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Effects of Benzyladenine and Naphthalene Acetic Acid Applications on Fruit Thinning and Quality of Some Apple Cultivars Grafted onto MM 106 Rootstocks

Berna TURAK[1], Ersin GÜLSOY[2]✉, Rafet ASLANTAŞ[3]
[1]Ministry of Food Agriculture and Forestry, Igdir, 76000 Turkey, [2]Igdir University, Faculty of Agriculture, Department of Horticulture, Igdir, 76000 Turkey, [3]Osmangazi University, Faculty of Agriculture, Department of Horticulture, Eskişehir, 26480 Turkey*
[1]https://orcid.org/0000-0001-6321-2981, [2]https://orcid.org/0000-0002-4217-0695, [3] https://orcid.org/0000-0002-1368-5673
✉: ersin.gulsoy@igdir.edu.tr

ABSTRACT
Fruit thinning is an essential practice to improve fruit size and quality, control alternate bearing and increase return bloom in the next season. Fruit thinning is performed by hand or by using some chemicals. In this study, the effect of chemical thinning, namely two doses of 5 and 10 ppm of Naphthalene Acetic Acid (NAA) or of 100 and 150 ppm of Benzyladenine (BA) on fruit thinning and some fruit quality traits Golden Delicious, Red Chief and Granny Smith apple cultivars grafted on MM 106 clone rootstock in 2015 was tested and compared with the effect of hand thinning. Chemical treatment was applied after three weeks of full bloom, while the hand thinning was made to be released a fruit per cluster on each branch in small fruit period after June-drops. The results showed that the highest fruit thinning ratio was found in the Granny Smith cultivars, with 5 ppm (93.80%) and 10 ppm (91.65%) of NAA, 100 ppm (89.88%) and 150 ppm 88.98%) of BA. It can be concluded that the applications of 10 ppm of NAA and 100 and 150 ppm of BA were found effective for fruit thinning and fruit quality. Furthermore, the hand thinning application increased the fruit weights more than all the chemical applications.

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Keywords
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MM106 Anacı Üzerine Aşılı Bazı Elma Çeşitlerinde Benziladenin ve Naftalen Asetik Asit Uygulamalarının Meyve Seyreltmesi ve Kalitesi Üzerine Etkisi

ÖZET
Meyve seyreltmesi, meyve büyüklüğü ve kalitesini iyileştirmek periyodisiteyi kontrol etmek ve sonraki yılın çiçek tomurcuğu oluşumunu arttırmak için yapılan önemli bir uygulamadır. Meyve seyreltmesi, elle veya bazı kimyasal maddeler kullanılarak yapılır. 2015 yılında yürütülen çalışmada MM 106 klon anacı üzerine aşılı Granny Smith, Golden Delicious ve Red Chief elma çeşitlerinde NAA'nın 5 ve 10 ppm'lik dozları ile BA'nin 100 ve 150 ppm'lik dozlarının meyve seyreltmesi ve bazı meyve kalite özellikleri üzerine etkisi araştırılmış ve elle seyreltme uygulamasıyla karşılaştırılmıştır. Elle seyreltme uygulaması Haziran dökümünden sonra her hüzmede ortada bir meyve kalacak şekilde yapılırken, kimyasal seyreltme uygulaması tam çiçeklenmeden 3 hafta sonra yapılmıştır. Çalışmada en yüksek seyreltme oranı Granny Smith çeşidinde sırasıyla NAA'nın 5 ppm'lik (%93.80) ve 10 ppm'lik (% 91.65), dozları ile BA'nin 100 ppm'lik (%89.88) ve 150 ppm'lik (% 88.98) dozlarından elde edilmiştir. Elde edilen sonuçlara göre NAA'nın 10 ppm'lik ve BA 'nin 100 ve 150 ppm'lik uygulamaları etkili meyve seyreltmesi ve meyve kalitesi için önemli bulunmuştur. Ayrıca elle seyreltme uygulaması kimyasal uygulamalara göre meyve ağırlığını daha fazla arttırmıştır.

