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Invasive Weed Alert

Tropical Spiderwort (*Commelina benghalensis*): A Tropical Invader Threatens Agroecosystems of the Southern United States[1]

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Abstract: Tropical spiderwort (more appropriately called Benghal dayflower) poses a serious threat to crop production in the southern United States. Although tropical spiderwort has been present in the United States for more than seven decades, only recently has it become a pest in agricultural fields. Identified as an isolated weed problem in 1999, tropical spiderwort became the most troublesome weed in Georgia cotton by 2003. Contributing to the significance of tropical spiderwort as a troublesome weed is the lack of control afforded by most commonly used herbicides, especially glyphosate. Vegetative growth and flower production of tropical spiderwort were optimized between 30 and 35 C, but growth was sustained over a range of 20 to 40 C. These temperatures are common throughout much of the United States during summer months. At the very least, it appears that tropical spiderwort may be able to co-occur with cotton throughout the southeastern United States. The environmental limits of tropical spiderwort have not yet been determined. However, the rapid spread through Georgia and naturalization in North Carolina, coupled with its tolerance to current management strategies and aggressive growth habit, make tropical spiderwort a significant threat to agroecosystems in the southern United States.

Additional index words: Exotic invasive weed, federal noxious weed, Benghal dayflower.

INTRODUCTION

Tropical spiderwort (*Commelina benghalensis*; also called Benghal dayflower) poses a serious threat to crop production in the southern United States (Figure 1). Tropical spiderwort has been present in the United States for more than seven decades (Faden 1993), but only recently has it become a pest in agricultural fields. Identified as an isolated weed problem in 1999, tropical spiderwort became the most troublesome weed in Georgia cotton (*Gossypium hirsutum* L.) by 2003 and was second only to Florida beggarweed [*Desmodium tortuosum* (Schwartz) DC.] in Georgia peanut (*Arachis hypogaea* L.). The apparently rapid spread of this weed in agronomic crop fields in Georgia as well as recent discoveries of infestations in North Carolina and Alabama suggest that tropical spiderwort is quickly spreading throughout the southern United States, with the potential to invade other crop-producing regions.

Contributing to the significance of tropical spiderwort as a troublesome weed is its tolerance to many commonly used herbicides, especially glyphosate. Since its commercial introduction in 1997, glyphosate-resistant cotton has readily been accepted by growers across the southeastern United States. Glyphosate-resistant cotton cultivars were planted on 89% of the 525,000 cotton hectares in Georgia, whereas neighboring states (Alabama, Florida, North Carolina, and South Carolina) adopted these cultivars on 91 to 100% of their cotton hectares (Fernandez-Cornejo and McBride 2002; U.S. Department of Agriculture [USDA]–Agricultural Marketing Service 2003). The technology has allowed growers to reduce both their use of soil-applied herbicides and their total herbicide use in cotton (Culpepper and York 1998, 1999). Glyphosate is used extensively throughout the region and is effective against most common weeds; however, it often is not effective in managing tropical spiderwort (<55% control) (Culpep-

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Figure 1. Commelina benghalensis L. (A) Whole plant, showing aerial and subterranean flowers. (B) Leaf sheath, which often is topped with characteristic red hairs. (C) Dissection of spathe in profile displaying floral buds. (D) Dissection of spathe in profile showing position of flowers. (E) Imperfect staminate flower. (F) Perfect flower. (G) Seed from subterranean fruit. (H) Dissection of seed from aerial fruit. Illustration by Cathy Pasquale and used with the permission of the U.S. Department of Agriculture–Animal and Plant Health Inspection Service.

per et al. 2004) because of herbicide tolerance and germination throughout the growing season.

DESCRIPTION

An herbaceous perennial weed in tropical climates, tropical spiderwort grows as an annual in the temperate climate of the United States (Holm et al. 1977). The difference in life cycle likely is attributed to a difference in ploidy level observed between tropical (hexaploid) and introduced accessions in the southeastern United States (diploid) (R. B. Faden, personal communication). Hexaploid tropical spiderwort is perennial and rarely produces subterranean flowers. Diploid tropical spiderwort is an annual (in the climate of the southeastern United States) and will produce subterranean flowers (Faden and Hafliger 1982; Holm et al. 1977). In southern California, hexaploid tropical spiderwort rarely thrives outside of frequently watered gardens (R. B. Faden, personal communication). Tropical spiderwort in California represents the only introduced *Commelina* spp. in the western United States (Faden 1993).

