Effects of Foliar Potassium Fertilization on Muskmelon Fruit Quality and Yield[1]

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ABSTRACT

Sugar content, aroma and texture are key quality traits that influence consumer preference of many fruits and vegetables such as muskmelon [*Cucumis melo* L. (Reticulatus Group)]. These quality traits are directly related to potassium (K)-mediated processes. However, soil-derived K alone is seldom adequate to satisfy these fruit quality processes. Controlled environment studies have shown that supplemental foliar K applications can overcome this apparent deficiency. However, the suitability of potential K salts as foliar sources is still uncertain. We evaluated six foliar K sources (potassium chloride - KCl, potassium nitrate - KNO_3, monopotassium phosphate – MKP, potassium sulfate - K_2SO_4, potassium thiosulfate - KTS , and a glycine amino acid-complexed K- Potassium Metalosate, KM) for effects on fruit quality parameters of field-grown muskmelon 'Cruiser' over two growing seasons, 2006 and 2007 in Weslaco, south Texas. Weekly foliar K applications were initiated at fruit set and continued to fruit maturity. Although soil K concentrations were very high, supplemental foliar K treatments resulted in higher K concentrations in plant tissues, suggesting that plant K uptake from the soil solution was not sufficient to saturate tissue K accumulation. In 2006, fruit yields were not affected by supplemental foliar K spray but in 2007, yields differed significantly among the foliar K sources with treated plots generally having higher yields than the control plots. Fruit from plots receiving supplemental foliar K had higher external and internal fruit tissue firmness than control fruit and this was associated with generally higher soluble solids concentrations (SSC) in both years. All the foliar K sources studied had positive effects on fruit quality parameters except for KNO_3 which tended to result in less firm fruit with lower SSC values. These results demonstrate that the apparent K deficiency caused by inadequate uptake can be alleviated by supplemental foliar K applications and that the effectiveness of foliar K fertilization will depend not only on the source of fertilizer K, but also on environmental conditions affecting soil K availability and overall plant growth and development.

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INTRODUCTION

Potassium (K) is an essential plant nutrient involved in numerous physiological processes that control plant growth, yield and quality parameters such as taste, texture and nutritional/health properties (Marschner, 1995; Lester, 2005). The majority of K in plant tissues is taken up by roots from the soil solution in its ionic form (K^+). Even though, K is abundant in most soils in Texas, both plant and environmental factors often limit adequate plant K uptake. In many crops, K uptake occurs mainly during the vegetative stages of plant growth when root growth is not inhibited by carbohydrate supply (Fisher et al., 1970). During reproductive development, competition for photoassimilates between developing fruits and vegetative organs limits root activity and nutrient uptake (Ho, 1988). Environmental factors such as soil type, soil moisture availability, and temperature also tend to control soil solution K levels and plant uptake capacity through a variety of mechanisms (Mengel and Kirkby, 1980). Hence, soil-derived K, which is essential for sugar production, transport and storage in fruit, is not always optimal during the critical fruit development period, and this is partly responsible for poor fruit quality, and yield.

Previous controlled environment studies (Lester et al., 2005, 2006) have shown that supplementing soil K supply with foliar K applications during fruit development and maturation can improve muskmelon fruit quality parameters such as fruit firmness, sugar content, ascorbic acid and beta-carotene levels. For field-grown plants, increasing soil fertilizer inputs may not be enough to alleviate the developmentally-induced K deficiency partly because of reduced root activity during reproductive development and also because of competition for binding sites on roots from cations such as calcium and magnesium (Clarkson, 1989; Engels and Marschner, 1993). Data of Lester et al. (2005) indicated that the beneficial effects of supplemental foliar K application on fruit quality were greater when an organic form of K (Metalosate®-K) was used compared to an inorganic (e.g. potassium chloride, KCl) source. Potassium chloride is the most widely used source of fertilizer K, however, its relatively high salt index (~120, Mortvedt, 2001) and its high point of deliquescence (POD, 86%, Schönherr and Luber, 2001) limits its use for foliar nutrition. A high POD increases the risk of crystallization following foliar sprays.

