Responses of Several Apple Cultivars to Chemical Thinning Sprays

George Ouma and Frank Matta

Department of Plant and Soil Sciences
Mississippi State University, P.O. Box 9555,
Mississippi State, Ms 39762, U.S.A.

Present Address
Department of Horticulture
Maseno University, P.O. Box 333,
Maseno, Kenya

Abstract

Studies were conducted in 1995 and 1996 at Pontotoc country, Mississippi, U.S.A. to find the effect of two chemical thinners namely: accel (N-phenylmethyl) (1H-purine 6-amine (6-BA) and carbaryl (1-Naphthyl carbamate) sprayed two weeks after bloom on the apple fruit characteristics such as fruit set, yield, etc. The three apple cultivars used were 'Empire', 'Jon-A-Red' and 'Braeburn'. The treatments comprised accel (25, 50 and 75 ppm), carbaryl (0.05, 0.1 and 0.2%) and unsprayed control.

It was found that accel and carbaryl thinned the three apple cultivars and yield (total fruit weight per tree), pH, sugar content were significantly (P≤ 0.05) increased by the chemical thinning sprays. Nevertheless, the treatments did not affect (P≤ 0.05) the number of seeds in the fruit, fruit length, fruit diameter and fruit length to diameter ratio. The chemical thinner and cultivar interactions were significant for some fruit characteristics.

Key Words: Fruit Thinning, Fruit Set, Yield and Quality.

Introduction

Chemical fruit thinning of apples after bloom is a common practice carried out to improve fruit size, quality, increase return bloom and reduce biennial bearing (Williams and Looney, 1986). The fruit size at harvest depends on earliness and the level of fruit thinning as long as tree vigor is adequate (Williams, 1979).

Thinning can be conducted at bloom time and during the early postbloom period. However, strongly biennial apple cultivars may require both a bloom and postbloom spray program for adequate thinning (Williams, 1979). There are two types of postbloom chemicals namely: hormone types which are used to upset the natural hormone balance of the tree and non-hormonal types which cause stress and embryo abortion (Williams, 1979).

Although the mode of action of the postbloom chemicals is not fully known, they are generally believed to interfere with endogenous hormones which control the flow of nutrients to the developing fruit (Williams, 1979). Embryo abortion may come before or occur simultaneously with fruit abscission but it is not regarded to be its cause. Fruit abscission will be increased by chemical stress of any kind which is applied to apple trees during the early period. (Williams, 1979).

Chemical thinning of apples can be done by ethephon (Jones *et al.* 1989), Gibberellins (Cohen and Greene, 1988), Benzyladenine (Greene, 1993), carbaryl (Wismer and Elfving, 1995), Naphthalene acetic acid (Williams, 1993), Cppu (N-2-chloro-4pyridyl)-N-phenyl urea) (Bound *et al.* 1991); accel (Stiles, 1995).

Most of the studies conducted previously on chemical thinning of apples are still inconclusive and are specific to particular apple cultivars and ecological and environmental settings. Further, accel, one of the chemical thinners used in this study is new and needs to be tested on different apple cultivars. A two-year study was therefore conducted to:

- Find the effect of Accel and Carbaryl at varying concentrations on apple fruit set.
- Find the effect of Accel and Carbaryl on yield, fruit weight, seed number, soluble solids, pH, fruit length, fruit diameter and fruit length to diameter ratio.

Materials and Methods

Two identical experiments were carried out using mature apple trees at the Mississippi State University Agricultural and Forestry Experimental Station (MAFES) at Pontotoc Ridge - Flatwoods Branch Experimental Station, Pontotoc. The Pontotoc experimental Station is located about 7 miles South of Pontotoc in the South Central part of Pontotoc country. The types of soil found at the station are classified as alfisol, ultisol, inceptisol and entisol orders with soils ranging from deep red and high in silt to gray having silt loam and finer textured subsoils having expansive montmorillonite clay.

