Macronutrient Removal by Muskmelons Grown on Calcareous Soils

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SUMMARY

Advances in understanding plant physiology and nutrient requirements now allow growers to supply crops with sufficient nutrients to optimize growth and yield. However, for certain high-value horticultural crops, fertilizer requirements for optimum yields often differ from the requirements for quality traits such as taste, flavor, texture and shelf-life. Timing of fertilizer application, as well as soil and plant factors, are also critical in quality considerations. Currently, there are no nutrient management guidelines for optimizing produce quality even though certain nutrient elements such as potassium (K) are known to influence quality development. Information on nutrient uptake and removal amounts is useful in developing fertility recommendations for crops with different nutrient requirements and quality standards. In this study, leaf, stem and fruit tissues of muskmelons (*Cucumis melo* L. var 'Cruiser') were sampled from fields differing in soil type and analyzed to calculate nutrient removal amounts. There were little differences in the concentration of major nutrients (N, P, K) in plant tissues (leaves, stems) during vegetative development. However after fruit set, the concentration of these nutrients was significantly reduced as developing fruits became sinks for these nutrient. Differences were also observed in tissue nutrient concentrations among the sampling sites and this was coincident with soil type; tissues sampled from sites with heavy soils tended to have higher nutrient concentrations than those from sites with light textured soils. Fruit yields ranged from 9-13 $t \cdot acre^{-1}$ and was greater in the heavy textured sites. Estimates of nutrient removal amounts ranged from 18-38 lbs N/acre, 3-6 lbs P/acre, and 35-80 lbs K/acre and varied significantly among sites. Exceptionally dry weather conditions during the 2009 growing season potentially affected the uptake and accumulation patterns of these nutrients since fruit yields were also generally lower than average. Data collected over multiple years under different weather conditions, soil types and yield scenarios will be needed to establish realistic nutrient removal values that can be used to develop fertilizer application guidelines aimed at improving fruit quality.

Keywords: Nutrient removal; fertilization; quality; muskmelon; soil

INTRODUCTION

Relatively high levels of fertilizer applications are required to ensure adequate yields and quality of many horticultural crops (including fruits and vegetables). During the course of the growing season, crops take up and accumulate various nutrients in biomass, some of which will eventually be removed from the site in harvested products. Factors such as crop species, cultivar, yield potential, and cultural practices influence the degree of nutrient uptake and removal. Among the essential mineral nutrients, potassium (K) is the element required in the largest amount (after nitrogen) especially in fruit crops (Marschner, 1995). Potassium plays a crucial role not only in boosting yields, but also in improving various quality traits (Usherwood, 1985; Jifon et al., 2009; Lester et al., 2006). Nutrient imbalance, especially inadequate K supply, is often a major factor contributing to the decline in vegetable crop yields and quality even though most soil tests commonly indicate sufficient levels (>150ppm) of soil K (Jifon et al., 2009; Lester et al., 2006). This is often the case in most calcareous soils in Texas and other major vegetable production regions where high levels of soil calcium (Ca), and magnesium (Mg) typically exacerbate the apparent K deficiency problem through competitive nutrient uptake inhibition interactions. Our previous research (Lester et al., 2006) has shown that supplementing soil-derived K with foliar applications can alleviate this apparent K deficiency and enhance quality traits of muskmelons such as sweetness, texture, color, vitamin C and beta-carotene contents (Lester et al., 2006). However, in order to develop foliar K recommendations for improving yield and quality, information regarding crop nutrient removal amounts is essential. Although nutrient removal amounts for many field crops are available, such values for fruit and vegetable crops are rare (Heckman et al., 2003). Furthermore, intensive cultivation, even in the face of improved soil fertility and management practices, tends to deplete soil nutrient pools through crop removal and leaching. In the long-term, a balance between nutrient inputs and crop removal is required. Knowledge of nutrient removal amounts by different crops during a growing season is critical in determining the amounts that must be applied to sustain yields and quality while maintaining soil fertility. The objective of this study was to estimate major nutrient (N, P, K) accumulation/removal amounts in relation to different yield expectations by a fruiting vegetable crop (muskmelons) grown in sites with contrasting soil types (light vs heavy) in S. Texas. This information is intended to be useful in developing guidelines for nutrient application rates to assure fruit quality and in selecting crop cultivars and species for specific sites based on their nutrient accumulation/removal capacities.

MATERIALS AND METHODS

This study was conducted during the 2009 growing season (February-May), in commercial fields in the Lower Rio Grande Valley, TX (annual rainfall ~22 inches). Soils are predominantly calcareous (Table 1). Four commercial netted muskmelon (*Cucumis melo* L.) fields differing in soil type were identified and used for tissue sampling. Soil type at two of the sites (Edinburg and Mission) was predominantly light textured (Brennan fine sandy loam and Delfina fine sandy loam, respectively) whereas at the other two sites (Santa Ana and Weslaco), it was heavy textured (Hidalgo sandy clay loam and Harlingen clay, respectively). The fields were direct planted in early spring (February-March) and managed following standard commercial practices for spring muskmelon production including irrigation, nutrient management, and pest control were followed. Soil samples were collected from each site from the top 30 cm soil layers for chemical analysis.

