Effects of MaxCel® on Fruit Set, Fruit Size, and Other Fruit Characteristics of Marshall McIntosh and Ace Spur Delicious Apples, 2004

Duane W. Greene, James Krupa, & Maureen Vezinna
Department of Plant, Soil, & Insect Sciences, University of Massachusetts

The thinning capability of benzyladenine (BA) has been known for over a quarter of a century. It was demonstrated by many investigators that it was a consistent thinner, and unlike other commercially-available thinners, it could increase fruit size beyond that which could be attributed solely to crop load reduction. It was not until 1994, however, that a thinner containing the active thinning ingredient BA was registered for use as a thinner. This product, Accel®, was an altered formulation of Promalin®, and it contained a small amount of gibberellin (GA). Initially, the small amount of GA present was considered too small to be physiologically significant. It soon became apparent, however, that the GA present in Accel could result in undesirable effects, especially the production of small and frequently seedless fruit. Further, the GA in the Accel interacted with naphthaleneacetic acid (NAA), which frequently resulted in the production of a large number of pygmy fruit.

In 2003, a new BA product was introduced that contained no GA (MaxCel®). Initial studies with this product suggested that MaxCel may be a superior product for thinning apples. The purpose of this investigation was to evaluate the new BA formulation as a thinner on apples and to determine if additional thinning could be achieved by the addition of carbaryl of carbaryl and oil.

Materials & Methods

Marshall McIntosh. Eighty mature Marshall McIntosh/M.26 were selected at the University of Massachusetts Cold Spring Orchard Research and Education Center (CSOREC) Belchertown, MA. At the pink stage of flower development, two limbs per tree, 10 to 15 cm in diameter, were selected, tagged and measured. All spur blossom clusters were counted and recorded on the tagged limbs. Bloom density was calculated. Trees were blocked into 8 groups (replications) of 10 trees each, based upon blossom cluster density. Treatments were applied on 21 May when fruit size averaged between 8 and 9 mm. The weather was partly cloudy with temperatures during the time of application ranging from the upper 60's into the mid 70's, but ultimately the temperature rose to the lower 80's later in the day. Treatments were applied as illustrated in Table 1 using a commercial airblast sprayer at a tree row volume of 135 gal/acre. Buffer trees were maintained between trees to assure that no tree received drift from an adjacent tree. At the end of June drop in July, the fruit on all tagged limbs were counted and recorded. On 16 September, five replications were harvested, and fruit were analyzed. The remaining three replications were harvested on 17 September and similarly processed. A 30-apple sample was harvested randomly from the periphery of each tree. Fruit were weighed, and red color was estimated to the nearest 10%. Further, the intensity of red color was evaluated to determine if fruit could be classified as US Extra Fancy. The percent of US Extra Fancy fruit was determined by counting all fruit that had at least 50% red color and had intensity that was great enough to meet the US Extra Fancy grade. A subsample of 10 fruit, representative of the harvested sample was selected. Flesh firmness was determined on two sides of each fruit using an Efegi penetrometer. Juice collected while doing the firmness determinations was pooled and the concentration of soluble solids was determined using a hand-held refractometer. Fruit were then cut at the equator, dipped in an iodine-potassium iodide solution, and starch reading made using the generic starch chart developed at Cornell University. The first four replications of treatments 1, 2, 3, and 10; Control, MaxCel 75 ppm , MaxCel 125 ppm, and NAA 7 ppm + carbaryl, respectively, were selected. All fruit were harvested from each tree (16 trees total) and separately identified. Fruit were taken to the laboratory where each fruit was measured with a hand-held caliper and placed in one of the following size categories: <2.25, 2.25,. 2.50, 2.75, 3.00, 3.25, 3.50, 3.75, and >3.75 inches. Fruit with a diameter of + 0.12 inches to - 0.13 inches of the sizes indicated above were placed into the indicated size categories. For example, a 3.00 inch fruit category would include all fruit with a diameter of 2.87 inches to 3.12 inches. Economic data were generated based upon prices that were received in the Boston Market in November 2004. The sizes of the fruit from each tree were known from caliper measurements. Dollar values were generated by dividing the box size into the number of fruit that were in each size category, then multiplying the price received for that box size in the market. These data were then adjusted to price received per acre by knowing the number of trees per acre. The cost of thinners is not included in the calculations.

