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# A review of the biology and ecology of Florida beggarweed (*Desmodium tortuosum*)

Theodore M. Webster
Corresponding author. Crop Protection and Management Research Unit, Tifton, GA 31794; twebster@tifton.usda.gov

John Cardina
Department of Horticulture and Crop Sciences, Ohio State University, Wooster, OH 44691

Florida beggarweed is native to the Western Hemisphere but is naturalized around the world. During the last century, the mechanization of agriculture has transitioned Florida beggarweed from an important forage component to a weed of significance in the coastal plain of the southeast United States. This herbaceous annual is naturalized and found in fields and disturbed areas throughout the southern United States. The characteristics that made Florida beggarweed a good forage crop also make it a formidable weed. This review describes the importance of Florida beggarweed as a weed in the southern United States and the taxonomy of this species and details the distribution throughout the world and within the United States. The ecology of Florida beggarweed and its interactions with crop plants, insects, nematodes, and plant pathogens also are summarized. Finally, management of Florida beggarweed in agricultural systems using cultural practices and herbicides is reviewed.

**Nomenclature:** Florida beggarweed, *Desmodium tortuosum* (Schwartz) DC. DEDTO.

**Key words:** Bean leaf beetle, *Belonolaimus gracilis*, burrowing nematode, *Cerotoma trifurcata*, *Colaspis bunner*, *Colletotrichum dematium*, *Colletotrichum truncatum*, corn earworm, cylindrocladium black rot, *Cylindrocladium parasiticum*, Desmodium yellow mottle tymovirus, grape colaspis, *Heliothis virescens*, *Heliothis zea*, herbaria survey, herbicide application decision support system, *Pseudopluscia includens*, *Pseudomonas viridiflava*, *Radopholus similis*, seed germination, soybean looper, sting nematode, tobacco budworm, tomato spotted wilt tospovirus, weed interference.

## Introduction

### Importance

Florida beggarweed was once regarded as a desirable warm-season forage crop, especially valuable as feed for horses and as a crop that improved soil structure. Today, it is considered among the most troublesome weeds in field crops of the southeastern coastal plain. Early references to Florida beggarweed discussed feeding value and forage management, but references since the late 1960s have focused on its negative effect on crop production, particularly concerning control measures and competitiveness with crops (Brown and Cardina 1992).

Florida beggarweed was ranked as the ninth most troublesome peanut (*Arachis hypogaea* L.) weed in a 1974 survey of the Southern Weed Science Society (Buchanan 1974). However, the importance of Florida beggarweed quickly rose to the rank of the second most troublesome peanut weed, as indicated in summaries of the 1983 and 1995 annual surveys (Elmore 1983; Webster and Coble 1997). This increase in importance of Florida beggarweed was probably linked to the introduction of herbicides that provided better control of species that were considered more important in 1974 (e.g., johnsongrass [*Sorghum halepense* (L.) Pers.], common cocklebur [*Xanthium strumarium* L.], copperleaf species [*Acalypha* spp.], morningglory species [*Ipomoea* spp.], and crabgrass species [*Digitaria* spp.]). Florida beggarweed was ranked as the most troublesome peanut weed species in Alabama, Florida, and Georgia in 2001, the second most troublesome species in South Carolina, and the seventh most troublesome weed species in North Carolina (Webster 2001). A survey of herbicide use estimated that 128,000 ha in the Florida beggarweed belt (Alabama, Florida, and Georgia; 37% of total peanut hectares) received a late-season application of chlorimuron solely to suppress escaped Florida beggarweed (Bridges 1992).

### Taxonomy

Florida beggarweed is a member of the Fabaceae (Leguminosae) family, Papilionoideae subfamily, the tribe Hedysareae, and subtribe Desmodium (Rotar and Urata 1967). Of the 300 species of *Desmodium* distributed throughout the world, only 23 species occur in the southeastern United States (Radford et al. 1968; Schubert 1980). In this group of 23 *Desmodium* species, Florida beggarweed is the only annual species. Florida beggarweed is quite variable in appearance and phenology, which may account for confusion in nomenclature. This species has several synonymous Latin binomials. In 1768, Miller described *Hedysarum procumbens* from a collection made in Jamaica in 1730 (Schubert 1940). This genus was included in the first edition of Linnaeus' *Genera Plantarum* published in 1737 (Vail 1892). More than 50 yr later (in 1788), Swartz described a similar species from Jamaica, *H. spirale*, using the genera ascribed by Miller. Both Miller and Swartz (in 1806) described the species that became known as Florida beggarweed, naming it *Hedysarum purpureum* Mill and *Hedysarum tortuosum* Swartz, respectively. The genus of this species was later altered twice, using the species name attributed to Miller, first to *Meibomia purpurea* (Mill.) Vail and then to *Desmodium purpureum* (Mill.) Fawcett & Rendle. The name *Desmodium* was chosen as the

FIGURE 1. Mature Florida beggarweed plant showing the trifoliate leaves and fruit at the top of the plant.

preferred name for the genus over *Meibomia* in the 1905 International Botanical Congress in Vienna (Schubert 1950). In 1825, De Candolle transferred Swartz's species names to the *Desmodium* complex, thus creating what is now the standard name, *Desmodium tortuosum* (Sw.) DC.

This species is recognized by many common names; however, the most prevalent is Florida beggarweed, a name attributed before 1900 (Smith 1899). Various other common names have made references to prominent characteristics, such as the large, cloverlike leaves or the hooked hairs that cause the fruits to cling to passing objects. Common aliases include "Dixie ticktrefoil," "beggar's lice," "beggar-ticks," "West Indian Honey," "Cherokee clover," "cockshead," "Florida clover," "stick tight," "tall tick clover," and "giant beggarweed" (Brown and Cardina 1992; Hume 1907; Mayo 1924; Smith 1899).

## Description

Florida beggarweed is an erect, highly branched, taprooted annual (Figure 1). At maturity, plants can exceed heights of 3.5 m. The stems of the mature plant are woody and up to 4.5 cm in diameter at the base, with many ascending branches. The cotyledons are blue-green in color, reniform shaped, and approximately 1.3 to 2.0 cm in length (Figure 2). Like many *Desmodium* species, Florida beggarweed has heteroblastic development characterized by distinct juvenile and adult morphological features (Cardina and Brecke 1989; Wulff 1985). Leaves are dimorphic, with unifoliate leaves dominating the early growth (Figure 3), occurring on Nodes 2 through 9 (Cardina and Brecke 1991). The first pair of unifoliate true leaves is arranged opposite to each other on the stem (2 leaves node$^{-1}$); leaves at all other nodes are arranged alternately on the stem (1 leaf node$^{-1}$) (Figure 4). The 10th node typically has the first trifoliate leaves (Cardina and Brecke 1991). As the plant grows, unifoliate leaves begin to senesce. Trifoliate leaves have persistent ovate to lance-shaped stipules at the base of the petiole that are 0.5 to 1.0 cm long (Figure 5).[1] The leaves (unifoliate and trifoliate) are obliquely rhomboid in shape and up to 12 cm long and 3 cm wide. Often leaves will have small, circular dark purple to brown discolorations in the interveinal tissue on the leaf surface (Figure 6). Stems are often green to purple with some red markings at the nodes and are typically covered with short stiff hairs (Brown and Cardina 1992). The leaves, stems, inflorescences, and fruits have small hooked glandular trichomes that allow the plant to readily

FIGURE 2. Florida beggarweed seedling illustrating the reniform-shaped cotyledons.

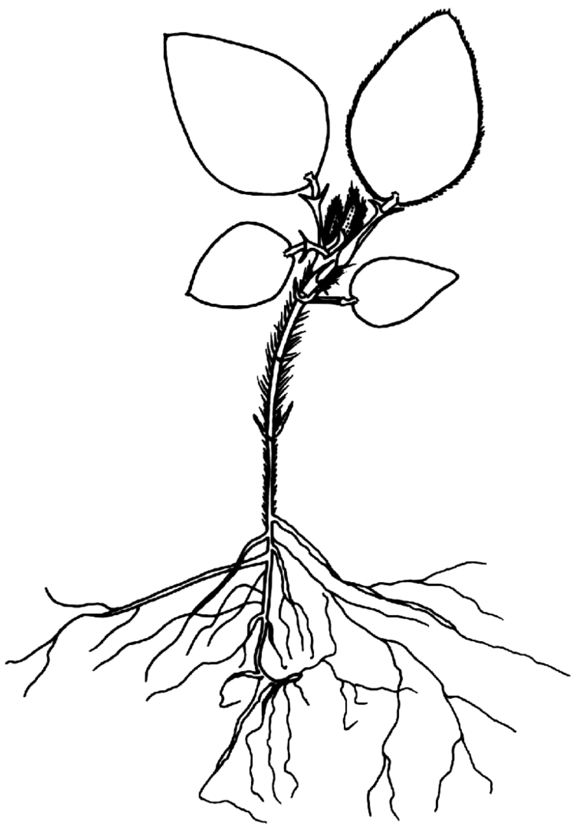

FIGURE 3. Florida beggarweed seedling illustrating the hairy stems and distinct leaf shape.

