

Effects of Temperature and Exposure Period to Heat on Cogongrass (*Imperata cylindrica*) Viability

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Cogongrass, a rhizomatous perennial, is among the world's most troublesome weeds. Research was conducted at the Southern Weed Science Research Unit, Stoneville, MS, to determine cogongrass rhizome mortality with increasing temperature and duration of exposure to heat and to determine if 2,3,5 triphenyl tetrazolium chloride (TTC) could be used to evaluate cogongrass rhizome mortality following heat treatment. Cogongrass rhizome mortality was 100% at 65, 79, 93, 107, 121, 149, 177, and 187 C at time periods greater than or equal to 25, 5, 2.5, 2.5, 2.5, 2, 2 and 1 min, respectively. The duration of heat required for cogongrass mortality decreases as temperature increased. The standard greenhouse bioassay was more effective than tetrazolium chloride in predicting viability of cogongrass rhizomes following heat treatments.

Nomenclature: Cogongrass, *Imperata cylindrica* (L.) Beauv. IMPCY.

Key words: Asphalt plant, heat mortality, tetrazolium chloride.

Cogongrass, a rhizomatous perennial, is among the most troublesome weeds worldwide and ranks as the world's seventh worst agricultural weed (Falvey 1981; Holm et al. 1977). It grows in tropical, subtropical, and some temperate regions of the world and is found on all continents except Antarctica (Akobundu and Agyakwa 1998; Bryson and Carter 1993; Holm et al. 1977; Hubbard 1944). Since its introduction to the United States, cogongrass has become an invasive weed in the southeastern United States (Byrd and Bryson 1999; Dickens 1974; Dickens and Buchanan 1971). Cogongrass is now established in Alabama, Florida, Georgia, Louisiana, Mississippi, Oregon, South Carolina, Texas, and Virginia (Bryson and Carter 1993; Byrd and Bryson 1999, Faircloth et al. 2005).

Foliage and culms of cogongrass ascend from scaly rhizomes and reach heights of 1.2 to 3 m (Brown 1944; Holm et al. 1977). Cogongrass spreads mainly by seed and rhizomes (Dozier et al. 1998), and thrives along roadways and in pastures, forests, pine plantations, infrequently cultivated areas, mining areas, parks, and other natural and recreational areas (Coile and Shilling 1993; Dozier et al. 1998; Willard et al. 1990). In these areas, cogongrass is extremely competitive with native and desirable plants and crops for light, water, nutrients, and physical space (Eussen and Wirjahardja 1973). It is highly adaptable to a wide range of environmental and edaphic conditions and frequently forms dense, monotypic stands over large areas (Chikoye et al. 1999; Garrity et al. 1996). Because cogongrass extracts soil moisture from shallow soil depths, it is particularly competitive with other perennial grasses (Dozier et al. 1998). Cogongrass also has potential to compete with other plant species via allelopathy (Casini et al. 1998; Eussen 1979; Inderjit and Dakshini 1991; Koger and Bryson 2004; Koger et al. 2004). Cogongrass is a pyrogenic

species that relies on fire for survival and propagule dispersal (Eussen and Wirjahardja 1973) and forms mega-grasslands or "sheet" *Imperata*, which can cover more than 10,000 contiguous ha in Indonesia (Garrity et al. 1996). Cogongrass maintains vegetative dominance because its dense thatch promotes very intense and hot fires that destroy most other aboveground vegetation, ultimately altering natural ecosystems (Eussen and Wirjahardja 1973; Lippincott 2000; Soerjani and Soemarwoto 1969). The subterranean cogongrass rhizomes are insulated from fire by the soil and give rise to dense, monotypic stands (Lippincott 2000).

The most effective herbicides for cogongrass management include glyphosate and imazapyr (Dozier et al. 1998; Udensi et al. 1999). At high rates, these herbicides provide partial control of cogongrass up to 1 yr after application (Miller 1999) and multiyear applications result in greater efficacy for both herbicides (Johnson et al. 1999). Multiple applications with glyphosate and/or imazapyr or single applications of soil sterilant herbicides such as bromacil or diuron + imazapyr provide acceptable but expensive cogongrass control (Dickens and Buchanan 1975; Johnson et al. 1999). However, imazapyr and other soil sterilant herbicides prevent reestablishment of much or all the desirable native vegetation, a critical component of rehabilitation process (Byrd and Bryson 1999; Johnson et al. 1999).

