Mission Statement for Soil and Crop Science Society of Florida

The objectives of the Soil and Crop Science Society of Florida shall be those of an educational and scientific corporation qualified for exemption under Section 501 (c)3 of the Internal Revenue Code of 1954 as amended, or a comparable section of subsequent legislation, in order that the Society is: 1) To advance the discipline and profession of soil and crop science in Florida a) by fostering excellence in the acquisition of new knowledge and in the training of scientists who work with crops and soils, b) through the education of Florida citizens, and c) by applying knowledge to challenges facing the State, and 2) to contribute to the long-term sustainability of agriculture, soils, the environment, and society by using scientifically-based principles of soil and crop science to promote informed and wise stewardship of Florida's land and water resources.

The Soil and Crop Science Society of Florida provides a non-regulatory and non-political forum to foster scientific ideas and exchange of information for those interested in agricultural production and the sustenance of the agro-ecosystem in Florida. The mechanisms by which this society fosters exchange and displays of objective information include: 1) The presentation, at annual meetings, of papers by those who have completed scientifically-designed and analyzed data on subject matter that is pertinent to agriculture and environmental quality. 2) The publication of scientifically-designed treatments and analyzed experiments in papers on specific subject matters that are peer reviewed and published in a long-standing series of the Proceedings (Soil and Crop Science Society of Florida Proceedings). 3) The publication of position papers in the Proceedings that are needed by those who design laws and statutes on contemporary and applied subject matters related to agriculture and the environment in Florida that require objective viewpoints based on scientifically-attained information. 4) The fostering and training of students to participate in scientific dialogue by providing them with a competitive forum at the annual meeting of the Society where they can present their scientifically-attained data on agriculture and the environment and by providing them with opportunities to interact with professional people from universities, commercial companies, agribusiness, and growers. 5) The establishment of educational credits (e.g. C.E.U.s) which allow professionals to maintain their competency and certified status.


Logo of the Soil and Crop Science Society of Florida. At the 40th Annual Business Meeting at 1120 h, 8 Oct. 1980 at the Holiday Inn, Longboat Key, Sarasota, FL, a report was presented by the ad hoc Logo Committee composed of J. J. Street, Chair, R. S. Kalmbacher, and K. H. Quesenberry. All Society members were eligible to participate in the contest which would result in the selection of a logo design for the SCSSE. The presentation of the winning entry would be made at the 1981 Annual Meeting. David H. Hubbell was announced as the winner of the contest and was awarded a free 10-yr membership in the Society. The design, shown above, depicted the chief interests of the Society: Florida Soils, and Crops. Soils and Crops were given equal weight with Florida. Soils was depicted as the soil texture triangle which shows the percentage of sand, silt, and clay in each of the textural classes, but simplified so as to permit clarity in reduction when printed. Crops was shown as a stylized broadleaf plant, including the roots. Florida was shown, minus its keys, with only one physical feature in its interior, Lake Okeechobee. Enclosed within nine rays such as might be envisioned as being made by the sun emitting light (sunburst) behind the symbols are two concentric circles containing the words "SOIL AND CROP SCIENCE SOCIETY" in the top semicircle and "FLORIDA" at the bottom of the lower semicircle. A schematic likeness of the State of Florida occupies 0.5 of the area within the smaller circle, while the symbol for Soils and the symbol for Crops occupy 0.25 of the area each, with the sum of the three parts totalling unity.

The first printing of Society stationery following the award on 28 Oct. 1981, and the printed program of the Society since the 1982 meetings, have featured the logo.

V. E. Green, Jr., Editor, Volume 45
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This Proceedings of the Soil and Crop Science Society of Florida is dedicated to the memory of Dr. Martin Bani Adjei, Associate Professor, University of Florida, Range Cattle Research and Education Center, Ona. Dr. Adjei was tragically killed in an automobile accident on August 15, 2006 near his home in Arcadia, Florida. Dr. Adjei was born on November 11, 1948 in Aburi Ghana West Africa. He grew up in Ghana and received his B.S. degree in Animal Science from the University of Ghana in 1973. In 1975 he completed a M.S. degree in Agronomy/Animal Science at the University of Florida. He then pursued a Ph.D. degree in Agronomy at the University of Florida, Range Cattle Research and Education Center, Ona and was awarded the Ph.D. degree in 1978. While working on his Ph.D. degree he received the outstanding graduate student award. He then returned to Ghana as an assistant professor to teach and do research at the University of Ghana. In 1985 he returned to the University of Florida, Ona as a Post Doctorate in Agronomy for five years. In 1990 he accepted an assistant professor position in Agronomy with the University of Virgin Islands, St. Croix where he worked for seven years.

In 1997 he returned to the University of Florida as an assistant professor in forage management, with a major thrust of his research in transferring experimental bio-control of mole crickets to grower’s pastures. He was also heavily involved in phytoremediation of soils with excessive phosphorus in an effort to protect Florida’s water quality resources. He was tenured and promoted to the rank of Associate Professor in 2003.

Dr. Adjei was a member of ASA and CSSA where he participated on numerous committees and was associate editor for the crop section of Agronomy Journal. In 2004 he was elected ‘Researcher of the Year’ by the Florida Cattlemen. At the time of his death, he was serving as President of the Soil and Crop Science Society of Florida.
GENERAL SESSION PAPERS

Evaluation of Native Legume Growth and Phenology under Shaded Conditions for Restoration of Longleaf Pine-Wiregrass Ecosystem

S. E. Cathey¹, T. R. Sinclair,² T.R. Sinclair,¹* L. R. Boring²

ABSTRACT

In fire-maintained longleaf pine (Pinus palustris) wiregrass (Arístida stricta) ecosystem, nitrogen-fixing legumes are important for replacing nitrogen lost from frequent prescribed burns. Restoration and maintenance of the ecosystem, including the wildlife habitat it provides, depends on a legume population that sustains nitrogen input to the system. The objectives of this study were to obtain information about the growth under unshaded and shaded conditions of eight native legumes that are candidates for introduction into the longleaf pine-wiregrass ecosystem. Measurements were made throughout the season on plant phenology and development, and final accumulated shoot and root mass at the end of the season. Observations were also reported on nodule number and morphology for each species. The legume species included represented all three major subfamilies of Leguminosae and two distinctly different growth forms: vining/spreading and erect herbs. Biomass accumulation was not significantly reduced by shade for any of the species. Although stem elongation responses to shade were only significant for three species, Clitoria mariana, Crotalaria rotundifolia, and Lespedeza hirta, a general pattern of vining/spreading under shaded conditions was evident. Mimosa quadrivalvis (L.) had the greatest mass accumulation, and was among those species with the highest root-to-shoot ratio. Nodules varied among species from spheroid to elongate to coralloid.

Keywords: Legume growth, Native legumes, Plant phenology, Shade tolerance.

INTRODUCTION

The variably shaded and frequently burned environment of the longleaf pine- (Pinus palustris Mill.) wiregrass (Arístida stricta Michx.) ecosystem supports many species of native herbaceous legumes. These legumes constitute more than 10 percent of the vascular species in longleaf pine savannas and occur in high densities across a great range of site conditions (Hainds et al. 1999). As a group, these native legume species are fire tolerant, adaptable to infertile and droughty soils, valuable as wildlife food, and may be significant fixers of atmospheric N₂ (Hainds et al. 1999; Hendricks and Boring 1999; Hiers et al. 2003). Although these are understory species, their shade tolerance has not been explored. N₂-fixing legumes are generally assumed to be shade intolerant species due to the high energetic cost of nodule production, maintenance, and N₂ fixation (Vitousek et al. 2002).

Since 1998, reforestation initiatives on public and private lands in southeastern United States have resulted in planting of approximately 283,000 ha of former agricultural fields, harvested pulpwood plantations and otherwise fire-suppressed land back into longleaf pine stands. About 48,000 ha of marginal coastal plain farmland in Georgia alone are being planted to pine-wiregrass vegetation as part of the USDA Conservation Reserve Program (Coffey and Kirkman 2004). Groundcover restoration is critical to recovery of soil organic matter and N-availability on these sites (Markewitz et al. 2002). Although the longleaf pine overstory has been successfully established, there is a great need to better determine the compatibility of legume groundcover species to shaded light conditions so that suitable species may be integrated into habitat restoration projects.

This study was designed to observe the effects of two light conditions on growth responses of eight species of legumes native to the longleaf pine-wiregrass ecosystem over a growing season. An unshaded treatment as well as a shade treatment resulting in about half normal irradiance on the plants was included. The half irradiance treatment is approximately that anticipated following a thinning tree harvest when legumes would be added to the restoration stand. Battaglia et al. (2003) and Pecot et al. (2005) reported that a full canopy still averages 40 % light penetration. The specific objectives of this research were: (1) to make observations of phenological development and nodule morphology for each species; and (2) to document the influence of shading on growth habits and biomass accumulation. Shoot, root and nodule mass accumulation as well as shoot elongation were measured to document the response to light. A companion study focused on measuring N₂-fixation responses of these species (Cathey et al., 2009).

MATERIALS AND METHODS

Plants

Young plants of eight species of native legumes were grown outdoors in Gainesville, Florida (82° 20' W, 29° 38' N) between April and November of 2004. Four letter abbreviations as listed in Table 1 are used in this paper to identify each species. One-half of the plants from each species were grown in the sun and one-half in a shade-cloth enclosure that excluded approximately 50% ambient

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light. Difference in photosynthetically active radiation (PAR) between light treatments was determined using a Li-Cor Quantum Sensor, LI-185A. Measurements were taken on a clear day, 19 March 2004, at approximately 13:00 Eastern Standard Time. Three readings each were taken under the shade cloth and in open sun adjacent to the potted plants. The PAR in the shaded area (753 ± 82 μmol s m⁻²) was 56 percent of full sun (1340 ± 51 μmol s m⁻²).

The seedlings for all species, except Chamaecrista nictitans (CHNI), were initially propagated at the Joseph W. Jones Ecological Research Center (JWJERC) from seed. Seeds were collected throughout the native woodland on the 12,500 ha Ichauway reserve, located in Baker County, Georgia, USA (31°19’N and 80°20’W). Seeds were scarified by physical abrasion and then sown in June/July 2003 into an organic-mix soil. Plug flats were collected at two sites at the Jones Center: a fine-loamy, kaolinitic, thermic Typic Kandiudult (Orangeburg Series), and a loamy, kaolinitic, thermic Arenic Kandiudult (Wagram Series) site. Soils were dug from the top 0 to 20 cm of the soil profile in areas with thriving and diverse legume populations. A mixture of equal parts of each native soil type was used as the bacteria inoculation source. The pots had been previously filled with a commercial topsoil (Walmart Corp.) to within 6 cm from the top, then 2 cm of native soil was added to the surface of all pots. Plants were transplanted into the pots, and additional topsoil was used to cover the roots as needed.

Water was applied to each pot by drip-irrigation every 12 hours (5:00 and 17:00 EST) using a battery-operated timer (Rainbird). The amount of the irrigation was adjusted as needed throughout the experiment to prevent excessive watering during periods of heavy rainfall. Gainesville experienced hurricane activity around 14 August and 3 September 2004. Some plants experienced leaf loss due to wind, and LEHI, which was moved indoors, suffered some water-deficit stress.

**Measurements**

Stem length was measured for all plants on a weekly basis as the distance from the soil surface to the furthest point on the plant. Representative stem length of vining plants such as MIQU, CEVI, and CLMA was considered to be the length of the longest stem. Each of these vines was measured until the date when the branches became too tangled for a measurement to be plausible.

Cumulative leaf production was measured by counting the number of leaflets on each plant on a weekly basis. This method was continued throughout the experiment for CLMA, LEHI, and TEVI. However, due to the very large number of leaflets on CEVI, MIQU, CRRO and ORLU, plant vigor was estimated by measuring the width of the plant. The width of CEVI and MIQU was determined by measuring the lengths of the two longest stems and adding them together. Widths of CRRO and ORLU were determined as the width of the plant at the widest point, leaf tip to leaf tip. Width measurements were taken using a measuring tape or ruler.

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**Table 1. Descriptions of native legumes used in the current study.**

<table>
<thead>
<tr>
<th>Species</th>
<th>Code</th>
<th>Common Name</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Subfamily Papilionoideae</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Centrosema virginianum (L.) Benth.</td>
<td>CEVI</td>
<td>Spurred Butterfly Pea</td>
</tr>
<tr>
<td>Clitoria mariana (L.)</td>
<td>CLMA</td>
<td>Butterfly Pea</td>
</tr>
<tr>
<td>Crotonalpia rotundifolia J.F. Gmel.</td>
<td>CRRO</td>
<td>Rabbitbells</td>
</tr>
<tr>
<td>Lespedeza hirta (L.) Hornem.</td>
<td>LEHI</td>
<td>Hairy Lespedeza</td>
</tr>
<tr>
<td>Crotalaria rotundifolia Michx.</td>
<td>ORLU</td>
<td>Piedmont Leatherroot</td>
</tr>
<tr>
<td>Tephrosia virginiana (L.) Pers.</td>
<td>TEVI</td>
<td>Goats Rue</td>
</tr>
<tr>
<td><strong>Subfamily: Caesalpinioideae</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chamaecrista nictitans (L.) Moench</td>
<td>CHNI</td>
<td>Sensitive/Partridge Pea</td>
</tr>
<tr>
<td><strong>Subfamily: Mimosoideae</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mimoso quadrivalvis (L.)</td>
<td>MIQU</td>
<td>Sensitive Briar</td>
</tr>
</tbody>
</table>

* Nomenclature follows Wunderlin and Hansen (2003).

* Codes listed will be used to refer to species names throughout the text.
The presence of flowers and fruits was noted weekly. Phenological phase were defined as: 1) more than 50% of the plants of each species had flowers 2) more than 50% of the plants had flowers and fruit, and 3) more than 50% of the plants had fruit only.

At the conclusion of the experiment, all plants were destructively harvested to obtain both above- and below-ground mass. Roots and nodules were washed free of soil. Nodules were removed from the roots, counted and the diameter of each spherical nodule recorded. Elongated nodules were measured across the longest axis. All tissues were dried to constant weight at 80°C and weighed.

Means were compared with analysis of variance using the General Linear Models procedure of SAS (SAS Institute, 2003). Species and light treatments were used as main effects. Where means differed (p < 0.05), Duncan’s multiple comparison post-test was used to compare means. Patterns of stem elongation were analyzed using a non-linear regression model (third-order polynomial), followed by an analysis of slope using the derivative (dh/dt). The slope (dh/dt) of the curve at selected points was calculated and compared using ANOVA to test for species and treatment effects. Student’s t-test (α=0.05) was used to test for differences in mean stem length, number of leaves and plant vigor (measured as plant width) response to light treatments within a species. Non-linear regression and t-tests were performed using Prism (GraphPad Prism, 1996).

RESULTS
Phenological Development

Shade- and sun-grown plants reached reproductive maturity at approximately the same time. The weekly observations of phenological phases did not allow sufficient resolution to determine treatment effects on flowering and fruit initiation, thus data for the two light treatments within a species were combined. All species examined in this study were late spring and summer-flowering and fruiting except for LEHI, which is considered to be fall flowering and did not begin to flower until around 24 September. MIQU was the first of the species to flower (28 May; Fig. 1) and to produce fruit (30 June), followed by CRRO, CLMA, CEVI, and LEHI, respectively.

Flowering and fruiting continued throughout the season for MIQU, CRRO and CEVI (Fig. 1). The lack of a narrow time frame for flowering and fruiting indicates that these species follow an opportunistic fruit production strategy. Both flowers and fruits were present on MIQU, CRRO and CEVI from the first fruiting until the end of the experiment. In contrast, CLMA, which stopped flowering around 14 September, had a much more determinant flowering and fruiting pattern. Flowers and fruits were only concurrently present for approximately 30 days on CLMA before fruit production ceased and the plant returned to a vegetative state. TEVI did not flower during this experiment. ORLU flowered for the shortest duration of any of the species in this study, only 20 days, but no fruits were detected.

Figure 1. Phenological stages of species over time. Bars represent the time at which over one-half of specimens for a species had reached the prescribed phenological phase, such as the onset of flowering. TEVI did not flower during the experiment.

Plant Development

Although these legume species were quite different in structure and life history, they could be categorized into two general morphological types, a vining/spreading herb or an erect herb. The vining/spreading species were CEVI, CLMA, CRRO and MIQU and the erect herbs are LEHI, ORLU, CHNI, and TEVI.

Out of the 20 individual plants of each species, an average of 10 survived, ranging from 8 (CHNI and CLMA, each) to 16 (LEHI) individuals remaining. There were sufficient plants for six of the eight species to make statistical comparisons of growth variables. Species MIQU and CEVI were not included in the statistical analysis of the development data.

Overall, stem elongation (stem length) patterns of all species showed rapid increase in stem elongation toward the beginning of the season, with the exception of CRRO, and LEHI. Growth curves were fitted to a third order polynomial (Fig. 2; Table 2). Stem elongation rates for all species were greatest around 14 May, followed by decline as the season progressed, with the exception of LEHI, which had its strongest elongation rate during the middle portion of the season, between 29 June and 19 August (Table 3). CHNI, CRRO and LEHI underwent a slight decline by the final measurement before harvest, 22 October.

Stem elongation rates of CRRO, LEHI, ORLU and TEVI diverged among treatments on 19 August and 22 October (Table 3). Stem length was also statistically different (unpaired t test, p< 0.05) at dates within the range that elongation rate diverged for CLMA, CRRO, and LEHI (Fig. 2). For CLMA, stem elongation rates in the shade were approximately twice that of sun-grown plants across all calculated dates. Slopes and stem lengths for CHNI were very similar for both sun and shade-grown plants throughout the growing season.
Figure 2. Stem elongation. Values are means ± SE. □ represents plants grown in the sun, and ▲ represents plants grown under the shade treatment. Goodness of fit values ($r^2$, $\alpha=0.05$) are given for each curve that was fitted with a third-order polynomial.
individual plants, this pattern was only significant on a few
grown in the sun. Due to large variability among
tended to have more leaves on a given date than those
June), and TEVI showed that plants grown in the shade
Leaf accumulation trends for CEVI, CRRO (after 15
maximum stem length among species as determined by
TEVI, CRRO, CHNI, and ORLU, respectively (Table 4).
Most species reached maximum stem length around 9 or
October. However, maximum stem length was
observed earlier in CHNI (15 August) and MIQU and
experienced a slight decline in measured height after
peaking due to stem breakage. There were differences in
maximum stem length among species as determined by
analysis of variance (p < 0.001), and treatment effect was
not significant due to the amount of variation between
individual plants. Without regard to treatment, LEHI and
CHNI and MIQU had the longest stems, followed by MIQU, CLMA,
TEVI, CRRO, CHNI, and ORLU, respectively (Table 4).

Leaf accumulation trends for CEVI, CRRO (after 15
June), and TEVI showed that plants grown in the shade
tended to have more leaves on a given date than those
grown in the sun. Due to large variability among
individual plants, this pattern was only significant on a few

Table 2. Regression equations for stem elongation curves of the form y= A + Bx + Cx² + Dx³.

<table>
<thead>
<tr>
<th>Species</th>
<th>Light</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td>CHNI</td>
<td>Sun</td>
<td>-107.0 ± 32.3</td>
<td>1.4 ± 0.5</td>
<td>-0.004 ± 0.002</td>
<td>-3.8x10⁶ ± 5.2x10⁶</td>
</tr>
<tr>
<td>CHNI</td>
<td>Shade</td>
<td>-63.2 ± 28.2</td>
<td>0.7 ± 0.5</td>
<td>-0.001 ± 0.002</td>
<td>-5.2x10⁷ ± 4.5x10⁶</td>
</tr>
<tr>
<td>CLMA</td>
<td>Sun</td>
<td>-71.0 ± 37.3</td>
<td>1.1 ± 0.6</td>
<td>-0.003 ± 0.002</td>
<td>4.8x10⁸ ± 4.8x10⁸</td>
</tr>
<tr>
<td>CLMA</td>
<td>Shade</td>
<td>-155.6 ± 129.7</td>
<td>2.1 ± 2.1</td>
<td>-0.007 ± 0.010</td>
<td>8.5x10⁸ ± 1.7x10⁹</td>
</tr>
<tr>
<td>CRRO</td>
<td>Sun</td>
<td>-48.5 ± 44.6</td>
<td>0.5 ± 0.7</td>
<td>-8.05x10⁵ ± 0.003</td>
<td>-2.3x10⁸ ± 6.0x10⁹</td>
</tr>
<tr>
<td>CRRO</td>
<td>Shade</td>
<td>-50.5 ± 51.6</td>
<td>0.3 ± 0.8</td>
<td>-9.77x10⁵ ± 0.004</td>
<td>-1.3x10⁸ ± 7.0x10⁹</td>
</tr>
<tr>
<td>LEHI</td>
<td>Sun</td>
<td>186.0 ± 60.9</td>
<td>3.6 ± 1.0</td>
<td>0.02 ± 0.004</td>
<td>-3.7x10⁷ ± 8.1x10⁹</td>
</tr>
<tr>
<td>LEHI</td>
<td>Shade</td>
<td>80.9 ± 120.1</td>
<td>2.1 ± 2.0</td>
<td>0.01 ± 0.01</td>
<td>-2.8x10⁷ ± 1.7x10⁹</td>
</tr>
<tr>
<td>ORLU</td>
<td>Sun</td>
<td>-69.9 ± 26.7</td>
<td>1.2 ± 0.4</td>
<td>-0.004 ± 0.002</td>
<td>7.1x10⁸ ± 3.5x10⁹</td>
</tr>
<tr>
<td>ORLU</td>
<td>Shade</td>
<td>-76.8 ± 29.5</td>
<td>1.3 ± 0.4</td>
<td>-0.005 ± 0.002</td>
<td>7.3x10⁹ ± 3.9x10⁹</td>
</tr>
<tr>
<td>TEVI</td>
<td>Sun</td>
<td>-48.1 ± 59.0</td>
<td>0.7 ± 0.9</td>
<td>0.001 ± 0.004</td>
<td>1.0x10⁹ ± 7.8x10⁹</td>
</tr>
<tr>
<td>TEVI</td>
<td>Shade</td>
<td>-120.4 ± 66.1</td>
<td>1.7 ± 1.1</td>
<td>-0.006 ± 0.005</td>
<td>7.9x10⁹ ± 8.7x10⁹</td>
</tr>
</tbody>
</table>

Table 3. Slopes calculated from the derivative of the non-linear regression equations given in Table 2 at the mean for each coefficient.

<table>
<thead>
<tr>
<th>Species</th>
<th>Light</th>
<th>dh/dt on date (2004)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>14 May</td>
</tr>
<tr>
<td>CHNI</td>
<td>Sun</td>
<td>0.462</td>
</tr>
<tr>
<td>CHNI</td>
<td>Shade</td>
<td>0.384</td>
</tr>
<tr>
<td>CLMA</td>
<td>Sun</td>
<td>0.319</td>
</tr>
<tr>
<td>CLMA</td>
<td>Shade</td>
<td>0.677</td>
</tr>
<tr>
<td>CRRO</td>
<td>Sun</td>
<td>0.346</td>
</tr>
<tr>
<td>CRRO</td>
<td>Shade</td>
<td>0.399</td>
</tr>
<tr>
<td>LEHI</td>
<td>Sun</td>
<td>0.294</td>
</tr>
<tr>
<td>LEHI</td>
<td>Shade</td>
<td>0.497</td>
</tr>
<tr>
<td>ORLU</td>
<td>Sun</td>
<td>0.263</td>
</tr>
<tr>
<td>ORLU</td>
<td>Shade</td>
<td>0.260</td>
</tr>
<tr>
<td>TEVI</td>
<td>Sun</td>
<td>0.311</td>
</tr>
<tr>
<td>TEVI</td>
<td>Shade</td>
<td>0.500</td>
</tr>
</tbody>
</table>

Most species reached maximum stem length around 9 or
22 October. However, maximum stem length was
observed earlier in CHNI (15 August) and MIQU and
ORLU (1 July to 5 September). CHNI and MIQU
experienced a slight decline in measured height after
peaking due to stem breakage. There were differences in
maximum stem length among species as determined by
analysis of variance (p < 0.001), and treatment effect was
not significant due to the amount of variation between
individual plants. Without regard to treatment, LEHI and
CEVI had the longest stems, followed by MIQU, CLMA,
TEVI, CRRO, CHNI, and ORLU, respectively (Table 4).

Leaf accumulation trends for CEVI, CRRO (after 15
June), and TEVI showed that plants grown in the shade
tended to have more leaves on a given date than those
grown in the sun. Due to large variability among
individual plants, this pattern was only significant on a few

Table 4. Maximum plant heights by species, regardless of treatment.

<table>
<thead>
<tr>
<th>Species</th>
<th>Day</th>
<th>Max. Height (cm) ¹</th>
<th>n</th>
</tr>
</thead>
<tbody>
<tr>
<td>CEVI</td>
<td>289 (15 October)</td>
<td>53.2 ± 27.6 a ¹</td>
<td>5</td>
</tr>
<tr>
<td>LEHI</td>
<td>296 (22 October)</td>
<td>102.0 ± 10.1 a</td>
<td>11</td>
</tr>
<tr>
<td>MIQU</td>
<td>225 (12 August)</td>
<td>81.3 ± 9.5 ab</td>
<td>6</td>
</tr>
<tr>
<td>CLMA</td>
<td>293 (19 October)</td>
<td>53.2 ± 9.7 bc</td>
<td>8</td>
</tr>
<tr>
<td>TEVI</td>
<td>296 (22 October)</td>
<td>46.6 ± 4.6 c</td>
<td>10</td>
</tr>
<tr>
<td>CRRO</td>
<td>283 (9 October)</td>
<td>44.5 ± 4.1 c</td>
<td>9</td>
</tr>
<tr>
<td>CHNI</td>
<td>228 (15 August)</td>
<td>33.6 ± 13.3 c</td>
<td>9</td>
</tr>
<tr>
<td>ORLU</td>
<td>249 (5 October)</td>
<td>31.4 ± 3.3 c</td>
<td>4</td>
</tr>
</tbody>
</table>

¹Values are means ± SE.
²Different letters indicate significant differences (α = 0.05) Duncan’s post-test.
dates for CRRO during the season (Fig. 3b). CLMA, CRRO (before 15 June), and LEHI leaf accumulation patterns revealed the opposite effect; more leaves were added on those plants grown in the sun than those in the shade. Again, due to large variability between individual plants, this effect was only significant for CLMA and LEHI on a few dates across the season (Fig. 3a). ORLU, MIQU, and CHNI did not show distinct patterns with regard to leaf accumulation over the season, and no statistical differences according to treatment were found on any dates.

**Nodule Morphology**

Inoculation with a mixture of native soils resulted in nodule development in all species. Nodule morphology differed among species. CEVI, CLMA, CHNI, LEHI, and ORLU all had spheroid nodules varying from 1 mm to nearly 10 mm in diameter (Table 5). CRRO and MIQU had coralloid nodules from >2 mm to <10 mm in length.

**Table 5. Descriptions of nodule morphology and size with respect to light environment.**

<table>
<thead>
<tr>
<th>Species</th>
<th>Nodules</th>
<th>Size: Sun</th>
<th>Size: Shade</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Subfamily: Papilionoideae</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CEVI</td>
<td>Spheroid</td>
<td>+++ (2)</td>
<td>++ (5)</td>
</tr>
<tr>
<td>CLMA</td>
<td>Spheroid</td>
<td>+++ (2)</td>
<td>+++ (5)</td>
</tr>
<tr>
<td>CRRO</td>
<td>Coralloid</td>
<td>++++ (8)</td>
<td>+++ (8)</td>
</tr>
<tr>
<td>LEHI</td>
<td>Spheroid</td>
<td>+++ (7)</td>
<td>++++ (6)</td>
</tr>
<tr>
<td>ORLU</td>
<td>Spheroid</td>
<td>+++ (3)</td>
<td>++ (2)</td>
</tr>
<tr>
<td>TEVI</td>
<td>Elongated</td>
<td>++++ (4)</td>
<td>+++ (7)</td>
</tr>
<tr>
<td><strong>Subfamily: Caesalpinioideae</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CHNI</td>
<td>Spheroid</td>
<td>-- (4)</td>
<td>++++ (3)</td>
</tr>
<tr>
<td><strong>Subfamily: Mimosoideae</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MIQU</td>
<td>Spheroid</td>
<td>++++ (4)</td>
<td>+++ (2)</td>
</tr>
</tbody>
</table>

Nodule sizes represent an average of ratings given to each individual nodule: -, no nodules; +, <1mm; ++, 1-2mm; +++ , <2 to≤6mm; ++++, >6mm to 10mm.

\(^1\) Number of plants examined to estimate nodule size is given in parentheses.
Coralloid nodules have a central branching point from which they randomly bifurcate, with occasional twice-bifurcation. TEVI nodules were elongate, cylindrical and often bifurcated. The length of TEVI nodules averaged >6 mm to 10 mm, although the largest nodules were >10-mm long.

Plant Growth

Mass accumulation was not significantly affected by light treatment for total mass, aboveground accumulation, or belowground accumulation, therefore, the data were pooled for the two light treatments. MIQU accumulated the largest total amount of mass over the season (Fig. 4a). There were no statistical differences among the remainder of the species except that CHNI and LEHI had greater mass than CLMA and ORLU.

Root-to-shoot ratios (R/S) showed no significant shade-treatment effect, but species effect was highly significant (p < 0.001). MIQU, TEVI, and ORLU had the greatest relative allocation of mass belowground (R/S>3, Fig. 4b). CLMA had twice as much allocation belowground versus aboveground (R/S>2). CEVI and CRRO had a balanced allocation pattern (R/S ~ 1). CHNI and LEHI favored aboveground accumulation (R/S < 1).

DISCUSSION

Plant Development

Native legumes in this study represented all three major sub-families of Fabaceae, as well as vining/spreading and erect forb growth forms. The life histories of these species represented a variety of strategies for overcoming shade, frequent fire and drought.

