# EFFECTS OF PLANT BIOREGULATORS ON THINNING OF YOUNG APPLE TREES CULTIVAR 'GOLDEN DELICIOUS REINDERS'

**BOBAN DJORDJEVIĆ, DEJAN DJUROVIĆ, GORDAN ZEC**
*University of Belgrade, Faculty of Agriculture*
*b.djordjevic@agrif.bg.ac.rs*

**Kaywords:** ***apple, fruit quality, thinning, yield***

## ABSTRACT

*For several decades, the use of intensive orchards has been proposed to improve profitability and yield, notably of early cropping, in apple orchards. Fruit yield is primarily depends of two components: fruit number and fruit size. Crop load, defined as the number of fruits per tree, has a significant impact on both fruit quality and tree physiology. Thinning of flowers or fruitlets is the most important technique in apple growing practice to improve fruit quality, increase return bloom and reduce biennial cropping. The highest crop loud per trees had control trees and trees thinning with NAA, 11.1 and 10.6 fruit cm$^{-2}$ TCSA respectively. Increasing of crop loud had significantly influence to return blooming. In third leaf of apple only trees thinning with metamitron prevent the occurrence of biennial cropping. The highest percentage of marketable fruits had trees thinning with metamitron and manual (more than 60%).*

## INTRODUCTION

Apple (Malus × domestica Borkh.) is the most important of the deciduous tree fruits in terms of production and a focus of research worldwide. The intensive orchards have been proposed to improve profitability and yield, notably of early cropping. A possible barrier for increased fruit consumption is insufficient fruit quality. Small fruit size is a limiting factor in marketing apples (*Malus* × *domestica*). Also, biennial bearing is defined as an alternating cropping pattern, where a heavy crop one year inhibits blossom initiation and results in few blossoms the following year (Marini et al., 2013). According to Stern 2014, several techniques have been used to improve this trait, among them blossom and fruit thinning with plant growth regulators such as auxins and cytokinins to reduce crop load. Also, used a different chemicals an average time spent on hand thinning was reduced from 40-80 day ha$^{-1}$ to 10-20 day ha$^{-1}$ (Wertheim, 2000).

Number of fruits per trees is a primary factor of apple trees yield (Radivojević et al. 2014). According to Treder et al. 2010, crop load, defined as the number of fruits per tree, has a significant impact on both fruit quality and tree physiology. Flower bud production for the next growing seasons can be negatively affected by an increase in crop load. In a young, high-density planting apple orchard, it is particularly important to know the ideal amount of fruit per tree to obtain optimum fruit quality, vegetative growth, and adequate yield.

An adequate number of flowers per tree are a prerequisite for an annual crop, thus sufficient flower-bud formation in the preceding year (Wertheim, 2000). Apple fruits through their seeds, affect flower-bud formation negatively. Hormones from fruits seeds probably play a major role in this negative effect. A too many flowers per tree set fruit are required a reduction in the number of fruits per tree by

thinning. Manual, chemical and mechanical methods are used, alone or in combination, but the method chosen depends upon species, climatic conditions and the historic reliability of the proposed method (Greene and Costa, 2013). Thinning apple trees is a common practice in intensive growing systems. It has been confirmed many times that thinning with bioregulators may affect regular bearing, yield and fruit quality of apple (Milić et al., 2012).

Thinning can be carried out during bloom but it is more often done later when fruits have 8-12 mm diameter, because growers want to be certain that fruit set is adequate. Thinning large numbers of trees by hand is neither practical nor economic. Therefore, thinning flowers or fruits by chemicals is customary. The apple trees flowering is quite limited after a year with heavy fruit load, while flowering is abundant after a year with few fruit (Haberman et al., 2016). Those authors expired that level of MdTFL1-2 gene in leaves had significant effect to alternative bearing on apples tree, same as fruit loud and gibberellins.