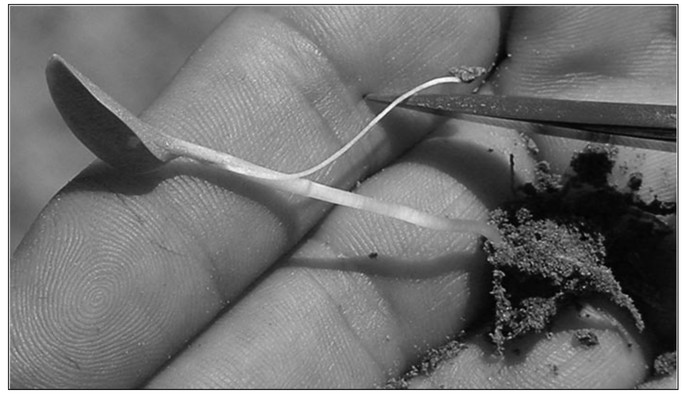

Figure 2. Recently germinated *Commelina benghalensis* seedling with thread-like cotyledonary stalk. Photo by Eric P. Prostko, University of Georgia, Tifton, GA.

Seedlings in the Commelinaceae produce a cotyledonary stalk (Figure 2), which is a filamentous structure that connects the embryo to the scutellum (retained in seed coat) as it grows toward the soil surface (R. B. Faden, personal communication). Tropical spiderwort leaf blades are ovate to ovate-elliptic in shape, 3 to 7 cm in length, and two- to threefold longer than they are wide. In Georgia, mature leaves have a leaf length-to-width ratio of approximately 1.7:1. Younger leaves are more variable, and these ratios can approach 3:1 (Figure 3). Leaf blades have parallel veination, entire leaf margins, and pubescence on the upper and lower leaf surfaces and margins (Faden and Hafliger 1982). Tropical spiderwort also may have long, red hairs at the summit of the closed sheath that surrounds the stem at the leaf base (Faden 2000; Faden and Hafliger 1982) (Figure 4). A related species, the native *Commelina virginica* L., also may have red or white hairs at the summit of the leaf sheath, but this species can be distinguished from tropical spiderwort by its long, narrow leaf blades, which are 6 to

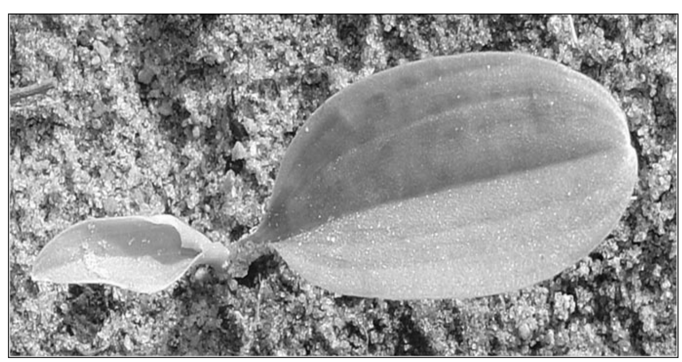

Figure 3. Young *Commelina benghalensis* plant, displaying the distinctive leaf blade that is characteristically shorter and wider than other *Commelina* spp. Photo by A. Stanley Culpepper, University of Georgia, Tifton, GA.

Figure 4. Leaf sheaths of *Commelina benghalensis* that are topped with the characteristic red hairs. Photo by Herb Pilcher, USDA–Agricultural Research Service, Tifton, GA.

20 cm in length and 4 to 6 times longer than they are wide (Faden 2000).

The succulent stems of tropical spiderwort are creeping or ascending, 10 to 30 cm in height, 20 to 90 cm in length, covered with fine pubescence, and dichotomously branched (Faden and Hafliger 1982). The stems will climb if supported; otherwise, they creep along the ground and root at the nodes. Broken vegetative cuttings of stems are capable of rooting and reestablishing after cultivation or disking (Budd et al. 1979). Leaf initiation on four-node stem segments began within 10 d after planting, whereas one-node segments required 14 d (Chivinge and Kawisi 1989). In Australia, short rhizomes developed approximately 6 wk after seedling emergence (Walker and Evenson 1985). By 12 wk, plants had an average of six rhizomes, each measuring 10 cm in length. In North Carolina, rhizome development has been observed to begin within 4 wk of emergence (M. G. Burton, personal observation).

