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Plant growth regulators on the pre-harvest period of 'Pêra' oranges

Reguladores vegetais aplicados na fase pré-colheita de laranjeira "Pêra"

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ABSTRACT

*This research evaluated the effects of auxins and gibberellins applied at pre-harvest on the quality of orange juice. Orange trees, **Citrus sinensis** Osbeck, cv. 'Pêra' were sprayed in three applications, at 45-day intervals, with the following treatments: GA_3 + 2,4-D at 12.5mg L^{-1} each; GA_3 + 2,4-D at 25mg L^{-1}; GA_3 + 2,4-D at 37.5mg L^{-1}; GA_3 + NAA at 12.5mg L^{-1}; GA_3 + NAA at 25mg L^{-1}; GA_3 + NAA at 37.5mg L^{-1}; NAA + 2,4-D at 12.5mg L^{-1}; NAA + 2,4-D at 25mg L^{-1}; NAA + 2,4-D at 37.5mg L^{-1}, and a control. The treatments did not change juice quality, and showed no plant growth regulator residues 110 days after the last application in every case below 0.05mg L^{-1}.*

Key words: ***Citrus sinensis***, *internal quality, plant growth regulators, residue.*

RESUMO

*Neste estudo, avaliou-se os efeitos de auxinas e giberelinas, combinados e aplicados em pré-colheita na qualidade interna de frutos de laranjeira "Pêra". **Citrus sinensis** Osbeck cultivar Pêra foram pulverizadas com três aplicações, em intervalos de 45 dias, com os seguintes tratamentos: GA_3 + 2,4-D a 12,5mg L^{-1} de cada; GA_3 + 2,4-D 25mg L^{-1}; GA_3 + 2,4-D 37,5mg L^{-1}; GA_3 + NAA 12,5mg L^{-1}; GA_3 + NAA 25mg L^{-1}; GA_3 + NAA 37,5mg L^{-1}; NAA + 2,4-D 12,5mg L^{-1}; NAA+2,4-D 25mg L^{-1}; NAA+2,4-D 37,5mg L^{-1} e testemunha (água). Os resultados mostraram que os tratamentos não prejudicaram a qualidade interna dos frutos. Além disso, os níveis de resíduo de reguladores vegetais no suco, ficaram abaixo de 0,05mg L^{-1}, 110 dias após a última aplicação.*

Palavras-chave: ***Citrus sinensis***, *reguladores vegetais, maturação, resíduo*

INTRODUCTION

The 'Pêra' cultivar (***Citrus sinensis*** Osbeck) is the most important citrus cultivar in Brazil, mainly because of industrial demand (DONADIO et al., 1995). In Brazil, orange harvest begins in April, with early cultivars, especially 'Hamlin'. In September and October, the main harvest consists of 'Pêra', with harvest of the late varieties 'Natal' and 'Valência' ending from November to January. This timing is ideal for each variety with regard to their ratio (soluble solids/acidity relation) in industrial processing. After January, the level of activity in the local citrus industry is reduced.

Therefore, the use of new technologies would be of benefit in anticipating or delaying the harvest of some cultivars, particularly 'Pêra', reducing some of the harvest planning problems, such as the oscillations in labor demand over the year, transport logistics, and especially fruit losses, either by natural fall or by quality loss for processing.

Plant growth regulators have been described in hundreds of scientific studies in the past 25 years, mainly dealing with the active regulation of endogenous processes (MONSELISE, 1979). There are several uses for plant growth regulators in citrus; they can be applied at different physiological stages of the plant and fruit, to enhance the economic value of the crop (EL-OTMANI, 1992).

The fall of ripe fruit is of great significance in commercial cultivars (RAGONE, 1992). Therefore, the application of plant growth regulators can control the hormone balance at the abscission layer, reducing or retarding the early fall of fruit, and harvest losses (PRIMO et al., 1966). The application of auxin prevents the fruit from falling by maintaining the cells in the abscission zone and preventing the synthesis of hydrolytic enzymes, such as cellulase (MONSELISE &

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GOREN, 1978). Authors have reported that hormone balance would act on the activity of polygalacturonase, which, together with cellulase would be responsible for degrading the main components of the cell wall, cellulose and pectin.

The application of 2,4-D and GA_3 (gibberellic acid) reduces pre-harvest fall by the action of auxin in retarding abscission, and of gibberellin in retarding rind softening and senescence (EL-OTMANI, 1992) and retarding chlorophyll degradation (RAGONE, 1992).

