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RESEARCH ARTICLE

Rapid kudzu eradication and switchgrass establishment through herbicide, bioherbicide and integrated programmes

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ABSTRACT

Among the most important and visible weeds in the Southeastern USA is the exotic invasive vine, kudzu (*Pueraria montana* var. *lobata*). Efforts to eradicate it typically involve many years of application of restricted-use pesticides. Recent availability of effective, non-restricted-use pesticides and developments with the application of the bioherbicide *Myrothecium verrucaria* has made possible new control programmes for kudzu management. Field trials at three sites over two years with aminocyclopyrachlor, aminopyralid, fluroxypyr, metsulfuron methyl and combinations of these herbicides achieved 99–100% reduction in aboveground kudzu biomass. Additionally, programmes were developed that eradicated kudzu while simultaneously establishing native vegetation. One of these successful programmes integrated bioherbicide application, mechanical removal of kudzu biomass and planting switchgrass (*Panicum virgatum*) in an entirely chemical herbicide-free system. These field tests demonstrate a variety of methods that can be used independently or in an integrated approach for rapid kudzu eradication.

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Introduction

A series of deliberate introductions of kudzu (*Pueraria montana* var. *lobata)* throughout the Southeastern USA resulted in the wide establishment of one of the world's worst exotic invasive weeds (reviewed in Forseth & Innis, 2004; Mitich, 2000). This perennial vine is notorious for overtaking rural structures, and interfering with utilities and rights-of-way. Where kudzu is established, it frequently becomes the dominant plant species and completely suppresses desirable vegetation as well as undermining economically productive uses of the land (Grebner et al., 2011).

Given the high visibility of kudzu and the considerable negative effects of kudzu infestation in the southern USA, there is comparatively little documentation of successful management of this weed. Much of the limited scientific literature on kudzu management is devoted to herbicide evaluations, especially picloram (e.g. Everest et al., 1999; Miller, 1985, 1986, 1996; Miller & Edwards, 1983), a herbicide with limited selectivity, and

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high environmental persistence and mobility in groundwater (Berisford et al., 2006). Metsulfuron methyl (MSM) is also often listed as an effective herbicide, and other reports have documented kudzu suppression with clopyralid and triclopyr (e.g. Ezell & Nelson, 2006; Harrington et al., 2003). Kudzu management guides recommend a sustained effort of up to 10 years to achieve eradication (reviewed in Forseth & Innis, 2004). More recently two active ingredients, aminopyralid (AMP) and aminocyclopryachlor (AMCP) have proven to be very effective at suppressing, or even eradicating kudzu (Minogue et al., 2011; Weaver et al., 2015, 2016). Beyond these herbicide-based control papers, a few researchers have considered alternative control methods including grazing (Bonsi et al., 1992); plastic sheeting (Newton et al., 2008) and insect-based biocontrol (Frye et al., 2007, 2012; Sun et al., 2006). We have published on the bioherbicidal properties of *Myrothecium verrucaria* (MV) on many weed species, including kudzu (e.g. Boyette et al., 2002; Hoagland et al., 2007) and demonstrated compatibility or synergy with several herbicides (e.g. Boyette et al., 2008; Weaver & Lyn, 2007). While MV is presently unregistered and not widely available, improved production and formulation techniques of MV (Boyette et al., 2008; Weaver, Hoagland, Boyette, & Zablotowicz, 2009, Weaver, Jin, Hoagland, & Boyette, 2009) have facilitated field testing of MV in direct comparisons with herbicides for kudzu suppression (Weaver et al., 2015, 2016).

Harrington et al. (2003) considered the use of integrated weed management by coupling herbicide application with pine tree establishment. Similarly, Grebner et al. (2011) evaluated the increase in land expectation value when using herbicides to suppress kudzu in pine or oak afforestation enterprises. Depending on the goals of the particular land manager, other species could be selected for revegetation to prioritise suppression of soil erosion, wildlife habitat or biofuel production. Native perennial grasses such as switchgrass have received much attention recently as a means to produce biofuel from marginal lands (e.g. Sanderson & Adler, 2008). It might be possible to pursue this goal during the process of kudzu eradication. This approach is attractive for several reasons: there is potential for an overall reduction in herbicide use; the land is rapidly transitioned to productive use; when properly executed it may help minimise soil erosion that may result from kudzu removal. Concern over emerging herbicide resistance indicates a need for development of alternative control tactics.

