Japanese Stiltgrass (*Microstegium vimineum*) Germination Pattern and its Impact on Control Strategies[1]

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Abstract

Field trials were conducted by Virginia Master Naturalists to determine the germination period for Japanese stiltgrass and its impact on timing of postemergence herbicide applications. Germination rates declined from April to June, with no germination seen after mid-June. Glyphosate applications in early May significantly reduced Japanese stiltgrass cover that month, but post-treatment germination resulted in approximately 25% cover by October, with 78% cover seen in untreated plots. However, no Japanese stiltgrass was observed in October when glyphosate was applied in either the third week of June or the third week of July. A single application of glyphosate was effective for Japanese stiltgrass control if applications are made in June after new germination had ceased, verified by multi-year herbicide field trials. Field trials conducted by Virginia Tech showed preemergence applications of prodiamine reduced Japanese stiltgrass stand from 30 to 94%, depending on rate and timing, but even in the most effective treatment there was still at least 19% cover by August. Prodiamine treatments that utilized May applications were more effective for crabgrass (Digitaria spp.) control than for Japanese stiltgrass, supporting the earlier germination pattern for Japanese stiltgrass. Inclusion of this work in this paper provides a more complete picture of the treatment options for Japanese stiltgrass. A timed postemergence herbicide application may be a better control option for this weed than use of a preemergence herbicide application.

Index words: herbicide application, invasive plants, weed control.

Chemicals used in this study: Glyphosate [N-(phosphonomethyl)glycine)], prodiamine (2,6-Dinitro-*N*,*N*-dipropyl-4-(trifluoromethyl)-1,3-benzenediamine).

Species used in this study: Japanese stiltgrass (*Microstegium vimineum* (Trin.) A Camus.).

Significance to the Horticulture Industry

Japanese stiltgrass is an invasive species that invades shady, moist sites. Germination peaks in early spring prior to June in eastern Virginia. Preemergence herbicide applications therefore need to be timed between December and March, as treatments utilizing May applications were less effective. Split dose applications of preemergence herbicides that utilize a May treatment are more effective for control of crabgrass species than Japanese stiltgrass, as germination has already commenced for Japanese stiltgrass. Japanese stiltgrass escapes following preemergence applications can grow significantly before frost, requiring other control measures. In comparison, a single glyphosate application in late June or July can be very effective for Japanese stiltgrass control, as emergence has occurred prior to treatment.

Introduction

Japanese stiltgrass (*Microstegium vimineum* (Trin.) A Camus.), also known as Asian stiltgrass, Nepalese browntop, annual jewgrass, bamboograss, or flexible sesagrass, is a summer annual C_4 grass. Shade tolerant and invasive in the United States, *M. vimineum* is native to China, Korea, Japan, Malaysia, and India (Tu 2000, Fryer 2011). *M. vimineum*'s earliest recorded appearance in the United States was in Knoxville, Tennessee in 1919 (Fairbrothers 1972). Its movement to the United States is likely due to its use in the early 1900s as a packing material for Chinese porcelain and for basket weaving (Tu 2000). Growing conditions for *M. vimineum* include shaded, low-elevated, mesic soils with outside disturbance that stimulate germination. Higher soil moisture favors Japanese stiltgrass germination and seed production while germination decreases with increasing leaf litter thickness (Warren 2013).

Previous research has shown that certain preemergence and postemergence herbicides can control Japanese stiltgrass (Judge et al. 2005a, 2005b). Little information exists on the pattern of Japanese stiltgrass germination as well as the effect of preemergence and postemergence herbicide timing on control of this weed. Optimum application timing may reduce the number of herbicide applications needed for control. It appears that seed of Japanese stiltgrass does not remain viable for very long, as most of it survived less than two years (Redwood et al. 2018).

The 3,200 acre Piney Grove Preserve, owned by the Nature Conservancy, is located in Sussex County, Virginia. Located within a pine savanna habitat, the native community in this preserve has several rare species. These species are accustomed to frequent ground fire treatments every 1 to 4 years to maintain an open mid-story with savanna-like groundcover necessary for the native ecosys-

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tem (Drew 1998). Many of these species are perennial and will regrow if the plant is burned to ground level (Van Lear et al. 2005). The preserve is the most northerly U.S. population for the federally endangered red cockaded woodpecker. The preserve management had concerns about how the spread of Japanese stiltgrass could impact the native ground cover. Ground subjected to controlled burning could provide an opportunity for Japanese stiltgrass to spread preferentially into these areas after competing plants and leaf matter are burned, leaving exposed soil.