Ace Spur Delicious. Seventy 16-year-old Ace Spur Delicious/M.26 were selected at the CSOREC, Belchertown, Mass. Bloom was assessed as previously described. Trees were organized in seven groups (replications) of ten trees each, based upon blossom-cluster density. Treatments were applied on 21 May 2004 when fruit size was approximately 7 mm in diameter. Treatments shown in Table 4 were applied at tree row volume dilute of 135 gal per acre, using a commercial airblast sprayer. Fruit set was determined at the end of June drop in July. On 4 October, a 30-apple sample was harvested randomly from the periphery of each tree. Fruit were weighed, and then the L/D ratio was determined on all 30 fruit by measuring collective length and then diameter in a V-shaped holder. Red color was not estimated, because all fruit had 90+% red color. Fruit quality evaluation was similar to that reported for McIntosh. The first four replications of treatments 1, 5, 6, and 10: Control, MaxCel 75 ppm + carbaryl, MaxCel 125 + carbaryl, NAA 7 ppm + carbaryl were selected. All fruit were harvested from each

Table 1. Effects of MaxCel, carbaryl, oil and combinations on fruit set of Marshall McIntosh apples. 2004. Means within column not followed by the same letter are significantly different at odds of 19 to 1.

Treatment	Blossom clusters (no./ cm^2 limb x-sectional area)	Fruit set (no./cm^2 limb x-sectional area	Fruit set (no./ 100 blossom clusters)
Control	8.4 a	6.7 a	85 a
MaxCel 75 ppm	8.2 a	4.9 bc	62 bcd
MaxCel 125 ppm	8.4 a	4.6 bcd	49 cde
Carbaryl (1 lb/100 gal) (C)	8.4 a	5.9 b	75 ab
MaxCel 75 + C	8.0 a	3.2 cd	42 bc
MaxCel 125 + C	8.2 a	2.5 d	31 e
Carbaryl + 1 qt/100 gal oil	8.1 a	6.3 b	78 abc
MaxCel 75 + C + Oil	8.2 a	2.8 cd	37 e
MaxCel 125 + C + Oil	7.8 a	2.6 d	33 e
NAA 7 ppm + C	8.2 a	5.0 bc	60 bcd
Significance	NS	***	***
BA	NS	l***	l***
Carbaryl	NS	l**	l**
BA + Carbaryl	NS	NS	NS

Table 2. Effects of MaxCel, carbaryl, oil and combinations on fruit quality and fruit characteristics of Marshall McIntosh apples. 2004. Means within column not followed by the same letter are significantly different at odds of 19 to 1.

Treatment	Weight (g)	Firmness (lb)	Soluble solids (%)	Red color (%)	US Extra fancy (%)	Starch rating
Control	151 d	16.3 a	11.4 de	66 ab	79 a	5.0 a
MaxCel 75 ppm	166 bcd	16.9 a	11.4 de	62 b	67 abc	4.7 bc
MaxCel 125 ppm	181 ab	17.0 a	11.9 bcd	63 b	72 ab	4.6 bc
Carbaryl (1 lb/100 gal) (C)	155 cd	16.8 a	11.3 e	68 a	77 a	4.8 abc
MaxCel 75 + C	171 bc	17.0 a	12.2 ab	62 b	65 abc	4.5 c
MaxCel 125 + C	181 ab	17.1 a	12.5 ab	62 b	63 abc	4.7 abc
Carbaryl + 1 qt/100 gal oil	161 bcd	16.5 a	11.5 cde	66 ab	78 ab	4.8 abc
MaxCel 75 + C + Oil	171 bc	17.0 a	12.1 abc	62 b	54 c	4.6 bc
MaxCel 125 + C + Oil	188 a	16.8 a	12.7 a	61 b	58 bc	4.6 bc
NAA 7 ppm + C	155 cd	16.7 a	11.3 e	68 a	73 ab	4.8 ab
Significance	***	NS	***	**	*	*
BA	l***	l*	l***	l***	l***	l*
Carbaryl	NS	NS	l**	NS	l***	NS
BA + Carbaryl	NS	NS	NS	NS	NS	NS

