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Yield and fruit quality of 'Nova' hybrid [*Citrus clementina* hort. ex Tanaka × (*C. reticulata* Blanco × *C. paradisi* Macfad)] and two Clementine varieties (*C. clementina* hort. ex Tanaka) as affected by self- and cross-pollination

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ABSTRACT

Low yields of 'Nova' citrus hybrid are common in single variety plantings (plantings consisting of one variety) due to its sexual self-incompatibility. Self-incompatibility may be overcome by cross-pollination with other compatible varieties. Fruit quality and yield of 'Nova' citrus hybrid as well as of the 'SRA63' and 'Marisol' Clementines, when either they were self-pollinated in single variety plantings or each one of the two Clementine varieties was used as a pollenizer for 'Nova' in mixed plantings (plantings consisting of more than one variety), were investigated. The study was carried out for two successive years under the same environmental and cultural conditions using three single variety plantings ('Nova' × 'Nova', 'SRA63' × 'SRA63', 'Marisol' × 'Marisol') and two mixed plantings ('Nova' × 'SRA63', 'Nova' × 'Marisol').

Cross-pollination of 'Nova' with either 'SRA63' or 'Marisol' significantly increased fruit yield of 'Nova' trees and mean fresh weight of 'Nova' fruits without affecting the other fruit quality parameters [rind thickness, percentage of juice, concentration of total soluble solids (TSS) and total acids (TA) in the juice, and TSS/TA ratio). Although the number of seeds per each 'Nova' fruit significantly increased due to cross-pollination (from 0.7 in 'Nova' × 'Nova' planting to 1.8 and 2.1 in 'Nova' × 'Marisol' and 'Nova' × 'SRA63' plantings, respectively), it remained in a range ($\leq$2.1) which is by far acceptable in the fresh fruit market. On the other hand, each fruit produced by cross-pollinated 'Marisol' and 'SRA63' trees with 'Nova' contained an average of 2.4 and 18.6 seeds, respectively. The effects of 'Nova' pollen on the other fruit quality parameters (weight, TSS, TA, TSS/TA, juice content, rind thickness) of 'Marisol' and 'SRA63' were not significant. Therefore, 'Marisol' was proved to be a good pollenizer for 'Nova' and vice versa. Furthermore, 'SRA63' can be used as pollenizer in 'Nova' orchards. Instead, the use of 'Nova' trees as pollenizers in 'SRA63' orchards should be avoided since the seediness of 'SRA63' fruits was increased very much.

1. Introduction

'Nova' (or 'Clemenville') is a valuable citrus hybrid which produces seedless fruits of high quality preferred in the European fresh fruit market. The value of this variety has been increasing rapidly in the last years, but the mean fruit yield per tree remains low. This is mostly due to the fact that fruit set of 'Nova' trees is low, when they were cultivated in solid plantings. Indeed, 'Nova' is self-incompatible and weakly parthenocarpic variety (Hearn, 1969; Barry and Bower, 1997; Yamamoto et al., 2006). Many researchers (De Lange et al., 1974; Burger, 1985; Vithanage, 1991; Burdette, 1993; Futch and Jackson, 2003; Chao, 2005), however, reported that using appropriate pollenizers is one of the most efficient and environmental-friendly agricultural practice to improve yield and fruit quality of self-incompatible citrus varieties, such as 'Nova'. Self-incompatibility of Clementine varieties was also reported in very early works (Soost, 1956).

The aim of this study was to investigate the yield and fruit quality of 'Nova' citrus hybrid as well as of 'SRA63' and 'Marisol' Clementines when they were self-pollinated in solid plantings or cross-pollinated in mixed variety plantings.