Following an initiative from the National Science Foundation (NSF) and the Virginia Master Naturalists (VMN) program to promote the training of citizen scientists, a meeting with the Nature Conservancy lead to the development of a proposal to establish test plots within the Piney Grove Preserve to assess the best practices for control of Japanese stiltgrass. In the fall of 2013, master naturalists surveyed the preserve and determined the best location for test plots. This study was unique in that the test plots in the preserve were monitored for two years after treatment to assess the long-term effectiveness of the control options. The objectives for the trials conducted at the Piney Grove Preserve and at the Hampton Roads Agricultural Research and Extension Center (HRAREC) were to 1) determine the germination pattern for Japanese stiltgrass, 2) determine the timing and application rate of a preemergence herbicide for its control, and 3) determine the optimum timing of a single glyphosate application for control.

Materials and Methods

Preemergence herbicide trial. This trial was established in 2002 and repeated in 2003. A randomized complete block with four replications was used for all trials. Plots were 1.8 m by 3.6 m (6 ft by 15 ft) for the Japanese stiltgrass trial in a wooded site at the Hampton Roads Agricultural Research and Extension Center in Virginia Beach, Virginia. The pH was 6.3 with 7.4% organic matter. Plots were 1.8 m by 4.6 m (6 ft by 15 ft) for the crabgrass (mixture of southern [*Digitaria ciliaris* (Retz.) Koeler] and smooth crabgrass [*D. ischaemum* (Schreb.) Schreb. ex Muhl.] trial in an established stand of 'Shenandoah' tall fescue (*Festuca arundinacea* Schreb.). The pH was 5.7 with 1.9% organic matter. Prodiamine was applied once at 0.84 kg·ha^{-1} (0.75 lb ai·A^{-1}) in December, March, or May, at 0.42 plus 0.42 kg·ha^{-1} (0.38 plus 0.38 lb ai·A^{-1}) in December and March, December and May, or March and May, or applied a total of three times at 0.42 kg·ha^{-1} in December, March, and May. For trial 1, the December application was made on December 4, 2002 under -1 C (30 F) air temperature, 6 C (43 F) soil temperature, 70% cloud cover, and 53% relative humidity, followed by freezing rain 6 hours after application. The March application was treated on March 4, 2003 under 12 C (53 F) air temperature, 12 C (54 F) soil temperature, 90% cloud cover, and 80% relative humidity, with 1.2 cm (0.49 in) rainfall occurring 8 hours after treatment. The May application was treated on May 5, 2003 under 14 C (57 F) air temperature, 72% relative humidity, and 100% cloud cover, with 0.4 cm (0.17 in) rainfall occurring 1 hour after treatment. For trial 2, the December application was made on December 4, 2003 under 6 C (43 F) air temperature, 7 C (44 F) soil temperature, 100% cloud cover, and 53% relative humidity, followed by 2.5 cm (0.95 in) rain one day later. The March application was treated on March 4, 2004 under 15 C (59 F) air temperature, 17 C (62 F) soil temperature, 90% cloud cover, and 83% relative humidity, with 1.3 cm (0.53 in) rainfall occurring within three days after application. The May application was treated on May 5, 2004 under 14 C (58 F) air temperature, 72% relative humidity, and 100% cloud cover. This led to a germination trial in the field which led to a multi-year study to assess optimum time of treatment.

Japanese stiltgrass germination trial. Experiments were initiated at the Piney Grove Preserve near Wakefield, Virginia in 2016. The trial was established at two locations in the preserve. A randomized complete block with four replications was used for all trials. Plot size was 1.2 m by 1.2 m (4 ft by 4 ft) with at least 0.3 m (1 ft) between plots. Japanese stiltgrass plants were counted within each plot every second week starting in early April. Counts were made utilizing a 0.09 square meter (one square foot) frame placed in a) the center of the plot, b) in the area of highest Japanese stiltgrass cotyledons and c) the area of lowest Japanese stiltgrass cotyledons. The average of the three counts was reported. Immediately after each count the plots were sprayed with glyphosate so that subsequent germination could be determined. Glyphosate (18%) was applied at 23 ml·L^{-1} (3 fl oz·gal^{-1}), which is half the strength of the label recommendation for general weed control but this rate completely controlled Japanese stiltgrass (data not shown). Counts were log transformed, resulting in a significant linear regression.

