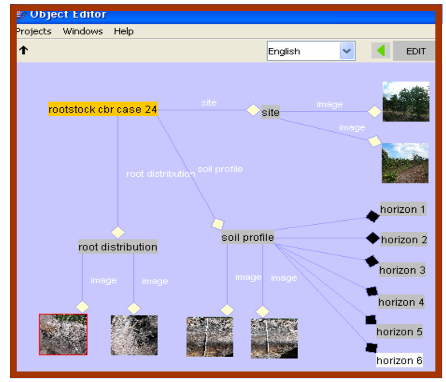
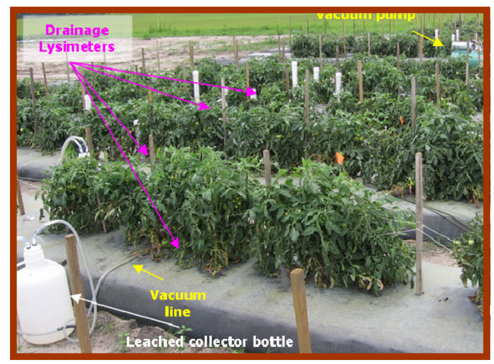
Issue No: 6
March, 2006

IFAS SOIL & WATER SCIENCE

# UF/IFAS Nutrient Management Education Core Group




*Inside This Issue:*



**Editors:**
**Rao Mylavarapu**
**Susan Curry**

**E-MAIL:**
**RaoM@ufl.edu**
**Scurry@ufl.edu**

UNIVERSITY OF FLORIDA
IFAS EXTENSION

Dr. Rao Mylavarapu, Soil and Water Science Department, 2169 McCarty Hall, Box 110290, University of Florida, Gainesville, Florida 32611, Phone: 352-392-1951, Fax: 352-392-3902. Email: raom@ufl.edu http://nutrients.ifas.ufl.edu

## Nutrient Management Education Core Group Background

Federal, state and regional agencies are working towards formulating regulations for agricultural operations to reduce nonpoint nutrient source pollution for water quality protection. Several of our IFAS faculty are currently involved with these agencies for developing Interim BMPs for various commodities. In all cases these efforts are interdisciplinary requiring frequent interaction among the UF/IFAS faculty statewide. Several of us feel the need for a stronger coordination among IFAS faculty in responding to these needs. The creation and successful functioning of the proposed Nutrient Management Core Group will enhance the credibility of UF/IFAS faculty and educational resources and create a nodal point for liaison with all the agencies and public that are interested in the issue. Several land grant institutions have formed similar core groups or self-directed teams and have developed educational material. We will interact with these institutions to benefit from their expertise and experience.

In February of 2001, this group coordinated the FDEP319 Prioritization meeting in Gainesville. This meeting was attended by state agencies and water management districts, growers, many commodity organizations and IFAS faculty and administration. All comments from this meeting were compiled in an electronic newsletter and distributed to all participants throughout the state.

# Bermudagrass response to K, S and Mg fertility at three Florida Locations

C.L. Mackowiak, Soil & Water Science, A.R. Blount, and P. Mislevy, Agronomy

Although comprised primarily of sand, Florida soils are diverse, where heavier coastal plain soils such as those found in the Florida Panhandle tend to hold more nutrients than the deep sands found in Peninsular Florida. Additionally, the spodic zone of flatwood soils found in the central and southern part of the state may provide nutrients for forage roots, unlike the deep sandy soils found along the Florida central ridge that have no spodic layer. Therefore it is adventitious to test forage fertilization practices with more than one soil type. Periodic supplementation with S may prove beneficial for some Florida soils that do not hold S in the topsoil or subsoil. Periodic S fertilization may enhance Florida forage production and quality in S deficient soils. The IFAS recommendations do not address forage grass secondary nutrient requirements specifically, but may in the future as data warrants.

In the spring of 2004, experimental plots (3 x 6 m) were laid out in established, non-irrigated hay fields of bermudagrass located at the Range Cattle Research and Education Center (RCREC), Ona (no perennial peanut), the North Florida Research and Education Center (NFREC), Live Oak and NFREC, Marianna, to test K fertility practices with and without supplemental sulfate of potash magnesia (K-Mg-S), as part of a larger study. The 5 treatments consisted of no fertilization (CHK), N and $P_2O_5$ only (CTL), low potassium (LK2O), high potassium (HK2O), low K-Mg-S (LKMG) and high K-Mg-S (HKMg). The K-Mg-S was provided at a rate to supply 25% of total $K_2O$. Nitrogen application values were approximately 80 kg $ha^{-1}$, $K_2O$ at 27 or 54 kg $ha^{-1}$ per cutting, and S at 7.5 kg $ha^{-1}$ or 15 kg $ha^{-1}$.

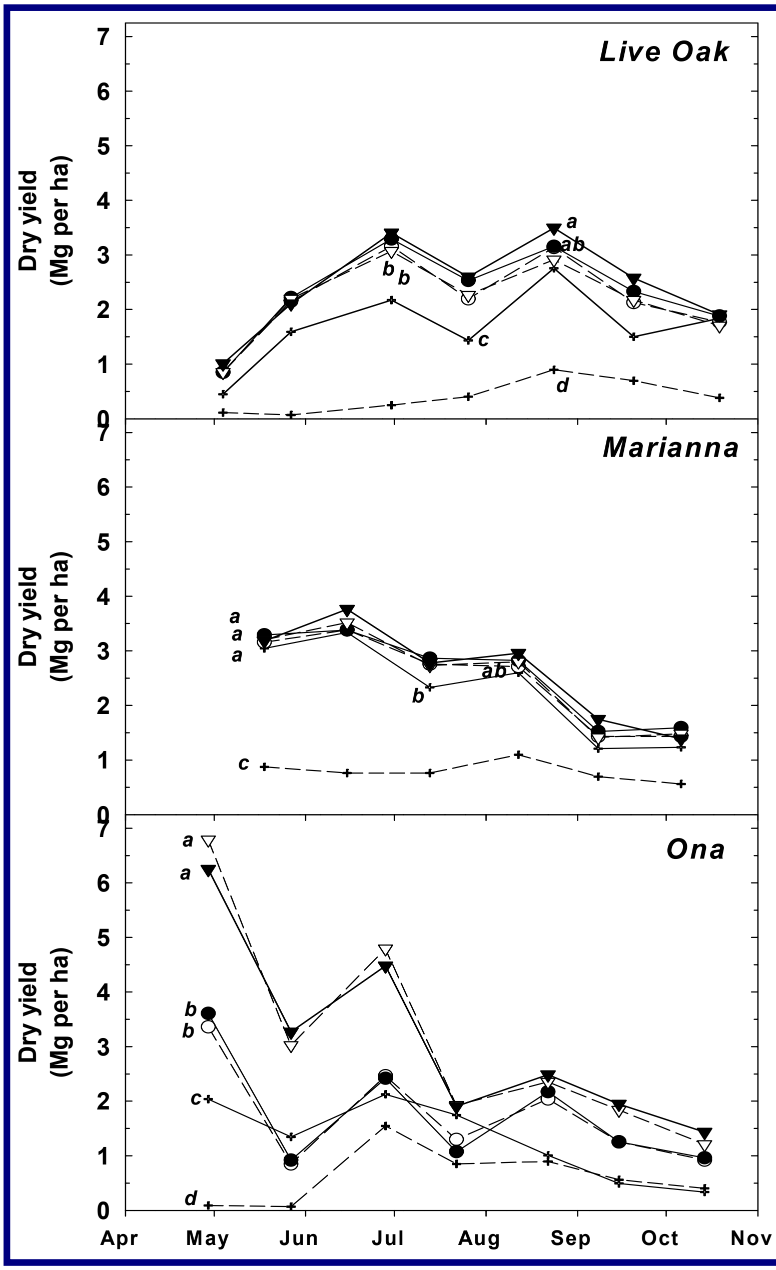



*Fig. 1. The 2005 bermudagrass yields. Each treatment mean (n = 6) is represented by a symbol, as follows: + = check (no fertilizer); + and dash line = control (N only fertilizer); O= LK2O; □ = HK2O; s = LKMG; q = HKMG. Mean differences are represented by different letters*

Treatments without any fertilizer or N only fertilization produced lower seasonal yields than the K fertilization treatments (Fig 1). Among K fertilization treatments, there were no bermudagrass yield differences at Marianna. Potassium fertilization with K-Mg-S at the highest rate resulted in somewhat greater yields at the Live Oak location. However, there was a strong fertilizer yield effect at the Ona location, where fertilization without supplemental S had a 50% decline in productivity. Only near the end of the season (September) did the yield differences diminish (Fig. 1). Yields between low and high K were similar, regardless of K source. This suggests that the lower K fertilization rate may be adequate for bermudagrass at this location (Fig 2). Among the best

*(Continued on page 4)*

*(Continued from page 3)*

treatments, seasonal yields were 17.1 Mg ha$^{-1}$ at Live Oak, 15.8 Mg ha$^{-1}$ at Marianna, and 21.8 Mg ha$^{-1}$ at Ona. Based on tissue analyses from 2004, tissue K, Mg, and S concentrations were adequate at the Marianna bermudagrass location. Soil extractable K and Mg were well above suggested low critical values. Although soil S was below suggested critical values in the Marianna topsoil, S values at 45 – 60 cm were above the threshold. In fact, the soil results reflect some S downward movement and accumulation in the 45 – 60 cm depth. This may have provided ample S for forage growth at Marianna in 2005.

Although top soil S was below the suggested critical concentration at all locations, Ona was the only location that also had critically low soil S at the 45 – 60 cm depth. Additionally, 2004 tissue composition results showed that the high K fertilization treatments became S deficient by mid summer, while the unfertilized and S supplemented treatments were sufficient in tissue. As expected, Ona bermudagrass yields without supplemental S were worse in 2005 (Figs. 1 and 2), as soil S became increasingly depleted.

Soil Mg values were well above the suggested critical threshold at Live Oak and Ona. However, soil extractable K was below the critical concentration at both locations. There appeared to have been some residual K in the Ona topsoil plots that carried over from 2004 to 2005, although they remained below the suggested critical low concentration.

***Figure. 2. Bermudagrass at the Ona location. Sparse vegetation in foreground = N only treatments and check treatments. Light green plots = K without supplemental KMag.***

Potassium deficiency in bermudagrass has often been associated with leaf-spot diseases such as *Helminthosporium* leaf spot. This disease thins the plant stand and reduces yield. While leaf spot was visible in 2005 in nearly all bermudagrass plots and at all locations, the severity varied depending on the fertility treatment.

Leaf spot appeared to be most damaging in Ona bermudagrass plots that received either no fertilizer (check treatment) or only N fertilization (control treatment). The control treatment had the highest leaf tissue necrosis rating (30% damage) but it was not significantly different than the check treatment (25% damage). We speculate that the control plots (N only fertilization) were more rapidly growing (dilution effect) than the check plots (no fertilization) and therefore were more K deficient, making the plant more susceptible to injury (Fig. 3). Plots receiving low or high K fertilization had significantly less damage (10% – 15%).

