

## A Summary of N, P, and K Research with Cucumber in Florida<sup>1</sup>

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Cucumber production in Florida in 1996-1997 was divided between the spring season, 65% of the harvest, and the fall season, 35% of the harvest (Fla. Dept. Agri.Consumer Serv., 1998). During the 1996-1997 season, farms in central Florida produced 28% of the state's cucumbers; 49% were grown along the east coast, 18% in the southwest, and 5% in northern areas of the state. Florida ranked first in production of fresh-market cucumbers in the U.S. and fourth in production of processing or pickling cucumbers (Rhodes, 1998). Crop value for 1996-1997 was \$59,000,000. Acreage planted to cucumber decreased from 16,000 acres in 1982 to 9400 in 1997. While cucumber acreage decreased during this 15-year period, the recorded yield per acre increased from 300 to 560 bushels/acre.

Much of the recent per acre-yield increases in cucumber production can be attributed to new cultivars, use of complete soil fumigants, increased plant populations, improved weed- and pest-management practices, refined fertilizer recommendations, and changes in the time of fertilizer application. The purpose of this publication is to summarize cucumber fertilization research over

the past 35 years and point out areas where further research is needed. Cucumber fertilization can represent up to 15% of total production costs where cucumbers are raised in a double-crop system as in southwest Florida (Smith and Taylor, 1996). The current Institute of Food and Agricultural Sciences fertilizer recommendations for cucumber are based on the research documented in this summary. Nitrogen (N), phosphorus (P), and potassium (K) recommendations are 150 lb/acre N and 120 lb/acre each of  $P_2O_5$  and  $K_2O$  when soil-test concentrations for these (P and K) nutrients are very low (Hochmuth and Hanlon, 1995). When soil-test concentrations are low, medium, or high the recommendations for  $P_2O_5$  and  $K_2O$  are lowered to 100, 80, and 0 lb/acre, for each respective soil-test interpretation. Fertilizer applied to Florida-grown cucumbers in 1994 was assessed by a USDA-administered survey, and actual fertilizer applications were 115, 137, and 119 lb/acre of N,  $P_2O_5$ , and  $K_2O$ , respectively (Fla. Agr. Stat. Serv., 1995). These average rates reflect P and K fertilization practices in excess of the recommended amounts, particularly where cucumber was grown as a second crop following tomato or pepper and

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elsewhere where residual soil P and K concentrations were typically high.

## Data Summary Method

To evaluate cucumber yield response to variable rates of fertilizer, a method was needed to standardize the numerous units used for quantifying statewide yield results such as kg/ha, hundred-weight (cwt)/acre, tons/acre, tons/ha, and 55 lb cartons/acre. In addition, yield responses to fertilizer varied depending on season, cultivar, and location in the state. Relative yield (RY), a calculated percentage, was chosen as the unit to express cucumber yield responses to fertilization. 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 was presented in 55 lb/bushel units per acre for the treatment corresponding to 100% RY. The RYs were plotted against rates of nutrient to determine how cucumber 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 to fertilization. For most studies, RYs of 95 to 100% were not significantly different.

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 bed of a 6-foot-bed-spacing crop as in the bed of a 4-foot-bed-spacing crop requires 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. 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 (1996). Fertilizer-rate expressions used in this 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 bed spacings among reports or experiments. Authors of a few reports chose to use the linear-bed-foot system to standardize fertilizer-rate expressions across

experiments and planting patterns. We will attempt to specify planting patterns and fertilizer rates for each experiment as far as we can determine from each report.

## Mixed Fertilizer Trials

Cucumber research, published from 1963 to 1986, established crop yield responses to rates of applied nutrient and to fertilizer application methods through the use of mixed fertilizers. Attributing crop response to a single nutrient, however, could not be done with certainty from a blended N-P-K material. Since N was usually the most limiting nutrient in sandy soils, yield responses in mixed studies are considered here as responses to N.

Cucumbers treated with a 30% organic 4-8-8 (N-P<sub>2</sub>O<sub>5</sub>-K<sub>2</sub>O) fertilizer produced higher yields in all three seasons of an Immokalee experiment than cucumbers fertilized with inorganic, 4-8-8 (N-P<sub>2</sub>O<sub>5</sub>-K<sub>2</sub>O) fertilizers with or without added minor elements (Everett, 1963). Subsurface irrigation was used in all experiments. Benefits associated with organic fertilizer include its ability to stabilize soil pH, act as a microbial medium, act as a source of soluble organic compounds and minor elements, improve water and nutrient holding capacity, and resist N leaching. With application of minor elements and chelating agents, researchers sought to increase yields of plants fertilized with inorganic fertilizers to those fertilized with the 30% organic fertilizer. These comparison studies resulted in unexpected responses from plants fertilized with the mixed organic fertilizer and raised additional questions as inorganic fertilizer sources became more widely used.

As a base of comparison an inorganic fertilizer containing NH<sub>4</sub>NO<sub>3</sub> and a 30% organic fertilizer containing Peruvian guano and sludge as 30% of the total N (a 4% N product) were applied without minor elements in 1960 (Everett, 1963). Three N applications of 40 lb/acre each were made from either the inorganic or organic source and an additional 86 lb/acre NO<sub>3</sub>-N were applied in six 14 lb/acre topdress applications to all base fertilizer treatments. Plants were thinned to one per hill with 18 inches between hills, and subsurface irrigation was

applied as needed. Beds were spaced 5 feet apart. Yield from plants fertilized with the inorganic N source was 111 bushels/acre, while yield with the organic N source was 760 bushels/acre; the bushel weight was not specified. Differences in yield were traced to concentrations of Fe, Cu, Mn, B, and Al in the leaf tissue. Although soil concentrations of N, P, K, Ca, and total soluble salts were similar with both treatments, plants fertilized with inorganic fertilizer had six times more Al and lower concentrations of Fe, Cu, Mn, and B than were found in tissue from organic-N-fertilized plants. Based on high Al concentrations in the leaf tissue, marginal leaf burn, and stunted plants observed at three weeks and throughout the season, aluminum toxicity was suspected in the inorganic-fertilized plants. Researchers theorized that other minor elements present in the organic fertilizer provided sufficient competition to prevent Al absorption, or a natural chelating agent present in the organic mix decreased Al absorption.

