

Response of Selected Grass and Broadleaf Species to Cogongrass (*Imperata cylindrica*) Residues¹

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Abstract: Effects of cogongrass foliage and rhizome plus root residues on germination and shoot and root growth of barnyardgrass, bermudagrass, browntop millet, hemp sesbania, Italian ryegrass, and prickly sida were investigated in greenhouse experiments. Ground residues of dried cogongrass foliage and rhizomes plus roots were mixed separately with sterilized sand to obtain residue concentrations of 0, 0.25, 0.5, 1, 2, 4, and 8%. These residue concentrations were investigated on bermudagrass and Italian ryegrass, and the 8% residue concentrations were also evaluated on hemp sesbania, prickly sida, barnyardgrass, and browntop millet. Foliage and rhizome plus root residues at concentrations as low as 0.25% inhibited seed germination and shoot and root growth of all species except hemp sesbania. Germination of bermudagrass and Italian ryegrass was reduced by as much as 97% and shoot and root growth by as much as 94% at the highest residue concentrations. Rhizome plus root residues reduced germination and shoot and root growth of bermudagrass and Italian ryegrass more than foliage residues. Foliage and rhizome plus root residues reduced germination and shoot and root biomass of prickly sida, barnyardgrass, and browntop millet at similar levels. Results indicate that cogongrass tissue may contain allelochemicals that contribute to its invasiveness and extreme competitiveness.

Nomenclature: Barnyardgrass, *Echinochloa crus-galli* (L.) Beauv. #³ ECHCG; bermudagrass, *Cynodon dactylon* (L.) Pers. # CYNDA; browntop millet, *Brachiaria ramosa* (L.) Stapf. # PANRA; cogongrass, *Imperata cylindrica* (L.) Beauv. # IMPCY; hemp sesbania, *Sesbania exaltata* (Raf.) Rydb. ex A. W. Hill # SEBEX; Italian ryegrass, *Lolium multiflorum* Lam. # LOLMU; prickly sida, *Sida spinosa* L. # SIDSP.

Additional index words: Allelochemical, allelopathy, germination, growth inhibition, plant residues, root growth, seedling, shoot growth.

Abbreviations: DAP, days after planting; DDW, double-distilled water.

INTRODUCTION

Cogongrass is a C₄, rhizomatous, perennial monocot that has become an invasive weed in many gulf states of the southeastern United States since its introduction to the United States in the late 19th and early 20th centuries (Byrd and Bryson 1999; Dickens 1974; Dickens and Buchanan 1971; Elmore 1986). Culms of cogongrass ascend from scaly rhizomes and typically reach heights of 1.2 m but can grow to heights of 3 m (Brown 1944; Holm et al. 1977). Cogongrass is among the most trou-

blesome weeds worldwide (Falvey 1981; Holm et al. 1977). It grows in tropical, subtropical, and some temperate regions of the world (Akobundo and Agyakwa 1998; Bryson and Carter 1993) and is found on all continents except Antarctica (Holm et al. 1977; Hubbard 1944). Cogongrass spreads mainly by seed and rhizomes (Dozier et al. 1998) and thrives in infrequently cultivated areas, roadways, forests, pastures, mining areas, pine plantations, parks, and other natural and recreational areas (Colie and Shilling 1993; Dozier et al. 1998; Willard et al. 1990).

Cogongrass is extremely competitive with crops and neighboring plant communities (Eussen and Wirjahardja 1973). Cogongrass has been reported to reduce corn (*Zea mays* L.) grain yield by 80 to 100% (Koch et al. 1990; Udensi et al. 1999). Koch et al. (1990) also reported >90% yield reduction for intercropped corn and cassava (*Manihot esculenta* Crantz) grown in cogongrass-infested fields. The ability of cogongrass to extract soil mois-

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³ Letters following this symbol are a WSSA-approved computer code from *Composite List of Weeds*, Revised 1989. Available only on computer disk from WSSA, 810 East 10th Street, Lawrence, KS 66044-8897.

