Herbicides are Effective for Reducing Dense Native Warm-season Grass and Controlling a Common Invasive Species, Sericea Lespedeza

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Abstract: Practices within the Conservation Reserve Program promote planting native grasses and forbs to improve habitat for northern bobwhite (*Colinus virginianus*) and other wildlife. However, native grasses often become dense and stands can be invaded by undesirable plant species that reduce habitat quality. We investigated three herbicides (clethodim, glyphosate, and imazapyr) at two rates to reduce native-grass density and five herbicides (aminopyralid, fluroxypyr+triclopyr, glyphosate, metsulfuron-methyl, and triclopyr) at two rates to control sericea lespedeza (*Lespedeza cuneata*), a common nonnative invasive species. We applied herbicide to reduce native grass cover at four sites in Kentucky and Tennessee in 2013–2014. We applied herbicide to control sericea at three sites in Kentucky in 2012–2013. We recorded vegetation composition at the end of the first growing season (1GAT) after treatment and the beginning of the second growing season (2GAT) after treatment. Both rates of glyphosate and imazapyr and the full rate of clethodim reduced native grasses 1GAT. Both rates of glyphosate and the full rate of imazapyr reduced native grasses 2GAT, but forb cover was increased 2GAT only with full-rates. Triclopyr, fluroxypyr+triclopyr, and glyphosate treatments reduced sericea 1GAT and 2GAT. We recommend applications of imazapyr (53.1% active ingredient (AI), 24 oz/acre) or glyphosate (42% AI, 2 qt/acre) to reduce dense native grass cover and increase forb cover. However, if desirable forbs are present, especially legumes, imazapyr should be used. We recommend glyphosate (42% AI, 1 qt/acre), fluroxypyr+triclopyr (16% and 45% AI, 12 oz/acre), or triclopyr (44%, 16 oz/acre) to control sericea lespedeza.

Key words: Conservation Reserve Program, herbicide, native warm-season grass, northern bobwhite, sericea lespedeza

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State and federal land set-aside programs, such as the Conservation Reserve Program (CRP), can lead to increased northern bobwhite (*Colinus virginianus*) populations and other wildlife associated with early successional communities by increasing habitat for those species (Blank 2013, Evans et al. 2014). These programs promote native warm-season grass (NWSG) and forb plantings to conserve soil and water resources and provide nesting, brooding, and foraging cover with an open structure at ground level (Washburn et al. 2000, Harper et al. 2007, USDA 2009). Native warm-season grasses typically are promoted over nonnative cool-season grasses because sod-forming cool-season grasses, such as tall fescue (*Schedonorus arundinaceus*) and orchardgrass (*Dactylis glomerata*), form a dense carpet of grass at ground level which impedes movement of some small wildlife species and reduces native plant establishment (Barnes et al. 1995, Harper and Gruchy 2009, Osborne et al. 2012). However, native grasses often are planted at relatively dense rates, and dense stands of native grass do not allow adequate coverage of desirable forbs or an open structure at ground-level that is required by northern bobwhite, wild turkey (*Meleagris gallopavo*) poults, and ground-feeding songbirds (Gruchy and Harper 2014).

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The USDA requires mid-contract management (MCM) in CRP fields to improve the structure and composition of vegetation (NRCS 2014). A majority of fields are dominated by native grasses (>70% coverage), providing poor structure and composition for nesting and brooding bobwhite (Taylor and Burger 2000). There are several MCM options available to landowners including prescribed fire, disking, interseeding with native forbs, and herbicide applications, but not all MCM techniques increase habitat quality or are appropriate in all situations (Gruchy and Harper 2014). For example, recent studies in southeastern United States have reported prescribed fire does not reduce native grasses (Holcomb et al. 2014, Yeiser et al. 2015) and fire alone also is not effective at reducing coverage of sericea lespedeza (*Lespedeza cuneata*; hereafter sericea) (Wong et al. 2012). Mid-contract management should aim to produce stands of vegetation that are consistent with the wildlife species these set-aside programs are intended to promote. Therefore, MCM techniques should be evaluated to provide landowners with accurate information on options when managing these areas.

