Influence of Soil Amendment on Forage Quality and Vegetation Structure in Old-Field Plant Communities

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Abstract: Old-field plant communities provide habitat components for several game species, including white-tailed deer (*Odocoileus virginianus*) and wild turkey (*Meleagris gallopavo*). Prescribed fire, herbicide application, and disking are commonly applied to improve forage and cover within old-fields, but plant response on sites with nutrient-poor soils is not always favorable. Although it is reasonable to expect vegetation to respond to liming and fertilization, little information exists on how forage nutrient content and vegetation structure of old-field plants are influenced by soil amendment. We designed an experiment to test the effects of three amendment treatments (lime, fertilizer, lime+fertilizer) on four fields across Tennessee. We tested soils during spring 2017 and 2018 and applied treatment amendments based on soil test recommendations. During summer 2018, we measured vegetation structure and collected young and old forage for nutritional analysis from four commonly-occurring early successional plants: (common ragweed (*Ambrosia artemisiifolia*), horseweed (*Conyza canadensis*), Canada goldenrod (*Solidago canadensis*), pokeweed (*Phytolacca americana*), and blackberry (*Rubus canadensis*). The effect of amendment treatment varied based on species and nutrient, but crude protein in old goldenrod leaves was the only forage/nutrient combination that soil amendment raised to meet minimum nutrition requirements of a lactating doe with twin fawns that was not already in excess of the minimum requirement for a lactating doe. Although soil amendment failed to consistently raise most nutrient values in old-fields, it did increase average vegetation height by 71% following fertilization and 65% following fertilizer+lime application. Additionally, visual obstruction from 50–100 cm, 100–150 cm, and 150–200 cm was greater following fertilizer and fertilizer+lime applications. In fields where cover is limited because of low soil productivity, amendments can be applied to increase vegetation structure for various wildlife species.

Key words: fertilization, habitat management, early succession, brooding cover

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Old-fields, or fallow plant communities, provide important habitat components for many wildlife species, including white-tailed deer (*Odocoileus virginianus*) and wild turkey (*Meleagris gallopavo*). Forbs selected by deer are common in old-fields, and these areas provide cover that adults and fawns may select for bedding (Huegel et al. 1986, Uresk et al. 1999, DePerno et al. 2003, Chitwood et al. 2017). Old-fields also provide vegetation structure that is selected by hen turkeys for nesting and brood-rearing (Sisson et al. 1991, Harper 2017, Wood et al. 2019). However, the quality of forage and cover present within old-fields varies widely based on species composition, vegetation structure, and soil fertility.

Past management practices and disturbances change both the seedbank and current plant species composition of old-fields (Thompson 1978, Gruchy et al. 2006, Wellstein et al. 2007, Cramer et al. 2008). For example, many old-fields have invasive species present within the seedbank that do not provide high-quality forage or cover (Gruchy and Harper 2014, GeFellers et al. in press). Likewise, some native species may dominate old-fields and reduce forage and cover for deer and turkey (Gruchy and Harper 2014, Brooke and Harper 2016). Plant composition also is influenced by soil fertility, as species diversity and native plant coverage may change based on nutrient availability (Wight 1976, Gough 2000, Rajaniemi 2002). Old-fields with better soil fertility have greater plant growth, which may change habitat quality by increasing cover and forage (Rajaniemi 2002, Burton et al. 2006). Additionally, available nutrition for deer may vary across soil resource regions (Jones et al. 2008).

Soil fertility can be improved through the application of amend-

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ments. Lime and fertilizer are commonly applied in agricultural crop fields and wildlife food plots to increase yield (Haby et al. 1979, Cerrato and Blackmer 1990, Osborne and Riedell 2006, Harper 2019). Aglime is most commonly used to increase soil pH, and fertilizers are applied to increase availability of specific nutrients, such as nitrogen, phosphorus, and potassium (Brady and Weil 2010). For some time, managers have been interested in applying soil amendments to native and naturalized plants to increase deer forage availability as well as to enhance brooding cover (Sisson et al. 2017). In addition to increased growth following soil amendment, nutritional content of deer forage plants may be greater on sites with better soil fertility (Jones et al. 2008). Previous studies have reported increases in biomass and quality of Japanese honeysuckle (*Lonicera japonica*) following fertilization to improve forage for deer (Segelquist et al. 1975, Dyess et al. 1994), as well as an increase in woody browse production (George and Powell 1977). However, forbs generally provide greater nutritional content for deer than the woody species examined in the previous studies (Lashley et al. 2011, Nanney et al. 2018). Shaw et al. (2010) applied soil amendments to a variety of native plants within closed-canopy forests and observed limited changes in forage quality or quantity, but low sunlight availability may have buffered vegetation response. Despite the interest of many managers in using fertilization to increase habitat quality, no study has examined the influence of soil amendment on nutritional content and vegetation structure for deer and turkey on old-field plant communities.