This work evaluated the effects of auxin and gibberellin, mixed and applied at pre-harvest, on the maturation and internal quality of the fruit, and on residue levels of these substances in the juice, in order to determine whether it is possible to delay the harvest of ‘Pêra’ oranges without economic loss.

MATERIAL AND METHODS

The study was carried out on São João Farm, a property of Citrovita Agro Industrial Ltda., located in Itapetininga, State of São Paulo, Brazil. Orange plants (***Citrus sinensis*** Osbeck) of the Pêra cultivar were used, grafted onto five-year-old ‘Cravo’ lemon stock.

Treatments used were: GA_3 + 2,4-D at 12.5mg L^{-1} each; GA_3 + 2,4-D at 25mg L^{-1}; GA_3 + 2,4-D at 37.5mg L^{-1}; GA_3 + NAA at 12.5mg L^{-1}; GA_3 + NAA at 25mg L^{-1}; GA_3 + NAA at 37.5mg L^{-1}; NAA + 2,4-D at 12.5mg L^{-1}; NAA + 2,4-D at 25mg L^{-1}; NAA + 2,4-D at 37.5mg L^{-1}; and a control (water). The treatments were added of the surfactant Extravon at 0.3%, containing 250g L^{-1} of alkyl-phenol-polyglycol ether. The plants were sprayed by tractor with 4 liters of solution each, using a JACTO PH 600 sprayer, with a constant pressure of 200Lb. Three applications were made during the experiment, the first on May 24, when the fruits started to change color, and the others at 45-day intervals after the first.

The experiment was organized as a completely random design, with ten treatments and six replicates, with six plants per row, distributed through the orchard; four trees in the middle were used to evaluate fruit fall, and two trees at the ends were used to analyze the chemical substances in the juice. Plots on the same row were separated by at least one tree, and rows of treated trees were separated from other rows by an untreated row in the middle, to avoid any drift effects.

The following characteristics were evaluated, over seven harvests: quantity of soluble solids (SS) (°Brix), titratable acidity (% anhydrous citric acid), relation between SS and acidity (ratio), percentage of natural fall of fruits (%), and plant growth regulator residues in the juice (mg L^{-1}). The first harvest was made on May 24, and the others were done at 45-day intervals, the last on Jan 29.

The quantity of SS was obtained with a digital refractometer. Acidity was obtained by titration of the samples, using NaOH 0.5N (AOAC, 1970). For these analyses, five fruit were randomly picked from each of the two end plants, ten fruit in each sample. Residue levels were determined by standards set in one of IBAMA’s Normative Instructions (gov’t environmental agency); determinations were carried out at the Laboratory of Chromatography of the Molecular Chemistry and Physics Dept., São Paulo University - USP, using high performance liquid chromatography (HPLC) and high resolution gas chromatography (HRGC). These analyses were made to verify and quantify the presence of GA_3, 2,4-D, and NAA residues in the juice. Due to the high cost of this analysis, only two residue analyses were carried out, without replication, at 81 and 110 days after the last application of treatments.

The percentage of natural fall was obtained by weekly counting the numbers of fruit fallen under the tree, discounting those fruit with insect damage, by each lot of four trees, with the numbers fallen since the last collection added to each collection date, and expressed as a percentage of total fruit existing in each tree plot (EL-OTMANI & COGGINS JR, 1991).

The multivariate linear model was used to analyze the data. The differences for each variable studied were tested using the Profile software program (ROSA, 1994). The five hypothesis tested were: H_1= the ten profiles are parallel, and have the same behavior; H_2= accepting H_1, there are no differences among the ten groups, thus the profile is considered to be universal; H_3 = accepting H_1, there are no differences among the four conditions in all ten groups; H_4 = there are no differences among the four conditions within each group; and H_5 = analysis of variance, to determine effects on each group under each condition.

Because the number of replicates (six) was less than the number of evaluations (seven), it was necessary, for statistical analysis, to divide the number of harvests into two periods: first period, harvests I, II, III, and IV, and second period, referring to harvests V, VI, and VII. In the results tables of the multivariate analysis, the first values of the tests refer to the first period, while the second values refer to the second period. In the statistical analyses, a 5% probability level was adopted.

