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A Summary of N Research with Squash in Florida[1]

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The purpose of this publication is to summarize squash fertilization research results leading to current University of Florida nitrogen (N) recommendations for squash fertilization and to summarize needs for continued research. Production of squash in Florida represents almost 2% of the state's vegetable industry, or $28,246,000 (Fla. Dept. of Agric. and Consumer Services, 1998). Planted squash acreage has decreased steadily through the years from 17,400 acres planted in 1981 to 9500 acres planted in 1996. Major squash production areas are in southeast Florida, where 60% of the squash is grown, followed by the southwest, 16%, and lesser production areas in the east, west, and central regions of the state. Peak harvest and out-of-state shipping months occur in December and May, though harvest of squash continues from October to June each year with harvest of acorn, butternut, yellow crookneck, white, and zucchini squash. Florida-grown squash represent 21% of the squash shipped by truck to cities throughout the U.S.

Data Summary Method

Responses to fertilizer can vary depending on season, cultivar, and location in the state. Evaluation of yield data was performed by using relative yield (RY), a calculated percentage, as the unit to express squash yield responses to fertilization. The highest yield for each fertilizer experiment was assigned a 100% RY, value and other yields were expressed as a percentage of the highest yield. The actual yield (in 42 lb bushel units per acre) was presented for the treatment corresponding to 100% RY. The RYs were plotted against rates of nutrient to determine how squash 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 from each other.

Fertilizer rates are expressed on a per-acre basis (amount of fertilizer used on a crop growing in an area of 43,560 square feet). Changes in bed spacing often lead to needed changes in fertilizer amounts used per acre. 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 express rates on a per-acre basis, irrespective of variations in bed spacings among reports or experiments. Authors of a few reports choose to use the linear-bed-foot system to standardize fertilizer-rate expressions across experiments and planting patterns.

In this publication, we attempt to specify planting patterns and fertilizer rates for each experiment as far as

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we can determine from each report. Current standardized fertilizer recommendations for squash are based on a standardized 6-foot-row (bed) spacing. All published squash research results are from studies with mixed N-P-K fertilizers or are N studies.

Nitrogen

Mixed Fertilizer Trials

Most (67%) of the experimentation with nitrogen (N) fertilization of squash was conducted with mixed fertilizers. Yield responses from these experiments were presented in Fig. 1, and yield responses with experiments where N effects were isolated were presented in Fig. 2.

Experimentation with reduced rates of fertilizer was conducted in north Florida, largely to economize on production costs where the vegetable growing season was similar to other areas of the country and increased competition resulted in lower profits (Robertson and Young, 1964). Increased rates of 6-8-6 (N-P_2O_5-K_2O) were applied to Norfolk loamy fine sand soils, described as poorly drained, in a spring 1961 experiment in Quincy (Robertson and Young, 1964). Experimental plots, four rows four feet apart, were irrigated with an unspecified irrigation system. Prefertilization application of 15 tons of fresh manure (undescribed type) per acre, 1 ton of dolomite per acre, 20 lb/acre N from 15-0-15 (N-P_2O_5-K_2O) and 50 lb/acre N from NH_4NO_3 were made to increase the soil organic-matter content, raise the pH, and increase soil fertility. As the manure source was not documented in this experiment, the total applied N could not be calculated, and yield data could not be presented in Fig. 1. Additional N was applied preplant from 6-8-6 (N-P_2O_5-K_2O) for N treatments of 0, 35, 65, 100, 130, and 165 lb/acre. Marketable yield of ‘Early Prolific’ squash increased quadratically (5% probability) through the first N increment, 35 lb/acre N resulting in 193 bushels/acre (100% RY). Yield with the highest N rate, 165 lb/acre, was equivalent to the yield with zero lb/acre, 61% RY. Nitrogen present in the manure was responsible for the

