

## THINNING 'GOLDEN DELICIOUS' APPLES USING SINGLE OR COMBINING APPLICATION OF ETHEPHON, NAA OR BA

### REDČENJE PLODIČEV JABLANE PRI SORTI 'ZLATI DELIŠES' Z UPORABO ETEFONA, NAA IN BA TER NJIHOVIH KOMBINACIJ

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Manuscript received: February 9, 2007; Reviewed: March 1, 2007; Accepted for publication: July 13, 2007

#### ABSTRACT

Thinning of 'Golden Delicious' apples was studied after single application of ethephon 200 ppm at the balloon stage, of naphthaleneacetic acid (NAA) 10 ppm or benzyladenine (BA) 100 ppm at 10 mm fruit diameter, after sequential application of ethephon followed by NAA or/and BA or tank mixed NAA + BA application. The single application of ethephon, NAA or BA, as well as the sequential application of ethephon applied first at the balloon stage and NAA or BA applied at 10 mm fruitlet diameter did not cause a significant reduction of final crop load nor did it cause an increase of the mean fruit weight. The treatment of tank mixed application NAA + BA at 10 mm fruit diameter and, similarly, the treatment of sequential spray of ethephon followed by tank mixture of NAA + BA had both a significant effect on thinning in the studied year with the significant reduction of final fruit retention and the significant enhancement of fruit weight. No additional thinning due to the ethephon application happened in the sequential treatments when ethephon was applied first and NAA + BA mixture was applied afterward.

**KEYWORDS:** apple thinning, ethephon, 1-naphthaleneacetic acid, 6-benzyladenine

#### IZVLEČEK

Proučevali smo redčenje plodičev jablane pri sorti 'Zlati delišes' pri samostojni aplikaciji sredstev za redčenje plodičev (etefon 200 ppm v stadiju balona, NAA 10 ppm ali BA 100 ppm v stadiju velikosti plodičev 10 mm) ter pri kombiniranih aplikacijah sredstev, kjer je bil najprej apliciran etefon, nato pa še NAA ali BA, kjer sta bila NAA in BA združena v škropilni mešanici in kjer je aplikaciji etefona nato sledila še aplikacija NAA in BA združena v škropilni mešanici. Samostojna aplikacija etefona 200 ppm v stadiju balona, kakor tudi samostojna aplikacija NAA 10 ppm oziroma BA 100 ppm v stadiju velikosti plodičev 10 mm ni imela statistično značilnega vpliva na redčenje plodičev, ker ni povzročila značilnega zmanjšanja števila plodov ob obiranju, kakor tudi ne značilnega povečanja velikosti plodov. Podoben rezultat brez statistično značilnega učinka na redčenje plodičev je bil dobljen pri obravnavanjih s kombinacijo sredstev, kjer je bil najprej apliciran etefon v balonskem stadiju, nato pa še NAA oziroma BA pri velikosti plodičev 10 mm. Edini statistično značilen vpliv na redčenje plodičev je bil dosežen pri obravnavanju, kjer so bila sredstva NAA in BA nanešena skupaj kot škropilna mešanica pri velikosti plodičev 10 mm, kakor tudi pri obravnavanju z zaporedno kombinacijo sredstev, najprej etefona, nato pa NAA + BA v škropilni mešanici. Iz rezultatov kombiniranih nanosov je razvidno, da predhodni nanos etefona v času cvetenja ni imel vpliva na kasnejša redčenja z NAA ali BA, niti kadar sta bila nanešena samostojno, niti kadar sta bila nanešena kot škropilna mešanica.

