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Factors Limiting the Distribution of Cogongrass, *Imperata cylindrica*, and Torpedograss, *Panicum repens*[1]

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Abstract. **Greenhouse, growth chamber, and laboratory studies were conducted to determine anatomical and morphological characteristics and cultural practices limiting the distribution of cogongrass, torpedograss, and johnsongrass in the United States. Cogongrass did not produce axillary buds along most of the rhizome nor regenerate when apical six-node-long rhizome segments were buried deeper than 8 cm. Both torpedograss and johnsongrass produced axillary buds along the entire lengths of their rhizomes. Torpedograss shoot emergence decreased at burial depths between 8 and 16 cm. Shoot emergence from johnsongrass rhizomes was not affected by burial as deep as 16 cm. Rhizomes of all three species were tolerant of desiccation. Cogongrass grew better in soil at pH 4.7 than in soil at pH 6.7, whereas torpedograss and johnsongrass grew equally well in either pH. It is postulated that cogongrass spread is limited by lack of axillary bud formation on most of the rhizome and the inability of rhizomes to send up new shoots if buried deeper than 8 cm. These factors could account for the intolerance of cogongrass to cultivation. Torpedograss appears to spread only vegetatively due to the lack of viable seed production. Nomenclature: Cogongrass, *Imperata cylindrica* (L.) Beauv. #[3] IMPCY; torpedograss, *Panicum repens* L. # PANRE; johnsongrass, *Sorghum halepense* (L.) Pers. # SORHA.**

Additional index words. **Replacement series, temperature, *Sorghum halepense*, PANRE, IMPCY, SORHA.**

INTRODUCTION

Cogongrass and torpedograss are perennial, rhizomatous, C_4 grasses introduced into the United States in the late 19th and early 20th centuries. Currently, both are serious weeds in certain areas of Florida and along the Lower Coastal Plains of Alabama and Mississippi (2, 5, 11, 22).

Cogongrass spreads by rhizomes and seed (4, 11, 12). A single plant may produce as many as 3000 seed (8). The small, plumed, one-seeded spikelets may be carried great distances by wind but average flight is approximately 15 m (9). Seed are capable of germinating immediately. Cogongrass seed does not require an afterripening period (3). It germinated best (>70%) in light at about 30 C and remained viable for at least 1 yr under laboratory conditions. The spread of cogongrass from coastal areas inland in Asia appears to be by seed, primarily along rights-of-way bordering highways and railways (9). The distribution and spread of cogongrass northward in Alabama from 1973 to 1985 appears to have been due to the northeasterly prevailing winds off the Gulf of Mexico along Interstate 65 (22).

The ready production of rhizomes by cogongrass plants facilitates rapid spread at new colonized sites. In controlled-environment experiments, it was found that cogongrass started from rhizome fragments could produce up to 168 new rhizomes in 87 days (11). When plants were started from seed, rhizome production began within 30 to 40 days (11).

Cogongrass is controlled by cultivation (7, 13) and hence is rarely found in cultivated fields (13). Little regrowth from cogongrass rhizomes occurs under simulated cultivated field conditions (13). This was attributed to a lack of adaptation to regeneration from cultivation. Also there was reported difficulty in regenerating plants from rhizome fragments unless individual plantlets were planted (13). However, even small fragments of cogongrass rhizomes could produce new plants (9). New plants were produced from terminal sections of rhizomes (12). Peng (13) and Hubbard (9) failed to report whether the rhizome fragments they used were terminal sections. Most viable buds are located at the nodes on the apical portion of the rhizome (17).

In the United States, torpedograss is believed to spread only by rhizomes. In Taiwan, torpedograss does not produce viable seed (13), but in Portugal, torpedograss is spread by seed[4]. In Florida, torpedograss reportedly can spread by both seed and rhizomes (19). However, no citations or data are presented to substantiate this claim. Unlike the situation with cogongrass, moderate cultivation fails to control torpedograss; rather it may accelerate its rate of spread (13). This is attributed to a lack of apical dominance of torpedograss rhizomes, a high rhizome regeneration rate, and the ability of the plant to absorb and store water and nutrients during periods of environmental stress.

