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EFFECTS OF FOLIAR APPLICATIONS OF UREA OR NUTRIPHITE ON FLOWERING AND YIELDS OF VALENCIA ORANGE TREES

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Abstract. Valencia orange yields have been related to the number of flowers in the spring bloom, and the number of induced flower buds is determined by climatic stress factors such as cold and drought. Winter foliar sprays of urea have been reported to enhance the number of flower buds, flowers per inflorescence and yields under California conditions. Sprays of urea (28-31 kg N/ha) or Nutriphite (6.1 l/ha of 0-28-26 product) were applied to mature Valencia trees in two locations in South Florida in 1994-95. Urea or Nutriphite applied between the dates of 25 Dec. and 11 Jan. increased flowers. With continued annual treatment for 4 yr, Nutriphite treatment increased yields whether applied annually in the winter or later, just before full bloom. Winter urea sprays on the same plots for 4 consecutive years significantly increased yields. Orange juice soluble solids per ha were increased by both treatments when compared to the control plots. Possible mechanisms for these yield responses are discussed.

Valencia orange yields can be closely related to total flowers in the spring bloom even though most of the flowers do not set fruit that remain until harvest (Moss, 1971). Climatic stress factors such as cold and drought (Davies and Albrigo, 1994; Davenport, 1990) are natural inducers of flower buds in citrus. In Florida, winter temperatures may not be adequate to induce maximum flowering every year. Foliar sprays of urea have been reported to enhance the number of flower buds, flowers per inflorescence and yields under California winter conditions (Lovatt et al., 1988; Ali and Lovatt, 1992). Whether this is due to short-term ammonium or urea concentration stress due to phytotoxicity (Krogmeier et al., 1989) in the buds or leaves or due to nutritional enhancement factors (Lovatt et al., 1988) was not clear. Timing of applications or other factors may be critical as Rabe (1994) was not able to duplicate this response in South Africa. Competition for the carbohydrate supply may also limit flower bud formation (Moss, 1971; Ruiz and Guardiola, 1994; Spiegel-Roy and Goldschmidt, 1996). After flower bud differentiation starts, the trees may not be able to translocate sufficient major nutrients (N, P, K) for the needs of up to

50,000 to 100,000 flowers/tree (Erickson and Brannaman, 1960). Nutrition could influence the number of flowers and fruit set. Work in Spain has demonstrated a depletion of N, P, and K of old leaves during the flowering and fruit set periods along with a large increase in nutrients in new leaves and setting fruit (Sanz et al., 1987; Ruiz and Guardiola, 1994). It is not known if nutrient competition occurs prior to flowering during the flower bud differentiation and expansion period.

Commercial forms of N (Lea-Cox and Syvertsen, 1995) and K (Albrigo, unpublished data) that are readily absorbed by leaves are available and can increase foliage and fruitlet nutrients shortly after spray application. Suitable sources of phosphate for foliar feeding other crops have been reported (Barel and Black, 1979), but have not been determined for citrus. Phosphorous acid ($H_2(HPO_3)$) is taken up by plants (Smillie et al., 1989), is highly mobile (d'Arey-Lameta, and Rompeix, 1991) and if buffered with KOH or KCO_3 is a source of K. HPO_3^{-2} is reportedly phytotoxic (MacIntire et al., 1950; Forster et al., 1998; Lucas et al., 1979), can result in poor plant growth for one year after soil application (MacIntire et al., 1950), and is slowly converted to PO_4 in soils (Adams and Conrad, 1953). Phosphite appears to interfere with PO_4 metabolism also (Griffith et al., 1990; Carswell et al., 1996). Although PO_3 and its derivative (Aliette) can be phytotoxic to citrus at higher concentrations (Albrigo and Grosser, 1996), they are active as fungicides and alter several phases of fungal or plant metabolism (Smillie et al., 1989; Saindrenan et al., 1988).

The purpose of this work was to examine whether flowers and yields of Valencia oranges in Florida can be increased by induction period sprays of urea or by buffered HPO_3^{-2} sprays. Additionally, data are reported on effects from bloom sprays of Nutriphite on flowering, fruitlet set, and yield.

