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Effect of NAA and CPPU on Fruit drop, Yield and Quality of Avocado Trees

Laila Y. Mostafa[1], Yehia S. Mostafa[2] and Islam M. El-Berry[2]
[1]*Tropical Fruit Research Department, Horticulture Research Institute, Agricultural Research Centre, Cairo, Egypt.*
[2]*Pomology Department, Faculty of Agriculture, Alexandria University, Alexandria, Egypt.*

THIS work conducted to investigate the effect of NAA and CPPU on fruit set and retained/panicle, accumulative and relative fruit drop %, fruit quality and yield, changes in total soluble sugars on Bacon avocado (*Persea Americana* Mill.) trees. The selected trees were foliar sprayed twice, at full bloom and beginning of fruit set, with one of the following treatments, water (control), NAA at 15 or 30 ppm, CPPU at 5 or 10 ppm, and their combinations. Avocado trees treated with 30 ppm NAA + 5 ppm CPPU resulted in the highest fruit set/panicle, fruit retained/panicle and significantly reduced the peak of fruit drop happen 2 weeks after fruit set. Also, 30 ppm NAA + 5 ppm CPPU and 5 ppm CPPU produced the highest fruit weight, fruit dimension and yield. All the treatments with NAA or CPPU significantly decreased the content of total soluble sugars in the leaves from the 3rd to 8th weeks after fruit set and starch from the 1st to 3rd week after fruit set. Based on this study, NAA and CPPU promoted the mobilization of carbohydrate from the leaves to the fruitlet. Hence, NAA or CPPU suppressed fruit drop in avocado by increasing the availability of carbohydrate in fruitlet and thus improved fruit retention.

Keywords: Avocado, Bacon, NAA, CPPU, Fruit drop, Yield and Fruit quality.

Introduction

Avocado (*Persea americana* Mill.) is an evergreen subtropical fruit tree native to Central America. It is belongs to the Lauraceae family and one of the most commercial member of Persea genus. Avocado is one of the most nutritious fruits, good source for fiber, lipid-soluble antioxidant and monounsaturated fatty acids (Comerfor et al., 2016). In Egypt, the avocado cultivated area is too small, it was unfavorable fruit crop for the Egyptian consumer. But nowadays, avocado becomes one of the promising fruit crops due to the awareness increase about its nutritional value and economic view.

Under favorable conditions, avocado flowers are profuse and fruit set is very numerous, and a subsequent heavy fruit drop normally takes place. Two major fruit abscissions were recognized, the first occurs once the fruit set begin and continued three to four weeks after fruit set. This can be attributed to failure of fruit development, embryo abortion or due to environmental stresses (Gazit and Degani, 2002), which severely reducing the number of fruits. However, the second abscission takes place when the fruit reaches between 10% and 40% of its ultimate size (Whiley et al., 1988 and Wolstenholme et al., 1990). The sever competition among the fruits, roots and new shoots reducing the accumulation of photosynthates resulting in fruit drop (Gazit and Degani, 2002). Under these conditions, only the fruits of greatest vigour persist on the tree (Laskowski, 2006). Carbohydrate availability is considered a key factor in fruit abscission, as regarded by Mcfadyen et al. (2012) who

Corresponding author: Laila Y. Mostafa, E-mail: layla_yehya2009@yahoo.com, Tel. 00201123377222
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presumed that 80% of premature fruit are abscised in the 8 weeks following fruit set as a result of carbohydrate shortage. Techniques for promoting carbohydrate level increase the number and size of avocado fruits (Wolstenholme et al., 1990 and Lovatt, 2006).

It is quite known, that the fruit retention relates positively to the ability of the fruit to attract nutrients, which in turn is dependent on the fruit ability to produce growth promoting hormones (Wolstenholme and Robert, 1991). In fact, when the concentration of abscissic acid and ethylene increase in the panicle, abscission layer is formed at the site of fruit attachment, which ultimately drops down. Exogenous applications of plant growth regulators have variable success in reducing fruit drop (Chadha & Singh, 1964 and Abou Rawash et al., 1998). Naphthalene acetic acid (NAA) was found to improve the fruit retention capacity, fruit quality and yield of mangoes (Anila and Radha, 2003). Chattha et al. (1999) demonstrated that premature fruit drop in mango could be inhibited by NAA application. In the meantime, Sitofex (CPPU) i.e. N- (2-chloro-4-pyridyl)-N- phenyl urea) is a plant growth regulator, which has strong cytokinine effect, also responsible for promotion of fruit setting and reduced fruit drop. The CPPU involved in strengthening cell wall in the abscission zone through activating the biosynthesis of proteins, RNA, DNA and promoting the cell division, thus reducing flower and fruit shedding (Nickell, 1985).