2. Materials and methods

2.1. Plant material and growth conditions

Five orchards consisting of ten-year-old mandarin trees grafted on Swingle citrumelo rootstock (*Poncirus trifoliata* L. × *Citrus*

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paradisi Macf.) were employed in this study. All the experimental orchards were located in the area of 'Galatas' village (Chania, Crete). 'SRA63' Clementine (*C. clementina* hort. ex Tan.), 'Marisol' Clementine (*C. clementina* hort. ex Tan.) and 'Nova' hybrid [*C. clementina* hort. ex Tan. × (*C. reticulata* Blanco × *C. paradisi* Macf.)] were cultivated in three isolated one variety orchards. The combinations between 'Nova' and either 'SRA63' or 'Marisol' were also cultivated in each of the other two orchards as two varieties plantings. In these cases, the proportion between the main variety ('Nova') and the pollenizer ('SRA63' or 'Marisol') was 2:1, i.e., two rows of 'Nova' trees were followed by one row of 'SRA63' or 'Marisol' trees. In all the experimental plantings, the trees were planted at a spacing of 5 x 5 m. Furthermore, the cultivation practices (drip irrigation, fertilization program, etc.) applied to all experimental trees were exactly the same. As far as the soil properties of the five orchards are concerned, they were classified as L (loamy) or SL (sandy loam) and contained 7–12% free $CaCO_3$. Their pH values (soil:water, 1:2) ranged from 7.3 to 7.7 and the electrical conductivity of their saturation extracts from 1.1–1.5 dS m^{-1}. The mean maximum temperature of the experimental area ranged from 13.6 °C in January to 29.3 °C in July, and the mean minimum temperature from 5.9 °C (January) to 14.7 °C (August).

2.2. Fruit sampling and chemical analysis

The fruit sampling procedure was exactly the same for all cultivars and plantings. Samples consisting of fifteen fruits each were randomly collected form each one of 6 trees (totally, 90 fruits) of each variety cultivated in each orchard. The fruit samples were collected at mid-November of the two successive years. Consequently, the fruits were weighed and their juice was extracted. Afterwards, the concentration of total soluble solids (TSS) of the juice was determined with a temperature-compensated refractometer at 20 °C (PR-1 Digital Refractometer, Atago Co Ltd., Japan), while that of total acids (TA) was assessed by titration with 0.1 N NaOH using phenolphthalein as an indicator. The ratio of TSS/TA was also calculated. Finally, the total fruit yield per tree, the mean fresh fruit weight, the rind thickness and the number of seeds per fruit was measured.

2.3. Statistics

The data were analyzed using the SPSS 11.0.1 for Windows statistical package (SPSS, Inc., Chicago, U.S.A.). For comparison of the means, Student's *t*-test and Duncan's multiple range test, both for $P \leq 0.05$, were employed.

3. Results

The total yield per tree and the various fruit quality parameters of 'Nova' in relation to self- and cross-pollination with either 'SRA63' or 'Marisol' are presented in Table 1. Based on two years' data, the average fresh weight of 'Nova' fruits was significantly greater in both the two mixed orchards studied ['Nova' × 'Marisol' (121.09 g), 'Nova' × 'SRA63' (127.45 g)] than in the orchard consisting of 'Nova' trees only (107.64 g). The same was also observed concerning the total fruit load per 'Nova' tree ['Nova' × 'SRA63' (82.98 kg), 'Nova' × 'Marisol' (79.39 kg), 'Nova' × 'Nova' (65.78 kg)]. Furthermore, cross-pollination resulted in a significant increase of the number of seeds per 'Nova' fruit ['Nova' × 'SRA63' (2.10), 'Nova' × 'Marisol' (1.76), 'Nova' × 'Nova' (0.72)]. However, the values of the other quality parameters (TSS, TA, TSS/TA, rind thickness and percentage of juice) of 'Nova' fruits did not show any significant alteration due to a different pollen source used (Table 1). Finally, the split incidence in 'Nova' fruits varied between 7 and 9% both in single- and mixed-variety orchards (data not shown).

Table 1
Yield and fruit quality parameters of 'Nova' mandarin trees grown in single variety ('Nova' × 'Nova') or mixed variety ('Nova' × 'Marisol', 'Nova' × 'SRA63') plantings during the 1st and 2nd year of the study.

