Bulgarian Journal of Agricultural Science, 22 (No 5) 2016, 772–777
Agricultural Academy

EFFECTS OF CHEMICAL FRUIT THINNING ON FRUIT YIELD AND QUALITY IN 'GEMLIK' OLIVE (*OLEA EUROPAEA* L.)

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Abstract

ÇİĞDEM, Z., M. İSFENDİYAROĞLU and E. ÖZEKER, 2016. Effects of chemical fruit thinning on fruit yield and quality in 'Gemlik' olive (*Olea europaea* L.). *Bulg. J. Agric. Sci.*, 22: 772–777

In recent years, a large amount of 'Gemlik' olive variety started to be grown in Aegean Region. 'Gemlik' is a black table variety, but it is processed to oil in many areas. Since 'Gemlik' olive is a double purpose variety, chemical fruit thinning may be useful to control alternate bearing and standardization of the fruit size. In this study, clearing out the effects of chemical fruit thinning by potassium salt of naphtaleneacetic acid (NAA-K), on fruit yield and quality in 'Gemlik', which is one of the important olive cultivar of Turkey, was aimed. Olive trees treated with 180 ppm NAA-K gave 26.6 and 53.1 kg fruit/tree in "off" and "on" years respectively, while the untreated trees gave only 13.6 and 17.8 kg fruit/tree. 180 ppm NAA also gave rise to decreases in figures of most variables and delayed the fruit maturity in both thinning years. In "on" year, 120 ppm NAA increased the size (fruit/kg), and dimensions (width and length) of olive fruits together with 100 ppm. In "on" years, NAA treatments at 100–120 ppm might be useful to increase the fruit dimensions in 'Gemlik' olive.

Key words: Olive, fruit, thinning, NAA, yield

Introduction

Olive (*Olea europaea* L.) is a fruit species has been grown probably since before the recorded history. Turkey has an important position among the world olive growing countries with its proper ecological conditions. Olive growing has been conducted on acreage of 831.000 ha which is the 3.9% of the entire agricultural lands of Turkey concurrently. Production quantity was also more than 1.6 million MT fruit and 187.900 MT olive oil, respectively (FAOSTAT, 2013). In the near future, production figures will probably be more than doubled with new growing strategies and the increasing exports of olive oil was expected. The number of olive trees showed considerable increase in the last decade with rising subsidies. Recent years, most of the new olive plantings have been done by 'Gemlik' cultivar, because of its high adaptation capacity and the ease of propagation. The 80% of entire olive tree population of Marmara region (north-west) consists of this cultivar, but it has been widely grown in most olive lands of Turkey in recent years. The most predictive feature of 'Gemlik' olive is its deep black fruit color in maturity. Despite its availability for table processing, it has also a high content of oil up to 29%. Its fleshy fruit has a thin skin and a small pip. 'Gemlik' tree is generally medium sized, has an even round crown and medium vigor (Anonymous, 2000).

Olive is an evergreen plant and bears its flowers and fruits mostly on one year old shoots. As in some fruit species, olive produces a large crop one year followed by a small or negligible crop in the following year (Monselise and Goldschmidt, 1982). This phenomenon has been known as "Alternate" or "Biennial Bearing" and gives rise to a fluctuating fruit production in olive tree. This causes severe labour, marketing and thus economic problems can affect the entire sector (Lavee, 2007; Dag et al., 2009). Besides the selection of proper cultivar, the cultural practices (irrigation, fertilization, pruning,

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spraying) should be met to control alternate bearing (Therios, 2009). The excessive crop load should be decreased to mitigate the alternate bearing (Krueger et al., 2005). In fact, that only 1.2% of entire flower population needs to be involved to ensure a good commercial crop in olive (Jackson et al., 2011). Crop load control can be achieved by chemical thinning, pruning or hand thinning (Krueger et al., 2005). Chemical thinning is the most useful practice to control the fruit yield and consequently alleviate the alternate bearing in olive tree (Krueger et al., 2005; Lavee, 2007; Dag et al., 2009; Jackson et al., 2011). Chemical thinning also increases the fruit size and oil yield in table and oil cultivars and moreover, positively affects the flower bud differentiation and return bloom (Therios, 2009). Chemical fruit thinning has been used since 1950's in California olive growing sector (Krueger et al., 2002). Application of naphtaleneacetic acid (NAA) after post bloom controls the fruit quality, besides the shoot elongation (Krueger et al., 2005). However, chemical thinning either increases the production costs or can give uneven results due to the atmospheric temperature and the cultivar applied (Krueger et al., 2002). 'Manzanillo', 'Ascolano' and 'Mission' cultivars did positively respond to NAA applications, but 'Sevillano' cultivar did not (Krueger et al., 2005). While Turkey shared the highest percentage (approx. 35%) of entire production to table olives, difficulties in providing high quality raw material is the predominant problem of table olive sector.