**KLJUČNE BESEDE:** redčenje plodičev jablane, etefon, 1-naftilocetna kislina, 6-benziladenin

## DETAILED ABSTRACT / RAZŠIRJEN IZVLEČEK

V intenzivni pridelavi jabolk je kemično redčenje plodičev osnovni tehnološki ukrep, ki omogoča redne pridelke visoke kakovosti in preprečuje izmenično rodnost. Vsekakor pa je ukrep kemičnega redčenja zelo kompleksen in je predmet številnih raziskovanj, saj je njegova učinkovitost zelo odvisna od vremenskih razmer, sorte, bujnosti drevesa, časa tretiranja, uporabljenega sredstva za redčenje in njegove koncentracije ter še drugih dejavnikov. Cilj našega proučevanja je bilo ugotoviti učinkovitost nekaterih sredstev za redčenje plodičev (etefon, NAA in BA) pri pomembni sorti 'Zlati delišes', če so uporabljena samostojno ali v medsebojni kombinaciji. Nekateri raziskovalci poročajo namreč o močnejšem učinku redčenja, če so različna sredstva uporabljena v kombinaciji, to je zaporedoma v različnih fenoloških fazah rastline ali združeno v škropilni mešanici.

Raziskava ugotavljanja stopnje abscisije plodičev je potekala na šestletnih drevesih sorte 'Zlati delišes'/M.9 pri naslednjih obravnavanjih: 1) brez redčenja – kontrola, 2) ročno redčenje, 3) etefon 200 ppm, 4) NAA 10 ppm, 5) BA 100 ppm, 6) etefon 200 ppm + NAA 10 ppm, 7) etefon 200 ppm + BA 100 ppm, 8) NAA 10 ppm + BA 100 ppm – škropilna mešanica, 9) etefon 200 ppm + (NAA 10 ppm + BA 100 ppm – škropilna mešanica). Etefon je bil apliciran v stadiju balona, medtem ko sta bila NAA in BA nanešena v stadiju velikosti plodičev 10 mm. Ročno redčenje plodičev je bilo opravljeno ob koncu junijskega trebljenja. Za poskus izbrana drevesa so bila podobne bujnosti, s homogenim cvetnim nastavkom, to je s 160-180 cvetnimi šopi na drevo. Statistična zasnova je bila naključni blok z osmimi ponovitvami, pri čemer je posamezno drevo predstavljalo statistično enoto. Ob obiranju smo plodove prešteli, jih stehali ter jih glede na njihov premer razdelili v razreda manjših ali večjih od 70 mm.

Samostojna aplikacija etefona 200 ppm v stadiju balona, kakor tudi samostojna aplikacija NAA 10 ppm oziroma BA 100 ppm v stadiju velikosti plodičev 10 mm ni imela statistično značilnega vpliva na redčenje plodičev, saj ni povzročila značilnega zmanjšanja števila plodov ob obiranju, kakor tudi ne značilnega povečanja velikosti plodov (preglednici 1 in 2). Podoben rezultat brez statistično značilnega učinka na redčenje plodičev je bil dobljen pri obravnavanjih s kombinacijo sredstev, kjer je bil najprej apliciran etefon v balonskem stadiju, nato pa še NAA oziroma BA pri velikosti plodičev 10 mm. Pričakovati je bilo, da bo nanos etefona povzročil delno odpadanje cvetja, dodatno zmanjšanje rodne nastavka pa bo doseženo z aplikacijo NAA ali BA, vendar se to ni zgodilo. Edini statistično značilen vpliv na redčenje plodičev je bil dosežen pri obravnavanju, kjer so bila

sredstva NAA in BA nanešena skupaj, pomeni aplicirana kot škropilna mešanica pri velikosti plodičev 10 mm. Podobno statistično značilno redčenje je bilo opaženo tudi pri obravnavanju z zaporedno kombinacijo sredstev, najprej etefona v balonskem stadiju, nato pa NAA + BA v škropilni mešanici pri velikosti plodičev 10 mm. Pri obeh obravnavanjih z mešanico NAA + BA je bilo število plodov ob obiranju statistično značilno manjše od števila plodov na kontrolnih (neredčenih) drevesih, masa plodov pa je bila statistično značilno večja (preglednici 1 in 2). Iz rezultatov kombiniranih nanosov je razvidno, da predhodni nanos etefona v času cvetenja ni imel vpliva na kasnejša redčenja z NAA ali BA, niti kadar sta bila nanešena samostojno, niti kadar sta bila nanešena kot škropilna mešanica.

