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Effect of Some Plant Growth Retardants on Vegetative Growth, Spurs and Fruiting of 'Le - Conte' Pear Trees

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Authors' contributions

This work was carried out in collaboration between both authors. Authors HMS and SAA designed the study, performed the statistical analysis, wrote the protocol, and wrote the first draft of the manuscript and managed literature searches. Authors HMS and SAA managed the analyses of the study and literature searches. Both authors read and approved the final manuscript

Original Research Article

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ABSTRACT

This study was carried out during two successive seasons 2012 and 2013 on 5-years old 'Le Conte' pear trees grown under two types of soil. Selected trees were sprayed by some plant growth retardants such as, Paclobutrazol (Cultar) at 200 & 300 ppm conc., Mepiquat chloride at 150 & 250ppm, Succinic acid at 150 & 300 ppm and control. Treatments were sprayed with the specified solutions till run off at three times: before flowering, after fruit set stage and two months after fruit set. That was at early March, mid April and mid May. Herein, fruit quality and vegetative growth parameters were determined at the time of harvest. Results showed that significantly increased fruit set and improved fruit quality compared with the control. It should be noted that the best results were recorded in sandy soil compared with the clay soil. The highest concentration in all treatments improved fruit set, yield and fruit quality.

Keywords: 'Le-Conte' pear trees; plant growth retardants; paclobutrazol; mepiquat chloride; Succinic acid; fruit quality and vegetative growth.

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1. INTRODUCTION

Fruit tree are treated with plant growth retardants to restrict tree size, to control tree shape, to maintain balance between vegetative and reproductive growth, to increase spurs number, to improve fruit size and fruit production to obtain high yield of quality fruit. Plant growth retardants are an incredibly useful tool [1,2].

Most of the available plant growth retardants are anti-gibberellins; they inhibit the synthesis of gibberellins such as GA_3 within the plant and defined as organic compound, other than nutrients in a small amount inhibit [3]. Indicated that Paclobutrazol increased fruit set %, fruit weight and fruit size. Paclobutrazol is a gibberillic acid inhibitor which acts to reduce cell elongation. It is also supposed to increase the general health of the plant in the new foliage through having higher chlorophyll and carotenoid contents, resulting in higher photosynthetic efficiency [4,5]. Mentioned that Paclobutrazol caused decrease of vegetative growth and increase of yield and signification effects of fruit quality. Paclobutrazol uptake is slow, probably due to adsorption and desorption reactions between the chemical and organic matter in the media.

Chlormequat chloride (2, chlor- N, N, N- tri methyl thanaminium chloride) is another GA biosynthesis inhibitor which exhibits growth retarding effect in fruit trees [6,7]. Chlormequat chloride, also known as chlorocholine chloride, is an onium growth retardant containing a quaternary ammonium group [8], inhibits the cyclization of pyrophosphate to co palely pyrophosphate in the gibberellins biosynthesis pathway [7]. Chlormequat chloride and ABA are taken up rapidly and remain in solution. Uptake of these chemicals is by mass flow with the transpiration stream and could possibly be affected by factors affecting transpiration, such as light, temperature, or humidity, at or shortly after application [9].

Succinic acid, as one of the intermediary metabolites in the citric acid cycle. It may participate in the net synthesis of glucose, other sugars, fatty acids normally present in plant and dicarboxylic acids and it is not considered dangerous. Also, catalyses by the enzyme succinct dehydrogenase (or complex II of the mitochondrial ETC). The complex is a 4 subunit membrane-bound lipoprotein which couples the oxidation of succinct to the reduction of unique in one. Intermediate electron carriers are FAD and three 2Fe-2S clusters part of subunit B [10]. Succinic acid is an important platform molecule in the synthesis of a number of commodity, specialty chemicals and important biochemical intermediate that occurs in all living creatures [11]. [1] reported that Succinic acid was found to decrease the surface tension of water already at very low concentrations.

The aim of this study was to evaluate and investigate the influence of several chemicals, which action is based on different plant hormones metabolism regulation, on photosynthesis (chlorophyll content) and yield parameters of the 'Le – Conte' pear trees.

2. MATERIALS AND METHODS

This study was conducted in seasons 2012 and 2013 to determine the effect of plant growth retardants on 5-years old 'Le - Conte' pear trees (*Pyrus commuins* L.) budded on *Pyrus betulaefolia* pear rootstock. Twenty one trees were selected nearly similar in growth vigor and fruiting, free from any visual infections and received regularly the recommended horticultural practices in each soil. 'Le – Conte' pear trees grown under sandy soil (at Kaffer

dawood village in El-Sadat city) and clay soil (at darwa village) conditions in El - Mounifia Governorate. Trees were sprayed by Paclobutrazol, Mepiquat chloride and Succinic acid.

Trees were applied as a foliar spray three times at the start of growth in the first week of March, after flowering in the first week of April and after fruit setting by month. The experimental design was completely randomized, with seven treatments in three replicates consisting of three trees each. The applied treatments were as follows:-

- Paclobutrazol at 200ppm concentration.
- Paclobutrazol at 300ppm concentration.
- Mepiquat chloride (5%) at 150ppm concentration.
- Mepiquat chloride (5%) at 250ppm concentration.
- Succinic acid at 150ppm concentration
- Succinic acid at 300ppm concentration
- Tap water as a control.

Furthermore to evaluate the efficiency of the tested treatments on vegetative growth, tree fruiting and fruit quality the following measurements were made.

2.1 Vegetative Growth Measurements

Four main branches similar as possible were chosen at the four directions of each treated tree, being tagged and the average of the current shoot length, shoot diameter were measured (cm) on August, in both seasons. Ten mature leaves from 5 - 7 nodes were collected at random from each studied tree to determine leaf area by using Leaf Area meter model (1203, CID, Inc, USA).

2.2 Flowering

Four branches, in the different sides of each tree were tagged for determining the fruit set percentage and number of spurs.

2.2.1 Fruit set was calculated in relation to the total number of flowers as follow

Fruit set (%) = N. of developing fruitlets/Total N. of flowers x 100

2.2.2 Number of spurs was calculated by a count the total numbers in the labeled shoots

2.3 Leaf Chemical Composition

Samples of thirty leaves from the middle part of shoots were selected at random from each replicate (after harvest) to determine their content of N and C, using the kjeldahl digestion method for N as described by [12], and the colorimetric method for total carbohydrates (%) as outlined by [13]. Spurs content of nutrients were determined related to dry weight. Leaf chlorophyll reading was recorded using Minolta chlorophyll Meter SPAD-502 (Minolta camera. Co, LtD Japan) at the field. Average of ten readings was taken from the middle of leaves from canopy tree [14].

2.4 Fruit Quality

Fruits were collected at maturity stage on August from each tree a lot of replicates for estimating the following parameters.

