Efficacy of Herbicides to Control Bermudagrass for Enhancement of Northern Bobwhite Habitat

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Abstract: Bermudagrass (*Cynodon dactylon*) provides unsuitable vegetative structure for northern bobwhites (*Colinus virginianus*) by out-competing native vegetation, impeding foraging and movement of bobwhite chicks, and increasing heat loads. During 2000–2002, we examined the efficacy of four herbicides (three grass-selective translocated herbicides [GSH]; Clethodim, Fluazifop/Fenoxaprop, and Quizalofop; and one non-selective translocated herbicide: Imazapyr) for bermudagrass control in burned and unburned experiments in a field on River Bend Wildlife Management Area, Laurens County, Georgia. Herbicide treatments reduced bermudagrass cover 30 day, 60 day, and one year post-application ($P < 0.05$). Imazapyr resulted in complete necrosis of bermudagrass at 30 and 60 days post–application in both burned and unburned experimental plots. The GSH were not as effective, reducing bermudagrass coverage by only 50%–51% and 29%–42% on all plots 30 days and 60 days post–application, respectively. One year post–application, unburned plots treated with Imazapyr consisted of 77% less bermudagrass (4% coverage), 13% more thatch (18% coverage), 0.3% more bare ground (0.6% coverage), 41% more forbs (84% coverage), and 18% more partridge pea (*Chamaecrista fasiculata;* 30% coverage) than all other unburned herbicide treatment and control plots. Burned plots treated with Imazapyr consisted of 87% less bermudagrass (4% coverage), 10% more bare ground (11% coverage), 26% more forbs (84% coverage), and 10% more partridge pea (63% coverage) than all other burned herbicide treatment and control plots. Prescribed burning in the spring followed by applying Imazapyr in the summer was most effective for reducing bermudagrass cover and enhancing habitat for bobwhite quail.

Key Words: bermudagrass, herbicide efficacy

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Plant communities comprised of native grasses and forbs are an important component of northern bobwhite habitat, providing cover for foraging, nesting, and brood rearing. Productivity is an important factor affecting bobwhite population size (Roseberry and Klimstra 1984), and factors influencing reproductive success are important in quail management (Taylor et al. 1999). Quality brood habitat has abundant insects with bare ground, but with overhead cover to facilitate foraging and protection from predation (Hurst 1972, Taylor and Guthery 1994, Taylor et al. 1999, Taylor and Burger 2000). Early successional areas with abundant forbs increase invertebrate availability (Hurst 1972, Taylor and Guthery 1994, Harper et al. 2001), the primary foods of bobwhite chicks (Handley 1931). Bare ground facilitates brood foraging for insects and seeds by allowing unimpeded movement (Taylor et al. 1999). Northern bobwhites prefer canopied weeds for brood rearing and foraging (Greenfield et al. 2002), and management practices that increase bare ground and forb cover are commonly recommended.

Bermudagrass is a warm season perennial grass introduced into North America during the late 1600s from southern Africa (Ball et al. 1996). It commonly is used in pastures for livestock forage, along roads, terraces, disturbed sites to prevent soil erosion, golf courses, and turf grass farms (Skousen and Call 1987, Quisenberry 1990, Ball et al. 1996). Bermudagrass is considered an invasive exotic pest in crop fields, non-bermudagrass lawns, native plant restoration projects, and wildlife management areas (Hamilton et al. 1960, Harcomb 1989). It spreads rapidly by stolons and rhizomes (Fuls and Bosch 1990, Dong and de Kroon 1994), frequently inhabits disturbed sites (Whiteaker and Doren 1989), and increases seed production following spring burns (Burton 1944). Bermudagrass is difficult to control, replaces native vegetation, and forms dense thatch that may impede the foraging and movement of bobwhite chicks. The introduction of bermudagrass has degraded many sites throughout the Southeastern region of the United States for bobwhite quail. Burkhart (2004) observed that moderate to thick bermudagrass sites impeded mobility of bobwhite chicks and caused heat loads above the normal tolerance of chicks. Management practices commonly used for bobwhite habitat improvement, such as burning and disking, may increase bermudagrass abundance and distribution. Herbicides have been used to control bermudagrass, but additional research is needed to compare the efficacy of various treatments and their effects on quail habitat.