Land enrolled in set-aside programs often are invaded by aggressive nonnative plant species that arise from the seedbank after native grass and forb establishment or after MCM. Invasions of invasive species require additional maintenance to fulfill contractual obligations (NRCS 2014). Sericea is a common nonnative invasive species in the southeastern United States originally planted to control erosion, provide forge for livestock, and provide cover for wildlife (Harris and Drew 1943). However, extensive sericea invasions can reduce bobwhite habitat quality and lower bobwhite fecundity (Peters 2014, Brooke et al. 2015, Peters et al. 2015). Sericea is allelopathic and reduces establishment of native plants (Adams et al. 1973). Also, insect abundance is reduced in stands of sericea, and the hard seeds are indigestible by bobwhite, providing inadequate nutritional benefits (Bugg and Dutcher 1989, Blocksome 2006).

Gruchy and Harper (2014) reported strip-spraying (closing every other nozzle along the spray boom) fields dominated by native grasses was not an effective method to reduce rank native grass cover. However, whole field applications of herbicide can be an alternative (Yeiser et al. 2015). Herbicide application may be more beneficial than other MCM techniques because it can reduce native grasses and control problematic invasive species (Gruchy et al. 2009, Yeiser et al. 2015). Additionally, herbicide application may be more feasible for private landowners compared to other MCM options. Therefore, we conducted two separate field experiments to test three herbicides at two different rates to reduce native grass density and five herbicides at two rates to control sericea. Our objectives were to identify which herbicides were the most effective in reducing NWSG and controlling sericea.

Methods

We conducted our experiment on three sites dominated by sericea at Peabody Wildlife Management Area (PWMA) in western Kentucky and four sites dominated by dense native grasses at PWMA and Forks of the River Wildlife Management Area (FWMA) in east Tennessee. Soils on PWMA are dominated by Udorthernts that lack horizon development and are characterized by recent disturbance (mine reclamation). Soils on FWMA are dominated by Etowah series that are characterized as deep, semipermeable, and well-drained. Open areas on PWMA were dominated by sericea planted during surface mine reclamation and native grasses planted by the Kentucky Department of Fish and Wildlife Resources. Forks of the River WMA was dominated by early successional vegetation communities including areas planted to native grasses. Native grass species mixtures at both sites included big bluestem (*Andropogon gerardii*), indiangrass (*Sorghastrum nutans*), and little bluestem (*Schizachyrium scoparium*).

We conducted two independent but concurrent experiments, one to test the effectiveness of herbicides to reduce NWSG and the other to test herbicides to control sericea. We used three native-grass fields at PWMA and one field at FWMA in a randomized block design. We established a block of seven 4x15-m plots (0.006 ha) in each field. Each block contained six herbicide treatments and one control unit. We tested the effectiveness of three herbicides with varying selectivity at two rates on reducing native grasses. Herbicides applied were clethodim, glyphosate, and imazapyr (Table 1). Herbicides were tested at recommended rates for perennial grass control (full-rate) and half the recommended rate for perennial grass control (half-rate). Treatments were applied in June 2013 at PWMA and May 2014 at FWMA. We tested five herbicides at

Table 1. Herbicide information and rates for treatments applied to control dense native grasses and sericea lespedeza, Kentucky and Tennessee, 2013–2014.

Active ingredient	Trade name	Active ingredient (%)	Rate per hectare	Rate per acre	Manufacturer	Selectivity
Native Grass Control						
Clethodim	Select Max	12.6	1.2 L	16 oz	Valent U.S.A Corporation Agricultural Products	Grass-selective
			0.6 L	8 oz		
Glyphosate	Mad Dog Plus	41	4.8 L	2 qt	Loveland Products	Broad-spectrum
			2.4 L	1 qt		
Imazapyr	Polaris AC	53.1	1.8 L	24 oz	Nufarm Speciality Products	Broad-spectrum selective
			0.9 L	12 oz		
Sericea Control						
Aminopyralid	Milestone	40.6	0.53 L	7 oz	Dow AgroSciences	Broad-spectrum selective
			0.26 L	3.5 oz		
Glyphosate	Mad Dog Plus	41	4.8 L	2 qt	Loveland Products	Broad-spectrum
			2.4 L	1 qt		
Metsulfuron methyl	Escort XP	60	70.9 g	1 oz	DuPont Crop Protection	Broad-spectrum selective
			35.4 g	0.5 oz		
Triclopyr	Element 3A	44.4	2.4 L	32 oz	Dow AgroSciences	Broadleaf-selective
			1.2 L	16 oz		
Triclopyr+Fluroxypyr	Pasturegard HL	Triclopyr: 45.1	1.8 L	24 oz	Dow AgroSciences	Broadleaf-selective
		Fluroxypyr: 15.6	0.9L	12 oz		

