

Regulation of Navel Orange Cropping and Improvement of Fruit Quality Using Sitofex and Gibberellic Acid

Abd El Raheem, M.E.; Abd El- Rahman, G.F.; Hoda, M. Mohamed; and Elharony, S.B

Horticulture Res. Inst. Citrus Department, Agric. Res. Centre- Egypt.
gamalelashmanty@yahoo.com

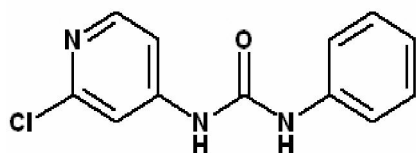
Abstract: Influence of Sitofex (CPPU) and gibberellic acid (GA₃) were studied on yield and fruit quality of navel orange trees (*Citrus sinensis*) during (2011, 2012) seasons. The trees were 20 years old, budded on Volkamer lemon rootstock (*Citrus volkameriana*, Ten & Pasq.) and were planted at 6x4m spacing in a private orchard at Badr area, El-Behiera Governorate. The study involved two experiments. The first (pre experiment) was done to define the suitable concentrations of CPPU application on citrus, (5, 7.5, 10 ppm) at full bloom stage. The second (main experiment), nine treatments were used as follow, where the plant growth regulator CPPU was sprayed at 2, 3, 4, and 5 ppm, either as a single application or in combination with 30 ppm GA₃ at full bloom stage, as well as, control treatment. Data indicated that, high concentrations of CPPU at 7.5 or 10 ppm caused the demolition of chlorophyll, decreased the concentrations of leaf chlorophyll (a&b) and led to flowers and leaves abscission, chlorosis and emergence of shoots dieback. While, there were no significant differences for leaf chlorophyll (a&b) between 5 ppm CPPU and control treatments. The previous results indicate that CPPU could be used at concentrations less or equal (5 ppm) for citrus. Results also revealed that, application of 3, 4 ppm CPPU either singly or in combination with 30 ppm GA₃ was superior for attaining the best total yield. All treatments significantly increased leaf area, fruit dimensions (length, diameter), fruit size and improved the fruit peel quality by increasing rind firmness. Also, CPPU treatments reduced TSS/Acid ratio beside a delay of maturity stage and fruit coloration especially at (3, 4 ppm alone or with 30 ppm GA₃) which led to extending the harvest season and therefore increasing the exportation rate. [Abd El Raheem, M.E.; Abd El- Rahman, G.F.; Hoda, M. Mohamed; and Elharony, S.B. **Regulation of Navel Orange Cropping and Improvement of Fruit Quality Using Sitofex and Gibberellic Acid**] *Nat Sci* 2013; 11(6): 13-21]. (ISSN: 1545-0740). <http://www.sciencepub.net>. 3

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1. Introduction

Plant growth regulators (PGRs) as foliar applications are the most powerful tools for manipulating tree growth, flowering, yield and fruit quality particularly fruit size, as well as, controlling fruit maturation. In addition, by hastening or delaying fruit maturation the growers can utilize peak demands, avoid unfavorable environmental conditions and extend the market period (Hegazi, 1980). Also, PGRs act as messenger and are needed in small quantities. Sitofex (CPPU) is one of plant growth regulators (N-(2-chloro-4-pyridinyl)-N'-phenylurea); common name forchlorfenuron) which plays a role in cell division and cell wall elongation,

(Nickell, 1985)

**Sitofex**

also, it is a cytokinin like substance which has strong cytokinin activity by inducing fruit growth at low rates in grape (Nickell, 1985); Ogata *et al.* (1988), pears; Banno *et al.* (1986), and kiwifruit; Iwahori *et al.* (1988), as well as increasing fruit set in melon (Tanakamaru, 1989). Also, Guirguis *et al.* (2003) found that CPPU treatment with 20 ppm increased the percentage of fruit set and fruiting when applied at full bloom on “Costata” persimmon trees. Moreover, Mervet *et al.* (2001) working on Thompson seedless grapevines found that, CPPU application at 5 ppm + GA₃ at 40 ppm gave the best bunch and berry quality. On the other hand, Bhat *et al.* (2011) found that, CPPU at 3 ppm and brassinosteroid (BR) at 0.4 ppm combination along with GA₃ at 25 ppm increased leaf area in grape. Several reporters i.e.; (El-Sabagh, 2002) on apple; Flaishman *et al.* (2001) on pear; Guirguis *et al.* (2009) on persimmon and Biasl *et al.* (1991) on Kiwi fruit, they confirmed the beneficial effects of using CPPU in reducing fruit drop and increasing productivity as well as improving fruit size. Also, Xiao *et al.* (2007) studied the influence of CPPU (with concentration 10 - 25 mg / L at 10 days after full bloom) on sugar and acid content of *Diospyros Kaki* cv. “Zenjimar” fruit

