Effect of Timing and Rates of NAA Chemical Thinner on Fruit Quality of Apple cv. 'Granny Smith'

Mladen FRUK [1]
Mushtaque A. JATOI [1,2]
Goran FRUK [1]
Marko VUKOVIĆ [1(✉)]
Josip BUHIN [1]
Tomislav JEMRIĆ [1]

Summary

Fruit thinning in apple crop plays a critical role to achieve marketable king size fruits with better fruit quality apples. The thinning experiments were conducted using naphthaleneacetic acid (NAA) at different concentrations (0, 10, 15 and 20 µl·l^{-1}) applied at three timings [full bloom (FBT), fruit (FT) and the combination of both (FBT + FT)] in order to evaluate the optimum level of thinner with best application timing on fruit quality attributes of cv. 'Granny Smith' fruits. Statistically significant differences were found regarding the effect of timing, concentration and combination of both, timing and concentrations, on firmness, soluble solids concentration (SSC) and titratable acidity (TA), while there were no significant differences with addition of timing for SSC/TA ratio, fruit mass and starch degradation level. The highest fruit mass (195.09 g) and TA (0.67%) was achieved using NAA at 20 µl·l^{-1} in FT time while NAA at 15 µl·l^{-1} resulted in highest fruit firmness (7.25 kg cm^{-2}), SSC (13.04° Brix) in FBT time. SSC/TA ratio was the highest (25.31) at FT time with the same NAA dosage. However, the highest starch degradation was achieved at FBT + FT time with 15 µl·l^{-1}. It can be concluded that application of 10 µl·l^{-1} NAA at FBT + FT time is recommended to achieve best results since it favourably affected the most quality parameters.

Key words

fruit quality, cv. 'Granny Smith', NAA, productivity, thinning

[1] University of Zagreb, Faculty of Agriculture, Department of Pomology, 10000, Zagreb, Croatia
✉ e-mail: mvukovic@agr.hr
[2] Shah Abdul Latif University, Date Palm Research Institute, 66020, Khairpur, Pakistan

Received: July 28, 2017 · Accepted: January 30, 2018

Introduction

The size of apple fruit has always been a critical factor in determining the market value of the produce. The potential size of a given apple fruit is determined early in the season and growth proceeds at a relatively uniform rate thereafter (Forshey and Elfving, 1977). Hence, fruit thinning has a paramount importance and always being considered to produce good sized fruit of high and uniform quality with regular yield in apple fruit crop (Greene and Lakso, 2013; Jemrić et al., 2003).

Thinning can be done manually or by using chemical thinners. Since hand thinning is laborious and costly, it has not become a general practice in orchard management (Stern, 2014), however chemicals thinning is customary (Dennis, 2000; Greene and Costa, 2013). Chemical thinning is a critical management activity that is done in all apple growing regions in the world to increase fruit size, elevate fruit quality, and to assure return bloom for sustained cropping (Greene and Lakso, 2013). The chemical thinners may consist of various chemicals, but usually plant growth regulators and some insecticides are used for thinning. Chemical thinners probably act by interfering mainly with the hormonal status of the fruitlet (ethephon and carbaryl), or with the plant as a whole (auxin and cytokinin-like compounds) (Bangerth, 2000; Dal Cin et al., 2007; Wertheim, 2000). Application of chemical thinners helps to reduce the biennial bearing effect and it is cost effective as compared to manual thinning. However, the use of chemical thinners in inappropriate application time, dosage or without knowing the varietal response often resulted in yield reduction (Byers and Carbaugh, 1991; Marini, 1996; Mcartney et al., 1995), reduced fruit growth (Jones et al., 1983), fruit russeting (Bound et al., 1993), fruit deformation (Rogers and Williams, 1977), poor fruit color (Byers and Carbaugh, 1991), and lower calcium concentrations in fruit (Elfving and Cline, 1993).