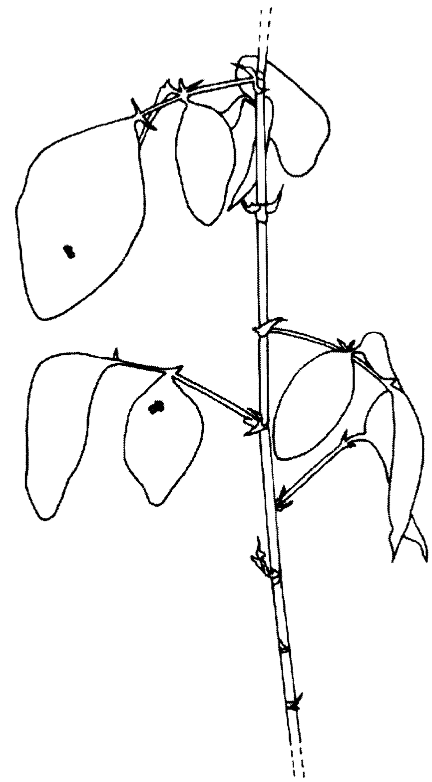

FIGURE 4. Close-up of Florida beggarweed plant illustrating the alternate (1 leaf node$^{-1}$) arrangement of trifoliate leaves on the stem.

attach itself to passing objects. Flowers are pink, pale blue, or purple papilionaceous blooms about 5 mm long (Figure 7) and are borne on slender 2-cm stalks (Figure 8). The inflorescence is an open panicle with occasional unifoliate leaves along the spreading branches. Fruits are loments with up to seven oval segments that are characterized by the distinct constrictions between seeds (Figure 9). These constrictions allow the mature fruit to readily separate at maturity. Each segment of the loment is approximately 3 to 3.5 mm long and 2.6 to 3.5 mm wide (Schubert 1980). The loments are densely pubescent with hooked hairs that readily attach to passing animals. The seed within the loment is light brown in color, reniform in shape (Figure 10), and 1.5 mm long and 1 mm wide (Schubert 1980). There are approximately 930,000 Florida beggarweed seeds kg$^{-1}$ (Whyte et al. 1953). The plant produces a taproot that branches occasionally near the soil surface. Roots form nodules in association with nitrogen-fixing *Rhizobium* bacteria.

Florida beggarweed is variable in size, leaf shape, branching, and degree of hairiness. It is distinguished from other *Desmodium* species by its erect nature, annual habit, and constrictions between the loment joints, which are equally deep on both edges. *Desmodium viridiflorum* (L.) DC is a perennial that resembles Florida beggarweed and can be found in similar habitats (i.e., field margins and fencerows), but the constrictions on the top of the loment are shallow relative to those of Florida beggarweed. As with many of the *Desmodium* species, the chromosome number for Florida beggarweed has been determined to be 2n = 22 in plants collected in Georgia (J. Cardina, unpublished) as well as Puerto Rico and Uruguay (Rotar and Urata 1967).

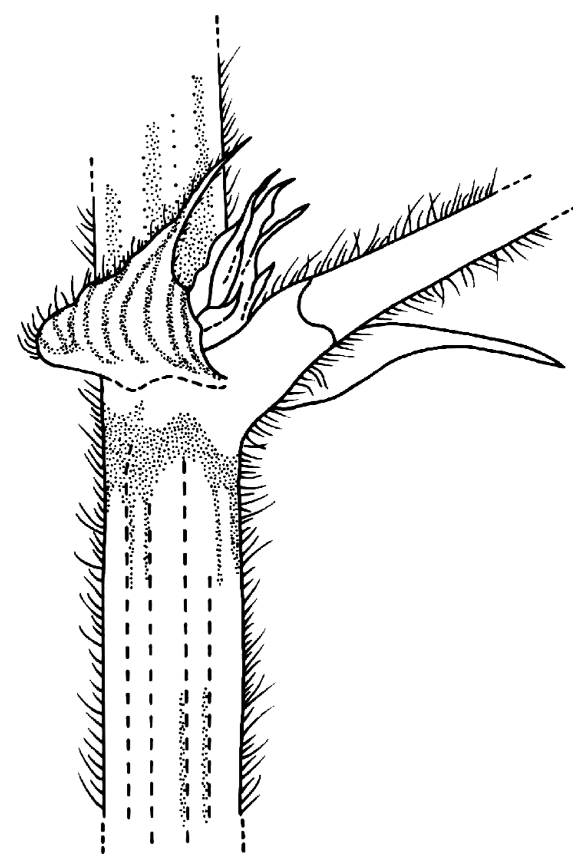

FIGURE 5. Close-up of a node on a Florida beggarweed stem showing the lance-shaped stipules at the base of the petiole.

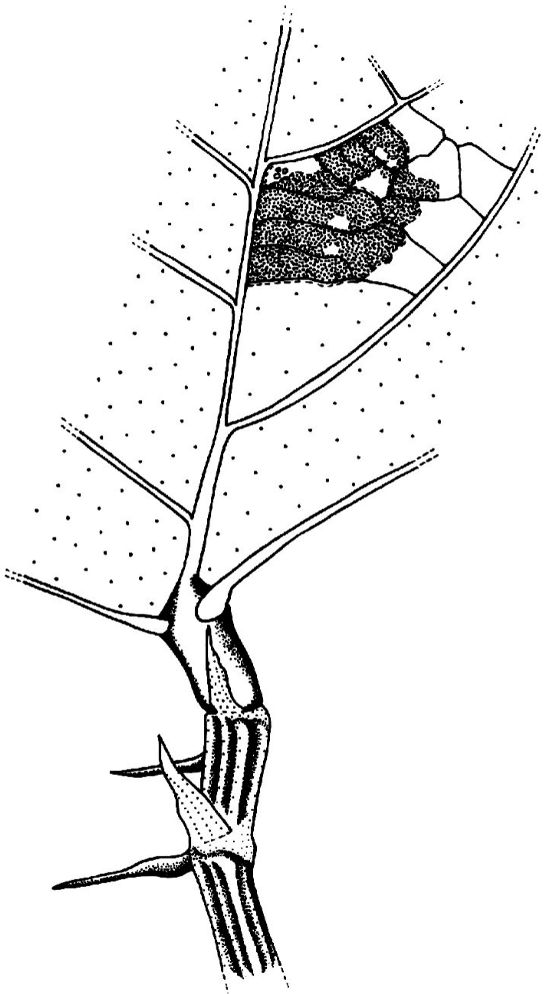

FIGURE 6. Detailed drawing of a Florida beggarweed leaf, including a purple discoloration often seen on the leaves.

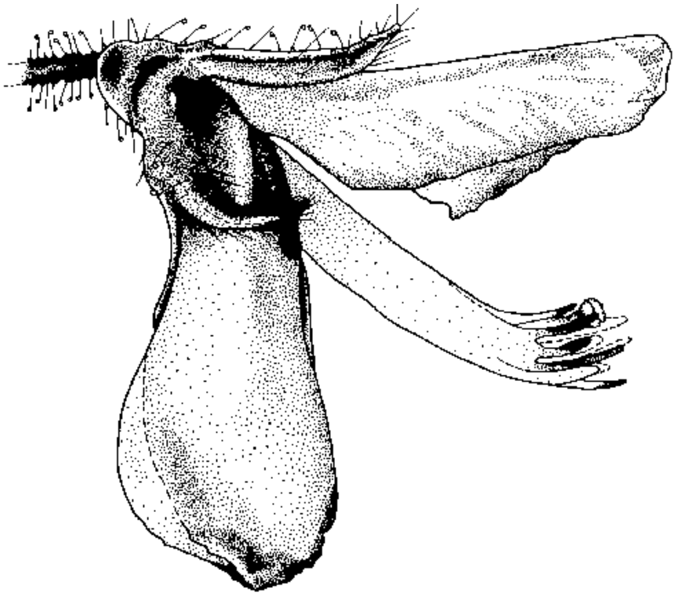

FIGURE 7. Profile of the flower of Florida beggarweed.

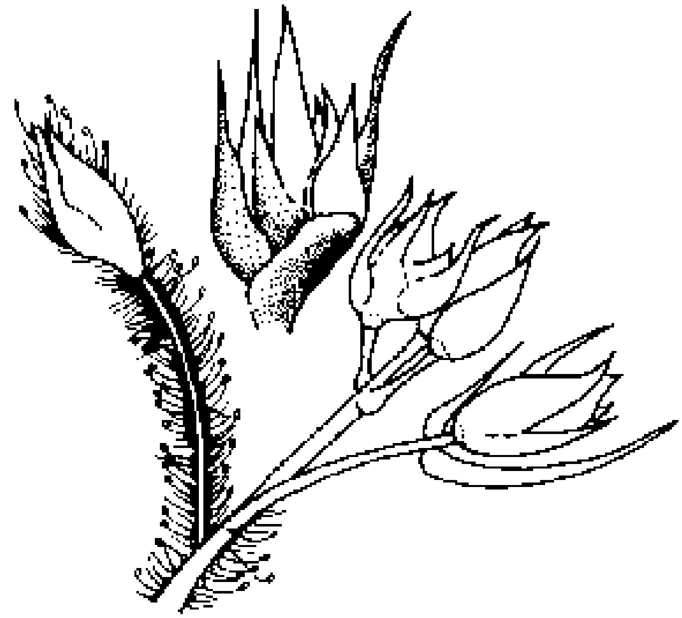

FIGURE 8. Florida beggarweed flower buds.

## Origin and Distribution

### *Global Distribution*

*Desmodium* species are common throughout the world in temperate and tropical areas, with the exception of Europe, New Zealand, and the United States west of the Rocky Mountains (Schubert 1980). The native range of Florida beggarweed includes the West Indies (including Cuba, Hati, Dominican Republic, Jamaica, Puerto Rico, Trinidad-Tobago, and Barbados) (Grisebach 1864; Piper 1921). Other reports suggest that Florida beggarweed also may be native to the Americas (Hume 1907; Smith 1899). Florida beggarweed has been documented in Central America (Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua, and Panama), North America (Mexico and United States), and South America (Argentina, Belize, Brazil, Columbia, Ecuador, Paraguay, Peru, and Venezuela) (Fawcett and Rendle 1920; Hooper 1978; Hume 1907; MacBride 1943; Schu-

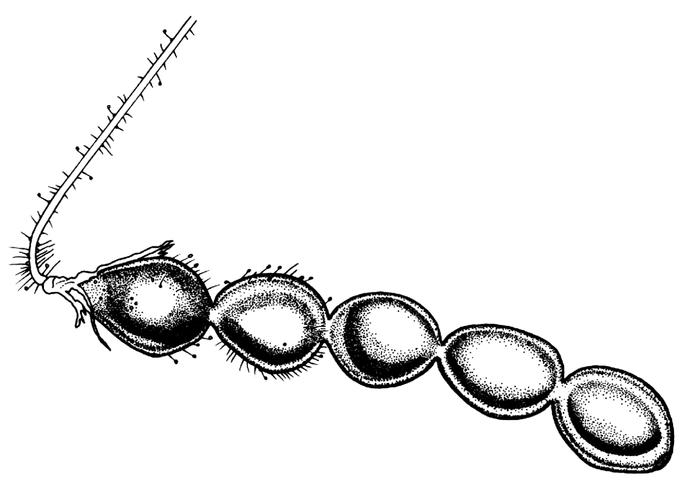

FIGURE 9. Florida beggarweed loments with up to seven oval segments that are characterized by distinct constrictions between seeds.