Of the approximately 170 species of the genus *Commelina*, tropical spiderwort is unique in that it is vegetatively distinct; most other *Commelina* spp. require differentiation using primarily reproductive characteristics (Faden 1992). A combination of vegetative characteristics that distinguish tropical spiderwort from other *Commelina* species in the United States include the following: a proportionally broad and short leaf blade, presence of long hairs at the summit of the leaf sheath, presence of rhizomes, and annual growth habit (R. B. Faden, personal communication) (Faden 1993). However, positive identification of tropical spiderwort seedlings with fewer than three leaves can be difficult.

Asiatic dayflower (*Commelina communis* L.) is another nonnative *Commelina* spp. found throughout the eastern United States, and it has leaf blades that are 5 to 12 cm in length and 3 to 5 times longer than they are wide (Faden and Hafliger 1982). Spreading dayflower (*Commelina diffusa* Burm.f.), which is native to the United States, has leaf blades that are 1.5 to 8 cm in length and 2 to 8 times longer than they are wide (Faden and Hafliger 1982).

Flowers of the Commelinaceae lack nectar, but they often are showy and either insect- or self-pollinated, but never wind-pollinated (Faden 2000). Dayflower is an accurate description of these species, because the flowers are very short-lived. The flowers will open early in the morning and begin to wilt by midday. Tropical spiderwort possesses the almost unique ability to produce both aerial and subterranean flowers, both of which are borne in leafy bracts (spathes) (Maheshwari and Maheshwari 1955; Maheshwari and Singh 1934). Spathes often are clustered, funnel-shaped, fused on two sides, 10 to 20 mm in length, 10 to 15 mm in width, and on short peduncles 1 to 3.5 mm in length (Faden 2000; Faden and Hafliger 1982) (Figure 5). Aerial flowers (staminate and perfect) are chasmogamous (typical, open flowers) (Figure 6), whereas subterranean flowers (perfect) develop on rhizomes and are cleistogamous (flowers that do not open) (Figure 7). Chasmogamous flowers consist of three petals 3 to 4 mm in length. The upper two petals are blue to lilac in color, and the lower petal is either lighter in color or white and less prominent. Subterranean flower formation was reported to begin by 6 wk after plant emergence, whereas aerial flowers form 8 to 10 wk after emergence (Walker and Evenson 1985). Others have found that differentiation of subterranean flowers began in the field when plants had 7 to 10 leaves,

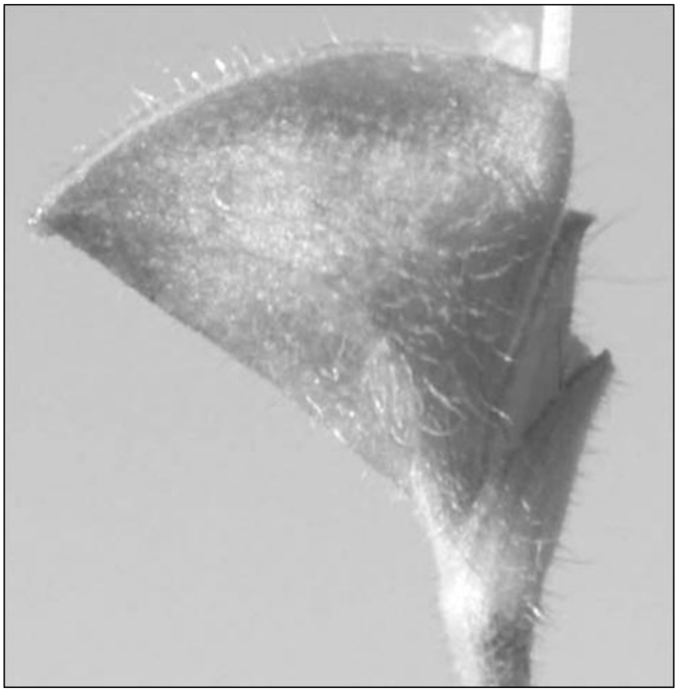

Figure 5. Funnel-shaped spathe (modified leafy bract) of *Commelina benghalensis*. Photo by Theodore M. Webster, USDA–Agricultural Research Service, Tifton, GA.