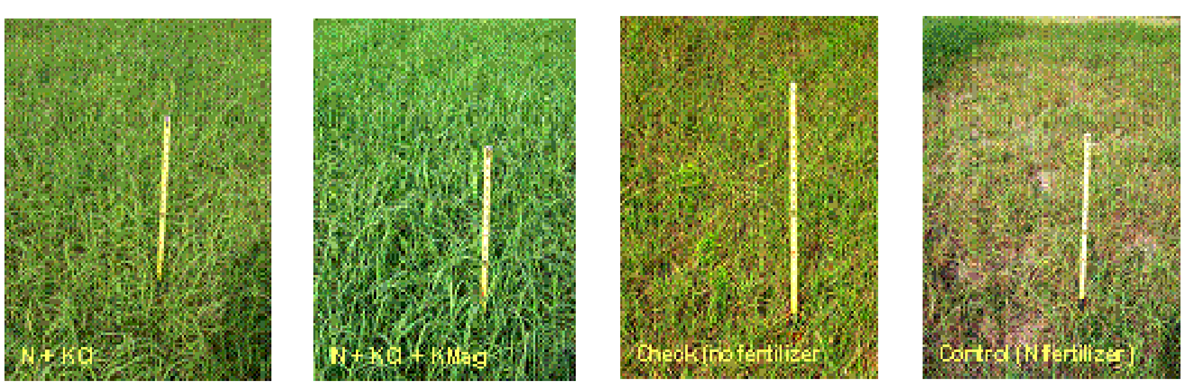



***Figure. 3. Bermudagrass at the Ona location. Sparse vegetation in the control plot related to disease pressures.***

# Crop Phytoremediation of Phosphorus-Enriched Soils in the Lake Okeechobee Region

J.M.S. Scholberg, M.B. Adjei, Y.C. Newman, J. E. Rechcigl, and C.G. Chambliss

**Background:**

Excess accumulation of soil phosphorus (P) associated with intensive agricultural operations has been linked to periodic algae blooms, degradation of natural ecosystems, and it may also impact recreational use of surface waters. One of the key objectives of the Lake Okeechobee Protection Program (LOPP) is to develop and implement environmentally sound and cost-effective P-remediation programs. Non-biological remediation of high P-index sites has been shown to be effective in reducing P loading of surface waters. However, this approach typically requires application of up to 70,000 lbs (or 35 ton) of soil amendment per acre. Although many soil amendments (including water treatment residuals) may be obtained at no cost, transportation/application costs may still be on the order of $350-$2,500 per acre. This appreciable cost, combined with uncertainties about the long-term stability of precipitates and potential risk of hyper-accumulation and/or toxicity of certain compounds, may limit the application of soil amendments to specific areas. Use of wetlands for treatment of P- enriched systems has been quite successful but establishment cost may be on the order of $12,000-18,000/acre. Therefore, complementary and cost-effective approaches are required that will facilitate both P-remediation and sustained regional agricultural production as well.

Pasture production is the largest land use in the region surrounding Lake Okeechobee in Florida. Typically, grass yield and quality increase with increasing rates of N fertilization. However, interactions of N rates with the high residual P concentrations in the soil, commonly found in the vicinity of intensive agricultural enterprises such as dairy operations, are not well understood. The purpose of this program is thus to develop production strategies that will improve the mining and utilization of residual soil-P in regions with high P-index values by forage grasses.

We have, in collaboration with Butler Oak Dairy operations, established and maintained field studies and have been managing these forage fields for a period of two years. These studies aim to determine the effects of different N-fertilization rates on forage productivity, forage quality, forage P-removal rates, residual soil-P levels, and leaching and run-off of both phosphorus and nitrate.

**Program Objectives**:

The overall goal of this project is to determine the capacity of high-quality and high-yielding forage crops in the Lake Okeechobee region to remove phosphorus (P) from P-impacted sites. The specific objectives of this study are to 1) evaluate the effects of increasing N fertilizer rates applied to P-impacted sites on herbage production, P-harvesting capacity, and nutritive value of three most commonly used warm-season pasture species in S Florida (bahiagrass, limpograss, and stargrass); 2) To evaluate the interactive effects of variable soil P content and N-fertilizer application rates on productivity, forage quality, and P removal by forages; 3) To assess the effects of N-fertilizer application rates and pasture production on nitrate and ortho-P concentrations in both surface runoff and drainage water for the above pasture systems.

**Research Approach**

Based on a review of the literature and information provided by local extension specialists and the funding agency, we identified 3 species that were potentially viable candidates for phytoremediation of P impacted sites in the Okeechobee region. Selected species were: 1) Stargrass, Limpograss, and Bahiagrass. Selection criteria included i) forage production potential (yield and quality); ii) phosphorus content; iii) adaptation to south Florida conditions; and iv) current use and acceptance by local farmers.

During the spring of 2003 we, in collaboration with Butler Oak Dairy operations, established and maintained field studies that allowed us to assess the effects of different N-fertilization rates on forage productivity, P-removal rates, and residual soil-P levels. During the first year we established the field sites and developed the critical

*(Continued on page 6)*

*(Continued from page 5)*

infrastructure required for these field studies. Some of the pastures did not have adequate P levels and were amended with dairy manure to ensure that initial topsoil P levels were in the desired range of 25-30 ppm Mehlich-I extractable P. Some of the Stargrass plots were weedy and so replanted to ensure optimal pasture productivity. Because of these required modifications, we were not able to start collecting data the first year. After manure application we allowed for adequate time for mineralization and redistribution of the P within the upper soil layer. Overall soil P levels in the upper soil layer during the spring of 2004 were 25, 26, and 21 ppm Mehlich-I P for bahiagrass, limpograss and stargrass, respectively. We used a Randomized Complete Block experimental design with 4 replicates (blocks) and treatments included: 1) four levels of N fertilization rate per harvest (0, 45, 60, and 90 lbs N/acre); and 2) three pasture species (bahiagrass, limpograss, and stargrass).

## Forage production

Plot size was 1250 ft$^2$ (25 x 50 ft) for al three studies. A

***Table 1. Effects of N fertilizer rate on seasonal and total annual forage yield of bahiagrass during the 2004 growing season.***

| *N rate (lbs/acre)* | *H1 (5-21-04)* | *H2 (6-21-04)* | *H3 (7-19-04)* | *H4 (8-21-04)* | *H5 (9-16-04)* | *H6 (10-19-04)* | *H7 (11-19-04)* | *Total Annual* |
|---|---|---|---|---|---|---|---|---|
| | ------------------------------ton acre$^{-1}$---------------------------- | | | | | | | ton/acre-yr |
| 0 | --- | 0.29 b† | 0.57 c | 1.36 c | 0.31 b | 0.48 c | 1.30 b | 4.30 c |
| 45 | --- | 0.37 ab | 1.10 b | 1.79 b | 0.42 a | 0.65 b | 1.82 ab | 6.15 b |
| 60 | --- | 0.50 a | 1.50 a | 2.18 a | 0.37 ab | 0.81 a | 2.94 ab | 8.45 a |
| 90 | --- | 0.72 a | 1.50 a | 2.23 a | 0.35 ab | 0.76 ab | 3.32 a | 9.02 a |
| SE | --- | 0.11 | 0.13 | 0.11 | 0.07 | 0.08 | 0.55 | 0.56 |
| Contrast ‡ | | | | | | | | L** |

† Treatment means are not different if followed by the same letter (P>0.05).
‡ Orthogonal polynomial contrast for the effect of N rate (L= linear, **= P ≤ 0.01)

***Table 2. Effects of N fertilizer rate on seasonal and total annual forage yield of limpograss during the 2004 growing season.***

| *N rate (lbs/acre)* | *H1 (5-26-04)* | *H2 (7-21-04)* | *H3 (8-31-04)* | *H4 (10-19-04)* | *H5 (12-02-04)* | *Total Annual* |
|---|---|---|---|---|---|---|
| | ------------------------------ton acre$^{-1}$---------------------------- | | | | | ton/acre-yr |
| 0 | 0.13 b † | 1.96 b | 2.00 b | 0.59 b | 0.03 b | 4.74 b |
| 45 | 0.65 ab | 3.18 a | 2.85 a | 1.07 a | 0.35 a | 8.11 a |
| 60 | 0.58 ab | 3.25 a | 2.49 ab | 0.97 a | 0.42 a | 7.73 a |
| 90 | 1.27 a | 3.39 a | 2.37 ab | 1.20 a | 0.56 a | 8.77 a |
| SE | 0.24 | 0.18 | 0.23 | 0.15 | 0.09 | 0.61 |
| Contrast ‡ | | | | | | L** |

† Treatment means are not different if followed by the same letter (P>0.05).
‡ Orthogonal polynomial contrast for the effect of N rate (L= linear, **= P ≤ 0.01)

***Table 3. Effects of N fertilizer rate on seasonal and total annual forage yield of stargrass during the 2004 growing season.***

| N rate (lbs/acre) | *H1 (5-21-04)* | *H2 (6-21-04)* | *H3 (7-19-04)* | *H4 (8-21-04)* | *H5 (9-16-04)* | *H6 (10-19-04)* | *H7 (11-19-04)* | Total Annual |
|---|---|---|---|---|---|---|---|---|
| | ------------------------------ton acre$^{-1}$---------------------------- | | | | | | | ton/acre-yr |
| 0 | 0.81 a † | 1.06 c | 1.20 b | 1.31 a | 0.35 a | 0.08 c | 0.22 c | 5.03 c |
| 45 | 1.28 a | 1.43 bc | 2.48 a | 0.95 b | 0.39 a | 0.24 b | 0.59 a | 7.36 ab |
| 60 | 1.07 a | 1.63 ab | 2.46 a | 0.84 b | 0.39 a | 0.31 ab | 0.42 b | 7.13 b |
| 90 | 1.32 a | 1.94 a | 2.49 a | 0.81 b | 0.41 a | 0.37 a | 0.61 a | 7.96 a |
| SE | 0.02 | 0.20 | 0.24 | 0.08 | 0.07 | 0.04 | 0.05 | 0.25 |
| Contrast ‡ | | | | | | | | L**, Q* |

† Treatment means are not different if followed by the same letter (P>0.10) for H1 and (P>0.05) for H2-7.
‡ Orthogonal polynomial contrast for the effect of N rate (L= linear, Q= quadratic= P ≤ 0.05; ** = P ≤ 0.01)

strip of 10 x 3 ft within each plot was randomly selected and harvested to a 4-inch stubble for bahiagrass and stargrass and to 8-inch stubble for limpograss. Plots were harvested using a flail mower and dump wagon to collect the harvested forage. Harvest management was based on growth habit and was similar to that used by producers in the area. Bahiagrass and stargrass pastures (low-sod type) were harvested every 30 days. Limpograss (medium-high sod type) was harvested every 45 days. At each harvest date hand-plucked samples were collected for crude protein (CP), in vitro organic matter digestion (IVOMD), and P concentration determinations. Plots were harvested at relatively constant intervals with the following exceptions: The first bahiagrass harvest scheduled for 5/21/04 was injured because of herbicide drift from an adjacent field. That harvest was therefore skipped and plots were cleaned up to the regular 4-inch stubble and fertilized for the next harvest on 6/21/04. The August stargrass harvest was impacted by armyworm infestation. During 2004 there were a total of seven harvests for bahiagrass, five harvests for limpograss and seven harvests for stargrass. Limpograss harvest was rescheduled after the 7/1/04 harvest from a 35-d to a 45-d frequency in order to improve stand vigor and to prevent stand deterioration due to increased weed competition.

