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KNO_3 FOLIAR APPLICATION TO 'SUNBURST' TANGERINE

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Abstract. **A study conducted during the 1997-98 through 2001-02 seasons in a block of 'Sunburst' (*Citrus reticulata* Blanco × *C. paradisi* Macf.) orange located in Indian River County investigated effects of foliar potassium nitrate (KNO_3) sprays on fruit size and yield. The trees were either left untreated or had foliar applications of KNO_3 in February, April, and July. The treatment effects were measured by counting the number of fruit and determining the size distribution for 10 trees in each of four plots at time of harvest. In each season, trees receiving KNO_3 applications had a greater number of larger-sized fruit than control trees. Trees receiving the KNO_3 applications had over 30% more size 100 and larger fruit during the first spot picks in early November of each year. Trees receiving KNO_3 applications averaged $5.00 more per tree during the first spot each year in gross returns due to larger sized fruit compared to control trees.**

The ultimate size a particular fruit may achieve depends on many factors such as: overall fruit load of the tree, rainfall pattern, irrigation practices, fertilization rate and timing, hedging and topping operations, and the rootstock/scion combination. Of these factors, fertilization practices are probably the easiest to manipulate. Leaf K concentrations of 1.2% were reported by Reitz and Koo (1960) to result in high fruit yields of good quality. In contrast, Reitz and Koo (1959) reported decreased yields and small fruit on trees with leaf K contents in the range of 0.5-0.8%. Leaf K concentrations of 1.2-1.7% are now considered optimum for citrus production (Tucker et al., 1995).

While most of the N and K requirements of citrus are typically met through broadcast applications of granular materials or by fertigation, supplemental K applications have been shown to be effective in enhancing fruit size and overall yields in Florida flatwoods citrus. Post-bloom K applications were shown to be effective in increasing average size of both white and colored grapefruit (Boman and Hebb, 1998). Fall applications of K were less effective than post-bloom applications, but they significantly increased the average grapefruit diameter compared to non-sprayed control fruit in about half of the years studied (Boman, 1997). Larger fruit and higher soluble solids per acre were reported by Boman (2001) for 'Valencia' orange treated with dormant, post bloom, and summer K foliar applications as compared to non-treated trees.

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In addition, supplemental K foliar applications have been shown to be an effective method to correct K deficiencies for citrus in calcareous soils (Calvert and Smith, 1972) and to increase leaf K and fruit size while reducing rind disorders (Calvert, 1969). Foliar K sprays can also be used to rapidly increase the K content of leaves compared to ground applications of granular fertilizer materials (Calvert, 1969; Embleton et al., 1969).

The objective of this study was to determine if foliar potassium nitrate (KNO_3) applications during the dormant, post-bloom, and summer time periods could increase the size and returns from 'Sunburst' tangerine (*Citrus reticulata* Blanco x *C. paradisi* Macf.).

Materials and Methods

An experiment was conducted in a commercial citrus grove located in Indian River County, Florida during the 1997-98 through 2001-02 production seasons to evaluate the effectiveness of foliar nutritional sprays on 'Sunburst' tangerine. The block was planted on a Riviera fine sand soil in July 1992 with trees on sour orange (*Citrus aurantium* L.) rootstock. Trees were on 48-ft-wide double- row beds with a 10-ft within-row by 24-ft across-row spacing (181 trees/acre). The block was set up in a repeating pattern of two beds of 'Sunburst' followed by one bed of 'Orlando' tangelo (*C. reticulata Blanco* × *C. paradisi* Macf.). When the experiment began in Feb. 1997, the 'Sunburst' trees were approximately 10 ft tall, with canopies of adjacent trees just beginning to grow together to form hedge rows.

Each plot consisted of one double-row bed. Five uniform across-bed pairs of trees were selected in each plot to represent the plot in yield and leaf tissue sampling. Both the control plots and those receiving foliar KNO_3 applications were replicated four times in a randomized block experimental design. Each bed where data was collected was surrounded on both sides with beds that received the same treatment.

All plots were fertilized with applications of granular materials broadcast in late January or early February, early May, mid-July, and in October or early November each year. Typical applications each year consisted of 2.0 lb/tree of 12-0-10 or 12-0.9-12 (N-P-K) material for the February and July applications, and 2.5 lb/tree of the same materials for the May and October applications. The total N applied each year was 206 lb/acre. Potassium applications varied slightly, with 170 lb/acre of K applied in 1997, 1998, and 1999; 180 lb/acre in 2000; and 202 lb/acre in 2001 (multiply K application rate × 1.21 to get K_2O application rate).

