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A comparative study of olive (*Olea europea l.*) Removal techniques and their effects on fruit harvest

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ABSTRACT

Olives produced in Jordan are harvested mainly using hand labor. The main problems facing farmers are high cost and shortage of laborers. The cost of operation can be reduced and harvest can be carried out on time if an abscission agent was used. In the year 2012 an experiment was conducted in order to study the effects of the use of Ethephon as an abscission agent. The study was carried out on Nabali olive cultivar at three different locations As-Salt, Madaba and Jerash. Treatments were consisted of five ethephon concentrations, which are: 0, 1500, 3000, 4500 and 6000 ppm, each concentration was repeated 4 times. Two weeks after ethephon applications, data were collected and analyzed according to the randomized completely block design. Results revealed that ethephon dosage had significant effects on harvesting productivity at 0.05 levels. This effect was more pronounced at 4500 ppm concentration at As-Salt and Madaba locations, but it was considered harmful at Jerash location due to the high leaf drop that was attributed to the heavy load of trees at this location. Results showed positive correlations within all the olive orchard locations for the percent of leaf drop and the total harvested fruits.

Key words: Nabali olive cultivar, Ethephon, Fruit Harvesting, Shaking, Leaf drop.

INTRODUCTION

Olives (*Oleae uropaea L.*) which belongs to Moraceae Family are commercially grown throughout the world in areas of Mediterranean climate [1,2]. In the last few decades there has been a significant increase in the global consumption of olive oil, even in countries where it is not produced, such as Canada and Japan [3]. This is due to its nutritional and health-promoting effects [4].

Olive tree orchards are a typical feature of the Mediterranean landscape [5], and it covers about 9 million hectares of the worldwide surface area [6].The olive fruits production in Jordan during the year 2011-2012 was 221 thousand tons, which covers more than 75 % of areas planted by fruit trees. Most of olive fruits are used as source of oil, while 17 % were utilized as naturally ripe olive in brine [7]. Olive fruit harvesting is considered the most expensive stage of olive production; since olive harvesting consumes 50–80 % of the total expenses of growing olive [8]. Because the ratio between fruit mass and pedicel's strength is relatively small as compared with other fruits, a huge amount of force is required to shake off the fruits from olive trees [9].

Currently, olives are harvested by the hands in Jordan, expensiveness and provisions of the labor are the main difficulties in the olive harvesting [2].

When harvesting from higher trees, the workers use the method of “beating with a stick”. This damages the fruits and affects their quality and quantity, also this method of fruit harvesting is considered costly [10]. On the other hand mechanical olive harvesting is limited to a minor portion of the olive oil industry worldwide [11].

Different types of chemicals were tested to promote pedicel's loosening; positive results were only obtained by using the ethylene releasing compounds like ethephon. Ethephon (2-chloroethyl phosphonic acid) is a synthetic

plant growth regulator discovered some forty years ago, which acts by releasing ethylene when it penetrates plant tissues [12]. Ethephon is applied commercially to accelerate ripening, promote color development of fruits and fruit abscission for many fruit crops [13,14,15,16].Ethephon, were found to be able to promote pedicel's loosening and therefore increase the natural ratio between fruit mass and pedicel strength, so olive fruits can be easily mechanically harvested [9,11,17].

Ethephon show non-climacteric behavior and can accelerate chlorophyll degradation in olives[18]. When applying ethephon any water stress and or extreme temperatures may increase leaf drop [11,19,20]. Many factors can affect ethylene evolution rate like; pH of the water that is used for dissolving the chemical, atmosphere temperature and relative humidity [21].

Ethrel for olive harvesting showed that the percentage of the olive harvesting without using of abscission material was less than 50 % while using of Ethrel with the concentration of 3.125 and 6.25 ml/lit increased the harvesting productivity by 46 % and 103 %, respectively, and decreased the fruit-removal-force (FRF). Besides, using of 2000 ppm of Ethrel to promote the harvesting productivity through two shaking devices of mechanical and pneumatic types, one month before the olive harvesting has been suggested [22].

