

THINNING OF 'FUJI' APPLE TREES WITH ETHEPHON, NAD AND BA, ALONE AND IN COMBINATION

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A B S T R A C T

The aim of this study was to evaluate the effectiveness of several thinning agents in reducing fruit set in 'Fuji' apple trees. The agents tested were NAD, ethephon, and BA. BA was sprayed at two different times during the thinning period. Multiple sprayings with various combinations of these agents were also evaluated. Ethephon applied alone was the only treatment which significantly increased fruit count at harvest time. None of the treatments had a significant affect on yield, mean fruit weight, the number of first class fruits, or the number of pygmy fruits. Ethephon applied alone was the only treatment which significantly increased the number of second class fruits. All BA alone applications slightly reduced final fruit number and increased mean fruit weight, both not significant. Also BA applied alone significantly reduced the number of second class fruits, regardless of which formulation was used or when it was applied.

Key words: apple thinning, ethephon (2-chloroethylphosphonic acid), naphthaleneacetamid (NAD), benzyladenine (BA = N-phenylmethyl-H-purine-6-amine)

INTRODUCTION

Apple trees often form too many blossoms and set too many fruits to bear marketable crops year after year. Thinning blossoms or fruitlets improves fruit quality and return bloom, and has become a standard practice in the growing of many fruit crops (Wertheim, 1998).

Thinning apple fruitlets by hand is often impossible because of labor costs and the limited supply of

available labor. Therefore, chemical thinning has to be carried out to ensure profitable apple production.

Only a few thinning agents have been approved for use in apple orchards in the European Union.

Ethephon has long been used as a thinning agent. The main advantages of ethephon are that it greatly improves return bloom and that it can be applied over a longer period. However, the thinning effect of ethephon can vary considerably depending

on the temperature (Olien and Bukovac, 1982). Ethephon gives inconsistent results and can even cause over-thinning (Wertheim, 2000). For these reasons, it is not approved for use in many countries (Link, 1986).

Naphthaleneacetamide (NAD) has also long been in use. It acts as a synthetic auxin. NAD should be applied from the peak of the blossoming period to up to one week after the the end of the blossoming period (Westwood, 1993). NAD is considered to be a weak thinning agent which does not give satisfactory results if used alone. Trees thinned with NAD often have to be treated again later with another thinning agent (Schwallier, 1996). NAD cannot be used on 'Delicious' trees because it induces the formation of a high number of pygmy fruit which stay on the tree until harvest time (Wertheim, 2000).

Benzyladenine (BA) is a synthetic cytokine which has been recently found to be a good thinning agent. The main advantage of BA is that, in addition to acting as a thinning agent, it also increases fruit size by accelerating cell division. Apples from trees thinned with BA are therefore larger than would be expected on the basis of the thinning effect alone (Greene, 1993; Wismer et al., 1995). When used to thin 'Fuji' trees, BA is most effective when applied when the fruitlets are 10 mm in diameter. BA also improves return bloom (Robinson et al., 1998; Sally et al., 1991).

Newer apple varieties such as 'Gala' or 'Elstar' are often not very responsive to thinning agents. 'Fuji' is particularly resistant. Ethephon

had been used with some success in thinning 'Fuji' trees (Jones et al., 1991). NAD, on the other hand, strongly inhibits fruit growth in 'Fuji'. BA has given promising results with 'Fuji' when applied twenty days after the peak of the blossoming period (Sally et al., 1991).

Spraying with more than one thinning agent is sometimes recommended to ensure an adequate thinning effect and to limit the amount of each thinning agent used (Robinson et al., 1998). Repeated spraying with either one agent or a combination of agents is sometimes required when the first spraying does not result in adequate thinning (Dennis, 2000). Spraying two or three times is a good strategy because it increases the chances that at least one of the treatments is carried out under favorable weather conditions. Furthermore, multiple applications are safer because the treatments are generally less aggressive and the risk of over-thinning is lower (Greene, 2002).

'Fuji' is on its way to becoming the most marketable cultivar in the European Union. However, biennial bearing and small fruit size are still a serious problem for farmers who grow 'Fuji'.

The aim of this study was to evaluate the effectiveness of several thinning agents in reducing fruit set in 'Fuji' apple trees. The agents tested were NAD, ethephon, and BA. BA was sprayed at two different times during the thinning period. Multiple sprayings with various combinations of these agents were also evaluated. The experiment was carried out within the framework of

the EUFRIN Working Group for Chemical Fruit Thinning.

MATERIAL AND METHODS

Nine-year-old 'Fuji' apple trees were selected based on high blossom density and homogeneous growth vigor. The trees were grafted on M.9 rootstock and trained as slender spindles. The number of flower clusters per tree was counted to ensure the uniform blossoming intensity before the thinning protocols were implemented.

The experiment was carried out in a randomized block design with seven replications of one tree each. Pest control and other orchard management practices were the same for all the trees in the study.

