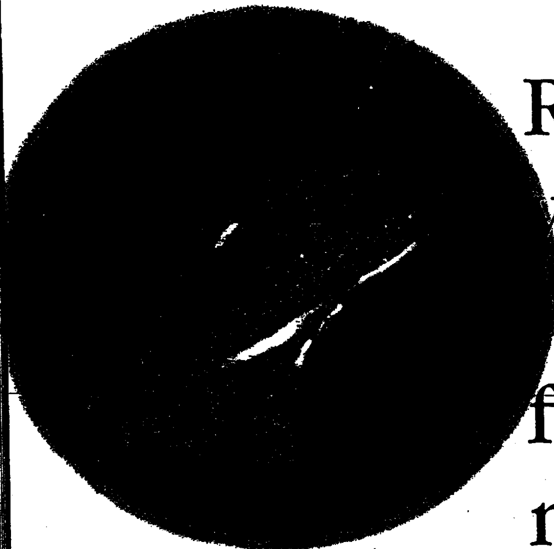

Response of understory vegetation important to the northern bobwhite following imazapyr and mechanical treatments

by James R. Welch, Karl V. Miller, William E. Palmer, and Timothy B. Harrington

Abstract In southern pine (*Pinus* spp.) stands, managers have used a variety of treatments to control hardwood encroachment and improve habitat conditions for northern bobwhites (*Colinus virginianus*). We compared use of the herbicide Arsenal® (BASF Corporation, Research Triangle Park, N.C.) (imazapyr) and traditional mechanical treatments, with and without fire, to control hardwood encroachment on study sites on Tall Timbers Research Station in the Red Hills Region near Tallahassee, Florida. Hardwood stem density decreased on herbicide and herbicide+burn plots but increased on all mechanically treated plots at 1 year after treatment. Herbicide and herbicide+burn treatments resulted in a >3-fold increase in forb coverage 1 year after treatment, whereas forb coverage did not increase in mechanically treated plots. A single application of imazapyr, with or without prescribed fire, can control hardwood encroachment and stimulate herbaceous species growth. Following treatment, vegetative communities likely can be maintained for prolonged periods by using traditional methods such as prescribed fire.

Key Words Arsenal®, *Colinus virginianus*, habitat, herbicide, imazapyr, northern bobwhite, vegetation

Historically, many southern pine (*Pinus* spp.) forests of the Coastal Plain were dominated by a longleaf pine (*Pinus palustris*) overstory and herbaceous understory comprised of forbs, grasses, and legumes (Frost 1993). Annual or biennial fires of natural or Native American origin (Landers et al. 1989) reduced ground debris and controlled encroachment of invasive hardwoods such as oak (*Quercus* spp.) and sweetgum (*Liquidambar styraciflua*). This ecosystem provided year-round habitat for northern bobwhites (*Colinus virginianus*) (Casey 1965). However, during and after European settlement, large-scale land clearing, free-ranging livestock, and fire sup-

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pression allowed species such as loblolly pine (*P. taeda*) and a variety of hardwoods to encroach on traditional longleaf sites. Development of a hardwood midstory and overstory in upland pine forests reduces the suitability of these forests for bobwhites (Wilson et al. 1995).

To combat hardwood encroachment, land managers traditionally relied on numerous manipulative techniques including fire, roller-drum choppers, harrows, and mowers (Brennan 1991). Fire controls aboveground hardwood stems and clears the ground of unwanted debris while stimulating growth of bobwhite forage and cover plants (Robbins and Myers 1992). Mechanical techniques, although more time-consuming and expensive, also are useful in manipulating vegetation structure and composition (Landers and Mueller 1986). Unfortunately, mechanical techniques eliminate or reduce pine recruitment and typically fail to kill hardwood rootstock (Shiver et al. 1990). The use of fire and mechanical treatments over several decades has resulted in a large hardwood root system from which new sprouts quickly grow and thereby exacerbate the problem.

To restore or improve habitat for northern bobwhites in pine forests areas where hardwood encroachment is severe (i.e, densities >5 stems/m^2), we recommend a one-time treatment of imazapyr.