In addition to normal grove fertilization, the challenge treatment (KNO_3) had 25 lb/acre of (KNO_3 added to each of the dormant, post bloom, and summer oil sprays. Typical applications (per acre) were: February dormant spray - 2.5 gal 435 spray oil + 25 lb KNO_3; May post-bloom spray - 7.5 lb Kocide 2000 + 2 lb Vendex + 25 lb KNO_3; July summer oil spray - 7.5 lb Kocide 2000 + 2.5 qt Ethion 4 E + 3 gal 435 spray oil + 25 lb KNO_3. Applications made with a speed sprayer (FMC Corp., Philadelphia, PA) using a 250 gal/acre rate of application.

In each season, 50 spring flush leaves were sampled from each plot in late July or early August following IFAS guidelines

(Tucker et al., 1995). Leaves were washed, dried, ground, and then subsamples were acid-digested for nitrogen analysis and ashed for analysis of other mineral concentrations using standard procedures at the University of Florida, IFAS Analytical Laboratory in Gainesville. During the normal commercial harvest of the block, fruit from 10 trees in each plot were picked and run through a portable optical fruit sizing machine (Autoline, Inc., Reedly, CA). Data collected from each tree included the total number of fruit and the weight and diameter of each individual fruit harvested. The diameter data were used to develop a fruit size distribution curve for each tree. The size distribution curve was used to calculate yield (in boxes per tree) by using a fruit diameter versus packed size regression curve developed from state size standards for fresh fruit.

The value of a fresh fruit crop is determined by the number of fruit in each size category, the price of each size fruit, and the number of eliminations due to peel defects and misshapen fruit. The gross packed value (GPV) for each treatment was calculated by multiplying the number of fruit in each of the commercial size categories by the average FOB price from the Market News Bulletin (Florida Citrus Mutual, 2002) published for the first date following harvest (Table 1). The GPV assumes no grade-lowering defects, no eliminations, and no reductions that would typically be incurred by the grower for items such as pick and haul, drench, elimination charges, marketing, packing charges, taxes, or other charges incurred in fruit harvesting and packing operations. Nevertheless, the GPV can provide relative comparisons between treatments and give an economic indication of the relative potential to increase the producer's net income.

During the 1997-98 season, trees were inadvertently spot-picked in early November, and therefore no yield data were collected. In the 1998-99 season, data was collected from spot picks (size 150 and larger) on 6 Nov. and 30 Nov., and trees were picked clean on 15 Dec. In the 1999-00 season, fruit were spot-picked (size 150 and larger) on 8 Nov. and picked clean on 23 Jan. During the 2000-01 season, trees were inadvertently spot-picked in the last week of October, and therefore no yield data were collected. In the 2001-02 season, yields were obtained from the first spot pick on 29 Oct. In late November, pickers once again moved into the block early and spot-picked experimental plots. Therefore, no additional yield data were collected in the season.

Results

The seasons over which the study was conducted represented very diverse rainfall conditions. Rainfall throughout much of 1997 was well distributed, with little irrigation required. In 1998, nearly 10 inches of rain fell in February and March, followed by below-normal rainfall through July. Overall, rainfall in 1999 was near normal. However, only about 1 inch of rain was received in July. Rainfall in 2000 was lowest in the last 50 yrs in the Indian River area, with a total of only 38 inches (average is 55.7 inches). Irrigation was required throughout the year. The drought continued through the first 5 months of 2001, when less than 10 inches of rain was received. The last half of 2001 had normal or above normal rainfall, resulting in an annual total of 50 inches.

Table 1. FOB prices ($ per 4/5 bushel carton) of 'Sunburst' tangerines as reported by Market News Bulletin for dates corresponding to harvest dates (Florida Citrus Mutual, 2002).

Pack size	1998			1999	2000	2001
	6 Nov.	30 Nov.	15 Dec.	8 Nov.	14 Jan	29 Oct
80	22.52	20.26	19.71	19.78	14.44	20.67
100	20.64	15.64	16.59	17.32	13.39	19.43
120	16.11	13.59	11.88	12.38	11.67	17.08
150	15.85	11.69	10.33	9.20	10.00	13.36
176	8.65	7.63	9.80	7.89	8.33	8.37

Table 2. Size characteristics of 'Sunburst' tangerines for first spot pick on 6 Nov. 1998 (fruit per tree)[z].