Glyphosate timing trial. The study was conducted at the Piney Grove Preserve. A randomized complete block with four replications was used for all trials. Glyphosate (18% active ingredient) was applied at 23 ml·L^{-1} (3 fl oz·gal^{-1}). Spraying was conducted on either May 7, 2016, June 23, 2016, or July 23, 2016. Percent ground cover for Japanese stiltgrass and other plant species was determined visually in all plots and recorded photographically. Observations were made on approximately a monthly basis during the growing season in 2016 through 2019. Japanese stiltgrass plants heights were also recorded. A randomized complete block with four replications was used for all trials. Plot size was either 1.8 m by 1.8 m (6 ft. by 6 ft) or 1.2 m by 1.2 m (4 ft by 4 ft) with at least 0.3 m (1 ft) between pots. Data was subjected to analysis of variance. Standard deviation was plotted in conjunction with treatment means.

On March 16, 2017, the test area was subjected to a controlled burn as part of the planned maintenance program for the pine savannah in the preserve. Despite this, the trial was continued into 2017 and beyond with further May, June and July 2017 treatments to Japanese stiltgrass that had germinated from any residual seedbank remaining from 2016. Observations continued, but no

Table 1. **Japanese stiltgrass stand in April and crabgrass (southern plus smooth) stand in July as affected by prodiamine application timing and rate in field trials.**

			Number per plot			
			Japanese stiltgrass	Crabgrass	Japanese stiltgrass	Crabgrass
Treatment	Rate ($kg \cdot ha^{-1}$)	Month	Trial 1		Trial 2	
Nontreated			512	346	197	58
Prodiamine	0.84	December	48	53	138	4
Prodiamine + Prodiamine	0.42 + 0.42	December + March	48	28	46	1
Prodiamine + Prodiamine	0.42 + 0.42	December + May	127	22	112	14
Prodiamine + Prodiamine + Prodiamine	0.42 + 0.42 + 0.42	December + March + May	44	8	50	1
Prodiamine	0.84	March	30	95	31	9
Prodiamine + Prodiamine	0.42 + 0.42	March + May	94	38	114	2
LSD 0.05			106	56	91	14

further glyphosate treatments were made in 2018 and 2019, to see if Japanese stiltgrass was able to reestablish itself.

Results and Discussion

Preemergence herbicide trial. In trial 1, all treatments reduced Japanese stiltgrass stand by at least 75% (Table 1). Treatments that included prodiamine at 0.84 $kg \cdot ha^{-1}$ applied in December or March or twice at 0.42 $kg \cdot ha^{-1}$ in December and March or three times at 0.42 $kg \cdot ha^{-1}$ all tended to provide greater reductions than that seen when prodiamine was applied twice at 0.42 $kg \cdot ha^{-1}$ in December plus May or March plus May. This matches the germination pattern seen in Figs. 1 and 2, where the bulk of the germination occurred prior to May. May preemergence applications would therefore be too late, as much of the Japanese stiltgrass germination would have already occurred. A different result was noted for crabgrass, where treatments utilizing a May application tended to provide greater control. A similar pattern for Japanese stiltgrass and crabgrass stand in spring as affected by prodiamine application was seen in trial 2 (Table 1). Japanese stiltgrass starts to germinate a week or more prior to crabgrass germination (J. Derr, unpublished data), supporting the need for earlier applications to control Japanese stiltgrass than crabgrass species. Besides the timing impact, the greater soil organic matter level for the Japanese stiltgrass location than the crabgrass trial most likely led to soil adsorption and thus lower overall effectiveness in the Japanese stiltgrass study.

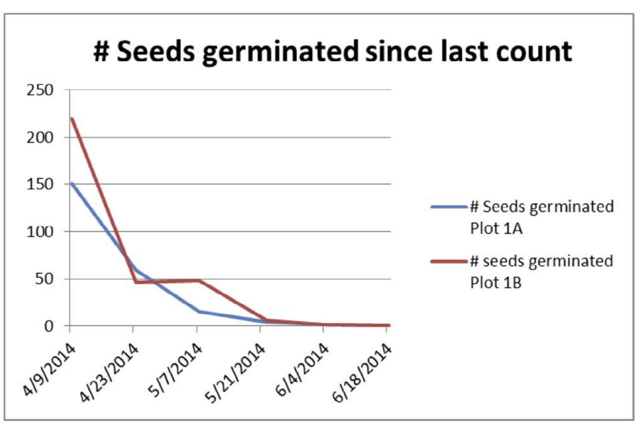

Fig. 1. Number of Japanese stiltgrass seedlings germinating over time at two locations in the Piney Grove Preserve. Seedlings were sprayed with glyphosate after each count.

