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POST BLOOM AND SUMMER FOLIAR K EFFECTS ON GRAPEFRUIT SIZE

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Abstract. **Experiments were conducted during the 1995/96 and 1996/97 seasons in blocks of mature grapefruit located in the Indian River area to determine the effects of post bloom and summer foliar potassium sprays on grapefruit size. The trees were either left untreated or had foliar applications of potassium nitrate (KNO_3) or monopotassium phosphate (MPK) in 1995/96 and MKP or dipotassium phosphate (DKP) in 1996/97. Foliar sprays were made at different rates (11.5, 23, 34.5 lb K_2O acre^{-1}) in April, May, and August/September in the 1995/96 season. In the 1996/97 season, applications of MKP and DKP were made at 5 lb K_2O acre^{-1} in April, April plus May, or April plus May plus July. In the 1995/96 experiment, fruit in each plot were tagged and the fruit diameters were measured at subsequent dates to determine effectiveness of foliar applications. All treatments except the 11.5 K_2O lb acre^{-1} app.$^{-1}$ MKP treatment were effective in increasing fruit diameter 2-5 mm with respect to the non-treated control. Higher rates of KNO_3 did not enhance the enlargement over lower rates. The high MKP rate (34.5 lb) was no different than the medium MKP (23 lb) K_2O rate. In the 1996/97 season, fruit from plots were measured in August ('Star Ruby') and September ('Marsh'). Fruit in both experiments receiving MKP or DKP were 4-5 mm larger than fruit on control trees. Trees that received additional applications of MKP or DKP in May and July had fruit that were larger than control treatment fruit, but of similar size to trees that had applications only in April.**

Introduction

Larger grapefruit generally bring higher fruit prices 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. Of all the factors that may affect ultimate fruit size, fertilization practices are probably the easiest to manipulate. 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 total soluble solids (TSS), acid, and vitamin C contents (Sites, 1950). Calvert (1974) reported that increased rates of K fertilization on grapefruit trees produced larger and heavier fruit.

The effects of low K on fruit production, fruit size, and leaf drop generally precede leaf deficiency symptoms (Koo, 1968). Leaf K concentrations of 1.2-1.7% are considered optimum for citrus production (Tucker et al., 1995). 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.

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 for ground applications, but rather are made as supplemental applications. Supplemental nutrient sprays have been shown to be effective in correcting K deficiencies for citrus grown on 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 of shortening the time required for uptake compared to soil applications (Embleton et al., 1969). Foliar applications of KNO_3 to citrus on calcareous soils were reported to increase leaf K and fruit size while reducing rind disorders (Calvert, 1969). Boman (1997) reported increases in average fruit diameter resulting from fall K-based foliar applications as compared to non-sprayed control fruit.

The objective of this study was to determine if foliar potassium applications during the post-bloom and summer periods could increase the size of grapefruit. Additionally, it was desired to investigate the effects of the foliar applications on fruit maturity and juice quality.

Materials and Methods

Experiments were conducted in commercial citrus groves in the Indian River area of Florida during the

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1995/96 and 1996/97 production seasons. In each of these studies, trees were either left untreated or received foliar applications of nutrients of potassium nitrate (KNO_3), monopotassium phosphate (KH_2PO_4), or dipotassium phosphate. KNO_3 is a highly soluble material that has a 10-0-46 N-P- K_2O ratio and a salt index of 75. Monopotassium phosphate (MKP) is also highly soluble with a 0-52-34 N-P-K_2O ratio and a salt index of 8.5. Dipotassium phosphate (DKP) is a 0-18-20 solution made by combining monopotassium phosphate and potassium hydroxide. 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.

1995/96 'Marsh' Grapefruit

The 1995/96 experiments were conducted in two commercial citrus blocks located in St. Lucie County, Florida, using foliar applications of KNO_3 and MKP. Both blocks were 'Marsh' grapefruit on sour orange rootstock trees planted in the mid-1960s. Trees were planted on 60-foot-wide double-row beds with a tree spacing of 24 ft within-row by 28 ft across-rows, resulting in a tree density of 61 trees acre^{-1}. Plots consisted of 12 across-bed pairs of trees (24 trees) in each block (H the bed).

The experiments were designed as randomized complete blocks with 4 replications of each treatment. Each experiment contained the foliar application treatments plus non-sprayed control plots (Table 1). Treatments were separated by two tree rows to minimize the effects of spray drift on adjacent plots. The first and last three trees in each plot served as buffer trees. They were sprayed with the rest of the plot, but no fruit measurements were taken from them.

Three rates of MKP (34, 68, and 102 lb MKP acre^{-1}) and two rates of KNO_3 (25 and 50 lb KNO_3 acre^{-1}) were used in Block A. In Block B, single rates of both MKP (68 lb acre^{-1}) and KNO_3 (50 lb acre^{-1}) were applied. In both blocks, 3 oz of Latron B-1956 surfactant was added to each tank (125 gal). Foliar applications were made with a tractor-mounted Rear's PTO PAK-BLAST model 100 airblast sprayer fitted with D8-25 nozzles and calibrated to deliver 125 gal acre^{-1} at 150 psi. Applications were made on April 21 and May 19 with passes made down row middles with both spray manifolds operating. Applications were then made on the water furrows with a single spray manifold operating. Each tree received a total of approximately 2 gal of spray material.

