Effect of Auxin Treatments on Calyx Senescence in the Degreening of Four Mandarin Cultivars

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Abstract. The degreening process is crucial in citrus fruit for the marketing of extra-early mandarins. Nevertheless, the application of ethylene during this treatment can be associated with calyx senescence. Citrus marketing regulations do not allow either alteration to fruit quality or the presence of calyx browning, especially on product exported to the United States. In this research, four synthetic auxins were tested for control of calyx disorders caused by degreening in different Clementine cultivars: Oronules, Clemenules, Marisol, and Clemenpons. All the tested auxins reduced calyx senescence, but the best results for all cultivars were obtained by 3,5,6-trichloro-2-pyridyloxycetic acid followed by 2,4-dichlorophenoxyacetic acid isopropyl ester. In general, the higher the doses, the smaller the calyx alterations. The most susceptible cultivar to calyx senescence was ‘Marisol’, whereas ‘Clemenules’ and ‘Clemenpons’ were the most tolerant. Treated fruit presented lower weight loss than untreated fruit. Every treatment achieved the commercial color index and no sensory alteration was observed.

The external color is an important attribute of citrus fruit quality. Consumers usually relate the external fruit color to its internal maturity, although in some circumstances, these factors are unrelated. This fact significantly influences the commercialization of citrus fruit for the fresh market.

Dегreening by ethylene is the postharvest technique that is most commonly used to modify the external color of early season citrus fruit. During this treatment, the orange color is revealed as the chlorophyll is destroyed. Recommended degreening conditions for Spanish citrus fruit are 1 to 2 ppm ethylene applied at 20 to 21 °C and relative humidity greater than or equal to 90% (Cuquerella et al., 2004). Nevertheless, the application of ethylene may accelerate senescence by increasing the respiration rate, transpiration and drying, browning, and abscission of the calyx (Cohen, 1978). The susceptibility to these undesirable effects of ethylene is cultivar-dependent. At the same time, the period of exposure to ethylene must be adequate using optimum conditions of temperature, ethylene concentration, humidity, and air renewal (Cuquerella et al., 2004).

The synthetic auxin 2,4-dichlorophenoxyacetic acid (2,4-D) is a plant growth regulator that has been widely used in citriculture since the 1950s to increase fruit size (El-Omari et al., 2000). As a postharvest treatment, 2,4-D has been used to retard calyx abscission, drying, and browning that occur as a consequence of the degreening process, thus maintaining the final quality of the exported fruit (Cuquerella, 1997). Nevertheless, at the present, European Union legislation has restricted the use of 2,4-D, making it necessary to find other synthetic auxins to avoid the physiological changes in the calyx.

The preharvest use of other synthetic auxins, like 2,4-dichlorophenoxy propionic acid (2,4-DP) or the 3,5,6-trichloro-2-pyridyloxycetic acid (3,5,6-TPA) (Maxim; Dow AgroSciences Ibérica, S.A., Madrid, Spain) increases fruit size, peel, pulp, juice, and acid contents and prevents fruit abscission (Agustí et al., 1994, 1995, 2006; Deng et al., 2002; García-Luis et al., 2002; Serciolo et al., 2003). At this time, these auxins are widely used by citrus growers. There are no studies into the effect of these auxins when applied postharvest, and although at present none of these products are yet registered in the European Union for postharvest application, it is very interesting to study them as a potential replacement for 2,4-D to control calyx senescence.

The objective of the present work was to study the effect of the postharvest application of different synthetic auxins on the incidence of calyx senescence induced by the degreening treatment in four early season Clementine cultivars.

Materials and Methods

Plant material and treatments. ‘Oronules’, ‘Marisol’, ‘Clemenpons’, and ‘Clemenules’ mandarins were harvested between October and November in Valencia, Spain. Before any treatment was applied, fruits were selected according to uniformity of size and external color by a color electronic calibrator.

For each cultivar, fruit were separated into two lots of 80 fruits according to external peel color index: fruit with green–yellow color (CI-I) and fruit with yellow–orange color (CI-II).