Figure 4. (a) Aboveground and belowground harvested biomass. Different letters represent significantly different total biomass (aboveground + belowground) values, and alphabetical order designates order of total biomass values, greatest to least (Duncan’s post-test, α = 0.05). (b) Root to shoot ratio of harvested biomass. Different letters represent significantly different root-to-shoot ratios (Duncan’s post-test, α = 0.05). For the entire figure, values shown are means ± SE and data are composited by species because light treatment effect is not significant.
conditions. However, of the forty native legume species that grow extensively across the Ichauway reserve, only two are annual species: *Chamaecrista fasciculata* and *C. nictitans* (CHNI; Hainds et al. 1999). Perennial growth form is common in many frequently-burned ecosystems (Knapp et al. 1998; Morgan 1999; Jacobs and Schloeder 2002) and is an effective adaptation to the frequently-burned longleaf pine ecosystem.

The effect of shading on stem lengths of CLMA, CRRO, and LEHI was significant after 15 June (Fig. 2). Shaded plants of CRRO and CLMA plants had significantly longer stems than the sun-grown plants at the end of the growing season. CRRO, which is a prostrate spreading plant, and CLMA, which is semi-erect to vining, both grow below and amongst or on the bunchgrasses of the native woodland, thus, their tolerance of shade is not surprising. LEHI, a tall semi-woody species, showed a more favorable growth response to sun than shade during the last weeks of the growing season (Fig. 2). In the woodland, LEHI quickly outgrows the surrounding grasses and avoids mutual shading in the understory more easily than the smaller-stature species.

CHNI and TEVI, which showed no significant responses to shading, attain the same height as commonly found for the surrounding grasses in the native woodland. The effects of shading on the two large vines, CEVI and MIQU, were not well defined in this study due to their poor survival in this experiment, and difficulties of measuring vines that intertwine and break easily. However, even if these vines have reduced shade tolerance, they still have the ability to climb over neighboring plants and to grow into light gaps in the woodland in order to reach more direct light than smaller species, such as ORLU.

**Nodule Development**

Nodule morphology descriptions for species in this study (Table 2) were similar to the variations described by Sprent (2000) where species were grouped by subfamily and tribe. MIQU fits the indeterminate nodule shape of the Mimosoideae subfamily. Of the species of the Caesalpinoideae subfamily, only the genus *Chamaecrista* is known to be nodulated in the temperate regions, and the nodules have an indeterminate morphology. Nodules of CHNI were coralloid and frequently-branched.

Species belonging to the large subfamily Papilionoideae occur in various tribes. Species from this study, CLMA and CEVI, of the tribe Phaseoleae, all had desmoidoid, spheroid nodules and bear lenticels on their surface. This spheroid nodule type is also common to the tribe Desmodieae, represented in this study by LEHI. Two species of Papilionoideae from this study had indeterminate nodules, CRRO (tribe Crotalarieae) and TEVI (tribe Millettieae), and nodules from each of these species matched the forms typical of the appropriate tribes (Table 2, Sprent 2000).

**Growth**

The 56% shading treatment in this study did not have a significant impact on total biomass (Fig. 4a), or R/S allocation patterns (Fig. 4b) on these eight native legumes. There were, however, substantial differences among species in both the total accumulated mass and the R/S partitioning. In particular, MIQU had the greatest mass accumulation and was among the species that partitioned the greatest fraction of the mass to the roots. The R/S for MIQU and TEVI was greater than 3 indicating a heavy investment in root growth.

Many of the species had a R/S ratio that was greater than one. In an ecosystem that is frequently-burned and prone to frequent drought, significant allocation to belowground biomass is a positive survival adaptation (Knapp et al. 1998). Those perennial species that can resprout quickly from nitrogen and carbohydrate reserves in the roots have a temporal and light-accessibility advantage over neighbors. MIQU plants excavated in the field had taproots exceeding 2 m long (personal observation). Plants that have greater R/S ratios and deep, branching root systems are also likely to be better at enduring droughty conditions (Kramer and Kozlowski 1979; Knapp et al. 1998), such as those that develop quickly in the coarse-sandy soils present in much of the longleaf-wiregrass ecosystem (Hainds et al. 1999). For a legume, an extensive root surface area also provides increased opportunity for rhizobial colonization.

**CONCLUSIONS**

It is clear in this study that legume species cannot be assigned common characteristics of development and growth. For the limited group of legumes in this study there was a substantial range in growth form, reproductive phenology, and seasonal growth cycle. The results of this study showed examples of legumes from this temperate climate with shade tolerance at the level imposed in this study similar to the observations of legumes in the tropics (Sprent 1999). Some species exhibited greater stem elongation with shading (Fig. 2), but none of the species in this study demonstrated decreased mass accumulation in response to the decreased light level (56% of ambient) treatment. Although a more heavily shaded treatment might have provided a greater effect upon several species, the light environment to which plants were exposed in this experiment is roughly the irradiance in the understory of a longleaf pine canopy especially following a thinning harvest. *Mimoso quadrivalvis* (L.) proved to have both rapid plant development and the greatest mass growth among the tested legumes indicating it to be a prime candidate for use in restoration of the longleaf pine – wiregrass ecosystem.
ACKNOWLEDGMENTS

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REFERENCES


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Agronomic Feasibility of Sunflower as an Oilseed Rotational Crop for Florida Vegetable Production Systems

D.O. Chellemi*

ABSTRACT

Oil-producing sunflower (Helianthus annuus) was evaluated as a multiple goal-oriented rotational crop for vegetable production within the Florida Everglades Watershed. The performance of mid and high oleic, traditional, dwarf and herbicide resistant sunflower hybrids were evaluated at two commercial tomato production farms. Large, replicated plots were used to permit the use of commercial production equipment for harvesting seed. Oil and meal were extracted from seed and analyzed chemically for the potential use as a biofuel and nutritional supplement for livestock, respectively. Yield of harvested seed varied from 913 to 2008 kg ha\(^{-1}\). Oil yields ranged from 329 to 869 l ha\(^{-1}\). Based upon a crop budget of $978 ha\(^{-1}\) for the fall 2007 crop, a return of $1.23 per l of oil was needed to offset crop production costs. However, the sunflower meal produced a high quality livestock nutritional supplement with low moisture (<7.6%) and highly digestible proteins (20.3% to 23.6%) and total digestible nutrients (73% to 81%), offering an additional source of revenue to growers. Integrating oil-producing sunflower into existing vegetable production systems as a rotational crop offers the potential to increase production of biofuels while simultaneously benefiting the production of food crops and improving the profitability of vegetable production systems.

INTRODUCTION

The Florida Everglades Watershed (FEW) encompasses 25,000 km\(^2\) in central and south Florida and is comprised of three distinct sections, the Kissimmee River Basin, Lake Okeechobee and the Florida Everglades (Dovell, 1947). The FEW is an area of ecological significance where agriculture must balance environmental stewardship with escalating production costs and the recurring threat of pest outbreaks. Many agricultural soils in the low lying flatwood areas of the FEW are poorly-drained Alfisols and Spodosols originating from unconsolidated marine materials and influenced by underlying alkaline material (Gilbert et al., 2002; Obreza and Collins, 2002; Watts and Stankey, 1980). They are comprised mostly of sand, are low in organic matter and nutrient holding capacity and are difficult to manage relative to improving soil fertility and crop productivity. Extensive monocultures and continuous cropping practices have further exasperated outbreaks of soilborne pests and led to a dependence upon methyl bromide soil fumigation for the production of high value crops including tomato and pepper (Cantliffe et al., 1995; Rosskopf et al., 2005). Rotational crops are temporary or seasonal crops that can protect and improve soil quality, enhance pest suppression and promote biological diversity within the FEW.

Despite knowledge of the benefits of crop rotation, many vegetable farmers dependent upon methyl bromide soil fumigation have been reluctant to plant them (Chellemi, 2009). The limited use of rotation crops in Florida vegetable production systems is attributable in part to a difference in the goals of those promoting rotational crops and the farmers being asked to plant them. Rotational crops are evaluated and promoted primarily to improve soil fertility and reduce the impact of soilborne pests (Francis, 2005). For many vegetable farmers, their primary goal is to sustain or increase the profitability of their production systems. Thus, improved soil fertility and pest suppression can be achieved through less expensive but easier to manage inputs such as fertilizer and pesticides.

Integrating multiple economic, environmental and social goals into the evaluation criteria for rotational crops may foster their adoption by farmers. If rotation crops can add revenue (economic goal) and be a source of biofuels that does not compete directly with food production (environmental and social goals) planting them would be facilitated. The goal of this study was to determine the agronomic potential of oil producing sunflower (Helianthus annuus) hybrids grown as a rotational crop during the fall 2006 and 2007 growing seasons by vegetable growers in the Florida Everglades Watershed. The specific objectives were to determine the yield potential and chemical quality of sunflower seed, oil and meal and to generate data that can be used for crop economic budgets and cost-return projections. Field study sites were selected in commercial tomato farms representative of agricultural production in the low flatwoods and grassy sloughs of the FEW where the water table is within a depth of 25 cm for 1-6 months a year.

MATERIALS AND METHODS

Fall 2006 experiment

The field experiment was located in Martin County, FL on a commercial tomato production farm. The soil type was a Holopaw fine sand (loamy, siliceous, hyperthermic, Grossarencic, Endoqualfs) (Watts and Stankey, 1980). A 2 ha section of the farm was divided into blocks of equal size (0.33 ha) that measured 152 m x 22 m. Three hybrid cultivars obtained from Triumph Seed Co. (Ralls, TX) were evaluated (Table 1). Each hybrid was planted in two separate blocks using a randomized
complete block design. On September 21, a 10-0-5 formulation of N-P₂O₅-K₂O consisting of 5% nitrate nitrogen - 5% ammoniacal nitrogen, and 5% muriate of potash was broadcast applied and incorporated to a depth of 15 cm. Corresponding fertility rates were 140-0-69 kg ha⁻¹ of N-P₂O₅-K₂O. Phosphorus was not applied as soil tests indicated the presence of high residual amounts (556 kg ha⁻¹ of P₂O₅) as a result of prior tomato management practices. On September 21, sunflower was sown at a density of 55,000 seed per ha⁻¹ using a John Deere precision vacuum planter with sunflower plates and a vacuum held at 20 cm of H₂O. The seed was sown directly into tilled ground. The row spacing was 76 cm and plant spacing (drill) was 23 cm. Herbicide (S-metolachlor, Syngenta Crop Protection, Inc.) was applied at 1.17 l ha⁻¹ in 374 l ha⁻¹ of water using a 9-m boom sprayer equipped with flat fan nozzles. No overhead irrigation was provided. Subsurface (seep) irrigation was maintained at 30 to 60 cm below the soil surface. No fungicides or insecticides were applied. No crop desiccant was applied prior to harvest.

Seed from the sunflower hybrids 545A, S672, 660CL were harvested on January 4, 11 and 12, respectively, using an ABCO 4.8-m small grain platform attached to a Gleaner Combine. Seed moisture at harvest varied from 10.4% to 17.0%. Harvested seed was dried over night (12 hr) at 24 C using forced air. Seed was cleaned, bagged and weighed. Oil content in bagged seed was determined using nuclear magnetic resonance (NMR).

**Fall 2007 experiment**

The field experiment was located in St. Lucie County, FL on a commercial tomato production farm. The soil type was a Pineda fine sand (loamy, siliceous, hyperthermic, Arenic, Glossaqualfs) (Watts and Stankey, 1980). A 1.6 ha section of the farm was divided into six blocks of equal size (0.27 ha) that measured 145 m x 18 m. The same hybrid cultivars were evaluated (Table 1). Each hybrid was sown in two separate blocks using a randomized complete block design. On 17 October the hybrid cultivars were evaluated (Table 1). Each hybrid was sown in two separate blocks using a randomized complete block design. On 17 October the weed fallow was mowed and the field cultivated using a till bedder. On October 18, sunflower was sown at a density of 55,000 seed per ha using a John Deere precision vacuum planter with sunflower plates and a vacuum held at 25 cm of H₂O. The seed was sown in the center of the raised beds. The row spacing was 76 cm and plant spacing (drill) was 23 cm. Herbicide (S-metolachlor, Syngenta Crop Protection, Inc.) was applied on 21 October at 1.17 l ha⁻¹ in 374 l ha⁻¹ of water using a 12 meter boom sprayer equipped with flat fan nozzles.

No overhead irrigation was provided. Subsurface (seep) irrigation was maintained at 30 to 60 cm below the soil surface. Liquid side-dress applications of fertilizer were made on 8 November (16-0-16 kg ha⁻¹ of N-P₂O₅-K₂O) and 20 November (54-0-54 kg ha⁻¹ of N-P₂O₅-K₂O). Thus, the total fertility applied was 190-24-190 kg ha⁻¹ of N-P₂O₅-K₂O. No fungicides were applied. Biological insecticides spinosad and Bacillus thuringiensis were applied on 9 and 29 November. No crop desiccant was applied prior to harvest.

Seed from the sunflower hybrids 545A, S672, 660CL were harvested on February 5, 11 and 11, respectively, using an ABCO 4.8 m small grain platform attached to a Gleaner Combine. Seed moisture at harvest varied from 16.0% to 41.5%. Harvested seed was dried overnight (12 hr) at 24 C using forced air. Seed was cleaned, bagged and weighed. Oil content in bagged seed was determined using nuclear magnetic resonance (NMR).

**Oil and Cake Extraction and Analysis**

Oil was mechanically extracted from the seed using an electric powered oil expeller (Model 6, Bar N.A. Inc, Champaign, IL) and collected into 19 l plastic barrels. The oil was allowed to settle in the barrels for several days and then decanted into clean barrels. A secondary chemical extraction was performed on the remaining sediment (70 - 74% oil) to separate the remaining oil using methylene chloride (200 g per l of sediment). After mixing, the oil was removed using a Buchner funnel and vacuum filtration. The methylene chloride was heat evaporated from the extracted oil using a rotoevaporator. Fatty acid methyl ester (FAME) preparation was performed using procedures outlined by Litchfield (1972) and FAME profiles were ascertained using gas chromatography/mass spectrometry. The sunflower meal (byproduct from oil extraction) was collected in plastic bins and air dried. A feed analysis was performed on samples (Waters Agricultural Laboratories, Inc., Camilla, GA) to determine the relative moisture, digestible protein, crude fat, crude

<table>
<thead>
<tr>
<th>Hybrid no.</th>
<th>Description</th>
<th>Maturity (days)</th>
<th>Oil content %</th>
<th>Plant height in.</th>
<th>Disease resistance</th>
</tr>
</thead>
<tbody>
<tr>
<td>545A</td>
<td>Traditional (linoleic oil)</td>
<td>80-90</td>
<td>46-50</td>
<td>48-56</td>
<td>Charcoal rot, Phoma, Downy Mildew 1,2</td>
</tr>
<tr>
<td>660 CL NuSun</td>
<td>Mid oleic, Clearfield*</td>
<td>95-105</td>
<td>44-48</td>
<td>50-60</td>
<td>Phoma, Downy mildew 1,2</td>
</tr>
<tr>
<td>S672 NuSun</td>
<td>Dwarf, mid oleic</td>
<td>95-105</td>
<td>42-45</td>
<td>36-38</td>
<td>Rust, Charcoal rot</td>
</tr>
</tbody>
</table>

*Contains gene for resistance to the herbicide Beyond®.
Table 2. Yield, oil content and oil recovery of sunflower hybrids grown in the fall 2006 field trial.

<table>
<thead>
<tr>
<th>Hybrid</th>
<th>Seed yield (kg ha(^{-1}))</th>
<th>Seed oil content</th>
<th>Oil recovery</th>
<th>Oil yield (l ha(^{-1}))</th>
<th>Cake yield (kg ha(^{-1}))</th>
</tr>
</thead>
<tbody>
<tr>
<td>545A</td>
<td>1071 ± 80</td>
<td>45% ± 2%</td>
<td>32% ± 6%</td>
<td>597 ± 20</td>
<td>740 ± 37</td>
</tr>
<tr>
<td>660CL</td>
<td>1192 ± 72</td>
<td>42% ± 2%</td>
<td>32% ± 4%</td>
<td>413±26</td>
<td>760 ± 42</td>
</tr>
<tr>
<td>S672</td>
<td>1071 ± 80</td>
<td>45% ± 2%</td>
<td>28% ± 6%</td>
<td>329 ± 18</td>
<td>700 ± 38</td>
</tr>
</tbody>
</table>

\(^{a}\)Mean and standard error.

Table 3. Yield, oil content and oil recovery of sunflower hybrids grown in the fall 2007 field trial.

<table>
<thead>
<tr>
<th>Hybrid</th>
<th>Seed yield (kg ha(^{-1}))</th>
<th>Seed oil content</th>
<th>Oil recovery</th>
<th>Oil yield (l ha(^{-1}))</th>
<th>Cake yield (kg ha(^{-1}))</th>
</tr>
</thead>
<tbody>
<tr>
<td>545A</td>
<td>1608 ± 64</td>
<td>45% ± 2%</td>
<td>34% ± 3%</td>
<td>596 ± 39</td>
<td>994 ± 50</td>
</tr>
<tr>
<td>660CL</td>
<td>1616 ± 81</td>
<td>45% ± 1%</td>
<td>36% ± 4%</td>
<td>643 ± 37</td>
<td>947 ± 45</td>
</tr>
<tr>
<td>S672</td>
<td>2008 ± 81</td>
<td>47% ± 2%</td>
<td>40% ± 3%</td>
<td>869 ± 43</td>
<td>1142 ± 54</td>
</tr>
</tbody>
</table>

\(^{a}\)Mean and standard error.

Table 4. Nutritional qualities of sunflower cake extracted from the fall 2006 field experiment (numbers are expressed as % wet wt).

<table>
<thead>
<tr>
<th>Hybrid</th>
<th>Moisture</th>
<th>Digestible protein</th>
<th>Crude fat</th>
<th>Crude fiber</th>
<th>Total digestible nutrients</th>
<th>Ash</th>
<th>Nitrate</th>
<th>Calcium</th>
<th>Phosphorus</th>
</tr>
</thead>
<tbody>
<tr>
<td>545A</td>
<td>7.2%</td>
<td>23.6%</td>
<td>15.7%</td>
<td>16.2%</td>
<td>75.5%</td>
<td>7.0%</td>
<td>0.1%</td>
<td>0.3%</td>
<td>1.3%</td>
</tr>
<tr>
<td>660CL</td>
<td>7.6%</td>
<td>20.3%</td>
<td>15.2%</td>
<td>19.9%</td>
<td>72.9%</td>
<td>6.5%</td>
<td>0.1%</td>
<td>0.3%</td>
<td>1.1%</td>
</tr>
<tr>
<td>S672</td>
<td>5.5%</td>
<td>23.2%</td>
<td>19.9%</td>
<td>17.6%</td>
<td>81.0%</td>
<td>6.6%</td>
<td>0.1%</td>
<td>0.5%</td>
<td>1.2%</td>
</tr>
</tbody>
</table>

Table 5. Nutritional qualities of sunflower cake extracted from the fall 2007 field experiment (numbers are expressed as % wet wt).

<table>
<thead>
<tr>
<th>Hybrid</th>
<th>Moisture</th>
<th>Digestible protein</th>
<th>Crude fat</th>
<th>Crude fiber</th>
<th>Total digestible nutrients</th>
<th>Ash</th>
<th>Nitrate</th>
<th>Calcium</th>
<th>Phosphorus</th>
</tr>
</thead>
<tbody>
<tr>
<td>545A</td>
<td>9.0%</td>
<td>26.0%</td>
<td>17.8%</td>
<td>14.6%</td>
<td>78.2%</td>
<td>6.5%</td>
<td>0.2%</td>
<td>0.3%</td>
<td>1.0%</td>
</tr>
<tr>
<td>660CL</td>
<td>9.1%</td>
<td>25.0%</td>
<td>16.3%</td>
<td>15.6%</td>
<td>75.9%</td>
<td>6.5%</td>
<td>0.2%</td>
<td>0.3%</td>
<td>0.9%</td>
</tr>
<tr>
<td>S672</td>
<td>8.3%</td>
<td>26.1%</td>
<td>14.8%</td>
<td>15.8%</td>
<td>75.2%</td>
<td>6.7%</td>
<td>0.2%</td>
<td>0.3%</td>
<td>1.1%</td>
</tr>
</tbody>
</table>

fiber, total digestible nutrients, ash, nitrate, calcium and phosphorus.

RESULTS AND DISCUSSION

In the fall 2006 field trial, yields ranged from 913 to 1071 kg ha\(^{-1}\) (Table 2). Except the dwarf S672 hybrid, the oil content in seed determined by NMR was slightly below the range reported by the seed company (Table 1). Oil recovery from the harvested seed ranged from 64% to 77% resulting in oil yields ranging from 397 to 413 l ha\(^{-1}\). Yields of sunflower meal ranged from 700 to 760 kg ha\(^{-1}\).

In the fall 2007 field trial, yields ranged from 1608 to 2008 kg ha\(^{-1}\) (Table 3). Higher yields in the 2007 trial were attributed to several factors. Nitrogen applications were increased from 140 kg ha\(^{-1}\) in the 2006 trial to 190 kg ha\(^{-1}\) in the 2007 trial. Furthermore, the additional amounts of N and K\(_2\)O were applied judiciously as a liquid near the rooting zone during two critical stages of crop growth providing a more efficient use of the applied N by the plants. Changes in the pre-plant cultural practices also helped to improve yields. Use of the 10-cm planting bed allowed the crown area and surface root zone to remain free of standing water during precipitation events. Extended periods of soil saturation are typical of the agricultural flatwoods soil in the FEW. Oil recovery from harvested seed also improved, ranging from 78% to 85%. Improved oil recovery was attributable to experience gained using the mechanical oil expeller. Oil yields in the fall 2007 trial ranged from 596 to 869 l ha\(^{-1}\). Yields of the sunflower meal ranged from 994 to 1142 kg ha\(^{-1}\).

Yields of the sunflower hybrids were within the range of yields reported on older sunflower varieties evaluated in North Florida (Rich and Dunn, 1982; Robertson and Green, 1981). The nutritional value of the sunflower meal was consistent from year to year (Tables 4, 5). The nutrient content of sunflower meal was comparable to nutrient contents of cottonseed meal and soybean meal. For example, the total digestible nutrients ranged from 71% - 81% (Tables 4, 5) while typical values in cottonseed meal and soybean meal range from 77% to 87% (Arthington, 2003; Myer and Hall, 2003). In 2003, the value of cottonseed and soybean meal was $160 and $210 per U.S. ton, respectively (Myer and Hall, 2003). Thus, sunflower meal offers the potential of significant economic returns when grown as a rotational crop by Florida vegetable producers.

Both the traditional linoleic and mid-oleic hybrids produced very high quality oils as indicated by their FAME profiles (Table 6). Only very low percentages of non-target FAMES were detected in both field trials. Vegetable oils high in linoleic and oleic acid content are highly desirable as a feedstock for biodiesel as they tend to have higher gelling and clouding points and are lower in rancidity.

The larger commercial scale field plots provided an opportunity to develop more realistic estimates of production costs. The estimated production budget of $978 ha\(^{-1}\) in Table 7 was similar to estimated budget of $1,076 ha\(^{-1}\) for irrigated grain sorghum in South Georgia (Smith et. al., 2007). Fertilizer accounted for 64% of the variable costs. The next greatest contributor to crop
Table 6. Fatty acid methyl ester (FAME) profiles for oil extracted from harvested sunflower seed.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Methyl palmitate (C_{16:0})</td>
<td>4.3%</td>
<td>4.5%</td>
<td>4.3%</td>
<td>4.1%</td>
<td>4.5%</td>
<td>4.9%</td>
</tr>
<tr>
<td>Methyl stearate (C_{18:0})</td>
<td>2.0%</td>
<td>3.3%</td>
<td>2.1%</td>
<td>2.4%</td>
<td>1.7%</td>
<td>2.4%</td>
</tr>
<tr>
<td>Methyl oleate (C_{18:1})</td>
<td>11.5%</td>
<td>12.6%</td>
<td>51.0%</td>
<td>48.1%</td>
<td>40.7%</td>
<td>43.1%</td>
</tr>
<tr>
<td>Methyl linoleate (C_{18:2})</td>
<td>81.0%</td>
<td>77.7%</td>
<td>40.7%</td>
<td>43.5%</td>
<td>43.5%</td>
<td>46.8%</td>
</tr>
</tbody>
</table>

Other FAMES detected at low concentrations (<0.1%) were methyl myristate, methyl palmitoleate, methyl arachidate, methyl behenate and methyl lignocerate.

Table 7. Variable costs budget for sunflower production using data collected from cultural activities performed and corresponding fuel consumption during the fall 2007 field trial.

<table>
<thead>
<tr>
<th>Activity</th>
<th>Cost ha^{-1}</th>
<th>Fuel Requirement (l ha^{-1})</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cultivation (2 times)</td>
<td>$40.00</td>
<td>28.1</td>
</tr>
<tr>
<td>Bed Rows (4-row bedder, tractor)</td>
<td>$15.00</td>
<td>14.0</td>
</tr>
<tr>
<td>Fertilizer</td>
<td>$628.00¹</td>
<td>---</td>
</tr>
<tr>
<td>Additional tractor use (side-dress fertilizer, lay by cultivation and insecticide applications)</td>
<td>$75.00</td>
<td>70.5</td>
</tr>
<tr>
<td>Seed (fungicide treated)</td>
<td>$65.00</td>
<td>---</td>
</tr>
<tr>
<td>Planting (4-row, tractor)</td>
<td>$15.00</td>
<td>28.1</td>
</tr>
<tr>
<td>Herbicide</td>
<td>$32.50</td>
<td>14.0</td>
</tr>
<tr>
<td>Insecticide</td>
<td>$20.00</td>
<td>14.0</td>
</tr>
<tr>
<td>Harvest using grain combine</td>
<td>$75.00</td>
<td>37.4</td>
</tr>
<tr>
<td>Transport to crusher²</td>
<td>$12.50</td>
<td>18.7</td>
</tr>
<tr>
<td>Total variable costs ha^{-1}</td>
<td>$978.00</td>
<td>224.8</td>
</tr>
</tbody>
</table>

¹Based on September 2008 price quote.
²Based on an 80 km round trip from field to crusher with a transport load of 11854 kg load^{-1}.

budget was the harvest cost (8%). Thus, future efforts to reduce inputs costs for sunflower production in Florida should be directed at soil fertility. Directed post-plant fertilizer applications and rotating crops with N fixing legume crops are two areas of investigation that offer the potential to reduce fertilizer costs. Based on the yields and recovery of oil extracted from the S672 dwarf hybrid in 2007, a price of $1.12 per l ($4.24 per gal) is needed to break-even (Table 8). Direct competition with petroleum based diesel fuel is unlikely at the break-even costs obtained in this study.

Table 8. Break-even prices based upon the crop budget estimated for the fall 2007 field trial ($978 ha^{-1}).

<table>
<thead>
<tr>
<th>Yield ha^{-1}</th>
<th>kg oil ha^{-1}</th>
<th>l oil ha^{-1}</th>
<th>price kg^{-1}</th>
<th>price l^{-1}</th>
</tr>
</thead>
<tbody>
<tr>
<td>1680</td>
<td>665.8</td>
<td>731.6</td>
<td>$1.47</td>
<td>$1.44</td>
</tr>
<tr>
<td>2008</td>
<td>795.8</td>
<td>874.5</td>
<td>$1.23</td>
<td>$1.12</td>
</tr>
<tr>
<td>2464</td>
<td>974.5</td>
<td>1073.0</td>
<td>$1.00</td>
<td>$0.91</td>
</tr>
</tbody>
</table>

¹Based on seed oil content of 46.9% and an oil recovery rate of 84.5%.
²Weight of sunflower oil is 0.91 kg l^{-1}

**CONCLUSIONS**

This study demonstrated that oil producing sunflower hybrids can be integrated into existing vegetable production systems in the FEW as a rotational crop. Traditional benefits that rotation crops often provide include improved soil quality, reduced soil erosion, improved pest suppression and enhanced biological diversity. This study demonstrated that rotational crops also offer the potential to increase production of biofuels while simultaneously benefiting, not competing with, food crop production.

**ACKNOWLEDGEMENTS**

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**REFERENCES**


Vapor Pressure Deficit Effects on Leaf Area Expansion and Transpiration of Soybean Subjected to Soil Drying

Andrew L. Fletcher,1 Thomas R. Sinclair,2* and L. Hartwell Allen Jr.3

ABSTRACT

The effect of both atmospheric vapor pressure deficit (VPD) and water deficit on transpiration rate (TR) of plants is fairly well documented. However, their effects on whole plant leaf area expansion (PLAE) are less well defined. Generally, both PLAE and TR are unaffected by soil drying until fraction transpirable soil water (FTSW) decreases to an approximate range of 0.25 to 0.35. High VPD increases TR and may decrease the expansion of individual leaves. However, the effect of VPD on PLAE and the potential interaction with soil drying has not been examined. This study examined the effect of soil drying, VPD, and their interaction on TR and PLAE. Individual soybean (Glycine max Merr. L.) plants with 4 trifoliate leaves were placed in growth chambers at either high VPD (mean = 2.08 kPa) or low VPD (mean = 1.27 kPa). Control plants were maintained well-watered, while a second set of pots was allowed to progressively dry over 12 to 14 d. The high VPD treatment increased TR of well-watered plants by 24% over the low VPD treatment. High VPD resulted in a progressive decrease in PLAE in well-watered plants, but not in treatments in low VPD. During soil drying, TR were similar to the well-watered control until FTSW < 0.25 in both VPD treatments. Similar to TR, as FTSW declined PLAE was unaffected until FTSW < 0.24 in both VPD treatments. By day 10 of the experiment the daily increase in PLAE in high VPD treatment was only 43% of the low VPD plants. These results showed that both decreasing FTSW and high VPD decreased PLAE, but that these two factors did not interact.