*Table 4. Effects of N fertilizer rate on herbage tissue P concentration and P removal during 2004.*

| N rate (lbs/acre/harvest) | Bahiagrass | | Limpograss | | Stargrass | |
|---|---|---|---|---|---|---|
| | P removal | P conc. | P removal | P conc. | P removal | P conc. |
| | -lbs/acre-- | ----%--- | --lbs/acre-- | ----%--- | --lbs/acre-- | ----%--- |
| 0 | 33 b | 0.37 a | 28 b | 0.28 a | 26 b | 0.25 a |
| 45 | 39 b | 0.31 b | 42 a | 0.26 b | 30 a | 0.20 b |
| 60 | 54 a | 0.31 b | 42 a | 0.27 a | 26 b | 0.18 b |
| 90 | 56 a | 0.30 b | 46 a | 0.26 b | 30 a | 0.19 b |
| SE | 4.7 | 0.02 | 4.3 | 0.01 | 1.8 | 0.01 |
| Effect [b] | L** | L**, Q¶ | L** | L* | C ¶ | L** |

[a] Treatment means are not different if followed by the same letter ($P > 0.05$).
[b] N rate effect on DM yield and herbage P concentration (L= linear, Q= quadratic, $P < 0.05$= **= $P < 0.01$)

*Table 5. . Effects of N rate on crude protein (CP) concentration and in vitro organic matter digestibility (IVOMD) of herbage for the 2004 growing season.*

| N rate (lbs/acre/harvest) | Bahiagrass | | Limpograss | | Stargrass | |
|---|---|---|---|---|---|---|
| | CP | IVOMD | CP | IVOMD | CP | IVOMD |
| | ---------------%--------------- | | | | | |
| 0 | 12 c | 49 c | 7 c | 56 b † | 12 c | 51 b |
| 45 | 14 b | 51 bc | 8 b | 57 b | 14 b | 52 b |
| 60 | 15 b | 51 ab | 9 b | 59 a | 15 a | 53 b |
| 90 | 16 a | 52 a | 9 a | 59 a | 16 a | 54 a |
| SE | 0.3 | 0.5 | 0.2 | 0.6 | 0.3 | 0.7 |
| Effect [b] | L** | L** | L** | L** | L** | L* |

[a] Treatment means are not different if followed by the same letter ($P>0.05$).
[b] N rate effect on CP and IVOMD (L= linear, *$P \leq 0.05$, ** $P \leq 0.01$).

All forage species showed a pronounced positive response to N-fertilizer application (Tables 1-3). Overall, annual forage productivity ranged from 8 to 9 ton/acre (1 ton = 2000 lbs) which is excellent for non-irrigated pastures. Forage productivity often increased with N up to the IFAS recommendation of 60 lbs N/acre per harvest and further yield response to additional N beyond this point was typical small and/or non-significant for most species and harvests. It is expected that the crop response to N-fertilizer may increase over time since the application of high manure rates to attain the required residual soil P levels during the previous year may still have provided some residual N via mineralization of the more recalcitrant organic matter fractions in the manure.

Total P harvested, calculated as forage dry matter yield x tissue P concentration, increased with fertilizer rate (Table 4). Forage P concentrations ranged from 0.30 to 0.37% for bahiagrass; from 0.26 to 0.28% for limpograss; and from 0.19 to 0.25% for stargrass. Although increasing N rate resulted in a slight <u>decrease</u> in P content in the tissue (dilution effect associated with increased growth) overall P removal <u>increased</u> linearly for both bahiagrass and limpograss. Maximum P-removal rates occurred at the highest N rate and corresponded to 56, 46, and 30 lbs of elemental P /acre/yr for bahiagrass, limpograss and stargrass, respectively. This translates to 126, 104, and 68 lbs $P_2O_5$ /acre annually for bahiagrass, limpograss and stargrass, respectively (this is the agronomic P application unit typically used in P-fertilizer recommendations). Long-term hay production may thus provide a viable strategy to reducing residual soil-P of sites.

*(Continued on page 8)*

*(Continued from page 7)*

Forage CP and IVOMD concentration in the herbage (Table 5) increased with increasing levels of N rate. Bahiagrass and stargrass CP increased 4 percentage units each from 12 (0 N) to 16% (90 lbs N/acre) while limpograss increments were more moderate (2 percentage units) from 7 to 9. Digestibility of the grasses (limpograss > stargrass > bahiagrass) was affected uniformly, increasing 3% at the highest fertilization rate compared to the control. So it is concluded that forage productivity, quality, and P-phytoremediation capacity are enhanced by increased N-fertilizer rates.

***Fig. 1. Effect of N rate on nitrate concentration in run off, shallow and deep wells for bahiagrass, limpo grass, and stargrass production systems (Okeechobee, 2004)***

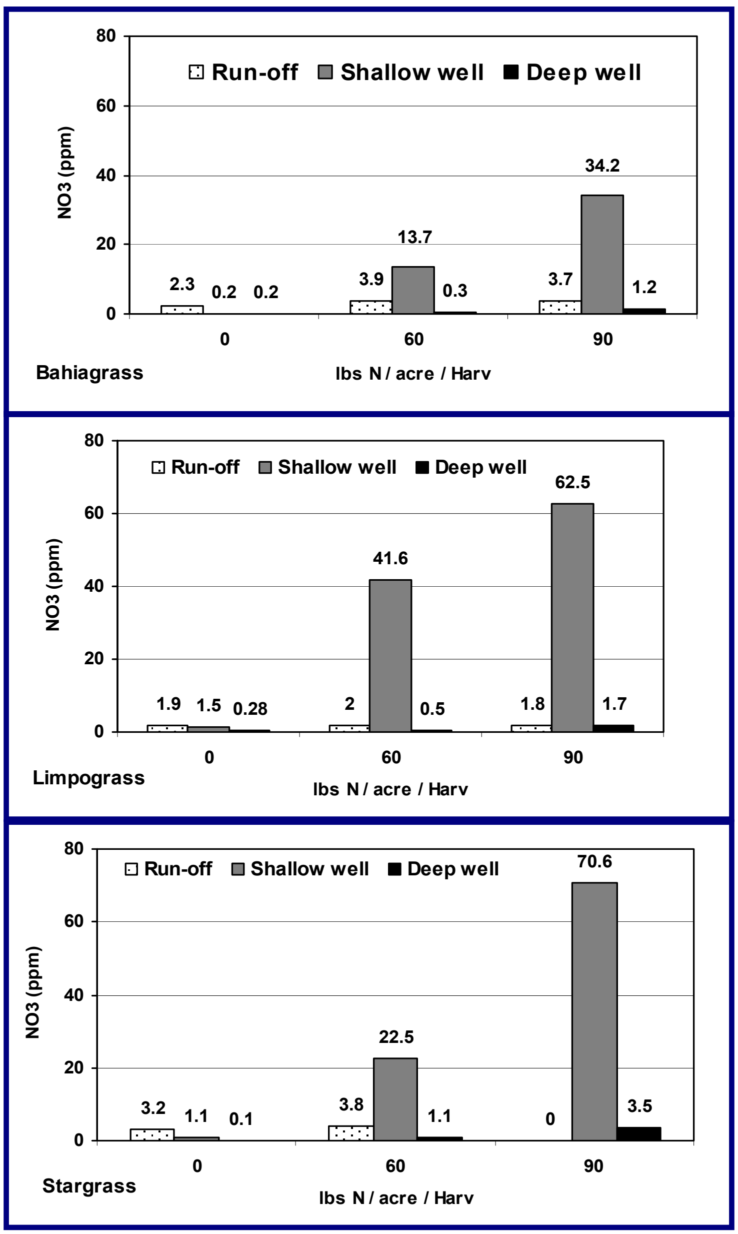
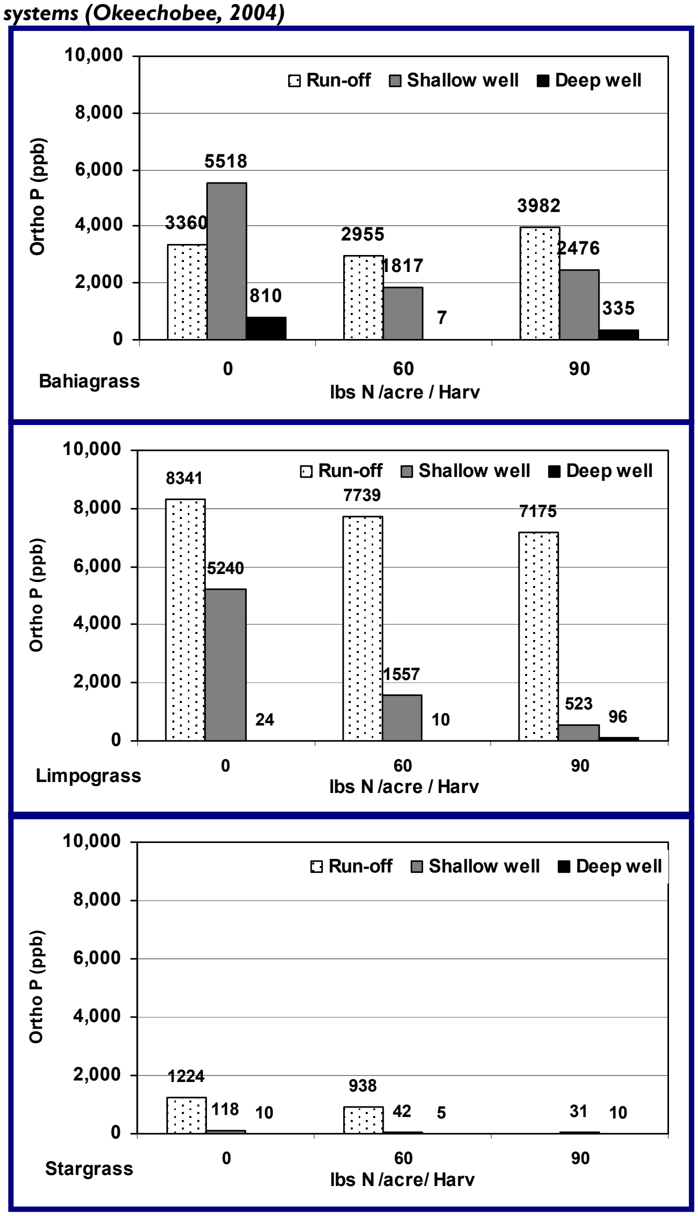



***Fig. 2. Effect of N rate on ortho-P concentration in run off, shallow and deep wells for bahiagrass, limpograss, and star grass production systems (Okeechobee, 2004)***




## Water Quality

During the 2004/2005 growing season we collected water samples from run-off collectors, shallow wells (which were positioned just above the spodic horizon), and deep wells (located just below the spodic horizon). Samples were collected at regular intervals or following major (>1 inch) rainfall episodes and were filtered before storing at -18 °C until chemical analysis (usually within 2 weeks). Samples were analyzed for inorganic phosphorus and nitrate-nitrogen.

