Table 3. Outdoor float hydroponics leafy salad crop marketability ratings.

	Commercially[z]		Color			Size		
Entry	Accept.	Unaccept.	Light	Good	Dark	Under	Good	Over
Romaine 'Valmaine'	4	3		5	2	5	2	
Chicory 'Salad King'	4	3	1	4	2	6	1	
Escarole 'NR65'	7			7		3	4	
Boston 'Esmarelda'	7		2	5			6	1
Green leaf 'Crisp & Green'	4	3	2	4	1	6	1	
Red leaf 'New Red Fire'	4	3	1	4	2	6	1	
Bibb 'Florabibb'	7			3	4		3	4

[z]No. of responses from 7 individual ratings at Zellwin Farms from harvest on 3/24/98.

and the chicory probably increased in size sufficiently to be marketable. The green and red leaf lettuces did not increase in size enough for Zellwin standards. However, for market garden and u-pick operations they would be satisfactory.

Results indicate the potential for commercial production of cool season leafy salad crops and warm season basil in 2 inch styrofoam floating panels. Four inch cell size perlite filled floating speedling flats showed potential for production of short season small rooted herbs and flowers. Additional work needs to be done to fine tune suitable crops and system dynamics to maximize production and minimize costs.

Literature Cited

Anonymous. Xxxx. ATTRA—Appropriate Technology Transfer for Rural Areas. Hydroponic vegetable production: Information package. Fayetteville, AR.

Fedunak C. A. and R. V. Tyson. 1997. Lettuce cultivars for low-tech non-circulating hydroponics. Proc. Fla. State Hort. Soc. 110:384-385.

Kratky, B. A., J. E. Brown and H. Imai. 1998. Observations on a noncirculating hydroponic system for tomato production. HortScience 23(5):906-907.

Kratky, B. A. 1996. Non-circulating hydroponic methods. DPL Hawaii, Hilo, HI.

Kratky, B. A. 1993. A capillary, non-circulating hydroponic method for leaf and semi-head lettuce. HortTechnology 3(2):206-207.

Lorenz, O. A. and D. N. Maynard. 1988. Knott's handbook for vegetable growers, 3rd ed. John Wiley & Sons, New York, NY.

Maynard, D. N. and G. J. Hochmuth. 1999. Vegetable production guide for Florida, SP 170. University of Florida/IFAS Publications, Gainesville, FL.

Resh, H. M. 1998. Hydroponic Food Production, 5th ed. Woodbridge Press Publishing Company, Santa Barbara, CA.

Tyson, R. V., K. W. King, J. M. White and J. A. Gargiulo. 1998. Greenhouse tomatoes in low-tech non-circulating water culture. Proc. Fla. State Hort. Soc. 111:224-226.

Proc. Fla. State Hort. Soc. 112:315-319. 1999.

TOMATO FERTILIZATION, GROUND COVER, AND SOIL NITRATE NITROGEN MOVEMENT

F. M. RHOADS
University of Florida
North Florida Research and Education Center
Quincy, FL 32351

C. S. GARDNER, O. S. MBUYA, G. L. QUEELEY
AND H. M. EDWARDS
Center for Water Quality, College of Engineering,
Science, Technology and Agriculture
Florida A and M University
Tallahassee, FL 32307

Additional index words. Ammonium nitrate, sorghum-sudangrass, ryegrass.

Florida Agricultural Experiment Station Journal Series No. N-01766. This project was supported in part by the Florida Department of Agriculture and Consumer Services.

Abstract. **Residual soil nitrate-nitrogen (N) can leach into groundwater in fallow soil, following removal of polyethylene mulch after harvest of fresh market tomatoes, during fall and winter (spring crop) and winter and spring (fall crop). The influence of N rates and ground cover following tomato (*Lycopersicon esculentum* Mill) on soil nitrate-N movement was monitored in spring and fall crops during 1998. Nitrogen rates varied from 0 to 360 lb/acre in the spring crop and from 0 to 600 lb/acre in fall tomato. Ground cover treatments were polyethylene mulch, fallow, and a cover crop. Cover crops were sorghum-sudangrass [*Sorghum bicolor* (L.) Moench] following spring tomato and ryegrass (*Lolium multiflorum* Lem.) following fall tomato. The soil type was an Orangeburg loamy fine sand (Typic Kandiudults, Fine- loamy, Siliceous, Thermic). Yield ranged from 1900 to 2600 boxes/acre in spring tomato, and from 1300 to 2700 boxes/acre in fall tomato. Fertilizer N rates above 180 lb/acre were excessive as shown by yield and residual soil nitrate-N levels. Residual soil nitrate-N was proportional to N application rate. Soil nitrate-N concentration following harvest was highest in the 1 to 3 ft depth range for spring tomato and 2 to 4 ft depth range for fall tomato. Polyeth-**