Figure 6. Aerial flower of *Commelina benghalensis,* which is characterized by two prominent, light-blue upper petals and one inconspicuous white lower petal. Photo by Herb Pilcher, USDA–Agricultural Research Service, Tifton, GA.

but under laboratory conditions, such differentiation occurred at the five-leaf stage (Kaul et al. 2002). In contrast, differentiation of aerial flowers began at the 17- to 19-leaf stage, at which time subterranean flowers had set fruit and seeds (Kaul et al. 2002). Aerial and subterranean flowers were produced under 8- and 18-h photoperiods, indicating a lack of sensitivity to daylength (Gonzalez and Haddad 1995). An immature fruit was formed within 3 d of aerial flowering, and viable seeds were present within 25 d of flowering under field conditions in Australia (Walker and Evenson 1985). In preliminary experiments under optimal conditions in the North Carolina State University Phytotron, aerial flowering began in as little as 4 wk after seedling emergence, and fruit dehisced 2 wk after flowering (Burton and York 2004). Under field conditions, plants produced more aerial flowers (240 per plant) than subterranean flowers (19 per plant), but individual seeds produced from subterranean flowers were greater in biomass (Kaul et al. 2002).

Fruit of tropical spiderwort is a pyriform (pear-shaped in cross-section) capsule that is two-valved (e.g., it splits at maturity by separation of the carpels and releases the seeds), 4 to 6 mm in length, and usually contains five dimorphic seeds. Typically, one large and four small seeds are produced per aerial fruit, whereas one large and two small seeds are produced per subterranean fruit. Seeds are approximately rectangular, 1.6 to 3 mm in length, 1.3 to 1.8 mm in width, brownish-black in color, and rugose-reticulate (netted appearance) (Faden and Hafliger 1982; Reed 1977) (Figure 8). Seeds have a cap over the embryo, which is dislodged during germination (Figure 1g, 1h). Field-grown tropical spiderwort plants are capable of producing between 8,000 and 12,000 seeds per plant in the absence of crop competition (Walker and Evenson 1985).

In addition to tropical spiderwort, three U.S. congeners are known to produce rhizomes (i.e., *C. virginica* L., *C. erecta* L., and *C. forskaolii* Vahl). However, with the exception of a single Dade County, FL, population

Figure 7. Plants of *Commelina benghalensis* displaying subterranean flowers. Photo by Arlene Mendoza, North Carolina State University, Raleigh, NC.

Figure 8. Dimorphic aerial seeds of *Commelina benghalensis.* Photo by Herb Pilcher, USDA–Agricultural Research Service, Tifton, GA.

of *C. forskaolii* (which may have been eradicated in 1984), no other *Commelina* spp. bears subterranean spathes on rhizomes (Faden 2000; Faden and Hafliger 1982).

DISTRIBUTION

Tropical spiderwort is listed among the world's worst weeds, affecting 25 crops in 29 countries (Holm et al. 1977). It has been documented as a weed problem throughout Africa in bananas (*Musa* spp.), corn (*Zea mays* L.), cotton, pastures, soybean [*Glycine max* (L.) Merr.], and wheat (*Triticum aestivum* L.) (Wilson 1981). The native range of tropical spiderwort is thought to be tropical Asia and Africa. The current distribution of the weed includes Australia, Africa (Cameroon, Congo, Ethiopia, Kenya, Madagascar, Malawi, Namibia, Nigeria, Uganda, South Africa, United Republic of Tanzania, and Zambia), Asia (China, Japan, India, Korea, and Indonesia), the Pacific Islands (Commonwealth of Northern Mariana Islands, Guam, Hawaii, Philippines, Samoa, Solomon Islands, Tonga, and Vanuatu), South America (Brazil, Bolivia, French Guiana, and Paraguay), the West Indies, and North America (United States and Mexico) (Australia's Virtual Herbarium 2004; Faden 1992; Faden and Hafliger 1982; Harvard University Herbaria 2004; Missouri Botanical Garden 2004; New York Botanical Garden 2004; Pacific Island Ecosystems at Risk 2004; Royal Botanical Gardens Kew 2004).

