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RESEARCH ARTICLE

Sericea lespedeza control with postemergence and preemergence herbicide applications in fields managed for northern bobwhite

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Abstract

Sericea lespedeza (*Lespedeza cuneata*) is an invasive nonnative legume that commonly occurs on sites managed for northern bobwhite (*Colinus virginianus*). Sericea reduces bobwhite habitat availability by outcompeting native plants that provide food and cover. Sericea can be controlled with postemergence herbicides such as glyphosate as well as a mixture of triclopyr with fluroxypyr, but these herbicides do not provide pre-emergence control. Imazapic has been effective at controlling a limited number of planted sericea seeds, but the efficacy of imazapic at various application rates to control sericea seedbank response following treatment with a postemergence herbicide has not been evaluated. We designed a field experiment to evaluate sericea control and changes in the plant community as related to bobwhite habitat with 2 postemergence herbicides followed by preemergence treatment of imazapic at 3 sites in Tennessee and Alabama, USA, 2018–2022. Specifically, we treated sericea with post-emergence broadcast applications of glyphosate or triclopyr with fluroxypyr in 2018 and applied spot treatment with the same herbicides in 2019–2021. We applied imazapic at 4 rates following prescribed fire in 2019 and 2022. We measured coverage of sericea, native forbs, annual grasses, perennial grasses, and bobwhite food plants before treatment in 2018 and after all treatments in 2022. Nearly all postemergence treatments reduced sericea coverage, but imazapic did not increase control compared to postemergence herbicides alone. Perennial grasses used for nesting and bobwhite foraging were maintained following treatments. We recommend managers use either glyphosate or triclopyr with fluroxypyr to control sericea postemergence and consider using a low rate of imazapic to reduce annual grasses if coverage is a problem on the site.

KEYWORDS

Colinus virginianus, early succession, imazapic, invasive species, *Lespedeza cuneata*, northern bobwhite, postemergence herbicide, preemergence herbicide

Sericea lespedeza (*Lespedeza cuneata*; hereafter, sericea) is a warm-season, perennial legume that is one of the most problematic invasive plants in the eastern U.S. Sericea was introduced to North America in 1896 for livestock forage and was planted over a broad geographical area during the 20th century to control erosion and provide food and cover for wildlife (Ohlenbusch et al. 2007). Sericea tends to form dense stands and outcompete native plant species (Eddy and Moore 1998, Brandon et al. 2004), and remains viable in the soil for at least 25 years because of hardness of the seed (Offutt and Baldridge 1973), which makes it difficult to eradicate. Controlling sericea is a priority when restoring early successional plant communities for wildlife, as plant diversity often is reduced by sericea invasion (Cummings et al. 2007, Brooke and Harper 2016, Harper 2017).

Sericea presents multiple problems when it occurs in early successional plant communities managed for northern bobwhite (*Colinus virginianus*; hereafter, bobwhite). Sericea responds positively to disturbance, such as prescribed fire (Wong et al. 2017), which is commonly used to manage bobwhite habitat. Bobwhite eat sericea seed, but they cannot digest the seed because of hardness (Newlon et al. 1964). Sericea consumption leads to reduced bobwhite weights, and extensive sericea coverage may lead to reduced bobwhite survival and fecundity (Newlon et al. 1964, Peters et al. 2015). In addition to being problematic as a food plant, sericea produces phytotoxins that reduce germination of other plants (Adams et al. 1973, Kalburtji and Mosjidis 1993). Invertebrates important for bobwhite chicks tend to avoid sericea relative to other plants (Bugg and Dutcher 1989). Given the requirement of early successional communities for bobwhite, sericea presents major limitations when managing for bobwhite across much of the South, Midwest, and Great Plains (Hessler et al. 2004, Cummings et al. 2007, GeFellers et al. 2020, Alexander et al. 2021).

Postemergence herbicides are often used to control sericea. For example, triclopyr, fluroxypyr, and metsulfuron methyl are effective at controlling sericea postemergence, but 2,4-D and dicamba are not (Altom et al. 1992, Koger et al. 2002, Bradley and Masters 2007). Brooke and Harper (2016) reported triclopyr, triclopyr with fluroxypyr, and glyphosate all effectively reduced sericea one and 2 growing seasons after treatment. However, because of seed hardness and longevity in the seedbank, sericea seed continue to germinate and establish years after initial postemergence treatment (Offutt and Baldridge 1973). Therefore, regular postemergence treatment is necessary, which can be problematic because all postemergence herbicides that control sericea also kill forbs beneficial to bobwhite (GeFellers et al. 2020).