Harvesting time plays a major role on oil's yield, quality, stability and sensory characteristics [23]. Harvesting plays a major role in the virgin olive oil production line: it is not only the most expensive single component [24], but it also has a significant effect on the whole year's produce. In selecting the timing for harvest, the grower is determining the quantity and quality of the year's fruit, as well as of the next season's crop [2]. Literature evaluating the simultaneous effect of harvesting time on olive yield and quality are very limited [25]. The increasing proportion of intensive orchards and the development of rapid tools for mechanized harvesting have brought about the need to determine the effects of harvest time and fruit maturity on oil yield and quality in relation to cultivar, environmental conditions and agronomic practices.

Since the ripening date the later the harvest of olive the less the quality of it, because of increasing acidity. Also, because of decreasing moisture, the weight of the yield decreased as well. Furthermore, the strength of the stalk is also reduced so that the yield is shed by a little wind on the ground [22].

The performance of the harvesting machines largely depends on the binding force the fruit of the stem, or in other words, it is the resistance shown by the fruits when vibrating, that influences the performance of the machines. Using the harvesting machine has the trouble that earlier on the time of natural ripening there are some fruits left over the trees and later on the time of natural ripening, other fruits shed on the ground. To ripen the fruits at the same time and so to promote the harvesting productivity, spraying the fruit trees with a solution which reduces the resistance of the fruit stalks on vibrating moment is recommended for mechanized harvesting [26,27].

Until now, no research project on the mechanized harvesting of the olive and using the abscission chemical has been conducted in Jordan. The objective of this research was to investigate the ways of the olive harvest using the various amounts of the abscission chemical of Ethephon in the harvesting of three olive orchards locations, This research has addressed the best way of the harvesting and the most suitable amount of abscission chemical for the three locations of the Nabali olive .

MATERIALS AND METHODS

This study was carried out on Nabali olive cultivar at three different orchard locations; the first orchard at As-salt area located at the west side of Jordan (32º 01'48.22"N; 35º 42'18.35"E), the second orchard at Madaba area located at the east side of Jordan (31º 73'12.25"N; 35º 45'54.15"E) and the third orchard at Jerash area located at the north side of Jordan(32º 19'30.77"N; 35º 54'36.27"E), and these locations represents the main areas of olive planting in Jordan. At each location, 20 different olive trees of about 12-15 years old were selected randomly in the field, and were chosen to carry nearly the

same amount of yield. Before treatment applications trees were irrigated with adequate water [28]. Then treatments were applied at the mid of November, 2012, during the start of purple color formation on the fruit, which considered the normal time for the start of olive harvesting in Jordan. Treatments used are consisted of five Ethephon concentrations; 0 ppm (control), 1500 ppm, 3000 ppm, 4500 ppm, and 6000 ppm, each concentration was repeated 4 times (sprayed on four trees), for each tree four shoots at shoulders level were selected and its leaves and fruits were counted and recorded, then the shoots were covered with a plastic mesh bag to collect the dropped leaves and fruits. Ethephon solutions have been buffered to pH 7 to speed up ethylene release and mitigate olive leaf loss [11]. Two weeks after Ethephon applications, the dropped leaves and fruits were collected from each plastic mesh bag, and used for calculating the leaf drop percent and the fruit abscission percent.

After removing the dropped leaves and fruits, the plastic mesh bags were returned to the shoots, then all the trees were shaken with the branch shaking devices (the hand held shaking ones) for 10 seconds per/branch, after that the dropped leaves and harvested fruits were collected from each plastic mesh bag, and used to calculate the percent of the leaf drop after shaking and the percent of harvested fruits.

Measured Parameters

The number of fruits and leaves on each covered branch was recorded, and then all data were collected two weeks after treatments applications and expressed as percentage.

Leaf abscission

Leaf drop percent: calculated by dividing the number of the collected leaves from the four plastic mesh bags, and divided over the total initial number of leaves of the four covered branches.

Leaf drop percent after shaking: calculated by dividing the number of the collected leaves after shaking the tree branches from the four plastic mesh bags, and divided over the total number of leaves that are remained on the branches after removing the dropped leaves before shaking.

Total leaf drop percent: all the dropped leaves before and after shaking were count and divided by the total number of the initial leaves count of the four plastic mesh bags.

Fruit harvest

Fruit abscission percent: calculated by dividing the number of the collected fruits from the four plastic mesh bags, and divided over the total initial number of fruits of the four covered branches.