the label-recommended rate for sericea control (full-rate) and half the label-recommended rate for sericea control (half-rate) on three fields at PWMA. We established plots similar to the native grass experiment. Each block consisted of 10 herbicide treatment units and 1 control unit. We tested herbicides with varying selectivity on sericea control including aminopyralid, glyphosate, metsulfuron methyl, triclopyr, and triclopyr+fluroxypyr (Table 1). Metsulfuron methyl was applied in August 2012; all other herbicides were applied in June 2013. Metsulfuron methyl was applied in August 2012 because previous studies have indicated sericea control with metasulfuron methyl is the greatest when applied during flowering (Koger et al. 2002).

All treatments in both experiments were applied using a 4-nozzle handheld boom (R&D Sprayers, Opelousas, Louisiana) with a 2-m swath width attached to a 15-L backpack sprayer (Solo USA, Newport News, Virginia). We added non-ionic surfactant (0.25% of solution) to all herbicide mixtures. We sampled vegetation within each treatment plot at the end of the first growing season after treatment (August 2013 in Kentucky and August 2014 Tennessee; 1GAT) and at the beginning of the second growing season after treatment (June 2014 in Kentucky and May 2015 in Kentucky; 2GAT). We collected vegetation composition data along a 15-m point transect within each plot (Bonham 2013). We documented the presence of all species at each 0.5-m interval along the transect. We determined species or plant group (i.e., sericea, native grass, or forb) cover by dividing the total number occurrences along the transect by the total number of points on the transect (30).

We tested for differences in the cover of sericea, native grasses, and forbs between herbicide treatments and control using randomized block design analysis of variance (ANOVA; SAS 2011) to determine the effectiveness of each herbicide on reducing native grasses or controlling sericea. We used site as a random term to control for variability among sites. Given the differences in plant phenology between our two sampling periods (1GAT and 2GAT), we analyzed these periods independently. We used a Tukey's Honestly Significant Different (HSD) mean separation test to determine differences among treatments. Significance for all tests was concluded at $P=0.05$. The Tukey's HSD tests allows for the comparison between pairs of means while adjusting for the inflation of error rates associated with multiple comparisons (Lane 2010).

Results

Both rates of glyphosate and imazapyr and the full-rate of clethodim were effective at reducing native grasses 1GAT ($F=23.72$, $P<0.001$; Table 2). Native grass cover in these plots averaged 5%–48% compared to 88% and 66% in control and half-rate of clethodim plots, respectively. Both glyphosate treatments and full-rate of imazapyr reduced native grasses 2GAT compared to control ($F=10.22$, $P<0.001$; Table 2). Native-grass cover averaged 10% in plots treated with the full-rate of glyphosate and 31% in plots treated with the full-rate of imazapyr or half-rate of glyphosate compared to 88% in control plots. Forb cover was similar between all treatments and control 1GAT ($F=0.83$, $P=0.565$; Table 2). However, forb cover was greater in plots treated with full-rates of glyphosate and imazapyr 2GAT ($F=4.80$, $P=0.004$; Table 2) compared to control plots, 50%, 47.5%, and 14.2% respectively.

Table 2. Native warm-season grass and forb cover (%±SE) one growing season (1GAT) and two growing seasons (2GAT) following herbicide applications to reduce dense native grasses in Kentucky and Tennessee, 2013–2015. Full rates are the labeled rates for grass control and half rates are half of the labeled rate for grass control.

