the water required for transpiration and thus can weaken or destroy the gradient. To be predictable the gradient must be the source of N-K. Nutritionally this is most important when the crop nutrient/water requirement is at a maximum.

Alternatives

In the early 1970's (Geraldson, 1973) in an effort to expand the use of the gradient concept, microirrigation rather than a water table was evaluated as a constant source of water. With a point source of water at the surface and a banded surface N-K source, the lateral gradient provided an experimentally feasible system.

In more recent times, because of potential water restrictions, microirrigation has been evaluated as a component in the production system. In-bed N-K and fertigated N-K have been included as nutritional components and thus as a nutritionally conventional system is unpredictable—previously described as a "black box."

Some commercial growers are utilizing an intermittent-point source of water (microirrigation) at the plant row with a banded parallel source of N-K within a wettable distance from the plant row to provide a lateral gradient. This procedure has been satisfactory but even with precise management it can become nutritionally vulnerable.

Most recently in an effort to provide a globally sustainable production system, a containerized gradient concept is being evaluated and has been most successful with a built-in water table. The water would be that required for transpiration and to maintain a gradient path from the surface to the root; pollution due to nutrient leaching would be minimized or eliminated; productivity based on a minimal unit cost has been projected as equivalent to and has the potential to advance beyond the conventional trial and error procedure. A hydroponic solution is designed also to provide an optimal nutritional environment but does not have a synchronized nutrient/water component and thus the stability is vulnerable and dependent on precise management. In contrast, the nutrient/water input of a functional gradient system is controlled by plant removal rather than the variances of management.

Commercial growers as well as home gardeners using the gradient concept (mulched or containerized) could grow a wide range of horticulture crops requiring only periodic additions of water to maintain the concept. Nutritionally the gradient concept is a paradigm shift and is fought with great vigor by the proponents of conventional procedure because it destroys the former investment. However because of the potential, it is suggested that to nutritionally advance productivity beyond the trial and error procedure, it is necessary to nutritionally optimize the contents of the "black box."

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WATER USE AND NITROGEN BALANCE FOR SUBIRRIGATED FRESH-MARKET BELL PEPPER PRODUCTION

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Abstract. **Self-contained drainage lysimeters located in field plots were used to determine water use and N balance for bell peppers (*Capsicum annuum* L.) grown in the 1992 fall production season. Each lysimeter unit, automatically irrigated by maintaining a water table at 20 inches below the soil surface, contained eight plants spaced at a density equivalent to 14,500 plants per acre and fertilized at an N rate of 300 lb/acre. Weekly determinations of water use and nitrate-N concentration of the water table were taken. Determinations of total-N uptake through plant tissue (foliage and fruit) and residual N in the soil and water at the end of the growing season were used to develop an N budget. Results showed that plant uptake accounted for 51.9% of the applied N, where as 15.1% remained in the soil solution below the root zone, and 10% remained in the upper soil profile. Approximately 23% of the applied N was unaccounted for, indicating a possibility that denitrification occurred. Seasonal crop water use was determined to be approximately 4.4 inches (plant use and soil evaporation), not including water needed for field preparation, transplant establishment, crop protection, or system inefficiencies. Crop coefficients were developed using adjusted pan evaporation for reference evapotranspiration and ranged from 0.4 to 1.28 depending on stage of growth.**

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Florida's sandy soils are highly susceptible to leaching losses of applied fertilizer necessary for production of high value vegetable crops. Although using raised, polyethylene mulch covered beds and subirrigation can help minimize losses, when fertilizer applications exceed crop needs, losses occur. Typically, to overcome the detrimental effects of possible fertilizer losses, excessive initial application of fertilizer (especially N) is practiced, sometimes 2 to 2.5 times the recommended rate.

The Lake Manatee Watershed Demonstration Project (Stanley et al., 1994; McNeal et al., 1994) was initiated to monitor the impact of current vegetable and citrus management practices on nutrient leaching (primarily nitrate) to groundwater and surface water bodies. Results to date indicate minimal nitrate leaching to shallow water table depths for subirrigated vegetable production during the growing season. However, in some vegetable production fields, elevated nitrate levels at shallow depths have been detected during the very early part of the growing season and late after the season is terminated. Early in the season, a phenomenon termed "fertilizer dropout" may be occurring when water table levels are maintained too close to the bed surface causing a high concentration of dry fertilizer to be solubilized. This solution has a greater density than the surrounding soil solution causing accelerated movement through the profile. When the polyethylene mulch is removed after cropping is terminated, residual fertilizer is exposed to rainfall causing rapid leaching to occur. Because the crop only uses a defined amount of N, the remainder is lost (in the form of NO_3) to the environment and can cause serious problems when leached into groundwater or surface water resources.

