MODELING OF APPLE CHEMICAL FRUIT THINNING

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Abstract

Crop load management in intensive apple orchards must be done precisely to produce a high yield with marketable fruit size. It also ensures the formation of flower buds on the tree for the next season and prevents alternative bearing. In addition to pruning, flower and fruit thinning is another management method that has a major impact on crop yield. Compared to other methods, chemical thinning is the cheapest, can be done quickly and allows fruit thinning at the right time, which guarantees better fruit quality. The decision on the type of chemical agent, concentration and timing of application is very complex and depends on the apple variety, flowering intensity and fruit growth phase, weather conditions during treatment and a few days after. Flower thinning is applied to very high-yielding varieties where fruit thinning is very difficult and tends to bear alternately. Ammonium thiosulphate or ethephon can be used for this purpose only in years with abundant flowering and in conditions where there is no risk of spring frosts. Regardless of whether flower thinning has been carried out or not, the fruits are chemically thinned in the period shortly after flowering. The usual chemical treatment(s) is (are) applied at the early stage of fruit development, when the diameter of the central fruits in a cluster on 2-year-old wood is 5 to 16 mm (in exceptional cases up to 20 mm). At this time, naphthalene acetamide (NAD), naphthalene acetic acid (NAA), 6-benzyladenine (6- BA), and metamitron are used to induce abscission of young fruit. These chemicals are used alone or in various combinations to improve the effect. If the thinning efficacy of the single application is weak, sequential applications of chemical thinners with different modes of action must be made 1-3 weeks after the previous application to reduce fruit set to a commercially acceptable level. To avoid under- or over-thinning of fruit of a particular variety, models that predict the effectiveness of chemicals based on short-term light and temperature forecasts are used to determine the optimal time to apply thinners. Immediately after the first application of thinning agents, the "fruit growth rate model" can be used for early assessment of apple tree response to thinning and the need for a new application.

Key words: *Malus domestica*, precision crop load, flower thinning, fruit thinning.

INTRODUCTION

All the new apple orchards in Serbia are intensively managed. In high intensive orchards trees very often tend to bear an abundant number of fruits per tree. As a result, the fruits are too small and their sale on the world market as fresh fruit is very difficult, so they have a low commercial value. In addition, harvesting is very labor intensive and therefore very expensive. Storage, packaging and transportation costs are very high. In addition, the formation of flower buds on the tree for the next season is insufficient and alternative cropping is very pronounced. Crop load management is the single most important yet difficult management strategy that determines the annual profitability of apple orchards (Robinson et al., 2017). There are two management practices that have large effect on crop load 1) winter pruning 2) flower or fruit thinning. Winter pruning is the first step in controlling fruit productivity, when the large numbers of fruiting buds have been removed by cutting off the unwanted fruiting wood. Winter pruning achieves a certain number of fruiting buds per tree, but the buds consist of five to seven flowers. However, a large number of flowers per tree and good conditions for their fertilization may determine the set of a high number of fruits that do not reach satisfactory commercial size (Radivojević et al., 2022). Therefore, the number of flowers or newly formed fruits on the tree must be reduced during several phenological stages to an acceptable level that ensures a high yield with good fruit quality.

Flower thinning can be done by chemicals or by machine, as well as thinning of formatted fruits by hand or by foliar application of some chemical compounds. Manual thinning is very costly, labor intensive, and can only be done in small and very young orchards (Radivojević et al., 2011). Also, additional hand thinning is recommended to remove excess fruit, especially small and deformed fruit remaining on the trees after chemical thinning, to further maximize fruit size and the percentage of marketable fruit (Maas and P.A.H. van der Steeg, 2011). Moreover, hand thinning is usually carried out too late (after June-drop), by which time only increases in fruit size are achieved and there is no reduction in alternate bearing (Maas, 2006). Chemical thinning, as compared to hand thinning, is a quick operation and allows thinning fruit at the right moment, guaranteeing better fruit quality and significantly reducing labor costs (Costa et al., 2006). Chemical thinners are applied at flowering and/or during the early post-bloom period (Bound, 2006). It is very difficult to make right decision about chemicals application because as a result must be overthinning or insufficient thinning. The precision chemical thinning component of “precise crop load management” begins with defining the optimum fruit number tree^{-1} (target fruit number) then applying sequential chemical thinning sprays with rates and timing thinning efficacy according to different factors (cultivar and subsequently by the fruit growth rate model to assess thinning efficacy in time to allow re-treatment when needed with the goal of reducing fruit number tree^{-1} in a step wise manner to the target fruit number to optimize crop value and reduce hand thinning costs (Robinson et al., 2017). Which model of chemical

thinning is used depends on many factors: variety, number of flower buds per tree, pollinator activity (honey bee, wild bee), temperature before and after application, time and intensity of sunlight.