Due to excessive rainfall resulting in impassable water furrows, spray applications in August and September were made to the bed tops only. The applications made on August 9 and September 14 were at the same concentrations as the April and May applications. Since only one side of the trees were sprayed, the effective rate on each of the August and September applications was one-half of the spring rates.

During July, 6 fruit on each of 8 trees in each plot were tagged and marked with a number. In Block A, measurements of the diameter of each fruit were taken on August 8, September 10, November 2, and November 29. In Block B, fruit diameters were measured on August 4, September 5, November 1, and November 28. Changes in fruit diameters were calculated relative to measurements taken in early August in both blocks. The percentage increase for a particular date was calculated by subtracting the August measurement of each fruit from the measurement taken on each subsequent date, dividing this number by the initial August diameter, and then multiplying by 100.

Spring-flush leaves were sampled from trees within each plot on September 14 (taken prior to foliar application), September 28, and October 28. On each sampling date, the collected leaves were washed, dried, ground, and then subsamples were acid digested for nitrogen analysis and ashed for potassium analysis. The leaves sampled in September were also analyzed for phosphorus concentrations.

Table 1. Treatments applied to 'Marsh' grapefruit Blocks A and B in 1995/96 season.

Treatment ID	Application rate (lb/ac)	Block A	Block B
Control	0	X	X
KNO_3-25	25	X	
KNO_3-50	50	X	X
MKP-34	34	X	
MKP-68	68	X	X
MKP-102	102	X	

At about 2-week intervals (September 14, September 28, October 28, and November 7), 10 fruit were harvested from each plot for juice analysis. Sizing rings were used to ensure that all fruit sampled were size 40. A commercial FMC extractor was used to obtain juice samples for analysis of total volume, Brix, and acid content for fruit from each plot. On January 30, 1996, the tagged fruit in each plot were harvested. Each fruit was cut in half, and the thickness of the peel was measured with a caliper.

1996/97 'Marsh' and 'Star Ruby' Grapefruit

The 1996/97 experiments were conducted in commercial citrus blocks located in Indian River County, Florida. Foliar applications of MKP and DKP were made to blocks with 'Marsh' and 'Star Red' grapefruit on Swingle citrumelo rootstock trees. Both blocks were on double-row beds with a spacing of 15 ft within-row by 24 feet across-rows on 48-ft wide double-row beds, resulting in a tree density of 121 trees acre^{-1}. The 'Star Ruby' trees were planted in 1985, while the 'Marsh' block was planted in 1987. The 'Star Ruby' plots consisted of 14 across-bed pairs of trees (28 trees) while the 'Marsh' plots contained 12 across-bed pairs of trees (24 trees). Both the 'Star Ruby' and 'Marsh' experiments were designed as a randomized complete blocks with 4 replications of each treatment.

Each experiment contained the foliar application treatments plus non-sprayed control plots (Table 2). Foliar applications were made with a Curtek sprayer with passes made down row middles only. Applications were made 1, 2, or 3 times during the season, with initial sprays made to all plots on April 25. On May 27, plots MKP-2 and MKP-3 received additional MKP + urea applications, while the DKP-2 and DKP-3 plots were sprayed with the DKP + urea solution. Applications were made on July 25 only to the MKP-3 and DKP-3 plots. At each date in the MKP treatments, 150 lb MKP + 25 lb low-biuret urea (46-0-0) were mixed in 325 gal water and applied at a rate of 32.5 gal acre^{-1} (equivalent to 5.4 lb acre^{-1} K_2O). The DKP treatments received 23 gal DKP + 25 lb low-biuret urea (46-0-0) mixed in 325 gal water and applied at a rate of 32.5 gal acre^{-1} (equivalent to 5.4 lb acre^{-1} K_2O) at each application.

On August 30, 6 fruit were measured with calipers on each of 10 trees in all of the 'Star Ruby' plots. The procedure was repeated on the 'Marsh' plots on September 25. On October 29, 40 fruit from each plot within both the 'Marsh' and 'Star Ruby' experiments were harvested at random. The juice from these fruit were analyzed by the Florida Department of Citrus Laboratory in Lake Alfred for juice content, Brix, and acid.

Table 2. Application dates for 'Marsh' and 'Star Ruby' grapefruit blocks in 1996/97 season.

	Variety		Application dates		
Treatment ID	'Marsh'	'Star Ruby'	April 25	May 27	July 25
Control	X	X			
MKP-1	X	X	X		
MKP-2	X	X	X	X	
MKP-3	X	X	X	X	X
DKP-1	X		X		
DKP-2	X		X	X	
DKP-3	X		X	X	X

Results and Discussion

1995/96 'Marsh' Grapefruit

The 1995/96 season experienced a dry post-bloom period with less than 0.4 inches of rainfall during a 5-week period from early mid-April through late May. The August through mid-October period was characterized by excessive rainfall and included high rains associated with Hurricane Erin and Tropical Storm Jerry. Nearly 38 inches of rainfall was recorded during this 2 ½-month period. The rainfall pattern changed considerably in mid-October, with less than 0.7 inches of rainfall occurring from late October through the end of December.

The September 14 leaf sampling was 5 weeks after the August 9 application, while the September 28 and October 28 samplings were 2 and 6 weeks following the September 14 application. The effects of foliar applications on leaf N concentrations were minimal (Table 3). Leaf N dropped slightly for all treatments in both blocks from September 14 to September 28, and then increased with the leaves sampled on October 28. There were no differences between treatments in leaf K on September 14. However, most of the foliar treatments resulted in increased leaf K compared to control trees on September 28 and October 28. Additional MKP or KNO_3 applications above the base rates did not result in increased leaf K.

