Nutrient Removal by Major Vegetable Crops Grown on Calcareous Soils in s. Texas

2010 Research Summary

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SUMMARY

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The role of fertilizers in improving crop yields under optimum field conditions is well established. However, for certain high-value fruits and vegetable crops (e.g., tomatoes, muskmelons), fertilizer requirements for peak yields can differ from the requirements for optimal quality traits such as taste, texture and shelf-life. 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. The goal of this 2-yr (2009, 2010) study was to characterize nutrient removal amounts by major vegetable crops grown on calcareous soils in south Texas, in order to develop fertilizer recommendations for quality improvement. Commercial muskmelon (*Cucumis melo* L. Var. *Reticulatus*) fields with contrasting soil types were randomly selected for this study and nutrient removal with harvested fruit was calculated. Fruit yields ranged from 9-16 $t \cdot acre^{-1}$ and were generally greater in 2010 than in 2009. In 2009, nutrient removal amounts ranged from 18-37 lbs N/acre, 7-11 lbs P/acre, and 44-90 lbs K/acre, compared to 47-73 lbs N/acre, 9-14 lbs P/acre, and 72-113 lbs K/acre in 2010. Removal amounts were generally higher in fruits from sites with heavy-textured soils compared to fruits from light soils. Fruit soluble solids ranged from 9.8-12% and were generally higher in fruits from heavy soils. Differences in fruit yields between the 2 study years likely reflect prevailing weather conditions during crop development in each growing season. High fruit yields from sites with heavier soils were associated with greater nutrient removals compared to sites with light-textured soils. Differences in fruit quality parameters (soluble solids) were also related to soil type and suggest that supplemental K fertilization would be required, especially on the light soils, to improve fruit quality and perhaps yields.

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

Relatively high levels of fertilizer applications are required to ensure adequate yields and quality of fruits and vegetable crops. During the course of the growing season, crops take up and accumulate various nutrients in biomass, some of which are eventually removed from the site with harvested products. Factors such as crop species, cultivar, yield potential, weather conditions 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. During the 2010 growing season we also estimated nutrient removal amounts by a leafy vegetable crop (spinach) and sweet onions. 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 trial was conducted during the 2009 and 2010 spring growing seasons (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 fruit sampling. In each year, two of the commercial fields were located in regions (Edinburg and Mission) with predominantly light-textured soils (Brennan fine sandy loam and Delfina fine sandy loam, respectively). The other two sampling sites (Santa Ana and Weslaco) have mostly heavy-textured soil types (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 residual nutrient analysis prior to planting.

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

Tissue mineral concentrations measured at the 12”-vine growth stage were generally within the recommended sufficiency ranges for muskmelons. However, just prior to harvest, the concentrations of major nutrients (N, P, K) were significantly lower than the sufficiency levels as developing fruits became stronger sinks for nutrients and assimilates. In both years, differences were 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 9-12 $t \cdot acre^{-1}$ and were slightly higher in 2010 compared to 2009 and also at locations with heavy soil types (Santa Ana and Weslaco) than at locations with lighter soil types (Edinburg and Mission). In both 2009 and 2010, yield trends mirrored observations in fruit total soluble solids and mineral nutrient contents (Table 3) 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%; Table 3) 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).

Estimates of macronutrients removed with fruit harvests were generally in 2010 than in 2009. This difference is probably due to poor weather conditions (freeze events) experienced during the 2009 season and the generally low yields in that year. The low removal amounts observed in 2009 could also be due to competitive uptake interactions between calcium, potassium and magnesium (Brady, 1984; Garcia et al., 1999). The 2010 removal estimates were slightly higher than those reported for muskmelons in other regions under ideal growing conditions (IPNI, 2001; Maynard and Hochmuth, 2007). Nutrient removal by sweet onion and spinach also followed a trend determined by soil type and yield level, with greater yields and removal amounts observed on sites with heavy soil textures (Table 4).

Given the very high levels of macronutrient (especially K, Ca, Mg) reserves in these soils (Table 1), the dramatic decline in tissue macronutrient contents during the late fruit developmental stages suggests that nutrient supply from the soil via root uptake was not enough to prevent these changes. This is plausible if competition for assimilates between roots and maturing fruits limits root activity and water/nutrient uptake. These observations also indicate that cumulative nutrient uptake prior to fruit set was not sufficient to support subsequent fruit development and leaf function during latter developmental stages. Overall fruit yields were within the long-term average values for this region. The close associations between soil texture, fruit mineral nutrient accumulation and TSS highlight the need for a reassessment of fertilizer management practices and sufficiency thresholds aimed at achieving superior fruit quality. 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.