Additional treatment following initial application of postemergence herbicides may improve long-term control of sericea. Spot spraying postemergence herbicides commonly is used to follow initial applications (Ohlenbusch et al. 2007, Brooke and Harper 2016). Targeted grazing and prescribed fire may reduce sericea coverage, but fire stimulates germination of sericea seed, and grazing is less effective unless plants are young and palatable

(Cummings et al. 2007, Bell 2012, Alexander et al. 2021). Farris and Murray (2009) reported recently seeded sericea was controlled with preemergence applications of flumioxazin, imazapic, fluometuron, diuron, sulfentrazone, atrazine, metribuzin, and metolachlor. These herbicides were applied separately at various rates, and planted sericea seedling survival was reduced with preemergence treatments (Farris and Murray 2009). Imazapic is of particular interest when managing for bobwhite, as many native species are tolerant of imazapic and it often is used to restore early successional plant communities (GeFellers et al. 2020). According to the Plateau® (BASF Corporation, Research Triangle Park, NC, USA) herbicide label, seedling sericea is not tolerant of imazapic (BASF 2011). However, field experiments using imazapic to control new seedlings on sites with established sericea are lacking.

We designed a field experiment to test the efficacy of different rates of imazapic applied preemergence following initial postemergence treatment of triclopyr with fluroxypyr or glyphosate for sericea control to improve bobwhite habitat quality. We hypothesized both postemergence treatments would reduce sericea coverage, and higher rates of imazapic would further improve control. We also hypothesized imazapic would reduce annual grass and overall vegetation coverage, which could benefit bobwhite by increasing openness at ground level. We predicted perennial grass would decrease and forbs would increase with glyphosate treatments compared to triclopyr with fluroxypyr treatments because triclopyr with fluroxypyr controls forbs but not grasses.

STUDY AREA

We established 3, 1.1-ha sites in Tennessee and Alabama to evaluate sericea control (Figure 1). Catoosa was located on Catoosa Wildlife Management Area (WMA) in Crossville, TN, and is owned by the Tennessee Wildlife Resources Agency (TWRA). Soil at the site was predominately Hendon silt loam (Natural Resource Conservation Service [NRCS 2022]). Guntersville was located on Tennessee Valley Authority (TVA) property in Guntersville, Alabama. Soil at the site was predominately Allen-Waynesboro sandy clay loam (NRCS 2022). Pea Ridge was located on Pea Ridge WMA and was owned by TWRA. Soil at the site was predominately Dickson silt loam (NRCS 2022). Mean annual temperature was 12.7–15.5°C, and mean annual precipitation was 134–138 cm (National Oceanic and Atmospheric Administration 2022). All sites were represented by early successional plant communities with at least 50% coverage of sericea prior to treatment. Sericea was present on all sites for at least 10 years prior to study initiation. No control efforts for sericea had been conducted prior to treatment implementation at any of the sites, and all sites had been maintained previously as open plant communities with periodic prescribed fire.

METHODS

Treatments

We divided each site into 9, 0.1-ha treatment units and assigned treatments in a complete random design. We randomly assigned one unit to serve as an untreated control. We randomly assigned a postemergence treatment to each of the remaining units, with 4 receiving each treatment: glyphosate or triclopyr with fluroxypyr. We then randomly assigned a preemergence treatment to the 4 units in each of the postemergence groups: 0 kg/ha, 0.07 kg/ha, 0.14 kg/ha, and 0.21 kg/ha acid equivalent of imazapic.