Flaishman et al. (2001) and Guirguis et al. (2003) reported the beneficial effects of using CPPU in reducing fruit drop and increasing productivity as well as improving fruit size in pear. The objective of the present study was to investigate the effect of foliar application with NAA, CPPU alone or in combination on fruit drop, productivity and fruit quality of avocado cv. Bacon.

Materials and Methods

Plant materials and experimental design

The present investigation was conducted on 20 years old avocado trees (*Persea americana* Mill.) cv. Bacon, grown at Al-Salmaia orchard (Latitude: 30.69863 and Longitude: 30.02922), at El-Nubaria region, El-Beheira Governorate, Egypt, during two seasons 2017 and 2018. The avocado trees in the orchard were grown in sandy soil at 6 × 7 m apart and subjected to drip irrigation system. Twenty seven avocado trees uniform as possible as can in shape, vigor, size, and productivity were selected and arranged in randomized complete block design (RCBD) to conduct this experiment. Nine foliar treatments were sprayed twice, at full bloom (30 and 24 March in 2017 and 2018 respectively) and beginning of fruit set (15 days after full bloom), with three replicates per treatment, using one tree as a unit of treatment in each replicate. The applied treatments were, control (sprayed with water only), NAA at 15 or 30 ppm, CPPU at 5 or 10 ppm and their combinations. Hybrid surfactant obtained from (Kanza group Co.), was added to all prepared solutions at 0.5 ml/l and trees were sprayed until run off.

Measurements

Fruiting parameters

Sixty bearing shoots similar in size from different positions on the canopy per each tree were selected and marked at the flowering stage. Thirty bearing shoots were used to measure number of fruit set/panicle, fruit retained/panicle, accumulative fruit drop and relative fruit drop, while the other thirty were used to follow up the leaf total soluble sugars and starch contents. Fruit set/panicle, was measured by counting the number of fruitlets per panicle 3 weeks after full bloom (initial fruit set). Number of fruit retained per panicle, was recorded at fruit maturity stage (a week before harvest).

The accumulative fruit drop rates, was the percentage of the total number of fruit drop from the day of treatment against the initial fruit set. However, the relative fruit drop rates were the percentage of fruit drop during the period between two investigation dates against the fruit number per panicle on the date of the first investigation (Zeng et al., 2016).

Yield and fruit quality

At harvest time (1st week of October), the weight of harvested fruits per tree were recorded by digital balance at all harvest times and cumulative fruit weight was used to express yield as (kg/ tree), and calculation of average yield per feddan as (ton/feddan). A sample of 10 mature fruits from each replicate was taken randomly at harvest time to determine fruit weight (g), fruit length (cm) and fruit diameter (cm).

Leaf carbohydrate content

Samples of ten mature avocado leaves from the second and third nodes on the bearing shoots were collected periodically at initial fruit set (zero time), 1, 2, 3, 4 and 8 weeks after fruit set, dried and ground into fine powders for analysis. Leaf total soluble sugars were extracted by 80 % ethanol and determined by phenol-sulfuric method according to Malik and Singh (1980). Starch content was determined in the residue remained after sugars extraction. A 0.1 gram of the residue was hydrolyzed with concentrated HCL for three hours under reflux condenser (A.O.A.C., 1995) and reducing potential of the hydrolysate was determined by the arsenate-molybadate method. A factor of 0.9 was used to calculate starch (Wood man 1941).

Statistical analysis

This experimental design was a randomized complete blocks design RCBD which carried out in 9 treatments and three replications (one tree / replicate) during the two seasons. Data in this study were statistically analyzed using the SAS (Statistical Analysis System) version 9.1 according to Gomez and Gomez (1984). New least significant differences (New L.S.D) at 0.05 used to compare the differences among means according to Snedecor and Cochran (1967).

