Proceedings From The Symposium on Tropical Spiderwort/Benghal Dayflower (*Commelina benghalensis*): An Exotic Invasive Weed in the Southeast US

29 November 2005

University of Georgia Tifton Campus Conference Center

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Symposium on Tropical Spiderwort (*Commelina benghalensis*): An Exotic Invasive Weed in the Southeast US

Tuesday, November 29, 2005
Tifton Conference Center, Tifton, Georgia

Agenda:

8:15 Welcome, **Dr. David Bridges**, Assistant Dean, University of Georgia, Tifton Campus and **Dr. Tim Strickland**, Location Coordinator, USDA-ARS, Tifton

8:30 to Noon

- "Tropical Spiderwort: Perspectives from a County Agent", **Mr. Tim Flanders** (University of Georgia, Cairo)
- "Demography of *Commelina benghalensis* in the Southern U.S.", **Dr. Mike Burton** (North Carolina State University, Raleigh)
- "After 5 Years of On-Farm Testing, Have We Learned How to Manage Tropical Spiderwort?", **Dr. Eric Prostko** (University of Georgia, Tifton)
- "Tropical Spiderwort: Winning the Battle in Georgia Cotton", **Dr. Stanley Culpepper** (University of Georgia, Tifton)
- "Impact of Tillage and Herbicides on Tropical Spiderwort", **Dr. Barry Brecke** (University of Florida, Jay)
- "Natural Variation in *Commelina benghalensis* (Commelinaceae)", **Dr. Robert Faden** (The Smithsonian Institution, Washington D.C.)

1:00 to 4:00

- "The Effect of Environment on Invasibility in the Commelinaceae", **Ms. Jean Burns** (Florida State University, Tallahassee)
- "The Ecology of Tropical Spiderwort in Agro-Ecosystems of the Southeast US", **Dr. Ted Webster** (USDA-ARS, Tifton)
- "Kill Tropical Spiderwort and Starve a Nematode", **Dr. Richard Davis** (USDA-ARS, Tifton)
- "Effect of Moistures Stress on Tropical Spiderwort Response to Herbicides", **Dr. Bill Vencill** (University of Georgia, Athens)
- "^{14}C-Herbicides Absorption and Mobility in Tropical Spiderwort", **Dr. Tim Grey** (University of Georgia, Tifton)

POSTERS

- "Georgia CAPS: An Interdisciplinary Program for Survey and Managing Species of Regulatory Concern", **Mr. Chris Evans** (Bugwood Network, University of Georgia, Tifton)
- "Effects of Elevated Atmospheric CO_2 on Invasive Species in Managed Ecosystems of the Southeast US", **Dr. Andrew Price** (USDA-ARS, Auburn)

Tropical spiderwort (*Commelina benghalensis*, also called Benghal dayflower) is an exotic invasive species that has quickly become the most troublesome weed in Georgia and Florida cotton and is a significant pest in agronomic and other crops. Tropical spiderwort is tolerant of glyphosate (the most common trade name is Roundup), one of the most commonly applied herbicides in the Southeast US. Tropical spiderwort increases weed control costs in Georgia an estimated $1 million annually. Tropical spiderwort was not a serious pest in agronomic crops in Georgia as recently as 1998. However, this weed has quickly become a serious pest in Georgia and Florida and poses a significant threat to the rest of the United States.

The purpose of this symposium is to:

1. Exchange information on the most current tropical spiderwort research and extension findings.

2. Bring together customers and stakeholders with research and extension scientists (University of Georgia, University of Florida, North Carolina State University, Clemson University, Florida State University, The Smithsonian Institution, and USDA-ARS) with tropical spiderwort expertise.

3. Open a dialogue between the various groups with an interest in tropical spiderwort

Summary of the Presentations from the Tropical Spiderwort Symposium

Theodore M. Webster

Presentations were made primarily by research and extension specialists from the Southeast region of the US, but also included a Research Botanist from Washington D.C. with expertise in the Commelinaceae. Each presenter supplied an abstract of his/her presentation (found in the next section and a copy of their presentation). The following is a summary of the presentations from notes that I recorded at the meeting.

Mr. Tim Flanders (Grady County Extension Coordinator, University of Georgia, Cairo) detailed his tropical spiderwort experiences with growers in southwest Georgia. Mr. Flanders was among the first county agents to bring this weed to the attention of University of Georgia (UGA) and USDA-Agricultural Research Service (ARS) personnel. Mr. Flanders' *hands-on* extension and research experience in Grady County have provided him with a greater knowledge of this weed than anyone else in Georgia. He initially began to receive questions from growers about this *dayflower* in 1998. As of 2000, it was the most troublesome cotton weed in the county and a year later the most troublesome peanut weed. Mr. Flanders estimates that 60 to 70% of the fields in Grady County have tropical spiderwort. He hypothesizes that tropical spiderwort has increased as a problem and has rapidly spread through the county due to: 1. increased use of conservation tillage, 2. large corn acreage that is not managed for tropical spiderwort following harvest, allowing tropical spiderwort to grow unchecked for nearly three months until a hard frost, and 3. introduction and widespread use of glyphosate-resistant cotton, coupled with changes in herbicide-use patterns (i.e. elimination of soil applied herbicides with residual activity against tropical spiderwort (e.g. fluometuron), and 4.) aggressive growth and reproductive characteristics of tropical spiderwort.

Dr. Mike Burton (Assistant Professor, North Carolina State University, Raleigh) followed with a presentation titled: "Demography of tropical spiderwort in the Southeast US". His presentation focused on 1.) tropical spiderwort propagation, 2.) tropical spiderwort dispersal, and 3.) the current distribution of tropical spiderwort in the US. Dr. Burton presented information concerning the ability of tropical spiderwort to survive and vegetatively propagate following disking. He also presented data to support the hypothesis that tropical spiderwort may have multiple generations per growing season and summarized preliminary data on tropical spiderwort seedbank longevity. Dr. Burton proposed several different mechanisms for tropical spiderwort dispersal, including movement with: 1.) equipment, 2.) plant material and soil, 3.) field disposal of gin trash, 4.) nursery and livestock, 5.) wind or water associated with floods and hurricanes, and 6.) animal wildlife. Tropical spiderwort has been found in Florida (as early as 1934), Georgia (33 counties), North Carolina (7 confirmed locations, which includes 2 retailers of nursery stock), South Carolina (1 nursery), Alabama (isolated plants), Louisiana and Missouri (adjacent to botanical gardens), and California (likely a different biotype from a separate introduction).