INTRODUCTION

It has been shown in a number of crop species that water loss via transpiration is determined by environmental demand for water until roughly 1/3 of the fraction transpirable soil water (FTSW) or less remains in the soil. At lower FTSW, stomatal conductance decreases and there is an approximately linear decline in transpiration until transpiration ceases when FTSW is 0 (Sinclair and Ludlow 1986, Hammer and Muchow 1990, Muchow and Sinclair 1991, Ray and Sinclair 1998, Sinclair et al. 1999, Ray et al. 2002, Hufstetler et al. 2007). This response is also expected based on theoretical considerations (Sinclair, 2005). Soil water deficit has similarly been shown to alter the whole-plant leaf area expansion (PLAE) in a range of crop species where PLAE is relatively constant until 1/3 or less of FTSW remains, after this PLAE declines linearly until PLAE ceases at an FTSW between 0.1 and 0 (Sinclair 1986, Hammer and Muchow 1990, Muchow and Sinclair 1991, Liu et al. 2003).

However, the impact of atmospheric vapor pressure deficit (VPD, difference between saturated vapor pressure and actual vapor pressure) in soybean (Glycine max Merr. L.) on plant transpiration during soil drying is not resolved. As VPD increases, and hence atmospheric demand for water increases, plant transpiration rate also increases (Sinclair and Bennett 1998). The data of Denmead and Shaw (1962) indicated that these expected differences in crop transpiration would alter the critical value of FTSW when transpiration begins to decline. At high transpiration rates, the decline in transpiration is proposed to begin at a greater FTSW. The calculations of Cowan (1965) support this conclusion. However, Cowan’s (1965) results were based on soil water potential rather than soil water content. The relationship between soil water potential and soil water content is not linear, as the soil water content declines the soil water potential declines exponentially. Although the differences in calculated values of critical soil water potential were large, these may have occurred over a narrow range of FTSW. Sinclair (2005) examined the theoretical response of transpiration rate to volumetric soil water content and concluded that when transpiration was compared to FTSW that the critical value was consistently around 0.3 regardless of transpiration rate. This is supported by the experimental results of Ray et al. (2002), which showed in maize (Zea mays L.) that the response of plant transpiration to declining FTSW was consistent irrespective of VPD. The direct response of long-term transpiration to VPD has not previously been tested with soybean.

Vapor pressure deficit may also affect the expansion of individual leaves. High VPD has been shown to decrease leaf elongation rates in a number of species (Clifton-Brown and Jones 1999, Bouchabke et al. 2006, Salah and Tardieu 1997). However, these studies were all focused on the extension of individual leaves and the short-term (hours) responses to VPD. The focus of this current paper is on VPD effects on the daily increase in leaf area of well-watered whole soybean plants to a long term (10 to 14 d) exposure to various VPD levels.

Sadras and Milroy (1996) interpreted the results of McIntyre et al. (1993) with pearl millet (Pennisetum glaucum L.) and found that at a crop evapotranspiration rate of 9 mm d⁻¹, leaf and stem expansion began to decline at an FTSW of 0.80, whereas when crop evapotranspiration was 6 mm d⁻¹ leaf and stem expansion
declined at FTSW < 0.30. Sadras et al. (1993) found similar results with sunflower (*Helianthus annuus* L.), in that at high evaporative demand leaf expansion declined at a greater FTSW than at lower evaporative demand. The apparent change in the critical FTSW when PLAE began to decline may arise from the ability of the plants to maintain leaf turgor at different VPD’s. At high transpiration rates, cell turgor could fall below a critical value for expansion at a greater FTSW than at low transpiration rates where decreasing soil water could balance the water loss to evaporation at lower soil water contents.

The first objective of this experiment was to test the effect of VPD on PLAE under well-watered conditions. The second objective was to examine the hypothesis that with soil drying the decline in transpiration rate is independent of VPD for soybean. The third objective was to test if the decline in PLAE with soil drying depended on VPD.

**MATERIALS AND METHODS**

**Experiment**

Seeds of Biloxi soybean (Maturity group VIII) were sown on 20 December 2006 into 2.2-L pots filled with Gardenplus top soil (#92432, Lowes Inc, North Wilkesboro, NC). The soil was previously sieved through a 3-mm screen to remove pieces of bark. Three to four seeds were sown in each pot and these were later thinned to one plant per pot. All pots were supplied with *Bradyrhizobium japonicum* (Nitragin, Brookfield, WI) and ~1.4g of Osmocote plant food (14% N-6.1% P-10% K).

Plants were placed in a glasshouse and grown for 41 d before the start of the experiment. Each plant had ~4 trifoliolate leaves at the beginning of the experiment. On the evening before the start of the experiment, pots were watered to dripping. Between 0830 and 1000 hours the next morning each pot was sealed at the base of the plant stem in a plastic bag. The pots were weighed on a laboratory balance to determine the initial weight of each pot. On each of the next two days the weight of individual pots was determined each afternoon. These initial measurements were used to calculate the daily transpiration of each pot for normalizing subsequent transpiration rates as described below.

Whole plant leaf area was determined each afternoon during the VPD treatments, and the difference in leaf area between successive days was the PLAE of each plant. Whole plant leaf area was determined non-destructively by measuring the length of each central leaflet on each plant. Using a previously determined independent regression (Figure 1) the length of the central leaflet was used to estimate the area of each trifoliolate leaf (Equation 1).

\[
\text{Trifoliolate area (mm}^2\) = 1.258 * [\text{Central leaflet length (mm)}]^2 \quad (R^2 = 0.94) \quad [1]
\]

Figure 1. Relationship between central leaflet length (mm) and trifoliolate leaf area (mm²) of Biloxi soybean used for estimating whole plant leaf area. The solid line is the regression line and the dashed line is the relationship of Serraj et al. (1999) for Braxton soybean.

This regression was almost identical to that developed by Serraj et al. (1999) for Braxton soybean (Figure 1). To minimize the effect of small day-to-day measurement errors in the subsequent calculations of whole plant leaf area a 3-d moving mean (i.e. the previous day, the current day, and the subsequent day’s leaf area were averaged) was used.

Following measurements in the glasshouse, pots were placed in Soil-Plant-Atmosphere Research chambers on the University of Florida campus on the third day of the experiment. These chambers have been described previously (Allen et al. 2003, Pickering et al. 1994). Two chambers each of either a high VPD or low VPD were used. However, one of the high VPD chambers malfunctioned during the experiment and data collected from it were unreliable and discarded. Consequently, there were two chambers at low VPD and one at high VPD. Both treatments were set to have an air temperature of 30°C during the day (0600 to 1800 hours) and 22°C during the night. The low VPD treatment was set to have a dew point temperature of 25°C during the day and 15°C during the night. The high VPD treatment was set to have a dew point of 10°C during the day and 6°C during the night. Therefore, the target settings for VPD values were 3.0 and 1.0 kPa in the high and low VPD chambers, respectively. Two “Reli On” 5-L humidifiers (#RCM-832N, Wal-Mart Stores Inc, Bentonville, AR) were placed in each of the two low VPD chambers, to help maintain the high dew point temperature.

There were a total of nine plants in each chamber, three were maintained as well-watered controls and six were allowed to dry progressively. Each day the transpiration of each plant was measured by weighing it on a laboratory balance. The three well-watered plants in each chamber were then re-watered to within 200 g of their initial water holding capacity. The six plants on drying soil in each chamber were re-watered each day if necessary to maintain the net daily decrease in soil water content at
no more than 80 g. Each drying pot was weighed each day until relative transpiration was 0.1 or less of the well-watered controls. This endpoint was defined as the lower limit of transpirable soil water and was used to calculate FTSW.

Analysis

In order to analyze the effect of VPD on transpiration and PLAE under well-watered conditions, only the data from the well-watered plants were used. The data obtained from the well-watered plants during the first two days were normalized for each plant so that their initial transpiration rate and PLAE values were centered on a value of 1.0 for each plant.

The responses to water-deficit of transpiration and PLAE were determined for the plants subjected to drying soil. The comparison among plants to soil drying was facilitated by calculating a normalized transpiration ratio (NTR). Procedures for calculating normalized transpiration ratio (NTR) and FTSW have been described previously (e.g. Sinclair and Ludlow 1986). FTSW was calculated daily using the initial pot weight and the pot weight when transpiration rate was 0.1 of the well-watered plants as the upper and lower endpoints of transpirable water, respectively. The first normalization was done by dividing on each day the transpiration rate of each stressed plant by the average transpiration rate of the well-watered control plants in that treatment. This normalization eliminated day-to-day variations in transpiration due to differences in cloudiness, etc. A second normalization was applied by dividing this value by the average initial normalized transpiration of that plant over the first two days of the experiment (when the plants were still in a common environment in the greenhouse). This second normalization to obtain normalized transpiration rate (NTR) minimized the effect of plant size on transpiration rate and centered each regression at NTR of 1.0.

Data were then analyzed using a double-linear plateau regression (Equation 2) model in Graph pad Prism 2.01 (Graph pad Software Inc, San Diego, CA, 1996).

\[
\text{If } \text{FTSW} < X_o, \text{NTR} = S (\text{FTSW}) + C \quad \text{(Line 1)} \\
\text{IF } \text{FTSW} \geq X_o, \text{NTR} = 1 \quad \text{(Line 2)}
\]

Where \(X_o\) is the critical threshold of FTSW below which NTR begins to decline; \(C\) is the intercept of the decline in NTR with the y-axis; and \(S\) is the slope of the decline in NTR. In the regression of NTR on FTSW, \(C\) was constrained to pass through 0.1 by the definition that NTR equals 0.1 at FTSW equal to 0.0.

This normalization procedure was also applied to PLAE for each day, using the three-day moving average of whole plant leaf area and then the data were also analyzed using Equation 2. However, \(C\) was not constrained to any particular value in the regression of PLAE.

RESULTS AND DISCUSSION

Overall, the environmental settings were maintained reasonably well during the afternoon (Fig. 2). However, there was a lag in the ability of the chambers to maintain 25°C dew point early in the morning (Fig. 2b). Also, in the high VPD chamber (low dew point) the air temperatures were up to 5°C lower than the set point of 30°C. This meant that for much of the day the VPD settings were lower than the 3.0 kPa setting in the high VPD treatment, and greater than 1.0 kPa setting in the low VPD treatment. Furthermore, these settings were not maintained for a short time each afternoon between 1500 and 1700 hours when each of the chambers were opened to allow the pots to be weighed and the leaf area estimated.
The mean daily VPD (weighted by photosynthetically active radiation) in the high and low VPD treatments during the experiment were 2.08 and 1.27 kPa.

The differences in air temperature between the high and low dew point VPD treatments was examined as having a possible effect on the comparison between leaf expansion of the well-watered treatment. However, at the end of the experiment the well-watered pots had between six and seven main-stem leaves in both treatments and the differences were not statistically significant. The differences in accumulated thermal units were also small, 190°C c.f. 166°C; using a base temperature of 10°C (Sinclair 1984), and was unlikely to have caused large differences in leaf expansion rate.

**Well-Watered Plants**

The high VPD treatment resulted in an average 24% increase in transpiration rate for the well-watered high VPD plants as compared to the well-watered low VPD plants (Figure 3a). Consequently, the 64% higher VPD in the high vs. low VPD chamber was not fully matched by the increase in transpiration rate. These results indicated that there was some degree of stomatal closure by the soybean plants when exposed to the high VPD treatment. Similar increases in transpiration rates relative to VPD were also reported by Ray et al. (2002) with maize. The high VPD treatment also resulted in a progressive decrease in PLAE in the well-watered plants compared with the low VPD treatment (Figure 3b). Mean normalized PLAE decreased progressively in the high VPD treatment and was 43% of the low VPD control treatment at day 10 of the experiment. The decrease in PLAE is consistent with previous studies (Clifton-Brown and Jones 1999, Bouchabke et al. 2006, Salah and Tardieu 1997) in which the results were at a much finer level of study, i.e. the extension of individual leaves at scales of hours or minutes. The data presented here confirm that these responses are applicable at a more highly aggregated level, i.e. whole-plant leaf area on a daily scale. These responses should be considered in models of crop growth in which potential leaf area increase is often driven solely by temperature.

**Water-Deficit Plants**

Soil drying had major implications for NTR. The initial regressions of NTR on FTSW showed no significant differences in $X_0$, i.e. the critical FTSW threshold, between the two VPD treatments. Therefore, a single regression was calculated for the combined data set. NTR was unaffected by water deficit until 0.27 or less of the FTSW remained (Figure 4a). When FTSW was less than this threshold, NTR decreased linearly to reach 0.1 when FTSW was 0. This response to soil drying was consistent irrespective of the two VPD treatments. These results are consistent with those reported previously (Ray et al. 2002) with maize. Both our results and the results of Ray et al. (2002) contradict the findings of Denmead and Shaw (1962), but confirm the theoretical analysis of Sinclair (2005) that the decrease in transpiration rate in a drying soil is independent of crop transpiration rate. The main difference between the current study and the results of Denmead and Shaw (1962) is that they had a wider range of crop transpiration rates (1.4 to 6.4 mm day$^{-1}$). However, it was only at the extremely high and low transpiration rates that there were marked differences in their critical soil water threshold. Furthermore, the range in transpiration rates obtained by Denmead and Shaw (1962) were from different days and may have been the result of additional environmental variations, e.g. incident solar radiation, rather than just VPD per se.

Similar to the transpiration response as the soil dried, PLAE remained unchanged until FTSW reached a critical point and then declined linearly with FTSW. The decrease in PLAE ceased at a FTSW of approximately 0. Our results showed that this response was constant for both VPD treatments; therefore a single regression was applied to the combined data set. The critical FTSW for leaf growth occurred at FTSW of 0.22 (Figure 4b). The lack...
of an interaction between plant transpiration rate and soil drying on PLAE is consistent with the results of Serraj et al. (1999). They produced mean soybean transpiration rates of 162 and 123 g H$_2$O plant$^{-1}$ day$^{-1}$ at atmospheric CO$_2$ concentrations of 360 and 700 ppm respectively and found that the responses of PLAE to FTSW changes were identical. However, the results in Figure 3b contradict previous field experiments (Sadras et al., 1993; McIntyre et al., 1993) in which leaf area expansion began to decline at high soil water content when crop transpiration rates were high. The source of these different results may be a consequence of a difference in the range of VPD’s to which the plants were subjected. In the current experiment, the two VPD treatments were 1.27 and 2.08 kPa, whereas in the experiment of Sadras et al. (1993) VPD treatments were 1.3 and 3.2 kPa; in the experiment of McIntyre et al. (1993) VPD treatments were between 3.7 and 5.2 kPa. Also, the previous studies may have been confounded by other environmental factors. For example, in the study of Sadras et al. (1993) the low VPD treatment (1.3 kPa) occurred when mean solar radiation was 16.0 MJ m$^{-2}$ day$^{-1}$ and maximum air temperature was 28.1°C, while the high VPD treatment (3.2 kPa) occurred when mean solar radiation was 28.2 MJ m$^{-2}$ day$^{-1}$ and maximum air temperature was 41.8°C.

Overall, these results demonstrated that increased VPD resulted in increased transpiration rate for well-watered plants. On the other hand, increased VPD was associated with a progressive decline in PLAE. The basis for this cumulative effect of exposure to continuous high VPD is unknown. For plants on drying soil, the response of transpiration to soil drying was insensitive to VPD. These results support the assumption that descriptors of soybean response to drying soil can be imposed without modification for the usual range of VPD often experienced by crops.

**ACKNOWLEDGEMENT**

The authors thank Maritza Romero for assistance in setting up the controlled environment chambers and providing chamber environmental data.

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Effects of Mulch Type on the Yield of Scotch Bonnet Hot Pepper

C.S. Gardner* and G.L. Queeley

ABSTRACT

The yield performance of Scotch Bonnet (Capsicum chinense Jacq.) hot pepper grown on black polythene (gage 50 µm) mulch was compared to a treatment mulched with chopped (dry) bahiagrass hay and a control treatment (bare soil). The study was conducted at the FAMU research farm at Quincy, Florida in 1999 and 2000. For both years of the study, the experimental design was a Randomized Complete Block with 3 replications. Data on fruit size, fruits plant⁻¹, fruits ha⁻¹, temperature and rainfall were collected. In 1999, plants mulched with bahiagrass hay produced significantly larger fruits (p < 0.05) compared to the black polythene mulch but not the control treatment. Fruits plant⁻¹ and fruits ha⁻¹ were not significantly different. In 2000, all three yield parameters were significantly higher (p < 0.05) for the bahiagrass treatment compared to the black polythene but not the control treatment. Weather data for the region showed the year 2000 to be significantly hotter and drier. Since environmental factors could have contributed to the yield pattern over the two years, the effects of these mulches on the yield of Scotch Bonnet hot pepper are inconclusive.

INTRODUCTION

The Scotch Bonnet hot pepper is popular within the Caribbean, Latin America, Africa and Asia. This variety of hot pepper is favored in these regions because of its aromatic flavor and high pungency. Our preliminary observational studies have shown that the crop can be successfully produced under north Florida growing conditions from mid-March to November. Florida ranks second to Texas, in terms of total acreage devoted to hot pepper production. Due to the existence of large numbers of immigrants from countries where the Scotch Bonnet hot pepper is popular and the growing demand for spicy condiments in the American diet, Scotch Bonnet production has potential for becoming a successful alternative enterprise for Floridian farmers. Like farmers in the Northeast, Southeastern farmers are continuously searching for new or niche crops to diversify production (Rangarajan and Ingall, 2001).

In order to recommend the Scotch Bonnet hot pepper as an alternative enterprise for Florida farmers, it is necessary to establish cultural practices for its growth and production. The choice of mulches for this experiment was based on the following two considerations: The first consideration was the time of year when hot peppers are grown. The crop is normally transplanted in spring (March 30th to May 30th) but the active growth and production stages are during the summer months.

Many farmers in the southeastern United States use black polythene mulch as a standard practice for growing row and field crops, despite the evidence that black polythene mulch has a tendency to elevate soil temperatures, sometimes well above desirable levels. Consequently, this practice had to be investigated. We therefore decided to include black polythene mulch as a factor so that we could make recommendations for its future use on Scotch Bonnet hot peppers. The second consideration was based on the popular belief that use of alternative and environmentally enhancing practices such as natural (organic) mulch materials can enhance sustainability in crop production with no apparent loss in yield. Therefore, the objective of our study was to evaluate the yield performance of Scotch Bonnet hot pepper grown using traditional mulch materials so that we could make recommendations on their use to Florida’s farmers.

The practice of mulching is widely used as a soil management tool in many parts of the world. As a result of this, the useful effects of mulches on crop production have become well documented. However, the effectiveness of mulches can be influenced by factors such as soil type, climate, type of mulch material used, and the rate of mulch application (Ghosh et al., 2006). Some of the findings from studies that focused on the influence of mulches on yield of horticultural crops include: higher crop yield and better weed control (Hutchinson and McGiffen, 2000; Dale, 2000; Sanders et al., 1999), earlier maturity and fruit set (Tarara, 2000) reduced nutrient leaching, reduced moisture loss, and improved fruit quality (Waterer, 2000).

Csizinszky et al. (1999) evaluated the effect of ultraviolet-reflective mulches on tomato yields. They concluded that spring tomatoes grown on reflective mulches were larger in size and produced greater marketable yields, compared to those grown on black polyethylene mulch. Hutchinson and McGiffen (2000) reported that mulch generated from the residue of a cowpea cover crop contributed to greater fruit weight, better plant growth and fruit production in desert grown peppers.

Organic mulches can also add nutrients to the soil when decomposed by microbes, and help in carbon sequestration (Ghosh et al., 2006).

MATERIALS AND METHODS

The experiment was initiated at the FAMU Research and Extension center at Quincy, Florida in May 1999 and repeated again in May 2000. The soil type at the experimental site is a Lakeland sandy loam soil. After
harrowing to the desired tilth, three raised beds, each measuring approximately 90 ft. in length x 3 ft. wide x 1 ft. in height (30 m x 1 m x 0.33 m) spaced 6 ft. (2.0 m) apart, were made using a tractor equipped with a bed layer. The beds were fumigated with Terr-o-gas (66 % methyl bromide and 33.3 % chloropicrin) which was kept in place by a layer of black polythene (gauge 50 µm) to control weeds, nematodes and other soil pathogens.

When it was deemed safe to return to the fumigated area, the area was sectioned off into three 90 square feet (8.36 m²) blocks, each maintaining the original 3 row pattern. In each of the 3 blocks, the black polythene was removed from two of the three 8.36 m² rows for the purpose of establishing the treatments. The single row of black polythene that remained intact in each block was used as the black polythene treatment. One of the two remaining rows was covered with approximately 2 inches (5.08 cm) of chopped dry bahia grass hay at a rate of approximately 6 pounds (2.73 kg) per 8.36 m² plot to establish the bahia grass treatment. The remaining row remained uncovered for the purpose of establishing the control (bare soil) treatment. This arrangement produced a Randomized Complete Block design with three replications and three treatments. This design was used for both years of the study. A drip irrigation system was installed to provide the moisture requirements of the crop.

Scotch Bonnet (Capsicum chinense Jacq.) hot pepper seedlings that were grown in the greenhouse were transplanted into the field during the first week of May. A 3 ft. (1 m) row spacing was used. Bi-weekly sampling (harvesting of marketable fruits) began in August and continued until the end of November. Data were collected from 10 randomly selected plants within each treatment. The selected plants were flagged in order to identify them for sampling over the duration of the experiment. Yield data such as fruits plant⁻¹, fruit size and yield ha⁻¹ were taken. Based on the assumption that smaller fruits should weigh less compared to larger fruits, fruit size was determined on a per weight basis, using the number of fruits required to weigh one pound (0.45 kg) as an index for fruit size. The data were analyzed by analysis of variance (ANOVA) using the SAS software (SAS institute, 1988, version 9.0, Cary, N. C.). When ANOVA results indicated significant F values, mean separation was done using Duncan’s Multiple Range Test (DMRT).

RESULTS

For the 1999 study, the bahia grass treatment produced significantly larger fruits with an average of 42 fruits per pound (0.45 kg), compared to black polythene with an average of 46 fruits per pound (p < 0.05). However, fruits from the bahia grass treatment were not significantly larger than those harvested from the control treatment. Despite being numerically higher, total fruit yield ha⁻¹ and fruits plant⁻¹ from the bahia grass treatment were not significantly different compared to that obtained from the black polythene and control treatments. (Table 1).

<table>
<thead>
<tr>
<th>Mulch type</th>
<th>Fruits/plant</th>
<th>Fruit size</th>
<th>Fresh Fruit Yield</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bahia grass</td>
<td>50 a</td>
<td>42 b</td>
<td>3036 a</td>
</tr>
<tr>
<td>Black polythene</td>
<td>42 a</td>
<td>46 a</td>
<td>2441 a</td>
</tr>
<tr>
<td>Control</td>
<td>49 a</td>
<td>44 ab</td>
<td>2858 a</td>
</tr>
</tbody>
</table>

Means in columns followed by the same letter are not significantly different. P < 0.05

For the 2000 study, all three yield parameters evaluated were significantly higher (p < 0.05) for the bahia grass mulch treatment compared to the black polythene mulch treatment. However, these yield parameters were not statistically different from that observed in the control treatment (Table 2).

<table>
<thead>
<tr>
<th>Mulch type</th>
<th>Fruits/plant</th>
<th>Fruit size</th>
<th>Fresh Fruit Yield</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bahia grass</td>
<td>23 a</td>
<td>42 a</td>
<td>1450 a</td>
</tr>
<tr>
<td>Black polythene</td>
<td>10 b</td>
<td>64 b</td>
<td>504 b</td>
</tr>
<tr>
<td>Control</td>
<td>16 ab</td>
<td>46 a</td>
<td>934 a</td>
</tr>
</tbody>
</table>

Means in columns followed by the same letter are not significantly different. P < 0.05

The yield values obtained from the 1999 experiment are within the range of those found in our previous on-station studies and reports from Jamaica, a country where the Scotch Bonnet is a major cash crop (McGlashan, 2003). However, those obtained from the 2000 experiment were much lower than average. Ambient air temperature and rainfall data representative of the experimental site were obtained from the Southeast Regional Climate Center (SERCC) and used to make inferences about yield values for both years of the study. These data are illustrated in Table 3. The 2000 growing season was drier and hotter compared to the 1999 growing season. For the most part, data specific to the critical period for crop growth (April to July) indicated lower rainfall and higher mean ambient air temperatures in 2000 compared to 1999. Total rainfall recorded during the critical stage of crop growth in 2000 was only 4.90 inches (124.46 mm) compared to 18.76 inches (476.5 mm) during the same period in 1999. Except for the month of April, mean ambient air temperatures for the 2000 growing season were also higher compared to the 1999 growing season (Table 3). This finding therefore suggests that the year 1999 may have been more favorable for growing the crop. A between-year comparison of yield parameters is shown in Table 4. In 1999, significantly higher fresh fruit yield (fruits/plant and total yield) were observed but fruit sizes were statistically the same for both years.
Table 3. Mean monthly ambient air temperature and total monthly rainfall during the 1999 and 2000 growing seasons.

<table>
<thead>
<tr>
<th>Month</th>
<th>1999 Growing Season</th>
<th>2000 Growing Season</th>
<th>Total Rainfall (inches)</th>
</tr>
</thead>
<tbody>
<tr>
<td>April †</td>
<td>56.5</td>
<td>83.0</td>
<td>69.8</td>
</tr>
<tr>
<td>May †</td>
<td>61.5 d</td>
<td>84.5</td>
<td>73.0</td>
</tr>
<tr>
<td>June †</td>
<td>69.6 d</td>
<td>87.7 d</td>
<td>79.0</td>
</tr>
<tr>
<td>July †</td>
<td>71.7</td>
<td>90.3</td>
<td>81.0</td>
</tr>
<tr>
<td>August</td>
<td>72.7 b</td>
<td>93.7</td>
<td>83.2</td>
</tr>
<tr>
<td>September</td>
<td>64.6 g</td>
<td>85.2</td>
<td>75.0</td>
</tr>
<tr>
<td>October</td>
<td>60.1</td>
<td>82.0</td>
<td>71.1</td>
</tr>
<tr>
<td>November</td>
<td>44.6</td>
<td>75.3</td>
<td>60.0</td>
</tr>
</tbody>
</table>

Source: Quincy 3 SSW, Florida.
Notes: a = 1 day missing, b = 2 days missing, c = 3 days missing…..etc., z = > 26 days with no observations.
* Monthly mean ambient air temperature values were computed as (Min. + Max.)/2
† Individual months not used for monthly statistics if more than 5 days are missing.
† = Critical months for crop growth and development.

Table 4. A two year comparison of three yield parameters of scotch bonnet hot pepper grown at the FAMU research and extension center, at Quincy, Florida in 1999 and 2000.

<table>
<thead>
<tr>
<th>Year</th>
<th>Yields/plant</th>
<th>Fruit size</th>
<th>Fresh Fruit Yield</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(#/3 plants)</td>
<td>(# / 0.45 kg)</td>
<td>(kg ha^-1)</td>
</tr>
<tr>
<td>1999</td>
<td>47 a</td>
<td>51 a</td>
<td>2778 a</td>
</tr>
<tr>
<td>2000</td>
<td>44 a</td>
<td>963 b</td>
<td></td>
</tr>
</tbody>
</table>

Means in columns followed by the same letter are not significantly different p < 0.05.

DISCUSSION

Black polythene mulches have traditionally been used to elevate soil temperature to support crop growth in fall and enhance early planting in spring. However, during the summer months, elevated soil temperatures have been known to have adverse effects on crop growth. This may have been a contributing factor to the higher yield realized from the bahiagrass and control treatments when compared to the black polythene mulch in 2000, the hottest of the two years over which the study was conducted.

The fact that Scotch Bonnet hot peppers grown on bahiagrass mulch produced higher yields and larger fruits in both years supports the fact that black polythene may not be suitable mulch for growing the crop especially when climatic factors such as temperature and rainfall are not favorable during the critical stage of crop growth. Among the negative effects observed from the use of black polythene mulch were smaller fruits and lower than average yields. These findings bear strong implications for farmers aspiring to profit from growing this crop. Bahiagrass mulch is often readily available and has been cited as having many beneficial effects in agriculture. These include improvements in soil water holding capacity, aeration, and nutrient status following the decomposition of the mulch material. Although the relative costs associated with obtaining and applying the different mulches were not taken into consideration, the findings can further initiate a drive to find sustainable cost-effective organic mulch materials that can optimize the production of Scotch Bonnet hot pepper in the region.

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http://www.sercc.com/cgi-bin/sercc/cliMAIN.pl?fl7429

Using Growth Analysis to Select Radish Cultivars for Salad-Crop-Production Systems


ABSTRACT

Early long-duration outpost missions (e.g., Moon) will benefit from salad-crop-production systems designed to supplement crew diets with fresh vegetables. A comparison of three candidate radish (Raphanus sativus [L.]) cultivars (‘Cabernet’, ‘Giant White Globe’, and ‘Cherry Belle’) was conducted to optimize productivity in future flight systems. The plants grew under high-pressure sodium (HPS) lamps at a light level of 300 µmol m⁻² s⁻¹, 65% relative humidity, 23°C air temperature, 1500±50 µmol mol⁻¹ CO₂ concentration, and a 16h day/8h night photoperiod.

Leaf area, shoot dry mass, total dry mass, and hypocotyl dry mass were measured in sequential destructive harvests at 7, 12, 16, 18, and 21 days after planting (DAP). These single-plant harvest data were used to calculate crop growth rate (CGR), leaf area index (LAI), and net assimilation rate (NAR) using growth analysis. ‘Cabernet’ produced the greatest edible dry mass in 21 DAP. ‘Giant White Globe’ produced twice as much leaf area as ‘Cabernet’ or ‘Cherry Belle’, but its leaf photosynthetic capacity, as measured by NAR, was only 66% that of ‘Cabernet’ and ‘Cherry Belle’. After 21 DAP, ‘Giant White Globe’ produced as much total biomass as ‘Cabernet’, but produced only half as much edible biomass. The photosynthetic capacity of ‘Cherry Belle’ was similar to that of ‘Cabernet’, but it had 11% less leaf area and produced 28% less total biomass. ‘Cabernet’ reached its peak CGR about 1 day earlier than ‘Cherry Belle’, and about 3 days earlier than ‘Giant White Globe’. The data suggest that ‘Cabernet’ could be harvested by 19 DAP, without significantly reducing the edible yield obtained. This earlier maturation could result in considerable savings in power dedicated to lighting in future spaceflight salad-production systems.