Leaf P levels were only measured on September 14 (Table 4). MKP applications increased leaf P levels over control and KNO_3 treatments in both blocks. The higher rates of MKP applications in Block A did not result in increased leaf P compared to the 34 lb MKP acre^{-1} rate.

In Block A, fruit from trees receiving MKP at the 102 lb acre^{-1} rate were found to have thinner peels than those from trees with the 50 lb acre^{-1} KNO_3 treatment (Table 5). However, neither of the treatments resulted in peel thicknesses that were significantly different than the control treatment. No differences in peel thickness were found in fruit from Block B.

Juice samples were analyzed on 5 dates at 2-week intervals for both blocks (Tables 6 and 7). No consistent trends were noted with respect to juice parameters and treatment. The MKP-102 treatment fruit had lower juice volume compared to the control fruit on September 14, but no difference at subsequent sampling dates. In Block B, the KNO_3-50 treatment fruit had higher Brix:acid ratio on September 14, but there were no differences at that date in Block A. Interestingly, the KNO_3-50 fruit had lower Brix:acid ratio than control fruit in Treatment A for the October and November measurements. When the

Table 3. Mean leaf N and K concentrations for 'Marsh' grapefruit trees picked at various dates in the fall of 1995.

	Leaf N (%)		Leaf K (%)	
Treatment	Block A	Block B	Block A	Block B
September 14				
Control	1.98	2.05	1.31	1.17
KNO_3-25	1.89		1.41	
KNO_3-50	2.03	2.11	1.58	1.04
MKP-34	2.00		1.36	
MKP-68	2.08	2.21 ns	1.61	1.01 ns
MKP-102	2.07 ns		1.55 ns	
September 28				
Control	1.96	2.00	1.27 b[z]	1.00 b
KNO_3-25	1.91		1.66 a	
KNO_3-50	1.86	1.99	1.64 a	1.47 a
MKP-34	1.87		1.42 ab	
MKP-68	1.86	1.94 ns	1.62 a	1.33 ab
MKP-102	1.88 ns		1.67 a	
October 28				
Control	2.00	2.19	1.14 b	1.13 b
KNO_3-25	2.02		1.54 a	
KNO_3-50	1.89	1.94	1.62 a	1.34 ab
MKP-34	2.01		1.45 a	
MKP-68	1.94	1.98 ns	1.69 a	1.55 a
MKP-102	1.80 ns		1.66 a	

[z]Means for each parameter on the same date with the same letter are not significantly different according to LSD test at P = 0.05 (n = 4).

Table 4. Mean leaf P concentration for leaves picked on September 14, 1995.

	Leaf P concentration (%)	
Treatment	Block A	Block B
Control	0.15 b[z]	0.13 b
KNO_3-25	0.15 b	
KNO_3-50	0.15 b	0.14 b
MKP-34	0.20 a	
MKP-68	0.21 a	0.19 a
MKP-102	0.20 a	

[z]Means with the same letter are not significantly different according to LSD test at P = 0.05 (n = 4).

data for the three treatments common to both blocks were combined (Fig. 1), the KNO_3-20 and MKP-68 treatments resulted in juice volume and Brix:acid ratios similar to the control treatment, except for a drop in the Brix:acid ratio for the KNO_3-50 treatment on October 13.

Both the MKP-68 and KNO_3-50 treatments in Block B had increased fruit enlargement compared to the control treatment at each measurement date (Table 8). The fruit on trees sprayed with MKP and KNO_3 had increased 1.9-2.4 mm more than fruit from control trees by the time the November 28 measurements were taken (Fig. 2). The differences for the KNO_3-50 and MKP-68 treatments in Block A were not as great as in Block B. Largest increases in Block A on both November 2 and November 29 were found with the MKP-102 treatment, while the MKP-34 treatment resulted in diameter changes that were no different from the control (Fig. 3).

Comparisons of changes in fruit diameters from Block B treatments were made when the fruit was grouped according to their diameter on August 4 (Fig. 4). Fruit diameter changes for both the KNO_3-50 and MKP-68 treatments were greater than the control for August 4 diameter classes greater than 75 mm. Although the mean for both treatments in the smaller 2 classes (<70 and 70-75 mm) were numerically higher than the control, the high variability and low number of replications (4) resulted in non-significant fruit diameter change differences for these classes. Unlike a previous experiment with fall foliar K applications that resulted in smaller fruit growing at a greater rate as a result of the foliar applications (Boman, 1997), there were no distinct changes in fruit expansion rates with respect to early August fruit diameter classes. In the November 28 measurements, the changes in fruit diameters were similar for each of the August 4 classes, about 2-3 mm.

Table 5. Mean peel thickness for fruit harvested January 30, 1996.

Treatment	Peel thickness (mm) Block A	Block B
Control	5.4 ab[z]	5.7
KNO_3-25	5.5 ab	
KNO_3-50	5.6 a	5.3
MKP-34	5.4 ab	
MKP-68	5.4 ab	5.3ns
MKP-102	5.0 b	

[z]Means with the same letter are not significantly different according to LSD test at P = 0.05 (n = 4).

Table 6. Mean juice analysis parameters for 10 size-40 'Marsh' grapefruit picked at various dates in the fall of 1995 (Block A).

