Eradicating Tall Fescue Using Glyphosate followed by Cool-season Grass Seedings

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Abstract: Tall fescue *(Festuca arundinacea)* grasslands do not provide quality habitat for northern bobwhite quail *(Colinus virginianus).* Converting tall fescue fields to other cool-season grasses and legumes (CSG) may provide more favorable wildlife habitat. We evaluated the effectiveness of spring and fall pre-emergence Round-Up PRO™ applications with and without prescribed burns for eradicating tall fescue and establishing CSGs. Two tall fescue fields were located in western Kentucky. Prescribed burns, herbicide applications, and CSG seedings were applied in 2 0.05-ha treatment plots during spring and fall 1996 and spring 1997 at each site. Mean planted CSG cover at both sites was higher ($P<0.05$) in treatments with fall plantings (range=12.0%–124.5%) compared to treatments with spring plantings (range=0.0%–18.1%) during the first growing season. Similarly, planted CSG cover levels in the fall-planted treatments ($\bar{x}$=43.5%, SE=3.91) were higher ($P<0.05$) than planted CSG cover levels in the spring-planted treatments ($\bar{x}$=17.0%, SE=2.82) during the second growing season. Plant species richness was higher ($P<0.01$) in all treatment plots (range=3.4–7.4 species/m^2) compared to the control (range=1.4–3.1 species/m^2) during the 2 growing seasons following treatment applications. In addition, some treatments produced higher levels of bare ground. Regardless of treatment, tall fescue conversion resulted in grassland habitats believed more favorable to bobwhite quail.

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Tall fescue has been planted on more than 14 million ha (Ball et al. 1993) for hay, pasture, surface-mine reclamation, and revegetation of Conservation Reserve Program (CRP) lands (Burns and Chamblee 1979). More than 95% of all tall fescue fields are infected with a fungal endophyte *(Neotyphodium coenophialum)* that produces toxins which can cause weight loss, reproductive problems, and a variety of diseases in livestock and domestic animals (see Ball et al. [1993] for a review). Tall fescue grasslands also cause nutritional problems for wildlife feeding on endophyte-infected fescue (Lane 1995, Madej and Clay 1991, Conover and Messmer 1996) and provides poor wildlife habitat (Betsill et al. 1979, Barnes et al. 1995).

Habitat manipulations and disturbances may improve tall fescue-dominated fields by converting these fields into grassland habitats more suitable to bobwhite quail and other wildlife species. Madison (1994) examined the use of prescribed burning, herbicide application, and disking for tall fescue conversion and found the most effective treatment for eliminating tall fescue was a spring glyphosate (product name Round-Up™) application. Spring and fall applications of glyphosate and sequential applications of glyphosate and paraquat (product name Gramoxone Super™) have also been found to provide effective tall fescue control (Smith 1992, Defelice and Henning 1990).

Madison (1994) found tall fescue reinvaded after the initial herbicide application. Planting cool-season grass and legume mixtures following herbicide applications may prevent fescue reestablishment. The effectiveness of using a prescribed burn followed by an herbicide application and seeding of cool-season grasses and legumes for killing tall fescue and improving wildlife habitat is currently unknown. The objectives of this study were: (1) to evaluate the effectiveness of spring and fall prescribed burns and applications of glyphosate for eradicating tall fescue and (2) to evaluate the effectiveness of prescribed burns, glyphosate applications, and no-till seedings for establishing other cool-season grasses (CSGs) and legumes and improving wildlife habitat.

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Methods

The study was conducted at 2 sites in Kentucky. The first site was a sloping (6%–12% grade) idle, tall fescue field located in the Western Kentucky Coal Field physiographic region. Soils consisted of Wellston and Zanesville silt loams which were deep and well-drained to moderately well-drained. A soil test (Univ. Ky. Div. Regulatory Serv.) indicated these soils had a pH of 5.7, 3.52% OM, 7 kg/ha P, 86 kg/ha K, 358 kg/ha Ca, and 62 kg/ha Mg. The second site, located in the Western Pennyroyal physiographic region, was a relatively flat to gently sloping (0%–6% grade) idle, tall fescue field recently released from the CRP program. Soil at this site consisted of a deep and well-drained Crider silt loam. A soil test indicated these soils had a pH of 5.3, 3.27% organic matter, 12 kg/ha P, 98 kg/ha K, 375 kg/ha Ca, and 50 kg/ha Mg.