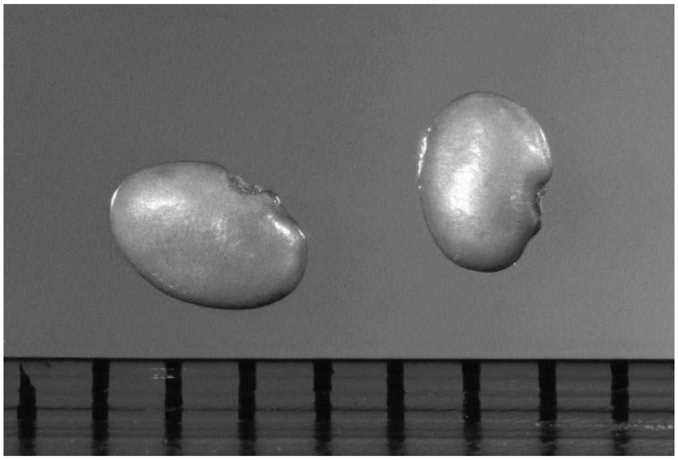

FIGURE 10. Reniform-shaped seed of Florida beggarweed.

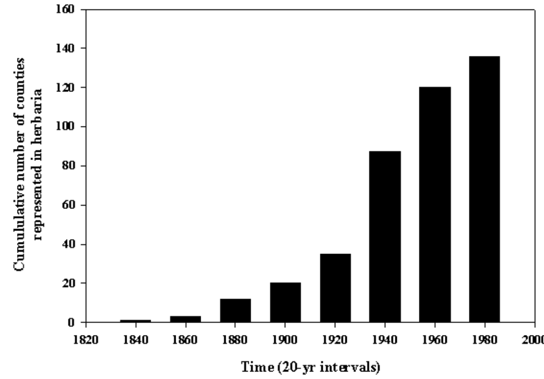


FIGURE 11. The cumulative spread of Florida beggarweed throughout the United States as tracked through herbaria data.

bert 1980; Small 1913; Smith 1899; Standley and Steyermark 1946; USDA-ARS 2001).

Although the center of origin is apparently in the Western Hemisphere, Florida beggarweed is naturalized around the world. This species has been documented in many African countries, including Angola, Burundi, Cameroon, Chad, Cote d'Ivorie, Democratic Republic of the Congo (formerly Zaire), Equatorial Guinea, Ghana, Guinea Bissau, Malawi, Mali, Mozambique, Nigeria, Sao Tome and Principe, Senegal, Sierra Leone, South Africa, Tanzania, Togo, Uganda, Zambia, and Zimbabwe (ILDIS 2001; USDA-ARS 2001). Florida beggarweed also is found in Australia, China, Fiji, Hong Kong, India, Madagascar, and Papua New Guinea (Corlett 1992; ILDIS 2001; USDA-ARS 2001).

*Distribution Within the United States*

The first documented populations of Florida beggarweed in the United States were in Florida and Texas (Britton and Millspaugh 1920; Small 1913). The current distribution of this species extends from the eastern half of North Carolina down through the eastern two-thirds of South Carolina to the southern half of Georgia, all of Florida, through the southern one-third of Alabama and Mississippi, to the southern two-thirds of Louisiana and into the southeastern one-third of Texas.[1] However, Florida beggarweed is a problem weed only in crops in the southeastern coastal plain.

A survey of herbaria (listed in the Acknowledgments) throughout the United States revealed that the earliest Florida beggarweed specimen was collected in 1843 in Leon County, in northern Florida on the Georgia border (Figure 11). Data obtained from herbaria document the presence of this species in a particular area and date. These data can be used to gauge an approximate distribution of this species over time, as has been done with other nonnative invasive weed species (Douglas et al. 1990; Forcella 1985) (Figure 11). Counties within Florida represent the majority of the samples that exist in the surveyed herbaria. Herbaria samples of Florida beggarweed were found for 43 of the 67 Florida counties (64%) (Figure 12), distributed relatively uniformly throughout the state. Of the 12 herbaria samples from the United States that were collected before 1900, 10 of them were from Florida.

In Georgia, the oldest Florida beggarweed herbarium specimen dates to 1905 in Thomas County on the Georgia–Florida border (Figure 12). With the exception of one specimen collected in Paulding County (northwest of Atlanta, GA) in 1966, all the Florida beggarweed herbarium samples originate from counties in the southern part of the state (south of Macon, GA, lat. 32.700°N) in the coastal plain. A survey in the late 1940s and early 1950s of vascular plants of southwest Georgia indicated that Florida beggarweed was a common plant of roadsides, old fields, and waste places (Thorne 1954).

The distribution of Florida beggarweed in Alabama is similar to that of Georgia. The majority of the herbaria samples originate in the southern portion of the state; all but three of the 19 Alabama counties with Florida beggarweed were south of Montgomery, AL (lat. 32.380°N) (Figure 12). The oldest specimen in Alabama was collected in 1927 in Barbour County, in the southeast corner of Alabama.

Florida beggarweed is distributed in the coastal counties of South Carolina (Figure 12). Of the 28 counties in the coastal plain of South Carolina, 19 (68%) have Florida beggarweed specimens in herbaria. The oldest specimen in South Carolina was found in Beaufort County in 1900. North Carolina appears to be the northern limit of this species in the United States. There are 10 counties in the

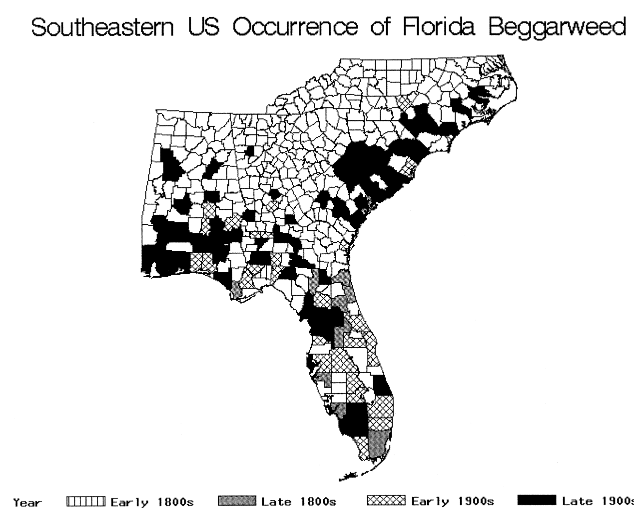


FIGURE 12. The distribution of Florida beggarweed in the North Carolina, South Carolina, Georgia, Florida, and Alabama based on herbaria data.

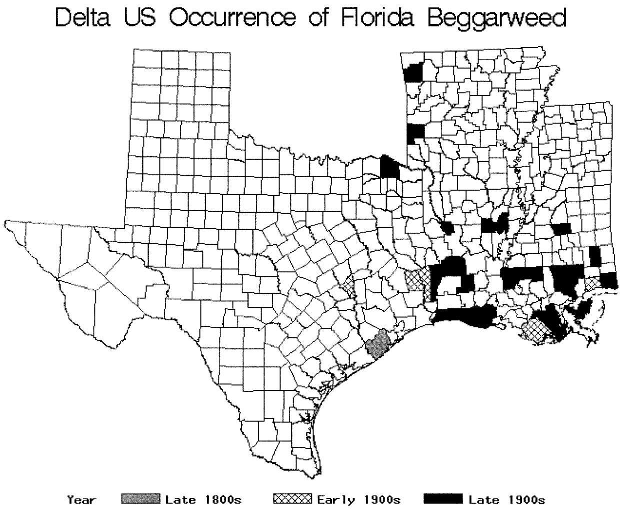


FIGURE 13. The distribution of Florida beggarweed in Mississippi, Louisiana, Arkansas, and Texas based on herbaria data.

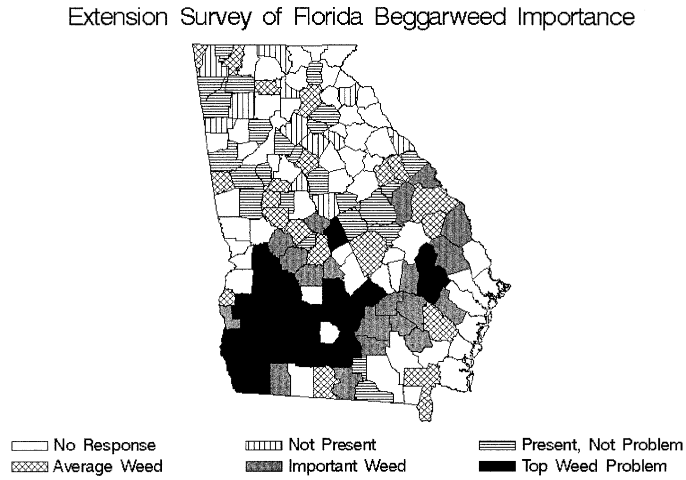


FIGURE 14. Results of a survey of the Georgia county extension agents concerning the importance of Florida beggarweed in their county.

coastal plain of North Carolina from which Florida beggarweed has been collected (Figure 12).

