf trees, but still use the older sprayers; the result is over-spraying of the target row and drift.

Spray drift from air-blast sprayers is an important and costly problem facing fruit growers (Landers, 2002). Drift results in damage to susceptible off target crops, environmental contamination to watercourses and an unintentionally reduced rate of application to the target crop, thus reducing pesticide effectiveness, (Landers 1999). Pesticide drift also affects neighboring properties, often leading to public outcry and conflict.

Sprayer Design and Drift

There are many interrelated factors affecting drift and deposition (see Table 1). Droplet size, air volume, speed and direction are the main factors from the sprayer. Landers and Schupp (2001), and Osborne et al. (2002) investigated increasing droplet size by using air induction nozzles and found that drift is considerably reduced while maintaining acceptable deposition levels for plant growth regulators.

Air speed and direction are critical if droplets are to be placed in the target canopy and not drift past the trees. The authors are currently researching methods of matching air volume, speed and direction to the growing canopy in order to find the optimum operating parameters.

Smaller droplets (<150 µm) can be carried some distance from the target row and up to 45 percent of spray particles emitted from hollow cone nozzles may be in the 30-100 µm size. The Spray Drift Task Force (1998) measured the droplet size spectrum from air-blast and mist blower (Ag Tec) classes of sprayer. The Volume Median Diameter (VMD) ranged from 138-210 µm from the air-blast and 73-110 µm from the mist-blower. The percentage of droplets <141 µm ranged from 26-52 percent for the air-blast and 65-90 percent for the mist blower. Both the VMD and the percent volume <141 µm confirm that the mist blower produced finer droplets and a higher volume of drift prone droplets. Thus, most currently used sprayer types produce considerable quantities of drift-prone droplets. The size of a droplet strongly influences its trajectory after being emitted from a hydraulic nozzle at a speed of 45-67 mph. The droplet rapidly decelerates due to friction until it attains a velocity that is solely a function of its diameter. Air movement in which the droplet descends also influences its trajectory.

TABLE 1

Interrelated factors affecting pesticide drift and deposition

Sprayer	Application	Target	Weather	Operator
Design	Application rate	Variety	Wind speed	Skill
Droplet size	Nozzle orientation	Canopy structure	Wind direction	Attitude
Fan size	Forward speed	Area	Temperature	
Air volume		Every row	Humidity	
Air velocity and direction		Alternate row		

Two types of drift can occur. The first is vapor drift from the airborne movement of highly volatile materials created by evaporation and the second, and more prominent, is droplet drift due to the movement of spray droplets in liquid form from the target area.

The Case Study

An apple grower in upstate New York was concerned with spray drifting from his property onto a neighbor's garden. He was using an AgTec 300 LP sprayer fitted with air shear nozzles to