The aim of this study to clear out the effects of chemical thinning using NAA on the fruit yield and quality of 'Gemlik' which is one of the important table olive cultivar of Turkey.

Materials and Methods

'Gemlik' olive was used as plant material in this study. Trees subjected to chemical thinning were grown in experimental plots of Olive Research Institute, İzmir/TURKEY. They are 35 years old and own rooted individuals. Planting density is 6x6 m.

Fruit thinnings were conducted in two consecutive years (2012 and 2013). Two methods were used to accurately time NAA applications. In May 2012, 12 and 18 days after full bloom (AFB) (Full Bloom in 2012: 10 May; in 2013: 1 May), thinning applications were done as dilute sprays of NAA-K (1-Naphtalene Acetic Acid, Potassium Salt, Amvac, USA) as 120 and 180 ppm respectively (10 ppm per each day was calculated for final concentration) when the tree appears to be white, with shoots containing 80 to 90 percent open, fresh flowers, with bright yellow anthers exposed, accepted as in full bloom (Krueger et al., 2005; Dag et al., 2009). Moreover, two different levels of NAA-K were also applied when average fruit size is between 3 to 5 mm in diameter (in 2012: 29 May; in 2013: 20 May) (Krueger et al., 2005).

In the second year (2013), all the treatments were done 9 days earlier following the phenology of olive trees. In two successive thinning years, treatments of 100, 150 and 180 ppm coincided almost the same time according to time schedule. Wetting agent was used in dilute solutions of NAA. In the first and second years of experiments, on the basis of fruit maturity index, trees were harvested in 15 November 2012 and 14 November 2013, respectively.

Determination of the effects of NAA treatments on fruit yield and quality: yield per tree (kg), fruit size (fruit number per kg), maturity index, flesh/pip ratio (%), fruit weight (g), width (mm), and length (mm) were determined. For determination of maturity level, calculation of maturity index was used on the basis of fruit skin and flesh color (Hermoso et al., 1991).

The design of the experiments was a completely randomized block design with tree replicates of a tree. Data were analyzed by ANOVA. Duncan's Multiple Range Test was used to identify differences between the treatments. All calculations were performed using SPSS software.

Results

During the experiments, calculated monthly temperature and relative humidity figures did not show considerable differences when two years were compared. However, winter (January-March) temperatures of 2013 seemed to be a few degrees higher than previous years'. The highest annual difference of calculated temperature was measured in October when the fruit skin color started to turn to black (Table 1).

Table 1
Changes in climatic data during experiments

Month	1	2	3	4	5	6	7	8	9	10	11	12
						2012						
Temperature (°C)	6.8	7.6	11.5	17.5	20.5	27.3	30.1	29.2	24.3	21.8	16.4	10.8
Humidity (%)	67.9	67.0	58.0	58.7	62.9	48.3	45.1	39.7	55.3	59.7	65.2	71.4
						2013						
Temperature (°C)	9.4	11.2	14.0	17.2	22.7	25.7	28.4	28.8	24.0	17.3	15.1	8.5
Humidity (%)	70.9	70.3	58.6	54.4	54.7	50.7	42.1	45.2	48.7	60.6	70.1	59.30

First year (2012) is the "off year" of olive trees. Results showed significantly ($P \leq 0.05$) higher yield in the second year (on year) of the experiments, and there is nearly 72% increase in yield compared to first year. NAA treatments influenced the yield ($P \leq 0.001$) and treatment of 180 ppm gave rise to more than 2.5 fold increase in fruit yield compared to untreated trees. Significant interactions found between years and treatments. In two consecutive years 180 ppm (18 days AFB) gave the highest fruit yields (26.6 and 53.1 kg, respectively) while the untreated trees gave only 13.6 and 17.8 kg ($P \leq 0.01$) (Table 2).