All herbicide treatments were applied using a 3-nozzle ATV boom sprayer applying 140 liters of water per hectare. We conducted initial broadcast postemergence treatments to each site in August 2018 prior to sericea flowering. Soil moisture at the timing of application was sufficient to promote plant growth and enable efficacy of the postemergence applications. We applied 1.7 kg/ha acid equivalent of glyphosate as Cornerstone® Plus (Winfield Solutions, St. Paul, MN, USA; 4.8 L/ha of 41% glyphosate) in the glyphosate treatment units. We applied 0.42 kg/ha acid equivalent of triclopyr with 0.14 kg/ha acid equivalent of fluroxypyr as PastureGard™ HL (Dow AgroSciences, Indianapolis, IN, USA; 1.2 L/ha of

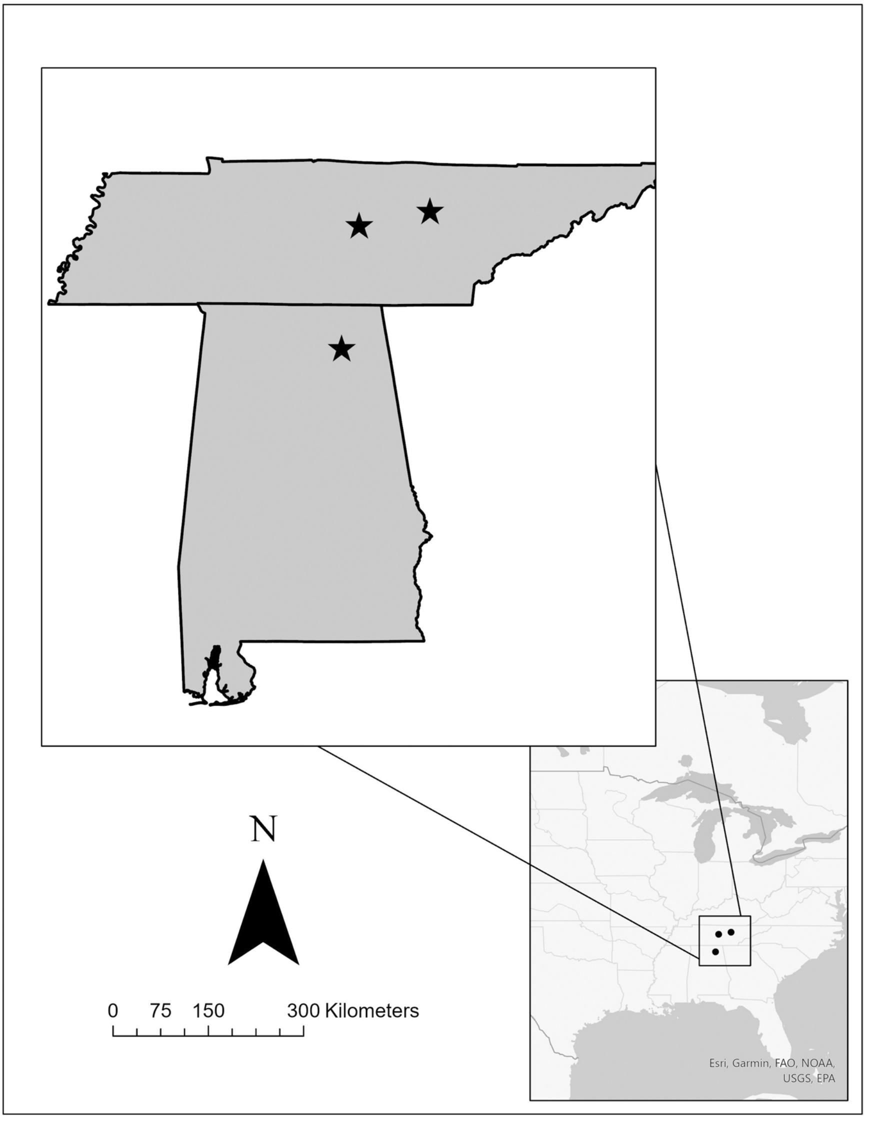

FIGURE 1 Map of locations in Alabama and Tennessee, USA, where sericea lespedeza control treatments were tested from 2018–2022. The Tennessee sites were located at Catoosa and Pea Ridge Wildlife Management Areas, which were owned and managed by the Tennessee Wildlife Resources Agency. The Alabama site was located at Guntersville, which was owned and managed by the Tennessee Valley Authority.