The use of naphthaleneacetic acid (NAA), 1- naphthyl N-methylcarbamate (carbaryl) and napthaleneacetamide (NAD) gained acceptance in the 1950's and 1960's and found to be effective in post-bloom thinning of many commercial apple varieties (Micke et al., 1991; Racskó, 2006). NAA is a synthetic auxin and one of the most commonly used apple chemical thinners, but its efficacy varies among different varieties and is also affected by environmental conditions following the application. Several reports are available on the physiological mechanisms by which NAA promotes the abscission of young apple fruitlets (Bangerth, 2000; Dennis, 2002). Principal among these mechanisms is a reduction in carbohydrate availability to the developing fruit either by interference with photosynthesis (Stopar et al., 1997; Yuan and Greene, 2000) or by reduced translocation of metabolites, including photosynthates, from leaves to the fruit (Schneider, 1978). When applied shortly after fruit set, some fruit abscise leading to improved fruit size and quality. Zhu et al. (2011) compared NAA-induced fruit drop with that caused by shading through gene expression profiling performed on the fruit abscission zone (FAZ) and identified more than 700 genes with significant changes in transcript abundance from NAA-treated FAZ. Moreover, they found that NAA, similar to shading, directly interfered with leaf photosynthesis by repressing photosystem II (PSII) efficiency within 10 minutes of treatment, suggesting that NAA and shading induced some of the same early responses due to reduced photosynthesis, which concurred with changes in hormone signalling pathways and triggered fruit abscission. Their obtained results showed that NAA, like shading, imposes a stress signal through photosynthesis impairment, causes altered hormone signalling and triggers fruit abscission. Milić et al. (2011) studied the effect of ammonium thiosulphate (ATS) and potassium thiosulfate (KTS) as flower thinners on cv. 'Braeburn' clone Mariri Red trees and found them more efficient when applied at 20% full bloom as compared to applied at 80% full bloom. In addition, both increased the average fruit mass but the highest chemical rates retarded fruit growth.

However, the thinning results of NAA are inconsistent and difficult to predict, sometimes leading to excess fruit drop or insufficient thinning that are costly to growers. This unpredictability reflects the incomplete understanding of the mode of action of NAA in promoting fruit abscission (Zhu et al., 2011).

Therefore, the aim of current study was to investigate the effect of different application time and dosages of NAA in order to achieve the proper thinning in cv. 'Granny Smith' apple. The idea of application of NAA as thinner at blossom and fruitlet stages is unique itself as there is scarcity of literature dealing with all these aspects in one study.

Materials and methods

The fruit thinning experiments were conducted to evaluate the fruit quality of cv. 'Granny Smith' in a commercial apple orchard near Krapina, Croatia (latitude 46° 09' N longitude15° 53' E). Commercial chemical thinner Diriger (NAA) with three different concentrations (10, 15 and 20 $\mu l \cdot l^{-1}$) was applied at one of two timings: full bloom thinning (FBT), fruit thinning (FT; when king fruitlets were 6-8 mm in diameter) or at both as a combination (FBT + FT). Experiments were carried out on adult trees (8 years old) of the apple cv. 'Granny Smith', planted with 3 m × 1 m distances and grafted onto M9 rootstock. Experiment was performed as complete randomized block with three replicates consisting of five trees per replicate. All cultural practices were applied regularly. Since NAA have not shown any thinning effect (data not shown), the effect of this thinner on fruit quality parameters (fruit mass, firmness, soluble solids concentration (SSC), titratable acids (TA), SSC/TA ratio and starch degradation level) is presented and discussed in this paper. The fruits were transported to the laboratory and visually inspected for damage and other defects. A sample of randomly selected 15 fruits per replicate, hence 45 fruits per thinning treatment was formed. After determining fruit mass on an analytical balance (Mettler Toledo P1210), fruit firmness, soluble solids content (SSC) and titratable acidity (TA) were determined.

Firmness (expressed in $kg \cdot cm^{-2}$) was measured using Effegi FT 327 penetrometer with 11 mm probe as an average value from four measurements made at opposite fruit sides at equatorial fruit zone.

The juice from each fruit was extracted with electric juicer and was used for determination of SSC (expressed in °Brix) with refractometer (ATAGO PAL-1, Japan) (Mitcham et al., 1996). Titratable acidity (TA) was determined by titration with 0.1 N NaOH and expressed in percent of malic acid per 100 ml of juice (Mitcham et al., 1996).

The parameters recorded were fruit mass, firmness, soluble solids concentration (SSC), titratable acids (TA), SSC/TA ratio and starch degradation level. The starch degradation level was scored using a 10 point CTIFL scale (Centre technique interprofessionnel des fruits et legumes, Paris, France). Chemical analyses were performed on 15 randomly selected fruits from replicate, hence 45 fruits per thinning treatment

Table 1. ANOVA table for the effect of timing, concentration and combination of both on chemical characteristics of apple cv. 'Granny Smith'

Source of variability	Fruit Mass (g)	Firmness (kg· cm^{-2})	SSC (° Brix)	TA (% as malic)	SSC/TA	Starch degradation
Timing	0.3023n.s.	0.0001***	0.0001***	0.0001***	0.24 n.s.	0.19 n.s.
Concentration	0.0041***	0.0001***	0.0001***	0.0001***	0.29 n.s.	0.0001***
T x C	0.0001***	0.0120**	0.0001***	0.0001***	0.41 n.s.	0.048*