In 1961, the same organic and inorganic 4-8-8 fertilizer sources were used plus a third 4-8-8 formulation of 30% N from  $\text{NH}_4\text{NO}_3$  and 70% N from  $\text{NH}_4\text{NO}_3$ ,  $(\text{NH}_4)_2\text{SO}_4$ , and ammonium superphosphate (Everett, 1963). These nutrients were applied as before with four additional topdress applications each 14 lb/acre of  $\text{NO}_3\text{-N}$ . Fritted FN-501 minor elements were applied with half of each fertilizer treatment at the time of the first 40 lb/acre N application. Cucumber plants were thinned to two per hill. Similar yields resulted, with or without application of minor elements, for plants fertilized with the organic source (1005 bushels/acre) or the inorganic,  $\text{NH}_4\text{NO}_3\text{-N}$  source (812 bushels/acre). Yields increased significantly (1% probability) with addition of minor elements to the third fertilizer formulation, from 788 bushels/acre without minor elements to 908 bushels/acre with minor elements. Leaf-tissue concentrations of Cu and Fe were highest in plants fertilized with the organic source, unaffected by minor elements in  $\text{NH}_4\text{NO}_3$ -fertilized plants, and had increased concentrations of Cu, Fe, and Mn when minor elements were applied with the third fertilizer formulation. A change in plot location with this experimental season appeared to eliminate Al-toxicity symptoms noted in the previous season.

The mixed organic and  $\text{NH}_4\text{NO}_3$  fertilizers were applied in three 40 lb/acre N applications as before, with an additional 40 lb/acre applied due to heavy rain and two 14 lb/acre  $\text{NO}_3\text{-N}$  sidedress applications (Everett, 1963). An interaction occurred this season between the addition of a chelating agent, a solution of 0.12 gm  $\text{Na}_4\text{EDTA/ml}$ , added minor elements Fe or Cu applied in chelated or soluble form, and fertilizer sources, in their effects on marketable yields. All treatments were applied as solutions in a sprayed 18-inch-wide band over the first fertilizer application and bedded to a depth of three inches. Plants fertilized with the organic fertilizer source and the chelating agent alone or chelated Fe or Cu resulted in average yields of 1004 bushels/acre. These yields were significantly higher than where organic fertilizers were applied without the chelating-agent solution or where Fe or Cu were applied in a soluble form (918 bushels/acre). Yields of plants fertilized with the inorganic,  $\text{NH}_4\text{NO}_3$  fertilizer, however, were not affected by chelated, or non-chelated treatments averaging 686 bushels/acre. The stimulating effect of the chelating agent among plants fertilized with organic fertilizers was unexplained by authors, and more research was recommended. Nitrogen and K leaching were not a factor in any season as leaf-tissue concentrations of these nutrients were comparable for plants with either fertilizer treatment.

Application of 15 tons/acre of fresh poultry manure on Norfolk loamy fine sands in Quincy contained sufficient N to sustain high cucumber yields in the spring of 1960 (Robertson and Young, 1964). Cucumber yield with the base manure application and zero lb/acre of applied N did not differ from yields where plants received 30, 60, 90, 120 or 150 lb/acre N applied in a single sidedress application. Beds were spaced 4 feet apart. The average marketable yield of 326 bushels/acre was considered good based on an average-to-good yield range from 135 to 436 bushels/acre for cucumbers grown in the U.S. at this time. Irrigation was applied at this site, but the type of irrigation used was not cited.

Fertilizer treatments of 207-118-236 lb/acre  $\text{N-P}_2\text{O}_5\text{-K}_2\text{O}$  and 319-187-366 lb/acre  $\text{N-P}_2\text{O}_5\text{-K}_2\text{O}$  were applied at the recommended rate (Agricultural

Extension Circular 225, no date given) and at 1.5 times the recommended rate, respectively (Bryan, 1966). Fertilizers were applied to Ruston loamy fine sand soils at the North Florida Experiment Station, Quincy, in bands eight inches to each side of the bed center, covered with soil, and mulched with clear, aluminum (black polyethylene sprayed with aluminum paint), or black polyethylene mulch. Beds were spaced on the standard 6-foot spacing. Yields with these treatments were compared to yields of unmulched plants fertilized as recommended in Circular 225, with a base and later sidedress fertilizer application. The unmulched beds and beds mulched with clear polyethylene were sprayed with herbicide. Polyethylene mulch had not been widely used in north Florida when this 1965 experiment was conducted. Irrigation was not described in this study.

Plants fertilized with 207 lb/acre N yielded 307 bushels/acre, 100% RY, compared to 50% RY from plants fertilized with 319 lb/acre N (Bryan, 1966). Yields were highest from plants mulched with clear polyethylene (324 bushels/acre), followed by those mulched with aluminum (282 bushels/acre), black polyethylene (171 bushels/acre), and unmulched plants (142 bushels/acre).