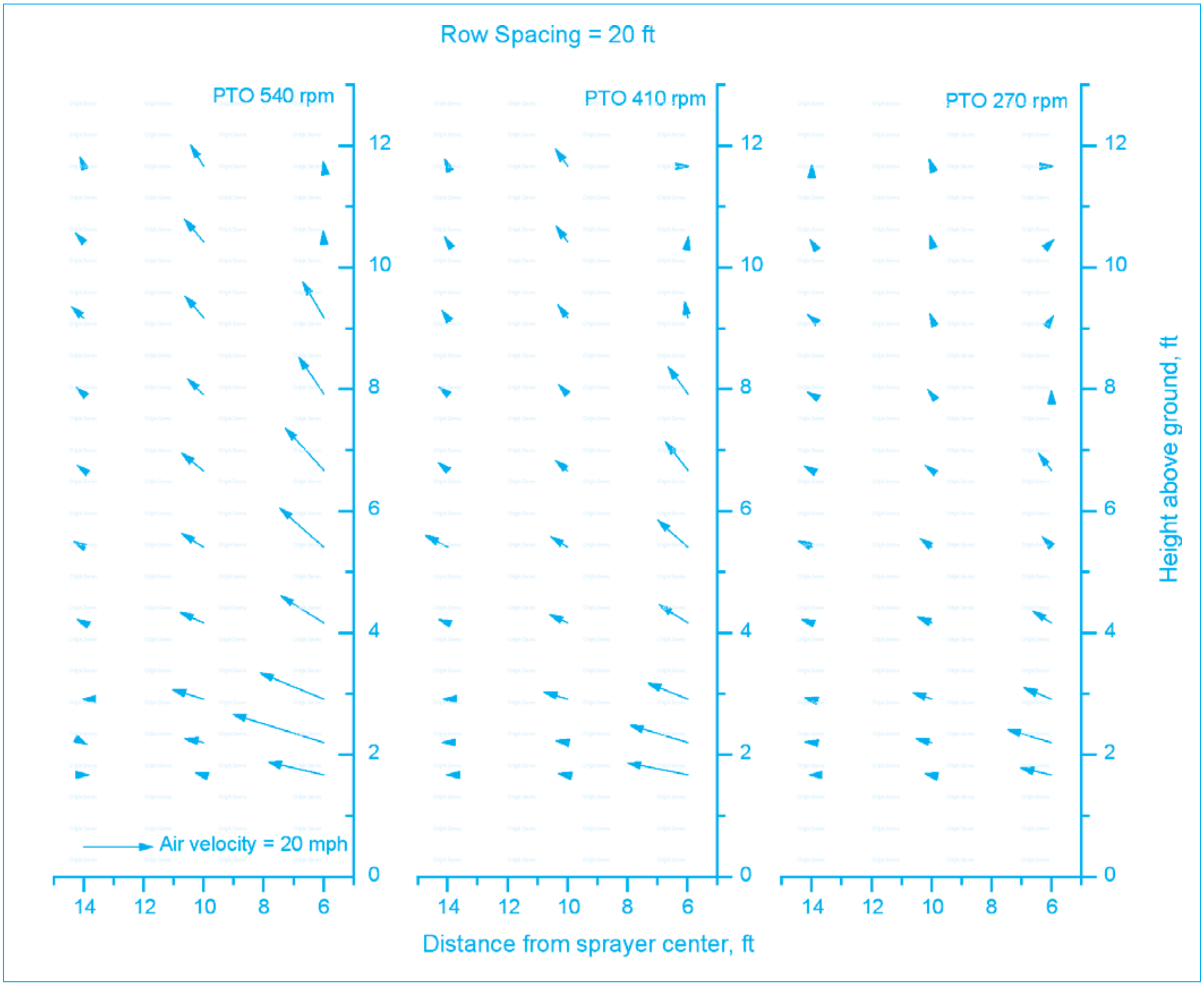


Figure 1. Air velocity patterns from left of AgTec sprayer for 12 ft. tall apple trees at 20 ft. row spacing for three tractor PTO speeds.

apply pesticides to a block of Crispin apple trees. The trees were spaced 20 feet between rows and 9 feet between trees in the row. They were 12 feet tall and 10 feet wide.

The AgTec sprayer used a low pressure pump (30 psi approximately) to deliver liquid to air-shear nozzles where liquid was sheared into fine droplets by an air stream passing over shear plates. Droplet size was determined by a balance between liquid/air at the shear plate. For the same liquid flow, the higher air velocity creates smaller droplets and vice-versa. Air shear nozzles tend to provide finer atomisation than hydraulic nozzles. Air speed at the shear plate was 180 mph (Donnell 2003).

During the winter of 2003, tests were conducted in a very large barn to measure air volume, speed and direction using an ultrasonic anemometer (model R3-50, Gill Industries Ltd, Hampshire, UK). Air velocity was measured at tractor PTO speeds of 540, 410, and 270 rpm. Velocity measurements were made at three distances from the sprayer center, on the left-hand side to mimic distances found in the orchard. One location was taken at one-half of the row spacing (row center) and one each at four ft on either side of the row center. At each horizontal location, measurements were made at 10 different heights above the ground from 1.6 to 11.8 ft. The deflector on top of the air outlet was adjusted to reach 12 ft tall apple trees. Fan speed for each tractor PTO speed was recorded using a tachometer. Air velocity measurements in a horizontal direction normal to sprayer travel and in the vertical were used to determine the velocity vectors away from the sprayer. The velocity vectors can be seen in Figure 1.

The velocity vectors at the measurement locations indicate that reducing the PTO rpm not only reduces the magnitude, but also the direction of air velocities especially at the upper heights. Using the sprayer and tree geometry, it was found that closest to the sprayer for each row spacing and at heights of 8 ft or more, the air velocities would cross over the tree and might not interact with the canopy.

For 20 ft row spacing, the air escaping at the tree height ranged from 0.3 to 24.4 mph. The velocities at eight ft height were 24.4 and 5.6 mph at 540 and 410 rpm. These velocities might carry considerable amounts of spray material with it. At other heights above and at 270 rpm, the range was 0.3 to 1.7 mph. At top center of the tree, the velocities ranged from 8.8 to 10.6 mph at 540 rpm, 5.0 to 5.7 at 410 rpm, 0.6 to 3.2 mph at 270 rpm. This air is also an added source of drift in this orchard


AgTec sprayer.


Field trials with AgTec sprayer.


Drift poles.