Size	Control	KNO_3
>2.94 in (100+)	78 b	104 a
2.69-2.94 in (120s)	157 a	155 a
2.50-2.69 in (150s)	55 a	46 a
Total picked	315 a	325 a
Avg. diameter (in)	2.80 b	2.83 a
GPV[y] ($ per tree)	$40.23 b	$44.58 a

[z]Means with the same letter in the same row are not significantly different according to *t*-test at P = 0.05.
[y]Gross packed value (GPV) calculated using average FOB prices from Florida Citrus Mutual Market News Bulletin for dates following harvest as listed in Table 1.

Mineral analysis of leaves collected from each plot showed no differences in concentrations among treatments. Over the 5 seasons, leaf concentrations averaged 2.3%, 0.12%, 1.2%, and 0.48% for N, P, K, and Mg, respectively. The KNO_3 treatments had slightly higher (but non-significant) Ca concentrations, averaging 6.8% compared to 4.2% for the control treatment trees.

In the first spot pick for size 150 and larger fruit in the 1998-99 season (6 Nov.), about 320 fruit were harvested from both treatments (Table 1). However, the KNO_3 treatment had a greater number of larger-sized fruit, with fruit diameters averaging 2.83 in as compared to 2.80 in for the control (Table 2). There were about 33% more size 100 and larger fruit for the KNO_3 treatment, averaging 26 pieces per tree or about 50 cartons/acre (4/5 bu.). Due to the greater count of larger fruit and the associated higher prices for large fruit, the GPV for the KNO_3 treatment was $4.35 per tree ($790/acre) more than the control treatment.

A little more than 3 weeks after the first spot pick, the block was again spot picked for size 150 and larger fruit. The average diameter of fruit from both treatments for the 30 Nov. harvest was identical, and both produced about the same numbers of fruit in each category (Table 3). The con-

Table 3. Size characteristics of 'Sunburst' tangerines for second spot pick on 30 Nov. 1998 (fruit per tree).[z]

Size	Control	KNO_3
>2.94 in (100+)	24 a	23 a
2.69-2.94 in (120s)	78 a	70 a
2.50-2.69 in(150s)	48 a	46 a
Total picked	187 a	168 b
Avg. diameter (in)	2.70 a	2.70 a
GPV[y] ($ per tree)	$18.04 a	$17.05 a

[z]Means with the same letter in the same row are not significantly different according to *t*-test at P = 0.05.
[y]Gross packed value (GPV) calculated using average FOB prices from Florida Citrus Mutual Market News Bulletin for dates following harvest as listed in Table 1.

Table 4. Size characteristics of 'Sunburst' tangerines for clean pick on 15 Dec. 1998 (fruit per tree).[z]

Size	Control	KNO_3
>2.94 in (100+)	15 a	15 a
2.69-2.94 in (120s)	29 b	41 a
2.50-2.69 in (150s)	81 b	112 a
2.38-2.50 in (176s)	112 a	117 a
2.25-2.38 in (210s)	283 a	262 a
Total picked	668 a	638 a
Avg. diameter (in)	2.29 b	2.33 a
GPV[y] ($ per tree)	$22.90 b	$28.40 a

[z]Means with the same letter in the same row are not significantly different according to *t*-test at P = 0.05.
[y]Gross packed value (GPV) calculated for size 176 and larger fruit using average FOB prices from Florida Citrus Mutual Market News Bulletin for dates following harvest as listed in Table 1.

trol trees had slightly more total pieces of fruit harvested (187 vs. 168 fruit per tree), but the GPV was not significantly different from the KNO_3 treatment.

When the trees were clean picked on 15 Dec., both treatment had about the same number of fruit harvested (Table 4). However the average diameter for the KNO_3 treatment fruit was about 0.04 in greater than for the control treatment. In addition, the KNO_3 treatment had 34% more (0.3 carton per tree or 55 cartons/acre) size 150 and larger fruit harvested. As a result, the GPV for the 23 Jan. harvest was $5.50 per tree ($995/acre) greater for the KNO_3 treatment than the control treatment. For the season, the cumulative GPV advantage for the KNO_3 treatment was $10.84 per tree or $1960/acre (Fig. 1).