Color index (CI) of each fruit per lot was measured with a Minolta colorimeter (model CR-300; Minolta Co. Ltd., Osaka, Japan) taking three measurements in the equatorial zone of each fruit. The mean values for lightness (L), red–green (a), and yellow–blue (b) Hunter parameters were calculated for each fruit and expressed as color index (CI = 1000a/Lb) (Jiménez-Cuesta et al. 1981). Thus, the mean initial CI presented for each color group per cultivar was: –1.81 (CI-I) and 4.52 (CI-II) for ‘Oronules’; –6.10 (CI-I) and 1.98 (CI-II) for ‘Marisol’; –8.88 (CI-I) and –1.21 (CI-II) for ‘Clemenpons’; and –7.27 (CI-I) and –2.03 (CI-II) for ‘Clemenules’.

Auxins used in treatments were: butylglycol ester of 2,4-D (Clemengros; Especialidades Técnico Industriales, Barcelona, Spain); 3,5,6-TPA (Maxim); 2,4-D isopropyl ester (Citrus Fix; Amvac Chemical Corp., Los Angeles, CA); and 2,4-D amine (Albar, 40% a.i.; Makkethshim, Ashdod, Israel).

Before degreening, lots of 80 fruit per color group for each cultivar were dipped in the following treatments at room temperature (18 to 20 °C) for 2 min: water (control fruit); 5 or 10 ppm of 3,5,6-TPA (TPA-5 and TPA-10); 5 or 10 ppm of 2,4-D-ester (De-5 and De-10); 5 or 10 ppm 2,4-D-amine (Da-5 and Da-10); and 20, 40, or 60 ppm 2,4-D (DP-20, DP-40, and DP-60).

After auxin treatments, fruits were air-dried and then submitted to the degreening treatment in the packinghouse under commercial conditions. The fruits were exposed to 2 ppm of ethylene in a chamber with continuous flow regulated at 21 °C and 95% relative humidity for 3 d in the case of the CI-II group and for 4 d in the case of the CI-I group. After degreening, fruit were stored at 20 °C for 7 d.

All the cultivars were evaluated for the following parameters at harvest and after 7 d of degreening: weight loss, firmness, titratable acidity, soluble solids content, ethanol content, and sensory evaluation. Color index and calyx senescence were also evaluated after 1 d of degreening.

Assessments. Twenty fruit per treatment were used to measure weight loss and the results were expressed as a percentage. Peel color was measured, as described previously, with a Minolta colorimeter using 30 fruit per treatment and three measurements were taken in the equatorial zone of each fruit. The mean values for (L), (a), and (b) Hunter parameters were calculated for each fruit and expressed as color index (CI = 1000a/Lb). Firmness measurements were made with an Instron Universal Testing Machine (model 3343; Instron Limited, Buckinghamshire, UK) using 20 fruit per treatment. The results were expressed as the percentage of millimeters
of fruit deformation resulting from 10 N pressure on the longitudinal axis at a constant speed. Per treatment, three samples of 10 fruit each were squeezed in an electric juice extractor with a rotating head. Titratable acidity (TA) was determined by titration with 0.1 N NaOH solution using phenolphthalein as an indicator and expressed as grams of citric acid per 100 mL juice. Soluble solids content (SSC) in the juice was determined by measuring the refractive index of the juice and the data were expressed as °Brix (Atago Digital Refractometer PR-1; Atago Co., Ltd., Tokyo).

For the ethanol content, three replicates from each juice sample per treatment were analyzed. Five milliliters of the juice were transferred to 10-mL vials with crimp-top caps, TFE/silicone septa sealed, and frozen (–20 °C) until analysis. Ethanol was analyzed using a gas chromatograph (model 1020; Perkin Elmer Corp., Norwalk, CT) with a flame ionization detector and a 1/8 in × 1.2 m Porapak QS 80/100 column. The injector was set at 175 °C, the column at 150 °C, the detector (FID) at 200 °C, and the carrier gas at 12.3 psi. A 1-mL aliquot of the headspace was withdrawn from vials previously equilibrated for 1 h at 20 °C and 10 min at 30 °C and injected in the gas chromatograph. Ethanol was identified by comparison of retention time with a standard solution and expressed as milligrams/100 mL.

Calyx senescence of 40 fruit per treatment was evaluated visually. This evaluation consisted of testing each fruit for a loose calyx by rubbing the hand over the calyx. Calyx counts were made at 1 and 7 d after degreening and the calyx were classified as calyx abscission, calyx initiating browning, and calyx browning. The results were expressed as the percentage of alteration compared with the total number of fruit.

Sensory evaluation was assessed by eight to 10 semitrained judges after degreening plus 7 d. Panelists rated flavor on a 9-point scale, in which 1 = extremely unpleasant, 5 = fair, and 9 = excellent. A sample consisted of segments of fruit four to five fruit per treatment was used. Samples were presented to panelists in trays labeled with random three-digit codes and served at room temperature. Spring water was provided for rinsing between samples.