The objective of this study was to evaluate the effectiveness of different K salts for foliar K fertilization on muskmelon fruit yield and quality parameters.

MATERIALS AND METHODS

Six K sources and a control were evaluated in field studies during the spring growing seasons of 2006 and 2007 in Lower Rio Grande Valley region of Texas, an area with a semiarid climate averaging approximately 500 mm of rainfall. Soil type at the study site was a Hidalgo sandy clay loam. Standard commercial practices for spring muskmelon production including irrigation, nutrient management, and pest control were followed. In both years, plots were established in a completely randomized design and replicated four times. Starting at fruit set, and continuing till fruit maturation, the following weekly foliar K treatments were established: (1) control (sprayed with de-ionized water), (2) potassium chloride (KCl) (3) potassium nitrate (KNO_3), (4) Monopotassium phosphate (MKP – Mora-Leaf® P&K 30% K_2O, Rotem BKG LLC, Ft Lee, NJ) (5) potassium sulfate (K_2SO_4), (6) potassium thiosulfate ($K_2S_2O_3$; KTS® , 25% K_2O, Tessenderlo Kerley Inc., Phoenix, AZ) and (7) a glycine amino acid-complexed K (Potassium Metalosate®, KM, 24% K_2O; Albion Laboratories, Inc, Clearfield, Utah). A non-ionic surfactant (Silwet L-77; Helena Chem. Co., Collierville, TN) was added to all spray treatments at 0.3% (v/v). All foliar

K solutions were formulated according to manufacturer recommendations and calibrated to supply ~4 lbs K_2O per acre during each foliar application. All treatments were applied between 0500 and 0800 HR on each spray event. A total of 5 foliar K applications (total ~20 lbs K_2O/ac) per treatment were made each year. At maturity, uniform fruits (7-10 per treatment) were harvested from each plot and analyzed for fruit sugars, fruit firmness, K concentration, soluble solids concentration, ascorbic acid, and β-carotene following the procedures previously described by Lester et al. (2005).

RESULTS AND DISCUSSION

Pre-plant soil tests indicated moderate to very high potassium (>550 $mg \cdot kg^{-1}$) levels, so no K was added to the soil. Phytotoxicity problems were not observed with any of the foliar K sources and concentrations used. The pH levels of spray solutions ranged from 6.5 to 7.7. Unbuffered solutions of most K sources tend to have alkaline pH levels that can cause leaf burns and this is more pronounced when applied during dry, hot weather conditions (Swietlik and Faust, 1984). In the present study, all treatments were applied between 0500 and 0800 when air humidity (>80%), temperatures (< 25°C) and wind speeds (<1mph) were less favorable for leaf burn development.

Plant tissues from plots receiving supplemental foliar K treatments generally had higher K concentrations than those from control plots, suggesting that soil K supply alone was not sufficient to saturate tissue K accumulation (Table 1). However, differences in tissue K concentrations among the foliar K sources were not highly significant except for KNO_3 treatments which generally had the least beneficial effect on tissue K concentrations, perhaps a dilution effect resulting from NO_3-enhanced vegetative growth.

Soluble solids concentrations differed significantly among the foliar K treatments in both years and were generally lower in 2007 than in 2006. With the exception of KCl and KNO_3, all the other foliar K sources significantly increased fruit SSC levels compared to the control treatment. Although SSC values were generally lower in 2007 than in 2006, the relative benefit from supplemental foliar K was observed in 2007. Unseasonable weather conditions (cold fronts) during the 2007 growing season delayed vegetative development and as a consequence, there was a substantial overlap between full canopy development and fruit maturation. This is a probable reason for the marginal SSC values observed in 2007. Nevertheless, a positive and more pronounced response to foliar K treatments was recorded in 2007. In 2006, similar trends were also observed for total and component sugars (glucose, sucrose and fructose; data not shown) but variability in individual observations resulted in inconsistent trends among the K sources. The general trend of increased SSC and sugar contents in fruit from of K treated plots is consistent with, but less dramatic than our previous observations with supplemental foliar K application in controlled environment studies (Lester et al., 2005). In 2006, total ascorbic acid and beta-carotene concentrations were also generally increased as a result of supplemental foliar K applications however, the trends were not consistent among the K sources. Preliminary analysis of fruit from the 2007 study also show a trend of increased ascorbic acid concentration in fruit from treated plots compared to those from control plots (data not shown).

