FOLIAR FERTILIZATION: IMPROVING THE HUMAN WELLNESS ATTRIBUTES OF MELON

G.E. Lester[1] and J.L. Jifon[2]
[1]Subtropical Agricultural Research Center,
U.S. Department of Agriculture, Weslaco, TX
glester@weslaco.ars.usda.gov (956)447-6322
[2]Texas A&M University, TAES, Weslaco, TX

ABSTRACT

Netted muskmelon [*Cucumis melo* L. (Reticulatus Group)] fruit quality (ascorbic acid, beta-carotene, total free sugars, and soluble solids concentration (SSC)) is directly related to plant potassium (K) concentration during fruit growth and maturation. During fruiting, soil fertilization alone is often inadequate due to poor root uptake and competitive uptake inhibition from calcium and magnesium. Foliar applications of Potassium Metalosate during cantaloupe fruit development has been shown to improve fruit quality, however, the influence of organic glycine-complexed K vs. an inorganic salt form has not been determined. In this study, the effects of two K sources; glycine-complexed K (Potassium Metalosate) vs. potassium chloride (KCl) with or without a surfactant were studied following application of K during fruit growth and maturation of glasshouse grown orange-flesh netted muskmelon 'Cruiser'. Plants were fertilized throughout the study with soil-applied N-P-K fertilizer. Flowers were hand pollinated and only one fruit per plant was allowed to develop. Starting at 3 to 5 d after fruit set, and up to 3 to 5 d prior to fruit maturity (i.e. full slip), entire plants were sprayed weekly, including the fruit, with Potassium Metalosate, (24% K diluted to 4.0 $mL \cdot L^{-1}$) or KCl, (24% K diluted to 4.0 $mL \cdot L^{-1}$) with or without a Silwett L-77 (surfactant). Fruit from plants receiving supplemental foliar K were firmer, both externally and internally, than those from non-treated control plants. Increased fruit tissue firmness was accompanied by higher cell pressure potentials of K treated plants vs. control. In general, all K treated fruit had significantly higher SSC, total sugars, total ascorbic acid, and beta-carotene concentrations than control fruit. Autumn grown fruit, generally had higher SSC, total sugars, total ascorbic acid and beta-carotene concentrations than spring-grown fruits regardless of K treatment. There were no consistent differences among the K sources (with or without surfactant) on these fruit quality parameters, however, addition of a surfactant tended to increase SSC and beta-carotene in some instances.

INTRODUCTION

With the exception of nitrogen, potassium is required by plants in much greater amounts than all the other soil-supplied nutrients (Tisdale et al., 1985). Adequate supply of fertilizer potassium is therefore necessary for sustainable crop production. Plants obtain K primarily from the soil in the form of K^+ which is also adsorbed by soil components particularly clay particles and is, therefore, of limited mobility in most soils (Brady, 1984; Tisdale, et al., 1985). Potassium uptake by plants from the soil solution is regulated by several factors including moisture conditions, pH, texture, aeration, and temperature (Mengel and Kirkby, 1980; Tisdale et al., 1985). Clay soils can adsorb and retain more K and thus generally provide more to the soil

