A Summary of N, P, and K Research with Sweet Corn in Florida[1]

George Hochmuth and Ed Hanlon[2]

Introduction

The purpose of this publication is to summarize the historical Florida research literature on nitrogen, phosphorus, and potassium fertilization of sweet corn. This document is not meant to present new fertilization recommendations. The intent of this document is to review literature from all sources that pertains to commercial sweet corn fertilization in Florida's growing conditions.

This publication documents the previous written literature, some of which now appears only in updated modern electronic format. All publications, including the reviewed, older, paper-format papers, will be placed in PDF portable document format (PDF) on the website for future reference. Research publications throughout the years have provided the scientific basis for the Florida Extension sweet corn fertilization recommendations. In turn, these recommendations formed the basis for Best Management Practices (BMPs) addressing water quality protection. As environmental regulation becomes more commonplace, it becomes more important that fertilization recommendations be based on research.

Fertilizer recommendations not only contain the recommended rate of fertilizer but also management strategies for getting the most out of the fertilizer investment while protecting the environment. These principles for fertilization of vegetables are summarized by Hochmuth and Hanlon (2010a). Fertilizer application rate is only a part of a modern fertilizer recommendation. Sound fertilizer recommendations also consider fertilizer materials, placement, and timing, among other aspects (Hochmuth and Hanlon 2010a, 2010b).

The fertilization recommendation addresses commercial yield and quality, the economics of crop production, and protection of the environment. Equally important is to have a mechanism available to the grower to adjust fertilization practices during the season due to leaching rains and extension of the growing season for additional harvests when market conditions are favorable. To address all of these concerns, UF/IFAS vegetable recommendations are given as a single target fertilizer rate that is projected to be sufficient for meeting the crop fertilizer needs for most growing seasons. This single target fertilizer rate is a recommended starting point and has been used historically in all vegetable fertilizer recommendations in Florida, as well as around the country. The target recommendation approach with footnotes was used by Montelaro (1978) and confirmed by Hochmuth and Hanlon (1995; 2000). The target value was derived from numerous fertilizer studies and represents a reasonable fertilizer rate that reflects the average maximum crop responses from all of the fertilizer research, not the extremes in responses. However the recommendation process recognizes some growing seasons are different, due to more leaching rains or increases in crop value than can lead to prolonged harvest windows. Hence the target

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2. George Hochmuth, professor, Soil and Water Sciences Department; and Ed Hanlon, professor, Soil and Water Sciences Department, UF/IFAS Southwest Florida Research and Education Center; UF/IFAS Extension, Gainesville, FL 32611.

fertilizer amount is accompanied by a series of footnotes that explain the addition of supplemental fertilizer during the growing season, which includes addressing leaching rains and additional harvests near the end of the season. It is logical to select a single target rate based on research that avoids excessive fertilizer applications that often reduce crop nutrient efficiency and increase the potential for environmental degradation. This publication does not replace current publications containing Extension fertilizer recommendations, rather the information summary and analyses presented herein should be used to review, in light of the summary, the current recommendations of both old and recent research findings.

This literature review includes all available published documentation concerning sweet corn yield and fertilizer use in Florida. We chose to present all the research without being selective, as that would introduce bias to the presentation. Inclusion of all Florida literature shows the development of the commercial production system and the fertilizer recommendations with respect to fertilizer use. Average commercial yields have been increasing, primarily due to the proper selection of new cultivars with traits that resist disease and pest pressures and more intensive farming practices. Since the basic plant has not changed, nutrient requirements of the plant have also been slow to change. In fact, nutrient use efficiency has increased while fertilizer rates have not.

This publication is an updated version of a previous research literature review by Hochmuth and Cordasco (1999, reviewed 2008) covering research through 1996. This new review adds any research reports conducted since 1996 and expands on the role of irrigation in managing fertilizer for crop production efficiency and environmental protection. The audience for this publication includes those educators, such as Extension specialists and agents, and commercial vegetable producers, consultants, and governmental agencies.

More than 50 years of sweet corn fertilization research has been conducted in Florida. During this time, many changes have occurred in sweet corn production practices including changes in cultivars and the introduction of new cultural systems such as closer row spacing. Sweet corn crop and fertilizer management recommendations, such as plant and row spacing, have changed with time in keeping with new developments in research (Guzman et al. 1967; Hochmuth 1988; 1996a; 1996b; Hochmuth and Hanlon 1989; 1995a; 1995b; 2000; Hochmuth et al. 1996; Kidder et al. 1989; Montelaro 1978; Ozores-Hampton et al. 2010; Simonne and Hochmuth 2010; Showalter 1984; Stall 1990). The most current recommendations for nutrient management for sweet corn and other vegetables are presented in the *Commercial Vegetable Production Handbook for Florida* (Olson and Simonne 2010). The early research focused largely on yield and ear quality in response to fertilization. Since the early research was conducted, and since the first review of the literature in 1999 (Hochmuth and Cordasco 2008), there have been increasingly strong interests in the incorporation of more environmental impacts (water quality) study into the fertilizer research. The state (Fla. Dept. of Agr. and Cons. Serv. 2005) has been formalizing BMPs and encouraging growers to implement them. Part of the definition of a BMP includes reference to the consideration of both economics and environmental components and that a BMP embodies the best available science.

Sweet corn production in Florida represents nearly 10% of the total vegetable production value in the state or \$156,704,000 (Fla. Agri. Stat. Bulletin 2009). Sweet corn production accounted for 12.5% of all vegetable production in the state for the 2007–08 growing season with 45,300 and 41,500 acres of planted and harvested acres, respectively. In 1995, maximum nutrient recommendations were 150 lb/acre nitrogen (N) and 120 lb/acre P_2O_5 and K_2O each for mineral soils with very low Mehlich-1 (M-1) soil-extractable P and K (Hochmuth and Hanlon 1995a, 1995b). The N rate was revised upward from 120 lb/acre recommended in 1989 (Kidder et al. 1989). The current target rate is 200 lb/acre N, and the P_2O_5 and K_2O recommendations for mineral soils with very low M-1 soil-extractable P and K are 150 lb/acre each (Hochmuth and Hanlon 2000). When residual soil concentrations of P and K are interpreted as low, medium, or high, the recommendations for P_2O_5 and K_2O are decreased to 120, 100, and 0 lb/acre, respectively. Sustained high yields can be expected with fertilization practices designed to supply crop nutrient requirements and protect the environment from excessive fertilization. Use of the M-1 soil test, initiated in 1979, refined the practice of fertilizer rate recommendation and resulted in a crop- and soil-specific guide to fertilizer application. Recommendations for N, P_2O_5, and K_2O fertilization were based on in-field experiments where optimum fertilizer rates were determined from yield responses to a range of fertilizer rates and with varying climatic conditions, soil types, and sweet corn varieties.