2.4.1 Fruit physical properties

At picking date twenty fruits from each tree under study were taken for determining the following: -

A- Weight of fruit (gm).
B- Fruit volume (ml^3).
C- Fruit length (cm).
D- Fruit diameter (cm).
E- Shape index (weight / volume ratio and length/diameter ratio).
F- Fruit firmness was estimated as firmness ($lb/Inch^2$) using IFRA Texture analyser on 5 ml inside the fruit skin by constant speed 2ml/sec.

2.4.2 Fruit chemical properties

Total soluble solids (TSS) were determined by a hand refract meter. Acidity of fruit juice was determined (as malic acid), according to [12].

2.5 Statistical Analysis

Data were statistically analyzed in factorial design according to the method of [15]; L.S.D at 5% level was used for comparison between means of each treatment.

3. RESULTS AND DISCUSSIONS

3.1 Vegetative Growth

3.1.1 Shoot length

Data in Table 1 showed that the effect of some plant growth retardants and soil types on shoot length is pronounced on shoot length of 'Le-Conte' pear. Data revealed that shoot length had significantly affected in the both seasons. It was found that lowest values were obtained from spraying Mepiquat chloride followed by Paclobutrazol and Succinic acid, whereas, the highest values were obtained from control trees in the both seasons. Moreover, the highest and least concentration of plant growth retardants gave the same effects in decreasing shoot length.

As for the type of soil, it was found that there was a significant effect between the two types of soil under study on shoot length in the both seasons. Sandy soil had effected by plant growth retardants more than clay soil.

A significant interaction was observed between effect of some plant growth retardants, concentrations and the types of soil. Results showed that spraying Mepiquat chloride at 250ppm under sandy and clay soil conditions recorded the lowest shoot length, whereas, the highest values were obtained from control trees either in clay or sandy soil in the both seasons.

In this respect, [16,7] reported that plant growth retardants are used to retard the shoot length without changing the phototoxic effects and reducing cell division or elongation.

3.1.2 Shoot diameter

From Table 1 it is cleared that shoot diameter of 'Le-Conte' pear trees had significantly affected by some plant growth retardants in the both seasons. It was found that highest values were obtained from spraying Succinic acid in the both concentrations and seasons, whereas, the least values were obtained from spraying Mepiquat chloride and Paclobutrazol in the both seasons. As well as, both concentrations gave the same effect.

Regarding the types of soil, it was found that 'Le-Conte' pear trees in clay soil significantly recorded higher shoot diameter than those in sandy soil in the both seasons. Shoot diameter had a significant effect by interaction between plant growth retardants, concentration and types of soil the results show that spraying Succinic acid at 300ppm and Mepiquate chloride 250ppm under clay soil recorded the highest shoot diameter followed by Paclobutrazol. In sandy soil, the lowest values were significantly obtained from spraying Mepiquat chloride at 250ppm followed by Succinic acid and Paclobutrazol in both concentrations compared by untreated trees in the both seasons 2012/2013, respectively.

Several researchers mentioned that spraying plant growth retardants on fruit trees, decreased shoot length and increased its thickness [17,18,19].

3.1.3 Leaf area

Regarding the effect of plant growth retardants and types of soil treatments under study on the leaf area, Table 1 revealed that they had significantly negative effect in the both seasons. It was found that least leaf areas were obtained from spraying Mepiquat chloride followed by Paclobutrazol and Succinic acid, whereas, the highest values were obtained from control trees in the both seasons.

Concerning, the types of soil, it was found that 'Le-Conte' pear trees in sandy soil significantly gave higher leaf area than trees in clay soil in the both seasons. A significant interaction was noticed between effect of some plant growth retardants and type of soil. Results show that spraying Mepiquat chloride at 150 & 250ppm followed by Succinic acid and Paclobutrazol under clay soil recorded the least leaf area. On the other hand, the interaction between plant growth retardants cleared a positive effect by reducing the leaf area and the highest conc. was best compared with the lowest one. Whereas, the highest values were obtained from control trees under two types of soil in the both seasons. Regarding to [20] on sunflower, [21] in cluster bean and [22] that Paclobutrazol as well constrained the elongation rate of the leaves and reduced leaf length of young date palm seedling.

Generally, the obtained data showed a significant negative relation between the foliar application by Paclobutrazol, Mepiquat chloride or Succinic acid and vegetative growth parameters under study. [23,24] In Consolida orientalis cleared that the mechanism effect of plant growth retardants on reduction of vegetative growth may be due to the inhibition of short time, the elongation of stem or cell division without changing on vital metabolic.

3.2 Flowering and Fruiting

3.2.1 Spurs number

As shown in Table 2 it is appeared that the effect of some plant growth retardants had significantly affected number of spurs of 'Le-Conte' pear trees in the both seasons. It was found that the highest values were obtained from spraying with Paclobutrazol, Mepiquat chloride and Succinic acid with both concentrations in the both seasons, whereas, the lowest values were obtained from control trees in the both seasons. Concerning the type of soil, it was found that 'Le - Conte' pear trees in sandy soil significantly recorded higher number of spurs than trees in clay soil in the both seasons.

A significant interaction was observed between effect of some plant growth retardants and the types of soil. Results show that spraying Paclobutrazol at 300ppm under sandy soil recorded the highest number of spurs followed by Succinic acid and Mepiquat chloride both concentrations in sandy soil. Moreover, in clay soil, it is noticed that, the highest conc. in all plant growth retardants gave the highest values compared by untreated trees. Our data goes in harmony with [3] in pear trees who reported that Paclobutrazol at 300ppm increased spurs number.

3.2.2 Fruit set (%)

Data in (Table 2 and Fig. 1) revealed that effect of some plant growth retardants had significantly affected the fruit set percentage of 'Le-Conte' pear trees in the both seasons. The maximum percentages were obtained from spraying Mepiquat chloride followed in a descending order by spraying Paclobutrazol and Succinic acid. The minimum percentages were obtained from control trees in the both seasons under study. Concerning the types of soil, it was found that 'Le-Conte' pear trees in clay soil significantly recorded appositive respond to increase fruit set percentage than trees in sandy soil in the first season only, while, it reflected no significant differences between them in the second season. Also, there was no significant effect of concentrations on fruit set in the both seasons under study.

A significant interaction was noticed between some plant growth retardants and the type of soil. Results show that spraying with Mepiquat chloride at 250ppm under clay soil recorded the highest fruit set percentage followed by Mepiquat chloride 150ppm, Paclobutrazol 200 & 300ppm and Succinic acid 150 & 300ppm. Sandy soil recorded a positive effect on increasing fruit set in all treatments. Whereas, the lowest percentage were obtained from control trees either in clay or sandy soil in the both seasons. It was noticed that there was a difference in the fruit set during the seasons of study that was due to the change of climate the second season. Results go in a harmony with [3] in pear, [25] in agynoecious cucumber, [26] in tomato, [4,5] in Strawberry who reported that plant growth retardants increased of fruit set. So, it could be seen that plant growth retardants, concentrations and types of soil significantly increased spurs number and fruit set and the increasing of spurs reflected the effect of plant growth retardants on reducing cell division or elongation.