Water management of vegetable crops is closely linked to fertilizer management since it can be instrumental in either causing excessive leaching or in facilitating efficient use of applied nutrients. Vegetable producers on flatwoods soils generally use microirrigation or a form of subirrigation. With microirrigation, it is critical that crop requirements and soil water holding characteristics are known since nutrients can easily be moved out of the root zone by excess application of water.

Field-located drainage lysimeters have been used in the past for determining tomato water requirements (Clark et al., 1993). Since quantifying the fate of applied N in field locations is difficult, this particular study was designed to use the drainage lysimeters to obtain both water use characteristics and determine a N balance for a bell pepper crop. The specific objectives of this study were to determine the extent that N leaches out of the root zone during the normal 4-month growth cycle, to develop a seasonal N budget for subirrigated peppers, and to determine crop water use characteristics for pepper production.

Materials and Methods

The drainage lysimeter facility located at the Gulf Coast Research and Education Center (GCREC) in Bradenton, Florida was used for this study which was initiated in the 1992 fall season. The setup consists of independently controlled lysimeter units, each outfitted with self-contained subirrigation and drainage systems. Because the units are self-contained, the ability to perform a N balance is available. Each unit consisted of four separate plastic barrels manifolded together to a common sump where the desired water table level (18-20 inches) was maintained. A float switch, located in the sump, opened or closed a water line connected to a reservoir which was used to supply water for water table level correction as needed when plant use occurred. A weekly account of water used was recorded.

Pre-application determination of the NO_3-N content of the soil used in the study was performed. The soil in the containers was an EauGallie fine sand, a common soil used for vegetable production, leached to the condition of minimal initial N present. The fertilizer (KNO_3 and NH_4NO_3) was applied in two 12-inch bands, 1.5 inches deep (covered) on the outside of the plants at a N rate of 300 lb/acre. Two plants for each of four subunits within a lysimeter unit were planted 12 inches apart with the fertilizer placed 8 inches from the plants. A total of 8 plants for each lysimeter unit were used. Three sets of lysimeter units were used in the study. The soil in all lysimeter units was mounded and covered with black polyethylene which prevented water entry from rainfall, thus, the measured water use was essentially plant transpiration only. All lysimeter units had buffer plants around them to simulate actual field conditions with a planting density of 14,500 plants per acre.

The water table in each lysimeter unit was sampled weekly for nitrate content determination and were performed with a rapid flow analyzer (colormetric determination) with detection sensitivity of 0.04-20.0 ppm. Fruit were harvested 3 to 4 times during the season and total N content in the fruit was determined. At the end of the growing season, all remaining top growth was harvested and again, total plant tissue N content was determined for each experimental unit. The top 8-10 inches of soil was removed and sampled for NO_3-N content. The residual NO_3-N remaining in the soil was then leached out and total remaining NO_3-N was determined.

Results and Discussion

Figure 1 shows the average weekly and accumulated water use for the growing season. Seasonal water use for bell peppers was measured at 4.4 inches, which compares Fig. 2 to approximately 5.6 inches for a fall-grown tomato crop (Clark et al., 1993). Figure 2 shows crop coefficients calculated using adjusted pan evaporation as reference evapotranspiration for two-week periods throughout the growing season. Values ranged from 0.4 early in the season

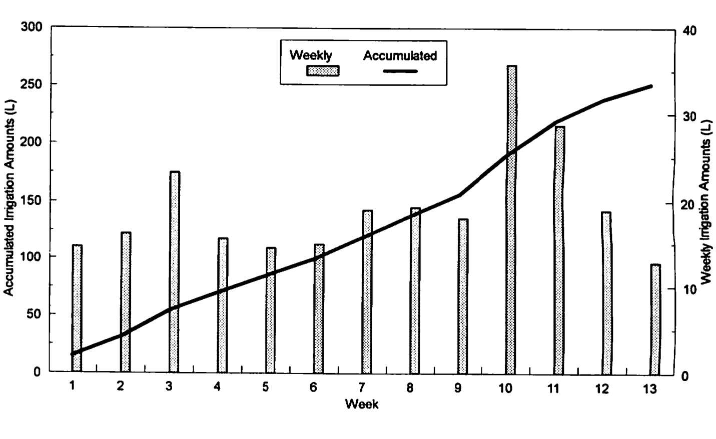

Figure 1. Average weekly and accumulated water use for subirrigated, lysimeter-grown bell pepper plants, 1992 fall season.

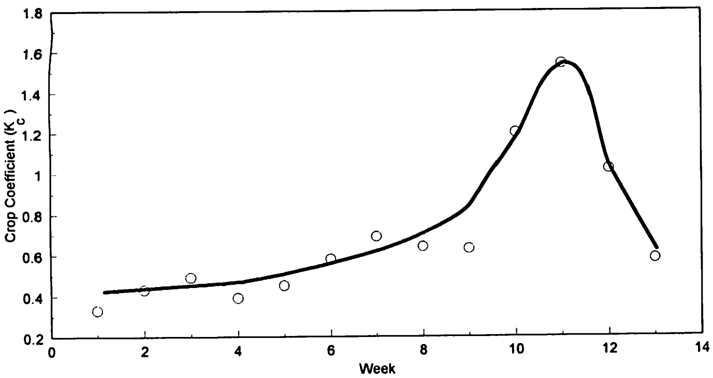

Figure 2. Average biweekly crop coefficients for subirrigated, lysimeter-grown bell pepper plants, 1992 fall season.