Dr. Eric Prostko (Associate Professor, University of Georgia, Tifton) presented data on his five years of experience with on-farm test with tropical spiderwort. In total, the Georgia Weed Science Group (University of Georgia and USDA-ARS colleagues) have completed 88 research trials since 2000. Dr. Prostko summarized his research findings: 1.) current crop production systems are to blame for the tropical spiderwort problem and short-term fixes will suppress tropical spiderwort, but long-term answers are still required; 2.) there are several good herbicides for the control of tropical spiderwort (e.g. 2,4-D; Dual Magnum; Aim; and Gramoxone), however, growers will have to spend significantly more money to control/suppress tropical spiderwort; 3.) tropical spiderwort control in corn was not profitable unless corn was planted late in the growing season (i.e. late-May or June) because tropical spiderwort did not affect corn yield when corn was planted in a timely manner. This was likely due to the emergence of tropical spiderwort in June and July after early-planted corn had already set ears; 4.) post-harvest weed control following corn may be critical for long-term management. However, post-harvest treatments will be difficult to convince growers to adopt unless research can demonstrate that there is a significant economic impact above and beyond the costs (i.e. costs associated with tillage, herbicides, and/or fuel prices).

Dr. Stanley Culpepper (Associate Professor, University of Georgia, Tifton) presented information on tropical spiderwort in cotton. The cotton industry in Georgia is an $804 million (2003 farm gate), second only to production of chicken broilers in Georgia, with 1.2 to 1.4 million acres of cotton planted annually. In 1999, tropical spiderwort was not listed among the top 10 most troublesome weeds in cotton, but it was the #1 most troublesome weed in Georgia cotton by 2002. All effective tropical spiderwort management programs are built around Dual Magnum. However, there are several caveats associated with the use of Dual Magnum in Georgia cotton: 1.) severe cotton injury can occur if Dual Magnum is applied preemergence to cotton; 2.) Dual Magnum must be applied after cotton emergence, but prior to tropical spiderwort emergence (i.e. it will not control emerged weeds); 3.) rainfall/irrigation is required for herbicide activation. Without moisture, Dual Magnum will not work; 4.) too much rainfall will move Dual Magnum out of the tropical spiderwort germination zone and reduce or eliminate herbicide efficacy; 5.) weed management costs are increased at least 25% by Dual Magnum, whether conditions are favorable for tropical spiderwort control or not. Further complicating the issue is the future adoption of Roundup Ready-Flex technology which allows for topical applications of Roundup throughout the growing season and at higher rates than are currently allowed (which will not improve tropical spiderwort control). The current recommendations for Georgia cotton fields with tropical spiderwort are: 1.) plant early in the season before the bulk of tropical spiderwort emerge in June or July; 2.) plant aggressive growing cultivars that form a crop canopy early in the season, shading the ground and suppressing tropical spiderwort emergence and growth; 3.) reduce seed production after crop harvest; 4.) reduce the alarming rate of spread; 5.) Cotoran preemergence, if planting cotton near the time of peak tropical spiderwort emergence; 6.) postemergence herbicides need to include Dual Magnum; 7.) layby options include: Aim, Dual Magnum, Direx, Valor, and MSMA. Dr. Culpepper estimates that conservatively in 2005 100,000 acres in Georgia were treated with 1 pt/acre of Dual Magnum to control tropical spiderwort, at a cost of $1.2 million.

Dr. Barry Brecke (Professor, University of Florida, Jay) presented information concerning the impact of tillage and herbicides on tropical spiderwort. Dr. Brecke observed that: 1.) tropical spiderwort infestations were worse in reduced tillage, 2.) Roundup was not effective in controlling tropical spiderwort, 3.) many peanut and cotton herbicides did not provide long-term control of tropical spiderwort, and 4.) tropical spiderwort had a germination pattern that allowed for emergence throughout the growing season. In long-term tillage and rotation studies that have been infested with tropical spiderwort since 2003, tropical spiderwort populations in conventional tillage were less than 5 plants/m^2, whereas strip tillage systems had population densities of 60 plants/m^2. In another study, tropical spiderwort population densities were four-times greater and two-times greater in strip-tillage relative to conventional and para-tillage, respectively. Tropical spiderwort control from Roundup plus Dual Magnum followed by Roundup was 20 to 35% higher than Roundup followed by Roundup in the three tillage systems. Conventional tillage that included Dual Magnum controlled tropical spiderwort at least 94%, while control in para-tillage and strip-tillage ranged from 75 to 92%. Dr. Brecke proposed that more research is needed to evaluate the influence of tillage treatments: on seed distribution in the soil profile, depth of tropical spiderwort emergence, seed predation, and seedbank longevity.

The morning concluded with a presentation by **Dr. Robert Faden** (Research Botanist, Smithsonian Institution, Washington D.C.) on the "Natural Variation in *Commelina benghalensis*". In the plant family Commelinaceae, there are 41 genera with approximately 650 species, most of which are tropical. *Commelina* is the largest genus in the Commelinaceae family, with 170 species, most of which are African. In the US there are nine species of *Commelina*, six of which are introduced, and the species are concentrated in the Southeast US, with no native *Commelina* species in the West Coast states. *Commelina* species are perennials or annuals with terminal inflorescences that may become leaf-opposed. The inflorescences are composed of one or two cymes enclosed in a spathe (leafy bract). The flowers are strongly zygomorphic; the lower petal is usually greatly reduced. Capsules can be up to five-seeded. Tropical spiderwort was first collected in Hawaii in 1909 and first reposted in Florida in 1934. In 1967, tropical spiderwort was found on Sapello Island off the Georgia coast. Tropical spiderwort was added to the Federal Noxious Weed List in 1983. In 1993, tropical spiderwort was reported in 13 counties in Florida, three counties in Georgia, and at one location in Louisiana. North Carolina reported tropical spiderwort in 2002. Tropical spiderwort is typically an annual plant with broad leaves, red hairs on the leaf sheaths, blue flowers, and underground cleistogamous flowers. Spathes are funnel-shaped with fused margins containing an upper cyme with a solitary male flower and lower cyme with perfect flowers. Lateral anthers possess white pollen, while the medial anther has yellow pollen. Dr. Faden indicated that there are two recognized varieties of tropical spiderwort. *Commelina benghalensis* var. *benghalensis* is an annual with underground cleistogamous flowers, found in mesic to dry open habitats throughout the range of the species and is diploid. *Commelina benghalensis* var. *hirsuta* is a perennial that normally lacks cleistogamous underground flowers, is found in mesic to moist habitats (including forests) in Africa and is tetraploid or hexaploid. There are four kinds of seed on each plant (2 each from the cleistogamous and chasmogamous flowers), and Dr. Faden indicated that there is no obvious means of seed dispersal. Dr. Faden proposed the following future research directions: 1.) morphological, anatomical, and cytological studies to work out the taxonomic entities within *Commelina benghalensis*; 2.) DNA studies to determine the phylogenetic relationships among the taxa within *Commelina benghalensis*; 3.) reproductive biological studies in the different taxa within *Commelina benghalensis*.