Results and Discussion

Fruiting characters

Fruit set and retained per panicle

The foliar spray with NAA or CPPU at all used concentrations, either alone or in combinations significantly increased fruit set per panicle as compared with control in both seasons (Table 1). The highest fruit set per panicle was found with 30 ppm NAA + 5 ppm CPPU treatment in both seasons. The second highest fruit set was noticed with 5 ppm CPPU and 30 ppm NAA + 10 ppm CPPU in both seasons, in addition to 10 ppm CPPU in 2017 only. Use of 30 ppm NAA either alone or combined with CPPU recorded higher fruit set per panicle than 15 ppm NAA in both seasons. Meanwhile, slight differences were noticed among used concentrations of CPPU on fruit set. Furthermore, all applied treatments significantly recorded higher fruit retained per panicle than control in both seasons (Table 1). Additionally, the most effective treatment was 30 ppm NAA + 5 ppm CPPU in 2017 and 2018. Use of 30 ppm NAA individually in 2017 or in combination with 5 or 10 ppm CPPU in both seasons was more effective than 15 ppm NAA. However, 5 ppm CPPU alone in 2018 or combined with 30 ppm NAA in both seasons recorded higher fruit retained per panicle than 10 ppm CPPU either alone or combined with NAA.

TABLE 1. The effect of foliar application with NAA, CPPU and their combinations on fruit set and fruit retained per panicle of avocado cv. Bacon in 2017 and 2018 seasons.

Treatment	Fruit set/ panicle		Fruit retained/ panicle	
	2017	2018	2017	2018
Control	6.70	8.90	1.30	1.50
NAA 15 ppm	8.60	11.40	2.00	2.33
NAA 30 ppm	10.23	12.13	3.05	2.23
CPPU 5 ppm	11.50	13.07	2.90	4.10
CPPU 10 ppm	11.12	12.50	2.70	3.00
NAA 15 ppm + CPPU 5 ppm	10.30	11.33	2.63	3.20
NAA 15 ppm + CPPU 10 ppm	10.10	10.90	2.53	2.90
NAA 30 ppm + CPPU 5 ppm	12.13	14.20	3.70	4.50
NAA 30 ppm + CPPU 10 ppm	11.03	13.30	3.00	4.07
New LSD at 0.05	0.56	0.49	0.34	0.29

Accumulative and relative fruit drop (%)

The effect of different foliar sprays on accumulative fruit drop percentage was found in Fig. 1. Results of both seasons showed that all treatments significantly decreased the accumulative fruit drop percentage. Within the first three weeks after fruit set, the rate of accumulative fruit drop rapidly increased, the treatment with 30 ppm NAA + 5 ppm CPPU recorded 66.7 and 61.67%, which was significantly lower than control (83.1 and 81.23) in 2017 and 2018, respectively. Subsequently, the accumulative fruit drop percentage maintained significantly lower than the control treatment from 3 to 8 weeks after fruit set, but the increase during this period was comparable between the treatment of 30 ppm NAA + 5 ppm CPPU with 6.2 and 10.57% and control with 5.93 and 12.06% in 2017 and 2018, respectively. The other tested treatments exerted a similar effect on the rate of accumulative fruit drop with intermediate value. These results indicating that, fruit drop fundamentally occurred through the early stages of fruit development.

Regarding to treatment effect on relative fruit drop rate, results in Fig. 2 revealed that all used treatments reduced relative fruit drop rate than control in both seasons. While, the lowest relative fruit drop was found with 30 ppm NAA followed by 30 ppm NAA + 5 ppm CPPU in 2017, and with 30 ppm NAA + 5 ppm CPPU followed by 5 ppm CPPU in 2018. In concern to dates effect, the relative fruit drop rate at one week after fruit set was markedly high, and increased to a higher value after 2 weeks, then gradually decreased up to 4 weeks, and subsequently slight increase was noticed after 8 weeks in both seasons. As for interaction, after the first week all applied treatments significantly suppressed fruit drop as compared with control in both seasons. The use of NAA at 15 or 30 ppm was more effective than CPPU at 5 or 10 ppm on reduction of fruit drop at the first week. The peak of relative fruit drop rate of all used treatments was noticed after 2 weeks from fruit set, whereas differences among all treatments were significantly higher than in all rest dates, except with control at the first week.

