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EFFECTIVENESS OF FALL POTASSIUM SPRAYS ON ENHANCING GRAPEFRUIT SIZE*

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Abstract. **Experiments were conducted over a period of three years in blocks of mature grapefruit located in the Indian River area to determine the effects of fall foliar potassium sprays on grapefruit size. The trees were either left untreated or had foliar applications of potassium nitrate (KNO_3, 13-0-46) or monopotassium phosphate (MPK, 0-52-36) in replicated field experiments. Foliar sprays (15-25 lb material per acre) were made in September and October each year. Fruit in each plot were tagged and the fruit diameters were measured to determine effectiveness of foliar applications. In the 1994/95 season, 'Marsh' grapefruit trees receiving the foliar KNO_3 applications increased 11.4% in diameter from 10 September to 23 November compared to 8.0% for fruit on the control trees and 45% of the fruit on trees receiving KNO_3 increased 2 or more sizes while only 14% of the non-sprayed control fruit increased a similar amount. In the 1995/96 season, fruit diameters were not significantly increased for 'Marsh' (KNO_3 applied) or 'Flame' (MKP applied), but MKP applications to 'Star Ruby' resulted in a 2.1% increase in growth rate 1 month after application. Late applications (October and November) of KNO_3 were not effective on increasing fruit size during the 1996/97 season on 'Marsh' grapefruit. Although average fruit diameter growth was only increased 0.6 to 2.4 mm for treated fruit as compared to control fruit, the greater growth in the smaller fruit sizes is likely to be economically significant in many years.**

Introduction

Nitrogen (N) and potassium (K) are essential nutrients for citrus fertilization in Florida. Recommended annual N and K_2O application for Florida grapefruit are in the range of 100-160 lb ac^{-1} (Tucker et al., 1995). Increased N fertilization for citrus is associated with greater total soluble solids (TSS) and higher acid content (Smith et al., 1969) while increased K fertilization is associated with larger fruit size, thicker rinds, and increased acid (Deszyck and Koo, 1957; Sites, 1950; Smith and Rasmussen, 1960). Potassium deficiencies in grapefruit under field conditions were reported to result in slowed growth, thinning of topmost foliage, increased pre-harvest fruit drop, smaller sized fruit, and decreased TSS, acid, and vitamin C contents (Sites, 1950). Calvert (1974) reported increased rates of K fertilization on grapefruit trees produced fruit that were larger and heavier.

The most common methods of applying N and K to citrus are the traditional broadcasting of granular materials or by injection of liquid nutrient solutions through the irrigation system. Nutritional K sprays are usually not a substitute to ground applications, but rather are made as supplemental applications Supplemental nutrient sprays have been shown to be effective in correcting K deficiencies for citrus in calcareous soils (Calvert, 1969, Calvert and Smith, 1972). Calvert (1969) also reported that foliar sprays of potassium nitrate (KNO_3) were more effective in rapidly increasing the K content of leaves than ground applied fertilizers. Foliar K sprays can be an effective method to shorten the time required for uptake compared to soil applications (Embleton et al., 1969).

The foliar symptoms of potassium deficiency are seldom seen in the field since the effects of low K on fruit production, fruit size, and leaf drop generally precede leaf symptoms (Koo, 1968). Leaf K concentrations of 1.2-1.7% are considered optimum for citrus production (Tucker et al., 1995). Young citrus was reported by Smith et al. (1953) to show K deficiency when the leaf K content was around 0.4%. 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% were reported by Reitz and Koo (1960) to result in high fruit yields of good quality. Foliar applications of KNO_3 to citrus on calcareous soils was reported to increase leaf K and fruit size while reducing rind disorders (Calvert, 1969).

The quantity of fruit harvested along with fruit size and packout percentage are major factors determining returns to fresh fruit producers. Fruit are sized at the packing house based on how many fit in a $\frac{4}{5}$ bushel carton. Larger fruit generally bring higher fruit prices, especially early in the season. There are many factors that contribute to the size of fruit in a particular year such as the fruit load, rainfall pattern, fertilization program, hedging and topping operations, and the rootstock/scion combination. It is difficult to predict how these factors combine to affect final fruit size at harvest until late summer when the fruit have attained a 2.5-3 inch diameter. The availability of a technique which could be implemented on blocks with small fruit in late summer to enhance fruit size would be of significant benefit by fresh-fruit growers. The objective of this study was to determine if potassium applications during late summer and early fall could increase the size of grapefruit.

Materials and Methods

Experiments were conducted in commercial citrus groves in the Indian River area of Florida during the 1994/95 through 1996/97 production seasons. In each of these studies, trees were either left untreated or received foliar applications of nutrients applied in late summer and/or fall. Spray materials used were potassium nitrate (KNO_3) and monopotassium phosphate (MPK - KH_2PO_4). KNO_3 is a highly soluble material that has a 13-0-46 N-P-K_2O ratio and a salt index of 75. MKP is also highly soluble with a 0-52-36 N-P-K_20 ratio and a salt index of 8.5. The salt index refers to the osmotic effect that a material adds to a solution and is defined relative to sodium nitrate (which has a value of 100). Generally, ma-

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terials with lower salt indices have less potential for phytotoxicity symptoms or "spray burn".