The results showed that the treatment could increase weight of individual fruit, reducing TSS content and TSS / acid ratio of fruit, but had no effect on acidity content. In addition, GA₃ affect fruit formation, abscission, cell elongation, apical dominance and photoperiod; Aboutalebi and Beharoznam (2006). Moreover, Gibberellins have been used in citrus production with several objectives including bloom reduction, increased fruit setting, improvement of fruit quality and improved maturation control; Agustí and Almela (1991). The application of gibberellic acid soon after flowering at doses between 10 and 15 ppm can result in delayed abscission and increased fruit set, mainly in Clementine tangerines Fornes *et al.* (1992); (El-Otmani, 1992). Also, GA₃ increased fruit set in navels orange (Smith, 1993); Babu and Lavania (1985), in tangerine hybrids; Brosh and Monselise (1977) and increased the yield either as number or weight of fruits per tree of Washington navel orange; Ibrahim *et al.* (1994). In addition, foliar sprays GA₃ at 50 ppm of trees with or without 0.5% urea were superior for inducing the highest increase of fruit set and yield, on Washington navel orange; Abd El-Rahman *et al.* (2012). The purpose of this study was to examine further the effects of Sitofex (CPPU) and Gibberellic acid (GA₃) on fruit growth rate, color break, yield and fruit quality of Washington navel orange trees.

2. Material and Methods

This investigation was conducted during 2011 and 2012 seasons on Washington navel orange trees (*Citrus Sinensis*). The trees were 20 years old, budded on Volkamer lemon rootstock (*Citrus volkameriana*, Ten & Pasq.) and were planted at 6×4 m spacing in sandy soil in a private orchard belong to Mr. Mustafa El-dyree located at Badr area, El-Behiera Governorate. The study involved two experiments. The first (pre experiment) was done to define the suitable concentrations of CPPU application of Washington navel orange trees. Sixteen trees were used for pre experiment by using (5, 7.5, 10 ppm CPPU) and control treatment at full bloom stage, with 4 single tree replicates with one tree for each replicate. The second (main experiment), thirty six trees according to vigor and number of flowers were used for data collection and to study the effect of foliar spray of both CPPU and GA₃ on fruit growth rate, yield and fruit quality on Washington navel orange trees. The experiment involved the following nine treatments. Control trees (untreated) and trees sprayed with CPPU at 2, 3, 4 and 5 ppm either singly or in combination with GA₃ at 30 ppm. Trees were sprayed until full drenching by hand sprayer at full bloom stage. The design was a completely randomized block with 4 singletree

replicates with one tree for each replicate. The untreated trees (control treatment) were sprayed with water only. The total number of flowers was counted before treatments and CPPU [N-(2-chloro-4-pyridinyl)-N-phenylurea] by using Sitofex compound (a.i. 0.01% CPPU) as a source of CPPU and Berelex (containing 92% GA₃ and 8% of other gibberellins) were used in the trials. All trees generally received adequate organic and inorganic fertilization under drip irrigation system. However, a balanced foliar fertilization of all microelements was adopted three times yearly (February, May and August). The following parameters of the studied treatments under two experiments were carried out.

First experiment (pre experiment).

Leaf chlorophyll (a&b).

Forty mature leaves were taken for each tree from all trees sides, and at the end of spring growth cycle (September) they were washed three times with tap water, and then washed again with distilled water, and leaf chlorophyll contents (a&b) were determined according to Moran and Porath (1980) method.

Second experiment (main experiment).

Leaf area (cm²). Forty mature leaves at different four sides of each tree were collected and average leaf area at the end of spring growth cycle (September) was calculated using the equation of (Chou, 1966). Leaf area = $\frac{2}{3}$ length × width.

Fruit growth rate.

In order to determine fruit growth rate, 40 fruits were carefully selected from nearly equal-sized fruiting shoots and distributed around the tree canopy. Estimates of fruit growth rate were made by measuring fruit diameter monthly (from mid June to mid December, during two seasons), using digital vernier caliper. The growth rate was calculated by account the difference in increasing fruit diameter between each two consecutive months.