ylene mulch maintained most of the soil nitrate-N in the 0 to 4 ft zone. The nitrate-N peak concentration was in the 2 to 4 ft zone of fallow soil following both spring and fall tomato. Sorghum-sudangrass plots contained only 41% as much residual nitrate-N from 1 to 6 ft as fallow plots. Ryegrass plots contained 63% as much residual nitrate-N from 0 to 8 ft as fallow plots.

Soil nitrogen management has become increasingly important in Florida due to ground water quality concerns. Development of best-management practices (BMP's) has focused on modification or manipulation of some management variables.

Nitrogen management variables mentioned by Rauschkolb and Hornsby (1994) were placement, rate, source, irrigation scheduling, timing of N application, and soil organic matter. There are two basic techniques for fertilizer N placement, broadcast and banding, all others are variations of these two. Injection of fertilizer N with drip irrigation is a banding technique. Placement techniques influence nitrate leaching, plant uptake, and N transformations such as nitrification, denitrification, mineralization, and immobilization. Fertilizer N rates are based on crop characteristics, such as amount of N removed in harvested portion, yield versus rate relationships, and sensitivity to excess applied N. Tomato is more sensitive to excess applied N than cotton (*Gossypium hirsutum* L.). Nitrogen sources include organic matter, manures, crop residues, and commercial fertilizers. Most commercial fertilizers contain either ammonium N or nitrate N, or both. Ammonium N is relatively immobile in most soils, while nitrate N is extremely mobile. Since 90% of ammonium N is converted to nitrate N in about 4 wk. (Scarsbrook, 1965) it is most practical to observe nitrate N movement when there is concern about groundwater pollution. Ammonium N is toxic to tomato in large quantities, therefore, ammonium nitrate which is one half ammonium N and one half nitrate N, is used to supply preplant N (40 to 50% of total N) and liquid nitrate N is used for injecting N into the drip irrigation system. Improper irrigation practices, especially the application of excessive amounts, can move residual nitrate out of the crop root zone and cause N deficiencies as well as contribute to ground water pollution. About 2% of the N in stable organic matter is mineralized each year (Rauschkolb and Hornsby, 1994), if organic matter level is 1% then 40 lb of N/acre would be released from one ft of topsoil each year.

According to Pratt (1984), the primary factors determining the amount of nitrate that leaches from irrigated agricultural soil are drainage volume and leachable nitrate. Therefore, high rates of fertilizer N and excessive rainfall tend to maximize nitrate leaching. Avoiding over fertilization with N is the logical place to start in order to reduce nitrate-N movement out of the crop root zone. Since fertilizer N is contained in unharvested crop residue it can be mineralized to nitrate and leached into ground water during seasons when crops are not growing. Aldrich (1984) pointed out that winter cover crops such as ryegrass, wheat (*Triticum aestivum* L.), etc. can recover residual soil N as it is released and immobilize it to plant-N which may be available for following spring and summer crops. He further stated that the maximum amount of N recovered, ranges from 20 to 30 lb/acre. However, this may not be true for tomato in north Florida. The spring tomato crop in north Florida is harvested in June which allows ample time for a summer planted crop of sorghum-sudangrass to mature and immobilize residual soil nitrate left following tomato. If the sorghum-sudangrass is harvested as green chop and fed to animals the residual nitrate is removed from the land with minimum potential for leaching. Another option is to leave the summer cover crop standing over winter and incorporating it back into the soil for part of the N supply to a spring crop. With proper crop rotation, a winter cover crop following fall tomatoes in north Florida could supply part of the N for a spring or summer crop the following year.

The objective of this research was to evaluate the influence of fertilizer-N rate and ground cover on soil-nitrate movement following spring and fall tomato in north Florida.

