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Effect of Girdling, Paclobutrazol and Application Date on Blooming, Fruiting and Fruit Quality of Manzanillo Olive Trees

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Abstract: A field experiment was carried out during 2011, 2012, 2013 and 2014 seasons on fourteen years old Manzanillo olive trees grown at El Maghara Station of Desert Research Center, North Sinai Governorate Egypt. This work aimed to study the effect of girdling and paclobutrazol foliar sprayed at two different concentrations, i.e. 500 and 1000 ppm and their application dates namely mid - June or mid - Nov. in the year prior to an expected "Off" years and their combinations on flowering, yield and fruit quality traits. Conclusively, girdling done in mid – June prior to "Off" year increased No. of flowers / panicles, perfect flowers % and fruit retention %. Moreover, girdling done in mid-Nov. Prior "Off" year improved No. of panicles / shoot, yield, fruit weight and pulp thickness in "Off" years (2012 and 2014). In additions, girdling done in mid-June improved yield, fruit weight and pulp thickness in "On" years (2011 and 2013). Furthermore, girdling done in mid- Nov. prior to "Off" year enhanced pulp/fruit weight % in the 2012 season. Girdling done in mid-June enhanced pulp/fruit weight % in "On" year (2013). Paclobutrazol at 1000 ppm done in mid-Nov. Prior to "Off" year minimized alternative bearing of olive trees. The results of our research support the hypothesis that olive flower induction occurs around the time of endocarp sclerification.

Keywords: Manzanillo olive, girdling, paclobutrazol, application date, flowering, yield, alternative bearing.

1. Introduction

The olive tree (*Olea europaea* L.) is one of the important crops in Egypt. "Manzanillo" olive cultivar is one of the important olive cultivar grown in Egypt. Olive has a high tendency toward alternate bearing pattern **[1]**. Horticulturists used the term of "alternate and biennial" bearings to describe production of a heavy fruit crop one year followed by a light crop the next year **[2]**. However, alternate bearing is a major problem for olive growing farmers and it had negative effect on oil olives industry **[3 and4]**.

Furthermore, study the alternate bearing of olive trees should focus on the early stages of the reproductive process. Previous researches mentioned that flower bud induction could occur during the summer and, more probably, before endocarp sclerification (pit hardening) **[5, 6 and7]**. Other researches indicated that flower bud induction of olive occurs early as 7 to 8 weeks after full bloom at about the same time of endocarp sclerification of the current season's fruit **[7, 8 and 9]**. However, heavy crops receive resources at the expense of shoot growth **[10]**. Thereon, a reduction in shoot growth decreases potential bearing positions for the next season, since the olive bear its fruit on one-year-old shoots **[11]**.

Girdling is considered an important practice responsible for improving fruit setting, productivity and fruit quality of olive through accumulation of carbohydrates and natural hormones above rings **[12, 13 and 14]**. However, girdling improved yield and fruit quality of Manzanillo olive trees **[15]**. Also, girdling enhanced number of inflorescence, flower count, perfect flowers percentage, and fruit set percentage, fruit weight, fruit size and pulp weight of olive trees **[16]**.

On the other hand, application date of girdling was investigated by **[17]** studied that girdling date (December, January and February) and treatments (single cut of 1 mm width, double cuts of 1 mm width, whole girdle of 20 mm width, 3/4 girdle of 20 mm width, and control) on olive trees. Results showed that the best time for girdling was in mid winter (December-February) prior to the major differentiation period. Also, the single and double cuts of 1 mm width were the most effective in enhancing the formation of flowers. In addition, more beneficial effects of girdling when done in mid-August increased fruit dry weight by 15%

and pulp/pit ratio by 20% with no differences between the girdling treatments of olive trees **[18]**. Girdling at the beginning of August and September increased the pulp dry mass as compared with control and stimulated differentiation of flower buds **[19]**. Moreover, winter girdling gave the highest yield of olive trees in the first year. Also, girdling significantly increased perfect flowers percentage in "Barnea" and "Picual" olive cultivars **[20]**. In addition, girdling at 15-day intervals from February 1st to March 1st on

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flowering parameters and fruiting of olive cv. "Uslu". Result showed that all treatments increased the perfect flower percentage, fruit set percentage and fruit harvest of olive trees. In 2005, the highest number of perfect flower percentage (22.73%) was recorded with girdling treatment on March 1st followed by that of February 15th (20.29%). Both dates were statistically non-significant during both years **[21]**.

Paclobutrazol (PBZ) is a synthetic plant growth regulator, which has been used in fruit tree crops to control vegetative growth and to induce flowering **[22 and 23]**. Also PBZ inhibits gibberellin synthesis and consequently cell elongation **[24 , 25 and 26].** PBZ is one of the known effective retardants in tree crops. It reduced vegetative growth in a wide range of species such as mango and avocado trees **[27 and 28]**. However, paclobutrazol application reduced plant vegetative growth until 60 days after treatment of olive trees **[29]**. Moreover, paclobutrazol application improved yield of olive trees **[30]**. Furthermore, paclobutrazol applications increased flowering and fruiting of apples trees **[31]**. In addition, olive trees treated with paclobutrazol showed a higher fruit set percentage (23.1%) than untreated trees control (12.6%)**[32]**. Furthermore, paclobutrazol application can retard growth and increased flowering due to enhanced carbohydrate accumulation in leaves of olive trees **[33]**. On the other hand, effect of application date of paclobutrazol was investigated by **[34]** who mentioned that paclobutrazol treatment in mid-December increased fruit diameter, fruit length, yield, fruit oil content percentage, fruit weight, fruit volume and fruit pulp weight of "Picual" olive trees.