Improvements in equipment used for fertilizer application prompted fertilizer-placement studies on unmulched cucumbers in Gainesville from 1962 to 1966 (Nettles and Hulburt, 1966). Applied N treatments from 6-8-8, N-P<sub>2</sub>O<sub>5</sub>-K<sub>2</sub>O, were 60 or 90 lb/acre in 1962 and 60, 90, or 120 lb/acre in 1963 and 1964. Cucumbers were grown as a fall crop on Arredondo fine sand soil in 1962 and 1964 and on Kanapaha fine sand in 1963. There were five fertilizer-placement methods. High-band fertilizer placements were 2.5 inches to one or both sides of the row and 2.5 inches below the seed level. Low-band placements were 2.5 inches to the side and 6 inches below the seed. Where high- and low-band placements were used together, the bands were placed on opposite sides of the plant row. Bed spacing and the type of irrigation used were not specified.

In 1962, half of the total fertilizer was applied in the various placement methods and half was applied as a side-dressing thirty days after planting (Nettles

and Hulburt, 1966). Plants fertilized with 90 lb/acre N yielded 223 bushels/acre (100% RY), and similar yields resulted with 60 lb/acre N (93% RY). Marketable yields did not differ when half of the applied fertilizer was placed in single or double high bands, when the fertilizer was broadcast and incorporated in an 18-inch band and in double high bands, when the fertilizer was split evenly between a high and a low band, or when a fourth of the fertilizer was applied in a high band and three-fourths in a low band. Marketable yields with these placement methods averaged 225 bushels/acre.

Cucumber plants in the 1963 experiment season received all of the applied fertilizer in the various placement methods at planting (Nettles and Hulburt, 1966). Marketable yields with 90 lb/acre N were 491 bushels/acre (100% RY), a significant increase from 81% RY with 60 lb/acre N. Yields remained at 100% RY with the 120 lb/acre N treatment. Fertilizer-placement method had an effect on marketable yields this season. Higher yields resulted when plants received fertilizer in high double bands, broadcast and in high double bands, and half in high and half in low double bands. These treatments resulted in an average marketable yield of 511 bushels/acre, compared to 423 bushels/acre from plants fertilized in a single high band or plants that received one-fourth of the fertilizer in a high band and three-fourths in a low band.

In 1964, fertilizer was applied either all at planting or 80% at planting, 20% side-dressed (Nettles and Hulburt, 1966). The timing of N application interacted with N rate this season. Marketable yields increased through 120 lb/acre N (140 bushels/acre, 100% RY) when fertilizer was split applied but did not increase with N when all of the fertilizer was applied at planting, resulting in similar yields with 90 and 120 lb/acre N (99 bushels/acre, 99 and 100% RY, respectively). Heavy rains between planting and sidedress fertilizer application resulted in erosion and loss of one of the four experimental replications and likely reduced overall yields this season.

Two spring experiments were conducted on previously mulched beds following a fall tomato crop in order to evaluate fertilizer rates and placement

methods in a two-crop system (Everett, 1978). Tomatoes grown in the fall (first planting) were unstaked "ground" tomatoes. Fertilizer was placed in a hole punched through the polyethylene at rates of 0, 0.5, 1.0, 2.0, or 4.0 ounces per hole. Fertilizer holes were 8 inches to one side of the plant, 8 inches to both sides of the plant, or halfway between the plants (in the "drill"). Nitrogen treatments of 0, 65, 130, or 260 lb/acre (18-0-25, N-P<sub>2</sub>O<sub>5</sub>-K<sub>2</sub>O) were calculated based on 5808 plants/acre (5-foot row spacing). Fields were subsurface irrigated to maintain soil moisture at field capacity before planting the spring tomato crop (3 weeks after removing fall-season plants).

Cucumber yields increased significantly with the first increment of applied fertilizer to 91% and 93% RY each season. Yield increases were not significant with N treatments above 65 lb/acre. Each season, 100% RYs occurred with 130 lb/acre N (780 and 801 bushels/acre). Fertilizer placement did not affect cucumber yields in either season.

Researchers chose old vegetable-production lands in Sanford (Central Florida REC) for several back-to-back, spring and fall, experimental seasons to trace residual nutrient concentrations and establish the optimum sidedress N rate for pickling cucumber (Forbes and White, 1982; Forbes and White, 1986). The Myakka or Immokalee fine sand soils chosen for these experiments were typical of those used in vegetable production for many years. All experimental sites were tile drained and received an initial preplant application of 30 lb/acre N from a 5-5-8, N-P<sub>2</sub>O<sub>5</sub>-K<sub>2</sub>O, 40% organic N fertilizer. Side-dressed fertilizer was applied to this base 30 lb/acre N treatment at rates of 0, 40, 80, 120, or 160 lb/acre (NH<sub>4</sub>NO<sub>3</sub>-N). Single-row beds were 5 x 26 feet. Residual soil nitrate concentrations were measured before fertilizer was side-dressed and at final harvest using the diphenylamine method. Overhead irrigation was applied to unmulched cucumbers in all experimental seasons.

A significant increase in yield occurred with the first sidedress N application or 70 lb/acre total N (203 bushels/acre, 96% RY) in the fall 1978 season (Forbes and White, 1982). Poor plant stands and reduced yields resulted from root-knot nematode

damage in the spring and fall seasons of 1979. Yields were maximized each season with 150 lb/acre total N (184 and 110 bushels/acre, 100 and 97% RY). On fumigated soils in the following spring, 1980, high yield occurred with 110 lb/acre N (352 bushels/acre, 100% RY). Side-dressed N increased soil NO<sub>3</sub> concentrations measured at final harvest from less than 3 ppm, where no N was side-dressed, to 7 through 20 ppm and above with the 120 lb/acre sidedress N treatment. Increased soil NO<sub>3</sub> concentrations late in the season resulted in fewer culled fruits and higher yields compared to plants that received no additional side-dressed N. Researchers concluded that 30 lb/acre preplant-applied N and sidedress application of 80 to 120 lb/acre N were required for optimum cucumber yields.