The relative competitive abilities of weed and crop species are not constant but vary with environmental conditions, including soil pH (1, 15, 23). Weed competitive ability varied with both soil pH and the competing species (21). Decreasing soil pH might result in gradual, long-term changes in weed species composition through competitive interactions. This may be an important factor in weed ecology because soil acidification is increased by the use of acid-forming nitrogenous fertilizers (21).

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[3] Letters following this symbol are a WSSA-approved computer code from Composite List of Weeds, Weed Sci. 32, Suppl. 2. Available from WSSA, 309 West Clark Street, Champaign, IL 61820.

[4] Moreira, I. 1978. Propagation of *Panicum repens* by seed. Weeds and herbicides in the Mediterranean Basin. Proc. Mediterr. Herb. Symp., Madrid, Spain. Ministerio de Agricultura. Vol. 1:1–7.

The objectives of this research were to determine: a) whether torpedograss produces viable seed; b) how cogongrass is controlled by cultivation; and c) whether soil pH affects the relative competitiveness of cogongrass, torpedograss, and johnsongrass (included for comparative purposes).

MATERIALS AND METHODS

Plant collection and growing conditions. Plants and seed of cogongrass were collected from Grand Bay, AL; torpedograss plants and seed were collected from Pascagoula, MS; johnsongrass seed and rhizomes were supplied by Dr. Gene Wills, Delta Branch Experiment Station, Stoneville, MS. The grasses were planted and maintained in flats in a greenhouse to produce a source of rhizomes for the experiments. The plants received natural light, and temperatures ranged from 15 to 40 C.

Torpedograss seed germination study. Mature seed of torpedograss were collected from Pascagoula, MS, in August of 1982 and 1983. The seed were air dried and stored in polyethylene bottles at room temperature.

For all experiments, lots of 50 torpedograss seed were placed on two layers of Whatman No. 1 filter paper moistened with 9.0 ml of distilled water or test solution in 9-cm-diam petri plates. Seed were recorded as germinated if after 14 days the radicle extended 2 mm through the pericarp. A completely randomized design was used for each experiment with four replications for each treatment, and each experiment was repeated three times. The germination experiments were conducted within 4 months of seed collection and were repeated 1 yr later for seed collected in August 1982.

Temperature and light. Seed were placed in either continuous light or dark, or in a 16-h photoperiod at continuous temperatures of 15, 20, 25, and 30 C or at alternating 30/25 and 25/20 C. The high temperatures in the alternating temperature regime coincided with the 16-h photoperiod. Complete darkness was obtained by wrapping the petri dishes in four layers of aluminum foil.

Scarification. Germination was measured after two different seed coat scarification methods: seed soaked in concentrated sulfuric acid for 5, 10, 15, or 20 minutes, then rinsed with three changes of water; and seed tumbled in a sandpaper-lined drum for 10, 20, or 30 s. Seed were then placed in continuous light or darkness or in a 16-h photoperiod at 25 C or 25/20 C.

Chemical stimulators. Germination was measured after two different potential chemical stimulation tests: GA_3 treatment at 1.0×10^{-8} M, 1.0×10^{-6} M, or 1.0×10^{-4} M; and seed treated with KNO_3 at 1.0×10^{-4} M, 1.0×10^{-2} M, or 1.0 M solutions.

Rhizome desiccation study. Apical, six-node-long rhizome sections were excised from plants and allowed to air dry at room temperature to various percentages (35 to 60%) of the initial fresh weights. Following desiccation, rhizomes were planted 2 cm deep in commercial potting soil[5] in 15-cm-diam pots (volume 1.6 L, one rhizome section per pot). Five replicates of each treatment for each species were used, with the experiment repeated twice. All pots were watered just to excess daily with demineralized water. Shoot emergence was recorded 30 days later.