Fruit harvesting: after shaking, the dropped fruits percent were calculated by dividing the number of the collected fruits from the four plastic mesh bags, and divided over the total number of fruits that are remained on the branches after removing the dropped fruits before shaking.

Total fruit harvesting percent: all the dropped fruits before and after shaking were counted and divided by the total number of the initial fruits count of the four plastic mesh bags.

Experimental design and statistical analysis:

For each experiment location data were collected and analysed separately. A randomized completely blocks design (RCBD), with five treatments and four replicates (trees) were used. All data obtained were statistically analysed by variance, according to the procedure outlined by [29]. The differences between means of the different treatments were compared by the Least Significant Difference (LSD) test using SAS software, and differences with probability value at $P = 0.05$ were considered significant.

RESULTS AND DISCUSSION

Leaves drop results

A significant difference was observed among the used ethephon concentrations at As-Salt location (Table 1). The highest leaf drop percent before shaking was obtained by the 4500 ppm, while the lowest was obtained by the control treatment, and all the used ethephon concentrations accelerate leaf drop.

After shaking the leaves drop percent were increased, but no statistical differences were observed between all the used treatment concentrations except with the control that produced the lowest significant difference. On the other hand when all the leaves dropped were considered, the highest significant total leaf drop percent were obtained by the 4500 and 6000 ppm with 11.53 and 11.19 %, respectively, but these results are still lower than 25 %, so all of the used concentrations do not have any harmful effect and its results could be accepted [30].

Results of leaf drop percent at Madaba location (Table 2), showed a significant statistical differences among the used ethephon treatment concentrations; results showed that a very low leaf drop percent were obtained before shaking, even though the highest (6.29 %) was obtained by the 4500 ppm, while the lowest (1.1 %) was obtained by the control treatment. Also, after shaking the leaf drop percent were considered very low and 4500 ppm still producing the highest percent of leaf drop with a significant differences with all the used ethephon concentrations. On the other hand, when all the dropped leaves were considered, the 4500 ppm still producing the highest percent of leaf drop with 17.77 %, but this percent is still low and could be accepted [30], since it's lower than 25 %. Since all of the used ethephon concentrations did not have any harmful effect on the olive trees leaves in Madaba location, any concentrations of the ethephon could be used depending upon the result of fruit harvest percent.

At Jerash location, before shaking; leaf drop percent showed a significant difference among the used ethephon concentrations (Table 3). The highest leaf drop percent before shaking was obtained by the 4500 and 6000 ppm with 25.35 and 29.7 %, respectively, while the lowest leaf drop (6.48 %) was obtained by the control treatment. Also, after shaking a high percent of leaf drop were observed in all of the ethephon applications in compare to the control treatment that produced the lowest percent of leaf drop. On the other hand, when considering all of the dropped leaf percent; results showed that, all of the used ethephon concentrations showed a very high percent of leaf drop, and the highest total leaf drop percent was obtained by the 6000 ppm with 47,07 % of total leaf drop. This percent of leaf drop (47 %) is considered a serious problem since its higher than that obtained by [30], whom considered any leaf drop percent higher than 25 % is a serious problem, because any leaf drop can adversely affect olive trees return bloom in the next year [20]. All of the used ethephon concentrations produced more than 25 % leaf drop, so at this location it is not recommended to use any of the applied ethephon concentrations, and it is advised to examine a lower concentrations.

Fruits harvesting results

In the control clusters, fruit abscission during the investigation period (Figure 1) is very low (5.5 %). However, ethephon application accelerated fruit abscission, and the highest percentage of fruit abscission (28.73 %) was obtained by the 6000 ppm Ethephon treatment without statistical differences with 4500 ppm treatment. But after shaking 4500 ppm ethephon treatment produced the highest fruit harvesting also without significance with 6000 ppm treatment. When considering the total fruit harvesting; all the ethephon applications promote olive fruit harvesting in compare to the control treatment which produced the lowest significant fruit harvesting. Best results of fruit harvesting 72.75 and 70.61 %, were obtained by the 4500 and 6000 ppm, respectively. Therefore, ethephon has performed well as a fruit-harvesting agent for Nabali olive fruit harvesting at As-Salt location and these results are in agreement with results obtained earlier [13,14]. In contrast, results obtained here show that ethephon at 4500 or at 6000 ppm caused fruit abscission, and could be used in olive fruit harvesting at As-Salt location.

