STEPS TO ENHANCE THE RETURN BLOOM OF APPLE TREES

Dr. John A. Cline and Mary Byl
University of Guelph, Department of Plant Agriculture
Horticultural Research Institute of Ontario
February 1999

INTRODUCTION

In apple trees there are two key processes involved in the formation of flower buds – flower initiation and flower development. Flower initiation, also referred to as “induction”, in most instances occurs 2-6 weeks after bloom. This is the period when vegetative buds differentiate and begin the process of forming flower buds which will ultimate bloom and set fruit the following year.

The initiation process, which occurs within the meristem (growing tip) at the cellular level, is relatively short in duration and last 1-2 weeks (Faust, 1989). The subsequent development of the flower bud takes longer with most of the anatomical parts of the flower present in the bud by the autumn (Faust, 1989). Development slows during late autumn and winter, but is a very important stage for successful bloom and high yields the following year. This is evident by decreased bloom the following year if harvest is delayed or premature defoliation before normal leaf fall occurs.

Flower initiation and development are influenced by internal and external conditions. Floral induction, while not well understood, is controlled, in part, by the level of endogenous hormones and photosynthates. Defoliation studies on cropping trees have shown that the removal of leaves from spurs early in the season or extension shoots later in the season, can inhibit the initiation and/or continued development of the flower buds. It is also well recognized that removal of fruit (thinning) has the opposite effect of promoting flower initiation - even to some extent up to 6 weeks after bloom.

The factors that influence the flowering of apple are intricate, complex, and interrelated, and at best, are poorly understood. Despite this, it is known that excessive nitrogen and pruning, vigorous rootstocks, and gibberellin sprays all inhibit flowering, while bending branches to the horizontal, branch ringing, dwarf rootstocks, ethylene sprays, and fruit thinning promote flowering.

The use of ethephon and NAA sprays to induce flowering will be the focus of this paper. The basis for understanding how ethephon promotes flowering relates to the level of the natural plant hormone gibberellic acid (GA). Luckwill (1970) reported that gibberellins inhibit flower initiation of apples. Dennis (1976) was able to demonstrate that apple seeds are high in GA-like substances and that these substances are implicated in the inhibition of flower bud formation. Gibberellins diffusing from developing fruit are the major cause of alternate

bearing (Williams and Edgerton, 1981). In a year when the tree is loaded with apples (the “on” year), the diffusing GA prevents flower bud initiation, and in the flowering year the trees will not bloom (the “off” year). During the ”off” year, there is ittle or no GA to inhibit flower bud development. This is the major reason for biennial production, and hence, the requirement for methods and strategies to enhance and ultimately regulate bloom.

Compounds that counteract GA, either by interfering with its biosynthesis or by its action tend to produce more flowers. Daminozide, paclobutrazol, and ethephon all produce more bloom in the year after application (Williams, 1981). The natural production of ethylene in flower buds also enhances the initiation and/or development of flower buds. Klein and Faust (1978) demonstrated that locations where flower bud development is likely contain higher levels of ethylene in comparison with non fruiting wood (ie, 1 yr extension shoots). Pruning, wounding, and branch bending can increase the rate of ethylene evolution (Klein and Faust, 1978) and enhance bud formation.

In the final analysis, the alternate bearing nature of apple trees and presence of fruit in the “on” year will influence flower bud formation the following year. Steps are necessary to regulate cropping by chemical thinning early to reduce the inhibiting effect of excessive fruit on flower bud initiation. Adequate levels of light, moisture and nutrients will also ensure optimal fruit bud development.

Multiple Low Dose Ethephon Applications to Promote Return Bloom

In an effort enhance cropping in “off” years, studies were conducted on ‘Fuji’, ‘Northern Spy’, ‘Jonagold’, and ‘Empire’. During the thinning period, which coincides with the period of flower initiation, low rates of ethephon have been used to encourage return bloom of apple while avoiding fruit abscission at higher rates (Byers, 1993). The response is cultivar and temperature dependent, and higher concentrations can contribute to fruit abscission.