The first experiment was started April 12, 1995 and terminated July 30 th, 1995. The second experiment was started May15, 1996 and terminated on August 30, 1996. The two experiments were started two weeks after bloom when the fruits were about 12mm in diameter. Before the spray chemicals were prepared, their amounts in each of the chemical thinner treatments were determined by calculating in terms of the active ingredients they contained. The amount of the spray chemicals to be added for each treatment was calculated from the known volume of the sprayer then added to water in the sprayer and thoroughly mixed with it before spraying. Spraying of the thinners was conducted on calm, clear and dry days from 1100 hours to 1700 hours, GMT. The surfactant Tween 20 (Sigma Chemical Co., St. Louis) at 0.1% was mixed with the chemical thinners to act as a wetting agent. The trees were sprayed to dripping point. The trees were sprayed with accel (N-(phenylmethyl) - purine-6-amine (BA) and carbaryl (Naphthylmethyl carbamate) at concentrations of 25ppm, 50ppm and 75ppm and 0.05%, 0.1% and 0.2% respectively. The control trees were sprayed with water only. Each treatment was applied with a hand sprayer (FMC 252, Food Machinery Corp; Jones boro, Ark).

The above treatments were replicated three times in a completely randomised design with a factorial arrangement. The study was conducted on 'Empire', 'Braeburn' and 'Jon-A-Red' apple cultivars because they were the main cultivars grown at the Pontotoc experimental station and by Mississippi farmers. Recommended cultural practices for commercial apple production i.e. fertilization, weeding, pest and disease control were applied (Westwood, 1993). Fruit harvesting started at the beginning of August each year. We determined fruit set, yield, seed number, length and diameters of the fruits, total soluble solids and pH.

Fruit set was determined by tagging four representative limbs of 12 to 15 cm in circumference before bloom for use in fruit set counts. (Forshey and Elfving, 1979a; 1979b, Lambard *et al*, 1988). The number of fruits were counted after June drop (i.e. one month after application of chemicals) and expressed as the number of fruits per unit limb cross sectional area. Fruit weight, mean weight and yield were determined by taking a sample of 20 fruits per tree and weighing using a mettler PE electronic scale (Fisher Scientific, Spring Field, N.J.) and weight expressed in kilograms. Mean weight was determined by dividing the total weight of the fruits by 20 while yield per tree was calculated from the total weight of fruits on the tree.

Juice was extracted from the apple fruits using a Mullinex juice extractor (Fisher Scientific Spring Field, N.J) and filtered through a 28 - mesh screen. From the extracted juice, was determined total soluble solids using a Bausch and Lomb optical refractometer (Fisher Scientific, Spring Field, N.J.) and expressed in degrees brix (°Brix) and pH determined by an accumet 925 laboratory meter (Fisher Scientific, Spring Field, N. J.). Fruit length and diameter were determined by laying the fruit end-to-end and side-to-side in a V-shaped trough and measuring the total length and diameter - using a hand caliper on a sample of 10 fruits and recorded in millimeters. The ratio of lengths of fruits to their diameters were then calculated.

The seed number per fruit was determined by dissecting the fruit at harvest and counting the number of seeds. An average seed number was then determined.

All statistical analyses were carried out using the general linear models (GLM) procedure of the statistical analysis system (SAS Institute, N. C., 1988) program package. Means were determined using the least significant difference (L.S.D.) at P≤ 0.05.

Results

Fruit set was expressed as the number of fruits per square centimetre limb cross sectional area (Forshey and Elfving,

Table 1. Effect of Accel and Carbaryl on fruit length, fruit diameter length to diameter ratio, yield and pH of the three apple cultivars grown at the Pontotoc Research and Extension Centre, 1995 experiment