Table 3. Effects of MaxCel and NAA plus carbaryl applied to Marshall McIntosh on the percent distribution of apples into specific fruit size classes. 2004. Means within column not followed by the same letter are significantly different at odds of 19 to 1.

	Fruit size (inches)						
Treatment	<2.50	2.50	2.75	3.00	3.25	3.50	3.75
Control	1.5 ab	6.8 ab	34.1 a	43.4 a	13.8 b	0.4 b	0.0 b
MaxCel 75 ppm	1.2 ab	5.7 ab	25.3 ab	43.2 a	22.7 ab	2.0 ab	0.0 b
MaxCel 125 ppm	0.9 b	3.5 b	18.8 b	41.2 a	30.4 a	5.1 a	0.3 a
NAA 7 ppm + carbaryl	2.3 a	8.3 a	33.7 a	41.7 a	13.7 b	0.4 b	0.0 b

tree (16 trees total) and separately identified. Fruit were individually measured using a hand-held caliper and placed into size categories between <2.25 inches to >3.75 inches in 0.25 inch increments as previously described. Economic data were generated similar to those described for Marshall McIntosh.

Results & Discussion

McIntosh. Bloom was uniform before treatments were applied. MaxCel at 75 and 125 ppm thinned comparably and to an ideal level (Table 1). Carbaryl by itself was less effective than MaxCel although statistically different from the control. As is expected when carbaryl is combined with MaxCel, increased thinning was observed. In our estimation these treatments thinned too much. When oil was combined with either MaxCel or carbaryl, no additional thinning was observed. This was somewhat surprising since there are several references in the literature to increased thinning when oil is included. This is the second year in a row that oil has not increased thinning activity when included with MaxCel and carbaryl or carbaryl alone. NAA + carbaryl thinned and it was statistically comparable to MaxCel. There were no interactions between BA and carbaryl.

Table 4. Effects of MaxCel, carbaryl, oil and combinations on fruit set of Ace Spur Delicious apples. 200 Means within column not followed by the same letter are significantly different at odds of 19 to 1.

Treatment	Blossom clusters (no./ cm^2 limb x-sectional area)	Fruit set (no./cm^2 limb x-sectional area	Fruit set (no./ 100 blossom clusters)
Control	9.1 a	6.1 a	69 a
MaxCel 75 ppm	9.3 a	5.8 ab	66 ab
MaxCel 125 ppm	9.2 a	5.0 abcd	54 abc
Carbaryl (1 lb/100 gal) (C)	8.9 a	5.8 ab	67 ab
MaxCel 75 + C	9.3 a	3.8 cd	48 bc
MaxCel 125 + C	9.2 a	3.6 d	41 c
Carbaryl + 1 qt/100 gal oil	9.1 a	5.7 ab	67 ab
MaxCel 75 + C + Oil	9.2 a	4.3 bcd	48 bc
MaxCel 125 + C + 0il	8.9 a	3.7 cd	44 c
NAA 7 ppm + C	9.3 a	5.3 abc	60 abc
Significance	NS	**	**
BA	NS	l***	l**
Carbaryl	NS	NS	l*
BA + Carbaryl	NS	NS	NS

Table 5. Effects of MaxCel, carbaryl, oil and combinations on fruit quality and fruit characteristics of Ace Spur Delicious apples. 2004. Means within column not followed by the same letter are significantly different at odds of 19 to 1.