The objective of this research was to: 1) evaluate the use of ethephon sprays to promote earlier bearing of ‘Jonagold’ and ‘Northern Spy’ trees; 2) to determine whether low doses of ethephon promote the return bloom of bearing ‘Jonagold’, ‘Empire’, and ‘Fuji’ trees, and; 3) to evaluate the use of multiple low dose applications of NAA to promote return bloom of bearing ‘Jonagold’ and ‘Fuji’ trees – a strategy which is being recommended elsewhere without corroborated evidence in the scientific literature.

MATERIALS AND METHODS

Experiment 1. Ethrel Applications to Non Bearing ‘Jonagold’ and ‘Northern Spy’ Trees.

Two experiments were established at the Horticultural Experiment Station (HES), Simcoe and a grower orchard in Clarksburg, Ontario in 1997 to evaluate the use of ethephon to encourage young, non-bearing orchards into production earlier.

At the University of Guelph's H.E.S orchard, 2-yr-old 'Jonagold'/M.9 and 'Northern Spy'/M.9 trees were treated with the following treatments: 1) untreated control; 2) 500 mg·litre^{-1} Ethrel applied 5 July; 3) 1000 mg·litre^{-1} Ethrel applied 5 July; 4) 500 mg·litre^{-1} Ethrel applied 5 July, 11 July. Treatments were applied in a randomized complete block design, 10 replications, using a commercial sprayer equipped with hand-gun. Approximately 2.6 litres of spray were applied per tree. Trees were spaced 4.5m x 1.75 m or 1270 trees/hectare and trained using a slender spindle system. The date of full bloom of flowering 'Jonagold' and 'Northern Spy' trees in neighboring blocks was 29-May and 30-May, respectively.

A second experiment was also established in 1997 in a 2-yr-old planting of 'Northern Spy'/M.9 T337 in a grower orchard in Clarksburg, Ontario, and treated with the following: 1) untreated control; 2) 750 mg·litre^{-1} Ethrel applied 6 July; 3) 1500 mg·litre^{-1} Ethrel applied 6 July; 4) 375 mg·litre^{-1} Ethrel applied 6 July, 12 July, and; 5) 750 mg·litre^{-1} Ethrel applied 6 July, 12 July, 19 July. Treatments were applied in a randomized complete block design with 10 replications, using a commercial air blast sprayer and sprayed to incipient run-off. Trees were spaced 4.3m x 1.7 m or 1367 trees/hectare and trained using a slender spindle type system. The approximate date of full bloom of flowering 'Northern Spy' trees in a neighboring block was 6- June.

Experiment 2. Ethrel Applications to Bearing 'Jonagold' and 'Fuji' Trees.

A trial was established in 1997 on a commercial orchard block of 7-year-old 'Jonagold'/M.9 and 'Fuji'/M.26 located in Grimsby. Trees were spaced 4.9 x 2.1 m or 971 trees/hectare and trained to a slender spindle-type systems. The objective of this trial was to determine the effect of Ethrel sprays to enhance the return bloom of cultivars which have very biennial tendencies.

The 'Jonagold' trees were treated with one of the following treatments: 1) untreated control; 2) 150 mg·litre^{-1} Ethrel applied 5 July; 3) 150 mg·litre^{-1} Ethrel applied 5 July, 12 July; 4) 150 mg·litre^{-1} Ethrel applied 5 July, 12 July, 18 July and; 5) 4 mg·litre^{-1} NAA applied 5 July, 12 July, 19 July. Treatments were applied in a randomized complete block design with 8 replications, using a commercial air blast sprayer and sprayed to incipient run-off. The date of full bloom was 28 May.

The 'Fuji' trees were treated with one of the following treatments: 1) untreated control; 2) 300 mg·litre^{-1} Ethrel applied 5 July; 3) 300 mg·litre^{-1} Ethrel applied 5 July, 12 July; 4) 300 mg·litre^{-1} Ethrel applied 5 July, 12 July, 18 July and; 5) 4

mg·litre^{-1} NAA applied 5 July, 12 July, 19 July. Treatments were applied in a randomized complete block design with 8 replications, using a commercial air blast sprayer and sprayed to incipient run-off. The approximate date of full bloom was 29 May.