These results suggested that, NAA or CPPU succeeded in reduced fruit drop and delayed the occurrence of the peak of young fruit drop by about week in avocado. It's widely known fact that fruit drop is a common phenomenon factors that play a major role in fruit drop is deficiency of auxins, gibberellins and cytokinins. This deficiency accompanied by high level of growth inhibitors i.e., abscissic acid and ethylene increase fruit drop enormously. The exogenous applied of NAA increase their concentration in the panicle and antagonizes the harmful effect of endogenous inhibitors, preventing the formation of abscission layer in the panicle. In this concern, El-Sabagh (2002) on apple trees and Guirguis et al. (2003) showed that a significant effect of CPPU in increasing fruit set may be due to ability of CPPU to mobilize assimilate to the metabolic active sites like fruitlets which responsible for improve fruit set and final fruit retention. It is also involvement in strengthening cell walls in the abscission layer through activating the biosynthesis of proteins, RNA, DNA and promoting cell division, this reducing fruit shedding (Nickell, 1985). Another possible reason for reduction of fruit drop, that may be due to CPPU a strong cytokinin responsible for promotion fruit setting and reduced fruit drop (Lei and Hongxian, 2011). The application of NAA and CPPU at different concentrations and at different times of application were beneficial to increase fruit set and ultimately for fruit retention (Guirguis et al. 2010).

A growing body of evidence has shown that CPPU treatment enhanced fruit set in many fruit species such as Lychee (Yang et al., 2015) and Citrus (Chen et al., 2002). In macadamia fruit Zeng et al. (2016) revealed that CPPU treatment suppressed fruit drop and delayed the peak of fruit drop by about 1 week.

Fruit quality and yield

All foliar applications with NAA, CPPU or their combinations increased fruit quality as compared with control in both seasons (Table 2). It is clear that fruit weight was significantly increased by all foliar treatments at all concentrations compared with control. The highest significant fruit weight was found with 30 ppm NAA + 5 ppm CPPU with percent of increase than control up to 9.04% and 9.90% in 2017 and 2018 seasons, respectively, followed by 5 ppm CPPU in both seasons. Results also showed that, the higher concentration of NAA significantly increased fruit weight than lower concentration, meanwhile the opposite trend was noticed with CPPU.

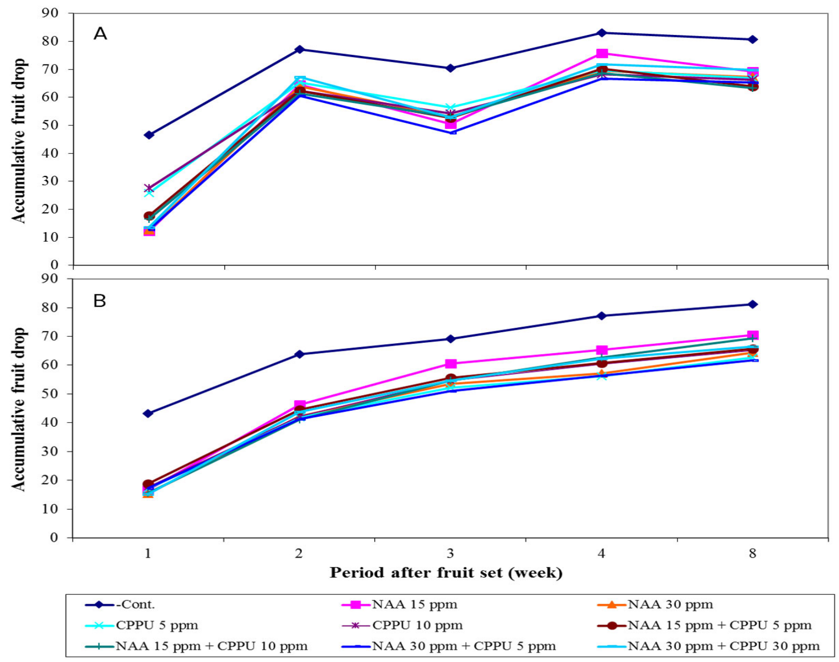

Fig.1. Effect of foliar spray of CPPU and NAA and their combinations on accumulative fruit drop of avocado cv. Bacon in 2017 (A) and 2018 (B).

