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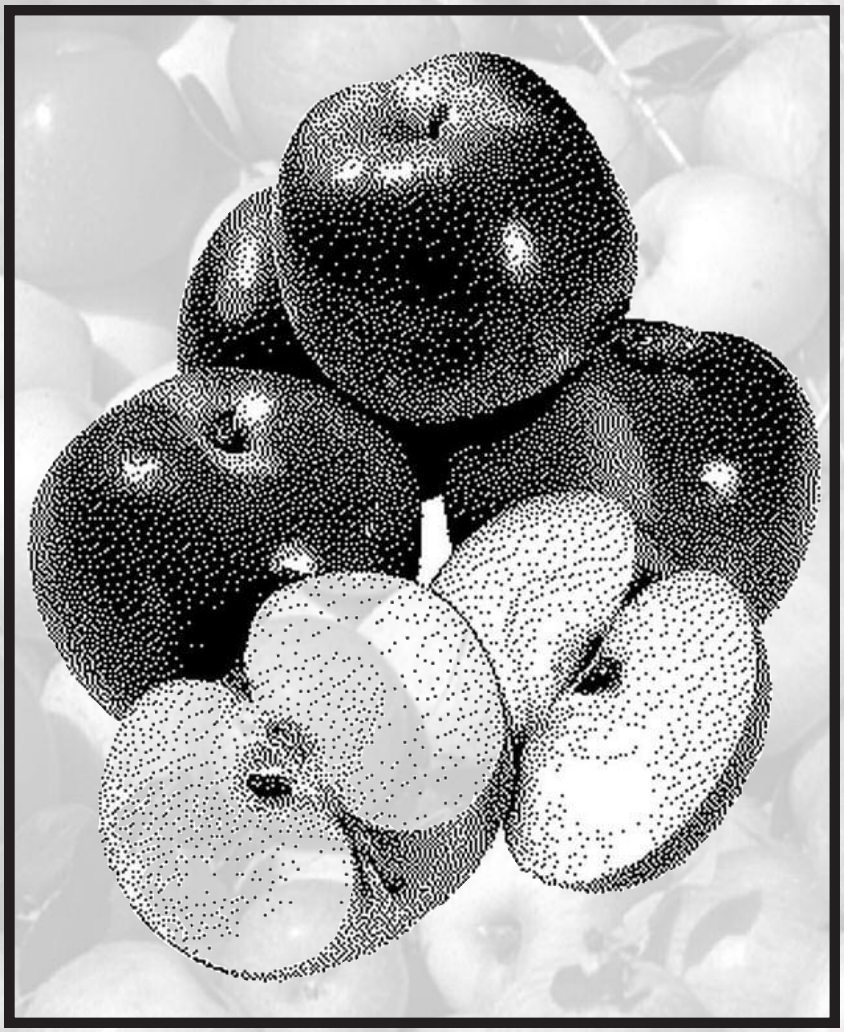
Apple Cultivar



Responses to Fruit Thinning Agents — ACCEL and CARBARYL — in Northern Mississippi

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Introduction

Chemical fruit thinning of apple (*Malus pumila* Mill) after bloom is a standard practice to improve fruit size, quality, increase return bloom, and reduce biennial bearing (Williams, 1979; Looney, 1986.) An apple tree with excessive fruit load produces many small, low-value fruit. In contrast, a tree that is overthinned and only has few fruits does not produce to its maximum potential. Insufficient thinning may also lead to alternate bearing, whereby an extremely heavy crop is produced every year.

Thinning can be accomplished at bloom or during the early postbloom period. Biennial cultivars may require both a bloom and postbloom spray program for adequate thinning (Williams, 1979). Postbloom thinning programs can be used at all apple-producing areas. Some postbloom chemicals (hormone types) are used to upset the natural hormone balance of the tree, whereas others (nonhormonal) cause stress that results in embryo abortion (Williams, 1979).