Materials and Methods

Tomato plants were transplanted 23 March, 1998 (spring crop) and 13 August, 1998 (fall crop) in research plots located at the FAMU Research and Extension Center, Quincy. The production system included drip irrigation, polyethylene mulch (black in spring and white in fall), and stakes to support and maintain plants in an upright position when plants were tied to the stakes with twine. Recommended cultural and pest-control practices were applied uniformly to all treatments (Hochmuth, 1988). Fertilizer-N rates were 0, 90, 180, 270, and 360 lb/acre for the spring crop and 0, 200, 400, and 600 lb/acre for the fall crop. In each crop preplant N supplied 50% of total and five injections (each supplying 10% of total) of liquid N into the drip system were applied 3, 5, 7, 9, and 11 weeks after transplanting. The source of N for both crops was ammonium nitrate preplant, and 4-0-8 (N-P-K) liquid injected. 'AgriSet-761' tomato plants were transplanted into 3ft wide mulched beds spaced 6 ft apart, with a single row per plot containing 15 plants spaced 24 inches apart within row. The 10 center plants in each row were harvested for yield. There were four harvests for the spring crop and five harvests for the fall crop. Harvested tomatoes were graded as culls, medium, large, and extra large fruit.

After tomato harvest was finished in the spring crop, the polyethylene mulch was removed from ⅔'s of the plots, ⅓ of the plots was left fallow, ⅓ was seeded to sorghum-sudangrass, and the mulch was left on the remaining ⅓ until the cover crop was mature. The same procedure was followed in the fall crop except ryegrass was seeded instead of sorghum-sudangrass.

Soil samples were collected in one ft increments after final harvest of each crop to a depth of 4 ft and at the end of cover crop growth cycles to a depth of 8 ft. Samples were ground to pass a 10 mesh screen. A hydraulic soil auger mounted on a tractor with a 3 point hitch was used to obtain soil samples from 4 and 8 ft depths. Soil nitrate-N was determined from a 10 g sample extracted with 25 ml of 0.015 M $CaSO_4$. Five ml of soil extract was mixed with one NitraVer 5 nitrate reagent powder pillow (Hach Co., P.O. Box 389, Loveland, CO 80539) and transmittance was measured with a Spectronic 20 spectrophotometer at 425 nm. Nitrate-N concentration was determined by comparing samples with standards derived from potassium nitrate. The soil type was an Orangeburg loamy fine sand (Typic Kandiudults, Fine-loamy, Siliceous, Thermic).

The experimental design was a randomized complete block with fertilizer-N rate and ground cover as factorial treatments in four replicates (Steel and Torrie, 1960). Analysis of variance procedures were used to evaluate treatment means for yield and soil nitrate concentration (Freed et al., 1989). Ftests were employed to determine if N rate and ground cover significantly influenced soil nitrate concentration. Orthogonal comparisons were used to determine if rate response was linear, quadratic, or cubic.

Results and Discussion

Spring crop.—Although, yield is not the primary objective of this research it can be quite useful in interpreting results of other measurements. Without favorable economic yields the influence of N rates and cover crops on nitrate movement is not meaningful in commercial tomato production systems. Yield was unusually high with no fertilizer N in the spring 1998 tomato crop (Fig. 1). This was most likely due to a long period of organic matter recycling in a bahiagrass sod and the subsequent release of N after tillage and accelerated mineralization. The recommended N rate for tomatoes in Florida is 175 lb/acre (Hochmuth, 1988). Since there was no significant yield difference between 90 and 360 lb of N/acre, it is quite clear that the recommended N level is adequate for this particular location. Yield response to N rates contained significant linear, quadratic, and cubic components.

Residual soil nitrate-N was significantly ($P < 0.05$) higher for the 270 and 360 lb N/acre rates than in the range of recommended rates, 90 and 180 lb of N/acre (Fig. 2). Residual soil nitrate-N was increased by 27% with 90 lb of N/acre, 63% with 270 lb of N/acre, and 80% with 360 lb of N/acre compared with the zero treatment. Peak nitrate-N concentration occurred between 1 and 3 ft depths where fertilizer N was applied. Response of residual soil nitrate-N to N rates contained significant linear and quadratic components.