Data Summary Method

To evaluate sweet corn yield responses to variable rates of fertilizer, a method was needed to standardize the numerous units used for quantifying statewide yield results such as lbs/acre, tons/acre, metric tons/hectare, or crates per acre (typically a 42-lb crate). In addition, vegetable yields varied with years, seasons, cultivar, and location in the state. Relative yield (RY), a calculated percentage, was chosen as the unit to express sweet corn yield responses to fertilization. Relative yield is an accepted scientific method for summarizing and presenting data across wide sources and reports (Brown 1987).

This paper uses percent relative yield to take into account the changing conditions associated with season, irrigation, pest pressures, and other cultural practices that directly affect yield. No single study is favored by the use of relative yield in the summaries of data. Percent relative yield has been critically reviewed and included in all modern books and papers dealing with plant yield and added nutrition completed by researchers in different locations and spanning large periods of time. The resulting information effectively avoids the confounding effects mentioned above. Differences between fertilization rates obtained from various research efforts are put on the same scale, allowing for comparisons that could not be obtained if actual yields were used. Percent relative yield provides for the practical inclusion of numerous research projects in the analyses rather than relying on a single study conducted in one location at one particular time.

In his book, C. Black (1992) summarized the advantages and disadvantages of the RY approach. There are valid statistical concerns about RY, but he concluded that, when applied properly and cautiously, the RY approach can be useful in displaying general relationships. Black demonstrates examples in his book where RY is helpful and where it was not. We chose the RY approach because we wanted to display the historical data without making biased decisions about what to include and what not to include in the presentation. Plotting absolute yield data in original units obviously would result in a scatter of data rendering any general interpretation impossible. Black (1992) points out that decisions can always be improved with further research, but the data on hand are the best we have at the time. The highest yield for each fertilizer experiment was assigned a 100% value, and other yields were expressed as a percentage of the highest yield. The actual yield corresponding to 100% RY was presented in 42-lb crates/acre units. The RYs were plotted against rates of nutrient to determine how sweet corn yields responded to fertilizer in Florida. The RY presentation allowed data from a variety of experiments to be included in the graphical summary of yield responses. For most studies, RYs of 90 to 100% were not significantly different.

Sometimes the argument is made that growers have expectations of greater yields than those obtained in research projects. It should be pointed out that realistic, regularly obtainable yields might be different from expected yields or "yield goals." Research on this subject has documented that 20% of growers actually reached their yield goals, and only 50% reached 80% of their yield goals (Schepers et al. 1986). Fertilizer rates should not be set on yield goals but rather on realistic goals based on research. The use of yield goals is not recommended in Florida, so the effect of overfertilization has been avoided by grounding expectations in measurement of observed yields. In effect, the current Florida fertilizer recommendation includes a component that addresses yield expectation versus actual production capability concern expressed by growers. Scientists throughout the years have conducted many replicated demonstration studies in growers' fields, with true commercial production practices, and those studies are included in this review where possible. Excessive fertilizer was justified in times past when fertilizer was viewed as inexpensive insurance against yield loss. Research with numerous crops has shown that nutrient use efficiency declines as nutrient rate, especially N, increases. Even given the best of production systems, N use efficiency rarely exceeds 70% of the applied N. Concepts and practices for managing nutrients in vegetable production were summarized by Hochmuth (1992; 2000). Further, it has been suggested that the yields in older studies were much lower than yields obtained today. However there are older research reports where yields were as high as yields achieved today. Fertilizer rates are expressed on a per-acre basis (amount of fertilizer used on a crop growing in an area of 43,560 sq ft). Changes in bed spacing often lead to needed changes in fertilizer amounts. For example, to maintain the same amount of fertilizer in the plant bed for a crop on 6-foot bed spacing as a crop with 4-foot bed spacing would mean an increase by a factor of 1.5 in the "per acre" rate of fertilizer for the crop growing in beds spaced 4-foot on center. The important aspect is to have the same amount of fertilizer per linear-bed-foot (LBF) because it is the bedded area where most of the roots are contained. This linear-bed-foot system is used by the University of Florida Extension Soil Testing Laboratory to express fertilizer rates. The concept is explained by Hanlon and Hochmuth (1989) and by Hochmuth and Hanlon (2009). A sweet corn fertilization recommendation is typically not provided using the LBF system but rather on an acre basis; however, information is provided to encourage banding of fertilizer whenever possible. Fertilizer rate expressions used in this review summary and its figures are those rates presented by the various authors in their research papers. Most authors expressed rates on a per-acre basis, irrespective of variations in row spacing among reports or experiments. We attempt to specify planting patterns and fertilizer rates for each experiment as far as we can determine from each report. Sweet corn production systems have varied with time largely due to differences in irrigation systems. Hence the irrigation method is referenced for the fertilizer research studies.

Nitrogen

Yield responses to N fertilization on sandy soils are presented in Figure 1. Early research with N fertilization of sweet corn focused on gaseous loss of N from unincorporated, surface-applied N fertilizer (Volk 1962). Experimental plots were established on beds treated with 0, 1900, or 4800 lb/acre lime in 1959. Experiments were conducted near Gainesville on Leon fine sand soils in both seasons. Yield responses were evaluated from plants fertilized with covered or uncovered side-dressed fertilizer and from plants fertilized with liquid N fertilizer. In 1961, 18 lb/acre N was applied "in-the-drill" at planting with additional N applied in one or two side-dress N applications at 47 lb/acre each from urea, NH_4NO_3, or Uran 32 solution (16.5% urea - N, 15.5% NH_4NO_3).