Treatment	Juice volume (ml)	Brix	Acid	Brix:acid Ratio (%)
September 14				
Control	1475 ab[z]	9.4 ab	1.52 ab	6.2
KNO_3-25	1540 a	9.5 ab	1.46 b	6.5
KNO_3-50	1333 bc	10.1 a	1.61 a	6.3
MKP-34	1382 abc	9.1 b	1.56 ab	5.9
MKP-68	1445 abc	9.3 ab	1.55 ab	6.0
MKP-102	1265 c	9.4 ab	1.57 ab	6.0ns
September 28				
Control	1533	10.1	1.51	6.7
KNO_3-25	1595	9.8	1.46	6.7
KNO_3-50	1548	10.2	1.50	6.8
MKP-34	1609	10.0	1.46	6.9
MKP-68	1585	10.4	1.46	7.1
MKP-102	1558ns	9.9ns	1.45ns	6.8ns
October 13				
Control	1915	9.4 bc	1.28 c	7.3 ab
KNO_3-25	1848	9.3 bc	1.36 abc	6.8 cd
KNO_3-50	1881	8.9 c	1.32 bc	6.7 d
MKP-34	1750	10.4 a	1.43 a	7.3 ab
MKP-68	1881	9.6 b	1.30 bc	7.4 a
MKP-102	1847ns	9.6 b	1.39 ab	6.9 bcd
October 28				
Control	1843 b	9.7 ab	1.25 ab	7.7 a
KNO_3-25	1926 ab	9.6 b	1.27 ab	7.5 abc
KNO_3-50	1990 a	8.8 c	1.24 b	7.1 d
MKP-34	1838 b	10.3 a	1.34 a	7.6 ab
MKP-68	1828 b	9.6 b	1.32 ab	7.2 cd
MKP-102	1880 b	9.7 ab	1.34 ab	7.3 cd
November 7				
Control	2199	9.2	1.18	7.8 a
KNO_3-25	2210	9.3	1.22	7.7 ab
KNO_3-50	2165	8.9	1.25	7.2 c
MKP-34	2161	9.5	1.27	7.4 bc
MKP-68	2109	9.6	1.26	7.7 ab
MKP-102	2100ns	9.6ns	1.26ns	7.6 ab

[z]Means for each parameter on the same date with the same letter are not significantly different according to LSD test at P = 0.05 (n = 4).

There is considerable overlap in the legal standards for the allowable diameters of adjacent sizes. 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 change required to go from the minimum of one size to the minimum of the next larger size increases as the pack count decreases. For instance, an increase from the minimum of size 56 to that for size 48 requires a diameter increase of 3.2 mm (1/8 inch) while going from size 48 to 40 requires an increase of 4.8 mm (3/16 inch). Typically for small fruit, a change in diameter of 4-5 mm is enough to allow the fruit to be packed as the next larger size. Plotting the distribution of fruit diameter changes for the Block B treatments

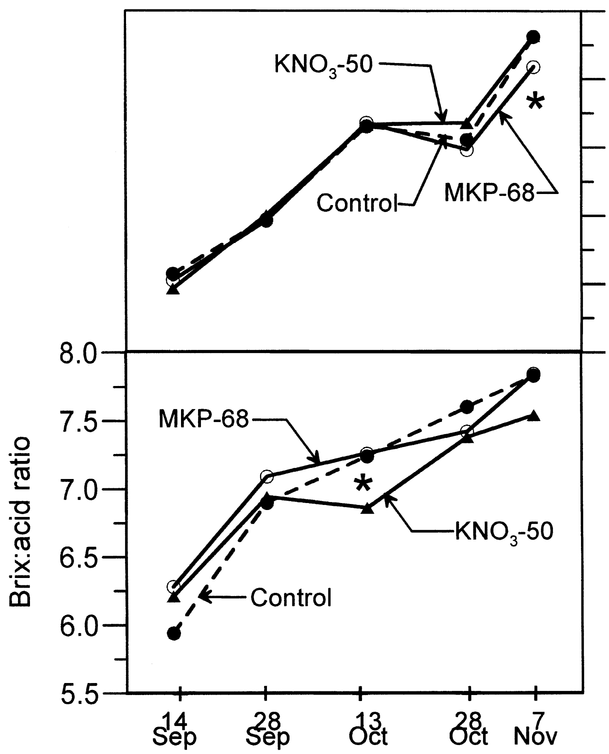

Figure 1. Juice volume (top panel) and Brix:acid ratios for 10 size-
vested from Control, KNO_3-50 and MKP-68 treatments combined for B
B in the 1995/96 season (parameters on dates with an asterisk are signi
ferent according to LSD test at P = 0.05, n = 8).

Table 7. Mean juice analysis parameters for 10 size-40 'Marsh' grapefruit picked at various dates in the fall of 1995 (Block B).

Treatment	Juice volume (ml)	Brix	Acid (%)	Brix:acid Ratio
September 14				
Control	1385	8.9 b[z]	1.6	5.7 b
KNO_3-50	1378	9.9 a	1.5	6.5 a
MKP-68	1440_{ns}	9.4 ab	1.5_{ns}	6.1 ab
September 28				
Control	1648	10.4	1.5	7.1
KNO_3-50	1590	10.4	1.5	7.1
MKP-68	1659_{ns}	10.2_{ns}	1.5_{ns}	7.1_{ns}
October 13				
Control	1813	9.9 a	1.4 a	7.2
KNO_3-50	1866	9.2 b	1.3 b	7.2
MKP-68	1855_{ns}	9.6 ab	1.4 a	*7.0*$_{ns}$
October 28				
Control	1805	9.9	1.3	7.5
KNO_3-50	1763	9.8	1.3	7.6
MKP-68	1755_{ns}	9.7_{ns}	1.3_{ns}	7.7_{ns}
November 7				
Control	2056 ab	9.8	1.3	7.8
KNO_3-50	1966 b	10.0	1.3	8.0
MKP-68	2100 a	9.8_{ns}	1.2_{ns}	7.9_{ns}

[z]Means for each parameter on the same date with the same letter are not significantly different according to LSD test at P = 0.05 (n = 4).

showed a shift to larger diameters for the MKP-68 and KNO_3-50 treatments (Fig. 5). Thirty-eight percent of the KNO_3-50 treatment fruit and 44% of the MKP-68 treatment fruit increased 20 mm or more from August 4 to November 28, compared to 20% of the control treatment fruit.