Experiments were conducted as replicated randomized block experiments with trees receiving foliar applications separated from non-sprayed control plots by at least one buffer bed. A general description of treatments is given in Table 1. Typically, the diameters of 30-60 fruit were measured prior to foliar applications and then at monthly intervals post application. Fruit measurement data were subjected to analysis of variance (SAS) to determine effectiveness of foliar applications on the fruit growth. The general SAS model statement [Diameter change = Treatment Replication (Treatment × Replication) Sample] was tested using the (Treatment × Replication) error term. Significance of mean diameter changes were determined according to F-test at P = 0.05 or at P = 0.10.

Fall 1994- KNO_3

The fall 1994 experiment was conducted in a block of mature 'Marsh' grapefruit on sour orange rootstock trees (25+ years old) located in St. Lucie County. Trees were planted on single-row beds with a 25 ft within-row by 30 ft across-row-tree spacing (58 trees ac^{-1}). The grove had been fertilized in February by broadcasting 60 lb ac^{-1} of granular 12-0-12-2.4 ($N-P_2O_5-K_2O-MgO$) and in July with 55 lb ac^{-1} of 15-0-15-3.6 material.

The trees in the experiment were either left untreated (control) or had foliar applications of KNO_3 with a 13-0-46 ratio of $N-P_2O_5-K_2O$. There were 3 trees in each of the control plots and 5 trees in the KNO_3 plots. The outside trees in the KNO_3 plots served as buffers. Each treatment was replicated 6 times.

Foliar sprays were applied with an airblast sprayer calibrated to apply 250 gal ac^{-1}. Due to the wide row spacing, the tractor was driven close to the tree row and the spray was delivered only from one side of the spray manifold. Passes were made down both sides of the tree row to thoroughly cover the entire tree. Each foliar application resulted in an application rate equivalent to 20 lb KNO_3 applied with 250 gal of water per acre, (about 4.3 gal per tree). Foliar applications were made on 9 September, 6 October, and 27 October 1994.

Prior to the initial applications, 10 fruit were randomly selected for measurements on each of 3 trees within each plot. The fruit were 2-5 ft off of the ground and distributed completely around the tree. These fruit were tagged with flagging tape and labeled consecutively. The diameter of each fruit was measured at its widest cross-section with a caliper on 10 September, 9 October, 27 October, and 23 November. A total of 180 fruit was measured for each treatment (10 fruit per tree × 3 trees per plot × 6 replicates) The change in growth was calculated by subtracting the 10 September measurement from measurements taken on subsequent dates. In order to compare growth rates of similar sized-fruit, the data were grouped by diameter in 5-mm (0.2 inch) increments based on fruit diameter measured on 10 September.

Table 1. Summary of 1994/95 though 1996/97 season fall K application experiments.

Season	Rate per acre	Application dates	Variety	Effectiveness[z]
KNO_3				
94/95	20 lb/125 gal	9/19, 10/6, 10/27	Marsh	++
95/96	20 lb/125 gal	9/7, 9/28	Marsh	o
96/97	25lb/250gal	10/1, 11/8	Marsh	o
MKP				
95/96	15 lb/32.5 gal	10/27, 11/21	Star Ruby	+
95/96	15 lb/32.5 gal	10/27, 11/21	Flame	o

[z]o = less than 1% increase, + = 1-3% increase, ++ = greater than 3% increase in fruit diameter compared to control.

Fifty summer flush leaves were sampled from each plot on 30 November for tissue analysis following IFAS guidelines (Tucker et al., 1995) and leaf mineral concentrations were conducted using standard procedures. Forty fruit from each plot were collected on 31 November and juice from the fruit was evaluated by the Florida Department of Citrus Lab in Lake Alfred. The number of fruit on each tree within each plot was counted on 16 December 1994 to estimate yield.

Fall 1995 - MKP

The fall 1995 MKP experiments were conducted in blocks of 'Star Ruby' grapefruit and 'Flame' grapefruit (both on Swingle citrumelo rootstock) in Indian River County. Both varieties were on double-row beds at a spacing of 15 ft within-row by 24 ft across-row (121 trees/acre). The 'Star Ruby' trees were planted in 1985 and the 'Flames' in 1987. Plots treated with MKP in the fall were compared to non-treated control plots in a randomized block design with 4 replicates. Plot size was 20 trees (10 across-row adjacent pairs of trees on the same bed).

Foliar applications of MKP were made on 27 October and 21 November. Each application consisted of 15 lb MKP per acre mixed with water (plus 6 oz Kinetic surfactant per 100 gal) and applied at a rate of 32.5 gal ac^{-1} on bed tops only. Thirty fruit were tagged in each plot (5 fruit on each of 6 trees). The diameter of each of the tagged fruit were measured on 31 October and 27 November.