The following thinning protocols were evaluated:

- 1) Hand thinning during the June fruit drop.
- 2) Ethephon 200 ppm (Ethrel 0.42 ml L⁻¹, Chromos Agro, Zagreb, Croatia), applied when 50% of the blossoms had opened.
- 3) NAD 100 ppm (Amid Thin 1.2 g L⁻¹, Isagro, Milano, Italy), applied at petal fall.
- 4) BA 150 ppm (VBC 7.5 ml L⁻¹, Valent Biosciences, IL, USA), applied early when the fruitlets were 9 mm in diameter.
- 5) BA 150 ppm (Gobbi 7.5 ml L⁻¹, Campo Ligure, Italy), applied early when the fruitlets were 9 mm in diameter.
- 6) BA 150 ppm (VBC 7.5 ml L⁻¹, Valent Biosciences, IL, USA), applied late when the fruitlets were 14 mm in diameter.

- 7) Ethephon + BA: Treatment 2, followed by Treatment 6.
- 8) NAD + BA: Treatment 3, followed by Treatment 6.
- 9) Control (no thinning).

Spraying was carried out with a hand sprayer. No surfactant was used.

At harvest, fruits were counted, weighed and sorted into three size classes: first class (> 70 mm), second class (45 to 70 mm), and pygmy (< 45 mm).

All data were elaborated by analysis of variance, followed by means separation using Duncan's multiple-range t-test at P≤0.05. Analysis of covariance was carried out using either the number of flower clusters per tree or the number of flower clusters per cm² trunk cross-sectional area (TCSA) in order to reduce the effect of flower density on fruit count and fruit size at harvest time. All calculations were performed using the Statgraphics 5.0 software package (STSC, Rockville, IL, USA).

RESULTS AND DISCUSSION

The number of flower clusters per tree and the number of flower clusters per cm² TCSA cross-sectional area showed homogeneity before the treatment protocols were implemented (Tab. 1).

Only light hand thinning (Treatment 1) needed to be carried out because the fruit set that year was not over-abundant. Therefore, all results obtained with hand thinning were not significantly different from the control values (Tab. 1 and 2).

Table 1. Number of blossom clusters before thinning and fruit count at harvest time in 'Fuji' apple trees subjected to different thinning protocols

Treatment	Flower clusters		Fruit at harvest time		
	number per tree	number per cm ² TCSA	number per tree	number per 100 flower clusters	number per cm ² TCSA
1) Hand thinning	118 a*	12.4 a	69 ab	61 ab	7.25 ab
2) Ethephon alone	108 a	10.4 a	91 b	81 b	8.50 b
3) NAD alone	110 a	10.6 a	72 ab	63 ab	6.91 ab
4) BA (Valent) early	114 a	12.3 a	47 a	42 a	4.88 a
5) BA (Gobbi) early	114 a	12.7 a	59 a	54 a	6.72 ab
6) BA (Valent) late	117 a	14.1 a	56 a	48 a	5.29 a
7) Ethephon + BA	111 a	11.1 a	47 a	43 a	5.08 a
8) NAD + BA	120 a	10.9 a	70 ab	60 ab	6.63 ab
9) Control (no thinning)	110 a	14.8 a	73 ab	64 ab	8.18 b

*Means followed by the same letter are not significantly different with Duncan's multiple-range t-test at $P \leq 0.05$

Table 2. Yield, mean fruit weight and fruit size distribution per tree at harvest time in 'Fuji' apple trees subjected to different thinning protocols

Treatment	Yield [kg/tree]	Mean fruit weight [g]	Number of first class fruits per tree	Number of second class fruits per tree	Number of pygmy fruits per tree
1) Hand thinning	10.0 ab*	147 a	33 a	35 abc	0.8 a
2) Ethephon alone	13.0 b	147 a	38 a	51 c	1.6 a
3) NAD alone	11.3 ab	158 a	44 a	27 abc	0.3 a
4) BA (Valent) early	8.2 a	169 a	30 a	14 a	2.3 a
5) BA (Gobbi) early	10.7 ab	180 a	46 a	13 a	0.6 a
6) BA (Valent) late	9.1 ab	162 a	40 a	14 a	1.4 a
7) Ethephon + BA	7.9 a	173 a	30 a	16 ab	1.3 a
8) NAD + BA	11.0 ab	156 a	42 a	27 abc	1.6 a
9) Control (no thinning)	10.7 ab	147 a	31 a	41 bc	0.9 a

*Explanations, see Table 1

Ethephon (Treatment 2) did not reduce fruit set. In fact, the fruit count at harvest time was higher with ethephon than in the control, although the difference was not significant (Tab. 1).

In a previous study using 'Fuji' apple trees, satisfactory thinning was obtained when ethephon was sprayed at a dose of 400 ppm (Jones et al., 1991). However, in another study, ethephon caused over-thinning when applied at a dose of 400 ppm when the trees were in the balloon stage (Stopar and Tojnko, 2005). The main disadvantage of ethephon is that the results obtained after spraying are highly inconsistent and difficult to predict (Wertheim, 2000; Link, 1986).