Rhizome depth-of-emergence study. Apical, six-node-long rhizome sections were planted at depths of 2, 4, 8, and 16 cm in the commercial potting soil[5] which had been watered to field capacity and placed inside 15-cm-diam plastic pipe sections (30 cm long) standing upright on aluminum plates. One rhizome section was used per pipe section. Pipe sections were weighed and watered daily to maintain the soil at field capacity.

The experiment was conducted in a growth chamber for a 30-day period with a 16-h photoperiod and a day/night temperature regime of 29/21 C. Photosynthetic photon flux density (PPFD) at the top of the pots was 450 $\mu E \cdot m^{-2} \cdot s^{-1}$. Cylinders were arranged in a randomized complete block, each block of three species at each of the treatment planting depths was replicated four times, and the experiment was performed four times. The number of emerged aerial shoots after 30 days was recorded for each species. At the start of each experiment, an additional four, six-node-long, apical rhizome sections of each species were oven dried for 48 h at 60 C, and weighed, and mean dry weights per section were calculated.

Germination of rhizome sections. Apical rhizome sections (10 cm long) were excised from vigorously growing plants of each species. The apical 2 cm was excised from one-half of these sections to give 8-cm-long sections without apices. Both decapitated and intact rhizome sections were planted 2 cm deep in commercial potting soil[5] in 15-cm-diam pots (volume 1.6 L, one rhizome section per pot). All pots were watered just to excess daily with demineralized water.

The experiment was conducted in a greenhouse with an average day/night temperature regime of 32/21 C. Thirty days after planting, shoot emergence was recorded.

Pots were arranged in a randomized complete block, each block of six treatments (three species with two rhizome lengths) was replicated 15 times, and the experiment was repeated three times.

Location of axillary buds on rhizomes. Intact rhizomes and cross-sections of the nodal regions of rhizomes of each species were examined for the presence of axillary buds with a dissecting microscope. The same rhizome sections and nodal cross-sections were fixed in FAA, dehydrated through an alcohol series, and transferred to amyl acetate. Next, the specimens were critical-point dried in a pressure bomb by replacing the amyl acetate in the tissue with liquid CO_2 and then increasing the temperature and pressure of the system until all the CO_2 present simultaneously entered the gaseous phase. This method produces dry specimens undamaged by the effects of surface tension (14). Specimens were mounted on aluminum stubs with double-stick tape, coated with gold-palladium, and examined with a

[5] Pro-mix. Capitol Agric. Serv. and Supply Co., Montgomery, AL.

scanning electron microscope[6] at 5 kV to confirm the light microscope findings.

Soil pH and interference. A greenhouse study was conducted to investigate the effects of soil pH and inter- and intraspecific plant interference on the growth and relative competitiveness of cogongrass, torpedograss, and johnsongrass. The plants received natural light supplemented with 16 h of incandescent light (10 $\mu E \cdot m^{-2} \cdot s^{-1}$ PPFD) for photoperiod control only. Temperatures varied between 14 and 41 C with an average temperature of 34 C day and 22 C night. The soil was fertilized before the start of the experiment as prescribed for forage production by the Alabama Cooperative Extension Service. Thirty days before the start of the experiment, 2.0 g $CaCO_3$/296 g soil was added to some of the soil (Rhodic Paleudult) and watered daily with demineralized water. This 30-day period permitted soil pH level to stabilize before planting. The two soil pH levels were 4.7 and 6.7, representing typical pH's for uncultivated and cultivated soil in the Southeastern United States.