Table 1. Effect of some plant growth retardants on vegetative growth of 'Le-Conte' pear trees under two types of soil in 2012/2013 seasons

Treatments		Shoot length (cm.)				Shoot diameter (cm)				Leaf area (cm^2)			
Growth retardants (A)	Conc. (B)	Soil (C)		Mean A x B	Mean (A)	Soil (C)		Mean A x B	Mean (A)	Soil (C)		Mean A x B	Mean (A)
		Clay	Sandy			1st s clay	Sandy			Clay	Sandy		
							1st season						
Paclobutrazol	200 ppm	60.14c-e	64.92a	67.53AB	66.74AB	0.967b-d	0.877de	0.922B	0.931AB	28.01cd	25.30e	26.66C	25.09C
	300 ppm	66.13bc	65.78b-d	65.96AB		0.967b-d	0.913c-e	0.940B		27.25d	23.80f	25.52D	
Mean A x C		63.14C	70.35AB		59.43C	0.967BC	0.895DE		0.930AB	27.63C	24.55E		25.57C
Mepiquat chloride	150 ppm	60.93c-e	59.43de	60.18CD		1.00bc	0.837e	0.918B		27.65d	23.59fg	25.62D	
	250 ppm	58.94e	58.40e	58.67D	64.96B	1.033b	0.850e	0.942B	0.970A	28.60cd	22.44g	25.52D	27.02B
Mean A x C		59.94CD	58.92CD			1.017AB	0.843E			28.12C	23.01F		
Succinic acid	150 ppm	78.63a	49.13f	63.88BC	68.67A	0.967b-d	0.880de	0.923B	0.910B	29.03c	24.00f	26.51C	32.11A
	300 ppm	68.63b	63.43b-e	66.03AB		1.133a	0.900c-e	1.017A		27.64d	27.40d	27.52B	
Mean A x C		73.63A	56.28D		Mean (B)	1.050A	0.890DE		Mean (B)	28.33C	25.70D		Mean (B)
Control	Tap water	68.67b	68.67b	68.67A	65.06A	0.900c-e	0.920c-e	0.910B	0.918A	31.05b	33.17a	32.11A	27.73A
	Tap water	68.67b	68.67b	68.67A		0.900c-e	0.920c-e	0.910B		31.05b	33.17a	32.11A	
Mean A x C		68.67B	68.67B		64.83A	0.900C-E	0.920CD		0.952A	31.05B	33.17A		27.67A
Mean C		66.34A	63.55B			0.983A	0.887B			28.78A	26.61B		
Mean B x C		67.09A	63.04B	65.59AB	64.07AB	0.958B	0.878C	1.008A	0.896C	28.93A	26.51B	28.63A	26.70B
							2nd season						
Paclobutrazol	200 ppm	68.38ef	68.92c	73.65C	72.46B	1.200c	0.887h	1.043C	1.084B	23.60de	25.70c	24.65C	24.16C
	300 ppm	70.38d-f	72.17de	71.27C		1.300b	0.950f-h	1.125B		23.20e	24.13de	23.67C	
Mean A x C		69.38C	75.54B		67.94C	1.250B	0.918F		1.152A	23.40F	24.92DE		18.22D
Mepiquat chloride	150 ppm	70.64d-f	74.01cd	72.32C		1.300b	0.917gh	1.108B		0.00f	24.07de	12.03D	
	250 ppm	59.50g	67.63ef	63.56D	79.86A	1.367a	1.027e	1.197A	1.076B	24.70cd	24.03de	24.42C	25.96B
Mean A x C		65.07D	70.82C			1.333A	0.972EF			12.40G	24.05EF		
Succinic acid	150 ppm	103.50a	75.00cd	89.25A	78.23A	1.133d	0.923gh	1.028C	1.008C	29.40b	26.03c	27.72C	31.59A
	300 ppm	75.03cd	65.92f	70.47C		1.267b	0.980e-g	1.123B		23.80de	24.60c-e	24.20C	
Mean A x C		89.26A	70.46C		Mean (B)	1.200C	0.952EF		Mean (B)	26.60C	25.32D		Mean (B)
Control	Tap water	70.00d-f	86.47b	78.23A	78.36A	1.000ef	1.017ef	1.008C	1.047B	30.48b	32.70a	31.59A	24.00B
	Tap water	70.00d-f	86.47b	78.23A		1.000ef	1.017ef	1.008C		30.48b	32.70a	31.59A	
Mean A x C		70.00C	86.47A		70.89B	1.000D	1.017D		1.113A	30.48B	32.70A		25.97A
Mean C		73.43B	75.82A			1.196A	0.965B			23.22B	26.74A		
Mean B x C		78.13A	78.60A	68.73C	73.04B	1.158B	0.936D	1.233A	0.993C	20.87D	27.13A	25.57C	26.36B

Means separated within column using LSD test at P≤0.05; Means followed by the same letter were not significantly different'

Table 2. Effect of some plant growth retardants on spurs number and fruit set (%) of 'Le-Conte' pear trees under two types of soil during 2012/2013 seasons

Treatments		Spurs number				Fruit set %			
Growth retardants (A)	Conc.(B)	Soil (C)		Mean	Mean (A)	Soil (C)		Mean	Mean (A)
		Clay	Sandy	A x B		Clay	Sandy	A x B	
					1st season				
Paclobutrazol	200ppm	13.17h	19.33ef	16.25C	18.13A	5.54b	3.13ef	4.34B	4.10B
	300ppm	15.00g	25.00a	20.00A		4.56cd	3.15ef	3.86C	
Mean A x C		14.08D	22.17A		17.22B	5.05B	3.14D		4.72A
Mepiquat chloride	150ppm	15.44g	21.00cd	18.22B		5.08bc	3.62e	4.35B	
	250ppm	11.89h	20.53de	16.21C	18.46A	6.76a	3.41e	5.09A	3.20C
Mean A x C		13.67DE	20.77B			5.92A	3.52C		
Succinic acid	150ppm	12.89h	22.25bc	17.57B	15.56C	4.28d	2.64f	3.46D	1.69D
	300ppm	15.95g	22.75b	19.35A		3.14ef	2.75f	2.96E	
Mean A x C		14.42D	22.50A		Mean(B)	3.71C	2.70E		Mean(B)
Control	Tap water	12.78h	18.33f	15.56C	16.90B	1.60g	1.77g	1.69F	3.46A
	Tap water	12.78h	18.33f	15.56C		1.60g	1.77g	1.69F	
Mean A x C		12.78E	18.33C		17.78A	1.60F	1.77F		3.39A
Mean C		13.74B	20.94A			4.07A	2.78B		
Mean B x C		13.57C	20.23B	13.90C	21.65A	4.13A	2.79B	4.02A	2.77B
					2nd season				
Paclobutrazol	200ppm	16.17g	25.67b	20.92C	23.42A	4.05a	3.81ab	3.93AB	3.52B
	300ppm	21.25d	30.58a	25.92A		3.00c	3.23bc	3.12C	
Mean A x C		18.71E	28.13A		19.79B	3.53B	3.52B		
Mepiquat chloride	150ppm	17.78f	23.17c	20.47C		3.77ab	4.42a	4.10AB	
	250ppm	15.38g	22.83c	19.10D	22.92A	4.39a	4.42a	4.41A	3.40B
Mean A x C		16.58F	23.00C			4.08A	4.42A		
Succinic acid	150ppm	19.83de	25.67b	22.75B	15.83C	3.67a-c	3.66bc	3.67B	1.66C
	300ppm	20.50de	25.67b	23.08B		3.15bc	3.11bc	3.13C	
Mean A x C		20.17D	25.67B		Mean(B)	3.41B	3.38B		Mean(B)
Control	Tap water	12.67h	19.00ef	15.83E	19.99B	1.38d	1.94d	1.66D	3.34A
	Tap water	12.67h	19.00ef	15.83E		1.38d	1.94d	1.66D	
Mean A x C		12.67G	19.00E		20.98A	1.38D	1.94C		3.08A
Mean C		17.03B	23.95A			3.100A	3.32A		
Mean B x C		16.61D	23.38B	17.45C	24.52A	3.22AB	3.46A	2.98B	3.17AB

