

REDUCED PHOSPHORUS FERTILIZATION EFFECTS ON YIELD AND QUALITY OF SWEET CORN GROWN ON A CALCAREOUS SOIL

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Abstract. Sweet corn (*Zea mays* L.) is a major cash crop grown on approximately 4,000 acres in Miami-Dade County. As sweet corn is intensively managed and fertilized, nutrients (especially P) may accumulate in fields that have been cultivated for many years. A large-scale field trial with reduced rates of P was conducted in a grower's field during the 2002/2003 season. Phosphorus rates were 1.5 (no P added), 38.9 (50% reduced P rate) and 71.5 (grower's standard P rate) lb/acre created by pre-plant applications of 8-0-6.6 (N-P-K), 8-3.5-6.6, and 8-6.6-6.6, respectively, and foliar P applications totalling 3.5 lb/acre. Plant population, plant height, leaf chlorophyll content, ear yield (number and weight), and quality (ear length, diameter, tip fill, visual appearance, and flag chlorophyll content) were measured. The effect of reducing P rate was not significant for most measurements. These results suggest that reducing P fertilization for one season did not reduce sweet corn growth, yield, and quality in Miami-Dade County. These results support previous reduced P-rate research in the same area. Applying a half rate of P together with foliar analysis as a means to monitor P nutrition may be a temporary set of practices to reduce P applications without affecting sweet corn yield and quality, and thereby decrease the risk of off-site P movement.

Sweet corn (*Zea mays* L.) is an important vegetable cash crop produced in the Homestead area of Miami-Dade County on approximately 3,000 to 4,000 acres, with an estimated value of \$12.8 million in the 1997/1998 growing season (Degner et al., 2001). Approximately 10% of the state's sweet corn production occurs in Miami-Dade County. The unique marine-subtropical climate of south Florida allows growers to produce sweet corn in winter and early spring before harvest be-

gins in other sweet corn producing areas. In Miami-Dade County, sweet corn is grown on both calcareous marl and rocky soils, which are characterized by very low nutrient and water holding capacities, an alkaline pH in the 7.4-8.4 range, and levels of calcium carbonate (CaCO₃) ranging from 1% to 100% (Li, 2001). In these soils, frequent applications of fertilizers are needed to ensure economical yields. Because no calibrated soil test is available for the calcareous soils of Florida, N, P, and K should be applied based on the crop's nutritional requirement (CNR; Mylavarapu and Kennelly, 2002). Sweet corn CNR is defined as the lowest amount of fertilizer needed to produce 95% to 100% of the economic optimum yield (Simonne and Hochmuth, 2002). Yet, most growers rely on empirical practices to determine their fertilizer programs. As the cost of fertilizer only represents 10% to 20% of the total production cost for sweet corn, some growers view applying P amounts above the CNR as an insurance for producing high yields. While sweet corn yields are not adversely affected by excess P, this practice has led to increased production costs and may have a negative effect on the environment (Schaffer and O'Hair, 2001).

Recent studies conducted on commercial farms in the Homestead area showed no or little response of sweet corn yield and quality to P application (Hochmuth et al., 1995). The lack of yield response to additional P in calcareous soils is due to high levels of available P as a result of years of P fertilizer applications. In the soil, P is less mobile than N and K, and it is fixed by CaCO₃ through adsorption and precipitation (Zhou and Li, 2001). As these reactions are reversible, P is slowly released back into the soil solution, thereby becoming available to plants (Li et al., 1997). Phosphorus has accumulated in these long-farmed fields because P removal by the harvest of sweet corn ears usually accounts for less than 9 lb/acre per crop (Maynard and Hochmuth, 1997). Hence, most of the applied P remains in the soil in the form of residual P, where it may accumulate. Residual P should be considered when making fertilizer decisions for the next production season. With increased environmental concerns and shrinking profit margins, growers have started realizing that reduced P rates may be used on these soils without affecting sweet corn yields. The objective of this study was to demonstrate and evaluate the effects of reduced P rates on plant growth, marketable yield, and ear quality of sweet corn.

Materials and Methods

The experiment was conducted in the 2002-2003 growing season on a commercial field located in the Homestead area where the soil is a typical calcareous Krome very gravelly loam. This 200-acre field, which is over-head irrigated with a linear-move system, has been used for sweet corn production for several consecutive years by the same grower. Therefore, residual P concentration was expected to be high. Cultural practices, fertilizer (except P) applications, and pest control measures were performed by the farm crew according to the grower's management decisions. On 20 Nov. 2002, the field was disked. On the next day (0 d after planting, DAP), sweet

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Table 1. 'Prime Time' sweet corn growth and yield responses to P rates in 2002-03 in Miami-Dade County.