The experiment was arranged as a randomized complete block experiment with a factorial arrangement of treatments, combining two soil pH levels [untreated soil (pH 4.7) and $CaCO_3$-adjusted soil (pH 6.7)] each with three interference levels (nine treatments) giving a total of 18 treatments. The nine interference treatments were obtained through the use of a modified replacement series design (15) and were grouped into three levels. The first level of three treatments had no competition (plants of each species growing with one plant/pot). The second level had three treatments with intraspecific competition (each species growing in monoculture at a density of two plants/pot). The third level consisted of three treatments with interspecific competition (cogongrass with johnsongrass, cogongrass with torpedograss, torpedograss with johnsongrass) with one plant of each species/pot. Treatments with one plant/pot (first level of treatments) provided a check for the effect of intraspecific and interspecific competition. The six treatments with two plants/pot (second and third levels of treatments) can be interpreted as three interlocking replacement series, one for each of the three possible pairs (6). Each block of nine interference treatments was replicated six times at each of the soil pH levels. The entire experiment was repeated. Six-node-long apical rhizome sections were planted 2.5 cm deep in 15-cm-diam pots (volume = 1.6 L) containing 1.2 L of soil. All pots were watered just to excess with demineralized water each morning. To minimize interference between plants in different pots, a bench area of 0.4 m^2 was allocated to each of the nine pots.

Plants were harvested after 56 days and roots and rhizomes were washed free of soil. Plant height (to the tip of the longest extended leaf) and leaf area were measured. Plants then were separated according to species, treatment, and plant part (leaves, stems, or roots and rhizomes). The plant parts were oven dried for 48 h at 60 C. Leaf, stem, root-rhizome, and total dry weights were recorded. At the start of the experiment, an additional 10, six-node-long, apical rhizome sections of each species were dried for 48 h at 60 C, and mean dry weights/section were calculated to determine average initial dry weights.

Analyses of variance were performed with selected comparisons of treatment means made by analysis of variance partitioning of degrees of freedom with single degree of freedom contrasts. Data from duplicate experiments were combined because results of the replicate experiments did not differ significantly according to analysis of variance.

RESULTS AND DISCUSSION

Torpedograss seed germination study. Torpedograss seeds failed to germinate with any of the germination-inducing treatments (data not shown). These results support Peng's Taiwan findings (13) that torpedograss does not produce viable seed. Thus, torpedograss apparently spreads only vegetatively in the lower coastal plains of the United States. However, since no vital test, such as tetrazolium, was performed, the possibility of deep dormancy cannot be discounted. Both cogongrass and johnsongrass growing in this area produce viable seed (data not shown).

Rhizome desiccation study. Air-drying of cogongrass, torpedograss, and johnsongrass rhizomes to 35 to 60% of initial fresh weight had no effect on subsequent regrowth (data not shown). The marked tolerance to desiccation of all three species would suggest that cogongrass intolerance to cultivation probably is not due to desiccation following exposure of previously buried rhizomes.

Rhizome depth-of-emergence study. Emergence of cogongrass and torpedograss was significantly reduced at burial depths greater than 4 cm, but the emergence reduction for cogongrass was much greater than for torpedograss (Table 1). Johnsongrass emergence was not significantly reduced at any burial depth. The reduced emergence of cogongrass when rhizomes are buried deeper than 4 cm may partially explain why this grass is controlled by cultivation (7, 13).

Table 1. Effect of planting depth on the emergence of cogongrass, torpedograss, and johnsongrass shoots.

Planting depth	Shoot emergence from 16 rhizomes after 30 days[a]		
	Cogongrass	Torpedograss	Johnsongrass
(cm)	(no.)		
2	15 a	14 a	15 a
4	15 a	16 a	15 a
8	3 b	11 c	14 a
16	0 c	4 b	13 a

[a]Treatments sharing the same letter within each row and column are not significantly different at the 5% level (selected comparisons made by analysis of variance partitioning of degrees of freedom with single degree of freedom contrasts).

[6]Model ISI SS-40. Internation Scientific Instruments, Massan, South Korea.

Table 2. Effect of removing the apical 2 cm of rhizomes of cogongrass, torpedograss, and johnsongrass rhizomes on shoot emergence.