45.1% triclopyr + 15.6% fluroxypyr) with 0.5% Preference® (Winfield Solutions, St. Paul, MN, USA) nonionic surfactant in the triclopyr with fluroxypyr treatment units. The rates were based on label recommendations for sericea control (WinField Solutions 2017, Dow Agrosciences 2020). We burned all treatment units and the control at each site in early March 2019 to facilitate preemergence treatment applications. We broadcast imazapic as Plateau® (23.6% imazapic) in corresponding treatment units (0 ml/ha, 292.2 ml/ha, 584.3 ml/ha, and 876.5 ml/ha, respectively) in early April 2019. Hereafter, treatments will be referred to as postemergence herbicide + imazapic rate (kg/ha ai). Seedling sericea is labeled as intolerant of 0.07 kg/ha imazapic (BASF 2011), and we wanted to test whether doubling or tripling the rate would result in greater residual control and how that might affect other food and cover plants for bobwhite. Each unit received the corresponding rate of imazapic, and sites received sufficient rainfall within 7 days to ensure the herbicide was incorporated into the soil solution.

We conducted postemergence spot treatment of sericea using backpack sprayers to further control sericea in early summer 2019, 2020, and 2021. We applied a 5% solution of glyphosate and a 1% solution of triclopyr with fluroxypyr in the respective posttreatment units. We wet the foliage according to the respective herbicide label recommendations during spot treatment to ensure sufficient herbicide was applied to all sericea plants present.

Following 3 years of sericea spot treatment during the summers of 2019–2021, we burned sites again in early March 2022 to prepare for a second preemergence application. We decided to apply a second preemergence application because sericea was continuing to emerge from the seedbank and we were interested to see if a second application would provide control. We applied imazapic at all sites again in early March 2022. Each unit received the corresponding rate of imazapic, and all sites received sufficient rainfall within 24 hours of treatment to incorporate the herbicide into the soil solution.

Data collection

We collected pretreatment data in 2018, and posttreatment data in 2019, 2020, 2021, and 2022. We measured plant coverage along 3, 20-m point-intercept transects in each unit during late May–early June. We documented plant species occurring every 1.5 m along each transect for a total of 39 observations per experimental unit. Following collection, we calculated coverage of all plants to species within each treatment unit.

Analysis

We used analysis of covariance (ANCOVA) in in Program R (v. 4.20, R Core Team 2022) to determine the influence of postemergence and preemergence treatments on sericea control and the overall plant community. We included site as a covariate along with treatment to account for variation between study sites. Although we collected data every year of the study, we were interested in the cumulative results following a control program that involved initial broadcast postemergence treatments, subsequent spot treatments each year, and 2 preemergence herbicide treatments over 5 years. We analyzed the change in coverage of sericea and all other plants from 2018 to 2022. We grouped other plants into native forbs, annual grasses, perennial grasses, and bobwhite food plants. To account for differences in pretreatment plant coverage in each treatment unit, we calculated change in coverage of each plant type from 2018–2022, and analyzed the data based on the calculated value. We used the Tukey procedure to determine significant differences between treatments. We set $\alpha = 0.05$ for all statistical tests.

RESULTS

Average pretreatment coverage of sericea was 70.1% (Figure 2). All treatments except glyphosate + 0 reduced sericea coverage from 2018–2022 compared to control ($F_{8,16} = 5.3$, $P = 0.002$; Table 1), and the change in sericea coverage differed by site ($F_{2,16} = 15.7$, $P < 0.001$). No differences in efficacy were observed among any of our treatments. All sites had 100% overall vegetation coverage in 2018. Overall vegetation coverage change varied by site ($F_{2,16} = 6.4$, $P = 0.009$) but not treatment ($F_{8,16} = 1.9$, $P = 0.126$).

Average pretreatment coverage of native forbs was 59.0% (Figure 2). We documented a change in native forb coverage by site ($F_{2,16} = 13.7$, $P < 0.001$), but not treatment ($F_{8,16} = 2.3$, $P = 0.079$; Table 2). We documented several abundant native forb species at each site, but no nonnative forb other than sericea had >1% coverage at any site. Average pretreatment coverage of bobwhite food plants was 23.2%. We did not document change in bobwhite