Treatment	Weight (g)	Firmness (lb)	Soluble solids (%)	L/D ratio	Starch rating
Control	161 c	17.5 a	10.6 c	0.940 c	3.5 a
MaxCel 75 ppm	179 bc	17.3 ab	10.5 c	0.959 bc	3.6 a
MaxCel 125 ppm	203 ab	17.2 abc	10.8 bc	0.958 bc	3.4 a
Carbaryl (1 lb/100 gal) (C)	185 bc	16.9 bc	10.7 c	0.943 c	3.6 a
MaxCel 75 + C	222 a	16.9 abc	11.2 ab	0.952 c	3.5 a
MaxCel 125 + C	224 a	17.0 abc	11.2 ab	0.984 a	3.7 a
Carbaryl + 1 qt/100 gal oil	181 bc	16.8 bc	10.7 c	0.960 bc	3.3 a
MaxCel 75 + C + Oil	203 ab	17.0 abc	10.9 abc	0.975 ab	3.4 a
MaxCel 125 + C + 0il	227 a	17.0 abc	11.3 a	0.981 a	3.3 a
NAA 7 ppm + C	192 b	16.6 c	10.7 c	0.954 c	3.5 a
Significance	***	NS	**	***	NS
BA	l***	NS	l*	l***	NS
Carbaryl	l*	l*	NS	l**	NS
BA + Carbaryl	NS	NS	NS	NS	NS

Table 6. Effects of MaxCel and NAA plus carbaryl applied to Ace Spur Delicious on the percent distribution of apples into specific fruit size classes. 2004. Means within column not followed by the same letter are significantly different at odds of 19 to 1.

	Fruit size (inches)								
Treatment	<2.25	2.25	2.50	2.75	3.00	3.25	3.50	3.75	>3.75
Control	3.4 a	8.7 a	27.8 a	35.0 a	22.6 b	2.5 c	0.0 b	0.0 b	0.0 a
MaxCel 75 ppm + carbaryl	0.0 c	0.5 b	4.1 b	12.3 c	25.7 b	31.6 a	21.9 a	3.5 a	0.3 a
MaxCel 125 ppm + carbaryl	1.3 bc	2.5 b	7.6 b	20.3 bc	31.4 ab	30.7 ab	6.6 b	0.0 b	0.0 a
NAA 7 ppm + carbaryl	2.3 ab	3.2 b	11.6 b	29.6 ab	35.6 a	16.3 bc	1.5 b	0.0 b	0.0 a

All MaxCel treatments increased fruit size (Table 2). It appears that the increase in fruit size is the result of reduced competition due to thinning and also to increased cell division due to MaxCel. There was no size benefit from thinning with NAA plus carbaryl. This is noteworthy since the NAA concentration is not excessive, and NAA was applied at a time when a negative effect on fruit size is generally not observed. NAA can reduce fruit size or have no effect even if thinning is done if NAA is applied when fruit are large (above 15 mm), a high rate of NAA is applied, or if hot temperature follows application. The amount of thinning with carbaryl may not be great enough to influence size. No treatment affected flesh firmness. MaxCel significantly increased soluble solids. Most likely this is due to a more favorable leaf to fruit ratio caused by thinning rather than a direct effect of MaxCel. MaxCel significantly and linearly reduced red color. This is most apparent when looking at the US Extra Fancy fruit where the quality or intensity of red color is also taken into account. Generally we do not recommend a MaxCel concentration over 100 ppm for color-sensitive varieties, such as McIntosh and Macoun, because of the possibility of reducing red color. This year, red color was reduced at 75 ppm. Interestingly, the addition of oil appeared to have an effect on reducing red color (although not significantly) even though it had no effect on thinning. This effect warrants watching in the future. No treatment influenced the time of ripening, based upon starch index values.