Yield.

Total yield per tree was harvested at mid December in the two studied seasons. The total number and weight of mature fruits per tree was determined at the harvesting time.

Fruit quality.

Ten fruits of Washington navel orange were randomly taken from the yield in two seasons for each replicate and the following determinations were carried out:

Average of fruit weight (gm), fruit size (ml) was determined from the volume of water displaced by immersing the fruit sample in graduated jar filled with water and average volume was calculated. Fruit length and diameter (mm) in each individual fruit and peel thickness (mm) were measured by using a digital vernier caliper. The average peel thickness was calculated and recorded for each sample. Fruit

firmness was measured with Effegl, Pentrometer (11.1 mm diameter prop, Effegl, Alfonsing, Italy) and expressed as Lb/inch². Juice weight percentage was calculated and recorded. Total soluble solids (T.S.S %) was determined by using Zeiss hand refractometer. Total acidity (%) was determined in fruit juice as percentage of anhydrous citric acid according to (A.O.A.C, 1995). Total soluble solids/acid ratio was calculated from the values of total soluble solids divided by values of total acids.

Color break (Hue angle).

Color break measurement (Hue angle) was determined by using a Hunter colorimeter type (DP-9000) for the estimation of a, b and hue angle (h°). In this system of color representation the values a*, and b* describe a uniform two-dimensional color space, where a* is negative for green, and positive for red, and b* is negative for blue and positive for yellow. From a & b values, a/b were calculated Hue angle ($h^\circ = \arctan b^*/a^*$) determines the red, yellow, green, blue, purple, or intermediate colors between adjacent pairs of these basic colors Hue angle (0°= red-purple, 90° = yellow, 180°=bluish-green, 270°= blue), as described by (McGuire,1992).

Statistical analysis.

The experiment was designed in completely randomized block design with four replicates for each treatment and each replicate was represented by one tree. The obtained data of both seasons were subjected to analysis of variance according to Clark and Kempson (1997) and the means were differentiated using Duncan multiple range test at 5% level (Duncan, 1955).

3. Results and Discussion

First experiment (pre experiment).

Leaf chlorophyll (a&b). Data in Table (1) showed that, the chlorophyll (a & b) of navel orange leaves were influenced by different rates of CPPU. Trees treated by 5ppm CPPU and control treatments had the highest values with no significant differences between them. While, high concentrations of CPPU at 7.5 or 10 ppm caused the demolition of chlorophyll, its application decreased the concentrations of leaf chlorophyll (a&b) and led to flowers and leaves abscission, chlorosis and emergence of shoots dieback. Analogous results were observed by Mebelo *et al.* (1997) who found that, application of 20 ppm CPPU singly or in combination with other growth regulators (200 ppm GA₃ and 10 ppm 2,4-D) at anthesis increased total sugar content, reduced fruit set, caused severe leaf chlorosis, and leaf drop on Ponkan (*Citrus reticulata* Blanco). The previous results revealed that CPPU

could be used at lower or equal 5ppm for Washington navel orange.

Second experiment (main experiment).

Leaf area: Data presented in Table (2) displayed that, there were significant differences among growth regulators treatments on leaf area, whereas, all treatments increased leaf area compared to control treatment especially trees treated by 4 ppm CPPU + 30 ppm GA₃ had significantly the largest leaf area in the first season (27.38 cm²); while, 4, 5 CPPU alone or with 30 ppm GA₃ recorded the

Table (1). Leaf chlorophyll contents (a&b) of navel orange Trees as affected by Sitofex.

Treatments	Season, 2010	
	Chlorophyll a (µg/cm ²)	Chlorophyll b (µg/cm ²)
Control	47.53 a	15.09 a
CPPU at 5ppm	45.37 a	14.79 a
CPPU at 7.5ppm	21.50 b	7.37 b
CPPU at 10ppm	19.72 bc	4.25 c

Mean separation within columns by Duncan's multiple range test, 5% level. Values that don't share the same letter are significantly different.

highest significant values of leaf area in the second season (24.90 & 24.92) and (24.49 & 24.73 cm²) compared to control treatment (21.51 & 20.06 cm²) in the first and second seasons, respectively. In addition, the other treatments were in between during 2011 and 2012 seasons. Higher leaf area values recorded with higher CPPU and in combination with GA₃ may be due to increased concentration of photosynthesis in the shoot Nunez *et al.* (1998); Zofoli *et al.* (2009) and Zahoor *et al.* (2011) on grape.