The route of introduction of tropical spiderwort to the United States is not clear (Holm et al. 1977). First observed in the continental United States in 1928, it was reportedly common throughout Florida in the mid-1930s (Faden 1993). However, the first published occurrence of tropical spiderwort in the United States was from Sapelo Island, GA, in 1963 (Duncan 1967). Tropical spiderwort was identified in North Carolina in 2000 (Burton et al. 2003b, 2003c; Krings et al. 2002), in California in 1980 (Faden 1993), in Alabama in 2003 (A. J. Price, personal communication), in Louisiana in 1991 (Thomas and Allen 1993), and in Missouri in 1961 (although this was actually *C. benghalensis* subsp. *variegata*) (Missouri Botanical Garden 2004). Tropical spiderwort is widespread in Georgia and Florida, but the known North Carolina infestation is locally focused to approximately 50 ha near Goldsboro, NC. In cooperation with USDA–Animal and Plant Health Inspection Service (APHIS) and North Carolina State University, the North Carolina Department of Agriculture and Consumer Services initiated a tropical spiderwort eradication program for the known location in 2004. The level of infestation in Alabama, California, Louisiana, and Missouri is not well defined.

In 1983, the USDA designated tropical spiderwort as a federal noxious weed (USDA-APHIS 2000). Tropical spiderwort was present in Georgia in 1998 but was not considered to be a common or troublesome weed of cotton (Dowler 1998). In 1998, county extension agents in Georgia ranked dayflower species among the top 39 most troublesome weeds averaged across all crops (Webster and MacDonald 2001). Tropical spiderwort had become problematic and was ranked as the ninth most troublesome weed in Georgia cotton by 2001 (Webster 2001). By 2002, tropical spiderwort clearly was the most troublesome weed threatening Georgia cotton producers in several southern counties. Based on inquiries from county extension agents in Georgia, five counties near the Florida border had tropical spiderwort in agronomic crop fields in 1999 (Figure 9). In 2004, the Georgia Department of Agriculture confirmed the presence of tropical spiderwort in 29 Georgia counties (Figure 10). The southwest corner of Georgia, on the Florida border, appears to have the most intense concentration of tropical spiderwort. However, tropical spiderwort appears to span the coastal plain of Georgia except for the southeastern corner of the state. It is estimated that more than 80,000 ha in Georgia are currently infested with tropical spiderwort.

The WSSA-approved common name for *C. benghalensis* is tropical spiderwort, but the common name ''spiderwort'' most often is associated with *Tradescantia*, a related genus within the Commelinaceae. Tropical spiderwort also is known as Benghal dayflower, although other common names are used throughout the world, some of which appear to be an Anglo-corruption of the

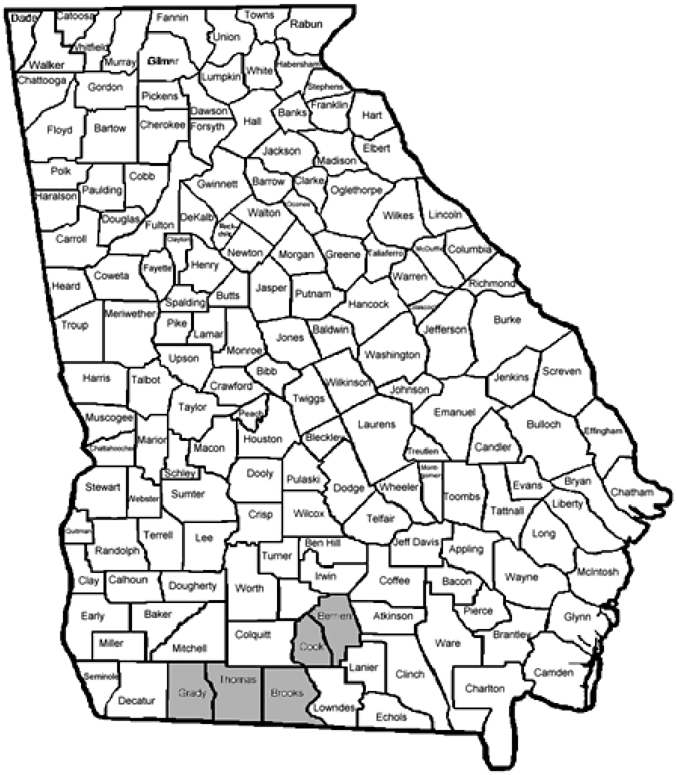

Figure 9. Estimated distribution of *Commelina benghalensis* in 1999 based on the number of queries concerning weed control in cotton and peanuts.