Chemical and cultural control of cogongrass is very difficult because of vigorous rhizome expansion and the extensive rhizome biomass in relation to the aboveground biomass (Tominaga 1993; Tominaga et al. 1989). Three types of cogongrass rhizomes were designated as pioneer rhizomes, secondary colonizing rhizomes and tillering rhizomes (Tominaga 1993). Of these types, the "pioneer" rhizomes are larger and thicker than the other two types, elongate vigorously up to 25 cm from parent shoots, are 3 to 4 mm in diameter, and play an important role in invading new areas (Tominaga 1993).

Less expensive, nonrecurring alternative methods for control of cogongrass are being sought by various federal, state, and local departments of transportation and utility companies to eliminate cogongrass from right-of-ways. We hypothesize that

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excavated cogongrass rhizomes may be killed by exposure to high temperatures under conditions produced in furnaces of asphalt plants, such as temperature of 160 to 177 C with an operating time of approximately 10 min followed by storage in a silo for an additional 3 to 4 hr awaiting truck delivery to site (personal communication, David Thompson). Once cogongrass rhizomes are heat killed, the dead cogongrass debris and soil could be returned as fill, providing a suitable substrate for reestablishment of acceptable vegetation.

TTC is effective in determining seed viability (ISTA 1985), but it has not been utilized to determine rhizome viability in perennial grasses such as cogongrass. TTC serves as a terminal electron acceptor, in lieu of oxygen, for many nonspecific dehydrogenases (Mattson et al. 1947). Thus, when organs are actively respiring, they reduce TTC to triphenyl tetrazolium formazan, a compound with deep red color. The objectives of this research were to determine the amount and duration of heat required to kill cogongrass rhizomes and to determine if tetrazolium chloride could be used as a rapid assay technique to evaluate cogongrass survival.

Materials and Methods

Cogongrass rhizomes were harvested from an established solid stand of cogongrass located in a contained area at the USDA Southern Weed Science Research Farm, Stoneville, MS (33°N latitude) during the summer of 2003. Of the three types of cogongrass rhizomes designated by Tominaga (1993), only pioneer rhizomes were used for this research. The soil in which the cogongrass was established was a Dundee silt loam (fine-silty, mixed, thermic Aeric Ochraqualfs) with soil textural fractions of 26% sand, 55% silt, and 19% clay. At harvest, cogongrass foliage formed a solid stand 0.8 to 1.2 m tall and most rhizomes (80% total plant fresh weight) were in the top 20 cm of the soil. Cogongrass rhizome of 0.6 to 0.7 cm diameter were cut transversely into 10 10-cm-long segments and subjected to temperatures of 52, 65, 79, 93, 107, 121, 149, 177, and 187 C at each time period of 0.5, 1, 1.5, 2, 2.5, 5, 10, 15, 20, 25, and 30 min. A control treatment (nontreated) was established for each replication. Cogongrass rhizomes were harvested and cut into sections prior to each treatment. Replications were run independently and usually required 1 to 2 d for completion of each replication. A countertop laboratory oven¹ was used to achieve the required temperatures. The oven was brought to target temperature prior to inserting cogongrass rhizomes. Cogongrass rhizome segments were placed on a metal pan and into the oven for each time period. Following heat treatment, five cogongrass rhizome segments for each temperature and time period were weighed and placed in 8 × 15 cm trays in a 50/50 v/v Bosket sandy loam soil (Mollic Hapludalfs)/sphagnum mixture, covered lightly with the soil mixture, and allowed to sprout in the greenhouse. Soil in trays was watered lightly as needed to maintain soil moisture. The greenhouse was maintained at temperatures of 20/30 ± 3 C night/day without supplemental lighting. Fresh and dry weight of each rhizome segment and corresponding shoots were recorded separately at 6 wk.

