Effects of Fruit Thinning Method on Crop Load and Yield on "Golden Delicious" Apple Cultivar, Under Gjakova's Climate Conditions

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Abstract

The study on effects of fruit thinning method od crop load and yield on "Golden Delicious" apple cultivar, trained on slender spindle and improved pyramidal shapes, was carried out during 2013, in Skivjan, Gjakova, in the South-Western part of Kosovo. Two different fruit thinning methods (hand thinning and chemical thinning using a combination of Carbaryl 1000 ppm + NAA 40 ppm, with 1200 L ha^{-1} spraying solution) and two replications, with 10 apple trees for each variant on each replication for each system shape, were used. Apple intensive orchard was constructed since 2006 in a hill of 400 m elevation, using saplings grafted on M-9 rootstock and planted at 3.8 m between rows and 1.8 m within a row (1462 trees ha^{-1}). Fruit thinning was carried out 15 days after bloom, when fruit diameter was 10-12 mm. At the harvest time, there were measured several biometric features of each apple tree such as: tree height (m), crop load diameter and radius (m), yield (kg $tree^{-1}$), volume of crop load (m^3), and were counted the mean values for each thinning method. Observed results showed that thinning method (hand and chemical) affected significantly the crop load and yield of "Golden Delicious" apple cultivar, on both training systems. Chemical fruit thinning using CB + NAA increased the crop load by 13.6% and 14.7%, while the yield per tree was increased by 11.3% and 12.8%, respectively, for slender spindle and pyramidal shapes.

KEYWORDS: *Malus domestica* Borkh, Carbaryl, chemical, crop load, fruit thinning, Naftalene Acetic Acid (NAA), hand thinning, yield.

INTRODUCTION

Fruit thinning of apple (*Malus domestica* Borkh.), as to the other fruit trees, must be applied regularly with the aim of getting high and regular productivity yaer-by-year, getting uniform apple fruits, and creating a balanced rate of vegetative and productive mass (Çakalli and Thomaj, 2005). Fruit thinning of apple can be applied mechanically (hand thinning method), which is a very high cost process, or using different chemicals or combinations (chemical thinning method). For apple tree, both methods are being used and reccommended, separately or in combination to each other (Ferraj and Thomaj, 2014). According to Schumacher *et al.* (1989), chemical thinning application of apple trees is justified because of three reasons: chemical thinners reduce biennial production, reduce the cost of manual thininng, and their use affect the improvement of apple fruit

quality. However, sometimes, except positive effetcs such as the increase of fruit mass (Pavicic and Paulic, 1989) and reduction of periodical productivity (Link, 1998), chemical fruit thinning can cause negative effects such as reduced yield (Elfving and Cline, 1993/a; Elfving and Cline, 1993/b), fruit deformation at cv "Golden Delicious" (Rogers and Williams, 1977), poor fruit coloration at cv Mutsu (Byers and Carbaugh, 1991; Daugaard and Grauslund, 1999), low calcium concentration in fruit at cv Boscop (Hess *et al.*, 1996), etc. Hand fruit thinning is a very high labour cost process which is being used mainly to new orchards and in limited areas, while chemical thinning can be applied easily and is less expensive (Zajmi *et al.*, 2007).