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INTRODUCTION

One of the most important goals in apple growing as in other fruit species is to obtain high yield and high-quality products. Thinning of the apples increases the value of the product by improving the quality characteristics such as size, color and taste, and by allowing the trees to produce products on a regular basis every year. Therefore, the fruit thinning is considered as an important factor determining profitability in apple growing (Link, 2000).

Thinning is the process of removing excessive flowers and fruits from the tree using certain methods of removal (Dennis, 2000; Webster, 2002). Thinning is carried out manually, mechanically, or in the form of thinning of flowers and fruits by the use of some chemical substances (Ryugo, 1988; Rom, 2001). The efficiency of the thinning used in apple cultivation may vary depending on factors such as species, varieties, climate factors, type of chemical and application dose, physiological structure of tree (Jones et al. 2000; Greene, 2002).

NAA is the first synthetic auxin type chemical agent used in apple thinning (Wertheim, 2000). NAA is absorbed from the leaf and promotes the formation of the separation layer by promoting the formation of ethylene, thus forming the breakdowns (Tromp, 2000). The most effective application time of NAA as a chemical thinner is when the fruit diameter reaches 11-13 mm or 7-9 mm (Greene, 2002; Pesteanu, 2013).

Generally, the efficient amount of NAA concentration is between 5 and 20 ppm (Keserovic et al. 2016). As the dose of application increases, the thinning rate increases as well, but the higher doses cause damage to the leaves and the fruits remain small (Burak et al. 1997).

Benzyladenine (BA) is a more effective and stable compound in apple thinning by increasing fruit size and quality, but decreasing the fruit yield (Greene et al., 1990). Through the stimulation of cell division, BA leads to the production of bigger fruits by increasing the number of cells per fruit (Yuan and Greene, 2000). Even though it is stated that BA responds to thinning in the period when fruits reach a larger diameter (Elfving and Cline, 1993), the most effective period of application is when the fruit diameter reaches 10 mm (Basak, 1996).

The aim of this study was to determine the effect of thinning applications on some fruit properties and fruit quality. The effects of some chemical substances (NAA, 5 and 10 ppm; BA, 100 and 150 ppm) were tested and compared to the hand thinning in Golden Delicious, Red Chief and Granny Smith apple varieties grafted on clone rootstock MM 106.

MATERIAL and METHOD

Study field

Having a microclimate feature and a vegetation period between 137-191 days according to the Frost Calendar of Turkey (Simsek et al., 2017), Igdir province and its surroundings sustain a different position in the Eastern Anatolia Region in terms of climatic conditions and plant variety. Igdir plain with an average of 850 m elevetion from the sea is surrounded by altitudes of 1200-2000 meters. This geological structure of Igdir province can sometimes be advantageous (agricultural diversity) and sometimes cause difficulties (drainage problem, salinity, cold air mass subsidence).

Soil properties of study field are as follows: Textures of study fields were clay loam, and pH, EC%, OM%, lime%, potassium (kg da^{-1}) and phosphorus (kg da^{-1}) values were between 7.25-7.30 (slightly alkaline); 0.031-0.048 (salt-free); 2.17-4.40 (medium, good and high); 6.16-6.98 (medium calcareous); 81.90-124.60 (much and too much); 0.17-0.38 (very low), respectively.

According to 2010-2015 average, temperature, rainfall and relative humidity of Iğdır province are given in Table 1. According to these values, summers are hot and dry, winters are cold and dry. Springs are more rainy with a insufficient level.

Orchard

This study was conducted in Iğdır in 5-6 years old apple orchard in 2015. The experiment site included semi-dwarf Golden Delicious, Granny Smith, and Red Chief apple trees grafted onto MM 106 clone rootstock. The trial was set as a completely randomized design with three replication.

Table 1. Some climate parameters of Igdir (2010-2015).