Statistical analysis. Statistical procedures were performed using a commercial statistical software (Statgraphics plus 5.1; Manugistics, Rockville, MD). All data were subjected to analysis of variance, and means were compared using Duncan’s multiple range test at P ≤ 0.05. The values of calyx senescence were arcsine-transformed because the values were originally recorded as percentages. The transformed data were subjected to analysis of variance using the previously described process.

Results and Discussion

Evaluation of calyx senescence. In general, green fruit (CI-I) showed a higher percentage of total calyx senescence than yellow fruit (CI-II) (Tables 1 and 2) as a consequence of a longer degreening period for CI-I.

In the case of ‘Oronules’, the control fruit achieved 93% and 79% of total calyx disorders in groups CI-I and CI-II, respectively. For CI-I (Table 1), every treatment significantly reduced calyx senescence when compared with the control. Nevertheless, this reduction was higher for TPA-10 and De-10, which both showed less than 46% of the fruit as having calyx senescence. For CI-II (Table 2), the differences were less pronounced. Treatments 2,4-DP and 2,4-Da did not show significant differences with respect to the control, and only TPA-10 and De-10 reduced calyx senescence to under 46%.

‘Marisol’ mandarins were more susceptible to calyx senescence after degreening than the other cultivars being studied. Only 1 d after degreening, 90% and 50% of the control fruit in groups CI-I and CI-II, respectively, showed disorders (data not shown). After 7 d of storage, the control of group CI-I showed 97% of fruit with disorders. TPA-10 and De-10 significantly reduced these alterations, although they also showed a high percentage of fruit with symptoms of calyx senescence (71% and 77%, respectively) (Table 1). For yellow fruit (CI-II), no treatment significantly reduced the calyx alterations compared with the previous described process.

| Cultivars | Treatment* | Calyx abscission (%) | Calyx initiating browning (%) | Calyx browning (%) | Total (%)* |
|-----------|-------------|----------------------|------------------------------|-------------------|-----------|
| Oronules  |             |                      |                              |                   |           |
|           | CTL         | 38                   | 10                           | 45                | 93 d      |
|           | TPA-5       | 29                   | 4                            | 20                | 53 ab     |
|           | TPA-10      | 28                   | 8                            | 44 a              | 77 ab     |
|           | De-5        | 19                   | 15                           | 20                | 54 ab     |
|           | De-10       | 24                   | 11                           | 11                | 46 a      |
|           | Da-5        | 39                   | 11                           | 15                | 65 abc    |
|           | Da-10       | 33                   | 9                            | 14                | 56 ab     |
|           | DP-20       | 34                   | 11                           | 25                | 70 bc     |
|           | DP-40       | 46                   | 4                            | 27                | 77 c      |
|           | DP-60       | 27                   | 23                           | 14                | 64 abc    |
| Marisol   |             |                      |                              |                   |           |
|           | CTL         | 78                   | 1                            | 18                | 97 b      |
|           | TPA-5       | 52                   | 24                           | 15                | 91 ab     |
|           | TPA-10      | 40                   | 12                           | 19                | 71 a      |
|           | De-5        | 42                   | 17                           | 18                | 77 a      |
|           | De-10       | 41                   | 24                           | 22                | 87 ab     |
|           | Da-5        | 47                   | 12                           | 22                | 81 ab     |
|           | Da-10       | 77                   | 0                            | 19                | 96 b      |
|           | DP-20       | 59                   | 5                            | 27                | 91 ab     |
|           | DP-40       | 58                   | 5                            | 26                | 89 ab     |
| Clemencouns |            |                      |                              |                   |           |
|           | CTL         | 23                   | 17                           | 13                | 53 c      |
|           | TPA-5       | 17                   | 18                           | 1                 | 36 bc     |
|           | TPA-10      | 7                    | 4                            | 0                 | 13 a      |
|           | De-5        | 5                    | 11                           | 0                 | 16 a      |
|           | De-10       | 4                    | 13                           | 1                 | 18 a      |
|           | Da-5        | 4                    | 14                           | 1                 | 19 a      |
|           | Da-10       | 1                    | 11                           | 0                 | 12 a      |
|           | DP-20       | 11                   | 12                           | 6                 | 29 ab     |
|           | DP-40       | 5                    | 17                           | 4                 | 26 ab     |
|           | DP-60       | 12                   | 14                           | 1                 | 27 ab     |
| Clemenules |            |                      |                              |                   |           |
|           | CTL         | 54                   | 4                            | 1                 | 59 b      |
|           | TPA-5       | 48                   | 4                            | 0                 | 52 ab     |
|           | TPA-10      | 39                   | 6                            | 1                 | 46 ab     |
|           | De-5        | 24                   | 3                            | 0                 | 27 ab     |
|           | De-10       | 15                   | 4                            | 0                 | 19 a      |
|           | Da-5        | 34                   | 5                            | 0                 | 39 ab     |
|           | Da-10       | 23                   | 3                            | 0                 | 26 ab     |
|           | DP-20       | 25                   | 4                            | 1                 | 30 ab     |
|           | DP-40       | 35                   | 3                            | 1                 | 39 ab     |
|           | DP-60       | 22                   | 4                            | 0                 | 26 a      |