We developed an experiment to determine the influence of soil amendments on habitat components for white-tailed deer and wild turkey in old-fields. We tested two hypotheses related to native plant growth in response to increased soil fertility. First, we hypothesized plants will increase growth following application of lime and fertilizer, which will result in taller vegetation structure. This hypothesis is based on numerous studies investigating native plant growth and soil fertility (e.g., Wight 1976, Gough 2000, Rajaniemi 2002, Burton et al. 2006). Second, we hypothesized that forage quality of young plant tissue will not be increased following fertilization, as the young tissue of many native forages is relatively high-quality, even on infertile sites (Lashley et al. 2015), and data indicate that native plants do not decrease nutrient concentrations in young tissue even when under stress (Chapin 1980).

Study Area

We conducted our study on four old-fields in east and central Tennessee, located on Bridgestone-Firestone Wildlife Management Area (WMA) (hereinafter, BSFS), Laurel Hill WMA (LAHI), Oak Ridge WMA (OARI), and Rankin Bottoms WMA (RABO). BSFS is in White County, and soils consist primarily of Lonewood loam. LAHI is in Lawrence County, and soils consist primarily of Etowah silt loam. OARI is in Roane County, and soils consist primarily of silt loam. RABO is in Cocke County, and soils consist primarily of Holston loam (Natural Resource Conservation Service [NRCS] 2020). All old-field sites were previously used for agriculture but had not been planted for more than 30 years. Prior to treatment initiation for our study, the four sites had been primarily managed with mowing. Mean annual temperature for the four sites ranged from 13.7° to 14.5° C, and mean annual precipitation ranged from 121.7 to 138.2 cm (NOAA 2020).

We disked each site in March in 2017 and 2018 to promote forbs for brooding cover and deer forage. Common species that dominated fields during the study included common ragweed (*Ambrosia artemisiifolia*), giant foxtail (*Setaria faberi*), American burnweed (*Erechtites hieraciifolius*), horseweed (*Conyza canadensis*), daisy fleabane (*Erigeron strigosus*), blackberry (*Rubus canadensis*), Canada goldenrod (*Solidago canadensis*), pokeweed (*Phytolacca americana*), and johnsongrass (*Sorghum halepense*).

Methods

We created four 0.08-ha treatment units in each old-field: control, lime, fertilizer, and lime+fertilizer. We collected soil subsamples at 10 random points in each treatment unit to test for pH, phosphorus, and potassium in late winter 2017 and 2018. Testing was conducted by the University of Tennessee Soil, Plant, and Pest Center using Mehlich-1 extractant. We initiated treatments in March/April 2017 to allow time for lime applications to affect soil pH, and continued treatments in March/April 2018, where indicated by soil test, to fully realize our objectives of bringing soil pH to 7.0 and soil P and K to high levels. We disked each field following treatment application in March 2017 and 2018 (Tables 1 and 2) to set back succession and maintain a plant community dominated by annual forbs which are important to white-tailed deer and wild turkey.

In the lime-only and the lime+fertilizer treatments, we amended the soil with aglime to increase soil pH to 7.0. In the fertilizer-only and lime+fertilizer treatments, we applied 70 kg/ha of nitrogen (16-0-0) as well as triple super phosphate (0-46-0) and muriate of potash (0-0-60) fertilizers to increase soil phosphorus to a minimum of 34 kg P/ha and soil potassium to a minimum of 180 kg K/ha (Hanlon and Savoy 2007). All amendments were applied with a hand spreader.

We collected vegetation measurements and forage samples in July 2018. Following Nudds (1977), we measured visual obstruction for deer and turkey using a black and white vegetation profile

Table 1. Soil test results and amendments applied to four old-field sites in Tennessee, 2017. Sites were located on Bridgestone-Firestone Wildlife Management Area (BSFS), Laurel Hill Wildlife Management Area (LAHI), Oak Ridge Wildlife Management Area (OARI), and Rankin Bottoms Wildlife Management Area (RABO). Four treatment units occurred at each site, including control (C), lime (L), fertilizer (F) and lime+fertilizer (LF). All values associated with nitrogen (N), phosphorus (P), potassium (K), and lime are provided as kilograms per hectare. Amendments not part of a particular treatment are listed as N/A, whereas those not applied because soil test results indicated they were not necessary are listed as 0.

