

Fruit thinning of 'Gala' apple trees using ethephon, NAA, BA and their combinations

Prorjeđivanje plodova jabuke sorte 'Gala' pomoću ethephona, NAA i BA te njihovih kombinacija

M. Stopar, S. Tojanko, B. Ambrožič Turk

ABSTRACT

The thinning response was studied on six years old trees of 'Gala'/M.9. The treatments of 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 as well as the sequential treatments of ethephon followed by NAA or/and BA and tank mixed NAA + BA treatment were performed. A non significant thinning was obtained in treatments when ethephon, NAA and BA were used separately. No additional thinning occurred even in the combinations when ethephon was applied first at the balloon stage and NAA or BA applied later at 10 mm fruitlet diameter. Significant thinning response occurred only when tank mixed treatment of NAA + BA and sequential treatment of ethephon followed by tank mixture of NAA + BA were carried out. In this experiment, mean fruit weight and the share of bigger sized fruits (>70mm) increased significantly in all thinning treatments compared to the non thinned control trees.

Key words: apple thinning, fruit size, yield, ethephon, 1-naphthaleneacetic acid, 6-benzyladenine

SAŽETAK

Proučavali smo odaziv prorjeđivanja na šest godina starim stablima sorte 'Gala'/M.9. Izvedeni su postupci pojedinačnih aplikacija etefona 200 ppm u fenofazi crvene glavice, naftiloctene kiseline (NAA) 10 ppm ili benziladenina (BA) 100 ppm kada je promjer ploda iznosio 10 mm kao i uzastopni postupci etefonom nakon čega je slijedila NAA, odnosno BA ili u tanku pomiješani NAA + BA. Prorjeđivanje nije bilo signifikantno kod postupaka, u kojima su etefon, NAA i BA primijenjeni pojedinačno. Do dodatnog prorjeđivanja nije došlo ni u postupcima kada je etefon primijenjen najprije u balonskom stadiju, a NAA ili BA primijenjeni kasnije, kada je promjer plodova iznosio 10 mm. Signifikantan odaziv na prorjeđivanje dogodio se samo kada je izveden postupak s u tanku pomiješanim NAA + BA i uzastopni postupak etefonom nakon čega su slijedili u tanku pomiješani NAA + BA. U tom pokusu prosječna težina

plodova i udio većih plodova (> 70 mm) signifikantno su se povećali kod svih postupaka prorjeđivanja u usporedbi s neprorjeđivanim stablima kontrole.

Ključne riječi: prorjeđivanje plodova jabuke, veličina plodova, prinos, etefon, 1-naftiloctena kiselina, 6-benziladenin

INTRODUCTION

Apple (*Malus x domestica* Borkh.) is a biennial bearing tree. An excessive crop in one year usually results in a smaller crop the next year. The application of blossom or fruitlet thinners is an essential part of the commercial apple production to improve fruit size at harvest and fruit quality characteristics, to increase return bloom, thereby reducing the biennial bearing habit of apple trees (Wertheim, 1997).

Chemical thinning response depends on many factors such as treated variety, the type and concentration of the chemical thinner used, the environmental factors during and after application, tree factors, the timing of application, etc. Naphthaleneacetic acid (NAA) and ethephon have been widely used chemicals for apple thinning for many years, although they both give variable results in thinning response. Part of this can be attributed to a weather/temperature dependent thinning response and to cultivar sensitivity as well (Wertheim, 2000). The effectiveness of ethephon also depends on flower/fruitlets stage of development (Wertheim, 1997; Greene, 2002). Ethephon has demonstrated a good effect on return bloom in the following spring (Jones et al., 1983; Stopar, 2000). A disadvantage of NAA could also be its negative effect on fruit growth since NAA application may not increase the fruit size even though the thinning response occurred and crop load is substantially reduced (Ferree, 1996; Link, 2000; Stopar and Lokar, 2003). Some reports indicate that higher concentrations or late applications of NAA tend to depress the fruit size (Greene, 1943; Bound, 2001).

Cytokinin benzyladenin (BA) was found to be more consistent and effective thinning compound for several apple cultivars, since it reduced the crop load, increased the fruit size and had a positive influence on the return bloom (Greene et al., 1990; Ferree, 1996). BA had shown to increase fruit size even in the absence of fruit thinning (Link, 2000). BA contributed to larger fruit size through an increased cell division rate in the fruit cortex (Wismer et al., 1995). It caused a greater increase in fruit size than an equal reduction in crop load caused by other thinning agents (Elfving and Cline, 1993; Ferree, 1996). It was the most effective if applied when fruit diameter averaged about 10 mm (Greene, 1993).