These experiments were continued in the spring and fall of 1981 and 1982 and the spring of 1983 with the slicer cucumber, 'Poinsett' (single-row beds 5 x 26 feet) (Forbes and White, 1986). The fall harvests were generally limited by cooler weather, shorter days, and disease problems typical of this growing season. The optimum spring harvests ranged from 550 to 816 bushels/acre, while optimum fall harvests ranged from 240 to 287 bushels/acre. A preplant/incorporated N application of 30 lb/acre was applied as in the previous experiments. Cucumber yields generally did not increase with sidedress N applications greater than 80 lb/acre. Relative yields with 80 lb/acre side-dressed N (110 lb/acre total N) were 98% (spring 1981), 94% (fall 1981), 100% (fall 1982), and 100% (spring 1983). A side-dressed N application of 150 lb/acre was required in the spring of 1982 for optimum yield of 593 bushels/acre (100% RY) compared to 82% RY with 80 lb/acre side-dressed N. Researchers concluded that slicing and pickling cucumbers required from 80 to 120 lb/acre of side dressed N (110 to 150 lb/acre total N) for high yields in both spring and fall seasons. Residual soil NO<sub>3</sub> concentrations from 7 to 14 ppm were measured at final harvest sampling each season where 80 lb/acre N were side-dressed. These NO<sub>3</sub> concentrations were sufficient to sustain late-season yields without leaving excessive N to leach through the wet summer season.

## Summary Mixed Fertilizer

Cucumber yield responses to increased N applied in mixed fertilizers are presented in Figure 1. Yields in 64% of these experiments were optimized with between 90 and 130 lb/acre N applications, with plants in 79% of experiments reaching optimum yield with 150 lb/acre N or less. Plants fertilized with a 30% organic 4-8-8, N-P<sub>2</sub>O<sub>5</sub>-K<sub>2</sub>O formulation consistently produced higher yields than with two inorganic 4-8-8 sources. Yields approached those with the organic mixed fertilizer when minor elements were added to an inorganic N mix of NH<sub>4</sub>NO<sub>3</sub>, (NH<sub>4</sub>)<sub>2</sub>SO<sub>4</sub>, and ammonium superphosphate. High yields occurred with 90 lb/acre N when all of the fertilizer was applied preplant in two experiments, but yields increased through 120 lb/acre N when fertilizer was split, 80% preplant and 20% side-dressed. By reversing the application ratio to 20% preplant and 80% side-dressed, late-season soil NO<sub>3</sub> concentrations were increased, the formation of cull-grade cucumbers late in the season decreased, and total yields subsequently increased. Cucumbers fertilized in double bands 2.5 inches beside and beneath the seed, or 2.5 inches and 6 inches beneath the seed, or broadcast and double banded resulted in higher yields in one of three experimental seasons than yields where fertilizer was placed in a single band. Yields were higher in these early studies when cucumbers were mulched with clear polyethylene as compared to those mulched with aluminum-painted polyethylene, black polyethylene, or unmulched cucumbers.

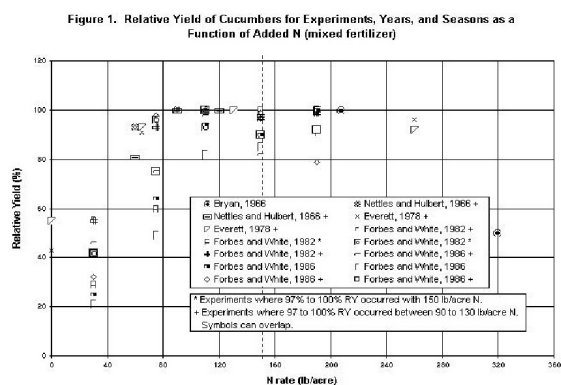


Figure 1.

## Nitrogen

Early fertilizer recommendations for cucumbers grown on irrigated mineral soils called for a base N fertilizer application of 90 lb/acre to which an additional one to four sidedress applications of 30 lb/acre could be added if leaching conditions occurred (Marvel and Montelero, 1967). Researchers in 1977 sought to test cucumber yield responses to the recommended N rate and to excess N applied to Kanapaha fine sand soils in Gainesville (Cantliffe and Omran, 1977). A base fertilization of 0, 90, or 180 lb/acre N from NH<sub>4</sub>NO<sub>3</sub> was applied to the bed surface and tilled in preplant. Beds were spaced on 4-foot centers. As the vines began to form, 30 lb/acre N was side-dressed to all plots, raising the total base N rate to 30, 120, and 210 lb/acre. A simultaneous experiment was conducted using ethephon to chemically induce female flowering in cucumber. The effects of all of these treatments were observed on 'Poinsett' and 'Gemini' slicing cucumber cultivars, irrigated with two inches of water per week and spaced six inches apart. Yield differences between this experiment and earlier experiments were likely due to increased plant populations compared to the earlier hill planting method (Everett, 1963). Cucumbers were planted in hills spaced 18 inches apart and thinned to one to two plants per hill.