	Test results			Amendments			
	pH	P	K	Lime	N	P	K
BSFS- C	6.0	4.5	142.4	N/A	N/A	N/A	N/A
BSFS- L	6.0	4.5	137.9	627.8	N/A	N/A	N/A
BSFS- F	6.0	3.4	124.4	N/A	69.4	108.8	171.5
BSFS- LF	6.0	3.4	142.4	627.8	69.4	108.8	171.5
LAHI- C	5.8	3.4	74	N/A	N/A	N/A	N/A
LAHI- L	5.9	5.6	83	829.5	N/A	N/A	N/A
LAHI- F	6.0	5.6	108.7	N/A	69.4	99.5	135.9
LAHI- LF	5.9	3.4	74	829.5	69.4	108.8	240.1
OARI- C	5.4	498.8	167	N/A	N/A	N/A	N/A
OARI- L	5.7	495.5	281.4	1121	N/A	N/A	N/A
OARI- F	5.8	476.4	199.5	N/A	69.4	0	114.3
OARI- LF	5.7	433.8	225.3	1121	69.4	0	88.8
RABO- C	6.3	30.3	58.3	N/A	N/A	N/A	N/A
RABO- L	6.4	35.9	79.6	269	N/A	N/A	N/A
RABO- F	6.6	41.5	100.9	N/A	69.4	81.5	255.6
RABO- LF	6.4	41.5	100.9	269	69.4	70.1	213.2

Table 2. Soil test results and amendments applied to four old-field sites in Tennessee, 2018. Sites were located on Bridgestone-Firestone Wildlife Management Area (BSFS), Laurel Hill Wildlife Management Area (LAHI), Oak Ridge Wildlife Management Area (OARI), and Rankin Bottoms Wildlife Management Area (RABO). Four treatment units occurred at each site, including control (C), lime (L), fertilizer (F) and lime+fertilizer (LF). All values associated with nitrogen (N), phosphorus (P), potassium (K), and lime are provided as kilograms per hectare. Amendments not part of a particular treatment are listed as N/A, whereas those not applied because soil test results indicated they were not necessary are listed as 0.

	Test results			Amendments			
	pH	P	K	Lime	N	P	K
BSFS- C	5.5	7.8	113.2	N/A	N/A	N/A	N/A
BSFS- L	6.3	5.6	154.7	672.6	N/A	N/A	N/A
BSFS- F	5.9	23.5	252.2	N/A	69.4	113.4	106.3
BSFS- LF	6.2	16.8	227.6	728.7	69.4	120.1	131.2
LAHI- C	5.4	7.8	99.8	N/A	N/A	N/A	N/A
LAHI- L	6.5	6.7	88.6	0	N/A	N/A	N/A
LAHI- F	5.8	37	311.6	N/A	69.4	99.5	47.1
LAHI- LF	6.4	26.9	272.4	582.9	69.4	109.8	86.1
OARI- C	5.4	424.9	211.9	N/A	N/A	N/A	N/A
OARI- L	6.0	390.1	321.7	896.8	N/A	N/A	N/A
OARI- F	5.5	389	384.5	N/A	69.4	0	0
OARI- LF	6.1	464.1	359.8	896.8	69.4	0	0
RABO- C	6.3	42.6	86.3	N/A	N/A	N/A	N/A
RABO- L	6.8	52.7	87.4	168.2	N/A	N/A	N/A
RABO- F	6.5	47.1	196.2	N/A	69.4	89.2	162.8
RABO- LF	6.4	49.3	228.7	560.5	69.4	87.1	129.8

board. Measurements were taken at five random points per treatment unit with the observer kneeling 10 m from the board. The vegetation profile board was 2 m tall and 0.5 m wide, and was divided into five strata. The bottom two strata were each 0.25 m in height, whereas the upper three strata were each 0.5 m in height. The two strata lowest to the ground were the height of vegetation important for turkey broods (<0.5 m; Campo et al. 1989), and the strata from 0.5 to 1.5 m represent the height of vegetation important for nesting hens (Badyaev 1995, Kilburg et al. 2014). Greater visual obstruction in the upper three strata is also important for neonate and adult deer (Huegel et al. 1986, DePerno et al. 2003). We measured maximum vegetation height to the nearest 5 cm at each random point.

To determine the influence of soil amendment on deer forage quality, we sampled leaves from five plants known to be selected by deer at our sites (GeFellers 2019). We sampled common ragweed, horseweed, Canada goldenrod, pokeweed, and blackberry from multiple individual plants across each treatment unit. We sampled young and old leaves from these plants separately as outlined by Lashley et al. (2014), as old and young leaves may differ in both nutrient concentration and response to stress (Chapin 1980, Lashley et al. 2014). We considered young leaves as those nearer to twig tips that were easily removed from the stem. We collected multiple young and old leaves within each treatment unit from ten individual plants of each species. To ensure that we sampled across the treatment unit, we chose plant subsamples within a species that were spaced at least 5 m apart. We combined the subsamples following collection to prepare a single treatment unit sample for young and old plant tissue of each species. Forages were dried to constant mass at 50° C, and wet chemistry nutritional analysis was conducted by the Agriculture Service Laboratory at Clemson University.

