Fertigation with potassium increases size and yield in fresh figs growing in California

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Abstract

Nutritional status and evolution throughout the growing season has been studied in fig (*Ficus carica* L.) cultivars intended for drying; however, the literature is scarce regarding the effect of macronutrient concentrations on fresh figs. Research indicates that the levels of nitrogen (N), phosphorus (P), potassium (K) and calcium (Ca) are important in generating high yields of marketable fruit. We quantified the effects of an intense fertigation program of potassium and calcium on two cultivars of fresh figs, 'Black Mission' and 'Sierra', on yield, marketable yield, fruit size, soluble solids concentration (SSC), titratable acidity (TA), and the reduction of culls. We also monitored leaf macronutrient concentrations throughout the growing season. As leaf macronutrients reached a plateau after June, leaf sampling collected in midsummer (July-September) is recommended for fresh fig. In general, nutrient evolution was similar in both cultivars with leaf N, P and K levels decreasing during late spring (May) to fall (October). These low N and K leaf levels in control trees late in the season suggest the potential benefits of applying N and K during the season. The fertigation program significantly increased yield and marketable yield in both cultivars, and increased fruit size in 'Sierra'. In 'Sierra' figs, leaf K concentration was positively correlated with yield, marketable yield, and fruit size. Fertigation had no effect on fruit SSC or TA for either cultivar.

Keywords: culls, fruit weight, quality attributes, ostiole-end splitting, side cracking, leaf sampling, macronutrients

INTRODUCTION

California ranks first in the United States for fig (*Ficus carica* L.) production, and the market for fresh figs in the state has grown recently (Crisosto et al., 2010; USDA NASS, 2009). The benefits of nitrogen (N), phosphorous (P), and potassium (K) fertilization with additional calcium (Ca) or K treatments during the growing season increasing overall quality by reducing the number of fruit with ostiole-end cracking and sunscald on 'Calimyrna' or 'Sarılop' figs (İrget et al., 2008), and others (Aksoy and Anac, 1994; Opara et al., 1997; Antunes et al., 2008; Irfan et al., 2013) have been reported from several countries. Under California conditions, we evaluated the benefits of K and Ca, both foliar and fertigation applications on fresh fig fruit size, yield, and sound fruit during two seasons. A foliar spray mixture of K and Ca applied to 'Black Mission', 'Brown Turkey' and 'Sierra' reduced the incidence of side cracking and increased fruit size (C.H. Crisosto, pers. commun.). However, the response to foliar treatments was highly variable between plants, suggesting uptake problems. Additionally, an increase in the percentage of fruit with ostiole-end splitting in 'Sierra' figs was observed. We speculated that this was due to the gravitational collection of the spray mixture on the ostiole-end of the fruit. For that reason, during the last two years, we focused on K and Ca applied through a drip line (fertigation). Our objective was to evaluate fertigation with K and Ca on increasing yield, marketable yield, fruit size, and reducing culls.

We also were interested in evaluating leaf nutrient evolution throughout the fig growing season in trees treated and untreated (control) with K and Ca. High-vigor and low-

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vigor fig orchards in central California were surveyed for macronutrients, but no values were deemed to be optimal for production (Brown, 1994). A defined optimal macronutrient concentrations in fig leaves was attempted from orchards fertilized three times a year with 250 kg ha^{-1} calcium superphosphate, 200 kg ha^{-1} potassium chloride, 200 kg ha^{-1} ammonium nitrate and 1,000 kg ha^{-1} organic matter after four consecutive years of sampling (Moreno et al., 1998). By monitoring concentrations of N, P, K, and Ca in trees under K and Ca fertigation and control (32 units of N ha^{-1}), and then comparing that to yield and quality attributes we can aim to generate a preliminary consensus of what leaf macronutrient concentrations are optimal, as well as how to efficiently achieve those levels through fertigation.