For the SS/acidity relationship (ratio), since it was a calculated parameter, no profile analysis was made, since this variable does not follow the basic assumptions made for this analysis. Therefore, results were discussed over the means obtained in the treatments.

RESULTS AND DISCUSSION

The average gains in soluble solids (SS) of the fruit (%) in the ten treatments presented profiles that were both parallel and coincident (p>0.05), without significant differences among them (Tables 1 and 2). These results agree with those obtained in oranges by EL-OTMANI (1992), and ALMEIDA et al. (2004), and in tangerines by GARCIA-LUIZ et al. (1992) and BARROS (1992).

Significant differences can be observed between harvests (time effect), where the SS mean for harvest I was lower than for harvest II, which in turn was the same as the third, remaining constant until the fifth, when SS achieved the highest value found in the series (Table 1). These data indicated that senescence was near, thereby establishing the limit date for commercial harvest. The increase in SS was mainly due to continuing maturation and to the accumulation of photosynthetic matter.

There were no significant differences in the effect of treatments on acidity, but differences could be observed due to conditions such as harvest date (Table 1). The decrease in acidity, expressed as percentage, in the ten treatments showed parallel and coincident profiles (P>0.05) up to the first period, without any significant differences among them (Tables 1 and 2); however, from the second period on there were significant differences between treatments.

These results agree with the data presented by ALMEIDA et al. (2004), where the application of GA_3, 2,4-D, and NAA at 5, 12.5, and 25mg L^{-1} on 'Hamlin' oranges did not affect fruit acidity in treated trees.

As to the harvests, it can be seen in table 2 that there was a decrease in acidity level from the first to the sixth harvest, then remaining stable until the last harvest. As mentioned above, maintaining the fruit on the tree until senescence is reached will cause a loss in quality. Table 2 shows that the average acidity in the

Table 1 - Multivariate analysis results of profiles of soluble solids (%), titratable acidity (%) of the juice, and natural fall (%) of 'Pêra' orange fruit, submitted to treatment with plant growth regulators, at harvest.

Statistical hypothesis	Statistical analysis results	Conclusion
soluble solids *(%)*		
Parallelism among profiles (H_{01})	θ= 0.419 (P > 0.05) θ= 0.279 (P > 0.05)	There is similarity among profiles
Coincidence among profiles (H_{02})	F= 1.610 (P > 0.05) F= 0.760 (P > 0.05)	1 = 2 = 3 = 4 = 5 = 6 = 7 = 8 = 9 = 10 1 = 2 = 3 = 4 = 5 = 6 = 7 = 8 = 9 = 10
Time effect (H_{03})	F= 25.75 (P < 0.05) F= 2.74 (P > 0.05)	I < II = III = IV (I < III; IV) V = VI = VII
titratable acidity *(%)*		
Parallelism among profiles (H_{01})	θ= 0.252 (P > 0.05) θ= 0.248 (P > 0.05)	There is similarity among profiles
Coincidence among profiles (H_{02})	F= 1.00 (P > 0.05) F= 15.66 (P < 0.05)	1 = 2 = 3 = 4 = 5 = 6 = 7 = 8 = 9 = 10 1 = 2 = 3 = 4 = 5 = 6 = 7 = 8 = 9 = 10 (1 ≠ 3)
Time effect (H_{03})	F= 759.67 (P < 0.05) F= 4.43 (P < 0.05)	I > II > III > IV V > VI = VII
Natural fall of fruit *(%)*		
Parallelism among profiles (H_{01})	θ= 0.535 (p > 0.05)	There is similarity among profiles
Coincidence among profiles (H_{02})	F= 5.23 (p < 0.05)	1 = 2 = 3 = 4 = 5 = 6 = 7 = 8 = 9 = 10 1; 2; 3 ≠ 10
Time effect (H_{03})	F= 203.07 (p < 0.05)	IV < V < VI < VII

Table 2 - Means for soluble solids (SS) and titratable acidity (TA) in the fruit juice of 'Pêra' oranges, submitted to treatment with plant growth regulators at seven harvests.