## INTRODUCTION

Apple (*Malus x domestica* Borkh.) is a biennial bearing tree. This is characterized by heavy bloom and heavy set of fruit throughout the growing season with several negative consequences associated with small, poorly coloured, low quality fruits. Furthermore, flower bud formation for the following year is significantly reduced, resulting in low cropping and inferior quality fruit that has a reduced postharvest storage life. Thinning of the fruitlets is the removal of a portion of the crop before it matures on the tree to increase the marketability of the remaining fruit and to break the biennial bearing tendency of the tree [9].

Chemical thinning is an economic necessity for regular cropping of quality fruit. Chemical thinners and their concentrations, the timing of their application, the environmental factors encountered before, during and after application as well as tree factors, they all influence the ultimate thinning response. Naphthaleneacetic acid (NAA) is an auxin-type thinner and was the first hormone-type thinner used commercially. Its thinning action is not reliable enough since it is much dependent on climatic conditions and on cultivar sensitivity as well [20]. Another negative side-effect is that NAA application may not increase fruit size even though the thinning response occurred and crop load is substantially reduced [15, 1, 17]. Thinning with NAA could cause severe fruit growth inhibition known as 'pygmy' fruit on Red 'Delicious' [10] or 'Fuji' apples [12]. Some reports indicated that higher concentrations or late applications of NAA tend to depress the fruit size [10, 3]. Ethephon induces the biosynthesis of plant hormone ethylene which stimulates abscission. Ethephon is considered more as a flower thinner but it is also characterized as an inconsistent thinning agent. Part of this can be attributed to a temperature dependent

thinning response; its effectiveness also depends on cultivar and on flower/ fruitlets stage of development [19]. In some years ethephon may cause overthinning [14]. Ethephon has demonstrated a good effect on return bloom in the following spring [11, 16]. The newest, promising thinner introduced to regulate cropping level is cytokinin benzyladenine (BA), although it is still not registered in many EU countries. Several reports indicated that BA is an effective thinner of many apple cultivars [7, 6] and it is most effective if applied when fruit diameter averages about 10 mm [8]. BA reduced the crop load, increased the fruit size and enhanced the return bloom. It caused a greater increase in fruit size than an equal reduction in crop load caused by other thinning agents [5]. BA contributed to larger fruit size by increasing the number of cells per fruit through the stimulation of cell division [21].

Combinations of thinning agents may cause stronger thinning response than the compounds used separately [19]. Combining of BA and NAA caused overthinning of 'Empire' or resulted in higher percentage of small fruits in Redchief 'Delicious' if compared to BA and NAA used as single sprays [4]. Overthinning occurred if 'Jonagold' was thinned with NAA 10 ppm followed by ethephon 50 ppm while the same applications thinned 'Pink Lady' much lighter [13]. Another experiment of the same report demonstrated that the ethephon treatment followed by BA reduced crop load for both cultivars substantially but was the most effective regarding the increase in fruit growth and fruit quality (higher fruit soluble solids and fruit firmness).

The objective of the study reported here was to evaluate the effectiveness of the most commonly used thinning agents (NAA, BA, ethephon) as applied separately on hard to thin, important cultivar 'Golden delicious' and to study the possible enhancement of thinning response if thinning agents were applied in sequence or as tank mix spray.

## MATERIALS AND METHODS

The experiment was conducted on six years old trees of 'Golden delicious'/M.9, spaced at 3 x 1 m in the north-south rows and trained to a slender spindle form. Standard commercial practices for fertilization and pest control were followed during the experiment. Selected trees were of similar growth vigor and bloom density, approximately 160-180 flower clusters per tree. The experiment was designed as a complete randomized block with eight replications of single tree experimental units per treatment. The treatments consisted of:

- 1) Non thinned
- 2) Hand thinned
- 3) Ethephon 200 ppm (4.2 mL Ethrel / 10 L water - Chromos, Zagreb, Croatia)
- 4) NAA 10 ppm (2.5 mL Nokad / 10 L water - Isagro, Mozanica, Italy)
- 5) BA 100 ppm (56 mL VBC 30001 / 10 L water - Valent Biosciences Corp. IL, USA)
- 6) Ethephon 200 ppm + NAA 10 ppm
- 7) Ethephon 200 ppm + BA 100 ppm
- 8) NAA 10 ppm + BA 100 ppm (tank mix)
- 9) Ethephon 200 ppm + (NAA 10 ppm + BA 100 ppm (tank mix))

Spray treatments were performed to the drip point with a hand sprayer to whole trees. Ethephon was applied at the balloon stage while NAA and BA were applied at 10 mm fruit diameter. In treatments where ethephon was in combination with NAA or BA, ethephon was applied first at the balloon stage and then NAA or BA was applied when fruit diameter reached 10 mm. Hand thinned treatment was done at the end of June drop. Fruits were collected at harvest, counted, weighted and graded by diameter into two classes (<70mm, >70mm). Data were subjected to analysis of variance (ANOVA) using the statistical program Statgraphics 5.0 (STSC, Rockville, USA). ANOVA was calculated as randomized complete block design and means were separated using Duncan's multiple range test at P= 0.05.

## RESULTS AND DISCUSSION

Hand thinning performed at the end of June drop resulted in a reduced final number of fruit per tree and an increased mean fruit weight, but they were not significant. Hand thinning should be done more rigorously to reach the commercial fruit size about 150 g per fruit.

Spraying of ethephon at 200 ppm at the balloon stage slightly reduced the fruit number per tree at harvest time while the fruit size remained almost the same compared to the non thinned control trees (Table 1, 2); this means that ethephon sprayed alone in this concentration and stage of flower development did not have any thinning effect. Similar conclusions were obtained for 'Summerred' treated with the same concentration of ethephon [17]. On the other hand, 'Golden Delicious' treated with ethephon (350 ppm) at the balloon stage caused a satisfactory thinning of fruit by decreasing the fruit set and increasing the fruit weight as well as the number of fruits larger than 70 mm [11].

The alone application of NAA 10 ppm and BA 100 ppm at 10 mm fruitlet diameter in this experiment did not

cause a satisfactory thinning response since they had little effect on the final crop load (number of fruit/tree, number of fruit/100 clusters, number of fruit/cm<sup>2</sup>) and the mean fruit weight as well as larger sized yield did not increase significantly compared to the non-thinned trees (Table 1, 2). The results obtained in this study with BA sprayed alone did not support the findings contained in many reports which indicated that BA at this concentration significantly reduced the crop load and increased the fruit weight of different apple cultivars [7, 2, 21, 17]. Weather or tree factors could be the reason for such inconsistent thinning response, a phenomenon normally known also to other thinners.

Similar thinning response as described for the separate applications happened when treatments of sequential application of ethephon 200 ppm and NAA 10 ppm or sequential application of ethephon 200 ppm and BA 100 ppm were performed (Table 1, 2). It was presumed that ethephon would cause some thinning effect in the first place and then BA or NAA would cause additional thinning, but this did not happen.

The tank mix application of NAA 10 ppm + BA 100 ppm significantly reduced the final fruit retention almost to the half and increased the fruit weight, consequently, it influenced significantly the reduction of the total

yield (Table 1, 2). Similar findings of independent and additive thinning response when BA and NAA were tank mixed were reported by Elfving and Cline [1993]. The combination spray of two chemical thinners which thinned more effectively than the individual compounds was also reported by Greene et al. [1990] and Bukovac, et al. [1994]. It seems that this tank mix application of NAA + BA had a strong, significant effect on the thinning even in the year unfavorable for apple thinning.

Sequential spray of ethephon at balloon stage followed by a mixture of NAA + BA applied at 10 mm fruitlet diameter was the most appropriate treatment in this experiment with a significant thinning effect that reduced the fruit number per tree, significantly enhanced the fruit growth and increased the yield of larger fruit class with little effect on final yield (Table 1, 2). However, with regard to the thinning results, this treatment was similar to the previous NAA + BA tank mixed application treatment. If the last two treatments are compared, the preceding application of ethephon did not increase the thinning intensity of NAA + BA mixture applied later. The same treatment of ethephon followed by the tank mixed application of NAA and BA resulted in the strongest thinning effect on 'Summerred' [18].