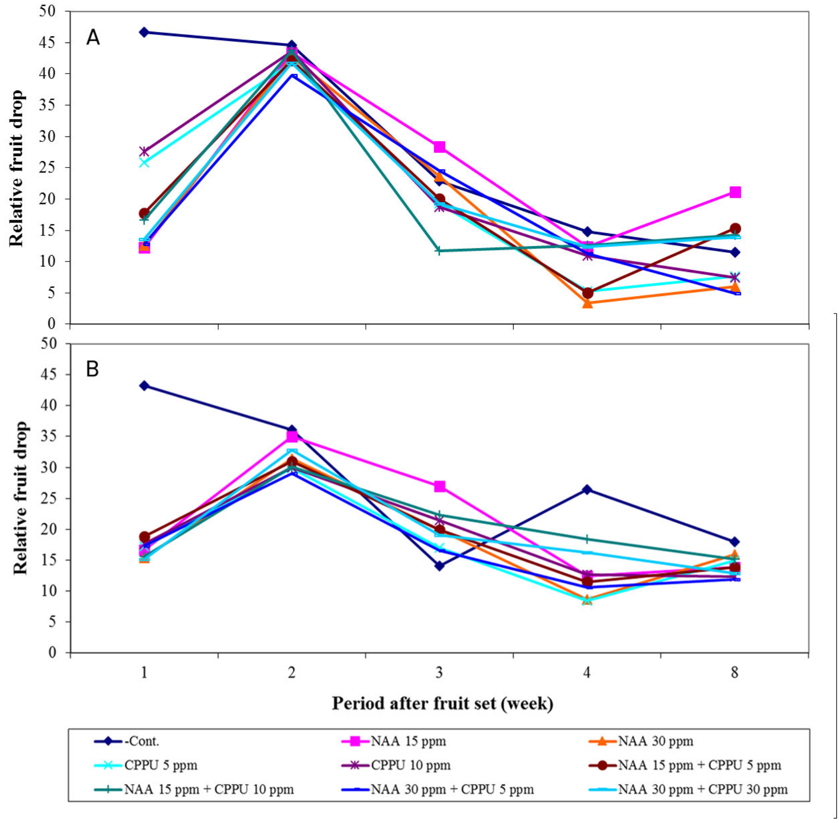

Fig. 2. Influence of foliar application of CPPU and NAA and their combinations on relative fruit drop of avocado cv. Bacon in 2017 (A) and 2018 (B) .

Regarding to fruit dimensions, NAA and CPPU treatments significantly increased fruit length and diameter as compared with the control treatment in both seasons. In this respect, the highest fruit length was found with 5 ppm CPPU either alone or in combination with 30 ppm NAA in the first season, without significant difference with 30 ppm NAA + 10 ppm CPPU, while it was with 30 ppm NAA + 5 ppm CPPU in 2018 season. Furthermore, NAA and CPPU treatments at all concentrations and combinations significantly increased fruit diameter as compared with control in both seasons. Avocado trees treated with 30 ppm NAA + 5 ppm CPPU produced the highest fruit diameter followed by 5 ppm CPPU in both seasons. Results also showed that, higher concentration of NAA markedly increased fruit length and diameter than lower one, while the opposite trend was occur with CPPU in 2017 and 2018.

The enhancement in the fruit weight, length and diameter regulated by foliar application with NAA and CPPU could be due to their effects on cell division and enlargement resulted in bigger fruit size as they improve the strength of carbohydrate sink (Kassem et al., 2012). NAA and CPPU enhance faster movement of simple sugars which involved in cell expansion and cell elongation *(*Brahmachari et al., 1996). CPPU is responsible for the production and transport of plant sugars which cause an increase in cell size and stimulate cell division and cell elongation, ultimately increasing fruit weight (Notodimedjo, 1999 and Dokoozlain, 2000).

Kuiper (1993) reported that sink strength is gained and regulated by NAA and CPPU, which have an essential role in the transport of plant nutrient via the phloem, as well as modification of the strength of the sink, increasing the ability for sugar unloading from the phloem. They may also have an effect on metabolism and compartmentalization of metabolites and sugars of the tree (Brenner and Cheikh, 1995). On grapes, Nampila et al. (2010) gathered that CPPU showed a positive effect on fruit growth, thus, it can be deduced that fruit expands and becomes bigger in size, due to powerful attraction of cells to plenty of water, minerals and carbohydrates. These results are in agreement with the findings of Greene (2001) and Said (2002) on apple and Stern et al. (2002) on pear.