	SS							TA						
Treatments	I	II	III	IV	V	VI	VII	I	II	III	IV	V	VI	VII
GA_3 +2,4-D 12.5mg L^{-1}	8.6	9.2	9.5	9.8	9.6	9.5	10.2	1.57	1.10	0.94	0.72	0.57	0.59	0.55
GA_3 + 2,4-D 25mg L^{-1}	8.5	9.0	8.8	8.8	8.7	8.9	8.9	1.48	1.05	0.85	0.64	0.52	0.49	0.51
GA_3 +2,4-D 37.5mg L^{-1}	8.6	9.1	9.3	8.9	9.0	8.4	8.4	1.48	1.07	0.92	0.66	0.54	0.50	0.47
GA_3 + NAA 12.5mg L^{-1}	8.9	8.9	9.5	9.2	9.7	9.8	9.4	1.50	1.06	0.93	0.70	0.61	0.58	0.55
GA_3 + NAA 25mg L^{-1}	8.6	8.9	8.8	8.6	9.1	8.9	10.1	1.46	1.13	0.86	0.67	0.57	0.53	0.58
GA_3 + NAA 37.5mg L^{-1}	8.4	8.9	8.6	8.7	8.7	8.5	8.2	1.57	1.09	0.86	0.64	0.54	0.51	0.48
NAA + 2,4-D 12.5mg L^{-1}	8.2	9.1	9.0	9.9	9.5	9.8	9.8	1.45	1.12	0.89	0.77	0.60	0.62	0.59
NAA + 2,4-D 25mg L^{-1}	8.7	9.3	9.2	9.5	9.4	10.0	10.0	1.63	1.18	0.95	0.74	0.60	0.60	0.60
NAA + 2,4-D 37.5mg L^{-1}	8.6	9.2	9.3	8.9	9.2	9.3	10.4	1.51	1.15	0.93	0.66	0.59	0.55	0.59
Control (water)	8.3	9.3	8.8	9.3	10.0	10.3	10.6	1.48	1.15	0.93	0.71	0.64	0.63	0.64
Means	8.6	9.1	9.1	9.2	9.3	9.3	9.6	1.51	1.11	0.91	0.69	0.58	0.56	0.56

treatments at the last harvest was 0.5%, which leads to unpleasant fruit taste (AGUSTÍ & ALMELA, 1991).

The decrease in acidity shown here agrees with CHITARRA & CHITARRA (1990), who affirmed that such decrease is due to the use of acids in the respiration process or in sugar conversion, whereas AGUSTÍ & ALMELA (1991) reported that the increase in free acids in the fruit during the first stages of development, remaining constant until maturity and then decreasing, occurs as a result of dilution caused by the increase in fruit size.

Ratio was similar in all treatments, with no differences among them, but values increased during the experiment (Table 3). AGUSTÍ & ALMELA (1991), and GARCIA-LUIZ et al. (1992) reported that with maturation, there is an increase in SS and a decrease in acidity in citrus fruits, resulting in increased ratio values, which is the basis for determining commercial maturity (ratio values above 18), showing that the fruit is in senescence, the juice being characterized by what is known as an 'off' or 'insipid' flavor.

Ratio will increase in fruit maintained on the tree, according to EL-OTMANI & COGGINS JR (1991), although no statistical differences are seen when compared with fruit from trees treated with GA_3 and 2,4-D, either individually or mixed. This information also agrees with results obtained by ALMEIDA et al. (2004), where again no significant differences in ratio were observed in 'Pêra' orange fruits treated with GA_3, 2,4-D, and NAA, at 5, 12.5, and 25mg L^{-1}, applied as a mixture. In this work, the similar increase of 'ratio' values for all treatments was due to the fact that acidity percentage, as well as, SS levels were similar in all treatments, at each harvest.

Although no significant difference was observed among treatments involving plant growth regulators, the greatest reductions in natural fall of 'Pêra' orange fruit were obtained with the use of GA_3 + 2,4-D (Table 3).

The role of gibberellins does not seem to be decisive for abscission control, but the exogenous application of gibberellic acid does seem to have a relationship with an increase of cellulase activity in explants of leaves of 'Shamoutie' oranges, resulting in abscission stimulation (RASMUSSEN, 1975). However, at the same time, the periods in which ethylene is less effective in promoting abscission correspond to those in which the endogenous contents of gibberellins in the fruit are highest. In view of this, it is suggested that gibberellins probably interact with endogenous abscisic acid, according to experiments made with 'Valencia' oranges, in which GA application inhibited the synthesis of ethylene and reduced fruit fall, leaving no doubt that the effect of ABA falls during ethylene synthesis, which, in turn, would stimulate the synthesis of hydrolytic enzymes; as a consequence, the degradation of cell walls in the abscission zone would begin, resulting in cell separation.