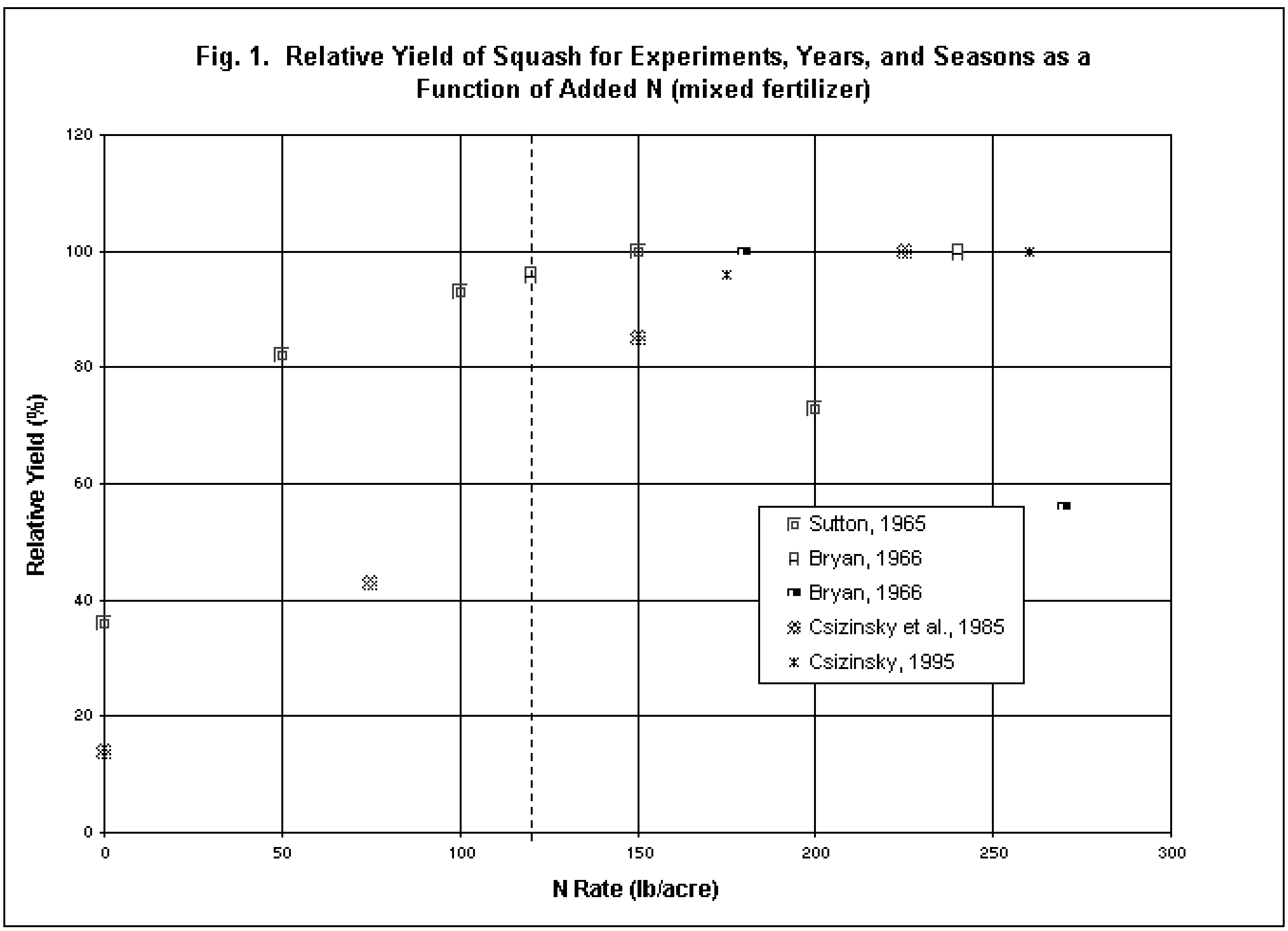

Figure 1.