Increasing N rates did not result in a significant increase in nitrate concentration of water collected from run-off or deep wells but it did increase nitrate levels in the water collected from shallow wells (Fig. 1). The dissipation of nitrate with increasing water depth may be related to both crop uptake and denitrification, which is commonly observed under anaerobic conditions in Florida associated with perched water tables in spodosols. Soluble reactive phosphorus (SRP) concentrations were much greater for the recently amended production sites (bahiagrass and limpograss) compared to the stargrass site that did not receive any additional fresh manure (Fig. 2). For bahiagrass, an increase in N rate reduced P levels in the shallow and deep wells but it slightly increased surface run-off. For the other grasses, an increase in N rate reduced P concentrations in both surface run-off and the shallow wells. In general, it is concluded that increasing N-fertilizer rates in excess of IFAS recommendation did not appear to result in excessively high nitrate-N levels in either run-off or deep wells.

**Soil Samples (Okeechobee):**

After manure application we allowed for adequate time for the manure to be mineralized and overall soil P levels in the topsoil layer during the spring of 2004 were 25, 26, and 21 ppm phosphorus for Bahia, Limpo and Starr grass, respectively. Representative samples for the Ap, E and Bh soil horizons from each plot were collected during the 2003/2004 winter season. This procedure was repeated at the end the 2004/2005 winter season. Samples were dried, processed and analyzed for Ca, Mg, Fe, Al, P and K by Mehlich I extraction. Based on the 2004 soil sampling results it appears that forage production resulted in an overall reduction in Mehlich-I soil P for bahiagrass of 7, 8, 10, and 13 ppm P for the 0, 45, 60, and 90 lbs N/acre treatments. Corresponding values for limpograss and stargrass were 4, 5, 4, 9; and 5, 6, 14, and 13 ppm P, respectively. Overall, soil P reduction were 17 ppm for the deepest (spodic or Bh) soil layer (this layer typically accumulates most of the P over time), 6 ppm for the surface (Ap) soil layer and 1 ppm for the E-horizon.

**Conclusions**

Although use of soil amendments and wetlands provide partial solutions for reducing P-loading rates of Lake Okeechobee, complementary and more cost-effective solutions may also be required. Current studies demonstrated that increasing N rates, improved forage production and quality and also increased P mining capacity of forage grasses. Although forage P concentration typically decreased with N rate, overall P removal by crop increased up to the IFAS recommended N rate. Overall, annual P removal rates averaged 30, 46 and 56 lbs P/acre (67, 104, and 126 lbs $P_2O_5$/acre) for bahiagrass, limpograss and stargrass, respectively. Phosphorus mining capacity of pasture grasses increased with N rate and overall soil P values decreased by 9-13 ppm during the first year of this study. Reductions in residual soil P in the surface soil layer were on the order of 5-7 ppm compared to a decrease of 15-17 ppm in the spodic layer. Although bahiagrass appears to have the greatest soil P mining capacity, many growers may opt to apply relatively low N rates to bahia pastures which could prevent attainment of the maximum P mining capacity for that grass. Even the cooperating dairy producer stated that our research demonstration results have changed his perception of the responsiveness of bahiagrass to N-fertilizer. Nitrogen concentration in shallow wells increased with N rate but N concentration in deep wells did not significantly increase, possibly due to crop uptake and denitrification. Increasing N-fertilizer rate reduced P concentrations in shallow wells but had no significant effect on P concentrations in run off water during the first year. Continuation of these studies along with parallel studies at the University of Florida's Range Cattle Research and Education Center at Ona will allow us to select the best crops for P-phytoremediation and evaluate the effect of reduced soil P levels on P runoff, pasture productivity, and P mining capacity over time.

**Acknowledgements**

This work was funded by the Florida Department of Agricultural and Consumer Services (FDACS) via grant # 007350. We want to thank John Folks in particular for the continued support of this work. We greatly value the support of the Okeechobee Extension Office agents (Pat Miller and Pat Hogue) for their assistance with identifying suitable collaborators and their help during establishment of field studies. We feel very privileged to be hosted by Buttler Oaks Dairy. Through their southern hospitality and willingness to go the extra mile, they have supported us in many possible way and their continuous collaboration and participation in this project are greatly appreciated. It is inspiring to partner with professionals who are proactive and provide local leadership for best stewardship of land resources managed by them. Last but not least, we want to thank Cindy Holley for her invaluable assistance with the establishment, maintenance, and sampling of field studies.

# Ontologies and Their Application in Agriculture

Camilo Cornejo, Howard W. Beck, Dorota Z. Haman, Agricultural & Biological Engineering

Increasing number of information resources requires improved information management systems. Ontologies provide a new approach for information management, organization, locating information; also facilitate the publication of the information contained in the ontology.

An ontology is a collection of the concepts, their definition, and their interrelationships occurring within a particular domain. They provide a structure for organizing information within a domain. Ontologies are dictionaries in which the definitions are interpretable by machines, giving rise to natural language access to information (multi-lingual resources, ontology-assisted search, and information extraction).

Ontologies are widely used in Knowledge Engineering, Artificial Intelligence and Computer Science, in applications related to knowledge management, natural language processing, e-commerce, intelligent integration of information, information retrieval, database design and integration, and education.

A formal ontology is a controlled vocabulary expressed in an ontology representation language, a model for describing the world that consists of a set of concepts, descriptions or properties, and relationships. This language has a grammar for using vocabulary terms to express something meaningful within a specified domain of interest. However, it is important to remark that the model can only be considered an ontology if it is a shared and consensual knowledge model agreed by a community.

From now on we will be referring to domain ontologies. Domain ontologies are reusable in a given specific domain (medical, engineering, law, irrigation, etc.). These ontologies provide vocabularies about concepts within a domain and the relationships among those concepts, about the activities taking place in that domain, and about the theories and principles present in that domain.

At UF's Agricultural and Biological Engineering Department, domain ontologies are being used to manage content stored in various agricultural databases. Examples include a database of agricultural extension publications, a

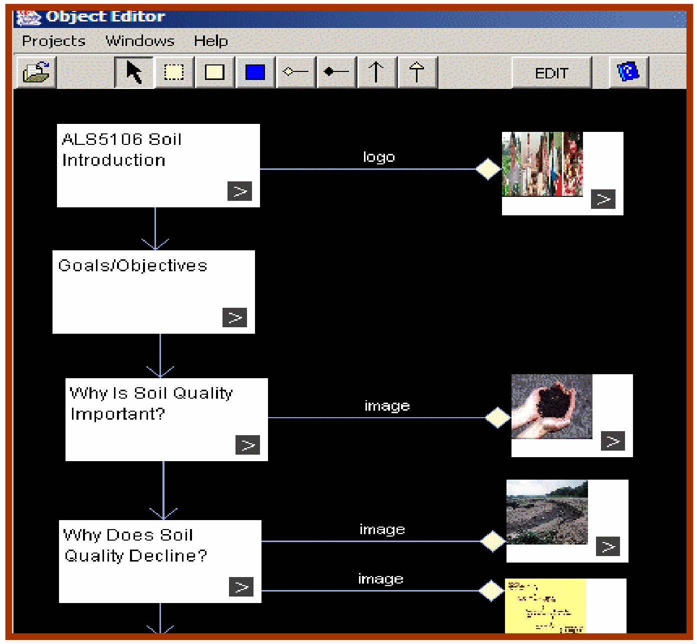



***Figure 1. Content modeling for Ag and Natural Resources (ALS5106)***

content manager for agricultural educational materials, a database of dynamic simulations of irrigation, nutrient management, and an irrigation ontology. The general architecture of all these applications is based on a database that uses an ontology for organizing concepts. A formal language is used to construct an ontology that provides a terminological basis for referring to concepts in the domain. Advantages of incorporating an ontology include better ways of representing concepts, ability to support natural language-based references to objects, graphic browsing based on data visualization of ontologies, and ontology assisted search.

One of the most obvious uses for ontologies is for organizing agricultural information systems consisting of documents, images, and other media. In the short term ontologies provide conceptual maps to which media can be attached and which people can navigate to find information. In the long term, ontology-assisted search (e.g., Amazon's A9® Web Search) promises to give better performance than conventional search engines.

Two courses at UF are being developed using tools like ObjectEditor. Introduction to Visual Programming (AOM4430), and Agriculture and Natural Resources (ALS5106 under development). The second is a course on soil, water, crop production practices, and world trade. Part of the design of the content for this course is presented in Figure 1.

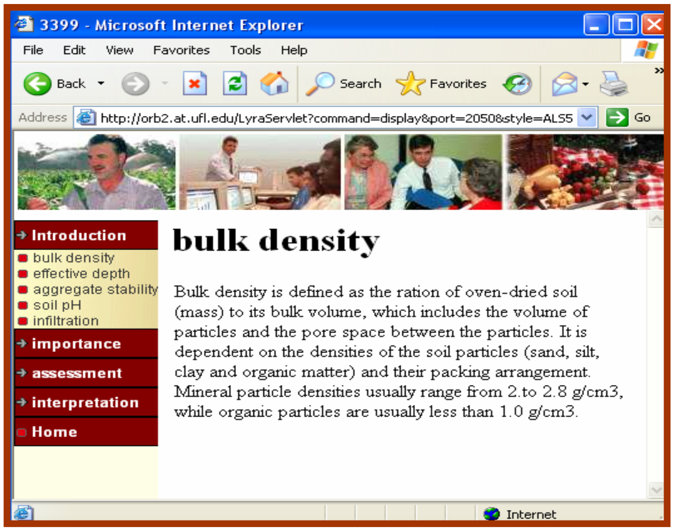



*Figure 2. Web page for Ag and Natural Resources (ALS5106)*

In this course, server-side object-oriented database management system is used to store all content. The ontology is used to model and manage the information. This will facilitate the production materials in multiple formats like web pages, presentations, posters, and leaflets. An example of an automatically generated Web pages created from the stored content is presented in Figure 2. From the same content in the ALS5106's ontology, a presentation can be created using vector graphics. This "PowerPoint-Like" presentation uses Scalable Vector Graphics technology (SVG) to create a slide-show style presentation, again using the same content as in the web page example (Figure 3).