The main target of this study is to explore the effect of girdling, paclobutrazol foliar spraying treatments and their application dates (mid-June or mid-Nov.) on flowering, yield, and fruit quality of "Manzanillo" olive trees.

2.Materials and methods

This study was carried out during four successive seasons of 2011, 2012, 2013 and 2014 at Experimental Orchard of El Maghara Station of Desert Research Center, North Sinai Governorate (latitude 30.35 N, longitude 33.20 E) in Egypt. Fourteen years old "Manzanillo" olive trees grown in sandy soil, and spaced 5 x 5 m apart under drip irrigation system from well were devoted for this study. Physical and chemical analysis of the experimental soil shown in Table, 1 meanwhile the chemical analysis of used irrigation water is recorded in Table, 2.

Forty eight trees healthy, nearly uniform in shape and size and productivity and received the same horticulture practices selected for this study.

However, this study involved two factors as follows:

1. Effect of horticultural practices (girdling and paclobutrazol "PBZ" treatments).

Selected trees were treated with one of the following treatments: a. Control without girdling or paclobutrazol treatment; b. Trunk girdling; c. Paclobutrazol "PBZ" foliar spray at 500 ppm and Paclobutrazol "PBZ" foliar spray at 1000 ppm.

Girdling process was conducted at the smooth part of the trunk by removing 10 mm width ring of bark 70 cm above the tree crown. Paclobutrazol (25% active ingredient) of the commercial product was used. Furthermore, the control trees were sprayed with tap water and Tween-20 was added at 0.1% as a surfactant to PBZ spray solutions including the control "tap water". Spraying was carried out using compression sprayers (5 L solution/tree).

2. Effect of tested treatments application date.

The tested treatments were conducted in two dates i.e. mid-June and mid-Nov. during 2011 and 2013 seasons an expected "On" years and thereupon the treated trees are going to (2012 and 2014) an expected "Off" years.

This experiment considered a factorial experiment (4 horticultural practices x 2 application dates). The experiment was laid out in randomized complete block design. Each treatment was replicated three times and each replicate was represented by two trees.

Response of Manzanillo olive trees to the tested two factors evaluated through the following determinations.

2.1. Flowering parameters

In an expected "Off" years (2012 and 2014), forty shoots (one year old) selected at four branches at the four directions were tagged. The basic flowering and fruiting parameters measured on these twigs. At the full bloom stage (80% open at flower stage) the following parameters determined on tagged twigs; i.e. number of panicles/ shoot, number of flowers/ panicle and number of perfect flowers/ panicle for measuring percentage of perfect flowers [(number of perfect flowers/total number of flowers) x100].

2.2. Fruiting parameters

In an expected "Off" years (2012 and 2014), initial fruit set percentage (three weeks after full bloom) was determined as follows: [(number of initial set fruits/number of total flowers at full bloom) x100] and percentage of retained fruits at harvest was determined as follows: [(number of retained fruits at harvest/total number of flowers) x100].

2.3. Yield (kg/tree)

Under the experiment conditions the time of harvest was determined in mid-December of each season "Off" year (2012 and 2014) and "On" year (2011 and 2013); yield (kg) per each treated tree was weighed and recorded.

2.4. Biennial bearing index

Biennial bearing index of the different treated trees was calculated according to **[35]** using the following formula: (Differences in yield between successive years / Sum of yield of successive years) x100.

2.5. Fruit physical properties

A random sample of hundred fruits was taken at harvest from each treated tree for the following fruit physical proporties determinations: Fruit weight (g), pulp thickness (cm) and pulp/fruit weight percentage.

Table 1. Analysis of experimental soil of El-Maghara Station, North Sinai Governorate, Egypt

Soil Depth (cm)	Texture class	Organic matter (%)	PH Soil past	E.C. (dSm-1)	Soluble cations (mequiv./l)				soluble anions (mequiv./l)			
					Ca^{+2}	K^{+}	Na^{+}	Mg^{+2}	Cl^{-}	$SO4^{2-}$	HCO_3^{-}	CO_3^{-2}
0-30	sand	0.24	7.70	0.60	2.50	0.05	1.26	1.50	1.40	2.11	1.80	-
30-60	sand	0.23	7.70	0.70	3.00	0.08	1.57	2.00	2.00	2.85	1.80	-

Table 2. Chemical analysis of water used for irrigation at El-Maghara Station, North Sinai Governorate, Egypt

PH	E.C.	Soluble cations (mequiv./l)				soluble anions (mequiv./l)			
	(dSm-1)	Ca^{2+}	Mg^{+2}	Na^{+}	K^{+}	CO_3^{-2}	HCO_3^{-}	Cl^{-}	SO_4^{-2}
8.36	4.38	11.40	3.48	24.60	0.69	-	4.40	3.57	32.20

Statistical analysis

The obtained data in 2011, 2012, 2013 and 2014 seasons were subjected to analysis of variance according to **[36]** using MSTAT-C program version 7 (1990). Means differentiated using **[37]** multiple range test at the 0.05 level.

3. Results

3.1. Flowering and Fruiting parameters

3.1.1. No. of panicles/shoot

Table, 3 indicates that girdling and paclobutrazol foliar spray at 500 and 1000 ppm induced higher positive effect on number of panicles per shoot as compared with the control treatment in an expected "Off" years (2012 and 2014). Generally, girdling treatment was the most efficient treatment in this concern.