It is noticed from (Table 2) that all treatments significantly increased yield as kg/tree or ton/feddan than the control in both seasons. The obtained results indicated that, the highest significant yield as kg/tree or ton/feddan was noticed with treatments of 30 ppm NAA + 5 ppm CPPU. Also, 5 ppm CPPU produced the highest yield (24.93 and 25.75 kg) and (2.49 and 2.57 ton/feddan) in 2017 and 2018 seasons, respectively. On the other hand, the control trees exhibited the lowest yield (12.3 and 13.59 kg/tree) and 1.23 and 1.36 ton/feddan) in 2017 and 2018, respectively.

The application of NAA has shown increased fruit yield as it causes cell elongation by stimulating enlargement of vacuoles and increasing cell wall plasticity by loosening the cell wall (Agrawal and Dikshit, 2008). Another factor in increasing fruit yield is application of CPPU at different fruit growth stages. CPPU significantly increases fruit set and fruit retention, ultimately enhancing the number of fruits (Kulkarni et al., 2017).

The positive effect in yield attributed to Sitofex (CPPU) application is due to increasing fruit size and weight (Banyal et al., 2013) on apple, Fawzi and Hafez (2004) on grapevines. Nimbolkar et al. (2016) suggested that the possible reason for yield improvement may be due to correlation of increasing fruit retention percentage and reducing fruit drop.

Leaves carbohydrate content

Leaf total soluble sugars and starch

All applied treatments had the same patterns of total soluble sugars and starch as control, decreasing gradually at the period from 1st to 3rd weeks after fruit set, then slightly increasing up to 8 weeks in both seasons.

However, leaf soluble sugars content of all treatments with CPPU or NAA were significantly lower than those of control in the period from 3rd up to 8th weeks after fruit set in the two experimental seasons Fig. 3. Data in Fig. 4 showed that, all tested treatments caused a significant effect on leaf starch content of avocado trees as compared with control treatments which recorded the highest starch content in the period from the 1st to 3rd week after fruit set.

TABLE 2. The effect of foliar application with NAA, CPPU and their combinations on fruit weight, length, diameter and yield of avocado cv. Bacon in 2017 and 2018 seasons.

Treatment	Fruit weight (g)		Fruit length (cm)		Fruit diameter (cm)		Yield/ tree (kg)		Yield/ feddan (ton)	
	2017	2018	2017	2018	2017	2018	2017	2018	2017	2018
Control	236.5	236.1	9.50	9.30	5.30	5.50	12.30	13.59	1.23	1.36
NAA 15 ppm	246.9	249.5	10.15	10.33	5.80	5.90	20.00	19.50	2.0	1.95
NAA 30 ppm	251.8	254.5	10.50	10.40	6.20	6.00	22.20	24.68	2.22	2.47
CPPU 5 ppm	259.2	260.2	11.03	11.00	6.30	6.40	24.93	25.73	2.49	2.57
CPPU 10 ppm	255.9	256.6	10.80	10.90	6.00	6.10	22.73	23.12	2.27	2.31
NAA 15 ppm + CPPU 5 ppm	245.5	247.3	10.30	10.40	5.90	6.00	20.94	21.80	2.09	2.18
NAA 15 ppm + CPPU 10 ppm	248.2	250.0	10.50	10.30	5.80	5.70	21.44	22.74	2.14	2.27
NAA 30 ppm + CPPU 5 ppm	260.0	262.0	11.02	11.30	6.80	7.00	24.68	26.10	2.46	2.61
NAA 30 ppm + CPPU 10 ppm	256.6	258.8	10.90	10.75	6.00	5.80	22.90	23.12	2.29	2.31
New LSD at 0.05	0.75	0.33	0.14	0.07	0.08	0.06	0.99	1.15	0.09	0.11