FLOWER THINNING

Flower thinning is applied to cultivars where fruit thinning is very difficult and which prone to alternate bear (Elstar, Golden Delicious, Fuji...) and in years with abundant flowering. Reduction of flowers very early is useful and promotes good fruit quality and the formation of flower buds for the next season. However, it can only be recommended if there is no threat of spring frost during flowering and a few weeks after flowering. The main objective of flower thinning is to allow pollination and fertilization only central flowers in the cluster, which are the first to open in apples and regularly provide the largest fruits, and to prevent pollination or fertilization of the lateral flowers by applying thinning agents. The mechanism of action of the agents used for chemical thinning of flowers is based on the prevention of pollination and/or fertilization or damage to certain flowers, resulting in their decline (Denis, 2002). Ethephon (2- chloroethylphosphonic acid) becomes of PGR and its action is unpredictable and depends on temperature. Another frequently used option is the application of caustics, such as the nitrogen fertilizer ammonium thiosulphate (ATS), which at high concentrations damages the pistil's stigma, preventing pollination and fertilization (Radivojević, 2020). The effect of the applied agent depends on the flowering characteristics, the concentration of the thinning agent, the amount of water used and the weather conditions during application. Figure 1 shows the effect of flower thinning treatments on the yield of the 'Golden Delicious' variety.

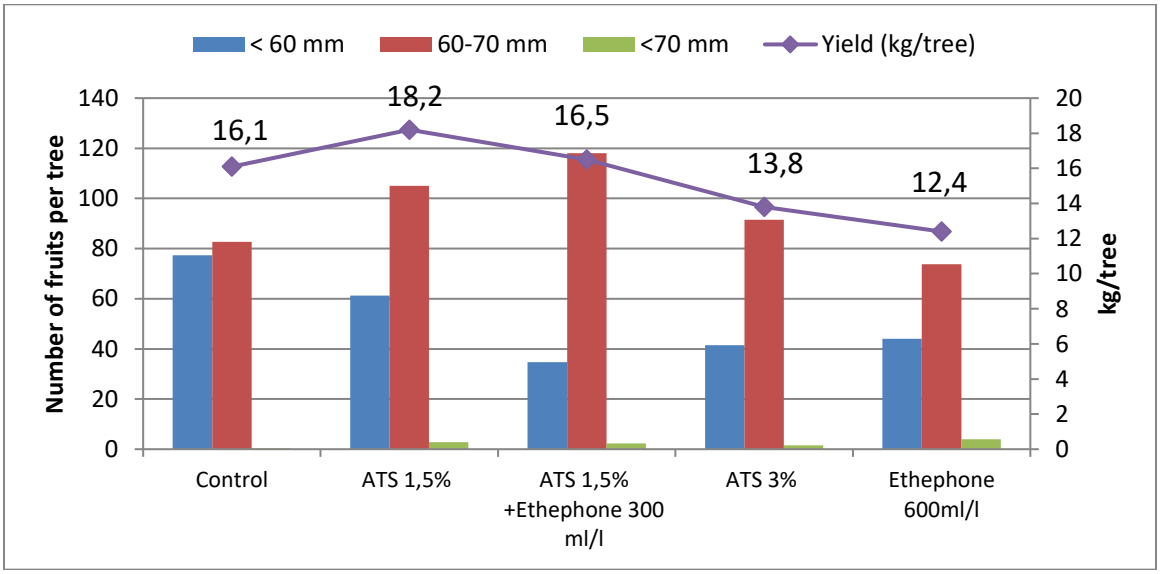

Figure 1. Effect of flower thinning treatments on number of fruit, fruit size distribution and the yield of the cultivar 'Golden Delicious'

Applied treatments reduced the share of very small fruits (<60 mm) in the total yield compared to control treatment. However, none of these treatments met our expectations in terms of number of fruits per tree (targeted number of fruits on the tree was 80) and their size (diameter >70mm), so chemical fruit thinning had to be applied