ture from shallow soil depths makes it extremely competitive toward other grass species, particularly desirable perennial grasses (Dozier et al. 1998). Cogongrass also competes with other plant species via allelopathic-type mechanisms. Research by Casini et al. (1998) found that liquid extracts of cogongrass residues reduced germination and early development of rice (*Oryza sativa* L.). Rice germination was reduced 11 to 15%, and plant height and leaf number per plant were reduced 22 and 43%, respectively. However, allelopathic-type research of cogongrass up to this point has focused on in vitro assays using liquid extracts of cogongrass tissue. Inderjit et al. (2001) reported that residues of the allelopathic species in question mixed with a soil-type medium are closer to a true-field ecological setting than those of in vitro aqueous extracts of the potential allelopathic species. In addition, information on the effect of cogongrass residues on grasses, common to the same terrestrial areas as cogongrass, such as roadways, pastures, mining areas, parks, and other natural and recreational areas, is lacking. Therefore, the objectives of this research were to determine the effect of cogongrass residues, mixed in a soil-based medium, on germination and growth of bermudagrass and Italian ryegrass, two desirable grasses commonly found in areas with cogongrass, as well as various annual dicotyledonous and monocotyledonous weed species.

MATERIALS AND METHODS

Cogongrass residues were prepared by harvesting foliage and rhizome plus root (rhizome–root) biomass of mature plants from an established solid stand of cogongrass located at the U.S. Department of Agriculture Southern Weed Science Research Farm, Stoneville, MS (33°N latitude). The soil was a Dundee silt loam (fine-silty, mixed, thermic Aeric Ochraqualf) with soil textural fractions of 26% sand, 55% silt, and 19% clay. Foliage and rhizome–root biomass was harvested in mid-August 2002 when plants were in the postbloom growth stage. Foliage was harvested by clipping all aboveground biomass from randomly selected 31- by 31-cm areas. After removing foliage, the top 15 cm of soil plus rhizome–root biomass was removed with a shovel from these 31- by 31-cm areas. Four 5-cm-diam by 15-cm-deep soil cores (soil moisture cores) were collected with a hand soil probe, weighed, and sealed in plastic bags so that soil moisture could be determined. Foliage and soil plus rhizome plus root samples were placed in separate plastic bags that were sealed and placed in coolers for transport to the laboratory. Soil plus rhizome–root samples

were weighed before washing rhizome and roots free of soil with water. Foliage, rhizome–root, and soil moisture core samples were placed in a forced-air oven and dried at 45 C until dry. Each sample was then weighed, and the foliage and rhizome–root samples were ground in a Wiley mill equipped with a 1-mm-mesh sieve. Ground residues of foliage and rhizomes–roots were placed in separate screw-top sterilized plastic bottles and stored in the dark at 4 C until further use.

Concentrations of cogongrass foliage and rhizome–root residues were determined according to observed shoot:rhizome–root:soil concentrations (wt/wt) in the field from which the samples were obtained. The average total dry weight of foliage plus rhizomes–roots plus soil for each 31-cm-long by 31-cm-wide by 15-cm-deep sample was 24 kg. The proportion of dry to wet weight of the soil moisture cores was used to account for the weight of moisture in soil plus root samples. Foliage and rhizomes–roots accounted for 1.5 and 5% of the total sample dry weight, respectively. The concentrations evaluated for foliage and rhizome–root residues on a separate basis were 0, 0.25, 0.5, 1.0, 2.0, 4.0, and 8.0% (wt/wt). Designated amounts of foliage and rhizome–root residues were mixed separately with 500 g of sterilized silica sand in self-sealed plastic bags to obtain the proper cogongrass residue concentrations. For example, 40 g of dried, ground foliage or rhizome–root tissue was mixed with 500 g sand for the 8% (wt/wt) concentration. Mixtures of cogongrass residue and sand were placed on top of a sterilized Whatman #1 filter paper⁴ in sterilized 11-cm-diam plastic pots. Sand, filter papers, and pots were heat sterilized in a forced-air oven at 110 C for 1 h (three times) at 48-h intervals.