Materials and Methods

Trees were selected at two locations in Florida on shallow, bedded flatwoods soils with 'Valencia', a moderate yielding alternate bearer, as the test cultivar. Four grove blocks of trees at an Immokalee, FL site were divided into three nearly equal groups. In each block a none sprayed control, a urea sprayed, and a Nutriphite sprayed plot were randomly selected. At a second farm south of Lake Placid, six grove blocks of Valencia trees were selected in two separate areas for two additional replications of the three treatments. Grove blocks for each replicate were selected on the basis of proximity, uniform trees size, previous yields, similar age and rootstock. This was a factorial design with three treatments in six blocks over 4 yr. In this test, the treated trees were first sprayed in late Dec. 1993 or early Jan. 1994 with 31 kg/ha N as urea or with 4.8 l/ha of a 0-40-0 phosphorous acid product buffered on-site with KOH to pH 7). In the second year, Nutriphite (6.1 l/ha of 0-28-26) was applied at 5-10% open bloom according to a protocol agree-

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ment. In the third and fourth years, the bloom timing of the Nutriphite was continued in four blocks (Immokalee), but winter timing was reinstituted in the two plots at the Lake Placid site. Details of each site location, plot size, and treatments are as follows:

Immokalee (Flatwoods)—Valencias (10 yr old) in four blocks were divided into controls, urea, and Nutriphite plots of 4.1 to 11.5 ha in each block to give four replications. In the first season of tests, treatment sprays were applied on 29 Dec. 1993. Nutriphite plots were sprayed at 5 to 10% open flowers in the second through fourth years, while the urea was sprayed each year from 25-31 Dec.

Lake Placid (Flatwoods)—Valencias (12 yr old) blocks were selected for two replications of control, urea, and Nutriphite plots of 6.5 to 13.3 ha in each block. In the first season of tests sprays were applied from 7-11 Jan. 1994. All Nutriphite plots were sprayed at 5 to 10% open flowers in yr 2, but were changed back to winter, late December, applications for the third and fourth years.

Flowering and fruitlets were counted in G m² frames from the surface to the center of the tree. Six frame counts were done in three pairs of trees on opposite sides of the drive middle in each of four beds evenly spaced across each plot (24 counts/plot on healthy, average sized trees). Counts were made within the frame to the tree trunk at two thirds of tree height. This position approximately represents the average fruit distribution in the tree (Albrigo et al., 1975; Albrigo, unpublished data). Frame positions were marked around the edges with white paint. Counts were taken of remaining fruit in these same frame areas after the May-June drop. The frame counts were accumulated per bed and statistically analyzed as four nested samples per plot in the factorial design, of three treatments, in six blocks and for 4 yr. Each plot was harvested for total yield and soluble solids per ha was obtained for the Lake Placid plots. All data was subjected to ANOVAR by a SAS statistical package with Duncan's multiple regression for appropriate comparisons (SAS VMS, SAS Institute, Cary, NC 27511 USA). Individual years were looked at in a two-way ANOVAR with nested data for frame counts.

Results and Discussion

In 1994-95, urea and Nutriphite significantly increased flowers/frame for the Immokalee location (Table 1). Nutriphite plot yields in boxes per ha were greater than the controls but not significantly greater than the urea treatment. Flower counts were higher for treatments at the second location compared to the control, but the difference was not significant (not shown). This increase in flowers and yield agrees with the findings of Lovatt et al. (1988), and Ali and Lovatt (1992), for winter foliar sprays of urea on navel oranges in California. Valencia trees have fewer blooms than navels (Erickson and Brannaman, 1960) and, therefore, would be expected to benefit more from such treatments. Moss (1971) related flower number to yield of Valencia orange trees. The timing of these winter sprays under Florida conditions may be more critical than in California as differentiation begins, usually by late January

Table 1. Total flowers and fruitlets (post-drop) per six frames (one bed's count) and yields in 40.9 kg boxes/ha (boxes/ac) for Valencia trees near Immokalee, Florida for 1994-95 following winter applications of foliar urea or nutriphite (four replications).