Means separated within column using LSD test at P≤0.05; Means followed by the same letter were not significantly different'

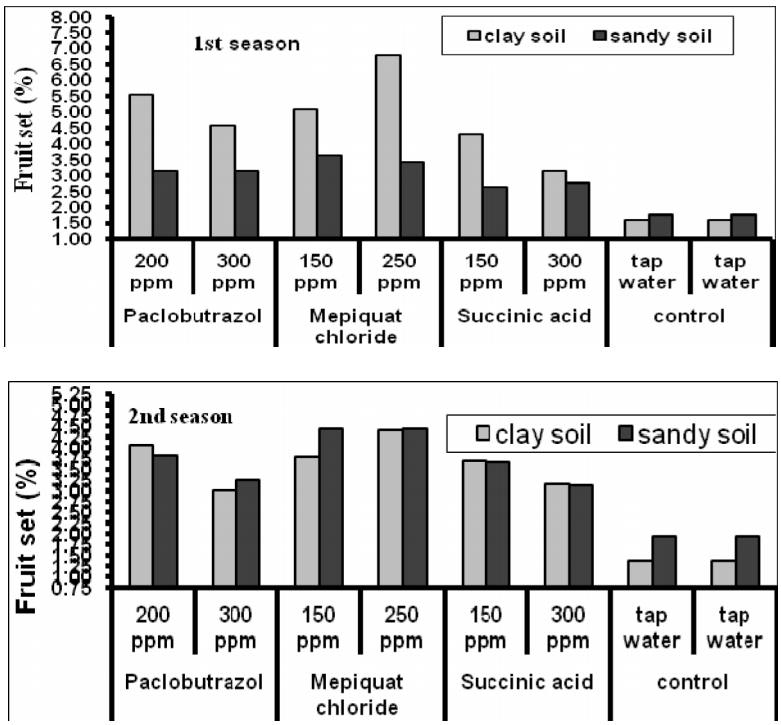

Fig. 1. Effect of some plant growth retardants on fruit set of 'Le- Conte' pear trees during 2012/2013 seasons

3.3 Leaf Chemical Composition

3.3.1 Chlorophyll content

Data in Fig. 2 indicated that foliar application with Paclobutrazol, Mepiquat chloride and Succinic acid in both concentrations increased chlorophyll content significantly. It was noticed that there was a positive relation between the concentration of plant growth retardants and chlorophyll content. Also, types of soil were affected on responding of plant growth retardants. Sandy soil gave a higher response than clay soil. In other words, it's clearly from the interaction between treatments that the highest chlorophyll content values were obtained by spraying Succinic acid in sandy soil but in clay soil, Mepiquat chloride recorded highest chlorophyll content values. [27] In safflower reported that foliar application of cycocel at 500 &1000ppm in sunflower increased chlorophyll content significantly over control.

3.3.2 C/N ratio

Regarding the effect of different plant growth retardants and types of soil under investigation Figs. 3 and 4 revealed that the lowest values of C/N ratio were recorded with plant growth retardants treatments compared to the untreated trees. Whereas, the interaction between the experimental treatments had a significant effect on C/N ratio. It was noticed that Paclobutrazol at 300ppm recorded the best values in C/N ratio in sandy soil compared to the all treatments but in sandy soil the untreated trees gave the highest values in both seasons

under study, respectively. Generally sandy soil gave the highest values compared to clay soil. Several researchers mentioned that the amount and variety of carbohydrates found in plants differ in various plant organs and conditions all throughout the growing season. Herein, it reverses on C/N ratio on plants [28,29,30] in "Braeburn" apple.

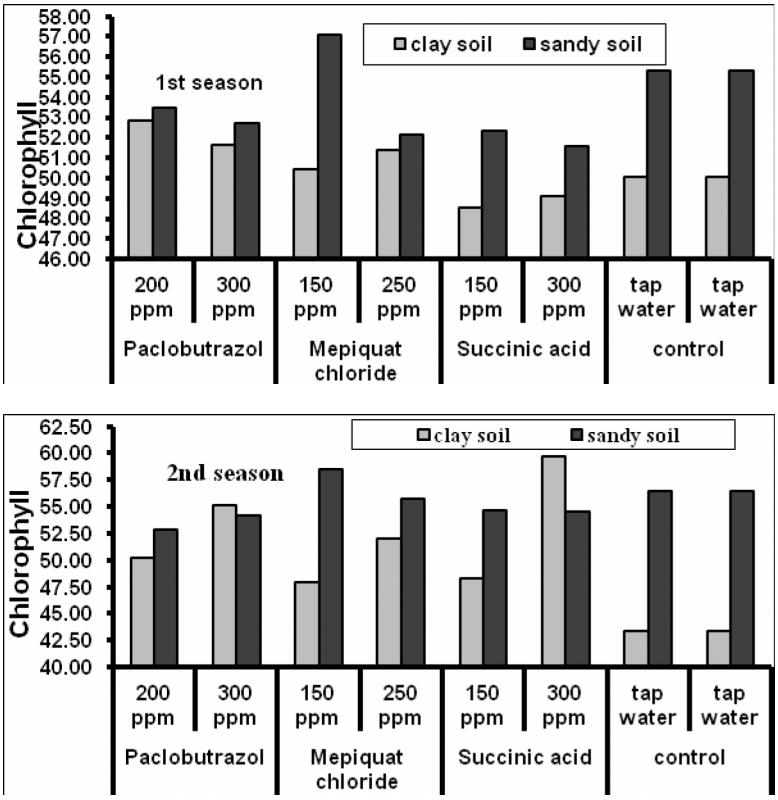

Fig. 2. Effect of some plant growth retardants on chlorophyll content of 'Le-Conte ' pear trees during 2012/2013 seasons3.4 Fruit physical properties

3.4.1 Fruit weight

It is appeared from Table 3.that the effect of some plant growth retardants had significantly affected fruit weight of 'Le-Conte' pear fruits in the both seasons. It was found that the highest values were obtained from spraying Paclobutrazol and Mepiquat chloride followed in a descending order by Succinic acid in the both seasons, whereas, the lowest values were obtained from control trees in the both seasons.