P/M	1	2	3	4	5	6	7	8	9	10	11	12	A
T	0.1	3.1	8.4	14.2	18.9	24.6	28.0	27.0	22.8	14.1	6.6	-0.4	13.9
Pr	7.8	11.0	33.1	46.4	54.4	29.8	8.0	11.4	7.3	62.2	8.6	14.6	294.5
RH	68.4	62.1	48.7	49.6	54.3	43.2	38.6	41.1	44.7	67.2	68.2	72.4	54.8

P: Parameters; M: Months; A: Annual; T: Average temperature (°C); Pr: Precipitation (mm), RH(%): Relative Humudity.

Thinning applications

Two thinning applications were applied. Hand thinning was performed after June drop for each cultivar and left one fruit per cluster when fruit diameter was between 12-16 mm. Chemical thinning treatments were applied at 5 and 10 ppm concentration for NAA, at 100 and 150 ppm concentration for BA. The chemicals were applied 20 days after the full flowering dating 11th May of 2015. The control group trees were left untreated.

In the harvested fruits, fruit size, weight, firmness, yield efficiency, total soluble solids content and titratable acidity were determined. The fruit diameters were measured using a digital calliper. The fruits weighted by a sensitive scale (sensitive to 0.01 g). Fruit firmness was measured with a penetrometer by tipped 7/16 inch from Yilmaz (2008). The total soluble solids were determined by refractometer and expressed as percentage TSS in the juice. The titratable acidity (TA) was measured by titration with 0.1 N NaOH to pH 8.1 at juice extraction and expressed as percentage in malic acid (Ersilia, 2003).

Statistical Analysis

The study data was analyzed by SPSS 17.0 and the means were compared by Duncan's multiple range test. The P values of less than 0.05 were considered to be significant (George, 2011).

RESULTS AND DISCUSSION

The fruit size, yield efficiency, thinning ratio and the mean values of the total soluble solids content were found to be significant in the study ($P < 0.05$) and no significant interactions among the cultivars x thinning applications were found.

In the study, the highest fruit width of 3 apple varieties was obtained by hand thinning application. The highest average fruit width and length were found in Granny Smith with 77.84 mm and 71.95 mm, respectively. According to the results obtained in terms of fruit width and length statistical difference was observed in the cultivars of apples (Table 2). Fruit sizes increased in all three cultivars through hand thinning application. When the applications were compared with the control group, the doses of NAA at 10 ppm and BA at 150 ppm were slightly increased in all 3 varieties of fruit width and length (Table 2). Sadeler and Bolat (1999) have reported that Golden and Starking apple varieties of different doses of NAA and NAAm applications increase fruit size, and Yilmaz (2008), has reported a slight increase with the increase in the application doses in the apple size of Starkrimson Delicious and Granny Smith cultivars and Hehnen et al. (2012), has reported increase in the apple sizes of Buckeye Gala apple varieties in both chemical and mechanical thinning applications.

When the applications were compared with the control group in terms of yield efficiency, all of thinning applications increased the productive efficiency in Red Chief. In Golden Delicious, in all the applications except the BA 150 ppm dose the yield efficiency reduced. In Golden Delicious and Granny Smith varieties BA application of 150 ppm increased efficiency (Table 2). In some of the previous literature, thinning applications are associated with lower yields (Paul and Proctor 1995; Meland, 1997; Türkeli and Barut, 2003; Karakuş and Kalyoncu 2010) while in some other cases, there is no trace of significant effect on yield (Stopar, 2006; Reyes et al. 2008; Yılmaz, 2008).

According to the results, all applications increased the thinning rate in all 3 cultivars when compared to the control group. The highest thinning ratio gained in Granny Smith of NAA 5 ppm (93.80%) application, the lowest thinning ratio gained in Golden Delicious of BA 100 ppm (62.72%) application. In the study, the highest thinning rate was found in Granny Smith with an average of 88.04%. While the increase of NAA and BA doses in the Golden Delicious and Red Chief increased the Thinning rate, increasing the dosage of both chemicals decreased the thinning rate slightly in Granny Smith (Table 2). In terms of thinning ratio, the differences between varieties may be caused by different auxin content of Golden Delicious, Granny Smith and Red Chief varieties in the NAA and BA application time.