Data Analysis

We used a mixed-effect analysis of variance (ANOVA) in package "nlme" (Pinheiro et al. 2017) in Program R (R Core Team 2020) to examine the relationship between soil amendments and vegetation height, with treatment unit nested within site as random effects. We also used a mixed-effect ANOVA to evaluate the effect of soil amendment on visual obstruction at <25 cm, 25–49 cm, 50–99 cm, 100–149 cm, and 150–200 cm, with treatment unit nested within site as a random effect. We analyzed the visual obstruction of each strata separately because we were interested in how treatments may influence vegetation height. For both vegetation height and visual obstruction analysis, we retained each point measurement as the unit of analysis. Finally, we used a mixed-effect ANO-

VA to compare crude protein, phosphorus, and calcium content of young and old tissue of deer forage plants among treatments, with treatment unit nested within site as random effects. Separate analyses were conducted for young and old tissue of each individual plant because we were interested in the response of each forage to soil amendment treatments. Given the importance of crude protein, phosphorus, and calcium to deer, we compared nutrient concentrations to the peak nutrient requirements of a lactating doe. Therefore, we used a 14% crude protein, 0.5% phosphorus, and 0.3% calcium threshold, which correspond with the requirements of a lactating doe with twin fawns (Hewitt 2011). For all statistical tests we set $\alpha = 0.05$ and used a critical value of $F_{(3,9)}=13.48$.

Results

Visual obstruction did not differ at the <25 cm or 25–49 cm strata in any of our treatments (Table 3). However, visual obstruction at the 50–99 cm, 100–149 cm and 150–200 cm strata were greater in fertilizer and lime+fertilizer treatments than in control (Figure 1). Average vegetation height was increased by 71% following fertilization and 65% following fertilizer+lime (Table 4).

Soil amendment did not consistently affect forage quality of either young or old plant tissues. Percent crude protein was greater in young ragweed, young and old goldenrod, and young and old pokeweed following fertilization. Crude protein also increased following application of lime+fertilizer in young and old pokeweed (Figure 2). Fertilization increased percent calcium in young and old pokeweed, whereas percent calcium declined following fertilization in young and old horseweed and young and old goldenrod. Lime increased percent calcium in old ragweed, old goldenrod, and young blackberry, whereas calcium declined following liming in old pokeweed. Calcium increased following application of fertilizer+lime in young ragweed, old pokeweed, and old blackberry, whereas it declined in young and old goldenrod (Figure 3). Fertilization increased percent phosphorus in young and old goldenrod, whereas phosphorus declined in young and old horseweed and young pokeweed following fertilization. Lime decreased phosphorus in old pokeweed, and lime+fertilizer decreased phosphorus in young and old horseweed and young and old pokeweed. Lime+fertilizer applications increased phosphorus in young and old goldenrod (Figure 4). Despite these changes in nutrient concentration following treatment, crude protein in old goldenrod following fertilization was the only forage that treatment raised nutrient content above minimum nutrient thresholds for a lactating doe that were not met in the control.

Table 3. Means and standard errors for visual obstruction scores in old-fields in Tennessee following soil amendment treatments. Scores assigned on scale of 1–5, where 1 = 0–19%, 2 = 20%–39%, 3 = 40%–59%, 4 = 60%–79%, and 5 = 80%–100%. In the stratum <25 cm, all sampling points within all treatments had a score of 5, so LCL and UCL are not provided. *P*-values are a comparison of each treatment to the control within a strata.

	$\bar{x}$	SE	LCL	UCL	*P*-value
<25 cm					
Control	5	0	N/A	N/A	
Lime	5	0	N/A	N/A	1
Fertilizer	5	0	N/A	N/A	1
Lime+fertilizer	5	0	N/A	N/A	1
25–49 cm					
Control	5	0.04	4.92	5.078	
Lime	4.92	0.06	4.80	5.038	0.16
Fertilizer	5	0.06	4.88	5.12	1
Lime+fertilizer	5	0.06	4.88	5.12	1
50–99 cm					
Control	4.08	0.3	3.49	4.67	
Lime	4.5	0.36	3.79	5.21	0.28
Fertilizer	5	0.36	4.29	5.71	0.03
Lime+fertilizer	5	0.36	4.29	5.71	0.03
100–149 cm					
Control	2.42	0.63	1.19	3.65	
Lime	3.08	0.56	1.98	4.18	0.26
Fertilizer	4.58	0.56	3.48	5.68	0.004
Lime+fertilizer	4.58	0.56	3.48	5.68	0.004
150–200 cm					
Control	1.67	0.85	0.004	3.34	
Lime	2.25	0.7	0.88	3.62	0.43
Fertilizer	4	0.7	2.63	5.37	0.009
Lime+fertilizer	4.25	0.7	2.88	5.62	0.005

Table 4. Vegetation height (cm) during July 2018 in old-fields in Tennessee following soil amendment treatments. *P*-values are a comparison of each treatment to the control.