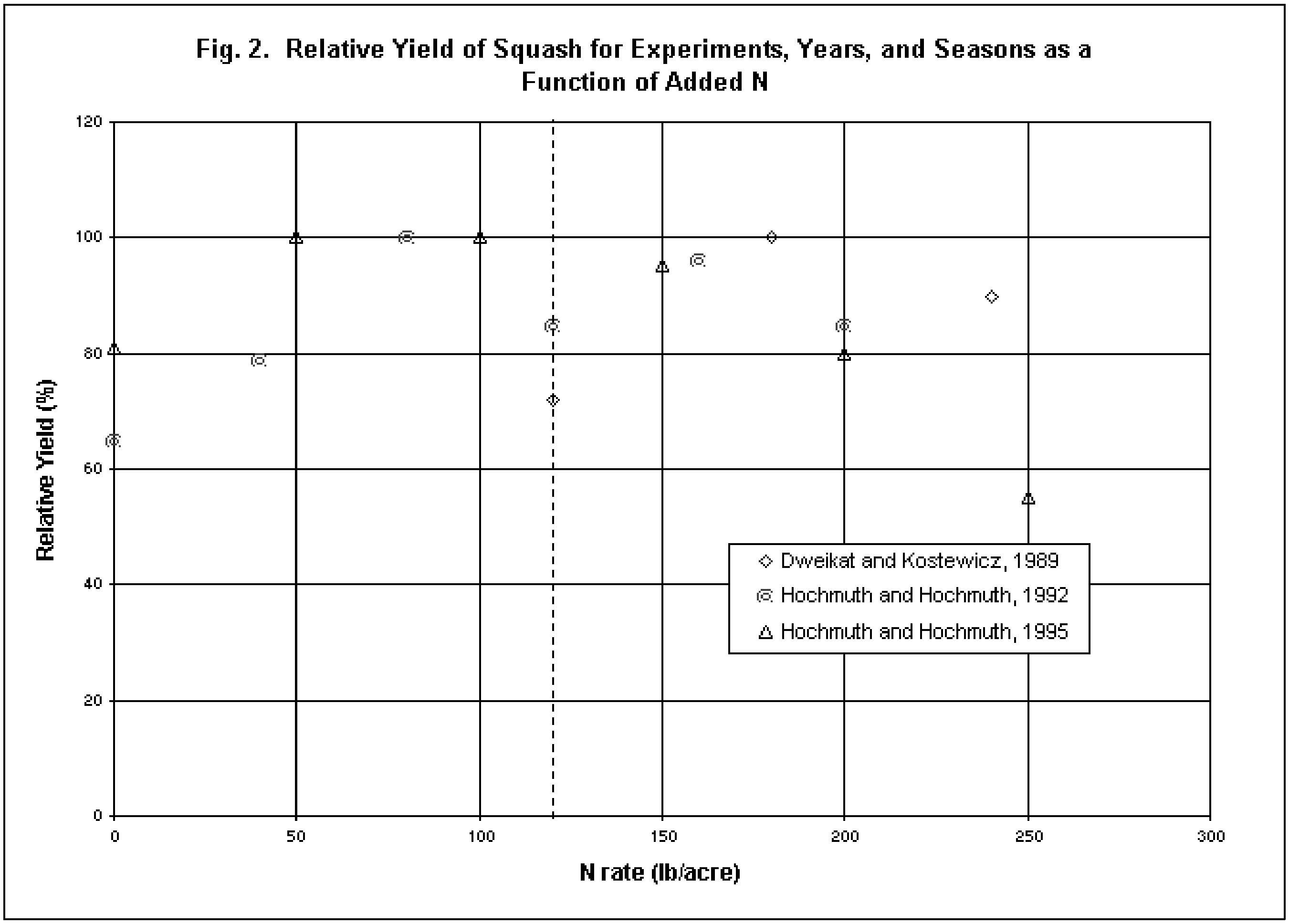

Figure 2.

limited response to applied fertilizer N.

Early Yellow Summer Crookneck squash was grown in the spring seasons of 1964 and 1965 in Dover, Florida (Sutton, 1965). Experiments were conducted on Scranton fine sand soils that had not been cropped recently. Squash plants, established in hills 12 inches apart, were thinned to one plant/hill. Rows were 4 feet apart. Five N rates, 0, 50, 100, 150, or 200 lb/acre from NH_4NO_3 and five rates of phosphorus (P) and potassium (K) were applied in two equal bands on March 23 and April 13. Beds received overhead irrigation (mulch use was not indicated). Marketable yields increased quadratically for optimum yields with 100 lb/acre N, 93% RY, and 150 lb/acre, 100% RY (159 bushels/acre, bushel weight was not specified). Researchers noted that squash grown with higher N rates had a rougher surface than those grown with lower N rates.