Outside of the coastal plain of the southeast United States, the distribution of Florida beggarweed appears to be limited. There are only five counties in Mississippi that have herbaria specimens of Florida beggarweed (Figure 13). Each of these counties is within 160 km of the Gulf of Mexico, and four of them are within 50 km. Florida beggarweed has been collected from 17 parishes in Louisiana (25% of the total number of parishes—including those cited by MacRoberts [1988]). The majority of these samples are from the southern third of the state; however, there are some samples from the northern parishes, although all samples have been collected south of Monroe, LA (lat. 32.516°N), and Interstate 20 (Figure 13). The earliest specimen was collected in 1916 in Terrebonne Parish, which is along the Gulf of Mexico south of Baton Rouge, LA.

In Texas, herbaria samples indicate that Florida beggarweed is primarily found in the eastern part of the state (Figure 13). The dominant vegetation in this area is a mixed pine–hardwood forest with pine plantations and pastures accounting for the agricultural uses in this region (Hatch et al. 1990). The oldest Florida beggarweed sample in Texas was collected in 1899, southeast of Houston.

Other states that have herbaria samples of Florida beggarweed include Arkansas, Arizona, Hawaii, and California. The Arkansas samples were collected on the western border of the state in two counties in 1976 (Washington and Polk counties) (Figure 13). The Arizona sample was collected in Santa Cruz County in 1927 in the town of Nogales, very close to the Mexican border. The Hawaiian sample was collected in 1939 and may have been an escape from a tropical forage research program that was initiated in 1913 and included various *Desmodium* species. The sample from California is a relatively recent collection (1995) and was found in San Bernardino County on the Nevada border in southern California, northeast of Los Angeles.

*Distribution and Importance Within the Southeast United States*

An annual weed survey of extension specialists in the southern region of the United States indicated that Florida beggarweed was the most troublesome and second most common weed affecting the southeastern U.S. peanut production region that extends along the coastal plain from South Carolina to the northern half of Florida and west into Alabama (Webster 2001). Its importance has increased in some areas. Florida beggarweed was ranked as the ninth most troublesome weed in South Carolina peanut production in 1974 but increased to the second most troublesome in 1998 (Buchanan 1974; Dowler 1998). Florida beggarweed is less important in North Carolina, where it ranks as the seventh most troublesome peanut weed (Webster 2001). Florida beggarweed is among the most common weeds in corn (*Zea mays* L.), soybean (*Glycine max* Merr.), and cotton (*Gossypium hirsutum* L.) crops in Georgia, Florida, and Alabama (Webster 2000, 2001). However, Florida beggarweed is not among the most troublesome weeds other than in peanut, except in Louisiana soybean crops, where it is the 10th most troublesome weed (Elmore 1989).

In Georgia, where most of the southeast U.S. peanut production is centered, Florida beggarweed is listed as a coastal plain species (Duncan and Kartesz 1981) and is well distributed throughout the southern half of the state. In a survey of county extension agents in Georgia, agents were asked to rate Florida beggarweed in their county in one of the following five categories: 5 = top weed problem; 4 = important weed, but there are other species that are more important; 3 = average weed problem; 2 = exists in the county, but it is not a problem weed; and 1 = does not occur in this county. Results indicated that southwest Georgia is the area of the state that is most affected by Florida beggarweed (Figure 14).

Georgia is divided into nine climatological divisions, three each in the northern, central, and southern areas of the state. Based on the numerical category of the responses, the average value of the classification of Florida beggarweed from each of the responding counties was calculated. The southwest district had the highest rating, with a value of 4.8, followed by districts in the south-central part of the state (4.2), with the southeastern district next with a rating of 4.0. The importance of Florida beggarweed in Georgia decreases as one moves north, with the central districts rating from 2.6 to 3.4 and northern tier districts rating from

1 to 1.9, indicating that if the weed is present it is not economically important.

In this same survey, county agents were asked to rank the most troublesome weeds in each of nine crops (Webster and MacDonald 2001). Florida beggarweed was listed among the 10 most troublesome weeds in peanut (ranked No. 1), tobacco (*Nicotiania tabacum* L.) (ranked No. 2), corn (ranked No. 7), vegetables (ranked No. 9), and cotton (ranked No. 10). Florida beggarweed was identified as a troublesome species in seven of the nine surveyed crops, and averaged over all crops it was the sixth most troublesome weed in Georgia (Webster and MacDonald 2001).

### Forage Use

Smith (1899) declared that Florida beggarweed is a good choice as a forage crop because it "never becomes a bad weed." The recommended sowing rate was 5 to 7 kg $ha^{-1}$ when it was to be grown for seed and 10 to 11 kg $ha^{-1}$ when grown for hay. Florida beggarweed was characterized as one of the best forage crops for the southeastern United States because of its ease in cutting with a mower, high quality as a green manure crop in orchards where it does not climb into the trees, and its freedom from attack by the root knot nematode (*Meloidogyne* sp.) (Smith 1899, 1900). Florida beggarweed was said to be the best leguminous forage for light sandy soils, where most other crops fail (Tracy 1898). Florida beggarweed requires 72 to 80 d for the crop to mature (Smith 1900). Cutting Florida beggarweed for hay was recommended before the plant reached a height of 0.75 m, after which the stems become woody (Tracy 1898). Reported yields of Florida beggarweed hay ranged from 9,000 to 13,000 kg $ha^{-1}$ (Smith 1900). Two crops of beggarweed hay were cut per season; the second crop has fewer stems and was reported to be among the best hay when properly cured (Pickell 1890). Florida beggarweed was considered very palatable forage for horses, cattle, and mules to the point that it would disappear from fields because of overgrazing (Smith 1900).

Florida beggarweed has been studied as a potential forage legume in many tropical areas. It was the first species of *Desmodium* introduced in Hawaii in 1913 as a forage crop (Younge et al. 1964). But of the 50 or so additional species of *Desmodium* evaluated for their suitability in Hawaiian agriculture, *D. intortum* and *D. canum*, both native to South America, were found to be more suited as Hawaiian forages than was Florida beggarweed. These two species became important forage crops in Brazil and were subsequently introduced to Guatemala, Taiwan, and Australia (Younge et al. 1964). In Zimbabwe (formerly Rhodesia), Florida beggarweed was found to be a more suitable forage than alfalfa (*Medicago sativa* L.) because of superior drought tolerance and lack of special soil fertility requirements (Mundy 1921). As recent as 1977, Florida beggarweed was recommended as a good tropical forage plant because of its ability to recover vigorously from cutting or grazing, its adaptation to a wide range of soils, and its rapid growth and quick canopy closure (Bogdon 1977; Skerman and Riveros 1977).

In the southern United States, superior forage crops, such as velvetbean [*Mucuna deeringiana* (Bort) Merrill] and cowpea [*Vigna unguiculata* (L.) Walp.], replaced Florida beggarweed because of their higher nitrogen fixation capacity and biomass accumulation (Stokes et al. 1936). A relative of Florida beggarweed, Florida carpon desmodium (*Desmodium heterocarpon*), a native of subtropical Asia, became a better choice as a commercially available perennial forage legume in south Florida grass pasture mixes (Kretschmer et al. 1979).

Florida beggarweed is still regarded as a desirable plant for wildlife. University of Georgia Wildlife specialists recommend planting Florida beggarweed so that seeds will be produced to feed quail (Carlton and Jackson 2001). A seeding rate of 11 kg $ha^{-1}$ of scarified Florida beggarweed seed is recommended, planted no later than June 1, allowing approximately 150 to 180 d for maturity. The seed will reportedly serve as a food source for quail from November through February.

## Biology and Ecology

### Plant Biology

#### *Seed Germination and Seedling Emergence*

Florida beggarweed is a warm-season annual with a broad temperature range (18 to 38 C), in which germination may occur, and an optimum temperature range of 21 to 38 C (Cardina and Hook 1989). Under conditions of adequate moisture, Florida beggarweed seeds germinate 3 to 4 d after the average daily soil temperatures have exceeded 21 C. Florida beggarweed seed germination exceeded 90% after 48 h at osmotic potentials of 0 and − 0.2 MPa, but germination was less than 40% after 168 h at − 0.4 MPa. Lower osmotic potentials (− 0.5 to − 0.8 MPa) resulted in less than 10% Florida beggarweed germination after 168 h, whereas seeds in solutions lower than − 0.8 MPa failed to germinate (Cardina and Hook 1989).

Florida beggarweed emergence in the field was strongly related to the occurrence of rainfall and soil disturbance (e.g., field cultivation) (Cardina and Hook 1989). The peak of Florida beggarweed emergence, up to 40% of the total season emergence, was observed after the first rainfall after cultivation. Cultivation alone was not sufficient to stimulate germination because no Florida beggarweed emergence occurred after disturbance in the absence of rainfall (Cardina and Hook 1989).

The depth of the seed in the soil profile also is an important factor that governs weed emergence. There was an inverse quadratic relationship between Florida beggarweed emergence and planting depth ($r^2 = 0.63$ to 0.93) (Hooper 1978). When Florida beggarweed seeds were planted at soil depths of 1.6, 3.2, and 6.4 cm, emergence was 81 to 95%, 76 to 83%, and 21 to 50% respectively. In one trial, Florida beggarweed seeds planted at 8 cm had 29% emergence. Therefore, operations that bring seeds from deeper in the soil profile to near the surface (depth < 8 cm) may increase Florida beggarweed problems.