Size of olive fruits were significantly influenced by years and treatments of NAA. First year (off year), fruits were larger than those harvested in the second year. 180 ppm NAA gave the highest number of fruits (i.e. the smallest fruits) per kg. Interaction of Year x Concentration significantly ($P \leq 0.001$) affected the fruit size; the smallest fruits were obtained by 180 ppm NAA in both years. However, 100 ppm markedly decreased the fruit number per kg followed by 120 and 150 ppm respectively, compared to untreated trees in the second year (Table 3).

Fruit maturity index did not significantly influenced by years, but effects of different NAA concentrations found to be significant ($P \leq 0.001$), treatment of 180 ppm resulted with more than 22 % decrease in index value compared to control. Insignificant interactions found between year and different NAA concentrations applied. However, index value remarkably decreased with 180 ppm NAA particularly in the second year when the crop load was high (Table 4).

Different years significantly affected the fruit flesh/pip ratio together with different NAA concentrations ($P \leq 0.001$). Flesh/pip ratio decreased in the second year and 180 ppm also gave the lowest figure. Despite the insignificant interactions of year and NAA concentrations, 180 ppm seemed to decrease the % value compared to the control and the rest concentrations up to 150 ppm (Table 5).

Fruit weight is an important variable on the table olives. Either the year and NAA concentration significantly ($P \leq 0.001$) affected the fruit weight. In the second year (on year), fruit weight was decreased as 38% of the first year. 180 ppm NAA also gave the lowest value. Interactions of Year x Concentration insignificantly affected the fruit weights and 180 ppm NAA decreased the fruit weights almost 30% in both years compared to trees that left without spraying (Table 6).

Table 2
Effect of year and NAA concentration on tree yield (kg)

Year	Concentration (ppm)					Mean
	0	100	120	150	180	
2012	13.60 c**	13.20 c	14.20 c	23.97 ab	26.67 a	18.32 B*
2013	17.83 bc	27.40 bc	36.07 ab	23.27 bc	53.13 a	31.54 A
Mean	15.72 B***	20.30 B	25.13 B	23.62 B	39.90 A	

$^{*}P_{(year)} \leq 0.05$; $^{***}P_{(concentration)} \leq 0.001$; $^{**}P_{(year\ x\ concentration)} \leq 0.01$

Table 3
Effect of year and NAA concentration on fruit size

Year	Concentration (ppm)					Mean
	0	100	120	150	180	
2012	187.33 c***	226.00 bc	223.33 bc	194.67 c	253.00 b	216.87 B*
2013	271.33 b	199.67 c	228.67 bc	258.33 b	367.00 a	265.00 A
Mean	229.33 B***	212.83 B	226.00 B	226.50 B	A	

$^{*}P_{(year)} \leq 0.05$; $^{***}P_{(concentration)} \leq 0.001$; $^{***}P_{(year\ x\ concentration)} \leq 0.001$

Table 4
Effect of year and NAA concentration on fruit maturity index

Year	Concentration (ppm)					Mean
	0	100	120	150	180	
2012	5.48	5.25	5.45	5.89	4.18	4.73
2013	4.61	5.15	5.54	4.65	3.70	5.25
Mean	5.04 A***	5.20 A	5.50 A	5.27 A	3.94 B	

$P_{(year)}$:nonsignificant; $^{***}P_{(concentration)} \leq 0.001$; $P_{(year\ x\ concentration)}$: nonsignificant

Table 5

Effect of year and NAA concentration on fruit flesh/pip ratio (%)

Year	Concentration (ppm)					Mean
	0	100	120	150	180	
2012	76.25	72.66	72.86	76.89	69.75	73.68 B***
2013	86.23	86.05	85.19	87.23	81.44	85.23 A
Mean	81.24 AB***	79.36 B	79.02 B	82.06 A	75.59 C	

***$P_{(year)} \leq 0.001$; ***$P_{(concentration)} \leq 0.001$; $P_{(year\ x\ concentration)}$: nonsignificant

Table 6

Effect of year and NAA concentration on fruit weight (g)