Note: n.s., *, **, *** - nonsignificant or significant at P ≤ 0.05, 0.01 or 0.001 level, respectively

Table 2. Effect of thinner application time and concentration on chemical characteristics of fruits of cv. 'Granny Smith'

Treatments	Thinner conc.	Fruit Mass (g)	Firmness (kg· cm^{-2})	SSC (° Brix)	TA (% as malic)	SSC/TA	Starch degradation
Full bloom thinning (FBT)	0	164.28 bc	6.95 b	12.78 ab	0.48 b	24.32 a	6.47 a
	10	183.74 a	6.95 b	12.30 c	0.56 ab	21.81 a	7.00 a
	15	171.11 b	7.25 a	13.04 a	0.51 ab	20.60 a	6.66 a
	20	156.77 c	6.78 b	12.54 bc	0.58 a	21.62 a	7.06 a
Fruit thinning (FT)	0	166.65 bc	6.93 a	12.76 a	0.52 b	24.35 a	6.46 b
	10	175.98 b	6.82 ab	11.61 b	0.54 b	21.51 b	6.93 ab
	15	161.37 c	6.75 ab	12.86 a	0.51 b	25.31 a	7.33 a
	20	195.09 a	6.65 b	11.79 b	0.67 a	17.67 c	7.46 a
FBT + FT	0	168.63 a	6.91 a	12.70 a	0.50 b	24.29 a	6.42 c
	10	170.84 a	6.67 b	12.31 b	0.65 a	18.87 b	6.73 bc
	15	175.60 a	6.65 b	12.00 b	0.67 a	18.03 b	7.80 a
	20	175.93 a	6.31 c	11.52 c	0.62 a	18.53 b	7.13 b

Note: means followed by the same letter within the same timing are not significant according to the LSD test at P ≤ 0.05 level

Data were statistically analysed using SAS statistical software ver. 9.1 (SAS Institute, NC) using ANOVA and LSD test (p≤0.05) and correlation analysis.

Results

Since NAA has not shown any thinning effect, data are not shown. The data presented in Table 1 clearly indicated the statistically significant differences regarding the effect of timing, concentration and combination of both timing and concentrations on fruit quality. Statistically significant differences were found regarding the effect of timing, concentration and combination of both timing and concentrations on firmness, soluble solids concentration (SSC) and titratable acidity (TA), while there were no significant differences with addition of timing for SSC/TA ratio, fruit mass and starch degradation level.

NAA application significantly affected the fruit biochemical traits in all treatments in cv. 'Granny smith' (Table 2). The highest fruit mass (195.09 g) and TA (0.67%) were achieved using 20 μl·l^{-1} NAA at FT time while 15 μl·l^{-1} NAA resulted in highest fruit firmness (7.25 kg cm^{-2}), SSC (13.04° Brix) at FBT time. SSC/TA ratio was the highest (25.31) at FT time with the same NAA dosage. However, the highest starch degradation was achieved at FBT + FT time with 15 μl·l^{-1} NAA (Table 2), which means that fruit maturity is significantly advanced when higher dosage of fruit thinner is used. The most quality parameters were favourably affected when 10 μl·l^{-1} NAA at FBT + FT times was used.

Discussion

Milić et al. (2012) on apple cv. 'Braeburn' in both years of study found no significant differences between three NAA treatment concentrations on yield (kg) per tree, and in the first year of study regarding number of fruits per cm^2 of TCSA (trunk cross-sectional area), what is in accordance with our study where NAA showed no thinning effect. Our results are in context with Misimović et al. (2012) who reported higher firmness in unthinned apple fruits in relation to thinned trees. The fruit firmness in our study increased in case of FBT while decrease in case of FTB + FT as compared to untreated trees. The minor variations in results might be occurred due to type of cultivar & thinner, time of application and climatic conditions.

