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Woody Shrubs as a Barrier to Invasion by Cogongrass (*Imperata cylindrica*)

Lisa Y. Yager, Deborah L. Miller, and Jeanne Jones*

Cogongrass invades forests through rhizomatous growth and wind-dispersed seeds. Increased density and abundance of woody vegetation along forest edges may strengthen biotic resistance to invasion by creating a vegetative barrier to dispersal, growth, or establishment of cogongrass. We evaluated differences in dispersal of cogongrass spikelets experimentally released from road edges into tallgrass-dominated and shrub-encroached longleaf pine forests (*Pinus palustris*). Average maximum dispersal distances were greater in the pine–tallgrass forest (17.3 m) compared to the pine–shrub forest association (9.4 m). Spikelets were more likely to be intercepted by vegetation in pine–shrub forests compared to pine–tallgrass forests. Results suggest that dense woody vegetation along forest edges will slow spread from wind-dispersed cogongrass seeds.

Nomenclature: Bluestem grasses, *Andropogon* spp., *Schizachyrium* spp.; **c**ogongrass, *Imperata cylindrica* (L.) Beauv.; longleaf pine, *Pinus palustris* Mill.

Key words: Biotic resistance, invasibility, invasive barrier, seed dispersal.

Cogongrass [*Imperata cylindrica* (L.) Beauv.], the seventh worst weed in the world, has invaded pine forests of the southeastern United States, where it displaces native vegetation and alters fire regimes (Brewer 2008; Holm et al. 1977; Lippincott 2000). Initial introduction near forests along roadsides may result from transport of seeds and rhizomes on equipment or in contaminated soil (MacDonald 2004). However, absent human or other mechanisms of dispersal, spread into forests from roadsides occurs from clonal growth and wind-dispersed seeds (MacDonald 2004). Dense and abundant woody vegetation along forest edges has the potential to increase biotic resistance to invasion by creating a vegetative barrier to dispersal, growth, or establishment of invasive species (Brothers and Springarn 1992; Cadenasso and Pickett 2001). Clonal growth of cogongrass was reduced in pine forests containing a dense shrub midstory and cogongrass growth was negatively related to shrub cover (Yager et al. 2010). Further evaluation of this concept to consider seed dispersal will assist with developing recommendations for management of cogongrass and similar invasive species in forested systems.

Fire suppression in southeastern pine forests results in dense shrub midstories replacing fire-maintained tallgrass understories (Frost 2006). Wind dispersal of seeds of multiple nonforest species from an adjacent old field was reduced into a deciduous forest of the northeastern United States where midstory woody vegetation of the forest edge was left intact (Cadenasso and Pickett 2001). A woody midstory may prevent or slow seed dispersal by wind into forests because the woody midstory acts as a physical barrier to seeds and slows wind speed within the forest. Thus, we hypothesized that cogongrass spikelets would disperse farther into pine forests with tallgrass understories compared to pine forests with shrub midstories.

Materials and Methods

Study Area. Camp Shelby Training Site (CSTS), one of the largest National Guard Training installations in the United States, is located in Perry, Forrest, and George counties of Mississippi. Topography is mostly gently rolling, stream-dissected hills (Yager et al. 2010). The installation is contained within the longleaf pine (*Pinus palustris* Mill)–bluestem (*Andropogon* spp., *Schizachyrium* spp.) portion of the Gulf Coastal Plain physiographic province (Yager et al., 2010).

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Interpretative Summary

It has been suggested that dense woody vegetation along forest edges may form a barrier to invasive species either through effects on microhabitat or effects on seed dispersal. This study evaluated use of dense woody vegetation along forest edges as a barrier to seed dispersal into forest interiors. In this study, more cogongrass spikelets dispersed farther into open longleaf pine forests with a tallgrass understory compared to longleaf pine forests with dense shrubby understories. Reduced wind speed and increased vegetative interception of spikelet in the shrub-encroached forests may have prevented greater dispersal into these forests. However, a few spikelets released into open or shrubby forests dispersed farther than could be measured. These results suggest that managers seeking to control cogongrass may benefit by maintaining dense woody edges along forests and prioritizing management techniques that prevent spread of or treat cogongrass growing near less densely wooded habitats. These results also suggest that although dense woody vegetation may slow spread of cogongrass into forest interiors, such vegetation is unlikely to completely prevent invasion. Therefore, managers will need to implement additional control techniques in order to protect these forested areas from invasion.