Florida beggarweed seed germination was related to the level of seed maturity measured as days after flowering (Hooper 1978). Developing seeds were removed from the parent plant at fixed intervals, and their germination was determined. There was a linear relationship between Florida beggarweed germination and time (10 to 22 d) after flowering ($r^2 = 0.68$). Seeds have the ability to germinate under favorable conditions when removed from the mother plant 10 d after flowering. Approximately 50% of the seed germinated when harvested 15 d after flowering, and all seeds were capable of germination by 22 d after flowering. Maximum seed weight was achieved at 25 d after flowering, whereas 50% of maximum seed weight occurred at 13 d after flowering. Seeds change color from green to dark olive 15 to 17 d after flowering (Hooper 1978). However, nothing is known of their dormancy or ability to overwinter at these different stages of seed development.

*Morphology*

In peanut production, Florida beggarweed is often considered a late-season weed, but this may be a misconception because of its hidden growth habit within the peanut canopy. Florida beggarweed plants that appear in the later part of the season were actually found to emerge within the first 6 wk after crop planting (Hauser et al. 1982). Cardina and Brecke (1991) observed that Florida beggarweed germinated at approximately the same time as peanut but remained shorter than the crop for the first 45 d of the growing season. This hidden growth within the peanut canopy also serves to protect Florida beggarweed from control measures. Florida beggarweed emerged through the peanut canopy after producing 11 to 12 nodes (two- to three-trifoliate stage), during the R-3 stage of peanut growth. This often gives the appearance that fields that were seemingly weed free early in the season instantly become infested with Florida beggarweed at a stage that is difficult to control. After Florida beggarweed grows above the peanut canopy, its growth rate is approximately fourfold greater than that of peanut, with stem elongation up to 1.6 cm $d^{-1}$ compared with 0.4 cm $d^{-1}$ for peanut (Cardina and Brecke 1991). By the time Florida beggarweed emerges above the peanut canopy, the crop is flowering and is at a stage of growth that is susceptible to disease development if soil is moved onto the lower branches of the crop.

Branching patterns of weeds can be an indication of their success in exploiting the resources available in its environment. Florida beggarweed began producing branches 20 d after planting when growing without competition, but with competition from peanut, branch production was not initiated until 45 d after planting (Cardina and Brecke 1991). Although branch initiation was hindered by peanut competition, the rate of branch expansion remained constant in both environments. Florida beggarweed leaf development was limited by competition with peanut; leaf area of Florida beggarweed when growing alone was 400 $dm^2$ at 100 d after planting, whereas the leaf area of Florida beggarweed growing in competition with peanut was reduced 98%. Canopy area of Florida beggarweed increased ninefold (to an area of 1,680 $cm^2$) once Florida beggarweed exceeded the peanut crop height, whereas Florida beggarweed growing without competition increased 21-fold (to an area of 9,360 $cm^2$). The reduction in Florida beggarweed leaf area and branching due to peanut competition resulted in 87% reduction in Florida beggarweed biomass (Cardina and Brecke 1991).

A study was conducted in 1986 and 1987 to evaluate the influence of crop planting date on Florida beggarweed biomass accumulation, Florida beggarweed seed number produced per plant, and reduction in peanut pod biomass (J. Cardina, unpublished data). Treatments included seven different planting dates beginning on April 4 and every 2 wk thereafter until June 27. Florida beggarweed and peanut were planted on the same date in each treatment. Maximum Florida beggarweed biomass (550 g $plant^{-1}$) was achieved from the second planting date (April 18), whereas maximum Florida beggarweed seed production (15,000 seeds $plant^{-1}$) was achieved from plants in the third planting date treatment (May 2). With the exception of the fifth planting date (May 30), which reduced peanut yield 14%, all other Florida beggarweed plantings were not different from one another and reduced peanut yield between 16 and 26% (J. Cardina, unpublished data).

Common garden studies conducted in Tifton, GA, and Jay, FL, evaluated the growth of four different populations of Florida beggarweed from Georgia, one from South Carolina, and one from Florida (Cardina and Brecke 1989). These studies indicated that Florida beggarweed possesses a great deal of phenotypic plasticity in terms of plant height, canopy width, number of branches and nodes, dry weight, and seed production per plant. One of the Georgia ecotypes, GA-1, was 20% shorter, with 23 to 41% fewer nodes and 72% less biomass at Tifton, which produced 67% fewer seeds relative to another ecotype, GA-2, that was originally collected from the same field (Cardina and Brecke 1989).

Growth of Florida beggarweed was severely reduced in soils with low pH (Buchanan et al. 1975). At a soil pH of 5.4, Florida beggarweed growth was reduced 50% relative to the growth at pH 6.3, whereas Florida beggarweed seedlings died at pH 4.7. By comparison, the nonnodulating legume species sicklepod [*Senna obtusifolia* (L.) Irwin and Barneby] and coffee senna (*Cassia occidentalis* L.) had similar growth at pH 4.7 and 5.2, respectively. Results suggested that Florida beggarweed would not be a major weed problem in soils with pH less than 6.0 (Buchanan et al. 1975).

*Reproductive Morphology*

Ecotypes of Florida beggarweed had different minimum requirements for the initiation of flowering and fruit production (Cardina and Brecke 1989). Selections of Florida beggarweed from Georgia and South Carolina, grown in a common garden in Tifton, GA, and Jay, FL, revealed differences in the time to flower initiation and fruit production. Florida beggarweed ecotypes from South Carolina and Georgia (GA-1) were the first to initiate flowering 67 and 70 d after planting, respectively, when grown in Tifton, GA (J. Cardina and B. J. Brecke, unpublished data). However, at the Jay, FL, research station, there were no differences in flower initiation among the ecotypes. In Tifton, the GA-1 Florida beggarweed ecotypes flowered and set seeds after reaching a height of about 80 cm, whereas GA-2 plants did not flower until they had reached a height of more than 2 m, and some never did flower (J. Cardina and B. J. Brecke, unpublished data).

Florida beggarweed flowering and fruiting periods are day-length dependent (Leach 1924). A study was conducted to determine the photoperiod necessary to stimulate flowering (D. T. Patterson, unpublished data). Plants were grown in either a short-day (SD) growth chamber that received 9 h (8:00 A.M. to 5:00 P.M.) of incandescent light (50 $\mu mol\ m^{-2}\ s^{-1}$) and 8 h (8:30 A.M. to 4:30 P.M.) of fluorescent light (400 $\mu mol\ m^{-2}\ s^{-1}$) or a long-day (LD) growth chamber that received 16 h (4:30 A.M. to 8:30 P.M.) of incandescent light and 8 h (8:30 A.M. to 4:30 P.M.) of fluorescent light. The night period in the LD chamber was interrupted with 1 h (12:00 A.M. to 1:00 A.M.) of incandescent light. The growth chambers had a 30 C day temperature (6:30 A.M. to 6:30 P.M.) and a 24 C night temperature. Treatments included a single transfer of Florida beggarweed plants from SD to LD and from LD to SD weekly for 7 wk. Transfers were initiated approximately 4 d after Florida beggarweed emergence. Treatments also included nontransferred controls.

Minimum requirements for appearance of the first open flower ranged from 68 to 79 d under SD growing conditions (D. T. Patterson, unpublished data). All Florida beggarweed transferred from LD to SD and the plants maintained in the SD growing conditions flowered during the study. Plants transferred from the SD to LD, as well as the group that remained in LD, did not flower. Long days prevented flowering and short days stimulated flowering. Florida beggarweed plants become receptive to the flower-inducing stimulus of short days after more than 7 wk but before 10 wk. This conclusion is based on the lack of flowering in plants that were transferred from SD to LD during the first 7 wk, whereas all plants transferred from LD to SD flowered within 10 wk.

## Seed Dormancy and Longevity

A long-term burial study was begun in Stoneville, MS, in 1972 to investigate the viability of common weed seeds over time (Egley and Chandler 1978). Florida beggarweed germination at the time of burial was relatively low, even after scarification (≤ 10%). However, Florida beggarweed seed viability was estimated to be 94% based on the results of tetrazolium staining, indicating that Florida beggarweed may have some type of physiological dormancy in addition to a hard seed coat. The viability of Florida beggarweed seeds held in low-temperature dry storage for 30 and 66 mo was 99 and 87%, respectively (Egley and Chandler 1978, 1983). After 30 mo in dry storage, only 11% of the seeds germinated when put under favorable condition, whereas 88% of the seeds that did not germinate initially did so after scarification (Egley and Chandler 1978). Similarly, after 66 mo of dry storage, 18% of seeds germinated when placed under favorable conditions, whereas 57% germinated when scarified (Egley and Chandler 1983).

After 6 mo of burial, Florida beggarweed viability was ≤ 63% at 8-, 23-, and 38-cm burial depths (Egley and Chandler 1978). Viability at 18 and 30 mo was ≤ 15 and ≤ 7%, respectively, and declined to < 5% viability after 66 mo of burial (Egley and Chandler 1978, 1983).

## Interference

During a 4-yr study, peanut yields were reduced between 8.8 and 16.6 kg for each Florida beggarweed plant per 10 $m^2$ when tested over a range of Florida beggarweed densities (up to 12 Florida beggarweed plants $m^{-2}$) (Hauser et al. 1982). Although Florida beggarweed biomass accounted for a greater amount of the variation in peanut yield than did Florida beggarweed density, a significant correlation between Florida beggarweed biomass and density indicates that either could be used to predict peanut yield reduction. Hooper (1978) documented a linear relation between peanut yield loss and Florida beggarweed density ($r^2 = 0.67$). Peanut yield loss approached 36% from the maximum Florida beggarweed density of 8 plants $m^{-2}$.