Vegetative tissues (leaves/petioles and stems) were sampled before and after fruit set for chemical analysis. Samples were rinsed with distilled water, dried (70 °C for 48 h), ground in a Wiley mill to pass a 40-µm screen and ashed (500 °C, 5 h), before tissue analysis. During the fruit maturation period, vegetative tissues and matured (full slip), marketable fruits were harvested, weighed and analyzed for mineral contents. Total nitrogen (N) concentration of tissues was analyzed by the Kjeldahl method. Mineral nutrient concentrations (P, K, Ca, Mg,) were analyzed by inductively coupled plasma (ICP) emission spectroscopy, following tissue digestion with nitric acid and hydrogen peroxide. Nutrient removal amounts were estimated from fruit yields, dry matter, and mineral nutrient concentrations.

RESULTS AND DISCUSSION

Soils in all the study locations are highly calcareous with calcium as the dominant cation and pH levels generally exceeding 7.5 (Table 1). Soil concentrations of the major mineral elements were also generally high. There were no significant differences in the concentration of major nutrients (N, P, K) in plant tissues (leaves, stems) during the vegetative growth stages (data not shown). However after fruit set, the concentration of these nutrients was significantly reduced as developing fruits became strong sinks for nutrients and assimilates. Differences were also observed in tissue nutrient concentrations among the sampling locations and this was coincident with soil type; tissues sampled from sites with heavy soils tended to have higher nutrient concentrations than those from locations with light textured soils. Average fruit yields ranged from 9-13 $t \cdot acre^{-1}$ and were slightly higher at locations with heavy soil types (Santa Ana and Weslaco) than at locations with lighter soil types (Edinburg and Mission). This trend was mirrored in the fruit mineral nutrient contents (Table 2) especially for fruit potassium concentrations. Fruits from the Santa Ana location had the highest potassium concentrations and this was associated with higher total soluble solids concentrations in fruit (10-12%; data not shown) compared to fruits from the other locations (9-11%). This is consistent with previous greenhouse and field observations on the mineral nutrient factors limiting muskmelon fruit quality (Jifon et al., 2009; Lester et al., 2006). Estimates of nutrient removal amounts ranged from 18-38 lbs/acre for nitrogen, 3-6 lbs/acre for phosphorus, and 35-80 lbs/acre for potassium and also varied significantly among locations (Table 3). The macronutrient removal values observed in this study were generally lower than the few reported values in the literature (IPNI, 2001; Maynard and Hochmuth, 2007). Given the very high levels of macronutrient reserves in these soils (Table 1), the low removal amounts observed could be due to interacting soil, plant and weather factors. Competitive uptake interactions between calcium, potassium and magnesium are well established (Brady, 1984; Garcia et al., 1999) and could be partially responsible for the low removal rates. The overall fruit yield levels were also relatively low compared to long-term averages for this region; this was probably due to the prevailing severe drought during most of the study period in 2009, despite adequate irrigation. Data collected over multiple years under different weather conditions, soil types and yield scenarios will be needed to establish realistic nutrient removal values that can be used to develop fertilizer application guidelines aimed at improving fruit quality. Long-term nutrient removal studies including other important horticultural crops (onions, watermelons, citrus) grown in this region are ongoing.

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Table 1: Pre-plant soil chemical properties of 0–30 cm soil depth at each study location. Phosphorus (P), potassium (K), and calcium (Ca), were extracted using the Mehlich III procedure (Mehlich, 1984), while nitrate-nitrogen (NO_3-N) was determined by the reduction method (Keeney and Nelson, 1982).

	pH	NO_3-N	P	K	Ca	Mg
			mg·kg^{-1}			
Edinburg	8.2	33.4	110.0	558.5	2805.6	297.3
Mission	8.1	126.5	39.0	385.0	2805.6	537.8
Santa Ana	8.3	19.5	46.5	779.0	13807.8	507.3
Weslaco	8.3	78.0	59.8	624.0	17247.8	747.3

Table 2. Average fruit mass and concentrations of major mineral element in muskmelon ('Cruiser') fruits grown at different locations in south Texas.

	Fruit wt	N	P	K	Ca	Mg
	lbs	mg·kg^{-1}				
Edinburg	4.3	9.0	1.5	17.9	11.8	1.1
Mission	4.2	10.1	1.7	20.3	12.7	1.3
Santa Ana	4.6	12.6	2.1	25.2	13.5	1.6
Weslaco	4.6	11.9	2.0	23.9	14.8	1.5

Table 3. Content of mineral nutrient elements removed with fruits at different locations/yield levels.

Location	Edinburg	Mission	Santa Ana	Weslaco
Fruit yield level (tons/ac)	9.5	9.78	12.4	10.2
	lbs/ac			
N	18.4	21.8	37.7	31.3
P	3.1	3.6	6.3	5.2
K	36.8	43.6	75.4	62.5
Ca	24.7	27.6	40.4	38.9
Mg	2.3	2.7	4.7	3.9