When applied according to label directions, forestry herbicides have little potential for direct toxic effect on wildlife (Ahrens 1994, Tatum 2004), although they may affect wildlife by altering the composition and structure of plant communities (McComb and Hurst 1987). When applied at the proper rate and scale, herbicides can improve habitat for some wildlife species (Hurst 1987, Miller et al. 1989, Stritzke et al. 1991). For example, in Mississippi abundant legume growth provided excellent bobwhite habitat 2 years after site preparation with hexazinone and a late-summer burn (Hurst and Palmer 1988). In Georgia bobwhite food plants were more abundant on plots treated with imazapyr versus those treated with triclopyr+picloram or hexazinone at 2–4 years after treatment (Witt et al. 1993). Similarly, a South Carolina study reported increased abundance of select northern bobwhite food plants and increased availability of nesting cover on areas site-prepared with imazapyr (Feken 1995).

Because mechanical treatments are a costly annual vegetation management technique, we investigated the possibility of integrating herbicidal vegetation manipulation with fire and mechanical treatments. Specifically, we compared the response of understory vegetation to prescribed fire, an application of Arsenal® (BASF Corporation, Research Triangle Park, N.C.) (imazapyr) herbicide with and without fire, and mowing or drum-chopping with and without fire. We selected imazapyr because it effectively controls a wide variety of woody species while having little effect on native legumes (Wigley et al. 2002). Additionally, imazapyr is one of the most commonly used silvicultural herbicides in the southern United States (Shepard et al. 2004). We focused on the response of hardwood root sprouts and the suitability of the vegetation response to northern bobwhites as a result of each treatment combination. We interpreted a reduction in hardwood sprouts and an increase in ground cover of selected grass and forb species (Rosene and Freeman 1988) as an enhancement in northern bobwhite habitat quality.

Study area and methods

We conducted our experimental trials on Tall Timbers Research Station (TTRS) in the Red Hills Region near Tallahassee, Florida. Soils were well drained, gently sloping Dothan, Faceville, and Orangeburg sandy loams. The TTRS was dominated by open, upland pine forests that have been maintained for decades by prescribed fire applied every other year, and by mowing and drum-chopping. Narrow hardwood drains accounted for approximately 5% of upland areas. Loblolly and, to a lesser extent, longleaf pine were present in the pine stands. Hardwood species encroaching into upland areas included live oak (*Quercus virginiana*), water oak (*Q. nigra*), sweetgum, and hickory (*Carya* spp.).

In July 1997 we established 3 blocks, each containing 7 plots (1 ha/plot), in a randomized complete block design in 3 open, mature pine stands (1 block/stand). Within each block we randomly assigned 1 of 7 treatments (burn, herbicide, herbicide+burn, mow, mow+burn, chop, or chop+burn) to 1 plot. Pine basal area varied among blocks (range=2–23 m^2/ha) but was relatively consistent among plots within each block.

In August 1997 we characterized pretreatment vegetation within each of the 21 plots. We divided each plot into a 3 × 4 grid (25 m × 33 m), and placed a sample point at each gridline intersection (i.e., 12 sample points per plot). At each sample point we placed a 1.5-m-long pipe flat on the ground with 1 end of the pipe located at the sample point. Rotation of the pipe around the center point resulted in a 3-m-diameter circle (7.07 m^2) in which we enumerated, identified, and measured height (m) of all live hardwood stems.

We used a 1-m^2 wire-mesh grid consisting of 200 small squares (50 cm^2) to characterize understory vegetation at each sample point. The grid was held 1 m above the ground at approximately 0.5 m east and then west of the 3-m circle, resulting in 2 grid-board sample points per 3-m circle (n=24/per plot). We counted the number of grid squares occupied by live plant species at all understory cover layers, bare ground, and debris to generate percentage cover values. We assigned pretreatment measurements as covariates for each of the appropriate tests. We determined plant species used to calculate cover of important bobwhite plants according to Rosene and Freeman (1988) and included ragweed (*Ambrosia artemisiifolia*), broomsedge (*Andropogon* spp.), partridge pea (*Cassia* spp.), spurred butterfly pea (*Centrosema virginianum*), beggarweed (*Desmodium* spp.), milk pea (*Galactia* spp.), lespedeza (*Lespedeza* spp.), panic grass (*Panicum* spp.), blackberry (*Rubus* spp.), and goat's rue (*Tephrosia* spp.). Forb (herbaceous nongrass plants) cover, grass (*Poaceae*) cover, and preferred bobwhite plant cover were calculated as the sum of the individual species coverages within these categories.