TABLE 1. The effect of delay in weed emergence and row proximity on Florida beggarweed weight (J. Cardina, unpublished data).[a]

| Delay in emergence | Florida beggarweed dry biomass | | | |
|---|---|---|---|---|
| | 0 cm[b] | 10 cm | 20 cm | 30 cm |
| d | g | | | |
| 0 | 79 e | 195 a | 155 c | 169 b |
| 10 | 52 f | 80 e | 76 e | 110 d |
| 20 | 8 h | 34 g | 27 g | 45 f |
| 30 | 14 h | 15 h | 9 h | 14 h |

[a] Values are the means of six replications. Fisher's Protected $LSD_{0.05}$ for comparison of proximity within an emergence time is 10.0; Fisher's Protected $LSD_{0.05}$ for comparison of emergence time within proximity is 6.0; proximity and delay in emergence account for 73% of the variation in weed weight; the emergence time by proximity interaction was not significant ($P > F = 0.64$).

[b] Proximity of Florida beggarweed plant to the crop row.

Although Florida beggarweed reduced peanut yield potential, peanut was found to be a good competitor with Florida beggarweed. Competition from peanut reduced Florida beggarweed biomass by 70, 96, and 99% when plots were kept weed free for 0, 4, and 8 wk, respectively, relative to Florida beggarweed that did not compete with peanut for the same timings (Buchanan et al. 1976). The proximity of Florida beggarweed to the peanut row influenced the growth of this weed. Florida beggarweed seeds were planted at various distances from the crop row (0, 10, 20, and 30 cm) at 0, 10, 20, and 30 d after peanut planting. When Florida beggarweed emerged simultaneously with the peanut crop, Florida beggarweed in the crop row had 50 to 60% less biomass than those plants spaced 10 to 30 cm from the crop row (Table 1). This trend continued with a 10- and 20-d delay, relative to peanut, in Florida beggarweed planting dates. Florida beggarweed plants that were farthest from the crop row had the greatest biomass, whereas those that were within the crop row consistently had the lowest biomass (J. Cardina, unpublished data). Despite the effect of peanut on Florida beggarweed, Cardina and Brecke (1991) found that peanut yield within 60 cm of a single Florida beggarweed plant was reduced 19% when peanuts were grown in rows planted 91 cm apart. One means of minimizing weed–crop proximity and optimizing the competitiveness of peanut is to reduce crop row spacing. During a 3-yr period, when the space between peanut rows was reduced from 81 cm to either 40 or 20 cm, the Florida beggarweed fresh plant biomass was reduced 27 or 42%, respectively (Hauser and Buchanan 1982). However, this study maintained a constant crop planting density within the crop row; therefore, the rows spaced 40 and 20 cm apart had peanut populations (on a per hectare basis) double and quadruple that of the conventional 80-cm row spacing, respectively.

Buchanan et al. (1976) evaluated the effect of the delay in Florida beggarweed emergence in relation to peanut planting time with and without cultivation. Florida beggarweed biomass from plants that emerged 4 and 8 wk after peanut emergence was reduced in cultivated plots 62 to 96% and in noncultivated plots 91 to 99%, respectively, relative to Florida beggarweed plants in similar treatments that emerged with peanut (Buchanan et al. 1976). Growth of Florida beggarweed that emerged 4 and 8 wk after planting was similar in the cultivated and noncultivated treatments; however, the noncultivated Florida beggarweed plants that emerged with peanut were sixfold larger in terms of biomass than those that were cultivated and emerged with peanut. Plant biomass of Florida beggarweed that emerged 8 wk after planting was reduced 96% relative to plants that emerged with the peanut crop, indicating that late-emerging Florida beggarweed plants will not be very competitive with peanut for resources. However, this is not to say that Florida beggarweed plants that appear above the canopy during the late season will not be troublesome. Cardina and Brecke (1991) found that many of the Florida beggarweed plants that suddenly appear above the peanut canopy emerged at or near peanut emergence and remained cloaked within or under the peanut canopy.

There is only a limited amount of data on the effects of Florida beggarweed interference in crops other than peanut. A replacement series experimental design was established to evaluate the influence of soil water stress on the relative competitiveness of Florida beggarweed in soybean (Griffin et al. 1989). Soybean leaf area and aboveground biomass were greater than Florida beggarweed when moisture was optimum. However, under conditions of limited water, Florida beggarweed was more competitive than soybean (Griffin et al. 1989).

## Herbivores and Pathogens

*Insects*

Two important pests, tobacco budworm [*Heliothis virescens* (F.)] and corn earworm (*Heliothis zea*), use Florida beggarweed as a late-season host in the southeast (Jackson et al. 1984; Snow and Burton 1967). Newly hatched larvae of tobacco budworm were capable of equivalent weight gain when fed either tobacco or Florida beggarweed (Jackson and Mitchell 1984). However, larvae that were aged 3 and 7 d survived better and attained greater weights on a diet of tobacco relative to one of Florida beggarweed (Jackson and Mitchell 1984). A ranking of the success of six different food sources in the growth and development of tobacco budworm include (from least successful to most successful) (1) Florida beggarweed plant with leaves and buds only, (2) Florida beggarweed with leaves, flowers, and green seeds, (3) Florida beggarweed with leaves and mature seeds, (4) tobacco plants with leaves and buds, (5) tobacco plants with leaves, flowers, and flower buds, and (6) an artificial diet of pinto beans (Jackson and Mitchell 1984). Despite the increased growth on tobacco, tobacco budworm was more common on Florida beggarweed in the late summer; therefore, Florida beggarweed is probably very important to the success of the overwintering population of this species (Jackson and Mitchell 1984; Jackson et al. 1984). In a large field of Florida beggarweed, it was estimated that these plants had on average 25 larvae per plant, with greater than 90% identified as tobacco budworm, whereas less than 10% were identified as corn earworm (Snow and Burton 1967).

Beach and Todd (1988) found that the soybean looper [*Pseudoplusia includens* (Walker)] was successfully grown on Florida beggarweed. When compared with a susceptible and insect-resistant variety of soybean, Florida beggarweed had the greatest digestibility. Instar weight gain and growth rate from the susceptible soybean variety and Florida beggarweed were equivalent, whereas the insect-resistant variety had reduced weight gain and growth rates (Beach and Todd 1988). The efficiency of the soybean looper in converting Florida beggarweed to food also was noted; less Florida beggarweed leaf tissue was consumed by the soybean looper relative to the susceptible soybean variety, which may be due to the increased water content of Florida beggarweed leaves (Beach and Todd 1988). These researchers only observed the soybean looper on Florida beggarweed in a year with very high populations of the insect; soybean loopers have not been documented previously to feed on Florida beggarweed in the field.

A survey conducted in Arkansas sought to identify insect species associated with Florida beggarweed and soybean. The bean leaf beetle (*Cerotoma trifurcata* Forster) and the grape colaspis (*Colaspis brunner* Fabricius) have been linked to the vectoring of the bean pod mottle virus (Walters 1964). Bean leaf beetle was found on Florida beggarweed from mid-May through late-September, with eggs at the base of the plant early in the season (Tugwell et al. 1973). Grape colaspis also was found on Florida beggarweed from mid June through late September. Adults of both species were observed in cages that were placed over the plants during the larval stages, indicating that Florida beggarweed was an adequate source of food for both bean leaf beetle and grape colaspis (Tugwell et al. 1973). Cages that were placed over Florida beggarweed growing on clay loam soils had more adult insects than those cages placed over Florida beggarweed growing on loamy sand (Tugwell et al. 1973). The survey identified a total of 133 species of insect on Florida beggarweed throughout the growing season with approximately 70% of these species also occurring in soybean fields (Tugwell et al. 1973).

*Nematodes*

Florida beggarweed has been shown to be an alternate host for sting nematode (*Belonolaimus gracilis* Steiner), a significant plant parasitic nematode of several southeast U.S. crops, including corn, cotton, peanut, pepper (*Capsicum annuum* L.), soybean, squash (*Cucumis* spp.), and strawberry (*Fragaria* spp.) (Holdeman and Graham 1953). Of the 37 crop and weed species evaluated, only fescue (*Festuca* spp.) had a higher sting nematode population index value than Florida beggarweed. Most of the legumes tested had high sting nematode population index values, as did most of the Poaceae species (Holdeman and Graham 1953).

In Florida, a *Desmodium* sp. was found to be a host to the burrowing nematode [*Radopholus similis* (Cobb) Thorne] under field conditions (Brooks 1955). The burrowing nematode attacks many crops, including corn, cucurbits, solanaceous crops, leguminous crops, and citrus crops, and can reproduce on more than 250 species (O'Bannon 1977). There are two races of burrowing nematode worldwide, and there is some variability in their host specificity and distribution. The citrus race burrowing nematode is found only in Florida, and in addition to citrus species ($>$ 1,200 susceptible varieties of citrus), this race also attacks peanut, soybean, and corn (O'Bannon 1977). The second is the banana race burrowing nematode, and although morphologically similar, it is more widespread and appears to only be an economically important pest of bananas (O'Bannon 1977). The citrus race burrowing nematode also can cause economic damage to bananas.

*Pathogens*

Many common pathogens of agronomic and vegetable crops have been reported to infect Florida beggarweed. In southeastern Georgia, Florida beggarweed was found to be infected with cylindrocladium black rot (by *Cylindrocladium parasiticum*), a common disease of peanut (Padgett and Brenneman 1995). Greenhouse trials confirmed that cylindrocladium black rot survived on Florida beggarweed in the absence of peanut (Padgett and Brenneman 1995).

Desmodium yellow mottle tymovirus was first identified in Arkansas (Walters and Scott 1968) and found to only infect members of the Fabaceae family in the United States. Along with Florida beggarweed, this tymovirus has been documented to infect a cultivar of dry bean (*Phaseolus vulgaris* L. cv. Great Northern), white clover (*Trifolium repens* L.), and another weed species hemp sesbania [*Sesbania exaltata* (Raf.) Rydb.Ex A.W.Hill] (Brunt et al. 1999; Walters and Scott 1972). Nonsusceptible host species of the Fabaceae family are alfalfa, certain cultivars of dry bean (e.g., red kidney and small white), and soybean, as well as species outside the Fabaceae family, including tobacco, common lambsquarters (*Chenopodium album* L.), and jimsonweed (*Datura stramonium* L.) (Brunt et al. 1999; Walters and Scott 1972).

