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Prebloom Foliar Urea Application Increases Fruit Set, Size, and Yield of Clementine Mandarin

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Abstract. **'Clementine' mandarin (*Citrus clementina* Hort. ex Tan.) is self incompatible and has low fruit setting ability and undergoes severe alternate-bearing. Urea has been shown to increase flowering and fruit set and yield in several fruit species. In this study, locally available urea (containing 46% N) was applied as foliar spray to 'Nour' clementine mandarin at flower initiation/differentiation. The rates tested were 0.8% and 1.6% (w/v) urea in 10 L of water per tree (i.e., to supply 37 and 74 g N/tree, respectively). A significant increase in yield was obtained particularly for treatments applied in January. Yield increase was due to an increase in fruit number and size. As a consequence, export yield was increased and more fruit were harvested at the first harvest date. Urea concentration within the ranges tested had no effect on tree response in October or November, whereas in December and January greater yield was obtained at 1.6% urea. Application of urea at 0.8% and 1.6% was compared with a soil application of ammonium nitrate which supplied 75 or 150 g N/tree to 'Cadoux' clementine trees at prebloom. Total and export yields were similar for the four N treatments. In addition, trees that received these N treatments had similar number and size of fruit at harvest. Urea is a very efficient way to supply N to 'Nour' clementine trees and should be included in fertilizer programs to supply, at least partially, the N needs of the trees during periods of high demand, thus reducing the risk of soil and groundwater pollution.**

Lord and Eckard (1987) demonstrated that flower initiation in navel orange [*Citrus sinesis* (L.) Osb.] occurred before the end of January, flowering in February to early March, physiological drop in late April to early July and fruit growth from July to November. For clementine mandarin grown in Morocco, Nadori et al. (1998) and Ben Ismail and Bentabet (1998) showed that flower initiation and differentiation occurred before the end of January but intensity level varied from year-to-year (Nadori et al., 1998). Flowering occurred from the end of February to early April and its timing and intensity varied with climatic conditions that prevailed during the fall/winter months.

In citrus as is the case in most of the other tree fruit species, a certain amount of N is necessary for optimum and regular year-to-year yields. Embleton and Jones (1974) reported that for a fully grown orange tree these annual quantities are in the range of 0.45 to 0.60 kg N/tree. Davies and Albrigo (1994) indicated that of all elements, N has the greatest effect on tree growth and yields. It increases yields primarily by increasing fruit number rather than fruit size, and trees receiving optimum N are more densely foliated and produce more flowers than N-deficient trees. Excessive N is not economically justified and may contaminate soil and groundwater. In a production system where optimization of imputs is the rule, N supply should coincide with the period of tree needs using an efficient method to minimize N loss and avoid/reduce soil, water and environmental pollution.

Sharples and Hilgeman (1969) demonstrated that supply of N in the form of urea at specifically targeted developmental stages increased yield of 'Valencia' orange. A similar conclusion was made by Embleton and Jones (1974). However, this technique of supplying N to the trees was not used in a large scale in many countries particularly because early research experiments used urea containing phytotoxic levels of biuret. Furthermore, several spays are often necessary to supply the necessary N to attain economically viable yields.

With recent work by Lovatt et al. in California (Lovatt et al., 1988; Ali and Lovatt, 1994) and the progress made in production of urea with a low biuret content, N supply to the tree via foliar application has regained interest. In fact, Ali and Lovatt (1994) showed that for 'Washington' navel orange, foliar urea sprays during the period from November-to-February (i.e., flower initiation/differentiation) significantly increased yield through an increase in fruit number without any effect on fruit size. In addition, Lovatt (1999) reported that on navel orange trees, foliar urea sprays at full bloom and at physiological drop increased fruit number, and total yield.

In an earlier report, we have shown that foliar urea sprays (at 0.8% to 1.6% w/v) on clementine mandarin during the period the end of October to January increased total number of inflorescences particularly when the application is made during the period of end of November to January (El-Otmani et al., 1998a). These treatments also increased the number of leafy (number of leaves ≥ number of flowers), as well as of leafless (number of leaves < number of flowers) inflorescences and fruit set (El-Otmani et al., 1998a, 1998b; Tadili, 1995). In this paper, we present information and data regarding the effect of urea treatments on yield and fruit size of 'Nour' clementine mandarin and on the efficacy of foliar urea as a source of N compared to soil application of similar quantities of N using ammonium nitrate.

Materials and Methods

Trial of 1994–95. The study was carried out in a grove located in the Souss valley area where average minimum and maximum temperature is 13.8 °C and 25.4 °C, respectively.

Trees of 'Nour' clementine (*Citrus clementina* Hort. ex Tan.) topworked onto 'Cadoux' clementine in 1990 which was grafted onto sour orange rootstock (*Citrus aurantium* L.) and planted in 1996 at a spacing of 5 × 5 m were used. They were uniform in size and showed no symptoms of nutritional deficiency, disease, or insect damage. They received cultural practices that are optimal of the region.