	$\bar{x}$	SE	LCL	UCL	*P*-value
Control	98.25	20.37	58.32	138.18	
Lime	101.8	14.58	73.22	130.38	0.81
Fertilizer	168.25	14.58	139.67	196.83	0.001
Lime+fertilizer	162.6	14.58	134.02	191.18	0.002

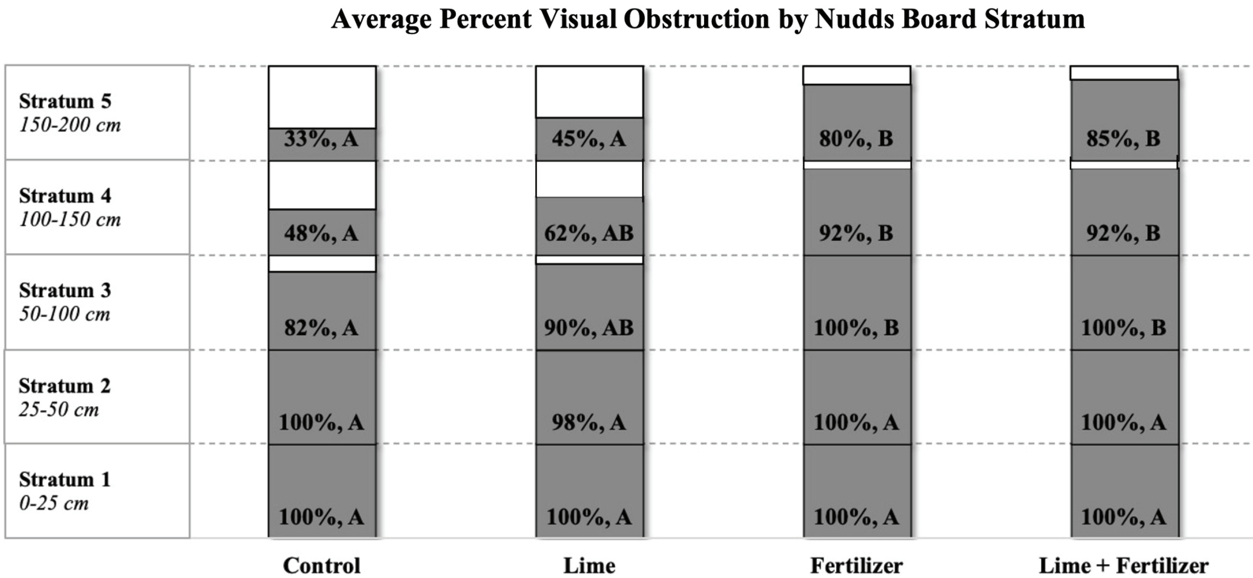

Figure 1. Average percentage visual obstruction during July 2018 in old-fields in Tennessee following soil amendment treatments. Different letters between treatments within a stratum represent significant differences in visual obstruction.