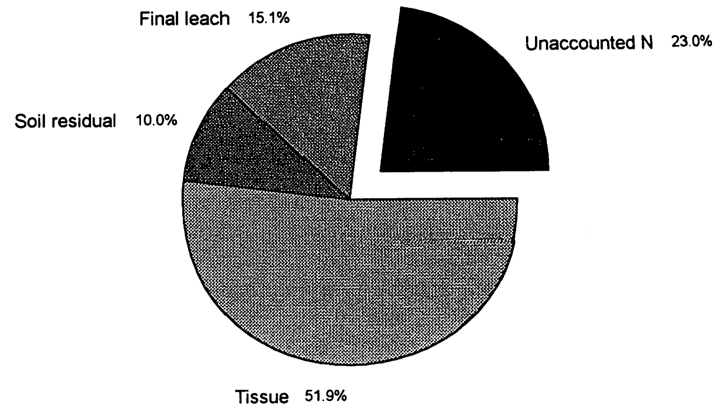

Figure 4. Fate of applied N for subirrigated, lysimeter-grown bell pepper plants, 1992 fall season.

to 1.28 late in the season when maximum crop canopy coverage was achieved.

Figure 3 shows the averaged results of the weekly sampling of the water table for NO_3-N concentration. Aside from an initial elevation of concentrations probably due to handwatering for transplant establishment, NO_3-N levels were less than 1 ppm for the season. This was expected since with this subirrigation system the net movement of water is upward to the root zone from the water table. Since the applied N moves with water flow, it primarily remained in the upper soil profile and did not leach to the water table.

Average plant matter production per plot was 30.6 lb fresh weight (1.7 lb dry weight) for fruit and 6.7 lb fresh weight (1.04 lb dry weight) for stems and leaves. The average N content in the plant dry matter was 2.9% for fruit and 3.0% for stems and Fig. 4 leaves. Figure 4 shows the averaged final N distribution as it was measured in plant tissue, soil residual, a final leaching of the remaining soil, and unaccounted N. The tissue N accounted for 51.9% of the N applied which equated to approximately 156 lb N/acre (current N fertilizer recommendations for bell pepper production range from 160 to 175 lb/acre). Approximately 25% of the applied N remained in the soil (summation of soil residual and the final leaching of the lysimeters) and approximately 23% of the applied N was not accounted for with the methods used. Since the required prerequisites for denitrification to occur were most likely to be present (including anaerobic conditions existing near and below the water table, an ample NO_3 source, a microbial population capable of denitrification, and a carbon source), it is speculated that the denitrification process may be active in this environment and account for some of the N not found. Denitrification has been shown to occur on soils where similar growing conditions existed (Aulakh et al., 1992). If this is the case, then the loss of N (as N_2O) to the atmosphere may be of more concern than NO_3-N losses to groundwater and surface water bodies as long as the water table is maintained at a stable level.

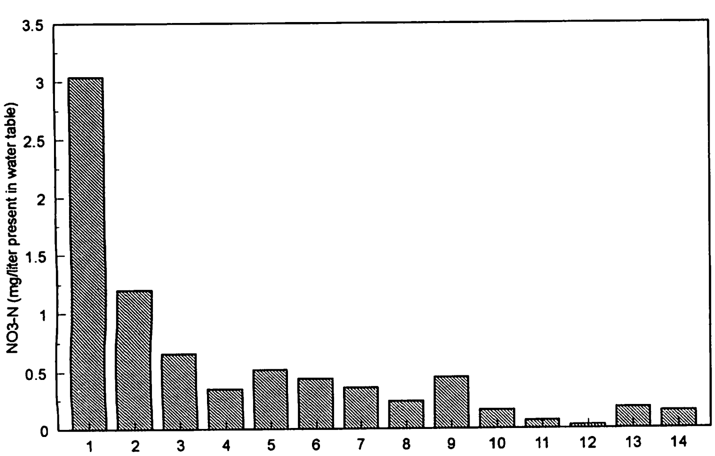

Figure 3. Average weekly nitrate-nitrogen concentrations in the water table for subirrigated, lysimeter-grown bell pepper plants, 1992 fall season.

Based on the results of this study, our future field work should concentrate on the possibility that significant denitrification may be occurring with subirrigated vegetable production. These results reinforced our observations in field studies that minimal leaching occurs during the growing season. Understanding when and how N losses can occur provides practical information that shows reduction of fertilizer application rates are justified when water management is a high priority production practice.

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