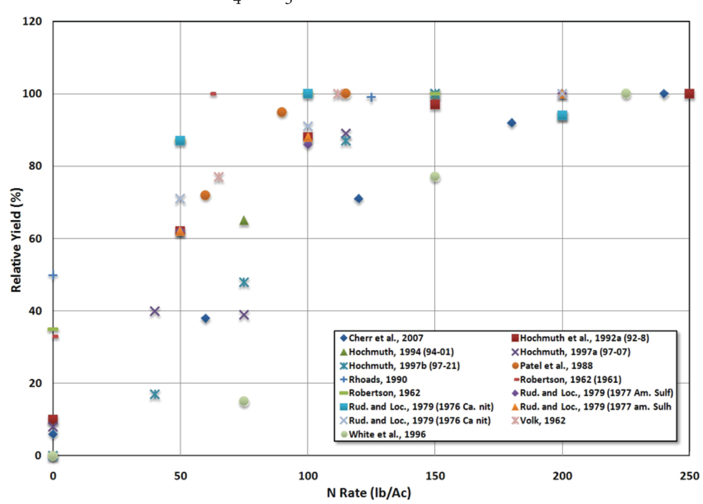

Figure 1. Response of sweet corn to N fertilization on sandy soils in Florida.

Results with corn yield response to N fertilization are presented in Figure 1. Yields averaged using the three N-source treatments, on previously limed and unlimed beds (pHs 4.5, 5.2, and 5.7), and covered or uncovered N fertilizer were optimized when fertilizer was side-dressed twice for a total of 112 lb/acre N (239 crates/acre, 100% RY). A lesser yield resulted from plants fertilized with the single side-dress N application of 65 lb/acre N, 77% RY. With the higher N rate, plants with covered fertilizer yielded 14% more than plants where fertilizer was uncovered (227 and 200 crates/acre, respectively). Researchers observed that more late-developing ears were harvested when plants received the second fertilizer side-dressing than those side-dressed once and that lime treatments had similar effects on yield. Yields were not different between liquid and dry N sources, but urea-fertilized plants produced yields 6% to 8% lower than plants fertilized with other N sources.

A second experiment was conducted in 1962. The same N sources were used as in the previous experiment with two additional treatments, Feran 21 (NH_4NO_3 solution) and Pril-Cal [plastic coated $Ca(NO_3)_2$]. Fertilizers were applied once at planting, 18 lb/acre N, followed by a single side-dress application of 75 lb/acre N. Dolomitic limestone was applied uniformly to all beds (fall 1961) for low, medium, and high pH plots (5.2, 5.9, and 6.2, respectively). Plants fertilized with non-urea fertilizer yielded 3% more when the fertilizer was covered than when it was uncovered. Plants fertilized with urea produced similar yields with either covered or uncovered fertilizer. Researchers concluded that covering the fertilizer improved N availability regardless of N source. As in the previous season, lime increased the yield of late developing ears.

Simultaneous experiments were conducted in 1961 and 1962 in Gainesville with N sources $NaNO_3$, NH_4NO_3, Uran, Pril Cal, and urea applied in single or split applications (1961) and $NaNO_3$, NH_4NO_3, and urea applied single or split totaling 50, 100, or 150 lb/acre N (1962) (Robertson 1962). Dolomitic lime was applied and incorporated at 1 ton/acre. 'Iona' sweet corn seeds were planted both seasons on Ona-Kanapaha fine sand complex soils fertilized with 12 lb/acre N at planting. The corn was cultivated when plants were 10, 18, and 24 inches tall. Irrigation was not needed in 1961, but two sprinkler irrigations of 1 acre-inch each were applied in 1962.

In 1961, plants received no N or 50 lb/acre N from each N source side-dressed and incorporated when plants were 10 inches tall. Total N application, including the 12 lb/acre N applied at planting, was 62 lb/acre. Marketable yields were similar with all applied N sources resulting in an average high yield of 165 crates/acre from fertilized plants compared to 55 crates/acre from unfertilized plants. Nitrogen sources also did not affect the number of ears/acre, the weight/ear, or tissue N concentrations sampled from whole leaves at tasseling. Tissue N concentration, averaged over all N source treatments, was 1.43%, which was less than the adequate range of 1.5 to 2.5%.

In 1962, fertilizer was applied and incorporated when plants were 10 inches tall or applied half at this height and half when plants were 24 inches tall. Sweet corn yields responded linearly to N rate with $NaNO_3$ and urea N sources through 150 lb/acre (306 and 286 crates/acre, respectively, 100% RY) but responded quadratically with NH_4NO_3 - N. Equal yields resulted from plants fertilized with 100 lb/acre NH_4NO_3 - N (305 crates/acre, 100% RY) as those fertilized with 150 lb/acre $NaNO_3$ or urea - N. Yield from NH_4NO_3 fertilized plants was reduced to 93% RY with 150 lb/acre N. Researchers noted that reduced stands resulted from the single application of 150 lb/acre NH_4NO_3 - N. Yield responses were generally higher with all N sources when N was split applied compared with the single N application. As in 1961, plants fertilized with covered NH_4NO_3 or $NaNO_3$ yielded more than urea fertilized plants through 100 lb/acre N. Leaf-tissue N concentrations at tasseling averaged 2.4% and 2.5% with 100 and 150 lb/acre N, respectively, and were within the adequate range of 1.5% to 2.5% (Hochmuth et al. 1991; 2009).

Experimentation with N fertilization of sweet corn was continued the summer of 1976 and spring of 1977 when field experiments were conducted near Gainesville (Rudert and Locascio 1979a). Nitrogen sources, rates, time of application, and the nitrification inhibitor nitrapyrin were evaluated for their effects on yield and tissue nutrient concentrations. Kanapaha fine sand soils with 1.0% organic matter and an after-lime pH of 6.5 received factorial applications each year of 50, 100, or 200 lb/acre N from $(NH_4)_2SO_4$; 0, 0.5, or 1 lb/acre nitrapyrin; and fertilizer application at preplant or 50% preplant, 50% side-dress (5 weeks after seeding). An adjacent experiment was conducted with the above N rates from $Ca(NO_3)_2$ - N and 0 or 1 lb/acre nitrapyrin in 1976 and no nitrapyrin in 1977. The fertilizer was banded 3 inches from the row and 3 inches below the bed surface, and 'Silver Queen' seeds were planted.