Key words Radish, Raphanus sativus, growth analysis, salad machine, edible biomass

INTRODUCTION

Future lunar-outpost missions will be constrained in terms of available mass, volume, and electrical power, thereby limiting the role of crop production in early life-support systems (Wheeler et al., 2001; Monje et al., 2003). However, the impact of plants on these missions could be profound, especially with regard to enhancing diet diversity through fresh produce (Goins et al., 2003). Indeed, the concept of including a salad machine aboard manned spacecraft for providing small quantities of fresh vegetables for crew consumption evolved very early in the discussion of advanced life-support (ALS) systems (MacElroy et al., 1992). In addition, the presence of plants aboard spacecraft may provide psychological advantages; hence, there is a need to study the contribution of salad-crop-production systems to the diet and well being of crews living in confined habitats (Patterson et al., 2008). Several salad-crop species have been studied extensively in controlled environments using fixed-area planting trays for ALS applications (e.g., lettuce, radish, and tomato), whereas others have been studied very little (e.g., cabbage, onion, carrot, and herbs) (Wheeler and Strayer, 1997). In fixed-area planting trays, however, plant density decreases as plants are harvested sequentially and older plants intercept more light than if they had been grown in at a constant planting density.

Careful selection of the appropriate cultivars of candidate salad crops will help in optimizing productivity in flight systems and reduce the risk of crop failure. In this study, plant-growth analysis was used to quantify and describe growth of radish cultivars. Single-plant harvest data collected during sequential harvests from fixed-area planting trays was fitted using the logistic equation and used to discern changes in plant morphology and net partitioning of photosynthates between leaves and edible biomass (Hunt, 1982).

MATERIALS AND METHODS

Plant Cultural Conditions

Three radish (Raphanus sativus [L.]) cultivars: ‘Giant White Globe’ (NK Land and Garden Co., Chattanooga, TN), ‘Cabernet’ (Sieger’s Seed Co., Zeeland, MI), and ‘Cherry Belle’ (W. Atlee Burpee & Co., Warminster, PA) were grown in white plastic fixed-area planting trays (0.25 m² growing area) by recirculating nutrient-film culture using a modified ½-strength Hoagland’s solution (Hoagland and Arnon, 1950). Solution pH was automatically controlled at 5.8 with additions of dilute nitric acid (0.4 M HNO₃). Water depletion from the nutrient reservoirs due to evapotranspiration was monitored and manually replaced daily to maintain constant liquid level. Solution electrical conductivity was monitored and maintained near 1200 µS cm⁻¹ by addition of ½-strength Hoagland’s replenishment solution. The solution nutrient concentration was analyzed weekly. Four separate nutrient-solution-delivery systems were used for this study with each system circulating solution between two planting trays. One cultivar was planted per tray, and two cultivars shared each nutrient delivery system. The experiment was repeated four times to provide experimental replications within the same chamber under the same spectral quality and aerial environmental conditions.

Key words Radish, Raphanus sativus, growth analysis, salad machine, edible biomass

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Key words Radish, Raphanus sativus, growth analysis, salad machine, edible biomass
conditions. Nutrient solution temperature was 25°C throughout the test.

Two or three seeds were sown between two strips of hydrophilic nylon (Nitex) fabric serving as a nutrient-solution wick. The wicks were placed in 12 equally spaced locations in the planting tray. The trays were covered for the first 4 days with a white, translucent acrylic cover to maintain high humidity around the germinating seeds. Seedlings were thinned at 7 days after planting (DAP) to one per planting position. The initial planting density at 7 DAP was 48 plants m⁻² (12 plants per 0.25 m²).

Environmental Parameters

Each experiment was performed in a walk-in environmentally controlled chamber (EGC, Model M-48, Chagrin Falls, OH). Lighting was provided from high-pressure sodium (HPS) lamps programmed to provide a 16-h photoperiod on a 24-h cycle. Photosynthetic photon flux (PPF) was maintained at 300±20 µmol m⁻² s⁻¹. Air temperature was maintained at constant 23°C and relative humidity was maintained at a constant 65%.

Plant-Growth Measurements

Canopy height and PPF were measured weekly. PPF was measured at canopy height with a quantum sensor (LiCor, Model LI-250A, Lincoln, NE). Time-course harvests for growth analysis were performed at 7, 12, 16, 19 and 21 DAP. Two plants per tray were harvested and leaf area, dry mass of shoots, and swollen hypocotyl were measured. Root dry mass per plant was not measured because it became entangled in the hydroponic trays and removed during harvest. Effective plant density was 48, 40, 32, 24, and 16 plants m⁻² from 0-7, 8-12, 13-16, 17-19, and 20-21 DAP. Leaf area was measured with a leaf-area meter (LiCor Model LI-3000A, Lincoln, NE). Plant tissues were oven-dried at 70°C for 72 h to determine dry mass.

Growth-Analysis Calculations

The average leaf area, total dry mass, shoot dry mass, and hypocotyl dry mass were determined on a per-plant basis for each harvest date (n=4). Leaf area index, total dry mass per m² ground area, and hypocotyl dry mass per m² ground area for each harvest date was obtained by multiplying average single-plant values by the planting density at 7 DAP. This assumes that the entire 0.25 m² tray was populated by 12 plants throughout the course of the 21 days of the experiment, although two plants per tray were removed at each harvest date.

Leaf area vs. time and total dry mass per m² ground area vs. time for each cultivar were fitted to logistic curves using nonlinear regression software (CurveExpert Version 1.37, Starkville, MS) and used to describe increases in leaf area and dry mass over time (Hunt, 1982). The curve fits for dry biomass per m² ground area were used to generate the daily crop-growth rate (CGR; g dry mass m⁻² d⁻¹) for each cultivar. The curve fits for leaf area were used to generate daily curves of leaf area index (LAI; m² leaf m⁻² ground area) by dividing the leaf area of 12 plants by the tray area (0.25 m²) at each harvest. These two parameters were used to calculate net assimilation rate (NAR = CGR/LAI; g dry mass m⁻² leaf area d⁻¹), which is a measure of the photosynthetic capacity of the crop (Watson, 1958; Charles-Edwards, 1982).

Carbon Partitioning

Each cultivar has a different strategy for partitioning carbon fixed photosynthetically among its organs: leaves, petioles, hypocotyl, and roots. Although edible harvest index (the ratio between hypocotyl dry mass and total dry mass) is the most important measure of a salad-crop-production system, much can be learned by examining how the different cultivars allocate dry mass to the other organs. Shoot / Total dry mass was calculated as the ratio between shoot dry mass and total dry mass. Specific leaf area could not be calculated because leaf dry mass was not measured separately, but is approximated by the ratio of leaf area to shoot dry mass as petiole mass is small.

Experimental Design

Each tray containing each cultivar was considered an experimental unit and each plant a sub-sample (n=1). The experiment was repeated four times with cultivars/trays being re-randomized for each test (n=4). After repeated tests, ANOVA and mean-separation tests were used to test for yield differences between cultivars (SAS Institute, 1994).

RESULTS

The three radish cultivars differed in their rates of dry mass accumulation (Fig. 1). At 16 DAP, ‘Cabernet’ produced 35% greater biomass than the other two cultivars. However, ‘Cabernet’ and ‘Giant White Globe’ attained the same final dry mass (145 g m⁻²) by 21 DAP, which was 32% greater than that of ‘Cherry Belle’.

These cultivars also differed in how they partitioned dry mass. The harvest index of ‘Cabernet’ was 16% greater than that of ‘Cherry Belle’ and 55% greater than that of ‘Giant White Globe’ (Table 1). In contrast, ‘Cherry Belle’ partitioned 76% more biomass to shoot biomass than ‘Cabernet’ and 24% more than ‘Cherry Belle’ (Table 1). The cultivars had similar ratios of leaf area to shoot dry mass (Table 1), indicating that they had similar specific leaf areas. The changes in partitioning among the cultivars were also reflected in their LAI (Fig. 2). At 16 DAP, ‘Cabernet’ and ‘Giant White Globe’ had 37% more leaf area than ‘Cherry Belle’. However, ‘Giant White Globe’ continued to produce more leaves, such that it had an LAI of 2.2 by 21 DAP, compared to an LAI of 1.2 for ‘Cabernet’ and an LAI of 1.0 for ‘Cherry Belle’. These
Table 1. Carbon partitioning to edible dry mass (DM) and the ratio of leaf area to shoot dry mass.

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>Harvest Index</th>
<th>Shoot / Total DM</th>
<th>Leaf Area / Shoot DM (m²/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cabernet</td>
<td>0.68±0.10</td>
<td>0.36±0.05</td>
<td>23.5</td>
</tr>
<tr>
<td>Cherry Belle</td>
<td>0.57±0.08</td>
<td>0.46±0.05</td>
<td>23.2</td>
</tr>
<tr>
<td>Giant White Globe</td>
<td>0.31±0.06</td>
<td>0.66±0.05</td>
<td>22.8</td>
</tr>
</tbody>
</table>

Figure 1. Time course of dry mass accumulation of three radish cultivars: Cabernet, Giant White Globe, and Cherry Belle. The logistic curve was fitted to measured average dry mass values (symbols) and used to predict dry mass vs time (solid lines).

Figure 2. Time course of calculated leaf area index (LAI) was different among the three radish cultivars.

differences in partitioning and leaf area resulted in large differences in swollen hypocotyl mass (Table 1; Fig. 3), which is the edible yield. ‘Cabernet’ produced hypocotyls that were 1.6 times larger than Cherry Belle and 2 times greater than those of ‘Giant White Globe’ by 21 DAP.

Figure 3. Time course of swollen hypocotyl (edible portion) dry mass production of three radish cultivars.

Growth analysis allows the calculation of the CGR (Fig. 4), which represents the daily rate of dry mass accumulation. The peak CGR of ‘Cabernet’ was 58% greater than that of ‘Cherry Belle’, but only 12% greater than that of ‘Giant White Globe’. The growth of ‘Cabernet’ peaked 1 day earlier than ‘Cherry Belle’ and 3 days earlier than ‘Giant White Globe’.

The daily leaf photosynthetic capacity, expressed on a leaf area basis, was calculated from CGR and LAI. The NAR of ‘Cabernet’ and ‘Cherry Belle’ increased up to a maximum near 16 DAP and declined thereafter (Fig. 5). The leaves of ‘Giant White Globe’ were the least productive overall, but they were more productive early in the life cycle up to 11 DAP.

Figure 4. Crop growth rate (CGR), or the daily accumulation in biomass, was calculated from growth rate (derivative of line in Fig. 1).

Figure 5. Net Assimilation rate (NAR), a measure of leaf photosynthetic capacity, was calculated from CGR and LAI.

**DISCUSSION**

The analysis presented provides quantitative information describing the growth of three radish cultivars. Selection of the most suitable cultivar could be based entirely on the final edible yield observed after 21 days of growth. On this basis alone, ‘Cabernet’ is preferred since it produces the greatest edible biomass (Fig. 3; 93 g m⁻²).

Growth analysis allows a more detailed description of how ‘Cabernet’ was able to attain this higher yield compared to the other cultivars. However, the CGR and LAI used for the analysis are biased due to the inherent changes in plant spacing that occur when fixed-area planting trays are used. Clearly, older plants in this study had access to more PPF and probably developed greater
leaf areas than if they had been growing in a closed canopy. In addition, higher variability is possible due to a diminishing number of plants available for random sampling. These effects would be smaller if the plants had been grown in single pots, which could then be rearranged to preserve a constant planting density throughout the duration of the experiment. Nevertheless, the analysis presented is valid for future salad-crop-production systems because plants would be removed for consumption by the crew, leaving gaps between plants and decreasing planting density.

‘Giant White Globe’ partitioned a greater portion of photosynthetic carbon to the production of shoot biomass (Table 1). In fact, it had almost twice as much leaf area than ‘Cabernet’ or ‘Cherry Belle’ (Fig. 2). However, the net photosynthetic capacity of its leaves, as measured by NAR, was only about 50% that of ‘Cabernet’ and ‘Cherry Belle’ (Fig 5). Since the total biomass of ‘Giant White Globe’ equaled that of ‘Cabernet’ after 21 DAP (Fig 1), it is apparent that partitioning to the edible biomass (swollen hypocotyl) is only 45% that of ‘Cabernet’. After 21 DAP, ‘Cherry Belle’ produced 40% less total biomass than ‘Cabernet’, even though it had similar photosynthetic efficiency. The reason for its slower CGR is because it has less leaf area than ‘Cabernet’ since 10 DAP (Fig. 2). In addition, its harvest index is 10% smaller than ‘Cabernet’ (Table 1), resulting in the production of 60% less edible biomass.

Growth analysis conducted during this study differentiated three distinct growth patterns exhibited by these cultivars, and indicated different patterns in carbon allocation. These differences in allocation ultimately led to varying rates of daily CGR. Cabernet grew faster and reached its peak CGR about 1 day earlier than ‘Cherry Belle’. It grew slightly faster than ‘Giant White Globe’ but peaked about 3 days earlier. The data suggests that ‘Cabernet’ could be harvested after 19 DAP, without significantly reducing the edible yield obtained. This earlier maturation could result in considerable savings in power dedicated to lighting if these cultivars were grown in controlled-environment chambers in surface outpost missions.

REFERENCES


Review of Current Sugarcane Fertilizer Recommendations: A white paper from the UF/IFAS Sugarcane Fertilizer Standards Task Force


ABSTRACT

The Sugarcane Fertilizer Standards Task Force was assembled to conduct a comprehensive review of research results on selected sugarcane fertilizer nutrients. The objectives of the task force were to: 1) improve recommendations and best management practices, and 2) determine the need for additional crop nutrient research. Substantial data have been collected on the effects of selected fertilizer nutrients on yield of sugarcane grown on organic soils (Histosols) in Florida. Currently, nitrogen is not recommended for sugarcane production on Histosols because N mineralization rates are nearly equal to or exceed crop demand. Phosphorus recommendations are based on soil test results: separate calibrations for sand and organic soils with appropriate extractants for improved recommendations are being determined. Silicon is described as a beneficial plant nutrient, but not essential. However, sugarcane yields are enhanced by applications of Si on Histosols. Other nutrients such as Mg not required on Histosols or in the case of S are recommended to adjust soil pH. Approximately 20% of sugarcane acreage is currently on the sandy Entisols and Spodosols of south Florida, but little information has been developed for sugarcane nutrition on these soils which have low water and nutrient retention relative to muck soils. Application rate and timing research on many of these nutrients are currently being conducted. Additional data on annual N and P application rate are needed for sandy soils along with soil P test calibration for both organic and sandy soils. Likewise, field testing of Si, Mg, and S rates need to continue before appropriate recommendations can be established, particularly on sandy soils.

INTRODUCTION

Sugarcane is Florida’s most valuable row crop, produced on approximately 164,000 ha. Approximately 80% of Florida sugarcane is grown on organic “muck” soils (Histosols) south of Lake Okeechobee that comprise the Everglades Agricultural Area (EAA). These soils are fertile, highly productive and have relatively high water and nutrient holding capacities. Approximately 20% of sugarcane in Florida is grown on sandy soils bordering the EAA. Sugarcane grown on sandy soils typically has lower yields than sugarcane grown on muck soils due to the poor water holding and nutrient retention capacity of these soils. Currently, annual nutrient application recommendations for sugarcane production are not fully utilized by growers in south Florida due to uncertainty regarding sufficient nutrient rates for optimum sugarcane production particularly on sandy soils. These uncertainties and lack of field scale data are compounded by the fact that current sugarcane fertilizer recommendations for both organic and sandy soils were developed decades ago. The current production environment includes considerably higher yielding cultivars, improved cultural practices (e.g. improved fertilizer application methods, better weed control, and mechanical harvesting), and an expansion into sandy soil with low organic matter and poor cation exchange capacities. Given these important changes in production factors, some growers question the relevancy and/or accuracy of current sugarcane fertilizer recommendations. To address these issues the University of Florida/Institute of Food and Agricultural Sciences (UF/IFAS) established a Sugarcane Fertilization Standards Task Force in 2006. The task force consisted of UF/IFAS agronomists and soil scientists from the Everglades Research and Education Center in Belle Glade and Southwest Florida Research and Education Center in Immokalee, multi-county agents from UF/IFAS Extension Offices in Palm Beach and Hendry counties, and local grower representatives. The objectives of this task force were to: 1) review current fertilization recommendations for sugarcane, 2) review all pertinent data that have been generated with particular emphasis on recent unpublished data, 3) identify pertinent data that can be utilized in making fertilizer recommendations, 4) identify gaps in existing data, 5) develop changes, if any, to current fertilization recommendations, and 6) develop a strategic plan for fertilization research including demonstrations and on-farm trials.

CURRENT SUGARCANE FERTILIZER RECOMMENDATIONS

Current fertilizer recommendations for sugarcane production are based on soil testing and estimated crop nutrient requirements similar to other agronomic and horticultural crops. Recommendations for sugarcane production were reviewed to determine if adequate information was available to determine appropriate nutrient recommendations under Florida environmental conditions. Best management practices (BMPs) utilize these recommendations to counter balance the nutritional needs of the crops for optimum or near-optimum growth and yield, while at the same time reducing the risk of potential ground and surface water contamination. The task force determined that the fertilizer elements in most need of review were N, P, Mg, S, and Si. Potassium (K) was not included in this list because grower and environmental concerns regarding K application to sugarcane were of lower priority than other nutrients.
Nitrogen

Little nitrogen (N) is applied to sugarcane grown on Histosols of the Everglades Agricultural Area (EAA) in southern Florida because soil mineralization in these soils high in organic matter releases large quantities of N (360 to 1500 kg N ha⁻¹ hr⁻¹; Anderson, 1990) on an annual basis. Sugarcane grown on the sandy soils (Entisols and Spodosols) adjacent to the EAA typically has lower yields relative to sugarcane grown on muck soils due to the lower water holding and nutrient retention capacity of the sandy soil compared with that of muck. Therefore, improved management practices are needed to make sugarcane production on sandy soils more cost effective. In a review, Anderson (1990) stated that N is an essential nutrient for sugarcane growth with a critical nutrient level of 1.8% (defined as the nutrient concentration level in a plant at which yield will likely decline by 5 to 10%). The critical nutrient level is normally determined at stage 3 which normally occurs in Florida between May and August (Table 1). Anderson (1990), citing Barnes (1974) and Malavolta et al. (1962), reported the amount of N removed from the soil by a sugarcane crop ranged from 38 to 130 kg for 55 and 80 Mg ha⁻¹ crops, respectively.

Table 1. Sugarcane growth stages with descriptions of growth activities and estimated length of time under Florida conditions (source: Gascho, 1985).

<table>
<thead>
<tr>
<th>Growth stage (number)</th>
<th>Growth Activity</th>
<th>Time after planting or rationing (months)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Emergence and establishment</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>Tillering and canopy establishment</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>Expansion of the plant internodes and increase in plant height “grand growth period”</td>
<td>7</td>
</tr>
<tr>
<td>4</td>
<td>Maturation or ripening</td>
<td>2</td>
</tr>
</tbody>
</table>

Few sources of original data could be found for N rate studies conducted in Florida between 1960 and 1990. In Everglades Research Station Reports, Le Grand and Hortenstine (1961) suggested 100 to 112 kg ha⁻¹ of N be applied annually, with 56 kg ha⁻¹ applied at planting and 45 kg ha⁻¹ side-dressed in April on sands of less than 5% organic matter (OM). The recommendation decreased to a side-dressing of 34 kg ha⁻¹ as OM increased beyond 5%. In a later report, Gascho and Freeman (1971) restated the recommendation to be 100 to 123 kg ha⁻¹ for sands and mucky sands. Recommended applications were 34 to 56 kg ha⁻¹ at first application (N rate varied with P and K soil test), and three supplemental applications of 22 kg ha⁻¹ each. An extra 22 kg ha⁻¹ was recommended in the event of excessive rain, for a total maximum of 146 kg ha⁻¹. In subsequent reports, Gascho and Freeman (1974) and Gascho and Kidder (1975) later increased their N recommendation to 156 to 168 kg ha⁻¹ for sands. Recommended applications were similar to their previous recommendation with 56 to 67 kg ha⁻¹ applied at first application, and three supplemental applications of 34 kg ha⁻¹. The supplemental application in case of excessive rain was maintained at 22 kg ha⁻¹ bringing the annual maximum N application to 190 kg ha⁻¹; this is the current sugarcane recommendation for sandy soil in Florida.

Phosphorus

Water-extractable soil P (Pₚₑ) is currently used for sugarcane fertilizer P recommendations (Gascho and Freeman, 1974). The water-extractable soil test was developed for organic soils in the EAA by Forsee (1945, 1950). Recommendations range from 0 to 37 kg P ha⁻¹ with no P recommended for the plant cane crop with Pₑ values higher than 4.4 mg dm⁻³. All P recommendations for plant and ratoon crops are based on soil samples taken before planting. This is based on the recommendation of Gascho and Kidder (1979) to sample only before the plant cane crop because of increased soil-nutrient variability in ratoon fields results from banded fertilizers and nutrient gradients caused by crop uptake. Current fertilizer recommendations include a 20 kg P ha⁻¹ application for ratoon crops at Pₑ values higher than 4.4 mg dm⁻³ to ensure adequate P availability as soil P is depleted with cropping, otherwise no P is recommended. These recommendations are based on field work done between 1968 and 1972 and are used on both organic and mineral soils in south Florida.

Magnesium

Magnesium (Mg) availability in organic soils of the EAA is generally considered to be adequate for sugarcane production. The Everglades Soil Testing Laboratory does not recommend Mg fertilizer for sugarcane grown on organic soils (Rice et al., 2006). A survey of commercial sugarcane fields in south Florida in 2004 found few muck fields with leaf Mg concentration less than optimum (0.15-0.32%; Anderson and Bowen, 1990), but there were a substantial number of fields with negative Mg DRIS indices (Diagnosis and Recommendation Interactions and Imbalances (Anderson, 1990) suggesting possible imbalance of Mg uptake relative to other nutrients in some situations on organic soils (McCray, 2004). Current IFAS recommendations call for adding 6.6 kg Mg ha⁻¹ when the soil test Mg value is less than 112 kg ha⁻¹. This recommendation may be outdated at this point and may not be adequate. There is current research examining Mg nutrition on mineral soils. Based on available information at this time regarding sugarcane production on sands, growers should supply Mg by using dolomite to maintain soil pH at 5.5 or higher.

Sulfur

Although sulfur (S) is an essential plant nutrient, the UF/IFAS literature addressing crop nutrition concerns for sugarcane grown on the organic soils of the EAA does not address S use from the standpoint of directly supplying S nutrition to the plant. Instead, loosely-based UF/IFAS
recommendations for S applications to sugarcane evolved from the realization that acidifying properties of various S sources could bring about reductions in soil pH, which in turn would favor increased availability of micronutrient elements, particularly Mn. From this perspective, S application to sugarcane is not a fertilization effort, but rather a soil conditioning effort.

**Silicon**

Silicon (Si) is described as a functional or beneficial plant nutrient, but not as essential (Rice et al., 2006). Sugarcane and rice yields have been increased with the application of calcium silicate slag to soils low in soluble Si (Anderson et al., 1987; Anderson et al., 1991; Elawad et al., 1982; Snyder et al., 1986). Application of calcium silicate for sugarcane production on sands and low-mineral organic soils in Florida is an accepted practice by growers. Economic analysis of the use of calcium silicate indicates that grower revenues can be increased if applications are directed to soils with insufficient soluble Si (Alvarez et al., 2004). Florida sugarcane growers currently apply up to a 6720 kg ha⁻¹ rate of calcium silicate slag to soils testing low in available Si. There is not an official IFAS recommendation for Si application for sugarcane production, but a general suggestion is made that a 6720 kg ha⁻¹ rate will likely support a favorable yield improvement for soils testing less than 10 ppm Si (Rice et al., 2006).

**REVIEW OF RECENT SUGARCANE FERTILIZER RESEARCH**

Research on sugarcane nutrition in Florida was reviewed to document the current knowledge base and identify gaps in knowledge that would suggest needs for additional research. Literature from other sugarcane growing regions was also included where applicable.

**Nitrogen**

Wood et al. (1996) found that low leaf N concentration limited leaf photosynthesis and thus sugar yields. Under non-limiting N conditions (325 kg N ha⁻¹, in a single application), a relationship of leaf N and total crop N with days after planting or ratoon re-growth was found to exist for growing conditions on an unspecified soil in Queensland, Australia. It was found that N accumulation ceased before biomass accumulation. As a result, crop N accumulation reached a maximum at 198 and 151 days after planting or ratoon growth, respectively, and did not change over the next 150 and 200 days, however, biomass continued to accumulate over this period. Leaf N concentration decreased throughout the study from approximately 2% just after planting or start of ratoon growth, to a range of 1.5 to 1.3% from 100 to 300 days after planting or ratoon re-growth.

Few recent reports of annual N rate on yield have been written. Muchow et al. (1996) reported increased cane yield with increased annual N rate using 56, 107, and 268 kg ha⁻¹ on a fine sandy loam in Queensland, Australia. However, stalk sucrose concentrations were reduced with increasing N rate resulting in similar sugar yields at all annual N rates. In this study 56 kg N ha⁻¹ was applied to all treatments at planting with one additional application applied to the moderate rate and high rates. Additionally, the high annual N rate treatment received 7 applications by drip fertigation. Crop sugar yield was nearly equal for all N rates resulting in reduced nutrient use efficiency (NUE) or the amount of sugar produced per amount of N applied (t kg⁻¹) with increased N rate. In this study, stalk N concentration increased with N rate, indicating little correlation between cane N concentration above the critical level and sugarcane growth and yield.

A recent N rate study on sandy soils in Florida by Muchovej et al. (2004a) found no significant yield (stalk weight or sugar) increase at annual N rates above 170 kg ha⁻¹, but the 390 kg ha⁻¹ rate numerically increased sugar yield by 11.5 Mg ha⁻¹ (15%). In the same study, mean leaf N increased by only 0.02% from 1.05 to 1.07% for the 170 and 390 kg ha⁻¹ annual N rates, respectively. Additionally, N application rates above 70 kg ha⁻¹ significantly increased groundwater NO₃-N concentrations above 10 ppm drinking water maximum contamination limit (Muchovej et al., 2004b). As in the N rate study conducted by Muchow et al. (1996), little correlation between leaf N concentration and yield was found even at mean leaf values that are considered low.

In a three year study on sandy soils in Florida, Obreza et al. (1998) found that applying the same amount of N 13 times on an annual basis increased yield by 12.8% when compared to seven applications. On a 3-yr average basis, the high N frequency treatment annually yielded 75.8 Mg ha⁻¹ of sugarcane and 9.4 Mg ha⁻¹ of sugar, compared to 66.5 Mg ha⁻¹ of sugarcane and 8.2 Mg ha⁻¹ of sugar with the low N frequency treatment. Therefore NUE can be increased by increased numbers of applications possibly by use of fertigation through drip irrigation or use of controlled release forms of N.

Placement of fertilizer was found to be an important factor in N uptake from a clay soil in Queensland, Australia (Prasertsak et al., 2002). Urea placed on the soil surface had significantly reduced N uptake compared with urea incorporated into the soil. Total N loss was reduced from 59.1% to 45.6%, or a savings of 13.5% of annual N applied.

Various studies in Louisiana (Carter and Floyd, 1973, Carter et al., 1988) and Florida (Pitts et al., 1993, Obreza et al., 1998) have demonstrated increased sugarcane yields resulting from water table management. Under Florida sandy soil conditions, it was concluded that 60 cm water table depth produces optimal yields, and provides
necessary upward water flux. Furthermore, they speculated that this water table depth increased yield because the water table was not close enough to impact root health or remove N from the root zone due to leaching or denitrification.

Using $^{15}$N labeled fertilizer at 120 kg ha$^{-1}$, Ng Kee Kwong et al. (1999) found NUE [defined as the ratio of crop biomass N to N applied] to be 53% for drip irrigated sugar cane compared with 29% for subsurface irrigated crops in Mauritius on silty clay. The annual N rate of 160 kg ha$^{-1}$ was referenced as the highest recommended nitrogen rate under conditions common to Mauritius (Bholah et al., 1991; Halais and Nababsing, 1971). Drip irrigated sugarcane increased NUE to 87% for N annual applications of 160 kg ha$^{-1}$. In the same study, yield at 80 kg ha$^{-1}$ N applied with drip irrigation was equal to 120 kg ha$^{-1}$ with soluble N sources. Leaf area index was similar for 120 and 160 kg ha$^{-1}$ and greater than 80 kg ha$^{-1}$ regardless of irrigation practice. Tillering was similar for all N rates. However, yield decreased at 160 kg ha$^{-1}$ due to luxury consumption. This observation was confirmed by Fritz (1974) and Wiedenfield (1995) when they found lower sugar yields with 160 kg ha$^{-1}$. Thornburn et al. (2003) found similar yield results compared with Ng Kee Kwong et al. (1999) on sandy loam and sandy clay soils in Australia. No increase in biomass or sugar yield was observed at annual N rates greater than 80 kg ha$^{-1}$ when fertigated with four equal split applications using drip irrigation. Yields for the 120 kg ha$^{-1}$ annual N rate using soluble sources applied once in November were similar compared with sugarcane produced at an annual N rate of 80 kg ha$^{-1}$ using drip irrigation.

**Phosphorus**

Soil testing is used to determine appropriate P fertilizer application rates on both organic and mineral soils. There has been a substantial amount of research done on organic soils in Florida in the last 20 years with sugarcane production response to phosphorus (P) fertilizer. Korndorfer et al. (1995) examined fertilizer studies on organic soils from 1968 to 1990 and determined that soil-test P values produced with 0.5 N acetic acid extractions ($P_a$) related better to sugar yield than soil-test values produced using water as the extractant ($P_w$). In this work Korndorfer et al. (1995) proposed three classes of $P_a$ adequacy for sugarcane production on organic soils. Andreis and McCray (1998) developed a P soil test calibration for sugarcane on organic soils using the Bray 2 extractant (0.03 M NH$_4$ in 0.1 M HCl; Bray and Kurtz, 1945).