The afternoon sessions began with **Ms. Jean Burns** (Ph.D. Student, Department of Biological Sciences, Florida State University, Tallahassee) presenting "The Effect of Environment on Invasibility in the Commelinaceae". Five pairs within the Commelinaceae were selected with similar morphology, with one classified on an invasive species list and the other not listed as invasive. Ms. Burns discussed a series of studies involving these five pairs of species in the Commelinaceae family to evaluate whether there were some specific traits associated with these invasive species. In the first study, Ms. Burns evaluated the role of environmental quality (high and low nutrient and moisture regimes) and found the invasive Commelinaceae species to be more fecund (in terms of more seed biomass produced) and have greater vegetative production. Greater fecundity and higher vegetative production with invasive Commelinaceae are associated with higher relative growth rates, higher specific leaf area, and greater plasticity in root to shoot biomass ratio. In a second study, an invasive Commelinaceae species responded more opportunistically to increases in resource availability and had higher specific leaf area (i.e. thinner leaves capable of greater light interception) than non-invasive Commelinaceae. Ms. Burns concluded from a third study that invasive Commelinaceae species are not less resistant to herbivory and have less tough leaves than non-invasive Commelinaceae species.

I presented "The Ecology of Tropical Spiderwort in Agro-Ecosystems of the Southeast US", which is thoroughly summarized in the abstract on page 17.

Dr. Richard Davis (Research Plant Pathologist, USDA-ARS, Tifton) presented "Kill Tropical Spiderwort and Starve a Nematode or Tropical Spiderwort as a Host for Plant Pathogenic Nematodes". He indicated that there are approximately a dozen nematode genera with economic importance in the Southeast US. Most nematode species have a fairly wide host range, but there are some differences. These differences are the basis of crop rotation as a means of managing nematode problems. Important nematodes in cotton include southern root-knot (*Meloidogyne incognita*) and reniform (*Rotylenchulus reniformis*). Peanut root-knot (*M. arenaria*) is a significant pest in peanut. Southern root-knot reproduces well in corn. Weeds can serve as hosts for nematodes, allowing for reproduction even when a suitable crop host is absent from the field. Dr. Davis concluded that tropical spiderwort is a good host for southern root-knot nematode and a moderate host for reniform nematode and peanut root-knot nematode. Due to its host status, tropical spiderwort possesses the potential to significantly reduce the effectiveness of crop rotation and/or host plant resistance as a nematode management tactic.

Dr. Davis also presented some results from collaborative research with Dr. Tim Brennemen (Professor, Plant Pathology Department, University of Georgia, Tifton) on soil-borne fungal diseases of peanut. Southern stem rot or white mold (*Sclerotium rolfsii*) and cylindrocladium black rot (CBR) (*Cylindricladium parasiticum*) are the primary reasons for a three-year rotation cycle in peanut. Tropical spiderwort plants demonstrated signs of the pathogen (40 to 100% of the plants). Dr. Davis indicated that the pathogen is normally lethal to susceptible plants under these conditions, but tropical spiderwort branches with necrotic tissue simply put down roots at the next node from the infected area and continued growing. Tropical spiderwort will probably cause some increases in southern stem rot levels, but the fungus will have minimal effects on the weed. In the CBR trial, there was poor disease development on peanut and tropical spiderwort. While this test was not definitive of tropical spiderwort susceptibility to CBR, the fungus appeared to be weakly pathogenic. Tropical spiderwort will likely have little effect on CBR inoculum density and CBR will likely have minimal effect on tropical spiderwort growth.

Dr. Bill Vencill (Professor, University of Georgia, Athens) presented information on the "Effect of Tropical Spiderwort Response to Herbicides". Studies were conducted in which tropical spiderwort plants were grown in three moisture regimes (25, 50, and 100% of field capacity) for three weeks. Cuticle thickness and trichome frequency were characterized using a scanning electron microscope. Wax content for each leaf was also quantified. Dr. Vencill observed that cuticle thickness, trichome frequency, and wax content per leaf increased with drought stress. A subsequent study evaluated the influence of drought stress on herbicide response, using the same three watering regimes. Herbicides were applied postemergence to tropical spiderwort plants and included 2,4-D; diclosulam; flumioxazin; glufosinate; imazapic; sulfentrazone; atrazine; glyphosate; *s*-metolachlor; and glyphosate plus *s*-metolachlor. In most instances, herbicide efficacy was reduced by drought stress. Tropical spiderwort response to diclosulam, glyphosate, and *s*-metolachlor was not affected by drought stress. Foliar uptake of 2,4-D, flumioxazin, glyphosate, and *s*-metolachlor were reduced by moisture regime, while uptake of diclosulam, imazapic, sulfentrazone, and atrazine was not affected by moisture.

The final presentation was by **Dr. Tim Grey** (Assistant Professor, University of Georgia, Tifton) was titled "Herbicide Absorption and Translocation in *Commelina benghalensis*". Three herbicides (diclosulam, imazapic, and *s*-metolachlor) were applied to roots, shoots, and underground flowers of tropical spiderwort plants in greenhouse studies. After 48 hours, the plants were divided into above- and below-ground parts, dried, and oxidized. Herbicide movement was quantified using a liquid scintillation spectrometer. Dr. Grey reported that all three herbicides were mobile in the plant, but diclosulam tended to remain in the shoot, *s*-metolachlor was primarily recovered in the root tissue, and imazapic was found throughout the plant. Dr. Grey also presented data from a field trial that evaluated tropical spiderwort emergence (up until cotton canopy closure) across eight rates of *s*-metolachlor. There was a rate response observed at one month after application that existed until cotton canopy closure.

