THE FACILITATION AND IMPACTS OF *MICROSTEGIUM VIMINEUM* COLONIZATION IN AN EASTERN HARDWOOD FOREST

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Abstract—*Microstegium vimineum* is an annual, invasive Asian grass that occurs across the southeastern United States. Research on *M. vimineum* suggests there is a suite of environmental conditions that contribute to the species' spread. We have synthesized the results of two studies that tested 1) the effects of winter litter disturbance on the spread of *M. vimineum* under various canopy conditions, and 2) the impacts that establishment and growth of *M. vimineum* have on woody species density and diversity. Plots with winter litter disturbance experienced *M. vimineum* expansion rates 4.5 times those measured in undisturbed plots. Native woody species density and diversity both decreased with increasing *M. vimineum* percent cover. Land managers who have found *M. vimineum* on the forestland they manage may benefit by removing the species prior to any site manipulation to avoid the plant's spread and a subsequent decline in woody regeneration success.

INTRODUCTION

Microstegium vimineum is an annual, shade-tolerant grass introduced from Asia into the southern United States in the early 1900s (Barden 1987). The species is identified by its sprawling form, alternate leaf arrangement, and lanceolate, sparsely hairy leaves with offset mid-vein (Miller 2003). With its rapid invasion in many southern forests and floodplains, *M. vimineum* has garnered attention in the last few decades (Barden 1987, Horton and Neufield 1998, Oswalt and others 2004, Cole and Weltzin 2004, Buckley and Marshall 2005, Cole and Weltzin 2005, Oswalt and others 2007). Multiple, interacting mechanisms combined with *M. vimineum's* ability to compensate for light and/or moisture limitations have hampered researchers' efforts to narrowly define the driver(s) of *M. vimineum* distribution. *M. vimineum* can persist year after year as a small, inconspicuous plant in low-light conditions (Horton and Neufeld 1998) while producing copious seed that may persist in the soil for 3 to 5 years, and that vigorously respond to increased light (Barden 1987, Miller 2003, Oswalt and others 2004, Oswalt and others 2007).

Barden (1987) found that *M vimineum* was able to rapidly invade floodplain forests in North Carolina following canopy disturbance. Cole and Weltzin (2004) documented negative correlations between *M. vimineum* biomass and litter mass in all but one site (a clearcut) in a Tennessee study. The overall plasticity of the species and its wide ecological amplitude suggest that a variety of environmental factors facilitate spread and growth, including light availability associated with canopy density and light availability associated with litter on the forest floor.

This paper synthesizes results from two previously published studies (Oswalt and others 2007, Oswalt and Oswalt 2007) and, in addition, uses information from other pertinent literature with respect to the facilitation and impacts of *M. vimineum* invasions in Eastern hardwood forests. We also consider implications of the developing knowledge of *M. vimineum* invasions for timberland management within its currently known range. Lastly, we suggest modes of management that may aid in reducing the spread and impacts of this highly-invasive grass.

STUDY SITE

Both studies were conducted on The Ames Plantation in southwest TN in the headwaters region of the North Fork of the Wolf River (NFWR) (35°09´ N, 89°13´ W). Part of the Southeastern Mixed Forest Province (Bailey 1995), the site primarily is composed of mixed hardwood forest dominated by various oak species (*Quercus* sp.) and yellow-poplar (*Liriodendron tulipifera*). Historically, the study site was used for agriculture, grazing, and timber production. Surrounding properties include woodlands interspersed with soybean, cotton, and other agricultural crops common to the southeast.

METHODS

Microstegium vimineum Expansion Study

In late summer 2004, we identified and marked established *M. vimineum* patches for future relocation and plot/treatment installation. In December 2004, we established 40 plots (2 by 0.5 m) within 10 blocks of 2 replicates each (2 plots per replicate, 2 replicates per block). Each block comprised one established *M. vimineum* patch located beneath an undisturbed, closed hardwood canopy and controlled for slope and aspect. In addition, plots were selected to avoid large differences in initial leaf litter thickness. Plot installation resulted in each plot radiating 2 m out from the established *M. vimineum* patch with the 0.5-m face adjacent to the patch (fig. 1). One of two treatments was randomly assigned to each plot within a block. Treatments included a disturbed (litter removed) and undisturbed (no litter removed) litter layer. For the disturbed treatment all leaf litter was removed from the plot and special care was taken to leave the A horizon intact. Plots were visually marked in such a way as to minimize the chance of further anthropogenic disturbance. Linear spread and cover expansion from established *M. vimineum* patches were documented after one complete growing season—in the fall of 2005—for each plot. Linear spread was quantified by measuring the linear distance (meters) from the previously delineated boundary between the plot and established *M. vimineum* patch to the furthermost stem of *M. vimineum*. Cover expansion was quantified by estimating percent *M. vimineum* cover for each of four 0.5-m^2 subsections of the plot (fig. 2), defined as 0.0 to 0.5, 0.5 to 1.0, 1.0 to 1.5, and 1.5 to 2.0 m in progressive 0.5-m divisions from the established *M. vimineum* patch.