Chemical thinners include different chemicals, but plant growth regulators and some insecticides are used for thinning in most cases. Results from the recently published literature point to advantages of combining certain growth regulators and insecticides for apple fruit thinning (Jemrić *et al.*, 2003). Combination of carbaryl and 1-naphtaleneacetic acid has given good results in some years and climate conditions, but caused excessive thinning in some other years and climate conditions (Rogers and Williams, 1977). Generally, mixtures of growth regulators (Elfving and Cline, 1993/b), or growth regulators and insecticides (Marini, 1996; Byers and Carbaugh, 1991) are being used, particularly for cultivars which are not easily mechanicaly thinned (Byers and Carbaugh, 1991). In such cases, it is possible to reduce the concentration of individual thinner. This is extremely important from the environmental point of view (Jemrić *et al.*, 2003). The most used chemical apple fruit thinners are Ethephon (ETH), Carbaryl (CB), Naphthalene Acetic Acid (NAA), 6-Benzyladenine (6-BA), and fish oil (Reyes *et al.*, 2008; Greene, 2002; Lakso *et al.*, 2000; Marini, 1996; Zucconi, 1992), which are being used for chemical treatment of little fruits (10-15 mm) (Ferree and Schmid, 2001; Vercamen, 1997), 2-3 weeks after bloom, and are being applied as liquid solution in given concentrations (Marini, 2000; Bergamini, 1991). Through winter pruning and green operations, such as branch top cutting, flower and fruit thinning, etc., fruit growers ams to ensure 30-40 healthy leaves for each fruit and try to avoid the high yield the first growing years of apple trees, which causes premature aging of apple trees (Bellini, 2002; Krebs and Widmer, 1992).

"Red Delicious" and "Golden Delicious" are some of the most widely planted apple cultivars in Albanian and in Kosovo's orchards. These cultivars are reported as difficult to thin by hand (Marini, 2002). To overcome this problem, there is being applied the chemical thinning using Carbaryl (CB) and Naphthalene Acetic Acid (NAA), which are the most used chemical thinners in Kosovo and other countries. Reyes *et al.* (2008) report that chemical thinning using Carbaryl and fish oil reduced the periodical yield of cv "Golden Delicious", while ethephon and 6-BA negatively affected the second year bloom.

Marini (2004), Jemrić *et al.* (2003), Pavičić (1993), etc., have reported that chemical fruit thinning had affected the year-by-year yield of cv "Golden Delicious", reducing the genetic tendency for biennial yield. Reduction of fruit number per tree affects pozitively the vegetative growth of shoots, leaves, and crop load, as well (Mika, 1986). Sometimes, "Golden Delicious" apple cultivar asks for additional thinning of the fruits by hand after chemical thinners (Ferraj and Thomaj, 2014; Schumacher *et al.*, 1989) or for combining of Carbaryl with Naphthalene Acetic Acid (NAA) ose 1-naphthaleneacetamide (NAD) (Vercamen, 1997) to achieve optimal results. Our aim was to determine the effect of hand

and chemical thinning (Carbaryl 1000 ppm + NAA 40 ppm) on crop load and yield of "Golden Delicious" apple cultivar, trained on slender spindle and improved pyramidal shapes.

MATERIALS AND METHODS

Orchard placement

Study was carried out in 2013 in Skivjan, Commune of Gjakova, Kosovo, a very known area for orchard development, in general, and, especially, apple orchards. "Golden Delicious" apple orchard was planted in November 2006, with saplings grafted on M-9 rootstock, planted 3.8 m between rows and 1.8 m within a row (1462 apple trees ha^{-1}). Rows orientation was North-South. Orchard was constructed in a hill 400 elevation. Apple trees were normally healthy and with a same vegetative growth and development. "Golden Delicious" apple cultivar is the most widely planted cultivar in Gjakova's region, as well as in Albanian and Kosovo's orchards. Apple trees were trained on slender spindle, with hanged shoots, and improved pyramidal shapes, for better use of solar energy. Space between rows was grassed with tapecant cereals and all cultural other cultural practices were applied regularly, as in other apple orchards.

Apple fruit thinning

The main objective of the study was to determine the effect of hand and chemical thinning (Carbaryl 1000 ppm + NAA 40 ppm) on crop load and yield of "Golden Delicious" apple cultivar, trained on slender spindle and improved pyramidal shapes. Apple fruit thinning was applied 15 days after bloom, when the fruit equatorial diameter was 10-12 mm. There were tested two thinning methods (two variants):

1. Hand thinning (mechanical thinning), leaving 1 fruit per cluster
2. Chemical thinning, using Carbaryl 1000 ppm + NAA 40 ppm, with a sprying volume of 1200 L per ha.