MATERIALS AND METHODS

The fertigation study took place at the Kearney Agricultural Research and Extension Center (KARE), Parlier, California. The fig plot was planted in 2008 on sandy loam soil and contains six cultivars: 'Black Mission', 'Brown Turkey', 'Kadota', 'Sequoia', 'Sierra', and 'Tina'. The planting design is a randomized complete block with ten rows. Each cultivar is replicated in each of the ten rows with 5 trees $replicate^{-1}$. Each cultivar's position in each row was randomly assigned. The trees are spaced 5.4 m between rows and 2.4 m between trees within the row (771 trees ha^{-1}). The irrigation system consists of a single drip lateral per row with 6 drip emitters $tree^{-1}$. Trees were irrigated at 100% ET during the duration of the experiment. Nitrogen (32 units ha^{-1}) was applied in three applications to all trees (treated and control) through the drip system at a rate of 47 L ha^{-1} (4/6/2015, 5/6/2015 and 6/2/2015).

Potassium (K) and calcium (Ca) fertigation treatments

The treated rows of the KARE fig plot received fertigation of KTS (25+17S) (1.4 units of K ha^{-1}) and CaTs (6Ca+17S) (0.28 units of Ca ha^{-1}) at a rate of 47 L ha^{-1} nine times for a total of 12.6 units of K ha^{-1} and 2.5 units of Ca ha^{-1}. The applications took place on 4/17/2015, 5/17/2015, 5/19/2015 (KTS only), 5/29/2015 (CaTs only) 6/10/2015, 6/17/2015, 7/2/2015, 7/23/2015, 7/30/2015 and 8/13/2015.

Leaf macronutrient concentrations

Leaf samples were collected on 5/12/2015, 6/29/2015, 8/10/2015 and 9/11/2015 from 'Black Mission' and 'Sierra.' Each leaf sample consisted of 20 leaves of the youngest fully expanded exposed leaves on non-fruiting branches from the perimeter of each tree at a 2.5 m height (Brown, 1994). Samples were washed and dried and then delivered to the UC Davis Analytical Lab to determine percentage of N, P, K and Ca by dry weight basis.

Quality measurements

Fruit quality evaluations were conducted only on 'Black Mission' and 'Sierra' which included: yield, fruit size (weight), soluble solids concentration (SSC), titratable acidity (TA) and visual inspection of culls based on skin damage (side cracking and ostiole-end splitting) according to previous work (Kong et al., 2013).

Data analysis

Data were analyzed by statistical analysis software (SAS). The analysis of variance was conducted to check for normal distribution and to determine if there were differences between treatments. This analysis was followed by Tukey's test for mean comparisons.

RESULTS

Yield and quality measurements

K and Ca fertigation treatment increased yield in both cultivars. The percentage culls in 'Black Mission' was 49% for control and 43% for treated trees. Similar results were obtained in 'Sierra' with 42% for control and 36% for treated trees. Thus, marketable yield was higher for treated than control trees for both cultivars. Only fruit size was significantly improved by fertigation in 'Sierra', while SSC and TA were not affected in either cultivar (Table 1).

Table 1. Influence of potassium and calcium fertigation (12.6 units of K ha^{-1} and 2.5 units of Ca ha^{-1}) on yield and fruit quality attributes of 'Black Mission' and 'Sierra' fresh figs grown at the Kearney Agricultural Research and Extension Center, Parlier, CA.

Cultivar	Treatment	Yield (t ha^{-1})	Marketable yield (t ha^{-1})	Fruit size (g $fruit^{-1}$)	SSC (%)	TA (%)
Black Mission	Control	26.5a[1]	13.6a	36.9a	20.5a	0.3a
	Treated	32.6b	18.9b	36.8a	18.2a	0.3a
Sierra	Control	19.1a	9.1a	38.7a	19.3a	0.3a
	Treated	21.7b	11.7b	40.4b	19.6a	0.3a

[1]Same letters within the column indicates no significant differences.