On 21 October 1997, a skidder equipped with boombuster nozzles applied a mixture of 1.7 L/ha of Arsenal and 0.5–0.7% V:V surfactant (Timberland® 90, UAP Timberland LLC, Monticello, Ark.) to the appropriate plots. We conducted burning, mowing (Brown tree-cutter), and chopping (1.2-m roller-drum) on the appropriate plots in April 1998. We conducted post-treatment sampling identical to pretreatment methods during June 1998.

During summer 1998 the Red Hills experienced a severe drought. Average rainfall for May and June was, respectively, 106.1 and 126.5 mm less than average precipitation for those months (National Oceanic and Atmospheric Administration 1998). Over the entire summer (May–August) the Red Hills was 151.8 mm below average rainfall.

We averaged values for vegetation characteristics measured in subplots to acquire a mean for each treatment plot (experimental unit). Mean residuals varied from normality ($P < 0.05$). Therefore, percentage data were normalized with an arcsine, square-root transformation, and stem-density data were log-transformed. We subjected each vegetation characteristic to analysis of covariance (ANCOVA) in PROC GLM using a randomized complete block (fixed-effect) design with the testing of 6 orthogonal contrasts (Table 1; SAS Institute Inc. 1990). Statistical significance on all tests was determined at $P \leq 0.05$.

Table 1. Orthogonal contrasts tested for each treatment combination. Treatments were burned only (B), chopped only (C), chopped and burned (CB), herbicide only (H), herbicide and burned (HB), mowed only (M), and mowed and burned (MB), Tall Timbers Research Station, Florida, 1997–1998.

Orthogonal contrasts	Treatment combinations
Burned plots vs. unburned plots	B, CB, HB, MB vs. C, H, M
Burned plots: herbicide vs. mechanical	HB vs. CB, MB
Burned plots: chopped vs. mowed	CB vs. MB
Unburned plots: herbicide vs. mechanical	H vs. C, M
Unburned plots: chopped vs. mowed	C vs. M
Burn only vs. combination burned plots	B vs. CB, HB, MB

Results

There was a significant treatment effect on forb coverage ($F_{6, 19}$=16.9, $P \leq 0.001$). Percent cover by forbs increased >3-fold on both herbicide and herbicide+burn plots but did not change or slightly decreased on other treatments (Figure 1). On burned areas herbicide-treated plots had a higher percent coverage of forbs (40.5%) than mechanically treated plots (16.1%; $F_{1, 19}$=30.7, $P \leq$ 0.001). Likewise, on unburned areas herbicide-treated plots had a higher percent coverage of forbs (56.5%) than mechanically treated plots (11.2%; $F_{1, 19}$=57.4, $P \leq$ 0.001). We found no difference in percent cover of important bobwhite grass species among treatments.

Grass coverage changed little between years on any of the treatment plots, while percent coverage of important bobwhite plants decreased on all plots between years. Orthogonal contrasts (Table 1) indicated that post-treatment grass coverage was greater on mowed plots (41.4%)