Moreover, girdled trees in mid-Nov. had high number of panicles per shoot than those trees girdled in mid-June in 2014 season.

In general, the interaction between two factors showed that girdling treatment done in mid-June and mid-Nov. gave similar and higher positive effect on number of panicles per shoot as compared with the control treatment in 2012 season. However, girdling treatment done in mid-Nov. gave the highest positive effect on number of panicles per shoot in 2014 season.

3.1.2. No. of total flowers/panicle

Table, 3 illustrates that girdling treatment enhanced number of flowers/panicle of Manzanillo olive trees as compared with the control treatment in 2012 and 2014 seasons. Moreover, paclobutrazol foliar spray at 500 and 1000 ppm gave an intermediate values of number of flowers/panicle of Manzanillo olive trees in 2014 season.

However, trees treated in mid-June gave a pronounced positive effect on number of flowers/panicle than those treated in mid-Nov. of 2014 season.

The interaction between two factors showed that girdling treatment done in mid-June enhanced number of flowers/panicle of Manzanillo olive trees as compared with the control treatment of "Off" years (2012 and 2014) and the superior combination in this respect. Other combinations gave an intermediate values in this concern.

3.1.3. Perfect flowers(%)

Table, 4 shows that girdling and paclobutrazol foliar spray gave similar and higher positive effect on perfect flowers percentage as compared with the control treatment in 2012 and 2014 seasons. Generally, girdling treatment was the most efficient treatment in this respect.

Furthermore, perfect flowers percentage of Manzanillo olive tree in "Off" years (2012 and 2014) didn't show response to treatments application date.

In addition, the interaction between the two tested factors showed that girdling treatment done in mid-June and mid-Nov. gave similar and higher positive effect on perfect flowers percentage as compared with the control treatment in "Off" year (2012). However, girdling treatment done in mid-Nov. improved perfect flowers percentage in 2014 season. Other combinations treatments gave an intermediate values in this sphere.

3.1.4. Initial fruit set (%)

Table, 4 indicates that girdling and paclobutrazol foliar spray at 500 and 1000 ppm treatments increased initial fruit set percentage as compared with the control treatment in "Off" year (2014). Generally, girdling treatment was the most efficient treatment in "Off" year (2014) followed by paclobutrazol at 500 ppm treatment.

However, trees treated in mid-June and mid-Nov. failed to induce any positive effect on initial fruit set percentage of Manzanillo olive trees in "Off" years (2012 and 2014).

On the other hand, the interaction between the two tested factors showed that girdling treatment done in mid-Nov. improved initial fruit set percentage of Manzanillo olive trees as compared with the control treatment during "Off" years (2012 and 2014) and it was the most efficient combination in this concern. Other combination treatments gave an intermediate values in this respect.

3.1.5. Fruit retention (%)

Table, 5 shows that girdling and paclobutrazol foliar spray at 500 and 1000 ppm enhanced fruit retention percentage as compared with the control treatment in "Off" years (2012 and 2014). Generally, girdling treatment was the most efficient treatment in 2012 and 2014 seasons followed by paclobutrazol at 500 ppm.

Moreover, treated trees in mid-Nov. showed high fruit retention percentage than those treated in mid-June in "Off" years (2012 and 2014).

Table 3. Effect of girdling, paclobutrazol (PBZ) treatments and their application date on Number of panicles per shoot and Number of total flowers per panicle of "Manzanillo" olive trees (2012 and 2014 seasons).

	No. of panicles /shoot					
	2012 "Off" year			2014 "Off" year		
Treatments	Mid- June	Mid- Nov.	Mean	Mid- June	Mid-Nov.	Mean
Control	5.06 f	5.11 f	**5.09 D**	5.06 h	6.10 g	**5.08 D**
Girdling	6.84 a	6.90 a	**6.87 A**	6.56 b	6.83 a	**6.69 A**
PBZ at 500 ppm	6.11 c	6.25 b	**6.18 B**	6.01 d	6.12 c	**6.06 B**
PBZ at 1000 ppm	5.86 e	6.01 d	**5.94 C**	5.69 f	5.77 e	**5.73 C**
Mean	**5.97 A**	**6.07 A**		**5.83 B**	**5.95 A**	
	No. of total flowers/panicle					
	2012 "Off" year			2014 "Off" year		
Treatments	Mid- June	Mid- Nov.	Mean	Mid- June	Mid-Nov.	Mean
Control	14.50 c	13.20 e	**13.85 B**	15.40 c	14.40 d	**14.90 C**
Girdling	16.70 a	15.40 b	**16.05 A**	19.20 a	16.26 b	**17.73 A**
PBZ at 500 ppm	13.70 de	14.00 cd	**13.85 B**	16.26 b	15.00 cd	**15.63 B**
PBZ at 1000 ppm	13.40 de	14.00 cd	**13.70 B**	16.30 b	14.80 cd	**15.55 B**
Mean	**14.57 A**	**14.15 A**		**16.79 A**	**15.11 B**	

Means followed by the same letter (s) within each row, column or interaction are not significantly different at 5% level.

Table 4. Effect of girdling, paclobutrazol (PBZ) treatments and their application date on perfect flowers percentage and initial fruit set percentage of "Manzanillo" olive trees (2012 and 2014 seasons).