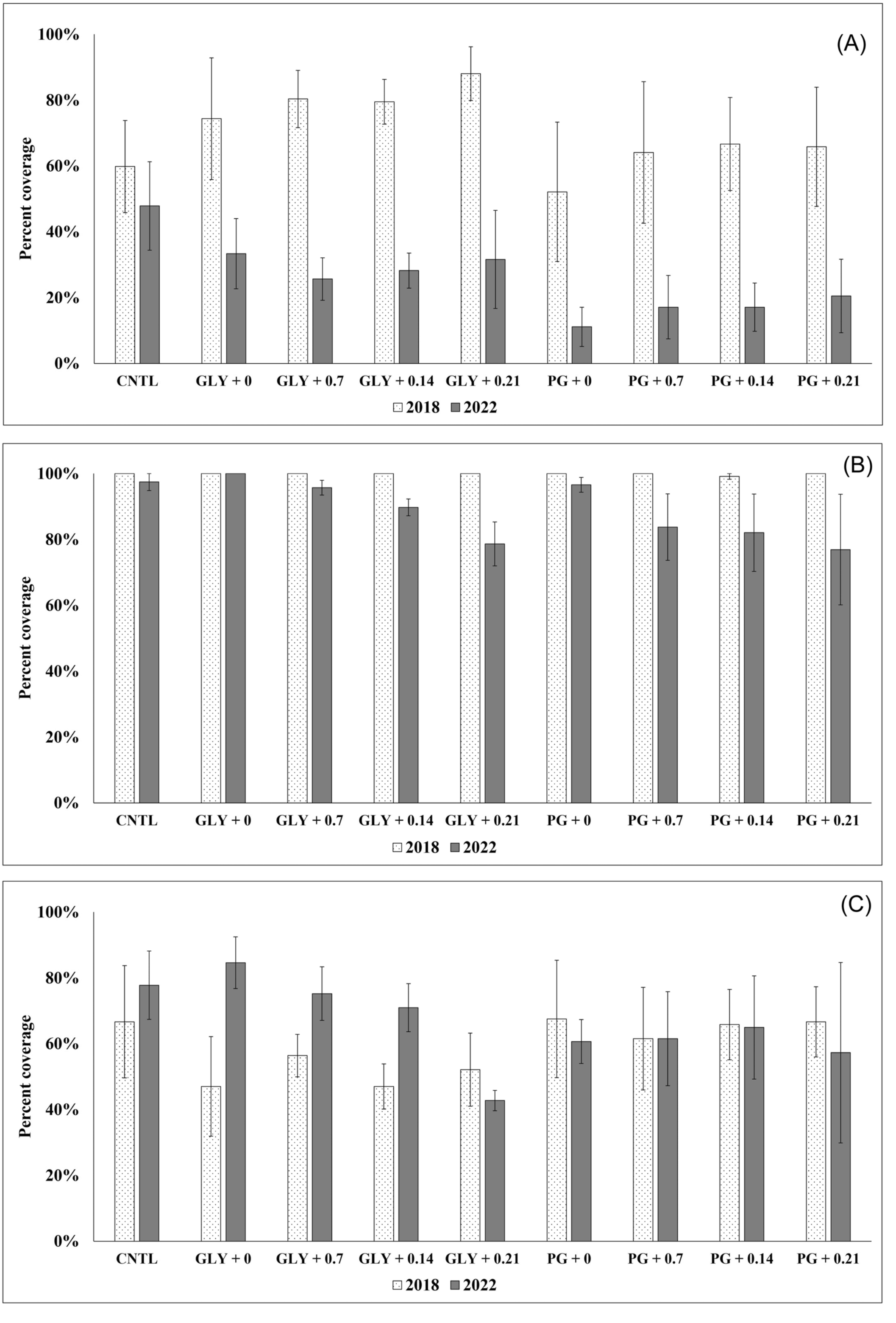

FIGURE 2 (See caption on next page)

TABLE 1 Beta (β), standard error (SE), and *P*-values from ANCOVA evaluating herbicide treatments on percent change in sericea lespedeza (*Lespedeza cuneata*) coverage from 2018–2022 in early successional communities managed for northern bobwhite (*Colinus virginianus*) in Tennessee (Catoosa and Pea Ridge sites) and Alabama (Guntersville site), USA. Glyphosate and triclopyr with fluroxypyr treatments were paired with imazapic rates, and treatments are referenced as postemergence herbicide + preemergence imazapic rate. The intercept value refers to the change in sericea coverage in the control at the Catoosa site. Treatments with different letters in the Differences category were significantly different from each other in a Tukey procedure. Sites with different letters in the Differences category were significantly different from each other in a Tukey procedure.