Treatments	Flowers/6 frames	Fruitlets/6 frames	Yield boxes/ha (/ac)
Control	1438 a	97	1146 a (464)
Urea	2092 b	97	1225 ab (496)
Nutriphite	2345 b	103	1334 b (540)

(Abbott, 1935), but in some years some differentiation can start as early as December and often begins by the first week in January. Lovatt et al. (1988) reported that some natural induction was required before the foliar urea spray would work. If differentiation of most flower buds had already begun when the spray was applied, urea could only benefit ovary growth through N nutrition, which might still enhance fruit set as larger, stronger fruitlets are more likely to set (Albrigo, unpublished data). A possible reason for the lack of response in South Africa (Rabe, 1994) may be that the application was too late in the winter, after the induction to differentiation transition had begun.

In spite of the apparent relationship between flower density and yields in 1994-95, the frame count replicates used in this study did not detect an increase in fruit set after the May-June drop period (Table 1). These counts/frame were small (mean = 10) and probably too variable to detect any differences, whereas the bloom counts were much higher (ct/frame = >260).

In 1995-96, the two locations (six reps) received Nutriphite at bloom and the urea was still applied in the winter. Flower and fruitlet counts were not significantly different for any treatments in this second year (Table 2), nor were yields (Table 3). The Nutriphite treatment application at bloom in the second year was too late to affect flower numbers. Although no significant response was detected, it is important that the yields for both the urea and Nutriphite treatments were not lower than the controls in the second year (Table 3), in spite of the treatment plots having increased yields the previous year which were significantly greater for Nutriphite. This indicates that alternate bearing was not increased as compensation for the increase in yield the first year.

In 1996-97 and 1997-98, the Immokalee location with four replications received Nutriphite again at bloom while at the other location Nutriphite was applied in the winter. There was still no significant effect detected on flower or fruitlet numbers by either treatment based on the measurement technique (Table 2). Since yields were significantly higher in both these individual years for

the Nutriphite treatment (Table 3), there should have been signifi-

Table 2. Flower counts and post May-June drop fruitlet counts (flowers or fruitlets per six frames) for Valencia trees for the 1995-96 through 97-98 seasons in two South Florida locations after application of urea in winter or Nutriphite at winter or bloom time.

Treatment	Flowers/Fruitlets per 6 frames		
	Control	Urea	Nutriphite
95-96—Immokalee	1289/35	1195/37	1164/41
96-97—Immokalee	989/74	1103/37	1034/46
97-98—Immokalee	796/76	640/71	374/52
95-96—Lake Placid	1114/16	1156/23	1048/27
96-97—Lake Placid	965/37	1036/46	939/38
97-98—Lake Placid	371/35	459/57	524/56

Table 3. Average yield/year (40.9 kg boxes/ha (boxes/ac)) and average yields for four consecutive years of treatment of Valencia trees in South Florida for two locations with six replications combined.

Treatment	Boxes/ha or boxes/ac ()				
	Year 1	Year 2	Year 3	Year 4	Avg/year
Control	1193 (483) a	892 (361)	1000 (405) a	823 (333) a	978 (396) a
Urea	1289 (522) ab	921 (373)	1107 (448) ab	981 (397) ab	1074 (435) b
Nutriphite	1442 (584) b	968 (392)	1158 (469) b	1030 (417) b	1150 (466) b

cantly higher flower or at least fruitlet counts. It appears that the counting method covered insufficient canopy area of the plots to detect differences after the initial treatment response. Attempts to use covariance analysis in order to adjust for specific previous frame fruit or flower count variance did not result in significant differences in the next flower or fruitlet counts in year 2 through 4.

Even though the Nutriphite treatments were not applied at the same time each year, the 4 yr totals for this and the winter urea treatment on Florida flatwood soils favored the treatments over the control (Table 3). Because the Nutriphite treatment timing of the single application either in the winter or spring did not appear critical (timing averages not shown), all Nutriphite plots regardless of treatment timing for the 4 yr were included in this yield summary. The Nutriphite and urea treatments were numerically higher than the control every year, but only the Nutriphite treatment was significantly different in individual years 1, 3, and 4. Since there was no treatment times year interaction, the main treatment effects were finally analyzed for the four years of the experiment. An alternate bearing effect can be seen in that yields in the second and fourth years are lower, but treatment yields were still equal or greater than the control in those years further indicating that the treatments did not accentuate alternate bearing through 2 cycles.

In spite of initially selecting blocks for uniformity, yield variability was high with 110 to 148 boxes/ha (45 to 60 box/ac) differences required for significance on a yearly basis. Smaller randomized blocks would have been more desirable, but obtaining yields is difficult under Florida citrus harvesting schedules in commercial blocks.