By August, however, surviving Japanese stiltgrass plants in the preemergence-treated plots increased their cover over summer (Table 2). The lowest Japanese stiltgrass cover seen in trial 1 was 15% and in trial 2 was 19%. Although preemergence herbicides significantly reduced Japanese stiltgrass stand, surviving plants were able to produce significant cover by August through lateral growth of surviving plants. Although preemergence herbicide applications significantly reduced Japanese stiltgrass stand, other means would be required to control surviving plants, such as postemergence herbicide applications. Otherwise, the surviving plants would produce seed, replenishing the seedbank.

Germination trial. Japanese stiltgrass germination decreased from April to June (Fig. 1). No Japanese stiltgrass was observed on June 18, with the bulk of the germination having occurred before May. When the log of Japanese stiltgrass counts were plotted over time, (Fig. 2), a linear relationship was observed with an R^2 of 0.87. Japanese stiltgrass is an early-germinating summer annual, with peak germination occurring prior to June.

Glyphosate timing trial. Glyphosate applications in June or July provided excellent control of Japanese stiltgrass (Fig. 3A), as all treated plots showed zero surviving plants. Glyphosate applied in May significantly reduced Japanese stiltgrass cover, but later germinating plants resulted in over 25% cover by October. For a single application of glyphosate to be effective, it needs to be applied after germination has ceased, which appears to be sometime in June for eastern Virginia.

In early spring (March 16) 2017, the test areas were subjected to a controlled burn, part of the management program for the pine savannah. Despite this, monitoring and testing continued. The nontreated control plots showed reduced coverage of Japanese stiltgrass (down from 75% to 30% by the end of summer 2017), presumably attributable