FRUIT THINNING

Regardless of whether flower thinning has been performed or not, the fruitlets (very small fruits) are chemically thinned immediately after flowering by using various chemicals. If the orchard is planted with high quality nursery trees, which contain many lateral branches, fruit thinning is started in the second growing season and continue regularly in following years (Radivojevic et al., 2020). The usual chemical treatment(s) is (are) carried out at the early stage of fruit development, when the diameter of the central fruits in a cluster on 2-year-old wood is 5 to 16 mm (in exceptional cases up to 20 mm). Generaly, naphthaleneacetamide (NAD), Naphthalene-acetic acid (NAA), 6-benzyladenine (6-BA) and metamitron are applied as post bloom thinning agents to induce young fruit abscission during the first 3 weeks after bloom (McArtney and Obermiller, 2012). Synthetic auxins 1-naphthaleneacetic acid (NAA) or naphthaleneacetamide (NAD) activate ethylene, which induces the hydrolytic enzymes polygalacturonase and cellulase, which promote the formation of abscission layers and cause fruit drop (Stern, 2015). The cytokinine 6-benzyladenine (BA) block embryo development by causing severe reductions in carbohydrate levels; this, in turn, reduces polar auxin transport across the fruit pedicel and enhances the abscission zone's sensitivity to ethylene, leading to fruit drop. The triazinone herbicide metamitron inhibits photosynthesis by disrupting the photosynthetic apparatus 7 to 10 days after application, resulting in transient carbohydrate stress that may increase fruit abscission in apples.

The above chemicals are used alone, or if in certain circumstances the expected thinning effect is weak, they may be used in combination to improve the effect (Verjans et al., 2018).

In most cases, however, the thinning effect of the single application is not sufficient to achieve the desired number of fruits per tree. Consequently, during the same period (first 3 weeks after bloom), sequential applications of chemical thinners with different mode of action are used to reduce fruit set to commercially acceptable levels (McArtney and Obermiller, 2012). The subsequent application should be done 7-14 days after the previous one.

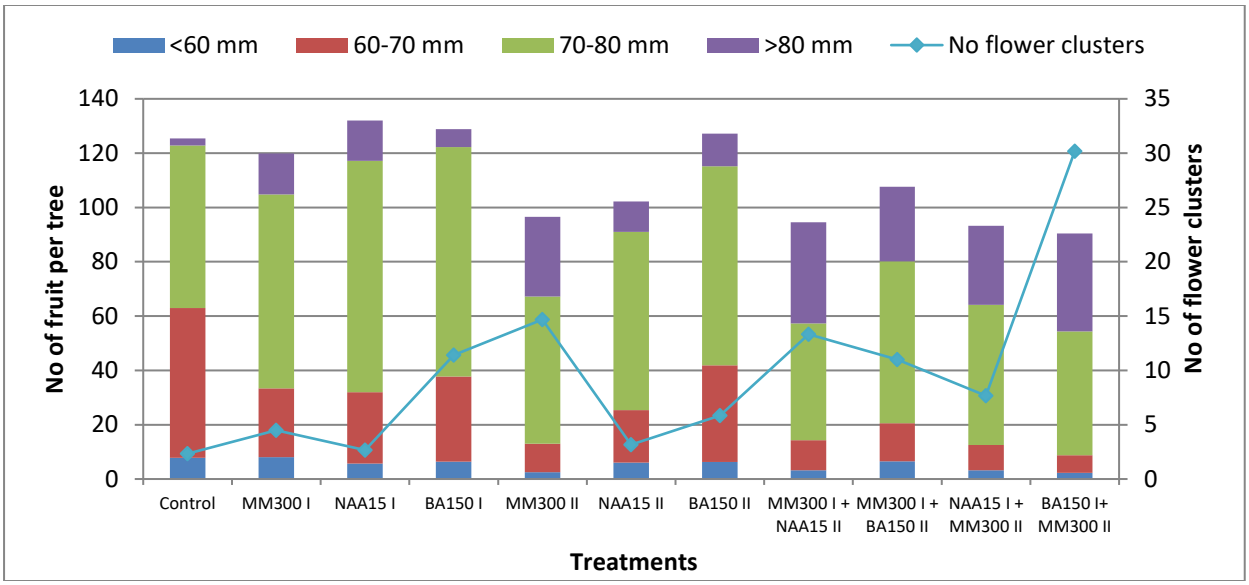

Figure 2. Effect of single and sequential application of BA, NAA and metamitron (MM) on fruit-size distribution and flowering bud formation in 'Golden Delicious' apple. All studied chemical compounds were applied once 7 days after full bloom (average diameter of king fruit was 6.1 mm = I) or 21 days after full bloom (average diameter of king fruit was 15.3 mm = II) or twice, on both dates, in combination only with MM (I+II). Concentrations applied were 300 mg L^{-1} MM, 150 mg L^{-1} BA and 15 mg L^{-1} NAA.