Fall 1995 - KNO_3

The fall 1995 KNO_3 experiment was conducted in a block of mature (>30 years old) 'Marsh' grapefruit on sour orange rootstock trees in Martin County. Trees were planted on 48 ft wide double-row beds at a spacing of 18 ft within-row by 24 ft across-row (100 trees ac^{-1}). Ground-applied broadcast fertilizer for both varieties were made at an annual rate of 160 lb ac^{-1} of N and K_2O applied in 3 split applications (February, May, October).

Experimental treatments included a non-treated control and foliar application of KNO_3, with each treatment replicated 6 times. Foliar applications were made both on the bed tops and the water furrow sides of the tree rows to thoroughly cover the entire tree. Application rate was 25 lb of KNO_3 per acre in 125 gal of water for each application. Foliar applications were made on 7 September and 28 September.

The diameters of 60 tagged fruit from each plot (10 fruit on each of 6 trees) were measured 28 August, 27 September, 20 October, and 30 November. Ten size 40 fruit were collected from each plot for juice analysis on 19 September, 5 October, 24 October, and 6 November. Leaves were sampled from each plot on 19 September, 25 September, 5 October, 24 October, and 6 November and analyzed for N and K concentrations.

Fall 1996- KNO_3

The fall 1996 KNO_3 experiment was conducted in a block of 'Marsh' grapefruit on sour orange rootstock trees in Martin County that were planted in late 1960s. Trees were planted at 18 ft within-row by 24 ft across-row on 48 ft wide double beds (100 trees ac^{-1}). Treatments included a non-treated control and foliar application of KNO_3, with each treatment replicated 6 times.

Application rate was 25 lb of KNO_3 per acre in 250 gal of water for each application. Foliar applications were made to both the bed tops and the water furrow sides of the trees on 1 October and 8 November. Fruit were not tagged and re-measured in this experiment. Rather, 5 fruit were randomly selected on each of 12 trees per plot (60 fruit per plot) and measured 20 November. This process was repeated on 6 January, 1997 with a separate random selection of fruit.

Results and Discussion

Fall 1994 - KNO_3

The weather in September and early October on 1994 was considerably more rainy and overcast than is typical for the autumn in southeast Florida. Monthly rainfall was 14.3 inches in September, 12.9 inches in October, and 5.6 inches in November. There were 16 days in September on which more than 0.1 inch of rain was recorded, 19 days in October, and 19 in November. Daily rainfall of over 2.0 inches was recorded on 6 days during the study period.

Based on mean fruit size and numbers of fruit per tree, the average fruit yields were estimated to be about 3.2 boxes (270 lb) per tree for each treatment, with no statistical difference in mean fruit size or yield between treatments. No differences in juice quality were noted with respect to the control and KNO_3 treatments (Table 2). Both treatments had a Brix:acid ratio of 9.5 for fruit sampled on 31 November. In comparison, Calvert (1969) found slightly lower Brix:acid ratios in 1 of 2 years for 'Hamlin' and 'Temple' orange trees sprayed with KNO_3 at a similar rate.

Leaves sampled 4 weeks after the last KNO_3 application had no differences in leaf concentrations of any of the elements tested (Table 3). Leaf N and K were low with respect to recommended levels (Tucker et al., 1995) for leaves 4-6 months old. The low levels may be due to the decrease in leaf N and K contents associated with sampling dates late in the year (Smith, 1966).

At the 9 October measurements, the diameters of KNO_3-applied fruit had increased about 1.7 mm more than the control fruit (Table 4). By 27 October, the diameter of control fruit had increased 5.3 mm while the KNO_3 fruit had enlarged an average of 7.2 mm. After the last KNO_3 application on 26 October, the rates of enlargement for both treatments slowed. However, the enlargement rate for the fruit that received KNO_3 applications was slightly greater than the control fruit. The average diameter increase from 10 September to 23 November for the KNO_3 applied fruit was 9.2 as mm compared to 6.8 mm for the control trees. Overall, the trees receiving the foliar KNO_3 applications increased 11.4% in diameter from 10 September to 23 November as compared to 8.0% for the control trees (Table 4).

Table 2. Average juice quality parameters for Fall 1994 KNO_3 experiment for fruit sampled on 31 November. Differences in means are all non-significant according to F-test (P = 0.05, n = 6).

Treatment	Juice content (%)	Acid (%)	Brix (%)	Brix:acid Ratio	Solids per box (lb)
KNO_3	61.0	1.04	9.9	9.5	5.1
Control	61.6	1.08	10.2	9.5	5.5

Table 3. Average mineral content of leaves for Fall 1 994-KNO_3 experiment sampled on 30 November 1995. Differences in means are all non-significant according to F-test (P = 0.05, n = 6).

	Leaf mineral concentration (%)				
Treatment	N	P	K	Ca	Mg
Control	1.23	0.14	0.76	4.04	0.27
KNO_3	1.53	0.13	0.72	4.04	0.28

One month after the KNO_3 applications had been made, differences were already apparent in the fruit growth patterns of the two treatments. The control fruit increased at about the same rate regardless of the 10 September size class (Fig. 1). For the fruit that received the KNO_3 applications, the smaller 10 September fruit averaged a diameter increase of about 1 mm more than the larger fruit. Similar trends were noted for the 27 October measurements when the smaller 10 September fruit in the KNO_3 treatment had the greatest growth increases. The relationship between initial size and the amount of fruit enlargement for the KNO_3 treatment was less evident with the final measurements than with previous measurements. Within the KNO_3 treatment, the 70-75 mm group averaged 10.3 mm enlargement from September to November compared to 7.9 for the >95 mm class. The middle 4 classes (in the 75-95 mm range) averaged 9.0 mm increase in diameter during the same period.