While foliar K applications generally increased fruit firmness in both years, no significant differences were found among the K sources except for KNO_3 which tended to result in less firm fruit compared to controls (Table 2). Firmness measurements are a good indicator of fruit texture and shelf life. In a previous study it was found that fruit firmness was closely correlated with fruit tissue pressure potential (ψ_p; Lester et al., 2006), with fruit from K-treated plants having significantly higher ψ_p values than those of control plants. Fruit yields averaged 6,000 lb/ac based on a once-over harvest during peak fruit maturity in 2006, and 20,100 lb/ac in 2007 based on harvests over a 2wk period. Significant yield differences between supplemental foliar K treatments and the control were observed only in 2007 and consistent with SSC results, yields from KCl-treated plots were not significantly different from those of control plots. Individual fruit fresh weights of K-treated fruit did not differ significantly from those of fruit from control plots. However, fruit counts from treated plots were slightly greater than those from control plots (data not shown) potentially accounting for the increased yields. Studies of yield responses to supplemental K are mixed. Hartz et al. (2005) reported that K fertigation (supplemental K injected into the irrigation water) increased yields and improved fruit color of tomatoes even when exchangeable soil K concentration was high; they found no effect of foliar applied K on yield and quality, perhaps due to confounding factors related to soil processes and climatic conditions. In other studies, Hartz et al. (2001) concluded that supplemental K fertilization did not have any effect on fruit yield, SSC, or juice color in situations where initial soil exchangeable K exceeded ~130 $mg \cdot kg^{-1}$. These conflicting results demonstrate that the benefit of supplemental foliar K application on field-grown crops will depend on other prevailing environmental conditions controlling available soil K and plant development. Such factors can either intensify or mask the beneficial effects of supplemental foliar K applications.

Results of the current study generally support our previous controlled environment findings that supplementing soil K supply with foliar K applications during fruit development and maturation can improve muskmelon fruit quality by increasing firmness, sugar content, and perhaps yield under unfavorable environmental conditions. The current data also provide additional evidence of differences among potential foliar K sources, with KNO_3 consistently having the least beneficial effects on fruit yield and quality.

LITERATURE CITED

Clarkson, D.T. 1989. Ionic relations, p. 319-353. In: M. Walkins (ed.). Advanced plant physiology. John Wiley & Sons, N.Y.

Engels, C. and H. Marschner. 1993. Influence of the form of nitrogen supply on root uptake and translocation of cations in the xylem exudate of maize (*Zea mays* L.). J. Exp. Bot. 44:1695-1701.

Fisher, J.D., D. Hausen, and T.K. Hodges. 1970. Correlation between ion fluxes and ion stimulated adenosine triphosphatase activity of plant roots. Plant Physiol. 46:812-814.

Hartz, T.K., G. Miyao, R.J. Mullen, and M.D. Cahn. 2001. Potassium Fertilization Effects on Processing Tomato Yield and Fruit Quality. Acta Hort., 542:127–133.

Hartz, T.K., P.R. Johnstone, D.M. Francis and E.M. Miyao. 2005. Processing tomato yield and fruit Quality improved with potassium fertigation. HortScience 40(6):1862-1867.

Lester, G.E. 2005. Whole Plant Applied Potassium: Effects on Cantaloupe Fruit Sugar Content and Related Human Wellness Compounds. Acta Hort. 682:487-492.

Lester, G.E., J.L. Jifon and D.J. Makus. 2006. Supplemental Foliar Potassium Applications with and without surfactant can enhance netted muskmelon quality. HortSci. 41(3):741-744.

Lester, G.E., J.L. Jifon and G. Rogers. 2005. Supplemental Foliar Potassium Applications during Muskmelon (*Cucumis melo* L.) Fruit Development can Improve Fruit Quality, Ascorbic Acid and Beta-Carotene Contents. J. Amer. Soc. Hort. Sci. 130:649-653.