The combined effects of mulch and fertilizer on yield were the focus of experiments with several vegetable crops at a time when mulches were becoming more widely used (Bryan, 1966). Experiments in the spring of 1965 were conducted on Ruston loamy fine sand soils at the North Florida Experiment Station, Quincy. Plots, 50 x 6 feet, were fertilized with 120-80-140 lb/acre N-P_2O_5-K_2O or 240-160-280 lb/acre N-P_2O_5-K_2O. Fertilizers were banded 8 inches to each side of bed center with a basic and sidedress application for unmulched plants and a single preplant application for mulched plants. Double rows of ‘Early Prolific’ Straight Neck summer squash were direct seeded through black, aluminum-painted black, or clear polyethylene mulch. In a separate experiment, a single row of Butternut squash transplants were planted through the same mulch treatments or into unmulched beds. Fertilizers, applied as before, included 180-120-210 lb/acre N-P_2O_5-K_2O or 270-180-315 lb/acre N-P_2O_5-K_2O.

Yields of mulched and unmulched plants were averaged, and optimum, 100% RYs occurred with 240 lb/acre N with the straight-neck squash (362 bushels/acre) and with 180 lb/acre for the Butternut squash (255 bushels/acre). Nitrogen applied at 270 lb/acre reduced yield of Butternut squash to 56% of the yield with 180 lb/acre N. Straight-neck squash plants grown with black or aluminum mulches produced 30% more squash than the unmulched plants, while yields of Butternut squash were similar with or without mulch. In 1964, 'Bush Table Queen' squash plants were grown in double rows to compare yield responses of mulched plants (clear, black, or white/black polyethylene mulches) with yield responses of unmulched plants. Unmulched plants received preplant and sidedress fertilizer applications while mulched plants were fertilized at preplant only. Both treatments were fertilized with 220-180-315 N-P_2O_5-K_2O. Plants mulched with white/black polyethylene had nearly double the early yield (242 bushels/acre) and 1.5 times the total marketable yield (560 bushels/acre) of unmulched plants.

Zucchini squash were grown as a second crop following a fall-grown, mulched tomato crop at the Gulf Coast Research and Education Center in Bradenton (Csizinszky et al., 1985). The squash were placed on EauGallie fine sand beds, irrigated by subsurface irrigation, and spaced on 4.5-foot centers with fertilizer rates calculated on the standard 6-foot bed spacing for squash. Fertilizer was applied factorially at three rates: (0), 75, 150, or 225 lb/acre N (7,500 linear bed feet of crop per acre); and three application schedules: 100% preplant, 50/50 preplant/midgrowth, or 33/33/33 preplant/midgrowth/prior to harvest. Fertilizer from a 6-1.1-5 liquid N-P_2O_5-K_2O solution was applied as a basic application of 75-13-62 lb/acre (N-P_2O_5-K_2O) and increased 2 and 3 times for the three fertilizer rates. A liquid-fertilizer injection wheel was used to apply the fertilizer through the polyethylene mulch. Zucchini transplants were spaced 24 inches apart in a single row on the bed. Marketable fruit yields increased linearly through 225 lb/acre N (100% RY, 834 bushels/acre) compared to 85% RY with 150 lb/acre N and 14% RY with zero N. Zucchini yields were significantly greater (1% probability) when the fertilizer was applied twice (50% preplant and 50% at midgrowth, resulting in 785 bushels/acre), compared to yields of plants fertilized once. Plants fertilized in a single preplant application produced 335 bushels/acre, and plants fertilized in three equal applications produced 782 bushels/acre.

Yields were evaluated for squash grown as a succession crop in experiments at Gainesville on fine sand soil and at Quincy on loamy fine sand soil (Clough et al., 1990). 'Dixie Yellow' squash were direct seeded in the spring, (1994), through holes in the polyethylene, where broccoli had grown the previous fall. Combined N and K_2O rates were increased respectively from 120-220 lb/acre to 240-435 lb/acre, including an unfertilized treatment and a uniform application of 230 lb/acre P_2O_5. Nitrogen, P, and K sources—NH_4NO_3, concentrated superphosphate, and KCl—were applied preplant through holes spaced 1 foot apart (overhead irrigation) or applied 40% preplant (N and K), with the remainder injected in weekly increments with the irrigation water for 10 weeks. Overhead irrigation and drip irrigation were applied to meet pan evaporation with adjustments made for rainfall. Residual soil soluble salt concentrations, determined by water extraction, were lower where broccoli was grown with drip irrigation, and researchers cited the significantly higher broccoli harvests and greater leaching potential with drip irrigation compared to overhead irrigation.