There were used two variants and two replications, with a variant size of 10 apple trees per replication. There were used 40 apple trees for for each trained shape under study. Apple trees were marked with plastic labels.

Measurements and analysis

There were measured several features for each apple tree under study, such as: plant (tree) height (H) starting from the first bifurcation of the first skeletal branches up to the top (m), mean diameter (D) and mean radius (R) of the apple tree crown (m), yield (kg $tree^{-1}$), and, then, were calculated crop load (m^3) for each apple tree and for each treatment, and mean yield (kg $tree^{-1}$). All measurements were carried out at harvest on 10 apple trees per treatment per replication. Harvest date has been determined according to the standard method and fruits were harvested on September 15, 2013. Fruits of each plant were weighed separately with an analytical balance and was calculated the mean yield (kg $tree^{-1}$) for each thinning method and each trained shape.

Crop load calculation for apple trees trained on slender spindle shape was based on the diameter and radius of the circle formed on the bottom part of the tree crown and tree height, according to formula (1):

$$V_b = \frac{1}{3} (R^2 \times \pi \times H) \quad (1),$$

where:

V_b – crop load of the tree on slender spindle shape (m^3)

R – radius of the circle formed on the bottom part of the tree crown (equal to ½ D) (m)
H - tree height starting from the first bifurcation of the first skeletal branches up to the top (m)

Crop load calculation for apple trees trained on improved pyramidal shape was based on the diameter and radius of the circles formed on the bottom part and the upper part of the tree crown, and tree height, according to formula (2):

$$V_p = \frac{1}{3} (R + r)^2 \times \pi \times H \qquad (2),$$ where:

V_p - crop load of the tree on improved pyramidal shape (m^3)
R - radius of the circles formed on the bottom part of the crown (m)
r - radius of the circles formed on the upper part of the crown (m)
H - tree height (height of the central axis, starting from the first bifurcation of the first skeletal branches up to the top (m)
Crop load was calculated for each tree separately and, after that, was calculated mean value of each thinning method and each trained system.

Data analysis and presentation of the observed results

The obtained data were subject of descriptive and statistical methods (ANOVA: Two-Factors Without Replication) ($\alpha = 0.05$) (Papakroni, 2001). Observed results are presented in tables and graphs.

RESULTS AND DISCUSSION

Effects of thinning methods on crop load and yield of "Golden Delicious" apple cultivar were observed for training methods, ***slender spindle*** and improved pyramidal shape. Observed results showed that thinning method has affected significantly the crop load and yield of "Golden Delicious" apple cultivar on both training systems.

Crop load (m^3) and yield (kg $tree^{-1}$) of "Golden Delicious" apple cultivar, trained on slender spindle system

Observed results showed that thinning method (hand or chemical) has affected significantly the crop load (m^3) and yield (kg $tree^{-1}$) of "Golden Delicious" apple cultivar, trained on slender spindle system. Mean crop load of trees using hand thinning method was 3.72 m^3, while mean crop load of trees using chemical thinning method (Carabaryl 1000 ppm + NAA 40 ppm) was 4.22 m^3 (0.505 m^3 or 13.6% higher for chemical thinning compare to hand thinning). Difference between treatments (thinning methods) for mean values of crop load was significant and statistically confirmed at $p \leq 0.05$ (Table 1 and Table 3).

Mean yield of hand thinning was 33.25 kg $tree^{-1}$, while mean yield of trees using chemical thinning (Carabaryl 1000 ppm + NAA 40 ppm) was 37 kg $tree^{-1}$ (3.75 kg $tree^{-1}$ or 11.3% higher for chemical thinning compare to hand thinning). Difference between treatments (thinning methods) for mean values of crop load was significant and statistically confirmed at $p \leq 0.05$ (Table 1, Table 3 and Figure 1).