Species	Shoot emergence from 30 rhizomes after 30 days[a]	
	Apex removed	Apex intact
	(no.)	
Cogongrass	1 a	29 b
Torpedograss	28 b	29 b
Johnsongrass	29 b	28 b

[a]Treatments sharing the same letter within each row and column are not significantly different at the 5% level (selected comparisons made by analysis of variance partitioning of degrees of freedom with single degree of freedom contrasts).

Germination of rhizome sections. The removal of the apical 2 cm of a 10-cm-long apical rhizome section generally prevented new shoot regrowth from cogongrass rhizomes but not from johnsongrass and torpedograss rhizomes (Table 2).

Location of axillary buds on rhizomes. An investigation of the whole rhizome systems of cogongrass showed an interesting developmental pattern. During the process of aerial shoot formation the rhizome apex grew upwards, and axillary buds at that site grew out to form new rhizomes. However, rhizome nodes further from the apex lacked axillary buds. Investigation of those nodes by stripping away the leaf sheath and observing the rhizome surface with the SEM (Figure 1) failed to disclose any evidence of axillary bud formation.

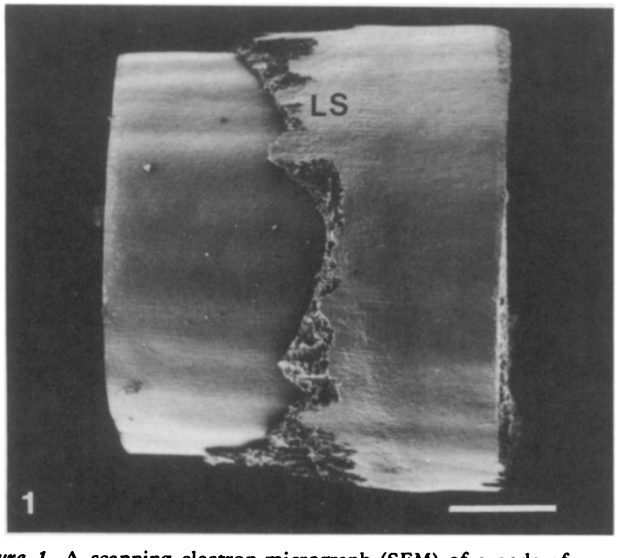

Figure 1. A scanning electron micrograph (SEM) of a node of cogongrass at some distance from the site of aerial shoot formation. The leaf sheath has been partially removed. No axillary bud is present. LS = leaf sheath. Bar equals 0.5 mm.

Generally, disconnection and fragmentation of a rhizome into nodal segments induces activation of buds in many rhizomatous grasses (10). Based on these observations, it would appear that much of the cogongrass rhizome system fails to produce axillary buds. Both torpedograss (Figure 2) and johnsongrass (Figure 3), however, produce axillary buds along the entire lengths of their rhizomes. Figure 2 is a scanning electron micrograph of an axillary bud on a rhizome node of torpedograss. Growth of these axillary buds leads to the subsequent production of numerous aerial stems. Figure 3 shows a surface view of an axillary bud at the node of a johnsongrass rhizome.

Restriction of axillary bud formation to the apical region of cogongrass is probably of major importance in slowing the spread of the species. Absence of axillary buds along the rest of the rhizome length, together with the inability of terminal rhizome fragments to grow if buried deeper than 4 cm, could explain why cogongrass is controlled by cultivation (7, 13). Fragmentation of the cogongrass rhizome system by cultivation would produce many rhizome fragments, but only a few apical pieces would be capable of producing aerial shoots. This lack of regrowth potential, plus the deep-turning action of a moldboard plow burying