Quadratic yield responses occurred with $(NH_4)_2SO_4$ fertilized plants with yields leveling off above 100 lb/acre N in 1976 and 1977. Relative yields, respectively, corresponding to 50, 100, and 200 lb/acre N were 62%, 86%, and 100% (208 crates/acre, 1976) and 62%, 88%, and 100% RY (310 crates/acre, 1977). Nitrogen leaching, due to heavy weekly rainfall, was cited as the cause of the lower summer yields in 1976 compared with the dry, irrigation-supplemented spring 1977 season. During the wet season, plants fertilized with $(NH_4)_2SO_4$ yielded 65% more than $Ca(NO_3)_2$ fertilized plants. Plants fertilized with $Ca(NO_3)_2$ - N had similar yields with all N rate treatments. Soil analysis revealed that most of the soil N had leached below the top 12 inches 2 weeks after application of $Ca(NO_3)_2$.

In nonleaching conditions in the spring of 1977, a linear yield response to N rate resulted with $Ca(NO_3)_2$ fertilizer (289 crates/acre with 200 lb/acre N, 100% RY). Leaf-tissue N concentrations from ear leaves sampled at tasseling (11 weeks) were less than the adequate range of 1.5 to 2.5% with all N rates and both N sources. Lower tissue N concentrations occurred in $(NH_4)_2SO_4$ fertilized plants compared with $Ca(NO_3)_2$ fertilized plants. Yield responses to N rates and N sources for these experiments were presented graphically in Figure 1.

Yields responded similarly in both seasons to single or split N applications, regardless of fertilizer source or soil moisture conditions. Use of nitrapyrin—intended to inhibit the conversion of NH_4^+ to NO_3^- and stabilize soil NH_4^+ - N content—did not influence yields of sweet corn in either experimental season. Researchers suspected high soil temperatures acted to denature the nitrapyrin, but in later research, NH_4 - N was found to leach at a fast rate in sandy soils (Rudert and Locascio 1979b). Maximum nitrapyrin effectiveness occurred within 2 to 4 weeks of application on Kanapaha fine sand soils, and thereafter, NH_4 - N had moved below nitrapyrin in the soil.

Sweet corn responded to more N than recommended in a study in Central Florida (Sanford) on sandy soils (Patel et al. 1988). Yield was improved by split applications compared to single, preplant applications.

Researchers concentrated on finding the optimum N rate and N placement method for sweet corn production in an experiment at the UF/IFAS North Florida Research and Education Center–Quincy in 1990 (Rhoads 1990). As with previously summarized research, the objective was to minimize N movement in the soil and maximize yields. Nitrogen treatment rates of 125 and 200 lb/acre were achieved with application of 50 lb/acre at plant emergence and 75 lb/acre 5 weeks before harvest (for 125 lb/acre) and an additional 75 lb/acre N applied 7 weeks before harvest (for 200 lb/acre). Fertilizer was broadcast between the rows (row middles) or banded to one side or both sides of the row. The row middles were alternately compacted by wheel traffic or noncompacted.

Sweet corn yield, averaged using all placement methods, was optimized with 125 lb/acre N (283 crates/acre), 99% RY, a 50% increase in yield compared to plants with the zero N treatment. Leaf tissue sampled 5 weeks before harvest had N concentrations within the adequate range of 2.5 to 4.0% with N treatments of 125 and 200 lb/acre, but N concentrations were inadequate with the zero N treatment. Analysis of whole-plant N content revealed that, from each N respective treatment (125 and 200 lb/acre), plants absorbed 85 and 70 lb/acre N with 40 and 130 lb/acre N unrecovered by the plants. Nitrogen recovery increased when fertilizer was banded near the root zone. From a single band of fertilizer with 125 lb/acre of applied N, 88 lb/acre was recovered, and when fertilizer was banded on both sides of the plant row, 100 lb/acre of N was recovered. Less N was recovered from 125 lb/acre of applied N where fertilizer was broadcast across compacted or noncompacted row middles, 74 to 79 lb/acre of N, respectively. Researchers concluded that plant recovery of N decreased with N rates above 125 lb/acre, that N fertilizer applied in bands near the root zone increased N recovery, and that the 120 lb/acre recommended N rate (Kidder et al. 1989) resulted in optimum yields.

Researchers at the UF/IFAS Suwannee Valley Agricultural Research and Education Center near Live Oak applied N at rates in 50 lb/acre increments from 0 to 250 lb/acre to field test the N recommendation of 120 lb/acre (Hochmuth et al. 1992a, b; Kidder et al. 1989). Preplant NH_4NO_3 - N was applied at 30 lb/acre, except with the zero N treatment, to Lakeland fine sand soil with 2.0% organic matter content. The remaining N was applied as a single side-dress application with the 50 lb/acre treatment and in two equal side-dress applications with the other treatments. Side-dress applications were made when plants were 6 inches tall and when plants were 18 inches tall. Sprinkler irrigation was applied to maintain soil water potential at -12 centibars as measured by tensiometer.

Marketable corn yield increased quadratically resulting in greatest yield with 150 lb/acre N (330 crates/acre, 100% RY). As with yield, N concentrations of leaf tissue sampled at tassel emergence increased quadratically from 2.1% with 0 lb/acre N (deficient) to 3.3% with 100 and 150 lb/acre N (adequate) and leveled off thereafter to 3.5% with 200 lb/acre N (adequate). For this experiment, a leaf-tissue N concentration of 3.3% and total N rate at 150 lb/acre resulted in optimum yield. The quadratic equation and linear plateau mode, predicted maximum yield with N rates of 187 and 83 lb/acre, respectively. The midpoint of these two rates corresponded to the experimental high-yield rate of 150 lb/acre of N.

Ear quality factors, including ear diameter, ear uniformity, and ear tip uniformity, also increased quadratically with increased N rate, leveling off above 50 lb/acre N (ear diameter), above 100 lb/acre N (ear uniformity), and above 150 lb/acre (tip uniformity). With N treatments of 150 lb/acre and above, yield of cull corn was minimized, and yield of US No. 1 grade ears leveled off. Yield of No. 2 grade ears was unaffected by N rate while ear length increased only with the first increment of applied N. Yield was improved by split applications over single, preplant applications. In work on sandy soils at Live Oak, sweet corn yield was maximized at 350 crates/acre with 187 lbs N per acre (Hochmuth et al. 1992b).