There is considerable overlap in the legal standards for the allowable diameters of adjacent sizes (Table 5). For example, size 40 fruit can range in diameter from 95.3-109.5 mm while the next larger size (36) fruit can range from 100.0-114.3 mm. The diameter increase required from the minimum of one size to the minimum of the next larger size increases as the pack count decreases. An increase from the minimum of size 56 to size 48 requires a diameter increase of 3.2 mm ($\frac{1}{8}$ inch) while going from size 48 to 40 requires an increase of 4.8 mm ($\frac{3}{16}$ inch). In this analysis, 4 mm was selected as an average diameter necessary to qualify fruit for the next larger size. Using this 4 mm factor, 26% of the control fruit increased 2 sizes or more. In contrast, 61% of the fruit that received the foliar KNO_3 sprays enlarged 2 sizes or more (Fig. 2).

Fall 1995 - KNO_3

The August through mid-October of 1995 was characterized by excessive rainfall and included high rains associated with Hurricane Erin (2 August) and Tropical Storm Jerry (23-24 August). Nearly 38 inches of rainfall was recorded during this 2 H-month period. The rainfall pattern changed considerably in min-October, with less than 0.7 inches of rainfall occurring from late October through the end of December.

Leaf N and K were evaluated from control and treated plots 6 times during September through early November (Fig. 3), with little differences between the treatments. Leaf N concentrations (about 2.35% in early September), dropped 0.1-0.2% following 5 October. Leaf K concentrations were slightly lower for the KNO_3-treated trees (0.60% compared to 0.72% for the control treatment) in early September. Leaf K remained very low through 5 October, and increased during the last month of the study. At the final leaf sampling date, the average leaf K concentration from the KNO_3-treated trees was significantly higher (1.02%) than for the control trees (0.81%). The elevated leaf K concentrations reported by Calvert (1969) and Page et al. (1963) within 1-2 weeks of KNO_3 sprays were not evident in this experiment.

Little difference was noted between treatments in the juice measurements taken at approximately 2-week intervals beginning in mid-September (Table 6). From 19 September to 6 November, the volume of juice of fruit (size 40) from the KNO_3-applied trees

Table 4. Fruit measurement dates and diameter changes for 1994 and 1995 KNO_3 experiments and 1995 MKP experiments.

Experiment	Initial Measurement: Date	Average diameter: Control (mm)	Average diameter: Treated (mm)	Average diameter change: Date	Control (%)	Control (mm)	Treated (%)	Treated (mm)	Significance[z]
KNO_3-1994 (Marsh)	Sept. 10	86.0	81.4	Oct. 9	3.3	2.8	5.7	4.5	*
				Oct. 27	6.2	5.3	9.1	7.2	*10%
				Nov. 23	8.0	6.8	11.4	9.2	*
KNO_3-1995 (Marsh)	Aug. 28	84.7	82.9	Sept. 27	8.7	7.3	9.1	7.6	n.s.
				Oct. 20	15.0	12.7	16.0	13.3	n.s.
				Nov. 30[y]	17.4	14.7	19.0	15.8	n.s.
MKP-1995 (Flame)	Oct. 31	85.9	91.9	Nov. 27	2.7	2.3	3.2	2.9	n.s.
MKP-1995 (Star Ruby)	Oct. 31	94.8	92.0	Nov. 27	1.9	1.8	4.0	3.7	*

[z]Significance of mean diameter changes according to F-test are: non-significant (n.s.), significantly different at P = 0.05 (*), or significantly different at P = 0.10 (*10%).
[y]The 30 November, 1995 measurements are based on the fruit that remained after the spot picking (227 fruit for KNO_3 and 320 for the control treatment).

increased 52% as compared to 43% for fruit from the control trees. During this period, Brix remained nearly constant (about 9.5%) while acid dropped by about 25%, resulting in an increase in the Brix:acid ratio from 6.0 to 7.3 (control) and from 6.1 to 7.9 (KNO_3). Analysis of the juice from fruit picked on 6 November indicated higher juice volume and lower acid (P = 0.10) and a higher Brix:acid ratio for the KNO_3-treated trees (P = 0.05).

During the week prior to the 30 November fruit diameter measurements, the experimental block was inadvertently spot-picked. The harvesting crews were picking the larger fruit (generally size 40 and larger) for the export market. In this process, many of the fruit that had been tagged and measured previously were removed from the trees. Fruit on trees treated with KNO_3 were slightly smaller in diameter at the initial measurement (28 August). However, over 3 times as many of the tagged fruit from the KNO_3 treatment trees (37%) were removed compared to the control trees (1.1%), suggesting that the KNO_3-treated trees appeared larger. Data presented for the 30 November measurements are based on the fruit that remained after the spot picking (227 fruit for KNO_3 and 320 for the control treatment).