Twenty-five seeds of bermudagrass and Italian ryegrass, purchased from a local vendor,⁵ were placed on top of the cogongrass residue–sand mixture in four pots of each residue (foliage and rhizome–root) by concentration combination. Twenty-five seeds of barnyardgrass, browntop millet, hemp sesbania, and prickly sida, purchased from the same vendor,⁵ were placed in four pots of the 8% foliage and rhizome–root residue concentrations. A nontreated check comprising sand without cogongrass residue was included. Pots containing barnyardgrass, bermudagrass, browntop millet, hemp sesbania, and prickly sida were placed in a greenhouse maintained at 30/21 C (± 3 C) day/night temperatures. Pots with Italian ryegrass were placed in a separate adjacent greenhouse maintained at 22/15 C (± 3 C) day/night tem-

⁴ Whatman #1, Fisher Scientific, 711 Forbes Avenue, Pittsburgh, PA 15219.

⁵ Azlin Seed Service, P.O. Box 914, Leland, MS 38756.

peratures. Natural light was supplemented in both greenhouses with light from sodium vapor lamps (400 $\mu\text{mol}/\text{m}^2 \text{ s}$) to provide a 14-h photoperiod. All pots were sub-irrigated with double-distilled water (DDW) as needed for the first 10 d after planting (DAP), after which pots were subirrigated with DDW every third day and a 1% Hoagland solution (Hoagland and Arnon 1950) every tenth day. A plastic saucer was placed under each pot for the duration of the study to prevent loss of any water-soluble phytotoxic compounds that may have been present in the cogongrass residues.

Ten DAP, the number of germinated seeds in each pot was recorded and germinated seedlings were thinned to 3 plants/pot. Additional seeds that germinated after 10 DAP were counted and removed. Shoots were clipped at the soil surface, and roots of each plant were rinsed clean of cogongrass residue and sand with water 30 DAP. Shoots and roots were oven-dried at 40 C for 5 d.

Statistical Analysis. A randomized complete block design with four replications was used in all experiments. Each experiment was conducted twice. The data represent the average of the two experiments for each study because no experiment by treatment interaction occurred. Data were subjected to ANOVA using Proc Mixed with sum of squares partitioned to reflect a split-split-plot treatment structure for each study (SAS 2001). Plant species was considered the main plot, type of extract (foliage or rhizome-root) was treated as the subplot, and the extract concentration was treated as sub-subplot. For bermudagrass and Italian ryegrass, germination (total number of seeds germinated from 0 to 30 DAP) and shoot and root biomass data were presented as a percentage of the nontreated check. Polynomial regression analysis and ANOVA were used to determine the effect of cogongrass foliage and rhizome-root residue concentration on germination and shoot and root biomass of bermudagrass and Italian ryegrass. Pseudo R^2 values were calculated to assess the goodness of fit for individual regression equations. R^2 values were obtained by subtracting the ratio of the residual sum of squares to the corrected total sum of squares from one. The residual sum of squares was attributed to that variation not explained by the fitted line. The R^2 and residual mean squares were used to determine the goodness of fit to polynomial models. For barnyardgrass, browntop millet, hemp sesbania, and prickly sida, mean values of germination and shoot and root data were separated using Fisher's protected LSD test at $P = 0.05$.

Table 1. Effect of foliage and rhizome-root cogongrass residues on germination and growth of Italian ryegrass (LOLMU) and bermudagrass (CYNDA).

Cogongrass residue	Residue concentration	Germination ^a		Shoot biomass ^b		Root biomass ^c	
		LOL- MU	CYN- DA	LOL- MU	CYN- DA	LOL- MU	CYN- DA
		% (wt/wt)					
Foliage	0.25	97	68	56	64	60	57
	0.5	89	58	46	38	51	35
	1.0	84	32	41	28	42	27
	2.0	72	24	38	24	36	22
	4.0	56	15	28	13	32	11
	8.0	40	5	25	12	29	11
Root-rhizome	0.25	89	60	52	40	55	34
	0.5	85	38	38	24	49	21
	1.0	76	9	32	18	39	18
	2.0	63	5	29	17	31	16
	4.0	49	4	25	16	26	12
	8.0	40	3	18	6	24	6

^a Regression analysis—Foliage residue: LOLMU, $y = -16.3 \ln(x) + 78.7$, $R^2 = 0.96$; CYNDA, $y = -18.6 \ln(x) + 40.1$, $R^2 = 0.96$. Rhizome-root residue: LOLMU, $y = -15.1 \ln(x) + 72.2$, $R^2 = 0.97$; CYNDA, $y = -16.3 \ln(x) + 25.3$, $R^2 = 0.78$.