There are two references of plant viruses attacking Florida beggarweed outside of the U.S. Clitoria yellow vein tymovirus was first reported and is localized in Kenya (Bock et al. 1977). Along with Florida beggarweed, common hosts include peanut, coffee senna, soybean, and dry bean (Bock et al. 1977; Brunt et al. 1999). Species that have been identified as nonsusceptible hosts include alfalfa, cotton, jimsonweed, lima bean (*Phaseolus lunatus* L.), showy crotalaria (*Crotalaria spectabilis* Roth), soybean, sugar beet (*Beta vulgaris* L.), several members of the Cucurbitaceae family (cantaloupe [*Cucumis melo* L.], pumpkin [*Cucurbita pepo* L.], and watermelon [*Citrullus lanatus* (Thunb.) Matsum and Nakai]), tobacco, and white clover (Bock et al. 1977; Brunt et al. 1999). Cassia yellow blotch bromovirus was first identified and found to infect Florida beggarweed in Australia. Hosts of this bromovirus include corn, cucumber (*Cucumis sativus* L.), dry bean, and soybean (Brunt et al. 1999; Dale et al. 1984). Nonsusceptible hosts include barley (*Hordeum vulgare* L.), jimsonweed, oat (*Avena sativa* L.), pea (*Pisum sativum* L.), peanut, pigeon pea [*Cajanus cajun* (L.) Millsp.], sorghum [*Sorghum bicolor* (L.) Moench.], and sunflower (*Helianthus annuus* L.) (Brunt et al. 1999; Dale et al. 1984).

Johnson et al. (1996) found that Florida beggarweed was susceptible to tomato spotted wilt tospovirus (TSWV) but was not a preferred host for thrips (*Frankliniella* spp.) that vector the virus. A serious disease of peanut, many vegetable crops, and tobacco in the southeastern coastal plain, TSWV, has been documented throughout the continental United States. These researchers concluded that warm-season weeds (including Florida beggarweed) did not significantly contribute to the epidemiology of TSWV.

Florida beggarweed has been shown to serve as a host for *Pseudomonas viridiflava*, a disease associated with tomatoes (*Lycopersicon esculentus* Mill.) (Mariano and McCarter 1993). Colonies of *P. viridiflava* were detected 4 wk after inoculation on the leaves of Florida beggarweed, at a number that was numerically second only to the primary host of this disease, tomato. Colonies could not be isolated from the roots or leaves of Florida beggarweed at 8, 12, and 16 wk after inoculation, though colonies were isolated from the following weeds: buckhorn plantain (*Plantago lanceolata* L.), common cocklebur, smooth groundcherry (*Physalis subglabrata* Mackenz. & Bush), tall morningglory [*Ipomoea purpurea* (L.) Roth], and showy crotalaria (Mariano and McCarter 1993).

Wells and Forbes (1963) observed anthracnose on several species of *Desmodium* caused by *Colletotrichum dematium* f. *truncata* in the coastal plain of Georgia. Of the 22 species of *Desmodium* tested, 10 of the species had no reaction to the fungal isolates, whereas three species were listed as having a damage rating of 4 (on a scale of 0 = no damage to 5 = severe damage). Florida beggarweed was listed as having moderate damage (2.2), but there was a range of ratings from 1 to 4 (Wells and Forbes 1963). When seeds infected with *C. dematium* were planted and grown in the greenhouse, only five of the species had no damage, whereas 13 had severe damage (a rating of 5), including Florida beggarweed (Wells and Forbes 1963).

Cardina et al. (1988) studied the conditions under which a similar fungus, *Colletotrichum truncatum* (Schw.) Andrus and Moore, infects Florida beggarweed. The optimum conditions for the development of the disease included an incubation of 14 to 16 h at 100% relative humidity and temperatures between 24 and 29 C. Disease development was much slower when Florida beggarweed was grown at 18 C. Susceptibility of Florida beggarweed to infection was greatest in the cotyledon stage with subsequent growth reduction inversely related to plant size (Cardina et al. 1988). The isolates were found to be pathogenic to 10 of 17 species of *Desmodium* that were tested. Darkened leaf veins and margins characterized infected plants after 3 d of inoculation; plants were dead by 5 to 7 d (Cardina et al. 1988). However, the pathogen appeared to have a narrow range because all the crops tested were either immune or resistant to infection by the disease, including peanut, cotton, squash (*Cucumis pepo* L. 'Dixie hybrid yellow crookneck'), corn ('Funk's 6014X'), pepper (*Capsicum frutescens* L. 'Pip'), tomato ('E6203'), alfalfa ('Florida 66'), white clover ('Arcadia'), subterranean clover (*Trifolium subterraneum* L. 'Mt. Barker'), and 19 varieties of soybean. Several common weeds that also were not susceptible to infection by *C. truncatum* included hemp sesbania, sicklepod, coffee senna, velvetleaf (*Abutilon theophrasti* Medic.), prickly sida, Texas panicum (*Panicum texanum* Buckl.), wild poinsettia (*Euphorbia heterophylla* L.), and bristly starbur (*Acanthospermum hispidum* DC.) (Cardina et al. 1988). On the basis of these results, Cardina et al. (1988) concluded that *C. truncatum* was specific for the genus *Desmodium* according to Wapshere's method for host range determination.

## Management

There are several detailed reviews of weed control in peanuts that have included an analysis of herbicide-based systems for Florida beggarweed control (Buchanan et al. 1982; Hauser et al. 1973; Wilcut et al. 1994c). Because of the discontinuous germination pattern of Florida beggarweed throughout the season and the similarity of the weed and crop, many preemergence (PRE) herbicides that are used in peanut will not provide acceptable (> 80%) season-long weed control. Variable control of Florida beggarweed resulted from norflurazon applied PRE (58 to 98%; average, 83%) and diclosulam applied PRE or preplant incorporated (54 to 98%; average, 87%) (Grey et al. 2001, 2002). One PRE herbicide with potential for controlling Florida beggarweed is flumioxazin. Flumioxazin PRE controlled Florida beggarweed ≥ 90% at 125 d after application at four out of five locations in Georgia (Grey et al. 2002). A short half-life (< 17.5 d) for flumioxazin indicates that this herbicide could be beneficial to growers rotating fall vegetables, cotton, or corn after peanut (Grey et al. 2002; Vencill 2002).

A combination of cultivation and an intensive herbicide system that included dinoseb (no longer available for use) controlled Florida beggarweed 70 to 90% (Hauser et al. 1973). Dinoseb postemergence (POST) was most effective on small weeds; once true leaves on the Florida beggarweed plant began to expand, control rapidly diminished (Hauser and Buchanan 1974). There are several POST herbicides registered for Florida beggarweed control in peanut, including paraquat and pyridate plus 2,4-DB. Paraquat with the addition of bentazon provided better crop safety than when applied alone (Wehtje et al. 1992). However, Florida beggarweed control was antagonized by this mixture primarily because of reduced absorption of paraquat. Applications of 1.0 to 1.5 kg ai $ha^{-1}$ of pyridate controlled Florida beggarweed 79 to 96%, respectively (Hicks et al. 1990). Subsequent studies indicated that the addition of 2,4-DB did not improve Florida beggarweed control (Hicks et al. 1998). Neither paraquat nor pyridate has any soil residual activity for Florida beggarweed control. Imazethapyr and imazapic are registered for use in peanuts to control many weeds and provide soil residual activity (Richburg et al. 1995). However, although imazapic is generally more active against Florida beggarweed than imazethapyr, neither of these herbicides consistently controlled Florida beggarweed (Richburg et al. 1996; Webster et al. 1997; Wilcut et al. 1994a, 1994b, 1996). In addition, imazethapyr and imazapic have potential injury problems with rotational crops (e.g., 18 mo rotation restriction with cotton and 26 to 40 mo rotation restriction for many nonlegume vegetable crops) because of excessive persistence in the soil.[2]

Late-season applications of chlorimuron are primarily targeted for Florida beggarweed control. Chlorimuron can be applied during the interval between 60 d after peanut emergence and 45 d before crop harvest and will control Florida beggarweed plants that are less than 25 cm tall and are not in bloom.[3] Application before this interval may be ineffective because of the hidden growth habit of Florida beggarweed within the peanut canopy and excessive crop stunting (Cardina and Brecke 1991). By the time of this application, the crop yield loss due to weed interference cannot be recovered; however, this can be an important treatment to improve efficiency of peanut digging and harvest. Averaged across several weed management systems, net returns were reduced ≥ 15% when chlorimuron was a component of the system, attributed to crop injury (Wehtje et al. 2000). In addition, studies have demonstrated a differential tolerance to chlorimuron in terms of yield among peanut cultivars, and the application tended to reduce peanut grade across all cultivars tested (Johnson et al. 1992). Recently, chlorimuron applications also have been linked to increased incidence of TSWV (Prostko et al. 2002).

Florida beggarweed was controlled 65 and 96% 10 wk after treatment by glyphosate concentrations of 0.63 and 1.25% (v/v), respectively, with a surfactant (0.25%, v/v) and the addition of an antidrift agent applied using a recirculating sprayer (Hauser and Buchanan 1978). This method requires a height differential between the weed and the crop, which in this study averaged 30 to 60 cm above the peanut foliage. Peanut injury from this technique was minimal if a vertical distance of 10 to 15 cm was maintained between the peanut crop and the lowest horizontal stream of spray (Hauser and Buchanan 1978). Similar research determined that a wick-bar application of paraquat or glyphosate at a concentration of 25% (by volume) controlled Florida beggarweed greater than 85% (Johnson et al. 1999). Despite the relatively high level of Florida beggarweed control, these researchers did not see an increase in yield due to this late-season treatment. However, the effective control of these weeds may allow for more effective fungicide applications and improved harvesting efficiency and may prevent or suppress Florida beggarweed seed production (Johnson et al. 1999; Royal et al. 1997; Wilcut et al. 1994c).