Andreis and McCray (1998) reported that under low initial soil-P test levels, increasing fertilization rates beyond 36 kg ha$^{-1}$ of P (84 kg ha$^{-1}$ of P$_2$O$_5$) did not significantly increase sugar yields. In this work sugar production responses to P fertilizer were found in the ratoon crops, indicating the importance of maintaining adequate soil P levels through the ratoon crops. Research by Glaz and Ulloa (1994) indicated that growers benefit from selecting cultivars and determining fertilization needs based on specific location and cropping system.

Out of 13 crop years for 6 locations in studies conducted by Ron Rice and Yigang Luo, there have been 2 crop years with small responses of sugar yield to P fertilizer application (Luo, 2004). A small production response up to 18 kg ha$^{-1}$ of P (42 kg ha$^{-1}$ of P$_2$O$_5$) was found in the first ratoon crop of a current study by McCray and Luo (unpublished). Control plot $P_a$ soil test values in that location were 25 mg P/dm$^3$. When these data are combined with work done by Andreis and McCray (1998), Glaz et al. (2000), and Korndorfer et al. (1995) the primary sugarcane yield response to added P inputs is found at $P_a$ soil test values less than 20 mg P/dm$^3$. There is a smaller yield response up to approximately 50 mg P/dm$^3$.

Water-extractable P is currently used for sugarcane fertilizer P recommendations on organic soils, but this measure of soil test P does not relate to sugar production as well as the acetic acid soil test (Korndorfer et al., 1995). At a lower pH, water extracts a higher amount of soil P, but that does not translate into greater plant availability of soil P and does not lead to greater cane or sugar production.

There has been little recent work examining sugarcane production response to P fertilizer on mineral soils in Florida. Fertilizer guidelines for sugarcane on mineral soils in Florida are discussed by Rice et al. (2006), but these are primarily recommendations previously published by Gascho and Kidder (1979) which were based on work done 30 years ago or more. This work would have been done with sugarcane varieties not planted today and without today’s current grower knowledge of sugarcane response to silicon. There is a strong need to update not only P fertilizer recommendations for mineral soils but also recommendations for other nutrients as well. This update needs to include soil test calibrations specific for Florida mineral soils in sugarcane production.

**Magnesium**

Availability of soil Mg is often a limiting factor in sugarcane production on mineral soils in Florida (Anderson, 1990; Muchovej et al., 2000). Using tree regression analysis, Anderson et al. (1999) concluded that levels of soil Mg in mineral soils should be kept high for optimum sugarcane production. Dolomite has been found to be an excellent source for Mg, while also serving as an amendment for acid sandy soils because of its liming ability. Coale (1993) found that sugar yields on acid sands were substantially increased in the first ratoon crop by dolomite application. They concluded that maintaining productivity over a multi-year crop cycle is the primary benefit derived from liming acidic sandy soils. They also defined a threshold pH of 5.5, below which a yield response to dolomite application would be expected (Coale
and Schueneman, 1993). Surface soil pH was increased in their study by approximately 0.5 pH unit with 2240 kg ha\(^{-1}\) of dolomite. These findings are summarized in the current UF/IFAS recommendations for sugarcane grown on mineral soils (Rice et al., 2006). Other work in Florida emphasizes the importance of optimizing pH, Si, and Mg values for optimum growth on mineral soils (McCray, unpublished data; Muchovej et al., 2000).

**Sulfur**

Early (late-1920s) EAA crop production research efforts focused on developing management strategies to address widespread crop nutrient deficiency disorders that were encountered on recently cleared raw sawgrass peat soils. Allison (1928) provided a description of favorable sugarcane response to CuSO\(_4\) applications. Allison et al. (1927) acknowledged low mineral contents of raw peat soils and discussed the merits of numerous crop nutrient amendments for a variety of crops, including CuSO\(_4\), NiSO\(_4\), MnSO\(_4\), Cr\(_2\)(SO\(_4\))\(_3\), and ZnSO\(_4\).

Allison (1931) recognized that EAA organic soils were “different” in that soil reaction (soil pH) represented “a balance between natural acids of the organic components of the soil material and the lime of the soil waters brought up from the underlying (limestone) rock or marl.” The merits of CuSO\(_4\), MnSO\(_4\) and ZnSO\(_4\) inputs to overcome nutrient deficiencies were highlighted for a wide spectrum of crops. While CuSO\(_4\) inputs encouraged favorable sugarcane growth responses across a wide range of soil pH, no responses were observed with MnSO\(_4\) and ZnSO\(_4\) with soil pH < 5.5 to 6.0.

For increasingly alkaline soils, Allison (1931) suggested that “within practical limits”, growers could improve Mn availability by lowering soil pH with S applications. Within an EREC field of “abnormally high alkalinity” (soil pH 7.0 to 7.5), sugarcane failed to respond to MnSO\(_4\) applied at 84 to 168 kg ha\(^{-1}\) while 224 to 336 kg ha\(^{-1}\) of S applied in the furrow provided “good results”. Stevens (1941) reported markedly improved cane and sugar yields when applying 392 kg ha\(^{-1}\) of sulfate (soil pH was not reported).

Forsee (1950) acknowledged that crop growth responses to S applications are not due to any deficiency of the element itself, but to the favorable decline in soil pH that subsequently improves micronutrient and possibly P availability to the growing crop. Anderson (1985) provided an overall summary of UF/IFAS which suggested S application rates based on earlier literature review and soil test results. Suggestions for S applications ranged from 560 to 4480 kg ha\(^{-1}\) to increase soil pH by 0.3 to 1 unit.

**Silicon**

Mechanisms proposed to explain yield responses to Si application include induced resistance to drought stress; Al, Mn, and Fe toxicity alleviation; increased P availability; reduced lodging; improved leaf and stalk erectness; freeze resistance; and disease and pest resistance (Savant et al., 1999; Alvarez et al., 2004). Although suggestions of increased P availability with application of calcium silicate slag have been made (Matichenkov et al., 2002), leaf P or soil P concentrations have not been found to be increased with slag application (Anderson and Snyder, 1992). The extractant currently used by the Everglades Soil Testing Laboratory is 0.5 N acetic acid and is used for both organic and mineral soils for Si extraction. This extractant has performed well compared with other extractants in tests with upland rice (Savant et al., 1999). Leaf analysis is also a good indicator of Si status, and work in Florida has shown that leaf Si values less than 0.5% indicate insufficient Si and a likely production response to applied calcium silicate (McCray et al., 2006). This leaf Si critical value agrees with the value of 0.53% leaf Si at which Berthelsen et al. (2003) found that 95% relative sugarcane yield was reached in Australia. Work in Florida indicates that some sugarcane production response is likely up to about 0.7% leaf Si (McCray, unpublished data), but not likely as high as the earlier value of 1% suggested by Kidder and Gascho (1977). Areas where sugarcane production responses to Si have been found in Florida are the mineral soils and low-mineral organics. Torry muck soils are high in mineral content from historic overflows of Lake Okeechobee, support leaf Si values greater than 1%, and do not respond to applied calcium silicate. Sandy soils in south Florida have a high percentage of total Si, but generally have low levels of available Si. Sugarcane grown on these mineral soils generally demonstrate a production response to applied calcium silicate (Berthelsen et al., 2003; Snyder et al., 1986).

Research is currently being conducted on sugarcane response to applied Si on organic and mineral soils in Florida at three small-plot locations. This work is designed to develop recommendations for calcium silicate application for Florida sugarcane as well as to compare Si sources, rates, and application methods to examine cost-effectiveness of application. Thus far the study indicates that broadcast rates of 3360 and 6720 kg ha\(^{-1}\) of calcium silicate are superior to a banded rate of 1120 kg ha\(^{-1}\). Calcium silicate sources from Pennsylvania and Tennessee have generally provided similar production responses, while a magnesium silicate material from Colombia has not provided an acceptable response.

**DATA GAPS AND RECOMMENDED RESEARCH PRIORITIES**

Gaps currently exist to one extent or another in our knowledge of sugarcane nutrition. The majority of these gaps exist in the relationships of N and P fertilizer application rate to crop biomass and sugar yield on sandy soils. Likewise, large gaps exist in our knowledge of how these elements impact water quality. Improvements in
NUE for both N and P are essential to reducing the impact of sugarcane production on the environment.

Nitrogen

Relationships of annual N rate and yield from sugarcane producing areas outside of south Florida were generally on soils with finer texture and greater water and nutrient retention; however, recent N rate studies on sandy soils in Florida have been inconclusive. Therefore, additional data regarding N rate on sandy soils are required to determine if annual applications greater than 190 kg ha\(^{-1}\) are justifiable. Recent sugarcane cultivars have not been adequately tested for NUE in sandy soils. Selection of cultivars for use on sandy soils based on nitrogen NUE need to be performed in pot or small plot experiments with exceptional cultivars tested in large field plots in conjunction with plant breeders at the USDA ARS Sugarcane Field Station at Canal Point. Increases in NUE by the use of fertigation or controlled release fertilizers would greatly benefit sugarcane production on the sandy soils of south Florida and reduce the potential for water quality impacts. However, current fertilizer price structures and commodity prices to support the installation of fertigation systems and application of controlled release fertilizers with higher cost per unit of N may limit these options. A study is currently being conducted combining small plots and commercial sized plots to provide more reliable data on the effect of annual N rate on yield. It has been demonstrated that split applications of fertilizers increase sugarcane yields. Additional data need to also be collected on biomass and N accumulation over time at the selected annual N rate to determine the proper timing of fertilizer applications. Improved NUE of microelements through foliar applications should be studied.

The combination of improved N rate response and accumulation data will provide the information needed to determine N BMPs for sugarcane production that will insure sustainable yields while protecting the water quality of south Florida. To collect adequate data on N use in as efficient manner as possible, the above studies should be integrated with P soil test studies proposed by the task force.

Phosphorus

The sugarcane soil test P calibration for organic soils in Florida should be updated as soon as possible. It is important to replace the water extractable test with an extractant more closely correlated with sugar production. All available data should be used to determine the new calibration including data from on-going studies. A P rate project is currently being conducted on mineral soils to provide data for refinement of the soil test P calibration for sugarcane. This research should be a priority because of the large acreage of sugarcane now grown on mineral soils and because of environmental concerns in south Florida.

Other extractants currently being studied include modified acetic acid, Mehlich 3, and Bray 2. It should be possible to use available data from the sources cited to develop an updated soil test P calibration for organic soils. The current maximum P rate of 84 kg ha\(^{-1}\) of P\(_2\)O\(_5\) is supported by other work (Andreis and McCray, 1998; McCray, unpublished data). The acetic acid soil test should be compared with other extractants to determine the best choice, but there is a strong need to replace the water extractant for sugarcane P fertilizer recommendations as soon as possible.

Magnesium, Silicon, and Sulfur

Magnesium fertilizer recommendations should be reexamined, particularly for mineral soils because of the potential impact on sugarcane production, but this is a lower priority than N, P, S, and Si research. The task force recommends the implementation of S-related studies, particularly those investigating sugarcane agronomic and sugar responses to S rate and S source. A sulfur research working group has been established to coordinate IFAS sulfur research on sugarcane yields and environmental concerns. Sugarcane growers are using the acetic acid Si soil test to make decisions about silica application, but at this point there are not specific Si recommendations for sugarcane. Current research with calcium silicate will be completed over the next two years and then should be evaluated in addition to previous work to determine Si recommendations for sugarcane grown on organic and mineral soils.

CONCLUSIONS

Most current nutrient recommendations for sugarcane production were made 30 or more years ago for Histosols containing high organic matter levels. These soils have higher water and nutrient holding characteristics compared with most sandy soils in Florida. Cultivars and production practices have changed greatly since the current recommendations were made. Much of the field data used to establish current recommendations are no longer available or contain incomplete soil characteristic data. Sugarcane production on sandy Entisols and Spodosols has increased since most recommendations were established, making soil characteristic data important in determining applicability of current recommendations on these sandy soils. Application rate and timing research on many nutrients are currently being conducted on both organic and mineral soils. Additional data on annual N and P application rate on sandy soil are needed along with soil P test calibration for both organic and sandy soils. Likewise, field testing of Si, Mg, and S rates need to continue, before appropriate recommendations can be established, particularly on sandy soils.
REFERENCES


Impacts of Cultural Practices on USGA Ultradwarf Bermudagrass Golf Green Soil Properties

J.H. Rowland*, G.H. Snyder, J.L. Cisar, J.B. Sartain, A.L. Wright

ABSTRACT

Ultradwarf bermudagrasses [Cynodon dactylon (L.) Pers. x C. transvaalensis Burt Davy] are used on USGA golf greens in Florida due to their ability to tolerate high temperatures and produce fast greens. Their growth characteristics can negatively affect soil physical properties. This experiment was conducted to determine the effects of cultural practices on soil properties in a mature golf green constructed with a 90:10 (sand:sphagnum peat moss, v/v) USGA-specified soil mix. Three ultradwarf varieties — ‘FloraDwarf’, ‘TifEagle’, and ‘Champion’ — were subjected to: one, two, or three-time hollow tine aerification (HTA), five-time solid tine, three-time deep verticutting, and a topdressed control. Treatments were applied in Spring-Summer and Summer-Fall studies, and soil properties were determined from 9.5 cm deep cores. Soil organic matter was not reduced by cultural practice treatments in either study. Saturated hydraulic conductivity (Ksat) was increased by three-time HTA in both studies. Two-time HTA had lower bulk density than verticutting in the Summer-Fall study. Champion had lowest bulk density in both studies. Three-time HTA had more total and macropore space than verticutting in both studies. Champion had most total pore space in the Spring-Summer study. Hollow tine aerification, which had the greatest influence on soil properties, was more effective in the Spring-Summer study.

INTRODUCTION

Ultradwarf Bermudagrasses

Hybrid bermudagrasses for golf course putting greens have been available since 1953 when ‘Tiffine’ was released from the United States Department of Agriculture, Coastal Plain Experiment Station in Tifton, GA (Burton, 1991). ‘Tifgreen’ was released shortly thereafter in 1956, and was touted for having finer leaves and the ability to withstand daily mowing at 6.4 mm (Burton, 1991). Tifgreen sprigs sent to golf courses for early evaluation contained a natural mutation that was later isolated and increased for evaluation (Burton, 1991). This selection, now known as ‘Tifdwarf’ due to its smaller, shorter leaves, stems, and internodes, was released in 1965 (Burton, 1991). Tifdwarf tolerated lower mowing heights and provided the faster green speeds that golfers demanded (Burton, 1991).

The USGA version of the stimpmeter, introduced in 1976 to measure ball roll, brought about a green speed war where the motto was “the faster, the better” (Vermeulen, 1995). Golfers and superintendents preference for faster green speeds and advances in greens maintenance technology eventually necessitated improved grass varieties for greens (Vermeulen, 1995). In 1995, A.E. Dudeck of the University of Florida (UF) released ‘FloraDwarf’, which had a lower vertical growth characteristic, finer texture and increased shoot density (Dudeck and Murdoch, 1997). In 1997, ‘TifEagle’ and ‘Champion’, which had similar characteristics to FloraDwarf, were released from Tifton, GA and Bay City, TX, respectively (Busey and Dudeck, 1999). These denser, lower growing varieties, named “Ultradwarfs” by P. Busey of the University of Florida, can easily withstand regular mowing below 3 mm (Foy, 1997; Foy, 2000) and produce green speeds in excess of 3.35 m (Busey and Boyer, 1997), as measured with a stimpmeter.

USGA Putting Greens Specifications

United States Golf Association greens construction methods have been used for more than 40 years due to their successful, scientifically-tested guidelines (USGA Green Section Staff, 1993). Their recommendations for particle size distribution in root zone media is a predominant factor why these greens are so successful, as these profiles provide physical properties that can withstand continuous traffic (Carrow, 2003). Particle size diameters range from fine gravel (3.4 mm) to clay, which are smaller than 0.002 mm (USGA Green Section Staff, 1993). Limiting fine gravel and very coarse sand (1.0-2.0 mm) to ≤ 10% helps limit saturated hydraulic conductivity (Ksat), allowing sufficient water to be held in the root zone (USGA Green Section Staff, 1993). Total fines (i.e., silt and clay) are also limited to ≤ 10% so excessive moisture will not be held (USGA Green Section Staff, 1993). Compaction and reduction of Ksat are also controlled by limiting fines, as they can fill micropores that sand size particles cannot (Gaussoin et al., 2006). These guidelines create a total pore space range of 35-55%, which provides optimum air-filled and capillary porosity for plant growth and drainage (Brady and Weil, 1999). Over time, the beneficial characteristics supplied by USGA greens mix specifications can diminish from excessive soil organic matter (SOM) levels within the more aggressive ultradwarf bermudagrasses (Carrow, 2003; Hartwiger, 2004; White et al., 2004).

Control of Soil Organic Matter

Since conventional tillage cannot be used on turfgrass without destroying sod characteristics, other methods must
be used to control SOM (Beard, 1973; McCarty and Brown, 2004). These methods include solid and hollow tine aerification, vertical mowing, slicing, topdressing, and grooming (Beard, 1973; Christians, 1998; Cisar, 1999; Hanna, 2005; McCarty and Miller, 2002; Vavrek, 2006). These cultural practices can also increase soil aeration, rooting, infiltration, percolation, porosity and reduce bulk density (Beard, 1973; Bevard, 2005; Cisar, 1999; McCarty and Miller, 2002; Unruh et al., 1999). Seasonal timing of cultural practices can also be important, as SOM tends to accumulate more rapidly during times of maximum growth (Carrow, 2000; Carrow, 2004a), and turfgrass recovery is impeded when growth is limited. Therefore, we initialized an experiment incorporating cultural practices used to manage SOM in order to analyze their effects on soil physical properties.

**MATERIALS AND METHODS**

**Background**

This experiment was performed at the Fort Lauderdale Research and Education Center, University of Florida, on an ultradwarf bermudagrass research green from 2007 to 2008. The research green was established in 1999 with a 90:10 (sand:sphagnum peat, v/v), USGA specified greens soil mix (USGA Green Section Staff, 1993). FloraDwarf, TifEagle, and Champion ultradwarf bermudagrass varieties were planted due to their availability and popularity at the time (Cisar and Snyder, 2003; Foy, 2000). FloraDwarf is no longer commercially available, though the other two grasses are the most extensively planted ultradwarf cultivars. After seven years of growth, and a two-year period in which only minimal cultural practices were implemented, the ultradwarf research green had a 7.6 cm deep build up of organic matter and a soil organic matter concentration as high as 6.6% (by weight). The green was mowed daily at a 3 mm height, and fertilized with 100 g N m⁻² annually.

**Design and Statistical Analysis**

A split-plot, randomized complete block design was used in order to increase treatment effect precision (Littell et al., 2006). Grasses were oriented in east-west rows as whole plot units, with six cultural management treatments randomly assigned to each row as sub-plot units (Littell et al., 2006). Each row received all six treatments, which included HTA one, two, or three times yearly, monthly solid tine aerification, deep verticutting three times yearly, and an untreated control. To reduce spatial variability the experimental area was further separated into randomized blocks, with each block containing a complete replication (Littell et al., 2006). SAS® PROC MIXED and SAS® PROC GLIMMIX (SAS, 2004), both using Tukey’s multiple-comparison procedure, were used to determine significant differences (P<0.05).

A Spring-Summer and a Summer-Fall study were conducted. Treatments were initiated in March, and July 2007, respectively (Table 1). Hollow tine aerification and verticutting were applied at two month intervals, while solid tine aerification was performed monthly. Spring-Summer treatments were applied to eighteen rows of FloraDwarf, TifEagle, and Champion, making up six complete replications, while the Summer-Fall treatments were applied to a separate area of the green, and consisted of five rows each of FloraDwarf and TifEagle, and three rows of Champion.

**Turfgrass Cultivation Treatments**

USGA agronomists recommend impacting 15-20% of the putting green surface with hollow tine aerification yearly, and topdressing with 121.9-152.4 m³ (12.2-15.2 mm) USGA sand ha⁻¹ yr⁻¹ to dilute SOM (Hartwiger and O’Brien, 2001). Hollow tine aerification was performed with a walk-behind core aerator (model ProCore 648, The Toro Company, Bloomington, MN) one, two, or three times yearly. Putting green surface area and volumetric impact, at a depth of three inches, was 7.6, 15.2, and 22.8%, respectively, for the one, two, and three-time HTA treatments, respectively. Cores were pulled with 1.6 cm inner diameter hollow tines, on 5.1 cm centers (O’Brien and Hartwiger, 2003), set to a 7.6 cm depth. Ejected cores were picked up with a scoop shovel and discarded. Each HTA application required 47.2 m³ (4.7 mm) USGA sand ha⁻¹ to fill aerification holes and smooth the surface (Hartwiger 2004). An additional 42.7 m³ (4.3 mm) USGA sand ha⁻¹ yr⁻¹ was uniformly applied to all HTA treatments as surface topdressing in each study. This combination

### Table 1. Specifications and frequency of cultural practices applied to an ultradwarf bermudagrass research putting green in 2007.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Frequency</th>
<th>Tine Spacing (cm)</th>
<th>Tine Depth (cm)</th>
<th>Tine Width (cm)</th>
<th>Surface Area Impacted (%)</th>
<th>Volumetric Area Impacted † (%)</th>
<th>Sand Applied (m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control†</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>42.7</td>
</tr>
<tr>
<td>Hollow tine</td>
<td>One time:</td>
<td>5.1</td>
<td>7.6</td>
<td>1.6</td>
<td>7.7</td>
<td>7.7</td>
<td>42.7</td>
</tr>
<tr>
<td>Hollow tine</td>
<td>Two times:</td>
<td>5.1</td>
<td>7.6</td>
<td>1.6</td>
<td>15.4</td>
<td>15.4</td>
<td>94.4</td>
</tr>
<tr>
<td>Hollow tine</td>
<td>Three times:</td>
<td>5.1</td>
<td>7.6</td>
<td>1.6</td>
<td>23.1</td>
<td>23.1</td>
<td>141.6</td>
</tr>
<tr>
<td>Verticut</td>
<td>Three times:</td>
<td>1.3</td>
<td>2.5</td>
<td>0.2</td>
<td>46.8</td>
<td>15.6</td>
<td>63.9</td>
</tr>
<tr>
<td>Solid tine</td>
<td>Five times:</td>
<td>5.1</td>
<td>7.6 §</td>
<td>1.0</td>
<td>15.7</td>
<td>15.7</td>
<td>21.4</td>
</tr>
</tbody>
</table>

†Volumetric area impacted based on a 7.6 cm depth.
‡All cultural practice treatments received grooming 32 times yearly, and an additional 42.7 m³ (4.3 mm) USGA sand ha⁻¹ year⁻¹.
§Tine depth was 10.2 cm in the Spring-Summer study.
¶Topdressing sand applied was 39.6 m³ ha⁻¹ in the SpringSummer study.
resulted in a total of 89.9, 137.1, and 184.3 m³ (8.9, 13.7, and 18.4 mm) USGA sand ha⁻¹ yr⁻¹ for the one, two, and three-time HTA treatments, respectively. These HTA treatments were considered suboptimal, optimal, and supraoptimal in regards to yearly surface impact and topdressing, and mimicked the USGA’s “Big Holes, Big Spacing” approach (O’Brien and Hartwiger, 2003).

Deep (2.5 cm) vertical mowing treatments (i.e., verticutting) using a commercial scarifier (model 117462, Sisis Equipment (Macclesfield) Ltd., Cheshire, England), were performed three times yearly. Putting green surface area and volumetric impact, at a depth of three inches, was 46.8, and 15.6%, respectively. The 2 mm wide steel blades were set to a 2.5 cm depth and 21.3 m³ (2.1 mm) USGA sand ha⁻¹ was used to fill verticutting grooves and smooth the surface after any debris was swept up and discarded. An additional 42.7 m³ (4.3 mm) USGA sand ha⁻¹ yr⁻¹ was uniformly applied as surface topdressing between applications for a total of 106.6 m³ (10.7 mm) USGA sand ha⁻¹ yr⁻¹.

Solid tine aerification was performed with the same walk-behind aerator used for HTA. Treatments were implemented monthly in an attempt to increase infiltration, oxygen flow through the soil profile, Ksat, root growth (Vavrek, 2002), and increase decomposition of SOM (Carroll, 2003). In the Spring-Summer study 10.2 cm tines were used, but due to excessive turfgrass damage 7.6 cm tines were used in the Summer-Fall study. Damage caused by the longer tines required an additional 18.2 m³ USGA sand ha⁻¹ yr⁻¹ to smooth the surface.

The control received 42.7 m³ (4.3 mm) USGA sand ha⁻¹ yr⁻¹, applied as a surface topdressing, and light vertical mowing (i.e., grooming). Topdressing was applied using a calibrated rotary spreader (The Scotts Company, Marysville, OH) with rates and timings dependent on using a calibrated rotary spreader (The Scotts Company, vertical mowing (i.e., grooming). Topdressing was applied ha⁻¹ was used to fill verticutting grooves and smooth the surface after any debris was swept up and discarded. An additional 42.7 m³ (4.3 mm) USGA sand ha⁻¹ yr⁻¹ was uniformly applied as surface topdressing between applications for a total of 106.6 m³ (10.7 mm) USGA sand ha⁻¹ yr⁻¹.

Physical Measurements

Soil organic matter was determined in March (initial) and August 2007 (final) for the Spring-Summer study, and July 2007 (initial) and January 2008 (final) for the Summer-Fall study, by two sampling methods. The first method used 5.1 cm diameter and 9.4 cm deep soil cores with the top 1.8 cm of verduré, thatch and mat removed. The second used a 1.9 cm diameter handheld soil sampler with an open-side profile to remove 15 cm deep soil cores. The second sampling method was used to collect only the soil below the mat and above the lightly stained original greens mix. Soil samples were screened with a 2 mm (#10) sieve to remove contaminants (e.g., stems, and gravel), oven-dried at 105°C, weighed, ashed in a 350°C muffle furnace and re-weighed to determine SOM loss on ignition.

Root weights were determined from 10 cm diameter by 15 cm deep cup cutter cores in August 2007 and January 2008 at the end of each study after all treatments had recovered. Thatch and mat were removed from these cores with a long knife and the remaining soil was washed through a 2 mm (#10) screen to separate roots from the mineral fraction. Roots were collected and oven-dried at 105°C before weighing.

Saturated hydraulic conductivity, bulk density, and pore space were determined on 5.1 cm diameter by 9.4 cm deep soil cores, with 1.8 cm of verduré, thatch and mat removed by ASTM F method 1815-97, minus the cylinder loading step. Samples were taken in March (initial) and August 2007 (final) for the Spring-Summer study, and July 2007 (initial) and January 2008 (final) for the Summer-Fall study.

RESULTS AND DISCUSSION

There was no significant reduction in SOM among treatments in either study due to the limited amount removed by cultural practices and spatial variability of the root zone. Three-time HTA, which had the greatest impact on the root zone, theoretically removed 0.6 g cm⁻² of SOM, however there was an average standard deviation of 0.8 g cm⁻² among treatments and that precluded any significant differences among treatments. The 1.9 cm diameter by 15 cm deep hand held soil sampler produced an average of 41% more SOM than the 5.1 cm diameter by 9.4 cm deep soil cores. This was due to the more selective sampling method of the hand held device that allowed the exclusion of the original greens mix, which contained <1% SOM by weight. Average SOM concentration in the Summer-Fall study increased 18% (i.e., 0.6 g cm⁻²) over initial levels. Summer-Fall study root weights, sampled at a 15 cm depth, were 167% higher than those found in the Spring-Summer study. It would be reasonable to expect that this greater root mass, which developed between November and February, increased SOM in the Summer-Fall study. There were no significant differences in SOM or root weights among bermudagrass varieties in either study.

Three-time HTA had higher Ksat than the control and verticutting in both studies, and higher Ksat than all but...
two-time HTA in the Summer-Fall study (Table 2). In the Spring-Summer study Ksat for three-time HTA was 67% higher, while the control was 10% lower than initial levels. In the Summer-Fall study Ksat for three-time HTA was 58% higher, while the control was 83% lower than initial levels. Final Ksat for all cultural practice treatments in the Summer-Fall study were an average of 64% slower (i.e., 11.4 cm h\(^{-1}\)) than in the Spring-Summer study. Three-time HTA and the control had 30 and 89% slower final Ksat, respectively, in the Summer-Fall study compared to the Spring Summer study. The slower Ksat observed in the Summer-Fall study was attributed to a reduction in soil porosity, particularly macropore space, due to increased SOM and root mass (Carrow, 2004 a, c). Reduced Ksat has also been found to be indicative of increased bulk density (McCarty and Brown, 2004). There were no significant differences in Ksat among bermudagrass varieties in either study.

Bulk density was not reduced by any cultural practice treatment in the Spring-Summer study, although two-time HTA had lower bulk density than verticutting in the Summer-Fall study (Table 3). Overall, bulk density decreased marginally from 1.31 to 1.24 g cm\(^{-3}\) in the Spring-Summer study, while it increased substantially from 1.20 to 1.40 g cm\(^{-3}\) in the Summer-Fall study. These changes in bulk density seemed to have an effect on Ksat. In the Spring-Summer study overall Ksat increased 10.4 cm h\(^{-1}\), while in the Summer-Fall study Ksat decreased 3.2 cm h\(^{-1}\). Champion had the lowest bulk density among bermudagrass varieties in both studies due to its growth characteristics and somewhat higher (P=0.15) root mass.

Three-time HTA had more total pore space than the control and verticutting treatments in the Spring-Summer study (Table 4). Two and three-time HTA, as well as the control had more total pore space than verticutting in the Summer-Fall study. Overall, total pore space increased slightly from 51.2 to 54.1 % in the Spring-Summer study, while it decreased substantially from 53.1 to 35.3 % in the Summer-Fall study due to increased SOM and root mass. Champion had more total pore space than both FloraDwarf and TifEagle in the Spring-Summer study, which again is indicative of Champions’ differing summer growth habit.

Two and three-time HTA had higher macropore space than verticutting in the Spring-Summer study (Table 5). In the Summer-Fall study three-time HTA had more macropore space than one-time HTA, verticutting and the control. Overall macropore space increased from 12.4 to 17.7 % in the Spring-Summer study, while it decreased substantially from 18.0 to 9.8 % in the Summer-Fall study. This decrease in macropore space was likely due to increased SOM and root mass. There were no significant differences in macropore space among bermudagrass varieties in either study.