The dependence of abscission relative to the endogenous content of auxins has been demonstrated through exogenous applications of 2,4-D or NAA, since the transport of auxins by the plant takes a long time, and ethylene does not appear to affect it (AGUSTÍ & ALMELA, 1991).

These facts could also explain the low level of fall also found in the treatment involving the combination of GA_3 and NAA; the decrease in fall was due to the interaction between these two regulators,

Table 3 - Means for juice ratio (SS/acidity) and percentage of natural fall (fall) of 'Pêra' orange fruit, submitted to treatment with plant growth regulators, at seven harvests.

	ratio							fall						
Treatments	I	II	III	IV	V	VI	VII	I	II	III	IV	V	VI	VII
			SS /	Acid							%			
GA_3 +2,4-D 12.5mg L^{-1}	5.5	8.3	10.1	13.7	16.8	16.2	18.4	0.0	0.1	0.2	1.3	3.9	9.1	18.2
GA_3 + 2,4-D 25mg L^{-1}	5.8	8.5	10.3	13.7	16.7	18.0	17.4	0.0	0.0	0.1	0.8	2.0	4.8	10.5
GA_3 +2,4-D 37.5mg L^{-1}	5.9	8.5	10.1	13.6	16.6	16.7	18.0	0.0	0.0	0.1	0.6	3.3	9.6	18.8
GA_3 + NAA 12.5mg L^{-1}	5.9	8.3	10.2	13.3	16.1	17.1	17.1	0.0	0.0	0.2	1.9	4.5	8.8	20.8
GA_3 + NAA 25mg L^{-1}	5.9	7.9	10.2	12.9	16.1	16.7	17.4	0.0	0.1	0.3	3.3	7.1	12.7	23.5
GA_3 + NAA 37.5mg L^{-1}	5.3	8.2	10.1	14.0	16.4	16.7	17.1	0.0	0.0	0.3	3.4	6.8	11.2	23.9
NAA + 2,4-D 12.5mg L^{-1}	5.6	8.1	10.1	12.9	15.8	15.8	16.3	0.0	0.1	0.3	1.9	5.3	19.4	34.0
NAA + 2,4-D 25mg L^{-1}	5.4	7.9	9.7	12.7	15.7	16.8	16.6	0.0	0.3	0.4	1.1	4.0	16.8	26.1
NAA + 2,4-D 37.5mg L^{-1}	5.6	8.0	9.9	13.4	16.0	16.8	18.0	0.0	0.1	0.3	1.2	5.9	20.8	32.5
Control (water)	5.6	8.3	9.5	13.7	15.7	16.4	16.1	0.0	0.1	0.5	3.8	13.7	41.4	58.7
Means	5.6	8.2	10.0	13.4	16.2	16.7	17.2	0.0	0.1	0.3	1.9	5.6	15.5	26.7

both of which demonstrated as much effectiveness as the treatments containing GA_3 + 2,4-D.

An interesting fact that should be emphasized relates to treatments that contained only auxins, since these showed the highest fall percentages, second only to the control; this fact could be due to an excessive increase in auxin concentration, making them phytotoxic. This high concentration of auxin could promote increased ethylene synthesis, which would promote fruit abscission.

The data on residues of treatment chemicals in the fruit juice can be found in table 4, expressed in mg kg^{-1}. RUSSO et al. (1991) analyzed the juice of 'Sanguinello' oranges sprayed with 2-(2,4-dichlorophenoxy) propionic acid (2,4-DP) at 20, 30, and 40mg L^{-1}, and measured at 1, 5, 12, 20, 28, 40, 63, and 84 days after treatment, and reported no residues in the juice for three treatments tested. According to the same authors, the quantities of residue found in the rind were considerably lower than the legal limit set by the Government of Italy, 0.05mg L^{-1}, but significant differences were found among the quantities of residue originating in the various treatments. The same authors also reported that increased 2,4-DP concentrations did not cause proportional fruit fall percentages, and that maximum effect can be obtained with minimum concentration, allowing smaller environmental contamination.