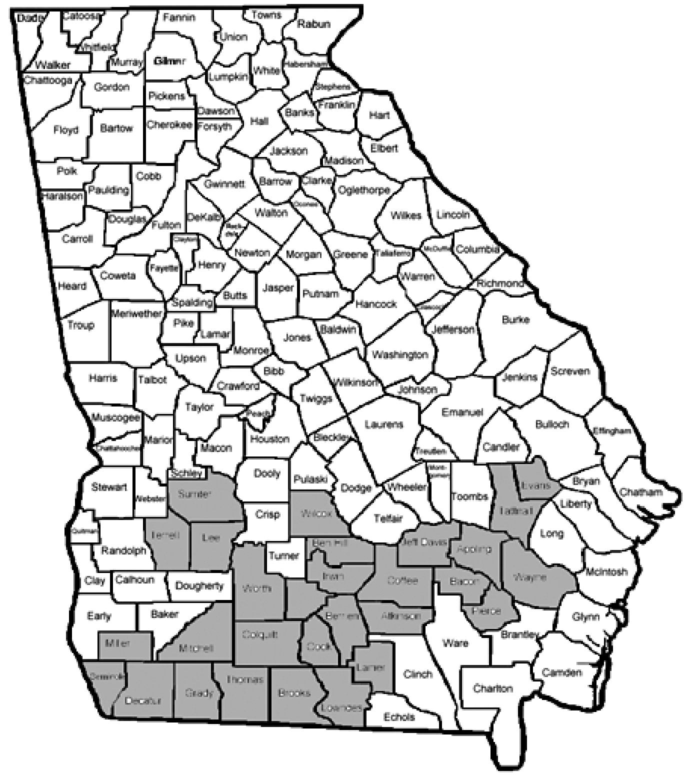

Figure 10. Distribution of tropical spiderwort in Georgia in 2004, as confirmed by the Georgia Department of Agriculture (Prostko et al. 2005).

name ''jio,'' which is associated with this weed throughout its native habitat. The distinctive vegetative characteristics (e.g., broad leaves) of tropical spiderwort most likely have contributed to the consistent application of the scientific name *C. benghalensis*, but there are several synonyms, such as *C. canescens* Vahl (from Yemen), *C. cucullata* L. (from India), *C. nervosa* Burm.f., *C. mollis* Jacq., *C. turbinate* Vahl., *C. procurrens* Schlechtend, *C. prostrata* Regel, and *C. delicatula* Schlectend (Clarke 1881; Faden 1992).

BIOLOGY AND ECOLOGY

In its native habitat, tropical spiderwort is a rainy season weed, requiring moist soil conditions for establishment (Kaul et al. 2002). The range of tropical spiderwort emergence in Japanese fields was extended by 2 mo in irrigated fields relative to that in nonirrigated fields (Matsuo et al. 2004). Once established, tropical spiderwort will survive dry soil conditions. Germination of aerial and subterranean seeds of tropical spiderwort occurred at 25 and 30 C, but no germination occurred at 10 C (Gonzalez and Haddad 1995). Optimum temperatures for germination ranged from 18 to 25 C for aerial seeds and from 21 to 28 C for subterranean seeds, although subterranean seeds tended to germinate faster than aerial seeds (Ferreira et al. 1999). The importance of light for germination is not clear. Light was not required for germination in one study (Gonzalez and Haddad 1995). However, another study indicated that the germination of aerial seeds was improved with light, whereas subterranean seeds were light-insensitive (Matsuo et al. 2004).

Preliminary studies regarding the biology of tropical spiderwort indicate that it is capable of rapid growth and reproduction. Tropical spiderwort plants that were 7 wk old added approximately six new leaves per day, whereas plants that were 8 wk old produced 2.5 new spathes per day (Webster 2004). Aerial spathes contain one staminate and as many as three perfect flowers, with each perfect flower producing a fruit that usually contains five seeds (Faden 2000). The rate at which tropical spiderwort was able to reproduce rivals that of any agronomic weed, including the vegetatively reproducing purple nutsedge (*Cyperus rotundus* L.) (Hauser 1962). Tropical spiderwort began to dehisce mature seeds by 45 d after plant emergence, and some of those seeds germinated 2 wk after dehiscing (M. G. Burton, unpublished data). With a continuous emergence pattern and rapid reproduction, tropical spiderwort has the potential to produce multiple generations within a single growing season.