Leaf macronutrient concentrations

In general, nutrient evolution was similar in both cultivars with leaf N, P and K levels decreasing during late spring (May) to fall (October) (Tables 2 and 3). These low N and K leaf levels in control trees late in the season suggest the potential benefits of applying N and K during the season. Contrary to that, Ca levels showed a slight increase late in the season (Ersoy et al., 2003). All of the leaf nutrients reached a plateau after the June sampling, suggesting that leaf sampling collected in midsummer (July-September) will be more stable and representative than earlier leaf sampling agreeing as previously recommended for California dry fig orchards (Brown, 1994; Brizola et al., 2005). Leaf sampling nutrients did not exhibit differences between trees treated and control with K and Ca, except late in the season for 'Black Mission'.

Relationships between leaf macronutrients, marketable yield and fruit size

Marketable yield in 'Sierra' was significantly correlated to leaf N levels (R^2=0.54 and P-value=0.038) and leaf K levels (R^2=0.53 and P-value=0.041) collected during midsummer. Thus, high marketable yield was attained with high leaf N and K values because to low incidences of ostiole-end splitting and side cracking. Fruit size was also significantly related to leaf K levels (R^2=0.51 and P-value=0.047). As leaf K increased fruit size increased suggesting that leaf K values equal to or higher than 2.0% should be preferred for fresh figs.

CONCLUSIONS

This research demonstrated that substantial fertigation of K and Ca can significantly increase marketable yield of 'Black Mission' and 'Sierra' fresh fig cultivars, which is imperative for the fresh fig producers since marketable yield determines revenue. Fruit size was also increased by fertigation treatment in 'Sierra' figs, and this increase in size is related to high leaf K concentrations.

Table 2. Mean macronutrient concentrations (% dry weight) of 'Black Mission' fig leaves collected on four sampling dates from trees fertigated with 12.6 units of K ha^{-1} and 2.5 units of Ca ha^{-1} grown at the Kearney Agricultural Research and Extension Center, Parlier, CA. Each mean is a composite sample of 10 trees.

Date	Treatment							
	Control N	Treated N	Control P	Treated P	Control K	Treated K	Control Ca	Treated Ca
May 12	2.89	2.99	0.156	0.164	1.27	1.36	2.40	2.24
Jun 29	2.24	2.30	0.119	0.123	1.23	1.35	3.12	2.90
Aug 10	2.14	2.21	0.122	0.115	1.21	1.20	2.46	2.94
Sept 11	1.98	2.13	0.109	0.109	1.08	1.42	3.33	3.32

Table 3. Mean macronutrient concentrations (% dry weight) of 'Sierra' fig leaves collected on four sampling dates from trees fertigated with 12.6 units of K ha^{-1} and 2.5 units of Ca ha^{-1} grown at the Kearney Agricultural Research and Extension Center, Parlier, CA. Each mean is a composite sample of 8 trees.

Date	Treatment							
	Control N	Treated N	Control P	Treated P	Control K	Treated K	Control Ca	Treated Ca
May 12	3.21	3.15	0.166	0.172	1.64	1.44	2.79	2.49
Jun 29	2.34	2.41	0.136	0.133	1.79	1.88	3.35	3.41
Aug 10	2.20	2.00	0.132	0.114	1.65	1.54	3.21	3.51
Sept 11	2.13	2.09	0.118	0.107	1.66	1.52	3.50	3.80

As leaf nutrients reach a plateau after June, leaf sampling collected in midsummer (July-September) is recommended for fresh fig as previously recommended for dry figs. Young, but fully expanded perimeter leaves on non-fruiting branches should be used for sampling in order to achieve standardized results and to diagnose orchards. Since yield, marketable yield, and fruit size positively correlated with leaf K concentration in 'Sierra' figs, we propose that leaf K concentrations equal to or higher than 2.0% are ample for commercial fresh fig orchards. This is almost twice the leaf K concentration values recorded by Brown (1994) in high vigor orchards not receiving potassium fertilization, but similar to levels surveyed by Proebsting and Warner (1954) in orchards fertilized with potassium. Our research, in conjunction with previous literature, suggests that more work needs to be done to fully understand critical leaf K concentrations for optimal yield and fruit quality of fresh figs.

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