Table (2). Leaf area of navel orange trees as affected by CPPU and GA₃ applications during two seasons (2011 and 2012).

Treatments	Leaf area (cm ²)	
	Season, 2011	Season, 2012
Control	21.51 d	20.06 e
CPPU at 2ppm	25.70 b	23.12 c
CPPU at 3ppm	26.09 b	21.96 d
CPPU at 4ppm	25.69 b	24.49 ab
CPPU at 5ppm	23.39 c	24.73 a
CPPU at 2ppm+ GA3 at 30ppm	21.74 d	23.70 bc
CPPU at 3ppm+ GA3 at 30ppm	23.59 c	23.09 c
CPPU at 4ppm+ GA3 at 30ppm	27.38 a	24.90 a
CPPU at 5ppm+ GA3 at 30ppm	25.88 b	24.92 a

Mean separation within columns by Duncan's multiple range test, 5% level. Values that don't share the same letter are significantly different.

Fruit growth rate.

Figure (1) showed that average of monthly fruit diameter growth rates from mid June to mid December on Washington navel orange trees treated

by CPPU alone or with GA₃. The maturity stage was the period which the increment of fruits diameter rate was decreased .So it can be noticed that, the maturity stage was at the first and second weeks of November with trees treated by 2 ppm CPPU and control treatments, while, fruit trees treated by (CPPU at 5 ppm) and (CPPU at 2,4 ppm plus GA₃at 30 ppm) matured at second and third weeks of November (mid late maturity), meanwhile, the other treatments reached maturity stage in the third and fourth weeks

of November (late maturity). This means that, trees sprayed with CPPU alone or in combination with GA₃ led to a delay in maturity stage and therefore, delayed ripening (softening) of fruits. The delaying effects of Sitofex on maturity were supported by the results of Jo *et al.*, and Kano, (2003). They stated that, Sitofex was responsible for improving fruit weight and dimensions, yield and delaying fruit maturity in stone fruit, and other related fruit crops.