Experiment 3. Ethrel Applications to Bearing 'Fuji' and 'Empire' Trees.

A third trial was established in 1997 on a block of 5- and 7-year-old 'Fuji Redsport #2'/M.9 T337 and 'Empire'/Mark trees, respectively, located at the Horticultural Experiment Station, Simcoe. Trees were spaced 4.0 x 1.75 m (1428 trees/hectare) and 5.5 x 2.4 m (758 trees/hectare), respectively, and trained to slender spindle-type systems. The objective of this trial was to determine the effect of Ethrel sprays to enhance the return bloom of two commercial cultivar, the former being very biennial.

The 'Fuji' trees were treated with one of the following treatments: 1) untreated control; 2) fruits singled and hand thinned to 15 cm spacing after June drop; 3) 300 mg·litre^{-1} Ethrel applied 5 July; 4) 300 mg·litre^{-1} Ethrel applied 5 July, 10 July; 5) 300 mg·litre^{-1} Ethrel applied 5 July, 10 July, 17 July and; 5) 4 mg·litre^{-1} NAA applied 5 July, 10 July, 17 July. Treatments were applied in a randomized complete block design with 10 replications, using a commercial sprayer equipped with hand gun and sprayed to incipient run-off. The date of full bloom was 30 May.

The 'Empire' trees were treated with one of the following treatments: 1) untreated control; 2) hand thinned to 15 cm spacing; 3) 150 mg·litre^{-1} Ethrel applied 5 July; 4) 150 mg·litre^{-1} Ethrel applied 5 July, 10 July; 5) 150 mg·litre^{-1} Ethrel applied 5 July, 10 July, 17 July and; 5) 4 mg·litre^{-1} NAA applied 5 July, 10 July, 17 July. Treatments were applied in a randomized complete block design with 10 replications, using a commercial sprayer equipped with hand-gun and sprayed to incipient run-off. The date of full bloom was 28 May.

RESULTS AND CONCLUSIONS

Experiment 1. Ethrel Applications to Non Bearing 'Jonagold' and 'Northern Spy' Trees.

While Ethrel sprays applied to 2-yr-old 'Jonagold' trees had no statistically significant effect on the number of blossom clusters per tree (with or without adjusting for tree size), there was a trend that an increasing number or total concentration of Ethrel sprays enhanced return bloom (Table 1). Ethrel sprays had no significant effect on crop density or yield the year following application, but did reduce average shoot growth in the year of application. There was no significant difference if sprays were applied as a single application at 1000

mg·litre^{-1} or two applications at 500 mg·litre^{-1}, however a single application at 500 mg·litre^{-1} tended to be less effective on return bloom.

On 2-yr-old 'Northern Spy' trees, Ethrel sprays significantly enhanced return bloom by as much as 23% in comparison with the untreated controls (Table 1). Crop load was also increased the following spring, however, this effect did not translate into increased yields at harvest. Average shoot growth tended to be lower for Ethrel treated trees. Trunk cross-sectional area growth, and indication of tree growth, was lower in the year of treatment for the trees treated with two sprays of Ethrel at 500 mg·litre^{-1} (Table 1).

One-yr-old 'Northern Spy' trees in Clarksburg, treated with Ethrel responded with enhanced return bloom the following spring. A single application of 1500 mg·litre^{-1} Ethrel was most beneficial and improved return bloom by 230% over the untreated control treatments (Table 2).

Experiment 2. Ethrel Applications to Bearing 'Jonagold' and 'Fuji' Trees.

Ethrel or NAA sprays applied to 7-yr-old bearing 'Jonagold' trees had no significant effect on return bloom (Table 3), but did improve the number of blossom clusters by as much as 417 percent in "Fuji" when compared against the untreated control treatments. The most effective treatment was three sprays of Ethrel at 300 mg·litre^{-1}. NAA was not significantly different from the untreated controls, nor where the single or dual application of Ethrel at 300 mg·litre^{-1} (Table 4).

Experiment 3. Ethrel Applications to Bearing 'Fuji' and 'Empire' Trees.