### Table 2. Saturated hydraulic conductivity (Ksat) for Spring-Summer and Summer-Fall studies.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Spring-Summer</th>
<th></th>
<th>Summer-Fall</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Initial</td>
<td>Final</td>
<td>P Value</td>
<td>Initial</td>
</tr>
<tr>
<td>Hollow Tine Aerification (1x yr(^{-1}))</td>
<td>18.8</td>
<td>32.8 ab†</td>
<td>4.6 b</td>
<td>18.4</td>
</tr>
<tr>
<td>Hollow Tine Aerification (2x yr(^{-1}))</td>
<td>20.9</td>
<td>41.7 a</td>
<td>29.3 a</td>
<td>20.2</td>
</tr>
<tr>
<td>Hollow Tine Aerification (3x yr(^{-1}))</td>
<td>24.9</td>
<td>18.5</td>
<td>2.2 b</td>
<td>23.1</td>
</tr>
<tr>
<td>Control</td>
<td>22.6</td>
<td>20.3 b</td>
<td>7.7 b</td>
<td>21.6</td>
</tr>
<tr>
<td>Verticutting (3x yr(^{-1}))</td>
<td>16.8</td>
<td>43.1 a</td>
<td>9.2 b</td>
<td>16.7</td>
</tr>
<tr>
<td>Solid Tine Aerification (5x yr(^{-1}))</td>
<td>22.4</td>
<td>11.3</td>
<td>4.6 b</td>
<td>22.2</td>
</tr>
</tbody>
</table>

†Mean estimates with same letter within column are not statistically different, at 0.05 significance level, using the Tukey-Kramer method.

### Table 3. Bulk density for Spring-Summer and Summer-Fall studies.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Spring-Summer</th>
<th></th>
<th>Summer-Fall</th>
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</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Initial</td>
<td>Final</td>
<td>P Value</td>
<td>Initial</td>
</tr>
<tr>
<td>Hollow Tine Aerification (1x yr(^{-1}))</td>
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<td>1.24</td>
<td>1.21</td>
<td>1.40 ab†</td>
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<tr>
<td>Hollow Tine Aerification (2x yr(^{-1}))</td>
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<td>1.25</td>
<td>1.20</td>
<td>1.37 b</td>
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<tr>
<td>Hollow Tine Aerification (3x yr(^{-1}))</td>
<td>1.30</td>
<td>1.22</td>
<td>1.19</td>
<td>1.37 ab</td>
</tr>
<tr>
<td>Control</td>
<td>1.31</td>
<td>1.23</td>
<td>1.19</td>
<td>1.39 ab</td>
</tr>
<tr>
<td>Verticutting (3x yr(^{-1}))</td>
<td>1.29</td>
<td>1.22</td>
<td>1.17</td>
<td>1.41 ab</td>
</tr>
<tr>
<td>Solid Tine Aerification (5x yr(^{-1}))</td>
<td>1.33</td>
<td>1.27</td>
<td>1.17</td>
<td>1.41 ab</td>
</tr>
</tbody>
</table>

†Mean estimates with same letter within column are not statistically different, at 0.05 significance level, using the Tukey-Kramer method.
Table 4. Total pore space for Spring-Summer and Summer-Fall studies.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Spring-Summer</th>
<th></th>
<th>Summer-Fall</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Initial</td>
<td>Final</td>
<td>Initial</td>
<td>Final</td>
</tr>
<tr>
<td>Hollow Tine Aerification (1x yr⁻¹)</td>
<td>50.3</td>
<td>53.5 ab</td>
<td>52.7</td>
<td>35.1 ab</td>
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<tr>
<td>Hollow Tine Aerification (2x yr⁻¹)</td>
<td>51.1</td>
<td>54.6 ab</td>
<td>52.6</td>
<td>37.1 a</td>
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<tr>
<td>Hollow Tine Aerification (3x yr⁻¹)</td>
<td>51.6</td>
<td>55.9 a</td>
<td>53.7</td>
<td>37.2 a</td>
</tr>
<tr>
<td>Control</td>
<td>51.5</td>
<td>53.2 b</td>
<td>53.3</td>
<td>35.3 a</td>
</tr>
<tr>
<td>Verticutting (3x yr⁻¹)</td>
<td>51.1</td>
<td>53.1 b</td>
<td>53.4</td>
<td>32.7 b</td>
</tr>
<tr>
<td>Solid Tine Aerification (5x yr⁻¹)</td>
<td>51.4</td>
<td>54.4 ab</td>
<td>53.0</td>
<td>34.9 ab</td>
</tr>
<tr>
<td>Grass</td>
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<td></td>
</tr>
<tr>
<td>Champion</td>
<td>53.3 a</td>
<td>55.6 a</td>
<td>53.2</td>
<td>36.1</td>
</tr>
<tr>
<td>FloraDwarf</td>
<td>49.9 b</td>
<td>53.4 b</td>
<td>53.6</td>
<td>35.9</td>
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<tr>
<td>TifEagle</td>
<td>50.2 b</td>
<td>53.3 b</td>
<td>52.5</td>
<td>34.2</td>
</tr>
<tr>
<td></td>
<td>P=0.002</td>
<td>P&lt;0.01</td>
<td>P=0.72</td>
<td>P&lt;0.001</td>
</tr>
</tbody>
</table>
|                                          | Mean estimates with same letter within column are not statistically different, at 0.05 significance level, using the Tukey-Kramer method.

Table 5. Macropore space for Spring-Summer and Summer-Fall studies.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Spring-Summer</th>
<th></th>
<th>Summer-Fall</th>
<th></th>
</tr>
</thead>
<tbody>
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<td></td>
<td>Initial</td>
<td>Final</td>
<td>Initial</td>
<td>Final</td>
</tr>
<tr>
<td>Hollow Tine Aerification (1x yr⁻¹)</td>
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<td>17.9 ab</td>
<td>18.8 a</td>
<td>9.7 b</td>
</tr>
<tr>
<td>Hollow Tine Aerification (2x yr⁻¹)</td>
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<td>18.6 a</td>
<td>17.6 a</td>
<td>10.0 ab</td>
</tr>
<tr>
<td>Hollow Tine Aerification (3x yr⁻¹)</td>
<td>12.4</td>
<td>18.8 a</td>
<td>19.7 a</td>
<td>11.9 a</td>
</tr>
<tr>
<td>Control</td>
<td>12.9</td>
<td>16.8 ab</td>
<td>18.6 a</td>
<td>9.0 b</td>
</tr>
<tr>
<td>Verticutting (3x yr⁻¹)</td>
<td>12.0</td>
<td>15.5 b</td>
<td>19.2 a</td>
<td>8.2 b</td>
</tr>
<tr>
<td>Solid Tine Aerification (5x yr⁻¹)</td>
<td>13.1</td>
<td>18.4 a</td>
<td>18.7 a</td>
<td>9.9 ab</td>
</tr>
<tr>
<td>Grass</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Champion</td>
<td>13.8</td>
<td>18.2</td>
<td>18.0</td>
<td>9.5</td>
</tr>
<tr>
<td>FloraDwarf</td>
<td>10.7</td>
<td>17.2</td>
<td>20.2</td>
<td>9.9</td>
</tr>
<tr>
<td>TifEagle</td>
<td>12.7</td>
<td>17.5</td>
<td>18.0</td>
<td>9.8</td>
</tr>
<tr>
<td></td>
<td>P=0.06</td>
<td>P=0.15</td>
<td>P=0.18</td>
<td>P=0.94</td>
</tr>
</tbody>
</table>
| Mean estimates with same letter within column are not statistically different, at 0.05 significance level, using the Tukey-Kramer method.

CONCLUSIONS

Naturally-occurring seasonal changes in turfgrass growth appeared to supplant the impact of cultural practices on most USGA green soil properties when applied later in the year. Because cultural practices were less effective and took longer to recover when applied later in the year, the optimal time to initiate these treatments was in the spring. This timing also allows additional aerification or verticutting applications to be made in the summer when fewer golfers are on the course and turfgrass recovery is fastest here in south Florida. Also, when play and greens fees are at their peak in the winter all cultural practice treatments would be fully recovered and the greens would be in optimum condition.

LIST OF REFERENCES


Comparative Influence of N Source on N Leaching and St. Augustinegrass Quality, Growth and N Uptake

J.B. Sartain*

ABSTRACT

Nitrogen fertilization of home lawns with soluble and controlled-release N sources has recently become an environmental concern. Cities and municipalities are imposing restrictions on home lawn fertilization with questionable scientific merit. A glasshouse study was conducted to evaluate the influence of N source and rate on the quantity of N loss through leaching and the growth and quality of St. Augustinegrass (Stenataphrum secundatum Walt. Kunze). Saint Augustine cv. ‘Floratam’ sod was placed on 45 by 60 cm tubs filled with Candlar fine sand (Typic Quartzipsamments, Hyperthermic, uncoated) which were engineered for gravity flow leachate collection. Moisture level was maintained such that no leaching occurred except during imposed leaching events. Soluble N sources (urea and UAN) were applied at 4.88 g N m⁻² every 30 days and controlled-release N sources (SCU and T-180 type staged nutrient release 15-2-15, a blend of primary nutrients differentially coated with a proprietary polymer coating) were applied at 9.76 g N m⁻² every 60 days as SCU or once at 7.32, 9.76 or 12.26 g N m⁻² as 15-2-15. Total shoot (clippings) dry matter over a 180 day period was taken weekly and leachates were collected every 30 days by adding ½ pore volume of water. Leachates were analyzed for urea, NH₄ and NO₃-N. There was no urea or NH₄-N detected in the leachates. Only the NO₃-N form of N was detected in the leachates which accounted for 4 to 8% of the applied N and was detected only during the first 30 d after application. An immature turfgrass root system was assumed to be responsible for the leaching losses during the early days of the study. Following the establishment of the root system and during the active growing period of the turfgrass no N was detected in the leachates. This indicates that 4.88 g N m⁻² every 30 day as soluble N and as much as 12.26g N m⁻² in a one-time application as a controlled-release N source can be applied without a negative environmental impact. In summary, results from this glasshouse study suggest soluble and controlled-release N sources can be applied to actively growing St. Augustinegrass at rates higher than currently recommended by the Urban Turf Fertilizer Rule without negative environmental impact.

INTRODUCTION

Fertilizer use on home lawns has recently become a subject of extreme interest and scrutiny because of environmental concerns and the assumed threat of groundwater pollution. In late 2007, the Florida Fertilizer Law was revised to include what is now referred to as the Urban Turf Fertilizer Rule through which the quantity of N and P labeled for home lawn use is limited. The rule states that no more than 0.7 lbs (3.42 g N m⁻²) of soluble N or 1.0 lbs (4.88 g N m⁻²) of total N may be applied per 1000 sq ft (92.9 m⁻²) per application, thus suggesting that an additional 30% of N can be applied as long as it is not soluble N. This suggests that soluble N sources leach more than controlled release N sources. Some research supports the concept of more N leaching from soluble N sources while some does not. Quirago-Garza et. al. (2001) reported that soluble N treated plots leached less nitrate-N than did controlled-release N treatments using ‘Tifgreen’ bermudagrass (Cynodon dactylon (L.) Pers. x C. transvaalensis Burtt-Davy). In contrast, Easton and Petrovic (2004) found increased nitrate loss from plots receiving soluble N sources. Brown et. al. (1982) reported more nitrate leached from plots receiving soluble N on greens planted to ‘Tifwarf’ bermudagrass when compared to controlled-release N sources. Saha et. al. (2007) observed more N leaching from soluble N sources than controlled-release N sources in St. Augustinegrass (Stenataphrum secundatum Walt. Kunze.). In general, the environmental impact of lawn fertilization can be minimized through the growth and maintenance of a healthy turfgrass stand using proper fertilization and irrigation practices.

Relatively few researchers have evaluated N leaching in lawn grass species; however, Erickson et. al. (2001) demonstrated minimal nitrate leaching in St. Augustinegrass. Leaching losses of 4.1 kg N ha⁻¹ from St. Augustinegrass fertilized at 300 kg N ha⁻¹ yr⁻¹ were reported, whereas, a mixed landscape planting lost 48.3 kg N ha⁻¹ after receiving 150 kg N ha⁻¹ yr⁻¹. Bowman et. al. (2002) reported that ‘Floratam’ St. Augustinegrass was the most efficient of 6 warm-season turfgrasses in nitrate uptake and that ‘Meyer’ zoysiagrass was the least efficient. Due to the limited availability of leaching data and the lack of agreement concerning the leaching characteristics of soluble and controlled-release N sources, a glasshouse study using ‘Floratam’ St. Augustinegrass was initiated with the following objectives: 1) To compare the leaching characteristics of soluble and controlled-release N sources, 2) To identify the form of N leached, and 3) To compare the influence of soluble and controlled-release N sources on quality, growth and N uptake of St. Augustinegrass.

MATERIALS AND METHODS

Saint Augustinegrass cv ‘Floratam’ was sodded to tubes (45 cm by 60 cm) in a glasshouse. Temperature was maintained between 20°C and 32°C during the 180 day growth period of May through October. Natural light intensity was not supplemented with artificial lighting. Tubs were mounted at a 10 degree angle and fitted with drain tubes to facilitate leachate collection. Following a two week sod establishment period, treatments were applied in a randomized complete block design and replicated four times. Soluble N sources of urea and UAN (30% N solution composed of urea and ammonium nitrate) were applied at 4.88 g N m⁻² every 30 days. Sulfur coated urea (SCU, 39% N with an approximate release rate of
Ammonium-N was not detected in the leachate collections at any time during the 180 day period (data not shown). These results mimic the results observed in previous studies. Ammonium-N is rapidly converted to nitrate-N through nitrification in a well aerated turfgrass soil. Thatch layers and root zones of actively growing turfgrass are microbially active and conversion of ammonium-N in a warm Florida soil is accomplished within 7 to 10 days (Havlin, et. al., 2005). Therefore, leachate collections at 30 days after application of any N source contains only nitrate-N as has been observed in many similar studies in the past.

Nitrate-N Analysis

Nitrate-N was detected in each of the six leachates. Quantities of nitrate-N found were related to the N source and rate of application (figure 1). The largest total quantity of N (29.28 g m$^{-2}$) was applied every 30 days in six gravimetrically equal quantities for a total of six times as urea and UAN and these two soluble N sources accounted for the largest quantity of NO$_3$-N leached (1.378 and 1.902 g m$^{-2}$, respectively). The experimental material, 15-2-15, and SCU leached statistically equivalent quantities of NO$_3$-N and less than the soluble N sources. It should be noted that there was a total of 29.28 g N m$^{-2}$ applied as the soluble N sources; whereas, the maximum rate of N applied as a controlled-release N source was 12.26 g N m$^{-2}$. Even though twice as much N was applied as SCU (4.88 mg m$^{-2}$ N every 60 days) as was applied using 7.32 g N m$^{-2}$ of 15-2-15 the two N sources leached statistically equivalent amounts.

On a percentage basis relative to the total quantity of N applied over the evaluation period, all of the N sources leached statistically equivalent amounts of NO$_3$-N (figure 2). Although the percentage of applied N leached ranged from 4.7 to 8.8% there was no statistical difference relative to the source of N. These data suggest that the controlled-release N sources were no more environmentally friendly than the soluble N sources in this application regime. It
approximately 25% of the applied soluble N leached during the first 30 days of the study. The fact that soluble sources leached the largest percentage of applied N at each application date as the soluble N source, yet the fact only 1/6 of the total experimental rate was applied at the beginning of the study as the 15-2-15 and 15-2-15, respectively. The quantity of N as the experimental controlled release source was 180 day management over the evaluation period. Means within columns followed by the same letter do not differ at P<0.05 by Duncan-Waller K-Ratio.

Percentage of applied N leached by month over the evaluation period is shown in figure 3. The largest percentage of applied N was leached during the first 30 days of the study with the soluble N sources accounting for the highest percentages. It should be noted that the soluble N sources leached the largest percentage of applied N during the first 30 days even though as much as 2.5 times more N was applied as the 15-2-15 material. Recall that all of the N as the experimental controlled release source was applied at the beginning of the study as the 15-2-15 and that only 1/6 of the total experimental rate was applied at each application date as the soluble N source, yet the soluble sources leached the largest percentage of applied N during the first 30 days of the study. The fact that approximately 25% of the applied soluble N leached during the first 30 days could be related to the maturity of the turfgrass root system. Sod pieces were placed on the tubs and allowed to establish for 14 days prior to treatment application. Most likely the turfgrass root system was not fully established at treatment application. The controlled-release N sources did not leach as much N because the N was protected from leaching losses due to the reduced solubility of the N in the controlled release materials. The turfgrass root system after 60 days of growth should have been extensive and active enough to efficiently absorb applied fertilizer N, thus resulting in minimal N leaching. These data suggest that a healthy turfgrass with a mature root system is capable of absorbing up to 4.88 g N m⁻² of soluble N every 30 days without detectible N loss through leaching. The quantity of N leached appears to increase after August for some N sources. In previous studies, turfgrass root growth has been shown to decline during August, September and October (Sartain, 2002). Thus, the increase in quantity of N leached during the latter stages of the study could be related to a declining root system and suggests that late season application of N may result in more N leaching than N applied during the active growth period of the warm-season turfgrass.

**Dry Matter Accumulation**

Clippings were collected a total of 21 times during the 180 day evaluation period. Clippings were collected approximately weekly during the first 4 months of the study. However, during the latter part of September and October growth slowed and clippings were collected when the height of the turfgrass reached approximately 10 cm. Since the soluble N sources were applied on a 30 day basis, clippings were grouped into 30 day increments for statistical analysis.

Mean dry matter accumulation relative to N source applied over the entire 180 day evaluation period did not differ significantly (figure 4). All sources produced statistically equivalent amounts of dry matter when averaged over the growth period. Only during the third and fourth 30 day harvest period did the 15-2-15 applied at 7.32 g N m⁻² and SCU applied at 4.88 g N m⁻² produce significantly less dry matter than the other N sources (data not shown). Overall, these data suggest that a controlled release N source (e.g. 15-2-15) applied once at 9.76 g N m⁻² during a 180 day period is capable of producing the same statistical quantity of dry matter as does a soluble source of N applied at 4.88 g N m⁻² every 30 days. Application of 12.26 g N m⁻² as 15-2-15 did not produce excessive growth during the first 30 days after application. In fact, the dry matter produced by the controlled N release source was equivalent to that of the soluble source applied at 4.88 g N m⁻² every 30 days.
N Uptake

All clippings were analyzed for total N content. Tissue N concentration was multiplied by the dry matter produced for that harvest to calculate the total quantity of N accumulated.

When averaged over the entire 180 day period the two higher rates of N (9.76 and 12.26 g N m⁻²) applied once as 15-2-15 supplied the same quantity of N as did the soluble N sources applied at 4.88 g N m⁻² every 30 days (figure 5). Even though not statistically significant there was a trend for less dry matter accumulation by the 15-2-15 applied once at 7.32 g N m⁻² this combined with less available N resulted in less total N uptake which suggests that the application of 7.32 g N m⁻² may not be sufficient to sustain growth and adequate tissue N.

Tissue N Concentration

Tissue N levels were highest during the first three 30 day evaluation periods and generally declined as the study progressed (data not shown). Tissue N concentration was influenced by N source at the end of the evaluation period (figure 6). Tissue N levels in response to the soluble N application were within the recommended sufficiency range for St. Augustinegrass (Sartain, 2007). However, turfgrass receiving the controlled-release N sources were somewhat below the recommended 20 g kg⁻¹ N concentration and would have been considered as low or deficient in tissue N. At this time of year (late October) these low tissue N levels may not be detrimental to the turf in that it is growing at a minimal rate and does not require a lot of N.

Visual Quality

Visual quality ratings were taken weekly on a 1 to 9 scale with 9 representing superior quality turf and 5.5 minimum acceptable quality. A total of 25 ratings were taken during the evaluation period.

In general, the turfgrass maintained very good quality throughout the study with a rating of 6 or better and with small differences relative to N source applied (figure 7). This suggests that a one-time application of a controlled release N source is capable of maintaining turfgrass quality over an extended period. It is interesting to note that a one-time application of a controlled-release N source maintained the same quality of turfgrass as did a soluble N source applied every 30 days at more than twice the total quantity of N.

SUMMARY AND CONCLUSIONS

The only form of N leached was NO₃-N which accounted for between 4 and 8 % of the total applied N with the vast majority of the leached N occurring during the first 30 days after application to a turfgrass with an immature root system. During the active growth months little to no N leached regardless of the rate or N source applied, thus demonstrating the capacity of St. Augustinegrass to uptake as much as 4.88 g N m⁻² every 30 days. Application of 12.26 g N m⁻² as a controlled release fertilizer in a one-time application did not result in excessive growth or N leaching. As was observed with the soluble N sources the controlled-release N sources leached most of their N during the first 30 days from turf with an undeveloped root system. Good quality turfgrass was maintained throughout the 180 day evaluation period with a one-time application of a controlled-release N source at 9.76 g N m⁻². Application of 7.32 N m⁻² as a 15-2-15 controlled-release N source was not sufficient to sustain adequate tissue N levels. In summary, soluble N sources
can be applied monthly at the 4.88 g N m⁻² during the active growth of St. Augustinegrass without promoting N leaching or excessive growth and a one-time application of a controlled release N source at the rate of 12.26 g N m⁻² will not promote excessive growth or N leaching.

REFERENCES


GRADUATE STUDENT FORUM
ABSTRACTS

Sensing Accuracy of Four Commercially Available Soil Moisture Irrigation Controllers

Bernard Cardenas-Lailhacar* and Michael D. Dukes

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Over-irrigation has been reported for homeowners having automatic irrigation systems in Florida. Soil moisture sensor (SMS) irrigation control systems have recently been commercialized for single family homes. Each SMS system consists of a probe to be buried in the irrigated zone, and a controller that has an adjustable soil moisture content (θ) set point, for irrigation bypass. The objectives of this research were to: a) determine a relationship between actual θ and the soil moisture content sensed (θS) by four different SMS system brands (Acclima, Rain Bird, Irrometer, and Water Watcher), and b) quantify the proportion of scheduled irrigation cycles that the different SMS systems could bypass. Three SMS probes from each brand were buried between 7 and 10 cm depth, on turfgrass plots, at the University of Florida, in Gainesville. In every plot, a calibrated ECH2O probe was also installed, at the same depth, to continuously monitor θ. The θ records were then compared to the θS readings. Overall, only one Irrometer and the three Acclima controllers resulted in a predictable relationship between actual θ and θS (r²=0.82 for the Irrometer, and between r²=0.66 and r²=0.89, for the Acclimas). Rain Bird and Water Watcher controllers did not produce θS readings related to θ. In spite of this, the SMS systems were able to follow the main wet and dry weather/soil conditions. Since wet conditions prevailed during the 308-day study period, the SMS systems bypassed between 32% and 92% of the scheduled irrigation cycles.

Tomato and Pepper Yield Response to Irrigation Management and Nitrogen Rates Under Plastic Mulch Conditions

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The objectives of this study were to evaluate the effects of different N-fertilizer rates and irrigation practices on the yield and water use efficiency (WUE) of pepper and tomato production systems during 2006. Three N-rates (166, 208, 312 kgN/ha) were evaluated across three different drip irrigation scheduling methods. A fixed time (FT) treatment was included to mimic grower practices and plants were irrigated once daily. Two treatments controlled by a soil moisture sensor (SMS) were allocated five irrigation application windows. If the volumetric water content exceeded the predefined SMS treatment threshold during a potential application event, irrigation was bypassed. The Acclima’s decide to irrigate the entire event or not at the very beginning. The QIC’s on the other hand can turn the system on/off in one minute increments. The programmed irrigation window was 24 min in length. For tomato, the effect of subsurface drip irrigation (SDI) coupled with a SMS was evaluated. Compared to FT, SMS treatments reduced water use by 40 to 45% and 12 to 66% for tomato and pepper, respectively. Tomato yield was higher on SMS/SDI treatments than FT, while pepper yield was not affected by irrigation. In general, SMS treatments increased irrigation WUE 2-3 times compared to FT treatments for both crops while N-rate did not affect yield. Average marketable fruit yields were 51, 15, and 39 Mg/ha for tomato, pepper, and fall-grown pepper, respectively. Use of SMS based systems appears to be promising as a management option to enhance WUE.
Evapotranspiration and Soil Moisture-based Irrigation Control on Turfgrass Compared to Theoretical Requirements

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A variety of commercially available technologies for reducing residential irrigation water use are available to homeowners. These technologies include soil moisture sensors, rain sensors and evapotranspiration (ET) based controllers. The purpose of this research was to evaluate the effectiveness of these various technologies based on irrigation applied, turfgrass quality measurements, and compared to theoretical irrigation requirements. Testing was performed on two types of soil moisture sensors (SMS, LawnLogic® and the Acclima Digital TDT® RS500) at low, medium, and high soil moisture threshold settings. Mini-Clik® rain sensors comprised seven time-based treatments, with three treatments pre-set for 3 mm of rainfall and the remaining 4 rain sensor treatments had sensors pre-set to bypass irrigation for 6 mm of rainfall. Two ET controllers were also tested, the Toro Intelli-Sense™ controller and the Rain Bird® ET Manager™. A time-based treatment with two days of irrigation per week and no rain sensor (2-WORS) was established as a comparison. SMS-based treatments resulted in 0-63% reductions in water use compared to 2-WORS. Rain sensor treatments resulted in 7-33% reductions in water use. ET-based irrigation resulted in 36% to 59% reductions in water use compared to 2-WORS. The SMS treatments at the low threshold settings resulted in high water savings, but reduced turf quality to unacceptable levels. The medium threshold setting SMS-based, time-based and both of the ET-based treatments produced good turfgrass quality while reducing irrigation water use compared to 2-WORS. Savings for the medium SMS-based systems ranged from 11-28%.

Characterization of Sorption of Hydrophobic Organic Pesticides in Carbonatic and Non-carbonatic Soils from Florida, Puerto Rico, and Uganda

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Sorption is a major process that influences the environmental fate of a pesticide once applied to agricultural soils. In US, there are about 500 soil series with carbonatic mineralogy and 12 of them occur in South Florida and 8 in Puerto Rico. A lot of research has been done on characterizing the sorption of organic pesticides in non-carbonatic soils but a literature search indicates lack of these data for Carbonatic soils. Eighty five percent of Florida’s vegetables and tropical fruits are grown on these soils. The sub-tropical climate in South Florida and Puerto Rico, and the tropical climate in Uganda encourage proliferation of pests. As a result, a variety of pesticides are used to control these pests. Several pesticides have been reported in both surface and ground water of South Florida and Puerto Rico. Our data on some of these pesticides (Atrazine, Ametryn, Duiron and Carbaryl) indicate that these pesticides adsorb less on Carbonatic soils compared to the non-carbonatic soils. This study aims at understanding the cause for the anomalous sorption behavior of hydrophobic organic pesticides applied to carbonatic soils. For comparison, soils associated with carbonatic soils and soils that differ in type and geographic location (Spodosols and Oxisols) were included in the study. The carbonatic soils in South Florida are very shallow, underlain by porous limestone bedrock and are characterized by a high water table. Their low sorption capacities for organic pesticides may pose threats to the environment and natural resources.
Estimation of Release Properties of Slow-Release Fertilizer Materials

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At present there is no official laboratory method for verification of nutrient release claims for slow-release fertilizer materials. A laboratory long term incubation methodology (182 day) has been developed which produces nutrient release constants over an extended period of time. In addition, a relatively short term extraction method (74 hr) has been developed to assess nutrient release under accelerated laboratory conditions. Through regression techniques the release constants established for individual slow-release nutrient sources using the incubation methodology are used in conjunction with the laboratory extraction data to verify the release claims of the slow-release fertilizer source. For select slow-release nutrient sources we have been able to predict the nutrient release curve with greater than 90% accuracy. Mixtures of slow-release nutrient has proven more difficult to predict. It is typical for soluble and slow-release nutrient sources to be mixed in commercial products. Successes and failures in predicting nutrient release from mixtures of soluble and slow-release nutrient sources will be discussed in detail. Ultimately, it is intended that these methodologies will be accepted as an official method for verifying the nutrient release claims placed on slow-release fertilizer materials.

Bahiagrass Yield, Nutritive Value and P uptake as Influenced by Cattle Manure Application Rate and Strategy

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We evaluated the effects of cattle manure (CM) applied alone or in combination with ammonium nitrate (AN) on dry matter (DM) yield and nutritive value of bahiagrass (Paspalum notatum L. Fluegge). The N rates were 200 and 400 kg N ha⁻¹ applied as CM or CM plus AN (50/50% combination). Nitrogen rates were applied either in a single or split dosage. Bahiagrass was clipped at 28-d intervals for DM yield, crude protein concentration (CP) and in vitro organic matter digestibility (IVOMD). During the 2-yr study, bahiagrass DM yield, IVOMD, and CP were greatest for the treatments that received CM+AN application. Increasing N rate from 200 to 400 kg ha⁻¹ increased DM yield, IVOMD, and CP for all application strategies, however nutrient uptake recovery was lower at the 400 kg ha⁻¹ N application rate compared to the 200 kg ha⁻¹ N rate. Averaged across the 2-yr, 44 to 69% of the applied P was recovered by bahiagrass when CM+AN was applied compared to 16 to 23% recovery when CM was applied alone. Soil test P in the A horizon (0 to 15 cm) on the average was reduced by 64 and 54% in 2005 and 2006, respectively, when CM+AN was applied compared to treatments that received only CM application. The results of this showed that applying CM in combination with an inorganic nitrogen source can provide greater forage yield of high nutritive value and also reduce P risk to the environment.