Sorghum-sudangrass reduced residual soil nitrate-N from 15 to 4 ppm in the 0 to 8 ft depth with the highest N rate (Fig. 3). Since the fallow soil and sorghum-sudangrass soil were exposed to the same leaching forces, it was assumed that the lower residual soil N in the sorghum-sudangrass plots was due to uptake by the cover crop. Nitrogen uptake by the cover crop was estimated from differences between residual soil nitrate in the cover crop plots and residual soil nitrate in either fallow or mulch covered plots. The cover crop could have recovered some of the N before leaching took place. Amount of N removed by the cover crop would be in the range of residual soil nitrate under plastic and residual nitrate in fallow plots minus residual soil nitrate in cover crop plots. To convert ppm N to lb N/acre divide by two, because only one-half of the land was fertilized (3 ft of bare middle was not fertilized), and multiply by 32 (4 million lb of soil/acre ft to 8 ft deep). Therefore, the estimated N in the cover crop was in the range of 93 to 183 lb of N/acre for the 360 lb N/acre treatment. Since dry-matter yield of sorghum-sudangrass was over 14 ton/acre, the estimated N concentration of the cover crop would be in the range of 0.33 to 0.65%.

A detailed examination of the soil profile to 8 ft depth shows the maximum nitrate-N concentration in the 1-2 ft depth range with polyethylene film and in the 3-4 ft range with fallow soil and sorghum-sudangrass treatments (Fig. 4). Background nitrate-N level was about 4 ppm, therefore, the

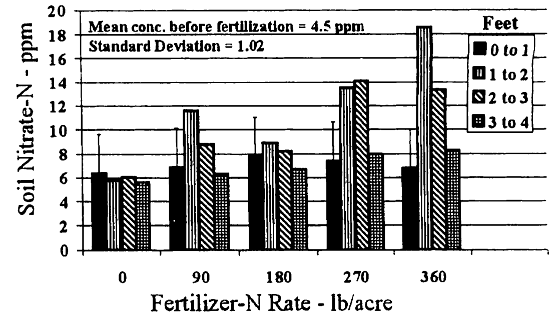

Figure 2. Effect of N rate and soil depth on soil nitrate-N concentration (before mulch was removed) after harvest of tomato crop—spring 1998. Error bars show $lsd_{0.05}$.

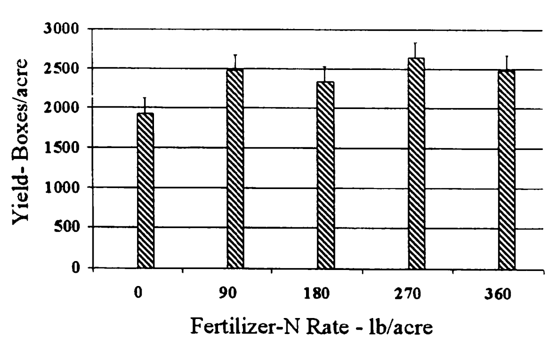

Figure 1. Effect of N rate on total market fruit yield of spring tomato crop—1998. Error bars show $lsd_{0.05}$.

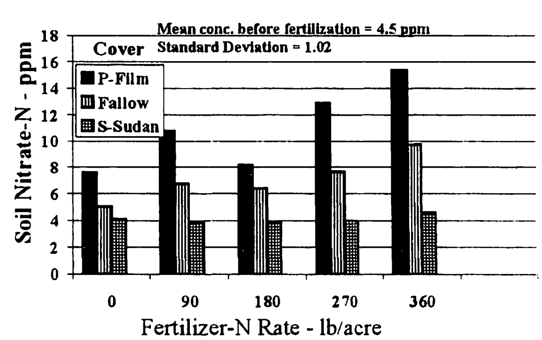

Figure 3. Effect of N rate and ground cover on nitrate-N concentration (averaged over 0 to 8 ft depth) after summer cover crop following spring tomato—1998.