1996/97 'Marsh' and 'Star Ruby' Grapefruit

Rainfall in March 1996 was considerably higher than normal with over 10 inches recorded. This was followed by a 6-week period in April and early May that had less than 1 inch of total rainfall. Through most of the rest of the season, rainfall was adequate and little irrigation was required.

No differences were noted with respect to MKP applications in the 'Star Ruby' block for Brix, acid, Brix:acid ratio, or solids per box of fruit (Table 9). The MKP-1 treatment, however, had lower juice percentage than the control when measured on October 29. In contrast, there were some differences with respect to treatments in the 'Marsh' block juice parameters (Table 10). The control fruit had slightly lower Brix than the MKP-1, MKP-3, DKP-2 and DKP-3 treatments for fruit harvested on October 29. However, there were not significant differences for acid content, Brix:acid ratio, or solids per box when treatments were compared to the control. Similar to the 'Star Ruby' block, fruit in the MKP-1 treatment in the 'Marsh' block had lower juice content than control treatment fruit.

Fruit in both the 'Marsh' and 'Star Ruby' blocks were larger in diameter than those in the control plots (Fig. 6). The MKP and DKP treatments resulted in fruit that were typically 4-5 mm larger than the untreated controls. It is apparent that the main benefit of the foliar applications resulted from the April (post bloom) application, as there were no additional increases in size from the second and third applications for either variety.

In the 'Star Ruby' experiment, fruit sizes peaked in the 76-80 mm (3.0-3.15 inches) diameter class while all of the fruit from trees receiving the MKP applications peaked in the 80-84 mm (3.15-3.31 inches) diameter class (Fig. 7). About 12% of the control treatment fruit was larger than 84 mm compared to 43%, 51%, and 43% respectively, for the MKP-1, MKP-2, and MKP-2 treatments.

Fruit receiving MKP or DKP in the 'Marsh' experiment also peaked in a larger size class than the control fruit (Fig. 8). Control fruit peaked in the 84-88 mm (3.31-3.46 inches) class. The size distributions of all MKP and DKP treatments were similar (therefore only MKP-1 and DKP-1 are presented in Fig. 8) and peaked in the 88-92 mm (3.46-3.62 inch) range. Only 10% of the control fruit was larger than 92 mm. This percentage is considerably less than for DKP-1 at 43%, DKP-2 at 38%, DKP-3 at 33%, MKP-1 at 43%, MKP-2 at 35%, and MKP-3 at 35% of fruit greater than 92 mm in diameter.

Table 8. Mean diameter changes for 'Marsh' grapefruit on various dates in the fall of 1995.

Treatment	Diameter Aug. 8 (mm)	Mean diameter change from measurement in August: Sept. 10 (mm)	Sept. 10 (%)	Nov. 2 (mm)	Nov. 2 (%)	Nov. 29 (mm)	Nov. 29 (%)
Block A							
Control	80.2	8.9 ab	11.2 a	15.9 c	19.9 b	17.4 c	21.8 c
KNO_3-25	83.4	9.4 a	11.4 a	17.1 b	20.5 b	19.1 b	23.0 b
KNO_3-50	84.2	8.6 b	10.2 b	16.7 bc	19.9 b	18.3 b	21.8 c
MKP-34	81.3	8.4 b	10.4 b	16.1 c	20.0 b	17.5 c	21.6 c
MKP-68	81.7	8.8 b	10.8 ab	17.0 b	21.0 b	18.9 b	23.4 b
MKP-102	81.4 ns	9.3 a[z]	11.5 a	18.1 a	22.3 a	19.9 a	24.6 a
Block B	Aug. 4	Sept. 5		Nov. 1		Nov. 28	
Control	80.8	4.2 b	5.6 b	12.3 b	15.3 b	14.3 b	17.8 b
KNO_3-50	79.0	5.9 a	7.6 a	14.6 a	18.7 a	16.2 a	20.7 a
MKP-68	79.5 ns	5.7 a	7.2 a	15.0 a	18.9 a	16.7 a	21.1 a

[z]Means in each column for each block with the same letter are not significantly different according to LSD test at P = 0.05.

