Influence of Mowing and Herbicide Application on White-tailed Deer Use of Perennial Forage Plantings

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Abstract: Plantings of perennial and biennial forage, such as white clover (*Trifolium repens*), red clover (*Trifolium pratense*), and alfalfa (*Medicago sativa*), commonly are used by managers to increase nutritional resource availability for white-tailed deer (*Odocoileus virginianus*). Regular mowing and selective herbicide applications are two common practices used to maintain perennial plantings and reduce weed competition. However, there is little information available on how these management activities influence perennial forages or wildlife response. We evaluated the effects of regular mowing on forage production, forage quality, weed coverage, and deer detections as a case study in a perennial forage planting in Tennessee, May–August 2020. We also evaluated deer detections following application of selective herbicides among four fields in Tennessee and North Carolina, October–November 2021. Regular mowing reduced forage availability by 37% and did not increase forage quality or deer use of the food plots. Additionally, regular mowing decreased coverage of clover and alfalfa, which led to increased weed competition by late summer. Deer use did not change the month following selective herbicide application, but we observed a 67% decrease in deer detections the week following herbicide application. Regular mowing was not an efficient strategy to manage perennial forage plantings. We suggest managers maintain perennial forage food plots with selective herbicide applications in spring and fall and by mowing once during the latter portion of the growing season. Selective herbicides may reduce deer use of forage plantings for a few days after application, but use likely returns to normal soon thereafter.

Keywords: deer forage, food plot, clover, mowing, herbicide

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Management to increase white-tailed deer (*Odocoileus virginianus*; hereinafter, deer) body size, antler size, and productivity often focuses on enhancing forage quality and availability (Mixon et al. 2009, Iglay et al. 2010, Nanney et al. 2018). Antler and body size are strongly influenced by diet quality (French et al. 1956, Harmel et al. 1988, Jones et al. 2010, Michel et al. 2016). Population growth is also influenced by diet, as females produce more offspring when forage availability is improved (Verme 1969, DeYoung et al. 2019). Habitat management practices such as canopy reduction, nonnative plant species control, and prescribed fire often are used to increase forage availability in forests and early successional communities for deer (Turner et al. 2020, Harper et al. 2021, Powell et al. 2022).

Agronomic forages are commonly planted by managers to supplement naturally occurring forage, thereby increasing overall forage quality and availability. Forage plantings (hereinafter, food plots) are particularly important during periods of limited natural forage availability. They also may be used to provide high-quality forage in landscapes where forage availability is limited (Johnson et al. 1987, Edwards et al. 2004). For example, annual warm-season plantings can increase high-quality forage in addition to forage available in managed forests during the growing season (Edwards et al. 2004, Lashley et al. 2011). Both warm- and cool-season forages commonly are used to raise deer diet quality, which will increase antler and body size if sufficient forage is provided (Johnson et al. 1987, Keegan et al. 1989). Food plots also may be used to attract deer for hunting and viewing, which may influence stakeholder satisfaction (Johnson and Dancak 1993). Perennial and biennial plantings of species such as white clover (*Trifolium repens*), red clover (*Trifolium pratense*), alfalfa (*Medicago sativa*), and chicory (*Cichorium intybus*), are intended to supplement forage availability during the gap of productivity between annual warm- and cool-season plantings (Harper 2019). Although perennial forages do not require planting each year, annual management is required to maintain forage production (Ball et al. 2015, Harper 2019).