*Figure 3. Presentation for Ag and Natural Resources (ALS5106)*

Another application of ontologies is the irrigation ontology. It covers topics aimed at teaching small-scale farmers basic principles of irrigation (Figures 4). It was created using ObjectEditor (http://orb.ifas.ufl.edu/ObjectEditor/

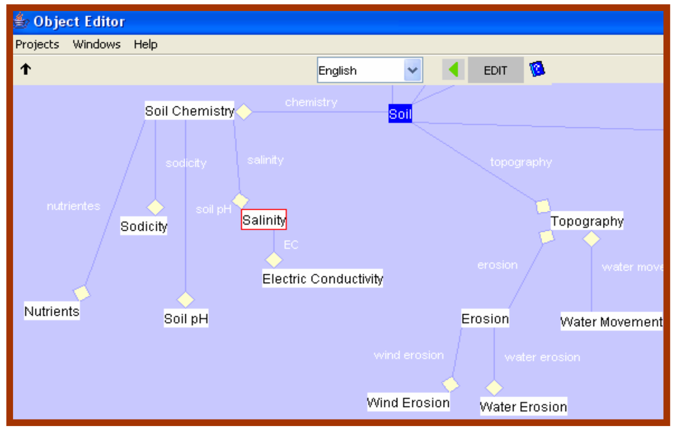



*Figure 4. Section of the soil module from the irrigation ontology.*

index.html). A section of the irrigation ontology covering some soil properties is presented in Figure 4. This ontology-based system provides the capacity to automatically generate presentations in a variety of different styles for a variety of different devices. Produce presentations on-the-fly from the ontology's content based on database queries.

The Rootstock CBR project also developed with ObjectEditor aims at providing an application to help specialist to select the best citrus rootstock according to specific local conditions (Figure 5).

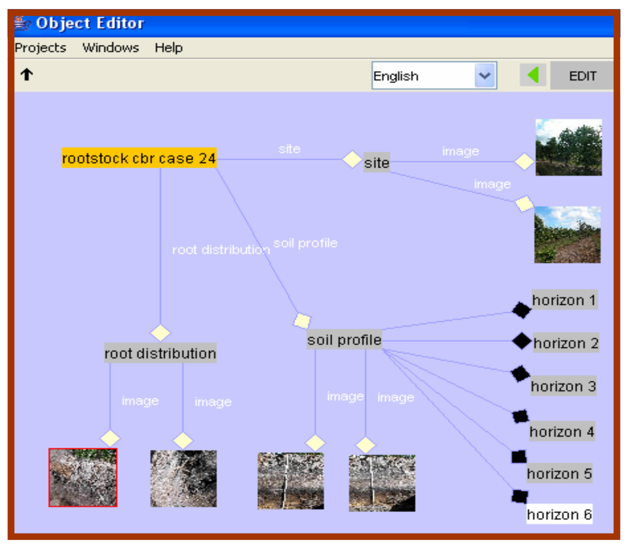



*Figure 5. View of a module from the Rootstock CBR project*

Some applications based on ontologies have been specifically developed for the soil sciences. For example, Renschler and Sorokine created an ontology for soil maps in GIS to help with the representation of soil processes and properties (2004 ASA-CSSA-SSSA), they also produced a soil mapping ontology (2005). As presented here ontology-based systems can also be used to manage course content, and to develop educational materials.

## Municipal Reclaimed Water Provides Reliable Irrigation for Local Golf Course

Peter Kalogridis CCA/CPAg

Far removed from urban Orlando, located in the south west corner of Orange County, Florida a regional golf course enjoys the benefits of the cities reclaimed water resources.

Located on approximately 1000 acres Orange County Regional Golf Center is an important part of the county's water reclamation project. Conserve II is jointly owned by the City of Orlando and Orange County Florida and represents the largest water reuse project of its kind in the World dispersing between 30-35 million gallons per day. Conserve II is permitted to irrigate crops for human consumption as well as for turf and ornamental horticultural crops and provides aquifer recharge through dispersing reclaimed water through rapid infiltration basins (RIBS) which are located throughout the property. Research which is conducted on the Conserve II site is performed entirely by The Mid Florida Research Foundation and is staffed by the faculty from the University's of Florida's Institute of Food and Agricultural Sciences. IFAS has concluded that no negative impacts to plant growth have resulted from the use of reclaimed water. Cooperating agricultural enterprises include citrus groves, ornamental shrub and tree farms, golf courses and even a browse field which grows green leafy plants for consumption by zoological animals located at a local theme park. Currently these agricultural and commercial customers utilize 60% of this reclaimed water while the remaining 40% is discharged through the twelve operating

RIB facilities which are located through out the Conserve II property of which six RIB basins are located on the golf course.

The Orange County National Golf Center utilizes 2 million gallons per day of reclaimed water on its turf areas. These areas include two 18 hole golf courses along with a par three course and a 45 acre driving range. RIB basins hidden between fairways throughout the golf courses disperse another 1 million gallons per day for a total dispersal of approximately one billion gallons of reclaimed municipal water per year. Because the course receives reuse water for irrigation from the City of Orlando there are no pumps to turn off and on. The water is pressurized and as much as one third of the course irrigation water can be applied at one time. The use of reclaimed water eliminates the need for drilling deep wells into the aquifer and causes a net positive effect of water recharging the aquifer instead of placing a demand on the natural underground water system. The reclaimed water also has been shown to enhance the growth of Bermudagrass which is the

dominate grass produced and maintained on these golf courses. Regular water testing is conducted and the data is made available to the golf course superintendent monthly (see graph). These water test results help to identify baseline nutrient capacities present in the reuse water so adjustments to the nutrient program can be made as necessary through out the growing season of the turf. In addition reclaimed water maintains the soil pH within the recommended range for optimum growth of Bermudagrass across the large turf acreage thereby eliminating the need for liming or sulfur applications.

**WATER CONSERV II**
**CITRUS IRRIGATION RECLAIMED WATER**
**CONSTITUENT CONCENTRATIONS**
**1/1/2006**

| CONSTITUENTS | MACL | August | September | October | November | December | January |
|---|---|---|---|---|---|---|---|
| Arsenic | 0.10 | <0.0032 | --- | --- | <0.0032 | -- | -- |
| Barium | 2.0 | 0.014 | 0.012 | 0.013 | 0.012 | 0.011 | 0.012 |
| Beryllium | 0.10 | <0.00052 | --- | --- | <0.00052 | -- | -- |
| Bicarbonate (Alkalinity) | 200 | 116 | 140 | 106 | 137 | 103 | 110 |
| CBOD5 (Carb Biochemical Oxygen Demand) | 30 | 3.2 | 2.1 | 1.8 | 2.1 | 1.8 | 1.2 |
| Boron | 1.0 | 0.130 | 0.150 | 0.150 | 0.140 | 0.160 | 0.140 |
| Cadmium | 0.01 | <0.00296 | --- | --- | <0.00296 | --- | -- |
| Calcium | 200 | 47.0 | 42.0 | 44.0 | 46.0 | 42.0 | 44.0 |
| Chemical Oxygen Demand | 120 | 39 | 27 | 17 | 51 | 86 | 52 |
| Chloride | 100 | 79 | 75 | 74 | 80 | 79 | 78 |
| Chlorine | 10.0 | 0.2 | 0.5 | 0.5 | 0.7 | 1.1 | 0.9 |
| Chromium | 0.01 | <0.0076 | --- | --- | <0.0076 | --- | -- |
| Cobalt | 0.05 | <0.00316 | --- | --- | <0.00316 | -- | -- |
| Copper | 0.20 | <0.0080 | <0.0080 | <0.0080 | <0.0080 | <0.0080 | <0.0080 |
| ECW (umhos) | 1100 | 620 | 613 | 576 | 652 | 663 | 696 |
| Fecal Coliform (CFU/100ml) | <1 | <1 | <1 | <1 | <1 | <1 | <1 |
| Iron | 5.0 | 0.08 | 0.04 | 0.07 | 0.09 | 0.05 | 0.09 |
| Lead | 0.1 | 0.001 | --- | --- | 0.001 | -- | -- |
| Lithium | 0.01 | 0.003 | --- | --- | 0.003 | -- | -- |
| Manganese | 0.20 | 0.012 | 0.007 | 0.007 | 0.008 | 0.006 | 0.012 |
| Magnesium | 25.0 | 7.9 | --- | --- | 8.3 | -- | -- |
| Mercury | 0.01 | <0.00008 | --- | --- | <0.000024 | -- | -- |
| Nickel | 0.20 | <0.0120 | --- | --- | <0.0120 | -- | -- |
| Nitrite | --- | 0.692 | 0.017 | <0.08 | <0.08 | 0.003 | 0.011 |
| Nitrate | --- | 5.34 | 6.02 | 5.28 | 5.73 | 5.58 | 5.88 |
| Nitrogen (Total) | 30 | 7.79 | 7.20 | 6.35 | 6.95 | 7.00 | 7.67 |
| Phosphorus | 10 | 1.31 | 1.90 | 0.92 | 1.30 | 1.81 | 1.57 |
| pH | 6.0-8.5 | 6.8 | 6.9 | 7.1 | 7.0 | 7.0 | 6.9 |
| Potassium | 30 | 12.0 | 11.0 | 14.0 | 15.0 | 13.0 | 14.0 |
| Selenium | 0.02 | <0.00360 | --- | --- | <0.00360 | --- | -- |
| Silver | 0.05 | <0.00840 | <0.00370 | <0.00840 | <0.00840 | <0.00840 | <0.00840 |
| Sodium | 70 | 59.8 | 59.0 | 58.8 | 61.2 | 58.8 | 60.5 |
| Sulfate | 100 | 33.6 | 36.4 | 31.7 | 37.8 | 30.3 | 32.1 |
| Total Suspended Solids | 5 | <1 | <1 | <1 | 1 | 1 | 1 |
| Zinc | 1.0 | 0.050 | 0.075 | 0.055 | 0.073 | 0.048 | 0.058 |

NOTES: 1. MACL - Maximum Average Concentration Limits
2. Limits in mg/l unless otherwise noted.
* No results due to lab error
---- Not Sampled

Perhaps the most important aspect of the reclaimed water project is the cooperative effort that exists between the City of Orlando and the other cooperators within the Conserve II system. According to Carl Benedict, Golf Superintendent for Orange County National cooperation among the users of reclaimed water is the key that keeps this operation running smoothly year round. "We have well over 60,000 rounds of golf played here annually which is like having all the fans at Tampa Stadium take a walk across our greens every year. Without cooperation among the conserve partners we would not be able to maintain this golf course to the condition to which it deserves." To maintain approximately 1000 acres of turf areas which comprise the golf center takes no less than a small army of dedicated employees. Currently there are 45-50 full time maintenance staff employees who utilize a fleet of over twenty five mowers and fifteen pieces of support implements for seasonal cultural practices. This staff includes full time irrigation specialists, pest control technicians along with three in house mechanics to maintain the daily repairs requirements along with preventative maintenance schedules.

In the years to come the use of reclaimed water will continue to increase. Other user groups are beginning to utilize reclaimed water. The area around the golf course is slated for urban development under the Horizons West Planned Urban Development (PUD) Plan. Demand for reclaimed water is expected to grow to the point that in 2013 The City of Orlando will begin charging the golf course for daily water usage. Therefore the future for reclaimed water utilization as a marketable commodity looks favorable and should insure this method of natural resource recovery here in Florida. For additional information refer to www.WaterConservII.com.

# Nitrogen and Irrigation Management: Is it possible to improve water use efficiency and reduce nitrate leaching of vegetables crops in Florida?