Previous research found various herbicides were ineffective for reducing bermudagrass. Meyer and Baur (1979) reported bromacil, dalapon, glyphosate, hexazinone, and tebuthiuron caused injury to bermudagrass for only 3–4 months following treatment; however, bermudagrass cover in treated plots was greater than or equal to untreated plots one year after application. Johnson (1983, 1988) observed that paraquat, metsulfuron, and sulfometuron did not effectively control bermudagrass. Bovey et al. (1974) observed no reduction in yield of established bermudagrass following treatment with 2,4–D, 2,4,5–T, and dicamba, regardless of rate or time of treatment. They also observed that picloram applied at 2.2 and 4.5 kg/ha during a drought severely reduced bermudagrass growth; however, the same rates applied during normal rainfall periods allowed more overall growth of bermudagrass (Bovey et al. 1974). Picloram at lower rates (≤ 1.1 kg/ha) sometimes injured bermudagrass but reduced growth was temporary and treated plots sometimes exceeded control plots.

Recently, there has been an increase in the number of conservation initiatives and programs designed to establish and improve habitat for northern bobwhites and other grassland species with an emphasis on grassland–forb management (e.g., 2002 Farm Bill—U.S. Department of Agriculture, Northern Bobwhite Conservation Initiative—Southeastern Quail Study Group, Bobwhite Quail Initiative (BQI)—Georgia Department of Natural Resources (GADNR), Northeast Missouri Open Lands Initiative—Missouri Department of Conservation, Cooperative Upland Habitat Restoration and Enhancement Program—North Carolina Wildlife Resources Commission, Farm Wildlife Program—Tennessee Wildlife Resources Agency, Virginia Bobwhite Quail Management Plan—Virginia Department of Game and Inland Fisheries). In GADNR's BQI, areas managed for bobwhite quail and other grassland species are commonly invaded by bermudagrass after being fallowed two to three years. We observed the following median bermudagrass composition by year for 37 fields with three years of bermudagrass composition data: year one 0.9% (range: 0.0%–21.0%), year two 5.2% (range: 0.0%–52.0%), and year three 12.2% (range: 0.0%–51.0%; GADNR unpublished data). Throughout the bermudagrass range, invasion likely will occur into fallowed plant communities and challenge the implementation of habitat restoration programs. Therefore, an effective method is needed to control bermudagrass and maximize benefits of habitat restoration efforts. The objective of this study was to determine the efficacy of four herbicides that are commonly used by Georgia landowners to control bermudagrass in burned and unburned areas. These included three GSH and translocated herbicides that were foliar active and would not damage desired forbs and woody vegetation and one non-selective translocated herbicide foliar and soil active.

Study Area

We prescribed treatments on a 2-ha field of bermudagrass with sandy loam soil located on the River Bend Wildlife Management Area in Laurens County, Georgia, within the Upper Coastal Plain physiographic province. Mean annual rainfall in this region was 113.4 cm (mean monthly rainfall range 5.5 cm [Oct]–12.2 cm [Mar]). Mean annual temperature was 18.0 C (mean monthly temperature range 7.4 C [Jan] to 27.3 C [Jul]). The field was deep plowed, disked, and leveled one year prior to application of treatments. The field was comprised of 97% bermudagrass (26–27 Apr 2001, GADNR unpublished data) prior to application of treatments.

Methods

Study Design

We tested the efficacy of four herbicide treatments to reduce bermudagrass coverage using two experiments and controls. We used Quizalofop (i.e., Assure II, a grass-selective herbicide, GSH), Fluazifop/Fenoxaprop (i.e., Fusion, a GSH), Clethodim (i.e., Select 2EC, a GSH) and Imazapyr (i.e., Chopper, a non-selective.). Burning has been shown to increase bermudagrass vigor and surface area (Burton 1944) and is commonly used as a management practice to enhance bermudagrass fields. Therefore, we chose burned (1 May 2001) and unburned experimental sites. We hypothesized that increased bermudagrass surface area on burned sites would subsequently increase the bermudagrass uptake of herbicide. We used 30 4.5 x 15 m herbicide plots per experiment (30 burned and 30 unburned). Each treatment was randomly assigned within six blocks using a randomized complete block design. We blocked to control for any variation in slope position. The burned and unburned experimental sites were separated by 2–3 m and the herbicide treatment plots were separated by approximately 1 m.

