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Effects of SevinXLR Plus and Accel on Pre-and Post-harvest Quality and Yield of 'McIntosh' Apples

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Abstract

Thinning with both Accel and SevinXLR Plus was more effective -than using either product individually. Application of the mixture Accel + SevinXLR Plus on 'McIntosh' trees thinned to a level comparable to hand-thinning as reflected in the total yield per tree. Mean fruit weight increased significantly when the mixture of Accel and SevinXLR Plus was applied as a thinning agent. The largest fruit were obtained after the application of the mixture, and the weight of treated apples was higher than that of hand-thinned fruit. Accel + SevinXLR Plus increased apple flesh firmness and soluble solids concentration at harvest time and after storage, respectively.

Introduction

Many apple cultivars can produce a heavy set of fruit. This results in overcropping with an increase in the number of under-sized fruit that are commercially undesirable. Overcropping may also suppress the development of fruit buds for the following year and start a cycle of irregular cropping (7,12). It is common practice to remove a proportion of the fruit at an early stage of development by applying a chemical thinning agent (14). Early season fruit thinning reduces the total yield but increases the number of higher-grade marketable fruit. Chemical thinning using Sevin (carbaryl), has proven useful for certain apple cultivars (13, 19). Sevin has the advantage, depending on the cultivar, of being reasonably consistent in its thinning effect and allowing some margin of error in time and rate of application (14). Although it is capable of thinning for about 4 weeks after petal fall, it is normally used two to three weeks after petal fall to permit an assessment of initial set and the need to thin (19). Its main effect is in reducing the amount of small fruit with an increase in the yield of larger apples. There is a tendency for trees thinned with Sevin to bear a higher proportion of king fruit (14).

Other thinning agents, such as Accel, have been used commercially and have a similar effect to that of Sevin. Accel contains the active ingredient benzyladenine (BA), which is an effective

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thinner on diverse cultivars (9, 16), including 'McIntosh' (11). Some chemicals have also been tested in combination, in an attempt to improve spray thinning. Combination sprays of naphthalene acetic acid (NAA) and carbaryl (15), NAA and naphthalene acetamide (NAD) (5), and NAD and carbaryl (20) caused greater fruit removal than either chemical agent used alone.

Several researchers have shown that chemical thinning enhances apple quality characteristics such as flesh firmness, fruit color, and soluble solids concentration (3, 10). Nevertheless, contradictory results have also been reported (11).

The objectives of this study were to compare the effects of SevinXLR Plus and Accel, alone and in combination, on the yield, harvest and storage quality, as well as size of apples produced by 10-year-old 'McIntosh' apple trees grown on M.26 rootstock.

Materials and Methods

A randomized complete block design with four replications was used to evaluate the effects of thinning chemicals. Sixty uniform 10-year-old 'McIntosh'/M.26 trees were selected. Trunk circumference was measured 25 cm above the graft union. Three trees were used per experimental unit. Two thinning chemicals 'SevinXLR Plus' (carbaryl) and 'Accel' [6-benzyladenine (BA), 6-benzylamino purine (Verdan), gibberellins (GA_{4+7})] were used in comparison to 'unsprayed' control and to 'hand thinned' treatment. On 9 June, 1997, at petal fall stage, the chemical treatments were applied using a motorized commercial sprayer using either Accel at 20g a.i./acre (200 mg/litre) (A), SevinXLR Plus at 2 litres/acre (S), or a mixture of 10g a.i. Accel with 1 litre/acre Sevin (A+S), or the trees were hand-thinned (H). Trees were hand-thinned when fruit were about 2.5 cm diameter, resulting in one apple per cluster and a distance of 17 to 25 cm between apples. At harvest, total yield per tree, fruit number were recorded. Fruit numbers were expressed as number per cm^2 trunk cross sectional area (TCA). Mean fruit weight was calculated as total yield divided by number of fruit per tree. On fifteen apples randomly selected from each plot, red color was estimated visually to the nearest 10% and flesh firmness was determined on two sides of apples, using an electronic pressure tester system (Model EPT-1R, Lake City Products, Kelowna, Canada). Soluble solids concentration (SSC) was determined using a digital refractometer (Abbe Mark II, Baxter Division Canlab, Canada) and titratable acidity (TA) was determined by titration to an end point of pH 8.1 (665 Dosimat, Metrohm Ltd. Switzerland) on the juice that was collected during the firmness test. The remaining apples were either stored in a refrigerator at 4°C for 152 days or in controlled atmosphere (CA) storage (2.5-3% oxygen, 2.5-5% CO_2, dark conditions, 3°C temperature) for 229 days. After storage, apples were evaluated for firmness, SSC and TA. Fruit were also examined for storage disorders, such as vascular breakdown (browning of the main vascular bundles and of some adjacent tissue without browning of cortex tissue) and senescence breakdown, after remaining for 7 days at room temperature.