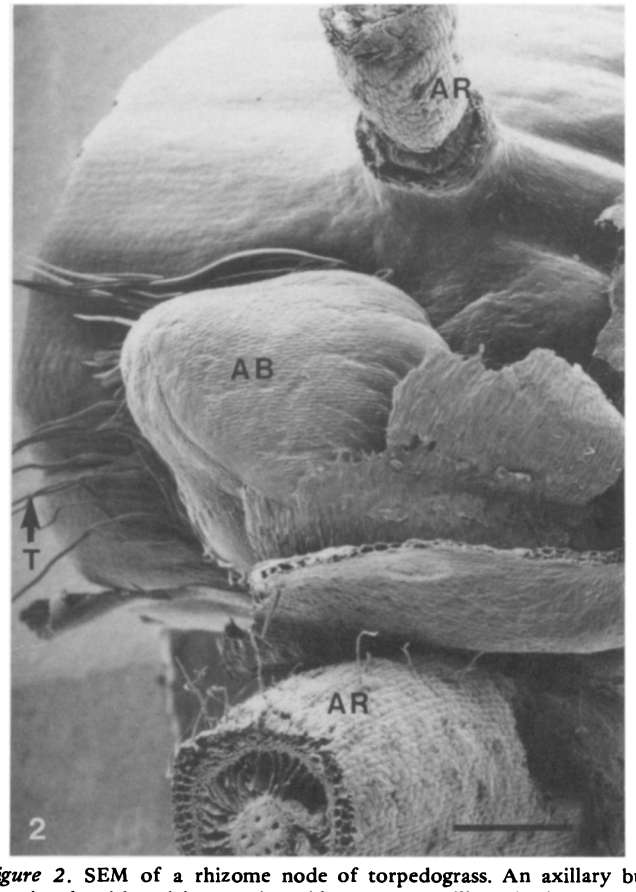

Figure 2. SEM of a rhizome node of torpedograss. An axillary bud associated with trichomes is evident. AB = axillary bud, AR = adventious root, T = trichome. Bar equals 0.5 mm.

Table 3. Effects of soil pH and species interference on dry matter production, height, and leaf areas of cogongrass.

Species	Competitor	Dry matter production[a]		Plant height[a]		Leaf area[a]	
		Soil pH					
		4.7	6.7	4.7	6.7	4.7	6.7
		(g/plant)		(cm)		(cm^2/plant)	
Cogongrass	None	5.8 a	4.4 b	24.9 a	23.7 a	460 a	330 b
	Cogongrass	2.9 bc	2.2 c	19.8 a	19.7 ac	210 b	160 c
	Torpedograss	3.5 b	3.3 bc	20.2 a	17.1 bc	260 bd	240 d
	Johnsongrass	2.3 c	2.3 c	13.5 b	13.9 b	160 c	160 c

[a]Treatments sharing the same letter within each species, row, and column are not significantly different at the 5% level (selected comparisons made by analysis of variance partitioning of degrees of freedom with single degree of freedom contrasts).

the cogongrass rhizomes, would effectively reduce regrowth. The lack of extensive axillary bud formation by cogongrass may provide an explanation for the contradictory findings of Peng (13), who reported no sprouting from rhizome fragments, and of Hubbard (9) who reported that even small rhizome fragments can generate new plants. Neither scientist reported whether apical portions were among the rhizome sections used.