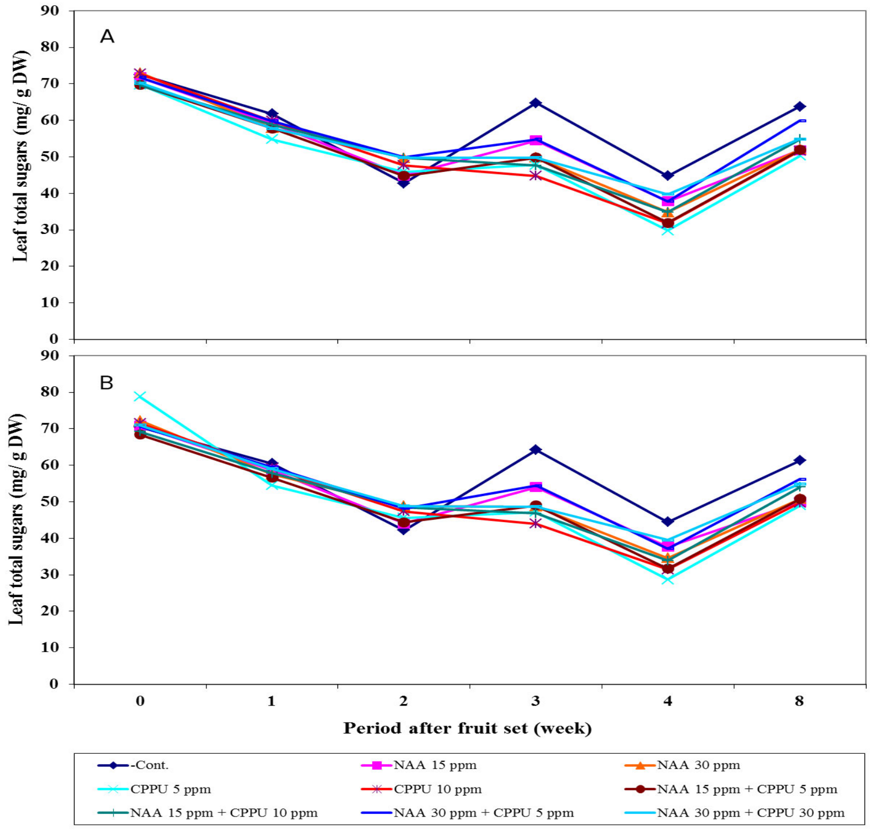

Fig. 3. Effect of foliar application of CPPU and NAA and their combinations on leaf total soluble sugars content of avocado cv. Bacon in 2017 (A) and 2018 (B).

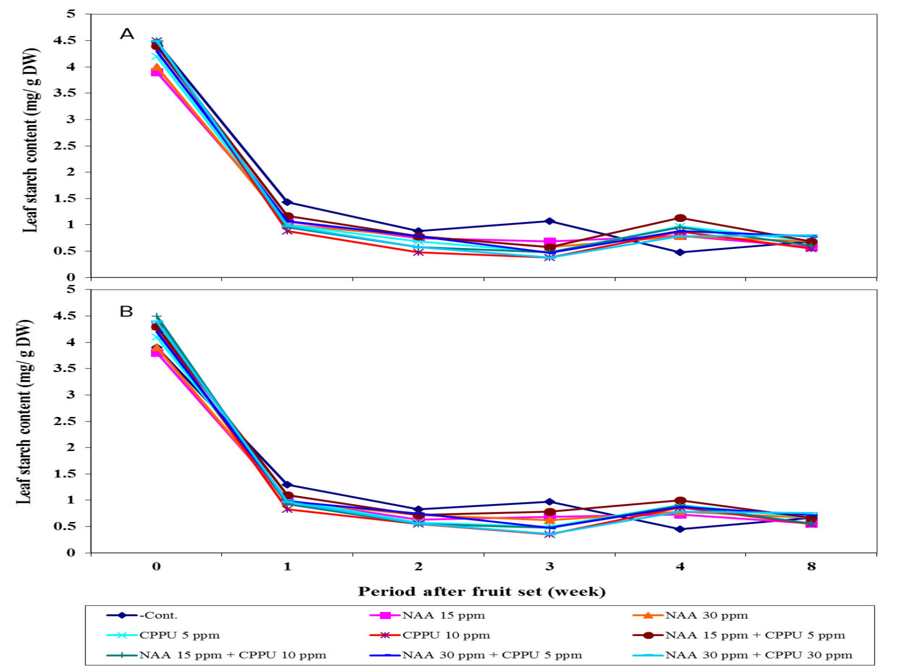

Fig. 4. Influence of foliar application of CPPU and NAA and their combinations on leaf starch content of avocado cv. Bacon in 2017 (A) and 2018 (B).