Prior to treatment applications, the 2 sites were typical tall fescue monocultures (Barnes et al. 1995). Tall fescue was the dominant plant species (range=85%–97.5% cover) and accounted for the majority of pre-treatment vegetation. Plant communities at site 2 ($\bar{x}$=7.3 species/m^2, SE=0.75) were more diverse than communities at site 1 ($\bar{x}$=2.8 species/m^2, SE=0.30). Goldenrods (*Solidago* spp.), blackberry (*Rubus* spp.), and horse nettle *(Solanum carolinense)* were present at both sites.

We implemented 6 treatments and an untreated control in 0.05-ha treatment plots using a randomized complete block experiment with 2 replicates at each site. Specific treatments were: 1) no manipulation (control), 2) spring herbicide–seed, 3) fall herbicide–seed, 4) spring burn–spring herbicide–seed, 5) spring burn–fall herbicide–seed, 6) fall burn–spring herbicide–seed, and 7) fall burn–fall herbicide–seed.

Spring burns were conducted during 15 March–10 April 1996. A fall burn was conducted on 29 August 1996. Prescribed burns were conducted using a strip head fire technique during early evening under conditions of low winds (2–16 kph), rising relative humidity (25%–60%), and air temperatures of 4–10 C in the spring and 21–27 C in the fall (Packard and Mutel 1997).

Spring and fall herbicide applications were made when the tall fescue was actively growing and approximately 15–20 cm in height. Round-Up PRO™ herbicide at 2.24 kg active ingredient (ai)/ha was applied following manufacturer label rates. Herbicide was applied to the appropriate spring treatment plots during 16–19 May 1996, to the fall treatment plots on 24 September 1996, and to the fall/spring treatment plots during 10–12 May 1997. Herbicides were broadcast applied with a 4-wheeler mounted Delta™ electric pump-powered sprayer unit with fan-type nozzles delivering a spray volume of 112 liters/ha at 414 kiloPascals (kPa) when air temperatures were 16–21 C, winds were 2–8 kph, and relative humidity was 40%–90%.

We seeded the CSG mixture at a rate of 7.2 kg pure live seed (PLS)/ha using a Truax™ no-till drill (spring and fall 1996) or a TYE™ no-till drill (spring 1997). The CSG mixture consisted of timothy *(Phleum pratense)* at 2.3 kg PLS/ha, orchardgrass *(Dactylis glomerata)* at 2.3 kg PLS/ha, common redtop *(Agrostis gigantea)* at 2.3 kg PLS/ha, red clover *(Trifolium pratense)* at 0.14 kg PLS/ha, and white clover *(Trifolium repens)* at 0.14 kg PLS/ha, and was seeded in the spring treatment plots during 3–10 June 1996, in the fall plots during 8–22 October 1996, and the fall/spring plots during 23–28 May 1997. These grasses and legumes are widely available, relatively inexpensive, have forage and cover value to wildlife, and are recommended by the Kentucky Department of Fish and Wildlife Resources.

Plant communities were described by randomly establishing and sampling 5 1-m^2 herbaceous sampling plots in each treatment plot during the 2 or 3 growing seasons following treatment applications. Total vegetative canopy cover (%), plant cover by species (%), planted CSG cover (%), bare ground (%), and plant species richness (species/m^2) were estimated for each sampling plot (Bonham 1989). Treatments completed in spring 1996 were described in fall 1996 (24 Oct–5 Nov), fall 1997 (23

Oct–8 Nov), and fall 1998 (16–27 Oct), whereas treatments completed in fall 1996 or spring 1997 were described in fall 1997 (23 Oct–8 Nov) and fall 1998 (16–27 Oct). Planted cool-season CSG cover was determined by totaling the cover estimates for all planted cool-season grasses and legumes in each sampling plot.