Concerning, the types of soil, it was found that 'Le-Conte' pear trees in clay soil significantly recorded higher fruit weight than trees in sandy soil in the both seasons. Referring the interaction effect, a significant effect was noticed between some plant growth retardants and the types of soil. Results show that spraying Mepiquat chloride at 250ppm under clay soil condition recorded the highest fruit weight, whereas, the lowest values were obtained from control trees under sandy soil in the both seasons.

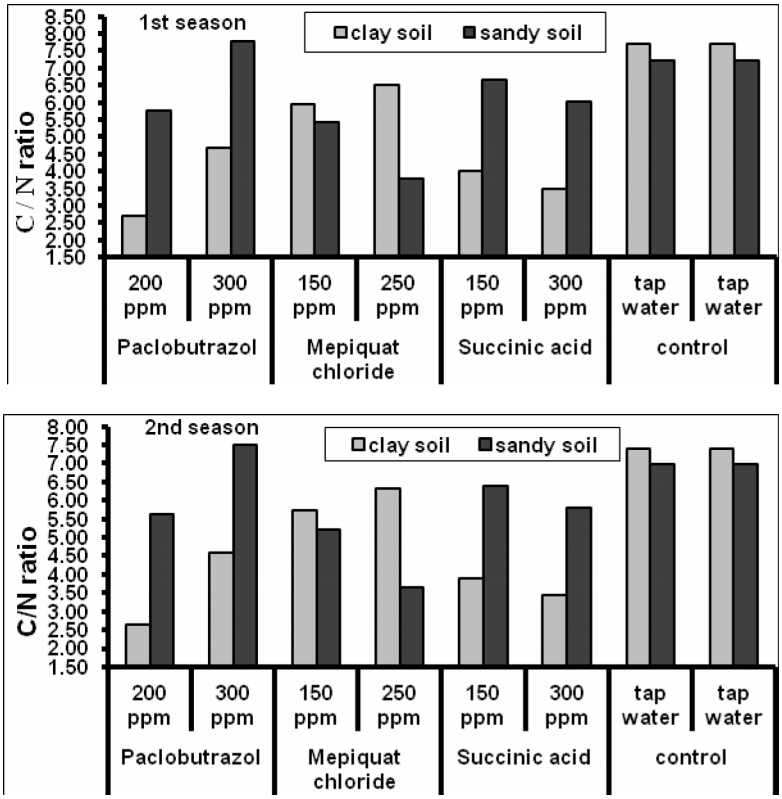

Fig. 3. Effect of some plant growth retardants on C/N ratio of 'Le-Conte' pear trees during 2012/2013 seasons

These results are in accordance with those who reported that plant growth retardants treatments affect fruit weight [7,3] in pear and [31] in pear.

3.4.2 Fruit volume

Data in Table 3 revealed that the effect of some plant growth retardants had significantly affected fruit volume of 'Le-Conte' pear in the both seasons. It is noticed that the best plant growth retardants were Paclobutrazol and Mepiquat chloride followed by Succinic acid compared by untreated ones. It was found that highest values were obtained from spraying with Mepiquat chloride at 250ppm followed in a descending order by spraying Paclobutrazol at 300ppm in the both seasons, whereas, the lowest values were obtained from control trees in the both seasons.

Regarding the types of soil, it was found that 'Le-Conte' pear trees in clay soil significantly recorded higher fruit volume than trees in sandy soil in the both seasons. A significant interaction was recorded between effect of some plant growth retardants and the type of soil. Results show that spraying Mepiquat chloride at 250ppm under clay soil gave the highest fruit volume, whereas, the lowest values were obtained from control trees under sandy soil in the both seasons.

3.4.3 Fruit diameter and length

From Table 4 it is appeared that effect of some plant growth retardants had significant affect on fruit diameter of 'Le-Conte' pear in the both seasons. It is noticed that the dimensions of fruits go in same trend with the weight. There is a positive significant increase between treatments in both seasons under study due to the increment in fruit weight (Table 4). Obtained results are in the same trend with the conclusion of [31] and [3] in pear who said that plant growth retardants are a synthetic substance which inhibit the elongation or cell division.

3.5 Fruit Firmness

Data in Table 4 revealed that the effect of some plant growth retardants had significantly affected fruit firmness of 'Le-Conte' pear in the both seasons. It was found that the highest values were obtained from spraying Succinic acid at both concentrations in the both seasons, whereas, the lowest values were obtained from control trees in the both seasons. Referring the types of soil, it was found that 'Le-Conte' pear trees planted in clay soil significantly recorded higher fruit firmness than trees planted in sandy soil in the both seasons.

A significant interaction was noticed between effect of some plant growth retardants and the types of soil. Results show that spraying with Succinic acid at 150ppm & 300ppm under clay soil condition recorded the highest fruit firmness, whereas, the lowest values were obtained from control trees under sandy soil in the both seasons.

3.6 Fruit Shape Index

3.7 Fruit Weight/ Fruit Volume Ratio

Present data in (Table 5), appeared that the effect of some plant growth retardants had not significant effect on fruit weight/fruit size ratio of 'Le-Conte' pear in the both seasons. For, the types of soil condition, it was found that there were no significant differences between 'Le-Conte' pear trees in clay or sandy soil on fruit weight/fruit size ratio in the both seasons.

No significant difference were obtained from interaction between effect of some plant growth retardants and the types of soil on fruit weight/fruit size ratio in the both seasons at all concentrations.

3.8 Fruit Length/Fruit Diameter Ratio

Present data summarizes the fruit shape index as affected by some plant growth retardants (Fig. 5). There had not significant effect on the fruit shape index of 'Le-Conte' pear in the both seasons. Concerning, the type of soil condition, it was found that no significant differences between 'Le-Conte' pear trees in clay soil or in sandy soil on fruit shape index in the both seasons.

No significant differences were obtained from interaction between some plant growth retardants and the type of soil condition on fruit shape index in the both seasons.