L. Zotarelli and J. M. Scholberg, Agronomy
M. D. Dukes and R. Munoz-Carpena, Agricultural & Biological Engineering

## Introduction

In Florida about 250,000 acres are under vegetable production and with a crop value of 1.3 billion dollars, vegetables are a major component of Florida agriculture. Tomatoes and peppers account for approximately 17% and 7% of the Florida vegetable acreage and have a combined crop value of more than 0.7 billion dollars. Most Florida soils have poor water and nutrient retention and thus are prone to nutrient leaching. Historically, excessive applications of water and nutrients were perceived to be a "cheap insurance premium" to minimize the risk of yield reductions associated with potentially unfavorable production conditions and a viable strategy to maximize profits. However, poor soil nutrient retention combined with excessively high N-fertilizer/irrigation rates and leaching rainfall events also greatly increased the risk of nitrate leaching.

Introduction of plastic mulch and drip irrigation reduced evaporation and thereby increased crop water use efficiency (WUE). Use of drip irrigation also facilitated frequent fertilizer injection in the irrigation system (fertigation), which allowed growers to improve the synchronization between nutrient application and crop nutrient uptake. On soils with poor nutrient retention, fertigation combined with plastic mulch thus may reduce nutrient leaching. However, more stringent environmental regulations and water use restrictions have placed additional production constraints on growers. During the past decade development of Best Management Practices (BMPs) facilitated more efficient use of water and nutrients and thereby allowed growers to remain in compliance with environmental regulations. Since Florida's soils have poor water and nutrient retention, improved irrigation management will be a key requirement for more efficient fertilizer use and thereby a critical component of fertilizer BMPs.

Our research program aims to combine technological advances in soil moisture monitoring with innovative irrigation system designs and thereby further reduce irrigation water requirements, N leaching, and environmental impacts associated with commercial vegetable production systems. The specific objectives of our study were to develop and evaluate irrigation systems/practices and to determine the interactive effects of irrigation practices and fertilizer rates on yield, fertilizer requirements, fertilizer use efficiency, and N-leaching of pepper and tomato production systems.

| Crop | Symbol | Description | VWC (%) | Volume Applied (mm) | N applied (kg ha$^{-1}$) | | |
|---|---|---|---|---|---|---|---|
| | | | | | 0.8 | 1.0 | 1.5 |
| Pepper | $L_{SI}$ | Low volume, surface irrigation and fertigation drip (QIC) | 10 | 122 | 154 | 192 | 288 |
| | $M_{SI}$ | Medium volume, surface irrigation and fertigation drip (Acclima) | 13 | 213 | 154 | 192 | 288 |
| | $F_{SI}$ | Farmer fixed irrigation schedule | >13 | 333 | 154 | 192 | 288 |
| Tomato | $L_{SI}$ | Low volume, surface irrigation and fertigation drip (QIC) | 10 | 135 | 166 | 208 | 312 |
| | $M_{SUI}$ | Medium volume, subsurface irrigation and surface fertigation drip (QIC) | 10 | 250 | 166 | 208 | 312 |
| | $F_{SI}$ | Farmer fixed irrigation schedule | >13 | 277 | 166 | 208 | 312 |

***Table 1. Irrigation and fertilization treatments.***

### Experimental conditions and treatments

Experiments were conducted at the Plant Science Research and Education Unit (PSREU) near Citra, FL. Bell peppers and tomatoes were planted on April 7th 2005 on plastic mulched using a bed spacing of 1.8m. Peppers were planted using twin rows spaced at 0.3 m with an in-row plant spacing of 0.3 m. Tomatoes were planted in single rows using a 0.3 m in-row spacing. The pepper and tomato trial evaluated the interactive effects of three nitrogen fertilizer rates (80, 100 and 150% of IFAS recommendation using $CaNO_3$ as N source) and three irrigation scheduling methods on crop production, N leaching and water use efficiency. Weekly fertigation rates for K and N were based on IFAS recommendation. An overview of experimental treatments and irrigation amounts is provided in Table 1. Crop water use (ETc) was based on a generic IFAS approach for calculating ET using climatic parameters obtained from a nearby FAWN station.

The following irrigation scheduling techniques were used for pepper:

1) $M_{SI}$ - use of a UF designed (QIC) irrigation control system that allowed time-based irrigation (up to 5 events per day) if TDR-measured soil water dropped below a volumetric water content (VWC) value of 13%;

2) $L_{SI}$ - use of commercially available "Acclima" soil moisture sensor with a VWC threshold value of 10 or 13% to allow time-based irrigation similar to the previous treatment;

3) $F_{SI}$ - "farmer" treatment with irrigation being applied at fixed daily durations of two hours per day.

The tomato study included the following irrigation scheduling/placement treatments:

1) $M_{SUI}$ - surface fertigation and subsurface irrigation (irrigation line was placed 15 cm below the bed surface to reduce N leaching) where subsurface irrigation was controlled by the QIC sensor with the threshold set at field capacity (~ 10%VWC);

2) $L_{SI}$ - surface drip fertigation and irrigation combined with the QIC irrigation control system and a threshold value set at field capacity;

3) $F_{SI}$ - "farmers" treatment with surface applied irrigation and fertigation using "fixed" irrigation times of 1-2 hours per day depending on the crop growth stage.

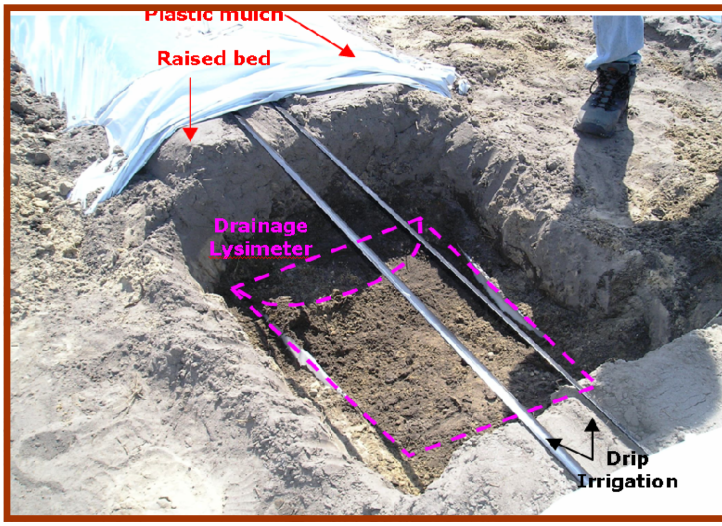



*Figure 1. – Overview of drainage lysimeters relative to bed geometry and the position of drip lines.*

Leacheate volumes were measured by drainage lysimeters that were constructed out of 208 L capacity drums cut in half lengthwise (Fig. 1). Lysimeters were buried approximately 0.75 m (2.5 ft) below the bed surface and the leachate was removed weekly one day prior to the next fertigation event by applying a partial vacuum (Fig. 2). Leachate volume was determined gravimetrically and subsamples were collected from each bottle for $NO_3$-N


*Figure 2. – Overview of vacuum system of drainage lysimeters in tomato field.*

*(Continued on page 16)*

*(Continued from page 15)*

analysis. Total N loading rates were calculated by multiplying leachate volume by N concentration for a representative production area. Composite soil samples were taken at the 0-30, 30-60, and 60-90 cm soil depths at two week intervals six days after the previous fertigation event and samples were analyzed for $NO_3$-N. Soil moisture was determined using TDR probes, capacitance probes installed in selected plots, or calculated from water loss of representative soil samples after drying.

## Research Findings

### Plant Growth

Plant growth of pepper during the first six weeks was not significantly affected by either irrigation or N rate. There was no clear response to N rate with the "Acclima" controller using a set-point of 13% VWC ($L_{SI}$) during most of the growing season but final plant biomass was greatest for the N2 treatment (IFAS recommendation). Using a higher (wetter) set point with the Acclima ($M_{SI}$) resulted in higher irrigation rates and a modest increase in plant growth but also required 50% higher N rates to attain maximum growth. However, even in this case final biomass was not increased at N rates above IFAS recommendation. For the farmer's treatment ($F_{SI}$) overall plant growth was typically also best following IFAS N-recommendations. For tomato placing the irrigation line 15 cm (6 inches) below the irrigation line (which is an innovative approach unique to this program) reduced leaching (Fig. 3) and thereby resulted in more efficient N-fertilizer use, and optimal plant growth was attained at 80% of the IFAS rate. Use of surface applied irrigation with a similar sensor showed no such benefits and with the farmer based irrigation treatment 70% extra fertilizer was required to attain similar growth. However, the subsurface treatment over-irrigated during initial growth before plant roots reached the water and sensor settings may have to be modified to further reduce water losses.

### Crop yield, irrigation requirements and water use efficiency

Pepper yields were highest with $M_{SI}$ followed by $L_{SI}$ and $F_{SI}$ (Table 2). With the use of the "Acclima" soil moisture sensors marketable fruit yield increased with greater cumulative irrigation rates (higher VWC% settings). Although the "QIC" sensor ($L_{SI}$) and farmer treatment ($F_{SI}$) received higher irrigation depths, yield and water use efficiency (WUE) were lower for these treatments. Maximum pepper yields could be attained at IFAS N-recommendation rates, except when excessive amounts of irrigation were applied (farmer's treatment). Tomato yields were similar for $M_{SUI}$ and $L_{SI}$ and lowest for the farmer's treatment (Table 2). With $L_{SI}$ there was no significant response to N rate whereas with $M_{SUI}$ both yield and WUE

| Irrigation Treatm. | 0.8 IFAS (N1) Yield (t ha$^{-1}$) | 0.8 IFAS (N1) Irrig. (mm) | 0.8 IFAS (N1) WUE (kg frt m$^{-3}$) | 1.0 IFAS (N2) Yield (t ha$^{-1}$) | 1.0 IFAS (N2) Irrig. (mm) | 1.0 IFAS (N2) WUE (kg frt m$^{-3}$) | 1.5 IFAS (N3) Yield (t ha$^{-1}$) | 1.5 IFAS (N3) Irrig. (mm) | 1.5 IFAS (N3) WUE (kg frt m$^{-3}$) | Average Yield (t ha$^{-1}$) | Average Irrig. (mm) | Average WUE (kg frt m$^{-3}$) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Pepper** | | | | | | | | | | | | |
| $M_{SI}$ | 18.6 | 315 | 6.4 | 21.5 | 309 | 8.0 | 20.9 | 309 | 7.6 | 20.3 b | 311 | 7.3 b |
| $L_{SI}$ | 22.7 | 126 | 19.2 | 25.4 | 120 | 21.5 | 24.2 | 120 | 21.2 | 24.1 a | 122 | 20.6 a |
| $F_{SI}$ | 23.3 | 337 | 7.6 | 23 | 331 | 7.3 | 27.7 | 331 | 8.8 | 24.7 a | 333 | 7.9 b |
| **Average** | **21.5** | **259** | **11.6** | **23.3** | **253** | **12.2** | **24.3** | **253** | **12.5** | **23.0** | **255** | **11.9** |
| **Tomato** | | | | | | | | | | | | |
| $L_{SI}$ | 33.6 | 132 | 27.6 | 33.3 | 184 | 19.0 | 33.1 | 136 | 25.4 | 33.3 a | 151 | 24.0 a |
| $M_{SUI}$ | 29.6 | 246 | 13.7 | 30.4 | 250 | 13.6 | 33.9 | 251 | 15.0 | 31.3 a | 249 | 14.1 b |
| $F_{SI}$ | 15.5 | 274 | 7.8 | 18.7 | 278 | 8.4 | 22.1 | 278 | 9.6 | 18.8 b | 277 | 8.6 c |
| **Average** | **26.2** | **217** | **16.4** | **27.5** | **237** | **13.7** | **29.7** | **222** | **16.7** | **27.8** | **225** | **15.6** |

***Table 2. Irrigation treatments and N rate effects on marketable fruit yield, irrigation use, and water use efficiency (WUE) for pepper and tomato.***

increased with N rate. Increased N requirements and reduced yield at lower N-fertilizer rates with the farmer's treatments may be related to excessive N leaching below the root zone.