solution for plant uptake than sandy soils. Both calcium and magnesium compete with K for root uptake, hence plants grown in soils with high levels of these elements can exhibit K deficiencies even though soil analyses indicate adequate K. Furthermore, neutral and acid soils tend to have a higher capacity to release K into the soil solution than alkaline soils. Increasing soil moisture increases movement of K to plant roots and enhances availability. However, if the soil is saturated, root activity declines due to poor aeration and thereby decreases K uptake. Adequate soil aeration is, therefore, necessary to supply oxygen for root respiration and K uptake. Low (<20 ºC) and high (> 30ºC) soil temperatures can impair root physiological processes involved in K uptake. Optimum soil temperature for uptake is 20-30°C (Tisdale et al., 1985). Plant developmental stage also influences the capacity for K uptake. More K is taken up during vegetative growth stages when roots are more active than in reproductive growth stages (Beringer et al., 1986). Developing fruits are stronger sinks for photoassimilates than roots and other vegetative tissues. This competition for photoassimilates reduces root growth and energy supply for nutrient uptake including K (Marschner, 1995). Therefore, during reproductive development, soil K supply is sometimes not adequate to support crucial processes such as sugar transport from leaves to fruit, enzyme activation, protein synthesis, and cell extension that ultimately determine fruit yield and quality. Previous research has demonstrated that this apparent K deficiency during fruit development and maturation can be mitigated through supplemental foliar K applications to netted muskmelon (Lester et al, 2005) and cotton (Howard et al., 1998). Lester et al. (2005) showed that foliar applied glycine amino acid-complexed K sprayed weekly throughout fruit growth and maturation significantly increased cantaloupe fruit ascorbic acid, free sugar, and beta-carotene concentrations. The objective of this study was to compare the effect of different foliar applied K sources with or without a surfactant, and the influence of growing season (spring vs. autumn) on cantaloupe quality attributes.

MATERIALS AND METHODS

Netted, orange-flesh muskmelon ('Crusier') fruit were grown in a glasshouse following the procedures previously described by Lester et al. (2005). Immediately after fruit set and up to fruit maturation entire plants including fruit were sprayed to runoff with one of the following K solution sources: (1) Potassium Metalosate (24% K; Albion Advanced Nutrition Inc., Clearfield, Utah) diluted to 4.0 $mL \cdot L^{-1}$, (2) Potassium chloride solution (KCl, 24% K) diluted to 4.0 $mL \cdot L^{-1}$ (0.096% K), (3) Potassium Metalosate solution plus a non-ionic surfactant (Silwet L-77; silicone polyether 100%; Loveland Ind. Inc. Greeley, Colorado), (4) Potassium chloride solution plus Silwet L-77 surfactant, or (5) de-ionized water. Ascorbic acid, beta-carotene, fruit sugars, fruit firmness, K concentration, soluble solids concentration were analyzed according to Lester et al. (2005) and fruit tissue pressure potential was evaluated according to Boyer (1969).

RESULTS AND DISCUSSION

Foliar applications of potassium during fruit growth and maturation resulted in significantly higher K concentrations in the edible fruit tissue than in non-treated control fruit (Table 1). Fruit from plants treated with amino acid–complexed-K (without surfactant) had higher edible fruit tissue K concentrations than those from plants treated with KCL without surfactant. However, this effect was significant only in the spring study. When surfactant was used, differences

between amino acid-complexed-K and KCl for edible fruit tissue concentration were not observed.

Table 1. Influence of foliar applications of Potassium Metalosate (KM) or KCL +/surfactant (S) on spring and autumn grown 'Cruiser' muskmelon edible fruit tissue: K concentration, external (minus peel) and internal firmness, and pressure potential (Ψ-potential).

Treatment	K conc. (mg/g FW)	External firmness (N)	Internal firmness (N)	Ψ- potential[Z] (bars)
		Spring 2005		
KM	2.73 a[Y]	15.8 a	10.3 ab	0.46 b
KCL	2.55 b	15.7 a	9.6 b	0.30 c
KM+S	2.60 b	16.8 a	10.0 ab	0.67 a
KCL+S	2.60 b	17.7 a	11.1 a	0.75 a
Control	2.35 c	12.7 b	7.5 c	0.00 d
		Autumn 2004		
KM	2.76 a	19.7 a	11.4 a	-
KCL	2.71 a	19.7 a	10.7 a	-
KM+S	2.74 a	18.8 a	11.5 a	-
KCL+S	2.64 a	19.2 a	12.0 a	-
Control	2.30 b	14.5 b	8.6 b	-

[Z] The small negative Ψ-potential for control was set to zero and all other values adjusted upward accordingly.