Herbicide Application

Herbicides were applied (30 Jul 2001) using an articulated 4-wheel drive all-terrain-vehicle (i.e., Pug) with a fixed boom consisting of 11 TJ AI 11003 nozzles spaced 6.5 cm apart. A TeeJet 844 spray controller was used to maintain a uniform output of 247.1 L/ha of total solution based on measured ground speed. Each herbicide was mixed in a total volume of 75.7 L within a 454.2-L spray tank. The spray tank was rinsed between each application and the boom and spray lines were flushed for approximately 45 seconds prior to application of each herbicide. Order of application, active ingredient (ai) amounts, and herbicide cost were as follows: 1) Quizalofop – 0.08 kg ai/ha [10 oz/ac of herbicide] + 2% volume per volume [v/v] of crop oil concentrate [coc], at a product cost of $26.86/ha; 2) Fluazifop/Fenoxaprop – 0.22 kg ai/ha [12 oz/ac] + 1% v/v coc, at a product cost of $33.06/ha; 3) Clethodim – 0.29 kg ai/ha [16 oz/ac] + 1% v/v coc, at a product cost of $62.39/ha; and 4) Imazapyr – 0.87 kg ai/ha [48 oz/ac] + Rivet 0.18 kg/ha, at a product cost of $186.25/ha. Rivet is a blend of methylated seed oil and silicone based nonionic surfactant. Imazapyr was applied last because it has soil residual properties and differs substantially in its mode of action from the other herbicides. Weather conditions during application were partly to mostly cloudy (30%–75% cloud cover), air temperature was 31.7–33.3 C, wind speed was variable at 4.8–19.3 kph and, vegetation and soil surfaces were dry. The bermudagrass appeared healthy and actively growing.

Data Collection and Analysis

We systematically sampled each plot using six 0.1-m^2 modified Daubenmire frames (Daubenmire 1959) to estimate bermudagrass necrosis cover 30 and 60 days (30 August 2001 and 27 September 2001, respectively) post-application. We also quantified percent coverage of live bermudagrass, thatch, bare ground, forbs (includes partridge pea), and partridge pea in each plot one year post-application (5–6 August 2002). We separated out partridge pea because of its documented usefulness for bobwhites (Stoddard 1931, Rosene 1969). We used SAS Proc Mixed ($\alpha = 0.05$) to examine herbicide treatments (fixed effect) within block (random effect) (Littell et al. 1996). Because all data were collected as percentages, analyses were conducted on the arcsine-transformed data (Sokal and Rohlf 1995).

Table 1. Mean and standard errors of 30-day (30 Aug 2001) and 60–day (27 Sept 2001) post-treatment percent (%) bermudagrass (Bermuda) necrosis and one–year post-treatment (5–6 Aug 2002) cover (%) of bermudagrass, thatch, bare ground (Bare), forbs (Forb—includes partridge pea [*Chamaecrista fasiculata*]), and partridge pea (P.Pea) of herbicide treatments within burned/unburned experiments on River Bend Wildlife Management Area, East Dublin, Georgia.