ANOVA

| Cultivars (C) (3) | 19,962.4* |
| Treatment (T) (9) | 3,849.5*  |
| Residual (40)    | 2,152.0   |

*Treatments applied included the following: control fruit (CTL); 5 or 10 ppm of 3,5,6,-TPA (TPA-5 and TPA-10); 5 or 10 ppm of 2,4-D-ester (De-5 and De-10); 5 or 10 ppm 2,4-D-amine (Da-5 and Da-10); and 20, 40, or 60 ppm 2,4-DP (DP-20, DP-40 and DP-60).

*Means with different letters within the column and for the same cultivars are significantly different according to Duncan’s multiple range test (P ≤ 0.05).

*Sum of squares for each factor. The degrees of freedom for each factor are indicated in parentheses. ns, "Nonsignificant or significant at P ≤ 0.05, respectively."
The control, 95% of which showed calyx senescence symptoms (Table 2). ‘Clemenpons’ and ‘Clemenules’ mandarins exhibited less incidence of calyx senescence after degreening than ‘Oronules’ and ‘Marisol’ cultivars.

In the case of ‘Clemenpons’, after 7 d of degreening, 53% and 27% of the control fruit in groups CI-I and CI-II, respectively, had calyx degreening, 53% and 27% of the control fruit of ‘Clemenules’ mandarins presented total calyx alterations in groups CI-I and CI-II, respectively (Tables 1 and 2). For group CI-I, only De-10 and DP-60 reduced significantly the total calyx senescence; meanwhile, for group CI-II, the treatments De-5, De-10, Da-5, and Da-10 were effective. Jiménez-Cuesta et al. (1983) reported the great effectiveness of 2,4-D treatment for controlling calyx abscission in ‘Oroval’ Clementine, even at very low concentrations. This treatment also resulted in the lowest percentage of calyx abscission in ‘Navelate’ ‘Marisol’ cultivars, and this effect was also observed in ‘Clemenpons’ fruit.

‘Clemenules’ from CI-I, treatments De-5, De-10, and DP-60 significantly delayed color evolution, whereas for fruit from CI-II, DP was the only treatment that significantly reduced the CI compared with the control (Fig. 2). This effect was also observed in ‘Clemenpons’ fruit.

In general and as expected, fruit harvested with a more advanced initial color (CI-II) reached a higher color index than fruit harvested green (CI-I), and this effect was especially marked for ‘Oronules’ and ‘Marisol’ cultivars.

The literature on the effect of the postharvest application of other auxins to control calyx abscission is limited. One point to note is that in ‘Clemenpons’ and ‘Clemenules’, the percentage of calyx initiating browning was in general higher than complete calyx browning compared with ‘Marisol’ and ‘Oronules’ cultivars. This suggests the higher susceptibility for calyx senescence of these last two cultivars, in which the calyx turned brown much faster than in the others cultivars. Jiménez-Cuesta et al. (1983) mentioned the great importance cultivar aptitude has on the susceptibility of citrus fruit to calyx alterations and observed that although ‘Oroval’ mandarin is enormously sensitive to calyx abscission, ‘Satsuma’ mandarin is to calyx browning.

Color evolution. ‘Oronules’ fruits were harvested with a higher CI than the other cultivars: 1.81 and 4.52 for groups CI-I and CI-II, respectively. After degreening, the control fruit from both color groups achieved a typical, intense orange–red color (15.8 for CI-I and 19.3 for CI-II). Treatments De-10 and Da-10 for CI-I and De-5 for CI-II delayed color evolution significantly compared with the control fruit (Figs. 1 and 2).