Treatments	Native warm-season grass			Forbs		
1GAT	%	SE		%	SE	
Control	88.3	(5.53)	a[a]	16.7	(12.4)	a
Clethodim (full)	48.3	(10.1)	bc	22.5	(19.2)	a
Clethodim (half)	65.8	(17.9)	ab	18.3	(17.2)	a
Glyphosate (full)	5.00	(3.19)	d	11.7	(6.74)	a
Glyphosate (half)	27.5	(9.75)	cd	7.50	(5.51)	a
Imazapyr (full)	6.67	(2.72)	d	5.83	(2.85)	a
Imazapyr (half)	33.3	(7.33)	cd	14.2	(8.86)	a
2GAT						
Control	87.5	(2.10)	a	14.2	(10.2)	c
Clethodim (full)	55.0	(17.3)	ab	24.2	(17.6)	abc
Clethodim (half)	83.3	(4.30)	a	19.2	(12.6)	bc
Glyphosate (full)	10.0	(5.27)	c	50.0	(8.82)	a
Glyphosate (half)	40.0	(7.82)	bc	29.2	(9.46)	abc
Imazapyr (full)	30.8	(4.79)	bc	47.5	(10.8)	ab
Imazapyr (half)	62.5	(10.2)	ab	37.5	(10.1)	abc

a. Means with the same letter within the same period (1GAT or 2GAT) and plant group are similar.

All herbicides except aminopyralid and metsulfuron methyl reduced sericea 1GAT ($F=5.68$, $P<0.001$; Table 3). Both glyphosate, triclopyr+fluroxypyr, and triclopyr treatments reduced sericea 2GAT, whereas sericea cover was similar among the aminopyralid, half-rate of triclopyr, and metsulfuron methyl treatments and control ($F=5.26$, $P<0.001$; Table 3). The full-rate of glyphosate and triclopyr and both rates of triclopyr+fluroxypyr resulted in ≤10% sericea cover 2GAT. Half-rate of metsulfuron methyl resulted in greater forb cover 1GAT compared to all other treatments and control ($F=4.78$, $P=0.001$; Table 3). Full-rate of glyphosate resulted in the greatest forb cover 2GAT and differed from control, whereas all other treatments were similar to control ($F=2.94$, $P=0.019$; Table 3). Although native-grass cover in plots sprayed to control sericea averaged <3% in glyphosate treatments 2GAT compared to >50% in triclopyr and triclopyr+fluroxypyr treatments, native-grass cover did not differ statistically between any treatments or control ($F=2.26$, $P=0.058$; Table 3).

Table 3. Sericea lespedeza, other forbs, and native warm-season grass cover (%±SE) one growing season (1GAT) and two growing seasons (2GAT) following herbicide application to control sericea lespedeza in Kentucky, 2012–2014. Full rates are the labeled rates for sericea lespedeza control and half rates are half of the labeled rate for sericea lespedeza control.

Treatment	Sericea lespedeza			Other forbs			Native warm-season grass		
1GAT									
control	95.6	(2.95)	a[a]	4.41	(1.13)	bc	13.3	(13.3)	a
aminopyralid (full)	75.6	(16.3)	ab	0.00	(0.00)	c	35.6	(25.8)	a
aminopyralid (half)	62.2	(29.5)	abc	0.00	(0.00)	c	4.44	(2.94)	a
glyphosate (full)	1.11	(1.11)	c	1.11	(1.11)	c	1.11	(1.11)	a
glyphosate (half)	4.44	(4.44)	c	1.11	(1.11)	c	1.11	(1.11)	a
metsulfuron methyl (full)	30.0	(15.2)	abc	53.3	(23.7)	a	2.22	(2.22)	a
metsulfuron methyl (half)	46.7	(26.0)	abc	57.8	(26.1)	ab	10.0	(10.00)	a
triclopyr (full)	12.2	(4.40)	bc	0.00	(0.00)	c	42.2	(28.6)	a
triclopyr (half)	20.0	(7.70)	bc	3.33	(1.92)	bc	55.6	(27.8)	a
triclopyr+fluroxypryr (full)	0.00	(0.00)	bc	0.00	(0.00)	c	50.0	(25.5)	a
triclopyr+fluroxypryr (half)	7.78	(4.01)	bc	0.00	(0.00)	c	52.2	(28.2)	a
2GAT									
control	97.8	(2.22)	a	4.44	(4.44)	b	17.8	(17.8)	a
aminopyralid (full)	80.0	(18.4)	ab	13.3	(6.94)	ab	35.6	(23.5)	a
aminopyralid (half)	68.9	(27.8)	abc	34.4	(20.0)	ab	10.0	(6.94)	a
glyphosate (full)	2.22	(2.22)	c	84.4	(9.69)	a	0.00	(0.00)	a
glyphosate (half)	15.6	(12.4)	bc	76.7	(11.7)	ab	0.00	(0.00)	a
metsulfuron methyl (full)	43.3	(21.7)	abc	15.6	(8.89)	ab	2.22	(2.22)	a
metsulfuron methyl (half)	55.6	(25.1)	abc	36.7	(5.77)	ab	4.44	(2.94)	a
triclopyr (full)	10.0	(6.94)	bc	31.1	(26.3)	ab	54.4	(29.2)	a
triclopyr (half)	21.1	(6.19)	bc	30.0	(20.4)	ab	61.1	(30.6)	a
triclopyr+fluroxypryr (full)	1.11	(1.11)	c	44.4	(27.8)	ab	57.8	(28.9)	a
triclopyr+fluroxypryr (half)	6.67	(1.92)	bc	35.6	(22.6)	ab	53.3	(26.7)	a