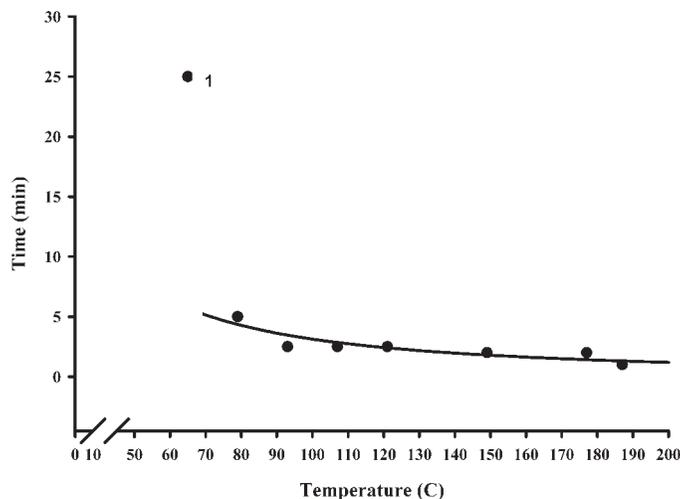


Figure 1. Time and temperature required to kill cogongrass rhizomes (• actual data) and an expected model (—). The expected model used a nonlinear regression to fit the trend: $Y = 1884 * \text{temperature}^{-1.39}$, $r^2 = 0.79$. 165 C was not included to develop the regression equation because this temperature is outside the temperature and time parameters for an asphalt plant.

Tetrazolium Chloride to Determine Cogongrass Viability.

Following exposure to temperatures of 52, 65, 79, 93, 107, 121, 149, 177, and 187 C at each time period of 0.5, 1, 1.5, 2, 2.5, 5, 10, 15, 20, 25, and 30 min, cogongrass rhizome segments (0.6 to 0.7 cm diameter by 10 cm long) were cut in half, then sectioned longitudinally. For each temperature and time combination, five cogongrass rhizome segments per treatment were placed individually in a screw cap 10-ml plastic vial. Five milliliters of a 1% (1 g/100 ml water) 2,3,5 triphenyl tetrazolium chloride (TTC)² solution was added to each vial and capped immediately. Capped vials were placed in the dark and maintained at a temperature of 22 ± 2 C. After 24 h, vial caps were removed and cogongrass rhizomes were visually determined to be stained pink or not.

Statistical Analysis. The experiment was conducted as a factorial design (9 temperatures by 11 time intervals) with five subsamples per treatment, four replications, and the experiments were repeated. From the five subsamples, cogongrass mortality was determined as the average percent of cogongrass rhizomes that produced no shoots. Traditional analysis of variance for rhizome mortality was not appropriate because it did not meet the assumption for homogeneity of variance among treatments. Regression was used to fit an exponential trend predicting time required for 100% mortality, because the main interest of the research was to predict the minimum time and temperature to achieve maximum rhizome mortality. This exponential trend was linearized by the log of time and temperature and to fit a log-linear trend.

The regression equation developed for predicting time as a function of temperature for 100% cogongrass mortality (Figure 1), and this equation the trend fit the data well ($f = 18.7$, $P \leq 0.01$, $r^2 = 0.79$). Because TTC was a poor predictor of 100% mortality, a predicted 95% mortality was calculated by interpolating between mortality greater than 95% and the percent mortality at the next lower time period. From data,

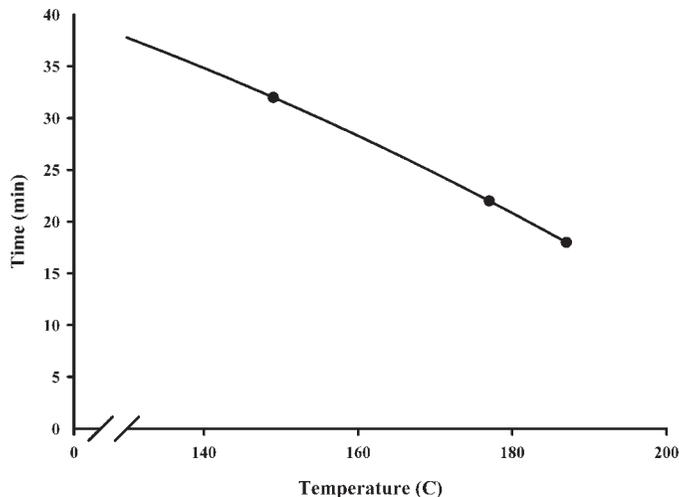


Figure 2. Time and temperature required for tetrazolium chloride to determine 95% cogongrass rhizome mortality effectively (● actual data) and an expected model (—). The expected model used a nonlinear regression to fit the trend: $Y = 55.47 + 0.015 * \text{temperature} - 0.0011 * \text{temperature}^2$, $r^2 = 0.99$.

only three points could be calculated for cogongrass mortality less than or equal to 95% level (Figure 2). A regression equation was developed for the efficacy of TTC to predict time as a function of temperature for 95% cogongrass rhizome mortality (Figure 2). In this equation, the trend fit the data well ($f = 16.2$, $P \leq 0.01$, $r^2 = 0.99$).