Results of Madaba location (Figure 2), proved that ethephon applications for olive fruits promotes abscission, the effect of ethephon on fruit abscission differs with concentrations; the highest percent (39.87 %) was obtained by the 4500 ppm, while the lowest was obtained by the control treatment with 5.7 %. But after shaking no significant difference were observed between 4500 and 6000 ppm treatments, which produced the highest fruit harvesting percent. In contrast, all

ethephon treatments increased the total fruit harvesting percent in compare to the control treated olive trees, and the highest significant total fruit percent (79.34) was obtained by the 4500 ppm ethephon concentration. Therefore, for this location (Madaba) it's concluded, that ethephon which considered as ethylene generating compound at 4500 ppm could be used as a harvesting agent.

Results of fruit harvesting in Jerash showed a high fruit abscission during the investigation period (Figure 3), and all the ethephon application treatments accelerated fruit abscission with higher percentages, even though, the control treatment produced the lowest fruit abscission (18.3 %), but this percent is considered high. Results of fruit harvesting after shaking is lower than before shaking, which means that in this location there is no need to wait two weeks after ethephon applications, or could be due to the heavy crop during this season, so when ethephon is applied it stimulate heavy leaves and fruits drop. When considering the total fruit harvesting percent; the highest results were obtained by the 4500 and 6000 ppm applications with 64.21 and 71.04 %. At this location it's recommended to do another study that considers the crop load and the environmental conditions.

On the other hand results for the percent of leaf drop and the total harvested fruits, showed a significant positive correlations within all the olive orchard locations (Table 4).

CONCLUSION

Our research indicates that all of the applied ethephon concentrations accelerate leaf drop percent, but all the used concentrations are acceptable at As-Salt and Madaba orchard locations, but it is considered harmful at Jerash orchard location. In contrast, the obtained results of fruit harvesting, showed that ethephon at 4500 ppm could be used in olive fruit harvesting at As-Salt and Madaba orchard locations and also at Jerash location, but since it produced a high leaf drop at Jerash orchard; its advised to consider the trees fruit load in addition to the environmental conditions in another chemical harvesting experiment at Jerash location. In addition for fruit harvesting, spraying the fruit trees with a solution which reduces the resistance of the fruit stalks on vibrating moment is recommended for mechanized harvesting. Also, positive correlations were found between the total leaf drop percent and the total harvested fruits.

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Tables

Table 1: Results of olive leaves drop percentage at "As-Salt" location*: leaves (table)

Ethephon treatments	Leaf drop % before shaking	Leaf drop % after shaking	Total leaf drop %
0 ppm (control)	1.075 d**	4.23 b	5.45 c
1500 ppm	4.350 b	5.93 a	10.02 b
3000 ppm	2.625 c	6.60 a	9.05 b
4500 ppm	6.053 a	8.83 a	11.53 a
6000 ppm	5.325 a	6.20 a	11.19 a
$LSD_{0.05}$	0.866	0.81	0.98

*: Values are the mean of four replicates.

**: Means within each column having different letters are significantly different according to LSD at 5 % level.

Table 2: Results of olive leaves drop percentage at "Madaba" location*:

Ethephon treatments	Leaf drop % before shaking	Leaf drop % after shaking	Total leaf drop %
0 ppm (control)	1.10 c**	4.84 c	5.88 d
1500 ppm	4.34 b	5.21 c	9.36 c
3000 ppm	4.90 b	4.88 c	9.55 c
4500 ppm	6.29 a	12.25 a	17.77 a
6000 ppm	5.37 ab	7.73 b	12.69 b
$LSD_{0.05}$	1.22	2.32	2.03

*: Values are the mean of four replicates.

**: Means within each column having different letters are significantly different according to LSD at 5 % level.

Table 3: Results of olive leaves drop percentage at "Jerash" location*:

Ethephon treatments	Leaf drop % before shaking	Leaf drop % after shaking	Total leaf drop %
0 ppm (control)	6.48 c**	8.57 c	14.48 c
1500 ppm	15.58 b	25.80 a	37.38 b
3000 ppm	14.75 b	26.87 a	37.63 b
4500 ppm	25.35 a	19.31 b	39.80 b
6000 ppm	29.70 a	24.77 a	47.07 a
$LSD_{0.05}$	5.18	2.74	4.31

*: Values are the mean of four replicates.