	β	SE	*P*-value	Differences
Sericea change				
Intercept	−35.2%	9.8	>0.001	A
Glyphosate + 0	−29.0%	11.2	0.265	AB
Glyphosate + 0.07	−45.2%	11.2	0.020	B
Glyphosate + 0.14	−41.2%	11.2	0.040	B
Glyphosate + 0.21	−44.8%	11.2	0.022	B
Triclopyr with fluroxypyr + 0	−61.2%	11.2	0.001	B
Triclopyr with fluroxypyr + 0.07	−55.8%	11.2	0.003	B
Triclopyr with fluroxypyr + 0.14	−52.1%	11.2	0.006	B
Triclopyr with fluroxypyr + 0.21	−49.0%	11.2	0.011	B
Site				
Guntersville	6.7%	6.5	0.001	A
Pea Ridge	34.2%	6.5	>0.001	A

food plants based on treatment ($F_{8,16} = 0.86$, $P = 0.570$; Figure 3), but did detect differences between sites ($F_{2,16} = 18.6$, $P < 0.001$).

Average pretreatment coverage of annual grasses was 1.3%, and average pretreatment coverage of perennial grasses was 55.9% (Figure 3). Annual grass coverage did not vary between sites ($F_{8,16} = 1.9$, $P = 0.138$) or treatments ($F_{2,16} = 1.4$, $P = 0.280$). All units had reduced perennial grass coverage in 2022. Perennial grass coverage differed between sites ($F_{2,16} = 7.7$, $P = 0.004$), but not by treatment relative to control ($F_{8,16} = 0.24$, $P = 0.98$; Figure 3).

DISCUSSION

We documented that coverage of sericea was reduced following postemergence applications of glyphosate and triclopyr with fluroxypyr. However, preemergence applications of imazapic did not influence sericea coverage. We saw few differences in plant community response based on which postemergence herbicide we used, and native

FIGURE 2 Coverage of sericea lespedeza (*Lespedeza cuneata*) (A), all vegetation (B), and native forbs (C) in early successional communities managed for northern bobwhite (*Colinus virginianus*) in Tennessee and Alabama, USA, before (2018) and after (2022) treatment with glyphosate (GLY) or triclopyr with fluroxypyr (PG) along with 4 rates of imazapic (0, 0.7, 0.14, 0.21 kg/ha ai). Glyphosate and triclopyr with fluroxypyr treatments were paired with imazapic rates, and treatments are referenced as postemergence herbicide + preemergence imazapic rate. Error bars represent standard error.

TABLE 2 Beta (β), standard error (SE), and *P*-values from ANCOVA evaluating herbicide treatments on percent change in native forb coverage from 2018–2022 in early successional communities managed for northern bobwhite (*Colinus virginianus*) in Tennessee (Catoosa and Pea Ridge sites) and Alabama (Guntersville site), USA. Glyphosate and triclopyr with fluroxypyr treatments were paired with imazapic rates, and treatments are referenced as postemergence herbicide + preemergence imazapic rate. The intercept value refers to the change in native forb coverage in the control at the Catoosa site. Treatments with different letters in the Differences column for each plant type were significantly different from each other in a Tukey procedure. Sites with different letters in the Differences category were significantly different from each other in a Tukey procedure.

	β	SE	*P*-value	Differences
Native forb change				
Intercept	23.2%	29.4	0.442	A
Glyphosate + 0	60.2%	37.6	0.791	A
Glyphosate + 0.07	−16.9%	37.6	1.000	A
Glyphosate + 0.14	2.0%	37.6	1.000	A
Glyphosate + 0.21	−58%	37.6	0.820	A
Triclopyr with fluroxypyr + 0	−43.2%	37.6	0.957	A
Triclopyr with fluroxypyr + 0.07	−31.7%	37.6	0.993	A
Triclopyr with fluroxypyr + 0.14	−48.0%	37.6	0.924	A
Triclopyr with fluroxypyr + 0.21	−71.0%	37.6	0.630	A
Site				
Guntersville	−9.3%	21.7	0.904	A
Pea Ridge	93.5%	21.7	0.001	B

forb coverage remained above 42% following all treatments. Perennial grass coverage averaged 15–26% across all treatments, providing suitable nesting cover for bobwhite. Imazapic applications did not reduce annual grass coverage at all our study sites, but coverage was relatively low and imazapic application may be useful at locations with greater annual grass coverage.