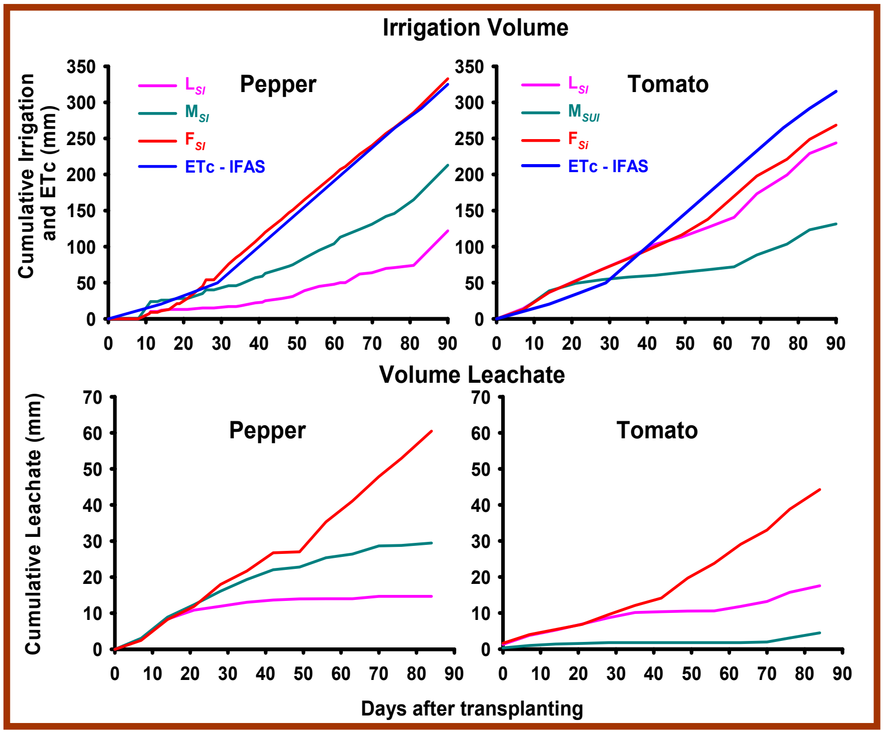



*Figure. 3 - Cumulative irrigation, calculated cumulative crop evapotranspiration (ETc) using IFAS calculations and cumulative leaching on drainage lysimeters.*

## Soil water and nitrate leaching

For pepper, use of a higher irrigation set point ($L_{SI}$ vs $M_{SI}$) increased VWC of the topsoil by 1-2 % and resulted in deeper wetting patterns (50-60 cm [20-24 inches] for $M_{SI}$ vs 40-50 cm [16-20 inches] for $L_{SI}$). In contrast with sensor based treatments, the top soil of the farmer treatment remained much wetter and wetting patterns extended up to 50-70 cm. For tomato, use of buried drip irrigation ($M_{SUI}$) did not affect soil moisture at the soil surface compared to the use of surface applied drip irrigation ($L_{SI}$), but it did result in 2-5% greater VWC values at the lower soil layers. Although this did not result in excessive N leaching (since the fertigation line is positioned above the irrigation line), it did reduce WUE as shown in Table 2. The farmer treatment ($F_{SI}$) showed fairly high VWC towards the end of the season when daily irrigation duration was increased to 90 minutes. In this case high VWC values did result in excessive N leaching and thereby increased the amount of fertilizer required for optimal yield.

Overall leaching amounts for pepper were 15, 27, and 60 mm, for $L_{SI}$, $M_{SI}$, and $F_{SI}$ respectively (Fig. 3). Nitrate leaching increased with irrigation and N rate (Fig. 4) and measured values ranged from 8 to 60 kg N $ha^{-1}$ (7-54 lbs N $ac^{-1}$). The farmer treatment ($F_{SI}$) had the highest N loading rates and appropriate use of soil sensor based irrigation reduce N leaching by 33 to 67%. Application of N-rates above IFAS recommendation increased N leaching by 186, 38 and 46% for $L_{SI}$, $M_{SI}$ and $F_{SI}$, respectively. Overall leaching amounts for tomato were on the order of 17, 5, and 43 mm, for $M_{SUI}$, $L_{SI}$, and $F_{SI}$ respectively (Fig 3). Nitrate leaching increased with irrigation and N rate (Fig. 4) and measured values ranged from 3 to 60 kg N $ha^{-1}$ (3-54 lb N $ac^{-1}$). The farmer treatment ($F_{SI}$) again resulted in highest N loading rates, whereas soil sensor based irrigation reduced N leaching by 89 to 95%. Appropriate use of this irrigation scheduling technique thus appears to be very promising.

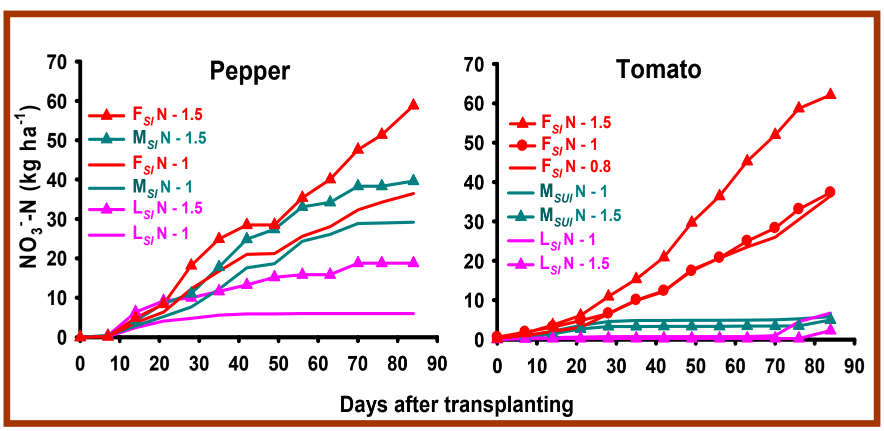



*Figure. 4 - Cumulative $NO_3$-N leaching amounts for pepper and tomato crops collected in drainage lysimeters at 75 cm for different irrigation and N fertilizer treatments.*

Despite a three fold increase in leachate volume for the buried drip irrigation system ($M_{SUI}$), this did not resulted in an appreciable increase in N leaching even at N application rate of 150% of the IFAS recommendation rate since the fertilizer line was positioned 15 cm above the irrigation line. We aim to refine the sensor settings during following years to minimize inefficient water use during initial growth. However, when properly managed, this approach should greatly reduce N displacement below the root zone after fertigation events and thereby

*(Continued on page 18)*

*(Continued from page 17)*

enhance crop N uptake and reduce N leaching as discussed below.

Results of soil sampling of pepper beds are shown in Fig. 5. In the upper row of graphs results are shown for the IFAS recommendation rate compared to the 1.5 IFAS rate (bottom row). Reduced irrigation rates ($L_{SI}$) resulted in higher residual soil N values six days after fertigation events. Increasing irrigation rates, on the other hand, resulted in dilution and/or displacement of fertilizer-N ($M_{SI}$ and $F_{SI}$) within 6 days after application and there by greatly reduce fertilizer use efficiency. Increasing fertilizer rates by 50%, increased residual soil N values by 100 to 350%. Although this increase may not necessary result in additional yield benefits it will increase potential N leaching. In the case of $F_{SI}$ leaching was often very intense resulting in complete N displacement prior to soil sampling and residual soil N values were invariably low despite high N application rates. For tomato, use of buried drip irrigation ($M_{SUI}$) resulted in improved nutrient retention and higher residual soil N levels in the upper part of the production bed (Fig. 6). The benefits of this system were most pronounced at the IFAS recommendation rate (N2). Similarly as for peppers, use of the farmer based irrigation ($F_{SI}$), resulted in excessive leaching and therefore relatively low residual soil N values and higher fertilizer requirements.

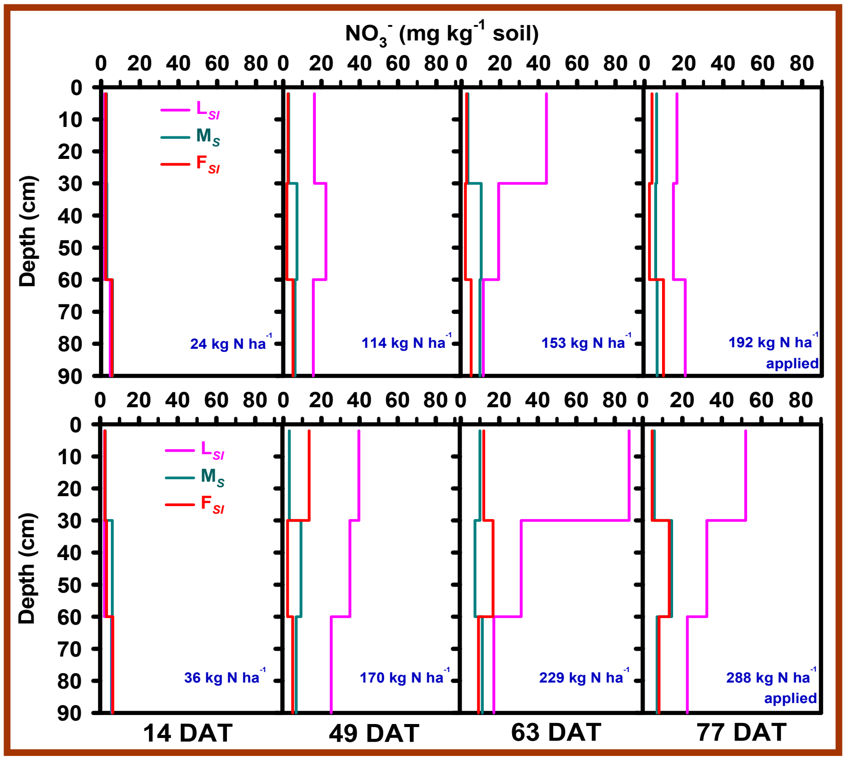



*Figure. 5 - Soil nitrate concentration (mg $NO_3$-N kg$^{-1}$ of soil) in the soil profile of peppers bed for the 192 (upper graph) and 288 (lower graph) kg N-fertilizer ha$^{-1}$ rate 14, 49, 63 and 77 days after peppers were transplanted. The blue values within each graph refer to the cumulative amount of fertilizer applied since transplanting.*