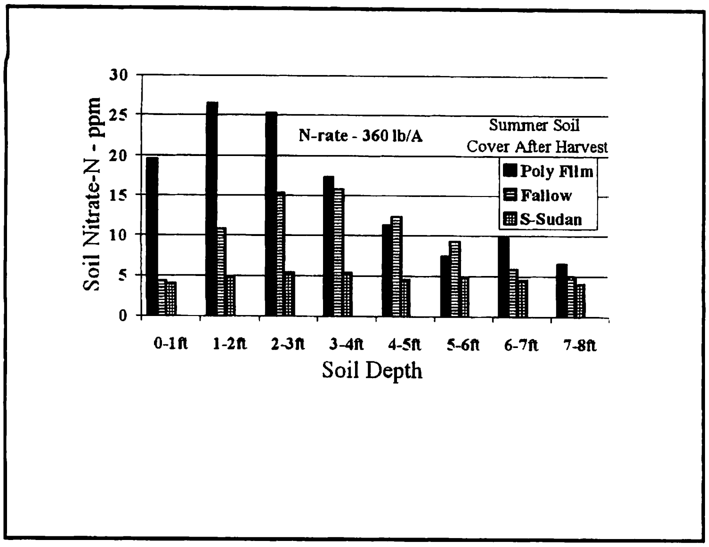

Figure 4. Effect of soil cover and soil depth on nitrate-N in fall samples from spring tomato after summer cover crop—1998.

higher levels in the 4-8 ft depth range with the polyethylene film treatment may be due to contamination at the time of sampling from the dry crumbly soil near the surface protected from rain by the film.

Fall crop.—Yield of the fall tomato crop without fertilizer N was about 1350 boxes/acre, which is similar to yields of previous spring crops on research plots without N (Fig. 5). Two hundred lb of N/acre produced over 2600 boxes/acre. These yields were high for fall tomato in comparison to average commercial yields, but the fall of 1998 was unusually warm allowing a fifth harvest in December, which accounted for almost ½ of the total yield. Sensitivity of tomato to high N rates is shown by decreasing yields between 200 and 400 lb N/acre (yield reduction of 1.8 boxes/lb of N) and between 400 and 600 lb N/acre (yield reduction of 3.4 boxes/lb of N). Yield response to N rate was significant for linear, quadratic, and cubic components.

Soil nitrate-N without fertilizer N was lower for the fall crop than the spring crop (Figs. 2 and 6). Residual soil nitrate-N concentration under the mulch increased 94% between 0 and 200 lb N/acre, 103% between 200 and 400 lb N/acre, and 67% between 400 and 600 lb N/acre (Fig. 6). The estimated (ppm N in treated plots + ppm N in zero N plots divided by two, multiplied by four million lbs/ft times four ft) levels of residual soil nitrate-N in lb/acre between 0 and 4 ft depths were 72 at 0 N/acre, 107 at 200 lb N/acre, 182 at 400 lb N/acre, and 275 at 600 lb N/acre. Estimates of lb/acre takes into account the space between mulched strips, therefore, % increases are smaller than those from concentration levels. Residual soil nitrate-N response to N rates was significant for linear and cubic components.

Ryegrass reduced residual soil nitrate-N concentration in relation to fallow soil by 12% with no N, 41% with 200 lb N/acre, 35% with 400 lb N/acre, and 13% with 600 lb N/acre (Fig. 7). The estimated reduction in lb/acre, which accounts for soil area between mulched strips, was 26 with no N, 71 with 200 lb N/acre, 135 with 400 lb N/acre, and 64 with 600 lb N/acre. These values are assumed to be minimum reductions in leaching potential because some residual soil nitrate-N should be recovered by the ryegrass before leaching reduced it to levels found in the fallow soil. Aldrich (1984) estimated that ryegrass would reduce leaching by 20 to 30 lb N/acre. However, this was true only for the zero N treatment, estimated leaching reduction ranged from 64 to 135 lb nitrate-N/acre for fertilizer N rates of 200 to 600 lb N/acre. Ryegrass yield was about 3 ton/acre of dry-matter, therefore, estimated N concentration of the cover crop was in the range of 1.07 to 2.25%. Total leachable nitrate-N, which was found in plots kept covered with film mulch, increased 71 lb/acre between 0 and 200 lb N/acre, 160 lb/acre between 200 and 400 lb N/acre, and 172 lb/acre between 400 and 600 lb fertilizer N/acre.