Overall, fruit on trees that had KNO_3 applications increased in diameter much less relative to the control fruit than in the 1994/95 season (Table 4). Although the KNO_3-treated fruit tended to have higher diameter increases than the control fruit (Table 4), the overall average change was non-significant (P = 0.05). Similar to the fall 1994-KNO_3 experiment, fruit that was smaller on 28 August had the greatest growth increases over the next 2 months (Fig. 4).

Fall 1995 - MKP

Fruit diameter measurements were taken on both the ‘Flame’ and ‘Star Ruby’ grapefruit about 1 month after the initial MKP application. Overall, tagged fruit in the ‘Star Ruby’ block that received the MKP applications increased 4.0% between 31 October and 27 November as compared to 1.9% for the control fruit (Table 4). On average, the diameters of MKP-treated fruit enlarged 2.5-3.0 mm more than for the control treatment fruit during this period (Fig. 5). Fruit in the smallest initial (31 October) fruit class (75-80 mm) that received the MKP applications had the largest diameter increases (Fig. 5).

The foliar applications were less effective on the ‘Flame’ variety than the ‘Star Ruby’. On 27 November, the tagged fruit that had been treated with MKP had increased 3.2% from 31 October as compared to 2.7% for the control fruit. In the month following the initial application, the fruit treated with MKP increased only about 0.3-0.5 mm more than the control fruit (non-significant at P = 0.05, Fig. 6).

Fall 1996- KNO_3

Rainfall in the late summer and fall of 1996 was considerably less than the excessive amounts received during this period in the previous 2 years. Monthly rainfall was 4.6, 7.2, 6.4, and 2.6 inches for the months of August through November, respectively.

The mean fruit diameter between treatments were not different (F-test, P = 0.05). The average fruit diameter (300 fruit) measured at random on 20 November was 90.5 mm for the control treatment plots as compared to 90.0 for the trees with the KNO_3 applications. On 6 January, 1996, fruit from the control plots averaged 91.2 mm compared to 90.6 mm for the KNO_3-treated plots.

Conclusions

Large grapefruit size is generally desirable and brings higher prices early in the season. The fall foliar applications were effective in increasing fruit growth rate relative to the non-sprayed control plots in two of the five tests. Although average fruit diameter growth was only increased 0.6 to 2.4 mm for treated fruit as compared to control fruit, the greater growth in the smaller fruit sizes is likely to be economically significant in many years. The greater fruit growth rate in the treated trees resulted in no detrimental shape or peel texture changes that were apparent from visual observations.

It is likely that little of the spring soil-applied potassium was available to the trees for much of the late summer and fall months in the years these experiments were conducted. Potassium is easily leached from the sandy soils on which the experiments were conducted. In addition, due to a shallow water table, the rooting depth of the trees in these experiments were limited to less than 24 inches. Excessive rainfall (with intensities of up to 4 inches day^{-1} in 1994 and 1995) during the summer and fall months probably leached most of the K from the root zones of the trees.

Table 5. Maximum and minimum diameters of grapefruit allowable for various grapefruit pack sizes (from Section 51.762 of Florida Citrus Code of 1949).

Size	Minimum diameter (in)	(in)	(mm)	Maximum diameter (in)	(in)	(mm)	Increment (in)	(in)	(mm)
18	5	5.00	127.0	5 9/16	5.56	141.3	5/16	0.31	7.9
23	4 11/16	4.69	119.1	5 4/16	5.25	133.4	5/16	0.31	7.9