Analysis of variance (ANOVA) techniques were used to test for differences in total vegetative canopy cover, tall fescue cover, planted CSG cover, bare ground, and plant species richness among the treatment plots (Neter et al. 1990). Data analyses were conducted on each site independently due to the presence of significant interactions ($P<0.05$) among treatment and site effects. Fisher's LSD tests were used for multiple comparisons when treatment effects were significant ($P<0.05$) (SAS Inst. 1985).

Results and Discussion

Treatment Effects on Tall Fescue

Pre-emergence herbicide applications in May or September reduced or eliminated tall fescue. Mean tall fescue cover across sites was lower ($P<0.05$) in all treatment plots (range=0.0%–76.5%) than in the control plots (range=93.0%–98.3%), with 1 exception. Tall fescue cover in the treatment that was burned in the fall and herbicided and seeded to CSGs the following spring ($\bar{x}$=88.5%, SE=1.30) was not different ($P>0.05$) from tall fescue levels in the control plot ($\bar{x}$=98.3%, SE=0.45) at site 2 during fall 1998.

All 6 treatments eliminated tall fescue (0% coverage) from site 1 by the end of the second or third growing season (Tables 1–3). In contrast, the treatments were less effective in removing tall fescue at site 2. Only 3 treatments (spring herbicide–seed, spring burn–spring herbicide–seed, and fall burn–fall herbicide–seed) reduced tall fescue coverage to less than 10% at site 2 during the first growing season. The spring herbicide and seed CSGs treatment had the least tall fescue cover ($\bar{x}$=16.0%, SE=3.79) at site 2 during the second growing season. Mean tall fescue cover exceeded 60% in the 2 spring treatments by the end of the third growing season (Table 3). Increases in tall fescue cover following the initial reductions were likely due to regrowth of tall fescue from undergrowth rootstock (Defelice and Henning 1990) or from seed produced by fescue plants that survived the herbicide applications.

Post-treatment tall fescue cover varied considerably between the 2 sites. After the initial removal of tall fescue by the herbicide applications, tall fescue was almost non-existent at site 1. In contrast, tall fescue reinvaded or increased from plants remaining in the treatment plots in the growing seasons following the Round-Up PRO applications at site 2. The site 2 plots were centered in a large tall fescue field, whereas the site 1 plots included most of the tall fescue field and were surrounded by woodlands. The surrounding tall fescue at site 2 provided a seed and tiller source and likely resulted in the reinvasion of tall fescue.

Our results agree with other studies that found glyphosate effectively kills tall fescue. Washburn and Barnes (2000) found spring and fall applications of glyphosate

Table 1. Average total vegetative canopy cover (%), tall fescue cover (%), planted cool-season grass and legume cover (%), bare ground (%) and plant species richness (*N* species/m^2) in the spring (Oct 1996), fall (Oct 1997), and spring/fall combination (Oct 1997) treatment plots that were seeded to CSGs at 2 study sites in western Kentucky.