Sweet corn yield responses to N fertilization presented thus far were conducted on sandy soils in northern areas of the state where high yield resulted with 100 to 150 lb/acre N. Research summarized in Figure 2 was conducted in Southern Florida during the winter season to evaluate sweet corn response to N fertilization and fill in gaps in research on sweet corn fertilization for southern production areas (Hochmuth et al. 1995; Hochmuth et al. 1998). Nitrogen treatments, in 50 lb/acre increments from 0 to 200 lb/acre from NH_4NO_3, were applied on rockland soils (1994) and on rockland and marl soils (identified as sites one and two, respectively) in 1995. All experiments were conducted on commercial farms near Homestead, Florida and included a grower fertilization program at each location. Half of the applied N and K fertilizers was banded along the plant row at plant emergence, and the remaining N and K was divided in equal band side-dressings applied at 4- and 8-inch plant height stages.

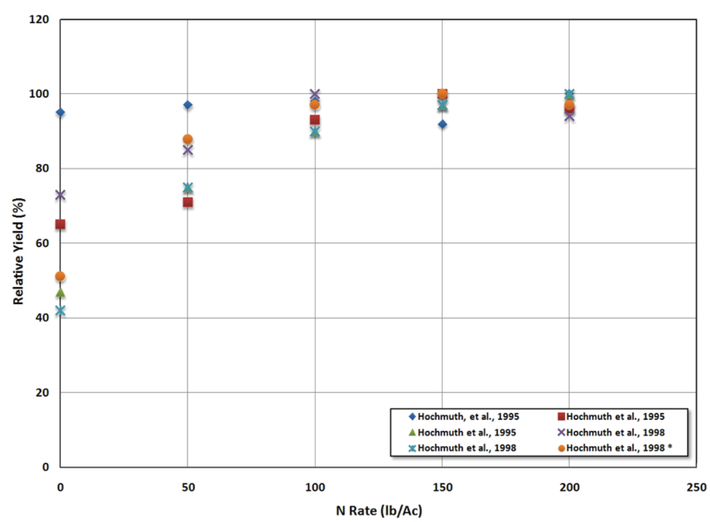

Figure 2. Responses of sweet corn yield to N fertilization on calcareous soils in Homestead, Florida.

Applied N had no effect on yield for sweet corn grown on rockland soil in 1994. The average yield with N treatments from zero to 200 lb/acre was 227 crates/acre. Yield with the grower N rate of 170 lb/acre was 232 crates/acre. Nitrogen concentrations measured in the whole plant at the 6-leaf stage increased linearly within the sufficiency range of 3.0 to 4.0%. Leaf-tissue N concentrations sampled at the 30-inch plant height and at full silk exceeded sufficiency ranges for treatments where no N was applied. At these sample dates, leaf-tissue N concentrations did not change with increased N. Sweet corn ear quality characteristics, including uniformity, diameter, length, and the amount of blank ear tips, were similarly unaffected by N rate treatments.

Sweet corn yields responded linearly to applied N in field tests on rockland soils at site 1 in 1995. Highest (100% RY) occurred with 150 lb/acre N (205 crates/acre) while yields with the grower treatment of 340 lb/acre N were 180 crates/acre. Parallel linear increases occurred in leaf-tissue N concentrations at the 10-week sample date. Nitrogen concentrations in the leaf tissue of unfertilized plants taken 6 and 10 weeks from planting were 3.4% and 3.1%, respectively. These leaf-tissue N concentrations exceeded the minimum concentrations of 2.5% and 1.5% N for each sample date, prompting researchers to question the published sufficiency ranges (Hochmuth et al. 1991). Increased N fertilization from 0 to 200 lb/acre resulted in a linear increase in corn ear diameter from 1.4 to 1.6 inches.

Sweet corn planted on marl soils at site 2, grower 2, (1995) resulted in a quadratic yield response to applied N. Yields leveled off above 150 lb/acre N (285 crates/acre, 97% RY) while yields with the grower fertilization treatment of 470 lb/acre N resulted in 290 crates/acre. Leaf-tissue N concentrations at the 8-week sampling were at the lower end of the adequate range and increased linearly with fertilization through 200 lb/acre N. At the 11-week sample date, leaf-tissue N concentrations leveled off above sufficiency concentrations with 150 lb/acre N, and researchers suggested sufficiency leaf N concentrations of 3.0 to 3.2% were more accurate for this sample date than the published 2.5%. All ear quality factors were affected by N fertilization this season with quadratic increases in ear diameter to 1.8 inches and ear length to 7.2 inches with 150 lb/acre N. The amount of "blank ear tip" decreased linearly from 1.6 inches/ear with 0 lb/acre N to 0.8 inches/ear with 150 and 200 lb/acre N. The number of 3-inch flags/ear increased linearly from 2.5/ear to 6.2/ear with 0 to 200 lb/acre N, respectively.

Based on the above experiments, optimum yields for sweet corn grown on marl or rockland soils occurred with 150 lb/acre N with no yield advantage from grower N rates of 170, 340, or 470 lb/acre. Tissue N concentrations associated with high yields were 5.0% from 8-inch whole plants and 4.0% and 3.0% from whole leaf samples of 30-inch plants and plants at full silk, respectively. Nitrogen was a factor in yield increases in two of the three experiments and a factor in improved ear quality at site 2 in 1995.

Additional winter sweet corn experiments near Homestead were conducted with growers 1 and 2 in the 1995–1996 season. These yield results were presented in a subsequent unpublished paper (Hochmuth et al. 1998). Soils were rockland (grower 1) and marl (grower 2). Both experiments received overhead irrigation. Fertilizer practices were the same as in the 1993–1994 experimental season. Yield responses were quadratic in both seasons leveling off above 100 lb/acre N (309 cartons/acre, 100% RY, and 349 cartons/acre, 97% RY, respectively). Nitrogen treatments ranged from 0 to 200 lb/acre. Similar yields resulted with the grower fertilization programs of 334 lb/acre N, grower 1, and 470 lb/acre N, grower 2. Ear uniformity (size, shape, and tipfill) was rated on a scale of 1 (low) to 5 (high). An optimum ear uniformity rating of 4 occurred with 0 and 150 lb/acre N in the experiment with grower 1, while ear uniformity was unaffected by increased N with the grower 2 experiment (3.5 average ear uniformity). Ear length and diameter increased linearly with N (grower 1) and increased quadratically (grower 2), leveling off above 50 lb/acre N. The length of the unfilled ear tips and the cumulative (5 ears) length of ear flag leaves decreased linearly with increased N in both experiments.