	Perfect flowers (%)					
	2012 "Off" year			2014 "Off" year		
Treatments	Mid- June	Mid- Nov.	Mean	Mid- June	Mid-Nov.	Mean
Control	46.63 b	46.93 b	**46.78 B**	37.31 e	38.19 de	**37.75 C**
Girdling	52.68 a	52.65 a	**52.66 A**	47.96 ab	49.80 a	**48.88 A**
PBZ at 500 ppm	48.86 ab	50.78 ab	**49.82 AB**	43.84 bc	44.72 bc	**44.28 B**
PBZ at 1000 ppm	47.76 b	49.28 ab	**48.52 B**	41.78 cd	41.22 cde	**41.50 B**
Mean	**48.98 A**	**49.91 A**		**42.72 A**	**43.48 A**	
	Initial fruit set (%)					
	2012 "Off" year			2014 "Off" year		
Treatments	Mid- June	Mid- Nov.	Mean	Mid- June	Mid-Nov.	Mean
Control	30.64 b	32.85 ab	**31.74 A**	27.96 d	29.91 cd	**28.93 C**
Girdling	34.15 ab	38.99 a	**36.57 A**	35.58 ab	36.88 a	**36.23 A**
PBZ at 500 ppm	32.33 ab	35.67 ab	**34.00 A**	33.61 abc	34.22 abc	**33.91 AB**
PBZ at 1000 ppm	31.87 ab	32.12 ab	**31.99 A**	31.37 bcd	32.21 bcd	**31.79 BC**
Mean	**32.24 A**	**34.91 A**		**32.13 A**	**33.30 A**	

Means followed by the same letter (s) within each row, column or interaction are not significantly different at 5% level.

Table 5. Effect of girdling, paclobutrazol (PBZ) treatments and their application date on fruit retention percentage of "Manzanillo" olive trees (2012 and 2014 seasons).

	Fruit retention (%)					
	2012 "Off" year			2014 "Off" year		
Treatments	Mid- June	Mid- Nov.	Mean	Mid- June	Mid-Nov.	Mean
Control	1.39 de	1.36 e	**1.37 D**	1.36 f	1.38 f	**1.37 D**
Girdling	1.59 b	1.66 a	**1.62 A**	1.55 b	1.59 a	**1.57 A**
PBZ at 500 ppm	1.48 c	1.54 b	**1.51 B**	1.46 c	1.42 d	**1.44 B**
PBZ at 1000 ppm	1.43 cd	1.44 cd	**1.44 C**	1.34 f	1.34 f	**1.34 C**
Mean	**1.47 B**	**1.50 A**		**1.43 B**	**1.44 A**	

Means followed by the same letter (s) within each row, column or interaction are not significantly different at 5% level.

The interaction between the two tested factors showed that girdling treatment done in mid-Nov. enhanced fruit retention percentage of Manzanillo olive trees as compared with the control treatment in "Off" years (2012 and 2014) and it surpassed the other tested combination in this respect. Other combinations gave an intermediate values in this sphere.

3.1.6. Yield (kg/tree)

Table, 6 reveals that girdling treatment induced the highest production trees as compared with control and paclobutrazol treatments in "On" years (2011 and 2013) and "Off" years (2012 and 2014). However, paclobutrazol foliar spray at 500 and 1000 ppm gave an intermediate values as compared with control in 2012, 2013 and 2014 seasons but failed to induce any positive effect on tree yield in 2011 season.

Generally, trees treated in mid-June produced higher tree yield than those treated in mid-Nov. in "On" year (2013). Anyhow all response treated trees in mid-June and mid-Nov. didn't show any positive in yield in 2011, 2012 and 2014 seasons.

On the other hand, the interaction between two factors showed that girdling treatment done in mid-Nov. improved tree yield of Manzanillo olive trees as compared with the control treatment in "Off" years (2012 and 2014). Moreover, girdling treatment done in mid-June enhanced yield as compared with the control treatment in "On" years (2011 and 2013). Paclobutrazol combination treatments gave an intermediate values in this concern.

3.1.7. Biennial bearing index

Table, 7 indicates that all tested girdling and paclobutrazol foliar spray at 500 and 1000 ppm treatments gave positive effect in reducing biennial bearing index as compared with the control treatment. Generally, paclobutrazol foliar spray at 1000 ppm proved to be the most efficient treatment to reduced biennial bearing index in this concern followed by paclobutrazol at 500 ppm and girdling treatment respectively.

However, trees treaded in mid-Nov. gave a pronounced positive effect in reducing biennial bearing index than those treaded in mid-June.

The interaction between the two tested factors indicated that paclobutrazol foliar spray 1000 ppm done in mid-Nov. gave a higher positive effect in reducing biennial bearing index of Manzanillo olive trees as compared with the control treatment and it surpassed the other combinations in this concern. Other combinations gave an intermediate values in this respect.

3.2. Fruit physical properties

3.2.1. Fruit weight (g)

Table, 8 illustrates that girdling and paclobutrazol foliar spray at 500 and 1000 ppm treatment increased fruit weight as compared with the control treatment in 2011, 2012, 2013 and 2014 seasons. Generally, girdling treatment was the most efficient treatment in this concern followed by 500 ppm paclobutrazol treatment.

However, trees treated in mid-Nov. showed high positive response in fruit weight than those treated in mid-June in "Off" year (2012). Moreover, treated trees in mid-June produced heavier fruits in "On" years (2011 and 2013).