Within each timing, NAA concentration significantly affected fruit quality parameters but results were not consistent. Radivojević et al. (2014) found no significant differences in total soluble solids (TSS) and total acidity (TA) in cvs. 'Gala' and 'Braeburn' as related to crop load, which is similar to our study. However, Wünsche et al. (2005) reported increased flesh firmness and dry matter with decreasing crop load in cv. 'Braeburn' in New Zealand. Furthermore, authors stated that typically, advanced maturity in light-cropping trees is indicated by greater starch degradation and a higher percent of soluble solids compared with fruit in high-cropping trees. Rakonczas (2008) found that timing at FT resulted in decrease of dry matter, fruit firmness and total sugars while increased in total acid in cvs. 'Gala Must' and 'Jonagold'. The above findings are not in agreement with results obtained in our study. Possible explanation might be interaction with other factors, such as climatic conditions, tree size etc. The results are in close confirmation with Radivojević et al. (2011) regarding SSC and TA who performed experiments on cvs. 'Gala' and 'Granny Smith' using NAA at 7 and 10 mg concentrations level.

However, the average fruit mass was still significantly higher as compared to the control in all treatments (Table 2). Thinning resulted with increased fruit mass that can compensate the reduction of fruit number per tree (Pavičić et al., 2004), although many authors reported reduced yields as result of thinning (Byers

& Carbaugh, 1991; Marini, 1996; Mcartney et al., 1995; Rogers & Williams, 1977). Milić et al. (2012) evaluated the effect of NAA and BA on fruit set, quality and the bearing potential of the apple cvs. 'Braeburn' and 'Camspur' in Serbia. They applied NAA at 6, 8, and 10 $\mu l \cdot l^{-1}$, BA at 50, 100 and 150 $\mu l \cdot l^{-1}$ dosages to cv. 'Braeburn' and 8, 10, 12 $\mu l \cdot l^{-1}$ NAA, 50, 100 and 200 $\mu l \cdot l^{-1}$ BA to cv. 'Camspur'. They found that both NAA and BA proven effective in reducing fruit set in cv. 'Braeburn' while the effects of thinning on fruit quality parameters in cv. 'Braeburn' were not consistent.

Conclusion

NAA at 10 $\mu l \cdot l^{-1}$ as chemical thinner proven to be the best for optimal quality of apples of cv. 'Granny Smith' when used at FBT and again at FT. These results show that there is cumulative effect of NAA concentration that is needed for achievement of high marketable yield of cv. 'Granny Smith' apple. However, higher concentration can have even detrimental effect on both yield and fruit quality. Significant differences in FBT+FT thinning were observed in starch degradation, which might significantly affect storage quality and, more specifically, superficial scald development. Therefore, further studies must be focused on the effect of preharvest fruit thinning on the postharvest quality and storage disorders susceptibility.

References

Bangerth, F., 2000. Abscission and thinning of young fruit and their regulation by plant hormones and bioregulators. Plant Growth Regul. 31, 43–59.

Bound, S.A., Jones, K.M., Graham, B., Oakford, M.J., Tichon, M., 1993. Modelling the effects of timing and rates of application of benzyladenine as a secondary thinner of Fuji apple after etephon. J. Hortic. Sci. Biotechnol. 68, 967–973.

Byers, R.E., Carbaugh, D.H., 1991. Effect of chemical thinning sprays on apple fruit set. Horttechnology 1, 41–48.

Dal Cin, V., Boschetti, A., Dorigoni, A., Ramina, A., 2007. Benzylaminopurine Application on two different apple cultivars (Malus domestica) displays new and unexpected fruitlet abscission features. Ann. Bot. 99, 1195–1202.

Dennis, F.G., 2002. Mechanisms of action of apple thinning chemicals. Hortscience 37, 471–474.

Dennis, F.G., 2000. The history of fruit thinning. Plant Growth Regul. 31, 1–16.

Elfving, D.C., Cline, R.A., 1993. Cytokinin and etephon affect crop load, shoot growth, and nutrient concentration of Empire apple trees. Hortscience 28, 1011–1014.

Forshey, C.G., Elfving, D.C., 1977. Fruit numbers, fruit size, and yield relationships in "McIntosh" apples. J. Am. Soc. Hortic. Sci. 102, 399–402.

Greene, D., Costa, G., 2013. Fruit thinning in pome- and stone-fruit: state of the art. Acta Hortic. 998, 93–102.

Greene, D.W., Lakso, A.N., 2013. Prediction of Initial Set and the Thinning Response to Postbloom Chemical Thinners on Apples. Int. J. Fruit Sci. 13, 430–440.

Jemrić, T., Pavičić, N., Blašković, D., Krapac, M., Pavičić, D., 2003. The effect of hand and chemical fruit thinning on "Golden Delicious cl. B" apple fruit quality. Curr. Stud. Biotechnol. 3, 193–198.

Jones, K.M., Koen, T.B., Meredith, R.J., 1983. Thinning Golden Delicious apples using etephon sprays. J. Hortic. Sci. Biotechnol. 58, 381–388.