a. Means with the same letter within the same period (1GAT or 2GAT) and plant group are similar.

Discussion

Fields enrolled in the Conservation Reserve Program provide habitat for northern bobwhite and can increase bobwhite abundance (Blank 2013, Evans et al. 2014). However, without management, CRP fields often become dense monotypic native-grass stands or become invaded with nonnative species that do not provide the structure or composition needed by nesting or brooding bobwhite (Burger et al. 1990, Gruchy and Harper 2014, Yeiser et al. 2015). Our data suggest native grasses are best reduced and desirable forbs can be increased by treating fields with glyphosate or imazapyr. Sericea was best controlled using a broad-spectrum herbicide (glyphosate) or a broadleaf-selective herbicide (triclopyr or triclopyr+fluroxypyr).

Native grasses can be important to nesting bobwhite (Townsend et al. 2001), but planted native grasses can outcompete planted and volunteering forbs leading to dense grass cover (>70%) that reduces the mobility and foraging ability of adult bobwhite and bobwhite broods (McCoy et al. 2001). Gruchy and Harper (2014) reported dormant-season disking effectively reduced native grasses and increased forbs, but strip-herbicide applications of clethodim were ineffective. Furthermore, recent studies have indicated prescribed fire, regardless of season, may not be effective at reducing native grasses (Holcomb et al. 2014, Yeiser et al. 2015). Our results, in addition to those of Yeiser et al. (2015), suggest rank native grass fields can be enhanced (reducing native grasses and increasing forbs) by treating them with glyphosate or imazapyr. However, Yeiser et al. (2015) suggested imazapyr treatments were more effective than glyphosate treatments at increasing bobwhite habitat quality in rank native-grass fields because glyphosate reduced native grasses below the hypothetical range for ideal bobwhite habitat (≤30% native grass cover). However, the cover of NWSG in both the imazapyr and glyphosate treatments 2GAT did not differ in our study and were within the range of NWSG at nest-sites in studies from Kansas, Mississippi, and New Jersey (10%–56%; Taylor et al. 1999, Taylor and Burger 2000, and Collins et al. 2009) suggesting both treatments were equally effective.

Bobwhite broods are commonly associated with areas dominated by forbs (Taylor et al. 1999, Collins et al. 2009, Martin et al. 2009) and seeds from various forbs makeup a majority of a bobwhite's diet during winter (Barlow et al. 2008). Reducing native grass density likely increased growing space for forbs in our study. Glyphosate full-rate and imazapyr full-rate treatments resulted in 50% and 47% forb cover 2GAT, which is slightly greater than forb cover (32%–41%) reported in brood microhabitat studies (Taylor et al. 1999, Collins et al. 2009, Martin et al. 2009). Areas treated with clethodim and lower rates of glyphosate or imazapyr did not increase forb cover likely because native grasses were still dominant.

Although glyphosate and imazapyr provided similar reductions in native grass cover and increases in forb cover, imazapyr may provide additional benefits in certain situations because of its selectivity. Many beneficial legumes tolerant to imazapyr (Shaner 1989, Anonymous 2015) would be controlled if glyphosate were applied and imazapyr can be effective in controlling nonnative warm-season grasses and cool-season grasses in native-grass stands (Bond et al. 2005, Bahm et al. 2011), both of which can reduce the quality of early successional areas for bobwhite (Osbourne et al. 2012, Martin et al. 2015). Furthermore, imazapyr is effective in controlling certain undesirable woody species that commonly invade early successional plant communities (Gruchy et al. 2009).