Commercially available urea (containing 46% N) was used at 0.8% and 1.6% w/v and applied as a foliar spray ≈ 10 L/tree on 31 Oct., 28 Nov., and 26 Dec. 1994, and 23 Jan. 1995 at the flower initiation/differentiation stage. For each date, control untreated trees were used for comparison. The urea treatments were used to supplement routinely applied fertilizer.

Because clementine fruits do not all mature at the same time, three harvests were made based essentially on color and size: 29 Dec. 1995, 11 Jan. 1996, and 4 Feb. 1996. For each harvest, yield, commercial fruit size, and export yield (i.e., fruit of diameter 51 mm) were determined.

It is noteworthy that prior to treatment, leaf N content was ≈ 1.9%. Forty-eight hours after treatment, leaf N was 2.3% and 2.5% for urea treatments at 0.8% and 1.6% (w/v), respectively (El-Hila, 1996).

Table 1. Treatment composition and time of application.

Treatment	Quantity per tree	Quantity of N/tree (g)	Date of application
Untreated control	0	0	-
Urea (0.8% w/v)	10 L of spray mix	37 N	3 Feb. 1997
Urea (1.6% w/v)	10 L of spray mix	74 N	3 Feb. 1997
Ammonium nitrate	225 g	75 N	3 Feb. 1997
Ammonium nitrate +Ammonium nitrate	225 g + 225 g	75 N + 75 N	3 Feb. 1997 + 19 Feb. 1997

Trial of 1997–98. In this trial trees of 'Cadoux' clementine grafted onto sour orange rootstock and planted in 1967 at a spacing of 6 × 6 m were used. Commercially available urea (containing 46% N) was used at 0.8% and 1.6% (w/v) and each tree received an average of 10 L of the spray mix (i.e., 37 and 74 g of N, respectively). Treatments were applied prebloom on 3 Feb. 1997 as a foliar spray. Nitrogen was also applied to the soil using microsprinklers to another group of trees using ammonium nitrate containing 33% N as the N source. In this case, N was applied at 75 g as a one-time application, and at 150 g split into two applications supplied at 2-week intervals (Table 1).

Because clementine fruit on a given tree does not mature and color at the same time, three harvests (30 Nov. 10 and 22 Dec. 1997) were made for each trial based on fruit size and color. Fruit were then taken to a packinghouse where its size distribution was obtained using a precalibrated packingline and commercial size classes.

It is noteworthy that leaf N was 1.95% prior to treatment application. Forty-eight hours after treatment, leaf N was 2.07%, 2.20%, and 2.27% after treatment application, respectively, for 0.8% urea, 1.6% urea, and ammonium nitrate applied twice, respectively (El Moufid, 1998).

Experimental design and data analyses. Trees were of comparable size and free of any visible symptoms of insect or pathogen attack and of any visible signs of nutritional deficiencies. Treatments were assigned to tree rows at random. A completely randomized design was used for the two experiments with 6 one-tree replications for the 1994–95 trial and 16 one-tree replications for the 1997–98 trial. Data were subjected to an analysis of variance and mean separation was performed using the Newman–Keuls test at the 5% level. An arcsin transformation was applied to percentage data prior to subjecting it to an analysis of variance.

Results

Effect of timing of urea application on yield. Urea significantly increased yield of 'Nour' clementine regardless of treatment date (Table 2); however, treatments applied at the end of January produced the greatest increase followed by the December applications. At these two dates, the 1.6% concentration produced the greatest effect, whereas for the October and November dates, the 0.8% and 1.6% were equally effective.

The 1997–98 trial on 'Cadoux' clementine showed that the increase in yield was due to an increase in fruit number and in size (Table 3).

Effect of urea on earliness of harvest and export yield. Export yield was significantly increased as a result of urea spray. with the 1.6% concentration having greatest effect for 'Nour' (Table 4). Urea concentration had no effect on export yield 'Cadou' clementine (Table 3). In addition, urea enhanced earliness of harvest as more fruit (in absolute numbers and in percent total yield) was harvested at the first harvest date for both treatment dates (Table 5). For 'Cadoux', export yield was at least doubled as a result of urea application with no significant difference between yield related to urea concentration (Table 3). More fruit (in kg/tree but not in percent total yield) was harvested at the first harvest date for urea-treated trees compared to untreated ones (Table 6).

Comparison between effects of N supplied as foliar urea and N applied as ammonium nitrate through the soil. Nitrogen applied to the soil during the prebloom increased yield (Table 3). This increase is a result of an increase in number of fruit per tree and in fruit size. Consequently, export yield was also increased. In addition, ammonium nitrate treatment supplying 150 g N/tree gave similar results to ammonium nitrate supplying 75 g N/tree which in turn gave identical results to urea treatment supplying either 74 g N/tree or 37 g N/tree (Table 3).

Discussion

Increased yield of clementine mandarin as a result of urea foliar application supports our previous results. In particular, this increase is primarily the result of increased fruit number per tree which is the

Table 2. Effect of urea applied during flower initiation/differentiation on yield of 'Nour' clementine mandarin.