	30–day	60–day	1–Year Bare				
Treatment	Bermuda necrosis	Bermuda necrosis	Bermuda	Thatch	Bare	Forb	P.Pea
Burned							
Control	0.0±0.00	3.5±0.70	92.2±1.39	0±0.00	0.2±0.07	54.4±3.80	48.1±3.11
Quizalofop	50.0±0.00	30.6±1.38	91.5±0.93	0±0.00	0.7±0.26	57.4±4.74	52.7±4.09
Clethodim	50.0±0.00	29.9±0.68	93.1±1.88	0±0.00	0.6±0.23	45.9±3.49	37.6±3.59
Fluazifop/ Fenoxaprop	50.0±0.00	30.6±0.86	92.8±1.04	0±0.00	0.7±0.11	49.4±8.75	42.4±8.84
Imazapyr	100.0±0.00	100.0±0.00	4.4±0.93	0±0.00	10.8±1.89	83.5±4.68	62.5±6.95
Unburned							
Control	0.0±0.00	9.0±0.70	92.8±2.11	3.3±0.57	0.1±0.05	34.3±4.03	11.3±3.98
Quizalofop	51.4±1.38	37.5±1.53	90.3±2.74	3.2±0.64	0.1±0.05	35.5±3.53	8.3±2.02
Clethodim	51.4±1.38	41.7±1.52	89.8±1.98	2.8±0.52	0.3±0.17	34.2±4.74	12.0±3.05
Fluazifop/ Fenoxaprop	50.0±0.00	42.4±1.67	81.2±4.83	3.9±0.90	0.1±0.12	42.7±5.08	11.0±4.17
Imazapyr	100.0±0.00	100.0±0.00	3.9±0.62	17.6±2.46	0.6±0.24	84.3±3.30	30.1±7.56

Results

Unburned Field

Herbicide treatments affected 30 day necrosis ($F_{4, 20}$ = 5,323.30, $P < 0.001$) and 60 day necrosis ($F_{4, 20}$ = 1,246.96, $P < 0.001$) of bermudagrass. Imazapyr caused 100% 30 day necrosis, which was greater than the necrosis caused by Quizalofop, Clethodim, and Fluazifop/Fenoxaprop. All herbicide plots exhibited ≥50% necrosis at 30 days while none occurred on the controls (Table 1). Imazapyr caused 100% 60–day necrosis, which was greater than the necrosis caused by Quizalofop, Clethodim, and Fluazifop/Fenoxaprop. All herbicide plots exhibited >28% more 60 day necrosis than the control (Table 1).

Herbicide treatments affected percentage of bermudagrass ($F_{4, 20}$ = 154.37, $P <$ 0.001), thatch ($F_{4, 20}$ = 154.37, $P < 0.001$), bare ground ($F_{4, 20}$ = 3.41, $P = 0.028$), forbs ($F_{4, 20}$ = 34.66, $P < 0.001$), and partridge pea ($F_{4, 20}$ = 7.57, $P = 0.001$). One year post-application, bermudagrass cover on plots treated with Clethodim, Fluazifop/Fenoxaprop, and Quizalofop did not differ from control plots. Imazapyr treated plots consisted of ≥77% less bermudagrass than all other treatments. Percentage of thatch on plots treated with Clethodim, Fluazifop/Fenoxaprop, and Quizalofop did not differ from control plots. Imazapyr treated plots consisted of >13% more thatch than all other treatments. Percentage of bare ground on plots treated with Clethodim, Fluazifop/Fenoxaprop, and Quizalofop did not differ from control plots. Imazapyr treated plots consisted of >0.3% more bare ground than all other treatments. Percentage of forbs on plots treated with Clethodim, Fluazifop/Fenoxaprop, and Quizalofop did not differ from control plots. Imazapyr treated plots consisted of >41% more forbs than all other treatments. Percentage of partridge pea on plots treated with Clethodim, Fluazifop/Fenoxaprop, and Quizalofop did not differ from control plots. Imazapyr treated plots consisted of >18% more partridge pea than all other treatments.

Burned Field

Herbicide treatments affected 30-day necrosis ($F_{4, 20}$ = 555,092.00, $P < 0.001$) and 60-day necrosis ($F_{4, 20}$ = 866.96, $P < 0.001$) of bermudagrass. Imazapyr caused 100% 30-day necrosis, which was greater than the necrosis caused by Quizalofop, Clethodim, and Fluazifop/Fenoxaprop. All herbicide treatments caused >50% necrosis at 30 days while none occurred on the controls (Table 1). Imazapyr caused 100% 60-day necrosis, which was greater than the necrosis caused by Quizalofop, Clethodim, and Fluazifop/Fenoxaprop. All herbicide treatments caused >26% more 60-day necrosis than in the control.