The interaction between the two tested factors showed that girdling done in mid-Nov. produced heavier fruits as compared with the control treatment in "Off" years (2012 and 2014) and it proved to be the superior treatment in this respect. However, girdling done in mid-June improved on fruit weight of Manzanillo olive trees as compared with the control treatment in "On" years (2011 and 2013) and showed to be the superior treatment in this concern. Paclobutrazol combination treatments gave an intermediate values in this concern.

3.2.2. Pulp thickness (cm)

Table, 9 demonstrates that girdling enduced high values of fruit thickness as compared with the control and paclobutrazol treatments in 2011, 2.12, 2.13, and 2014 seasons. However, paclobutrazol foliar spray at 500 and 1000 ppm gave an intermediate values in 2012, 2013 and 2014 seasons. Anyhow, paclobutrazol foliar spray at 500 and 1000 ppm produced insignificant effect on fruit thickness in 2011 season. Generally, girdling treatment was the most efficient treatment in this concern.

However, trees treated in mid-June produced thicker pulp than other ones treated in mid-Nov. in "On" year (2011). Meanwhile, trees treated in mid-June and mid-Nov. failed to showed any response in pulp thickness.

Anyhow, the interaction between the two tested factors showed that girdling treatment done in mid-Nov. recorded high fruit thickness values of Manzanillo olive trees as compared with the control treatment in "Off" years (2012 and 2014). Moreover, girdling treatment done in mid-June gave high enhancing effect on fruit thickness as compared with the control treatment in "On" years (2011 and 2013).

3.2.3. Pulp/fruit weight (%)

Table, 10 illustrates that girdling and paclobutrazol foliar spray at 500 and 1000 ppm induced similar and higher values of pulp/fruit weight percentage in "On" years (2011 and 2013) and "Off" years (2012 and 2014). Generally, girdling treatment was the most efficient treatment in 2012 and 2013 seasons.

Moreover, trees treated in mid-June showed high response of pulp/fruit weight percentage than other ones treated in mid-Nov. in 2011, 2012 and 2013 seasons. Meanwhile, trees treated in mid-June and mid-Nov. didn't show response in this respect to application date.

However, the interaction between the two tested factors showed that girdling treatment done in mid-Nov.and mid-June in "Off" year (2012) and girdling treatment done in mid-Nov. in "Off" year (2014) gave high values of pulp/fruit weight percentage of Manzanillo olive fruit as compared with the control treatment. Moreover, girdling treatment done in mid-June gave high positive effect on pulp/fruit weight percentage as compared with the control treatment in "On" year (2013). Moreover, girdling and paclobutrazol foliar spray at 500 and 1000 ppm done in mid-June in 2011 season induced similar and higher positive effect on pulp/fruit weight percentage.

Table 6. Effect of girdling, paclobutrazol (PBZ) treatments and their application date on yield of "Manzanillo" olive trees (2011, 2012, 2013 and 2014 seasons).

	Yield (kg)					
	2012 "Off" year			2014 "Off" year		
Treatments	Mid- June	Mid-Nov.	Mean	Mid- June	Mid-Nov.	Mean
Control	19.66 d	20.50 d	**20.08 C**	20.33 e	21.00 e	**20.66 D**
Girdling	24.66 ab	25.66 a	**25.16 A**	26.16 ab	27.16 a	**26.66 A**
PBZ at 500 ppm	22.83 bc	23.50 b	**23.16 B**	23.83 cd	25.16 bc	**24.50 B**
PBZ at 1000 ppm	22.00 c	23.33 b	**22.66 B**	22.66 d	24.00 cd	**23.33 C**
Mean	**22.29 A**	**23.25 A**		**23.25 A**	**24.33 A**	
	2011 "On" year			2013 "On" year		
Treatments	Mid- June	Mid- Nov.	Mean	Mid- June	Mid-Nov.	Mean
Control	36.50 c	36.83 bc	**36.66 B**	36.60 c	36.70 ab	**36.65 C**
Girdling	39.16 a	37.00 bc	**38.08 A**	40.20 a	37.13 b	**38.66 A**
PBZ at 500 ppm	37.46 b	36.70 bc	**37.08 B**	37.13 b	36.73 ab	**36.93 B**
PBZ at 1000 ppm	36.36 c	36.70 bc	**3.53 B**	36.93 c	36.43 ab	**36.68 C**
Mean	**37.37 A**	**36.80 A**		**37.71 A**	**36.75 B**	

Means followed by the same letter (s) within each row, column or interaction are not significantly different at 5% level.

Table 7. Effect of girdling, paclobutrazol (PBZ) treatments and their application date on Biennial bearing index of "Manzanillo" olive trees (2011, 2012, 2013 and 2014 seasons).

	Biennial bearing index		
Treatments	Mid-June	Mid-Nov.	Mean
Control	23.67 e	24.15 c	**23.91 C**
Girdling	23.89 d	24.15 c	**24.02 B**
PBZ at 500 ppm	25.30 a	24.47 b	**24.88 A**
PBZ at 1000 ppm	22.60 f	19.99 g	**21.29 D**
Mean	**23.86 A**	**23.19 B**	

Means followed by the same letter (s) within each row, column or interaction are not significantly different at 5% level.

Table 8. Effect of girdling, paclobutrazol (PBZ) treatments and their application date on fruit weight of "Manzanillo" olive trees (2011, 2012, 2013 and 2014 seasons).