		Canopy Coverage		Tall Fescue		Cool-Season Grasses		Bare Ground		Species Richness	
Treatment	*N*	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
Site 1											
Control	10	100.0*a*[a]	—	98.3*a*	0.75	—[b]	—	0.0*f*	—	2.1*a*	0.18
Spring herbicide[c]	10	54.5*c*	10.55	0.5*c*	0.50	0.7*a*	0.50	30.0*ab*	10.33	4.0*b*	0.48
Spring burn–spring herbicide[d]	10	47.0*c*	7.20	0.0*c*	—	0.0*a*	—	83.5*e*	1.67	4.7*b*	0.47
Fall herbicide[e]	10	84.5*b*	3.91	1.7*c*	1.49	35.0*c*	6.83	15.2*c*	3.86	6.4*c*	0.34
Fall burn–fall herbicide[f]	10	93.0*ab*	1.10	0.0*c*	—	12.0*b*	3.89	53.0*d*	1.86	4.3*b*	0.33
Spring burn–fall herbicide[g]	10	82.5*b*	2.50	0.7*c*	0.52	28.0*c*	5.39	33.5*b*	3.34	7.4*c*	0.34
Fall burn–spring herbicide[h]	10	90.3*ab*	2.21	6.0*b*	2.45	0.0*a*	—	18.0*ac*	2.81	7.4*c*	0.40
Site 2											
Control	10	98.8*a*	0.66	98.3*a*	0.75	—	—	0.0*a*	—	1.4*a*	0.16
Spring herbicide	10	57.5*c*	9.64	0.6*e*	1.51	3.5*a*	1.51	0.0*a*	—	3.4*b*	0.45
Spring burn–spring herbicide	10	76.0*c*	2.45	6.6*de*	6.52	18.1*a*	6.52	59.5*c*	6.60	6.4*d*	0.48
Fall herbicide	10	96.9*ab*	0.67	26.2*c*	8.44	73.0*b*	8.44	5.0*ab*	1.05	5.8*cd*	0.25
Fall burn–fall herbicide	10	98.4*a*	0.62	4.0*de*	3.76	124.5*c*	3.76	4.0*ab*	0.91	6.7*d*	0.15
Spring burn–fall herbicide	10	91.0*ab*	1.63	13.0*d*	8.26	69.0*b*	8.26	8.0*b*	1.11	5.2*c*	0.20
Fall burn–spring herbicide	10	86.9*b*	4.81	76.5*b*	1.69	9.2*a*	1.69	7.3*ab*	3.29	3.9*b*	0.28

a. Means within the same column and site with the same letter are not different ($P > 0.05$).
b. CSG mixture was not planted in the control plots.
c. Spring herbicide application followed by seeding of the CSG mixture.
d. Spring burn followed by a spring herbicide application and a spring seeding of the CSG mixture.
e. Fall herbicide application followed by a spring seeding of the CSG mixture.
f. Fall burn, followed by a fall herbicide application and a fall seeding of the CSG mixture.
g. Spring burn followed by a fall herbicide application and a fall seeding of the CSG mixture.
h. Fall burn followed by a spring herbicide application and a spring seeding of the CSG mixture.

Table 2. Average total vegetative canopy cover (%), tall fescue cover (%), planted cool-season grass and legume cover (%), bare ground (%) and plant species richness (*N* species/m^2) in the spring (Oct 1997), fall (Oct 1998), and spring/fall combination (Oct 1998) treatment plots that were seeded to CSGs at 2 study sites in western Kentucky.

		Canopy Coverage		Tall Fescue		Cool-Season Grasses		Bare Ground		Species Richness	
Treatment	*N*	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
Site 1											
Control	10	99.4*a*[a]	0.27	96.3*a*	0.92	—[b]	—	0.0*a*	—	2.7*a*	0.15
Spring herbicide	10	88.0*c*	2.60	10.5*b*	5.40	3.0*a*	2.00	11.5*a*	2.11	6.2*d*	0.20
Spring burn–spring herbicide	10	87.2*cd*	3.93	0.0*c*	—	2.0*a*	2.00	14.7*ab*	4.31	6.3*d*	0.30
Fall herbicide	10	91.2*bc*	2.25	0.0*c*	—	35.0*b*	11.76	23.5*bc*	6.46	4.4*b*	0.27
Fall burn–fall herbicide	10	90.0*bc*	1.97	0.0*c*	—	8.5*a*	6.58	31.5*c*	5.00	4.9*bc*	0.28
Spring burn–fall herbicide	10	96.2*ab*	1.23	0.0*c*	—	60.5*c*	6.26	4.2*a*	1.40	5.3*c*	0.26
Fall burn–spring herbicide	10	80.0*d*	4.65	0.0*c*	—	21.0*ab*	7.77	30.5*c*	4.61	4.3*b*	0.26
Site 2											
Control	10	99.5*a*	0.22	98.3*a*	0.45	—	—	0.0*a*	—	2.2*a*	0.13
Spring herbicide	10	83.5*c*	2.48	16.0*d*	3.79	14.0*a*	4.00	11.5*c*	1.67	4.9*cd*	0.50
Spring burn–spring herbicide	10	97.0*ab*	1.02	52.5*b*	6.84	49.4*c*	7.54	3.4*b*	0.69	5.3*cd*	0.30
Fall herbicide	10	95.6*b*	0.40	53.5*b*	6.50	30.5*b*	3.91	1.0*a*	0.67	5.1*cd*	0.28
Fall burn–fall herbicide	10	97.3*ab*	0.78	29.5*c*	3.61	74.0*d*	4.52	0.5*a*	0.50	4.5*c*	0.22
Spring burn–fall herbicide	10	99.2*a*	0.51	48.5*b*	5.00	52.5*c*	6.16	0.0*a*	—	5.7*d*	0.26
Fall burn–spring herbicide	10	98.3*ab*	0.62	88.5*a*	1.30	12.5*a*	1.71	0.0*a*	—	3.1*b*	0.18