Conclusions

Application of excessive rates of fertilizer N increased residual soil nitrate-N in direct proportion to the amount applied. Sorghum-sudangrass was effective in reducing residual

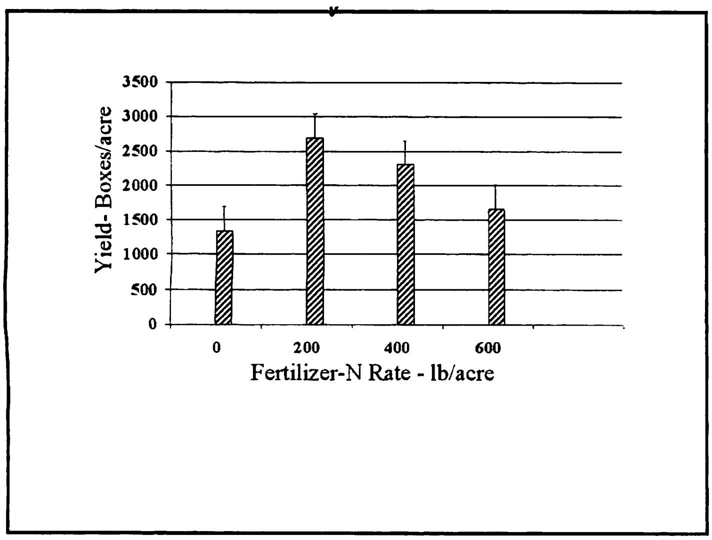

Figure 5. Effect of N rate on total market fruit yield of fall tomato crop—1998. Error bars show $lsd_{0.05}$.

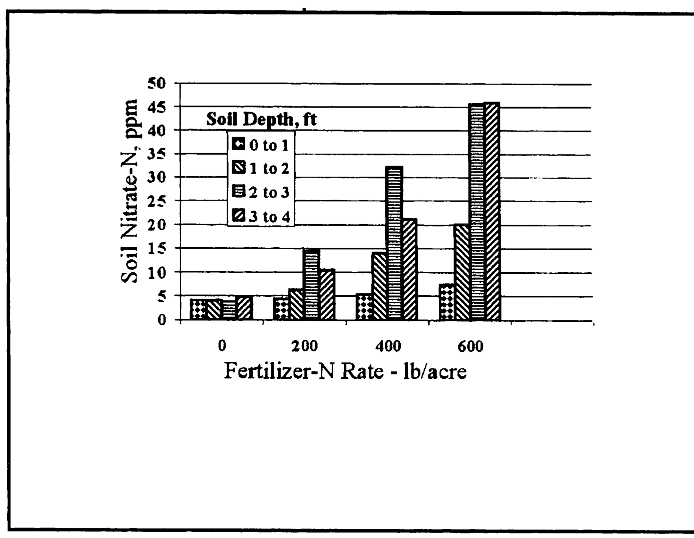

Figure 6. Effect of N rate and soil depth on soil nitrate-N (before mulch was removed) of fall tomato crop—1998.

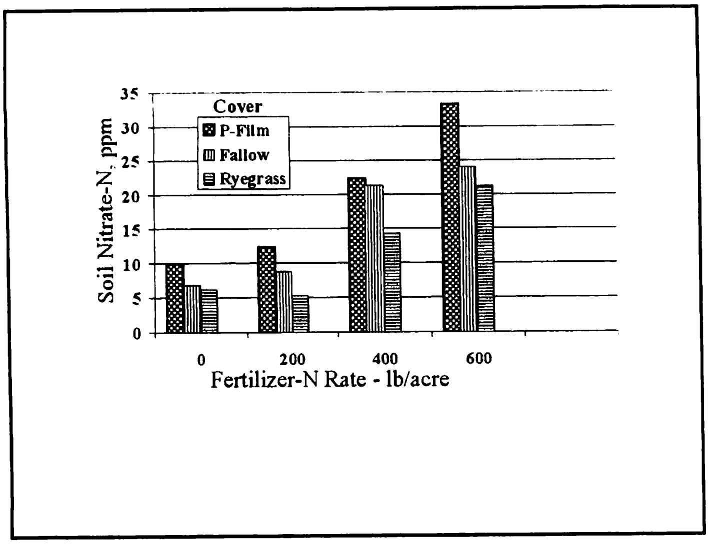

Figure 7. Effect of N rate and ground cover on soil nitrate-N after winter cover crop following fall tomato—1998.

soil nitrate-N below background levels from 0-8 ft depths with fertilizer N rates from 0-360 lb/acre. Ryegrass reduced residual soil nitrate-N by as much as 135 lb/acre.