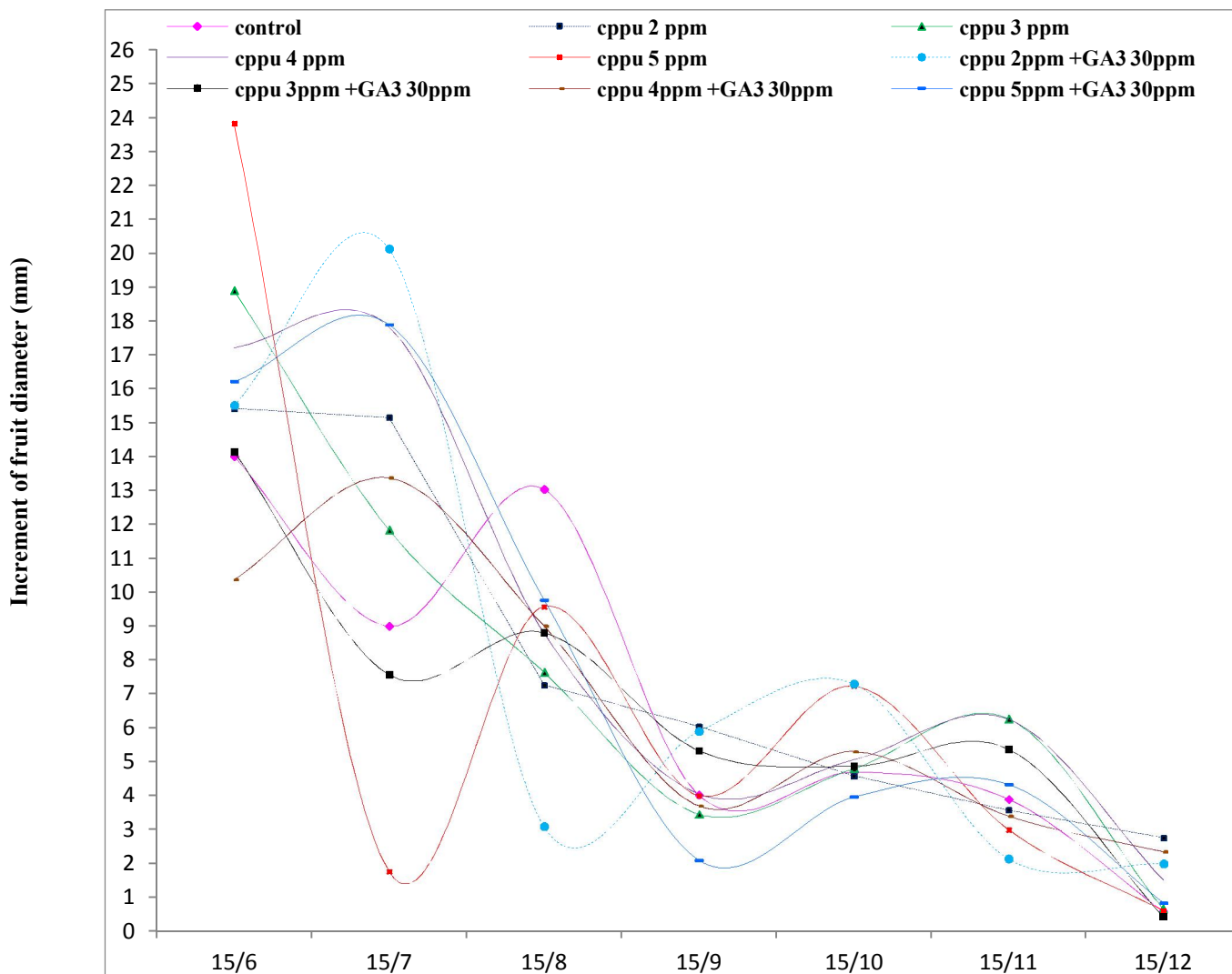


Fig. (1): Average of monthly fruit diameter increments of Washington navel orange as affected by CPPU and GA₃ applications during two seasons (2011 and 2012).

Yield.

Concerning to the effect of spraying combination of CPPU and GA₃ on yield per tree as number of fruits /tree, fruit weight (kg) / tree and fruit weight (ton) / feddan, Table (3) data indicated that, all treatments significantly increased the yield of Washington navel orange trees as compared to control treatment. Generally trees sprayed with CPPU at 3, 4 ppm singly or in combination with GA₃ treatments gave better fruit yield (25.7&25.5 ton/ fed.) and (24.5&24.4 ton/ fed.) than the other treatments in the first season, however, in the second season, trees sprayed with CPPU at 3 ppm with GA₃ was the best combination (31.0 ton/ fed.) followed by trees treated by 3 ppm CPPU and 4

ppm CPPU singly (26.6 & 24.8 ton/ fed.) and 4 ppm CPPU with GA₃ (26.6 ton/ fed.), on the other hand, the other treatments gave intermediate values during the two seasons of the study. Similar results were obtained by Mervet *et al.* (2001) who found that, the application of Sitofex (CPPU) at 3, 5, 7 ppm alone or with GA₃ at 40 ppm increased the total yield of Thompson seedless grapevines. Also Guirguis *et al.* (2003) and Fathi *et al.* (2011) indicated that, the use of CPPU alone or in combination with GA₃ increased the percentage of fruit set and fruit yield on “Costata” persimmon trees.

Table (3). Yield of navel orange trees as affected by CPPU and GA₃ applications during two seasons.

Treatments	Fruit weight(gm)		Fruit No. / tree		Yield K.G / tree		Yield ton / feddan	
	Seasons		Seasons		Seasons		Seasons	
	2011	2012	2011	2012	2011	2012	2011	2012
Control	294.0ab	286.7 a	331.3 c	366.7 g	97.4 cd	105.1 d	17.0 cd	18.4 d
CPPU at 2ppm	287.0ab	241.3 c	383.3bc	433.3 f	110.0bc	104.6 d	19.3bc	18.3d
CPPU at 3ppm	293.7ab	242.3 c	500.7 a	626.7 b	147.1 a	151.8 b	25.7 a	26.6 b
CPPU at 4ppm	294.0ab	277.3ab	495.0 a	511.7 d	145.5 a	141.9 b	25.5a	24.8 b
CPPU at 5ppm	286.7 b	264.7 b	336.7 c	416.7 f	96.5 d	110.3cd	16.9 d	19.3 cd
CPPU at 2ppm+ GA ₃ at 30ppm	287.7ab	266.0 b	401.7 b	461.7 e	115.6b	122.8 c	20.2 b	21.5 c
CPPU at 3ppm+ GA ₃ at 30ppm	293.3ab	268.7 b	477.3 a	660.0 a	140.0 a	177.3 a	24.5 a	31.0 a
CPPU at 4ppm+ GA ₃ at 30ppm	301.3 a	268.7 b	462.7 a	566.7 c	139.4 a	152.3 b	24.4 a	26.6b
CPPU at 5ppm+ GA ₃ at 30ppm	297.3ab	270.7 b	350.0bc	386.7 g	104.1bcd	104.7 d	18.2bc	18.3d

Mean separation within columns by Duncan's multiple range test, 5% level. Values that don't share the same letter are significantly different.