Table 1. Effect of thinning method on crop load (m^3) and yield (kg $tree^{-1}$) of "Golden Delicious" apple cultivar, trained on slender spindle system (* significant at $p \leq 0.05$)

Fruit thinning method	Crop load (m^3)	Yield (kg $tree^{-1}$)
- Hand thinning	3.72	33.25
- Chemical thinning (CB 1000 ppm + NAA 40 ppm)	4.22*	37*

Crop load (m^3) and yield (kg $tree^{-1}$) of "Golden Delicious" apple cultivar, trained on improved pyramidal system

Observed results showed that thinning method (hand or chemical) has affected significantly the crop load (m^3) and yield (kg $tree^{-1}$) of "Golden Delicious" apple cultivar, trained on improved pyramidal system. Mean crop load of trees using hand thinning method was 11.12 m^3, while mean crop load of trees using chemical thinning method (Carabaryl 1000 ppm + NAA 40 ppm) was 12.74 m^3 (1.625 m^3 or 14.7% higher for chemical thinning compare to hand thinning). Difference between treatments (thinning methods) for mean values of crop load was significant and statistically confirmed at $p \leq 0.05$ (Table 2 and Table 3).

Mean yield of hand thinning treatment was 38.125 kg $tree^{-1}$, while mean yield of trees using chemical thinning (Carabaryl 1000 ppm + NAA 40 ppm) was 43 kg $tree^{-1}$ (4.875 kg $tree^{-1}$ or 12.8% higher for chemical thinning compare to hand thinning). Difference between treatments (thinning methods) for mean values of crop load was significant and statistically confirmed at $p \leq 0.05$ (Table 2, Table 3 and Figure 1).

Table 2. Effect of thinning method on crop load (m^3) and yield (kg $tree^{-1}$) of "Golden Delicious" apple cultivar, trained on improved pyramidal system (* significant at $p \leq 0.05$)

Fruit thinning method	Crop load (m^3)	Yield (kg $tree^{-1}$)
- Hand thinning	11.12	38.125
- Chemical thinning (CB 1000 ppm + NAA 40 ppm)	12.74*	43*

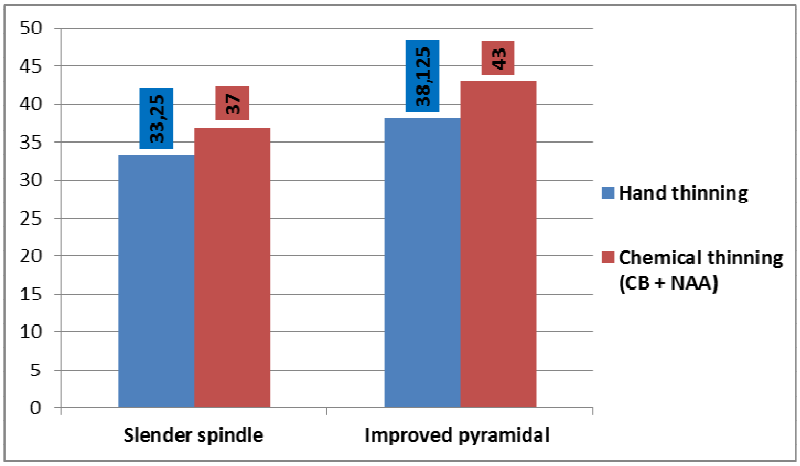

Figure 1. Mean yield (kg $tree^{-1}$) of "Golden Delicious" apple cultivar, trained on slender spindle and improved pyramidal system

Results of ANOVA *(ANOVA: Two-Factor Without Replication)* showed that the linkage between thinning method, crop load and yield was significant. Effect of chemical thinning on crop load and yield was statistically confirmed by F and P-value at $p \leq 0.05$, where F > Fcrit dhe P-value < $\alpha = 0.05$) (Table 3).