In 1998, the chemical thinners were applied at the same stage as in 1997 except

for the mixture (A+S), which was sprayed at 10 mm fruit diameter. At harvest, fruit were counted, weighed and the fruit weight was calculated from 50 apples randomly sampled from each tree (3 trees/ replicate, 4 replicates/treatment). Flesh firmness, SSC, TA at harvest and after storage were evaluated in a similar manner to that described in 1997 season.

Juice characteristics

Samples from all treatments were juiced right after the 1997 harvest and the juice was frozen at –20°C for 6 months before analysis. Total pectin was determined based on Blumenkrantz and Asboe-Hansen's method (2) for the quantitative determination of uronic acids. The pH of samples was measured using a glass electrode pH meter and total sugars were determined by the anthrone method (4). Titratable acidity was determined based on the AOAC method (1).

Data were analysed using SAS (17). Differences between the means were detected by Duncan's multiple range test.

Results and Discussion

In 1997, fruit number per cm^2 TCA, mean fruit weight and yield were significantly affected by the treatments (Table 1). When applied alone, neither Accel nor SevinXLR Plus significantly reduced the number of fruit as compared to the non-thinned control However, the mixture Accel + SevinXLR Plus (A+S) thinned to a level comparable to the hand-thinned treatment. Thus, fruit number and yield per tree were significantly lower than any other treatment, indicating that thinning was successfully achieved when Accel and SevinXLR Plus were applied as a mixture. Mean fruit weight was greatest with A+S treatment followed by hand-thinned and Accel treatments; fruit from the SevinXLR Plus and control treatments were the smallest.

In 1998, no significant effect of chemical thinners was noted on yield, whereas fruit number and mean fruit weight were significantly affected by these treatments (Table 1). Non-thinned trees had high fruit number and low mean fruit weight. A+S mixture application at 10 mm

Table 1. Effects of thinning with Accel and SevinXLR Plus on fruit number, mean fruit weight and yield of 'McIntosh' apples.

Treatment	Fruit number/ cm^2 trunk area		Mean fruit weight[z] (g)		Yield/tree (kg)	
	1997	*1998*	*1997*	*1998*[y]	*1997*	*1998*
Accel (A)	5.7a[y]	2.6ab	137ab	153bc	36.3a	44.8a
SevinXLR Plus (S)	4.6a	2.7ab	128c	160ab	28.7b	35.4a
Accel+SevinXLR Plus (A+S)	2.7b	2.5b	142a	164a	18.3c	37.9a
Hand-thinned (H)	2.6b	2.9ab	139ab	156bc	16.9c	41.0a
Control (unthinned) (C)	5.1a	3.3a	131bc	151c	30.9ab	42.3a

[z] Mean fruit weight is an average weight of 600 apples (150 apples / replicate, 4 replicates /treatment).
[y] Means not sharing a common letter are significantly different according to Duncan's test (P=0.05).

fruit diameter reduced fruit number. In contrast, thinning effects of Accel or SevinXLR Plus alone, or hand-thinning were not significantly different and their application was much less effective than A+S in reducing fruit number. Our results agree with those obtained on 'Empire' and 'Fuji' apples with the same chemical thinners (6,18).

Mean fruit weight increased significantly when the mixture of A+S was applied as a thinning agent (Table 1); the largest fruit were obtained with the mixture application and the mean weight of treated apples was higher than the weight of hand-thinned ones. However, the mean weight of hand-thinned apples was not significantly different from the weight of apples treated with Accel (Table 1). When Accel was applied alone, it resulted in the production of a high number of small apples (low weight/fruit). Although SevinXLR Plus seemed to perform comparatively to the mixture, the combination of SevinXLR Plus with Accel tended to result in less fruit number per cm^2 trunk area, as well as larger fruit.