Treatment	Fruit length	Fruit diameter	Length to diameter ratio	Yield weight per tree (Kg)	pH
'Empire'					
Carbaryl 0.05%	5.90	7.13	0.83	5.60	4.97
Carbaryl 0.1%	5.83	7.33	0.81	8.40	4.43
Carbaryl 0.2%	6.43	7.55	0.83	9.60	4.42
Accel 25ppm	5.93	7.16	0.80	6.40	4.48
Accel 50ppm	6.03	6.57	0.80	5.60	4.42
Accel 75ppm	5.97	7.48	0.87	8.00	4.56
Control	5.60	6.84	0.82	4.60	4.31
'Jon-A-Red'					
Carbaryl 0.05%	5.90	7.14	0.83	0.80	4.57
Carbaryl 0.1%	5.57	6.54	0.85	1.30	4.39
Carbaryl 0.2%	6.43	7.45	0.85	4.20	4.34
Accel 25ppm	5.73	7.00	0.81	0.80	4.40
Accel 50ppm	5.87	6.61	0.88	8.50	4.40
Accel 75ppm	6.13	7.24	0.83	7.70	4.60
Control	6.40	7.27	0.88	0.80	4.28
'Braeburn'					
Carbaryl 0.05%	6.00	7.17	0.80	5.90	4.30
Carbaryl 0.1%	6.30	7.57	0.85	10.50	4.51
Carbaryl 0.2%	6.18	7.18	0.87	17.80	4.28
Accel 25ppm	5.63	6.35	0.84	11.20	4.47
Accel 50ppm	6.16	7.23	0.87	17.20	4.34
Accel 75ppm	6.37	7.64	0.87	8.80	4.48
Control	6.17	7.33	0.85	4.90	4.45
L.S.D. (0.05)	0.69	0.02	0.06	7.80	0.24
Significance of 'F' tests					
Cultivar	NS	NS	NS	*	*
PGR	NS	NS	NS	*	*
Cultivar X PGR	NS	NS	NS	*	*

Key:
* = Significant at P≤ 0.05
NS = Not Significant at P≤ 0.05
PCLA = Per Cross Sectional Limb Area
PGR = Plant Growth Regulators (Chemical thinners)

Table 2. Effect of Accel and Carbaryl on number of fruit per cross sectional limb area, sugar content (Brix) and mean fruit weight of three Apple cultivars grown at the Pontotoc Research and Extension Centre, 1995 experiment No. of fruit per limb cross sectional area.

Chemical treatment	Empire	Jon-A-Red	Braeburn	Average no. of fruit per cross sectional Limb area
Carbaryl 0.05%	8.33	7.40	8.37	8.03ab
Carbaryl 0.1%	5.40	4.43	6.07	4.38c
Carbaryl 0.2%	3.13	3.03	4.43	3.53c
Accel 25ppm	6.10	0.37	4.00	3.49c
Accel 50ppm	4.23	2.07	5.87	4.06c
Accel 75ppm	1.67	0.23	1.43	1.11d
Control	11.67	12.68	12.80	12.38a
Cultivar average	5.79a	4.31b	6.13a	
L.S.D (0.05) for cultivar Averages	0.91			
L. S. D. (0.05) for chemical treatment average	1.41			
		Mean fruit weight		
Chemical treatment	**Empire**	**Jon-A-Red**	**Braeburn**	**Average mean fruit weight**
Carbaryl 0.05%	1.70	0.54	1.58	1.27b
Carbaryl 0.1%	1.80	0.64	1.58	1.34ab
Carbaryl 0.2%	1.80	0.94	1.76	1.50a
Accel 25ppm	1.40	1.55	1.14	1.36b
Accel 50ppm	1.60	1.60	1.53	1.60a
Accel 75ppm	1.20	1.26	1.83	1.43a
Control	1.26	1.14	1.14	1.18b
Cultivar average	1.54a	1.09b	1.51a	
L.S.D (0.05) for cultivar Averages	0.28			
L. S. D. (0.05) for chemical treatment average	0.19			
		Sugar Content (°Brix)		
Chemical treatment	**Empire**	**Jon-A-Red**	**Braeburn**	**Average °Brix**
Carbaryl 0.05%	12.00	13.00	13.50	12.83f
Carbaryl 0.1%	12.80	15.60	14.10	14.17b
Carbaryl 0.2%	13.30	16.00	14.80	14.70a
Accel 25ppm	14.50	13.10	13.10	13.57e
Accel 50ppm	14.60	15.00	13.40	14.33c
Accel 75ppm	15.10	13.00	13.50	12.87d
Control	12.60	13.00	12.90	12.83f
Cultivar average	13.56a	14.10ba	13.61a	
L.S.D (0.05) for cultivar Averages	0.05			
L. S. D. (0.05) for chemical treatment average	0.06			

Mean separation within row and column by least significant difference test ($P \leq 0.05$). No cultivar and chemical thinner interactions. Mean followed by the same letter(s) are not significantly different at 5% level.