The 8 Nov. spot pick (on size 150 and larger fruit) in the 1999-00 season (Table 5) resulted in a larger average fruit diameter for the KNO_3 treatment (2.84 in) as compared to the control treatment (2.78 in). In addition, the KNO_3 treatment had about 40% more fruit that were size 120 and larger (0.24 carton per tree or 43 cartons/acre) than the control treatment. At $23.66 per tree, the GPV for the KNO_3 treatment was $4.61 per tree ($835/acre) more than that for the control treatment.

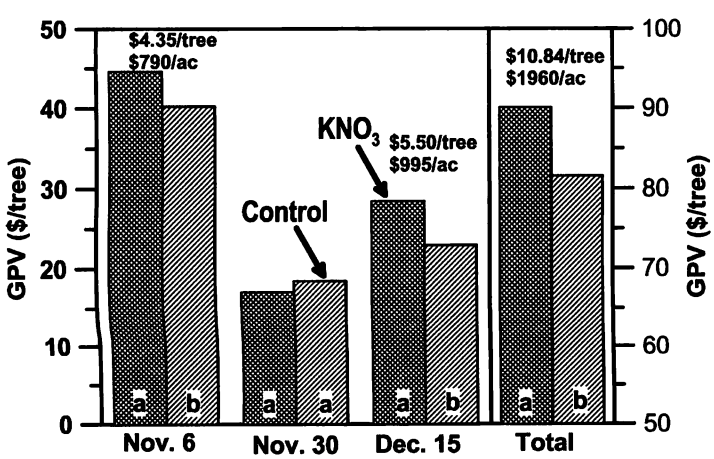

Fig. 1. Gross packed value (GPV) for 1998-99 season with spot picks on 6 Nov. and 30 Nov. and clean pick on 23 Jan., plus season total GPV calculated using average FOB prices listed in Table 1. Bars with the same letter for the same date are not are significantly different according to *t*-test at P = 0.05. For dates where there is a significant difference between treatments, the $ per tree and $ per acre advantage for the KNO_3 treatment are listed.

Table 5. Size characteristics of 'Sunburst' tangerines spot-picked on 8 Nov. 1999 (fruit per tree)[z].

Size	Control	KNO_3
>2.94 in (100+)	21 b	39 a
2.69-2.94 in (120s)	41 a	48 a
2.50-2.69 in (150s)	79 a	70 a
2.38-2.50 in (176s)	40 a	46 a
Total picked	181 a	203 a
Avg. diameter (in)	2.79 b	2.84 a
GPV[y] ($ per tree)	$19.05 b	$23.66 a

[z]Means with the same letter in the same row are not significantly different according to *t*-test at P = 0.05.
[y]Gross packed value (GPV) calculated using average FOB prices from Florida Citrus Mutual Market News Bulletin for dates following harvest as listed in Table 1.

Due to a dramatic drop in 'Sunburst' movement and prices in late November, no fruit was harvested until the trees were clean-picked on 23 Jan. At that time, the KNO_3 treatment trees had a larger average fruit diameter (2.84 in vs. 2.67 in) and over twice as many size 120 and larger fruit as the control treatment (Table 6). The GPV advantage for the KNO_3 treatment was $13.57 per tree ($2460/acre). For the season, the cumulative GPV advantage for the KNO_3 treatment was $18.18 per tree or $3290/acre (Fig. 2).

The 2001-02 season began as a continuation of the driest year on record. Although summer rains alleviated the drought, small fruit sizes were typical throughout the Indian River area in the 2001-02 season. The small sizes were evident in the experiment, even though they had received generally adequate amounts of irrigation water. During the first spot pick (size 150 and larger) on 29 Oct., more than twice as much fruit was harvested from the KNO_3 treatment trees than control trees (Table 7). The KNO_3 treatment had 0.37 cartons per tree (67 cartons per acre) more fruit that were size 120 and larger than the control treatment. In addition, the GPV of the KNO_3 treatment was $6.29per tree ($1140/acre) more than the control treatment.