The mode of action of the postbloom thinning chemicals is not fully known. They are generally believed to interfere with the endogenous hormones, which control the flow of nutrients to the developing fruit (Williams, 1979). Embryo abortion may precede or accompany fruit abscission but is not considered to be its cause. High temperatures or chemical stress of any kind applied to apple trees during the early postbloom period increases fruit abscission (Williams, 1979).

Chemicals used for apple thinning are ethephon (Jones et al., 1983, 1989; Knight and Spencer, 1987), gibberellins (Cohen and Greene, 1988; Greene, 1989), benzyladenine (Greene, 1993; Elfving and Cline, 1993a; 1993b; Greene et al., 1990), carbaryl (Wismer and Elfving, 1995; Stiles, 1995), naphthalene acetic acid (Williams, 1993; Nielsen and Dennis, 1993), CPPU [N-(2-chloro-pyridyl)-N-phenylurea] (Bound et al, 1991), and Accel (Stiles, 1995). Accel increases fruit size by increasing cell divisions, and it thins fruit to reduce competition. It is most effective when applied in combination with carbaryl. Accel is one of the most temperature-sensitive postbloom thinning materials and should only be applied under warm growing conditions. Accel is a relatively new chemical thinner on the market and needs to be tested under different environmental conditions and on several apple cultivars. The objective of this study was to investigate the effect of Accel and Carbaryl on fruit set, yield, and quality of three apple cultivars.

Materials and Methods

Two experiments were carried out using mature apple trees at the at Pontotoc Ridge-Flatwoods Branch Experiment Station, a unit of the Mississippi Agricultural and Forestry Experimental Station based at Mississippi State University. Soils at the experiment station are classified as Alfisols, Ultisols, Inceptisols, and Entisols. The first experiment was conducted between April 21 and July 31, 1995, while the second experiment was conducted between May 1 and August 30, 1996.

The apple cultivars ‘Empire,’ ‘Braeburn,’ and ‘Jon-A-Red’ were evaluated in this study. Trees were sprayed with chemical thinners on calm, clear, and dry days between 11 a.m. and 4 p.m. Trees were sprayed with Accel [(N- (phenylmethyl) - (Purine-6-amine) (BA)] at 25, 50, and 75 ppm and Carbaryl (Naphthyl-methyl-Carbamate) at 0.05%, 0.1%, and 0.2%. Control trees were sprayed with water only. Trees were spaced at 6x6 meters and trained to a freestanding central leader. Experiments were set up as a completely randomized design with three single-tree replications per treatment per cultivar. All data were subjected to analysis of variance using SAS PROC GLM procedure (Cary, North Carolina). Mean separation using the least significant difference test was used to separate treatment means.

Apple juice was extracted with a Mullinex juice extractor (Fisher Scientific, Spring Field, New Jersey) and filtered through a 28-mesh screen. Total soluble solids were determined using a Bausch and Lomb optical refractometer (Fisher Scientific, Spring Field, New Jersey) and expressed in degrees of brix. An Accument 925 laboratory meter (Fisher Scientific, Spring Field, New Jersey) was used to measure the pH of the extracted juice. Fruit length and diameter of the apples were measured by a hand caliper on a sample of 10 fruits. Fruit diameter was measured from the widest part of the apple or from shoulder to shoulder. The ratio of fruit length to diameters was calculated. Fruits were dissected and the number of seeds determined.

Fruit were removed from cold storage and gently wiped with a soft cloth. Fruit color was measured by placing the head of a portable colourimeter (Hunter Labscan 6000 Spectrocolorimeter, Reston, Virginia) at the midpoint between the stem and the calyx of the fruit (McGuire, 1992). A sample of 10 apples per treatment was evaluated. The red color was determined in 1995, and due to technical difficulties, the color measurements were not measured during 1996. Fruit set was expressed as the number of fruits per square centimeter limb cross-sectional area (Forshey and Elfving, 1977a, 1977b; Lombard et al, 1988).

Fruit shape was determined by the ratio of the longitudinal length to transverse diameter of the fruit (L:D ratio). This ratio is used to compare shapes of very small fruit in early season with large ones later on. The L:D ratio is regarded as the relative fruit length (i.e., the higher the value the more elongated the fruit).