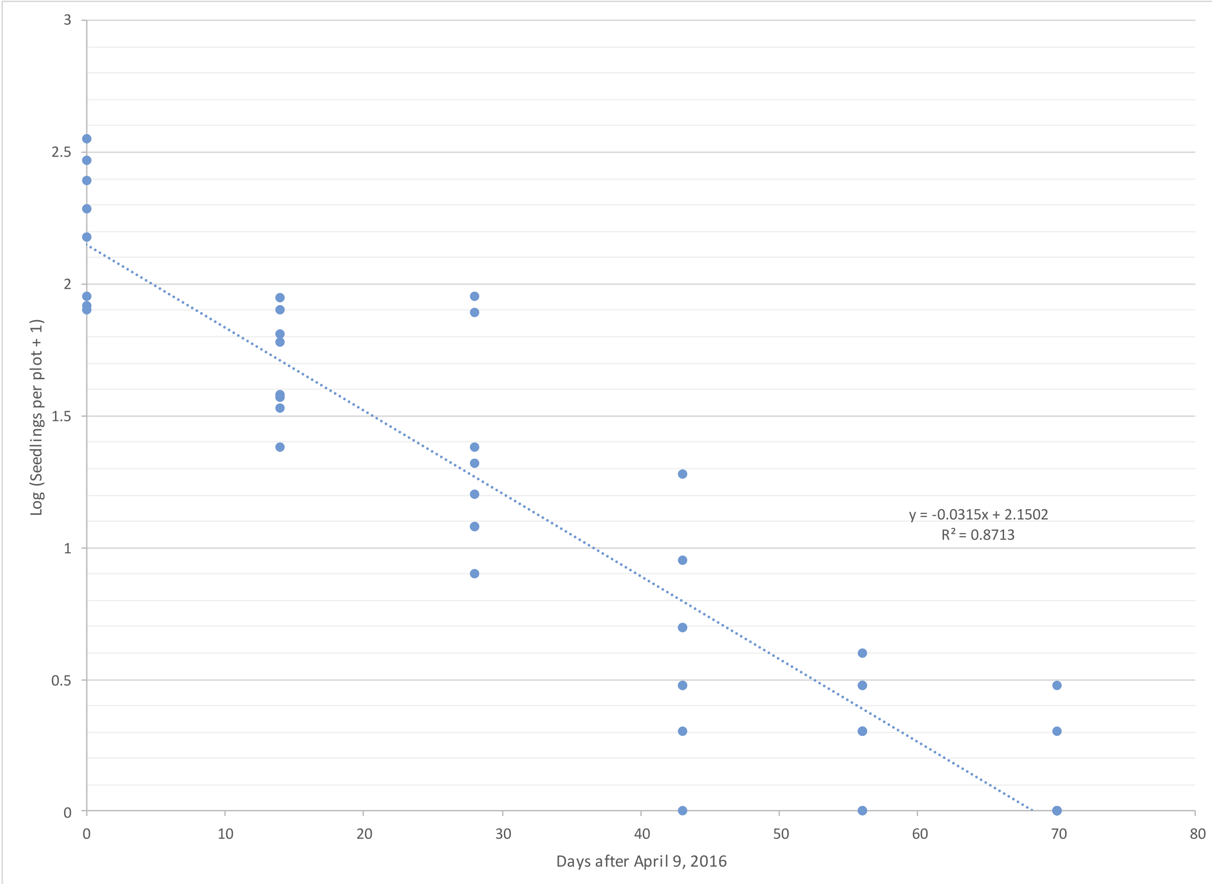

Fig. 2. Germination rate of Japanese stiltgrass in field studies at Piney Grove Preserve. Linear regression for the log of Japanese stiltgrass seedlings germinating over time, averaged across replicates in two discrete locations.

to the burn (data not shown). The plots treated in 2016 showed very low Japanese stiltgrass counts in 2017 (less than 1% coverage), presumably germinating from any residual seed bank. Data was recorded and treatment regimes in May, June and July were continued in 2017. By the end of summer 2017 the June and July treated plots showed zero Japanese stiltgrass present. These results have not been reported in detail as they were obviously impacted by the Spring burn.

In 2018 no further glyphosate treatments were conducted, but monthly observations continued to see how quickly the Japanese stiltgrass returned to the plots. In September 2018, the control plots showed 63% Japanese stiltgrass coverage and the May-treated plots had 30% coverage while the June and July treated plots showed an average of only 3% coverage from a few large plants that now had the space to increase in size (Fig. 3B). These few plants could be from a residual seedbank or just as easily from seed

Table 2. Japanese stiltgrass and Crabgrass (southern plus smooth) cover in August as affected by prodiamine application timing and rate in field trials.

			Percent cover in August			
			Japanese stiltgrass			
			Japanese stiltgrass	Crabgrass	Japanese stiltgrass	Crabgrass
Treatment	Rate (kg·ha^{-1})	Month	Trial 1		Trial 2	
Nontreated			83	73	78	53
Prodiamine	0.84	December	58	29	70	10
Prodiamine + Prodiamine	0.42 + 0.42	December + March	55	12	49	2
Prodiamine + Prodiamine	0.42 + 0.42	December + May	63	15	60	6
Prodiamine + Prodiamine + Prodiamine	0.42 + 0.42 + 0.42	December + March + May	15	6	44	2
Prodiamine	0.84	March	33	39	19	10
Prodiamine + Prodiamine	0.42 + 0.42	March + May	68	18	85	9
LSD 0.05			30	24	33	7

