Spread, Growth Parameters, and Reproductive Potential for Brown Flatsedge (*Cyperus fuscus*)

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Brown flatsedge (*Cyperus fuscus*) is widely distributed in Europe, Asia, the Indian subcontinent, and the Mediterranean region of Northern Africa. It was apparently introduced into North America in the late 1800s and has steadily moved southward and westward. Brown flatsedge is reported new to Arkansas and Mississippi herewith. Field observations from early spring until frost were made between 2003 and 2007 from populations present at three sites: Chicot County, Arkansas, and Pearl River and Washington counties, Mississippi. Under natural field conditions, brown flatsedge plants germinated from late March and early April until frost. Inflorescences were observed in mid-May and seed production continued until frost. In field populations, the average numbers of scales per spikelet, inflorescences per plant, and spikelets per inflorescence were 15, 28, and 33, respectively. Greenhouse experiments were established in 2008 at Stoneville, MS, to determine growth parameters and the reproductive potential of brown flatsedge. In greenhouse experiments, by 10 wk after emergence (WAE), brown flatsedge plants were 30.2 cm tall and 63.9 cm in diameter, and dry weights were 1.4, 1.0, 2.0, 0.5, and 1.9 g for roots, culms, leaves, bracts, and inflorescences, respectively. Brown flatsedge culms and inflorescences appeared 5 WAE, and by 9 WAE all plants were producing seed. Brown flatsedge could pose a threat to natural plant communities and rice agriculture in Arkansas, Louisiana, Mississippi, Missouri, Tennessee, and Texas. Additional research is needed to determine seed longevity and ecological range potential, and to develop inexpensive and effective control methods.

Nomenclature: Brown flatsedge, *Cyperus fuscus* L. CYPFU.

Key words: Invasive weed, ecological range, growth parameters, reproductive potential.

The sedge family (Cyperaceae) contains several of the world's worst weeds (Holm et al. 1977). Bryson and Carter (2008) list 447 species in the family and 147 *Cyperus* species as weeds. Brown flatsedge or brown galingale (*Cyperus fuscus* L.) was reported as a weed in semitropical areas of the Old World where it is a significant pest in rice (Holm et al. 1979). It is widely distributed in the Old World in Europe, Asia, the Indian subcontinent, and the Mediterranean region of Northern Africa, from Greenland and Iceland to China, south to Spain, Iran, Egypt, Algeria, and northern India (Kükenthal 1935 to 1936; McGivney 1938). Brown flatsedge was first discovered in the United States in 1877 in ballast or around wharfs in the Boston, MA, area (Knowlton et al. 1911). Since that time, it has been found in two Canadian provinces, Ontario and Quebec, and numerous states of the United States, including California, Connecticut, Kansas, Maryland, Massachusetts, Missouri, Nebraska, Nevada, New Jersey, Pennsylvania, South Dakota, and Virginia (Fernald 1950; McKenzie et al. 1998; Tucker et al. 2002; Weedon and Stephens 1969). In addition to the association with ballast and wharfs, dispersal of brown flatsedge seeds has been attributed to waterfowl and human activities, including construction equipment (Bryson and Carter 2008; McKenzie et al. 1998).

Taxonomically, brown flatsedge is closely related to smallflower umbrella sedge (*Cyperus difformis* L.), one of the world's worst weeds (Holm et al. 1977), and these species share a number of vegetative and habitat similarities. Both occur in disturbed, muddy soils, shallow water, and shorelines and are loosely clumping annuals with soft spongy culms that are easily compressed (Bryson and Carter 2008; Bryson and DeFelice 2009; Tucker et al. 2002). However, they are easily distinguished by inflorescence characteristics (Tucker et al. 2002), with the floral scales and styles of brown flatsedge 0.9 to 1.1 mm long and

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Interpretive Summary

Brown flatsedge is an annual, nonnative, invasive weed that continues to move south and westward in the United States. It was apparently introduced from contaminated ballast in the Boston, MA, area during the late1800s. Brown flatsedge is reported new to Arkansas and Mississippi and biological and ecological growth parameters are presented from field observations and controlled greenhouse experiments. In optimum environmental conditions, brown flatsedge grows rapidly, and populations are capable of producing multiple generations per year and from 69 million to 2.2 billion seeds ha^{-1} annually. Brown flatsedge plants produced seed by 9 wk after emergence, and the first culms and fruiting occurred by 5 wk after emergence. Currently, brown flatsedge seems poised to infest additional native plant communities and rice production areas in the southeastern United States. Additional research is needed to determine seed longevity and ecological range potential, and to develop inexpensive and effective control methods.