Year	Concentration (ppm)					Mean
	0	100	120	150	180	
2012	5.46	4.69	4.77	5.39	3.95	4.85 A***
2013	3.49	3.92	3.80	3.95	2.40	3.51 B
Mean	4.48 A***	4.31 A	4.29 A	4.67 A	3.18 B	

***$P_{(year)} \leq 0.001$; ***$P_{(concentration)} \leq 0.001$; $P_{(year\ x\ concentration)}$: nonsignificant

Table 7

Effect of year and NAA concentration on fruit width (mm)

Year	Concentration (ppm)					Mean
	0	100	120	150	180	
2012	18.56 b**	17.96 c	18.58 b	19.87 a	16.67 c	18.33 A*
2013	16.46 c	18.17 b	18.30 b	17.38 b	14.16 d	16.90 B
Mean	17.51 B***	18.07 AB	18.44 A	18.63 A	15.41 C	

*$P_{(year)} \leq 0.05$; ***$P_{(concentration)} \leq 0.001$; **$P_{(year\ x\ concentration)} \leq 0.01$

Table 8

Effect of year and NAA concentration on fruit lenght (mm)

Year	Concentration (ppm)					Mean
	0	100	120	150	180	
2012	24.63 ab***	22.82 cde	23.83 abc	24.78 a	22.03 de	23.62 A*
2013	21.69 d	23.29 bcd	23.72 abc	22.76 cde	18.86 e	22.06 B
Mean	23.16 A***	23.06 A	23.77 A	23.77 A	20.45 B	

*$P_{(year)} \leq 0.05$; ***$P_{(concentration)} \leq 0.001$; ***$P_{(year\ x\ concentration)} \leq 0.001$

Fruit width and length are both determinant variables on the fruit size and consequently more important parameters for the table olive industry. In the first year both of the variables were significantly higher than the second year (Table 7, 8). Concentration of 180 ppm also gave rise to significant ($P \leq 0.001$) decreases in mean width and length of olive fruits compared to the rest treatments (Table 7, 8). Significant interactions found between year and NAA concentrations due to the width and length of fruits, 180 ppm NAA decreased the width ($P \leq 0.01$) and length ($P \leq 0.001$) of olive fruits in both years, while concentrations up to 150 ppm significantly augmented the fruit dimensions in the first year (off year). But in the second year (on year), only 120 ppm increased the fruit dimensions compared to control trees, when the fruit number was essentially high (Table 7, 8).

Discussion

Calculated mean temperatures belonging to January, February and March 2013 were higher than the same months of the previous year. In olive, meeting the chilling requirement has been known as crucial for inflorescence differentiation and fluctuation bet ween 2–15°C are necessary for sufficient flower formation (Rallo and Martin, 1991; Martin et al., 2005; Therios, 2009). The relatively higher temperatures of 2013 were probably not determinative on fruit yield of the "on year".

Olive trees treated with 180 ppm NAA gave the highest figures of yield in both years. In the “off year”, 180 ppm resulted with two fold increase in yield/tree compared to trees left without thinning. But in the “on year”, almost three fold increase in yield observed in trees sprayed with 180 ppm NAA. It means that high NAA concentrations (180 ppm or more) can give rise to excessive fruit set particularly in loaded trees. Lower concentrations gave uneven results particularly in “on year” of olive trees (Table 2). In some cultivars showing intermediate and high tendency to alternate bearing, NAA applications 6–12th days after full bloom generally resulted with increases in yield/tree in “off years” (Dag et al., 2009; Barone et al., 2014). Although in regularly bearing ‘Manzanillo’ olive, increasing NAA concentrations regularly decreased the fruit yield of trees (Kruger et al., 2002; Crous, 2012). In ‘Gemlik’ olive, concentrations ranged between 150-180 ppm or more could be useful to partially tolerate the yield losses particularly occurred in “off” years or increase the fruit set especially for olives will be processed for oil rather than table.

As for the number of fruits per unit weight (kg) in the second year (on year), 100 ppm NAA markedly decreased the figure of fruit/kg followed by 120 and 150 ppm as opposed to the first year (off year). But at 180 ppm, number of fruits in unit weights was the highest in both years. It means that the size of the fruits decreased or the fruit settings increased (Table 3). In South African conditions, NAA treatments up to 400 ppm constantly increased the rate of large fruits in ‘Barouni’, ‘Mission’ and ‘Manzanillo’ olives (Crous, 2012). This showed that the efficiency of NAA on fruit number per unit weight partially depending on the cultivar tested.