Results

In 1995, there was no significant ($P \leq 0.05$) effect on the yield of 'Empire' by Accel or Carbaryl (Table 1). Accel at 50 and 75 ppm significantly ($P \leq 0.05$) increased the yield of 'Jon-A-Red.' The remaining treatments had no effect on yield of 'Jon-A-Red.' Yield of 'Braeburn' was significantly ($P \leq 0.05$) increased by Carbaryl at 0.2% and Accel at 50 ppm, whereas the remaining treatments had no effect on the yield. Carbaryl at 0.1% and Accel at 50 ppm significantly ($P \leq 0.05$) increased fruit quality of 'Empire,' but the remaining treatments had no effect. Accel and Carbaryl increased fruit quality of 'Braeburn.' All chemical treatments significantly ($P \leq 0.05$) increased percent red color in 'Empire' in 1995 (Table 1). Carbaryl at 0.05% had the highest percent red color, followed by Accel at 75 ppm. The treatments that significantly increased percent red color of 'Jon-A-Red' were Carbaryl at 0.1%, Accel at 25 ppm, Accel at 50 and 75 ppm; Carbaryl at 0.05% and 0.2% had no significant effect on red color (Table 1). Accel at 75 ppm significantly ($P \leq 0.05$) increased the red color of 'Braeburn.' Fruit length, fruit diameter, and L:D ratio were not significantly ($P \leq 0.05$) affected by the treatments. Similarly, seed number of the fruit was not affected by chemical thinning agents (data not represented).

In 1995, all the chemicals reduced fruit set (Table 2). All concentrations of Carbaryl and Accel significantly ($P \leq 0.05$) reduced fruit set of 'Empire' and 'Braeburn' in 1995 (Table 2). Similarly, most concentrations of Carbaryl and Accel significantly ($P \leq 0.05$) reduced the fruit set of 'Jon-A-Red,' except Accel at 25 ppm in 1996 (Table 3). There was no cultivar and chemical thinner interaction in 1995, as compared with 1996. All treatments significantly ($P \leq 0.05$) increased sugar content (Brix), except Carbaryl at 0.05% in 1995 (Table 2). In 1996, the sugar content of 'Empire' and 'Jon-A-Red' were significantly ($P \leq 0.05$) increased by all concentrations of Accel and Carbaryl, while sugar content of 'Braeburn' was not affected. In 1995, Carbaryl at 0.05% and Accel at 75 ppm significantly ($P \leq 0.05$) increased the pH in 'Empire' and 'Jon-A-Red,' while other treatments have no effect (Table 1 and 2). No treatment affected the pH in 'Braeburn' in 1995. The pH of 'Empire' was significantly ($P \leq 0.05$) reduced by Carbaryl at 0.05% in 1996, while all other chemical thinners had no effect (Table 3). Accel at 75 ppm was the only chemical treatment that increased pH in 'Jon-A-Red,' while Carbaryl at 0.1% and Accel at 50 ppm and 75 ppm increased the pH of 'Braeburn' in 1996.

Table 1. Effect of Accel and Carbaryl on fruit quality of three apple cultivars grown at the Pontotoc Ridge-Flatwoods Branch Experiment Station, Mississippi, 1995.[1]