As a result of past fire regimes and silvicultural practices, a variety of upland longleaf, loblolly (*Pinus taeda* L.) and slash (*Pinus elliottii* Engelm.) pine forest associations occur on CSTS (Yager et al. 2010). Frequently burned forests in this region are characterized by an open overstory canopy of pine and the occasional hardwood, a scattering of shrubs, and an abundant and diverse tallgrass understory dominated by bluestem grasses (Yager et al. 2010). Because of periods of fire exclusion, large areas of pine forest also exhibit closed canopies of pines and hardwoods, a dense midstory (shrubs and trees with heights between 1 and 3 m [3.3 and 9.8 ft]) of hollies (*Ilex* spp.) and other shrubs, and minimal herbaceous vegetation (Yager 2007).

Study sites included pine–tallgrass and pine–shrub forests adjacent and north of Davis Range Road on CSTS. Davis Range Road runs east to west. Sites contained a pine–tallgrass forest association with minimal woody midstory cover ($<$ 25%) and a pine–shrub forest association with $>$ 50% woody midstory cover. Topography was fairly flat. Primary wind direction for south Mississippi in May is from southwest to northeast (National Climatic Data Center 2008). Based on weather data collected at the nearest weather station (U.S. Forest Service Black Creek weather station at Wiggins, MS, unpublished data) for the months of May 1980 through 2010, mean wind speeds were 9.7 km h^{-1} (6 mi h^{-1}) with most wind gusts occurring in the 6 to 13 km h^{-1} range. For the same time period, mean daily temperatures ranged between 22 to 26 C (71 to 78 F) and mean daily relative humidity ranged between 69 and 73% (U.S. Forest Service Black Creek weather station at Wiggins, MS, unpublished data).

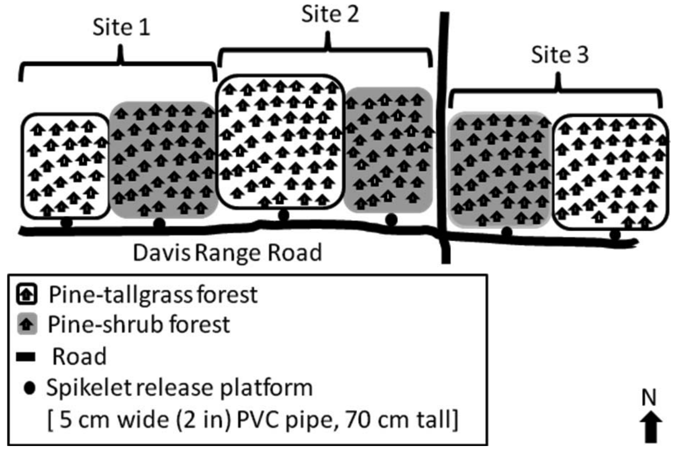

Figure 1. Schematic diagram of cogongrass spikelet release at Camp Shelby Training Site, MS. Forest associations varied in size but were of sufficient size that each association extended at least 50 m east and west of the polyvinyl chloride pipes inserted at the treelines.

Spikelet Dispersal. Cogongrass seed production in south Mississippi has been documented to occur in May (Yager 2007). Preliminary trials conducted in May 2003 indicated that spikelets generally followed the prevailing wind directions and did not usually enter the forest of interest unless released south of the forest (Yager 2007). Therefore, to ensure spikelet dispersal from roadsides into pine–tallgrass or pine–shrub forests and reduce variance associated with wind direction, we selected three sites (replicates and blocks) that occurred north of a road running east to west (Figure 1). Each site contained two forest associations, a pine–tallgrass forests with minimal midstory cover ($<$ 25%) and a pine–shrub forest with $>$ 50% woody midstory cover (Figure 1). Forest associations represented natural treatments for which differences in seed dispersal distance were tested.

Mean height of cogongrass inflorescences measured in May 2003 was 0.7 m (28 in) (Yager 2007). Because height of spikelet release can affect dispersal distance, we used the mean height as a standard that fell within the realistic range of inflorescence heights, but would prevent dispersal variability based on height. At the treeline edge of each forest association where the mowed roadside edge ended, we vertically inserted a 5cm polyvinyl chloride (PVC) pipe with PVC cap in the ground so that the cap was 0.7 m high (Figure 1). The forest association of interest extended at least 50 m to the east and west of each PVC pipe. To address variability of wind speeds associated with time of day, we released 50 spikelets at each treatment (pine–tallgrass and pine–shrub) of a replicate site during the same time period before moving to the next replicate site. We placed cogongrass spikelets on the PVC caps individually until the wind blew a minimum of 50 spikelets off the cap and into the forest association of interest. Spikelets that blew away from the forests were not counted. Sterile spikelets (i.e., spikelets lacking seeds) were used to prevent new introduction of cogongrass within the study areas. We observed spikelets visually until they fell upon an object or the ground. We flagged and later recorded the dispersal location using a Trimble Pro-XR global positioning system unit.[1] ESRI Arcview 3.2[2] was used to determine dispersal distance from the release platform (PVC pipe). We repeated this process on five different days for each site during May 18–26, 2004, mostly between 9 A.M. and 12 P.M. However for one of the release dates at two sites, spikelet releases began at 1:30 P.M. at one site and 3:30 P.M. at the other. Releases at each site took approximately 1 h.