Combinations of thinning agents may cause stronger thinning response than the compounds used separately (Wertheim, 1997). Combining BA and NAA caused overthinning of 'Empire' (Bukovac et al., 1994). In contrast, no additive thinning response was observed by Stopar, (2002), when tank mix spray of NAA and BA was applied to 'Gala' and 'Golden Delicious' if compared to single applications of both compounds. The combination of NAA and BA increase the fruit size of 'Summerred' as reported by Stopar and Lokar, (2003), while these spray combinations inhibit the fruit growth in Redchief 'Delicious' (Bukovac et al., 1994) and in 'Fuji' apples (Stopar and Tojnko, 2005).

The aim of this study was to estimate the thinning effect of ethephon, NAA and BA on hard to thin cultivar 'Gala' used separately or in combination applied in sequence or as tank mix spray.

MATERIALS AND METHODS

The experiment was conducted in a commercial orchard in the north-eastern part of Slovenia. Six years old trees of 'Gala'/M.9 were spaced at 3 x 1 m in the north-south oriented rows and trained to a slender spindle form. Selected trees had similar growth vigor and homogeneous bloom density, approximately 165-185 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 included were the following:

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))

The spraying was done with a hand sprayer to the drip point to whole trees. No surfactant was used. Ethephon was applied at the balloon stage while NAA and BA were applied at 10 mm fruit diameter. In combination treatments, 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. At maturity time fruits were harvested twice, counted, weighed and graded by diameter into two sized classes (<70mm, >70mm). Data were analysed using the procedure for analysis of variance (ANOVA) of 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 significantly reduced the final fruit number per trunk cross sectional area of tree (Table 1) and enhanced the fruit weight compared to non thinned trees (Table 2).

Table 1: Final fruit number per trunk cross sectional area, yield and fruit size distribution at harvest in 'Gala'/M.9 thinning experiment.

Tablica 1: Konačan broj plodova po presjeku debla, prinos i količina plodova većih od 70 mm kod berbe pokusa prorjeđivanja sorte 'Gala'/M.9.

Treatment *	Fruit - final (no./cm ²)	Yield (kg/tree)	Fruit > 70mm (kg/tree)	Fruit number > 70mm
1) No thinning	11,2 cd	10,0 ab	3,0 a	21 a
2) Hand thin	6,9 a	9,3 a	7,6 bc	46 b
3) Ethephon 200 ppm	9,8 bc	11,9 bcd	7,2 b	46 b
4) NAA 10 ppm	10,6 cd	11,7 bcd	7,7 bc	49 bc
5) BA 100 ppm	11,9 d	13,2 d	7,2 b	48 bc
6) Ethephon 200 ppm + NAA 10 ppm	9,9 bc	13,3 d	10,1 c	63 bc
7) Ethephon 200 ppm + BA 100 ppm	9,9 bc	13,1 cd	10,4 c	64 c
8) NAA 10 ppm + BA 100 ppm	8,3 ab	11,0 abc	8,4 bc	50 bc
9) Ethephon + (NAA + BA)	8,3 ab	10,8 ab	9,0 bc	53 bc

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

Regarding the chemical thinning results obtained in this thinning experiment, significant thinning response occurred only when tank mixed treatment of NAA + BA and sequential treatment of ethephon followed by tank mixture of NAA + BA were performed. The thinning effect was similar to that

Table 2: Fruit quality parameters at harvest in 'Gala'/M.9 thinning experiment.

Tablica 2: Parametri kvalitete plodova kod berbe pokusa prorjeđivanja sorte 'Gala'/M.9.

Treatment *	Mean fruit weight (g)	Firmness (kg/cm ²)	Soluble solids (%)
1) No thinning	114 a	8,1 a	10,9 c
2) Hand thin	156 de	8,6 b	10,8 bc
3) Ethephon 200 ppm	139 bc	8,3 ab	10,3 abc
4) NAA 10 ppm	141 bcd	8,5 b	10,3 abc
5) BA 100 ppm	133 b	8,5 b	9,9 a
6) Ethephon 200 ppm + NAA 10 ppm	149 cde	8,4 ab	10,4 abc
7) Ethephon 200 ppm + BA 100 ppm	152 cde	8,4 ab	10,0 a
8) NAA 10 ppm + BA 100 ppm	157 e	8,7 b	10,4 abc
9) Ethephon + (NAA + BA)	158 e	8,4 ab	10,4 abc