We present here the results from a multi-year, multi-site experiment to address several questions related to the goal of localised kudzu eradication. Our objectives were to determine if it is possible to achieve localised kudzu eradication more rapidly with a more intensive, integrated approach. Is it possible to eradicate kudzu without the use of synthetic herbicides by using mowing, bioherbicides and suppressive vegetation? How effective are the newest commercial products relative to established herbicide programmes and bioherbicide systems? How effectively can native vegetation be established in existing kudzu stands prior to kudzu eradication?

Materials and methods

Study sites.

Kudzu-infested sites were identified on private land near Eden Mississippi, USA (33°0′16.73″N 90°15′56.11″W); Byhalia, MS, (34°51′33.03″N 89°45′52.18″W); and Mound

Bayou, MS, (33°52′53.79″N 90°36′44.71″W). Sites that had a dense, uniform kudzu cover and were situated on terrain that was accessible by an all-terrain vehicle (ATV) were selected for experiments. Study sites were divided into experimental units 2 m wide and at least 15 m long. Two, 1 m wide plot borders were mowed every 7–14 days during the growing season (May through October) to prevent interplot spread of the kudzu vines.

Treatments and experimental design

Ten treatments plus an untreated control were established (Table 1), with 3 replicates at each site (99 plots total). Treatments at each site were arranged in a randomised complete block design. The first four treatments listed in Table 1 tested fall and spring treatments of two new commercial products (AMCP + MSM or Streamline, and AMP + MSM or Chaparral), either applied first in the spring or first in the fall, with three applications total over 2010 and 2011. The next two treatments were current standard herbicides (MSM and AMP), each applied twice, in fall 2010 and fall 2011. The 'Herbicide 3×' treatment was an herbicide-intensive programme, with four treatments total of various standard products at full label rates (Table 1). The 'Organic' treatment used the bioherbicide *M. verrucaria* (MV) in combination with mowing and revegetation with switchgrass, while the two 'Integrated' treatments combined standard herbicides with switchgrass revegetation, either with or without mowing prior to planting the switchgrass. The control plots were sprayed with surfactant only (Induce, Helena Chemical, Collierville, TN) (Table 1).

M. verrucaria (IMI 361690) was grown on a defined glucose and ammonium nitrate-based agar medium (VMG) (Vogel, 1956; Weaver, Hoagland et al., 2009) for 5–9 days in autoclavable boxes with translucent lids (Market Labs, Caledonia, MI, USA) at 28°C in a 12 h light–dark cycle. Spores were collected by scraping the surface of the culture with a spatula under a small volume of water. The spore suspension was homogenised by mixing briefly in a Waring blender and passed through a Miralcloth filter before concentrating spores via centrifugation. The supernatant was discarded and the spore pellet was resuspended in sterile water and centrifuged again for a total of three washings. The washed spores were checked via HPLC to verify that they had no detectable mycotoxins (Weaver et al., 2012). Spore inoculum concentrations were adjusted to 2×10^7 spores mL^{-1} (by haemocytometer) immediately before application.

Herbicide and bioherbicide application methods were as described previously (Weaver et al., 2015, 2016). All products were applied via two, overlapping passes of an ATV equipped with a boomless, single-nozzle (TeeJet TFW-12, TeeJet Wheaton, IL) spray system delivering 374 L ha^{-1}. All applications included induce non-ionic surfactant at a rate of 0.25% (v:v), consistent with the herbicide label directions and shown to increase the bioherbicidal activity of MV (Weaver, Jin et al., 2009). Treatments requiring spot sprays were made via backpack sprayer (Solo, Newport News, VA) typically at less than 200 mL/plot. Spot sprays were only made when the treatment plan prescribed a spot spray and if there was visible, living kudzu plants within the particular plot. Mowing of plot borders and of some plots as a kudzu suppression tactic was achieved via an ATV-pulled mower (Bush Hog GT42, Selma, AL). Descriptions of all treatments are provided in Table 1.

Switchgrass seeds (*Panicum virgatum* cv. Alamo, Turner Seed Company Breckenridge, TX) were germinated in soilless potting mix (Jiffy Mix, Jiffy Products, Batavia, IL) and

Table 1. Experimental programmes evaluated in field trials 2010–2011.