Table 3. Effect of some plant growth retardants on fruit weight (g) and fruit volume (ml^3) of 'Le-Conte' pear trees under two types of soil in 2012/2013 seasons

Treatments		Weight (g.)				Volume (ml^3)			
Growth retardants (A)	Conc. (B)	Soil (C)		Mean A x B	Mean (A)	Soil (C)		Mean A x B	Mean (A)
		Clay	Sandy			Clay	Sandy		
					1st season				
Paclobutrazol	200ppm	225.4c-e	213.9f-h	219.7B	225.8A	222.2bc	206.8de	214.5BC	216.6A
	300ppm	245.7b	218.0e-g	231.9A		226.6b	210.6cd	218.6AB	
Mean A x C		235.6B	216.0D		226.1A	224.4B	208.7C		219.0A
Mepiquat chloride	150ppm	231.2cd	211.5g-i	221.3B		220.0bc	205.5de	212.7BC	
	250ppm	257.4a	204.2h-j	230.8A	214.0B	253.3a	197.4ef	225.4A	208.1B
Mean A x C		244.3A	207.8E			236.7C	201.4C		
Succinic acid	150ppm	222.3d-f	198.6j	210.4C	174.4C	220.0bc	192.8f	206.4C	169.2C
	300ppm	233.0c	202.2ij	217.6B		227.8b	191.9f	209.8C	
Mean A x C		227.6C	200.4F		Mean (B)	223.9B	192.3D		Mean (B)
Control	Tap water	186.2k	162.6l	174.4D	206.4B	178.9g	159.4h	169.2D	200.7B
	Tap water	186.2k	162.6l	174.4D		178.9g	159.4h	169.2D	
Mean A x C		186.2G	162.6H		213.7A	178.9E	159.4F		205.7A
Mean C		223.4A	196.7B			216.0A	190.5B		
Mean B x C		216.3B	196.6C	230.6A	196.7C	210.3B	191.1C	221.7A	189.8C
					2nd season				
Paclobutrazol	200ppm	228.3e	212.6f	220.5C	229.4B	216.3de	206.2ef	211.3C	218.6B
	300ppm	248.0c	228.8e	238.4B		231.3c	220.4cd	225.9B	
Mean A x C		238.1B	220.7D		245.6A	223.8BC	213.3D		234.9A
Mepiquat chloride	150ppm	238.8cd	271.6a	255.2A		229.5c	262.5a	246.0A	
	250ppm	261.6b	210.2f	235.9B	218.7C	247.4b	200.3f	223.9B	206.2C
Mean A x C		250.2A	240.9B			238.5A	231.4AB		
Succinic acid	150ppm	227.6e	207.4f	217.5C	181.1D	219.2cd	199.7f	209.4CD	173.6D
	300ppm	234.4de	205.4f	219.9C		225.2cd	180.8g	203.0D	
Mean A x C		231.0C	206.4E		Mean (B)	222.2C	190.2E		Mean (B)
Control	Tap water	189.6g	172.6h	181.1D	218.6A	182.0g	165.2h	173.6E	210.1A
	Tap water	189.6g	172.6h	181.1D		182.0g	165.2h	173.6E	
Mean A x C		189.6F	172.6G		218.8A	182.0F	165.2G		206.6A
Mean C		227.2A	210.2B			216.6A	200.0B		
Mean B x C		221.1B	216.1C	233.4A	204.3D	211.8B	208.4B	221.5A	191.7C

Means separated within column using LSD test at P≤0.05; Means followed by the same letter were not significantly different'

Table 4. Effect of some plant growth retardants on firmness (lb/inch^2), fruit dimension (cm) of 'Le-Conte' pear trees under two types of soil in 2012/2013 seasons

Treatments		Firmness(lb/inch^2)				Diameter(cm)				Length(cm)			
Growth retardants (A)	Conc.(B)	Soil (C)		Mean A x B	Mean (A)	Soil (C)		Mean A x B	Mean (A)	Soil (C)		Mean A x B	Mean (A)
		Clay	Sandy			Clay	sandy			Clay	sandy		
							1st season						
Paclobutrazol	200ppm	16.78 de	13.76 hi	277.0C	280.8B	7.50 ab	7.27 b	7.38AB	7.41A	9.34ab	8.30e-g	8.82A	8.88A
	300ppm	16.30 e	15.06 f	284.6AB		7.48 ab	7.40 b	7.44AB		9.32ab	8.53d-g	8.93A	
Mean A x C		16.54 B	14.41 C		272.1C	7..49A	7.33AB		7.40A	9.33A	8.42CD		8.73A
Mepiquat chloride	150ppm	17.92 a	12.71j	277.9BC		7.11 bc	7.23 b	7.17B		8.89b-d	8.60c-f	8.75A	
	250ppm	16.62 e	12.73 j	266.3D	288.3A	7.87 a	7.37 b	7.62A	7.20A	9.44a	8.00g	8.72A	8.65A
Mean A x C		17.27A	12.72 E			7.49A	7.30AB			9.17A	8.30D		
Succinic acid	150ppm	17.74 ab	14.16 gh	289.5A	278.8B	7.10 bc	7.37 b	7.23B	6.43B	8.83b-e	8.50d-g	8.67A	7.65B
	300ppm	17.33 bc	14.33 g	287.2A		7.17 b	7.17 b	7.17B		9.15a-c	8.13fg	8.64A	
Mean A x C		17.54A	14.25 C		Mean (B)	7.13B	7.27AB		Mean (B)	8.99AB	8.32D		Mean (B)
Control	Tap water	17.18 cd	13.54 i	278.8BC	280.8A	6.69 c	6.17 d	6.43C	7.05A	8.69c-f	6.60h	7.65B	8.47A
	Tap water	17.18 cd	13.54 i	278.8BC		6.69 c	6.17 d	4.43C		8.69c-f	6.60h	7.65B	
Mean A x C		17.18A	13.54 D		279.2A	6.69C	6.17D		7.16A	8.69BC	6.60E		8.48A
Mean C		17.14A	13.72 B			7.20A	7.02B			9.05A	7.91B		
Mean B x C		17.41A	13.55 D	305.9B	252.5C	7.10AB	7.01B	7.30A	7.03B	8.94A	8.00B	9.15A	7.82B
							2nd season						
Paclobutrazol	200ppm	14.80 e	14.83e	268.8C	281.1B	7.92 ab	7.40 b	7.66A	7.68A	9.50a	8.70c	9.10A	9.01A
	300ppm	16.67c	15.67d	293.4A		7.65 ab	7.73 ab	7.69A		9.26ab	8.60c	8.93A-C	
Mean A x C		15.74B	15.25C		276.6BC	7.78A	7.57A		7.70A	9.38A	8.65B		8.93A
Mepiquat chloride	150ppm	17.09a-c	13.35gh	276.2BC		7.75 ab	7.73 ab	7.74A		8.93ab	8.70c	8.82A-C	
	250ppm	17.49a	13.05h	277.0BC	287.5A	7.87 ab	7.47 b	7.67A	7.67A	9.40a	8.67c	9.03AB	8.70B
Mean A x C		17.29A	13.20F			7.81A	7.60A			9.17A	8.68B		
Succinic acid	150ppm	16.78 bc	14.14f	280.6B	272.0C	7.68 ab	7.43 b	7.56A	6.62B	8.65c	8.80c	8.73BC	7.13C
	300ppm	17.38ab	15.06e	297.3A		7.37 b	8.20 a	7.78A		8.65c	8.72c	8.68C	
Mean A x C		17.09A	14.61D		Mean (B)	7.53A	7.82A		Mean(B)	8.65B	8.76B		Mean(B)
Control	Tap water	16.08d	13.91fg	272.0C	274.4B	6.83 c	6.40 c	6.62B	7.39A	8.57c	5.70d	7.13D	8.44A
	Tap water	16.08d	13.91fg	272.0C		6.83 c	6.40 c	6.62B		8.57c	5.70d	7.13D	
Mean A x C		16.08d	13.91fg		284.2A	6.83B	6.40C		7.44A	8.57B	5.70C		8.45A
Mean C		16.55A	14.24B			7.49A	7.36A			8.94A	7.95B		
Mean B x C		16.19B	14.06 D	306.7A	261.7C	7.55A	7.24B	7.43AB	7.45AB	8.91A	7.98B	8.97A	7.92B