ABSTRACTS

Tropical Spiderwort: Perspectives from a County Agent

J. Timothy Flanders
Grady County Extension Coordinator
University of Georgia, Cairo

In a 1994 weed survey of Grady County, several weed species were noted that were not major weeds in Georgia, including: wild poinsettia, ground cherry, redweed and tropical spiderwort. Although present in several locations in 1994, tropical spiderwort was not considered a troublesome weed. However, in 1998 this weed suddenly became a problem for growers of Roundup Ready cotton. In 1999 the first cotton research trials were conducted and a by 2000 tropical spiderwort had become the most troublesome weed in Grady County cotton. In 2001 the first peanut research trials were conducted and tropical spiderwort became the most troublesome weed in Grady County peanuts that same year. Today tropical spiderwort is present in 60 to 70% of the county's cropland, and in 80% of those fields it is the most predominate weed. In 1999, tropical spiderwort was known to exist in 5 Georgia counties based on inquiries made by county agents to extension weed scientist. By 2005 the Georgia Department of Agriculture had confirmed the existence of tropical spiderwort in 33 Georgia counties. The rapid spread of tropical Spiderwort can be attributed to several factors. The introduction of glyphosate resistant cotton has revolutionized weed management and allowed broad-scale adoption of conservation tillage. Florida research shows increased incidence of tropical spiderwort in conservation tillage systems. Contributing to the rapid adoption of the most troublesome weed status of tropical spiderwort is its natural tolerance to glyphosate. With the introduction of Roundup Ready technology, many older cotton herbicides, some which have activity on tropical spiderwort, were replaced with glyphosate-based herbicide programs. The growth and reproductive characteristics of tropical spiderwort has also promoted its rapid spread. Tropical spiderwort has tremendous reproductive characteristics with the ability to produce seed under field conditions in 40 to 45 days and the ability to produce multiple generations in a year. Tropical spiderwort also has the ability to germinate throughout the growing season putting extraordinary pressure on any weed management program. In the past 3 to 4 years, the largest contributor to the spread of tropical spiderwort in Grady County is related to the county's corn acreage. Grady County farmers' grow corn on 11,000 to 12,000 acres a year (20% of counties row crop land). This acreage is generally beginning to dry down by mid- to late-July, with most of the harvest taking place in August. Once corn starts to dry down, sunlight penetrates the canopy allowing tropical spiderwort to emerge and grow uncontrolled until frost. The lack of any widespread control strategies following corn harvest allows fields to become a monoculture of tropical spiderwort and allows a large soil seedbank to build for future crops.

Demography of *Commelina benghalensis* in the Southern US

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Why do we have so much of it? (Propagation)

- Vegetative reproduction – Simulated fall disking experiments indicate that a small to large fraction of stem fragments remain turgid after two weeks burial. Weather is believed to be a large factor in the variability observed over the two years of study. Less than 5% of stem fragments entered a reproductive phase by producing flowers or rhizomes bearing flowers. Seeds can be produced by these flowers.

- Sexual reproduction
  - In controlled environment studies (NCSU Phytotron), *C. benghalensis* flowered about 30 days after emergence (male imperfect and bisexual perfect flowers are present). Seeds dehisced from fruit 14 days after flowering. Some of the seeds produced germinated in the same environment 14 days after the fruit dehisced.
  - Subterranean flowers can also be produced on rhizomes. These flowers/fruit appear to mature more slowly, but spathe tissue decays about 30 days after subterranean spathe initiation.

- Seedbank Longevity – Field observations indicate a small fraction survives at least three years, but 2004 emergence was about 25% of that observed in 2003.

How is it getting around? (Dispersal)

- Moved with equipment (tillage, custom cotton/peanut/potato harvesters, mowers, etc.).
- Moved with seed/plant material/soil.
- Field disposal of gin trash (NC test: ~57 seeds per kg of seed cotton)
- Nursery and livestock industries
- Blown by wind or water erosion, floods, hurricanes.
- Animal movement [deer browse, doves (?), rodents].

Where is it now? (Distribution)

- Affected southern states: GA, FL, NC, SC, LA, AL
- Where is it going? Difficult to predict, however, at a minimum cotton, peanut and rice producing regions of the USA are at risk.

After Five Years of On-Farm Testing, Have We Learned How to Manage Tropical Spiderwort?

Eric P. Prostko
Peanut and Corn Extension Weed Science
University of Georgia, Tifton

Over the past several years, tropical spiderwort has become one of the most troublesome weeds in row crop agriculture in southern Georgia. In response to this threat, University of Georgia and USDA/ARS weed scientists have conducted more than 85 laboratory, greenhouse, and field trials to address the biology and control of this weed.

Generally, the control of tropical spiderwort in row crops will force producers to increase production inputs which will ultimately decrease economic returns. Several herbicides have been identified for use in potential management strategies including 2,4-D, *s*-metolachlor, carfentrazone, and paraquat. The discovery of adequate control programs in field corn have been elusive because the majority of tropical spiderwort emergence occurs after the critical period of weed control (i.e. after the time that corn growth is far enough along that new tropical spiderwort emergence will not affect corn yield) and/or when the field corn it is too tall to apply herbicide treatments. Consequently, production inputs for the management of tropical spiderwort in field corn might be better utilized post-harvest. However, growers are reluctant to implement post-harvest control tactics because of time constraints, current diesel fuel prices, and limited immediate, economic benefit from their use.

Despite significant research and extension efforts, tropical spiderwort continues to spread at an alarming rate in Georgia.

Tropical Spiderwort: Winning the Battle in Georgia Cotton

A. Stanley Culpepper
Cotton and Vegetable Extension Weed Science
University of Georgia, Tifton

Southeastern cotton weed control has changed drastically since the commercialization of Roundup Ready cotton in 1997. This technology was rapidly adopted by cotton farmers and occupies at least 94% of the acreage in the Southeast. Several weed control changes and challenges have occurred, at least in part, as a result of Roundup Ready technology, including the following: 1) greater adoption of conservation tillage (44% in Georgia); 2) reduction in mechanical weed control after crop emergence, with many growers relying completely on herbicides to manage weeds; and 3) reduction in the use of residual herbicides like fluometuron and norflurazon while relying very heavily on postemergence control from glyphosate. These factors have lead in part to weed shifts and resistance, which have become problematic in several areas throughout the southeast

Tropical spiderwort was not a pest of cotton in 1999, but because of its ability to adopt to conservation tillage and Roundup Ready cotton programs, the weed quickly emerged into being quite troublesome. It was ranked as the 9^{th} most troublesome weed in 2001 and became the most troublesome weed for Georgia cotton growers by 2002. It has maintained its dominance as the most troublesome weed facing Georgia cotton producers from 2002 through 2005.

Several scientists suggest that tropical spiderwort has simply become more troublesome because of its tolerance to glyphosate, as most cotton growers rely heavily on glyphosate for weed management. Although tropical spiderwort is tolerant to glyphosate, the weed can be controlled by glyphosate if applications are made to small (< 2 inch) plants growing in a favorable environment. Moreover, producers who have been challenged with this pest for several years now no longer rely simply on glyphosate to manage the weed. Growers quickly adopted other more effective herbicides such as *s*-metolachlor, carfentrazone, and diuron. In spite of the adoption of these more effective herbicide programs, tropical spiderwort continues to spread throughout Georgia, now infesting 33 Georgia counties.

