

## Thinning of 'Esbal' Clementine with 2,4-Dichlorophenoxyacetic Acid. Influence on Yield, Fruit Size and Fruit Quality

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**Abstract.** Esbal clementine, which originated as a bud sport from 'Fina', is a highly parthenocarpic early maturing cultivar with outstanding fruit quality. The popularity of this cultivar is nevertheless impaired by the small fruit size, as up to 40% of the total yield may be unmarketable for this reason. Extensive hand thinning and auxin applications at June drop have been tried to overcome this problem, with limited success. The application of a 2,4-D spray at or shortly after bloom effectively thins the number of fruits without affecting total yield, reducing the percentage of unmarketable fruit to 13% and increasing the mean size of the marketable fruit. This thinning effect is not related to an auxin-induced ethylene synthesis, but results from the selective enhancement of the growth of some fruits by the 2,4-D application. The 2,4-D applications had no direct effect on sugar and acid content of the fruit nor in the maturity index, but the increase in fruit size resulted in an earlier maturity. These applications resulted in a reduction in juice content, but this reduction was less than observed when auxins were applied at June drop.

An increase in fruit size resulting from the application of the synthetic auxin 2,4-dichlorophenoxyacetic acid (2,4-D) was first reported for oranges and grapefruits by Stewart and co-workers in the early 50's (Stewart *et al.*, 1951, 1952; Stewart and Parker, 1954). Further work extended these observations to some mandarin cultivars (Monselise, 1979, Guardiola, 1981). In most cases, the increase in fruit size was paralleled by a thinning effect. As a consequence it was reported that these applications had no effect on total crop yield or decreased it slightly.

The results obtained with these applications were considered to be too erratic to recommend them in commercial practice (Monselise, 1979). The reason for this variability was not ascertained, but a major factor could be that the parameters affecting the response were not precisely characterized. Thus, the optimal time recommended for spraying this auxin has been considered to be at flowering (Stewart *et al.*, 1951, 1952), within 4-6 weeks after flowering (Monselise, 1973) or 6-8 weeks from flowering (Erner *et al.*, 1993). Further, the influence of the species or cultivar in the response to these applications was only reported in a few cases (Guardiola, 1981). This variability, added to occasional adverse effects on fruit quality and

appearance, probably due to overdoses, resulted in the dismissal of this technique in practice and its substitution by other strategies of auxin applications (Guardiola, 1996).

In our studies on the development of the fruit of several mandarin cultivars we found that, when correctly used, applications of 2,4-D yielded consistent results as regards to thinning and fruit sizing (Guardiola, 1995). We report here some parameters affecting the response in 'Esbal' clementine. 'Esbal' is an early harvest, high quality cultivar which usually produces small sized fruits (Bono *et al.*, 1991). Fruit set is usually adequate, but up to 40% of the total number of fruits is too small for the export market, which necessitates an expensive and sometimes ineffective hand thinning. The application of 2,4-D obviates the need for hand thinning, markedly increases fruit size and improves the market value of the crop.

### Materials and Methods

**Plant material.** The experiments and observations were carried out in a 12-year-old commercial orchard of 'Esbal' clementine (*Citrus clementina* Hort. ex Tan.), grafted on sour orange (*Citrus aurantium* L.), located at Sagunto (Spain).

**Effect of 2,4-D on flower/fruitlet abscission.** The influence of 2,4-D (20 mg l<sup>-1</sup>) applications on the time course of abscission was determined in four single tree replicates. The treatments were: control (nonsprayed), 2,4-D sprayed at full bloom (April 14) and 2,4-D sprayed 2 weeks after full bloom (April 28). At both dates 20 mg l<sup>-1</sup> 2,4-D (isopropyl ester) was applied along with a non-ionic wetting agent (alkylpolyglycol ether, 100 mg l<sup>-1</sup>), with a hand-gun sprayer until run-off. Five litres of solution were used per tree.

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A net was spread under the trees above ground level in order to retain the abscised organs, which were collected at weekly intervals, classified according to their stage of development and counted.

The growth of the persisting fruitlets was determined by periodically measuring the equatorial diameter from at least 200 fruitlets borne on single flowered leafy inflorescences.

**Effect of 2,4-D on fruit set and yield.** The following treatments were tested: no treatment (control) and 2,4-D (20 mg l<sup>-1</sup>) sprayed at three different dates; namely April 14 (full bloom), April 28 (14 days after full bloom) and June 3 (50 days after full bloom). Other treatment details were as described above. A randomised block design with three replications of six trees each was followed.