^b Regression analysis—Foliage residue: LOLMU, $y = -8.7 \ln(x) + 42.1$, $R^2 = 0.97$; CYNDA, $y = -13.9 \ln(x) + 34.7$, $R^2 = 0.88$. Rhizome-root residue: LOLMU, $y = -8.8 \ln(x) + 35.4$, $R^2 = 0.93$; CYNDA, $y = -8.1 \ln(x) + 22.9$, $R^2 = 0.85$.

^c Regression analysis—Foliage residue: LOLMU, $y = -9.3 \ln(x) + 44.8$, $R^2 = 0.95$; CYNDA, $y = -12.8 \ln(x) + 31.5$, $R^2 = 0.91$. Rhizome-root residue: LOLMU, $y = -9.5 \ln(x) + 40.8$, $R^2 = 0.97$; CYNDA, $y = -7.9 \ln(x) + 20.1$, $R^2 = 0.92$.

RESULTS AND DISCUSSION

Bermudagrass and Ryegrass. Germination for nontreated bermudagrass and Italian ryegrass was 66 and 75%, respectively (data not shown). Average shoot and root dry weight biomass were 528 and 457 mg for bermudagrass and 2,080 and 1,665 mg for Italian ryegrass, respectively (data not shown).

Both foliage and rhizome-root cogongrass residues reduced germination of bermudagrass and Italian ryegrass (Table 1). Regression analysis for germination of both species best fit a nonlinear model, with quadratic reduction in germination as cogongrass residue concentration increased. Residue concentrations as low as 0.5% for Italian ryegrass and 0.25% for bermudagrass reduced germination compared with the nontreated check. Germination of Italian ryegrass ranged from 89 to 97% of the nontreated check at the lowest concentrations (0.25%) of rhizome-root and foliage residues and was 40% at the highest (8%) concentrations. Germination of bermudagrass was affected more by residues than Italian ryegrass, with a 44% higher degree of reduction in germination of bermudagrass than Italian ryegrass when pooled across residue type and concentration. Germination of bermudagrass ranged from 60 to 68% at the lowest concentration of rhizome-root and foliage residues

Table 2. Effect of foliage and rhizome plus root cogongrass residues (8%, wt/wt, concentration) on germination and shoot and root biomass of hemp sesbania, prickly sida, barnyardgrass, and browntop millet.^{a,b}

Cogongrass residue	Hemp sesbania			Prickly sida			Barnyardgrass			Browntop millet		
	Germ ^c	Shoot	Root	Germ ^c	Shoot	Root	Germ ^c	Shoot	Root	Germ ^c	Shoot	Root
	%	mg		%	mg		%	mg		%	mg	
Nontreated ^d	76	2,204	1,348	71	1,409	849	55	984	410	64	1,160	489
Foliage ^e	71	2,159	1,289	35	567	325	10	309	102	13	412	214
Rhizome–root ^e	71	2,084	1,257	30	501	251	7	278	108	8	387	145
LSD (0.05)	NS	NS	NS	6	245	198	7	187	121	6	114	138

^a Abbreviations: Germ, germination; NS, not significant.

^b Shoot and root biomass based on average weight of 3 plants/pot, harvested 30 d after planting and dried at 40 C.

^c Number of seeds out of a possible 25 per pot for each residue treatment that germinated between 0 and 30 d after planting.

^d Five hundred grams of sterilized sand.

^e Forty grams of residue mixed with 500 g of sterilized sand, resulting in an 8% (wt/wt) concentration.

to less than 6% germination at the highest concentrations of both residues. Overall, rhizome–root residues reduced germination of both species more than foliage residues, with 10% lower germination of both species when planted in rhizome–root residue compared with foliage residue.