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Simple analysis of variance (ANOVA) was used to test for significant differences between treatments for linear spread and cover expansion with α of less than 0.05 used to indicate differences. Fisher's Least Significant Difference (LSD) tests were used for post-ANOVA mean separation (SAS Institute Inc. 1999). A simple one-sample t-test was used to test if the linear spread of the undisturbed plots was different from zero.

Microstegium vimineum Impact Study

In fall 2001, we identified three experimental blocks based on landform and position. Differences in average stand basal area were significant among the blocks (20-36 m^2/ha, *P* = 0.04), which appeared to be a result of past selective cutting. Twelve 0.8-ha treatment units (approximately 61 by 122 m) were evenly distributed within the experimental blocks. Three canopy disturbance treatments (0 m^2/ha or 0 percent residual canopy; 3.2 m^2/ha or 10 percent residual canopy; and 4.6 m^2/ha or 20 percent residual canopy) and an undisturbed control (32.6 m^2/ha or 100 percent residual canopy) were randomly assigned to the 4 units within each of the 3 replicate blocks using a randomized complete block design. Canopy disturbance treatments were completed in the winter of 2001–2002.

To evaluate the impacts of *M. vimineum* on woody regeneration density and species diversity, we recorded percent cover estimates for *M. vimineum* in late summer 2003 from 60 systematically located 1-m^2 plots in each unit, for a total of 720 plots. Native woody species regeneration in four height classes (< 0.61, 0.61 to 1.22, 1.22 to 1.83, and > 1.83 m) was quantified using a 0.0004-hae (1/1000-acre) plot nested within a 0.004-ha (1/100-acre) plot. We recorded six plots for each unit, for a total of 72 plots. Each regeneration plot was classified into one of four broad *M. vimineum* cover classes (less than 25, 25 to 50, 51 to 75, and greater than 75 percent) through spatial association with the *M. vimineum* plots.

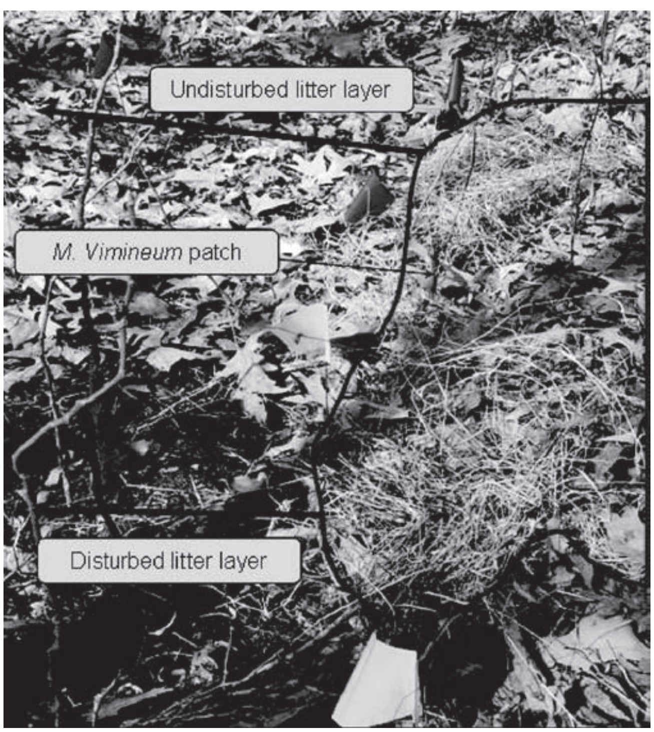

Figure 1—Undisturbed and disturbed litter layer treatments were aligned in transects adjacent to and leading away from previously established patches of *M. vimineum*.

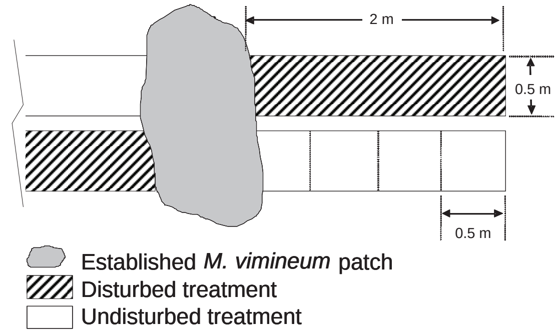

Figure 2—Plot layout illustration.