The aim of this study was to evaluate the thinning efficacy of different plant bioregulators such as auxin (NAA), gibberellins (BA), ethephon (Etrel) and metamitron (Brevis) to crop loud, yield, fruit quality and return blooming on young trees apple cultivar ‘Golden Reinders’.

## MATERIAL AND METHODS

The study was carried out at commercial orchard located in Stalać, Central Serbia, in the second and third growing years (2017/2018). The area has a temperate continental climate with an average annual rainfall of 645 mm. The orchard was established in spring 2016 with high-quality 1-year-old nursery trees that contained 5 or more lateral branches. Apple trees were grafted on M9 rootstock and planted on distance of 3.2*0.8 m (3.900 trees/ha).

In the spring of 2017, 25 trees per treatments were selected according to their uniformity (high bloom density and homogeneous growth vigor). The experiment was built by a random fields with five repetitions, where 5 trees were taken for a repeat. The treatments were as follows: 1) Non thinned (control); 2) Hand thinned (in time of June drop); 3) Ethephon 200 ppm (Ethrel 4,2 ml/10 l water); 4) BA 120 ppm (Globaril 12 ml/10 l water); 5) NAA 15 ppm (Ormorok 1.5 ml/10); 6) Metamitron 150 ppm (Brevis 10 g/10 l water); 7) NAA 5 ppm + BA 100 ppm/10 l water. Trees were sprayed with handheld atomizer when the diameters of fruits were 10-12 mm.

During a period of examined the following generative properties were studied: fruit mass and width, number of fruits per tree, number of flower buds per tree (return blooming), crop load (fruit $cm^{-2}$ TCSA), yield efficiency (kg $cm^{-2}$ TCSA), average yield per tree. Evaluation of inner fruit quality included following properties such as firmness, total soluble solids (TSS), total acid (TA) and maturity stage was determined with iodine-starch test.

Analysis of variance has been done with STATISTICA 7 software package. Mean separation was done by Tukey’s less significant difference test (LSD) at a 5% level of significance. Relationships among the investigated fruit parameters were measured using the Pearson correlation coefficient (r) and correlations were considered statistically significant, if the p-value was less than 0.05.

## RESULTS AND DISCUSSION

'Golden Delicious' apple cultivar is considered difficult to thin and prone to alternate bearing if crop load is not annually regulated (Milić et al., 2013). Total numbers of apple fruits per tree were between 29.8 and 61.6 (table 1). At harvest time of apples fruits control trees and trees thinned with mixed of NAA+BA had significantly highest number of fruits. Also, those treatment affected to highest numbers of apples which were smaller of 70 mm of fruit diameters. Trees sprayed with metamitron and mixed of bioregulators had the highest number of fruits which were higher of 70 mm of fruit diameters, 33 and 29.8 respectively. However, trees thinned by hand and metamitron had significantly the highest percentage of marketable fruits, over 60% of fruits higher of 70 mm in diameter. Basak (2011) recorded that a single treatment with metamitron positively influenced fruit size, the distribution of apples in size classes, and yield of apples with diameters of > 70 mm. Results indicate that metamitron reduced fruit set in a concentration-dependent manner and highest abscission rates were encountered when thinning was conducted at 12 mm fruit diameter (Stern 2016).