Maturity index is one of the most important criteria determining the fruit maturity level and consequently the correct harvest time. Despite the insignificant interactions of the maturity index of olive fruits, 180 ppm NAA markedly decreased the index value compared to the rest treatments particularly in the second year (on year) and consequently delayed the maturity of fruits (Table 4). However, increasing NAA concentrations constantly increased the percent mature fruit in ‘Manzanillo’ and ‘Mission’ olives (Hartmann, 1952; Crous, 2012). Therefore NAA sprayings less than 180 ppm might be useful to accelerate the maturity, particularly when the crop load was high in ‘Gemlik’ olive was thought. As a matter of fact, fruit ripening in olive has a close relationship with the crop load and in heavily loaded trees; black maturation can be delayed about 30 days compared with the slightly loaded trees in some Italian cultivars tested (Barone et al., 1994; 2014).

Olive trees sprayed with 180 ppm NAA gave rise to the lowest figures of flesh/pip ratio in two successive years. 150 ppm NAA applied when the fruit size reached up to 3-5 mm did slightly increase the flesh/pip ratio compared to untreated trees in both years (Table 5). In large fruiting ‘Nocellara del Belice’ trees treated with 200 ppm NAA gradually increased from 6 to 20 days AFB, flesh/pip ratio did not show significant increases compared to control and among the days tested in “on year” when the flesh/pip ratio is higher. In “off year”, NAA found to be ineffective (Barone et al., 2014). In general, the effect of NAA on the mesocarp thickness seems to be very slight or nil without regarding the fruit load of olive trees.

Year x Concentration interactions on fruit weight of olive trees were found to be insignificant. In “off year”, increasing concentrations of NAA did not increase the weight of fruits, but in “on year”, 150 ppm NAA increased the fruit weight about 13% of control. 180 ppm NAA sharply decreased the fruit weights particularly in the “off year” (Table 6). This appeared to be in relation with the high fruit settings with 180 ppm in two consecutive years (Table 2). As a matter of fact, in olive cultivars like ‘Picual’, ‘Barnea’, ‘Barouni’ and ‘Nocellara del Belice’, NAA applications up to 200 ppm generally increased the fruit weights in “on years” according to spraying day AFB (8–12 days). But in “off years”, NAA treatments were generally not effective when the fruit weights were already high (Dag et al., 2009; Crous, 2012, Barone et al., 2014). For this reason, NAA applications in “on years” at 150 ppm or less, 20 days AFB might be useful also for ‘Gemlik’ olive was thought.

Different years and NAA concentrations significantly affected the dimensions (width, length) of olive fruits. Both variables were higher in the first year and 180 ppm NAA did remarkably decrease the fruit width and length (Table 7, 8). Significant interactions found between Year x Concentration on dimensions of olive fruits. 180 ppm NAA (18 days AFB) dramatically decreased the width and length of fruits in two successive years. In the first year (off year), 150 ppm NAA gave rise to increase particularly in width of fruits. In the second year (on year), 120 ppm gave the highest figures of both width and length followed by 100 ppm (Table 7, 8). Effects of NAA on fruit dimensions seem to be depending on the olive cultivar applied. In ‘Barouni’, ‘Mission’ and ‘Manzanillo’ olives, 400 ppm NAA did not result with excessive changes in fruit diameters was reported (Crous, 2012). In “on years”, NAA treatment at 100-120 ppm might be useful to increase the fruit dimensions in ‘Gemlik’ olive.

Conclusion

‘Gemlik’ has been known as a cultivar that shows intermediate alternate bearing. It can even bear quite regular in its own ecology and under good care conditions. Results of two consecutive years pointed out significant differences of yield. NAA applications did not decrease the fruit set particularly in "on years". NAA was rather useful to augment the tree yields of two following years. NAA used 18 or 20 days AFB (i.e.180 and 200 ppm) might be useful for excessive yield particularly for oil processing because of the diminished size and flesh/pip ratio of fruits, particularly in "on years". On the other hand, NAA can be used at 100-120 ppm to obtain large fruits suitable for table processing when the crop load is high was concluded.

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Received October, 22, 2015; accepted for printing August, 29, 2016