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Jiménez-Cuesta et al. (1983) observed that 2,4-D applied at low doses (10 ppm) by dipping or drenching before degreening reduced calyx abscission and browning without affecting the color change, although the higher the concentrations of 2,4-D, the slower the color change during degreening. In their study, color change was visually detectable with 2,4-D doses higher than 200 ppm. Cronjé et al. (2005) observed a significant color reduction between degreened ‘Midnight Valencia’ oranges treated with 2,4-D

### Table 2. Effect of postharvest application of different auxins on calyx senescence in different Clementine cultivars harvested with a yellow color index (CI-II) after degreening plus 7 d at 20 °C.

| Cultivars | Treatment | Calyx abscission (%) | Calyx initiating browning (%) | Calyx browning (%) | Total (%)  |
|-----------|-----------|----------------------|-------------------------------|--------------------|-----------|
| Oronules  |CTL        |36                    |10                            |33                 |79 c       |
|           |TPA-5      |43                    |6                             |19                 |68 bc      |
|           |TPA-10     |28                    |4                             |13                 |45 ab      |
|           |De-5       |35                    |4                             |19                 |58 abc     |
|           |De-10      |18                    |3                             |17                 |38 a       |
|           |Da-5       |43                    |7                             |15                 |65 abc     |
|           |Da-10      |37                    |6                             |18                 |61 abc     |
|           |DP-20      |44                    |8                             |27                 |79 c       |
|           |DP-40      |44                    |3                             |20                 |67 bc      |
|           |DP-60      |49                    |8                             |12                 |69 bc      |
| Marisol   |CTL        |75                    |7                             |13                 |95 a       |
|           |TPA-5      |47                    |18                            |24                 |89 a       |
|           |TPA-10     |64                    |14                            |7                  |85 a       |
|           |De-5       |57                    |12                            |23                 |92 a       |
|           |De-10      |43                    |22                            |18                 |83 a       |
|           |Da-5       |58                    |17                            |23                 |98 a       |
|           |Da-10      |61                    |8                             |21                 |90 a       |
|           |DP-20      |58                    |3                             |37                 |98 a       |
|           |DP-40      |67                    |3                             |30                 |100 a      |
|           |DP-60      |64                    |4                             |27                 |95 a       |
| Clemepons |CTL        |6                     |6                             |15                 |27 c       |
|           |TPA-5      |8                     |5                             |1                  |14 abc     |
|           |TPA-10     |2                     |1                             |0                  |3 a        |
|           |De-5       |0                     |4                             |1                  |5 a        |
|           |De-10      |3                     |1                             |4                  |8 ab       |
|           |Da-5       |4                     |3                             |3                  |10 abc     |
|           |Da-10      |4                     |5                             |1                  |10 abc     |
|           |DP-20      |8                     |13                            |6                  |27 c       |
|           |DP-40      |3                     |8                             |3                  |14 abc     |
|           |DP-60      |12                    |10                            |3                  |25 bc      |
| Clemenules|CTL        |32                    |15                            |0                  |47 d       |
|           |TPA-5      |25                    |6                             |0                  |31 cd      |
|           |TPA-10     |24                    |6                             |0                  |30 cd      |
|           |De-5       |15                    |4                             |0                  |19 bc      |
|           |De-10      |4                     |3                             |0                  |7 a        |
|           |Da-5       |15                    |10                            |0                  |25 bc      |
|           |Da-10      |10                    |5                             |0                  |15 ab      |
|           |DP-20      |24                    |8                             |1                  |33 cd      |
|           |DP-40      |25                    |6                             |1                  |32 cd      |
|           |DP-60      |28                    |5                             |0                  |33 cd      |

ANOVA

| Cultivar (C) (3) | Treatment (T) (9) | C × T (27) | Residual (40) |
|------------------|-------------------|------------|---------------|
|                  |                   | 38,069.8*  | 3,440.95*     |
| x                |                   | 1,217.45 ns| 1,901.0       |

*Significant at *P* ≤ 0.05. ns, *Nonsignificant or significant at P ≤ 0.05, respectively.