	Fruit weight (g)					
	2012 "Off" year			2014 "Off" year		
Treatments	Mid- June	Mid- Nov.	Mean	Mid- June	Mid-Nov.	Mean
Control	4.81 g	4.71 h	**4.76 D**	4.89 e	4.67 g	**4.78 D**
Girdling	5.48 b	5.71 a	**5.59 A**	5.49 b	5.66 a	**5.58 A**
PBZ at 500 ppm	5.26 d	5.32 c	**5.29 B**	5.32 d	5.43 c	**5.38 B**
PBZ at 1000 ppm	4.95 f	5.08 e	**5.02 C**	5.22 e	5.31 d	**5.27 C**
Mean	**5.12 B**	**5.20 A**		**5.23 A**	**5.27 A**	
	2011 "On" year			2013 "On" year		
Treatments	Mid- June	Mid- Nov.	Mean	Mid- June	Mid-Nov.	Mean
Control	4.31 f	4.32 f	**4.31 D**	4.68 f	4.71 e	**4.69 D**
Girdling	4.78 a	4.41 d	**4.60 A**	4.95 a	4.79 b	**4.87 A**
PBZ at 500 ppm	4.64 b	4.35 e	**4.49 B**	4.79 b	4.75 d	**4.77 B**
PBZ at 1000 ppm	4.55 c	4.35 e	**4.45 C**	4.77 c	4.72 e	**4.74 C**
Mean	**4.57 A**	**4.35 B**		**4.80 A**	**4.74 B**	

Means followed by the same letter (s) within each row, column or interaction are not significantly different at 5% level.

Table 9. Effect of girdling, paclobutrazol (PBZ) treatments and their application date on pulp thickness of "Manzanillo" olive trees (2011, 2012, 2013 and 2014 seasons).

	Pulp thickness (cm)					
	2012 "Off" year			2014 "Off" year		
Treatments	Mid- June	Mid- Nov.	Mean	Mid- June	Mid-Nov.	Mean
Control	0.60 d	0.60 d	**0.60 C**	0.60 e	0.61 de	**0.60 C**
Girdling	0.64 ab	0.65 a	**0.64 A**	0.64 ab	0.65 a	**0.64 A**
PBZ at 500 ppm	0.62 c	0.63 bc	**0.62 B**	0.62 bcd	0.64 abc	**0.63 B**
PBZ at 1000 ppm	0.61 cd	0.61 cd	**0.61 B**	0.61 de	0.62 cd	**0.61 C**
Mean	**0.62 A**	**0.62 A**		**0.62 A**	**0.63 A**	
	2011 "On" year			2013 "On" year		
Treatments	Mid- June	Mid- Nov.	Mean	Mid- June	Mid-Nov.	Mean
Control	0.53 c	0.52 c	**0.53 B**	0.55 b	0.55 b	**0.55 B**
Girdling	0.58 a	0.53 c	**0.56 A**	0.64 a	0.59 ab	**0.62 A**
PBZ at 500 ppm	0.55 b	0.52 c	**0.54 B**	0.59 ab	0.56 b	**0.58 AB**
PBZ at 1000 ppm	0.55 b	0.52 c	**0.54 B**	0.56 b	0.55 b	**0.55 B**
Mean	**0.55 A**	**0.52 B**		**0.58 A**	**0.56 A**	

Means followed by the same letter (s) within each row, column or interaction are not significantly different at 5% level.

Table 10. Effect of girdling, paclobutrazol (PBZ) treatments and their application date on pulp/fruit weight percentage of "Manzanillo" olive trees (2011, 2012, 2013 and 2014 seasons).

	Pulp/fruit weight (%)					
	2012 "Off" year			2014 "Off" year		
Treatments	Mid- June	Mid- Nov.	Mean	Mid- June	Mid-Nov.	Mean
Control	83.60 ab	81.73 c	**82.67 C**	82.34 cd	81.97 d	**82.16 B**
Girdling	84.05 a	84.35 a	**84.20 A**	83.72 ab	84.77 a	**84.25 A**
PBZ at 500 ppm	83.99 ab	83.48 ab	**83.74 AB**	83.58 abc	84.09 ab	**83.83 A**
PBZ at 1000 ppm	83.59 ab	83.07 b	**83.33 B**	82.95 bcd	83.83 ab	**83.39 A**
Mean	**83.81 A**	**83.16 B**		**83.15 A**	**83.67 A**	
	2011 "On" year			2013 "On" year		
Treatments	Mid- June	Mid- Nov.	Mean	Mid- June	Mid-Nov.	Mean
Control	81.52 b	81.56 b	**81.54 B**	81.93 f	82.02 e	**81.97 D**
Girdling	82.86 a	81.79 b	**82.32 A**	82.91 a	82.34 b	**82.63 A**
PBZ at 500 ppm	82.76 a	81.68 b	**82.22 A**	82.34 b	82.17 d	**82.25 B**
PBZ at 1000 ppm	82.58 a	81.68 b	**82.13 A**	82.25 c	82.07 e	**82.16 C**
Mean	**82.43 A**	**81.67 B**		**82.36 A**	**82.15 B**	

Means followed by the same letter (s) within each row, column or interaction are not significantly different at 5% level.

4. Discussion

4.1. Flowering and fruiting parameters

From the obtained results on "Manzanillo" olive trees, it was clear that the girdling, paclobutrazol foliar sprays and their interactions gave a high positive effect on the studied flowering and fruiting parameters. Moreover, the results indicated that girdling and paclobutrazol foliar sprays induced high positive effect on number of panicles per shoot in "Off" years (2012 and 2014).