Herbicide treatments affected percentage of bermudagrass ($F_{4, 20}$ = 416.24, $P <$ 0.001), bare ground ($F_{4, 20}$ = 38.08, $P < 0.001$), forbs ($F_{4, 20}$ = 8.11, $P = 0.001$), and partridge pea ($F_{4, 20}$ = 2.70, $P = 0.053$). No thatch was observed in any plots. One year post-application, bermudagrass coverage on plots treated with Clethodim, Fluazifop/Fenoxaprop, and Quizalofop did not differ from control plots. Imazapyr treated plots consisted of ≥87% less bermudagrass than all other treatments (Table 1). Percentage of bare ground on plots treated with Clethodim, Fluazifop/Fenoxaprop, and Quizalofop did not differ from control plots. Imazapyr treated plots consisted of >10% more bare ground than all other treatments. Percentage of forbs on plots treated with Clethodim, Fluazifop/Fenoxaprop, and Quizalofop did not differ from control plots. Imazapyr treated plots consisted of >26% more forbs than all other treatments. Percentage of partridge pea on plots treated with Clethodim, Fluazifop/Fenoxaprop, and Quizalofop did not differ from control plots. Imazapyr treated plots consisted of ≥10% more partridge pea than all other treatments.

Discussion

Bermudagrass cover remained high on both burned and unburned control sites during the study. These sites provided unsuitable vegetative structure for bobwhites, especially for brood rearing (≤0.2% bare ground; Hurst 1972, Taylor and Guthery 1994, Taylor et al. 1999, Taylor and Burger 2000).

The GSH were the least expensive herbicides applied, but were ineffective in the long-term (one year) and only moderately effective in the short–term (<60 days) in reducing bermudagrass. The GSH plots appeared unsuitable for bobwhites, especially for brood-rearing (≤0.7% bare ground; Hurst 1972, Taylor and Guthery 1994, Taylor et al. 1999, Taylor and Burger 2000). Bermudagrass was growing again by 60-day post-application.

Imazapyr was the most expensive herbicide applied, but proved to be the most effective in reducing bermudagrass both short-term (30 and 60 days) and long-term (one year). Unburned experimental plots treated with Imazapyr had little bare ground and ≥17% thatch ground cover. In the burned experimental plots treated with Imazapyr observations indicated ≥10% bare ground and 0% thatch. Therefore, burning and treating with Imazapyr appeared to improve bobwhite habitat by increasing bare ground and reducing thatch. For the unburned site, Imazapyr killed all herbaceous vegetation at the time of application and therefore had greater thatch than GSH or control plots. For both burned and unburned sites, Imazapyr application resulted in forb cover that exceeded all other treatments. We hypothesize that the greater forb cover came from a reduction in bermudagrass competition and more space for forb growth to occur. Partridge pea composition also differed between Imazapyr and GSH. Therefore, burning and treating bermudagrass with Imazapyr provided suitable vegetative structure for chicks through increased bare ground, abundant forbs for production of insects and seeds, and increased overhead cover to facilitate foraging and protection from predation (Hurst 1972, Taylor and Guthery 1994, Taylor et al. 1999, Taylor and Burger 2000).

Management Implications

Spring burning and a summer application of Imazapyr (0.84 kg ai/ha [48 oz/ac]) was the most effective treatment in this study to reduce bermudagrass density and enhance habitat for bobwhite quail. This treatment decreased bermudagrass and thatch, and increased bare ground, forbs, and partridge pea. The best control occurred by spring burning and then applying Imazapyr when bermudagrass is actively growing (7.6–15.2 cm in length), not stressed, and before seed head production (M. Atwater–Weed Control Unlimited, Inc., personal communication). Even without burning, Imazapyr can be used to substantially reduce bermudagrass. Whether used with burning or not, caution should be used when applying Imazapyr because this herbicide is soil active and can impact adjacent vegetation. Future research should consider other herbicides, multiple applications, and effects over a greater number of growing seasons.

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