Parameter	Varieties' combination	1st year	2nd year	Average
Yield (kg)	'Nova' × 'Marisol'	80.35b	78.48b	79.39b
	'Nova' × 'SRA63'	84.63b	81.25b	82.98b
	'Nova' × 'Nova'	64.82a	66.74a	65.78a
TSS (%)	'Nova' × 'Marisol'	13.04a	12.40a	12.69a
	'Nova' × 'SRA63'	12.02a	12.04a	12.03a
	'Nova' × 'Nova'	13.06a	11.93a	12.45a
TA (%)	'Nova' × 'Marisol'	1.13a	1.11a	1.12a
	'Nova' × 'SRA63'	1.02a	0.99a	1.01a
	'Nova' × 'Nova'	1.09a	1.00a	1.04a
TSS/TA[a]	'Nova' × 'Marisol'	11.80a	11.32a	11.54a
	'Nova' × 'SRA63'	11.76a	12.19a	11.99a
	'Nova' × 'Nova'	12.11a	11.98a	12.04a
Juice (%)	'Nova' × 'Marisol'	54.34a	46.33a	50.35a
	'Nova' × 'SRA63'	53.54a	47.27a	50.41a
	'Nova' × 'Nova'	52.80a	48.00a	50.39a
Fruit weight (g)	'Nova' × 'Marisol'	124.20b	118.50a	121.09b
	'Nova' × 'SRA63'	122.80b	131.33b	127.45b
	'Nova' × 'Nova'	99.60a	114.33a	107.64a
Rind thickness (mm)	'Nova' × 'Marisol'	5.86a	2.00a	3.75a
	'Nova' × 'SRA63'	2.01a	1.90a	1.95a
	'Nova' × 'Nova'	1.94a	1.87a	1.90a
Seeds per fruit	'Nova' × 'Marisol'	0.88b	2.50b	1.76b
	'Nova' × 'SRA63'	1.54c	2.57b	2.10b
	'Nova' × 'Nova'	0.00a	1.32a	0.72a

$n = 6$; within the same column, means of each parameter with the same letter(s) do not differ significantly from each other at $P \leq 0.05$ (Duncan's multiple range test).
[a] Rounding off causes TSS/TA values to differ from actual ratio values.

The statistical analysis of the data obtained from the two years of the present study indicated that cross-pollination of 'SRA63' (Table 2) and 'Marisol' (Table 3) with 'Nova' did not affect either the total yield per tree or the most of fruit quality parameters determined (weight, TSS, TA, TSS/TA, juice content, rind thickness) for none of the two Clementine varieties. However, cross-pollination caused a significant increase in the number of seeds per fruit of 'Marisol' (2.39) and 'SRA63' (18.55). The mean seed number in 'Marisol' and 'SRA63' fruits was 0.90 and 1.35, respectively, when each one of these two varieties was cultivated in an isolated solid planting (Tables 2 and 3).

Table 4 presents statistics about the mean values of all parameters for all cultivars' combinations during the two years of the study in order to investigate whether there were significant differences among cultivars. It was found that the concentrations of total soluble solids (TSS) in the juice of 'Nova' fruits (12.03–12.69%) were significantly greater than those of the two Clementine varieties (10.00–10.66%), irrespective of the pollenizer. The average weight per 'Nova' (107.64–127.45 g) and 'Marisol' fruit (113.45–123.09 g) was significantly greater compared to 'SRA63' (76.28–84.80 g), irrespective of the pollen source. Furthermore, significantly greater juice content was found in 'Nova' fruits than in 'Marisol' and 'SRA63' fruits, both in single- and mixed-variety plantings. As far as the single variety plantings ('Nova' × 'Nova', 'Marisol' × 'Marisol' and 'SRA63' × 'SRA63') is concerned, 'SRA63' trees produced significantly higher yields than 'Marisol', and 'Marisol' than 'Nova'. Finally, no significant differences among the three studied cultivars were recorded concerning the number of seeds per fruit, the rind thickness, the concentration of total acids (TA) as well as the TSS/TA ratio (Table 4).