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

of hand thinned trees. The mean fruit weight was enhanced but the total yield (kg/per tree) remained almost equal (not significantly different) to the non thinned trees (Table 1, 2). Also, the share of the bigger sized fruits (>70mm) was more than doubled compared to the control trees, which means that the number of fruits persisting up to the harvest was reduced and the fruits retained on the crown were grown much stronger. These results get along fairly well with the results of the literature. Wertheim, (1997) reported that the combination of thinning compounds might cause additional thinning compared to the thinning caused by compounds applied alone. This is in accordance with the report of Bukovac et al., (1994), in which the tank mix combination of NAA and BA thinned 'Empire' much stronger than application of only NAA or BA. The heaviest thinning (overthinning) was also observed on 'Summerred' after the same sequential treatment of ethephon 200 ppm followed by the mixture of NAA 10 ppm and BA 100 ppm three weeks later (Stopar and Lokar, 2003). With the other experiment Stopar, (2002) found different response of 'Gala' and 'Golden Delicious', i.e. that tank mix spraying of NAA + BA thinned the

fruitlets of both cultivars significantly but the same rate as did the spraying of separate BA or NAA application.

All the other treatments (treatments 3, 4, 5, 6, 7) did not thin the fruits significantly since the final fruit number was just slightly lower compared to the non thinned control (Table 1). The single application of thinners (ethephon 200 ppm at the balloon stage, NAA 10 ppm or BA 100 ppm at 10 mm fruit diameter) did not cause significant thinning, but it enhanced better fruit growth (Table 1: fruits >70mm, Table 2: mean fruit weight). According to the literature this is quite unusual since only BA has been shown to increase the fruit size even in the absence of fruit thinning (Basak, 1996; Greene, 1993; Wismer et al., 1995), while ethephon and NAA may retard the fruit growth (Bound, 2001; Link, 2000). However, in our experiment with 'Gala', the number of bigger sized fruits and consequently the yield of commercially most important fruits (>70mm) was enhanced (Table 1) despite a poor, non significant thinning response of the trees. It has to be taken into account that 'Gala' is considered as a hard to thin cultivar, which is probably the reason for such insignificant thinning. The effect of enhanced fruit growth after the application of ethephon, NAA or BA probably has to be attributed to the chemical thinners alone, which does not correspond to the results of other authors in the case of ethephon and NAA (Bukovac et al., 1994; Link, 2000).

No additional thinning occurred when ethephon was applied first and NAA or BA were applied later compared to application of these thinners alone (Table 1). However, the sequential spray of ethephon at balloon stage followed by NAA or BA at 10 mm fruitlet diameter produced the largest amount of bigger, commercial sized fruits (around 75% of total yield). Consequently, these two treatments, including treatment 5 in which the BA at 100 ppm was applied alone, showed a significantly higher final yield per tree since the fruit number at harvest was not reduced significantly compared to the control trees (Table 1). Similar findings regarding the increased fruit weight and fruit size after the combination treatment of ethephon and BA were reported by Jones et al., (1997) for 'Jonagold' and 'Pink Lady', although in their study ethephon and BA combination influenced significantly the reduction of crop load for both cultivars. In the experiment performed by Dussi et al., (2006) for 'Royal Gala' it was observed that BA spraying 100 ppm applied alone at 8 mm fruit diameter was effective in fruit thinning and in increase in fruit weight, while repeated application of BA at 5 mm and at 8 mm fruit diameter, both times at 50 ppm, did not cause adequate thinning, though there was an important increase in fruit growth.

The measurements of inner fruit quality parameters at harvest showed that the hand thinned apples or apples treated with NAA, BA or mixture of NAA + BA were slightly, although significantly firmer than the control ones (Table 2), which is in accordance with the results reported by Basak, (1996) for BA treated apples, while apples treated with NAA were less firm than those of the control trees. However, Stopar et al., (2002) found that fruits from lower cropping trees had better flesh firmness and higher percentage of soluble solids in fruit flesh than fruits from higher cropping trees of 'Jonagold'/M.9. From the results of our experiment it was seen that the differences in % of soluble solids were similar for most treated apples, although apples from treatments 5 and 7, where BA was applied alone or in combination with ethephon, had fewer soluble solids (Table 2). In any case, none of the treatments differed heavily from the control (non thinning) treatment.

CONCLUSIONS

Significant fruit thinning in this experiment occurred in the case of tank mixed treatment of NAA + BA and sequential treatment of ethephon followed by tank mixture of NAA + BA, which agrees with the findings in the literature saying that combination spraying of thinning agents may result in a stronger thinning response (Wertheim, 1997). A non significant thinning was obtained in treatments when thinning compounds ethephon (applied at the balloon stage), NAA and BA (applied at 10 mm fruit diameter) were used separately as well as in the combinations consisting of ethephon applied first and NAA or BA applied later.

According to the results obtained in this trial and to the literature reports, BA enhanced fruit growth even in the absence of fruit thinning (Greene, 1993; Link, 2000). On the other hand this is not the case for ethephon or NAA. However, it was observed in our experiment that ethephon as well as NAA treatment caused bigger fruit size although the thinning was not significant in either.