Urea Concentration	Date of application (kg/tree)			
	10 Dec. 1994	28 Nov. 1994	26 Dec. 1994	23 Jan. 1995
0%	72.8 b[z]	68.6 b	79.3 c	86.3 c
0.8%	77.1 ab	75.0 a	88.4 b	113.8 b
1.6%	81.4 a	77.4 a	99.9 a	134.0 a
Level of significance	0	0	0	***

*, ** significant at (*) P ≤ 0.05 or (**) P ≤ 0.01

[z]Means within columns followed by the same letter are not significantly different by Newman-Keuls test.

Table 3. Effect of urea and ammonium nitrate applied pre-bloom on yield and export yield and fruit size for 'Cadoux' clementine mandarin.

Treatment	Total yield (kg/tree)	Fruit per tree (no.)	Fruit wt. (g)	Export yield (kg/tree)
Control (untreated)	43.2 b[z]	791 b	54.5 b	27.1 b
Urea (0.8% w/v)	75.6 a	1165 a	64.8 a	55.8 a
Urea (1.6% w/v)	87.7 a	1359 a	64.5 a	58.0 a
Amm. nitrate (225 g)	85.2 a	1279 a	66.6 a	61.1 a
Amm. nitrate (2 x 225 g)	89.4 a	1295 a	69.0 a	63.7 a
Sig.. level	***	***	***	***

*, ** significant at (*) P ≤ 0.05 or (**) P ≤ 0.01

[z]Means within columns followed by the same letter are not significantly different by Newman-Keuls test.

Table 4 . Effect of urea applied during flower initiation/differentiation on export yield (i.e., fruit with diameter > 51 mm) for 'Nour' clementine mandarin. Data within parentheses indicate percent of total yield.

Urea Concentration	Date of application	
	26 Dec. 1994	23 Jan. 1995
0%	68.5 c[z] (86)	62.1 c (72)
0.8%	73.6 b (83)	72.6 b (64)
1.6%	76.6 a (77)	81.5 a (61)
Sig. level	0	0

*, ** significant at (*) $P \leq 0.05$ or (**) $P \leq 0.01$.

[z]Means within columns followed by the same letter are not significantly different by Newman-Keuls test.

Table 5. Effect of urea application during flower initiation/differentiation on the distribution of yield among harvest dates (in percent of total yield) for 'Nour' clementine mandarin.

Date of application	Concentration of urea	Date of harvest		
		29 Dec. 1995	11 Jan. 1996	4 Feb. 1996
26 Dec. 1994	0.0%	31.4 b[z]	34.7 a	33.9 a
	0.8%	45.8 a	31.7 b	22.2 b
	1.6%	45.8 a	31.1 b	23.1 b
	Sig. Level	*	*	*
23 Jan. 1995	0.0%	29.1 b	30.6 b	40.3 a
	0.8%	42.8 a	33.0 b	24.2 b
	1.6%	44.4 a	36.7 a	18.9 c
	Sig. level	**	*	**

*, ** significant at (*) $P \leq 0.05$ or (**) $P \leq 0.01$.

[z]Means within columns followed by the same letter are not significantly different by Newman-Keuls test.

Table 6. Effect of urea and ammonium nitrate applied pre-bloom on yield for each harvest date of 'Cadoux' clementine mandarin.

Treatment	Harvest date		
	30 Nov. 1997	10 Dec. 1997 (kg/tree)	22 Dec. 1997
Control (untreated)	19.3 (45)	16.8 (39)	7.1 (16)
Urea (0.8% w/v)	22.7 (30)	41.7 (55)	11.2 (15)
Urea (1.6% w/v)	34.2 (39)	44.3 (50)	9.2 (11)
Amm. nitrate (225/tree)	31.3 (37)	44.0 (52)	9.9 (11)
Amm. nitrate (2 x 225 g/tree)	40.9 (46)	40.7 (45)	7.8 (9)

consequence of improved inflorescence and flower numbers and fruit set (El-Otmani et al., 1998a, 1998b, 2000a, 2000b). Ali and Lovatt (1992) and Lovatt (1999) demonstrated that urea application to navel orange trees during fall/winter months increased yield as a result of increased flower initiation and fruit set.

Foliar urea (37 g N/tree) produced similar effects as 75 or 150 g N/tree supplied to the soil as ammonium nitrate. This indicates that urea is a much more efficient form of citrus N fertilization particularly in periods of low soil temperatures and, thus, of low root activity and nutrient absorption. In addition, urea had a significantly greater effect on flowering and yield for trees that were in the "off year" cycle (El-Otmani et al., 1998a).

In conclusion, foliar urea is an efficient method of citrus nutrition and, therefore, should be part of grove fertilization programs particularly in situations where root activity and mineral absorption are restricted. It is also a technique that can be used to enhance flowering during the expected "off year", particularly in cultivars that have alternate bearing or those that have low flowering intensity such as some clementine selections. In addition, use of urea as a source of N would significantly reduce the risk of soil, water, and environmental pollution.

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