Table 2. Effects of thinning with Accel and SevinXLR Plus on fruit firmness, red color, soluble solids concentration (SSC) and titratable acidity (TA) of 'McIntosh' apples for the 1997 growing season.

Treatment	Flesh firmness[z] (N)	Red color (%)	SSC (%)	TA (malic acid g/L)
Immediately after harvest				
Accel	66.3d[y]	65.3b	11.6d	9.41c
SevinXLR Plus	67.7cd	72.2a	11.7cd	9.40c
Accel+SevinXLR Plus	73.8a	68.8ab	12.2b	11.60ab
Hand-thinned	69.5b	63.8b	12.7a	12.03a
Control (unthinned)	68.6bc	64.2b	12.1bc	10.47bc
After storage of 152 days at 4 °C				
Accel	49.1d	-	12.3b	5.61c
SevinXLR Plus	49.9c	-	12.6b	5.89b
Accel+SevinXLR Plus	54.1a	-	13.1a	6.67a
Hand-thinned	52.2b	-	13.6a	7.11a
Control (unthinned)	50.8c	-	12.5b	5.93b
After storage of 229 days in CA				
Accel	56.8[x]	-	11.8c	5.27c
SevinXLR Plus	57.0	-	12.2bc	5.70bc
Accel+SevinXLR Plus	58.6	-	13.1a	7.20a
Hand-thinned	56.2	-	13.3a	7.23a
Control (unthinned)	59.4	-	12.4b	6.06b
After storage of 229 days in CA, followed by 7 days at room temperature				
Accel	52.4[x]	-	12.0b	4.33c
SevinXLR Plus	52.3	-	12.1b	4.71c
Accel+SevinXLR Plus	53.8	-	12.9a	5.91a
Hand-thinned	51.5	-	13.0a	5.46ab
Control (unthinned)	53.4	-	12.5ab	5.02bc

[z] Means are an average value of tests run on 60 apples (15 apples / replicate, 4 replicates /treatment).
[y] Means not sharing a common letter are significantly different according to Duncan's test (P=0.05).
[x] Means with no letter(s) are not significantly different at the 0.05 level.

Table 3. Effects of thinning with Accel and SevinXLR Plus on fruit firmness, red color, soluble solids concentration (SSC) and titratable acidity (TA) of 'McIntosh' apples for the 1998 growing season.

Treatment	Flesh firmness[z] (N)	Red color (%)	SSC (%)	TA (malic acid g/L)
Immediately after harvest				
Accel	68.4ab[y]	77.7	11.2	7.48c
SevinXLR Plus	67.8ab	80.4	11.5	8.02b
Accel+SevinXLR Plus	69.2a	78.2	10.4	10.24a
Hand-thinned	67.9ab	80.4	11.4	7.63c
Control (unthinned)	67.2b	77.7	11.4	7.53c
After storage of 181 days in CA				
Accel	61.2[x]	-	11.0	4.88b
SevinXLR Plus	59.1	-	11.6	5.44a
Accel+SevinXLR Plus	58.7	-	11.8	5.21ab
Hand-thinned	59.3	-	11.4	5.10ab
Control (unthinned)	60.9	-	11.7	4.97ab
After storage of 181 days in CA, followed by 7 days at room temperature				
Accel	52.7	-	11.6	4.04
SevinXLR Plus	52.6	-	11.8	4.40
Accel+SevinXLR Plus	54.1	-	11.9	4.22
Hand-thinned	51.8	-	11.6	4.25
Control (unthinned)	53.7	-	11.7	4.03

[z] Means are an average value of tests run on 60 apples (15 apples / replicate, 4 replicates /treatment).
[y] Means not sharing a common letter are significantly different according to Duncan's test (P=0.05).
[x] Means with no letter(s) are not significantly different at the 0.05 level.