Continued spread of this weed is likely in response to: 1) the ability of the weed to avoid weed control tactics by often emerging after the weed management program has been completed, 2) the ability of this weed to proliferate in conservation tillage, 3) the lack of physical weed control (i.e. in-crop tillage) as growers now rely on herbicides for in crop weed control, and 4) the lack of use of effective residual herbicides applied throughout the season, a standard practice before Roundup Ready technology was so widely adopted.

Impact of Tillage and Herbicide on Tropical Spiderwort

Barry J. Brecke, Daniel O. Stephenson, IV, and Kendal Hutto
University of Florida, West Florida Research and Education Center, Jay, FL

Studies were conducted at the University of Florida, West Florida Research and Education Center, Jay, FL in an area naturally infested with tropical spiderwort to determine the effect of tillage and herbicides on management of tropical spiderwort.

In the first study, peanut and cotton were grown under two tillage regimes: 1) conventional tillage which included use of a moldboard plow, disk and field cultivator prior to planting and 2) and reduced tillage which included use of a strip-till implement fitted with an in-row subsoil shank, closing discs and rolling baskets. The strip-tillage operation left at least 50% of the soil surface undisturbed. Cotton and peanut were planted following the tillage operations. Weed counts indicated a lower tropical spiderwort density (3 weed/m^2) in the conventional tillage area compared with the strip-tillage area (60 weeds/m^2) in both cotton and peanut.

In a second study (with only cotton) three levels of tillage were evaluated for effect on tropical spiderwort. Conventional tillage and strip-tillage were employed as in the first study. The third tillage system involved the use of a para-till implement which resulted in a level of soil disturbance greater than strip-tillage but less than conventional tillage. Weed counts indicated that tropical spiderwort density was highest in strip-tillage (8 plants/m^2), next highest in para-till (4 plants/m^2) and lowest in conventional tillage (2 plants/m^2). Herbicide treatments were more effective in the conventional tillage area probably due to the reduced tropical spiderwort density. Two application of glyphosate in glyphosate tolerant cotton failed to provide adequate control of tropical spiderwort. Adding metolachlor to the first glyphosate application improved control to 96% in conventional tillage, 80% in para-till and 75% in strip-till cotton.

Natural Variation in *Commelina benghalensis* (Commelinaceae)

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Commelina benghalensis L., a paleotropical native, is one of six naturalized species of *Commelina*, out of a total of 9 species in the United States. The typical plant is an annual with broad leaves, red hairs at the summit of the leaf sheath, blue, chasmogamous, aboveground flowers, and cleistogamous underground flowers. The spathes are funnel-shaped, nearly sessile, and may be solitary or clustered. The inflorescence consists of 2 two cymes, the upper cyme producing a single male flower and the lower cyme several bisexual flowers. The anthers of the lateral fertile stamens have white pollen, whereas that of the medial stamen has yellow pollen. The aboveground capsules have up to 5 seeds, whereas the belowground capsules have up to 3 seeds. The seeds in both capsules are dimorphic for a total of 4 seed types. In Africa, two varieties of *C. benghalensis* are recognized, var. *benghalensis*, a diploid annual with cleistogamous flowers, and var. *hirsuta*, a polyploid perennial that lacks cleistogamous flowers. Other morphological variants occur in East Africa, especially Kenya, that do not belong to either of these taxa. Some features that occur among the variants are: very narrow leaves, purple-marked spathes, some flowers in the lower cyme cleistogamous, blue-lavender or white flowers, and yellow pollen in the lateral anthers. *C. benghalensis* has the unusual basic chromosome number $x = 11$. Diploids are known throughout the range of the species, but tetraploids and hexaploids are known from wild collections only from Africa. Within the U.S. *C. benghalensis*, arrived in Hawaii by 1909, in the southeast by at least the 1930s and in southern California by 1980. Southeastern plants are diploids ($2n = 22$), Hawaiian plants are probably diploids, and Californian plants probably hexaploids.

The Effect of Environment on Invasibility in the Commelinaceae

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Studies of the traits of invasive species have generally either confounded species characteristics with phylogenetic relationships or have compared a single invader with a related native. This series of studies examined traits associated with multiple invasive species in the Commelinaceae while controlling for shared evolutionary history. We compared invasive species to non-invasive species, rather than to native species, whose invasive potential is unknown. Comparisons between 5 pairs of invasive and non-invasive congeners were conducted in a greenhouse across a factorial water and nutrient experiment. Invasive Commelinaceae species had greater relative growth rate, fecundity, and vegetative reproduction than their noninvasive congeners. Other experiments found that thin, less tough leaves are also associated with invasiveness in these species. These traits may prove useful in predicting invasive ability in the Commelinaceae. Also, taking relatedness into account in comparative studies improves our ability to detect trait associations. However, trait differences between invasive and non-invasive species were environment-dependent, suggesting that care should be taken in generalizing about the traits of invasive species without taking into account the environmental conditions under which those traits were measured.

The Ecology of Tropical Spiderwort in Agroecosytems of the Southeast US

Theodore M. Webster
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There are numerous factors that have allowed tropical spiderwort to become a weed in our agroecosystems. Some factors are related to the biology of the plant, ecology of the tropical spiderwort-crop interactions, and management practices that do not deter tropical spiderwort growth. I will outline five of these factors. Tropical spiderwort is a persistent weed in Southeast agroecosystems due to: 1. its amazing growth habit, 2. unique emergence characteristics, 3. the ability to tolerate drought stress, 4. the slow growth habit of cotton, and 5. its ability to capitalize on unused resources following crop harvest.

Amazing growth habit. Greenhouse studies were conducted to evaluate tropical spiderwort growth. Five-leaf tropical spiderwort plants were transplanted into 30-cm diameter pots and growth evaluated over 11 weeks. There were five plants evaluated and the study was repeated over time. Plant growth was nearly linear between one and six weeks, with plants with 50 leaves, 10 shoots, and 10 aerial spathes (leafy bract that encloses the flowers and fruit). However, tropical spiderwort growth was geometric between six and 11 weeks after planting, with weekly additions of 70 leaves, 10 shoots, and 26 aerial spathes.

Emergence characteristics. The ability to predict tropical spiderwort emergence is critical for optimizing timing of control tactics. The lack of soil residual activity from glyphosate coupled with the plant size-linked tolerance of tropical spiderwort to glyphosate underscores the importance of understanding tropical spiderwort germination and emergence dynamics. The bulk of tropical spiderwort emergence (50 to 70%) in cotton fields in 2004 and 2005 occurred in July, which is at least a month later in the growing season than peak emergence for most other agronomic summer annual weeds. While up to 36% of the tropical spiderwort population emerged prior to July 1 (which will need to be addressed with some type of weed control tactic), the relatively late emergence characteristics of tropical spiderwort can be exploited to the benefit of the crop.