Treatment	Fruit length	Fruit diameter	Fruit length to diameter ratio	Yield	pH	Red color
	mm	*mm*		*kg/tree*		*%*
			'Empire'			
Carbaryl (%)						
0.05	5.9ab	7.1a	0.83ab	5.6a	4.9a	27a
0.1	5.8ab	7.3b	0.81a	8.4b	4.4bc	22a
0.2	6.4ab	7.5c	0.83ab	9.6a	4.4bc	25a
Accel (ppm)						
25	5.9ab	7.1d	0.80a	6.4a	4.4bc	25a
50	6.0ab	6.5e	0.80a	5.6a	4.4bc	25a
75	5.9ab	7.4f	0.87b	8.0a	4.0b	26a
Control	5.6a	6.8g	0.82ab	4.6a	4.3c	7b
			'Jon-A-Red'			
Carbaryl (%)						
0.05	5.9ab	7.1a	0.83ab	0.8a	4.5bc	19c
0.1	5.5ab	6.5c	0.85ab	1.3a	4.3bc	24a
0.2	6.4b	7.4h	0.85 b	4.2a	44.3bc	22a
Accel (ppm)						
25	5.7a	7.0i	0.81a	0.8ba	4.4bc	26a
50	5.8ab	6.6j	0.88a	8.5c	4.4bc	27a
75	6.1ab	7.2f	0.83b	7.7a	4.6d	27a
Control	6.4b	7.2l	0.88b	0.8ba	4.2c	24a
			'Braeburn'			
Carbaryl (%)						
0.05	6.0ab	7.1d	0.80a	5.9a	4.3c	19c
0.1	6.3ab	7.5m	0.85ab	10.5d	4.5b	18c
0.2	6.1ab	7.1d	0.87b	17.8d	4.2c	18c
Accel (ppm)						
25	5.6a	6.3n	0.84ab	11.2d	4.4b	17c
50	6.1ab	7.2o	0.87b	17.2d	4.3c	17c
75	6.3b	7.6p	0.87b	8.8e	4.4bc	20c
Control	6.1h	7.3g	0.85ab	4.9a	4.4bc	19c

[1] Means in columns followed by the same letter do not differ at the 0.05 probability level. Means separated by the least Significant Difference test by cultivar.

Table 2. Effect of Accel and Carbaryl on fruit set, °Brix, and mean fruit weight of three apple cultivars grown at the Pontotoc Ridge-Flatwoods Branch Experiment Station, Mississippi, 1995.[1]

Treatment	Fruit set (fruit/LCSA)[2]	Sugar content	Mean weight
	no.	*°Brix*	*g*
		'Empire'	
Carbaryl (%)			
0.05	8.33a	12.00a	1.7a
0.1	5.40be	12.80b	1.80a
0.2	3.13c	13.30c	1.80a
Accel (ppm)			
25	6.10db	14.50d	1.40b
50	4.23ec	14.60e	1.60c
75	1.67f	15.10f	1.20d
Control	11.67g	12.60g	1.26d
		'Jon-A-Red'	
Carbaryl (%)			
0.05	7.40a	13.00a	0.54a
0.1	4.43b	15.60b	0.64a
0.2	3.03bd	16.00c	0.94b
Accel (ppm)			
25	0.37c	13.10d	1.55c
50	2.07d	15.00e	1.60c
75	0.23c	13.00a	1.26d
Control	12.68e	13.00a	1.14d
		'Braeburn'	
Carbaryl (%)			
0.05	8.37a	13.50a	1.58a
0.1	6.07b	14.10b	1.58a
0.2	4.43c	14.80c	1.76b
Accel (ppm)			
25	4.00c	13.10d	1.14c
50	5.87b	13.40e	1.53a
75	1.43d	13.50a	1.83b
Control	12.80f	12.90f	1.14c

[1]Means in columns followed by the same letter do not differ at the 0.05 probability level. Means separated by the Least Significant Difference test by cultivar.
[2]Number of fruit per limb cross-sectional area (LCSA).

Table 3. Effect of Accel and Carbaryl on fruit quality of the three apple cultivars grown at the Pontotoc Ridge-Flatwoods Branch Experiment Station, Mississippi, 1996.[1]