***Table 1.***

**Effect of treatments to numbers and structure of apple fruits per tree**

| Treatmens | Number of fruits per tree | | | | | | |
|---|---|---|---|---|---|---|---|
| | Total | <70 mm | 70-75 mm | >75 mm | %<70 mm | %70-75mm | % >75 mm |
| BA | 41.0 d | 19.6 c | 17.6 bc | 3.8 bc | 44.9 c | 46.1 bc | 9.0 b |
| NAA | 53.2 b | 31.8 b | 19.4 c | 2.0 c | 59.3 b | 36.9 c | 3.8 c |
| NAA+BA | 59.2 a | 26.2 bc | 27.8 a | 5.2 ab | 44.7c | 46.1 bc | 9.2 b |
| Metamitron | 47.4 c | 17.6 c | 23.6 ab | 6.2 a | 36.9 d | 50.3 b | 12.8 a |
| Ethephon | 39.4 d | 24.6 bc | 11.8 d | 3.0 c | 62.7 ab | 29.3 cd | 8.0 b |
| Hand Thin | 29.8 e | 4.0 d | 21.6 b | 4.2 b | 13.4 e | 72.5 a | 14.0 a |
| Control | 61.6 a | 43.4 a | 16 c | 2.2 c | 70.4 a | 25.8 d | 3.8 c |
| lsd | 4.5 | 10.4 | 4.3 | 1.2 | 8.4 | 10.2 | 3.1 |

The highest weight of fruits had trees thinned by hand and metamitron, 170.7 g and 170.5 g respectively (table 2.). Those treatments and mixed NAA+BA had fruits higher diameter than 70 mm. Control and thinned trees with Ethephon had fruits of the smallest weight and the diameter. Fruit weight is one of the main factors determining yield level and, consequently, profitability of apple production. The negative impact of heaviest crop load on the average fruit weight observed in this study could be associated with a very high number of apples per tree. Ours results confirmed previous researches (Treader et al., 2010; Radivojević et al., 2014).

A thinning treatment had effects to maturity stage of fruits. Control and trees thinned with NAA had the highest level of Strach index in 10° scale. Also, fruits from those trees had the smallest values of firmness and the highest content of soluble solids. Hand thinned trees and treatment with metamitron caused a fruits with the smallest level of mature. An apples tree thinned with Ethephon had a fruits with the smallest content of soluble solids (15.0 Brix). Fruit quality parameters such as fruit size, fruit color, soluble solid content, and titratable acidity were improved by metamitron (Brunner, 2014). According to Lafer (2017) using a NAA contributed to lost firmness and early

maturity of apple fruits. BA frequently increased flesh firmness and soluble solids, but in order to do this it had be applied directly to the fruit (Greene, 1993).

***Table 2.***

**Effects of treatment to inner quality of apples fruit**

| Treatmens | Fruit mass (g) | Fruit diameter (mm) | Firmness ($kg/cm^2$) | Iodine-starch test (1-5) | SSC (brix) |
|---|---|---|---|---|---|
| BA | 162.0 b | 69.6 c | 8.0 | 2.6 | 15.5 |
| NAA | 152.6 c | 68.6 c | 7.2 | 3.5 | 16.2 |
| NAA+BA | 168.9 a | 70.0 bc | 7.9 | 3.2 | 15.6 |
| Metamitron | 170.5 a | 70.8 b | 8.2 | 2.8 | 16.0 |
| Ethephon | 152.9 c | 65.2 d | 7.0 | 3.2 | 15.0 |
| Hand Thin | 170.7 a | 72.1 a | 8.4 | 2.7 | 15.2 |
| Control | 132.6 d | 66.2 d | 7.3 | 3.9 | 16.9 |
| lsd | 4.6 | 1.1 | | | |

Effects of thinning treatments to productivity traits of apple trees are shown in table 3. The highest yield per trees had control treatment (7.34 kg), while the smallest yield had trees thinned with Ethephon (4.21 kg). Trees thinned with metamitron, NAA and BA+NAA had similar yield per trees. An expected control trees had significantly the highest values of crop loud (11.12), and the smallest trees thinned by hand (5.14).