Both foliage and rhizome–root cogongrass residues reduced shoot biomass of both grass species (Table 1). Reduction in shoot biomass of both grasses followed a similar trend as germination, with a nonlinear quadratic reduction in shoot biomass as residue concentration increased. Shoot biomass of Italian ryegrass ranged from 52 to 56% of the nontreated check at the 0.25% concentrations of rhizome–root and foliage residues and was 18 to 25% at the 8% concentrations. Rhizome–root residues had more impact on bermudagrass than foliage residues. Shoot biomass of bermudagrass was 6 to 40% of the nontreated when grown in rhizome–root residues, compared with 12 to 64% with foliage residues.

Root biomass of both grasses best fit a quadratic reduction with increasing concentration of cogongrass foliage and root residues (Table 1). Root biomass of both species was significantly reduced with each increase in residue concentration up to 2%. For both types of residue, there was no difference in root biomass of either species between the 4 and 8% residue concentrations. Root growth of bermudagrass was affected more by cogongrass residues than Italian ryegrass. Root biomass of bermudagrass was 6% of the nontreated check at the highest concentration of rhizome–root residue and 57% with the lowest concentration of foliage residue, whereas root biomass of Italian ryegrass was 24 to 60% (both foliage and rhizome–root residues) of the nontreated check. Type of cogongrass residue did not affect root biomass of Italian ryegrass, with 2 to 5% difference in Italian ryegrass root biomass between residue type at

each concentration level. However, rhizome–root residues reduced root biomass of bermudagrass by as much as 23% compared with foliage residues.

Overall, bermudagrass and Italian ryegrass responded similarly to foliage and rhizome–root cogongrass residues, with a nonlinear reduction in germination as well as shoot and root biomass. The nonlinear response for each parameter was attributed to substantial reduction, with an increase in residue concentrations between 0.25 and 2% and a leveling off in reduction between the 4 and 8% concentrations. Thus, there was often little difference between the 4 and 8% concentrations for either residue type with respect to germination and growth of both grasses. In general, rhizome–root residues suppressed germination and shoot and root biomass of both grasses more than foliage residues. However, in most cases, both residues often reduced germination and shoot and root biomass for both grasses at concentrations as low as 0.25%. Thus, both foliage and rhizome–root tissue of cogongrass may contain an allelopathic substance that elicits a competitive advantage for cogongrass by suppressing germination and growth of desirable grasses. The low concentration levels of residues evaluated in this research corresponded with subinfestation levels of cogongrass, whereas the higher residue concentrations of 2 to 8% were similar to those levels identified in the field from which cogongrass residues were obtained (solid-stand infestation).

Weeds. Percent germination and shoot and root biomass of nontreated weeds are listed in Table 2. Foliage and rhizome–root cogongrass residues (8% concentration of each) reduced germination as well as shoot and root biomass of prickly sida, barnyardgrass, and browntop millet (Table 2). There was no difference between the type of residue with respect to germination reduction or shoot

and root biomass for prickly sida, barnyardgrass, and browntop millet. Germination of prickly sida, barnyardgrass, and browntop millet was reduced 36 to 56% by both residue types. Shoot and root biomass of prickly sida, barnyardgrass, and browntop millet were reduced by 56 to 75% with foliage and rhizome–root cogongrass residues. Cogongrass residues had no effect on germination or shoot and root biomass of hemp sesbania. Some legumes are capable of competing with cogongrass. Velvetbean (*Mucuna pruriens* var. *utilis*) planted for a cover crop is capable of reducing stand density of cogongrass (Udensi et al. 1999).

Our results are similar to findings of Inderjit and Dakshini (1991), where root residue inhibited germination of several small-seeded broadleaf crop species more than foliage residue. Reduction of shoot growth of bermudagrass and Italian ryegrass followed trends similar to that of germination and root biomass reduction; however, there was no difference in the type of cogongrass residue with respect to shoot biomass reduction.

Based on this study, cogongrass probably contains an allelopathic substance that contributes to its extreme invasiveness and competitiveness. To determine the true phytotoxicity of a potential allelopathic substance, the substance must be isolated and the inhibitory mode of action identified. Inderjit and Dakshini (1991) found foliage and root residues of cogongrass to contain several phenolic compounds that inhibited germination and seedling development of radish, mustard, and tomato. Further research on the presence or absence of these compounds, as well as other potential allelopathic substances, in cogongrass biotypes is needed.

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