[Y] Means within a column and within a season followed by the same letter are not significantly different using Duncan's multiple range test at $P \leq 0.05$, n = 10

Fruit external tissue (under the peel) and internal edible tissue firmness were also significantly increased by foliar K applications in both seasons regardless of surfactant use. In spring, internal firmness of fruit treated with KCl plus surfactant was significantly greater than that of fruit treated with KCl alone. It is unlikely that this increased fruit firmness is due to greater membrane integrity, as is the case with exogenously applied calcium to melon fruit (Lester and Grusak, 1999). More likely, increased firmness resulted from increased bulk fruit tissue pressure potential (Table 1).

Accumulation of potassium and soluble solids (osmolytes) in cells within the fruit tissue leads to an increase in tissue osmotic pressure and as water moves into the cells, tissue turgidity increases. Mesocarp tissue pressure potentials were significantly higher in all potassium treated fruits compared to controls. Mesocarp tissue pressure potentials of fruits treated with Potassium Metalosate (without surfactant) were also significantly higher than those of fruit treated with KCl only. Addition of surfactant greatly increased the effect of foliar K application on mesocarp tissue pressure potentials (+46% and +150% for Potassium Metalosate and KCL, respectively). However, this K source difference disappeared when both K sources were mixed with surfactant.

Ascorbic acid, beta-carotene, sweetness and soluble solids concentrations (SSC) (Table 2) and fruit sugars (Table 3) were significantly higher in K treated versus control fruit. This effect probably resulted from a combination of improved leaf photosynthetic CO_2, assimilate

Table 2. Influence of foliar applications of potassium metalosate (KM) or KCL +/- surfactant (S) on spring and autumn grown 'Cruiser' muskmelon edible fruit tissue: total ascorbic acid, beta-carotene, relative sweetness and soluble solids concentration (SSC).

Treatment	Ascorbic acid (mg/100g FW)	Beta-carotene (µg/g FW)	Relative sweetness (mg/g sucrose equiv.)	SSC (%)
		Spring 2005		
KM	26.8 b[Z]	22.9 b	64.0 a[Y]	9.6 b
KCL	28.0 ab	23.1 b	61.5 b	9.7 b
KM+S	28.3 a	25.1 a	64.2 a	10.1 a
KCL+S	27.0 ab	26.6 a	63.3 ab	9.9 ab
Control	24.2 c	21.8 c	56.8 c	8.8 c
		Autumn 2004		
KM	36.4 a	30.9 a	75.7 b	9.7 a
KCL	33.5 b	26.6 c	74.6 b	9.5 a
KM+S	35.2 ab	29.6 ab	80.3 a	9.8 a
KCL+S	36.0 ab	28.6 b	74.3 b	9.7 a
Control	30.0 c	25.7 c	66.1 c	8.9 b

[Z] Means within a column and within a season followed by the same letter are not significantly different using Duncan's multiple range test at $P \leq 0.05$, n = 10.
[Y] Relative sweetness = 1.8 (mg/g FWT fructose) + 10.7 (mg/g FWT glucose) + 1.0 (mg/g FWT sucrose).

translocation from leaves to fruits, improved leaf and fruit water relations, increased enzyme activation and substrate availability for ascorbic acid and beta-carotene biosynthesis (Gross, 1991; Hopkins, 1963). In general, use of a surfactant tended to increase fruit tissue concentrations of sugars, SSC, ascorbic acid and beta-carotene however, the surfactant effect was not always consistent.

The beneficial effects of supplemental foliar K applications on melon fruit quality parameters were consistently positive regardless of growing season – spring or autumn. However, fruit produced in autumn had higher fruit firmness, ascorbic acid, beta-carotene, sugars and SSC (Tables 1, 2 and 3). These improved quality parameters in autumn- vs. spring-grown fruit probably resulted from cooler temperatures in the autumn which would have favored photosynthesis CO_2 assimilation, enzyme activation, substrate availability for ascorbic acid and beta-carotene synthesis (Mozafar, 1994).