Conclusions

In this experiment, three 25-lb/acre KNO_3 foliar applications per year were effective in increasing fruit size, and thus GPV per acre for 'Sunburst' tangerines. Applications were timed to coincide with typical grove operations in the dor-

Table 6. Size characteristics of 'Sunburst" tangerines clean picked on 23 Jan. 2000 (fruit per tree).[z]

Size	Control	KNO_3
>2.94 in (100+)	32 b	80 a
2.69-2.94 in (120s)	25 b	42 a
2.50-2.69 in (150s)	42 a	54 a
2.38-2.50 in (176s)	47 a	40 a
Total picked	237 a	67 a
Avg. diameter (in)	2.67 b	2.84 a
GPV[y] ($ per tree)	$16.49 b	$30.06 a

[z]Means with the same letter in the same row are not significantly different according to *t*-test at P = 0.05.
[y]Gross packed value (GPV) calculated using average FOB prices from Florida Citrus Mutual Market News Bulletin for dates following harvest as listed in Table 1.

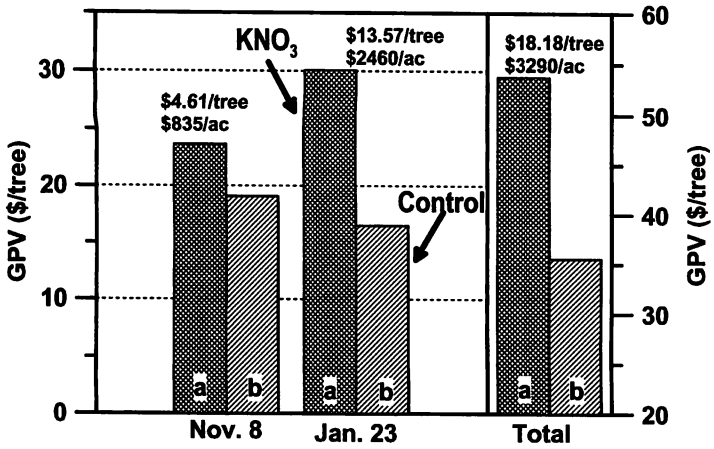

Fig. 2. Gross packed value (GPV) for 1999-00 season with spot pick on 8 Nov. and clean pick on 23 Jan., plus season total GPV calculated using average FOB prices listed in Table 1. Bars with the same letter for the same date are not are significantly different according to *t*-test at P = 0.05. The $ per tree and $ per acre advantage for the KNO_3 treatment are listed.

mant (February), post-bloom (April), and summer (July-August) spray application periods. These applications, which added only minimally to production costs, were able to increase returns by several hundred dollars per acre per year due to increased numbers of large-sized fruit with no apparent detrimental effects on fruit shape or internal quality.

In each of the years that data was obtained, the KNO_3 treatments resulted in 30% or more fruit of size 120 and larger during the first spot pick. In addition, in the two years when all the fruit from each tree was harvested, the KNO_3 treatment averaged 23% more total fruit of size 120 and larger for the entire season. Total gross returns were estimated to be $5.08 per tree ($920/acre) higher during the first spot pick for trees receiving the KNO_3 sprays as compared to the non-treated control trees. Average season total increase in GPV for the KNO_3 treatments was $14.14 per tree ($2626/acre) compared to the control. These results on 'Sunburst" tangerines are similar to those from previous studies on 'Valencia' orange (Boman, 2001) and grapefruit (Boman, 1998) where applications of K resulted in increased yield, fruit size, and solids produced.

The ultimate size a fruit will achieve is a result of complex processes that are difficult to understand and control. However, the results of this studies and others in the Indian River area (Boman, 1997, 2001; Boman and Hebb, 1998) suggest

Table 7. Size Characteristics of 'Sunburst" tangerines spot picked on 29 Oct. 2001 (fruit per tree).[z]

Size	Control	KNO_3
>2.94 in (100+)	7 b	16 a
2.69-2.94 in (120s)	32 b	66 a
2.50-2.69 in (150s)	16 b	32 a
Total picked	57 b	124 a
Avg. diameter (in)	2.76 a	2.77 a
GPV[y] ($ per tree)	$5.69 b	$11.98 a

[z]Means with the same letter in the same row are not significantly different according to *t*-test at P = 0.05.
[y]Gross packed value (GPV) calculated using average FOB prices from Florida Citrus Mutual Market News Bulletin for dates following harvest as listed in Table 1.

that foliar K applications at key times in the fruit development cycle can be effective in increasing fruit size, and most likely grower returns. As with any management decision, foliar K application decisions should be made within each individual block, considering historical fruit size distribution, the general nutritional status of the trees, effects of summer rains, fruit load, and the estimated benefit:cost ratio of the application.

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