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Effect of Paclobutrazol on Vegetative Growth, Flowering and Fruiting of the 'Nour' Clementine, an Alternate Bearing Cultivar

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Abstract. **The 'Nour' clementine is a late maturing clementine. It is harvested from early December- to end-January when compared to 'Cadoux', the reference cultivar, which is harvested from mid-October to early December. The 'Nour' has larger size fruit with firmer rind and an excellent eating quality. However, its production alternates greatly with an excessive number of vegetative shoots and almost no fruit production in the 'off year', to more than 150 kg of fruit per fully-grown tree, but with no new vegetative growth in the 'on year'. The objective of this research is to investigate whether paclobutrazol (a GA_3 biosynthesis inhibitor) applied at 200 ppm as foliar spray to fully grown trees, on 15 May 2002 (i.e. when newly formed spring vegetative shoots are fully grown and before appearance of the summer flush) would affect the vegetative cycle (i.e. spring + summer + fall flushes) and the fruiting cycle (i.e. flowering and fruit development) and evaluate whether this product could be used to regulate production and reduce the alternate bearing pattern of this selection. Results indicate that: 1) following its application, paclobutrazol had no effect on the length of the spring shoots nor on the yield, fruit number or fruit size, but it significantly reduced abundance of summer and fall shoots; 2) the following year (i.e. 2003), length and number of spring shoots were reduced but those of summer and fall growth flushes increased compared to those of the untreated trees. However, effect on flowering was not statistically significant but fruit number was greater on treated trees. Significance of these results in relation to alternate-bearing is discussed.**

Introduction

The 'Nour' Clementine is a citrus cultivar producing fruit of the easy-peeling type with excellent eating quality and adequate fruit size. It matures internally in early November but its peel coloring is delayed until early December. It is a bud sport of the 'Cadoux', a mid season Clementine characterized by a fragile skin and small-sized fruit. Fruit of 'Nour' is harvested from early Dec. to late January. However, one of the major constraints facing development of 'Nour' is its alternate-bearing pattern, in that during the 'on year' it produces excessive number of flowers with adequate to small fruit size whereas during the 'off year' it produces few flowers giving rise to none-to-few large fruit with rough and thicker skin. This alternation in the production is very regularly recorded in the 'Nour' orchards of Southern Moroco. In addition, production of vegetative shoots is abundant in the 'off year' but rare in the 'on year'. Therefore, to obtain a regular crop from year-to-year it is important to regulate flowering and vegetative growth. One way of doing this is through regulation of vegetative growth and particularly reducing it during the year of a light crop by using vegetative growth inhibitors.

Several authors reported that the competition between vegetative growth and reproductive development is a result of the balance between inhibitors and activators (Koshita et al., 1999; Okuda, 2000). Others indicated that reproductive-vegetative shoot development is linked to the tree carbohydrate status (Mataa and Tominaga, 1998).

Very limited research was done on citrus to control vegetative growth (see El-Otmani et al., 2000 and the references therein). Paclobutrazol (PP333), a gibberellic acid biosynthesis inhibitor, has been reported to retard the growth of citrus (Aron et al., 1985; Swietlik and Fucik, 1988). It also caused a reduction in fruit size in grapefruit (Swietlik and Fucik, 1988) and enhanced flowering in lemons (Harty and Van Staden, 1988). The present study aimed to investigate the effect of PP333, applied as foliar spray, on vegetative development of 'Nour' Clementine during an 'off year' and its subsequently effect on flowering and fruiting of the following season. Because most of the flowers are born on spring and summer growth of the previous year (unpublished data), the objective was to target reduction in summer and autumn growth of the 'OFF year' so that the available number of shoots and nodes for flowering of the next season is reduced, thus reducing the intensity of flowering and consequently reducing crop load of the 'on year'.

Materials and Methods

Trees of the 'Nour' Clementine (*Citrus reticulate* Blanco), grafted on sour orange (*Citrus aurantium* L) and planted on sandy clay soil in 1995, were used. They were of medium size and had similar vigor and crop load during the year of treatment application which was an 'off year'. PP333 was applied on 15 Mai 2002, as a foliar spray, to the point of run-off and at the concentration of 200 ppm. At this date all of the 2002 spring shoots have been formed and have reached their maximum growth (Table 1). Untreated trees were used as controls. There were 5 replications (i.e. trees). Five newly formed spring shoots were marked per tree at 1.5 m height. Sampling included the 4 quadrants of the tree. Their length was recorded at regular intervals and their number of nodes was counted. In addition, effect of PP333 was evaluated through counts of the summer and autumn 2002 shoots formed on these tagged spring shoots. The subsequent effect on flower intensity and vegetative shoot development on the 2002 spring shoots was also evaluated in the year 2003. Yield was also recorded for the 2 years of evaluation. At harvest, yield and fruit number and individual fruit weight were recorded.

Data were subjected to an analysis of variance using a completely randomized design.

Results and discussion

Vegetative growth and yield of the current cycle (i.e., year 2002). Because the treatment was applied after full growth of the current spring shoots, no significant effect of PP333 was recorded on these shoots (Table 1). However, the treatment retarded the appearance of summer shoots and partially inhibited their formation (Table 2) and reduced their length (Table 5). In addition, autumn shoot counts were smaller for the treated trees (Table 3).

Yield, fruit number and fruit size of the current cycle were not affected by the treatment (Table 4).