Fruit quality.

1. Fruit physical characteristics.

It is evident from the results shown in Table (4) that, all treatments increased diameter, length and size of fruits compared to control treatment for the two seasons. The increase in fruit size could be attributed directly to the CPPU effects whereas; exogenous application of CPPU acts as early and rapid on cell division in the fruitlet and also on subsequent growth. Thus, the fruit becomes bigger in size due to the increased cells, which are able attract so much water, minerals and carbohydrates that enable the fruit to expand to large size (Kano, 2003). Results in hand are in the line with those found by Curry and Green (1993) on apples, Mervet *et al.* (2001) on Thompson seedless Grapevines and Fathi *et al.* (2011) on “Costata” persimmon. Also, as shown in Table (3) data indicated that, application of CPPU singly or in combination with GA₃ significantly increased the fruit firmness of Washington navel orange as compared with control treatment, in addition, it is noticed that trees sprayed with CPPU alone had better fruit firmness than the mixed treatment plus GA₃ treatments during the two seasons. This response confirms previous reports indicating that, CPPU increased “McIntosh” flesh firmness (Greene, 1989); spur delicious apple Curry and Greene (1993) and Anna apple (El-Sabagh, 2002). Plant growth substances such as cytokinins and gibberellins have been shown to reduce or delay various aspects of ripening (softening). They share the ability to delay senescence by reducing the sensitivity of the fruit to ethylene Abeles *et al.*

(1992). Also, in most cases exogenous application of cytokinins counteract the promoting effects of ethylene on the senescence process (Arteca, 1990). In addition, data in Table (3) revealed that, fruits of control treatment were thicker than the other treatments; meanwhile, values of other treatments were in between during two seasons. On the other hand, CPPU at 4ppm significantly enhanced fruit juice weight percentage, While, the other treatments did not show any obvious trend with some slight fluctuations for both two seasons (2011, 2012).

2. Fruit chemical characteristics.

Data in Table (5) revealed that, as for TSS% there was no obvious trend for fruit T.S.S% with some fluctuations during two seasons. On the other hand, trees treated by CPPU at 3ppm increased fruit acidity% (1.12 & 1.44%) through two seasons, respectively, while, the minimum averages were obtained by control treatment (0.91%) in the first season and by 5 ppm CPPU treatment (1.19%) in the second season. Anyhow, the differences among the other treatments were high to be significant. So, Sitofex and GA₃ expresses promoted variation effects between treatments; this may be due to maturity date. TSS/acid ratio is commonly used measure of citrus fruit maturity, and it is an important characteristic for fruits exportation. Data presented in Table (5) showed that, both CPPU and GA₃ treatments reduced TSS/Acid ratio and the lowest significant values were obtained by foliar application of 3, 4ppm CPPU alone (8.04 & 8.19), (7.29 & 7.90) or with 30ppm GA₃ (8.49 & 9.02), (7.95 & 8.10), in the first and second season, respectively,

while the other treatments recorded the intermediate values. This means that, the use of CPPU either singly or in combination with GA₃ delayed fruit maturity. These finding confirmed the former results obtained by Guirguis *et al.* (2010) ; Fathi *et al.*

(2011) on “Costata” persimmon and Mervet *et al.* (2001) on grapevines , they found that, the application of Sitofex (CPPU) and GA₃ delay fruit ripening compared with non treated trees.

Table (4).Some Physical characteristics of navel orange fruits as affected by CPPU and GA₃ applications during two seasons (2011& 2012).