Determination of Soil Sorption Coefficient (Koc) of Strongly Hydrophobic Organic Chemicals (SHOCs) using Mixed Solvents Systems and the Solvophobic Model

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Determination of the sorption coefficients (Koc) of strongly hydrophobic organic chemicals (SHOCs) in aqueous systems is difficult due to their very low solubility and the potential to adsorb on container walls and vessels. Three probe SHOCs (β-endosulfan, anthracene and dieldrin) of aqueous solubility between 0.08 and 0.32 μg/ml were used. Sorption of these compounds on teflon lined centrifuge tubes was measured in methanol-water systems. The volume fraction of methanol (fc) ranged from 0.10 to 1. The solution concentrations of dieldrin and β-endosulfan were analyzed using High Pressure Liquid Chromatography (HPLC) with UV detection. Liquid Scintillation Counting (LSC) was used to measure anthracene in solution. Sorption coefficients in aqueous systems were obtained by use of the solvophobic model and extrapolating the sorption coefficient to zero fraction cosolvent. More than 50% of β-endosulfan and anthracene was calculated to be adsorbed
on the centrifuge tubes in aqueous systems. The sorption coefficients of dieldrin and anthracene on three carbonatic soils (Chekika, Krome and Perrine) were then determined in methanol-water systems at \(0.35 < \phi < 0.6\) that eliminated sorption on the centrifuge tubes. Using the Solvophobic model, the sorption coefficients in aqueous systems were extrapolated at \(\phi = 0\). The sorption coefficients were then normalized with soil organic carbon content to obtain \(K_{oc}\) values. These values will be compared to literature \(K_{oc}\) values when discussing the validity of the methods used in our study to measure \(K_{oc}\) of strongly hydrophobic organic chemicals.

### Evaluation and Demonstration of Evapotranspiration-Based Irrigation Controllers

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A new technology for single family home irrigation that uses evapotranspiration (ET) data is being used to apply appropriate irrigation to the landscape. This technology has proven to conserve water in the western U.S.; however, testing has not been performed in Florida where rainfall amounts exceed those found in the western states. Therefore, this study was designed to test ET controllers in residential landscape plots to determine irrigation savings compared to a homeowner irrigation schedule under Florida conditions. Twenty plots measuring 7.62 m x 12.2 m were constructed at the UF Gulf Coast Research and Education Center. They are partitioned into 65% St. Augustinegrass (\textit{Stenotaphrum secundatum}) and 35% mixed ornamentals to represent a typical Florida landscape. The ornamentals chosen are: Cape Plumbago (\textit{Plumbago auriculata}), Crape Myrtle (\textit{Lagerstroemia indica} ‘Natchez’), Gold Mound Lantana (\textit{Lantana camara} ‘Gold Mound’), Big Blue Liriope (\textit{Liriope muscari} ‘Big Blue’), and Indian Hawthorne (\textit{Raphiolepis indica}). Turfgrass areas are sprinkler irrigated and the ornamentals are irrigated with microirrigation. Three ET controllers are being tested and compared to two time-based treatments. The irrigation treatments are as follows: Smart Line Series controller (Weathermatic, Inc., Dallas, TX), Intelli-sense (Toro Company, Inc., Riverside, CA), Smart Controller 100 (ETwater Systems LCC, Corte Madera, CA), a time-based treatment determined by UF-IFAS recommendations (Dukes et al., 2002), and a time-based treatment that is sixty percent of the previous time-based treatment. Initial water application and turf quality results will be presented. In addition, controller performance will be compared to theoretical turfgrass needs.

### Tifton-9 Bahiagrass Performance in a Silvopastoral System with Boer x Spanish Goats and Loblolly Pines

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Tifton 9 Bahiagrass has become one of the most productive and widely used forage grass species in the Southeast United States. However, its performance in an agrosilvopastoral system is not well known. Similarly, there is limited documentation of goats as possible livestock entities in a silvopastoral system. The perception of using goats for vegetation management other than for a grazing livestock remains very high. The present study is being conducted to determine stocking rates of Boer x Spanish goat crossbreeds in a silvopastoral system of loblolly pines and Tifton-9 bahia grass. Two stocking rates, 10 goats and 17 goats per hectare respectively, were placed in paddocks in which Tifton-9 Bahia grass had been planted between tree rows of loblolly pines at a spacing of 4 m x 12 m. The experimental design was a split plot design with two replications. Results showed that the mean pre herbage mass for the shaded area in 2005 was 4675.8 kg ha\(^{-1}\) and 4450.28 kg ha\(^{-1}\). The post-herbage mass for 2005 was 4242.68 kg ha\(^{-1}\) for the shaded and 4122.24 kg ha\(^{-1}\) for the unshaded. The 2006 results showed pre-herbage mass for the shaded area as 4553.13 kg ha\(^{-1}\) and 4424.24 kg ha\(^{-1}\). The post herbage mass for 2006 was 4090.43 kg ha\(^{-1}\) for the shaded areas and 3942.17 kg ha\(^{-1}\) for the unshaded areas. It is anticipated that results obtained from these studies will be made available to producers’ especially small landowners and limited resource farmers.
Type and Frequency of Excreta Application to Bahiagrass (*Paspalum notatum*) Swards Affects Plant Responses

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Sixty to ninety percent of nutrients consumed by grazing livestock are returned to pasture in excreta, but distribution is heterogeneous. To better understand nutrient dynamics in pastures, more information is needed regarding the effects of excreta on forage responses. The objective was to determine the effect on bahiagrass herbage accumulation (HA) of excreta type and number of excreta applications per growing season. Treatments were the factorial combinations of excreta types (dung and urine) and application frequencies (1, 2, or 3/season). Dung and urine were collected from animals grazing bahiagrass and subsequently applied to ungrazed bahiagrass plots. A urine application was 2 L to a 60-cm diameter circle, while dung applications were 2 kg to a 30-cm diameter circle. Concentric circles (radii of 0-15, 15-30, and 30-45 cm) to a distance of 0.45 m away from the center of the excreta application were clipped monthly to measure HA. Total-season HA within the 0.45-m radius was greater following urine than dung (4260 vs. 2820 kg/ha). Number of dung applications had no effect on HA, but HA increased linearly from 3910 to 4670 kg/ha as urine applications increased from 1 to 3. HA decreased linearly as distance from the center of urine application increased (5330, 4850, and 3680 kg/ha for the three concentric circles). For dung the response was quadratic (2330, 3060, and 2770 kg/ha) with the lowest HA attributable to physical interference from dung. Urine had much greater impact on grass growth likely due to greater nutrient availability and less physical interference.

Use of Extracts from Native Grass Species for the Control of Cogongrass (*Imperata cylindrica* L.)

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Cogongrass is one of the most invasive species in Florida and other Gulf Coast States and poses a major problem on forested lands, natural habitats, rights-of-way interstate highways. The present study was undertaken to evaluate the performance of cogongrass when grown in extracts of muhly grass (*Muhlenbergia capillaris* Lam.). Genets and ramets of cogongrass were transplanted into magenta vessels containing 10% solution of root and shoot extracts of muhly grass and magenta vessels were placed in a growth chamber maintained at 28°C, at a 16/8 hour photoperiod and a relative humidity of 55%. The genets and ramets of cogongrass were evaluated for shoot and root growth, as well as rhizome extension at 7 days interval after transplanting. Preliminary results show that the extracts of muhly grass reduced shoot growth and rhizome extension of cogongrass. The muhly grass root extracts were the most effective in reducing the performance of cogongrass compared to muhly grass shoot extract. Root:shoot ratios of cogongrass also decreased by 50-70%. Thus, muhly grass extracts may contain some allelochemicals that could impact the invasiveness of cogongrass.

Bahiagrass Genotype Responses to Defoliation Frequency and Intensity

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Existing bahiagrass (*Paspalum notatum* Flügge) cultivars have minimal cool-season production likely due in part to a daylength response. A new genotype is less sensitive to daylength and possesses greater cold tolerance, but its response to defoliation is unknown. The objective was to compare productivity and persistence of a photoperiod insensitive, cold adapted (PICA) diploid genotype (Selection 4) to those of diploids ‘Pensacola’ and ‘Tifton 9’ and tetraploids ‘Argentine’ and ‘Tifton 7’. All were clipped every 7 or 21 d to 4- or 8-cm stubbles during May-October 2005 and 2006. There was no stubble height effect but there was genotype X frequency interaction for total-season dry matter (DM) harvested. For the 21-d frequency,
Argentine and Tifton 7 had greatest yields (12.8 and 12.7 Mg/ha), and Argentine (11.7 Mg/ha) was superior to all others for the 7-d treatment. PICA (10.4 Mg/ha) yielded less than all but Pensacola (10.7 Mg/ha) for the 21-d interval and was lowest yielding for the 7-d interval (7.8 Mg/ha). PICA yields were comparable to others early and late in the growing season but less during the warmest months. Cut to an 8-cm stubble during 2 yr, PICA cover (-17 percentage units) decreased more than all genotypes but Tifton 7, but at the 4-cm stubble only Argentine performed better than PICA. In conclusion, PICA was generally lower yielding than the others due to lesser summer yields, and although change in cover was not consistent across stubble heights the large decrease when PICA was clipped to 8 cm is concerning.

**Effects of Nitrogen Fertilization on the Dynamics of Regrowth and Yield for Tifton 85 Bermudagrass**

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With increased cost of nitrogen (N) fertilization and narrowing profit margins, cattle and hay producers cannot afford to expend resources to fertilize their pasture unnecessarily. However, they also cannot afford to lose yield as a result of inadequate fertilization. Experimental evaluation of the effects of varying levels of N fertilization will give producers an indication of how much N fertilization will be needed to maintain given yields as well as a healthy pasture. A field study was conducted at the University of Florida Beef Research Unit at Gainesville, FL on established Tifton-85 bermudagrass pasture during the summer 2006 season. Re-growth and yield responses of Tifton 85 Bermudagrass (*Cynodon spp.*) to four N rates were observed for four cutting cycles. Nitrogen effects were observed for fraction above-ground biomass and tiller number (p<0.10), and fraction leaf, leaf area index, and green area index (p<0.05) sampled weekly after cutting harvest. There were differences (p<0.05) in total annual yield (four cuttings) for all N fertilization rates compared to no applied N, but no significant differences (p<0.05) between 90 and 135 kg N/ha/cutting. Applying N fertilizer increased tiller initiation, shoot growth, and leaf area index resulting in a higher yield. However, we conclude that applying a high rate of N (135 kg N/ha) will not increase growth and yield significantly over the IFAS-recommended rate of N (90 kg N/ha) per monthly cutting.

**The Extraction of Chitosan from *Callinectes sapidus* (Blue Crab) on the Germination of Sweet Corn Seeds Inoculated with *Pythium aphanidermatum***

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Chitin, from which chitosan is derived, is the second most abundant polymer in nature after cellulose and is found mainly in crab, shrimp and prawn wastes. Chitosan is a hydrophilic polysaccharide, which is soluble in dilute aqueous organic acid solutions and insoluble in pure water. Chitosan has been used as a seed treatment and a pesticide. Seedling blight of corn (*Zea mays*) is caused by the fungus *Pythium aphanidermatum* can cause significant reductions in yield. The greatest damage to corn seedlings occur during germination either before or after emergence. Seed treatment is an important measure to inhibit the pathogen and for preventing the occurrence of the disease. The objective of this study is to extract chitosan from the blue crab exoskeleton and to investigate its effects on the germination of corn seeds inoculated with *Pythium aphanidermatum*.

**Biocontrol of Cogongrass (*Imperata cylindrical* L.) Using Fungal Pathogens**

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Mycobactericides have been effectively used as an alternative to chemical control of several weedy species due to its environmental safety in agricultural systems. This study evaluates fungal pathogens as bioherbicides of cogongrass and their effects on greenhouse grown native turf grasses: centipede (*Eremochloa ophiuroides* Munro.), St. Augustine (*Stenotaphrum secundatum* Walt.), bermuda grass (*Cynodon dactylon* L.) and bahiagrass (*Paspalum notatum* Flugge.), and amenity grasses;
muhlygrass (*Muhlenbergia capillar y* Lam.), switchgrass (*Panicum virgatum* L.), maidencane (*Panicum hemitomon* Schult.) and Johnson grass (*Sorghum halepense* L.). Fungi, *Nigrospora oryzae* and *Curvularia* spp. obtained from St. Augustine and *Bipolaris* spp. from cogongrass diseased leaves were isolated. Fungal conidia from these species were mass produced on PDA in the laboratory. Resultant aqueous suspensions of conidia were used as treatments and were sprayed onto leaves of the above grass species. One set of plants sprayed with sterile water served as controls. All treated plants were then subjected to 100% RH for 2-3 days and then returned to greenhouse conditions for one week. Preliminary results indicated that several different isolates of the *Bipolaris* spp. group of fungi were pathogenic to cogongrass as well as amenity grass (maidencane and switchgrass). Disease symptoms observed ranged from discrete lesions to leaf blighting. The greenhouse studies indicated pathogenicity of *Bipolaris* spp. and that further testing in the field is warranted.
GENERAL SESSION ABSTRACTS - CROPS

Water Deficit and Vapor Pressure Difference Effects on Leaf Area Expansion and Transpiration of Soybean

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The effect of both water deficit and atmospheric vapor pressure difference (VPD) on transpiration rate (TR) of plants is well understood. However, their effect on whole plant leaf area expansion (PLAE) is less well defined. Generally, both PLAE and TR are unaffected by soil drying until transpirable soil water (TSW) ≤ ⅓. High VPD increases TR and may decrease the expansion of individual leaves. However, the effect of VPD on PLAE and the potential interaction with soil drying has not been examined. This study examined the effect of soil drying, VPD, and their interaction on TR and PLAE. Individual soybean plants with ~4 trifoliate leaves were placed in growth chambers at either high (mean VPD weighted for PAR = 2.08 kPa) or low (mean =1.27 kPa) VPD. Control plants were maintained well-watered, while a second set of pots was allowed to progressively dry over 14 days. The high VPD treatment increased TR of well watered plants by 24 % over the low VPD treatment. In both VPD treatments TR were similar to the well watered control until TSW ≤ 0.25. Similar to TR, as TSW declined PLAE was unaffected until TSW 0.24 in both VPD treatments. High VPD resulted in a progressive decrease in PLAE in the control plant. By the end of the experiment the daily increase in PLAE was only 43 % of the low VPD plants. These results show that both decreasing TSW and high VPD decrease PLAE, but that these two factors did not interact.

Growing Scotch Bonnet Hot Peppers (Capsicum chinense Jacq.) in Shade Houses: Maximizing Production by Manipulating Light Intensity

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Hot peppers can grow well under various lighting conditions. However, since there is not much documentation on the optimum level of light required for production, growers tend to select levels of shade that may not give the best results. The objective of this experiment was to determine the optimum level of light (lux) required for production. The experimental design was a randomized complete block with 4 levels of shade providing the following lux measurements: Zero shade (10,000 lux), 27 % shade (6000 lux), 53 % shade (2000 lux) and 92 % shade (700 lux). Data were collected on growth and yield parameters of the crop and analyzed using regression and ANOVA procedures. By the completion of data collection, there was no evidence of flowering in the 700 lux treatment. We also found significantly fewer branches, larger leaves and taller plants compared to the other treatments. We found no significant difference in the times to flowering for the 10,000, 6000 and 2000 lux treatments. The 10,000 and 6000 lux treatments produced significantly larger fruits (p < 0.05) compared to the 2000 lux treatment. Fruits plant⁻¹ were the same for the 10,000 and 6000 lux treatments but the 6000 lux treatment produced significantly more fruits compared to the 2000 lux treatment. At 700 lux, absolutely no fruits were produced. However, marketable fruits plant⁻¹ at 2000 lux, 6000 lux and 10,000 lux were not significantly different.

Zinc Efficiency in Relation to Root Morphology, Ultrastructure and Antioxidative Enzymes in Rice (Oryza Sativa L.)

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To elucidate physiological mechanisms of the Zn efficiency in rice (Oryza sativa L.), comparative studies on root morphology, ultrastructure, and oxidative enzyme activities were investigated between Zn-efficient rice genotype (IR8192) and Zn-inefficient rice genotype (Erjiufeng) grown under severely Zn-deficient (pZn²⁺>11.5), moderate Zn-deficient (pZn²⁺=11.0), and sufficient Zn (pZn²⁺=9.7,) conditions. The results showed that Zn-deficiency decreased the biomass yield
and root activity of both genotypes, but IR8192 can maintain fairly high biomass and root activity under moderately Zn-deficiency whereas the biomass yield and root activities of Erjiufeng decreased rapidly. Moderately-Zn-deficiency increased the root length, root surface and root tips of both genotypes, but the increase was greater for IR8192 than Erjiufeng. Under Zn-moderately deficient condition, many swollen mitochondria were observed in the root tip cells of Erjiufeng, whereas most root cells in IR8192 remained intact. Severe Zn-deficiency destroyed the fine structures of both genotypes. Alteration in the ultrastructure of these organelles were accompanied with elevated hydrogen peroxide (H$_2$O$_2$) content, MDA content, and electrolyte leakage in both cultivars and the increases were less in IR8192 than in Erjiufeng. This may result from the differences existed in the activities of antioxidative enzymes between these two genotypes. In contrast to Erjiufeng, higher activities of antioxidative enzymes, ascorbate peroxidase (APX), peroxidase (POD), Catalase (CAT), and superoxide dismutase (SOD) were observed in IR8192 under Zn-deficient conditions. These results suggest that Zn efficiency in IR8192 is closely associated with its more efficient antioxidative system and intact root tip cell and functions under low Zn conditions.

Using Growth Analysis to Select Radish Cultivars for Salad Crop Production Systems

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Early outpost missions to the Moon will benefit from salad crop production systems designed to supplement crew diets with fresh vegetables. Careful selection of three candidate radish (Raphanus sativus L.) cultivars, Cabernet, Giant White Globe, and Cherry Belle was conducted to optimize productivity in actual flight systems. Leaf area and dry mass, total dry mass, and hypocotyl dry mass were measured in sequential destructive harvests at 7, 12, 16, 18, and 21 days after planting (DAP). Cabernet produced the largest edible dry mass in 21 DAP. Giant White Globe produced twice as much leaf area as Cabernet or Cherry Belle, but its leaf photosynthetic capacity was only about 50% that of Cabernet and Cherry Belle. After 21 DAP, Giant White Globe produced as much total biomass as Cabernet, but produced only 50% as much storage root mass. Cherry Belle produced 40% less total biomass than Cabernet, even though the photosynthetic efficiency of its leaves was similar. However, its crop growth rate (CGR) was slower because it had less leaf area than Cabernet during the last 11 DAP resulting in the production of 50% smaller storage roots. Cabernet reached its peak CGR about 1 day earlier than Cherry Belle, and about 3 days earlier than Giant White Globe. The data suggests that Cabernet could be harvested after 14 DAP, without significantly reducing the edible yield obtained. This earlier maturation could result in considerable savings in power dedicated to lighting in salad production systems.

Determining Aerodynamic Conductance of SPAR Chambers from Energy Balance Measurements

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The aerodynamic conductance (gA) of SPAR chambers was determined from measurements of energy balance and canopy temperature over a closed peanut canopy. gA was calculated from the slope of a plot between sensible heat flux (H) and the canopy-to-air temperature difference. H and the canopy-to-air temperature were varied by manipulating chamber CO$_2$ concentration or vapor pressure deficit. Net radiation was measured with a net radiometer, latent heat flux (LE) was calculated from gas exchange measurements of evapotranspiration (ET), and H was calculated by subtracting LE from Rnet. Canopy temperature was measured using two Apogee infrared thermometers placed at the same height as the net radiometer in a nadir viewing angle. The average gA over a 34 day-old peanut canopy was 3.9 mol m$^{-2}$ s$^{-1}$. The ability to determine gA in the SPAR chambers allowed the separation of canopy stomatal conductance (Gc) from contributions due to leaf boundary layer conductance and turbulent mixing penetrating the vegetation. Canopy Gc was calculated from surface conductance (Gs) and gA. Gs was estimated from rates of evapotranspiration measured with the SPAR gas exchange system. Gs of the 34 day-old peanut canopy was 0.45 mol m$^{-2}$ s$^{-1}$. The accuracy of the Gs measurements depends on the ability to measure the rate of soil evaporation within the chamber.
A UF/IFAS Task Force reviewed historical literature underlying fertilizer recommendations for sugarcane grown on organic and mineral soils in south Florida. Recently generated (but unpublished) nutrient response data were assessed and on-farm studies were designed to resolve knowledge gaps. Objectives were to confirm/update fertilizer recommendations and identify BMPs consistent with modern cultivars (higher yield potential) and evolving cultural practices (expansion into nutrient-deficient mineral soils and improved fertilizer sources). Nitrogen is generally not recommended for sugarcane production on organic soils (Histosols) since soil-N mineralization rates nearly equal or exceed the crop requirement. Phosphorus recommendations for Histosols are based on a soil-test water extraction that is increasingly unpopular with growers. Improved soil-P extraction chemistries for high-pH organic soils need to be investigated. Magnesium is rarely recommended, and sulfur inputs are only suggested as a soil-pH adjustment strategy to improve micronutrient availability. Approximately 24% of the sugarcane acreage has expanded into sandy mineral soils (predominantly Spodosols), yet nutrient response data for these low water and nutrient retention soils are limited. On-farm nutrient application rate and timing research are currently being conducted, emphasizing N and P. Soil-test P calibration research is nearing completion for organic soils, but much more is needed for mineral soils. Silicon is described as a “beneficial” plant nutrient (not essential) for sugarcane and current work with Si needs to be completed before recommendations can be made. Field testing of Mg and S rates is needed to develop appropriate recommendations.

Free-Air CO₂ Enrichment (FACE): Model Analysis of Gaseous Dispersion Arrays for Studying Rising Atmospheric CO₂ Effects on Vegetation

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Atmospheric concentrations of carbon dioxide (CO₂) have risen from about 280 to 380 μmol mol⁻¹ from the beginning of the industrial revolution to 2007, due mainly to burning of fossil fuels. Various systems have been devised for studying impacts of rising CO₂ and other potential global environmental changes on green plants. These systems include leaf chambers, growth chambers with artificial lighting, greenhouses, sunlit controlled-environment growth chambers, open-top field chambers, and field free-air CO₂ enrichment (FACE) arrays. Each system has unique capabilities and limitation, with the advantages of FACE systems being large areas with undisturbed environmental conditions that allow secondary treatments within each array. Disadvantages include cost of CO₂, complexity, and inability to provide CO₂ X temperature interactions across wide ranges of temperatures. This modeling study was undertaken to provide predictions of CO₂ dispersion with several types of emission arrays including ground-level area-source emitters, upwind vertical vent pipe emitters, elevated within-block area-source emitters, and combinations of each, for vegetation ranging from a 40-m tall forest to a 0.3-m short grassland. A two-dimensional vertical eddy diffusion and horizontal mass transport model was used to predict CO₂ dispersion using vertical profiles of eddy diffusivity and horizontal wind speed. The combination of elevated area-source emitters with upwind vertical vent pipes predicted the most uniform distributions of CO₂, but the upwind vertical vent pipe emitters alone gave satisfactory distributions, and are easier to set up in the real world. As expected, predicted CO₂ costs were proportional to the height and area of vegetation.
Evapotranspiration: A Measurement System and Remote-Sensing Method for Regional Estimates

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A method was developed for making evapotranspiration (ET) estimates based on measured air temperature, remotely sensed surface temperature, and net radiation (Rn). The slope and intercept of regressions of surface-to-air temperature gradients versus Rn were composite values of surface parameters. Five equations were developed to calculate ET from these composite values plus Rn and some combination of two of four surface parameters (bulk air transport, moisture availability, saturation deficit, and soil heat flux). The method was validated from ET measurements made over a pasture using the energy budget–profile Bowen ratio technique. A data acquisition and processing system, air sampling system, and time constant matched humidity, temperature, and radiation sensors were developed to log data and calculate half hour average surface energy budgets. Generally, radiation surface temperatures were not the same as effective heat transport surface temperatures. Because parameters were assumed constant, estimated instantaneous ET by this method was at times too high or low, but these errors tended to cancel in estimated cumulative ET. The method was well suited for use with 1-3 hour time resolution satellite data. The method evaluated surface parameters such as moisture availability, required no interpolation for ET estimates between data sets, was adapted to inevitable cloud-caused loss of satellite surface temperatures, and reduced calculation of ET to estimating total positive Rn and duration of positive Rn in a particular period. The ET estimates of this method were as accurate as the simple residual method which lacks some of the advantages of this method.


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Nematode incidence and damage in peanuts have steadily increased over the last decade in Columbia County, Florida. Nematode population increases in North Central Florida peanut crops are primarily due to: 1) concentration of peanut into larger production units, resulting in shorter rotation intervals; 2) low economic value of crops traditionally utilized in rotation with peanuts; and 3) lack of adapted nematode resistant peanut variety(s) adapted to the production areas. A survey was conducted in 2004 to document the extent of the problem in Columbia County. The survey included 100% of the peanut growers and 25% of the total peanut acreage in the county for 2004. Over 60% of the acreage surveyed was found to have populations of Meloidogyne arenaria race 1 (Rootknot) and Pratylenchus brachyurus (Lesion) sufficient to cause 20% or greater damage to the crop. Each grower received follow-up reports on the peanut field(s) sampled on their respective farm with a Crop Damage Potential Rating and recommendations for future nematode management of the field. As a result of the survey, we are in the second year of screening current peanut varieties and breeding lines in high incidence fields to identify any existing nematode tolerance/resistance for production and/or variety development.

Breeding for Root Knot Nematode Resistance in Peanut

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Root knot nematode is a yield limiting pest of peanut in several Florida counties. Breeding cultivars with resistance could boost yields and reduce the use of costly nematicides. The UF peanut breeding program is actively developing root knot resistant peanut material for eventual cultivar release. The primary source of resistance is a single gene introgressed from wild relatives of cultivated peanut by researchers at Texas A&M University. The gene confers near immunity, but current cultivars are not adapted to Florida, or the southeastern US primarily because of their susceptibility tomato spotted wilt virus
We have also discovered that AP-3 and Hull, genotypes that do not have this gene, seem to tolerate root knot nematode infection in comparison to other genotypes. These “tolerant” genotypes also have resistance to TSWV and are better adapted to the southeastern US. We are currently testing breeding lines that have parentage related to the Texas single gene, AP-3 or Hull. These lines show much improved resistance to TSWV and appear adapted to Florida growing conditions.

Nature and Extent of Plant-Parasitic Nematode Problems in Florida Cotton and Peanut Production

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Cotton and peanut are major agronomic crops in Florida and produced on greater than 36,000 and 50,000 ha, respectively, each year. Due to limited economic opportunities for production of other crops, these two crops are mono-cultured or grown in shortened rotation sequences which increase nematode problems in these crops. The most damaging nematode species affecting peanut are peanut root knot and lesion nematodes; on cotton, the southern root-knot and reniform nematodes are most damaging. Past surveys of nematode problems in Florida agronomic crops have been limited and were conducted 15-30 years ago. Significant cropping pattern shifts have since occurred with large increases in cotton and peanut production and dramatic decreases in field corn and soybean production. Surveys were conducted in late summer and fall of 2004-2006 in the major agronomic crop production areas of Florida. Selection of cotton and peanut fields for sampling was random to provide unbiased nematode assay results. A soil sample for nematode analysis represented 8-12 cores to 25-cm-deep taken randomly from a 10 ha area in farmer fields. Soil in a 100 cm³ sub-sample was processed using the modified sugar flotation-centrifugation extraction method. More than 200 farmer fields representing an estimated 7000 ha were sampled. Results showed that over 50% of the soil samples had nematode population densities capable of causing damage to a following crop. Damage caused by lesion nematodes was identified as an emerging problem in peanut and a greatly increased reniform nematode presence was found in cotton.