Similar yields resulted with N treatments of 30 or 120 lb/acre. Average yields with both N treatments were 829 bushels/acre with 'Poinsett' cucumbers and 653 bushels/acre with 'Gemini' cucumbers (Cantliffe and Omran, 1977). A cultivar x rate interaction occurred. 'Poinsett' cucumber yields fell significantly to 516 bushels/acre with N at 210 lb/acre, but a lesser yield reduction resulted with 'Gemini' cucumbers (600 bushels/acre). Overall, 'Poinsett' cucumbers produced higher yields, 40% fewer cull fruit, and better fruit color than the 'Gemini' cultivar. With ethephon treatments from 125 to 250 ppm, more fruit were produced, but the fruit were smaller and of lower color quality. Similar yields resulted with both the ethephon-treated and the untreated cucumbers.

Evolution of cultural practices with the use of polyethylene mulch and drip irrigation led to re-evaluation of N recommendations which were

based on older unmulched cucumber experiments (Hochmuth and Hochmuth, 1990). Nitrogen treatments of 0, 40, 80, 120, 160, and 200 lb/acre from  $\text{NH}_4\text{NO}_3$  (calculated on 8712 linear bed feet of crop per acre of 5-foot bed centers) were hand-applied and incorporated with a tiller on Klej fine sand beds at the Suwannee Valley REC near Live Oak. The beds were mulched with white on black polyethylene in experiments conducted in the fall of 1988 and 1989. Drip irrigation was applied to maintain soil moisture at -12 centibars as monitored by tensiometers placed at a 12-inch soil depth. Plants were thinned to one per hill, and hills were 12 inches apart in two rows per bed.

Over two September days in 1988, 4.7 inches of rain fell in an overall wet season where 16 inches of rain likely leached nutrients through planting holes, more numerous with cucumber than with other mulched crops (Hochmuth and Hochmuth, 1990). Peak early and total yields, as determined by a linear response and plateau procedure, occurred with 107 and 136 lb/acre N, respectively, for an early yield of 226 bushels/acre and a total yield of 700 bushels/acre. The total crop value was increased by these early yields which were largely Fancy and No. 1 grade fruit harvested when market values were high. Significant yield differences (1%), occurred with N treatments from 0 to 200 lb/acre, resulting in optimum yield with 160 lb/acre N (735 bushels/acre, 100% RY). These optimum N rates were above the 90 lb/acre recommended rate and indicated more N was needed during a wet season. In the fall of 1989, rainfall was limited to 4.5 inches for the season. Total yield leveled off with 57 lb/acre N (694 bushels/acre), as determined by a linear response and linear plateau procedure. Significant (1%) differences occurred between yields with increased N, and optimum yield occurred with 120 lb/acre N (713 bushels/acre, 100% RY), 97% RY with 80 lb/acre N. These optimum N rates in a drier season were nearer the 90 lb/acre recommended rate as compared to a 69% RY in the previous wet season with 80 lb/acre N. Leaf-tissue N concentrations sampled at early fruiting were between 3.5% and 4.0%, with the optimum N rates each season. Petiole sap  $\text{NO}_3\text{-N}$  concentrations were about 500 ppm when sampled at early fruiting.

Despite the polyethylene mulch and controlled water use with drip irrigation, cucumbers in the above experiment responded to greater rates of applied N during a wet season. Under similar experiment conditions; white-on-black polyethylene mulch and drip-irrigation; cucumbers grown in Gainesville were fertilized with polymer-coated Meister fertilizers (Helena Chemical Co.) in an attempt to further control the loss of N to leaching (Hochmuth, 1997). Two Meister fertilizers formulated as a 15-5-15 and a 19-5-14,  $\text{N-P}_2\text{O}_5\text{-K}_2\text{O}$ , were applied in a 10-inch band on the bed surface at 75, 125, 175, 225, and 275 lb/acre N. Three additional treatments were compared, a zero fertilizer check treatment, 175 lb/acre  $\text{NH}_4\text{NO}_3\text{-N}$ , and 175 lb/acre N Meister 15-5-15. These treatments were incorporated in the bed. Fertilizer-rate calculations were based on a 6-foot-bed-center spacing, although beds were spaced four feet apart. 'Dasher II' seeds were planted in the fall, 1996, in two rows per bed with 12 inches between plants. Irrigation was applied to maintain soil moisture at -10 centibars as monitored by tensiometers.

Cucumber yields responded quadratically to rates of both Meister fertilizers with average yields leveling off above 125 lb/acre N (1340 bushels/acre, 94% RY) (Hochmuth, 1997). Yields reached 99%, 97%, and 100% RYs (1427 bushels/acre) with N treatments to 275 lb/acre. These yields were high for a fall crop as compared to the state average of 457 bushels/acre for fall 1996 (Fla. Dept. Agri. Consumer Serv., 1998). Yield of U.S. No. 1 grade fruits, shorter or curved fruit, represented 10 to 15% of the total fruit yield, and cull fruits about 5%. Cull-fruit yields were unaffected by N treatment. Quadratic increases in leaf-tissue N concentrations were within the adequate range and reflected yield increases to applied N.

Where 175 lb/acre N of Meister 15-5-15 was incorporated in the bed, cucumber yields were 1484 bushels/acre, a yield increase of 12% from yields where the same fertilizer was applied in a 10-inch band on the bed surface (1325 bushels/acre) (Hochmuth, 1997). Cucumber plants fertilized with 175 lb/acre  $\text{NH}_4\text{NO}_3\text{-N}$  applied broadcast and

incorporated resulted in similar yields as plants fertilized with the incorporated Meister fertilizer.