Field experiments with N fertility were conducted in a spring 1996 experiment on Myakka fine sand at the UF/IFAS Central Florida Research and Education Center–Sanford (White et al. 1996). On March 25, seeds of supersweet sweet corn cultivar 'XP-7' were planted and fertilized with one-third of the 0, 75, 150, and 225 lb/acre N treatment rates. Due to 4.23 inches of rainfall in early April, the crop was replanted and fertilized with the second one-third fertilizer application on April 12. Researchers expected the initial fertilizer application was lost to leaching. The remaining one-third of the N fertilizer was applied when plants were between 4 and 8 inches tall. No marketable corn ears were harvested from plants that received 0 lb/acre N, but yield increased significantly through 225 lb/acre N (326 crates/acre, 100% RY). Leaf-tissue N concentrations also increased above 3.0% at sampling dates 4, 5, and 7 weeks after planting with 150 and 225 lb/acre N. These concentrations exceeded the adequate range of 1.5% to 2.5% N. Ear quality characteristics were optimized with N treatments of 150 and 225 lb/acre for an optimum ear weight of 0.7 lb, ear length of 7.1 inches, and ear width of 1.8 inches. With these N rates, ear kernel-fill was complete, and ears had tight and complete husk coverings.

Growth "enhancers" were evaluated for their effect on sweet corn yield in two Gainesville experiments in the spring of 1993 (Hochmuth 1994). Nitrogen rates were applied factorially with other treatments in experiment one, but rates of mixed N and K fertilizers prohibited evaluation of yield response to N in experiment two. Sweet corn was planted in double rows 15 inches apart in beds 24 inches wide with fertilizers and growth enhancers banded 3 inches deep in the bed center. Factorial applications of N at 75 or 150 lb/acre were banded 30% at planting and 70% at the five-leaf stage in experiment one. Growth enhancers, Agronomix (vitamin) in experiment one and GR-1 in experiment two, were applied 50% at planting and 50% side-dressed at 0 or 5 lb/acre Agronomix and 0, 1.5, and 4.5 lb/acre GR-1. Rates of fertilizer and growth enhancer were calculated on an average 30-inch row spacing (17,424 linear row feet/acre), and overhead irrigation was applied to maintain tensiometer readings of -10 centibars.

Sweet corn yield, ear quality criteria, and leaf N concentrations were unchanged by Agronomix or GR-1 in experiments one and two. No interactions occurred among factors with respect to yield or ear quality in either experiment one or two. Optimum yield in experiment one resulted with 150 lb/acre N (367 crates/acre, 100% RY), significantly different at 5% probability from yield with 75 lb/acre N, 65% RY. Yields in experiment two were optimized with the combined 150 lb/acre N, 100 lb/acre K_2O (342 crates/acre, 100% RY) compared with 73% RY with 75 lb/acre N and 50 lb/acre K_2O. In experiment one, more fancy, more No. 1 grade, and fewer cull ears were harvested with the 150 lb/acre N treatment compared with the lower N rate. Ear quality characteristics, size, tip fill, and uniformity were also significantly improved with higher fertilization rate, compared with ears harvested from plants with the 75 lb/acre N treatment. Leaf-tissue N concentrations measured at the early silk stage were adequate in both experiments with both N rates but increased significantly (1% probability) with increased N in experiment 1.

Experiments with growth enhancers continued in Gainesville, spring 1997, where researchers tested the hypothesis of higher yield results with lower N rates following application of Grow-Plex SP humate (Earthgreen Products Inc., Dallas, TX) (Hochmuth, 1997a). Grow-Plex humate was suspended in water with Earthgreen Synfactant and sprayed in the seed furrow at 0, 1, and 2 lb/acre humate. Nitrogen rates were 0, 25, 50, 75, and 100% of the recommended 150 lb/acre N or 0, 40, 75, 115, and 150 lb/acre N. Fertilizers were incorporated preplant at 20 lb/acre N and the remainder was banded to the side of the row when plants were 2 and 6 inches tall. Early plant vigor ratings, 1 for yellow and 5 for dark green, were made when sweet corn plants were at the 2 and 4 leaf stages. Overhead irrigation was applied to maintain soil moisture tension at -10 centibars using tensiometers.

Nitrogen and humate did not interact in their effects on sweet corn yields. Plant vigor ratings were not affected by increased N or increased humate, but yield increased significantly (1% probability) with added N to 150 lb/acre (454 crates/acre, 100% RY) and with added humate to 1 lb/acre (5% probability).

Gainesville experiments with Growplex humate were repeated in fall 1997 with additional experiments testing foliar humate applications (Hochmuth 1997b). Growplex humate was applied in the seed furrow at 0, 1, or 2 lb/acre as a solution of water and product; Earthgreen Synfactant was not used in the solution. Nitrogen treatments of 0, 40, 75, 115, and 150 lb/acre N were applied factorially with the three humate treatments for 15 total treatments. Preplant application of NH_4NO_3 - N and K_2SO_4 - K were incorporated at 20 lb/acre N and K_2O except in plots that received no N. Side-dress N and K applications were made between the two plant rows/beds when plants were thinned and again when plants were 8 inches tall. Additional treatments consisted of foliar GrowPlex SP sprayed on the plants at 4 oz/acre in 30 gallons of water to plants in separate plots fertilized with 115 lb/acre N and each of the three furrow-applied humate treatments. Foliar sprays were made when the sweet corn was 12 and 24 inches tall. Overhead irrigation was used to maintain soil moisture tension at -8 to -10 centibars.

Greatest average yields (1% probability) resulted where plants received 150 lb/acre N, 291 crates/acre (100% RY) as opposed to 87% RY where plants received 115 lb/acre N. Yields were not generally affected by Growplex humate except in one of the 15, N rate x humate, treatments where plants fertilized with 115 lb/acre N and 1 lb/acre Growplex humate resulted in yields near those of plants fertilized with 150 lb/acre N alone, 298 crates/acre compared with 319 crates/acre, respectively. Based on these results, researchers indicated high yields may be possible at lower N rates with furrow-applied humate. Significant yield differences (1% probability) resulted with foliar-humate applications, though yields of 177 crates/acre with two foliar humate applications, 2 lb/acre humate applied in the furrow, and 115 lb/acre N, were lower than yields with 150 lb/acre N and no humate, 319 crates/acre. Yields were lower overall with the foliar-applied humate compared with plants that received humate in the furrow with 115 lb/acre N. Plant vigor was unaffected by furrow-applied humate but was significantly (1% probability) improved with increased N.