0.3 to 0.4 mm long, respectively, compared to 0.6 to 0.8 mm long and 0.1 mm long, respectively, for smallflower umbrella sedge (Tucker et al. 2002).

Because brown flatsedge was recently detected in shallow water environments in disturbed soils adjacent to rice production areas of the Mississippi Delta Region, research was initiated at Stoneville, MS, to study its basic biology and ecology. Our objectives are to report new populations and to investigate growth rate and reproductive potential from field observations and controlled greenhouse experiments.

Materials and Methods

Field Observations. Plants were observed in and collected from Chicot County, Arkansas, and Pearl River and Washington counties, Mississippi (Figures 1 and 2). Following discovery of a population, data were recorded monthly for the number of plants m^{-2}; number of culms

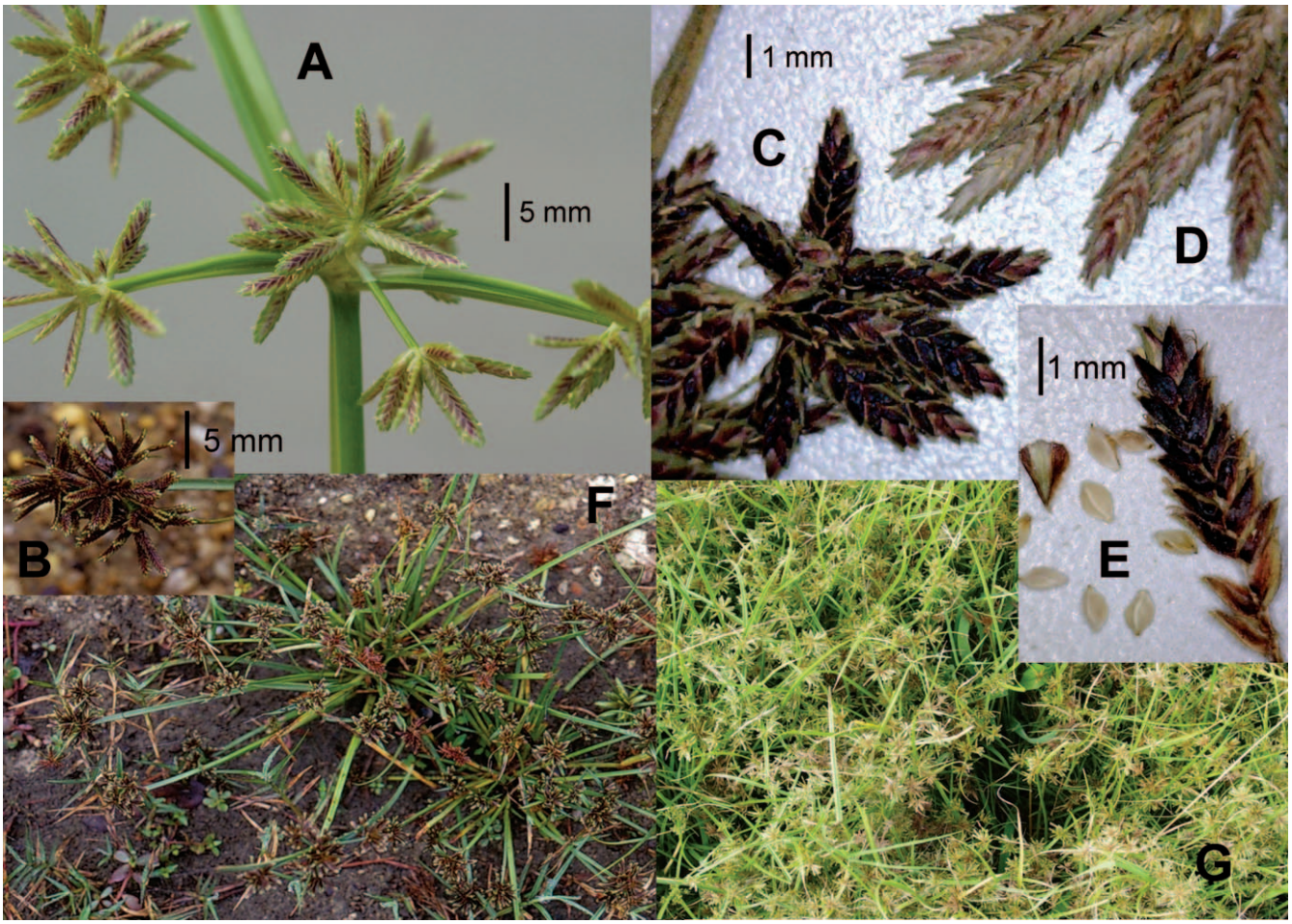

Figure 1. Photos of brown flatsedge: (A) summer inflorescence; (B) autumn inflorescence; (C) spikelet coloration differences between autumn (scales with more pigmentation) and (D) summer (scales with reduced pigmentation); (E) spikelet, scale, and achenes; and plant habit in (F) autumn and (G) summer. Photos of live plants or herbarium specimens correspond to collections as follows: A, D, and G from *Bryson 20,300*; B and F from *Bryson 16878 & Sudbrink*; and E from *Bryson 21944*.

Figure 2. Distribution of brown flatsedge in Canada and the United States. Circles, previously reported distribution; and triangles, new sites from Arkansas and Mississippi.

per plant; number of spikelets per inflorescence; number of seeds, scales, and both per spikelet; and other growth parameters in each of the three populations. The populations in 1998 from Chicot County, Arkansas, and in 2004 from Pearl River County, Mississippi, were present during periods of adequate moisture and were transient from year to year. The Washington County population was observed in 2004 to 2007 and it was the most constant, with adequate moisture being supplied from a leaky fire hydrant following a construction project. Once the hydrant was repaired 3 yr later and the constant soil moisture was eliminated, brown flatsedge plants disappeared during the summer of 2007.