Mixed-model analysis of variance and least square means were used to discern differences in native woody species (NWS) density (stems/ha) and NWS diversity among canopy disturbance levels (SAS Institute Inc. 1999). We compared total native woody species (NWS) density (stems/ha) among canopy disturbances, and across four height classes to ensure that the populations of comparison were similar. We then used polynomial regression to identify possible relationships and trends between total square-root transformed NWS stems/ha and mean *M. vimineum* cover.

Shannon's and Simpson's diversity indices, along with species richness, were used to quantify NWS diversity. To ensure that treatment was not a covariant factor in NWS diversity regression models, we compared species richness among three canopy treatments (no control) using ANOVA. We then used simple linear regression to identify possible trends and relationships between diversity and mean *M. vimineum* cover across two diversity indices (Shannon's H and Simpson's D). Further, we used protected, one-way analysis of variance (Tukey's studentized range test) to control for Type I experiment-wise error and to detect differences in both NWS density and diversity (Shannon's and Simpson's indices and species richness) among broad *M. vimineum* cover classes.

RESULTS

M. vimineum Expansion Study

Plots receiving the disturbed treatment experienced *M. vimineum* spread 4.5 times greater than plots receiving the undisturbed treatment (fig. 3, P < 0.0001). Linear spread averaged 1.66 and 0.37 m for the disturbed and undisturbed treatments, respectively. While mean *M. vimineum* cover decreased significantly as subsection distance from the established plot increased for both the undisturbed and disturbed plots, *M. vimineum* cover was significantly greater for each subsection within the disturbed plots (P < 0.001) (fig. 4). *M. vimineum* cover averaged 16, 4, 0, and 0 percent for the undisturbed treatment and 87, 64, 31, and 9 percent for the disturbed treatment in the 0.0 to 0.5, 0.5 to 1.0, 1.0 to 1.5, and 1.5 to 2.0 m subsections, respectively.

M. vimineum Impact Study

Regression models with *M. vimineum* percent cover as the independent variable indicated a strong negative relationship with total NWS stems/ha (r^2=0.80, slope=-1.1, P<0.001). Regression models also indicated that *M. vimineum* may have had a greater influence on the smaller height classes. The coefficient of determination was larger and its associated p-value smaller for height class 1 (r^2=0.82, P<0.0001). Progressing through larger height classes resulted in decreasing R^2 values and increasing p-values, until significant relationships no longer existed for the largest seedling height class (r^2=0.70, P<0.0001, r^2=0.50, P=0.002, r^2=0.16, P<0.11 for HC2, HC3 and HC4, respectively). Native woody species density (total stems/ha) differed among the four broad *M. vimineum* cover classes (P=0.0004) (table 1). The > 75 percent cover class resulted in significantly fewer stems/ha than both the < 25 percent and the 25 to 50 percent cover classes.

Simple linear regression using Shannon's H diversity index as the dependent variable, and mean percent cover of *M. vimineum* as the independent variable produced an R^2 value of 0.47, and a slope of -0.007 (P=0.002). Re-running this model using Simpson's D diversity index showed a weak negative relationship (r^2 = 0.31, slope = -0.02, P=0.02). Both species richness and Shannon's H diversity index differed among the broad *M. vimineum* cover classes (P=0.0002 and P=0.01, respectively) (table 1). Similar to the regression analysis, ANOVA results indicate that species richness consistently declined with progressively increasing *M. vimineum* percent cover. Differences are particularly noticeable between the < 25 and > 75 percent cover classes. Differences in Shannon's H among the broad cover classes include only a difference between the < 25 and > 75 percent classes (table 1).

DISCUSSION AND IMPLICATIONS

M. vimineum is an invasive species in southern forests that is gaining the attention of land managers. Two studies conducted in southwest TN suggest that, when *M vimineum* is present at a site prior to manipulation, winter litter disturbance and canopy disturbance can encourage the spread and growth of the species. The end result may be an overall decline in native woody species regeneration success. Logging operations or silvicultural treatments in the southern United States often result in what can be labeled a planned disturbance. The presence of heavy machinery of most logging operations can result in extensive disturbance to the forest floor litter layer (Buckley and Marshall 2005). If *M. vimineum* is present and left untreated prior to litter disturbance, site manipulation may further encourage its spread and establishment. Likewise, if *M. vimineum* is present in the understory prior to canopy removal, harvest may result in excessive growth and therefore negatively impact regeneration. While logging operations are not the only facilitator of *M. vimineum* spread, and other disturbances probably are influencing the species' growth, knowledgeable land managers should recognize the impact of this invasive grass and attempt to slow its spread.