Figure 2 shows the effect of single and sequential fruit thinning of the 'Golden Delicious' variety on the number of fruits per tree, the fruit size distribution, and the number of generative buds for the next season. The targeted final number of fruits on the tree was 90. Only a single application of metamitron 21 days after full bloom (MM II) achieved the target number of fruits per tree. All sequential applications, with the exception of the treatment metamitron 7 days after full bloom plus BA 21 days after full bloom (MM I+BA II), achieved the targeted number per tree and the excellent share of large fruits in the total yield. Only the last treatment (BA I+ MM II) resulted in a satisfactory number of generative buds per tree for the next season. Lafer (2010) confirmed that thinning efficacy of the single applications of Metamitron was inconsistent while more interesting effect was obtained with repeated application of Metamitron.

The biggest problem in chemical fruit thinning is the reaction of the trees to the applied chemicals, because it depends on many factors, which we can divide into the following three groups: 1) tree characteristics (cultivar, yield in the previous year, number of fruit buds per tree, position of buds in the canopy, fruit diameter at the time of chemical thinning); 2) weather conditions before, during, and after chemical thinning (daily maximum and minimum temperatures and light intensity); 3) chemicals used (concentration of chemicals, amount of water and spray coverage used, droplet size, drying times, addition of wetting agents or surfactants to the spray tank). Because the relative contributions of each of these factors to the effects of a thinning spray vary with each application of a thinning agent, it is unlikely that the final thinning response can be predicted

with a high degree of accuracy. When the thinner application coincides with a period of adequate temperature and light intensity then the combined effects will result in adequate thinning. The problem is over-thinning which will occur if thinners are applied in conjunction with a low light intensity and high temperature, especially during the night several days after thinners application. To predict the final response of an apple tree to fruit chemical thinning with a high degree of accuracy, some digital models can be used for each apple variety. They use short-term light and temperature forecasts to predict the efficacy of the chemicals applied. One of the best models is “Brevis Smart”, which was developed specifically for the Brevis product (i.e. a product containing metamitron).

Immediately after the first application of fruit thinners, the “fruit growth rate model” can be used for an early assessment of the thinning response (Greene et al., 2013) and help apple growers to make a decision on whether or not to perform a second chemical fruit thinning. The method takes into account the final number of fruits needed per tree and the number of flower clusters on the trees after pruning (by counting 5 representative trees) and calculates the percentage of initial flowers needed after thinning. If the response of the trees is not good and there is more fruit than the growers want, the second application must be made. In general, growers have enough time for two mentioned thinning applications.

If the result is not sufficient, sometimes, especially in varieties that are difficult to thin, it is possible to use two chemicals as a last resort for fruit thinning, when the diameter of the central fruit in a cluster is between 20 and 25 mm. These are etephon [(2-Chloroethyl) phosphonic acid] or the new agent ACC (1-aminocyclopropane-1-carboxylic acid), which is a natural precursor in ethylene synthesis. Ethephon thinned ‘Golden Delicious’ apples when applied at 20 mm stage of fruit development, and fruit thinning with ethephon was not influenced by increasing day/ night temperature from 21.1/10 to 32.2/15.6 C˚(Yuan, 2007)

CONCLUSION

Crop load management in intensive apple orchards must be done precisely to achieve a high yield with a marketable fruit size and to ensure the formation of flower buds on the tree for the next season. After pruning, the blossoms and/or fruit must be chemically thinned. The effect of the chemicals used depends on the apple variety, the flowering intensity and the growth phase of the fruit as well as the weather conditions during the treatment and a few days afterwards. Blossom thinning is used on high-yielding varieties where fruit thinning is very difficult and which tend to alternate bearing. Chemical fruit thinning agents are used in the early stages of fruit development, when the diameter of the central fruit in a cluster on two-year-old wood is 5 to 20 mm. At this stage, naphthalene acetamide (NAD), naphthaleneacetic acid (NAA), 6-benzyladenine (6-BA) and metamitron are used to reduce fruit set to a commercially acceptable level. If the thinning efficacy of the single application is weak, sequential applications of chemical thinning agents with different mechanisms of action must be made 1-3 weeks after the previous application. To avoid under-thinning or over-thinning of fruit of a particular variety, models that predict the effectiveness of chemicals

based on short-term light and temperature forecasts are used to determine the optimal time to apply thinning agents. After the application of thinning agents, the “fruit growth rate model” can be used for early assessment of the apple trees' response to thinning and the need for a new application.