Marini, R.P., 1996. Chemically thinning spur Delicious apples with carbaryl, NAA, and etephon at various stages of fruit development. Horttechnology 6, 241–246.

Mcartney, S.J., Tustin, D.S., Seymour, S., Cashmore, W., Looney, N.E., 1995. Benzyladenine and carbaryl effects on fruit thinning and the enhancement of return flowering of three apple cultivars. J. Hortic. Sci. Biotechnol. 70, 287–296.

Micke, W.C., Grant, J.A., Norton, M.V., Yeager, J.T., 1991. Thinning Granny Smith apples chemically. Calif. Agric. 45, 30–32.

Milić, B., Keserović, Z., Magazin, N., Dorić, M., 2012. Fruit quality and bearing potential of chemically thinned "Braeburn" and "Camspur" apples. Zemdirbyste-Agriculture 99, 287–292.

Milić, B., Magazin, N., Keserović, Z., Dorić., M., 2011. Flower thinning of apple cultivar Braeburn using ammonium and potassium thiosulfate. Hortic. Sci. 38, 120–124.

Misimović, M., Vukojević, D., Zavišić, N., Simić, J., 2012. Thinning of Apple Fruits with Foliar Fertilizers Goëmar BM 86 E and Goëmar Folical. Agric. Conspec. Sci. 77, 15–19.

Mitcham, B., Cantwell, M., Kader, A., 1996. Methods for determining quality of fresh commodities. Perishables Handl. Newsl. 85, 1–6.

Pavičić, N., Jemrić, T., Skendrović, M., Blašković, D., Krstulović, A., 2004. Mesurol - čimbenik redovitije rodnosti jabuke. Poljopr. 10, 28–31.

Racskó, J., 2006. Crop Load, Fruit thinning and their effects on fruit quality of Apple (Malus domestica Borkh.). J. Agric. Sci. 24, 29–35.

Radivojević, D., Zabrkić, G., Milivojević, J., Veličković, M., Oparnica, Č., 2011. Effect of chemical and hand thinning young apple tree on yield and fruit quality, in: Proceedings of the 46th Croatian & 6th International Symposium on Agriculture, Opatija, Croatia. pp. 1044–1047.

Radivojević, D.D., Milivojević, J.M., Oparnica, Č.D., Vulić, T.B., Djordjević, B.S., Ercişli, S., 2014. Impact of early cropping on vegetative development, productivity, and fruit quality of Gala and Braeburn apple trees. Turkish J. Agric. For. 38, 773–780.

Rakonczas, N., 2008. Relations of production technological elements, environmental factors and post-harvest quality attributes of apple. University of Debrecen, Hungary.

Rogers, B.L., Williams, G.R., 1977. Chemical thinning of spur-type Delicious apple fruit. Virginia Fruit 65, 23–28.

Schneider, G.W., 1978. Abscission Mechanism Studies with Apple Fruitlets. J. Am. Soc. Hortic. Sci. 103, 455–458.

Stern, R.A., 2014. The photosynthesis inhibitor metamitron is an effective fruitlet thinner for "Gala" apple in the warm climate of Israel. Sci. Hortic. (Amsterdam). 178, 163–167.

Stopar, M., Black, B.L., Bukovac, M.J., 1997. The effect of NAA and BA on carbon dioxide assimilation by shoot leaves of spur-type "Delicious" and "Empire" apple trees. J. Am. Soc. Hortic. Sci. 122, 837–840.

Wertheim, S.J., 2000. Developments in the chemical thinning of apple and pear. Plant Growth Regul. 31, 85–100.

Wünsche, J.N., Greer, D.H., Laing, W.A., Palmer., J.W., 2005. Physiological and biochemical leaf and tree responses to crop load in apple. Tree Physiol. 25, 1253–1263.

Yuan, R.C., Greene, D.W., 2000. Benzyladenine as a chemical thinner for "McIntosh" apples. I. Fruit thinning effects and associated relationships with photosynthesis, assimilate translocation, and non-structural carbohydrates. J. Am. Soc. Hortic. Sci. 125, 169–176.

Zhu, H., Dardick, C.D., Beers, E.P., Callanhan, A.M., Xia, R., Yuan, R., 2011. Transcriptomics of shading-induced and NAA-induced abscission in apple (Malus domestica) reveals a shared pathway involving reduced photosynthesis, alterations in carbohydrate transport and signaling and hormone crosstalk. BMC Plant Biol. 11, 138.

acs83_33