Discussion

Large grapefruit size is generally desirable and brings higher prices early in the season. In the 1995/96 experiments, post-bloom and summer applications of KNO_3 (25 and 50 lb KNO_3 $acre^{-1}$ $app.^{-1}$) and MKP (68 and 102 lb $acre^{-1}$ $app.^{-1}$) were found to increase average fruit size 1.9-2.4 mm over non-treated controls. Although the average change in diameter seems small, about 40% of the fruit that received the MKP-68 or KNO_3-50 treatments in 1995/96 increased 20 mm or more from August to November compared to only 20% for the non-treated control. In the data from the 1995/96 season, the fruit diameters in early August averaged about 80 mm for both Blocks A and B. The minimum diameter for size 40 grapefruit is 95.3 mm (3¾ inches) and the minimum for size 36 is 100.0 mm (3 15/16 inches). Assuming an initial 80 mm diameter and changes in diam-

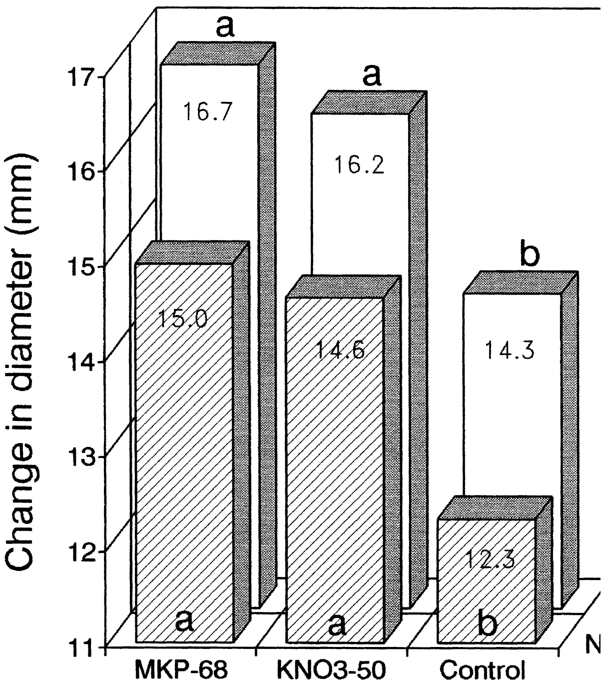

Figure 2. Average change in Block B fruit diameters from August
ber 1 and from August 4 to November 28, 1995 by treatment. Numbers
resent mean change in fruit diameter for the 192 fruit measured in eac
Bars with the same letter on the same date are not significantly differe
to LSD test at P = 0.05, n = 4

eter similar to that presented for Block B in the 1995/96 season, the foliar K applications would result in about 20% more fruit attaining the minimum diameter to be graded as a size 36 than the non-treated control.

The 1996/97 experiments showed 4-5 mm increases in fruit size due to the foliar DKP or MKP applications. When the 'Marsh' fruit were measured in September,

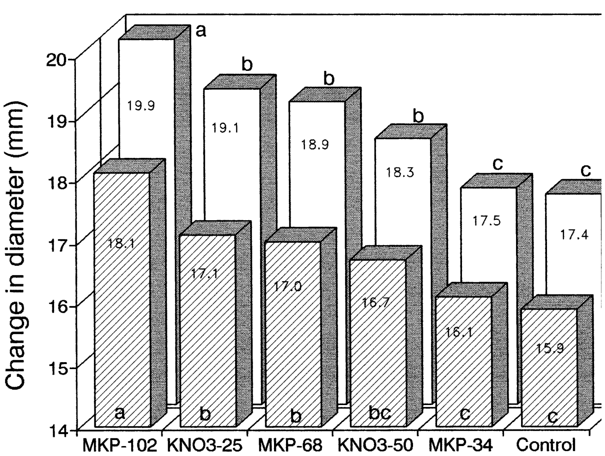

Figure 3. Average change in Block A fruit diameters from August
ber 2 and from August 8 to November 29, 1995 by treatment. Numbers
resent mean change in fruit diameter for the 192 fruit measured in eac
Bars with the same letter on the same date are not significantly differe
to LSD test at P = 0.05, n = 4

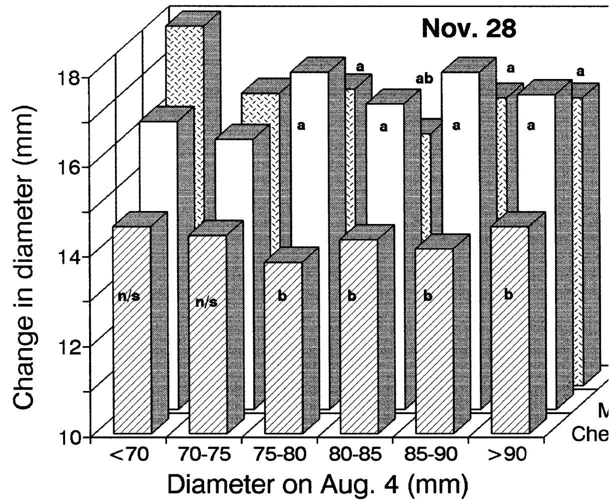

Figure 4. Change in fruit diameters for Block B treatments from Au
vember 28, 1995 by fruit size class on August 4. Bars with the same l
same class are not significantly different according to LSD test at P =

only 4% of the control fruit could pass as size 40 or larger compared to about 20% of the fruit receiving the MKP or DKP applications.

Foliar applications of DKP, MKP, or KNO_3 had no consistent effects on juice quality parameters compared to the control fruit. There was also little effect of the foliar applications on peel thickness. There were no visible differences in shape or peel texture in treated fruit compared to control fruit in any of the experiments.

Few effects have been observed on leaf N and K concentrations 30 days or more after foliar applications of MKP, DKP, or KNO_3. 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. Calvert (1969) also found the increase in leaf K after a KNO_3 spray to be temporary, with leaf K returning to initial levels 4 weeks after the application was made. Leaf P, however was found to increase following applications of MKP.