REFERENCES

Bound, S.A. (2006). Comparison of two 6-benzyladenine formulations and carbaryl for post-bloom thinning of apples. Sci. Hortic. (Amsterdam) 111 (1), 30–37

Costa G, Dal Cin V, Ramina A (2006). Physiological, molecular and practical aspects of fruit abscission. Acta Horticulturae 727: 301-310. doi: 10.17660/ActaHortic.2006.727.3

Dennis, Jr.F.G. (2002): Mechanisms of action of apple thinning chemicals. HortScience, 37(3): 471-474.

Greene, D. W., Lakso, A. N., Robinson, T. L., & Schwallier, P. (2013). Development of a Fruitlet Growth Model to Predict Thinner Response on Apples. *HortScience horts*, *48*(5), 584-587.

Lafer, G. (2010). Effects of chemical thinning with metamitron on fruit set, yield and fruit quality of ‘Elstar’. Acta Hortic. 884, 531–536 https://doi.org/10.17660/ActaHortic.2010.884.68.

Maas, F. (2006). Thinning ‘Elstar’ apple with benzyladenine. Acta Hortic. 727, 415–422 https://doi.org/10.17660/ ActaHortic.2006.727.50.

Maas, F.M. and van der Steeg, P.A.H. (2011). Crop load regulation in 'Conference' pears. Acta Hortic. 909, 367-379 DOI: 10.17660/ActaHortic.2011.909.41

McArtney SJ, Obermiller JD (2012). Use of 1-aminocyclopropane carboxylic acid and metamitron for delayed thinning of apple fruit. HortScience 47 (11): 1612-1616.

Radivojević D, Zabrkić G, Milivojević J, Veličković M, Oparnica Č (2011). Effect of chemical thinning of young apple tree on yield and fruit quality. Proceedings of 46th Croatian and 6th International Symposium on Agriculture. Opatija, Croatia, 1044-1047.

Radivojevic, D., (2020): Opste vocarstvo. Univerzitet u Beogradu, Poljoprivredni fakultet, Beograd.

Radivojevic, D., Milivojevic, J., Pavlovic, M., and Stopar, M. (2020). Comparison of metamitron efficiency for postbloom thinning of young ‘Gala’ and ‘Golden Delicious’ apple trees. Turk. J. Agric. For. 44 (1), 83–94 https://doi.org/10.3906/tar-1902-22.

Radivojevic, D., Fotiric, M., Milivojevic, J. and Oparnica, C. (2022). Chemical thinning induced by single and sequential application of BA, NAA and metamitron on ‘Gala’ and ‘Golden Delicious’ apple. Acta Hortic. 1341, 1-8 DOI: 10.17660/ActaHortic.2022.1341.1

Robinson, T.L., Lakso, A.N. and Greene, D.W. (2017). Precision crop load management: the practical implementation of physiological models. Acta Hortic. 1177, 381-390 DOI: 10.17660/ActaHortic.2017.1177.55

Spasojević, S., Oparnica, Č., Milivojević, J., Radivojević, D. (2022): Uticaj proređivanja cvetova na rodnost i karakteristike ploda sorte jabuke Golden Delicious. Voćarstvo, 56:211-212, 2022.

Stern, R. (2015). The photosynthesis inhibitor metamitron is a highly effective thinner for ‘Golden Delicious’ apple in a warm climate. Fruits 70 (3), 127–134 https://doi.org/10.1051/fruits/2015007 .

Verjans, W., Deckers, T., Vandermaesen, J., Bylemans, D., and Remy, S. (2018). A comparison of different fruit thinning agents in apple cultivar ‘Golden Delicious’. Acta Hortic. 1221, 9–16 https://doi.org/10.17660/ ActaHortic.2018.1221.2.

Yuan R (2007). Effects of temperature on fruit thinning with ethephon in ‘Golden Delicious’ apples. Scientia Horticulturae 113: 8-12. doi: 10.1016/j.scienta.2007.01.00