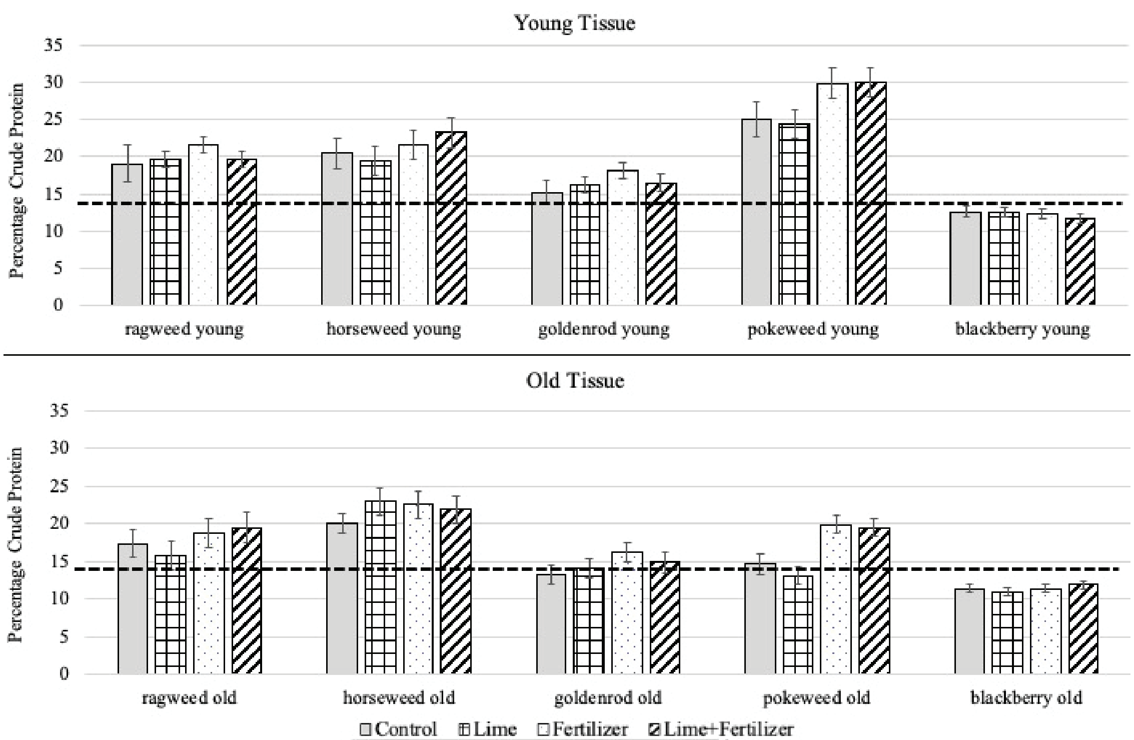

Figure 2. Average and standard error of the percentage crude protein of young and old deer forage plants in July following soil amendment treatments in old-fields in Tennessee. Bars of the same age and species with different letters are statistically different. Dashed line represents crude protein requirement of a lactating doe with twin fawns.

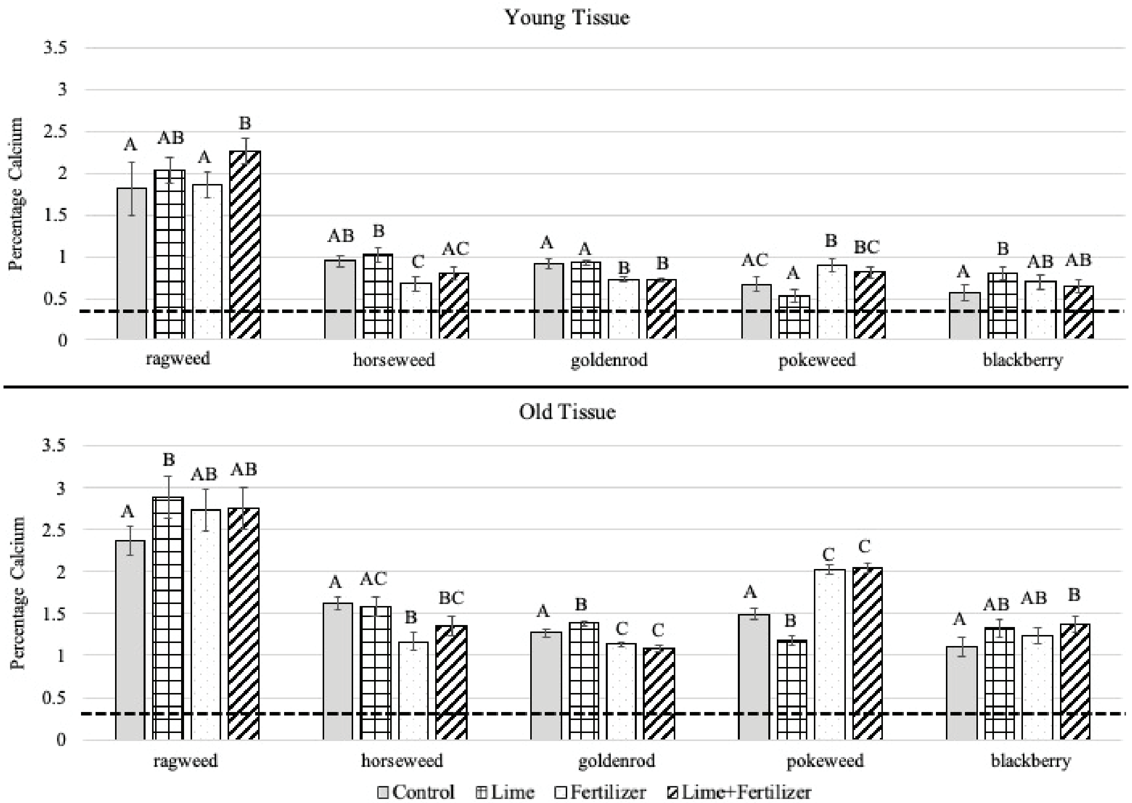

Figure 3. Average and standard error of the percentage calcium of young and old deer forage plants in July following soil amendment treatments in old-fields in Tennessee. Bars of the same age and species with different letters are statistically different. Dashed line represents calcium requirement of a lactating doe with twin fawns.