Treatment	Fruit set (fruit/LCSA)[2]	Fruit length	Fruit diameter	L:D ratio[3]	Weight per tree	pH	°Brix	Mean fruit weight
	no.	*cm*	*cm*		*kg*			*g*
				'Empire'				
Carbaryl (%)								
0.05	9.4a	5.2ab	6.6a	0.91a	4.5a	4.0a	12.0a	1.4a
0.1	4.6b	5.5a	6.8a	0.84a	21.2b	4.2a	12.2a	0.9a
0.2	0.2c	5.8ab	7.1a	0.82a	5.4c	4.2a	13.7b	1.5a
Accel (ppm)								
25	13.9d	5.6ab	7.0a	0.80a	9.3c	3.7a	13.4b	1.1ba
50	7.7e	5.2a	6.7a	0.86a	23.8b	4.2a	13.6b	1.5a
75	3.5f	6.0c	6.9a	0.78a	13.1d	4.2a	14.0b	1.6a
Control	14.6g	5.7c	6.9a	0.86a	3.6d	4.2a	11.6c	1.3a
				'Jon-A-Red'				
Carbaryl (%)								
0.05	4.4c	5.2a	6.6a	0.80a	23.4b	3.5b	12.9b	1.1a
0.1	1.8c	5.4a	6.4a	0.84a	21.7b	3.9a	13.7b	1.2a
0.2	1.6c	5.4a	6.5a	0.79a	23.4b	3.9a	13.7b	1.2a
Accel (ppm)								
25	7.4b	5.4a	6.8a	0.86a	9.7d	3.9a	13.1b	1.2a
50	2.4c	5.4a	6.3a	0.85a	37.1e	4.4a	13.5b	1.6b
75	0.8c	5.3a	6.3a	0.86a	37.1e	4.4a	13.5b	1.6b
Control	8.2a	5.6a	6.5a	0.80a	2.9c	3.7b	11.6c	1.0ab
				'Braeburn'				
Carbaryl (%)								
0.05	7.6b	5.8bc	6.7ab	0.87a	17.3b	4.0b	12.7b	1.0a
0.1	5.6b	5.9b	6.8ab	0.87a	22.3b	4.6b	14.6b	1.5b
0.2	1.3hc	6.0bc	7.0ab	0.84a	18.8b	4.1b	12.9b	1.6b
Accel (ppm)								1.4b
25	6.7ia	5.9bc	7.1ab	0.83a	21.3b	4.0b	12.1b	1.6b
50	4.9c	5.4bc	7.2ab	0.76a	21.4b	4.5c	13.7b	1.6b
75	0.7c	6.1bc	7.3b	0.84a	29.0b	4.7c	14.0d	0.9c
Control	12.3a	5.93bc	7.1b	0.83a	6.0a	4.0b	12.0b	1.1b

[1]Means in columns followed by the same letter do not differ at the P = 0.05 probability level. Means separated by the Least Significant Difference test by cultivar.
[2]Number of fruit per limb cross-sectional area (LCSA).
[3]Length-to-diameter ratio.

Discussion

The reductions of fruit set by Accel and Carbaryl in this study are due to their thinning effects. Thinning effects of Carbaryl and Accel are believed to be caused by competition in the partitioning of metabolites to fruiting structures. Metabolite stress caused by heavier fruit load normally causes reduction in subsequent vegetative growth and abscission of younger fruit. The thinning effects of Accel and Carbaryl observed in this study are in agreement with previous reports on these chemicals (Williams, 1993; Stiles, 1995; Elfving and Cline, 1993a; Hull et al., 1995) on 'Delicious,' 'Empire,' and 'Gala' apples. From the results, it is clear that Accel and Carbaryl can be used as effective apple thinners. The efficacies of these chemicals, however, depend on their concentration and the cultivar. Previous researchers used higher concentrations of chemical thinners than were used in this study. Thus, high concentrations of chemical thinners may not be necessary to achieve the desired thinning effect in apples.