Table 3. Effect of Accel and Carbaryl on fruit set, fruit length, fruit diameter, Yield, pH, Mean Fruit weight and number of seeds of the three Apple cultivars grown at the Pontotoc Research and Extension Centre, 1996 experiment.

Treatment	No of fruit PCLA	Fruit length	Fruit diameter	Length to diameter ratio	Yield (Weight per tree) (kg)	pH	°Brix	Mean fruit weight (g)	No of seeds
'Empire'									
Carbaryl 0.05%	9.47	5.21	6.60	0.91	4.57	4.09	12.07	1.40	6.33
Carbaryl 0.1%	4.63	5.59	6.81	0.84	21.27	4.25	12.20	0.90	6.66
Carbaryl 0.2%	0.23	5.84	7.11	0.82	5.43	4.24	13.77	1.53	6.67
Accel 25ppm	13.97	5.63	7.07	0.80	9.37	3.76	13.40	1.14	6.66
Accel 50ppm	7.73	5.27	6.70	0.86	23.87	4.22	13.67	1.55	6.33
Accel 75ppm	3.57	6.04	6.99	0.78	13.10	4.24	14.00	1.63	7.00
Control	14.60	5.77	6.97	0.86	3.63	4.28	11.60	1.33	6.67
'Jon-A-Red'									
Carbaryl 0.05%	4.43	5.28	6.63	0.80	23.43	3.52	12.97	1.13	5.66
Carbaryl 0.1%	1.80	5.43	6.43	0.84	21.77	3.97	13.77	1.27	6.33
Carbaryl 0.2%	1.63	5.40	6.57	0.79	23.47	3.97	13.77	1.27	6.33
Accel 25ppm	7.40	5.43	6.80	0.86	9.73	3.97	13.17	1.27	6.33
Accel 50ppm	2.43	5.47	6.37	0.85	37.10	4.42	13.53	1.65	7.00
Accel 75ppm	0.83	5.37	6.33	0.86	37.10	4.42	13.53	1.65	7.00
Control	8.20	5.67	6.55	0.80	2.97	3.76	11.67	1.07	5.33
'Braeburn'									
Carbaryl 0.05%	7.67	5.86	6.74	0.87	17.30	4.01	12.77	1.03	6.33
Carbaryl 0.1%	5.60	5.90	6.80	0.87	22.30	4.65	14.40	1.50	6.33
Carbaryl 0.2%	1.37	6.03	7.01	0.84	18.87	4.16	12.97	1.67	7.30
Accel 25ppm	6.73	5.93	7.13	0.83	21.33	4.00	12.13	1.40	6.00
Accel 50ppm	4.97	5.45	7.20	0.76	21.47	4.59	13.70	1.62	7.00
Accel 75ppm	0.73	6.16	7.34	0.84	29.03	4.74	14.00	1.69	7.00
Control	12.33	5.93	7.13	0.83	6.00	4.03	12.07	0.95	5.30
L.S.D. (0.05)	4.03	0.61	0.86	0.15	10.61	0.50	1.46	1.19	0.30
Significance of 'F' tests									
Cultivar	NS	NS	NS	NS	NS	NS	NS	NS	NS
PGR	*	NS	NS	NS	*	*	*	NS	NS
variety X PGR	*	NS	NS	NS	NS	NS	NS	NS	NS

Key

* = significant at $P \leq 0.05$

NS= Not significant at $P \leq 0.05$

PCLA = Per Cross sectional Limb Area

1979a, 1979b. Lombard *et al*, 1988). In 1995 all the chemical thinners significantly ($P \leq 0.05$) reduced fruit set (**Table 1**). There was no cultivar and chemical thinner interaction in 1995 as compared to 1996. Carbaryl and accel at all concentrations significantly ($P \leq 0.05$) reduced the fruit set of 'Empire' (**Table 3**) and 'Jon-A-Red' except at 25ppm in 1996. In comparison, the fruit set of 'Braeburn was significantly ($P \leq 0.05$) reduced by all the chemical thinner treatments (**Table 3**).