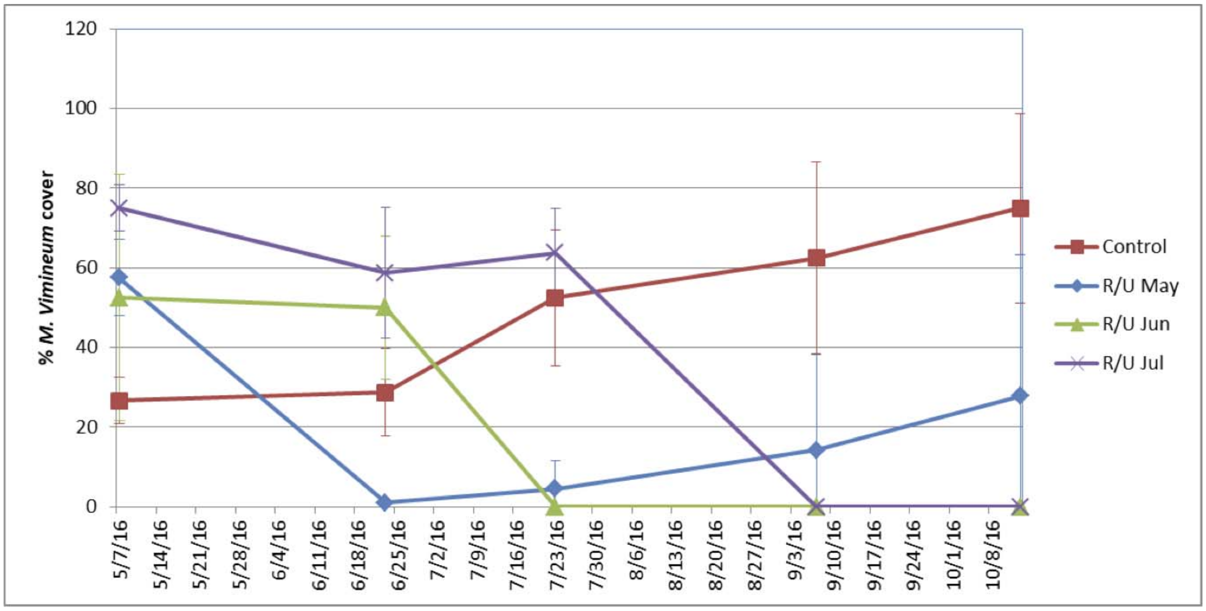

Fig 3A. Japanese stiltgrass coverage before and after single May, June and July 2016 treatments with glyphosate. Results are averages of replicate plots at Piney Grove Preserve. R/U May is glyphosate applied in May, R/U June is glyphosate applied in June, and R/U Jul is glyphosate applied in July. Bars denote standard error.

being transported into the test plots by animals, water flow or other means during the winter. It appears that eradication of Japanese stiltgrass after two years of glyphosate treatment resulted in essentially complete elimination of the seed bank.

Visual estimates of percent coverage in May/June were difficult as the emerging seedlings (cotyledons) are often covered by competing vegetation and leaf matter. Apparent decreases in Japanese stiltgrass coverage from May to June (as shown for the control plot in Fig 3B) are more likely due to the difficulty in measurement rather than any actual decline in Japanese stiltgrass plants.

Competing vegetation continued to grow well in the treated plots with some changes noted on the plant species present. Using glyphosate at one half the manufacturer's recommended application concentration apparently aided

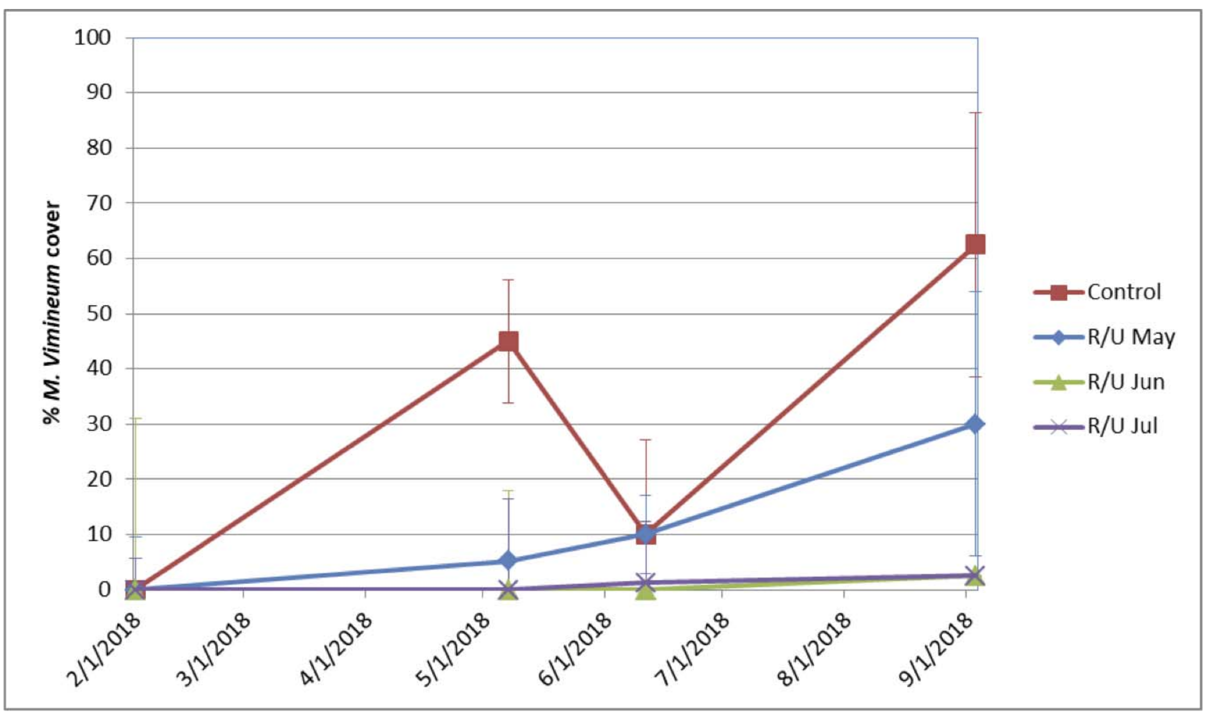

Fig. 3B. Japanese stiltgrass coverage in 2018 after single May, June and July glyphosate treatments in 2016 and 2017. Results are averages of replicate plots at Piney Grove Preserve. No treatments were applied in 2018. R/U May is glyphosate applied in May, R/U June is glyphosate applied in June, and R/U Jul is glyphosate applied in July. Bars denote standard error.