REFERENCES

- BASAK A., (1996) Benzyladenine (BA) as an apple fruitlets thinning agent – preliminary results. *Horticultural Science* 28 (3-4): 54-57.
- BOUND S.A., (2001) Managing crop load. in: Dris R., Niskanen R., Jain S.M. (Eds.), *Crop management and postharvest handling of horticultural products*. Volume I. Inc. Plymouth UK. Science Publisher. pp. 89-109.

- BUKOVAC M.J., BLACK B.L., HULL J., STOPAR M., (1994) Interaction between NAA and BA on cropping and fruit size in 'Delicious' and 'Empire' apples. *HortScience* 29: 472.
- DUSSI M.C., GHARDING G., REEB P., DE BERNARDIN F., APENDINO E., (2006) Fruit thinning effects in the apple cv. 'Royal Gala'. *Acta Horticulturae* 727: 401-408.
- ELFVING D.C., CLINE R.A., (1993) Benzyladenine and other chemicals for thinning 'Empire' apple trees. *J.Amer. Soc. Hort. Sci.* 118 (5): 593-598.
- FERREE D.C., (1996) Performance of benzyladenine as a chemical thinner on eight apple cultivars. *Journal of Tree Fruit Production* 1 (2): 33-50.
- GREENE D.W., AUTIO W.R., MILLER P., (1990) Thinning activity of benzyladenine on several apple cultivars. *J. Amer. Soc. Hort. Sci.* 115 (3): 394-400.
- GREENE D.W., (1993) A review of the use of benzyladenine (BA) as a chemical thinner for apples. *Acta Horticulturae* 329: 231-236.
- GREENE D.W., (2002) Chemicals, timing and environmental factors involved in thinner efficacy on apple. *HortScience* 37(3): 477-481.
- GREENE L., (1943) Growth regulators and fruit set with Starking apples. *Proc. Amer. Soc. Hort. Sci.* 42: 149-150.
- JONES K.M., KOEN T.B., MEREDITH R.J., (1983) Thinning Golden Delicious apples using ethephon sprays. *Journal of Horticultural Science* 58 (3): 381-388.
- JONES K.M., BOUND S.A., SUMMER C.R., OAKFORD M.J., (1997) Preliminary examination of thinning strategies on young 'Jonagold' and 'Pink Lady' apples. *Australian Journal of Experimental Agriculture* 37 (3): 377-382.
- LINK H., (2000) Significance of flower and fruit thinning on fruit quality. *Plant Growth Regulation* 31: 17-26.
- STOPAR M., (2000) Comparison of the most frequently used apple thinning compounds for the thinning of 'Jonagold', 'Elstar' and 'Golden Delicious' apples. *Res. Rep. Biot. fac. UL - Agriculture* 75 (1):89-94.
- STOPAR M., (2002) Thinning of 'Gala' and 'Golden delicious' apples with BA, NAA and their combinations. *Journal of Central European Agriculture* 3 (1): 1-6.

- STOPAR M., BOLCINA U., VANZO A., VRHOVSEK U., (2002) Lower crop load for Cv. Jonagold apples (*Malus x domestica* Borkh.) increases polyphenol content and fruit quality. *Journal of Agriculture and Food Chemistry* 50 (6): 1643-1646.
- STOPAR M., LOKAR V., (2003) The effect of ethephon, NAA, BA and their combinations on thinning intensity of 'Summered' apples. *Journal of Central European Agriculture* 4: 399-403.
- STOPAR M., TOJNKO S., (2005) Small fruit appearance on 'Fuji/M.9' apples thinned by the most known thinning agents. *Grønn kunnskap* 9 (105D):1-4.
- WERTHEIM S.J., (1997) Chemical thinning of deciduous fruit trees. *Acta Horticulturae* 463: 445-462.
- WERTHEIM S.J., (2000) Developments in the chemical thinning of apple and pear. *Plant Growth Regulation* 31: 85-100.
- WISMER P.T., PROCTOR J.T.A., ELFVING D.C., (1995) Benzyladenine affect cell division and cell size during apple fruit thinning. *J. Amer. Soc. Hort. Sci.* 120 (5): 802-807.

Adrese autora – Authors addresses:

Dr. sc. Matej Stopar
Mag. sc. Barbara Ambrožič Turk
Kmetijski inštitut Slovenije
Hacquetova 17
1000 Ljubljana, Slovenija
e-mail: matej.stopar@kis.si

Doc. dr. sc. Stanislav Tojnkó
Fakulteta za kmetijstvo, Univerza v Mariboru
Vrbanska 30
2000 Maribor, Slovenija