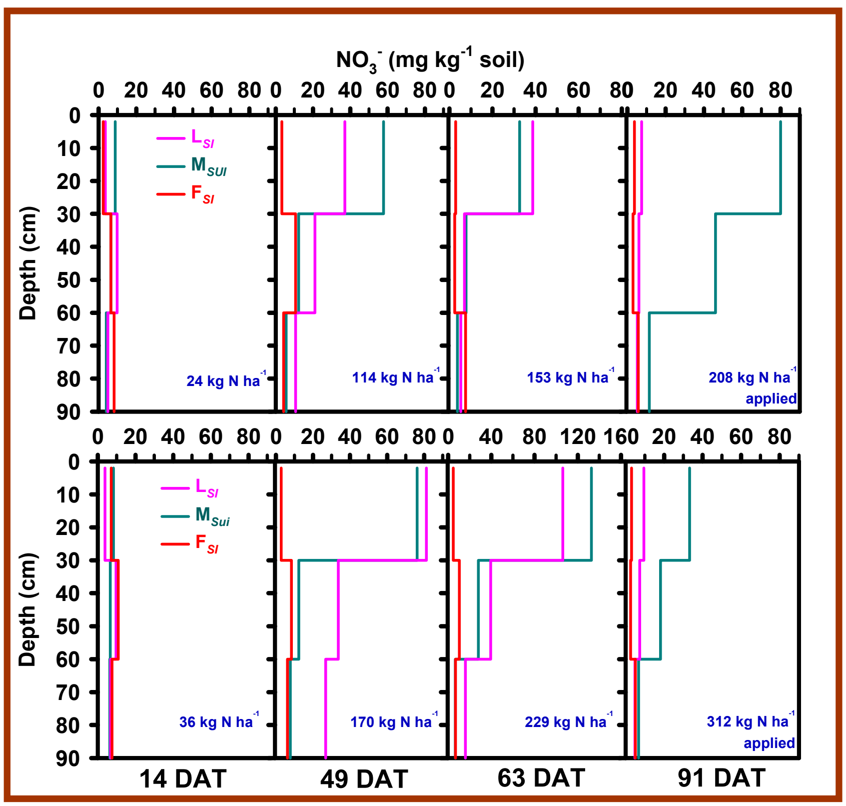



*Figure. 6 - Soil nitrate concentration (mg $NO_3$-N kg$^{-1}$ of soil) in the soil profile of tomato bed for the 192 (upper graph) and 288 (lower graph) kg N-fertilizer ha$^{-1}$ rate 14, 49, 63 and 77 days after tomatoes were transplanted. The blue values within each graph refer to the cumulative amount of fertilizer applied since transplanting.*

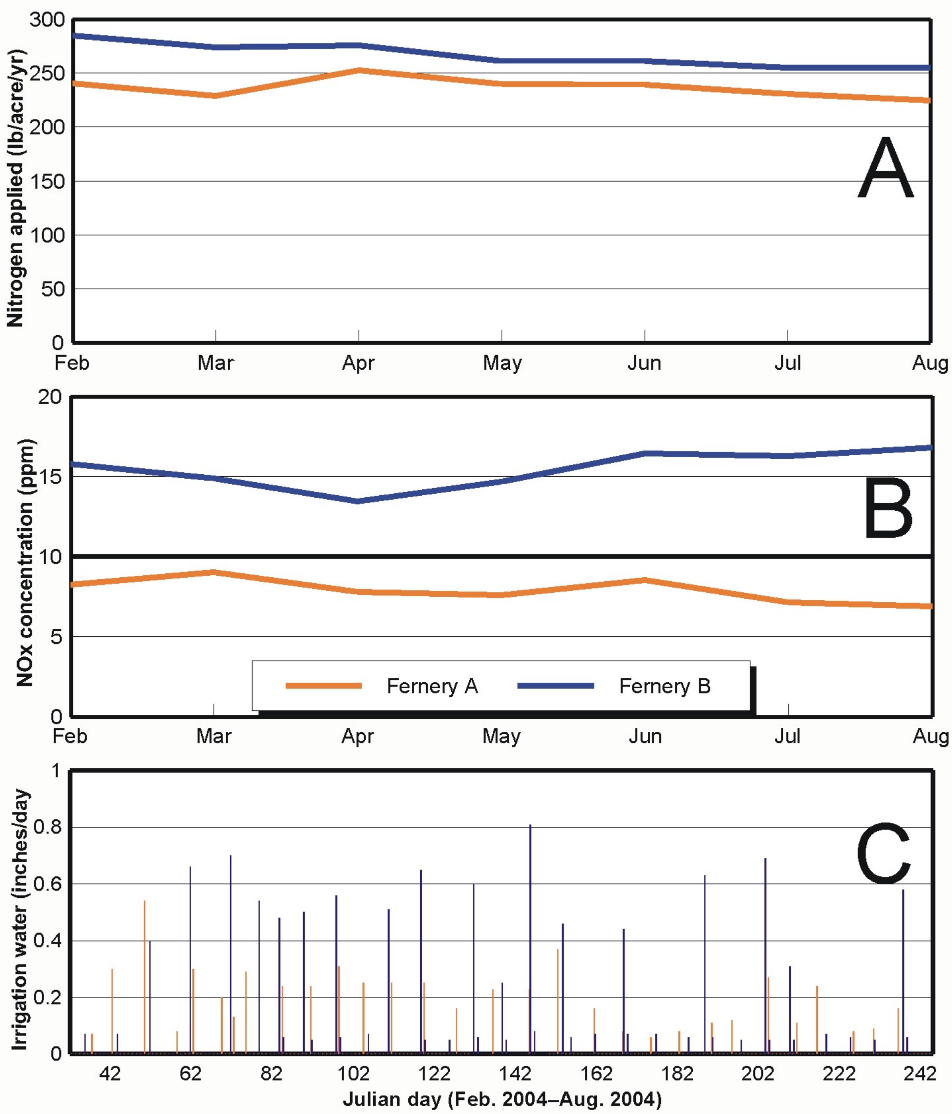
In conclusion, use of soil sensor based irrigation allowed more efficient use of irrigation water and thereby decreasing water displacement below the active root zone. It also greatly reduced N leaching and increased N retention in the upper soil layer there by facilitating more efficient fertilizer use. Placing the irrigation line below the fertigation line did not affected the crop yields but it reduced nitrate leaching via improved nutrient retention in the active root zone compared to the conventional treatments. However, additional fine-tuning of this system may be required to ensure more efficient use of irrigation water.

# Irrigation and Nutrient Management in Two Leatherleaf Ferneries

Robert H. Stamps and George R. Hewlett, Jr., Environmental Horticulture,
Mid-Florida Research and Education Center, Apopka

Despite the introduction of numerous competitive products and increased competition from areas with lower production costs, leatherleaf fern continues to be the predominant cultivated cut foliage (florists' green) crop in Florida where it is grown on highly permeable soils with high leaching potentials. We have been monitoring the surficial aquifer under six commercial ferneries in our efforts to determine the effects of irrigation and nutrient management practices on the leaching of nitrate/nitrite nitrogen ($NO_x$-N).

***Figure 1. Nitrogen (N) application rates, $NO_x$-N concentrations in the surficial aquifer and irrigation events and quantities as monitored at two leatherleaf ferneries.***




It is interesting to note that the two ferneries with the most similar nitrogen application rates are the two with the most disparate $NO_x$-N concentrations in the water directly below the ferneries. Fernery A is situated on Tavares fine sand and the soil under Fernery B is Astatula fine sand. Both soils have very low available water holding capacities (0.02–0.05 in/in) and, as mentioned above, very rapid (20+ in/hr) permeabilities. Figure 1A shows the trends in the annual nitrogen application rates at the two ferneries. The monthly nitrogen-applied numbers shown are the running averages for the previous twelve months of nitrogen fertilizer applications. Both growers were using liquid 8-0-8 fertilizer that was applied through the irrigation systems on a more or less weekly basis. Annual nitrogen application rates ranged from 225 to 252 and from 255 to 285 lb/acre for Ferneries A and B, respectively. During the seven month period shown in the figure, Fernery B's nitrogen application (on an annual basis) averaged 267 lb/acre compared to 237 lb/acre for Fernery A. Therefore, the nitrogen application rate for fernery B was about 13% higher than for Fernery A.

Despite this fairly small difference in nitrogen application rates, the $NO_x$-N concentrations, as determined by averaging the values for the top four water producing ports from five multi-level samplers at each site, were quite different (Fig. 1B). $NO_x$-N concentrations at Fernery A ranged from 6.9 to 9 ppm and

*(Continued on page 20)*

## Irrigation and Nutrient Management in Two Leatherleaf Ferneries (cont.)

*(Continued from page 19)*

averaged 7.9 ppm compared to a range of 13.4 to 16.8 ppm and an average of 15.5 ppm for Fernery B. $NO_x$-N concentrations in the surficial aquifer at Fernery B were consistently about twice as high as those at Fernery A.

The organic matter content (%) and cation exchange capacities were somewhat higher (1.8% and 3.2) at Fernery A than at Fernery B (1.4% and 2.9). These soil differences could have had some effect on $NO_x$-N concentrations but another factor that could be significant is differences in the management of the irrigation systems at the two sites.

Figure 1C is a record of the frequency of irrigation events and the amounts of water applied at each event as determined using calibrated flowmeters connected to battery-powered dataloggers. Water was applied 40% more frequently (42 events) and in about 35% greater amounts (0.27"/event) in Fernery B than in Fernery A (30 events averaging 0.2"/event) and, therefore, the amount of time that the applied nitrogen remained in the root zone of this shallow-rooted crop may have been reduced in Fernery B. In addition, the irrigation management practices may have been at least partially responsible for differences in the root zone depths at the two ferneries. Average root depths were only 5.8" at Fernery B and were 29% deeper (7.5") at Fernery A.

Tracer studies using potassium bromide have confirmed the longer retention time of nutrients in Fernery A as compared to Fernery B (data not shown). In addition, soil water potentials measured using recording tensiometers show that the soil is allowed to become much drier in Fernery A and, therefore, to frequently have greater water-storing capacity than the soil in Fernery B (data not shown). The lowest average daily water potential for Fernery B was –13.7 while at fernery A values as low as –87 kPa were recorded.

Irrigation system management is a key factor when producing a crop like leatherleaf fern and growers should not overlook the effects that it can have on nitrogen leaching as well as crop production and health.

**This newsletter was created to disseminate information on current projects in the Nutrient Management area. If you would like to submit an article for inclusion in a future newsletter please contact:**

**Susan Curry**
**PO Box 110290**
**Soil & Water Science**
**University of Florida**
**Gainesville, FL 32611**
**(352) 392-1951**

**IFAS SOIL & WATER SCIENCE**

**Rao Mylavarapu**
**PO Box 110290**
**University of Florida**
**Gainesville, FL 32611**

**Phone: 352-392-1951**
**Fax: 352-392-3092**
**Email: raom@ufl.edu**

nutrients.ifas.ufl.edu

UNIVERSITY OF FLORIDA
IFAS EXTENSION