Results and Discussion

Heat Treatments. The duration of heat required for cogongrass mortality decreased as temperature increased. Cogongrass rhizome mortality was 100% as long as temperatures were 65, 79, 93, 107, 121, 149, 177, and 187 C for time periods equal to or greater than 25, 5, 2.5, 2.5, 2.5, 2, 2 and 1 min, respectively (Figure 1). No cogongrass rhizome mortality occurred at 52 C at any time period and at 65, 79, 93, 107, 121, 149, 177, and 187 C at time periods less than or equal to 5, 2, 2, 1.5, 1, 0.5, 0.5, and 0.5 min, respectively (data not shown). Cogongrass mortality was 97, 50, 68, 29, 41, and 42% for temperatures of 65, 79, 93, 121, 149, and 177 C at time periods of 10, 2.5, 2, 1.5, 1, and 1 min, respectively (data not shown). The time required for 100% cogongrass mortality at 52 C was not used to develop the regression equation because cogongrass mortality was not achieved at time intervals less than or equal to 30 min. Likewise, 65 C was not included to develop the regression equation because a simple trend would not work to describe that point and because this temperature falls outside temperature and time parameters used in asphalt plants (Figure 1).

From the time intervals that were calculated for 95% cogongrass rhizome mortality, cogongrass rhizome mortality was calculated to require 9.5 min at 65 C. Time intervals for temperatures greater than or equal to 79 C were similar (less than 0.03 min.) to those required for 100% mortality (data not shown). However, use of a model for less than 100% mortality is not practical for cogongrass, because a single surviving

rhizome fragment would likely reproduce asexually, infesting additional sites, as has been documented by past dispersal events (Dickens 1974; Dickens and Buchanan 1971; Eussen and Wirjahardja 1973; Garrity et al. 1996; Hubbard 1944).

Excavation and transportation of cogongrass to an asphalt plant or to a furnace would add expense to the cost of killing cogongrass rhizomes. Likewise, separation of cogongrass rhizomes from soil prior to heat treatment in an asphalt plant or furnace could add expense and increase the likelihood for rhizome fragmentation and dispersal. Therefore, heat treatment of a mixture of soil and cogongrass would be recommended. In a cogongrass and soil mixture, time and temperatures required to achieve cogongrass rhizome mortality would be dependent on soil moisture content and size of soil particles encapsulating the rhizomes. Development of a mobile furnace for heat treatment might be cost effective when used at distant locations. Despite the cost for excavation, transportation, and heat treatment, the expense for cogongrass elimination may be less with this method than with multiple herbicide applications per year and over several years. Thus, additional research is needed to determine the time required to achieve cogongrass rhizome mortality under different soil conditions. However, from data presented herein (Figure 1), cogongrass rhizome mortality can be achieved at certain critical temperatures and duration of time.

Differential sprouting time of surviving cogongrass rhizomes was unexpected. Cogongrass rhizomes sprouted 7 to 10 days sooner for all time periods at temperatures of 52 C when compared to other temperature and duration of temperature regimes and when compared to cogongrass rhizomes that were not heat treated. Consequently, shoot dry weights were greater for treatments at 52 C when compared to the shoot dry weights of other temperature and duration of temperature regimes and rhizomes that were not treated with heat. At 52 C, cogongrass shoot dry weights were greater than or equal to 21.2 mg for duration of heat periods between 0.5 and 30 min was significantly greater than dry cogongrass shoot weight from rhizomes that were not exposed to heat treatments (11.5 mg) (data not shown). This response may explain why cogongrass regrowth and flowering was earlier following fire in the late winter and early spring than in unburned areas at several sites in Mississippi (Bryson, personal observations).