### Summary Nitrogen

Where high residual soil N concentrations occurred, cucumber yields on Kanapaha fine sand soils in a spring 1977 experiment optimized with 30 lb/acre N fertilizer. In most experiments, however, cucumber yields responded to N ranging from 60 to 160 lb/acre. Relative yield responses to N fertilization are presented graphically in figure 2, the dashed line indicates the current 150 lb/acre N recommendation. The graphed experimental results were from research areas in North Florida where only 10% of the state cucumber crop is produced. Additional research is needed from areas in the east, south, and central parts of the state for a more representative coverage of state cucumber production areas.

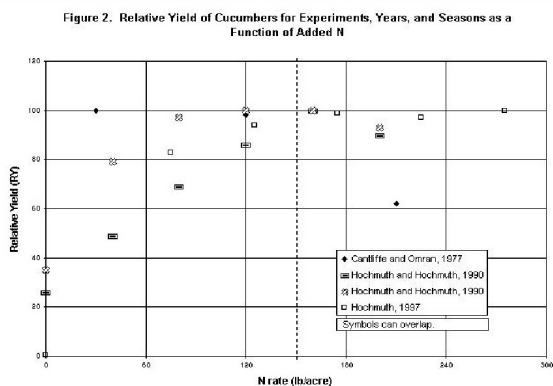


figure 2.

Changes in cultural practices, drip irrigation, and white-on-black polyethylene mulch resulted in higher yields of fall-grown cucumbers. Mulched and drip-irrigated beds fertilized with 120 or 160 lb/acre  $\text{NH}_4\text{NO}_3$ -N broadcast and incorporated resulted in 713 and 735 bushels/acre, respectively. These yields were above the state average of 460 bushels/acre for a fall cucumber crop. Further yield increases resulted when two formulations of polymer-coated fertilizer were applied in 10-inch surface bands with mulch and drip irrigation. Plant yields responded quadratically to both fertilizer formulations, leveling off above 125 lb/acre N with an average yield of 1336 bushels/acre. Broadcast incorporation of the 15-5-15 ( $\text{N-P}_2\text{O}_5\text{-K}_2\text{O}$ ) polymer-coated fertilizer increased yields to 1632 bushels/acre with 175 lb/acre N

compared to 1458 bushels/acre when the same fertilizer was applied in a 10-inch surface band. Researchers changed the 1989 recommendation of 90 lb/acre N (Kidder et al., 1989) to 150 lb/acre (Hochmuth and Hanlon, 1995) based on optimum yield results from mulched and drip-irrigated cucumbers fertilized with  $\text{NH}_4\text{NO}_3$ . Application of the recommended N rate provided some insurance against  $\text{NH}_4\text{NO}_3$ -N leaching through planting holes in the polyethylene during wet seasons, though high yields were possible with 125 lb/acre N when polymer-coated fertilizers were used. Plant-spacing recommendations were tightened from 18 inches between hills with one and two seeds per hill to between-plant spacings of 6 to 12 inches (Hochmuth, 1988).

## Phosphorus and Potassium

### Soil Testing

Knowledge of soil nutrient levels, particularly P and K, before planting is the starting point to predicting cucumber response to varying rates of applied nutrients. Using soil testing to determine preplant soil nutrient concentrations provides information so research results may be reviewed for degree of support of existing fertilization recommendations established by M-1.

### Phosphorus

Adjacent sites on newly cleared land were selected for experiments near Gainesville in 1971 and 1972 (Navarro and Locascio, 1979). The St. Johns fine sand soil had a pH of 3.9, 1 ppm Cu, and 5.5% organic-matter content. Soil P concentrations were not cited. Application of  $\text{CaCO}_3$  elevated the pH to 5.5, and before planting, 120 lb/acre N and 150 lb/acre  $\text{K}_2\text{O}$  were applied either in a band 2 inches beside bed center and 2 inches deep or broadcast and incorporated. Phosphorus from three P sources was applied factorially at four rates with four rates of Cu in either the band or broadcast placement methods. 'Poinsett' cucumbers were planted at bed center and thinned to two feet between plants on beds spaced 4-feet apart. An additional 30 lb/acre N were applied as a sidedress.

Cucumber yields increased significantly with application of 0 to 60 lb/acre  $P_2O_5$  (172 bushels/acre, 97% RY) in the 1971 experiment (Navarro and Locascio, 1979). A quadratic yield response occurred this season with 0 to 230 lb/acre  $P_2O_5$ . Yields from plants fertilized with superphosphate (SP) were 1.6 times higher than yields from plants fertilized with either diammonium phosphate (DAP) or concentrated superphosphate (CSP). Linear yield increases resulted with increased SP, but yields decreased with rates of CSP or DAP above 115 lb/acre  $P_2O_5$ . In 1972, Cu and P interacted in their effects on total yield. Yields did not differ with P sources this season. Leaf-tissue concentrations were sufficient with 0.4% P and 3.2 ppm Cu during fruiting. Phosphorus was taken up by the plant equally when placed in a band or when broadcast, but plant uptake of Cu was more efficient with broadcast placement. Increased P applications resulted in lower concentrations of Cu in the plant tissue during both seasons at the 30-day sampling date. Researchers noted that excess P fertilizer can result in Cu deficiency symptoms on soils with low Cu concentrations.