Similar studies reported that the thinning rate has shown differences depending on the thinning method, the cultivar and dose of the chemical thinners used, the time of application, the cultivar and the ecology (Bound et al. 1991; Türkeli and Barut 2003; Yılmaz, 2008; Radivojević, 2011; Sebek, 2016).

In the study, the highest total soluble solids content (TSS) was obtained in Red Chief in all applications and the lowest was obtained in Granny Smith (except NAA-5 ppm dose) (Table 2). In all applications, the highest TSS for all 3 varieties increased to a maximum in the dose of 150 ppm BA (Table 1). The increase in the doses of NAA and BA in the Golden Delicious increased the TSS and decreased in the Granny Smith and Red Chief. In a similar study in contrast to the results found in this study, thinning applications decreased the TSS in Golden Delicious and increased in Red Chief (Reyes et al. 2008). Another study reported that use of NAA or BA + CB as a thinner reduces the content of TSS (Khanizadeh et al., 2004). The researchers attributed the increase in the rate of TSS to the decrease in the product load (Kong et al. 2009), to the increase in the absorption rate of the fruit ratio and related to the larger leaf area, and to the better nutrition of the fruits (Henriod et al. 2011).

Table 2. The effect of different fruit thinning applications on some fruit characteristics and thinning rates in three apple cultivars

Cultivars	Control	Hand	NAA 5 ppm	NAA 10 ppm	BA 100 ppm	BA 150 ppm	Average
Fruit Width (mm)							
Golden Delicious	72.79b	79.71c	68.56a	74.27b	72.35b	74.59b	73.71B**
Granny Smith	75.14a	79.93b	78.46b	77.82a	78.53b	77.16a	77.84A
Red Chief	70.71a	75.81b	71.97a	70.91a	73.30ab	73.90b	72.77B
Average	72.88B**	78.48A	73.00B	74.33B	74.73B	75.22B	
Fruit Lenght (mm)							
Golden Delicious	67.36b	75.74d	65.40ab	69.81ac	67.26ab	70.86c	69.41B**
Granny Smith	68.57a	75.14c	71.46b	72.79b	72.00b	71.73b	71.95A
Red Chief	64.34a	69.88b	70.07b	66.41a	66.43a	68.10b	67.54B
Average	66.76C**	73.58A	68.98BC	69.67BC	68.57BC	70.23B	
Yield Efficiency (kg cm^{-2})							
Golden Delicious	3.12	1.90	2.10	2.43	1.78	3.20	2.42A**
Granny Smith	1.22	0.88	1.36	1.10	0.94	1.35	1.14B
Red Chief	0.19	0.25	0.23	0.22	0.25	0.20	0.22C
Average	1.51a*	1.01b	1.23ab	1.25ab	0.99b	1.58a	
Thinning Ratio (%)							
Golden Delicious	52.18	65.93	64.65	77.86	62.72	73.96	66.22C**
Granny Smith	73.72	90.21	93.80	91.65	89.88	88.98	88.04A
Red Chief	57.11	85.99	72.76	80.66	68.76	74.28	73.26B
Average	61.00C**	80.71A	77.07AB	83.39A	73.79B	79.07AB	
Total Soluble Solid Content (%)							
Golden Delicious	12.37	12.37	11.60	11.77	12.93	14.33	12.56B**
Granny Smith	12.10	11.97	12.07	10.63	12.10	12.20	11.84C
Red Chief	13.33	14.00	14.40	13.47	14.57	14.47	14.04A
Average	12.60ab*	12.78ab	12.69ab	11.96b	13.20a	13.67a	

** There are 5% differences between the averages shown in different letters in the same row and column. ÖD: There is no difference between the averages shown in the same letters on the same line.

In the study, the difference between apple varieties fruit weight, firmness and titratable acidity mean values ($P < 0.05$) was found to be very important and interaction between apple varieties x applications was found to be significant.

The highest (Hand thinning, 231.66 g) and lowest (NAA-5ppm, 144.92 g) fruit weight were determined in Golden Delicious. In all varieties, thinning applications increased fruit weight compared to the control group. Granny Smith showed the highest fruit weight with an average weight of 212.88 g (Figure 1).