Thinning treatments had a large effect on size distribution of the fruit on a tree (Table 3). The majority of all fruit in all treatment peaked in the 3-inch size category. MaxCel shifted fruit that normally would fall in the 2.5- and 2.75-inch categories into larger size classes, and more fruit were in the 3.25- and 3.5-inch size categories. This shift involved a substantial portion of the crop and it was statistically significant. Another interesting observation is that NAA had no influence on size distribution relative to the untreated control. In fact, the size distribution between control and NAA-treated fruit were almost identical.

Projected gross income from sale of the fruit is illustrated in Table 8. The yield and size distribution from four trees for each treatment was used. The information was then extrapolated to a per-acre basis. It

Table 7. Temperature at the University of Massachusetts Cold Spring Orchard Research & Education Center the day of application of thinners and for the following 14 days.

Date	Temp. Max. (°F)	Temp Min. (°F)
21 May	80.7	50.2
22 May	64.7	49.2
23 May	81.4	45.8
24 May	68.8	52.8
25 May	68.9	51.0
26 May	57.1	54.2
27 May	76.9	45.2
28 May	67.5	54.2
29 May	60.7	45.2
30 May	69.4	45.2
31 May	55.5	39.9
1 June	55.7	44.5
2 June	72.8	44.5
3 June	70.6	51.8

Table 8. Gross sales income adjusted to a per acre basis from the sale of fruit in all size categories. Marshall McIntosh.

Treatment	Gross income ($)
Control	9,233
MaxCel 75 ppm	7,365
MaxCel 125 ppm	9,647
NAA 7 ppm + carbaryl	9,246

was assumed that there was 100% packout. Yield in this block was quite high and neared 800 bu/acre. The greatest return was from the MaxCel at 125 ppm and the least from MaxCel at 75 ppm. Since set in this block was not heavy and thinning was not great, these numbers are not too surprising.

Delicious. Bloom was uniform before treatments were applied. MaxCel alone at 75 ppm and 125 ppm and carbaryl alone appeared to thin only modestly and this amount was not statistically different from control levels (Table 4). The addition of carbaryl to the MaxCel significantly increased the thinning response as was the case with McIntosh. The addition of oil to either carbaryl or MaxCel plus carbaryl did not increase thinning further. NAA plus carbaryl appeared to thin comparably to MaxCel alone.

MaxCel alone dramatically increased fruit size alone even though it thinned modestly (Table 5). When carbaryl was included with MaxCel an additional increase in fruit size was realized which was most likely due to thinning and the increased cell division caused by MaxCel. It is unclear if treatments influence flesh firmness. Carbaryl, however, significantly reduced flesh firmness; whereas, MaxCel had no effect. Generally, there is a reduction in flesh firmness as fruit size increases. Frequently BA increases fruit size with no effect on firmness. We interpret these data to mean that the increased number of cells in the MaxCel-treated fruit, which undoubtedly affect firmness, counteracted any potential reduction in flesh firmness resulting from increased fruit size. MaxCel and combinations increased soluble solids. As with McIntosh, some, if not all of this effect, can be attributed to the reduction in crop load which leads to a more favorable leaf to fruit ratio. MaxCel increased the L/D ratio. The response was linear with concentration and was greater when oil was included. We interpret this to mean that oil increased the uptake of MaxCel into the fruit. No treatment influenced the time of ripening, based upon starch index values. Red color was not assessed on Delicious, since all fruit, regardless of treatment, were 90% red or more. At no time, however, was it apparent that MaxCel had any detrimental effect on red color.

All thinning treatments increased fruit size and shifted the mean fruit size of Delicious to the larger categories (Table 6). MaxCel was more effective at increasing fruit size. These data clearly show that MaxCel did not increase the number of fruit below 2.25 inches (pygmy fruit). Although the numbers are relatively low, these data show that MaxCel produced significantly fewer very small pygmy-like fruit.