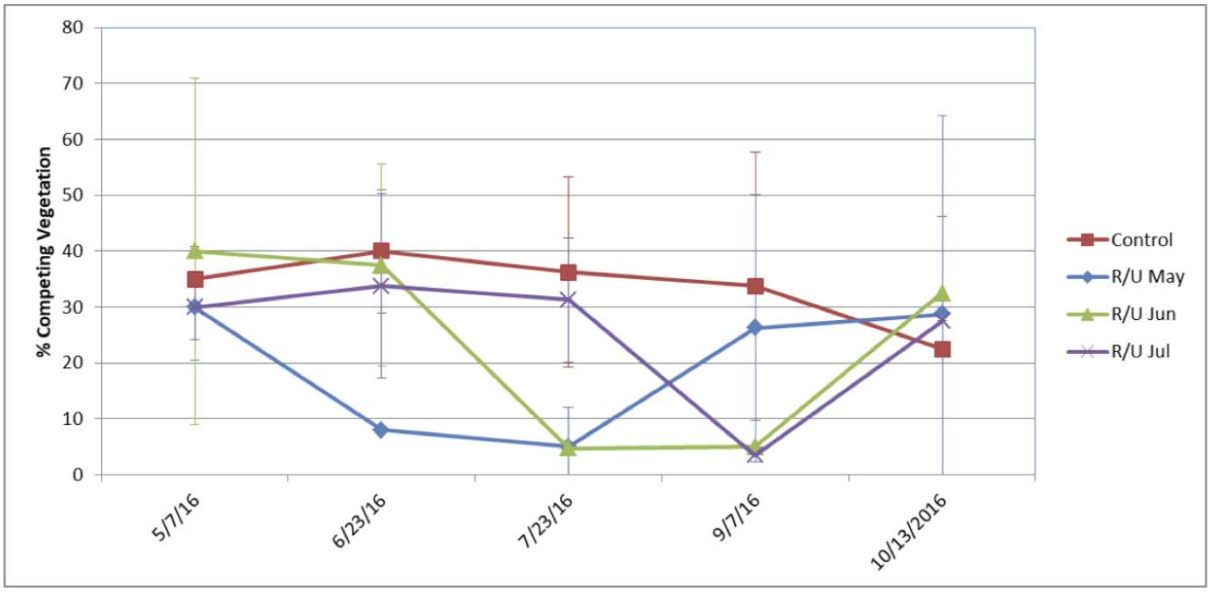

Fig. 4A. The effect of glyphosate treatments on competing vegetation within test plots at Piney Grove Preserve. Competing vegetation is able to recover after single treatments of glyphosate in May, June or July, 2016. R/U May is glyphosate applied in May, R/U June is glyphosate applied in June, and R/U Jul is glyphosate applied in July. Bars denote standard error.

competing plant survival. Fig 4B shows that percent competing plant coverage at the end of summer 2018 was a little higher than 2016 for all treatment regimes and for the control plots. The recommended June treatments eliminated Japanese stiltgrass while having minimal effects on competing vegetation.

In summary, single glyphosate application, if timed correctly, can be more effective than preemergence herbicide applications for Japanese stiltgrass control. Only low concentrations of glyphosate are needed to control Japanese stiltgrass. Herbicide treatments of Japanese stiltgrass should be delayed until mid-June in eastern Virginia to be fully effective. Leaving it later than this (July) makes effective spraying more difficult as competing vegetation may overshadow the Japanese stiltgrass. Japanese stiltgrass can be essentially eliminated after two consecutive years of June treatments. Most competing vegetation is able to withstand the low concentration of glyphosate recommended. Based on these results, the Piney Grove Preserve began a systematic June spraying program in 2017 and 2018 using suitable herbicides to reduce/eliminate Japanese stiltgrass.