a. Means within the same column and site with the same letter are not different ($P > 0.05$).

b. CSG mixture was not planted in the control plots.

Table 3. Average total vegetative canopy cover (%), tall fescue cover (%), planted cool-season grass and legume cover (%), bare ground (%) and plant species richness (*N* species/m^2) during fall 1998 in the spring treatment plots that were seeded to CSGs at 2 study sites in Kentucky.

		Canopy Coverage		Tall Fescue		Cool-Season Grasses		Bare Ground		Species Richness	
Treatment	*N*	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
Site 1											
Control	10	99.5a[a]	0.27	93.0*a*	0.82	—[b]	—	0.0*a*	—	3.1*a*	0.23
Spring herbicide	10	97.8*a*	0.66	0.0*b*	—	0.0*a*	—	9.5*a*	1.74	3.5*a*	0.17
Spring burn–spring herbicide	10	84.5*b*	5.06	0.0*b*	—	0.0*a*	—	28.5*b*	5.97	4.4*b*	0.37
Site 2											
Control	10	97.9*a*	0.67	94.3*a*	0.78	—	—	0.0*a*	—	2.5*b*	0.17
Spring herbicide	10	91.2*a*	3.17	59.5*b*	8.18	32.5*a*	3.35	0.5*a*	0.50	4.3*b*	0.33
Spring burn–spring herbicide	10	92.4*a*	2.98	63.0*b*	6.55	22.5*b*	4.23	0.0*a*	—	4.1*a*	0.28

a. Means within the same column and site with the same letter are not different ($P > 0.05$).

b. GSG mixture was not planted in the control plots.

at 2.24 kg ai/ha reduced tall fescue cover to less than 10% during the initial growing season following herbicide application. Similarly, Madison (1994) found a spring application of glyphosate at 2.24 kg ai/ha reduced tall fescue cover to less than 2% after 1 month. Defelice and Henning (1990) reported spring and late-summer treatments of glyphosate at 1.73 and 2.54 kg ai/ha were more effective than fall treatments for killing tall fescue in Missouri. Cooler temperatures during the fall compared to the spring may have resulted in lower fescue metabolism rates and decreased herbicide efficacy (Grossbard and Atkinson 1985). In contrast, Smith (1992) found fall applications of glyphosate at 0.44–2.89 kg ai/ha were superior to spring applications in Georgia. Georgia is located in the southern part of the tall fescue range (Burns and Chamblee 1979). Smith (1992) suggested the extended growth period in Georgia may have resulted in better tall fescue control compared to more northern areas.

Cool-season Grass and Legume Establishment

Planted CSG cover varied among the treatments, but overall cool-season grass and legume establishment was poor during this study (Tables 1, 2). Mean CSG cover at both sites was higher ($P<0.05$) in treatments with fall plantings (range=12.0%–124.5%) compared to spring-planted treatments ($\bar{x}$=0.0%–18.1%) during the initial growing season. Across sites, mean planted CSG cover levels in the fall-planted treatments ($\bar{x}$=43.5%, SE=3.91) were higher ($P<0.05$) than planted CSG cover levels in the spring-planted treatments ($\bar{x}$=17.0%, SE=2.82) by the end of the second growing season (Table 2).