The stale seedbed approach has been used effectively to reduce late-season populations of Florida beggarweed and to increase peanut yields relative to the conventional planting methods (Johnson and Mullinix 1995). The conventional system consisted of a deep-till (to 23 cm) and planting the same day, whereas the stale seedbed approach began with deep tillage 6 wk before planting and three shallow tillage (7.6 cm deep) operations at 2-wk intervals to kill emerged seedlings.

Herbicide options for Florida beggarweed control in cotton are more flexible than those in peanut because of the dissimilarity between crop and weed. The inclusion of fluometuron PRE in a weed management system that included POST and LAYBY applications of other herbicides increased Florida beggarweed control 26% compared with similar systems that lacked fluometuron PRE (Paulsgrove and Wilcut 1999). Other research indicates that pyrithiobac POST will control Florida beggarweed greater than 85%, and the addition of DSMA will increase Florida beggarweed control to greater than 91% (Monks et al. 1999). The use of bromoxynil-tolerant cotton may provide growers with an alternate management system in areas with high populations of Florida beggarweed. An early POST application of bromoxynil to plants at the four-leaf stage or smaller controlled Florida beggarweed greater than 90% (Paulsgrove and Wilcut 1999). The addition of glyphosate as an option in transgenic cotton provides another very efficient tool for managing Florida beggarweed. However, neither bromoxynil nor glyphosate has soil residual activity; therefore, a residual material may be required because of the discontinuous germination patterns of Florida beggarweed (Cardina and Hook 1989; Paulsgrove and Wilcut 1999). The effectiveness of glyphosate is often dependent on environmental factors. Glyphosate absorption and translocation in Florida beggarweed is maximized at 22 C (relative to 16 and 35 C) and 95% relative humidity (relative to 45 and 70%) (Sharma and Singh 2001). There are several effective postdirected options for Florida beggarweed control in cotton that include MSMA alone or in combination with lactofen, oxyfluorfen, diuron, or prometryn (A. S. Culpepper, personal communication).

TABLE 2. The effect of Florida beggarweed (1.1 plants m$^{-2}$) on corn, cotton, peanut, and soybean growth and the economic implications for managing this species.

| Crop | Yield loss[a] | Cost of weed presence | Weed control recommendation | Net return[b] | Total cost | Yield loss from noncontrolled weeds[c] | Cost of noncontrolled weeds |
|---|---|---|---|---|---|---|---|
| | % | \$ ha$^{-1}$ | | \$ ha$^{-1}$ | | kg ha$^{-1}$ | \$ ha$^{-1}$ |
| Corn[d] | 5 | 38.10 | 2,4-D (0.28 kg ae ha$^{-1}$) | 26.70 | 9.30 | 23 | 1.50 |
| | 5 | 38.10 | Atrazine (1.12 kg ai ha$^{-1}$) + crop oil concentrate (1.25%, v/v) | 18.50 | 17.50 | 23 | 1.50 |
| Cotton[e] | 40 | 414.80 | MSMA (1.12 kg ai ha$^{-1}$) | 401.00 | 13.50 | 0 | 0.00 |
| | 40 | 414.80 | Glyphosate (0.42 kg ae ha$^{-1}$) | 397.00 | 18.00 | 0 | 0.00 |
| Peanut[f] | 44 | 1,340.00 | Paraquat (0.14 kg ai ha$^{-1}$) | 1,280.30 | 11.34 | 103 | 69.20 |
| | 44 | 1,340.00 | Imazapic (70 g ai ha$^{-1}$) | 826.00 | 50.11 | 720 | 484.30 |
| Soybean[g] | 14 | 38.00 | Chlorimuron (11 g ai ha$^{-1}$) + thifensulfuron (3.6 g ai ha$^{-1}$) | 21.70 | 16.30 | 0 | 0.00 |
| | 14 | 38.00 | Glyphosate (0.42 kg ae ha$^{-1}$) | 22.20 | 15.90 | 0 | 0.00 |

[a] Yield loss and cost of weed presence is the estimated effect of 1.1 Florida beggarweed plants m$^{-2}$ on crop yield.

[b] Net return is the estimated benefit of controlling the weed, accounting for the cost of weed control.

[c] Yield loss from noncontrolled weeds and cost of noncontrolled weeds are the estimated crop effects of the Florida beggarweed presence when weed control operations are less than 100% effective.

[d] Parameters used in the HADSS model included an estimated weed-free corn yield of 8,064 kg ha$^{-1}$, corn selling price of \$0.09 kg$^{-1}$, weed size of 2.5 cm, crop size of 5 cm, and adequate soil moisture.

[e] Parameters used in the HADSS model included an estimated weed-free cotton yield of 1,120 kg ha$^{-1}$, cotton lint selling price of \$0.92 kg$^{-1}$, weed size of 2.5 cm, crop size of 5 cm, and adequate soil moisture.

[f] Parameters used in the HADSS model included an estimated weed-free peanut yield of 4,480 kg ha$^{-1}$, peanut selling price of \$0.67 kg$^{-1}$, weed size of 2.5 cm, and adequate soil moisture.

[g] Parameters used in the HADSS model included an estimated weed-free soybean yield of 1,560 kg ha$^{-1}$, soybean selling price of \$0.17 kg$^{-1}$, weed size of 2.5 cm, and adequate soil moisture.

Estimations of the economic effect of Florida beggarweed and subsequent weed control practices can be found in the Herbicide Application Decision Support System (HADSS) (Bennett et al. 2003; Scott et al. 2001; Wilkerson et al. 1991). This is a regional database designed for the major agronomic crops of the southern United States. HADSS guides weed management decision makers based on weed biology and herbicide efficacy data and the economic ramifications of both. A Florida beggarweed density of 1.1 plant m$^{-2}$ was determined in four agronomic crops using HADSS (Table 2) (Bennett 2003a, 2003b; Prostko et al. 2003; Webster and Culpepper 2002). All the dependent variables (e.g., expected weed-free crop yield, crop selling price, soil moisture status, and crop size) used in this analysis are listed as footnotes in Table 2. Corn and soybean were the most tolerant of Florida beggarweed (5% corn yield loss and 14% soybean yield loss from 1.1 Florida beggarweed m$^{-2}$), whereas cotton and peanut were the most susceptible (40% cotton yield loss and 44% peanut yield loss from 1.1 Florida beggarweed m$^{-2}$). The disparity in potential yield loss from Florida beggarweed across the four crops reflects the relative competitiveness of each crop. Corn is a fast-growing crop that will grow tall and minimize the branching of Florida beggarweed. In contrast, peanut is a low-growing crop that will not suppress Florida beggarweed growth once it outgrows the peanut canopy. For each crop, there was an economic benefit, expressed as net return, realized from eliminating this density of Florida beggarweed, which ranged from \$19 ha$^{-1}$ for corn to \$1,280 ha$^{-1}$ for peanut.

## Conclusions

Once touted as an important forage crop, Florida beggarweed quickly lost favor in Georgia for at least two reasons. First, as agriculture became more mechanized, the need for animal labor waned and Florida beggarweed was no longer required as a forage crop. Georgia growers quickly abandoned the mule for the tractor in the late 1940s and the early 1950s (J. E. Cheek, unpublished data). The characteristics that made Florida beggarweed a good forage crop also made it a formidable weed. Second, the peanut hectarage expanded in the early part of the 20th century in Georgia. Although peanuts were grown in Georgia for hog feed and local consumption in colonial America, significant commercial production of peanuts did not begin until about 1916, when the first shelling plants were constructed and 23,000 ha of peanuts were harvested (Branch 1993; J. E. Cheek, unpublished data). Initially, peanut hectareage increased quickly partly because of the severe cotton damage caused by the boll weevil; 79,000 ha of peanut were planted in 1917, 162,000 to 243,000 ha of peanut were planted between 1920 and 1940, and 405,000 ha of peanut were planted during the years of World War II (J. E. Cheek, unpublished data). Because many former Florida beggarweed hay fields probably became peanut fields and because peanuts and Florida beggarweed are both tropical legumes, it is not surprising that they would coexist. Also, marginal control of Florida beggarweed could be expected in a crop with similar phenology, adaptation, and presumably physiology—even if morphologically they are quite different. It seems that seed survival in the soil, due to a hard seed coat, is an important factor in the persistence of this species. This is difficult to counter in a management program, except by breaking the cycle of seed production. Emergence seems to be stimulated by soil disturbance as long as there is sufficient soil moisture, so some type of repeated tillage followed by a method of killing seedlings could be used to deplete the seed bank. The other factor that seems to be a key weedy trait is its rapid shoot elongation that allows it to penetrate and overshadow the peanut crop canopy. This allows beggarweed to be competitive with peanuts but explains why it is not as competitive with corn, a crop with rapid height development and a tall canopy. This suggests that a competitive rotation crop (i.e., corn), along with chemical and mechanical controls, might be an effective approach to reducing the effect of this weed in peanuts. Cotton and soybean also might be effective rotation crops, especially glyphosate-tolerant varieties.

## Sources of Materials

[1] Southern Weed Science Society Weed Identification Guide, Florida beggarweed. Sheet prepared by N. Hackett and D. S. Murray.

[2] Cadre herbicide product label and Pursuit herbicide product label. BASF Corporation Agricultural Products, 26 Davis Drive, Research Triangle Park, NC 27709.

[3] Classic herbicide product label, E. I. du Pont de Nemours and Company, Agricultural Products, Wilmington, DE 19898.

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