In 1995 the yield of 'Empire' was not significantly ($P \leq 0.05$) affected by accel or carbaryl. Only accel at 50ppm significantly ($P \leq 0.05$) increased the yield of 'Jon-A-Red' while the remaining treatments had no effect. (**Table 1**). The yield of 'Braeburn' was significantly ($P \leq 0.05$) increased by carbaryl at 0.2% and accel at 50ppm. The remaining treatments had no effect ($P \leq 0.05$) on the yield of 'Braeburn', carbaryl at 0.1% and accel at 50ppm significantly ($P \leq 0.05$) increased the yields of 'Empire' while all the other treatments had no effect. The yields of 'Jon-A-Red' was significantly ($P \leq 0.05$) increased by all the treatments.

Fruit length, fruit diameter, length to diameter ratio were not significantly affected by the treatments and so was the seed number in the fruits which was determined only in 1996.

The total soluble solids content (°Brix) was significantly increased by all treatments except carbaryl at 0.05% in 1995 (**Table 1 and 2**). The soluble solids contents of 'Empire and 'Jon-A-Red' were significantly increased by all the concentrations of accel and carbaryl while that of 'Braeburn' was unaffected (**Table 3**).

In 1995 carbaryl at 0.05% and accel at 75ppm significantly ($P \leq 0.05$) increased the pH of 'Empire' and 'Jon-A-Red' while the rest of the treatments had no significant effect (**Table 1 and 2**). The pH of 'Bareburn' was not affected by any treatment in 1995. Conversely, 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**). The pH of 'Jon-A-Red' was only increased by accel at 75ppm while that of 'Braeburn' was increased by carbaryl at 0.1%, accel at 50ppm and accel at 75ppm in 1996 (**Table 3**).

Discussion

The reductions of fruit set by accel carbaryl in the present study is attributed to their thinning effects. Several workers have reported thinning effects of accel and carbaryl (William, 1993; Stiles, 1995; Elfving and Cline, 1993). When carbaryl and Naphthalene acetic acid was compared as petal sprays in thinning apples, it reduced fruit set by one fruit per cluster (William, 1993). He reported that carbaryl applied at petal fall or at petal fall plus 7 days effectively reduced fruit set of 'Fuji' and 'Delicious' apple trees. Thinning effects of carbaryl has also been reported by other workers - Stiles, 1995; Elfving and Cline, 1993; Wismer and Elfving, 1995). Accel has also been reported to effectively thin apples at concentrations of 25 to 150ppm in 'Delicious', 'Empire' and 'Gala' apples (Hull *et al*, 1995) and at concentrations of 50ppm to 75ppm on 'Delicious' apples (Black *et al*, 1993) and at concentrations of 50ppm to 100ppm (Stiles, 1995) on 'Empire' apples. Competition in the partitioning of metabolites to fruit tissues which causes reduction in growth and eventual activation of abscission mechanisms is the probable cause of thinning effects of carbaryl and accel (Knight, 1983b).

Fruit size was generally increased by the chemical thinners because thinning of fruits causes increase in fruit size (Westwood, 1993). Thinning fruits increases the leaf to fruit ratio because removing some of the fruits causes the remaining ones to become larger in size but not in direct proportion to the increase in the number of leaves per fruit (Westwood, 1993). Yield is a function of such factors as flower bud number per bud, fruit number and fruit size (Davis, 1986). It has been assumed that these factors contribute equally to yield. The effect of thinning on yield has however, been controversial (Forshey and Elfving, 1977). The findings of the present study agree with the findings of Kaps and Cahoon, 1989; Stiles, 1995 and Wismer and Elfving, 1995 who obtained increased yield from thinning, but disagree with those of Valenzuela, 1992; Blanco, 1987, Gambrell *et al*, 1983; Nielsen and Dennis, 1993 and Hull *et al*, 1995 who reported decreased yields from fruit thinning. The latter differences could be attributed to the different experimental conditions under which the present study was conducted.