Several factors may have resulted in better CSG establishment in fall plantings compared to spring plantings. CSG and legume seed germination in the fall would correspond with the fall growth period, whereas germination in late spring would correspond with increasing temperatures and the onset of the cool-season grass summer dormancy period (Wolf et al. 1979, Smith 1989). Also, CSG seedlings from spring plantings faced severe competition from spring-germinating annual and perennial weeds. Glyphosate is a foliar-acting herbicide with no residual effect (Grossbard and Atkinson 1985) and provides no post-emergence weed control. Severe competition from "weedy" annual and perennial species has been shown to deter the establishment of no-tilled native warm-season grasses (Bragg and Sutherland 1989, Washburn et al. 1999). Although we undertook no post-planting activity in this study, the success of the spring plantings may have been increased by post-planting weed management.

Total precipitation levels were higher than normal (NOAA 1996, 1997) during the planting and establishment periods for the spring treatments at both study sites. Unavailable equipment and exceptionally high rainfall during March 1996 and 1997 delayed the timing of spring burns, extending the timing of herbicide applications and CSG planting dates beyond the preferred planting period. The late planting dates for the spring treatments may have resulted in the poor CSG establishment in this study. Consequently, implementing the spring burns, herbicide treatments, and CSG plantings earlier in the spring may significantly increase the amount of resulting CSG cover.

Overall, planted CSG cover levels at site 2 ($\bar{x}$=48.9%, SE=6.23) were higher (P<0.05) than at site 1 ($\bar{x}$=12.5%, SE=2.38) during the first growing season (Table 1). Similarly, planted CSG cover at site 2 ($\bar{x}$=38.8%, SE=2.47) was higher than at site 1 ($\bar{x}$=21.7%, SE=3.83) during the second growing season (Table 2). Planted CSG cover in the spring treatments at site 2 exceeded 23% during the third growing season, whereas no planted CSG cover was present at site 1. Differential CSG establishment between sites may have been influenced by weed community characteristics resulting from differences in the weed composition of the soil seedbank. Post-treatment plant communities at site 1 consisted of hairy crabgrass *(Digitaria sanguinalis),* fall panicum *(Panicum dichotomiflorum),* foxtail grasses (*Setaria* spp.), and buttonweed *(Diodia teres).* The growth form of these species resulted in a high density of plant material at the ground level. In contrast, the post-treatment plant communities at site 2 were dominated (>20% cover) by johnsongrass *(Sorghum halapense),* goldenrods (*Solidago* spp.), and marestail *(Erigeron canadensis).* The growth form of these species resulted in a tall canopy of vegetation and a lower density of plant material at the ground level. Less ground-level vegetation may have allowed for increased cool-season grass and legume seedling survival and the subsequent reinvasion by tall fescue from surrounding areas. However, the plant communities at site 2 would provide overhead canopy protection from predators, provide necessary invertebrate resources, and permit young quail to move and forage for invertebrates. The grasses would also provide nesting material and concealment necessary for nesting quail during the second and third growing seasons. Consequently, the plant communities at site 2 would provide good nesting and brood-rearing cover for bobwhite quail (Rosene 1969, Hurst 1972).

Planted CSG cover at site 1 consisted mostly of timothy ($\bar{x}$=14.3%) and common redtop ($\bar{x}$=36.5%) during the initial growing season and common redtop ($\bar{x}$=29.9%) during the second growing season. Timothy ($\bar{x}$=44.8%), common redtop ($\bar{x}$=26.5%), and orchardgrass ($\bar{x}$=8.3%) comprised most of the planted CSG cover at site 2. During the second growing season at site 2, timothy ($\bar{x}$=19.1%) and common redtop ($\bar{x}$=26.0%) comprised most of the planted CSG cover. Orchardgrass ($\bar{x}$=9.8%), timothy ($\bar{x}$=11.8%), and common redtop ($\bar{x}$=6.0%) comprised the planted CSG cover in the spring treatments at site 2 during the third growing season.