Treatments	Season, 2011					
	Fruit diameter (mm)	Fruit Length (mm)	Fruit Size (cm ³)	Fruit Firmness (mm)	Peel Thickness (mm)	Juice Weight %
Control	79.31 b	81.99 e	327.30 c	8.77 g	5.30 a	47.64cd
CPPU at 2ppm	79.34 b	86.28 bc	330.3 bc	10.73ef	4.26 c	51.03 ab
CPPU at 3ppm	81.45 a	88.34 ab	343.3abc	13.65cd	4.86 b	46.36de
CPPU at 4ppm	81.01 ab	84.70 cd	331.7abc	15.43 b	4.38 c	52.63 a
CPPU at 5ppm	81.80 a	86.78 bc	335.0abc	16.85 a	4.60 bc	52.00ab
CPPU at 2ppm+ GA ₃ at 30ppm	80.52 ab	83.58 de	338.3abc	9.68fg	4.95 ab	47.37cd
CPPU at 3ppm+ GA ₃ at 30ppm	80.59 ab	87.61 ab	338.3abc	11.42 e	4.95 ab	43.80 e
CPPU at 4ppm+ GA ₃ at 30ppm	79.38 b	83.85 de	346.7 a	12.83 d	4.61 bc	38.68 f
CPPU at 5ppm+ GA ₃ at 30ppm	81.97 a	89.03 a	346.3 ab	14.51bc	5.27 a	49.47 bc
Season, 2012						
Control	74.47 d	75.55 e	280.0 e	8.72 e	5.33 a	49.27 b
CPPU at 2ppm	74.88 cd	80.35 bc	306.0 cd	10.46 d	4.80 c	45.29 c
CPPU at 3ppm	75.85 c	77.88 d	331.7 a	14.19 b	5.02abc	45.88bc
CPPU at 4ppm	79.16 b	80.08 bc	322.0ab	16.88 a	4.93 bc	54.18 a
CPPU at 5ppm	79.31 b	79.21 cd	307.0cd	16.61 a	4.96 bc	49.23 b
CPPU at 2ppm+ GA ₃ at 30ppm	79.49 b	81.03 ab	300.0 d	10.45 d	5.14 ab	46.01 bc
CPPU at 3ppm+ GA ₃ at 30ppm	78.45 b	81.15 ab	309.7bcd	10.98cd	4.15 d	47.07bc
CPPU at 4ppm+ GA ₃ at 30ppm	78.52 b	79.44 c	309.3bcd	12.08 c	5.09abc	47.37bc
CPPU at 5ppm+ GA ₃ at 30ppm	80.76 a	82.21 a	315.0 bc	14.22 b	3.87 d	47.49bc

Mean separation within columns by Duncan's multiple range test, 5% level. Values that don't share the same letter are significantly different.

Table (5). Some chemical characteristics of navel orange fruits as affected by CPPU and GA₃ applications during two seasons (2011& 2012).

Treatments	T.S.S%		Acidity%		T.S.S/ Acid ratio	
	Season, 2011	Season, 2012	Season, 2011	Season, 2012	Season, 2011	Season, 2012
Control	10.25 a	10.50 b	0.91 e	1.29 b	11.22 a	8.20 cd
CPPU at 2ppm	8.50 e	11.50 a	1.04 c	1.30 b	8.17 fg	8.92 a
CPPU at 3ppm	9.00 d	10.50 b	1.12 a	1.44 a	8.04 g	7.29 e
CPPU at 4ppm	9.00 d	10.00 c	1.10 ab	1.27 bc	8.19 fg	7.90 d
CPPU at 5ppm	10.25 a	10.00 c	0.96 de	1.15 d	10.68 b	8.69 ab
CPPU at 2ppm+ GA ₃ at 30ppm	10.00b	9.75 cd	1.06 bc	1.19 cd	9.49 d	8.17 cd
CPPU at 3ppm+ GA ₃ at 30ppm	8.50 e	10.00 c	1.00 cd	1.26 bc	8.49 f	7.95 cd
CPPU at 4ppm+ GA ₃ at 30ppm	10.25 a	9.50 d	1.14 a	1.18 d	9.02 e	8.10 cd
CPPU at 5ppm+ GA ₃ at 30ppm	9.75 c	10.00 c	0.94 e	1.19 cd	10.34 c	8.38 bc

Mean separation within columns by Duncan's multiple range test, 5% level. Values that don't share the same letter are significantly different.