Accel + SevinXLR Plus increased apple flesh firmness at harvest time in 1997 and 1998 (Table 2, 3). Firmness was higher for the mixture after 152 days at 4°C in 1997, but not after 229 days in CA in 1998 (Table 2). There was no treatment effect when apples were stored in CA (Table 2, 3). Independent of the treatment effect, this might be due to the CA conditions, where the best results on 'McIntosh' were obtained with CO_2 level between 2-4% (3).

There was no treatment effect on SSC in 1998 (Table 3). In 1997, however, the SSC was highest when trees were hand-thinned, followed by those treated with A+S (Table 2). Although apples treated with A+S had a significantly lower SSC than the hand-thinned fruit when tested right after harvest, the difference was not significant after storage. Those apples had significantly higher SSC (close to 1%) after storage (Table 2). Whether tested right after harvest or after storage, apples thinned with either Accel or SevinXLR Plus alone had SSC comparable to apples harvested from the non-thinned controls. The SSC of the non-thinned controls was less than hand-thinned trees but greater than Accel treated trees after harvest and after storage at 4°C (Table 2). Since SSC is associated with sweetness, apples treated with the mixture of Accel and SevinXLR Plus may appeal more to consumers. Acidity, on the other hand, is associated with perceived tartness. According to Fisher and Kitson (8), 0.3-

0.4% acidity (medium range) in apples appears to be the most accepted by consumers. 'McIntosh', with an average of 0.54% and an acidity range of 0.33 to 0.74%, is a high acid apple (8). In this study, apples from all treatments had high acidity (Tables 2, 3). This might be due to the characteristics (environmental and physical factors) of the region where the apple trees were grown. Apples from hand-thinned trees or trees thinned with A+S had the highest acidity. These were the apples that also had the highest SSC, meaning that tartness resulting from the high acid may somewhat be masked by the sweetness of the soluble sugars.

When analyzed after CA storage in 1998, as well as after an additional 7 days storage at room temperature, the firmness, SSC and acidity of treated apples were not significantly different from those of hand-thinned or control apples (Table 3). Only acidity after CA storage showed some variability (Table 3). Apples treated with SevinXLR Plus alone had more acidity than those treated with Accel alone. However, apples treated with the mixture of Accel and SevinXLR Plus had an acidity comparable to those hand-thinned or untreated.

Some apples showed physiological disorders after CA storage, as well as after 7 days at room temperature. It is difficult to pin point the cause of the vascular breakdown or the light senescence breakdown that we observed. The results were variable; compared to others, the hand-thinned treatment seemed to have resulted in the highest number of apples with vascular breakdown after CA and CA+7 storage followed by A+S treated apples after CA+7 storage (Table 4). In case of senescence breakdown, all the treatments showed a low number of affected apples on the 60 apples examined. These physiological disorders could be the result of storage conditions or handling.

No significant differences in total pectin and total sugar content, or pH, were found among the different treatments. Mean total pectin ranged from 0.813 to 0.995 g galacturonic acid/liter, for the A+S and control treatment, respectively. Mean total sugar ranged from 9.84 to 10.9 g sucrose/100 ml, for the control and hand-thinned treatment, respectively. Mean pH ranged

Table 4. Number of apples with physiological disorders when stored under controlled atmospheric conditions (CA) followed by 7 days storage at room temperature (CA+7) (1997 harvest).

Treatment	Number of apples[z] with vascular breakdown		Number of apples with light senescence breakdown	
	After CA	*After CA + 7*	*After CA*	*After CA + 7*
Accel	4	6	5	1
SevinXLR Plus	2	4	0	2
Accel+SevinXLR Plus	2	17	0	1
Hand-thinned	12	18	5	5
Control (unthinned)	7	9	4	1

[z] Total number of apples with physiological disorders of 60 apples that were tested (15 apples/replicate, 4 replicates/treatment).

from 2.98 to 3.04, for hand-thinned and Accel treatment, respectively. However, there was significant difference between treatments for titratable acidity, with juice from A+S and hand-thinned apples being the most acid (1.08, 1.10 g malic acid/ 100 ml, respectively), and juice from apples treated with Accel the least acid (0.84 g malic acid/100 ml). This correlates with the acidity obtained immediately after the 1997 harvest (Table 2), where apples treated with Accel or SevinXLR Plus showed the least degrees of acidity and A+S and hand-thinned apples the most.

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