The post-bloom period appears to be the most important time to apply K to enhance grapefruit size. Potassium is one of the most important elements used in cell wall construction. Foliar K applications are recommended to supply abundant K to fruit during post-bloom cell division stage. Adequate K should also be present during the rapid cell enlargement phase that follows to ensure continued cell growth.

To achieve maximum benefit from the applied foliar materials, consideration should be given to timing of the

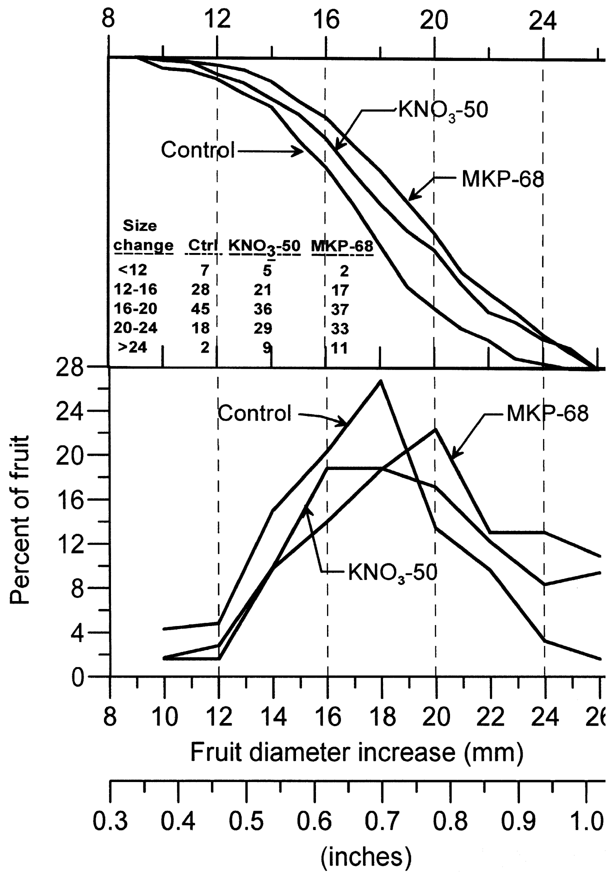

Figure 5. Distribution of fruit diameter changes (bottom panel) and tive percentage of fruit achieving various fruit diameter increases for B ments from August 4 to November 28, 1996.

Table 9. Mean juice analysis parameters for 'Star Ruby' grapefruit picked on October 29, 1996.

Treatment	Juice content (%)	Brix	Acid (%)	Brix:acid ratio (%)	Solids per box (lb)
Control	56.7 a[z]	11.0	1.3	8.7	5.3
MKP-1	54.8 b	11.0	1.3	8.7	5.1
MKP-2	56.1 ab	11.1	1.3	8.9	5.3
MKP-3	55.7 ab	11.3_{ns}	1.3_{ns}	8.8_{ns}	5.3_{ns}

[z]Means for each parameter with the same letter are not significantly different according to LSD test at P = 0.05 (n = 4).

Table 10. Mean juice analysis parameters for 'Marsh' grapefruit picked on October 29, 1996.

Treatment	Juice content (%)	Brix	Acid (%)	Brix:acid ratio (%)	Solids per box (lb)
Control	55.8 a[z]	9.9 b	1.2	8.0	4.8 ab
MKP-1	54.2 b	10.2 a	1.3	8.2	4.7 b
MKP-2	55.6 ab	10.1 ab	1.2	8.3	4.8 ab
MKP-3	55.8 ab	10.2 a	1.2	8.3	4.8 ab
DKP-1	55.5 ab	10.1 ab	1.3	8.1	4.8 ab

[z]Means for each parameter with the same letter are not significantly different according to LSD test at P = 0.05 (n = 4).

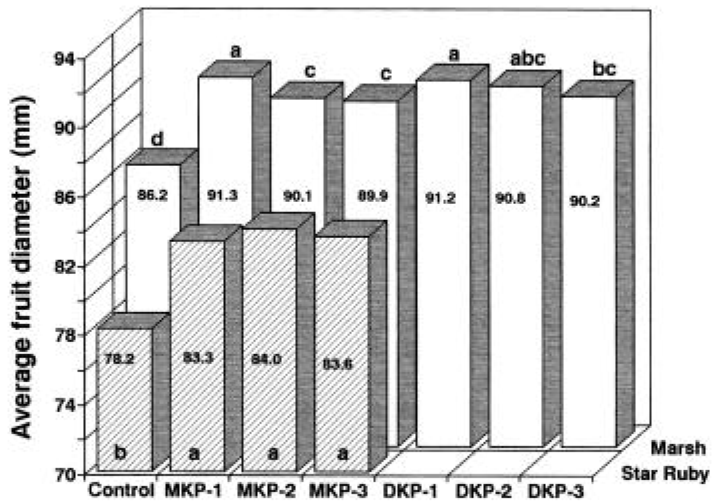

Figure 6. Average fruit diameters for fruit randomly measured on trees in ‘Star Ruby’ grapefruit plots (August 30, 1996) and ‘Marsh’ grapefruit (September 25). Mean fruit diameters (in mm) for each treatment are shown on bars. (Bars with the same letter for the same variety are not significantly different according to LSD test at P = 0.05, n = 4).

Table 10. Mean juice analysis parameters for ‘Marsh’ grapefruit picked on October 29, 1996.