The results obtained this paper, though short of replicates to support statistical analyses, and the sample used, based on an extract consisting of both peel and juice, since both participate in the production of frozen concentrated orange juice (FCOJ), disagree with RUSSO et al. (1991) with respect to the quantities of residues found. Those authors found a maximum 2,4-D level of 16.3 ppb in the peel, indicating that the use of these substances can be safe for Italian conditions, whereas under our conditions the maximum 2,4-D level found was 0.08 ppm, reached with the NAA treatment at 12.5mg L^{-1} + 2,4-D at 12.5mg L^{-1}, at 81 days after the last application; this level is therefore higher than that found by RUSSO et al. (1991), using a substance similar to 2,4-D.

However, 110 days after the last application, the residue levels of GA_3, 2,4-D, and NAA in the juice of 'Pêra' oranges was always below 0.05ppm, the legal limit as set by the Italian government. In Brazil, an official limit for the use of plant growth regulators has not been established. Therefore, considering the limit set by the Italian government, as well as by other European governments, the residue levels at harvest in this work were below the maximum limit imposed by the Italian government, presenting no threat to the human organism.

According to what has been observed here, the treatments applied to the fruit on the tree at color change time did not cause or inhibit the processes related to internal quality and maturation; there were no statistical differences regarding the quantity of juice in the fruit, amount of soluble solids, acidity, and ratio. However, the treatments did inhibit fruit abscission, keeping the fruit attached to the tree for a longer period of time.

Some field observations were made and recorded with regard to the color and external aspects of 'Pêra' orange fruits submitted to different treatments with plant growth regulators; these observations are important for the final external quality of the fruit.

Table 4 - GA_3, 2,4-D, and NAA residues (mg L^{-1}) in the juice of ‘Pêra’ oranges at 81 and 110 days after plant growth regulators were applied on the trees.

Treatments	GA$_3$		2,4-D		NAA	
	81	110	81	110	81	110
			mg L^{-1}			
GA_3 +2,4-D 12.5mg L^{-1}	0.02	0.01	0.03	0.03	-	-
GA_3 + 2,4-D 25mg L^{-1}	0.02	0.01	0.03	0.02	-	-
GA_3 +2,4-D 37.5mg L^{-1}	0.06	0.02	0.08	0.02	-	-
GA_3 + NAA 12.5mg L^{-1}	0.05	0.02	-	-	0.05	0.03
GA_3 + NAA 25mg L^{-1}	0.04	0.01	-	-	0.06	0.06
GA_3 +NAA 37.5mg L^{-1}	0.05	0.02	-	-	0.07	0.02
NAA + 2,4-D 12.5mg L^{-1}	-	-	0.06	0.01	0.08	0.01
NAA + 2,4-D 25mg L^{-1}	-	-	0.07	0.02	0.06	0.02
NAA + 2,4-D 37.5mg L^{-1}	-	-	0.07	0.01	0.08	0.03
Control (water)	0.00	0.00	0.00	0.00	0.00	0.00

During the experiment, the fruit from GA_3 treatments remained green for a longer time compared to fruit from the other treatments, with a delay in color change from green to orange. According to CHAPMAN (1983), exogenous applications of gibberellic acid at the citrus fruit color change stage will maintain the peel quality of late-harvested fruit, reducing mesocarp cracking and producing fruit with a greener color.

Juice content began to decrease starting at the fifth harvest, while acidity at the last harvest had an average value quite near 0.5%, which caused the fruit to have insipid taste. However, it is the ratio measure that denotes imminent senescence. At the last harvest, the mean ratio value was 17.25, which denotes juice with an unpleasant flavor. The use of plant growth regulators allows the harvest of ‘Pêra’ oranges to be extended for about three months after the otherwise ‘ideal’ harvest period, with no loss of internal and external fruit quality.

Although the fruit fall percentage allowed in commercial citrus plantations (8%) was reached in most treatments at the second to last harvest, the natural commercial harvest should have begun in the fifth collection, three months after the ideal ratio was obtained, demonstrating that the harvest period of ‘Pêra’ oranges can be extended for approximately three months with the use of plant growth regulators, after the otherwise ‘ideal’ harvest time, with no loss of internal and external fruit quality.

CONCLUSIONS

The use of plant growth regulators can delay the ideal harvest period of ‘Pêra’ oranges for up to three months, without changing the internal quality of the fruit. In particular, the most effective treatment consisted of GA_3 at 25mg L^{-1} + 2,4-D at 25mg L^{-1}. At fruit harvest time, the GA_3, 2,4-D, and NAA residue levels in the juice were less than 0.05ppm and posed no threat for human consumption.

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