The chemical thinners had no significant ($P \leq 0.05$) effect on the fruit length, fruit diameter and fruit length to diameter ratio. Fruit shape is determined by the ratio of the longitudinal length to transverse diameter of the fruit (L:D ratio). The length to diameter ratio may be thought of as relative fruit length, the higher the value, the more elongated the fruit. All fruits are relatively long early in the season, with the L:D ratio decreasing and finally leveling off before harvest (Westwood, 1993). Elongated fruit formation is caused by vigorous rootstocks and heavy thinning or light bloom resulting in a light crop. Fruit shape is affected by chemical thinners differently, e.g. Gibberellins and some cytokinins increase fruit length (Williams and Stahly, 1969) and Kinetin and Auxin do not affect fruit shape (Westwood, 1993). Since we did not get any significant effect on fruit length, fruit diameter and length to diameter ratio from the present study we can classify accel and carbaryl with the chemical thinners which do not affect fruit shape.

The chemical thinners did not affect the number of seeds in the fruit. It has been reported that bloom or postbloom sprays containing GA_3 or GA produce parthenocarpic fruit with fewer seeds (Greene, 1989) that are also low in Ca. Weis *et al* (1985) cited by Greene (1989) has demonstrated a direct and inverse relationship between fruit Ca and seed number. Bangerth (1976) cited by Greene (1989) has argued that basipetal transport of auxin into the fruit lacking seeds would have reduced levels of Ca because auxins usually produced by seeds would be present in reduced amounts. He therefore suggested that seed produced auxin is caused by Ca transport. Since we did not get any effect of the treatments on fruit Ca content (data not represented) we cannot link Ca transport with fruit seed produced auxin.

Conclusions

From the this study the following can be concluded:

- That accel and carbaryl can effectively thin the three apple cultivars, i.e. 'Empire', 'Braeburn' and 'Jon-A-Red' at the concentrations used here.
- Accel and carbaryl, when used to thin fruits, increases fruit yield of 'Empire', 'Braeburn' and 'Jon-A-Red'.
- That carbaryl at 0.05% and 0.1%, accel at 50ppm and 75ppm increases the pH of 'Empire' and 'Jon-A-Red'.
- That carbaryl and accel at the concentrations used in the present study increases the total soluble solids contents of 'Empire' and 'Jon-A-Red'.
- The fruit length, fruit diameter and fruit length to diameter ratio are not affected by the chemicals used in the present study and therefore fruit shape is also not affected.
- The chemicals used: accel and carbaryl do not affect the seed number.

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References

Black, B. L., M. J. Bukovac and M. Stopur (1993) Growth response of apple fruit to NAA and Accel: Effect of Intraspur competition and position on *Spur. HortScience* 30 (4): 756.

Blanco, A. (1987) Fruit thinning of peach trees (*Prunus persica* L. Batsch); The effect of Paclobutrazol on fruit drop and shoot growth. J. of *Hort. Sci.* 62:147-155.

Bound, S. A., K. M. Jones, T. B. Koen and M. J. Oakford (1991) The thinning effect of BA on red 'Fuji' apple trees. *J Hort. Sci.* 66: 789-794.

Cohen, R. A. and D. W. Greene (1989) GA_4, GA_7 and BA Influences fruit set, fruit quality and return bloom of the 'Golden Delicious' apples. *HortScience* 23 (3): 788-789.

Davis, F. (1986) Flower position, growth regulators and fruit set of Rabbiteye blue berries, *J Amer. Soc. Hort. Sci.* 3: 338-341.

Elfving, D. C. and R. A. Cline (1993a) BA and other chemicals for thinning 'Empire' apple trees. *J Amer. Soc. Hort. Sci.* 118: 593-598.