Soil phosphorus (P) concentrations at various experiment sites on old vegetable-production land in Sanford REC were very high, as determined by M-1 (double-acid) extraction (Forbes and White, 1982). Spring and fall cucumber crops did little to reduce soil P concentrations sampled before 34 lb/acre  $P_2O_5$  from superphosphate were incorporated and sampled again after the final harvest. The lowest soil P concentration was 320 ppm, and the highest was 540 ppm in the fall/spring experiment seasons from 1978 to 1980. Higher soil P concentrations extracted in spring and fall experiments from 1981 to 1983 were in the range of 500 to 633 ppm of extracted P (Forbes and White, 1986). These soil P concentrations had no apparent effect on cucumber yields in any season.

Where polymer-coated (Meister) fertilizers were applied from formulations of 15-5-15 or 19-5-14 (N- $P_2O_5$ - $K_2O$ ) in a Gainesville 1996 fall experiment, leaf-tissue P concentrations were similar with treatments of 25 to 90 lb/acre  $P_2O_5$  (Hochmuth, 1997). Leaf-tissue P concentrations of 1.0% and 1.1% with P fertilizer and 0.7% with the unfertilized

check treatment were above the adequate range of 0.3 to 0.6% at early-flower sampling.

### Summary Phosphorus

Yields increased quadratically, in two Gainesville experiments, to 60 lb/acre  $P_2O_5$ , where additional P resulted in reduced tissue Cu concentrations on soils with low Cu concentrations. On these same soils, added Cu reduced yields when P was applied at low rates. Plants fertilized with SP resulted in yields 1.6 times higher than plants fertilized with either DAP or CSP. Addition of P was probably not needed on old vegetable-production soils in Sanford, Florida, where soil P concentrations ranged from 320 to 633 ppm. Current P recommendations for cucumber specify no additional P application where soils test above 31 ppm (Hochmuth and Hanlon, 1995). No research was conducted on P fertilization of cucumber on the east coast or in southwest Florida, regions that represented 56% of the state cucumber production area. For a comprehensive review of P fertilization of cucumber, additional research is needed in these unrepresented areas.

### Potassium

Research with K fertilization of cucumber plants has not been done. References to K in work with cucumber were limited to comparisons of end-of-the-season soil K concentrations for plants receiving sidedress K applications and to leaf-tissue K concentrations as a response to increased K from mixed fertilizers or from specific K sources. This research is summarized here in lieu of yield responses to increased K fertilization.

Experiments were conducted over four experiment seasons on different field locations at Sanford, Central Florida Research and Education Center (Forbes and White, 1982). Soils were tile-drained Immokalee and Myakka fine sand, which were typically low in residual K despite long-term use in vegetable production. Soil samples were taken after 30-30-50 lb/acre (N- $P_2O_5$ - $K_2O$ ) were incorporated preplant and again at final harvest. At the first soil sampling, K concentrations, determined by M-1 (double-acid) extraction, were 67, 122, 50, and 68 ppm in the fall, 1978, spring, 1979, fall 1979,

and spring 1980, respectively. Where no K was side-dressed during the planting season, soil K concentrations taken at the final harvest were depleted to 35, 85, 30, and 13 ppm; generally low concentrations; from the first extracted concentrations in each respective season. Very high soil K concentrations; greater than 125 ppm; occurred where 200 lb/acre  $K_2O$  were side-dressed in fall 1978 and spring 1979. Where sidedress applications of 50 to 200 lb/acre  $K_2O$  were applied, soil K concentrations at final harvest were generally in the medium to high range in all seasons except spring 1980. In this season, larger harvests (326 to 349 bushels/acre) likely depleted final harvest soil samples to low K concentrations. Residual soil K concentrations at harvest were higher where 150 lb/acre  $K_2O$  were side-dressed from KCl than from  $K_2SO_4$ .

Experiments continued at Sanford REC, conducted as before on Immokalee or Myakka fine sand soils and fertilized with 30-30-50 lb/acre (N- $P_2O_5$ - $K_2O$ ) incorporated preplant (Forbes and White, 1986). Soil K concentrations were determined by Mehlich-1 soil-test extractant from samples taken after preplant fertilization and at final harvest. Spring soil-test results for 1981, 1982, and 1983 seasons averaged 83 ppm K with the first sampling and 52 ppm K, a medium soil K concentration, with the final harvest sampling from sites where K was not side-dressed. With side-dressed K applications through 200 lb/acre  $K_2O$ , soil K concentrations increased to 108 ppm, a high soil K concentration. In 1983, residual soil K concentrations sampled after 32 inches of rainfall from April through September were depleted to medium (38 to 45 ppm) concentrations from an average high range of spring harvest concentrations of 52 to 108 ppm. Average soil K concentrations for fall seasons 1981 and 1982 were 93 ppm after preplant fertilization, 62 ppm after harvest where no K was side-dressed, and 116 ppm where K was side-dressed with 200 lb/acre  $K_2O$ . Soil K concentrations did not differ after a sidedress application of 150 lb/acre  $K_2O$  from K sources KCl or  $K_2SO_4$ .

Cucumber plants mulched with white-on-black polyethylene and drip irrigation were evaluated for

yield responses to fertilizer rates and placement methods in an experiment in Gainesville, fall 1996 (Hochmuth, 1997). Leaf-tissue K concentrations were compared for plants that received no K fertilizer, plants fertilized with a blended polymer-coated 15-5-15 or 19-5-14 (N- $P_2O_5$ - $K_2O$ ) fertilizer applied to the bed surface in a 10-inch band or broadcast and incorporated, or plants fertilized with soluble  $KNO_3$  applied at 175 lb/acre  $K_2O$ . Leaf-tissue K concentrations sampled at early flowering and harvest did not differ with increased K from the polymer-coated fertilizers applied from 75 to 275 lb/acre  $K_2O$ ; with either the band or incorporated placement methods; or from the soluble K fertilizer source incorporated in the bed at 175 lb/acre  $K_2O$ . Average leaf-tissue K concentrations of 4.3% at early-flower sampling and 3.0% at late harvest sampling were high (adequate concentrations for these stages were 1.6 to 3.0%).