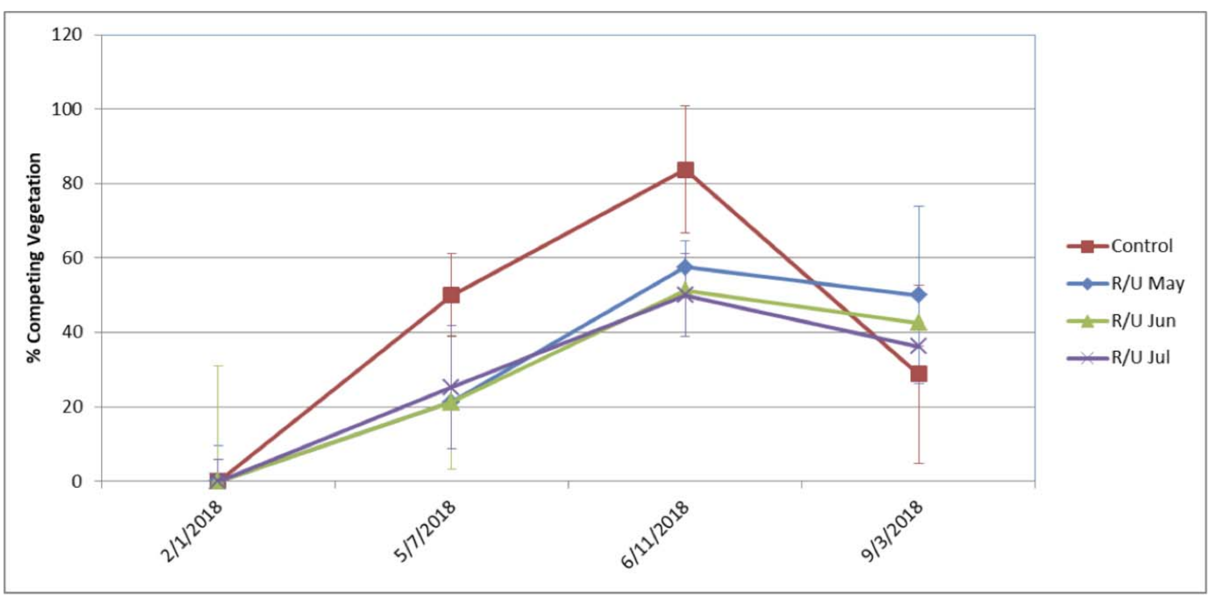

Fig. 4B. Percent competing vegetation in test plots in 2018 after single applications of glyphosate in May, or June, or July 2016, and 2017. Competing vegetation is able to recover after spraying with low concentrations of glyphosate. R/U May is glyphosate applied in May, R/U June is glyphosate applied in June, and R/U Jul is glyphosate applied in July. Bars denote standard error.

Literature Cited

Barden, L. 1987. Invasion of *Microstegium vimineum* (Poaceae), an exotic, annual, shade-tolerant, C 4 grass, into a North Carolina floodplain. American Midland Naturalist. 118. 40. https://dx.doi.org/10.2307/2425626.

Fairbrothers, E. D and R. Gray, J. 1972. *Microstegium vimineum* (Trin.) A. Camus (Gramineae) in the United States. Bulletin of the Torrey Botanical Club. 99(2): 97. doi:https://dx.doi.org/10.2307/2484205.

Flory, S. L. and J. Lewis. 2009. Nonchemical methods for managing Japanese stiltgrass (Microstegium vimineum). Invasive Plant Sci. Mgt. 2:301–308. doi:https://dx.doi.org/10.1614/IPSM-09-026.1

Fryer, J. L. 2011. Microstegium vimineum. *In*: Fire Effects Information System, [Online]. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory (Producer). http://www.fs.fed.us/database/feis/. Accessed October 19, 2017.

Judge, C., J. C. Neal, and J. F. Derr. 2005a. Preemergence and postemergence control of Japanese stiltgrass (*Microstegium vimineum*). Weed Technology 19:183–189.

Judge, C., J. C. Neal, and J. F. Derr. 2005b. Response of Japanese stiltgrass (Microstegium vimineum) to application timing, rate, and frequency of postemergence herbicides. Weed Technol. 194:912–917.

Redwood, M.E., C. Huebner, and G.R. Matlack. 2018. Seed longevity and dormancy state suggest management strategies for garlic mustard (*Alliaria petiolata*) and Japanese stiltgrass (*Microstegium vimineum*) in deciduous forest sites. Weed Sci. 66:190–198.

Tu, M. 2000. Element stewardship abstract for *Microstegium vimineum*. Nature Conservancy. https://www.invasive.org/gist/esadocs/documnts/micrvim.pdf. Accessed August 27, 2018.

Winter, K. and Schmitt, M., and G.E. Edwards. 1982. *Microstegium vimineum*, a shade adapted C4 grass. Plant Science Letters. 24:311–318. Doi:https://dx.doi.org/10.1016/0304-4211(82)90027-X.