Treatment name	Kudzu suppression method (commercial product name)	Rate of application (ai ha^{-1})[a]	Time of application[b]
AMCP + MSM SPRING/FALL	AMCP + MSM[c](Streamline)	131 + 42 g ha^{-1}	4 June 2010
		131 + 42 g ha^{-1}	1 September 2010
			6 June 2011
AMCP+MSM FALL/SPRING	AMCP + MSM (Streamline)	131 + 42 g ha^{-1}	1 September 2010
		131 + 42 g ha^{-1}	1 June 2011
			12 September 2011
AMP+MSM SPRING/FALL	AMP + MSM[d] (Chaparral)	72 + 11 g ha^{-1}	4 June 2010
		72 + 11 g ha^{-1}	1 September 2010
			6 June 2011
AMP+MSM FALL/SPRING	AMP + MSM (Chaparral)	72 + 11 g ha^{-1}	1 September 2010
		72 + 11 g ha^{-1}	1 June 2011
			12 September 2011
MSM	MSM[e] (Escort)	156 g ha^{-1}	1 September 2010
			12 September 2011
AMP	AMP[f] (Milestone)	122 g ha^{-1}	1 September 2010
			12 September 2011
Herbicide 3x	AMP+TCP[g] (MilestoneVM+)	125 + 1125 g ha^{-1}	1 June 2010
	MSM (Escort)	156 g ha^{-1}	21 June 2010
	Fluroxypyr (Vista)	561 g ha^{-1}	10 September 2010
	AMP+TCP[g] (MilestoneVM+)	125 + 1125 g ha^{-1}	1 June 2011
Organic	Mow	n.a.	1 June 2010
	Plant switchgrass	n.a.	21 June 2010
	MV[h]	7.5 × 10^{12} spore ha^{-1}	21 June 2010
	Mow	n.a.	1 July 2010[i]
	MV	Spot spray	10 September 2010
	MV	Spot spray	Two dates 2011[j]
Integrated	AMP + TCP (MilestoneVM+)	125 + 1125 g ha^{-1}	1 June 2010
	Mow	n.a.	21 June 2010
	Plant switchgrass	n.a.	21 June 2010
	MSM (Escort)	Spot spray	1 August 2010
	Mow	n.a.	20 August 2010[i]
	AMP+TCP[g] (MilestoneVM+)	125 + 1125 g ha^{-1}	1 June 2011
Integrated-no mow	AMP + TCP (MilestoneVM+)	125 + 1125 g ha^{-1}	1 June 2010
	Plant switchgrass	n.a.	21 June 2010
	MSM (Escort)	Spot spray	1 August 2010
	AMP+TCP[g] (MilestoneVM+)	125 + 1125 g ha^{-1}	1 June 2011
Control	Surfactant only (Induce)		

[a] Application rates expressed as g ha^{-1} of active ingredient(s).
[b] Time of application given is for the Byhalia site. Mound Bayou and Eden site treatments were within 1 week of the given date.
[c] Aminocyclopyrachlor (DPX-MAT28) + MSM.
[d] AMP+ MSM.
[e] Metsulfuron methyl.
[f] AMP = Aminopyralid.
[g] AMP + TCP Aminopyralid +triclopyr.
[h] Bioherbicide *M. verrucaria*.
[i] Treatment only applied at the Mound Bayou site.
[j] Dates of spot treatment varied across locations.

grown in 6 cm pots to a height of ca. 50 cm before transplanting in the field at a density of 1.7 plants m^{-2}. After transplanting, no supplemental water or fertiliser was provided.

Measurement of treatment efficacy

All aboveground, green kudzu biomass was collected from a 0.3 m^2 area, arbitrarily selected within each of the 99 plots in June of 2011 and June 2012, 12 and 24 months, respectively, after initiation of treatment programmes. In plots with kudzu suppression approaching 100%, multiple sampling grid placements were necessary to avoid false reporting of 100% control. The biomass was air-dried and the level of control was evaluated based on comparison to the biomass from surfactant only control treatments. Results were normalised by a square root of percent control transformation and differences between the control programmes analysed by analysis of variance and Tukey's mean separation test (JMP vers. 11.1.1). Measurements of switchgrass establishments were made in March of 2012 by collecting aboveground biomass and analysing as described for kudzu.

Results and discussion

Herbicidal treatments of kudzu

Kudzu biomass was reduced by all herbicide treatments and integrated programmes tested. In the first year, there was a significant treatment response and site response, but no site × treatment interactions. By the second year, all the treatments were approaching 100% reduction in above ground kudzu biomass, and at this point there was no significant difference between the treatment programmes or the sites (Table 2).

The MSM and AMP treatments represent the best of the current standard kudzu management recommendations. They include the maximum labelled rate of MSM and AMP, respectively, applied at the time of year most frequently recommended. These two products have proven highly effective in other published reports (Weaver et al., 2015, 2016) and were also highly effective at the three test sites reported here, resulting in >90% reduction in kudzu biomass after 1 year of application and 99% after a second year (Tables 3 and 4). We have observed higher efficacy with these products (previously and in this study) than has been reported elsewhere. This variation may be attributable to minor differences in application methods such as surfactant selection, or site-specific factors such as differences in kudzu biotype or regional climate. All three sites in the present study were further north than either of the sites reported in Minogue et al. (2011) and while kudzu is found much further north, it is possible that kudzu plant vigour is diminished at these latitudes. In fact, the overall response to all treatments in the present study was better at Byhalia, the northern-most site than at Eden, the southern-most site.