Ethrel sprays applied to bearing 5-yr-old 'Fuji' trees at HRIO, Simcoe had a similar effect as that observed in Experiment 2, however, statistically the treatment differences were not different (Table 5). Dual or triple application of Ethrel at 150 mg·litre^{-1} or triple applications of NAA at 4 mg·litre^{-1} all significantly improved the return bloom of 5-yr-old 'Empire' trees (Table 6).

SUMMARY

Ethrel sprays can successfully be used to enhance the return bloom of non-bearing and bearing apple trees. Higher rates can be used on non-bearing trees since there is no concern of excessive fruit thinning. 'Northern Spy' was more responsive than 'Jonagold'. Single applications between 1000-1500 mg·litre^{-1} Ethrel are as effective as split applications at 50% of these rates. A reduction in tree growth can be expected in the season of application.

Ethrel sprays can also be used to enhance the return bloom of bearing apple trees. Lower rates of 150 or 300 mg·litre^{-1} significantly improved the return bloom of 'Empire' and 'Fuji', respectively. At least two applications are required to obtain

this benefit. Three sprays of NAA at 4 mg·litre^{-1} was effective for enhancing the return bloom of ‘Empire’ but not ‘Fuji’ or ‘Jonagold’.

Use of Ethrel sprays to increase the precocity of slow-to-bear cultivars such as ‘Northern Spy’ would have a positive impact on the economics of the apple orchard. As a means to regulate cropping and break the biennial bearing cycle, Ethrel sprays to ‘Fuji’, and ‘Empire’ trees will help to ensure a more consistent and uniform crop load. Further research is underway to evaluate these treatments on bearing ‘Northern Spy’ trees. Complete or partial loss of fruit in high-density apple plantings can result in excessive shoot growth that normally is controlled by cropping. Applications of Ethrel may be an additional management tool to regulate this excessive vigor.

LITERATURE CITED

Byers, R.E. 1993. Controlling growth of bearing apple trees with ethephon. HortScience 28:1103-1105.

Dennis, F.G. 1976. Gibberellin-like substance in apple seed and fruit flesh. J. Amer. Soc. Hort. Sci. 101:629-633.

Faust, M. 1989. Physiology of Temperate Zone Fruit Trees. John Wiley and Sons, New York.

Klein, J.D., and M. Faust. 1978. Internal ethylene content in buds and woody tissues of apple trees. HortScience 13:164-166.

Luckwill, L.C. 1970. The control of growth and fruitfulness of apple trees. “In Physiology of Tree Crops” pp. 247-254. L.C. Luckwill and C.V. Cutting, eds. Academic Press, New York.

Williams, M.W. 1981. In Reproduction Strategies in Plants. W. Meudt (ed). Allanheld. Osmum. Granada. London.

Williams, M.W. and L.J. Edgerton. 1981. Fruit thinning of apple and pears with chemicals. U.S. Dept. Agr. Information Bull. 289.

Table 1. Effect of early season Ethrel sprays applied at different concentrations and timings on yield and tree growth of 2-yr-old 'Jonagold' and 'Northern Spy' on M.9 rootstock planted in 1995. HRIO, Simcoe. Treatments applied in 1997.