Planted legumes (red and white clover) were not present (0% cover) at site 1 during all 3 growing seasons. At site 2, mean red and white clover ranged from 1% to 22.5% during the first growing season, was less than 5% during the second growing season, and was not present during the third growing season. Similarly, Fribourg et al. (1978) reported poor red and white clover establishment from late-spring no-till plantings following a glyphosate application. Several factors may have resulted in the poor establishment of planted legumes in our study. Severe competition from annual and perennial weeds may have deterred clover establishment. Our seeding rates were much lower than rates typically used for pasture renovation because we wanted to produce wildlife habitat and not livestock forage (Ball et al. 1991). In addition, the legume seed we planted was not inoculated. Higher seeding rates and use of an appropriate inoculant may result in better legume establishment.

Plant Community Characteristics

Treatment applications increased plant species richness compared to the control plots at both study sites. Plant species richness was higher ($P<0.01$) in all treatment plots (range=3.4–7.4 species/m^2) than in the control (range 1.4–3.1 species/m^2), with 1 exception (Tables 1–3). Plant species richness in the spring burn–spring herbicide–seed CSG treatment ($\bar{x}=3.5$ species/m^2, SE=0.23) was similar ($P>0.05$) to plant species richness in the control ($\bar{x}=3.1$ species/m^2, SE=0.17) at site 1 during the third growing season (Table 3). Removal of tall fescue by the pre-emergence Round-Up PRO applications increased plant species richness and allowed for more invasion and germination of soil seedbank annual and perennial "weedy" species. Similarly, Madison (1994) found disturbances to tall fescue dominated-fields increased plant species richness.

Bare ground is an important plant community characteristic that influences the quality of grassland habitats for wildlife species such as bobwhite quail (Rosene 1969, Hurst 1972). There was little bare ground in the control plots which is consistent with other studies (Madison 1994, Barnes et al. 1995). In contrast, bare ground in all 6 treatments (range=15.2%–83.5%) was higher ($P<0.05$) than bare ground in the control ($\bar{x}=0.0\%$, SE=0.00) at site 1 during the first growing season (Table 1). The spring burn–spring herbicide–seed ($\bar{x}=59.5\%$, SE=6.60) and the spring burn–fall herbicide–seed ($\bar{x}=8.0\%$, SE=1.11) treatments had more ($P<0.05$) bare ground than the control ($\bar{x}=0.0\%$, SE=0.00) at site 2 during the first growing season (Table 1). During the second growing season, 3 treatments at site 1 (fall herbicide–seed, fall burn–fall herbicide–seed, and fall burn–spring herbicide–seed) and 2 treatments at site 2 (spring herbicide–seed and spring burn–spring herbicide–seed) had higher ($P<0.05$) bare ground levels than the control plots (Table 2). Bare ground exceeded 28% in the spring burn–spring herbicide–seed treatment plots at site 1 during the third growing season (Table 3). Although our treatments were not effective in establishing pure stands of CSGs, good quail habitat was produced in several cases. Plant communities consisting of some cool-season grasses, some clover, and substantial annual broad-leaved weeds would provide better quail habitat than plant communities consisting only of planted cool-season grasses and legumes.

Management Implications

A single pre-emergence application of Round-Up PRO herbicide with or without a prescribed burn and no-till seeding of CSGs was not consistently effective for converting tall fescue to CSGs. Post-treatment plant communities were characterized by a mixture of planted CSGs and native species. Tall fescue conversion techniques resulted in grassland habitats with characteristics favorable to bobwhite quail. Grassland communities resulting from the treatments were high in plant species diversity, were dominated by plants that provide preferred quail foods (i.e., foxtail grasses and common ragweed *(Ambrosia artemisiifolia)* and/or cover (i.e., broomsedge bluestem *(Andropogon virginicus)*, and had significant bare ground. Consequently, the tall fescue conversion techniques may be effective tools for creating good nesting, brood rearing, or winter feeding habitat for bobwhite quail.

Although the tall fescue conversion methods used in this study were effective in reducing the amount of tall fescue during the initial 2 or 3 growing seasons, reinvasion of tall fescue is an important concern for managers. Further research is needed to identify management techniques (i.e., burning, additional herbicide applications) that are effective in excluding tall fescue and providing favorable wildlife habitat in the long-term.

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