**: Means within each column having different letters are significantly different according to LSD at 5 % level.

Table 4. Results of correlations between total leaf drop percent and total fruit harvesting percent in the three locations:

Location	Correlation of total leaf drop % to Total fruit harvest %
As-Salt	0.970
Madaba	0.983
Jerash	0.997

Figures

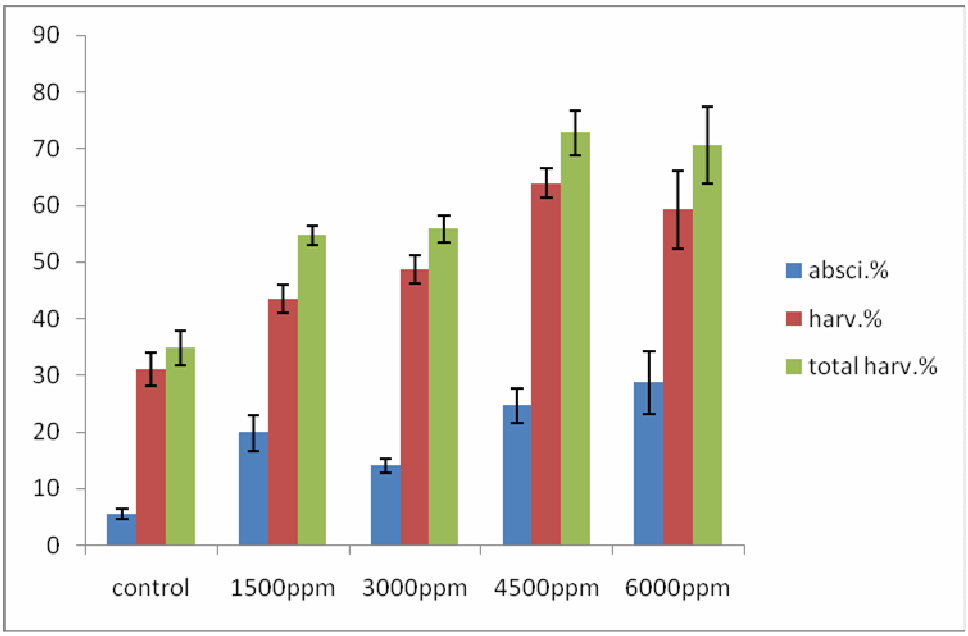

Figure 1: Results of olive fruits chemical harvesting at "As-Salt" location.