***Table 3.***

**Effects of treatments to productivity traits of apple trees**

| Treatmens | Yield kg/tree | Crop loud | Yield efficiency | Number of flowers buds per tree | Subsequent blooming scale (5-very abundant) |
|---|---|---|---|---|---|
| BA | 5.78 b | 7.33 b | 1.03 b | 38.2 c | 3.0 |
| NAA | 6.96 a | 10.60 ab | 1.40 a | 18.4 d | 1.5 |
| NAA+BA | 6.67 a | 10.18 ab | 1.16 b | 25.4 c | 2.0 |
| Metamitron | 6.67 a | 8.70 b | 1.23 ab | 51.0 b | 4.0 |
| Ethephon | 4.21 c | 8.39 b | 0.92 b | 20.8 d | 1.5 |
| Hand Thin | 5.52 b | 5.14 c | 0.95 b | 61.8 a | 5.0 |
| Control | 7.34 a | 11.12 a | 1.32 ab | 9.8 e | 1.0 |
| lsd | 1.2 | 2.39 | 0.26 | 7.27 | |

Treatment with high values of crop loud had a higher coefficient of yield efficiency. The highest values of this parameter had trees thinned with NAA (1.4), while the smallest had trees thinned with Ethephon. High values of coefficient of correlation was found between crop loud and yield efficiency ($r= 0.80$; $p<0.05$).

Number of flowers bud per trees in next growing season was between 9.8 (control) and 61.8 (hand thinned). Treatments which contributed to higher values of crop loud effected to a low values of flowers bud. Marini et al (2013) recorded that a flower density was negatively related to the previous season's crop density in a linear manner 43%. Trees with higher values of crop

loud than 10 fruits $cm^{-2}$ had a less estimated values on blooming scale. According to De Salvador et al (2006) determined that the crop load of 6 fruits $cm^{-2}$ TCSA as standard, whereas 8 fruits $cm^{-2}$ TCSA is considered a high crop load. A heavy fruiting can partially or completely inhibit flower bud initiation in some apple cultivars. The consequences of high fruit load are reductions in floral returns and flowering patterns in the following season, the latter being dependent on the cultivar (Yuri et al., 2011). According to Radivojević et al. (2014) a trees of 'Gala' and 'Breaborn' cultivars could be loaded to 13 fruit $cm^{-2}$ TCSA in the third growing year, which provided a yield of about 50 t $ha^{-1}$ without a negative influence on the fruit quality and potential crop in the following growing season. Hand thinned and trees sprayed with metamitron had the highest number of flower buds in following growing seasons, while the smallest had control and trees thinned with ethephon. On the other hand, Meland and Kaiser (2011) recommended that ethephon applied at a rate of 375 $mg \cdot L^{-1}$ when king flowers open or at a rate of 625 $mg \cdot L^{-1}$ when the average fruitlet size is 10 mm in diameter, return bloom was improved. Low effects of ethephon in ours research due to inadequate time and concentartion of applied.

## CONCLUSION

A using different plant bioregulators had statistical significant effects to thinning and quality traits of apples fruits. Total numbers of apple fruits per tree were between 29.8 (hand thinned) and 61.6 (control). Apple trees thinned by hand and metamitron had significantly the highest percentage of marketable fruits, over 60% of fruits higher of 70 mm in diameter. Those treatments and mixed NAA+BA had fruits higher average diameter than 70 mm. Treatments with NAA and control trees had contributed an early maturity of fruits.

The highest yield per trees had control treatment (7.34 kg), while the smallest yield had trees thinned with Ethephon (4.21 kg). Number of flowers bud per trees in next growing season was between 9.8 (control) and 61.8 (hand thinned). Treatments which contributed to higher values of crop loud effected to a low values of flowers bud. Treatments which contributed a crop loud less than 10 fruits per $cm^{-2}$ TCSA did not had negatively effect to return bloom in following growing season, except ethephon. Ours results confirmed that used a plant bioregulators had strong effects to thinned apple and improved quality of fruits. Using metamitron and BA to fruits thinning can be a recommended like techniques in young orchard.

## ACKNOWLEDGMENT

This study was supported by the Serbian Ministry of Education, Science, and Technological Development projects TR31063.