Table 1. Effect of Paclobutrazol applied in the Spring (at 200 ppm on 15 May 2002) on length of spring shoots (in cm) of 'Nour' clementine

Treatment	Date of observation	
	17 May2002	16 July 2002
Paclobutrazol	13.7	13.8
Untreated control	13.5	13.9
Significance level[z]	NS	NS

[z]NS: Not significant

Table 2. Effect of Paclobutrazol applied in the spring (at 200 ppm on 15 May 2002) on abundance of the subsequently born summer shoots of 'Nour' clementine. Data are in number of summer shoots/ 100 spring shoots.

Treatment	Date of observation		
	11June 02	16 July 02	1August 02
Paclobutrazol	0 ± 0	24 ± 4	32 ± 8
Untreated control	60 ± 12	76 ± 4	82 ± 4
Significance level[z]	***	***	***

[z]***: Significant at 0.1%

Table 3. Effect of Paclobutrazol applied in the spring (at 200 ppm on 15 May 2002) on abundance of autumn shoots newly formed on previous spring shoots of 'Nour' Clementine. Data are in number of autumn shoots/ 100 spring shoots.

Treatment	Date of observation	
	11/09/02	08/10/02
Paclobutrazol	64 ± 12	114 ± 5
Untreated control	96 ± 16	126 ± 6
Significance level[z]	*	*

[z]*: Significant at 5%

Table 4. Effect of Paclobutrazol applied in the spring (at 200 ppm on 15 May 2002) on yield and on weight of individual fruit at harvest. Harvest was done on 24 Dec. 2002 and 28 Jan. 2003)

Treatment	Yield (kg/tree)	Number of fruits/tree	Fruit weight (g/fruit)
Untreated control	34	262	130
Paclobutrazol	29	220	132
Significance level[z]	NS	NS	NS

[z]NS: Not significant

Table 5. Effect of Paclobutrazol applied in the spring (at 200 ppm on 15 May 2002) on flowering and vegetative shoots produced the following season on the spring and summer shoots of 2002. Data were taken at the date of maximum flowering of the year 2003.

Treatment	Number of nodes/Shoot type produced in 2002		Number of vegetative shoots/100 nodes		Number of inflorescences/ 100 nodes		Number of flowers per inflorescence		Number of flowers /100 nodes	
	Spring shoots 2002	Summer shoots 2002	Spring shoots 2002	Summer shoots 2002	Spring shoots 2002	Summer shoots 2002	Spring shoots 2002	Summer shoots 2002	Spring shoots 2002	Summer shoots 2002
Untreated control	9.9	7.7	27	24	25	43	1.7	1.0	38	61
Paclobutrazol	9.6	4.2	28	9	40	38	1.4	0.8	63	74
Significance level[z]	N.S	*	N.S	*	N.S	N.S	N.S	N.S	N.S	N.S

[z] Not significant (NS) or significant at 5% (*)

Flowering, vegetative growth and yield of the following cycle (i.e., year 2003). The year following treatment, the number of vegetative shoots and that of inflorescences per 100 nodes of the previous spring growth were not affected by treatment, nor was the abundance of flowers per 100 nodes (Table 5). However, the number of vegetative shoots born on the summer shoots of the previous cycle was reduced due to a reduction in the number of nodes which correlates with shoot length.

In addition, the following year PP333 reduced spring growth but summer and autumn vegetative growth increased (Tables 6 and 7) indicating that PP333 had a lasting inhibitory effect until the following spring.

Table 6. Effect of Paclobutrazol applied in the spring (at 200 ppm on 15 May 2002) on abundance of vegetative shoots of year 2003 born on spring growth of the year 2002. Date of observation: 16 September 2003. Data are in number of shoots newly born on 100 marked spring shoots of the year 2002.

Treatment	Type of shoot born in 2003		
	Spring	Summer	Autumn
Paclobutrazol	372 ± 19	86 ± 13	28 ± 18
Untreated control	536 ± 38	46 ± 15	8 ± 8
Significance level[z]	***	*	NS

[z] Not significant (NS) or significant at 5% (*) or 0.1% (***)

Table 7. Effect of Paclobutrazol applied in the spring (at 200 ppm on 15 May 2002) on length (in cm) of vegetative shoots born on spring 2002 shoots. Date of observation : 16 September 2003.

Treatment	Type of shoot born in 2003		
	Spring	Summer	Autumn
Paclobutrazol	4.42	3.28	1.63
Untreated control	7.14	2.73	0.24
Significance level[z]	**	N.S	N.S

[z] Not significant (NS) or significant at 1% (**)

An evaluation of the number of fruits born on the vegetative spring shoots of 2002 was performed in September 2003 and it showed that PP333-treated trees had more than 4 times more fruit than the untreated control trees (143 *vs* 30 fruit per 100 spring shoots born in 2002). At harvest, yield obtained from the flowers of the year that followed the treatment was almost tripled for the trees that received PP333 (Table 8). This increase was likely the result of the reduced vegetative growth and the use of carbon and energy by the tree in the production of fruit rather than shoots.

These result show a clear competition between vegetative and generative development and that use of growth inhibitors such as PP333 can manipulate that towards a more balanced situation. Whether this technique can be used to regulate cropping of the 'Nour' Clementine still remains to be demonstrated through additional trials in which effect of PP333 dosage, stage of application etc. can be tested. Effect of this treatment on fruit quality also needs to be assessed.

Table 8. Effect of Paclobutrazol applied in the spring (at 200 ppm on 15 May 2002) on yield and individual fruit weight at harvest. Harvest was done on 18 and 31 Dec. 2003.

Treatments	Yield (kg/tree)	Number of fruits/tree	Fruit weight (g/fruit)
Untreated control	38	491	82
Paclobutrazol	98	1138	87
Significance level[z]	**	**	NS

[z] Not significant (NS) or significant at 1% (**)

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