Greenhouse Experiments. Brown flatsedge seed were collected from Washington County, Mississippi, in the fall of 2006 and planted during the summer of 2008. Seeds were planted in 15-cm diam plastic pots filled with a 1 : 1 mixture of potting media[1] and soil (Bosket sandy loam, fine-loamy, mixed thermic Molic Hapludalfs). Plants were thinned to one plant per pot using forceps and grown in a greenhouse set to 30/22 C (± 3 C) day/night temperature. Natural light was supplemented with sodium vapor lamps to provide at least 14 h of photoperiod. Pots were placed in plastic trays, and plants were watered from beneath as needed until harvested.

Plants were grown in the greenhouse for 1 to 10 wk in a randomized complete block arrangement with week of harvest as treatments and 10 repetitions per treatment (individual plants), and the experiment was repeated. Time of emergence, plant height, diameter, and number of leaves and culms per plant, and days to first flower were recorded. At 10 wk after emergence (WAE), plants were harvested weekly, washed, separated by plant part, and oven-dried; dry weights were recorded for roots, culms, leaves, bracts, and inflorescences.

Means and standard errors for quantitative parameters were calculated with SAS.[2] Box plots for selected plant parameters were constructed with Sigma Plot.[3] For other plant parameters, regression analysis was performed and plotted with Sigma Plot.

Results and Discussion

Field Observations. Our collections are the first report of brown flatsedge from Arkansas and Mississippi (Figures 1 and 2) as follows:

Voucher Specimens. *United States, Arkansas. Chicot County.* Chicot Lake County Park, N side of Lake Chicot along lake shoreline on mud flats created by low water level in lake (33°16′44.35″N, 91°13′08.04″W), 15 Oct 2004, *Bryson 20,408* (MO, NY, SWSL, UARK, VDB, VSC, herb. Bryson).

United States, Mississippi. Pearl River County. Picayune, 0.2 mi. E of jct. Hwy I-59 and MS 43 then ca. 0.2 mi. S on frontage road to E of I-59 in open area on sandy to sandy loam soil mudflats S of Hwy MS 43 (30°31′00.43″N, 89°39′40.19″W), 28 Oct 1998, *Bryson 16878 & Sudbrink* (BRIT, DAV, DSC, FLAS, GH, IBE, JSU, MICH, MISS, MISSA, MMNS, MO, NY, SWSL, UARK, USMS, VDB, VSC, herb. Bryson).