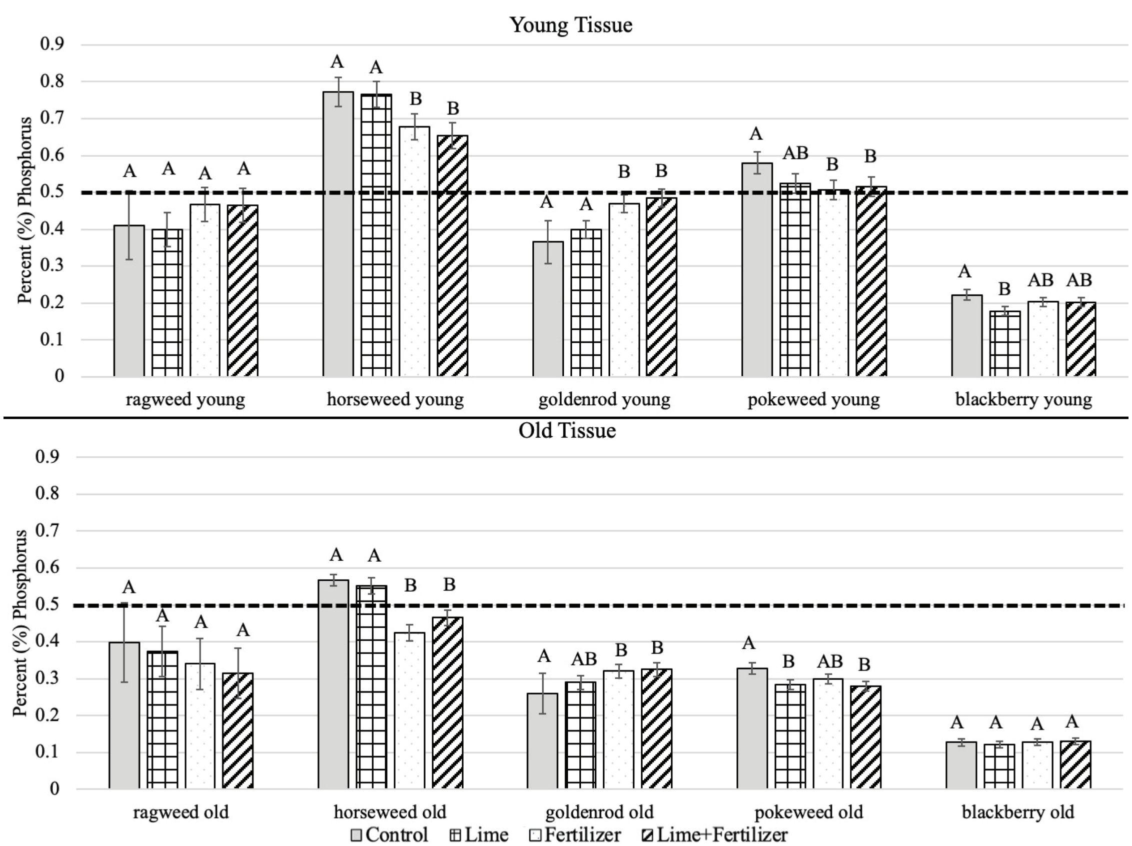

Figure 4. Average and standard error of the percentage phosphorus of young and old deer forage plants in July following soil amendment treatments in old-fields in Tennessee. Bars of the same age and species with different letters are statistically different. Dashed line represents the phosphorus requirement of a lactating doe with twin fawns.

Discussion

Application of soil amendments to old-fields increased vegetation growth but had mixed effects on nutrient concentration of deer forages. Visual obstruction and vegetation height varied between soil amendment treatments with fertilizer and fertilizer+lime producing taller vegetation with greater visual obstruction. We did not observe a consistent effect of amendment on forage nutrient concentration, and amendment generally did not increase forage quality above the requirements of a lactating doe if a plant did not already meet those requirements prior to soil amendment. These results support our hypothesis that vegetation structure would be increased by soil amendment, and partially supports our hypothesis that amendment would have limited or no effect on quality of young forage material.