Treatment[y]	Spray Date(s)	Number of blossom clusters on tree Spring 1998	Number of blossom clusters per cm^2 TCSA Spring 1998		Crop density (fruit/cm^2 TCSA) (Harvest 1998)		Yield (kg) 1998	Average Fruit Weight (g) 1998	Average shoot length (cm) Fall 1997		TCSA (cm^2) Fall 1997		Porp. increase in TCSA (('98-97) /'97)
JONAGOLD													
Untreated Control	-	84.6	16.6		3.0		5.6	235	23.1	a	4.8		0.80
1x 500 ppm Ethrel	7/5	93.8	20.8		3.6		5.7	220	19.8	b	4.4		0.74
1x 1000 ppm Ethrel	7/5	110.4	23.0		4.2		7.0	213	20.1	b	4.8		0.66
2x 500 ppm Ethrel	7/5,7/11	110.9	26.6		4.4		6.2	220	18.5	b	4.3		0.60
significance[z]		ns	ns		ns		ns	ns	**		ns		*
LSD (p=0.05)		40.0	7.7		1.2		2.2	23	2.7		0.7		0.14
NORTHERN SPY													
Untreated control		83.2	10.5	bc	4.1	bc	14.2	291	33.0		7.6	a	0.57
1x 500 ppm Ethrel		72.6	9.3	c	3.8	c	12.9	288	33.5		7.7	a	0.56
1x 1000 ppm Ethrel		88.2	12.1	ab	4.7	ab	14.1	281	30.9		7.2	ab	0.49
2x 500 ppm Ethrel		88.4	13.0	a	5.1	a	13.4	277	30.3		6.6	b	0.51
significance[z]		ns	**		*		ns	ns	ns		*		ns
LSD (p=0.05)		16.8	2.0		0.9		2.7	15	4.0		0.8		0.10

[z] ns, ***, **, *, indicates non significance and statistical significance at *P=0.001* , *P=0.01* , and *P=0.05* , respectively

[y] 1 ppm is equivalent to 1 $mg \cdot litre^{-1}$

Table 2. Effects of early season Ethrel sprays applied at different concentrations and timings on the number of blossom clusters the following spring on 1 year old 'Northern Spy' trees. Clarksburg. Treatments applied in 1997.

Treatment[y]	Spray Date	Number of blossom clusters per tree Spring 1998	TCSA (Spring 1998)	Number of blossom clusters per cm^2 TCSA		Number of blossom clusters per limb Spring 1998
Untreated Control	-	15.9	4.8	3.1	b	1.8
1 x 750 ppm Ethrel	7/6	26.8	5.2	5.1	ab	2.9
1 x 1500 ppm Ethrel	7/6	33.6	4.8	7.2	a	3.1
2 x 375 ppm Ethrel	7/6, 7/12	30.1	4.3	7.0	a	3.5
2 x 750 ppm Ethrel	7/6, 7/12	23.4	4.5	5.3	ab	2.6
significance[z]		ns	ns	*		ns
LSD (p=0.05)		13	0.7	2.7		1.5
CONTRASTS						
Control vs. Ethrel		*	ns	**		ns
750 vs. 1500 ppm Ethrel		ns	ns	ns		ns
1 spray vs. 2 sprays		ns	*	ns		ns
				Percent of Control		
Untreated Control		100	100	100		100
1 x 750 ppm Ethrel		169	108	165		161
1 x 1500 ppm Ethrel		211	100	232		172
2 x 375 ppm Ethrel		189	90	226		194
2 x 750 ppm Ethrel		147	94	171		144

[z] ns, ***, **, *, indicates non significance and statistical significance at *P=0.001* , *P=0.01* , and *P=0.05* , respectively

[y] 1 ppm is equivalent to 1 $mg \cdot litre^{-1}$

Table 3. Influence of sprays of Ethrel and NAA, applied at different times to 'Jonagold'/M.9 trees planted in 1991 on 1998 return bloom. Grimbsy. Treatments applied 1997.

Treatment[y]	Spray Date(s)	number of blossom clusters per branch 1998	number of blossom clusters per cm^2 LCSA 1998
Untreated Control	-	0.8	0.16
1 x 150 ppm Ethrel	7/5	1.6	0.36
2 x 150 ppm Ethrel	7/5, 7/11	1.7	0.34
3 x 150 ppm Ethrel	7/5, 7/11, 7/18	1.9	0.41
3 x 4 ppm NAA	7/5, 7/11, 7/18	1.7	0.29
significance[z]		ns	ns
LSD (p=0.05)		3.9	0.6
			Percent of Control
Untreated Control		100	100
1 x 150 ppm Ethrel		200	225
2 x 150 ppm Ethrel		213	213
3 x 150 ppm Ethrel		238	256
3 x 4 ppm NAA		213	181

[z] ns, ***, **, *, indicates non significance and statistical significance at *P=0.001* , *P=0.01* , and *P=0.05* , respectively

[y] 1 ppm is equivalent to 1 $mg \cdot litre^{-1}$

Table 4. Influence of sprays of Ethrel and NAA, applied at different times to 'Fuji'/M.9 trees planted in 1991 on 1998 return bloom. Grimsby. Treatments applied 1997.