Table 1: The number of flower clusters per tree when starting the experiment and the final fruit retention at harvest in 'Golden Delicious'/M.9 thinning experiment.

Preglednica 1: Število cvetnih šopov ob začetku poskusa ter število plodov ob obiranju pri poskusu redčenja sorte 'Zlati delišes/M.9.

Treatment *	Flower clusters		Fruit (final)		
	no./tree	no./cm <sup>2</sup>	no./tree	no./100 clusters	no./cm <sup>2</sup>
1) No thinning	162 a	15,5 a	130 c	81 c	12,3 c
2) Hand thin	179 a	15,7 a	108 bc	60 abc	9,3 b
3) Ethephon 200 ppm	180 a	16,7 a	118 bc	67 abc	10,7 bc
4) NAA 10 ppm	171 a	14,6 a	125 bc	75 bc	10,6 bc
5) BA 100 ppm	174 a	15,2 a	113 bc	66 abc	10,1 bc
6) Ethephon 200 ppm + NAA 10 ppm	171 a	16,3 a	104 abc	62 abc	9,6 bc
7) Ethephon 200 ppm + BA 100 ppm	175 a	15,7 a	116 bc	66 abc	10,4 bc
8) NAA 10 ppm + BA 100 ppm	167 a	14,3 a	76 a	46 a	6,4 a
9) Ethephon + (NAA + BA)	172 a	15,5 a	95 ab	55 ab	8,5 ab

\* Mean separation within column by Duncan's multiple range test, P = 0.05.



Table 2: Yield and fruit size parameters at harvest in 'Golden Delicious'/M.9 thinning experiment.  
Preglednica 2: Pridelek in parametri velikosti plodov ob obiranju pri poskusu redčenja sorte 'Zlati delišes/M.9.

Treatment *	Yield (kg/tree)	Mean fruit weight (g)	Fruit > 70mm (kg/tree)	Fruit number > 70mm
1) No thinning	14,4 b	114 a	5,7 ab	37 ab
2) Hand thin	13,6 ab	127 ab	7,7 abc	52 ab
3) Ethephon 200 ppm	12,8 ab	110 a	4,5 a	32 a
4) NAA 10 ppm	14,8 b	125 ab	8,3 bc	51 ab
5) BA 100 ppm	13,6 ab	121 a	6,8 abc	51 ab
6) Ethephon 200 ppm + NAA 10 ppm	12,6 ab	124 a	5,9 ab	40 ab
7) Ethephon 200 ppm + BA 100 ppm	14,8 b	128 abc	7,7 abc	54 ab
8) NAA 10 ppm + BA 100 ppm	11,0 a	147 c	8,2 bc	49 ab
9) Ethephon + (NAA + BA)	13,4 ab	144 bc	9,7 c	60 b

\* Mean separation within column by Duncan's multiple range test,  $P = 0.05$ .

## CONCLUSIONS

Single application of thinning agents ethephon 200 ppm at balloon stage and NAA 10 ppm or BA 100 ppm at 10 mm fruitlet diameter did not cause thinning response of 'Golden delicious'/M.9 in this experiment. Similar results of insignificant thinning were obtained when treatments of sequential application of ethephon applied first and NAA or BA applied 10 days later were performed, although additional fruit abscission was expected by the sequential use of thinning agents. Tank mixed application of NAA + BA at 10 mm fruit diameter and, similarly, the treatment of sequential spray of ethephon followed by tank mixture of NAA + BA, had both a significant effect on thinning in the studied year. Furthermore, it was observed that no additional thinning due to the ethephon application happened when ethephon was applied first and NAA + BA mixture was applied afterward. Likewise, no additional abscission occurred when ethephon was followed by single application of NAA or BA.

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