TABLE 2

The effect of fan speed on spray drift from an Ag Tec sprayer

Tractor[1] PTO Speed, rpm	Sprayer Fan Speed, rpm	Row 1	Row 2	Row 3	Row 4
		Spray Coverage, %			
540[2]	2076	75.90	69.00	16.60	10.10
405[3]	1557	16.70	0.20	0.10	0.04
		Cards Covered over 50 % (Total cards = 8)			
540	2076	6	8	0	0
405	1557	0	0	0	0

[1] John Deere 5520 tractor

[2] Mean wind was 5.5 mph coming from NW with gusts of 10.5 mph

[3] Mean wind was 7.7 mph coming from NW with gusts of 12.5 mph

TABLE 3

The effect of fan speed on canopy coverage and droplet size

Tractor PTO Speed, rpm	Sprayer Fan Speed, rpm	Ground Speed, mph	Spray Coverage, %	VMD	VD(0.1)	VD(0.9)
540	2076	3.70	36.1	351	144	786
405	1557	3.43	27.5	460	180	737

application.

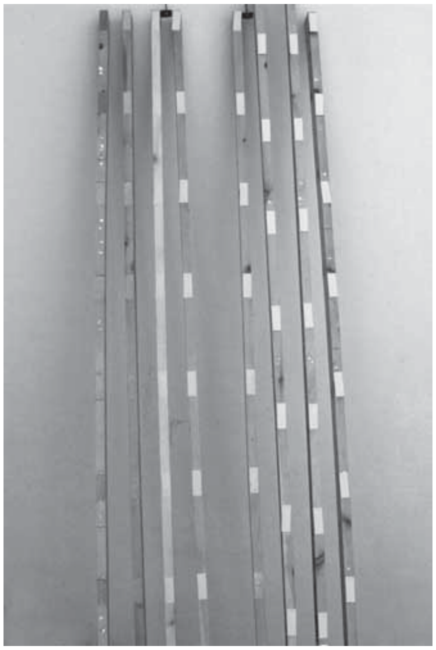
It should be noted that air velocity measurements were taken inside a barn in the absence of apple canopies. With measurements in the presence of apple trees, the difference between row spacing will be more prominent. For orchards with wider row spacing, the distance between sprayer and the canopy also plays a role by helping air diversion, in addition to droplet fall off due to gravity and increased evaporation. The air tries to divert around the trees coming in its way. As the distance between sprayer and tree decreases, the air will have more opportunity of diverting around the tree. The air released at a considerable upward angle to reach the treetop will have an initial boost for upward diversion and might cross over the tree.

During June 2004, when the trees were in full canopy, tests were conducted in the orchard. The effect of tractor PTO speed on in-canopy deposition, droplet size and off-target drift was studied using water sensitive cards (Syngenta).

For drift evaluation, cards were attached to one-inch-wide vertical poles. Eight cards were attached at 12-inch intervals starting from 8 feet above the ground to a height of 14 feet. Four such poles were placed at intervals of 20 feet from the center of the target row, covering 80 feet distance. For in-canopy deposition, 18 cards were randomly attached to leaves in the canopy. Coverage on the cards was determined using an HP 6200C scanner and WRK Droplet scan image program (WRK, Cabot, AR).

We measured the effect of reducing tractor PTO speed and fan speed by 25 percent. At a standard fan speed of 2076 rpm, drift was detected up to 80 feet from the target row where 10 percent card coverage was recorded at the furthest drift pole (Table 2 and 3). Reducing the fan speed by 25 percent resulted in considerably less drift. Card coverage at 20 feet and 40 feet from the target row was 16.0 percent and 0.2 percent, respectively.

Reducing fan speed increased droplet size from 360 mm VMD at 2076 rpm to 460 mm VMD at 1557 rpm. Changes in droplet VMD was of interest due to airflow and speed being critical to provide droplet creation with an air-shear nozzle.


Water sensitive cards attached to drift poles.

Conclusions

Reducing fan speed by 25 percent provides a simple, inexpensive method of reducing drift from an AgTec sprayer. Other methods of fan speed reduction include reducing engine speed, fitting a hydraulic motor to provide infinitely variable speed control, or applying an air restrictor to the air intake. Reducing air speed over the AgTec air shear nozzles by 25 percent only increased droplet VMD by 31 percent and still provided acceptable coverage.

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Acknowledgements

We wish to thank Bruce Wadhams, Eric VanHemel, Gary Wood and Rob Lasher for their technical assistance. Funding for this project was provided by the NYS Apple Research and Development Program, the Viticultural Consortium-East, Lake Erie Regional Grape Program, Grape Production Research Fund, New York Wine Growers, the Wine and Grape Foundation and NYSERDA.

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