Treatment effects interacted for squash yields with a significantly higher yield (5% probability) where overhead-irrigated plants were fertilized with 240 lb/acre N, 955 bushels/acre compared to 809 bushels/acre for plants fertilized with 120 lb/acre N. Increased N did not affect yields of drip-irrigated plants in Gainesville nor drip- or overhead-irrigated plants in Quincy. Very low yields resulted from unfertilized plants in both the overhead- and drip-irrigated plots.

Leaf- and fruit-tissue mineral concentrations were compared for plants, in the previous publication, grown with drip irrigation or overhead irrigation (Clough et al., 1992). Squash leaf-tissue N concentrations, sampled six weeks after emergence, and fruit-tissue N concentrations sampled at first and final harvest, were similar and within sufficient ranges with N rates of 120 or 240 lb/acre. Less-than-adequate leaf-tissue N concentrations occurred where fertilizer was not applied. Nitrogen accumulation, from whole-plant analysis at harvest, was 63 to 105 lb/acre with N rates of 120 and 240 lb/acre, respectively. Irrigation method did not affect plant tissue N concentrations.

A seaweed foliar spray was applied at three rates to 'Senator' zucchini in an experiment at the Gulf Coast Research and Education Center, Bradenton, in spring 1993 (Csizinszky, 1995). Plants in the main plots received no seaweed spray, 4 28-fluid-ounce applications in April and May, or 7 24-fluid-ounce applications in April through June 8. Subplots received N and K_2O rates of 175 and 240 lb/acre or 260 and 360 lb/acre derived from a 15-0-25 N-P_2O_5-K_2O fertilizer. Nitrogen and K fertilizers were applied in a 2-inch-deep furrow at bed center. All plots received 105 lb/acre P_2O_5 from superphosphate. Beds spaced 5 feet apart were mulched with polyethylene, and zucchini were seeded in double rows through holes punched in the mulch.

Plants treated with the seaweed sprays alone yielded similarly to those treated with water, averaging 656 bushels/acre. An interaction between seaweed spray and applied fertilizer resulted in an optimum 734 bushels/acre when plants received 7 seaweed spray applications and 260 lb/acre N. Plants fertilized with 175 and 260 lb/acre N (and no foliar seaweed spray) produced yields of 641 and 670 bushels/acre, respectively. These yields were plotted in Fig. 1. Yields above the state average of 276 bushels/acre (Fla. Agric. Statistics, 1993) were likely due to a long harvest, the cultivar, and production system. Analysis of the dry-matter content of fruits indicated similar macro- and micronutrient concentrations with all fertilizer treatments.

Nitrogen Summary

A spring 1961, Quincy, Florida, experiment was conducted on Norfolk loamy fine sand soil described as poorly drained (Robertson and Young, 1964). Experimental plots, four rows four feet apart, were irrigated with an unspecified irrigation system. Prefertilization application of 15 tons of fresh manure (unspecified type) per acre and 1 ton of dolomite per acre were made to increase the soil organic-matter content and raise the pH to 6.5. Increased rates of NH_4NO_3-N were side-dressed in the spring of 1961 at rates of 0, 30, 60, 90, 120, and 150 lb/acre with an additional 125 lb/acre P_2O_5 and K_2O. ‘Early Prolific’ squash yields this season were similar with all rates of side-dressed N including the zero N treatment, where an 85% RY reflected the prefertilization manure application. Slightly higher yields occurred with 150 lb/acre N, resulting in 707 bushels/acre (100% RY). Yields from this experiment could not be presented in Fig. 2 since the N content of the manure was uncertain.