Two new commercial products were tested here that represent new formulations of previously tested active ingredients. These formulations, AMCP + MSM and AMP + MSM were applied twice per year at half the maximum labelled rate. Both of these products provided excellent kudzu suppression, as measured in June 2011 after they had been applied twice in the previous year. When AMP + MSM had only been applied once, however, the kudzu suppression was only 88% overall and localised kudzu eradication had only been achieved in one of the nine plots (Table 3). By June 2012, when these products had

Table 2. Analysis of variance of effects on kudzu suppression.

Source	Degrees of freedom	*F* ratio		Prob > *F*[a]	
		After 12 months	After 24 months	After 12 months	After 24 months
Whole model	29	1.679	0.946	**0.047**	0.554
Site	2	3.722	1.058	**0.030**	0.354
Treatment	9	3.001	1.037	**0.005**	0.445
Site*treatment	18	0.771	0.899	0.723	0.582

[a]Values in bold are significant at the .05 level.

Table 3. Kudzu aboveground dry weight reduction expressed as percentage of untreated control.

Treatment Name	Average Control[a] 12 month	Average Control[a] 24 month	Byhalia 12 month	Byhalia 24 month	Eden 12 month	Eden 24 months	Mound Bayou 12 month	Mound Bayou 24 month
AMCP + MSM SPRING/ FALL	98 a	100 a	100	100	100	100	95	100
AMCP + MSM FALL/ SPRING	91 ab	100 a	97	100	82	100	93	98
AMP+MSM SPRING/ FALL	97 a	99 a	99	97	96	100	97	100
AMP+MSM FALL/ SPRING	88 b	100 a	90	100	86	100	86	100
MSM	93 ab	99 a	96	100	90	100	93	98
AMP	90 ab	99 a	89	100	90	98	91	99
Herbicide 3x	98 a	100 a	99	100	94	100	100	100
Organic	91 ab	95 a	93	100	94	99	88	86
Integrated	95 ab	100 a	100	100	95	100	90	100
Integrated-no mow	96 ab	100 a	100	100	95	100	92	100
Site Average[c]			96.5 a	99.6 a	92.2 b	99.7 a	92.4 ab	98.1 a

[a] Values within a column with the same letter in common are not significantly different by Tukey test of differences.

been applied three times, >99% control was realised, regardless whether the treatments began in June or September. Overall, after 2 years, the AMCP + MSM and the AMP + MSM treatments each resulted in apparent localised kudzu eradication on ≥16 of 18 plots, regardless of whether treatments were applied first in fall or first in spring (Table 4).

The herbicide-intensive programme (herbicide 3x) made use of the full label application rate of three herbicides in one growing season and then retreatment with a full label herbicide application rate the following season. In the experiments presented here, this herbicide-intensive programme resulted in no less than 94% control after 1 year (the Eden location) and 100% control in all plots at all three sites after 2 years. This treatment programme may seem impractically expensive, but is actually quite reasonable when compared to the possible alternatives of repeated applications for 3–10 years. Even if the slower, traditional

Table 4. Number of plots with apparent localised kudzu eradiation.

Treatment name	Overall 12 months	Overall 24 months	Byhalia 12 months	Byhalia 24 months	Eden 12 months	Eden 24 months	Mound Bayou 12 months	Mound Bayou 24 months
	Number of Plots with zero observed kudzu[a]							
AMCP + MSM SPRING/FALL	8	9	3	3	3	3	2	3
AMCP + MSM FALL/ SPRING	1	8	1	3	0	3	0	2
AMP+MSM SPRING/ FALL	4	8	2	2	1	3	1	3
AMP+MSM FALL/ SPRING	1	8	1	3	0	2	0	3
MSM	0	8	0	3	0	3	0	2
AMP	2	6	1	3	0	2	1	1
Herbicide 3x	5	9	1	3	0	3	2	3
Organic	1	4	1	2	0	0	0	2
Integrated	6	9	3	3	0	3	0	3
Integrated-no mow	3	9	3	3	0	3	0	3
Site Total	31	78	16	28	4	25	6	25

[a] Number of plots with apparent localised eradiation, out of a possible 3 for each site and 9 for overall.

method uses spot applications in the later years, to save on herbicide costs, it would still incur substantial application costs for up to a decade. The more rapidly kudzu eradication can be achieved, the sooner the land can be returned to economic or ecosystem productivity.