Based on observations of tropical spiderwort emergence patterns, it was hypothesized that early planted cotton (i.e. April or May) would be more competitive than late planted cotton (i.e. June) as the crop would have more time to establish prior to peak tropical spiderwort emergence and would form a crop canopy faster. A light-limiting crop canopy has been observed to curtail tropical spiderwort emergence. Studies were conducted to evaluate the interval that cotton must be kept free of tropical spiderwort in order to avoid a yield loss of greater than 5%. There is a time at the beginning of the season that cotton can tolerate the presence of tropical spiderwort (or any weed) as resources (i.e. water, nutrients, and especially light) are not limited. Likewise, there is also a point at which cotton has established itself and newly emerged tropical spiderwort populations will not influence cotton yield. The interval between these two times is the critical period of weed control (CPWC) during which all tropical spiderwort needs to be controlled.

May-planted cotton had narrow CPWC intervals between 475 and 525 growing degree days (GDD; calculated with a base temperature of 10 C) in 2004 and approximately 300 to 500 GDD in 2005. In contrast, June-planted cotton had wide CPWC intervals between 200 and 750 GDD in 2004 and 200 and 900 GDD in 2005. These data indicate that cotton was more competitive and required less aggressive management tactics when cotton was planted in May relative to June. Also supporting this contention is the maximum yield loss in the weedy controls; when tropical spiderwort competed with May-planted cotton for the entire season, yield loss was 20%. However, yield loss was at least double in the weedy control in the June-planted cotton (40 to 45%).

Drought stress. Preliminary studies indicated that tropical spiderwort is affected by drought stress, but maintained green leaves and produced spathes under extreme drought. Single plants were grown in the greenhouse for eight weeks in replicated trials. Treatments included four weekly watering regimes: field capacity (1X), half of field capacity (½X), one-fourth of field capacity (¼X), and one-eighth of field capacity (1/8X). Tropical spiderwort width was a more robust measurement of growth than was plant height, as tropical spiderwort is a low-growing, sprawling plant. Plant width was reduced greater than 50% by watering at ½X relative to 1X. Plants from all watering regimes produced aerial and subterranean spathes and numbers increased in a linear manner with amount of water.

Tropical spiderwort in cotton. Field studies were conducted in Grady County, Georgia in 2004 and 2005 to evaluate the effect of crop type on tropical spiderwort emergence and growth. Corn, cotton, peanut, and soybean were planted the final week of April in replicated plots with a naturalized tropical spiderwort population. Tropical spiderwort emergence was similar among crops early in the season, with divergence among crop types occurring around 450 GDD in 2004 and 300 GDD in 2005 (T_b=10C). Total season emergence was greatest in cotton in both seasons. Peanut and soybean had 30 and 40% less emergence than cotton, respectively. Cotton is slow to form a light-limiting canopy relative to soybean and peanut; low light levels tended to suppress tropical spiderwort emergence. Emergence in corn was variable between seasons, but 8 to 22% less than cotton. Tropical spiderwort biomass in the non-cropped (fallow) plots were greater than in any of the crop treatments. However, only soybean had less tropical spiderwort biomass than peanut, which had the most tropical spiderwort biomass per plant in the four crops. Therefore, while cotton allowed the most new tropical spiderwort seedlings to emerge throughout the season, once established tropical spiderwort plants growing in competition with peanut attained the greatest growth.

Corn is often planted prior to the last week in April in Georgia, therefore the comparisons of growth between the crops in the above study may not reflect the differences in actual planting dates that occur in south Georgia. Another study was conducted in 2005 where corn was planted April 14; cotton, peanut, and soybean planted May 16; and 1-leaf tropical spiderwort transplanted June 16. These dates were selected to simulate the differences in crop planting dates as well as the late emergence characteristics of tropical spiderwort. At 12 weeks after tropical spiderwort transplanting (WATr), tropical spiderwort plants in corn and soybean were less than one-third the plant width of those in cotton and peanut. Similarly, there were less than 5 aerial spathes per plant in corn and soybean treatments, while peanut and cotton had 40 and 55 aerial spathes per plant, respectively. Leaf area, leaf biomass, and total plant biomass revealed similar trends (data not shown).

Post-crop harvest reproduction. Corn is a silent accomplice to tropical spiderwort, allowing populations in the soil seedbank to increase. Research indicated that tropical spiderwort growth in corn is less than in cotton and peanut during the growing season. However, tropical spiderwort capitalizes on the corn growth habit. Corn is planted and completes much of its lifecycle prior to tropical spiderwort emergence. By the time peak tropical spiderwort emergence occurs, corn foliage is beginning to desiccate, which allows more light through the crop canopy and tropical spiderwort plant establishment. Following corn harvest, most fields are left undisturbed, allowing tropical spiderwort populations to grow until frost, all the while increasing propagules in the soil seedbank.

Research Needs: It is vital that cropping systems are developed that possess low susceptibilities to tropical spiderwort invasion (preventing new tropical spiderwort establishment) and high tolerance to tropical spiderwort presence (suppressing impact of an existing tropical spiderwort population). These cropping systems will be characterized by: 1. elimination of tropical spiderwort safe-sites (conditions that allow for tropical spiderwort germination, emergence, and establishment), 2. optimized benefits of cultural practices (i.e. early planting dates, aggressive crop cultivars, inclusion of some type of tillage), 3. utilization of aggressive control tactics, including the use of *s*-metolachlor in cotton and effective herbicides rotation crops, and 4. elimination of the opportunity for tropical spiderwort reproduction, especially following crop harvest.

Studies are also needed to evaluate: 1. tropical spiderwort seedbank longevity, 2. primary dispersal mechanisms, and 3. post-crop harvest management. A critical need for the southern region is the development of a model that characterizes the environmental limits of tropical spiderwort in the US. A proactive approach to minimize the spread of tropical spiderwort to susceptible habitats is key for minimizing the regional impact of this weed in our agroecosystems.