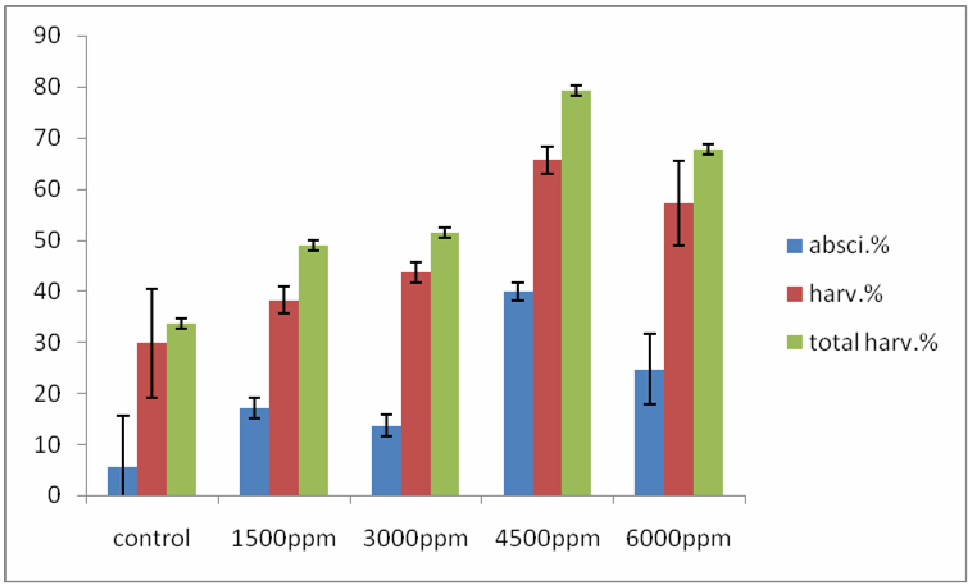

Figure 2. Results of olive fruits chemical harvesting at "Madaba" location

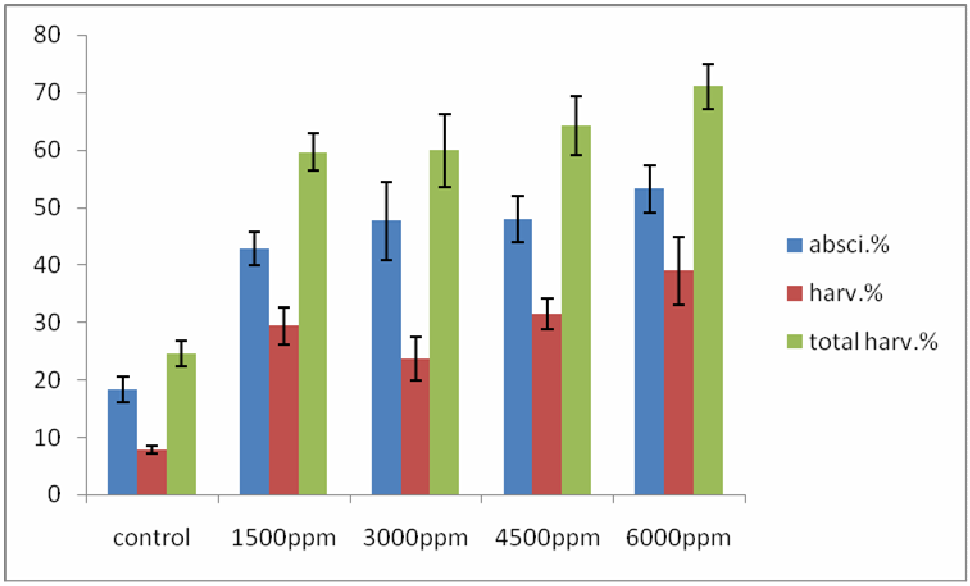

Figure 3. Results of olive fruits chemical harvesting at "Jerash" location.

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الملخص العربي

دراسة مقارنة تقنيات إسقاط الزيتون(*Olea europea L.*) وتأثيراتها على حصاد الثمار

طالب راتب أبوزهرة

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الزيتون الذي ينتج في الأردن غالباً ما يحصد بواسطة الأيدي العاملة. المشاكل الأساسية التي تواجه المزارعين هي التكلفة العالية و نقص العمالة. يمكن تخفيض تكاليف هذه العملية وإجراء الحصاد في وقته إذا تم استخدام مواد تسبب السقوط. في العام ٢٠١٢ تم إجراء تجربة لدراسة تأثيرات استخدام الايثيفون كمادة تسبب السقوط. تم إجراء التجربة على ثمار الزيتون صنف النبالي و ذلك في ثلاثة مواقع مختلفة: السلط، مادبا وجرش. تكونت المعاملات من خمسة تركيزات من الايثيفون وهي: ٠، ١٥٠٠، ٣٠٠٠، ٤٥٠٠ و ٦٠٠٠ جزء/بالمليون، كل تركيز تم تكراره ٤ مرات. بعد أسبوعين من استخدام الايثيفون، تم جمع وتحليل البيانات باستخدام نظام القطاعات العشوائية المتكامل. أظهرت النتائج وجود تأثير معنوي لتركيز الايثيفون على معدل الحصاد و ذلك على المستوى ٠,٠٥ . هذا التأثير كان أكثر وضوحاً باستخدام التركيز ٤٥٠٠ جزء بالمليون في موقعي السلط ومادبا، ولكنه كان مؤذياً في موقع جرش بسبب السقوط الكبير في الأوراق والذي يعزى للحمل الغزير في أشجار ذلك الموقع. أظهرت النتائج وجود ارتباط ايجابي في كل مواقع بساتين الزيتون وذلك ما بين نسبة سقوط الأوراق وحاصل الحصاد الكلي للثمار.