Washington County. Stoneville, USDA-ARS, Jamie Whitten Delta States Research Center, behind five-story building, open weedy area, wet, around leaky fire hydrant (33°25′31.68″N, 90°54′42.67″W), 6 Jul 2004, *Bryson 20,300* (BRIT, DAV, DSC, FLAS, GH, IBE, JSU, MICH, MISS, MISSA, MMNS, MO, NY, SWSL, UARK, USMS, VDB, VSC, herb. Bryson); 1 Sep 2004, *Bryson 20326* (BRIT, DAV, DSC, FLAS, GH, IBE, JSU, MICH, MISS, MISSA, MMNS, MO, NY, SWSL, UARK, USMS, VDB, VSC, herb. Bryson); 12 Oct 2006, *Bryson 21929* (BRIT, DAV, DSC, FLAS, GH, IBE, JSU, MICH, MISS, MISSA, MMNS, MO, NY, SWSL, UARK, USMS, VDB, VSC, herb. Bryson); 15 Nov 2006, *Bryson 21944* (DSC, FLAS, IBE, MICH, MISS, MISSA, MMNS, MO, NY, SWSL, USMS, VDB, VSC, herb. Bryson); 1 Dec 2006, *Bryson 21944A* (MISSA, MO, SWSL, VSC, herb. Bryson); Greenville, ca. 0.5 mi. S jct. of Hwy MS 1 and VFW Road in wet open area to W of Hwy MS 1 in front of Lowe's parking lot (33°22′04.10″N, 91°02′23.17″W), 1 Nov 2008, *Bryson 23037 & Bryson* (MO, SWSL, VSC, herb. Bryson).

The Arkansas population of brown flatsedge was found along the shores of Lake Chicot in a natural setting with grasses and other sedges. All of the Mississippi populations of brown flatsedge were from anthropogenically disturbed sites in areas with soil that remained wet for several months of the year. During dry periods, brown flatsedge plants disappeared.

The emergence time and end of seed production were variable among years. The longest period of growth and reproduction was observed in 2006 at Stoneville, MS, when brown flatsedge plants emerged as early as late March and early April, initiated flowering in May, and continued to emerge and produce culms, inflorescences, and seeds as late as December 1, 2006. The following week a frost killed all brown flatsedge plants. In 1998 and 1999, fruiting plants were observed at Picayune, MS, as early as mid-August and continued to flower and fruit until killed by frost. Subsequently, the area was cleared and a restaurant was built over the site. Fruiting brown flatsedge plants were detected in September 2004 following a natural draw-down of the water levels on Chicot Lake near Lake Village, AR; they continued to produce fruits until killed by frost. Few brown flatsedge plants were observed in Chicot County during 2005, because the water levels remained high and open, moist shoreline was unavailable.

Field observations at the three sites in Arkansas and Mississippi showed that brown flatsedge was dependent on persistently moist soil or shallow standing water for establishment, growth, and seed production. Once the soil dried at any one of these locations, brown flatsedge plants begin to die and seedlings were not present until the soil was persistently wet again and temperatures were above 24/16 C day/night. The availability of soil moisture during the dryer summer and fall months in the southeastern United States may explain why brown flatsedge populations are sporadic and only appear in wet soils along exposed margins of lakes and streams and other open habitats with constant soil moisture. For example, average precipitation for Washington County, Mississippi, during the summer and early autumn is less ($\leq$ 9.9 cm mo^{-1}) than late fall, winter, and spring ($\leq$ 11.4 cm mo^{-1}) (MS 2009).

Brown flatsedge plants produced an average of 28 culms and inflorescences when pooled over all field observations (Figure 3). The average number of spikelets per inflorescence was 33 and was variable ranging from 9 to 75 spikelets per inflorescence (Figure 3). The number of scales ranged from 7 to 31 per spikelet and averaged 15 scales per spikelet (Figure 3). The total number of plants m^{-2} was variable from site to site, from year to year, and time of year. Over all observations, brown flatsedge population density ranged from a single plant to 32 plants m^{-2}. Therefore, if one-half of the flowers, subtended by a single scale, produced a seed, the number of brown flatsedge seeds produced could range from 6,900 to 220,800 seeds m^{-2} or 69 million to 2.2 billion seeds ha^{-1} annually. Currently, there are no data on viability and longevity of brown flatsedge seed; however, brown flatsedge plants are not detected each year and were observed only under optimal environmental conditions (P. M. McKenzie et al., unpublished data).