### Summary Potassium

Sidedress K applications from 50 to 150 lb/acre  $K_2O$  were shown to hold soil K at medium to high concentrations through harvest, compared to low concentrations where no K was side-dressed in fall and spring experiments from 1978 to 1983. In continued fall and spring experiments from 1981 to 1983, end-of-season K concentrations were medium where no K was side-dressed and high where 50 to 200 lb/acre  $K_2O$  were side-dressed. Residual soil K concentrations were higher with KCl fertilizer than with  $K_2SO_4$  fertilizer in some experiments and did not differ in other experiments. Mulched and drip-irrigated cucumber plants had similar and above-adequate leaf-tissue K concentrations when fertilized with either of two polymer-coated fertilizers applied from 75 to 275 lb/acre  $K_2O$  placed in a band or incorporated, or from incorporated  $KNO_3$  fertilizer applied at 175 lb/acre  $K_2O$ .

### Overall Summary

A substantial amount of research with N fertilization of cucumber has been conducted in Florida, and in most cases, the current recommendation of 150 lb/acre N was supported. No research has been reported that addresses management of N and irrigation in relation to nutrient

leaching. More research is needed also on P and K fertilization of cucumber.

### Literature Cited

- Bryan, H. H. 1966. Effect of plastic mulch on the yield of several vegetable crops in north Florida. Proc. Fla. State Hort. Soc. 79:139-146.
- Cantliffe, D. J., and A. F. Omran. 1977. Nitrogen fertilization rates for slicing cucumbers treated with ethephon. Proc. Fla. State Hort. Soc. 90:373-376.
- Everett, P. H. 1963. Minor element and nitrogen studies with cucumbers. Proc. Fla. State Hort. Soc. 76:143-149.
- Everett, P. H. 1978. Fertilizing tomatoes or cucumbers as second crops on plastic mulched beds. Proc. Fla. State Hort. Soc. 91: 317-319.
- Florida Agr. Statistics Serv. 1995. Vegetable Chemical Use. 8 pp. Fla. Agric. Stat. Serv., Orlando, FL.
- Florida Dept. of Agriculture and Consumer Services. 1998. Florida Agricultural Statistics&shy;&shy;Vegetable Summary 1996-1997. 70 pp. Fla. Agric. Stat. Serv., Orlando, FL.
- Forbes, R. B., and J. M. White. 1982. Nitrogen and potassium side-dressing of pickling cucumbers. Soil Crop Sci. Soc. Fla. Proc. 41:182-185.
- Forbes, R. B., and J. M. White. 1986. Fertilization of slicer cucumbers in central Florida. Soil Crop Sci. Soc. Fla. Proc. 45:87-90.
- Hanlon, E., and G. Hochmuth. 1989. Calculating fertilizer rates for vegetable crops grown in raised-bed cultural systems in Florida. Fla. Coop. Ext. Serv. Spec. Series SS-SOS-901.
- Hochmuth, G. J. 1988. Cucumber production guide for Florida. Fla. Coop. Ext. Serv. Circ. 101E.
- Hochmuth, R. C., and G. J. Hochmuth. 1990. Nitrogen requirement for mulched slicing cucumbers. Soil Crop Sci. Soc. Fla. Proc. 50:130-133.
- Hochmuth, G. 1995. Commercial vegetable fertilization guide. Fla. Coop. Ext. Serv. Circ. 225D.
- Hochmuth G. J., and E. A. Hanlon. 1995. IFAS standardized fertilization recommendations for vegetable crops. Fla. Coop. Ext. Serv. Circ. 1152.
- Hochmuth, G. 1996. Vegetable fertilization pp. 3-17. IN: G. Hochmuth and D. Maynard (eds.) Vegetable production guide for Florida. Fla. Coop. Ext. Serv. Circ. SP 170.
- Hochmuth, G. J. 1997. Response of cucumber to Meister controlled-release fertilizers. Fla. Agr. Expt. Sta. Research Report. Suwannee Valley REC 97-01.
- Kidder, G., E. A. Hanlon, and G. J. Hochmuth. 1989. IFAS standardized fertilization recommendations for vegetable crops. Fla. Coop. Ext. Serv. Spec. Ser. SS-SOS-907.
- Marvel, M. E., and J. Montelaro. 1967. Cucumber production guide. (cited in, Cantliffe, D. J., and A. F. Omran. 1977).
- Navarro, A. A., and S. J., Locascio. 1979. Copper nutrition of cucumber (*Curcumis sativus* L.) as influenced by fertilizer placement, phosphorus rate, and phosphorus source. Soil Crop Sci. Soc. Fla. Proc. 39:16-19.
- Nettles, V. F., and W. C. Hulburt. 1966. Effect of placements and levels of fertilizer on the yield of vegetables. Proc. Fla. State Hort. Soc. 101:185-191.
- Rhodes, D. 1998. <http://www.hort.purdue.edu/rhodcv/hort410/cucumb/cu00003.htm>
- Robertson, W. K., and H. W. Young. 1964. Response of vegetables grown in the Quincy area on Norfolk loamy fine sand to fertilizer and soil amendments. Proc. Fla. State Hort. Soc. 77:198-204.
- Smith, S. A., and T. G. Taylor. 1996. 1995-96 Production cost for selected vegetables in Florida. Fla. Coop. Ext. Serv. Circ. 1176.