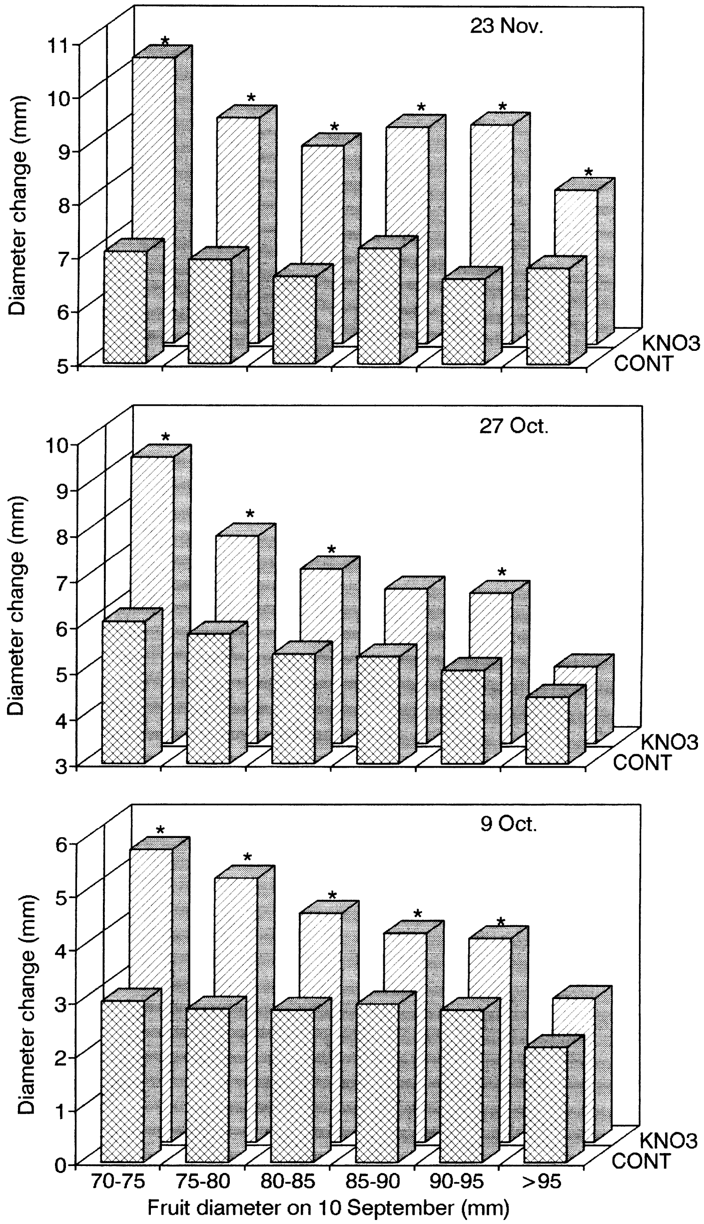

Figure 1. Average fruit diameter increases by size classes for KNO_3-1994 experiment. Fruit diameter changes are relative to measurements taken 10 September, 1994. Means of size classes with an asterisk (*) are significantly different according to F-test (P = 0.05).

Table 5. Maximum and minimum diameters of grapefruit allowable for various grapefruit pack sizes (from Section 51.762 of Florida Citrus Code of 1949).

	Minimum diameter			Maximum diameter			Increment		
Size	(in)	(in)	(mm)	(in)	(in)	(mm)	(in)	(in)	(mm)
27	4 6/16	4.38	111.1	4 15/16	4.94	125.4	3/16	0.19	4.8
32	4 3/16	4.19	106.4	4 12/16	4.75	120.7	4/16	0.25	6.4
36	3 15/16	3.94	100.0	4 8/16	4.50	114.3	3/16	0.19	4.8
40	3 12/16	3.75	95.3	4 5/16	4.31	109.5	3/16	0.19	4.8
48	3 9/16	3.56	90.5	4 2/16	4.13	104.8	2/16	0.13	3.2
56	3 7/16	3.44	87.3	4	4.00	101.6	2/16	0.13	3.2
63	3 5/16	3.31	84.1	3 14/16	3.88	98.4			

The absorption of K into citrus leaves following KNO_3 foliar applications has been shown to be rapid. Calvert (1969) found increased leaf K content 2 weeks after foliar KNO_3 applications while Page et al. (1963) detected elevated leaf K within a week of KNO_3 sprays. In the experiments where leaf K was measured (Fall 1994-KNO_3 and Fall 1995-KNO_3), leaf K concentrations were relatively unaffected (with the exception of the 6 November 1995 measurement) by the additional K applied (Table 3, Fig. 2). Calvert (1969) also found the increase in leaf K after a KNO_3 spray to be temporary, returning to initial levels 4 weeks after the application was made. It is speculated that the applied K was used in the fruit growth process since it was generally was not stored in leaves.

To achieve maximum benefit from the applied foliar materials, consideration should be given to timing of the sprays. As the days get shorter in the fall, less energy is available to drive fruit growth. In the 1994/95 season, average fruit enlargement remained fairly constant at 0.15 mm day^{-1} for the KNO_3 treatment and 0.11 mm day^{-1} for the control treatment from 10 September through the 27 October measurements. These enlargement rates dropped nearly in half between 27 October and the final measurements on 23 November, when the average daily diameter increase dropped to 0.07 and 0.06 mm day^{-1} for the KNO_3 and control treatments, respectively.

Increased size early in the grapefruit season, with no reduction in maturity, internal quality, or external appearance, has the potential for increased grower returns. Further study is required to determine the effects of application timing, nutrient status, climatic factors, and other cultural practices on the effectiveness of K foliar applications to increase fruit size. The following observations and recommendations are based on the experiments presented in this paper.