In summary, supplementing soil K with foliar K applications during muskmelon fruit development and maturation improved fruit quality by increasing firmness, sugar content, ascorbic acid, and beta-carotene levels. Differences between the two K sources (an organic form Potassium Metalosate or a inorganic form KCl) were minimal and use of a surfactant tended to have a positive effect on the supplemental foliar K applications. These quality improvements were obtained by implementing a simple management tool: foliar applied K, during fruit

development, using generally available K compounds plus a surfactant that growers the world over can adopt.

Table 3. Influence of foliar applications of potassium metalosate (KM) or KCL +/- surfactant (S) on spring and autumn grown 'Cruiser' muskmelon edible fruit tissue: fructose, glucose, sucrose and total sugar.

Treatment	Fructose (mg/g FW)	Glucose (mg/g FW)	Sucrose (mg/g FW.)	Total sugars (mg/g FW)
		Spring 2005		
KM	14.5 a [Z]	9.4 bc	31.3 ab	55.3 a
KCL	12.9 c	9.1 cd	31.9 ab	54.0 a
KM+S	13.8 b	9.6 ab	32.7 a	56.2 a
KCL+S	13.8 b	10.0 a	31.5 ab	55.4 a
Control	12.4 c	9.0 d	29.8 b	51.2 b
		Autumn 2004		
KM	9.2 a	10.8 a	33.6 ab	63.6 b
KCL	19.0 a	11.1 a	32.1 ab	62.2 b
KM+S	17.5 b	10.8 a	41.2 a	69.5 a
KCL+S	17.3 b	10.0 a	36.2 ab	63.5 b
Control	16.8 c	9.9 a	29.0 b	55.7 c

[Z] Means within a column and within a season followed by the same letter are not significantly different using Duncan's multiple range test at $P \leq 0.05$, n = 10.

REFERENCES

Beringer, H. K. Koch, and M.G. Lindhauer. 1986. Sucrose accumulation and osmotic potentials in sugar beet at increasing levels of potassium nutrition. J. Sci. Food Agric.37:211-218.

Boyer, J.S. 1969. Measurments of the water status of plants. Ann. Rev. Plant Physiol. 20:351-364.

Brady, N.C. 1984. Supply and availability of phosphorus and potassium. p 327-362. In. Brady, NC. (ed) The Nature and Properties of Soils, 9 ed. MacMillan Pub. Co. New York.

Gross, J. 1991. Carotenoids, p. 75-278. In: J Gross (ed.). Pigments in vegetables: Chlorophylls and carotenoids. Van Nostrand Reinhold, New York.

Howard, D.D., C.O. Gwathmey, and C.E. Sams. 1998. Foliar Feeding of Cotton: Evaluating Potassium Sources, Potassium Solution Buffering, and Boron. Agron. J. 90:740–746.

Hopkins, F. 1963. Vitamin C, p. 205-210. In: J.B.S. Braverman (ed.). The biochemistry of foods. Elsevier, New York.

Mengel, K and E.A. Kirkby. 1980. Potassium in crop production. Adv. Agron. 33:59-110.

Lester. G.E. and M.A. Grusak. 1999. Postharvest application of calcium and magnesium to honeydew and netted muskmelons: effects on tissue ion concentrations, quality and senescence. J. Amer. Soc. Hort. Sci 124:545-552.

Lester, G.E., J.L. Jifon and G. Rogers. 2005. Supplemental foliar potassium applications during muskmelon fruit development can improve fruit quality, ascorbic acid, and beta-carotene contents. J. Amer. Soc. Hort. Sci. 130:649-653.

Marschner, H. 1995. Ion uptake mechanisms of individual cells and roots: Short-distance transport, p. 6-78. In: H. Marschner (ed.). Mineral nutrition of higher plants 2nd Edition. Academic Press, N.Y.

Mozafar, A. 1994. Plant vitamins: Agronomic, physiological and nutritional aspects. CRC Press, Boca Raton, Florida.

Tisdale, S.L., W.L. Nelson, and J.D. Beaton. 1985. Soil and fertilizer potassium. p 249-291. In. Tisdale, S.L., Nelson, W.L. and Beaton, J.D. (eds.) Soil Fertility and Fertilizers, 4 ed. MacMillan Pub. Co. New York.