Means separated within column using LSD test at P≤0.05; Means followed by the same letter were not significantly different'

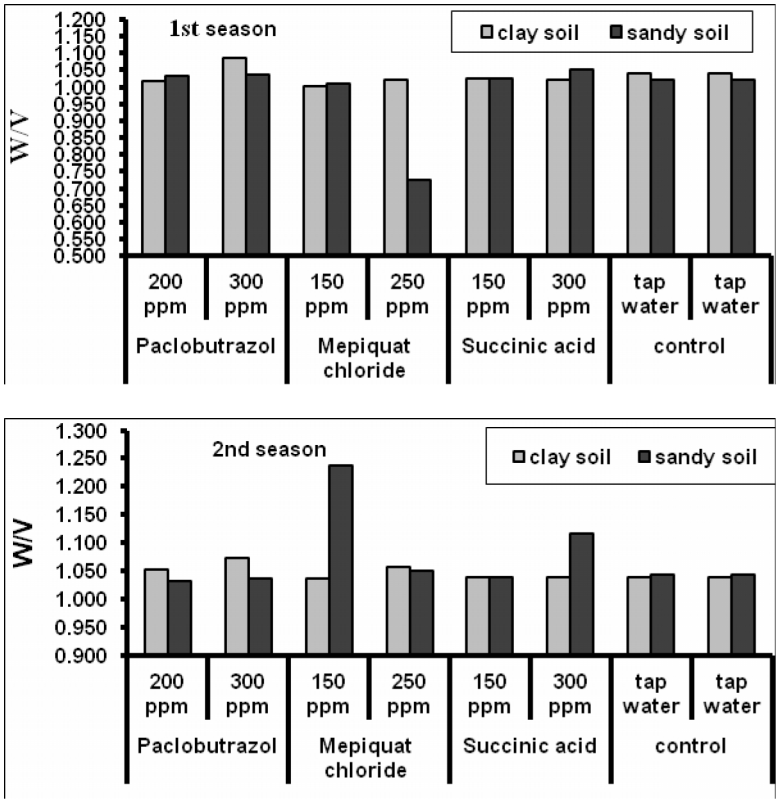

Fig. 4. Effect of some plant growth retardants on fruit weight/ fruit volume (W/V) ratio of 'Le-Conte' pear under two types of soil in 2012/2013 seasons

3.9 Fruit Chemical Properties

Data concerning the values of TSS and total acidity as affected by plant growth retardant treatments are shown in Table 5. Total soluble solids percentage of 'Le-Conte' pear fruits were significantly affected by all different treatments and types of soil in both seasons.

From (Table 5) it is appeared that effect of some plant growth retardants had significantly affected on fruit TSS of 'Le-Conte' pear in the both seasons. It was found that the highest values were obtained from spraying Succinic acid at in the both seasons, whereas, the lowest values were obtained from spraying Paclobutrazol in the both seasons. For the type of soil condition, it was found that 'Le-Conte' pear trees in sandy soil significantly recorded higher fruit TSS than trees grown in clay soil in the both seasons. A significant interaction was recorded between effect of some plant growth retardants and the type of soil condition, the results show that spraying Succinic acid under sandy soil condition recorded the highest fruit TSS, whereas, the lowest values were obtained from spraying Paclobutrazol under clay soil in the both seasons.

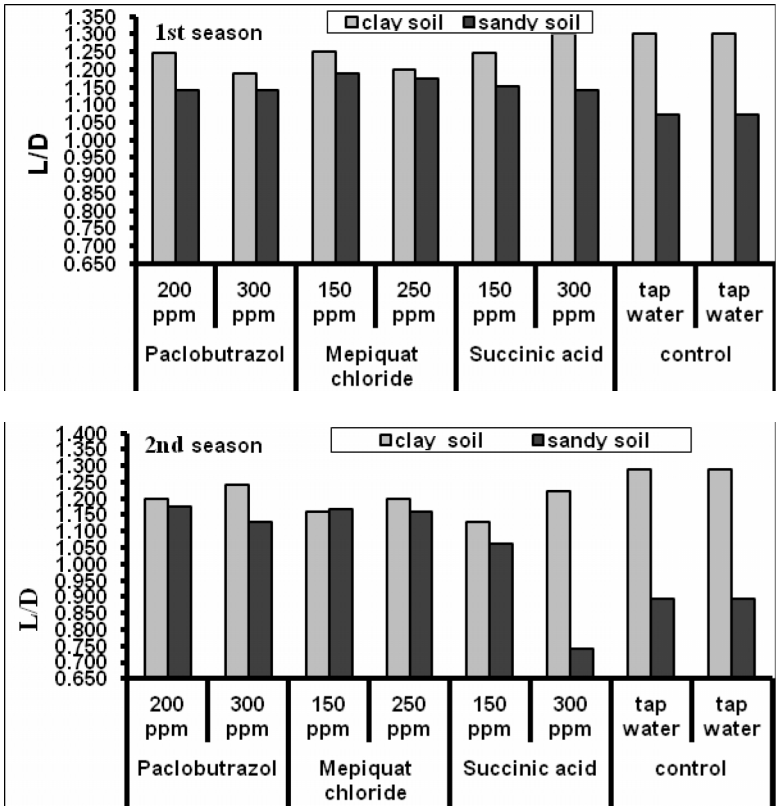

Fig. 5. Effect of some plant growth retardants on fruit length / fruit diameter (L/D) ratio of 'Le-Conte' pear under two types of soil in during 2012/2013 seasons

(Table 5) revealed that the effect of some plant growth retardants had significantly affected fruit acidity of 'Le-Conte' pear in the both seasons. It was found that the lowest values were obtained from spraying Succinic acid in the both seasons, whereas, the highest values were obtained from spraying Paclobutrazol in the both seasons.

As for the type of soil condition, it was found that 'Le-Conte' pear trees grown in sandy soil significantly recorded lower fruit acidity than trees grown in clay soil in the both seasons. A significant interaction was observed between effect of some plant growth retardants and the type of soil condition, the results show that spraying Succinic acid under sandy soil condition recorded the lowest fruit acidity, whereas, the highest values were obtained from spraying with Paclobutrazol under clay soil in the both seasons.