Elfving, D. C. and R. A. Cline (1993b) Cytokinin and ethephon affect crop load, shoot growth and nutrient concentration of 'Empire' apple trees. *HortScience* 28: 1011-1014.

Forshey, C. G. and D. C. Elfving (1979a) Fruit numbers, Fruit size and Yield relationships in 'McIntosh' apples. *J Amer. Soc. Hort. Sci.*102: 399-402.

Forshey, C. G. and D. C. Elfving (1979b) Branch samples for yield and fruit size comparison in apple. *HortScience* 14: 143-144.

Gambrell, C. E., D. C. Cosrom and E. T. Sims, Jr. (1983) Results of 8 years with CGA- 15281 as a post bloom thinner for peaches. *J Amer. Soc. Hort. Sci.* 108: 605-608.

Greene, D. W. (1989) Regulation of fruit set in the fruits with plant growth regulators. *Acta Horticulturae* 239: 323-334.

Greene, D. W., W. R. Auto and P. Miller (1990) Thinning activity of BA on several apple cultivars. *J Amer. Soc. Hort. Sci.* 115: 394-400.

Greene, D. W. (1993) A review of the use of benzyladenine (BA) as a chemical thinner. *Acta Hortculturae* 329: 231-236.

Hull, J. Jr., M. J. Bukovac and Black, B. C. (1995) Effect of concentration and time of Accel application on cropping of selected cultivars. *Hortscience* 30 (4):765.

Jones, K. M., T. B. Koen and R. J. Meredith (1983) Thinning 'Golden Delicious' apples using ethephon sprays. *J Hort. Sci.* 58: 381-388.

Jones, K. M., T. B. Koen, M. J. Oakford and S. Bound (1989) Thinning response of 'Fuji' apples with ethephon or NAA. *J Hort Sci. 64:* 527-532.

Kaps, M. L. and G. A. Cahoon (1989) Berry thinning and Cluster thinning Influence vegetative growth, yield, fruit composition and net photosynthesis of 'Seyual Blanco' grapes. *J Amer. Soc. Hort. Sci.* **114:** 20-24.

Knight, J. N. (1980) Fruit thinning of the apple cultivar Cox's Orange Pippin. *J. Hort. Sci.* 55: 267-273.

Knight, J. N. and J. E. Spencer (1987) Timing of application of carbaryl used as an apple fruit let thinner. *J Hort. Sci.* 62:11-16.

Lombard, P. B., N. W. Callan, F. G. Dennis, Jr., N.E. Looney, G. C. Martin, A. R. Renquist and E. A. Mielke (1988) Towards a standardized nomenclature, procedures, values and units in determining fruit and nut yield performance. *HortScience* 23: 813-817.

Looney, N.E. (1986) Chemical thinning of apples: Some new strategies and important refinements to old procedures. *Acta Horticulturae* 179: 597-604.

Nielsen, J. C. and F G. Dennis (1993) Thinning 'Delicious' apples; Trials and Tribulations. *HortScience* 28 (5): 484.

SAS Institute (1988) SAS (STAT Users' Guide) SAS Institute, Cory, N. C.

Stiles, W. C. (1995) 'Empire' apple tree responses to fruit thinning chemicals. HortScience 30-(40): 765.

Valenzuela, J. R. C. (1992) Regulating blue berry Vaccinium ashe read crop. Ph.D. Dissertation, Mississippi State University.

Westwood, M. N. (1993) Temperate zone Pomology. Third Edition, PP.259-269 Timber Press, Portland, Oregon.

Williams, M. W. (1979) Chemical thinning of apples in J. Janick (ed) Avi Publishing Company, Inc. PP. 270-298.

Williams, M. W. (1993) Comparison of NAA and carbaryl petal fall sprays on fruit set of apples. *HortTechnology* 3 (4): 428-429.

Wismer, P. T. and Elfving, D. C. (1975) Benzyladenine affects cell division and cell size during apple fruit thinning. *J Amer. Soc. Hort. Sci.* 120 (5): 802-807.