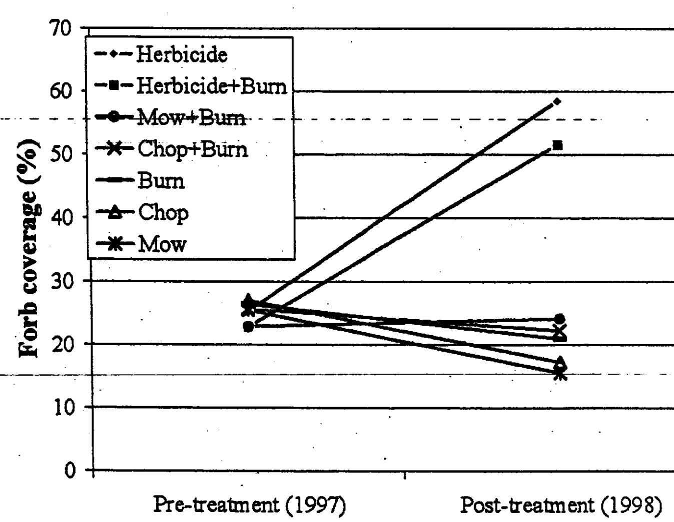

Figure 1. Mean percent forb coverage pre- and post-treatment on Tall Timbers Research Station, Leon County, Florida during the summers of 1997 and 1998, respectively.

Table 2. Mean (SE) percent coverage of grasses, total vegetation, and important northern bobwhite food and cover plants and mean (SE) live hardwood stem density (live hardwood stems/m^2) and height (cm) pre- and post-treatment on Tall Timbers Research Station, Leon County, Florida during the summers of 1997 and 1998, respectively.

Group	Herbicide	Herbicide + burned	Chopped	Chopped + burned	Mowed	Mowed + burned	Burned
Pretreatment							
Grasses	15.6 (4.8)	15.7 (5.3)	22.6 (12.4)	25.9 (6.3)	25.2 (8.7)	17.9 (8.3)	26.5 (6.4)
Total vegetation	97.0 (1.4)	97.1 (0.8)	95.4 (1.0)	96.1 (0.8)	96.9 (0.6)	96.1 (0.4)	95.8 (1.5)
Quail plants[a]	37.4 (5.7)	40.7 (6.5)	47.8 (12.4)	51.6 (12.2)	42.3 (22.3)	38.9 (14.6)	43.5 (11.9)
Hardwood density	3.2 (1.3)	4.2 (1.1)	3.3 (0.6)	3.9 (0.8)	3.1 (0.9)	3.1 (0.6)	2.3 (0.7)
Hardwood height	156.7 (23.2)	148.9 (10.6)	110.8 (0.1)	198.9 (62.1)	116.3 (49.1)	141.4 (30.8)	99.4 (26.4)
Post-treatment							
Grasses	10.0 (6.9)	10.0 (1.8)	15.7 (11.0)	15.9 (4.4)	41.4 (17.0)	11.1 (4.8)	32.1 (10.5)
Total vegetation	74.7 (13.5)	43.6 (18.5)	90.7 (6.7)	70.3 (9.5)	86.6 (1.8)	60.9 (5.9)	64.5 (10.0)
Quail plants	16.5 (1.2)	18.1 (1.4)	5.9 (1.2)	6.1 (1.0)	8.2 (2.1)	7.2 (2.5)	10.3 (1.3)
Hardwood density	0.7 (0.2)	0.2 (0.1)	5.2 (0.1)	6.9 (0.8)	4.7 (1.0)	11 (2.8)	4.9 (0.6)
Hardwood height	32.3 (11.8)	15.5 (6.4)	28.6 (1.1)	33.8 (1.6)	28.5 (5.3)	32.2 (7.6)	31.3 (7.4)

[a] Quail plant species selected from Rosene and Freeman (1988).

than on chopped plots (15.7%; $F_{1,19}$=5.11, P=0.047). On burned areas herbicide plots had a higher percent coverage of forbs important to bobwhites (21.3%) than did mechanically treated plots (6.6%; $F_{1,19}$=14.09, P= 0.003). Percent total vegetative cover decreased 1 year after treatment (Table 2) and was lower on sprayed plots (44.7%) than on mowed and chopped plots (88.3%; $F_{1,19}$ =13.90, P=0.003).

Hardwood stem density (number of live hardwood stems/m^2) increased on all treatment plots between years, except on herbicide and herbicide+burn plots (Table 2). Of the burned plots, hardwood-stem density was lower on herbicide plots ($\bar{x}$=0.29/m^2) than on mechanically treated plots ($\bar{x}$=8.8/m^2; $F_{1,19}$=27.74, $P \leq 0.001$). Likewise, on unburned areas herbicide plots also had a lower hardwood-stem density ($\bar{x}$=0.41/m^2) than chopped and mowed plots ($\bar{x}$=5.1/m^2; $F_{1,19}$=6.80, P=0.02).