Treatment	Juice content (%)	Brix	Acid (%)	Brix:acid ratio (%)	Solids per box (lb)
DKP-2	56.8 a	10.2 a	1.2	8.2	4.9 a
DKP-3	56.8 a	10.2 a	1.2_{ns}	8.2_{ns}	4.9 a

[z]Means for each parameter with the same letter are not significantly different according to LSD test at P = 0.05 (n = 4).

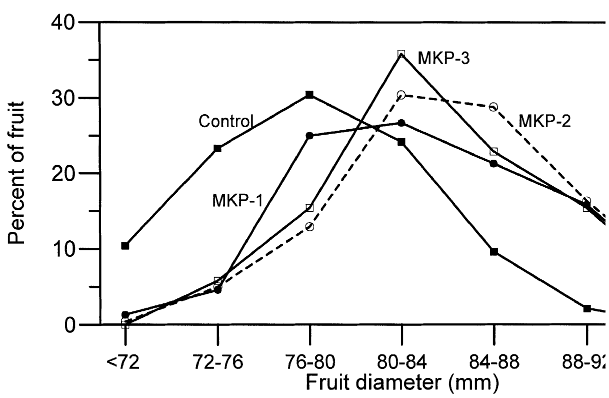

Figure 7. Fruit diameter distribution for ‘Star Ruby’ grapefruit conti treatments measured on August 30, 1996.

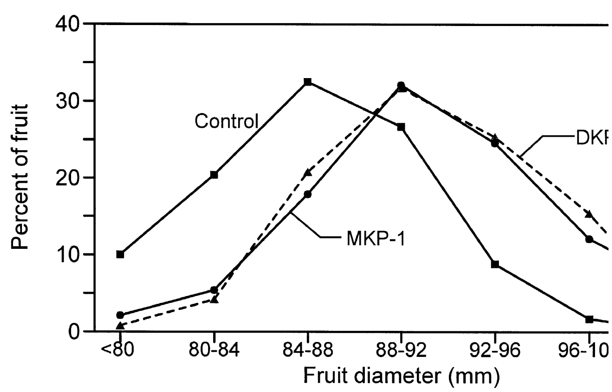

Figure 8. Fruit diameter distribution for ‘Marsh’ grapefruit control, DKP-1 treatments measured on September 25, 1996.

sprays. In the 1996/97 season, no additional benefit was obtained from May and July applications. However, previous work (Boman, 1997) showed some benefit from fall foliar applications that enhanced fruit size in grapefruit. Potassium is easily leached from the sandy soils on which much of Florida citrus is grown. Therefore, little of the spring-applied K is available following the normal summer rainy season.

The ultimate size a grapefruit will achieve is the result of many complex factors. In order that foliar K applications afford maximum effectiveness in achieving grapefruit size enhancements, they should be scheduled during the post-bloom period. If additional applications are desired, they should be applied in August or early

September when their effectiveness may be greatest. Application decisions should be made on an individual block basis considering fruit size distribution, general nutritional status of the trees, effects of summer rains, fruit load, and estimated benefits of the applications.

Literature Cited

Boman, B. J. 1997. Effectiveness of fall potassium sprays on enhancing grapefruit size. Proc. Fla. State Hort. Soc. 110: 1-7.

Calvert, D. V. 1969. Spray applications of potassium nitrate for citrus on calcareous soils. Proc. 1st Int'l Citrus Symposium. 3:1587-1597.

Calvert, D. V. 1974. Response of 'Marsh' grapefruit trees in the Indian River area to potassium application - yield and fruit quality. Proc. Fla. State Hort. Soc. 86:13-19.

Calvert, D. V. and R. C. Smith. 1972. Correcting potassium deficiency of citrus with KNO_3 sprays. Agricultural and Food Chemistry. 20(3):659-661.

Deszyck, E. J. and R. C. J. Koo. 1957. Potash fertilization in a mature Duncan grapefruit orchard. Proc. Soil and Crop Sci. Soc. Fla. 19:302-310.

Embleton, T. W., W. W. Jones, A. L. Page and R. G. Platt. 1969. Potassium and California citrus. Proc. 1st Int'l Citrus Symp. 3:1599-1603.

Koo, R. C. J. 1968. The role of potassium in agriculture. Amer. Soc. Agronomy. Madison, WI. p. 469.

Page, A. L., J. P. Martin and T. J. Ganje. 1963. Foliar absorption and translocation of potassium by citrus. Proc. Amer. Soc. Hort. Sci. 82:165-171.

Reitz, H. J. and R. C. J. Koo. 1959. Effect of nitrogen and potassium fertilization on yield and fruit quality of Valencia orange on calcareous soil. Proc. Fla. State Hort. Soc. 72:12-16.

Reitz, H. J. and R. C. J. Koo. 1960. Effect of nitrogen and potassium fertilization on yield, fruit quality, and leaf analysis of Valencia orange. Proc. Amer. Soc. Hort. Sci. 75:244-252.

Sites, J. W. 1950. The effects of variable potash fertilizer on the quality and production of Duncan grapefruit. Proc. Fla. State Hort. Soc. 63:60-68.

Smith, P. F. and G. K. Rasmussen. 1960. Relationship of fruit size, yield, and quality of marsh grapefruit to potash fertilization. Proc. Fla. State Hort. Soc. 73:42-49.

Tucker, D. P. H., A. K. Alva, L. K. Jackson and T. A. Wheaton. 1995. Nutrition of Florida citrus. Univ. of Fla., IFAS, SP-169. 61pp.