In previous studies, it was reported that chemical thinning applications had more effect on increasing fruit weight than hand thinning (Sadeler and Bolat 1999; Mert and Soylu 2001; Yılmaz, 2008). Albeit hand thinning in this study was more effective in increasing fruit weight than chemical thinning applications, this difference is thought to be due to the application time, application dose, effectiveness and interaction with annual maintenance works.

The highest fruit firmness was obtained from Granny Smith with 100 ppm (8.91 kg) application and the lowest was obtained from the application of hand thinning (Golden Delicious-4.57 kg). The highest fruit firmness 8.32 kg of was obtained via BA-100 ppm thinning in Granny Smith (Figure 2). In the hand thinning application, the fruit firmness was found to be low in all varieties compared to the controls. Although the highest firmness was obtained from the control group in similar studies (Bound et al.1991; Elfving and Cline 1993; Türkeli and Barut 2003), the highest value was obtained in the chemical applications in this study.

It has been reported that the increase in fruit firmness may be the result of the reduction in the number of fruits and yield due to the thinning causing increase in the amount or activity of related enzymes (Jemric et al. 2003).

The highest titratable acidity was found in Granny Smith in all applications (Figure 3). As compared to the control group, the highest titratable acidity in Golden Delicious and Red Chief was obtained from 150 ppm of BA and 100 grams of BA in Granny Smith. In a previous study, it was determined that hand thinning increases titratable acidity by 20% more than control group (Henriod et al. 2011).