Discussion

Land managers in southern pine forests have traditionally used mechanical treatments and fire to manage pine stands for the northern bobwhite. The goal has been to reduce woody vegetation and increase herbaceous ground cover. Unfortunately, mechanical treatments such as mowing and chopping, when combined with prescribed fire, have not reduced hardwood encroachment but rather have increased prevalence of hardwood sprouts. Because only aboveground stems are removed by mechanical treatments, hardwoods recover quickly via root or collar sprouting. Imazapyr kills or severely suppresses both aboveground and belowground portions of hardwood species; therefore, few hardwood stems resprout the following growing season. With reduced competition, herbaceous plants are able to respond quickly.

In our study hardwood-stem density increased on all treatment plots except herbicide and herbicide+burn treatments. Forb coverage was significantly greater on herbicide-treated plots than on mechanically treated plots, which likely resulted from reduced competition for resources. In mechanically treated areas, hardwood stems likely will continue to increase in abundance and coverage over time and ultimately reduce the abundance and diversity of grasses and forbs. Total post-treatment plant coverage appeared to have been reduced by all of the treatments. However, during our study drought conditions likely affected plant-community recovery time. In addition, post-treatment sampling occurred earlier during the growing season than pretreatment sampling.

In our study cover of bobwhite food plants was similar on herbicide-treated and mechanically treated areas, indicating that bobwhite food production was not negatively impacted 1 year after treatment. In a similar study conducted in longleaf pine forests of Florida, Provencher et al. (2002) reported increases in graminoid and forb cover following hardwood midstory removal and prescribed fire. In their study northern bobwhite populations increased in all hardwood-reduction plots. Likewise, a Mississippi study of the combined use of Arsenal and prescribed fire in a thinned loblolly pine stand increased species richness and coverage of grasses, forbs, and native legumes (Edwards et al. 2002, Thompson 2002). Because of the dramatic reduction in hardwood stems in our study, we suspect that responses of bobwhite food plants would be greater on herbicide-treated plots in a year of more normal rainfall.

Herbicide use can be a valuable tool for managing hardwood invasion and improving habitat for Northern Bobwhite in mature pine stands.

In the southeastern United States, one of the primary factors contributing to loss of habitat for vertebrates such as northern bobwhites, which require open, park-like habitats, is hardwood encroachment associated with fire exclusion (Brennan et al. 1998). To restore or improve habitat for northern bobwhites in pine forests areas where hardwood encroachment is severe (i.e, densities >5 stems/m^2), we recommend a one-time treatment of imazapyr. The Northern Bobwhite Conservation Initiative (Dimmick et al. 2002) recommended altering silvicultural treatments on approximately 50 million acres of forest lands, primarily southern pine forests, to encourage favorable grass and forb communities. Selective use of herbicides, with or without fire, could play an important role in accomplishing these goals. Additionally, various Farm Bill programs such as the Conservation Reserve Program and the Wildlife Habitat Incentives Program, as well as some state-level initiatives such as Georgia's Bobwhite Quail Initiative, provide cost-sharing for selective herbicide use.

We caution against total elimination of hardwood coverts that could reduce bobwhite loafing, roosting, and escape cover and thereby lower habitat suitability for bobwhites. Rather, within treated areas, small plots (1–2 ha) of cover should be protected from herbicides to maintain a patchwork of vegetation successional stages. Prescribed fire is recommended post-spray to reduce debris and maintain hardwood or pine regeneration at appropriate levels. Over the long term, the use of frequent fire will help reduce hardwood and pine competition. However, in the short term we noticed that herbicide-induced vegetative changes may limit available fuels for 2–3 years post-spraying. Therefore the choice of when to burn areas post-spray (e.g., 0, 1, or 2 years post-spray) should be carefully considered. For example, burning too soon may create an opportunity for regeneration of pines that will be difficult to control with fire as fuels may be limited for ≥2 years.

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