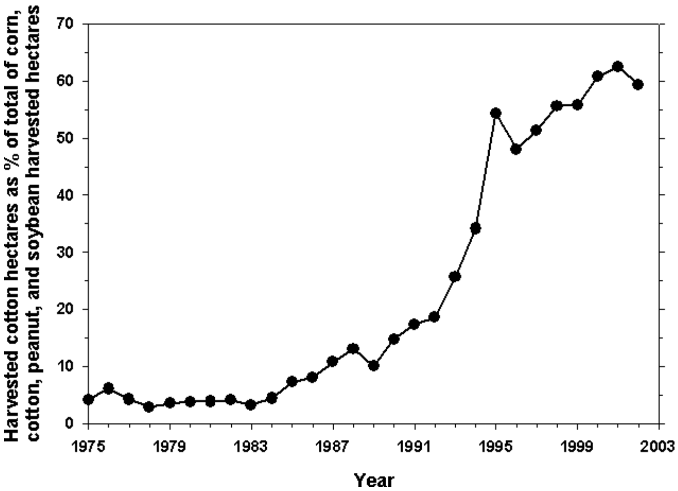

Figure 11. Harvested cotton hectares in Georgia expressed as a percentage of the total number of summer agronomic crop hectares (the sum of corn, cotton, peanut, and soybean hectares). This increase in the proportion of cotton hectares relative to other agronomic crops may help to explain, at least in part, the rapid increase in the importance and spread of *Commelina benghalensis* in Georgia (Abbe and Messer 2002, 2004; Bass and Messer 2000; Snipes and Hammer 1986, 1991, 1996).

The increased importance of tropical spiderwort as a weed of agronomic crops has coincided with a recent resurgence in cotton production in Georgia. Cotton hectares in Georgia increased from 105,000 in 1989 to 603,000 in 1995, in part because of the successful boll weevil (*Anthonomus grandis*) eradication program (Haney et al. 1996). Cotton was a relatively minor crop in Georgia in 1986, comprising less than 10% of the summer agronomic crops (sum of corn, cotton, peanut, and soybean) hectares. However, cotton hectares quickly increased, comprising more than 50 and 60% of the summer agronomic crop hectares in 1995 and 2001, respectively (Figure 11). Cotton has a slow-growth habit that may provide an environment more conducive to the establishment of tropical spiderwort than to that of peanut or corn. Also, several herbicides can be used to manage tropical spiderwort in peanut and corn (Prostko et al. 2005). This increase in cotton hectares is complicated by the rapid and widespread adoption of glyphosate-resistant cotton cultivars and poor control of tropical spiderwort by glyphosate (Culpepper et al. 2004). Glyphosate-resistant cotton has lead to reduced use of herbicides with soil residual activity (Culpepper and York 1998, 1999). For instance, fluometuron was used on 90% of Georgia cotton in 1996 but only 10% in 2001 (USDA–National Agricultural Statistics Service 2004). Another recent trend is the abandonment of cultivation as a management tool. In the early 1990s, less than 1% of the Georgia cotton hectares were managed using conservation tillage practices (S. M. Brown, personal communication). Cultivation of cotton was a primary weed-management tool before the introduction of glyphosate-resistant cotton cultivars, with each hectare receiving two to three cultivations during the crop season (S. M. Brown, personal communication). Currently, conservation tillage accounts for 40 to 45% of the Georgia cotton hectares, with less than 15% of the remaining hectares being cultivated. The reduction in soil disturbance may have provided an ecological niche for tropical spiderwort in agroecosystems of the southeast United States.

Vegetative growth and flower production of tropical spiderwort were optimized between 30 and 35 C, but growth occurred over a range of 20 to 40 C (Burton et al. 2003a). These temperatures are common throughout much of the United States during the summer months. At the very least, it appears that tropical spiderwort may be able to co-occur with cotton throughout the southeastern United States. Georgia is the second largest cotton-producing state (in terms of planted hectares), but it represents only 11% of the 4.8 million ha of U.S. cotton (USDA–Economic Research Service 2003). The environmental limits of tropical spiderwort have not yet been determined. However, the rapid spread through Georgia and the naturalization in North Carolina, coupled with its tolerance to current management strategies and its aggressive growth habit, make tropical spiderwort a significant threat to agroecosystems in the southern United States.

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