### Notes

1. Treatments applied included the following: control fruit (CTL); 5 or 10 ppm of 3,5,6,-TPA (TPA-5 and TPA-10); 5 or 10 ppm of 2,4-D-ester (De-5 and De-10); 5 or 10 ppm 2,4-D-amine (Da-5 and Da-10); and 20, 40, or 60 ppm 2,4-D (DP-20, DP-40, and DP-60).

2. Means with different letters within the column and for the same cultivars are significantly different according to Duncan’s multiple range test (*P* ≤ 0.05).

3. *Sum of squares for each factor. The degrees of freedom for each factor are indicated in parentheses.

4. *NS, Nonsignificant or significant at P ≤ 0.05, respectively.

The overall trend observed in ‘Clemenpons’ and ‘Clemenules’ mandarins was that 2,4-D applied at low doses (10 ppm) by dipping or drenching before degreening reduced calyx abscission and browning without affecting the color change, although the higher the concentrations of 2,4-D, the slower the color change during degreening. In their study, color change was visually detectable with 2,4-D doses higher than 200 ppm. Cronjé et al. (2005) observed a significant color reduction between degreened ‘Midnight Valencia’ oranges treated with 2,4-D...
and untreated fruit, although all treatments reached a commercial color (CI greater than 6). Our results show that 2,4-De at 5 or 10 ppm produced this color delay effect in ‘Clemenules’ mandarins harvested green (CI-I), whereas the same treatments did not affect the color change for fruit harvested with a more advanced peel color (CI-II). Nevertheless, in ‘Marisol’ and ‘Clemenpons’, all treatment significantly reduced the CI compared with the control in CI-II.

Fruit quality. Fruit organoleptic quality was determined by measuring weight and firmness loss, SSC, TA and ethanol content of juice, and sensory evaluation.

Because the differences between treatments observed for each cultivar and color group were very small for each fruit quality parameter analyzed, Table 3 only shows the results for ‘Oronules’ and ‘Clemenpons’ and for one color group.

After harvesting, citrus fruit lose a great amount of weight as a consequence of transpiration, and this represents an important economical loss and induces peel senescence (Cuquerella et al., 2004). In the present study, auxin treatments did not significantly increase the weight loss; some treatments even reduced this parameter if compared with the control fruit (Table 3). This difference was more pronounced for ‘Clemenules’ and ‘Clemenpons’ (data not shown), which could be a consequence of the smaller incidence of calyx senescence observed in treated fruit. Saraswathi and Azhakiamanavalan (1997) studied the postharvest effect of 2,4-D (100, 200, or 500 ppm) in mandarin fruit and observed a reduced percentage of weight loss and extended storage life.

In general, all cultivars registered very low ethanol content in juice for all treatments after degreening plus 7 d. The treatments DP-40 and DP-60 significantly increased the ethanol content in ‘Oronules’, and in ‘Clemenpons’, the treatments with significantly higher ethanol values were TPA-10, Da-10, and DP-20. Nevertheless, all treatments applied presented an acceptable commercial flavor and there were no differences between treatments, including the control (Table 3).

It is important to note that the different cultivars showed different ethanol content at harvest, being reflected in the amounts of ethanol reached after storage.

As observed by other authors (Coggins, 1981; Davies, 1986), all the auxin treatments showed commercial firmness, Brix, TA, or SSC/TA. Bello et al. (2004), simulating transportation to the European Union from Argentina, did not observe any change in the final quality of ‘Ellendale’ and ‘Cadenera’ mandarins (cultivars not degreened) treated with 2,4-D.

Conclusions

Calyx senescence caused by ethylene degreening treatment was strongly cultivar-dependent. ‘Marisol’ was more susceptible to calyx alterations induced by degreening than the other cultivars. This shows the importance of the intrinsic cultivar characteristics in the postharvest behavior of fruit.

In general, the most effective treatment for the reduction of calyx senescence in degreened fruit was 2,4-D, although treatment 3,5,6-TPA also showed very good results for all the cultivars under study. The efficiency of the synthetic auxins applied were dependent of the cultivar, CI, and application dose.

Although some auxin treatments delayed color evolution, this reduction was not relevant from a commercial point of view, because in all cases, the CI achieved was always superior to the commercial one, even for the fruit with green initial color. The application
of different auxin treatments did not affect the sensory quality of any of the cultivars. The positive results obtained with 3,5,6-TPA suggest that this auxin could be a potential alternative to 2,4-D treatment in the future.