We released spikelets under weather conditions that were typical for May in south Mississippi. Weather conditions on release dates were clear to partly cloudy, with mean daily temperature between 23 and 26 C and relative humidity between 70 and 80% (U.S. Forest Service Black Creek weather station at Wiggins, MS, unpublished data). Primary wind directions for release dates at the Black Creek weather station were south to north or southwest to northeast with mean wind speeds between 3 and 13 km h^{-1} (U.S. Forest Service Black Creek weather station at Wiggins, MS, unpublished data).

We categorized and reported each spikelet's landing location as bare ground, litter, herbaceous plants, or woody plants; but for purpose of statistical analysis, landing locations were considered either intercepted by vegetation or not. We recorded maximum wind speed at each release location for each period of spikelet release using a Skywatch Meteos anemometer[3] placed 1 m above the ground and 5 m from the release platform into the forest association of interest.

Analysis. We calculated the mean dispersal distance, maximum dispersal distance, percentage of spikelets that traveled more than 5 m after each release, and percentage of spikelets intercepted by vegetation for each of the five release dates for each forest association at each roadside site. We used the SAS software's general linear model to analyze differences in mean and maximum dispersal distances for the two forest associations (Quinn and Keough 2002; SAS Institute, Inc. 2004). We used the SAS software's generalized linear model to analyze differences for percentage of spikelets dispersing farther than 5 m and percentage of spikelets intercepted by forest association type (Quinn and Keough 2002; SAS Institute, Inc. 2004). For the analyses above, roadside sites were considered replicates ($n = 3$) and blocks and the five release dates were subsamples of each replicate site's forest association (Ott 1988). Data were tested for normality and equality of variance. We created histograms of the total number of spikelets by 1-m distance intervals for each forest association. We also tested whether maximum wind speed was correlated with maximum dispersal distances for all vegetation associations, roadside sites, and release dates ($n = 30$) using Pearson's correlation coefficient (Ott 1988).

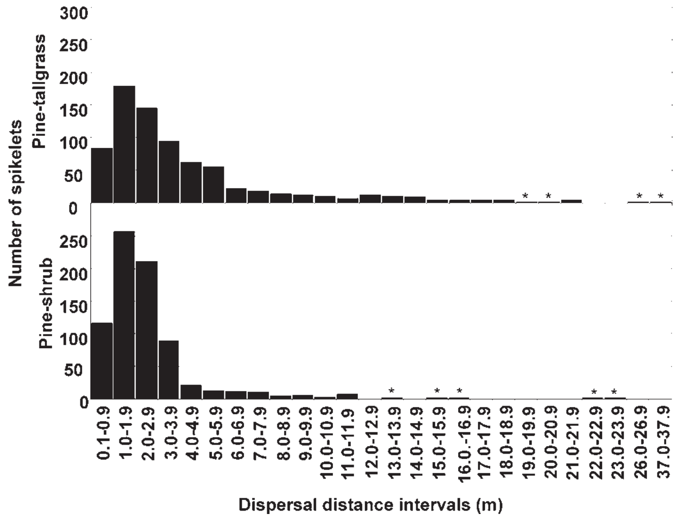

Figure 2. Histogram of total number (750) of spikelets by dispersal distance intervals into three pine–shrub and pine–tallgrass forest associations at Camp Shelby Training Site, MS. An asterisk (*) indicates there was one spikelet within that dispersal distance interval.

Results and Discussion

Mean dispersal distance into the pine–tallgrass association (4.1 m)was not significantly different from mean dispersal distance into the pine–shrub association (2.5 m) ($F_{1,5} = 4.70$, $P = 0.120$). However more spikelets (25%), dispersed farther than 5 m into the pine–tallgrass association compared to the pine–shrub association (8%) ($\chi^2_5 = 40.73$, $P < 0.001$) (Figure 2). Furthermore, the mean maximum dispersal distance was greater in the pine–tallgrass association (17.3 m) compared to the pine–shrub association (9.4 m) ($F_{1,5} = 251.15$, $P = 0.004$). Maximum dispersal distance recorded for cogongrass spikelets within the pine–tallgrass association was 37 m, whereas maximum dispersal distance within the pine–shrub association was 23 m.