The effect of leguminous green manure (GM) as a substitute for chemical inorganic fertilizers was evaluated during the 2002–03 growing season on a sweet corn crop at the Plant Science Research and Education Unit near Citra, Florida (Cherr et al. 2007). Treatments were arranged in four randomized complete blocks with individual 7.6 m x 8.8 m plots. Treatments receiving GM were supplemented with 0, 60, 118 lb/acre chemical N. These treatments were compared with control treatments that had no GM and only had chemical N (ammonium nitrate) additions of 0, 60, 118, 178, and 238 lb/acre N. The results show that all the N rate treatments that had GM additions demonstrated greater corn ear yields than those without GM. The best yields were, however, obtained with the highest rates (178 and 238 lb/acre N) of chemical N (which had no GM).

A study conducted at the University of Florida looked at the effect of fertilizer residence time on N uptake efficiency (Zotarelli et al. 2008). This column study with N applied either 1, 3, or 7 days before a weekly leaching event used KNO_3 solution (total of 393 kg N ha^{-1}). The researchers found a linear response of plant growth and yield to the fertilizer residence time with cooler conditions, whereas a quadratic response occurred with warmer conditions. The findings of this research suggest that increasing N fertilizer residence time, which is indicative of better irrigation practices, enhances overall growth, yield, N uptake in sweet corn and fertilizer use efficiency (FUE). Increased FUE will minimize loss of fertilizers from the root zone.

Nitrogen Summary

Nitrogen research summarized here was conducted in the state's sweet corn production on the mineral soils in most production areas of Florida. Most of the summarized experiments resulted in optimum yields with N rates equal to or less than the recommended 200 lb/acre. The remaining 50% of sweet corn production occurred on organic soils in the Everglades, and this research was summarized in a review of fertilization practices on organic soils (Hochmuth et al. 1996).

Plants fertilized with 170, 340, or 470 lb/acre N on marl or rockland soils resulted in yields equivalent to those fertilized with 150 lb/acre. Split N application increased yield 14% in a 1962 experiment compared with yields from plants fertilized in a single application. The remaining experiments were fertilized with the split method, recommended for nonmulched crops where leaching and fertilizer burn might occur with the single application method. Nitrogen recovery was improved when fertilizer was banded in the root zone to one side or to both sides of the plant row. Yield responses from plants fertilized with NH_4NO_3 or $(NH_4)_2SO_4$ were generally quadratic and leveled off above 100 lb/acre N. Quadratic responses to increased N also were found for leaf-tissue N concentrations and ear quality characteristics, ear length and diameter, with peak responses between 100 and 150 lb/acre N. In some experiments, the length of ear blank-tip decreased with N rates from 0 to 150 lb/acre, yield of cull ears decreased, and yield of fancy and No. 1 grade ears increased with 150 lb/acre N compared with yields with lower N treatments. Treatments added to inhibit nitrification or enhance growth with vitamin application (Agronomix or GR-1) were generally not effective.

Phosphorus and Potassium Soil Testing

Mehlich-1 extractant indices (expressed as ppm soil-extracted nutrient) are classified as very low, low, medium, high, and very high; and a crop specific fertilizer recommendation is made from that classification (Hochmuth and Hanlon 1995; 2000; Mylavarapu 2009). The M-1 solution became the accepted extractant standard in 1979 at the University of Florida. Prior to M-1 introduction, ammonium acetate and water extractants were used. Indices recorded from these methods cannot be directly equated with M-1 indices or fertilizer recommendation rates, but the review of these studies presents a profile of sweet corn response to fertilizer with varying conditions. Water management practices, fertilizer sources, and application methods are also summarized. Very few studies on P and K fertilization of sweet corn have been completed in Florida, especially for sandy soils.

Phosphorus

Subsurface irrigated fertilizer studies conducted on organic soils in South Florida were designed to measure the effect of different P rates on the yields of sweet corn (Sanchez et al. 1991). The studies were conducted across six site-seasons during 1988 and 1989. The 'Florida Staysweet' variety was used in experiments conducted during spring 1988, fall 1988, and spring 1989. 'Summer Sweet-7210' was used in experiments during spring 1989b through fall 1989. Concentrated superphosphate fertilizer was broadcast (surface applied and disked) and band applied (applied approximately 3cm below the corn seeds). Application rates for P were 0, 25, 50, 75, and 100 kg P ha^{-1}. Sweet corn responded to P in all experiments except spring 1988 and fall 1988. Total marketable yield—the yield of sweet corn of U.S. Fancy grade—and quality of U.S. Fancy ears were increased by P rate. Marketable yields significantly differed by P placement in all studies in which sweet corn responded to P rate. The banding method required less fertilizer to obtain specific yields, and it also resulted in higher total marketable yield.

Phosphorus was applied on rockland soils in 1994 and on rockland and marl soils in 1995 (Hochmuth et al. 1995; Hochmuth et al. 1998). No soil test has been calibrated for the calcareous soils in South Florida. Soil P was extracted using the ammonium bicarbonate-diethylenetriamine pentacetic acid extractant (AB-DTPA), the Mehlich-3 extractant (M-3), and the water extractant procedures for the purpose of comparison. Results from the water extractant analysis proved the most variable and therefore least reliable of the extractants used. Based on data from AB-DTPA and M-3 extractants, no yield response was expected with P or K fertilization. Plants fertilized with 0, 50, 100, 150, or 200 lb/acre P_2O_5 (banded at planting) produced similar yields, ear quality, and leaf nutrient concentrations (above adequate) in all three experiments (Figure 3). Yields averaged using all P treatments resulted in 237, 190, and 274 cartons/acre from respective experiments. Both the AB-DTPA and M-3 extractants accurately predicted sufficient soil P concentrations to support high yield, but researchers questioned the use of M-3 due to potential reaction with high soil carbonate concentrations. The AB-DTPA soil-extracted P concentrations at these sites were 70, 77, and 75 ppm, respectively. Experimentation is needed on calcareous soils with varying P concentrations to calibrate the AB-DTPA extractant at lower concentrations of soil P.