Fruit is a very important metabolic sink, and fruit drop is largely dependent on carbohydrates availability (Trueman, 2010). Insufficiency of carbohydrates resulted in excessive fruit drop has been showed by Botton et al. (2011) in apple and Yang et al. (2011) in longan. Also, Fang et al. (2000) and Li and Yu (2001) revealed that carbohydrate allocation is regulate by CPPU. It has been noted that CPPU and NAA promote carbohydrate apart from the leaves starting with consumption of starch then conversion of starch into soluble sugars, after foliar application of CPPU and NAA a significant reduction in starch level and total soluble sugars was found in comparison with control, and that starch reduction occurred prior to soluble sugars. These results indicated that foliar sprayed CPPU and NAA accelerate the utilization and transport of assimilates from the leaves to the fruits, thus explaining the decrease in carbohydrate level in the leaves. The results are in agreement with the findings of Antognozzi et al. (1996) in kiwi fruit, Li et al. (2011) in muskmelon and Zeng et al. (2016) in macadamia fruit.

Conclusion

Avocado is one of the promising fruit crops in Egypt. However, the high fruit drop severally reduced productivity and profitability. The foliar spray of NAA and CPPU even alone or in combinations twice at full bloom and 15 days after full bloom, markedly increased fruit set and retained fruit per panicle, fruit quality and yield. Treatment of NAA at 30 ppm either alone or combined with CPPU at both concentrations was more effective than lower NAA treatments. However, avocado trees treated with 5 ppm CPPU alone or in combination with 30 ppm NAA produced higher yield and fruit quality as fruit weight and dimensions than 10 ppm CPPU treatments in both seasons. All used treatments significantly reduced accumulative and relative fruit drop than control, while the lowest accumulative fruit drop was found with 30 ppm NAA+5 ppm CPPU. Used treatments delayed the peak of relative fruit drop to the 2nd week after fruit set, while it was at 1st week in control.

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Conflicts of interest

The author declares that there are no conflicts of interest related to the publication of this study.

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تأثير المعاملة بنفثالين حمض الخليك والسيتوفاكس على تساقط الثمار والمحصول فى الافوكادو

ليلى يحيى مصطفى[1] ، يحيى صلاح مصطفى[2] و اسلام محمد البرى[2]
[1] قسم الفاكهة الاستوائية - معهد بحوث البساتين - مركز البحوث الزراعية - القاهرة - مصر.
[2] قسم الفاكهة - كلية الزراعة - جامعة الاسكندرية - الاسكندرية - مصر.

اجريت هذه الدراسة خلال موسمى ٢٠١٧-٢٠١٨ على اشجار الافوكادو النامية فى مزرعة السالمية بمنطقة النوبارية. حيث تم رش الاشجار بنفثالين حمض الخليك بتركيزى ١٥ و٣٠ جزء فى المليون والسيتوفاكس بتركيزى ٥ و١٠ جزء فى المليون بصورة منفردة او خليط بينهما خلال مرحلتى (التزهير الكاملة وبداية العقد) وذلك لدراسة تاثير هذه المعاملات على عدد الثمار العاقدة والمتبقية /فرع ونسبة الثمار المتساقطة ومحتوى الاوراق من النشا والسكريات الذائبة الكلية وكذلك المحصول وجودة الثمار.

اظهرت النتائج ان المعاملة (٣٠جزء فى المليون نفثالين حمض الخليك + ٥جزء فى المليون سيتوفاكس) كانت فعالة فى زيادة عدد الثمار العاقدة والمتبقية /فرع وكذلك تقليل موجة التساقط فى الثمار خلال الاسبوع الثانى من العقد مقارنة بالاشجار غير المعاملة .ايضا اوضحت النتائج ان المعاملة ب (٥جزء فى المليون من السيتوفاكس) و(٣٠ جزء فى المليون نفثالين حمض الخليك+٥جزء فى المليون سيتوفاكس) ادت الى زيادة وزن وطول الثمار وكذلك المحصول. كل المعاملات المستخدمة مع النفثالين حمض الخليك والسيتوفاكس قللت نسبة السكريات الكلية الذائبة فى الاوراق خلال الفترة من ٣-٨ اسابيع من العقد بينما قللت محتوى الاوراق من النشا خلال الفترة من١-٣ اسابيع من العقد وهذا يوضح ان المعاملات شجعت سرعة انتقال الكربوهيدرات من الاوراق الى الثمار العاقدة مما ادى الى منع تساقط الثمار وبالتالى زيادة الثمار المتبقية .