Tetrazolium Chloride to Determine Cogongrass Viability. Although TTC is effective in determining seed viability (ISTA 1985), it was not effective in predicting 100% mortality of cogongrass rhizomes following heat treatments. Of the 99 treatment combinations (9 temperatures by 11 time intervals), TTC predicted 100% cogongrass rhizome mortality correctly 5 times and correctly determined 100% survival of cogongrass rhizomes 25 times when compared to the standard greenhouse bioassay (data not shown). When 95% cogongrass mortality was used, the predictability of mortality was improved twofold (Figure 2), but TTC still did not correlate with the standard greenhouse bioassay (Figure 1) and correctly predicted mortality and survival less than 60% of the time (data not shown). As was discussed previously with regard to temperature, a method that is not effective in predicting 100% cogongrass mortality is not practical. A standard greenhouse

bioassay for cogongrass rhizome mortality was more accurate than a chemical test using TTC.

We conclude that a source of heat, such as available in the furnace of an asphalt plant, could be utilized to kill excavated cogongrass rhizomes effectively. Temperature, duration, and additional time in an asphalt storage silo of greater than or equal to 150 C, 2 min, and 3 to 4 h, respectively, are adequate to kill cogongrass rhizomes alone. Additional research is needed to determine the effects of soil particle size and moisture content on heat treatment to kill of cogongrass rhizomes still attached to soil, rocks, and other debris. A temperature probe could be used to determine when a mixture of cogongrass rhizomes and soil, rocks, and other debris reach the temperature required for cogongrass rhizome mortality. From preliminary data (not shown), the time required to reach the minimum temperature for cogongrass rhizome mortality is highly dependent on moisture content and the particle size of mixtures of soil, rocks, and other debris. Soil mixtures with higher moisture content and larger particles of soil, rock, and other debris require longer time intervals to reach temperatures for cogongrass rhizome mortality than are required for rhizomes alone. Although a standard greenhouse bioassay requires 4 to 6 weeks following heat treatment, it is more effective in determining cogongrass rhizome mortality than TTC.

Sources of Materials

¹ Thelco Model 28, Precision Scientific, 3737 West Cortland St., Chicago, IL 60647-4793.

² Sigma-Aldrich Co., P.O. Box 14508, St. Louis, MO 63178.

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Literature Cited

- Akobundu, I. O. and C. W. Agyakwa. 1998. A Handbook of West African Weeds. 2nd ed. Ibadan, Nigeria: International Institute of Tropical Agriculture, 496 p.
- Brown, D. 1944. Anatomy and Reproduction in *Imperata cylindrica*. Aberystwyth, Wales, United Kingdom: Imperial Agricultural Bureaux Joint Publication No. 7:15-18. 66 p.
- Bryson, C. T. and R. Carter. 1993. Cogongrass, *Imperata cylindrica*, in the United States. *Weed Technol.* 7:1005-1009.
- Byrd, J. D., Jr. and C. T. Bryson. 1999. Biology, Ecology, and Control of Cogongrass [*Imperata cylindrica* (L.) Beauv.]. Jackson, MS: Mississippi Department of Agriculture and Commerce, Bureau of Plant Industry, Fact Sheet 1999-01. 2 p.
- Casini, P., V. Vecchio, and I. Tamantini. 1998. Allelopathic interference of itchgrass and cogongrass: Germination and early development of rice. *Trop. Agric.* 75:445-451.
- Chikoye, D., F. Ekeleme, and J. T. Ambe. 1999. Survey of distribution and farmers' perceptions of speargrass [*Imperata cylindrica* (L.) Raeuschel] in cassava-based systems in West Africa. *Int. J. Pest Manag.* 45:305-311.