Integrated management programmes for kudzu eradication

Published guides for kudzu control often recommend that herbicides be applied in the fall to maximise translocation and kill the plant before the carbohydrate reserves accumulate in the root (reviewed in Forseth & Innis, 2004). We did not restrict ourselves to this model, and instead the organic, herbicide 3x, and two integrated programmes were designed explicitly to kill as much kudzu as possible, as rapidly as possible, and to maintain season long pressure on any recovering plants. This continuous pressure was largely successful in preventing kudzu regrowth during the entire growing season and contributed to the low rates of observed kudzu regrowth.

The decision of which kudzu suppression programme to follow is conditioned on several factors, one of which is topography. The sites selected in this study avoided extreme slopes, and mowing would have been possible on any of the plots studied here. While we have proven that mowing alone, as little as once per year, can have an effect on kudzu suppression (Weaver et al., 2016), it is not possible on all sites. In our two integrated programmes, the addition of mowing had no discernable effect, with statistically similar results after 1 and 2 years of treatment and both yielded apparent localised kudzu eradication on all plots at every site after the second year. Thus, within the context of the multiple, aggressive steps to kill kudzu in the integrated treatments, mowing had no measurable, additional benefit.

The organic treatment programme represents the greatest departure from the traditional kudzu management prescriptions. Instead of relying on herbicides, we integrated multiple approaches that each were likely to have some efficacy, but were each unlikely to produce kudzu eradication when used alone. In work previously reported (Weaver et al., 2016), a single mowing event and two MV broadcast applications only resulted in 41% and 29% kudzu suppression, respectively, after 1 year. Here, by combining a single mowing event, 1 MV broadcast application and 2 MV spot sprays and planting switchgrass, we realised 91% kudzu suppression, overall, after 1 year. The overall efficacy of the organic programme was 91% and 95% after 1 and 2 years, respectively, and statistically equivalent to the best of the herbicide programmes. There is significant, and growing attention paid to the emergence of herbicide resistant weeds (e.g. Heap, 2014). A recent review and prospectus expressed concern regarding the 'unwillingness of many weed researchers to conduct real integrated weed management research' generally and the need for integration of non-herbicide-based tools specifically (Shaner & Beckie, 2014). We have demonstrated here that the overreliance on herbicides is not only unfortunate, but unnecessary.

Switchgrass establishment

There are several reasons to revegetate kudzu-infested sites with switchgrass. Areas of kudzu infestation coincide with some of the most erodible soils in the USA and switchgrass is among the favoured plant species for stabilising soils. Switchgrass is a native species and valued for the systemic ecosystem services it provides. It is a perennial grass that grows