Methyl Bromide Transition Strategy For Florida Fruit and Vegetable Crops

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Florida growers, who have continued to rely on existing and internationally approved CUE supplies of methyl bromide, painfully recognize an increase in price, a future of diminishing supply, and the limits to which methyl bromide use rates can be reduced without loss of pesticidal efficacy and crop yield. Transition to another IPM strategy will require coapplication of different fumigants and herbicides and new cultural practices to achieve pest control efficacy and crop yield response similar to that of methyl bromide. Transition to the other chemical alternatives will also require significant changes to current practices, integration of new fumigant distribution and soil injection technologies, and new tillage and irrigation practices to enhance the performance of alternatives and reduce potential fumigant emissions from treated fields. Future use of the chemical alternatives will be subjected to further restrictions requiring reduced rates, expanded buffer zones, personal protective equipment, emission reduction strategies including more gas retentive plastic mulches to reduce overall field application rates and soil emissions of fumigant gases. Use of more gas retentive mulches will require changes in field application and soil injection equipment to insure accurate and uniform dispensing of such low fumigant application rates. Transition to the multi-chemical combination treatments will be more difficult and less forgiving than that of methyl bromide, and unavoidably, some factors that affect response inconsistency are not completely manageable or resolvable.
The Importance of Fumigant Synergies with Chloropicrin

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Given the importance of methyl bromide to Florida agriculture and diminishing supply of new production, it is imperative that the ways and means of reducing levels of methyl bromide usage in Florida agriculture continue to be evaluated. Mandated use of gas-tight, virtually impermeable plastic mulch film (VIF) in combination with methyl bromide formulations with increased chloropicrin content (i.e., 50% Mbr / 50% Chloropicrin and 30% Mbr / 70% Chloropicrin) has been proposed as a viable means of soilborne pest and disease control, and as a means of further reducing future CUE appropriations to Florida agriculture. The scientific basis for such efficacy claims regarding pest control synergies between methyl bromide and high proportions of chloropicrin (>50%) needs to be field validated under Florida conditions to substantiate claims of pest control efficacy and fumigant synergy. The primary objective of these studies were to evaluate lethal dosage and pest control synergies between different methyl bromide, methyl iodide and chloropicrin formulations, reduced application rates, and use of gas retentive mulch films. In these studies, superior control of yellow or purple nutsedge at reduced application rates for methyl bromide or methyl iodide and chloropicrin was achieved only with gas retentive films. Chloropicrin was observed to contribute little, either directly or synergistically with other fumigants for control of nematodes or yellow or purple nutsedge.
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Past President............................................................. Ken Boote
Secretary–Treasurer...................................................... Ken Boote
Director........................................................................ Greg McDonald
Director........................................................................ Samira Daroub
Director........................................................................ Vacant
Proceedings Editor.............................................................. Ken Boote

2007 PROGRAM SUMMARY

Sunday, 03 June 2007

<table>
<thead>
<tr>
<th>Time</th>
<th>Event</th>
<th>Room</th>
</tr>
</thead>
<tbody>
<tr>
<td>12:00 Noon</td>
<td>Registration begins</td>
<td>Atrium Courtyard</td>
</tr>
<tr>
<td>3:00 PM</td>
<td>Board Meeting</td>
<td>Canterbury A</td>
</tr>
<tr>
<td>6:00-7:00 PM</td>
<td>Welcome Reception</td>
<td>Pool Deck</td>
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</table>

Monday, 04 June 2007

<table>
<thead>
<tr>
<th>Time</th>
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<th>Room</th>
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<tbody>
<tr>
<td>7:00 AM</td>
<td>Registration continues</td>
<td>Atrium Courtyard</td>
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<tr>
<td>7:00-8:00 AM</td>
<td>Continental Breakfast</td>
<td>British Open Ballroom</td>
</tr>
<tr>
<td>8:30-9:45 AM</td>
<td>Joint General Session</td>
<td>British Open Ballroom</td>
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<tr>
<td>10:00-12:00 Noon</td>
<td>Graduate Student Forum I</td>
<td>Legends B</td>
</tr>
<tr>
<td>1:15-3:00 PM</td>
<td>Graduate Student Forum II</td>
<td>Legends B</td>
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<tr>
<td>3:30-5:00 PM</td>
<td>General Session</td>
<td>Legends B</td>
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Tuesday, 05 June 2007

<table>
<thead>
<tr>
<th>Time</th>
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<tbody>
<tr>
<td>8:30-9:45 AM</td>
<td>Business Meeting</td>
<td>Legends B</td>
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<tr>
<td>10:00-12:00 Noon</td>
<td>General Session</td>
<td>Legends B</td>
</tr>
</tbody>
</table>
2007 SESSIONS
Monday AM, 04 June 2007

2007 GRADUATE STUDENT FORUM PAPER SESSIONS

Sensing Accuracy of Four Commercially Available Soil Moisture Irrigation Controllers -- Bernard Cardenas-Lailhacar* and Michael D. Dukes


Evapotranspiration and Soil Moisture-based Irrigation Control on Turfgrass Compared to Theoretical Requirements -- Mary L. Shedd*, Michael D. Dukes and Grady L. Miller

Characterization of Sorption of Hydrophobic Organic Pesticides in Carbonatic and Non-carbonatic Soils from Florida, Puerto Rico, and Uganda -- Gabriel Kasozi*, Peter Nkedi-Kizza, José A. Dumas-Rodriguez, Yucong Li, David Hodell, Willie Harris and David Powell


Determination of Soil Sorption Coefficient (Koc) of Strongly Hydrophobic Organic Chemicals (SHOCs) using Mixed Solvents Systems and the Solvophobic Model -- Augustine Muwamba*, Peter Nkedi-Kizza, Roy D. Rhue, Jeffrey Keaffaber and Kafui Awuma

Evaluation and Demonstration of Evapotranspiration-Based Irrigation Controllers -- Stacia Davis*, Michael D. Dukes, Sudeep Vyapari and Grady L. Miller

Tifton-9 Bahiagrass Performance in a Silvopastoral System with Boer x Spanish Goats and Loblolly Pines -- N. Gordon-Bradley* And O. U. Onokpise

Type and Frequency of Excreta Application to Bahiagrass (Paspalum notatum) Swards Affects Plant Responses -- U. Renée White*, Lynn E. Sollenberger, Kenneth R. Woodard, Don A. Graetz, Yoana C. Newman and Joao M.B. Vendramini

Use of Extracts from Native Grass Species for the Control of Cogongrass (Imperata cylinrica L.) -- Lissa D. Reid*, Oghenekome U. Onokpise and Jeff L. Nercini

Bahiagrass Genotype Responses to Defoliation Frequency and Intensity -- Sindy M. Interrante*, Lynn E. Sollenberger, and Ann R. Blount

Effects of Nitrogen Fertilization on the Dynamics of Regrowth and Yield for Tifton 85 Bermudagrass -- Phillip D. Alderman*, Kenneth J. Boote, and Lynn E. Sollenberger

The Extraction of Chitosan from Callinectes sapidus (Blue Crab) on the Germination of Sweet Corn Seeds Inoculated with Pythium aphanidermatum -- Camille Webster*, Oghenekome U. Onokpise, J.J. Muchovej, Michael Abazinge and Elijah Johnson

GENERAL PAPER SESSIONS

Crops

Water Deficit and Vapor Pressure Difference Effects on Leaf Area Expansion and Transpiration of Soybean -- Andrew L. Fletcher and Thomas R. Sinclair*

Growing Scotch Bonnet Hot Peppers (Capsicum chinense Jacq.) in Shade Houses: Maximizing Production by Manipulating Light Intensity -- C. Gardner, G. Queeley* and T. Hylton

Zinc Efficiency in Relation to Root Morphology, Ultrastructure and Antioxidative Enzymes in Rice (Oryza Sativa L.) -- W.R. Chen, Z.L. He,* X.E. Yang, Y. Feng

Using Growth Analysis to Select Radish Cultivars for Salad Crop Production Systems -- Oscar Monje*, Neil C. Yorio, Sharon L. Edney, Gary W. Stutte, and Raymond M. Wheeler


Nutrients, Crops/Climate, and Pest Management

A Review of Sugarcane Fertilizer Nutrient Requirements for Different South-Florida Production Environments -- K.T. Morgan*, J.M. McCray, and R.W. Rice

Free-Air CO₂ Enrichment (FACE): Model Analysis of Gaseous Dispersion Arrays for Studying Rising Atmospheric CO₂ Effects on Vegetation -- Leon Hartwell Allen, Jr.* and S.E. Beladi


Breeding for Root Knot Nematode Resistance in Peanut -- Barry L. Tillman*, Dan W. Gorbet, Jim Rich and Bill D. Thomas


Methyl Bromide Transition Strategy For Florida Fruit and Vegetable Crops -- J. W. Noling

The Importance of Fumigant Synergies with Chloropicrin -- J.W. Noling* and J. P. Gilreath
Tom Obreza called the meeting to order at 8:35am, June 5, 2007.


Minutes of last Business Meeting on 6 June 2006. The minutes were distributed. There were no questions or concerns about last year’s minutes. Larry Duncan moved to approve the minutes, and Bill Thomas, seconded. The motion passed.

Treasurer’s Report: Ken Boote distributed and discussed the 2005-2006 Financial Report. The Audit Committee (Ken Quesenberry and Larry Duncan) reviewed the Financial Report for 7/1/05 to 6/30/06, as well as the Register of bank receipts and disbursements for 7/1/05 up to the present. Ken Boote read their statements, in which they stated the Register and books appeared to be accurate and complete, and that the finances of the society were going as well as could be expected, considering the declining membership.

Ken reported the beginning and ending balances and indicated that society financial activity has been reduced, no pub cost, but no receipts. Meeting costs are covered from registration receipts. In addition we cover grad student rooms.

Assets from 7/1/05 to 6/30/06 declined less than $300 in our last fiscal year in which we had both printing cost ($5991 for volume 64) and $3994 page charges received from IFAS Administration. In the current fiscal year (06-07 not yet completed), volume 65 will be produced electronically (eliminating the printing cost) and IFAS Administration will no longer cover page charges. Since last year’s printing cost exceeded the page charge receipts by about $2000, we anticipate these two items will offset each other, leaving us with stable balanced budget, although sale of proceedings may also be down.

Since annual meeting costs are now designed to be met by registration fees, the Society’s annual income will be primarily Dues and Sale of Proceedings, while the primary expenses will be Graduate Student Awards and the Graduate Student Hotel Room cost. Larry Duncan asked how many were current in paying dues, but we did not have the information available at this meeting. Greg Means was requested to summarize that information and also to send reminders to members who have not paid their dues. We discussed the need and group desire to continue to encourage graduate student participation with the Graduate Awards Contest (including contests in two categories: Soils-Environmental and Crops). So this expense will continue. We discussed the need to encourage major professors to cover students’ room and travel expense, as passed in a motion at the 2006 business meeting. Greg Means and the Incoming Program Chair are requested to design a sentence for the Abstract and Title submission form that asks whether the major professor can cover the student’s hotel expense, stating the Society will cover the expenses only if the student indicates that the major professor cannot cover it. The Florida A & M students indicated that they would not be able to attend without the society covering their travel expense. We will continue to cover their expenses if they have no support from their major professors or from IFAS or UF travel grants to students. Larry Duncan asked whether we had a 2-year commitment to meet with the FSHS. The answer was "yes". Larry Duncan asked about current membership, and payment of dues. Greg Means indicated about 100 listed (paid in last 5 years), but the number is more likely less than 75. We need to continue to send out dues notices.
Larry Duncan moved to approve the treasurer’s report. The motion was seconded by Dave Calvert. The motion passed.

**Graduate Student Contest Report:** Tom Obreza commented that the Graduate Student Contest was very successful with 12 students, five presentations in the Soils-Environmental Section and seven in the Crops session, and that the quality of the presentations was very good. He thanked Craig Stanley for arranging the judges (3 per session) and organizing the contest competition. Tom Obreza chaired both sessions. Student winners in the Soils-Environmental session were: 1st place – Augustine Obaur, 2nd place – Mary Shed, 3rd place – Gabriel Kasozi. Student winners in the Crops session were 1st place tie – Sindy Interrante and Renee’ White, 3rd place – Nadine Gordon-Bradley. This year, all the students stayed until Awards Ceremony held 5pm on Monday.

**Necrology Report.** Jerry Bennett is chair. He announced that seven former members passed away during the past year: Martin B. Adjei, William G. Blue, Victor W. Carlisle, James M. Davidson, Leonard S. Dunavin, Nathan Gammon, Jr, and Darel E. McCloud. There was a moment of silence to honor these valued colleagues.

**Dedication of Proceedings and Honorary Membership Report.** Lynn Sollenberger and George O’Connor provided their report to Tom Obreza. The committee recommended dedicating the Volume 67 of the Proceedings to Martin B. Adjei. The committee nominated Rob Kalmbacher and Paul Mislevy as honorary members, as there are now 16 honorary members out of a total of 20 available. Rob Kalmbacher was our SCSSF editor for many years and Paul Mislevy was a mainstay of our society for many years. David Calvert moved to accept the report and Jerry Bennett seconded. The motion passed.

**Program Planning.** This year we match up with the same deadlines as FSHS and the timing worked well. Tom Obreza reported that there were a total of 28 papers submitted this year, with 15 being graduate student papers. Abstracts came in on time. While this number is less than last year when more than 40 papers were submitted, the number of 28 is actually a nice fit to the total FSHS/SCSSF meeting, because the number of papers in the SCSSF section is about the same as those in each of the five sections of the FSHS and thus, we did not require two separate concurrent sessions (as we had to do last year). With this number of papers, we match up nicely as a section in the joint meeting. Given the declining membership in SCSSF, we think this number of papers, with emphasis on graduate student presentations, is a viable number that will allow SCSSF to be an active viable society within the framework of continued cooperative arrangement/relationship with the FSHS.

**Nominating Committee Report.** Bill Thomas and Ken Quesenberry are the nominating committee, and Bill Thomas made the nominations report: President-Elect (Program Chair) – Bob McGovern; President – Tom Obreza; Secretary-Treasurer (for 2nd year) – Ken Boote; New incoming director – Jacque Breman. With no additional nominees being suggested, it was moved by Larry Duncan, and seconded by Hartwell Allen, that we accept these nominees as being elected by acclamation. The motion was passed.

**Proposal for Electronic Publishing.** This discussion was led by Tom Obreza. Based on discussion and request at Board of Directors meeting in May 2007, Greg Means developed a proposal and flowchart for producing and distributing an all-electronic proceedings. The proposal was handed out for members to read and comment. Greg also distributed two copies of the 2005 proceedings placed into a format as the old one for electronic publication to include title mock-up, program, abstracts, papers, as well as color figures. Greg explained the flow chart and publication process, with editors handing the manuscripts through the level of scientific quality review, followed by Greg Means putting the WORD documents into pdf print format (similar to past print copies). The entire pdf file will be placed on CD-ROM, for sale at the SCSSF website and also for distribution to libraries and members. David Calvert asked if he could print the CD and what the cost would be. The answer is yes, these are pdf and will print in color, and a place like Kinkos could even use heavy paper for the outer two pages. Hartwell Allen asked how these would be abstracted and connected to database citation sources. We were not sure, but assumed this would be handled by current normal process? Greg and Tom indicated that libraries were happy with getting a CD, and that citation indexing would still continue. Larry Duncan indicated that to really keep people reading our articles we want them to be freely available on the website. Most of the members present wanted to have individual papers available free on the website, although the whole year’s edition would be available for $30. Larry Duncan suggested that we consider placing the individual and total pdf copies on the website run by the Florida Center for Library Automation, so the papers would be freely available by point and click. This is how the Florida Entomology and Nematology Society handles their papers. There was also discussion about converting back issues of the Proceedings to electronic pdf files. After considerable discussion of member desires, Tom Obreza reminded us that we needed to make a decision today whether to go to electronic publication. Ken Boote moved that we follow the electronic publication procedure described by Greg Means: editors will handle the papers through the level of scientific quality, then Greg Means, in house, will format the individual papers and all other Proceedings information (program, abstracts, dedications, etc) from WORD to pdf files, preparing CD-ROM of the full publication for distribution to libraries and members, payable via check or Paypal. We will also create individual pdf papers and make them freely available at no charge from our website.
or via appropriate abstracting services including the Florida Center for Library Automation. Larry Duncan seconded. Motion passed. Ken Boote mentioned that possibility of working either the ASHS or ASA as the publishers, if we truly wanted to maintain a hard-copy distribution. Discussion followed about whether to bill paper authors for page charges. Larry Duncan moved and Jerry Bennett seconded that we do away with page charges, since IFAS administration was no longer paying them and electronic publication was less expensive and our goal was to obtain wide and free distribution. Motion was passed. Jerry Bennett and Larry Duncan expressed appreciation to Greg Means for his contribution to this effort, as the in-house aspect of pdf and CD-ROM file creation would not happen without his assistance.

Editor - SCSSF. Mimi Williams expressed the desire to end her term as Editor of the Proceedings after this year. So the President and Board of Directors will need to recruit a new Editor.

Membership/Marketing. There was no membership report this year, but all of us know the need to encourage membership. Tom Obreza proposed that we consider a new approach that was more like marketing. Nothing happens unless we announce and promote, and it is more than asking our colleagues to join. For example, the Caribbean Food Society (CFS) recently sent an announcement to some of us, about their future meetings. We should do the same and announce on their email lists and even work to invite one or more people from that region to the combined FSHS/SCSSF meetings. Considering the CFS interest in fruits and vegetables, they should be very keen on coming to this meeting.

Future meetings with FSHS. Last year, we voted to continue meeting with FSHS for a 2 year period, so we will be meeting with FSHS next June 1-4, 2008, at Fort Lauderdale Marriott North, Fort Lauderdale, FL. A sense of member poll was requested in this meeting. Nearly all of us wanted to continue the relationship with FSHS in the future beyond 2008, because we feel it is the best way to remain viable considering our current size, rather than trying to hold our own independent meetings. We feel we are a good fit as an additional section within the joint meeting structure. The concept of sharing a joint session was proposed, except for the requirement that FSHS papers must be written and submitted prior to the meeting. We have many shared interest especially in BMPs. We need to get program chairs to coordinate better to prevent conflicts of papers of joint interest. Hartwell Allen moved that we adjourn. Motion was seconded by Tom Obreza.

Soil and Crop Science Society of Florida Executive Board Meeting 03 June 2007

Tom Obreza called the meeting to order at 3:00 pm, June 3, 2007

Attendees: Tom Obreza, Ken Boote, Greg Means, Samira Daroub

We discussed the program for this meeting, in which 28 papers were submitted of which 15 are graduate student presentations. There will be two graduate sessions (one set of 7 and another of 8) for the graduate student competition. The abstract and registration deadlines worked out fine. We discussed the need to ask major professors to cover hotel expenses in the future and proposed that SCSSF would only cover hotels if students indicated on the form that they lacked funding. We also need students to register and pay directly to FSHS. We discussed the need to market and promote membership in SCSSF, especially among the Caribbean Food Science Society.

Necrology Report will be presented by Jerry Bennett.

George O’Connor and Lynn Sollenberger submitted report recommending Martin Adjei for Dedication of Proceedings, and recommending Rob Kalmbacher and Paul Mislevey for Honorary Membership.

Ken Boote will present Audit Report.

Nominating Committee report from Ken Quesenberry and Bill Thomas, recommended Bob McGovern as President-Elect/Program Chair. We still need a nominee for member of the Executive Board.

Craig Stanley, Graduate Student Contest Committee, has lined up judges for the Graduate Student contest.

We discussed electronic publication. Greg Means handed out a proposal on how electronic publication could be handled. We discussed this and will present this proposal at the Business Meeting. The proposal includes an example Proceedings and in-house creation of pdf files for the electronic publication. We discussed giving CDs to members and to those who subscribed (latter could use PayPal to purchase). Mimi Williams indicated the desire to step down as Editor. Possible persons to request to be Editor include Hanlon, Allen, Crow, and Boote. During the Business Meeting, we need to discuss whether we want to ask for page charges to be paid. We also discussed our publication relative to how the ASHS is handling publications for the Florida Horticultural Society, and whether we could try that possibility.

We discussed a marketing activity relative to the membership list.
SOIL AND CROP SCIENCE SOCIETY OF FLORIDA FINANCIAL REPORT
July 1, 2005 through June 30, 2006

ASSETS IN BANK (July 01, 2005)
Checking Account - Bank of America .......................................................................................................................... 6515.25
Certificate of Deposit - Bank of America (XXX XXX XXXX 2783) .................................................................................. 12364.99
Total in Bank ............................................................................................................................................................ 18880.24

RECEIPTS
Dues ........................................................................................................................................................................... 2340.00
Sale of Proceedings .................................................................................................................................................. 1495.00
Gifts Received .......................................................................................................................................................... 10.00
Annual Meeting Expenses ........................................................................................................................................ 790.00
Certificate of Deposit (300 000 7062 2783) ........................................................................................................... 239.31
Checking Account Interest ....................................................................................................................................... 6.18
Total Receipts ......................................................................................................................................................... 8964.24

DISBURSEMENTS
Printing SCSSF Proceedings Vol 64 ....................................................................................................................... 5990.84
Postage .................................................................................................................................................................. 429.84
Checking account service charge .......................................................................................................................... 66.00
Annual Meeting Expenses
Grad student awards ......................................................................................................................................................... 950.00
Grad student hotel rooms ......................................................................................................................................... 1489.54
Student Registration .................................................................................................................................................... 160.00
Office Supplies ......................................................................................................................................................... 55.53
Annual license fee to Florida Dept of State ............................................................................................................ 61.25
Total disbursements ............................................................................................................................................... 9203.00

UNCLEARED DISBURSEMENTS (as of June 30, 2006)
Grad student awards .................................................................................................................................................... 250.00
Student Registration ................................................................................................................................................... 10.00
Total uncleared disbursements ............................................................................................................................... 260.00

ASSETS IN BANK (June 30, 2006)
Checking Account - Bank of America ...................................................................................................................... 6037.18
Certificate of Deposit - Bank of America (XXX XXX XXXX 2783) ........................................................................... 12604.30
Total in Bank ........................................................................................................................................................ 18641.48

2006-2007 COMMITTEES
(Date in parenthesis indicates year each member rotates-off after the annual meeting.)

Audit
Ken Quesenberry (2007)
Larry Duncan (2008)

Necrology
Jerry Bennett (2007)
Ed Hanlon (2008)

Membership
Robert McGovern (2007)
Oghenekome Onokpise (2007)
Ken Quesenberry (2008)
Peter Nkedi-Kizza (2008)

Graduate Student Presentation Contest
Anne Blount (2007)
Craig Stanley (2007)
Mark Clark (2008)
Vimala Nair (2008)

Site Selection Local Arrangements
Paul Mislevy (2007)
Jack Rechcigl (2008)

Dedication of Proceedings and Honorary Lifetime Member Selection
George O'Connor (2007)
Lynn Sollenberger (2008)
### MEMBERSHIP LISTS

**Regular Members 2007**

<table>
<thead>
<tr>
<th>Name</th>
<th>Organization</th>
<th>Address</th>
</tr>
</thead>
<tbody>
<tr>
<td>L. H. Allen</td>
<td>University of Florida</td>
<td>P.O. Box 110965, Gainesville, FL 32611-0965</td>
</tr>
<tr>
<td>D. D. Baltensperger</td>
<td>University of Nebraska</td>
<td>4502 Ave. I, Scottsbluff, NE 69361-4939</td>
</tr>
<tr>
<td>Iian Bar</td>
<td>Netafim USA</td>
<td>116 Beufort Dr., Longwood, FL 32779</td>
</tr>
<tr>
<td>Ray Bassett</td>
<td>Aglime Sales, Inc.</td>
<td>1375 Thornburg Road, Babson Park, FL 33827</td>
</tr>
<tr>
<td>J. M. Bennett</td>
<td>University of Florida</td>
<td>P.O. Box 110500, Gainesville, FL 32611-0500</td>
</tr>
<tr>
<td>J. A. Berger</td>
<td>North Florida Rec</td>
<td>55 Research Rd., Quincy, FL 32351-5677</td>
</tr>
<tr>
<td>Kenneth J. Boote</td>
<td>University of Florida</td>
<td>P.O. Box 110500, Gainesville, FL 32611-0500</td>
</tr>
<tr>
<td>Barry J. Brecke</td>
<td>West Florida Rec</td>
<td>5988 Hwy 90, Bldg 4900, Milton, FL 32583</td>
</tr>
<tr>
<td>Jacqueline W. Breman</td>
<td>University of Florida</td>
<td>Route 3, Box 299, Lake Butler, FL 32054</td>
</tr>
<tr>
<td>Eric C. Brevik</td>
<td>Valdosta State University</td>
<td>Dept of Physics, Astron &amp; Geoscience, Valdosta, GA 31698-0055</td>
</tr>
<tr>
<td>J. B. Brolmann</td>
<td>FL. Pierc, FL 34982</td>
<td>2914 Forest Terrace, Ft. Pierce, FL 34982</td>
</tr>
<tr>
<td>Robin Bryant</td>
<td>Tropicana Inc.</td>
<td>1001 13th Ave. East, Bradenton, FL 32087</td>
</tr>
<tr>
<td>David V. Calvert</td>
<td>Indian River Rec</td>
<td>2199 S. Rock Road, Ft. Pierce, FL 34945-3138</td>
</tr>
<tr>
<td>Kenneth L. Campbell</td>
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<td>P.O. Box 110570, Gainesville, FL 32611-0500</td>
</tr>
<tr>
<td>Ming Chen</td>
<td>Everglades Rec</td>
<td>P.O. Box 8003, Belle Glade, FL 33430</td>
</tr>
<tr>
<td>William Crow</td>
<td>University of Florida</td>
<td>P.O. Box 110620, Gainesville, FL 32611-0620</td>
</tr>
<tr>
<td>A. A. Cziszinsky</td>
<td>Gulf Coast Rec</td>
<td>5007 60 Street East, Bradenton, FL 34203-9324</td>
</tr>
<tr>
<td>Samira Daroub</td>
<td>Everglades Rec</td>
<td>3200 E. Palm Beach Rd, Belle Glade, FL 33430</td>
</tr>
<tr>
<td>Donald W. Dickson</td>
<td>University of Florida</td>
<td>P.O. Box 110630, Gainesville, FL 32611-0630</td>
</tr>
<tr>
<td>Spencer G. Douglass</td>
<td>Douglass Fertilizer</td>
<td>1180 Spring Center Blvd., Altamonte Springs, FL 32714</td>
</tr>
<tr>
<td>Michael Dukes</td>
<td>University of Florida</td>
<td>P.O. Box 110570, Gainesville, FL 32611-070</td>
</tr>
<tr>
<td>Larry Duncan</td>
<td>Citrus Rec</td>
<td>700 Experiment Station Road, Lake Alfred, FL 33850-2299</td>
</tr>
<tr>
<td>Joe Eger</td>
<td>Dow Agro Sciences 2606 S. Dundee Blvd.</td>
<td>Tampa, FL 33629</td>
</tr>
<tr>
<td>Ike Ezenwa</td>
<td>Range Cattle Rec</td>
<td>3401 Experiment Station, Ona, FL 33865-9706</td>
</tr>
<tr>
<td>James Ferguson</td>
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<td>P.O. Box 110690, Gainesville, FL 32611-0690</td>
</tr>
<tr>
<td>Clyde W. Fraisse</td>
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<tr>
<td>Raymond Gallaher</td>
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<td>P.O. Box 110730, Gainesville, FL 32611-0730</td>
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<tr>
<td>Maria Gallo-Meagher</td>
<td>University of Florida</td>
<td>P.O. Box 110300, Gainesville, FL 32611-0300</td>
</tr>
<tr>
<td>Cassel S. Gardner</td>
<td>Florida A&amp;M University</td>
<td>Agron Prog &amp; Cen for Water Qual, Perry-Paige Bldg South, RM 202J</td>
</tr>
<tr>
<td>Robert Gilbert</td>
<td>Everglades Rec</td>
<td>P.O. Box 8003, Belle Glade, FL 33430</td>
</tr>
<tr>
<td>Barry Glaz</td>
<td>USDA-ARS</td>
<td>12990 US Highway 441, Canal Point, FL 33438</td>
</tr>
<tr>
<td>D. W. Gorbet</td>
<td>North Florida Rec</td>
<td>3925 Highway 71, Miamiana, FL 32446</td>
</tr>
<tr>
<td>Edward A. Hanlon</td>
<td>Southwest Florida Rec</td>
<td>2686 SR 29 North, Immokalee, FL 33438</td>
</tr>
<tr>
<td>Zhenli He</td>
<td>Indian River Rec</td>
<td>2199 South Rock Road, Ft. Pierce, FL 34945</td>
</tr>
<tr>
<td>George J. Hochmuth</td>
<td>North Florida Rec</td>
<td>155 Research Road, Quincy, FL 32351-5677</td>
</tr>
<tr>
<td>Edward W. Hopwood, Jr.</td>
<td>University of Florida</td>
<td>5200 NW 62nd Court, Gainesville, FL 32653</td>
</tr>
<tr>
<td>R. N. Inserra</td>
<td>University of Florida</td>
<td>P.O. Box 147100, Gainesville, FL 32614-7100</td>
</tr>
<tr>
<td>Jennifer M. Jacobs</td>
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<td>P.O. Box 116580, Gainesville, FL 32611-6580</td>
</tr>
<tr>
<td>Jay Jayachandran</td>
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<td>Dept., Miami, FL 33199</td>
</tr>
<tr>
<td>Jonathan D. Jordan</td>
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<td>P.O. Box 110570, Gainesville, FL 32611-0570</td>
</tr>
<tr>
<td>Tawaina Katsvairo</td>
<td>North Florida Rec</td>
<td>155 Research Road, Quincy, FL 32351</td>
</tr>
</tbody>
</table>
RAYMOND SNYDER  
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David Jacobus Alway
Charles Ernest Millar
John Gordon DuPris, M.D.

1954 Lyman James Briggs
Hardrada Harold Hume
Firmus Edward Bear

1959 Wilson Popenee

1960 Pettis Holmes Senn
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James A. McMurray, Jr.
Herbert Kendall Hayes
Harold Gray Clayton
Thomas Ray Stanton
Gotthold Steiner
Emil Truog
John William Turrentine
George Dewey Scarseth

1961 Joseph R. Neller
Howard E. Middle顿

1962 Frank L. Holland

1963 Herman Gunter
Frank E. Boyd

1964 Henry Agard Wallace

1965 Robert Verrill Allison

1966 Richard Bradfield
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William Gordon Kirk
Frederick Buren Smith
Marvin U. Mounts

1970 William Thomas Forsee, Jr.
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1974 Joseph Riley Beckenbach

1975 J. Cooper Morecock, Jr.
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1954 C. F. Eno
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1956 Walter Reuther
1957-1973 G. D. Thornton
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1974 E. S. Horner
1975 E. S. Horner
1976 E. S. Horner
1977 E. S. Horner
1978 E. S. Horner
1979 E. S. Horner
1980 E. S. Horner
1981 E. S. Horner
1982 E. S. Horner
1983 W. G. Blue
1984 V. E. Green, Jr.
1985 V. E. Green, Jr.
1986 V. E. Green/E. S. Horner
1987 W. G. Blue
1988 W. G. Blue
1989 W. G. Blue
1990 W. G. Blue
1991 P. L. Pfläger
1992 P. L. Pfläger
1993 P. L. Pfläger
1994 B. L. McNeal
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2004 R. S. Kalmbacher
2005 R. S. Kalmbacher
2006 M. J. Williams
2007 Kenneth Boote

*Prior to 1953, the minutes printed in the Proceedings do not name the Editor, although a publication report is printed and an Editor is mentioned. The minutes imply, but do not explicitly state, that for the first several years there was an Editorial Committee with the Chairman of the Committee serving as Editor.

The Soil Science Society of Florida was formed on 18 April 1939 under the leadership of Drs. R. V. Allison, R. A. Carrigan, F. B. Smith, Michael Peech, and Mr. W. L. Tait. In 1955 the name was changed to the Soil and Crop Science Society of Florida. The Society was incorporated as a non profit organization of 6 June 1975. The articles of incorporation were published in Volume 35 of the Proceedings, and the By-Laws in Volume 41.

Volumes 31 and 44 of the Proceedings listed the previous officers of the Society. The information listed above draws heavily upon those two volumes and the minutes of the Society published in each volume. I discovered a few errors, especially in the Board of Directors, and all have been corrected to the best of my knowledge.

## Dedication of Proceedings

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*In the earlier years, the Proceedings bear a date which coincides with the year of the annual meeting. During the years of World War II, publication was irregular and at least some of the volumes were published after the war. Also, the actual year that a publication is available becomes the “legal” date of a issue, not the year the meeting was held. Thus, volumes 32 and after bear a date one year after the annual meetings.*