The lack of efficacy to control sericea following preemergence applications of imazapic contrasts with Farris and Murray (2009), who documented control of planted sericea in a field experiment. Both our 2019 and 2022 imazapic applications occurred within one week of rain events that allowed the herbicide to incorporate into the soil solution. Density of sericea seed in the seedbank at our sites likely contributed to the difference in sericea control that we observed compared to Farris and Murray (2009). Our sites had a long history of sericea coverage, and the amount of seed in the seedbank was far greater than that in the treatments Farris and Murray (2009) applied.

Previous research has documented reduced preemergence herbicide efficacy on sites with greater weed seed density (Taylor and Hartzler 2000, Ou et al. 2018). Sericea annually produces 336–953 kg/ha of seed, which may remain viable for at least 25 years (Ohlenbusch et al. 2007). Sericea had been present and contributing to the seedbank on our sites for at least 10–20 years according to site managers. Similar situations are common when controlling sericea, and differs from the fields Farris and Murray (2009) planted with 30 kg/ha of seed. Our experiment demonstrates that imazapic applied preemergence fails to control sericea seedlings in fields where sericea has been established for some time.

Although imazapic failed to control sericea, it may be useful for other applications in bobwhite management. For example, nonnative, annual, cool-season grasses including cheat (*Bromus secalinus*) and downy brome (*Bromus tectorum*) may suppress native plants and reduce mobility for bobwhite and other bird species because of the dense