P rate (lb/A)	Stand (%)	Plant height (inch)	Leaf chlorophyll (0-100) ^y	Flag leaf chlorophyll (0-100) ^y	Mkt. ears (No./a)	Mkt. weight (lbs/a)	Ear length (inch)	Ear diam. (inch)
1.5	89 a ^z	18.5 a	39 a	38 a	20,328 a	14,976 a	7.5 a	1.72 a
38.9	83 a	17.8 a	40 a	38 a	18,731 a	13,344 a	7.5 a	1.69 a
71.5	84 a	18.4 a	39 a	37 a	18,731 a	13,344 a	7.5 a	1.75 a
R ²	0.64	0.80	0.64	0.32	0.53	0.61	0.22	0.36
CV	7	4	3	4	8	10	2	4
p-value	0.07	0.25	0.63	0.28	0.14	0.12	0.98	0.33

^zWithin columns, means followed by different letters are significantly different according to Duncan's Multiple Range Test at the 5% level.

^ySPAD meter values.

Table 2. 'Prime Time' sweet corn fresh and dry weight partitioning responses to P rates in 2002-03 in Miami-Dade County.

P rate (lb/A)	Total fresh weight (g/plant)	Total dry weight (g/plant)	Root fresh weight (g/plant)	Root dry weight (g/plant)	Shoot fresh weight (g/plant)	Shoot dry weight (g/plant)	Ear fresh weight (g/plant)	Ear dry weight (g/plant)
1.5	867 a ^z	218 a	87 a	64 a	450 a	71 a	330 a	83 a
38.9	890 a	227 a	93 a	67 a	453 a	75 a	343 a	85 a
71.5	886 a	190 b	76 b	39 b	477 a	70 a	333 a	81 a
R ²	0.41	0.53	0.43	0.57	0.44	0.27	0.52	0.20
CV	10	10	22	33	12	15	11	8
p-value	0.89	0.03	0.31	0.06	0.65	0.67	0.81	0.48

^zWithin columns, means followed by different letters are significantly different according to Duncan's Multiple Range Test at the 5% level.

corn ('Prime Time'; yellow, sh₂-type kernels; 79 d to maturity for spring plantings; Siegers Seed Co., Holland, Mich.) was planted at a within-row spacing of 10 inches and a row-to-row distance of 30 inches, resulting in a seeding rate of approximately 20,900 seeds per acre. Phosphorus rates were created by applying the same volume (106 gal/acre) of three liquid fertilizers containing the same amount of N and K, and different amounts of P. The grades of the three fertilizers (N-P-K) used were 8-0-6.6 ('no P added'), 8-3.5-6.6 ('reduced P rate'), and 8-6.6-6.6 ('grower's P rate'). Actual soil P application rates for the three treatments were of 0, 37.4, and 70 lb/acre, respectively. Each treatment was applied to one demonstration plot that was 8 rows wide (20 ft) and 2,600 ft long. Two sidedress applications of liquid fertilizer were made on 21 and 35 DAP using 1,200 lb/acre of 13-0-8.3, which provided N at 156 lb/acre. Foliar applications of a blend of a 20-8.8-16.6 fertilizer at a rate of 3.5 lb/acre and chelated micronutrients at a rate of 2.5 pints/acre were made over the entire field five times throughout the growing season. These applications provided a P total of 1.5 lb/acre evenly over the entire field. Total (soil + foliar) amounts of P applied during the production season were 1.5, 38.9, and 71.5 lb/acre, for the no-P, reduced-P, and grower's-P rates, respectively.

In each demonstration plot, six, 10-ft long sections were randomly selected and clearly marked along the central two rows for use as experimental units. Each experimental unit was handled as a replication. For each replication, data collection consisted of plant stand (25 DAP), plant height (from 10 randomly selected plants; 25 DAP), leaf chlorophyll measurement (one reading on each plant on the most recently expanded, fully mature leaf with a SPAD meter; 25 DAP), leaf samples (most recently expanded, fully mature leaf from 10 random plants; 50 and 86 DAP). Leaf samples were washed sequentially with tap water, 1% detergent solution, 1% HCl so-

lution, and deionized water. Leaf samples were then dried in a forced-air oven at 165 °F until constant weight was reached and ground in a Wiley mill to pass a 20-mesh screen. A 0.5-g aliquot was dry-ashed at 980 °F for 6 h, allowed to cool, and dissolved into 10 mL aqua regia (a dilute solution of hydrochloric and nitric acids). Phosphorus, K, Ca, Mg, Cu, Mn, Zn, and Fe concentrations were determined by inductively coupled argon plasma emission spectroscopy (ICAPES; Mylavaram and Kennelly, 2002) and were compared to sufficiency ranges (Hochmuth et al., 2002). At harvest, five plants were selected randomly from each experimental unit, partitioned into root, shoot, and ear, and fresh weights were determined. The parts of one representative plant randomly selected were then placed in a forced-air oven at 165 °F until constant weight was reached for dry weight determination. Total fresh and dry weights were calculated as the sum of the root, shoot, and ear fresh and dry weights, respectively. Leaf tissue samples were analyzed by the UF/IFAS Analytical Research Laboratory in Gainesville.