At commercial maturity the fruit of the different replicates was harvested, counted and weighed separately. From these figures the average fruit weight was calculated. The combined harvest from the three replicates of each treatment was sized on a belt-and-roller sizer and classed according to fruit diameter.

Results were subjected when appropriate to an analysis of variance. Mean separations were performed using Duncan's test at P = 0.05.

## Results

**Fruitlet early growth and abscission** - The trees used in this experiment formed a high number of flowers (ca. 58,000), but most were shed within 3 months after anthesis. The final fruit set represented 3.7% of the total number of flowers. A significant proportion of the reproductive organs were shed at the flower bud stage, before reaching anthesis (Fig. 1).

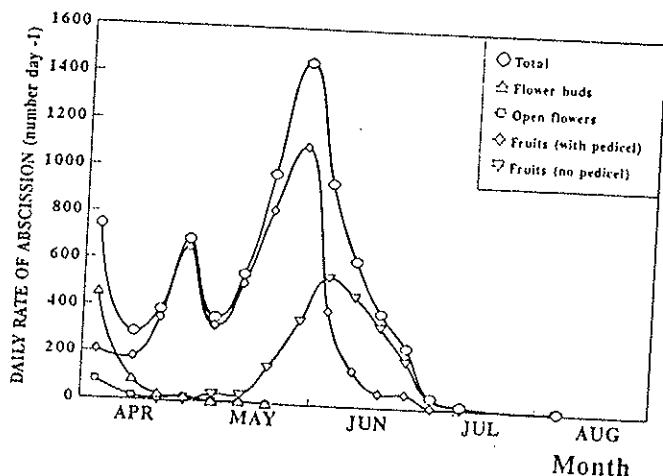


Figure 1. Daily rate of abscission of reproductive structures in the control trees. The fallen structures have been classed according to the stage of development at abscission as flower buds (before reaching anthesis), open flowers (at anthesis) or fruitlets. The latter have been separated into two groups according to the position of the separation layer either at the base of the pedicel (with pedicel) or at the base of the ovary (without pedicel)

Two main peaks of drop occurred, 2 and 6 weeks after bloom. In both, the fallen organs were mostly fruitlets which detached at the base of the pedicel without having made much growth (Fig. 2).

At the end of the main peak of drop, during June, most of the fallen organs were fruitlets which detached at the base of the ovary. Those fruitlets had achieved significant growth at the time of abscission (Fig. 2).

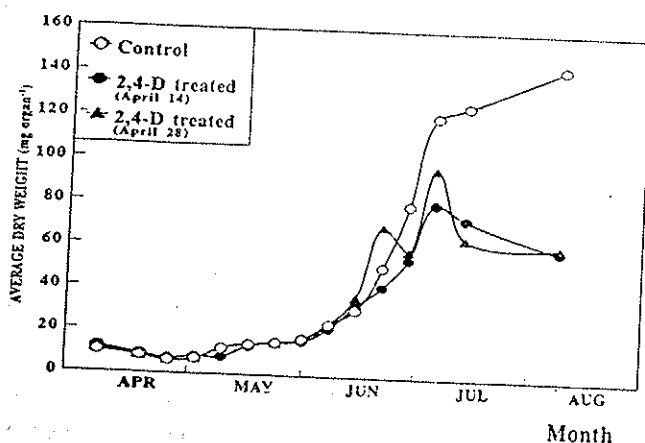


Figure 2. Average dry weight of the reproductive organs at the time of abscission. Data for untreated (controls) and trees sprayed with 20 mg l<sup>-1</sup> 2,4-D on April 14 (flowering) or April 28 (2 weeks after bloom)

**The effect of 2,4-D applications on fruitlet growth and abscission.** The application of 2,4-D selectively enhanced the growth rate of some of the fruitlets borne on leafy inflorescences, but had no effect on the growth rate of most of the fruitlets (evidence not presented). This selective enhancement of the growth rate of some fruitlets persisted until harvest.