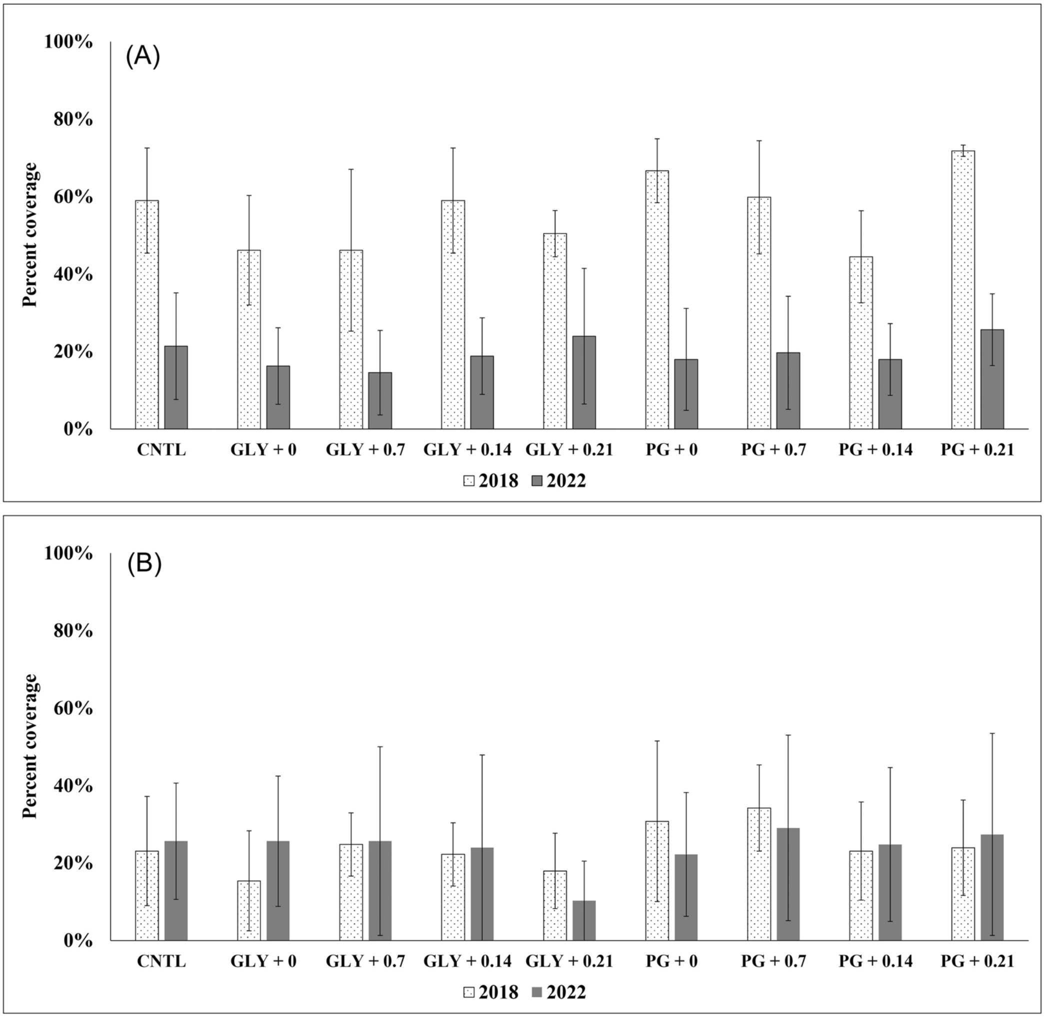

FIGURE 3 Coverage of perennial grasses (A) and northern bobwhite (*Colinus virginianus*) food plants (B) in early successional communities managed for bobwhite in Tennessee and Alabama, USA, before (2018) and after (2022) treatment with glyphosate (GLY) or triclopyr and fluroxypyr (PG) along with 4 rates of imazapic (0, 0.7, 0.14, 0.21 kg/ha ai). Glyphosate and triclopyr with fluroxypyr treatments were paired with imazapic rates, and treatments are referenced as postemergence herbicide + preemergence imazapic rate. Error bars represent standard error.

structure at ground level (Catling 2005, Hendrickson and Lund 2010, Ellis-Felege et al. 2013). We did not document changes in nonnative, annual, cool-season grass coverage with imazapic applications, likely because of limited coverage at our sites, but others have documented effective control of annual grasses using imazapic (Davison and Smith 2007, Morris et al. 2009, Mangold et al. 2013). Managers at sites with extensive coverage of annual grasses may consider preemergence applications to improve openness at ground level for bobwhite and other species.

Continued postemergence spot treatment is critical to control sericea given seed production and longevity in the seedbank. Even after an initial broadcast treatment and 3 years of spot treatment, we documented 11–33% coverage of sericea in treatment units. Brooke et al. (2015) reported bobwhite selected areas treated to control sericea over untreated sites with up to 50% coverage of sericea. Thus, coverage of sericea following our treatments certainly was within that documented as selected by bobwhite. Our results indicate triclopyr with fluroxypyr may be more effective for long-term spot treatment of sericea than glyphosate. However, triclopyr with fluroxypyr does not control grass, so continued spot treatment with this herbicide may lead to grass-dominated systems (Harper 2017), which would not be desirable for bobwhite. Perennial grass coverage often is emphasized for nesting, but areas with only 15% coverage of native grass support successful nesting and sustainable populations (Peters et al. 2015, Brooke et al. 2017). Therefore, spot treatment with glyphosate may be the better option when bobwhite, pollinators, or other species that require considerable forb coverage are focal species for management. Spot treatment with glyphosate does not favor any type of plant, and all plants germinating from the seedbank then have equal chance of establishing, including forbs and grasses. Sericea persistence in the seedbank highlights a major problem in plant community restoration for bobwhite, as there is no herbicide that can selectively control sericea without killing native forbs. Many managers opt to plant native grasses and forbs following initial control of nonnative species, while failing to recognize they may have to kill the planted forbs to control incoming sericea. Our data indicated that managing the seedbank response often is a more effective and efficient approach to restoring early successional plant communities for bobwhite than planting native grasses and forbs (GeFellers et al. 2020, Harper et al. 2021, Powell et al. 2022).

MANAGEMENT IMPLICATIONS

We recommend managers use either glyphosate or triclopyr with fluroxypyr to effectively reduce sericea lespedeza when using broadcast applications to initially control widespread sericea in fields managed for bobwhite. Our postemergence treatments improved conditions for bobwhite by reducing negative nutritional influence of sericea while maintaining bobwhite food plants and nesting cover. Managers should consider using glyphosate when spot spraying sericea because a broadleaf-selective herbicide may lead to a grass-dominated plant community. Annual spot treatment will be necessary to maintain limited coverage of sericea over time because of the hardness of sericea seed that allows it to persist for many years in the seedbank. Although managers are unlikely to eliminate sericea from a site, coverage of sericea can be controlled such that it does not dominate a site while allowing important food and cover plants for bobwhite to flourish.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

ETHICS STATEMENT

No ethical information provided.

DATA AVAILABILITY STATEMENT

Research data are not shared.

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