Research on reclaimed surface mine land dominated by sericea suggests habitat quality for bobwhite is reduced by extensive sericea cover (Brooke et al. 2015, Peters et al. 2015, Unger et al. 2015). Multiple herbicides were effective in reducing sericea cover in our study. Our results are similar to studies in Oklahoma suggesting treatments containing triclopyr and fluroxypyr provide superior sericea control compared to metsulfuron methyl (Altom et al. 1992, Koger et al. 2002). Sericea control following metsulfuron methyl applications was variable; sites ranged from 0%–90% sericea cover 1GAT. Variability in sericea cover following treatment with metsulfuron methyl may potentially be a result of inconsistent flowering or seedbank response. Metsulfuron methyl applications are recommended when a majority of the stand is flowering (Cummings et al. 2007), but a precise application can be difficult to achieve and may influence the effectiveness of the treatment.

Unfortunately, all herbicides effective at controlling sericea also control other forbs, but our results suggest when sericea is controlled, other species in the seedbank will occupy the voided growing space. Although only the glyphosate full-rate treatment significantly increased forb cover compared to control 2GAT, forb cover in plots treated with triclopyr and triclopyr+fluroxypyr was similar (≥30%) to areas selected by bobwhite broods (Townsend et al. 2001, Collins et al. 2009, Martin et al. 2009).

Our results and the results of studies from Oklahoma suggest reduced rates of triclopyr and triclopyr+fluroxypyr are equally as effective at controlling sericea as full rates but may be more cost effective (Altom et al. 1992, Koger et al. 2002). Furthermore, triclopyr and triclopyr+fluroxypyr are broadleaf-selective herbicides and do not reduce native grasses. These herbicides would be advantageous to use for control of sericea in areas where native grasses are not dense and need to be retained. We likely did not detect a difference in grass cover between triclopyr and triclopyr+fluroxypyr treatments and control because of the variation in native-grass cover between sites prior to treatment. Native-grass cover varied from 0%–100% in plots treated with triclopyr or triclopyr+fluroxypyr to control sericea as well as the associated control plots.

One important aspect that we did not consider in this study is the change in structure of vegetation following treatment. Certainly, a decrease in the density native grasses with a concurrent increase in forb cover may promote the open structure needed to facilitate bobwhite movement (Doxon and Carrol 2010, Gruchy and Harper 2014), but the thatch remaining after herbicide treatments may reduce a bobwhite's ability to obtain food. Litter depth following strip-herbicide applications to reduce native grasses in a Tennessee study were similar to untreated plots, whereas disking and prescribed fire reduced litter depth compared to control (Gruchy and Harper 2014). Additionally, Yeiser et al. (2015) suggested additional treatments to reduce thatch may be needed to improve the quality of these stands. Therefore, it is likely that stands in our study would benefit (reduction in thatch) from subsequent management such as prescribed fire or disking. Our results are limited to two growing seasons after herbicide application; future studies should focus on the temporal effectiveness of treatments and the impacts of follow-up treatments to reduce the litter created by herbicide application.

Management Implications

Managing fields of dense, planted, native grass and fields invaded by undesirable nonnative species can enhance habitat quality for northern bobwhite and other species. When dense native grasses are problematic, we recommend application of imazapyr (1.8 L/ha) or glyphosate (4.8 L/ha) to decrease grass density and increase forb cover (Table 1). If beneficial legumes are present, land managers should consider imazapyr instead of glyphosate. Of course, spot-spraying instead of whole-field application is appropriate where patches of dense grasses occur in fields with otherwise suitable grass and forb cover. Extensive invasions of sericea may be treated with a broadcast application of glyphosate (2.4 L/ha). If native grasses are present and are not too dense, broadcast applications of triclopyr (1.2 L/ha) or triclopyr+fluroxypyr (0.9 L/ha) should be considered (Table 1). Small invasions should be treated with spot-spray applications. Our results should be applicable across the Mid-South region and managers should be proactive in controlling dense native grasses or aggressive nonnative species to mitigate potential impacts. Proper management of early successional plant communities created through land set-aside programs will increase bobwhite habitat quality and potentially increase bobwhite populations.

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