Fruitlet abscission was initially retarded by the 2,4-D applications (Fig. 3). This retardation in abscission lasted for 5 weeks for the trees in which the 2,4-D application was performed at flowering, and for 3 weeks for those treated 2 weeks after flowering. After that time the rate of abscission was faster for the 2,4-D treated trees, and final fruit set was reduced by the 2,4-D applications (Fig. 3). The reduction in set was maximal in this experiment for the applications performed within 2 weeks of full bloom, and was somewhat smaller when this application was performed at day 50 (Table 1). Complementary trials showed that abscission was maximal when the 2,4-D was applied from flowering up to 4 weeks after bloom (data not reported).

The average dry weight of the fallen organs was similar for the control and the 2,4-D treated trees up to the end of June (Fig. 2). The delay in abscission did not result therefore in an increase in the use of dry matter in fructification.

The average dry weight of the fruitlets detached from the tree after June was significantly higher for the control

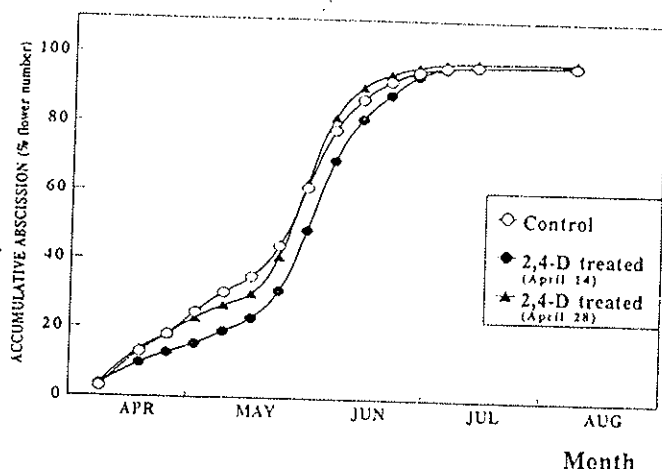


Figure 3. Accumulative abscission of reproductive structures in untreated (controls) and 2,4-D treated trees on April 14 (flowering) or April 28 (2 weeks after flowering). Abscission expressed as a percentage of the initial number of flowers

than for the 2,4-D treated trees. The number of fruitlets fallen during this time was, however, small, and did not significantly affect the total dry matter loss through abscission.

The effect of 2,4-D applications on crop yield and fruit size. The application of 2,4-D reduced fruit number at harvest and increased the average fruit weight (Table 1). These effects compensated each other, and total crop yield was not significantly affected by the 2,4-D applications.

Commercial yield was markedly increased by the 2,4-D applications (Table 1). The number of fruits of a diameter smaller than 48 mm, which represented a significant proportion of the total fruit count in the controls, was markedly reduced by the 2,4-D applications (Fig. 4). These applications resulted therefore in an increase in the number of marketable fruits, and particularly in the number of fruits of bigger diameters. These two factors contributed to the increase in the economic value of the crop.

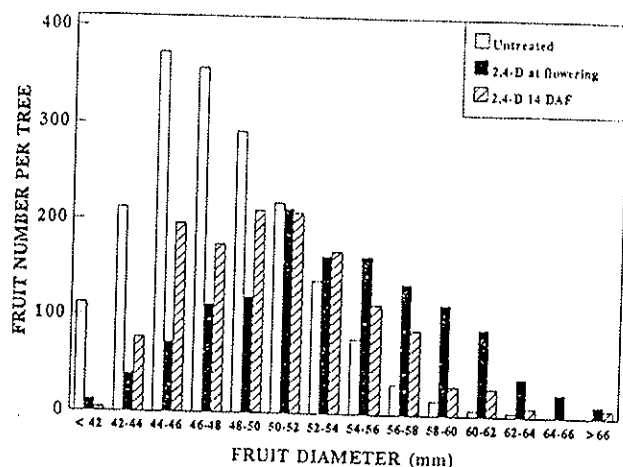


Figure 4. Fruit sizing at harvest for control and 2,4-D-treated trees either at flowering or 2 weeks (14 days) after flowering. Results expressed as number of fruit per tree

Table 1. The effect of the time of 2,4-D application on yield, fruit count and average fruit size at harvest

Time of 2,4-D application (days from flowering)	Fruit count (number tree <sup>-1</sup> )	Average fruit weight (g fruit <sup>-1</sup> )	Total yield (kg tree <sup>-1</sup> )	Commercial yield (kg tree <sup>-1</sup> )
April 14 (Full bloom)	1.304 a	61 a	80	69 a
April 28 (14 DAFB)	1.313 a	58 ab	76	65 a
June 3 (50 DAFB)	1.593 ab	55 b	88	72 a
Control (Untreated)	1.835 b	46 c	84	52 b
Standard error	96	1.6	5.4	3.5
Significance	0.05	0.01	N.S.	0.05