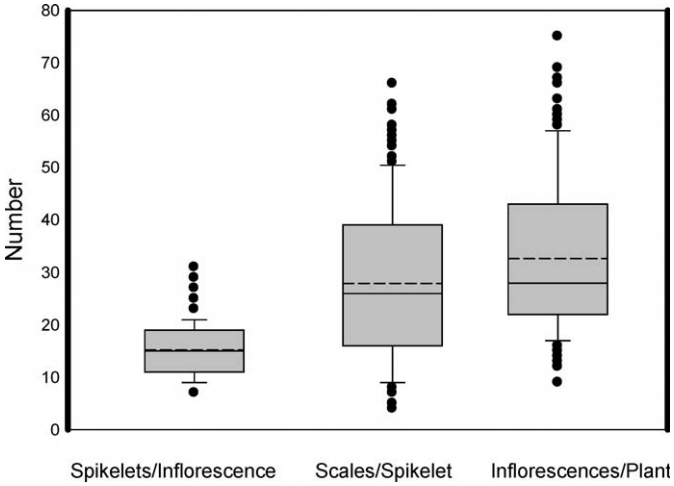

Figure 3. Average number of brown flatsedge spikelets per inflorescence, scales per spikelet, and inflorescences per plant from populations in Chicot County, Arkansas, and Pearl River and Washington counties, Mississippi. Boundary of box closest to zero indicates the 25th percentile, a solid line within the box marks the median, a dashed line within the box delineates the mean, and the boundary of the box farthest from zero indicates the 75th percentile. Error bars above and below the box indicate the 90th and 10th percentiles, and solid dots indicate outliers. The number of independent observations is 175 for each character.

Greenhouse Experiments. Because there was no treatment by experiment interaction, data were combined. Average measurements and dry weights for brown flatsedge are provided in Figure 4. One week after emergence, brown flatsedge plants comprised one to two thread-like leaves and averaged 1.8 cm tall (Figure 4A) and 1.6 cm diameter from leaf tip to leaf tip and had a dry weight of less than 0.5 mg. By 10 WAE, average plant height was 30.2 cm tall (Figure 4A). By 10 WAE, many of the culms were decumbent and plants were about twice as wide (63.9 cm wide) as the plant height (data not shown). The number of new leaves initiated declined following the development of culms (Figure 4B). A maximum average number of leaves (147 leaves $plant^{-1}$) was recorded at 8 WAE and declined thereafter to an average of 62.0 leaves $plant^{-1}$ by 10 WAE (Figure 4B).

By 10 WAE, whole plant dry weights averaged 6.8 g, and average root dry weight was 1.4 g (Figure 4C). At 10 WAE, average total dry weights of leaves vs. components directly supporting fruit production (i.e., culm, bract, and inflorescence) were 2.0 and 3.4 g $plant^{-1}$, respectively, and the average dry weights per plant of culm, bract, and inflorescence excluding bracts were 1.0, 0.5, and 1.9 g, respectively (Figures 4D–F). By 9 WAE, the reproductive