Kill Tropical Spiderwort and Starve a Nematode

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The major plant-parasitic nematodes in the southeastern US are soil-borne microscopic worms that feed on plant roots. They are obligate parasites which can only feed on plants. Most nematodes have a wide range of plants on which they can feed (their host range), but nematode host ranges do differ, and those differences are the reason that crop rotation can be used to reduce nematode population levels. Nematodes are the most damaging pathogens of cotton, and one of the most important pathogens of peanut. The southern root-knot nematode (*Meloidogyne incognita*) reproduces well on cotton and corn, but not on peanut; the peanut root-knot nematode (*Meloidogyne arenaria*) reproduces well on peanut, but not on cotton or corn; and the reniform nematode (*Rotylenchulus reniformis*) reproduces well on cotton, but not on peanut or corn. Therefore, crop rotation sequences utilizing cotton, peanut, and corn can be selected to manage these nematodes. However, weeds also can support nematode reproduction, and the amount of reproduction on some weeds can be enough to reduce the effectiveness of crop rotation as a nematode management tool. In addition to the host status of the weed, the amount of nematode reproduction will be affected by the weed population density (plants/m^2) and root mass: a weed that produces a lot of root mass, has a high plant density, and is a good host may support as much nematode reproduction as would a susceptible crop thereby negating the nematode-suppressive benefit of a crop rotation. Tropical spiderwort (*Commelina benghalensis*) typically has high plant population density with a lot of root mass, but its host status for nematodes was not known. We initiated a study to document the relative host status of tropical spiderwort for *M. incognita*, *M. arenaria*, and *R. reniformis*, each of which was tested in two separate experiments. We also evaluated the host status of tropical spiderwort for fungal pathogens *Sclerotium rolfsii*, which causes southern stem rot or white mold of peanut, and *Cylindrocladium parasiticum*, which causes Cylindrocladium black rot (CBR) of peanut: these diseases are the primary reason that peanuts in the southern US usually are grown in a given field only once every three years. Tomato was grown as a susceptible standard for *M. incognita* and *M. arenaria*, and cotton was grown as a susceptible standard for *R. reniformis*. Peanut was used as a susceptible standard for *Sclerotium rolfsii* and *Cylindrocladium parasiticum*. Tomato, cotton, and peanut were started from seed, and *C. benghalensis* was started from vegetative cuttings. Each pot contained one plant in 1,100 cm^3 of soil and was inoculated with 8,000 nematode eggs approximately 3 weeks after planting. A reproductive factor (RF) was calculated for each nematode and host combination as the final population level divided by the initial population level (Pf/Pi). Only egg counts were used to calculate RF for *M. incognita* and *M. arenaria*, but egg and vermiform counts were used to for *R. reniformis*. Galling was estimated on a 0 to 10 scale for the *Meloidogyne* species. Data from the two trials with *M. incognita* were statistically similar, so the data were combined into a single analysis. Data from the trials with *M. arenaria* also were combined, but data from the trials with *R. reniformis* could not be combined. *Meloidogyne incognita* reproduced well on *C. benghalensis*, leading to a mean gall rating of 3.1 and a mean RF of 15.5 on *C. benghalensi*. *Meloidogyne incognita* caused a mean gall rating of 6.4 and a mean RF of 41.3 on tomato. *Meloidogyne arenaria* also reproduced well on *C. benghalensis*, with a mean gall rating of 2.1 and a mean RF of 7.2. *Meloidogyne arenaria* caused a mean gall rating of 6.3 and a mean RF of 12.4 on tomato. In the first trial with *R. reniformis*, the RF was 2.4 on *C. benghalensis* and 1.4 on cotton. In the second trial, the RF was 3.6 on *C. benghalensis* and 13.5 on cotton. In soils more conducive to reproduction by *R. reniformis*, the RF on cotton can be much higher than observed in this study, and it is likely that the RF also would be higher on *C. benghalensis* in such soils. The severity of symptoms caused by *Sclerotium rolfsii* was estimated on a 0 to 10 scale. In the first trial, peanut had a mean disease severity rating of 4.0 and *C. benghalensis* had a mean rating of 1.4, and the fungus could be seen growing on 40% of the *C. benghalensis* plants. In the second trial, peanut had a mean disease severity rating of 10.0 and *C. benghalensis* had a mean rating of 5.0, but the fungus could be seen growing on all of the *C. benghalensis* plants. *Sclorotium rolfsii* is a virulent pathogen that will kill a wide range of hosts. It is noteworthy that *C. benghalensis* was able to survive complete girdling by *S. rolfsii* lesions by forming new roots from nodes above the lesions. Such plants exhibited growth similar to the non-inoculated controls. The trials with *Cylindrocladium parasiticum* were inconclusive due to low infection rates, but the fungus appears to be weakly pathogenic to *C. benghalensis*. In conclusion, it appears that *C. benghalensis* is a sufficiently good host for some of the primary nematode and fungal pathogens of major crops in the southeastern US that its presence at high plant population densities can greatly reduce the pathogen-suppressive effects of crop rotation.

Effect of Moisture Stress on Tropical Spiderwort Response to Herbicides

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The objective of this research was to observe the effects moisture stress has on greenhouse grown tropical spiderwort plants and also to observe the effects of herbicidal control, uptake and translocation. Leaf characterization was observed under a scanning electron microscope to determine differences caused by moisture stress. Treatments were subjected to three different moisture stress levels (25, 50 and 100% of field capacity), and sprayed post emergence with selected herbicides. Translocation of diclosulam, imazapic and S-metolachlor into the roots and shoots was observed. Foliar uptake of diclosulam and imazapic were not affected by changes in moisture stress. Studies were conducted to observe the effects of varying rates of different herbicides on aerial and underground seed. S-metolachlor had the greatest control of aerial and underground seed.

Results of these studies reveal that soil moisture has an impact on the morphology and can impact herbicidal control of tropical spiderwort. As the soil moisture content decreased from 100% to 25% of field capacity, the thickness in cuticle increased approximately 27%, trichome frequency increased approximately 44%, and wax content increased almost 26%. This change in morphology most likely affects the uptake of foliar applied herbicides.

Herbicides affected by soil moisture content were atrazine, flumioxazin and imazapic. The ED_{50} values decreased with increasing moisture. The foliar uptake of these herbicides increased when moisture content increased. Diclosulam and sulfentrazone foliar uptake was not affected by moisture content. Although glyphosate alone did not provide effective control, the foliar uptake was increased at the highest (100% field capacity) moisture level. This is one reason why tropical spiderwort is such a problem in glyphosate-resistant crops, since growers in these cropping situations use glyphosate as the main form of herbicidal control. S-metolachlor, was translocated from the shoots to the belowground parts. The translocation of S-metolachlor may affect the germination of underground seed.

Application of S-metolachlor to aerial and underground seed resulted in the lowest germination percentage when compared to technical diclosulam and imazapic. Diclosulam and imazapic did not effectively inhibit aerial or underground tropical spiderwort seed germination, regardless of rate. Further studies are needed on the aerial and underground seed of tropical spiderwort to learn how to effectively control this weed.