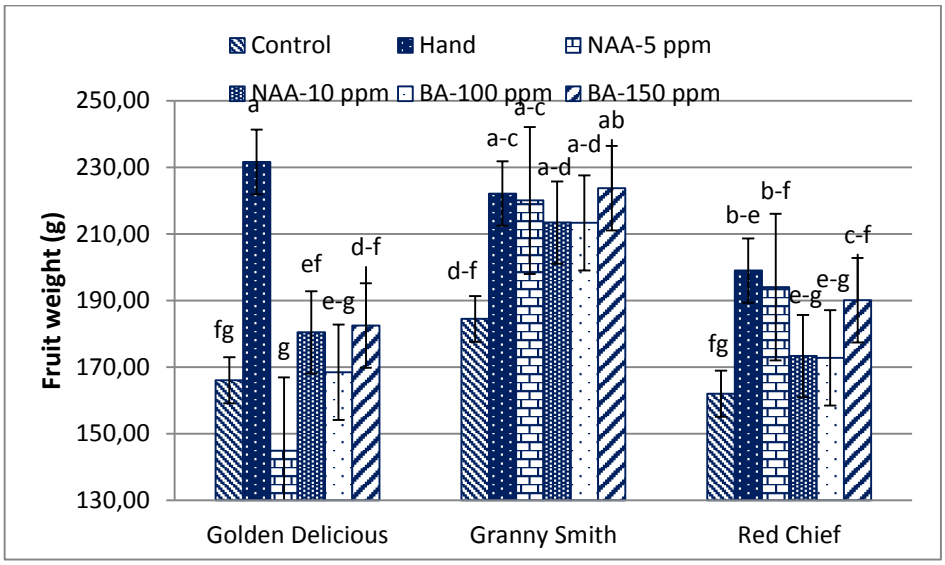

Figure 1. Variation of fruit weight in terms of x application interaction

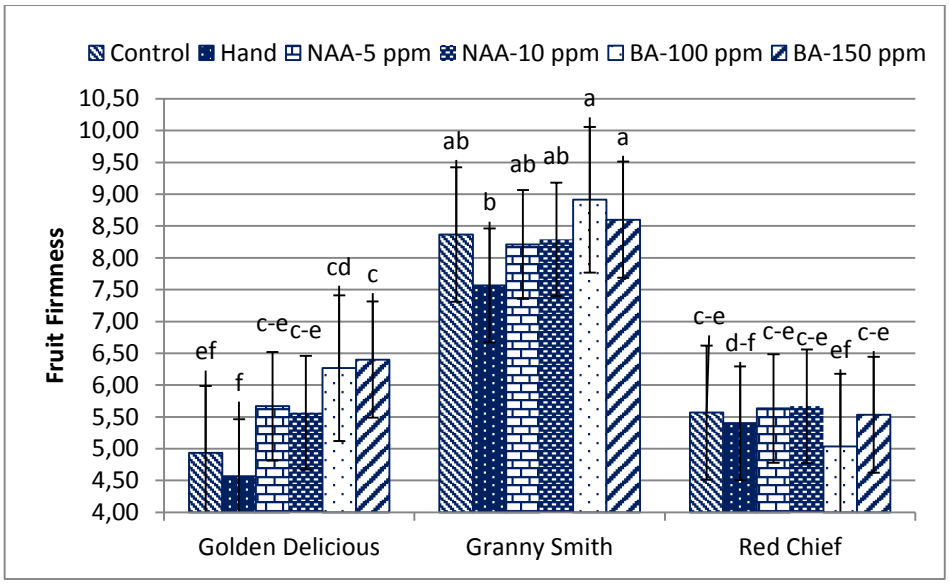

Figure 2. Cultivar x application interaction in terms of fruit firmness

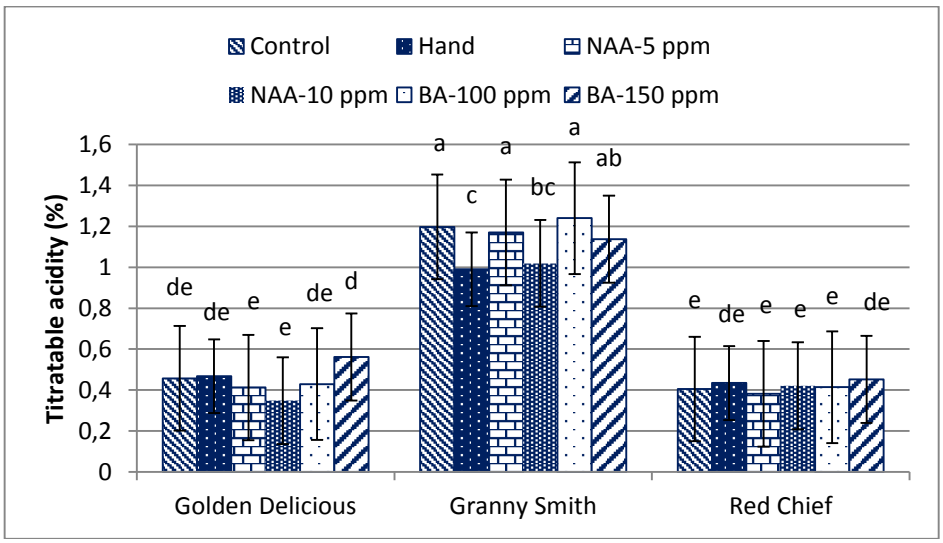

Figure 3. Cultivar x application interaction in terms of titratable acidity fruit firmness.

Similar results were obtained in this study. When titratable acidity was compared with previous studies Yılmaz, (2008) titratable acidity was higher than the results of Radivojevic et al. (2011) and it was lower than the results of Türkeli and Barut, (2010).

CONCLUSION

In this study, both hand thinning and NAA and BA applications were positively effective in thinning the fruits of Golden Delicious, Granny Smith and Red Chief cultivars. All applications increased the thinning rate in all 3 cultivars compared to the control groups. The increase in NAA and BA doses in the Golden Delicious and Red Chief increased the thinning rate, whereas the same chemical doses decreased the thinning rate slightly in the Granny Smith.

In terms of thinning ratio, different results were obtained between cultivars and these differences can be attributed to differences in the auxin content of Golden Delicious, Granny Smith and Red Chief cultivars at the time of thinning. The variation of the BA's response to thinning may be partly due to differences in environmental conditions during application. In terms of increasing the fruit weight hand thinning application leads to better results than chemicals. The highest fruit weight was recorded in Granny Smith according to the average of all applications. According to the results of the study, 10 ppm of NAA with 100 and 150 ppm of BA were found to be important for fruit thinning and fruit quality.

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