We documented varying responses of plant nutrient concentration to soil amendment. In general, liming tended to increase calcium concentration, but the response of other nutrients varied widely between treatments, species, and tissue age. Some plants are unable to increase accumulation rates of specific nutrients in response to increased growth, which may account for the lack of change or even slight decrease in nutrient concentration in some species following amendment (Fleming 1973, Shaver and Chapin 1980). The minor increases in some nutrients that we documented are similar to those that Gilliam et al. (2018) observed, as they found forage nitrogen concentration in common blackberry (*Rubus alleghaniensis*) increased slightly following soil amendment but other nutrients were not increased. Although old goldenrod was raised above the 14% crude protein requirement following fertilization, average crude protein in old goldenrod in the control was just below the minimum requirement at 13.2% (±1.3). More importantly, deer selectively forage on young plant tissue, and young goldenrod in the control had an average crude protein value of 15.1% (±1.6). The majority of the tested forage tissues met crude protein and calcium requirements of a doe during lactation, but most failed to meet minimum phosphorus requirements. Nonetheless, deer are more selective of forages when resources are limited (Lashley and Harper 2012), and it is likely they are able to obtain their phosphorus needs by selectively foraging on plants with higher phosphorus concentrations, such as the young horseweed and pokeweed in our study, if they are available (Lashley et al. 2015).

Examining different forage classes and plant species contributed to results that differ from previous studies. Plant response to fertilization is likely species-specific, and wild plants may respond differently to increased soil fertility than cultivated species (Chapin 1980, Dykes et al. 2018). Past studies on wild plant fertilization for deer focused on vines, shrubs, and trees (Segelquist et al. 1975, George and Powell 1977, Wood and Tanner 1985, Dyess et al. 1994), whereas we sampled four forbs and one bramble species. Deer select forbs when they are available, and they tend to be higher in crude protein than browse (Lashley et al. 2011, Nanney et al. 2018). We were interested in how fertilization might influence quality of forbs and brambles, as they are important diet components of deer during spring and summer when nutritional demands are greatest. Of the forage/nutrient combinations that we examined, 50% had increased nutrient content following application of at least one amendment treatment. Regardless, the relatively minor changes that we recorded and the general failure of amendment to increase nutrient levels in various forages to meet the nutritional demand of a lactating doe suggests soil amendment has little if any biological significance with regard to nutrient concentration of native deer forages. Likely much more important is availability of high-quality forbs on properties managed for deer.

Fawn and adult bedsites typically are located in areas with taller vegetation that provide greater visual obstruction (Huegel et al. 1986, Uresk et al. 1999, DePerno et al. 2003, Chitwood et al. 2017). Taller vegetation structure in the fertilizer and lime+fertilizer treatments provided greater visual obstruction within the three highest strata, enhancing cover for deer (Figure 1). Fertilizer and lime+fertilizer treatments produced similar vegetation structure which, combined with the lack of a response in the lime-only treatment, indicates nutrient levels were limiting growth on our study sites, but not soil pH. Soil pH in our old-fields prior to 2017 was apparently not low enough to limit soil nutrient availability (Table 1). However, plants may respond differently in fields with a lower soil pH because availability of several nutrients decreases as soil pH declines below 5.7 (Brady and Weil 2010, Harper 2019).

Cover selected by nesting wild turkey was increased following application of fertilizer and lime+fertilizer (Figure 1). Turkey often select nest locations with greater visual obstruction from 0.5–1.5 m (Kilburg et al. 2014), and Badyaev (1995) reported that obstruction from 0.5–1 m increased turkey nesting success. Brooding cover for turkey was not improved by soil amendment, as all treatments had 100% visual obstruction in the <0.25 cm stratum, and all had greater than 97% visual obstruction in the 0.25–0.5 m stratum (Campo et al. 1989, Wood et al. 2019). However, vegetation responses to soil amendment may vary across the soil fertility gradient, and necessity of soil amendment to improve cover is dependent on site quality as well as objectives related to vegetation structure.

Cost can be a prohibitive factor when considering soil amendment applications in old-fields. Current soil pH, nutrient availability, and size of area to treat obviously influence cost of amendment treatment. Average cost of our lime treatments was US$563/ha whereas our fertilizer treatments cost $687/ha. These costs will vary considerably, as our amendments were purchased bagged. Bulk amendment purchases for larger fields should decrease cost (Harper 2019). Our data indicate, however, it is not necessary to increase soil pH above 5.8 to realize increased plant growth from fertilization, and sufficient increases in growth to meet vegetation structure objectives may be realized with lower fertilizer input. Additionally, amendment application may not be required annually, which should further decrease annual cost. Our results indicate that amending soils with lime to a soil pH of 6.0–6.8 and adding fertilizers to increase N, P, and K to high levels may not increase nutrient concentration in several common deer forages, but on properties with poor soil fertility, amendment of old-field soils is a valid option for managers who wish to increase visual obstruction for wildlife species.

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