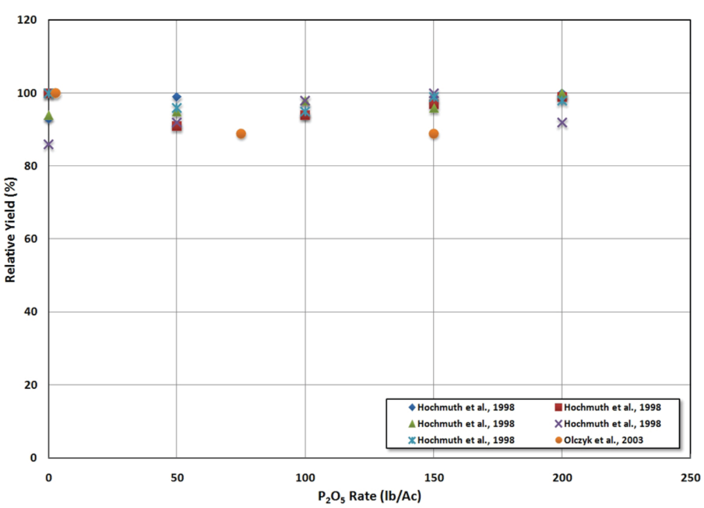

Figure 3. Response of sweet corn to P fertilization on calcareous soils in Homestead, Florida.

Two additional Homestead experiments were conducted in 1995–1996 with banded P and overhead irrigation (Hochmuth et al. 1998). Soil P concentrations extracted with AB-DTPA were 547 ppm (grower 1) and 317 ppm (grower 2). As with the above experiments, sweet corn yields did not respond to P application rates of 0, 50, 100, 150, and 200 lb/acre P_2O_5. Average yields for each season were 290 and 332 cartons/acre. Ear quality factors were also not affected by increased P rates. Later studies on calcareous soils documented no reduction in yield when P fertilization was reduced to less than 5 lb per acre (Olczyk et al. 2003).

A summary of P fertilizer research on sandy soils showed that soil test results using the Mehlich-1 extractant correlated with crop response (Hochmuth et al. 1993).

Potassium

Experimentation with potassium (K) fertilization of sweet corn was limited mostly to work in Homestead, Florida. Potassium was applied on rockland soils in 1994 and on rockland and marl soils in 1995 (Hochmuth et al. 1995; Hochmuth et al. 1998). Plants fertilized with 0, 50, 100, 150, or 200 lb/acre K_2O (banded at planting) produced similar yields, ear quality, and leaf nutrient concentrations (above adequate) in all three experiments (Figure 4). Sweet corn responded (Figure 5) to more K than recommended in a study in Central Florida (Sanford) on sandy soils (Patel et al. 1988). Sweet corn yield response was linear throughout the range of 0 to 100 lb K per acre with 100% RY (324 crates/acre) with 50 lb/acre K_2O (Hochmuth 1994).

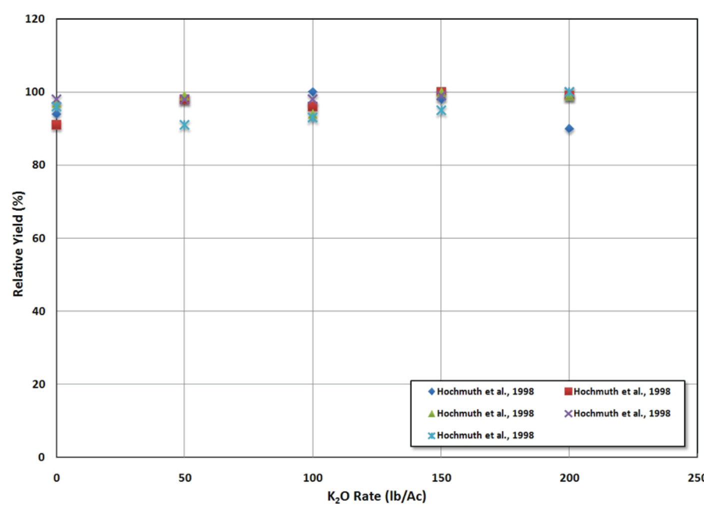

Figure 4. Response of sweet corn to K fertilization on calcareous soils in Homestead, Florida.

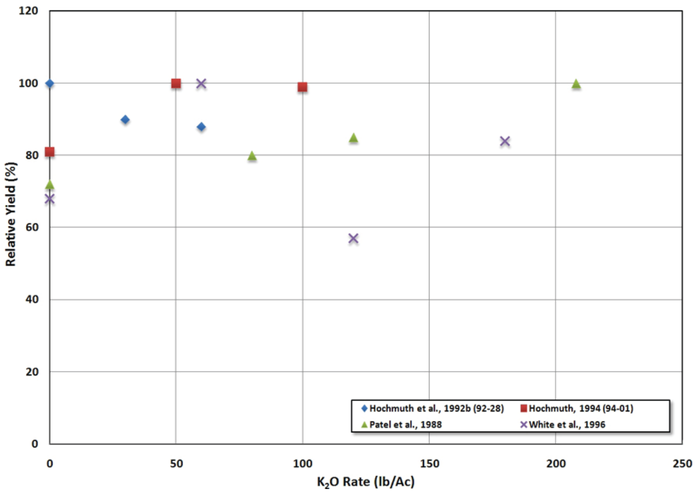

Figure 5. Response of sweet corn to K fertilization on sandy soils in Florida.

POTASSIUM SUMMARY

Sweet corn yields responded to K rates that were less than the M-1 soil test recommendation in Gainesville and Sanford experiments where soils were low in M-1 soil-extracted K. Yields were optimized with half to nearly half (50 and 60 lb/acre K_2O) of the recommended 100 lb/acre K_2O in each experiment. Certain ear quality characteristics were also optimized with the minimum K treatment. These were ear length and weight in the Gainesville experiment and husk cover, tip fill, length, and width in the Sanford experiment. No yield advantage resulted from increased rates of applied K. Yields leveled off in Gainesville and decreased in Sanford with K rates exceeding 50 and 60 lb/acre, respectively. Additional experiments are needed to evaluate the K needs and efficiency of this crop in extracting soil K.

Overall Summary

Sweet corn fertilizer needs have not been researched as completely as they have for tomato or potato. Most fertilization research for sweet corn has been done with N. Most of this work supports an N target recommendation of 200 lb/acre for the west, north, central, and extreme southeastern portions of the state (rockland and marl soils). Since sweet corn is grown without polyethylene mulch, careful management of N fertilization is critical to minimize leaching losses of N. More research is needed to study the relationship of N management to N leaching. Very little research with P and K fertilization of sweet corn has been conducted.

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