- Coile, N. C. and D. G. Shilling. 1993. Cogongrass, *Imperata cylindrica* (L.) Beauv.: A Good Grass Gone Bad! Tallahassee, FL: Florida Department of Agriculture and Consumer Services, Division of Plant Industry, Botany Circular, Vol. 28. 3 p.
- Dickens, R. 1974. Cogongrass in Alabama after sixty years. *Weed Sci.* 22:177-179.
- Dickens, R. and G. A. Buchanan. 1971. Old weed in a new home—that's cogongrass. *Highlights Agric. Res.* 18:2.
- Dickens, R. and G. A. Buchanan. 1975. Control of cogongrass with herbicides. *Weed Sci.* 23:194-197.
- Dozier, H., J. F. Gaffney, S. K. McDonald, E.R.L. Johnson, and D. G. Shilling. 1998. Cogongrass in the United States: History, ecology, impacts, and management. *Weed Technol.* 12:737-743.
- Eussen, J.H.H. 1979. Some competition experiments with alang-alang [*Imperata cylindrica* (L.) Beauv.] in replacement series. *Oecologia* 40:351-356.
- Eussen, J.H.H. and S. Wirjahardja. 1973. Studies of an alang-alang [*Imperata cylindrica* (L.) Beauv.] vegetation. *Biotrop. Bull.* 6:1-24.
- Faircloth, W. H., M. G. Patterson, J. H. Miller, and D. H. Teem. 2005. Wanted dead or alive: Cogongrass. Auburn University, AL: Alabama Cooperative Extension Publ. ANR-1241. 4 p.
- Falvey, J. L. 1981. *Imperata cylindrica* and animal production in southeastern Asia: a review. *Trop. Grassl.* 15:52-56.
- Garrity, D. P., M. Soekardi, M. Van Noordwijk, R. De La Cruz, P. S. Pathak, H.P.M. Gunasena, N. Van So, G. Huijun, and N. M. Majid. 1996. The *Imperata* grasslands of tropical Asia: area, distribution, and typology. *Agrofor. Syst.* 36:3-29.
- Holm, L. G., D. L. Pucknett, J. B. Pancho, and J. P. Herberger. 1977. The World's Worst Weeds. Distribution and Biology. Honolulu, HI: University Press of Hawaii. 609 p.
- Hubbard, C. E. 1944. *Imperata cylindrica*. Taxonomy, Distribution, Economic Significance, and Control. Aberystwyth, Wales, United Kingdom: Imperial Agricultural Bureaux Joint Publication No. 7, Imperial Bureau of Pastures and Forage Crops. 53 p.
- Inderjit and K.M.M. Dakshini. 1991. Investigations on some aspects of chemical ecology of cogongrass. *Imperata cylindrica* (L.) Beauv. *J. Chem. Ecol.* 17:343-352.
- [ISTA] International Seed Testing Association. 1985. International rules for seed testing: *Seed Sci. Technol.*, 13:307-513.
- Johnson, E.R.R.L., J. F. Gaffney, and D. G. Shilling. 1999. The influence of discing on the efficacy of imazapyr for cogongrass [*Imperata cylindrica* (L.) Beauv.] control. *Proc. South. Weed Sci. Soc.* 52:165.
- Koger, C. H. and C. T. Bryson. 2004. Effects of cogongrass (*Imperata cylindrica*) extracts on germination and seedling growth of selected grass and broadleaf species. *Weed Technol.* 18:236-242.
- Koger, C. H., C. T. Bryson, and J. D. Byrd Jr. 2004. Response of selected grass and broadleaf species to cogongrass (*Imperata cylindrica*) residues. *Weed Technol.* 18:353-357.
- Lippincott, C. L. 2000. Effects of *Imperata cylindrica* (L.) Beauv. (cogongrass) invasion on fire regime in Florida sandhill. *Natural Areas J* 20(2):140-149.
- Mattson, A. M., C. O. Jensen, and R. A. Ducher. 1947. Triphenyl-tetrazolium chloride as a dye for vital tissue. *Science* 106:294-295.
- Miller, J. H. 1999. Refining rates and treatment sequences for cogongrass (*Imperata cylindrica*) control with imazapyr and glyphosate. *Proc. South. Weed Sci. Soc.* 53:181.
- Soerjani, M. and O. Soemarwoto. 1969. Some factors affecting germination of alang-alang *Imperata cylindrica* rhizome buds. *PANS* 15:376-380.
- Tominaga, T. 1993. Rhizome systems and sprouting pattern of shoots in *Imperata cylindrica*. *Jpn. J. Trop. Agric.* 37:120-123.
- Tominaga, T., H. Kobayashi, and K. Ueki. 1989. The seasonal change in the standing crop of *Imperata cylindrica* var. *koenigii* grassland in Kii-Oshima Island of Japan. *Weed Res. Jpn.* 34:204-209.
- Udensi, E. U., I. O. Akobundu, A. O. Ayeni, and D. Chikoye. 1999. Management of cogongrass (*Imperata cylindrica*) with velvetbean (*Mucuna pruriens* var. *utilis*) and herbicides. *Weed Technol.* 13:201-208.
- Willard, T. R., D. W. Hall, D. G. Shilling, J. A. Lewis, and W. L. Currey. 1990. Cogongrass (*Imperata cylindrica*) distribution on Florida highway rights-of-way. *Weed Technol.* 4:658-660.

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