Land managers in states where *M vimineum* is present would benefit by taking note of whether the plant is present in or adjacent to their forests where site manipulation is expected. Current research indicates that *M. vimineum* can be treated in the late fall and winter with a pre-emergence herbicide and then again after the first growth flush in the spring with a post-emergence, grass-specific herbicide (Miller 2003). A challenge is presented by the fact that extirpating *M. vimineum* from a site may take more than one year because of a large seed bank.

Land managers, foresters, and loggers should be made aware of the potential impact and range of *M. vimineum* invasions. Managing an identified population before a natural or planned disturbance should limit both the spread

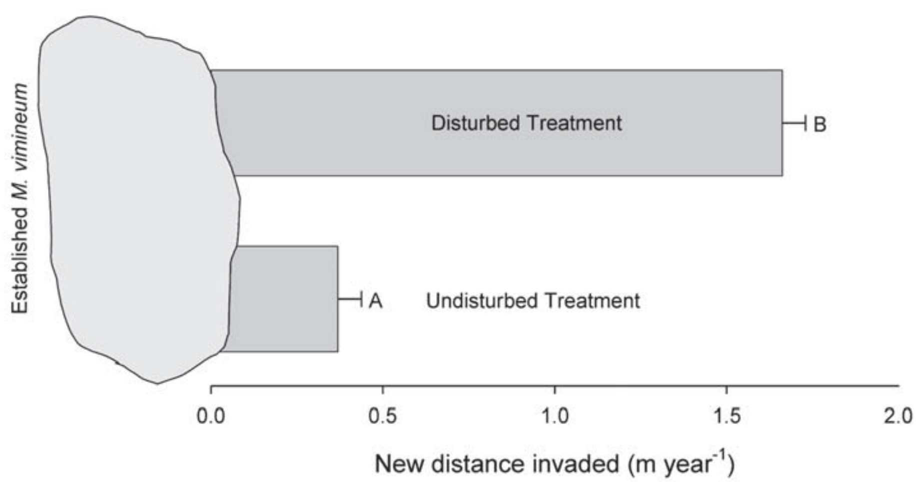

Figure 3—Mean linear distance invaded by *M. vimineum* for the disturbed and undisturbed treatments. Lettering indicates differences (P < 0.0001) between treatments.

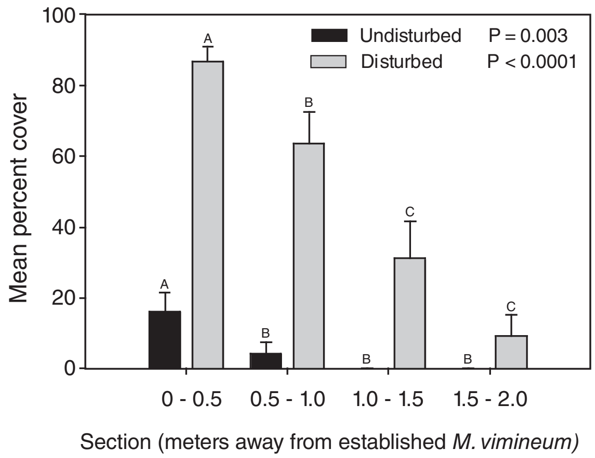

Figure 4—Mean percent cover of *M. vimineum* in each of four measured plot sections for the disturbed and undisturbed treatments. Lettering is used to indicate differences within a treatment.

of *M. vimineum* through leaf litter displacement and the subsequent negative impacts on the density and diversity of native woody species. A proactive management approach may lessen the impact of this invasive grass.

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Table 1—Mean density, species richness and Shannon's H diversity index for each of four broad *M. vimineum* cover classes

Broad cover class	Density		Richness		Shannon's H	
percent	Stems/ha	se	Species/plot	se		se
Less than 25	36412 A	5554	15.7 A	1.1	1.93 A	0.08
25 to 50	28911 AB	1236	13 AB	2	1.96 AB	0.15
51 to 75	6425 BC	2718	9.5 BC	1.5	1.87 AB	0.21
Greater than 75	4098 C	1043	6.3 C	0.9	1.38 B	0.12

Lettering indicates differences among cover classes.