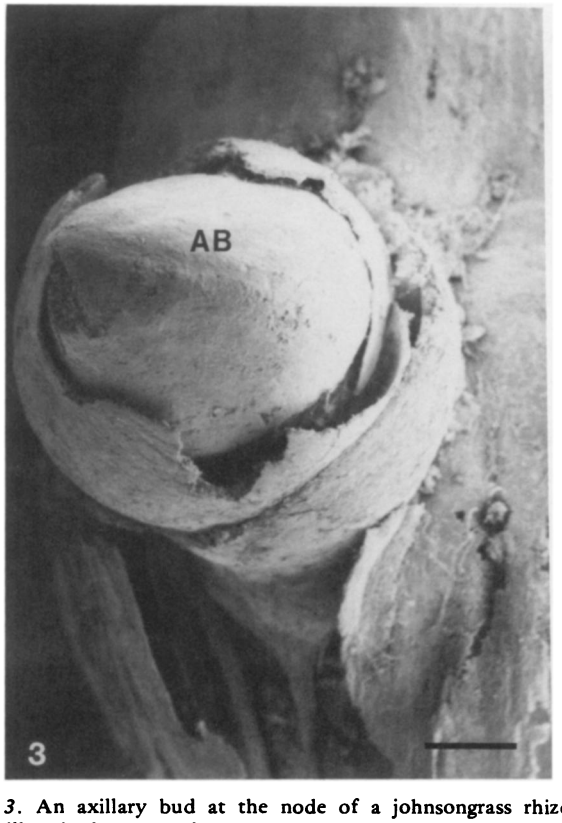

Figure 3. An axillary bud at the node of a johnsongrass rhizome. AB = axillary bud. Bar equals 0.5 mm.

In contrast, mechanical cultivation of johnsongrass or torpedograss would produce numerous fragments, most of which would bear axillary buds capable of producing aerial shoots even if buried relatively deeply in the soil.

Soil pH and interference. Soil pH treatments never affected dry matter production (DMP) and height, or biomass partitioning in torpedograss or johnsongrass (data not shown) and rarely in cogongrass. Cogongrass DMP (Table 3) in the absence of interference was lower at the higher pH level of 6.7. The reduced cogongrass DMP at pH 6.7 may be in part the result of reduced cogongrass leaf areas (Table 3) at pH 6.7, both in the absence of interference and with intraspecific interference. However, cogongrass leaf weight ratios (LWR) (Table 4) were lower at pH 4.7 than at pH 6.7 in the presence of intraspecific interference or interspecific interference from johnsongrass. Cogongrass root-rhizome weight ratios (RRWR) (Table 4) were lower at pH

Table 4. Effects of soil pH and species interference on biomass partitioning in cogongrass[a].

Species	Competitor	Root-rhizome weight ratio[b]		Leaf weight ratio[c]	
		Soil pH			
		4.7	6.7	4.7	6.7
		(g/g)			
Cogongrass	None	0.45 a	0.40 b	0.42 a	0.45 ab
	Cogongrass	0.44 a	0.38 b	0.41 a	0.46 b
	Torpedograss	0.46 a	0.40 b	0.38 a	0.46 b
	Johnsongrass	0.47 a	0.38 b	0.41 a	0.46 b

[a]Treatments sharing the same letter within each species, row, and column are not significantly different at the 5% level (selected comparisons made by analysis of variance partitioning of degrees of freedom with single degree of freedom contrasts).

[b]Root-rhizome weight ratio (RRWR) = root-rhizome dry weight/total dry weight, (g/g).

[c]Leaf weight ratio (LWR) = leaf dry weight/total dry weight, (g/g).

6.7 regardless of presence or type of interference. Teem et al. (20) found that a low soil pH reduced the elongation of primary roots of three weed species (prickly sida, *Sida spinosa* L.; sicklepod, *Cassia obtusifolia* L.; and tall morningglory, *Ipomoea purpurea* (L.) Roth.) to different extents. Previous research (18) has shown that cogongrass grows better in acid soils.

Generally, johnsongrass and torpedograss competition reduced DMP and height of cogongrass about equally. Johnsongrass usually reduced cogongrass leaf area more than torpedograss. There were no consistent effects of interference on biomass partitioning in any species. Soil pH treatments affected biomass allocation more than competition treatments (Table 4).

The slight but significant changes in growth (DMP and height) with changes in soil pH suggest that the gradually decreasing soil pH in agricultural fields, from frequent applications of acid-forming nitrogen fertilizers, may result in long-term changes in weed species composition through gradual competitive interaction effects (1, 21). Research (16) has indicated that plant dry matter production may be a more accurate indicator of the influence of environmental and competitive interactions than other growth parameters.

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