1. To achieve maximum effectiveness of the late summer/fall foliar K applications, they should be scheduled in August and September when their effectiveness may be greatest. In

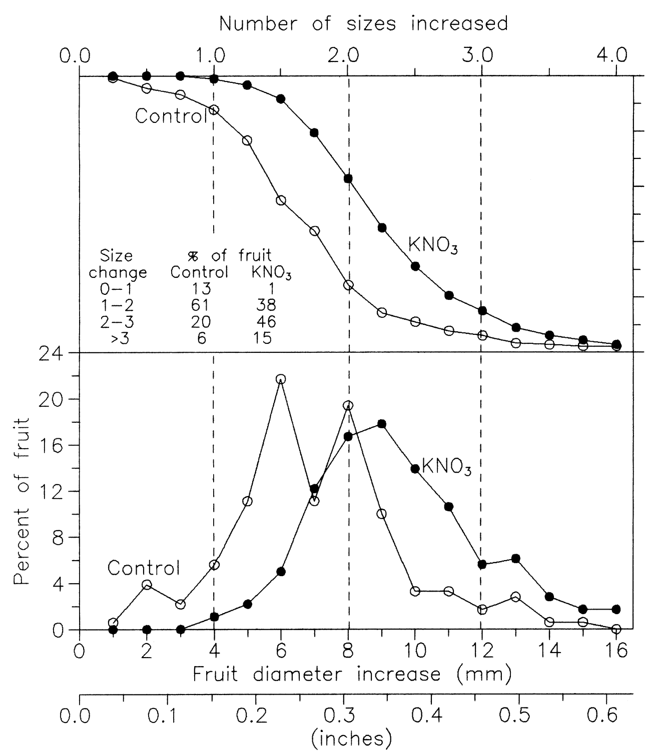

Figure 2. Distribution of fruit diameter increases and size changes from 10 September to 23 November (n = 180) for KNO_3-1994 experiment. Size increases based on 4 mm increments.

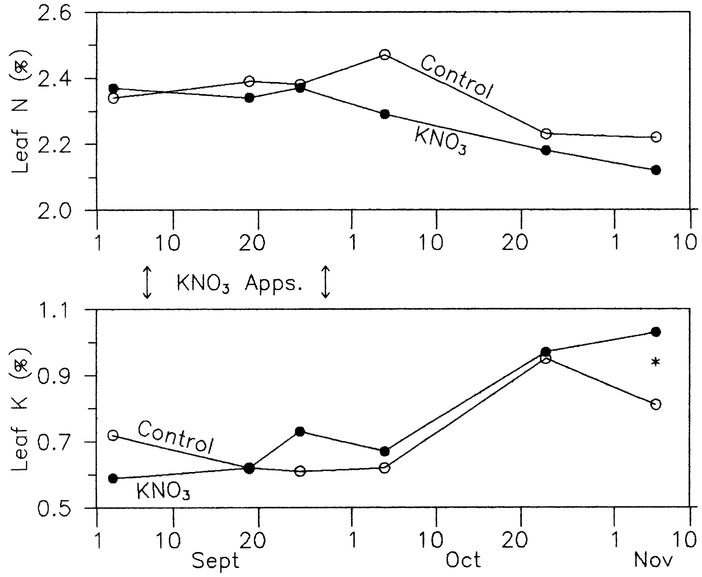

Figure 3 Mean leaf nitrogen (top panel) and potassium (bottom panel) concentrations for KNO_3-1995 experiment (arrows represent dates of foliar applications). Only the 6 November K means are significantly different according to F-test (P = 0.05).

some cases October applications may be of little value in in-

Table 6. Mean juice quality parameters from fall 1995 KNO_3 experiment for 10 size-40 fruit randomly sampled from within each plot by date (unless indicated, means are not significantly different according to F-test at P = 0.05).

Date	Treatment	Juice volume (ml)	Brix (%)	Acid (%)	Brix:acid Ratio
Sep 19	Control	1332	9.5	1.6	6.0
	KNO_3	1308	9.4	1.6	6.1
Oct 5	Control	1555	9.7	1.4	6.7
	KNO_3	1572	9.4	1.5	6.3
Oct 24	Control	1867	9.5	1.4	7.1
	KNO_3	1862	9.5	1.3	7.3
Nov 6	Control	1908[z]	9.5	1.3[z]	7.8[y]
	KNO_3	1982	9.6	1.2	7.9

[z]Means are significantly different at P = 0.10.
[y]Means are significantly different at P = 0.05.

creasing fruit size (1996-KNO_3).

2. Satisfactory results can be obtained from applications to one side of tree (bed tops) only, but the relative effect compared to complete coverage has not been studied. (MKP-1995 experiment).
3. Under the right conditions, fall foliar K applications can increase average fruit size 2-4 mm, which may be equivalent to H-1 pack size.
4. The foliar K applications resulted in little or no difference in juice volume, acid, Brix, or Brix:acid ratios.
5. The diameters of smaller fruit tended to increase more than larger fruit when foliar K applications were made.
6. There were no "burn" problems at the concentrations applied: KNO_3 at 20 lb in 125 gal ac^{-1} or MKP at 15 lb in 32.5 gal ac^{-1}. Observations in the fall of 1996 with 15 lb MKP with 1 lb low-biuret urea applied with 10 gal water ac^{-1} by airplane also showed no "burn" on grapefruit.