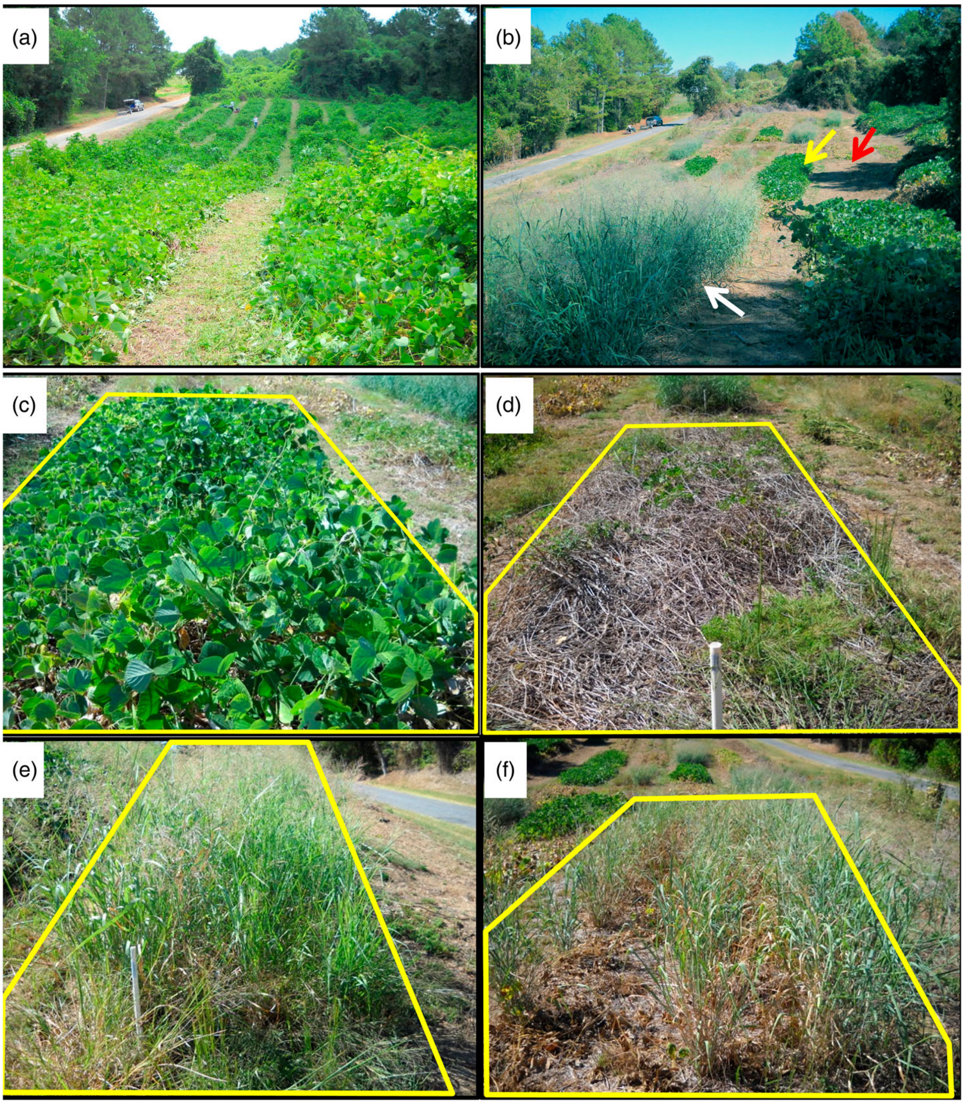

Figure 1. (Colour online) Representative results from the first four months of kudzu suppression programmes. All photos taken 3 June 2010 (a) and 29 September 2010 (b) at the Byhalia site. In panel (b) untreated kudzu is clearly visible as deep green plots (yellow arrow) and switchgrass establishment is visible in the organic and integrated plots (white arrow). Other successful kudzu suppression programmes can be seen as bare or brown plots (red arrow). More detailed images are presented from representative plots with untreated kudzu (c), herbicide 3× (d), integrated (e) and organic (f) programmes. Plot borders are indicated with yellow overlay.

well on marginal soils without supplemental fertility and produces enough biomass to be a viable biofuel crop (reviewed in Mitchell et al., 2012; Sanderson & Adler, 2008). Switchgrass may be especially suitable for lands as they transition out of kudzu infestation because it is highly tolerant to many of the herbicides deployed against kudzu. The bioherbicide MV is also not known to attack any grass species (Walker & Tilley, 1997).

In our efforts to establish switchgrass there was no significant effect of the kudzu control treatment, but a significant effect of location. Switchgrass yield in March 2011, 10 months after planting, ranged from 8.9 t ha^{-1} (±3.2) at the Eden site to 25.9 t ha^{-1} (±6.4) at the Byhalia site. In all three programmes that included switchgrass there was some kudzu suppression activity prior to planting, either an herbicide application (integrated-no mow), a mowing event (organic) or both (integrated). It was somewhat easier to hand plant the switchgrass seedlings in the mowed plots than in the unmowed, but there was no effect on the switchgrass biomass yield the following spring. A qualitative indication of the successful establishment of the switchgrass was the emergence of volunteer switchgrass plants in 2011 in the plot borders and even within other plots at the study site. Switchgrass is more commonly planted from seed using small-grain planting drills (Duffy & Nanhou, 2002), but this was not possible in our small-plot work. Planting seedlings likely gave the switchgrass an advantage in successful establishment in this warm, dry year, which offset the liability by the atypically late planting.

There are several factors that may contribute to the fate of a site after successful kudzu eradication. One possible outcome is bare ground, particularly if the kudzu infestation has depleted the local seed bank or if the herbicide regimen was not appropriately selective. Portions of Mississippi immediately outside of the Alluvial Delta, for example, the Loess bluffs, are known as some of the most erodible soils in the USA (Langdale et al., 1985). Kudzu was often introduced in this region to prevent soil erosion (reviewed in Forseth & Innis, 2004), and it would be inadvisable to trade an invasive weed problem for an erosion problem.

Figure 1(a) and (b) present an overview of the Byhalia site just before the kudzu treatments began and four months post-initiation of the programmes. Figure 1(c)–(f) provide a closer look at the development of an untreated plot; herbicide 3× plot; integrated and organic plot, respectively.

Conclusion

We have demonstrated here that rapid localised kudzu eradication is possible. Through use of new, selective herbicides, it is possible to simultaneously eradicate kudzu and introduce desirable native vegetation. Furthermore, the bioherbicide MV and mowing could be integrated into a kudzu eradication and switchgrass establishment programme with success similar to the best herbicides.