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Table 1: Pre-plant soil chemical properties of 0–30 cm soil depth at each study location.

	Soil Texture	Soil Organic Matter (%)	pH	NO_3-N	P	K	Ca	Mg
				(mg·kg^{-1})				
				2009				
Edinburg	light	0.89c	8.2a	33.4c	22.0c	558bc	2805.6b	297.3b
Mission	light	0.97c	8.1a	126.5a	39.0bc	385c	2615.0b	537.8a
Santa Ana	heavy	1.21bc	8.3a	19.5c	46.5b	779a	13807.8a	507.3a
Weslaco	heavy	2.01a	8.3a	78.0b	59.8a	624b	17247.8a	747.3a
				2010				
Edinburg	light	0.96b	7.1b	37.2b	56.1ab	410.6b	2524.3b	307.1b
Mission	light	1.08b	6.9b	19.8c	44.3b	463.1b	2915.3b	601.3a
Santa Ana	heavy	2.03a	8.1a	64.2a	78.6a	801.6a	12602.7a	584.2a
Weslaco	heavy	1.13b	7.9a	45.7ab	86.2a	719.4a	17834.9a	699.2a
Critical limit			6.5	-	50	175	180	50

Means in each column followed by the same letter are not significantly different (P = 0.05). Where no letters follow means, no significant differences were found.

Table 2: Average whole leaf macro- and micronutrient concentrations at early vine development and pre-harvest growth stages of melon ('Cruiser') plants at two commercial field sites.

Nutrient	Unit	Edinburg 12" vine	Edinburg Pre-harvest	Weslaco 12" vine	Weslaco Pre-harvest	Sufficiency range
N	(%)	4.2	2.3*	5.1	2.9*	2-5
P	(%)	0.39	0.21*	0.56	0.29*	0.3-0.5
K	(%)	4.3	1.1*	4.9	1.3*	2-5
Ca	(%)	3.5	3.2ns	4.1	3.8ns	2-5
Mg	(%)	0.32	0.49ns	0.42	0.43 ns	0.3-0.5
S	(%)	0.33	0.35ns	0.42	0.48*	0.2-0.5
Fe	ppm	136	152ns	185	179ns	40-100
Mn	ppm	42.8	44.2ns	35.7	66.3*	20-100
Zn	ppm	26.4	28.5 ns	44.6	58.2*	20-60
B	ppm	26.1	27.3 ns	38.7	51.3*	20-80
Cu	ppm	6.8	7.1 ns	7.3	8.4*	5-10

*significant differences in means between early and late development sampling for each site; ns - no significant differences.

Table 3: Average fruits yields, fruit total soluble solids (TSS) and estimates of macronutrients removed with muskmelon fruit harvests at several locations with contrasting soil types.

	Fruit Yield tons/ac	Fruit TSS %	N	P	K	Ca	Mg
			lbs/ac				
					2009		
Edinburg	9.5b	8.9b	18.4c	7.0c	44.1c	24.7b	2.3b
Mission	9.8b	9.6b	21.8bc	8.3bc	52.3bc	27.6b	2.7b
Santa Ana	12.4a	11.2a	37.7a	14.4a	90.5a	40.4a	4.7a
Weslaco	10.2a	11.9a	31.3ab	11.9b	75.0b	38.9a	3.9a
					2010		
Edinburg	10.5a	9.7a	47.0b	9.2b	72.3c	27.1b	2.5b
Mission	11.7a	10.8a	55.8b	10.9b	85.8b	30.6b	2.9b
Santa Ana	12.6a	12.2a	73.5a	14.4a	113.1a	44.4a	5.0a
Weslaco	12.2a	11.1a	72.7a	14.2a	111.8a	42.4a	4.3ab

Means in each column followed by the same letter are not significantly different (P = 0.05). Where no letters follow means, no significant differences were found.

Table 4: Average yields, and macronutrient removal estimates by sweet onions (cv. Sweet Sunrise) and spinach grown on calcareous soils in south Texas.

Crop	Location	Soil texture	Yield tons/ac	N	P	K
				lbs/ac		
Sweet Onion	Weslaco	Heavy	18 a	87 a	26a	109a
	La Feria	Light	15 a	76 a	16b	95ab
Spinach	Weslaco-1	Light	8 a	68 b	9c	88b
	Weslaco-2	Heavy	11 a	72 ab	14b	96a

Means in each column followed by the same letter are not significantly different (P = 0.05). Where no letters follow means, no significant differences were found.