When used alone, ethephon had no significant effect on mean fruit weight and fruit size distribution (Tab. 2). Ethephon also had no significant effect on fruit growth in this study. In other studies, however, ethephon was found to inhibit fruit growth (Ebert and Bander, 1986; Stopar, 2000).

NAD (Treatment 3) did not reduce fruit set (Tab. 1). NAD also had no effect on fruit growth, and did not cause an increase in the proportion of pygmy fruit as compared to the control (Tab. 2). In a study carried out the year before on 'Fuji' apple trees growing in the same orchard, NAD was applied at the same dosage and at approximately the same time as in this study. NAD was found to have no significant thinning effect, although it inhibited fruit growth and increased the proportion of pygmy fruits (Stopar and Tojnko, 2005). NAD applied alone can not be recommended for thinning 'Fuji' apple trees.

BA (Treatments 4, 5 and 6) reduced fruit count at harvest time, regardless of which formulation was used or when it was applied (Tab. 1). BA also increased fruit weight, although the difference was not significant (Tab. 2). There were no significant differences in effect between the two formulations tested, or between early treatment and late treatment. There was a significant reduction in the number of second class fruits with all three treatments, although no significant change in the number of first class fruits was observed (Tab. 2).

In a previous study, BA was found to be an effective thinning agent for use on apple trees when applied at 50 and 100 ppm (Greene, 1993). In another study, BA was found to be effective in thinning 'Fuji' apple trees when applied twenty days after the peak of the blossoming period (Sally et al., 1991). BA caused over-thinning in 'Elstar' when applied at a dose of 200 ppm when the fruitlets were 10 mm in diameter (Stopar and Zadravec, 2003).

Because BA effectively reduces fruit set, it can be expected to improve return bloom.

Ethephon in combination with BA (Treatment 7) reduced fruit set to about the same level as BA alone (Tab. 1). There was a slight reduction in yield, although the difference was not significant. The number of first class fruits was about the same as in the control. The number of second class fruits was slightly lower than in the control, although the difference was not significant (Tab. 2).

In an earlier study, there was also generally no difference between

spraying ethephon (200 ppm) in combination with BA (200 ppm) and spraying BA (200 pm) alone, except with 'Elstar', in which fruit set was much lower after the combination treatment than after spraying with BA alone (Stopar and Zadavec, 2003). In an earlier study on 'Empire' apple trees, crop load was significantly lower and fruit size was significantly larger when different thinning agents were applied in combination at different times than when one thinning agent was applied only once (Stover et al., 2002).

NAD in combination with BA (Treatment 8) had no significant effect on fruit set or fruit size at harvest time (Tab. 1 and 2).

In conclusion, ethephon applied alone was the only treatment which significantly increased fruit count at harvest time. None of the treatments had a significant affect on yield, mean fruit weight, the number of first class fruits, or the number of pygmy fruits. Ethephon applied alone was the only treatment which significantly increased the number of second class fruits. BA applied alone significantly reduced the number of second class fruits, regardless of which formulation was used or when it was applied. The number of pygmy fruits observed in this study was low with all of the treatment protocols evaluated.

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PRZERZEDZANIE NA JABŁONIACH ODMIANY 'FUJI' ZA POMOCĄ ETEFONU, NAA I BA, STOSOWANYCH ODDZIELNIE I W KOMBINACJACH

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S T R E S Z C Z E N I E

Celem badań była ocena wpływu kilku preparatów przerzedzających zawiązki na redukcję zawiązywania owoców jabłoni odmiany 'Fuji'. Oceniano preparaty NAD, etefon i BA. Benzyloadeniną opryskiwano jabłonie w okresie przerzedzania w dwóch różnych terminach. Oceniano także skutki wielokrotnego opryskiwania drzew preparatami.

Stwierdzono, że żaden z zabiegów nie wpłynął istotnie na plon, przeciętną wielkość owoców, liczbę owoców pierwszego wyboru i liczbę owoców bardzo małych zwanych pigmejami. Natomiast etefon zastosowany oddzielnie, spowodował istotny wzrost liczby jabłek na drzewach opryskiwanych i istotnie zwiększył liczbę jabłek drugiego wyboru. Wszystkie traktowania samą BA spowodowały nieznaczną redukcję liczby jabłek i nieistotny przyrost przeciętnej masy jabłka. Traktowanie benzyloadeniną oddzielnie także istotnie redukowało liczbę jabłek drugiego wyboru, niezależnie od formulacji preparatu i terminu opryskiwania drzew.

Słowa kluczowe: Przerzedzanie jabłoni, etefon (kwas 2-chloroetylofosforowy), amid kwasu 1-naftylooctowego (NAD), benzyloadenina (BA= N-fenylometyl-H-purino-6-amina)