Table 3. *Anova: Two-Factor without Replication* for testifying the effect of thinning method on crop load and yield of "Golden Delicious" apple cultivar, trained on slender spindle and improved pyramidal system ($p \leq 0.05$)

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F-crit*
Rows	37.22609	7	5.318090	1.494478	0.223028	2.487577
Colums (thinning methods)	517.9979	3	172.666	**48.52291**	***1.28E-09***	***3.072467***
Error	74.72729	21	3.558442			
Total	629.9513	31				

The obtained data of the study are similar to Marini (2002) for "Golden Delicious" apple cultivar in Virginia, USA, and El Salhy (1996) for "Dorsett Golden", who report on yield increase, but are contrary with Rogers and Williams (1977), Byers and Carbaugh (1991), who report on yield reduction. Carbaryl affects on the increase of specific leaf weight, leaf area per spur and bourse shoot length on the most productive spurs which increase fruit weight (Looney, 2000), while NAA has a favourable effect on fruit growth, increase of the volume of spur and leaf cells (Marini, 2004; Marini, 2002). Chemical thinners used in our study (Carbaryl and NAA) contributed together on better leaf/fruit ratio and higher crop load and yield.

Several authors report that weather conditions have a strong influence on the apple thinner efficacy (Reyes *et al.*, 2008; Greene, 2002), and, an other important factor is thinner concentration since when used in larger doses they could cause phytotoxicity in some apple cultivars (Jemrić *et al.*, 2003; Pfammater and Dessimoz, 1999). Some other important factors affecting the response of apple to thinning, except crop load, are age of trees, flower bud quality, competition within vegetative and productive mass, etc (Jemrić *et al.*, 2003; Link, 1998).

Achieved results of the study showed that thinning method affects the crop load and yield of "Golden Delicious" apple cultivar, regardless of the training system of the orchard, at least in the ecological conditions of Skivjan, Gjakova, Kosovo.

CONCLUSIONS

Fruit thinning method significantly affects the vegjetative growth (crop load) and productivity of "Golden Delicious" apple cultivar under climatic conditions of Skivjan, Gjakova, Kosovo. Chemical fruit thinning using Carbaryl 1000 ppm + NAA 40 ppm increased the crop load of "Golden Delicious" apple cultivar trained on slender spindle and improved pyramidal system by 13.6% and 14.7%, respectively. Yield (kg tree^{-1}) of "Golden Delicious" apple trained on slender spindle and improved pyramidal system, using chemical thinning was 3.75 kg tree^{-1} and 4.875 kg tree^{-1} or 11.3% and 12.8% higher, respectively.

Differences between thinning methods were statistically confirmed by ANOVA-test (F >

F-crit and P-value < α = 0.05), which means that there exist a significant relationship between fruit thinning method, crop load and yield.

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References

Bergamini, A. (1991). Froticoltura Speciale. REDA – Italy: pp. 72.

Bellini, E. (2002). Cultural practices for persimmon production Options – Mediterraneenes: pp. 53.

Byers, R. E., Carbaugh, D. H. (1991). Effect of chemical thinning sprays on apple fruit set. Hort. Technol: pp. 41-48.

Çakalli, D., Thomaj, T. (2005). Special Pomology (Student's textbook): pp. 44.

Daugaard, H, Grauslund, J. (1999). Fruit colour and correlations with orchard factors and post – harvest characteristics in apple cv. Mutsu. J Hort Sci Biotechnol: pp. 283-287.

El Salhy, A. M. (1996). Effect of hand and chemical thinning on fruit retention and quality of Dorsett Golden trees. Assiut J Agric Sci 27: pp.119-132.

Elfving, D. C., Cline, R. A. (1993/a). Benzyladenyne and other chemicals for thinning Empire apple trees. J Amer Soc Hort Sci 118: pp. 593-598.

Elfving, D. C., Cline, R. A. (1993/b). Cytokinin and etephon affect crop load, shoot growth, and nutrient concentration of Empire apple trees. Hort. Science 28: pp. 1011-1014.

Ferraj, B., Thomaj, T. (2014). Pomology I, main species" (Student's textbook): pp. 22, 53.

Ferree, D. C., Schmid, J. C. (2001). Chemical thinning 'Gala' apple in the Midwest. J. Amer. Pomol. Soc. 55: pp. 109-113.

Greene, D. W. (2002). Chemicals, timing, and environmental factors involved in thinner efficacy on apple. Hort Science 37: pp. 477-481.