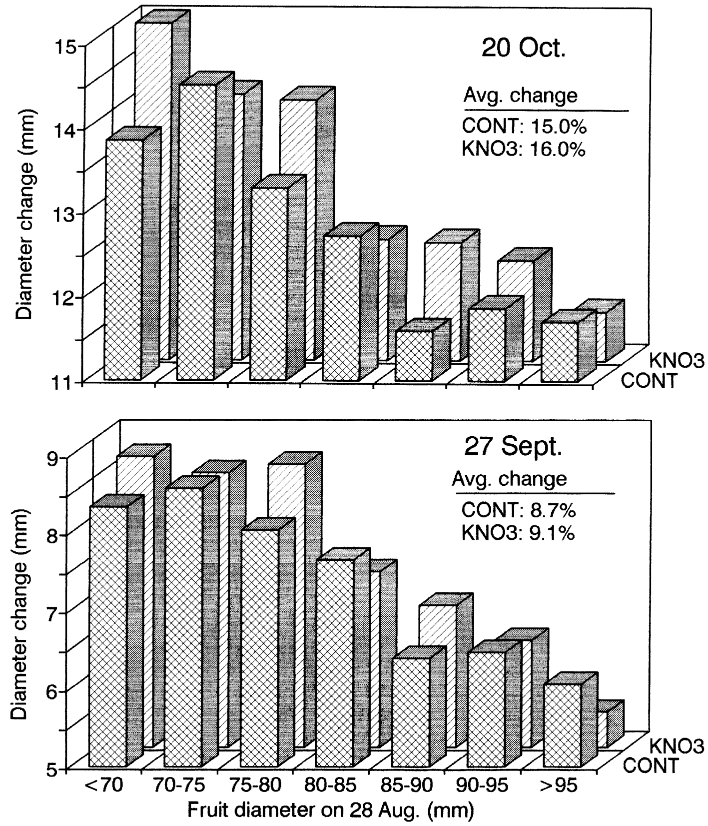

Figure 4. Average fruit diameter increases by size classes for KNO_3-1995 experiment. Fruit diameter changes are relative to measurements taken 28 August,1995. Means of size classes are not significantly different according to F-test (P = 0.05).

7. The ultimate size a grapefruit will achieve is a result of complex processes. At this time, the effectiveness of late summer/fall K foliar applications is unpredictable. Application decisions should be made on an individual block basis considering fruit size distribution, the general nutritional status

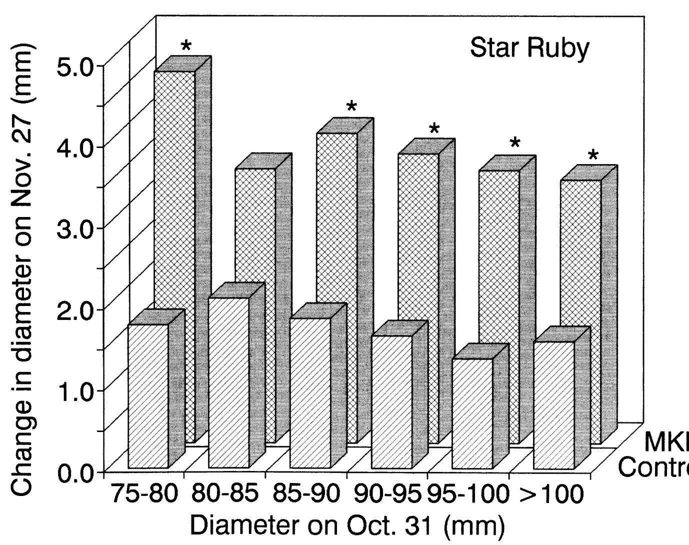

Figure 5. Average fruit diameter increases by size classes for 'Star Ruby' grapefruit in MKP-1995 experiment. Fruit diameter changes are relative to measurements taken 31 August, 1995. Means with an asterisk (*) are significantly different according to F-test (P = 0.05).

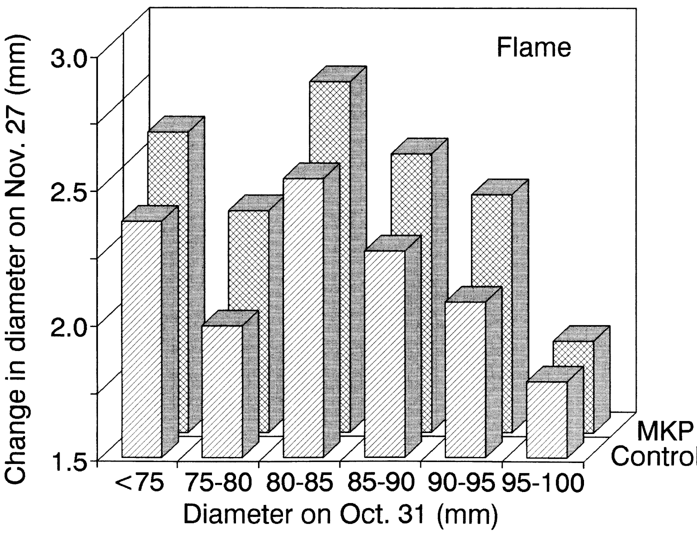

Figure 6. Average fruit diameter increases by size classes for 'Flame' grapefruit in MKP-1995 experiment. Fruit diameter changes are relative to measurements taken 31 August, 1995. Means of size classes are not significantly different according to F-test (P = 0.05).

of the trees, effects of summer rains, fruit load, and the estimated benefit:cost ratio of the application.

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