Mowing and selective herbicide applications are commonly used to maintain perennial food plots and reduce weed competition (Schreiber 1967, Cudney et al. 1992, Green and Legleiter

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2018). Regular mowing stimulates regrowth of perennial plants, which may increase nutritional quality at the whole-plant level (Cassida et al. 2000). However, as concentrate selectors, deer do not eat the less digestible stems, but rather concentrate their foraging on the more digestible leaves of the plant (Lashley et al. 2014). Therefore, the reduction of forage biomass by mowing may be of more importance than the increase in nutrient availability. Herbicides are also used to control weeds and increase forage availability. For example, several grass-selective, broadleaf-selective, and broad-spectrum-selective herbicides can effectively manage weed competition and lead to greater forage availability in perennial forage plantings (Harper 2019). However, little information exists on how deer respond following herbicide applications. Given the common use of mowing and selective herbicides to manage perennial food plots for deer, managers would benefit from quantifying deer use following their applications and the effect of these practices on forage availability and quality. Additionally, this information should be of interest to hunters who may be concerned about deer attraction to food plots if they are mowed or sprayed just prior to or during the hunting season.

We used data from two field experiments to test how mowing and selective herbicide applications influence forage availability, weed control, deer use, and deer detections in perennial food plots. We hypothesized deer detections would be influenced by both mowing and herbicide applications, and predicted both treatments would result in decreased detections. Additionally, we hypothesized mowing would influence forage biomass, but not quality of young and old plant tissues. Finally, we hypothesized mowing would not reduce weed coverage relative to unmowed plantings.

Study Area

We conducted the mowing experiment in 2020 on an established perennial forage planting in a 1.8-ha field on private property in Union County, Tennessee. We established this planting in fall 2017 in a mixture of red clover, white clover, and alfalfa. Soil was Talbott silty clay loam (NRCS 2022). Mean annual precipitation was 125.5 cm, and mean annual temperature was 13.4 C (NOAA 2022).

We conducted the herbicide experiment in 2021 on four established perennial plantings at two sites in North Carolina and Tennessee. Each planting served as a replicate, and average field size was 0.8 ha. All plantings were established in 2018–2019, maintained with an annual treatment of imazethapyr and clethodim, and mowed once annually during August–September to prepare for fall herbicide treatments. The North Carolina site was located on private property in Alamance County and had one, 0.8-ha replicate. The field was planted with a mixture of white and red clover, and soil on the site was Enon sandy loam (NRCS 2022). Mean annual precipitation was 114.6 cm, and mean annual temperature was 14.3 C (NOAA 2022). The Tennessee site was on private property in Union County and had three replicates of various sizes (i.e., 0.1 ha, 1.1 ha, and 1.8 ha). Each field was at least 400 m apart. The 0.1-ha and 1.1-ha fields were planted to a mixture of white and red clover, and the 1.8-ha field was planted to a mixture of white clover, red clover, and alfalfa. Soil at the Tennessee sites was Talbott silty clay loam (NRCS 2022), mean annual precipitation was 125.5 cm, and mean annual temperature was 13.4 C (NOAA 2022).

Methods

Mowing Case Study

We divided the 1.8-ha field into six equal-sized treatment units and randomly assigned three units as mowed and three units as unmowed controls. Prior to study initiation in early May 2020, we sprayed all units with a mixture of 876 ml ha^{-1} of Cleanse™ 2 EC (26.4% clethodim; WinField Solutions, St. Paul, Minnesota) and 292 ml ha^{-1} of Pursuit® (22.9% imazethapyr; BASF Corporation, Research Triangle Park, North Carolina). Rates were based on product label recommendations for control of common weeds in forage plantings and we sprayed based on recommendations for perennial food plot management leading into the growing season (Harper 2019). We also included 0.5% nonionic surfactant (Preference®; WinField Solutions) based on label recommendations. We cut the mowed treatment units the first week of June, July, and August 2020 using a rotary mower at a height of 15–20 cm based on common frequency and height recommendations for perennial food plot management (Tesar and Ahlgren 1950, Kammermeyer et al. 2006).