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Disclosure statement

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References

Berisford, Y. C., Bush, P. B., & Taylor, J. W. (2006). Leaching and persistence of herbicides for kudzu (*Pueraria montana*) control on pine regeneration sites. *Weed Science*, *54*, 391–400. doi:10.1614/WS-04-094R2.1

Bonsi, C., Rhoden, E., Woldeghebriel, A., Mount, P., Solaiman, S., Noble, R., & Cash, B. (1992). Kudzu-goat interactions – A Pilot Study. In S. G. Solaiman, & W. A. Hill (Eds.), *Using goats to manage forest vegetation, a regional inquiry* (pp. 84–88). Tuskegee, AL: Tuskegee University Agricultural Experiment Station.

Boyette, C. D., Hoagland, R. E., Weaver, M. A., & Reddy, K. N. (2008). Redvine (*Brunnichia ovata*) and trumpetcreeper (*Campsis radicans*) controlled under field conditions by a synergistic interaction of the bioherbicide, *Myrothecium verrucaria*, with glyphosate. *Weed Biology and Management*, *8*, 39–45. doi:10.1111/j.1445-6664.2007.00272.x

Boyette, C. D., Walker, H. L., & Abbas, H. K. (2002). Biological control of kudzu (*Pueraria lobata*) with an isolate of *Myrothecium verrucaria*. *Biocontrol Science and Technology*, *12*, 75–82. doi:10.1080/09583150120093031

Duffy, M. D., & Nanhou, V. Y. (2002). Costs of producing switchgrass for biomass in southern Iowa. In J. Janick, & A. Whipkey (Eds.), *Trends in New crops and new uses*(pp. 252–266). Alexandria, VA: ASHS Press.

Everest, J. W., Miller, J. H., Ball, D. M., & Patterson, M. (1999). *Kudzu in Alabama history, uses, and control*. Alabama A&M and Auburn Universities, Alabama Cooperative Extension System ANR-65

Ezell, A. W., & Nelson, L. (2006). Comparison of treatments of controlling kudzu prior to planting tree seedlings. In K. F. Connor (ed.) *Proceedings of the 13th Biennial Southern Silvicultural Research Conference* (pp. 148–149). US Department of Agriculture, Forest Service, Southern Research Station, Asheville, NC. General Technical Report SRS-92.

Forseth, I. N., & Innis, A. F. (2004). Kudzu (*Pueraria montana*): History, physiology, and ecology combine to make a major ecosystem threat. *Critical Reviews in Plant Sciences*, *23*, 401–413. doi:10.1080/07352680490505150

Frye, M. J., Hough-Goldstein, J., & Kidd, K. A. (2012). Response of kudzu (Pueraria montana var. lobata) to different types and levels of simulated insect herbivore damage. *Biological Control*, *61*, 71–77. doi:10.1016/j.biocontrol. 2012.01.008

Frye, M. J., Hough-Goldstein, J., & Sun, J. H. (2007). Biology and preliminary host range assessment of two potential kudzu biological control agents. *Environmental Entomology*, *36*, 1430–1440. doi:10.1603/0046-225X(2007)36 [1430:BAPHRA]2.0.CO;2

Grebner, D. L., Ezell, A. W., Prevost, J. D., & Gaddis, D. A. (2011). Kudzu control and impact on monetary returns to non-industrial private forest landowners in Mississippi. *Journal of Sustainable Forestry*, *30*, 204–223. doi:10.1080/10549811.2011.530559

Harrington, T. B., Rader-Dixon, L. T., & Taylor Jr, J. W. (2003). Kudzu (*Pueraria montana*) community responses to herbicides, burning, and high-density loblolly pine. *Weed Science*, *51*, 965–974. doi:10.1614/02-142ik

Heap, I. (2014). Global perspective of herbicide-resistant weeds. *Pest Management Science*, *70*, 1306–1315. doi:10.1002/ps.3696

Hoagland, R. E., Boyette, C. D., Weaver, M. A., & Abbas, H. K. (2007). Bioherbicides: Research and risks. *Toxin Reviews*, *26*, 313–342. doi:10.1080/15569540701603991