Chemical fruit thinners reduce fruit set, thus increasing fruit size of the remaining fruit. It has been suggested that the yield of a blueberry plant is a function of such factors as inflorescence number, number of flowers per inflorescence, fruit number per plant, and fruit size (fruit weight) (Davis, 1986). It has been assumed that these factors contribute equally to yield. This should be determined experimentally to ascertain the how much each factor affects yield. Nevertheless, the effects of thinning on yield have been contradictory (Forshey and Elfving, 1977). Some workers have reported increases in yield, while others have reported decreases. The findings of the present study support the works by Kaps and Cahoon (1989), Stiles (1995), and Wismer and Elfving (1975), who reported increased yields from thinning. However, these findings are at odds with other studies (Valenzuela, 1992; Blanco, 1987; Gambrell et al., 1983; Nielsen and Dennis, 1983; Hull et al., 1995) that reported decreased yields from thinning. These differences may be attributed to different cultivars, soils, temperature, rainfall patterns, or other factors that could have affected parameters such as flowering, pollination, fertilization, seed number, and fruit development.

Direct light to the fruit is required for adequate red color development in apples. Pruning, thinning, fertilizer levels, temperature, and light influence red pigmentation. Factors that increase the level of carbohydrates in the fruit during the preharvest period tend to increase anthocyanin pigment, which affects color development (Westwood, 1993). Pruning, tillage, fruit thinning, fertilizer use, and pest control affect fruit color to the extent that they influence effective leaf area, leaf-to-fruit ratio, carbohydrate level, and the degree of fruit shading before harvest (Westwood, 1993). Fruit with a low sugar content and low leaf-to-fruit ratio failed to develop adequate red color even when exposed to optimum sunlight (Magness and Overly, 1929). Heinecke (1964) demonstrated that the best apple color was developed when fruits and leaves were exposed to 70% full sun, while adequate color was found at 40–70% full sun. He also reported that plants exposed to 40% full sun did not develop adequate color. Fruit color development was closely correlated with soluble solids, which are directly correlated to sunlight exposure. Our findings support the above observations. In other words, fruit thinning by Accel and Carbaryl increased the fruit soluble solids content and hence red color development of the fruit.

Factors that induce fruit elongation are vigorous rootstock and heavy thinning, resulting in a light crop. All fruits are relatively long early in the season, with the L:D ratio decreasing and finally leveling off before harvest (Westwood, 1993). Chemical thinners affect shape differently; Gibberellins and some cytokinins increase fruit length, and Kinetin and Auxin have no effect on fruit shape (Westwood, 1993). In this study, we observed no significant effect on fruit length, fruit diameter, and L:D ratio. Fruit shape affects fruit marketability and quality because consumers only prefer fruit that are wide. Long fruits are classified as low-quality fruits and fetch low prices (Westwood, 1993).

Chemical thinners did not affect the number of seeds in the fruit. There is a link between growth regulator sprays that influence seed number and fruit storage potential. Greene (1989) reported that sprays containing gibberellic acid (GA) increased seedlessness in 'McIntosh' apples and that these seedless fruit were very prone to senescent breakdown. Other researchers report that bloom or postbloom sprays containing GA_3 or GA_{4+7} produced parthenocarpic fruit with fewer seeds (Greene, 1989) that are also low in calcium. Green (1989) demonstrated a direct and inverse relationship between fruit calcium and seed number. Greene (1989) suggests that basipetal auxin transport into the fruit lacking seeds have reduced amounts of calcium.

Summary and Conclusion

This study was conducted to determine the effect of Carbaryl and Accel on thinning three apple cultivars in Mississippi. Experiments were conducted in 1995 and 1996 to investigate the effect of Accel (6-benzyladenine plus gibberellin A4 and gibberellin A7) and Carbaryl (1-Naphthyl methyl carbamate) sprayed 2 weeks postbloom on fruit set, yield, and fruit quality of three apple (*Malus Pumila* Mill) cultivars, 'Empire,' 'Jon-A-Red,' and 'Braeburn.' Treatments consisted of Accel (25, 50, and 75 ppm), Carbaryl (0.05, 0.1, and 0.2%), and unsprayed control. Thinning trials conducted over 2 years indicated that Accel and Carbaryl consistently thinned the three apple cultivars. Yield (total fruit weight per tree), pH, sugar content, and percent fruit red color were also increased by the treatments. Treatments did not influence fruit length, fruit diameter, and fruit length to diameter ratio.

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