Marschner, H. 1995. Functions of mineral nutrients: macronutirents, p. 299-312. In: H. Marschner (ed.). Mineral nutrition of higher plants 2nd Edition. Academic Press, N.Y.
Mengel, K. and E. A. Kirkby. 1980. Potassium in crop production. Adv. Agron. 33:59-110.
Mortvedt, J.J. 2001. Calculating Salt Index. Fluid Journal. Spring 2001.
Schönherr, J, and M. Luber. 2001. Cuticular penetration of potassium salts: effects of humidity, anions and temperature. *Plant and Soil* 236: 117–122.
Swietlik, D. and M. Faust. 1984. Foliar nutrition of fruit crops. p. 287-356. In: J. Janick (ed.). Horticultural Reviews Vol. 6. Avi Pub. Co. Westport, Conn.

Table 1. The effects of foliar potassium (K) sources (potassium chloride – KCl, potassium nitrate - KNO_3, Monopotassium phosphate – MKP, potassium sulfate - K_2SO_4, potassium thiosulfate - KTS, and Potassium Metalosate - KM) on tissue K concentrations and fruit soluble solids concentrations (SSC) of field-grown muskmelon ('Cruiser') fruit in south Texas. Weekly foliar K applications were made between fruit set and fruit maturity during the spring growing season in 2006 and 2007.

Treatment	Leaf ($mgK \cdot gdw^{-1}$)		Petiole ($mgK \cdot gdw^{-1}$)		Stem ($mgK \cdot gdw^{-1}$)		SSC (%)	
	2006	2007	2006	2007	2006	2007	2006	2007
Control	11.9cd	12.9b	48.2d	54.3b	42.9d	46.1c	9.2b	8.1b
KCl	11.6d	14.1a	55.2bc	63.4a	49.3c	53.7b	10.0ab	9.3ab
KNO_3	10.7d	13.1b	47.6d	54.9ab	41.6d	47.8bc	9.7ab	8.7b
MKP	13.2bc	15.9a	51.6cd	59.4ab	46.7cd	53.7b	10.6a	10.1a
K_2SO_4	14.7a	14.9a	50.2cd	58.7ab	64.0a	69.6a	10.5a	9.7a
KTS	13.9ab	16.8a	64.2a	73.9a	55.4b	63.7a	10.7a	10.4a
KM	14.7a	15.4a	57.8b	66.5a	48.1c	53.5b	10.3a	9.8a

[z] Means with the same letter, within a column and location are not significantly different at Duncan's MRT 95% probability level (n=6-16).

Table 2. Effects of foliar potassium (K) sources (potassium chloride – KCl, potassium nitrate - KNO_3, Monopotassium phosphate – MKP, potassium sulfate - K_2SO_4, potassium thiosulfate - KTS, and Potassium Metalosate - KM) on the yield, average fruit weight and fruit firmness of field-grown muskmelon ('Cruiser') fruit. Weekly foliar K applications were made between fruit set and fruit maturity during the spring growing season in 2006 and 2007.

Treatment	Yield 40lb-boxes/acre		Fruit Weight (g)		External Fruit firmness (N)		Internal Fruit firmness (N)	
	2006	2007	2006	2007	2006	2007	2006	2007
Control	144.5a[z]	455.9b	1826.3a	2148.4a	41.7b	41.2a	10.2bc	8.9b
KCl	148.8a	506.2a	1867.5a	2295.7a	43.0b	44.7a	10.6abc	9.9ab
KNO_3	136.1a	429.9b	1770.9a	2191.3a	39.6b	39.9a	9.8c	8.4b
MKP	160.2a	530.0a	1763.7a	2384.7a	43.3b	46.1a	11.2abc	10.9a
K_2SO_4	155.8a	517.0a	1977.8a	2298.1a	57.8a	45.2a	12.8ab	10.3ab
KTS	166.9a	573.9a	1805.2a	2496.0a	51.8ab	46.8a	13.1a	11.1a
KM	151.4a	521.9a	1936.3a	2337.4a	43.6b	45.7a	11.2abc	10.7a

[z] Means with the same letter, within a column and location, are not significantly different at Duncan's MRT 95% probability level (n=6-16).