Table 2. The influence of fruit size on some fruit quality parameters. Pooled data from all 2,4-D treatments

Fruit diameter (mm)	% juice	TSS (°Brix)	Acidity (g/100 ml)	Maturity index (TSS/Acidity)
47	57.7 ab	9.8 a	1.30 a	7.6 a
54	58.3 a	10.1 b	1.15 b	8.7 b
59	56.6 b	10.1 b	1.05 c	9.6 c
SE	0.4	0.07	0.03	0.16

Mean separations by Duncan's test at  $P \leq 0.05$

Table 3. The effect of the time of 2,4-D applications on some fruit quality parameters. Data from fruit of  $47 \pm 1$  mm equatorial diameter

Treatment	% juice	TSS (°Brix)	Acidity (g/100 ml)	Maturity index (TSS/acidity)
Untreated	59.1 a	10.0	1.29	7.7
(controls)	58.0 ab	9.9	1.31	7.6
2,4-D at bloom	58.2 ab	9.9	1.25	7.9
2,4-D 2 WAB	57.0 b	9.7	1.35	7.2
2,4-D 6 WAB	0.7	0.12	0.05	0.27
SE				

Mean separations by Duncan's test at  $P \leq 0.05$

The effect of 2,4-D on fruit sizing was significant for the three dates of application tested. However, its effectiveness decreased as the application was delayed. Best sizing results were obtained with the full bloom applications.

*The influence on fruit quality.* The 2,4-D applications had no adverse effects on fruit appearance and pigmentation (data not shown). The effects on fruit quality resulted mainly from the effect on fruit size, which significantly influences some quality parameters. A bigger fruit size resulted in an advance in maturation mostly due to the reduction in titratable acidity (Table 2). Also, it caused a slight increase in total soluble solids. For this reason, the 2,4-D applications resulted in a slightly earlier harvest.

When fruits of the same diameter were compared, no effect of 2,4-D applications on TSS, titratable acidity and maturity index was detectable (Table 3). The only significant effect was the reduction in juice content in fruits treated six weeks after flowering. A trend towards a smaller juice content as compared to the control was also observed for the fruits treated at flowering or shortly after. This reduction in juice content, in part caused by the method of reporting the results (on a fruit weight basis) did not reach the level of statistical significance.

### Discussion

The application of 2,4-D at flowering effectively thinned the 'Esbal' clementine and resulted in a marked increase in final fruit size and in crop value. This thinning effect does not seem related to auxin-induced ethylene synthesis by the fruit, which usually is complete within three weeks of auxin application (Guardiola, 1996). In the present work fruitlet thinning occurred in some treatments some six-seven weeks after auxin application, and the timing of this auxin-induced thinning was unrelated to the timing of the auxin applications. Rather than a direct effect of the auxin on the fruit it may result from changes in the source-sink relationships in the trees.

The reproducible results we report here contrast with the rather erratic results previously reported for 2,4-D

applications (see references in earlier).

There are at least two reasons for these apparently different results. From one aspect not all cultivars thin the fruits in response to early auxin applications (Guardiola, 1995). In some cases, fruit size may be significantly increased but without a reduction in fruit number. In these cultivars, the 2,4-D fruit sizing effect is usually smaller than reported here. Further, the time of 2,4-D application determines the extent of thinning, and late applications (6 to 8 weeks after flowering) as sometimes recommended (Monselise, 1973; Emer, 1993) result in a less thinning (Table 1) and a much higher tree-to-tree variability in response (evidence not presented).

The fruit sizing effect reported in this work is at least as good as that reported for auxin applications at the end of June drop (Agustí *et al.*, 1992). As compared with these late auxin applications, the 2,4-D application offers several advantages since (a) not much skill is needed to determine the correct time of application, (b) the applications performed from flower opening up to 4 weeks from flowering are effective, and (c) this earlier auxin application seem to have a markedly smaller effect than later ones on fruit juice content. Further, no adverse effects were observed on leaf expansion and subsequent vegetative growth of the tree. However, this aspect should be carefully checked in those cultivars in which leaf expansion has been reported to occur after flower opening, since auxin applications at the leaf expansion stage may result in some leaf curling.

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