Hess, B., Stadler, W., Bertschinger, L., Krebs, C., Schumacher, R. (1996). Alternanz und fruchtqualität von Boskoop bei unterschiedlicher ausdünnung und bodenpflege. Obst und Weinbau 132: pp. 282-274.

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. Current Studies of Biotechnology (02/2003) 3: pp. 193-198.

Krebs, C., Widmer, A. (1992). Mikado - und Drilling- System – zwei neue Baumformen in Prüfung. Schweiz: pp. 128; 297.

Lakso, A. N., Robinson, T. L., Goffinet, M.C., White, M.D. (2000). Apple Fruit Growth Responses to Varying Thinning Methods and Timing. ISHS Acta Horticulturae (ISHS) 557: VII International Symposium on Orchard and Plantation Systems: pp. 407-412. http://www.actahort.org/books/557/557_54.htm

Link, H. (1998). Effects of thinning in a long term trial with six apple cultivars on yield and fruit size. Acta Hort 466: II Workshop on Pome Fruit: pp. 59-64.

Looney, N. E. (2000). Some effects of carbaryl on the growth and development of apple

leaves: a possible mechanism for fruitlet thinning. Acta Hort 527: pp. 127-136.
Marini, R. P. (2004). Combinations of ethephon and Accel for thinning 'Delicious' apple trees. J. Amer. Soc. Hort. Sci. 129: pp. 175-181.
Marini, R. P. (2002). Thinning 'Golden Delicious' and spur 'Delicious' with combinations of Carbamates and NAA. Hort.Science 37: pp. 534-538.
Marini, R. P. (2000). Training and Pruning Apple Trees in Intensive Orchards. Revised by T. Woolf and A. Smith (2009). Virginia Cooperative Extention.*http://pubs.ext.vt.edu/422/422-024/422-024.html*.
Marini, R. P. (1996). Chemically thinning spur Delicious apples with carbaryl, NAA, and etephon at various stages of fruit development. Hort. Technol, Vol. 6(3): pp. 241-246.
Mika, A. (1986). Physiological responses of fruit trees to pruning. Horticultural Reviews 8: pp. 249.
Papakroni, H. (2001). Programe përdorimi në kompjuter 2, Excel: pp. 153, 171.
Pavičić, N. (1993). Kemijsko prorjedivanje plodova sorte Idared. Agronomski glasnik: pp. 41.
Pavicic, N., Paulic, N. (1989). Effect of chemical thinning on the goldspur (Auvil spur) cultivar on the amount of yield, diameter, rustiness and the degree of ripeness of the fruit (in Croatian). Agron. Glas. 55: pp. 3-11.
Pfammatter, W., Dessimoz, A. (1999). Eclaircissage chimique de pommiers Royal Gala et Braeburn. Rev Suiss Vitic Arboric Hortic Vol. 31: pp. 299-302.
Rogers, B. L. , Williams, G. R. (1977). Chemical thinning of spur-type Delicious apple fruit. Virginia Fruit 65: pp. 23-28.
Reyes, D. I. B., Chacón, A. R., Campos, Á. R. M., Prieto, V. M. G. (2008). Apple fruit chemical thinning in Chihuahua, México. Rev. Fitotec. Mex. Vol. 31 (3): pp. 243-250.
Schumacher, R, Stadler, W, Weidmann, G. (1989). Chemische fruchtausdünnung zur verbesserung der fruchtqualität bei der sorte Golden Delicious. Schweiz. Zeitschr. Obst – und Weinbau 125: pp. 503-513.
Vercamen, J. (1997). L'eclaircissage chimique du pommier: une technique don't on ne peut plus faire ion. Fruit Belge 65: pp. 51-54.
Zajmi, A., Sylanaj, S., Berisha, B. (2007). Pemëtaria Praktike: pp. 90, 95.
Zucconi, F. (1992). Controllo dello sviluppo nelle piante arboree, introduzione alla fisiologia della potatura: pp. 7, 54.