Herbicide Absorption and Translocation in *Commelina benghalensis*

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The translocation of diclosulam, imazapic, and *S*-metolachlor were investigated for *C. benghalenis* using ^{14}C-labeled isotopes for each herbicide. Live cuttings were placed in Styrofoam cups filled with soil. The cups were split vertically so they could be opened up to reveal the root and underground floral structures. Plants were allowed to grow for three weeks prior to treatment. The cups were opened up to reveal the roots and underground flower. Plants were then treated with the respective ^{14}C-herbicide either on the shoot, root, or underground flower with a spot application. After 48 hrs, plant parts were divided into above and below ground sections, dried, ground into a powder, and then oxidized, and ^{14}C quantified by liquid scintillation spectrometry.

For ^{14}C-diclosulam applied to shoots, 74% remained in the shoot with less than 26% moving into the root. When the root was treated with diclosulam, 63% remained in the root while 37% translocated to the shoot. The underground flower treated with diclosulam resulted in equal distribution with 46% moving into the root and 53% to the shoot. Diclosulam distribution was dependent on site of uptake, and thus could provide activity via soil or foliar uptake.

C. benghalenis shoots treated with ^{14}C-imazapic retained 63% of the herbicide while 37% translocated to the roots. When the root was treated, the inverse occurred with 80% remaining in the root and only 20% moving to the shoot. In contrast, when the underground flower was treated, 24% translocated to the root while 76% went to the shoots. As with diclosulam, these data indicate that imazapic absorption can occur via root, shoot, or underground flower with some translocation occurring through out the plant.

Eighty two percent of shoot applied ^{14}C-*S*-metolachlor was translocated to the root with only 18% remaining in the shoot. In contrast, 56% of the root applied herbicide remained in the root while 44% translocated to the shoot. When the underground flower was treated, similar results occurred with 60% going to the roots and 40% to the shoots. Thus, *S*-metolachlor soil applied would translocate to the entire plant but as a foliar application it would move to the roots. Previous research has indicated that *S*-metolachlor does not provide foliar control of *C. benghalenis* and this is probably due either lack of absorption or to translocation from the shoot to the roots.

Similar trends for translocation of ^{14}C-diclosulam and ^{14}C-imazapic occurred for the specific treated plant part (i.e. root, shoot, or underground flower). The speculation for this similarity could be because both are ALS herbicides that have pre- and post-emergence activity. In contrast, ^{14}C-*S*-metolachlor is a residual chloracetamide herbicide that has only pre-emergence activity. Translocation of ^{14}C-*S*-metolachlor did occur, but it was uniquely different from ^{14}C-diclosulam and ^{14}C-imazapic.

Effects of Elevated Atmospheric Co_2 on Tropical Spiderwort

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Invasive weeds are estimated to cost U.S. agricultural and forest producers $34 billion each year from decreased productivity and increased weed control costs. One neglected aspect of global change is how invasive plants might react to the increasing atmospheric CO_2 concentration. Since elevated CO_2 stimulates photosynthesis, resource use efficiency, and carbon allocation to belowground plant structures, it may impact the competitiveness of invasive plants. Tropical spiderwort (*Commelina benghalensis* L.) is considered an invasive noxious weed and is becoming more of a problem in agricultural settings of the southeastern US. This recently funded National Institute for Global Environmental Change (Southeast Regional Center) research project evaluates tropical spiderwort responses to CO_2 enrichment. Tropical spiderwort was grown under ambient and elevated levels of CO_2. Under elevated CO_2 conditions, plant organ parts exhibited significant increases in dry weight (leaf, +36%; flower, +30%; stem, +48%) and the overall increase in total aboveground biomass was 44%. Total stem length was unaffected by CO_2 level while total leaf number and total flower number showed trends for increase (~20%) due to additional CO_2. The strong growth responses of tropical spiderwort suggest that its competitive ability with native plants will be enhanced in a future high CO_2 environment.

Invasive.Org: The Source for Information and Images of Invasive and Exotic Species.

Chris W. Evans, G. Keith Douce, David J. Moorhead, and Charles T. Bargeron.

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The University of Georgia's Bugwood Network (www.bugwood.org) developed Invasive.org as a tool for collecting, providing and maintaining information and images related to invasive and exotic species for North America. This includes plants, insects, pathogens, nematodes, mollusks and vertebrates, as well as many biological control agents. Identification, ecology and management information is easily accessible for many of these species. Invasive.org currently provides information and/or images for over 600 different species. The project has been funded in part by the USDA Forest Service and USDA APHIS PPQ. The overall goal of the project is to cross agency and organizational barriers to provide the most useful information to the largest audience. In order to accomplish this goal cooperation is required at a regional, national and even international level.

Photographs From The Meeting

Introduction by Dr. Tim Strickland, Location Coordinator, USDA-ARS, Tifton

Presentation by Mr. Tim Flanders

Presentation by Dr. Mike Burton

Presentation by Dr. Stanley Culpepper

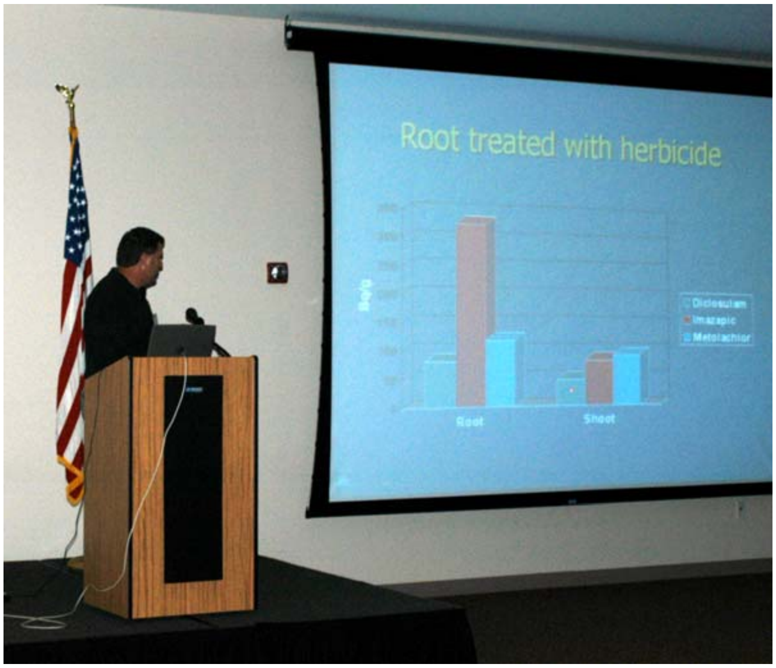
Presentation by Dr. Eric Prostko

Presentation by Dr. Robert Faden

Presentation by Ms. Jean Burns

Presentation by Dr. Richard Davis


Presentation by Dr. William Vencill



Presentation by Dr. Tim Grey

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