Color break:

Results presented in Table (6) clarified that, there were different between fruits of Washington navel orange for its color break under different treatments from mid October to mid December, whereas, the beginning of color break was in the first and second weeks of November in trees treated by CPPU at 2ppm and control treatments in the first season. Also, the color break of fruit trees sprayed with (3, 4 ppm CPPU alone or with 30 ppm GA₃) was in the third and fourth weeks of November (late maturity) during two seasons. On the other hand, the other treatments reached to color break in the second and third weeks of November in the first and second seasons. Also, it can be noticed that, there were

different between Washington navel orange fruits as affected by foliar application of different rates of CPPU and GA₃ for its rind color in the harvest time (mid December) whereas, fruits treated by (CPPU at 2, 5 ppm alone or with GA₃ at 30 ppm) and control treatments were **very deep yellow (mid late ripening)**, while, the other treatments were **very deep yellow green (late ripening)**. So it can be noticed that, CPPU treatments delayed color development especially at (3, 4 ppm alone or with 30 ppm GA₃). This delay of fruit maturation is being benefit for the growers and can utilize peak demands, avoid unfavorable environmental conditions and extend the market period (Hegazi, 1980).

Table(6). Rind color (Hue angle) measurements for Washington navel orange as affected by CPPU and GA₃ applications during two seasons (2011 & 2012).

Treatments	Season, 2011							
	Dates of October		Dates of November				Dates of December	
	16-23	24-31	1-7	8-15	16-23	24-30	1-7	8-15
Control	172.210	165.730	153.391	146.490	135.431	122.330	104.930	95.457
CPPU at 2ppm	174.431	167.813	158.780	151.431	139.553	124.781	113.281	100.735
CPPU at 3ppm	178.670	174.215	170.723	163.350	153.671	148.921	138.330	122.634
CPPU at 4ppm	173.331	170.553	168.441	162.392	157.850	147.040	137.434	125.820
CPPU at 5ppm	178.820	172.761	165.432	156.303	144.970	135.000	118.736	94.974
CPPU at 2ppm+ GA ₃ at 30ppm	174.220	170.453	163.083	154.650	143.353	129.921	116.812	93.456
CPPU at 3ppm+ GA ₃ at 30ppm	177.035	173.980	170.891	164.920	150.864	142.780	136.992	124.330
CPPU at 4ppm+ GA ₃ at 30ppm	179.00	175.252	171.771	165.340	157.340	151.361	115.433	99.000
CPPU at 5ppm+ GA ₃ at 30ppm	174.653	169.660	163.000	155.341	145.220	138.710	129.230	117.230
Season, 2012								
Control	171.032	163.781	158.663	144.430	129.815	125.450	110.660	93.343
CPPU at 2ppm	179.923	177.732	166.630	156.242	146.008	135.632	130.981	117.761
CPPU at 3ppm	179.651	175.251	171.782	165.076	155.781	142.224	133.860	125.762
CPPU at 4ppm	178.019	173.432	170.710	163.784	159.824	148.654	138.761	129.229
CPPU at 5ppm	176.009	174.221	168.330	147.815	143.783	129.663	117.443	101.920
CPPU at 2ppm+ GA ₃ at 30ppm	173.784	169.453	157.913	145.241	140.321	133.771	113.924	105.970
CPPU at 3ppm+ GA ₃ at 30ppm	176.000	173.078	168.984	162.443	154.000	144.980	139.953	128.341
CPPU at 4ppm+ GA ₃ at 30ppm	175.963	174.341	171.860	165.772	153.672	147.980	115.815	95.566
CPPU at 5ppm+ GA ₃ at 30ppm	175.330	172.780	167.342	151.693	143.440	126.350	118.445	108.393

Where: If hue angle measurement is from 180 to 160 the rind color will be **very deep green**.

From 160 to 140 the rind color will be **very deep yellowish green**. (Color break).

From 140 to 120 the rind color will be **very deep yellow green**.

From 120 to 90 the rind color will be **very deep yellow**.

From 90 to 60 the rind color will be **very deep orange yellow**.

From 60 to 30 the rind color will be **very deep reddish orange**.

Maturity – related characteristics.

It seems from the foregoing results that, CPPU treatments had a profound improving effect on fruit quality and peel firmness. There is a positive

correlation between fruit quality and maturity, such as fruit growth rates, color break time, TSS/acid ratio for Washington navel orange as affected by Sitofex (CPPU) and GA₃ applications.

Conclusion.

In brief, it could be concluded that, application of 3 or 4 ppm CPPU either singly or in combination with 30 ppm GA₃ were superior as compared with other treatments for achieving the best total yield. Moreover, these treatments delayed fruit maturity, thus these plant growth regulators showed considerable promise for the citrus industry of Egypt, as it is considered world's fifth largest exporter of fresh citrus fruit (Food and Agriculture Organization, 2012) and thus from the economical point of view, such applications could be benefited substantially by prolonging harvest and marketing season.

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