Maximum wind speeds ranged between 1.8 and 10.4 km h^{-1} for the pine–tallgrass association and between 1.1 and 8.6 km h^{-1} in the pine–shrub association. Mean maximum windspeeds were greater in the more open pine–tallgrass association (6.1 km h^{-1}, SE 0.65) compared to the pine–shrub association (4.7 km h^{-1}, SE 0.58). However maximum dispersal distances were not correlated with maximum wind speeds. Spikelets were less likely to be intercepted by vegetation in pine–tallgrass forests ($\chi^2{}_5 = 38.84$, $P < 0.001$) (Table 1).

Table 1. Percentage of cogongrass spikelets by primary dispersal location after five releases into three pine–tallgrass and pine–shrub vegetation associations at Camp Shelby Training Site, MS.

	Mean (range) of spikelets by location (%)	
Primary dispersal location	Pine–tallgrass	Pine–shrub
Bare ground	8 (0–22)	2 (0–10)
Litter	26 (6–62)	14 (4–20)
Herbaceous vegetation	46 (30–60)	20 (14–32)
Woody vegetation	16 (4–24)	65 (52–80)
Other (e.g., spiderwebs)	4 (0–6)	0 (0–0)

There were a few (less than five) instances in pine–shrub and pine–tallgrass associations in which cogongrass spikelets were lofted too high and far to be followed. Such instances suggest the potential of long-distance dispersal in either forest.

The handling of spikelets and absence of seeds could result in some differences in dispersal distances than those that might occur in nature; however, results still provide good information on relative differences between the two forest association types. Furthermore it is unlikely that handling or absence of seeds would have affected interception by vegetation. More spikelets dispersed farther in the less wooded, pine–tallgrass association, probably as a result of decreased interception by vegetation and possibly because of decreased wind speeds. These results support Cadenassso and Pickett's (2001) theory that dense woody vegetation along forest edges may serve as a barrier to slow or preclude invasion through wind-borne seed dispersal.

Protection and restoration of plant communities will be assisted by manipulation of factors that interfere with reproduction, dispersal, germination, or growth of an invasive species (D'Antonio and Meyerson 2002). Plant community resistance to invasion is determined by propagule pressure and conditions occurring within the community (Radosevich et al. 2003; Rejmanek et al. 2005). Results of this study indicate that invasive spread by wind-borne seeds of cogongrass is likely to be more rapid in forest associations with open midstory structure. Vegetative rate of spread of cogongrass was also greater into pine–tallgrass forests than into pine–shrub forests (Yager et al. 2010). In addition, fire increased vegetative rate of spread of cogongrass into both forest association types (Yager et al. 2010). Together these results have some interesting implications for those seeking to maintain more open forests for biological diversity or other reasons, especially where these forests types depend upon fire for midstory control. In cases where resources for invasive plant control are limited, managers should prioritize control of cogongrass infestations that are in close proximity or adjacent to these more open forest associations to reduce the potential for spread of propagules into these vulnerable habitat types. These results also suggest that use of fire to reduce woody vegetation in fire-dependent forest systems may provide a feedback loop that enhances invasion by cogongrass unless fire activities are coordinated with cogongrass control. Finally, results do suggest that allowing a dense woody edge to develop or maintaining an already overgrown woody edge may increase biotic resistance for those seeking to restore or maintain more open forest associations.

Depending on the resources available and propagule pressure in the area, there may be some benefit to planting native woody vegetation to "seal" the edges against wind-borne dispersal as suggested by Cadenasso and Pickett (2001). However, woody vegetation may be a less effective barrier for non–wind-borne dispersal mechanisms, such as the vegetative spread of cogongrass. Some invasive plants, such as cogongrass, are tolerant of or adapted to shade or moisture conditions (Gaffney 1996). These species within forest communities are likely to eventually establish and spread despite a woody barrier. Therefore, if invasive plants already occur along forest edges, use of resources to control seed production and other spread may give more immediate protection to forest interiors, whereas woody plantings may take longer periods of time to establish.

Sources of Materials

[1] Trimble Pro-XR GPS unit, Trimble Navigation, Ltd., 935 Stewart Dr., Sunnyvale, CA 94085.

[2] Arcview 3.2, ESRI, Redlands, CA 92373.

[3] Skywatch Meteos Anemometer, Forestry Suppliers, Inc., 205 West Rankin St., Jackson, MS 39201.

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