Nutrient Removal Estimates for Major Fruits and Vegetable Crops Grown on Calcareous Soils in South Texas

Research Summary

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SUMMARY

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

The impacts of fertilizer input on crop productivity and quality are well documented. For many high-value fruits and vegetable crops (e.g. melons, tomatoes, citrus), 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 objective of this long-term project is to determine nutrient removal values for major fruits and vegetable crops grown on calcareous soils in South Texas, and to use the information to refine fertilizer recommendations for yield, quality. During the spring growing season of 2011, nutrient removal amounts were estimated for muskmelons (*Cucumis melo* L. Var. *Reticulatus*) and onions from fields that were previously investigated in 2009. Removal rates by grapefruits from commercial orchards were also estimated. Pre-plant soil N, P_2O_5 and K_2O test levels were slightly lower in 2011 than in previous years. Melon yields ranged from 11-19 $t \cdot acre^{-1}$ and were generally greater than those recorded in 2009. Estimated nutrient removal amounts in 2011 ranged from 45-84 lbs N/acre, 7-17 lbs P/acre, and 60-128 lbs K/acre compared to 18-37 lbs N/acre, 7-11 lbs P/acre, and 44-90 lbs K/acre respectively in 2009. Nutrient removal estimates for sweet onion were also higher in 2011 than in 2009, consistent with higher yields in 2009. Grapefruit yields averaged 311 80lb-boxes per acre (12.4 ton/acre fresh fruit) and nutrient removal estimates ranged from 24-31 lbs N/acre, 6-9 lbs P/acre, and 60-71 lbs K/acre.

Keywords: Nutrient removal; fertilization; quality; muskmelon; onion; grapefruit

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INTRODUCTION

The impacts of fertilizer use on crop productivity and basic nutritional quality parameters (proteins, minerals, vitamins and essential oils) are well documented (FAO, 1981; Marschner, 1995; Havlin et al., 2005; Stewart et al., 2005). Relatively high levels of fertilizer applications are required to ensure adequate yields and quality of many high-value 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. Crop nutrient uptake is influenced by soil and climatic conditions. Low soil moisture, poor aeration due to compaction or excessive moisture, low soil temperatures, high lime in the root zone, nutrient imbalances, and other factors may restrict uptake of plant nutrients. Nutrient imbalances, especially inadequate K supply, often contribute significantly to poor 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 the predominantly calcareous soils in South Texas and other major vegetable production regions where high levels of soil calcium (Ca) and magnesium (Mg) typically exacerbate the apparent K deficiency problem. Accurate estimates of crop nutrient requirements (amounts) as well as timely supply and placement of the appropriate nutrient sources is essential for improving yields, quality, and profitability while protecting the environment. Nutrients in crop residues that are left in the field can partially add to soil nutrient reserves as the residues decompose. Information regarding crop nutrient removal amounts is essential in determining the amounts that must be reapplied to sustain yields and quality while maintaining soil fertility. The objective of this long-term project is to obtain nutrient removal values for major fruits and vegetable crops grown on calcareous soils in South Texas, and to use this information in developing guidelines for nutrient management to assure yield and quality as well as in selecting varieties for specific sites based on their nutrient accumulation/removal capacities.

MATERIALS AND METHODS

Commercial vegetable fields (melons and onions) in the Lower Rio Grande Valley, TX (annual rainfall ~22 inches) were sampled in 2009, 2010 and 2011; more recently, grapefruit orchards were also sampled during the 2010-2011 harvest season. Soils are predominantly calcareous (Table 1). In 2011, commercial melons (cantaloupe) and sweet onions field that were initially sampled in 2009 were used for fruit and bulb sampling. Soils in these fields are predominantly calcareous (average pH 7.6) and heavy-textured (Harlingen clay). Onions were planted in mid-October 2010 and harvested in April 2011. Melon fields were direct-planted in early spring (February-March) and harvested in late May. All fields were managed following standard commercial practices including irrigation, nutrient management, and pest control. 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/bulb initiation 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. At harvest, vegetative tissues and marketable fruits and onion bulbs were sampled, 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/bulb yields, dry matter, and mineral nutrient concentrations.

RESULTS AND DISCUSSION

Soil mineral nutrient concentrations determined prior to planting in 2011were generally lower than those found in 2009 (Table 1) however, these levels (except for nitrogen) were substantially higher than sufficiency ranges. Mineral nutrient concentrations in vegetative tissues measured just prior to harvest were significantly lower than sufficiency levels for each of the three crops (melons, onions and grapefruit) as developing fruits and bulbs became stronger sinks for nutrients and assimilates. Tissues sampled in 2011 also had slightly lower nutrient concentrations than those sampled in 2009 (Table 2).