Fruit TSS/acid ratio, as shown in Table 5, it is appeared that effect of some plant growth retardants had significantly affected on fruit TSS/acid ratio of 'Le-Conte' pear in the both seasons. It was found that the highest values were obtained from spraying Succinic acid in the both seasons, whereas, the lowest values were obtained from spraying Paclobutrazol at in the both seasons. As for the type of soil condition, it was found that 'Le-Conte' pear trees in sandy soil significantly recorded higher fruit TSS/acid ratio than trees planted in clay soil in the both seasons.

Table 5. Effect of some plant growth retardants on chemical properties of 'Le-Conte' Pear trees under two types of soil during 2012/2013 seasons

Treatments		TSS				Acidity				TSS/acidity			
Growth retardants (A)	Conc. (B)	Soil (C)		Mean A x B	Mean (A)	Soil (C)		Mean A x B	Mean (A)	Soil (C)		Mean A x B	Mean (A)
		Clay	Sandy			Clay	sandy			Clay	sandy		
							1st season						
Paclobutrazol	200ppm	11.17h	11.23fg	11.20C	11.22D	0.397a-c	0.300e	0.348A	0.350B	28.39f	37.44a-d	32.92AB	32.81BC
	300ppm	11.20gh	11.27f	11.23C		0.403ab	0.300e	0.352A		27.84f	37.56a-c	32.70AB	
Mean A x C		11.18F	11.25E		12.22B	0.400AB	0.300E		0.361AB	28.11D	37.50A		34.46AB
Mepiquat chloride	150ppm	12.17d	12.27ab	12.22A		0.400ab	0.300e	0.350A		30.57ef	40.89a	35.73A	
	250ppm	12.20cd	12.23bc	12.22A	12.25A	0.403ab	0.340b-e	0.372A	0.353B	30.40ef	35.98a-d	33.19AB	35.18A
Mean A x C		12.18C	12.25B			0.402SB	0.320DE			30.49CD	38.44A		
Succinic acid	150ppm	12.20cd	12.30a	12.25A	12.15C	0.383a-d	0.333c-e	0.358A	0.388A	32.33d-f	37.17a-d	34.75AB	31.90C
	300ppm	12.20cd	12.30a	12.25A		0.373a-d	0.320de	0.347A		32.68c-f	38.54ab	35.61A	
Mean A x C		12.20C	12.30A		Mean (B)	0.378BC	0.327DE		Mean (B)	32.51BC	37.85A		Mean (B)
Control	Tap water	12.10e	12.20cd	12.15B	11.95A	0.427a	0.350b-e	0.388A	0.361A	28.45f	35.34b-e	31.90B	33.82A
	Tap water	12.10e	12.20cd	12.15B		0.427a	0.350b-e	0.388A		28.45f	35.34b-e	31.90B	
Mean A x C		12.10D	12.20C		11.96A	0.427A	0.350CD		0.365A	28.45D	35.34AB		33.35A
Mean C		11.92B	12.00A			0.402A	0.324B			29.89B	37.28A		
Mean B x C		11.91B	12.00A	11.93B	12.00B	0.402A	0.321B	0.402A	0.328B	29.94B	37.71A	29.84B	36.85A
							2nd season						
Paclobutrazol	200ppm	11.77g	11.30h	11.53E	11.51C	0.427ab	0.370b	0398A	0.386A	27.84b-d	30.54a-c	29.19BC	30.00B
	300ppm	11.67g	11.30h	11.48E		0.387b	0.360b	0.373A		30.18a-c	31.43a-c	30.80A-C	
Mean A x C		11.72F	11.30G		12.58A	0.407B	0.365B		0.384A	29.01BC	30.99AB		33.06A
Mepiquat chloride	150ppm	13.00a	12.37de	12.68A		0.427ab	0.370b	0.398A		30.52a-c	33.42ab	31.97A-C	
	250ppm	12.63c	12.33de	12.48C	12.55A	0.370b	0.370b	0.370A	0.388A	34.95a	33.33ab	34.14A	30.37B
Mean A x C		12.82A	12.35D			0.398B	0.370B			32.74AB	33.38A		
Succinic acid	150ppm	12.77b	12.43d	12.60B	12.25B	0.390ab	0.387b	0.388A	0.413A	32.81ab	23.13d	27.97C	29.99B
	300ppm	12.57c	12.43d	12.50C		0.420ab	0.357b	0.388A		30.64a-c	34.90a	32.77AB	
Mean A x C		12.67B	12.43C		Mean (B)	0.405B	0.372B		Mean (B)	31.72AB	29.01BC		Mean (B)
Control	Tap water	12.20f	12.30ef	12.25D	12.27A	0.427a	0.370b	0.413A	0.400A	26.74cd	23.24ab	29.99BC	29.78A
	Tap water	12.20f	12.30ef	12.25D		0.457a	0.370b	0.413A		26.74cd	33.24ab	29.99BC	
Mean A x C		12.20E	12.30D		12.18B	0.457A	0.370B		0.386A	26.74C	33.24A		31.93A
Mean C		12.34A	12.10B			0.417A	0.369B			30.05A	31.65A		
Mean B x C		12.43A	12.10C	12.27B	12.09C	0.425A	0.374B	0.408A	0.364B	29.48B	30.08B	30.63B	33.23A

Means separated within column using LSD test at P≤0.05; Means followed by the same letter were not significantly different'

A significant interaction was observed between effect of some plant growth retardants and the type of soil condition, the results show that spraying Succinic acid under sandy soil condition recorded the highest fruit TSS/acid ratio, whereas, the lowest values were obtained from spraying Paclobutrazol under clay soil in the both season. The present results also agreed with [3] in pear and [30] in apple.

4. CONCLUSION

This study to evaluate the effect of three plant growth retardants Paclobutrazol, mepiquat chloride and Succinic acid on vegetative and fruiting growth as well as on fruit quality. Generally, Paclobutrazol, Mepiquat chloride, Succinic acid significantly reduced the rate of vegetative growth by decreasing shoot length and leaf area. An effect of those plant growth retardants were noticed in increasing fruit size and fruit weight of 'Le-Conte' pear trees. Paclobutrazol caused in significant increasing of fruit quality with increase as well as the TSS fruit content and decrease total acid content. Mepiquat chloride improved fruit quality and reduced vegetative growth.

It can be recommended that spraying Succinic acid at 150 & 300ppm increased spurs number followed by Paclobutrazol at 300ppm and Mepiquat chloride at 150ppm. While, fruit set (%) increased by spraying Mepiquat chloride at 150 & 250ppm followed by Paclobutrazol at 200 & 300 ppm and Succinic acid150 & 250ppm. Also, the highest concentration for all plant growth retardants used improves fruit quality especially in sandy soil. Spraying plant growth retardants in clay soil reduced vegetative growth compared with sandy soil.

COMPETING INTERESTS

Authors declare that there are no competing interests.

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