Table 3. Ear quality ratings response to P rates for 'Prime Time' sweet corn grown in 2002-03 in Miami-Dade County.

P rate (lb/A)	Eye appeal rating	Tip fill rating	Quality index rating
1.5	4.38 a ^z	4.35 a	8.73 a
38.9	4.34 a	4.36 a	8.70 a
71.5	4.42 a	4.45 a	8.87 a
R ²	0.22	0.41	0.30
CV	3	2	2
p-value	0.64	0.17	0.33

^zWithin columns, means followed by different letters are significantly different according to Duncan's Multiple Range Test at the 5% level.

Table 4. Leaf tissue composition response to P rates for 'Prime Time' sweet corn in 2002-03 in Miami-Dade County.

P rate (lb/A)	P (%)	K (%)	Ca (%)	Mg (%)	Cu (mg/kg)	Fe (mg/kg)	Mn (mg/kg)	Zn (mg/kg)
1.5	0.35 a ^c	2.36 a	0.64 a	0.18 a	15 a	125 a	34 a	39 a
38.9	0.35 a	2.42 a	0.67 a	0.18 a	14 a	121 a	35 a	40 a
71.5	0.33 a	2.12 a	0.65 a	0.16 a	14 a	98 b	34 a	37 a
Sufficiency range ^y	0.2-0.4	2.5-4.0	0.5-0.8	0.2-0.4	4-10	40-100	40-100	25-40

^aWithin columns, means followed by different letters are significantly different according to Duncan's Multiple Range Test at the 5% level.

^yFrom Hochmuth et al., 2002.

Ears were hand-harvested when they reached commercial maturity. Marketable yield was calculated by converting ear weight per plot to ear weight per acre by using a conversion factor of 871. Ear quality at harvest was determined by rating eye appeal, tip fill, and quality index, and color of the ear flag. Eye appeal and tip fill were rated on a 1-to-5 scale, where 1 = poor, 3 = average, and 5 = perfect. Quality index was calculated as the sum of the eye appeal and tip fill ratings, and therefore ranged from 2 to 10. The chlorophyll content of the flag of 10 ears was determined with a SPAD chlorophyll fluorescence meter (Minolta Corp., Ramsey, N.J.) to estimate flag color. Ear length and diameter were also measured.

Data were analyzed with analysis of variance and Duncan's Multiple Range Test (5% level; SAS, 2000). Coefficients of determination (R^2) and of variation (CV) were reported.

Results and Discussion

Growing conditions in the 2002/2003 season were representative of a typical winter growing season found in Miami-Dade county and sweet corn reached maturity in 85 d. Differences in stand, plant growth characteristics, and yield were not significant (Table 1). Probability values ranged from 0.07 for stand to 0.80 for plant height. For each measurement, means for the three P treatments were numerically close and CV were low for field data. The CV ranged from 2% for ear length to 10% for marketable yield. High probability values together with low CVs indicate that residual levels of P were adequate for sweet corn production and that P fertilization was unnecessary. None of the contrasts were significant either. Sweet corn growth and dry matter partitioning were generally not significantly affected by P fertilization rates (Table 2). The 71.5 lb/acre P rate significantly ($P < 0.05$) reduced root fresh and dry weight as compared to the other rates. Sweet corn ear quality ratings were high, and were not significantly affected by P treatments ($P > 0.17$) and varied within a narrow range (Table 3). Eye appeal and tip fill ratings averaged 4.4 and 8.7 on scales of 1-to-5 and 2-to-10, respectively. Phosphorus rates did not significantly affect foliar nutrient concentrations, except those of Fe (Table 4). Iron concentration was only 98 mg·kg⁻¹ with the highest P rate, which was significantly lower than the 125 and 121 mg·kg⁻¹ obtained with the 0 and 38.9 lb/acre P rates, respectively. However, Fe foliar levels as well as those of other nutrients were within or close to the sufficiency ranges. Foliar P concentrations were numerically identical as P rates increased, showing no plant response to preplant added P. Reducing P rates did not limit plant growth.

Reducing the amounts of P application for one growing season in a commercial field did not reduce sweet corn growth, yield, or quality. This type of study needs to be conducted over several years in the same field to determine how long the residual P will supply adequate P for sweet corn. This information will be needed to convince growers to abandon the practice of systematically applying P preplant. Based on these 1-year results, applying a half-rate of P together with foliar analysis as a means to monitor P nutrition may be a temporary set of practices to reduce P applications and decrease the risk of off site P movement.

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