Average melon fruit yields in 2011 ranged from 15-20 $t \cdot acre^{-1}$ and were slightly higher compared to 2009. Fruit soluble solids ranged from 9.6 to 11.9% and were highly correlated with fruit potassium concentrations. This is consistent with previous greenhouse and field observations on melons (Jifon et al., 2009; Lester et al., 2006). Estimates of nutrient removal amounts for melons in 2011 ranged from 26-39 lbs/acre for nitrogen, 10-14 lbs/acre for phosphorus, and 66-82 lbs/acre for potassium and were significantly higher than estimates for 2009. The 2011 removal estimates were also slightly higher than the averages reported for muskmelons in other regions under ideal growing conditions (IPNI, 2001; Maynard and Hochmuth, 2007). These differences may be due to poor weather conditions (freeze events) during the growing season in 2009 and the generally low yields that year; favorable weather conditions during the growing season in 2011 and the associated higher fruit yields likely contributed to the higher removal rates.

Sweet onion bulb yields ranged from 17 to 22 tons/acre and were also higher in 2011 than in 2009. Average nutrient removal estimates in 2011 for sweet onion (61.3, 19.4, 75 lbs/acre for nitrogen, phosphorus, and potassium respectively) were however, not significantly different from those observed in 2009 due in part to low mineral concentrations in bulbs.

Grapefruit yields ranged from 290 to 321 boxes per acre (average 311 boxes/acre or 12 ton/acre fresh fruit). At the time of grapefruit harvest, leaf mineral nutrient concentrations were significantly lower than recommended levels (table 2). Calculated nutrient removal rates with marketable fruits ranged from 28.9, 8.1, and 66.1 lbs/acre of marketable fresh fruit for nitrogen, phosphorus and potassium respectively.

Even though pre-plant soil macronutrient (especially K, Ca, Mg) reserves were high in both years, a clear decline in tissue macronutrient contents during the late fruit developmental stages was observed, indicating that nutrient supply from the soil via root uptake was insufficient. This is plausible if competition for assimilates between roots and maturing fruits limits root activity and water/nutrient uptake. For fields that were sampled in 2009 and again in 2011, there was a slight decline in average values of pre-plant soil nutrient concentrations. For macronutrients (K, Ca, Mg) with typically high levels, it is customary in this region not to apply supplemental fertilizers. However, high yields, high crop removal rates, and the declining trends in soil reserve levels over time highlight the need for a reassessment of fertilizer management practices, especially those aimed at achieving superior fruit quality. Continued sampling over multiple years, and locations with varying weather conditions, soil types and yield scenarios will be needed to establish realistic nutrient removal values that can be used to develop improved fertilizer management guidelines.

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Table 1: Average values of pre-plant soil mineral concentrations for each crop (from the 0–30 cm soil depth.

Crop	Soil Organic Matter (%)	pH	NO_3-N	P	K	Ca	Mg
			(mg·kg^{-1})				
			2009				
Melon	2.3	8.2	71.0	57.4	524	16300	646
Onions	1.7	7.1	49.2	48.3	788	12802	502
Grapefruit	-	-	-	-	-	-	-
			2011				
Melon	1.1	7.7	44.2	75.2	719.4	17834.9	699.2
Onions	1.2	8.6	36.1	67.3	801.6	12602.7	584.2
Grapefruit	1.9	7.8	104.6	40.2	416.2	3628	417

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.

	N	P	K	Ca	Mg	S	Fe	Mn	Zn	B	Cu
	%	%	%	%	%	%	ppm	ppm	ppm	ppm	ppm
					Melons						
2009	2.6	0.28	2.7	4.2	0.51	0.49	188	52.3	48.2	61.1	7.3
2011	2.1	0.26	1.3	3.4	0.39	0.38	129	46.4	38.3	42.3	6.9
Sufficiency range	3-5.5	0.3-0.6	3-5	2-5	0.3-0.8	0.2-0.5	40-100	20-200	7-30	50-200	25-60
					Onions						
2009	3.0	0.28	2.3	2.8	0.40	0.49	181	65.2	51.6	51.1	8.0
2011	2.4	0.20	1.9	1.9	0.31	0.38	167	59.9	37.4	48.6	7.1
Sufficiency range	3-6	0.3-0.5	2-5	2-5	0.3-0.5	0.5-1.0	60-300	50-65	20-60	30-50	5-10
					Grapefruit						
2009	-	-	-	-	-	-	-	-	-	-	-
2011	2.1	0.09	0.7	1.5	0.2	0.14	36	18	18	21	3.1
Sufficiency range	2.5-2.7	0.12-0.16	1.2-1.7	3.0-4.9	0.30-0.49	0.20-0.39	60-120	25-100	25-100	36-100	5-16

Table 3: Average yields and estimates of macronutrients removed with muskmelon fruit harvests at several locations with contrasting soil types.

Yield	Yield tons/acre	N	P	K lbs/acre	Ca	Mg	S
				Melons			
2009	15.2a	79.7b	15.2a	98.8b	32.2b	5.1b	
2011	19.8a	92.3a	18.2a	121.4a	43.5a	7.9a	
				Onions			
2009	10.2b	44.2b	15.3b	55.0b	26.9b	3.7a	
2011	13.8a	61.3a	19.4a	74.6a	31.9a	4.9a	27.2a
				Grapefruit			
2009	-	-	-	-	-	-	-
2011	12.2a	28.9	8.1	66.1	15.6	5.0	2.5