Also, it enhanced number of total flowers per panicle in "Off" year (2014) and it increased perfect flowers percentage in "On" year (2013). Generally, girdling treatment was the most efficient treatment in this respect. Moreover, girdling and paclobutrazol foliar sprays gave a high positive effect on fruit set in "Off" year (2014), fruit retention percentage in "Off" years (2012 and 2014). It also improved tree yield in 2012, 2013 and 2014 seasons. Generally, girdling shows superiority in this respect.

On the other hand, Manzanillo olive trees treated in mid-Nov. gave a high positive effect on number of panicles per shoot than trees treated in mid-June in "Off" year (2014). Moreover, trees treated in mid-June induced enhanced effect on number of total flowers per panicle than trees treated in mid-Nov. in "Off" year (2014). Moreover, perfect flowers percentage did not show response to trees treated in (mid-June and mid-Nov.) in "Off" years (2012 and 2014). Furthermore, trees treated in mid-Nov. gave a high positive effect on fruit retention percentage than trees treated in mid-June in "Off" years (2012 and 2014). Moreover, trees treated in mid- June gave a high positive effect on yield than trees treated in mid-Nov. in "On" year (2013). However, fruit set percentage did not show response to trees treated in (mid-June and mid-Nov.) in "Off" years (2012 and 2014).

The interaction between two factors showed that girdling done in (mid-June and mid-Nov.) gave a high positive effect on number of panicles per shoot in "Off" year (2012) and girdling done in (mid-Nov. exerted a pronounce effect on number of panicles per shoot in "Off" year (2014).

Moreover, girdling done in mid-June induced a positive effect on number of flowers per panicle, perfect flowers percentage and fruit retention percentage in "Off" years (2012 and 2014). Furthermore, girdling done in mid-Nov. improved tree yield in "Off" years (2012 and 2014). Whereas, girdling done in mid-June gave a positive effect on tree yield in "On" years (2011 and 2013).

The improvement of flowering, fruiting and yield of Manzanillo olive trees by girdling may be due to that girdling enhanced the internal hormonal and carbohydrate level of the tree canopy **[12 and 13]**. Also, fruit set requires large amounts of carbohydrates, which provided by the photosynthesis of the current season's leaves and/or by the reserves accumulated during the winter. Furthermore, girdling increases fruit set and yield by improving carbohydrate balance and increase their availability **[38]**.

The obtained results of the effect of girdling on flowering, fruiting and yield go in line with the findings of **[15]** who reported that girdling improved yield in quantity and quality of Manzanillo olive trees Moreover, girdling increased number of inflorescence, flower count, perfect flower percentage, fruit set percentage, fruit drop percentage and fruit harvest percentage of olive trees **[16]**. Furthermore, the positive effect of girdling application date on flowering, fruiting and yield are in harmony with the findings of **[17]** who indicated that the best time for girdling was in mid winter (December-February) prior to the major differentiation period. Also, girdling at the beginning of August and September stimulated differentiation of flower buds **[19]**. Moreover, winter girdling gave the highest yield trees in olive in the first year **[20]**. In addition, girdling at 15-day intervals from February 1st to March 1st on flowering parameters and fruiting of olive cv. "Uslu". Results showed that all treatments increased the perfect flower percentage, fruit set percentage and fruit harvest of olive trees. In 2005, the highest number of perfect flower percentage (22.73%) was recorded with girdling treatment on 1 March, followed by that of February 15th (20.29%). Both dates were statistically non-significant during both years **[21]**.

On the other hand, the positive effect of paclobutrazol which was reflected in enhancing the studied flowering and fruiting parameters may be attributed to its positive effect of paclobutrazol as potent specific inhibitor of GA_3 biosynthesis, could have restricted the GA_3 synthesis in leaves and fruits **[24]**. However, gibberellins is an inhibitors of flowering, when gibberellins is below critical level of gibberellins induced flowering but when it is above critical level of gibberellins suppress the flowering in citrus **[39]**. So applications of gibberellins-biosynthesis inhibitors like paclobutrazol enhance the flowering. Therefore, flower induction in olive may be attributed to the reduced level of gibberellins below critical level for flowering. In addition, paclobutrazol application highly restricted vegetative growth and increased the non-structural carbohydrate of the shoots. Hence the improved in flowering and fruit yield **[39]**.

The obtained results of paclobutrazol on flowering and fruiting go in line with the findings of Antognozzi and Preziosi (1986) they indicated that application of paclobutrazol increased total yield of olive, and **[30]** on oranges. Moreover, paclobutrazol increase flowering and fruiting parameters in apples **[31]**. Furthermore, paclobutrazol improved fruit set in mango **[40]**. Also, paclobutrazol gave the highest number of flowers per panicle of citrus **[41].** and confirmed by **[22]** on mango. Also, paclobutrazol enhanced percentage of hermaphrodite than male flowers of mango **[42]**.

The obtained results of the effect of paclobutrazol application date on flowering, fruiting and yield go in line with the findings of **[34]** who mentioned that paclobutrazol treatment in mid December increased yield of "Picual" olive trees.

4.2. Biennial bearing index

The results indicated that girdling, paclobutrazol foliar sprays and their interactions gave positive effect in reduced biennial bearing index.

The results indicated that girdling and paclobutrazol foliar sprays induced high positive effect in reduced biennial bearing index. Generally, paclobutrazol foliar spray at 1000 ppm proved to be the most efficient treatment in reduced biennial bearing index in this concern.