Table 3. Effect of postharvest application of different auxins on the quality parameters in different Clementine cultivars harvested with a green color index (CI-I) and a yellow color index (CI-II) after degreening plus 7 d at 20°C.

| Treatment | Wt loss (%) | Firmness (%def.10N) | SSC (%Brix) | TA (g/100 mL) | SSC/TA | Ethanol (mg/100 mL) | Flavor |
|-----------|------------|---------------------|------------|--------------|--------|-------------------|--------|
| Oronules (CI-I) |          |                     |            |              |        |                   |        |
| Harvest  | 6.15 bc    | 6.26 bc             | 11.43 bcd  | 1.18 e       | 9.64 a  | 9.78 a            | 6.3 a  |
| CTL      | 5.73 ab    | 6.30 bc             | 11.60 cd   | 1.15 bc      | 10.06 ab| 11.26 ab          |        |
| TPA-5    | 5.76 ab    | 5.67 a              | 11.60 cd   | 1.07 ab      | 10.82 bc| 12.13 abc         |        |
| De-5     | 5.64 a     | 5.94 ab             | 11.71 d    | 1.17 c       | 9.96 ab | 7.37 a            |        |
| De-10    | 6.33 c     | 6.16 bc             | 11.21 ab   | 1.09 abc     | 10.26 ab| 10.96 ab          | 6.3 a  |
| Da-5     | 5.91 abc   | 6.47 c              | 11.68 cd   | 1.18 c       | 9.82 a  | 9.71 a            |        |
| Da-10    | 5.88 abc   | 6.24 ab             | 11.35 abc  | 0.98 a       | 11.54 c | 15.98 bcd         | 6.1 a  |
| DP-20    | 5.65 a     | 6.19 bc             | 11.36 abc  | 1.09 bc      | 10.36 ab| 10.35 ab          |        |
| DP-40    | 5.82 ab    | 6.02 abc            | 11.05 a    | 1.05 ab      | 10.46 ab| 18.59 d           |        |
| DP-60    | 5.68 a     | 5.62 a              | 11.25 ab   | 1.14 bc      | 9.87 a  | 17.59 cd          | 5.1 a  |
| Clementpons (CI-II) |        |                     |            |              |        |                   |        |
| Harvest  | 5.45 e     | 6.75 abc            | 10.75 ab   | 0.77 a       | 13.92 bcd| 3.24 a            | 6.9 a  |
| CTL      | 5.14 cde   | 6.40 a              | 11.25 c    | 0.79 ab      | 14.32 d | 3.13 a            |        |
| TPA-5    | 4.90 abc   | 6.69 ab             | 10.90 abc  | 0.77 a       | 14.15 d | 5.15 c            | 6.2 a  |
| De-5     | 5.30 de    | 6.83 abc            | 10.63 a    | 0.80 ab      | 13.26 ab| 3.28 a            |        |
| De-10    | 4.99 bcd   | 7.00 c              | 10.80 ab   | 0.75 a       | 14.35 d | 3.86 abc          | 6.8 a  |
| Da-5     | 4.96 bcd   | 6.67 abc            | 10.83 ab   | 0.79 ab      | 13.66 abcd| 3.42 ab        |        |
| Da-10    | 4.94 abcd  | 6.64 ab             | 10.87 abc  | 0.81 ab      | 13.39 abc| 4.87 c           | 6.8 a  |
| DP-20    | 4.58 b     | 6.64 abc            | 11.05 bc   | 0.78 a       | 14.15 cd| 4.67 bc          |        |
| DP-40    | 4.75 ab    | 6.46 ab             | 10.92 abc  | 0.79 ab      | 13.78 bcd| 4.42 abc         |        |
| DP-60    | 4.15 a     | 6.88 bc             | 10.92 abc  | 0.84 b       | 13.02 a | 3.19 a            | 6.8 a  |

*Means with different letters within the column are significantly different according to Duncan’s multiple range test (P ≤ 0.05).

Fig. 2. Effect of postharvest application of different auxins on the color index (CI) in different Clementine cultivars harvested with a yellow color index (CI-II) after degreening plus 1 d at 20°C. Treatments applied included the following: control fruit (CTL); 5 or 10 ppm of 3,5,6-TPA (TPA-5 and TPA-10); 5 or 10 ppm of 2,4-D-ester (De-5 and De-10); 5 or 10 ppm 2,4-D-amine (Da-5 and Da-10); and 20, 40, or 60 ppm 2,4-D (DP-20, DP-40 and DP-60). Vertical bars represent least significant difference intervals (P ≤ 0.05).

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