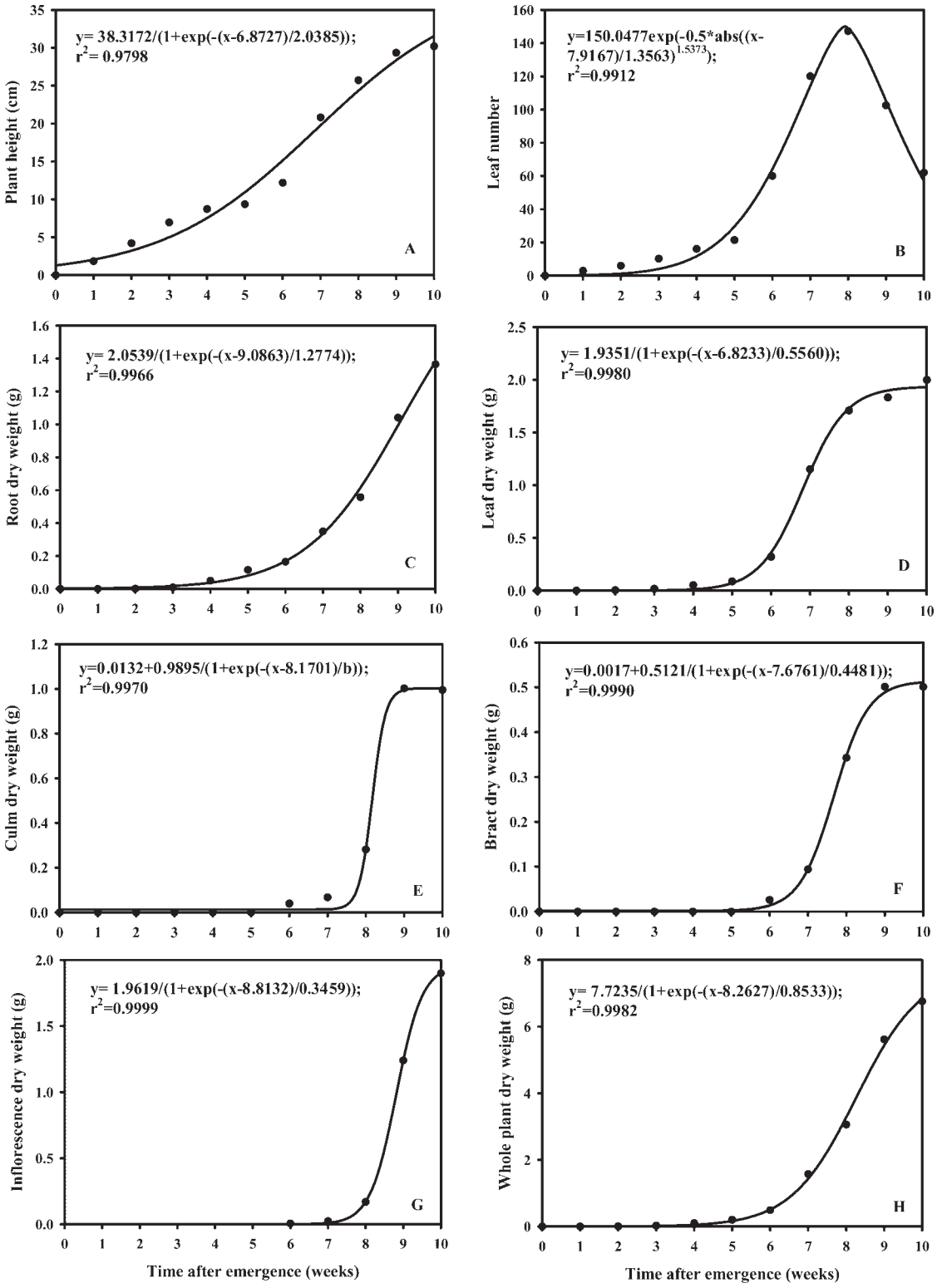

Figure 4. Growth and dry weights of brown flatsedge in greenhouse experiments conducted at Stoneville, MS. (A) Average plant height; (B) number of leaves; and dry weights for (C) roots, (D) leaves, (E) culms, (F) bracts, (G) inflorescences, and (H) whole plants.

portions (i.e., culms, bracts, and inflorescence) of brown flatsedge plants (2.7 g) was greater than 50% of total plant weight (5.6 g) (Figure 4H). Dry weights of bracts and culms were similar between 9 and 10 WAE (Figures 4E and 4F). This trend was similar to field observations in which the length of bracts and culms produced on older plants were shorter than those in younger plants.

The first culm appeared 5 WAE, and all brown flatsedge plants were producing inflorescences and seeds by 9 WAE (Figure 4G). As plants grew and culms developed, older leaves began to die and were not replaced by new leaves. Average dry weight of leaves and culms (Figures 4D and 4E) show the transition from a vegetative mode to a reproductive mode starting at 6 WAE. This phenomenon is not unusual for Cyperaceae. Smallflower umbrella sedge and *Cyperus haspan* L. possess more culms than leaves at maturity (unpublished data), and Bernard and Fiala (1986) determined that as longhair sedge (*Carex comosa* Boott) plants increase in size, flowering culms total and percentage of weight increased in relationship to weights of vegetative shoots.

The life history and population dynamics of brown flatsedge seem to be similar to smallflower umbrella sedge. Holm et al. (1979) reported that smallflower umbrella sedge can produce a generation every 4 to 6 wk in optimum environmental conditions. With the possibility of multiple generations per year and high seed numbers annually, brown flatsedge could pose a threat to the native flora and rice agriculture in Arkansas, Louisiana, Mississippi, Missouri, Tennessee, and Texas. Additional research is needed to determine seed longevity and ecological range potential, and to develop inexpensive and effective control methods for brown flatsedge.

Sources of Materials

[1] Jiffy mix, Jiffy Products of America Inc., Batavia, IL 60510.

[2] SAS software, Version 8.3. SAS Institute Inc., Box 8000, SAS Circle, Cary, NC 27513.

[3] Sigma Plot 10.0, Systat Software Inc., San Jose, CA 95110.

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