## BIBLIOGRAPHY

1. **Basak, A.** (2011). *Efficiency of fruitlet thinning in apple 'Gala Must' by use of metamitron and artificial shading*. Journal of Fruit and Ornamental Plant Research, 19(1): 51-62.
2. **Brunner, P.** (2014). *Impact of metamitron as a thinning compound on apple plants.* Acta Hortic. 1042: 173-181.
3. **De Salvador, F.R., Fisichella, M., Fontanari, M.** (2006). *Correlations*

*between fruit size and fruit quality in apple trees with high and standard crop load levels.* J Fruit Ornam Plant Res 14: 113–122.

4. **Greene, D.W.** (1993). *A review of the use of benzyladenine (BA) as a chemical thinner for apples.* Acta Hortic. 329, 231-236.
5. **Greene, D., Costa, G.** (2013). *Fruit thinning in pome- and stone-fruit: state of the art.* Acta Hortic. 998: 93-102.
6. **Haberman, A., Ackerman, M., Crane, O., Kelner, J.J., Costes, E., Samach, A.** (2016). *Different flowering response to various fruit loads in apple cultivars correlates with degree of transcript reaccumulation of a TFL1-encoding gene.* The Plant Journal 87: 161–173.
7. **Marini, R.P., Autio, W.R., Black, B., Cline, J., Cowgill, W.R., Crassweller, R.M., Domoto, P.A., Hampson, C., Moran, R., Quezada, R.A., Robinson, T., Ward, D.L., Wolfe, D.** (2013). *Return bloom on 'Golden Delicious' apple trees as affected by previous season's crop density on three rootstocks at 11 locations.* Journal of the American Pomological Society 67(2): 73-79.
8. **Milić, B., Čabilovski, R., Keserović, Z., Manojlović, M., Magazin, N., Dorić, M.** (2012). *Nitrogen fertilization and chemical thinning with 6-benzyladenine affect fruit set and quality of golden delicious apples.* Scientia Horticulturae, 140: 81-86.
9. **Milić, B., Keserović, Z., Magazin, N. and Dorić, M.** (2013). *Effects of BA and NAA on thinning and fruit quality of apple cultivars 'Golden Delicious' and 'red Delicious'.* Acta Hortic. 981: 301-306.
10. **Radivojević, D., Milivojević, J., Oparnica, Č., Vulić, T., Đorđević, B., Ercisli, S.** (2014). *Impact of early cropping on vegetative development, productivity, and fruit quality of Gala and Braeburn apple trees.* Turk J Agric For, 38: 773-780.
11. **Stern, R.A.** (2016). *The photosynthesis inhibitor Metamitron is an effective fruitlet thinner for 'Gala' apple in the warm climate of Israel.* Acta Hortic. 1119: 15-24.
12. **Treder, W., Mika, A., Krzewińska, D.** (2010). *Relations between tree age, fruit load and mean fruit weight.* J Fruit Ornam Plant Res 18: 139–149.
13. **Yeh, M., Ickes, S.B., Lowenstein, L.M., Shuval, K., Ammerman, A.S., Farris, R., Katz, D.L.** (2008). *Understanding barriers and facilitators of fruit and vegetable consumption among a diverse multi-ethnic population in the USA.* Health Promotion International, 23(1): 42-51.
14. **Yuri, J.A., González Talice, J., Verdugo, J., Pozo, A.** (2011). *Responses of fruit growth, quality, and productivity to crop load in apple cv. Ultra Red Gala/MM111.* Sci Hortic-Amsterdam 127: 305–312.
15. **Wertheim, S.J.** (2000). *Developments in the chemical thinning of apple and pear.* Plant Growth Regulation 31: 85–100.
16. **Meland, M., Kaiser, C.** (2011). *Ethephon as a blossom and fruitlet thinner affects crop load, fruit weight, fruit quality, and return bloom of 'Summerred' apple (Malus ×domestica) Borkh.* Hortscience 46(3): 432–438.