Treatment[y]	Spray date(s)	Number of blossom clusters on limb		Number of blossom clusters per cm^2 LCSA	
Untreated Control	-	4.9	b	0.6	b
1 x 300 ppm Ethrel	7/5	5.5	b	1.0	b
2 x 300 ppm Ethrel	7/5, 7/11	12.8	a	1.5	ab
3 x 300 ppm Ethrel	7/5, 7/11, 7/18	16.3	a	2.5	a
3 x 4 ppm NAA	7/5, 7/11, 7/18	4.9	b	0.6	b
Significance[z]		**		*	
LSD (*p=0.05*)		6.9		1.3	
		Percent of Control			
Untreated Control		100		100	
1 x 300 ppm Ethrel		112		167	
2 x 300 ppm Ethrel		261		250	
3 x 300 ppm Ethrel		333		417	
3 x 4 ppm NAA		100		100	

[z] ns, ***, **, *, indicates non significance and statistical significance at *P=0.001* , *P=0.01* , and *P=0.05* , respectively

[y] 1 ppm is equivalent to 1 $mg \cdot litre^{-1}$

Table 5. Influence of sprays of Ethrel and NAA, applied at different times to 'Redsport Fuji'/M.9 trees planted in 1993 on 1998 return bloom. HRIO Simcoe. Treatments applied 1997.

Treatment[y]	Spray date(s)	Number of blossom clusters/ tree	Number of blossom clusters per cm2 TCSA
Untreated control	-	0.3	0.0
Hand thinned control	-	1.3	0.4
1 x 300 ppm Ethrel	7/5	1.7	0.8
2 x 300 ppm Ethrel	7/5, 7/10	1.9	0.8
3 x 300 ppm Ethrel	7/5, 7/10, 7/17	9.2	3.1
3 x 4 ppm NAA	7/5, 7/10, 7/17	4.9	1.5
Significance[z]		ns	ns
LSD (*p=0.05*)		6.6	2.3
		Percent of Control	
Untreated control		100	-
Hand thinned control		433	-
1 x 300 ppm Ethrel		567	-
2 x 300 ppm Ethrel		633	-
3 x 300 ppm Ethrel		3067	-
3 x 4 ppm NAA		1633	-

[z] ns, ***, **, *, indicates non significance and statistical significance at *P=0.001* , *P=0.01* , and *P=0.05* , respectively

[y] 1 ppm is equivalent to 1 $mg \cdot litre^{-1}$

Table 6. Influence of sprays of Ethrel and NAA, applied at different times to 'Empire'/M.9 trees planted in 1993 on 1998 return bloom. HRIO Simcoe. Treatments applied 1997.

Treatment[y]	Spray date(s)	Number of blossom clusters/ tree	Number of blossom clusters per cm2 TCSA	
Untreated control	-	34.9	4.7	b
Hand thinned control	-	52.4	7.3	ab
1 x 150 ppm Ethrel	7/5	48.7	6.6	ab
2 x 150 ppm Ethrel	7/5, 7/10	46.9	9.5	a
3 x 150 ppm Ethrel	7/5, 7/10, 7/17	61.4	8.2	a
3 x 4 ppm NAA	7/5, 7/10, 7/17	53.6	9.2	a
Significance[z]		ns	*	
LSD (*p=0.05*)		21.2	3.2	
			Percent of Control	
Untreated control		100	100	
Hand thinned control		150	155	
1 x 150 ppm Ethrel		140	140	
2 x 150 ppm Ethrel		134	202	
3 x 150 ppm Ethrel		176	174	
3 x 4 ppm NAA		154	196	

[z] ns, ***, **, *, indicates non significance and statistical significance at *P=0.001* , *P=0.01* , and *P=0.05* , respectively

[y] 1 ppm is equivalent to 1 $mg \cdot litre^{-1}$