In an experiment with ‘Senator’ zucchini squash, within-row plant spacings interacted with N rate in their effects on marketable yield in the fall 1982 experiment season (Dweikat and Kostewicz, 1989). Yield results from the spring 1983 experiment are presented here. Both experiments were conducted on Mulat fine sand soils in Gainesville. Nitrogen was applied 60% preplant and 40% at 4 weeks from planting for total N rates of 120, 180, or 240 lb/acre NH_4NO_3. Phosphorus and K, derived from concentrated superphosphate and K_2SO_4 were applied at 180 lb/acre P_2O_5 and K_2O. Fertilizers were applied 8 inches to either side of bed center on beds spaced 4 feet apart. Hills in single or double rows were planted, 2 seeds/hill, with hills in the double-row method staggered to 1, 1.5, 2, or 2.5 feet between hills (1 foot between rows). All hills were thinned to one plant per hill. Beds received overhead irrigation, and mulch use was not specified.

Eleven harvests occurred with the spring planting, resulting in a quadratic yield response to N, averaged over all plant spacings. Peak yield occurred with plants fertilized with 180 lb/acre N: 529 bushels/acre (100% RY). Relative yield was reduced with 240 lb/acre N to 90% of the yield with the lower N rate. Optimum plant density with this experiment occurred with plants in double rows (1 foot between rows) in hills staggered 1.5 feet apart. Yield increases this season over the previous fall were attributed to the longer harvest (11 compared to 7 harvests) and application of 180 lb/acre N split 60% preplant and 40% side-dressed at 4 weeks, compared to all fertilizers applied preplant in the fall.

Yields of ‘Lemondrop’ summer squash were evaluated for response to N rates of (0), 40, 80, 120, 160, and 200 lb/acre NH_4NO_3 in a spring 1990 experiment conducted at the Suwannee Valley Research and Education Center near Live Oak (Hochmuth and Hochmuth, 1992). Nitrogen fertilizers, plus 100 lb/acre K_2O from $K_2Mg(SO_4)_2$, were broadcast in a 36-inch swath and tilled into beds prepared on 5-foot centers. No phosphorus was applied due to high soil concentrations of this nutrient. Beds were mulched with black polyethylene, seeded two rows per bed (15 inches between rows), and drip irrigated to maintain soil moisture at -10 to -12 centibars (monitored by tensiometers). Plants were spaced 1.5 feet apart within each row. Marketable yields in a ten-harvest season responded quadratically (1% probability) to increased N, with peak yield from plants fertilized with 80 lb/acre N (847 bushels/acre, 100% RY). Peak early yield (significant at 5% probability) also occurred with 80 lb/acre N (333 bushels/acre). Upper and lower limits of N fertilization were calculated at 100 to 120 lb/acre based on maximum yield with 76 lb/acre N using the linear-plateau model and 126 lb/acre using the quadratic model. Researchers cited 100 lb/acre N as sufficient for optimum squash yield based on the results of this experiment. Concentration of N in leaf tissue peaked with 120 lb/acre N at 4.4%.

Yields of ‘Waltham Butternut’ squash, seeded in the fall of 1990 on Lakeland fine sand soils at the Suwannee Valley Research and Education Center near Live Oak, also responded quadratically to increased N (Hochmuth and Hochmuth, 1995). Nitrogen rates of (0), 50, 100, 150, 200, or 250 lb/acre from NH_4NO_3 were broadcast in a 30-

inch swath with 50 lb/acre P_2O_5 (concentrated superphosphate) and 150 lb/acre K_2O (KCl). Fertilizers were tilled into beds spaced 7.5 feet apart, mulched with white polyethylene, and planted in a single row with 18 inches between plants. Drip irrigation was applied to maintain soil moisture at -8 to -12 centibars (monitored by tensiometers). Peak yield resulted from plants fertilized with 50 lb/acre N: 285 bushels/acre (100% RY). Yields were reduced above 150 lb/acre N to 55% RY, where plants received 250 lb/acre N. Using the quadratic equation, 97 lb/acre N was calculated as the maximum-yield N rate.

Overall Summary

Only a few studies have been conducted with squash fertilization where effects of N were isolated. The current recommendation is for 120 lb/acre N for squash planted in beds on 6-foot centers. This same rate would equal 180 lb/acre N for squash on beds spaced 4 ft. apart. These rates were confirmed by most of the research conducted with squash where the effects of N were isolated from effects of other nutrients. No research reports were found for P and K fertilization of squash. More research is needed for fertilizer management with squash, especially studies on the relationship of fertilization and water management with nutrient leaching.

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