From the obtain result it was clear that tree treated in mid-Nov. gave a pronounced positive effect in reduced biennial bearing index than trees treated in mid-June.

The results indicated that paclobutrazol foliar spray at 1000 ppm done in mid-Nov. induced high reduction in biennial bearing index of Manzanillo olive trees.

The enhancement effect of girdling on biennial bearing index may be attributed that girdling of olive trees increased the internal hormonal and carbohydrate level of the canopy **[12 and 13]**. That reflected on reduced biennial bearing index of Manzanillo olive trees.

The improvement effect of paclobutrazol on biennial bearing index may be attributed that Paclobutrazol as potent specific inhibitor of GA_3 biosynthesis, could have restricted the GA_3 synthesis in leaves and fruits **[24]**.

Anyhow, the effect of paclobutrazol was more than the effect of girdling on minimized the alternative bearing of Manzanillo olive trees. This is due to paclobutrazol application reduced plant vegetative growth until 60 days after treatment of olive **[29]**.

4.3. Fruit quality

It is clear that girdling, paclobutrazol foliar sprays and their interactions gave a high positive effect on fruit quality.

The results indicated that girdling and paclobutrazol foliar sprays induced high positive effect on fruit weight in ("On" and "Off" years), pulp thickness in "Off" year and pulp / fruit weight percentage in "Off" and "On" years. Generally, girdling was superior treatment in this respect of study.

From the obtained result it was clear that tree treated in mid - June gave a high positive effect in fruit weight than trees treated in mid-Nov. in "On" years (2011 and 2013). However, trees treated in mid- June exerted a high positive effect on fruit weight than trees treated in mid-Nov. in "Off" year (2012). Moreover, trees treated in mid-June induced high positive effect on pulp thickness than trees treated in mid-Nov. in "On" year (2011). Furthermore, trees treated in mid-June on pulp/fruit weight percentage in mid-Nov. in 2011, 2012 and 2013 seasons.

The results indicated that girdling done in mid-June gave a high positive effect on fruit weight and pulp thickness in "On" years (2011 and 2013). Whereas, girdling done in mid-Nov. exerted high positive effect on fruit weight and pulp thickness in "Off" years (2012 and 2014). However, girdling done in mid-June enhanced pulp/fruit weight percentage in

2013 season and girdling done in mid-Nov. enhanced pulp/fruit weight percentage in 2012 season.

The enhancing effect of girdling on fruit physical properties may be attributed that girdling enhanced the internal hormonal and carbohydrate level of the canopy of olive trees **[12 and 13]**, hence it was reflected on enhancement of fruit quality.

The obtained results of the effect of girdling fruit physical properties go in line with the findings of **[15]** who mentioned that girdling improved fruit quantity of Manzanillo olive trees. Moreover, girdling improved fruit size, fruit weight and pulp weight were of olive trees**[16]**.

However, the obtained results of girdling application date their positive effect on fruit physical properties are in harmony with the findings of **[17]** who indicated that the best time for girdling was in mid winter (December-February) prior to the major differentiation period.

In addition, girdling done in mid-August increased fruit dry weight by 15% and pulp/pit ratio by 20% with no differences between the girdling treatments of olive trees **[18]**. Moreover, girdling done in June increased pit dry mass. Also, girdling at the beginning of August and September increased the pulp dry mass as compared with control**[19]**.

The enhancement effect of paclobutrazol on fruit physical properties may be attributed that paclobutrazol as potent specific inhibitor of GA_3 biosynthesis **[24]**. Also, paclobutrazol application highly restricted vegetative growth and increased the non-structural carbohydrate of the shoots. Hence it increases in fruit quality.

The obtained results of paclobutrazol on fruit physical properties go in line with the findings of **[30]** who reported that paclobutrazol enhanced fruit quality were of olives.

The obtained results of paclobutrazol application date of their positive effect on fruit physical properties are in harmony with the findings of **[34]** who mentioned that paclobutrazol treatment in mid December increased fruit diameter, fruit length, fruit weight, fruit volume and fruit pulp weight of "Picual" olive trees.

5. Conclusions

Thereupon, girdling application enhanced No. of panicles/shoot, No. of total flowers/panicle, perfect flower % and fruit retention % in "Off" years (2012 and 2014) also, it enhanced fruit set % in "Off" year (2014). Moreover, girdling treatment improved yield, fruit weight, pulp thickness and pulp/fruit weight % in "On" years (2011 and 2013) and "Off" years (2012 and 2014). Furthermore, Manzanillo olive trees treated in mid-Nov. improved No. of panicles/shoot than others in mid-June in "Off" year (2012). Moreover, trees treated in mid-Nov. improved No. of flowers/panicle than others in mid-June in "Off" year (2014). Moreover, trees treated in mid-Nov. improved fruit retention % than trees treated in mid-June in 2012 and 2014 seasons. However, trees treated in mid-Nov. improved yield than trees treated in mid-June in 2013 season. Moreover, trees treated in mid-June increased fruit weight in 2012 season and pulp thickness in 2011 season and pulp/fruit weight % in 2011, 2012 and 2013 seasons than other treated in mid Nov.

Conclusively, girdling and paclobutrazol at 1000 ppm applied in mid-June or mid-Nov. in an expected "On" year prior to an expected "Off" year enhanced the studied blooming and fruiting parameters of "Off" year and minimized the alternative bearing habit of Manzanillo olive trees.

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