Langdale, G. W., Denton, H. P., White Jr., A. W., Gilliam, J. W., & Frye, W. W. (1985). Effects of erosion on crop productivity of southern soils. In R. F. Follett, & B. A. Stewart (Eds.), *Soil erosion and crop productivity* (pp. 252–267) Madison, WI: ASA, CSSA, and SSSA.
Miller, J. H. (1985). Testing herbicides for kudzu eradication on a Piedmont site. *Southern Journal of Applied Forestry*, *9*, 128–132.
Miller, J. H. (1986). *Kudzu eradication trials testing fifteen herbicides*. In Proceedings Southern Weed Science Society, 39th annual meeting (pp. 276–281). Nashville, TN, USA.
Miller, J. H. (1996). Kudzu eradication and management. In D. Hoots, & J. Baldwin (Eds.), *Kudzu: The vine to love or hate* (pp. 137–149). Kodak, TN: Suntop Press.
Miller, J. H., & Edwards, B. (1983). Kudzu: Where did it come from? And how can we stop it? *Southern Journal of Applied Forestry*, *7*, 165–169.
Minogue, P. J., Enloe, S. F., Osiecka, A., & Lauer, D. K. (2011). Comparison of aminocyclopyrachlor to common herbicides for kudzu (*Pueraria montana*) management. *Invasive Plant Science and Management*, *4*, 419–426. doi:10.1614/IPSM-D-11-00024.1
Mitchell, R., Vogel, K. P., & Uden, D. R. (2012). The feasibility of switchgrass for biofuel production. *Biofuels*, *3*, 47–59. doi:10.4155/bfs.11.153
Mitich, L. W. (2000). Kudzu [*Pueraria lobata* (Willd.) Ohwi] 1. *Weed Technology*, *14*, 231–235.
Newton, C. H., Nelson, L. R., Dewalt, S. J., Mikhailova, E. A., Post, C. J., Schlautman, M. A., & Hall, K. C. (2008). Solarization for the control of *Pueraria montana* (kudzu). *Weed Research*, *48*, 394–397. doi:10.1111/j.1365-3180.2008.00660.x
Sanderson, M. A., & Adler, P. R. (2008). Perennial forages as second generation bioenergy crops international. *Journal of Molecular Sciences*, *9*, 768–788. doi:10.3390/ijms9050768
Shaner, D. L., & Beckie, H. J. (2014). The future for weed control and technology. *Pest Management Science*, *70*, 1329–1339. doi:10.1002/ps.3706
Sun, J. H., Liu, Z. D., Britton, K. O., Cai, P., Orr, D., & Hough-Goldstein, J. (2006). Survey of phytophagous insects and foliar pathogens in China for a biocontrol perspective on kudzu, Pueraria montana var. lobata (Willd.) Maesen and S. Almeida (Fabaceae). *Biological Control*, *36*, 22–31. doi:10.1016/j.biocontrol.2005.09.007
Vogel, H. J. (1956). A convenient growth medium for Neurospora. (medium N.). *Microbial Genetics Bulletin*, *13*, 42–43.
Walker, H. L., & Tilley, A. M. (1997). Evaluation of an isolate of *Myrothecium verrucaria* from sicklepod (*Senna obtusifolia*) as a potential mycoherbicide agent. *Biological Control*, *10*, 104–112. doi:10.1006/bcon.1997.0559
Weaver, M. A., Boyette, C. D., & Hoagland, R. E. (2012). Bioherbicidal activity from washed spores of *Myrothecium verrucaria*. *World Journal of Microbiology and Biotechnology*, *28*, 1941–1946. doi:10.1007/s11274-011-0996-8
Weaver, M. A., Boyette, C. D., & Hoagland, R. E. (2016). Management of kudzu by the bioherbicide, *Myrothecium verrucaria*, herbicides and integrated control programmes. *Biocontrol Science and Technology*, *26*, 136–140. doi:10.1080/09583157.2015.1072762
Weaver, M. A., Hoagland, R. E., & Boyette, C. D. (2015). Kudzu response to foliar applied herbicides. *American Journal of Plant Sciences*, *6*, 856–863. doi:10.4236/ajps.2015.67093
Weaver, M. A., Hoagland, R. E., Boyette, C. D., & Zablotowicz, R. M. (2009). Macrocyclic trichothecene production and sporulation by a biological control strain of *Myrothecium verrucaria* is regulated by cultural conditions. *World Mycotoxin Journal*, *2*, 35–43. doi:10.3920/WMJ2008.1026
Weaver, M. A., Jin, X., Hoagland, R. E., & Boyette, C. D. (2009). Improved bioherbicidal efficacy by *Myrothecium verrucaria* via spray adjuvants or herbicide mixtures. *Biological Control*, *50*, 150–156. doi:10.1016/j. biocontrol.2009.03.007
Weaver, M. A., & Lyn, M. E. (2007). Compatibility of a biological control agent with herbicides for control of invasive plant species. *Natural Areas Journal*, *27*, 264–268. doi:10.3375/08858608(2007) 27[264:COABCA]2.0.CO;2