Over the 4 yr for the two replications at the Lake Placid location, the urea and Nutriphite treatments significantly increased soluble solids/ha (SS/ha) over the controls (Table 4). The two treatments were not significantly different in SS/ha, although the Nutriphite treatment produced slightly more boxes/ha each year. The smaller treatment difference may indicate that total carbohydrates available for fruit solids were nearly maximized for both treatments compared to the control. Soluble solids per box were similar

between treatments (not shown). Thus, boxes of fruit were increased through fruit numbers and not fruit size, as larger fruit/box give lower SS/box (Blair, 1966).

The Nutriphite treatments clearly increased yields in boxes/ha for both winter and bloom applications. The first year effect could have been a phytotoxic stress enhancement of the flower bud induction process (Davenport, 1990). Under Florida conditions in the winter of 1993-94, the response had to occur in the time of one or two weeks. In the following years, application at bloom could not have produced this yield response through direct flowering effects. A recent review of use of phosphites as fertilizers gives little support to the concept that PO_3 can be readily converted to PO_4 for quick use by plants in normal phosphorous metabolism (Rickard, 1999), but this concept has not been disproved either. On the other-hand, PO_3 could have produced a number of alternative effects: fungicidal against *Phytophthora* (Smillie et al., 1989), interference with PO_4 metabolism (Carswell et al., 1996), alteration of plant metabolism (Saindrenan et al., 1988), temporary inhibition of vegetative growth (MacIntire et al., 1950; Lucas et al., 1979; Forster et al., 1990). This last possible effect might favor fruit set as the spring flush expansion competes for carbohydrates (Ruiz and Guardiola, 1994) and nutrients (Sanz et al., 1987). HPO_3^{-2} can accumulate in the roots (d'Arey-Lameta and Rompeix, 1991) and might reduce root growth. More carbohydrates and less gibberellic acid would be available which would favor fruit (Spiegel-Roy and Goldschmidt, 1996). All these mechanisms should be examined to ascertain the mode of action of PO_3 . Whatever the mechanism, continuous treatment for four years appeared to have a consistent effect of increasing yields compared to the control.

Over 4 yr with several whole block replications, the increases in yield for both treatments were significantly greater than for the controls without a deleterious effect of accentuating alternate bearing. These treatments appear to be effective for Valencias under Florida flatwood soil conditions. According to Lovatt et al. (1988) for effective use of urea in the winter, sprays need to be applied after some natural induction has occurred but before most differenti-

ation starts. In Florida, in some years, significant induction may not start until late December and in other years some buds may be differentiating by early January (Valiente & Albrigo, unpublished

data). A greater understanding of the induction-differentiation process, particularly in Florida, is needed in order to optimize use of flower bud induction enhancing treatments. Growers attempted to

Table 4. Yield of pounds solids for Valencia oranges on trees treated with urea in late winter or Nutriphite in late winter or at bloom at Lake Placid.

Treatment	kg soluble solids/ha or pounds solids/ac ()				
	Year 1	Year 2	Year 3	Year 4	Avg/year
Control	4027 (3591)	3252 (2900)	3772 (3364)	2749 (2451)	3450 (3077) a
Urea	4309 (3843)	3555 (3170)	3648 (3253)	3490 (3112)	3751 (3345) b
Nutriphite	4196 (3742)	3641 (3247)	3670 (3273)	4102 (3658)	3902(3480) b

use these treatments during the period of the test and since. Many reported satisfactory results during the tests but not during the last 2 yr. These later years had very high spring temperatures and heavy fruitlet drop. Our experiments were not continued into these years and growers usually did not use adequate controls. Still the possibility has to be considered that the potential benefit in increased fruit set from these treatments may not be carried through adverse climatic conditions for fruit set.

Although the increased yield response from the treatments was fairly consistent, particularly for the PO₃, the data for flowers and fruitlets after year one do not show a consistent response. These data may be weak because of too few frame counts of flowers and fruitlets. Never-the-less, we do not have a strong case that the yield response was due to increased flowers and/or fruit set. As noted, the yields were composed of nearly equal sized fruit and therefore the increased boxes/ha were probably due to more fruit/ha.

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