Projected income from sales of the fruit is illustrated in Table 9. Yield from the four trees per treatment and size distribution of those fruit were used to generate these data. Yield from the four trees was extrapolated to a per-acre basis. It was assumed that packout was 100%. Total yield in this block was quite high and approached 1200 bu per acre, thus the very high numbers. MaxCel at 75 ppm + carbaryl had the greatest income whereas MaxCel at 125 ppm + carbaryl had the least. Differences between the two MaxCel rates are due to greater thinning with 125 ppm and to some tree-to-tree variability.

Temperature. The maximum and minimum temperatures for the day of application and the subsequent 14 days are presented in Table 7. The day of application was warm, but currently we dis-

Table 9. Gross sales income adjusted to a per acre basis from the sale of fruit in all size categories. Ace Spur Delicious.

Treatment	Gross income ($)
Control	14,008
MaxCel 75 ppm + carbaryl	15,621
MaxCel 125 ppm + carbaryl	11,525
NAA 7 + carbaryl	14,369

miss the temperature at the time of application a having any significant effect on subsequent thinning. The day after application, the temperature was quite cool, but the next day the maximum temperature exceeded 80°F. Three and four days after application the temperature was acceptable for thinning but on the lower range of what we hope for. Our interpretation of the temperature profile is that the weather was acceptable to somewhat favorable for a good thinning response. Temperature may be important since previous experience with BA indicates that good thinning is dependent upon above-average temperatures following application. We interpret this, base not upon this year's data but previous years experience, that the current formulation of BA, MaxCel, is less influenced by unfavorable temperatures following application than experienced with Accel and other earlier BA formulations. Thus, we feel that MaxCel may thin well over a wider temperature range.

* * * * *

A Method to Predict Chemical Thinner Response on Apples

Duane W. Greene, James Krupa, & Maureen Vezina
Department of Plant, Soil, & Insect Sciences, University of Massachusetts

Alan N. Lakso & Terence L. Robinson
Department of Horticultural Science, Cornell University, NYAES Geneva

Chemical thinning is one of the most important management activities an orchardist is required to do because of the importance of the decisions involved and the uncertainties associated with the outcome. Poor thinning will have significant repercussions for two years. In the year of application, inadequate thinning will result in small fruit that will bring a very low price. The year following poor thinning, return bloom is likely to be inadequate or nonexistent.

Traditionally, the majority of thinning was done at the time fruit are most vulnerable to chemical thinners, at the 7 to 10 mm stage of fruit development (Williams and Edgerton, 1981; Forshey, 1986). In many years thinner activity is variable, due in large part, to variable weather following thinner application, (Byers et al., 1990; Williams and Fallahi, 1999) and varying sensitivity. The loss of crop due to over-thinning is obvious, but occurs less often than under-thinning. The negative economic consequence of insufficient thinning have forced most orchardists to reappraise the thinning strategy used in the past which was based upon a single thinner application. Increasingly, local thinning recommendations suggest using multiple thinner applications, starting as early as bloom (Greene, 2002; Schwallier, 1996). Increased thinner activity is often achieved, because thinner applications have greater probability to coincide with weather that is favorable for thinning. Using this thinning strategy, growers are urged to observe responses to earlier thinner application and make a decision about the need for additional sprays. A problem with this approach is that no guidelines have been provided to help growers estimate the effects of the first thinning treatment in a timely manner. An easy-to-use system is needed to help growers decide if a supplemental thinner application is necessary to achieve adequate thinning.

A number of researchers have noted that fruit destined to drop during the June drop period, stop growth well in advance of the time that they actually abscise (Byers et al., 1991; Greene and Krupa, Lakso et al., 2001; 1999; Marini, 1998; Ward and Marini, 1999). Ward and Marini (1999) evaluated a number of ways to assess thinner response and concluded that fruit growth measurements were the only accurate and practical way to assess thinner response. Greene and Krupa (1999) suggested that measurements of fruit growth