Suggested BMP's.—Do not apply more fertilizer N to a tomato crop than recommended by the cooperative extension service. Apply multiple applications of fertilizer N by injecting liquid N into the drip irrigation system. Plant sorghum-sudangrass immediately following tomato harvest (spring crop) and mulch removal in early summer. Green chop sorghum-sudangrass when mature and feed to livestock. Leave polyethylene mulch in place for fall tomato crops until late fall and plant ryegrass on the area immediately after mulch removal. If a summer cover crop is not compatible with the local farming system, mulch from the spring crop could be left until late fall and removed to plant ryegrass. The ryegrass may be incorporated back into the soil in spring, as a source of N for spring or summer crops.

Literature Cited

Aldrich, S. R. 1984. Nitrogen management to minimize adverse effects on the environment. pp. 663-673. *In* R. D. Hauck (ed.). Nitrogen in crop production. Amer. Soc. Agron. Madison, WI.

Freed, R. D., S. P. Eisensmith, E. H. Everson, M. Weber, E. Paul and D. Isleib. 1989. MSTAT-C, a microcomputer program for the design, management, and analysis of agronomic research experiments. Michigan State Univ. East Lansing.

Hochmuth, G. J. (ed.). 1988. Tomato production guide for Florida. Fla. Coop. Ext. Circ. 98C.

Pratt, P. F. 1984. Nitrogen use and nitrate leaching in irrigated agriculture. pp. 319-333. *In* R. D. Hauck (ed.). Nitrogen in crop production. Amer. Soc. Agron. Madison, WI.

Rauschkolb, R. S. and A. G. Hornsby. 1994. Nitrogen management in irrigated agriculture. Oxford Univ. Press, New York.

Scarsbrook, C. E. 1965. Nitrogen availability. pp. 481-502. *In* W. V. Bartholomew and F. E. Clark (ed.). Soil nitrogen. Agron. Monogr. 10. ASA, Madison, WI.

Steel, R. G. D. and J. H. Torrie. 1960. Principles and Procedures of Statistics. McGraw-Hill, New York.

Proc. Fla. State Hort. Soc. 112:319-322. 1999.

THE GRADIENT CONCEPT: A NUTRITIONAL PARADIGM SHIFT

C. M. Geraldson (Retired)
1111 99th Street NW
Bradenton, FL 34209

Additional index words. Diffusion, massflow, nutritional stability.

Abstract. **The gradient concept is designed with a soluble source of N-K banded on the soil bed surface in conjunction with a continuing source of water which synchronizes the nutrient/water input with rate of removal by the root. By placing the N-K on the surface rather than conventionally in the bed, nutrient movement to the root shifts from mass flow to diffusion. Nutrients that move by mass flow are a function of water requirement and potentially a source of nutritional instability. With the shift to movement by diffusion, nutrients move independently of the water to replace those removed from the gradient by the root. The gradient with a continuing nutritional stability replaces the variable and limited stability potential of the soil. Commercial tomato yields in Florida more than doubled with the shift to the gradient-mulch procedure. A containerized version of the concept (The Earth Box™) has been most successful for the home gardener and substantiates the validity of the gradient. Most innovative procedures with the gradient as the buffer component minimize pollution, require minimal management, and use minimal water when microirrigation is used as the water delivery source. In order to better understand the gradient concept and utilize the procedure, it may be necessary to consider the procedure as a nutritional paradigm shift.**

Introduction

During the 1950s, the concentration and ratio of ions in the soil or hydroponic solution were evaluated as nutritional variations that could weaken or destroy nutritional stability. Such variations were associated with the prevalence and severity—and control—of black heart of celery and blossom-end rot of tomatoes (Geraldson, 1957). In order to further evaluate nutritional stability as a productivity factor, the intensity and balance soil testing procedure was developed to monitor significant correlations (Geraldson, 1977). It was concluded that in order to provide correlations, the nutrition had to be stabilized.

During the 1960s, a full-bed mulch procedure was initiated and developed in Florida which provided the potential for nutritional stability. The Gradient Concept as a non-conven-