We measured pretreatment plant coverage and forage biomass to quantify existing plant species composition and biomass from all units during late May 2020 as well as 2 and 4 wk after each mowing event, for a total of six sampling periods. During each sampling period, we collected all forage present within one randomly placed 0.5-m^2 frame in each unit to quantify biomass and quality of forage plants. All random placement for sampling in the study was conducted using ArcGIS Pro 2.5 (ESRI 2020). We also collected forage from one randomly placed 0.5-m exclusion cage in each unit to quantify deer use of perennial forages. Cages were initially placed 2 wk before the first data collection period, and frames and exclusion cages were moved following collection to avoid sampling the same location multiple times. We sorted forages by species and separated young and old tissue to determine whether quality differed based on plant age as has been documented elsewhere (Lashley et al. 2014, Turner et al. 2021). We separated forages based on Lashley et al. (2014) by considering smaller leaves near the tips of stems as young tissue and larger leaves farther down the stems as older tissue. We did not include lignified stems in biomass or nutrient analysis because they do not represent what deer typically select. We weighed forages after drying at 50˚C for 72 h and calculated kg ha^{-1} of biomass of the total young and old tissue within each treatment unit for each collection. To quantify deer consumption of forages within mowed and unmowed plots, we calculated kg ha^{-1} of forage consumed by subtracting the forage production inside exclusion cages versus biomass available outside the exclusion cages. Samples of each species (both young and old tissue) from each treatment and control plot were sent to Clemson University for wet chemistry nutrient analysis of crude protein, phosphorus, calcium, acid detergent fiber, and neutral detergent fiber (Mills and Jones 1996). These nutrients were selected based on their importance to deer nutrition and diet selection (National Research Council 2007, Dykes et al. 2020).

We also used point-intercept transects (Floyd and Anderson 1987) to quantify whether mowing reduced weed coverage During each data collection period, we documented all species present directly under each 1-m mark along a randomly placed 30-m transect in each unit. We then calculated the percent coverage of planted forages (alfalfa/clover), grass, and broadleaf weeds in each unit.

We quantified deer use of each treatment unit with camera traps from June–August. We randomly placed one Reconyx® HyperFire 2 (Reconyx, Holmen, Wisconsin) in each treatment unit on a t-post following the first mowing event. We removed cameras prior to each mowing event and placed them back in same location after mowing. We set the camera to a 1-min delay, with one picture being taken each time the camera was motion activated. To standardize the detection area for each camera, we placed another t-post 1.8 m from the camera and visually judged whether deer were behind or in front of the post. We counted all deer within the picture frame that were between the camera and the t-post and calculated the total deer detections per day in each treatment unit to compare use between treatment and control. We did not identify individual deer, and some individuals likely were counted multiple times within a day. However, given our objective of quantifying relative use, this was not an issue because deer detections were counted the same way in both treatment and control units.

Herbicide Application Trial

We divided each of the four herbicide study replicates into two equal-sized treatment units. We mowed each entire replicate in early September 2022 as annual maintenance of perennial forage plots (Harper 2019). Following mowing, we randomly assigned half of each replicate as the control with no herbicide application, and the other half of the unit was assigned as the treatment to receive herbicide applications. During mid-October 2021, we applied a mixture of clethodim and imazethapyr with a tractor boom sprayer using approximately 140 L ha^{-1} water in each treatment replicate to control grass and broadleaf weeds. We applied 876 ml ha^{-1} of Cleanse™ 2 EC (26.4% clethodim), and 292 ml ha^{-1} of Pursuit® (22.9% imazethapyr). These rates were based on product label recommendations to control various weeds in perennial forage plantings, and we also included 0.5% nonionic surfactant as Preference® based on label recommendations.

We randomly placed three camera traps in each control and treatment unit 1 mo prior to herbicide application to quantify deer use before and after treatment. We used Reconyx® HyperFire 2 or Browning Strike Force® (Prometheus Group, Birmingham, Alabama) cameras, and each replicate received the same model to control for potential differences in detection between camera models. We placed cameras on t-posts 1 m above ground facing north and set to take one motion-activated picture with a 1-min delay. We placed a t-post 1.8 m from each camera to establish our detection area. Cameras were deployed for 4 wk before and 5 wk after herbicide application in treatment and control units, and we counted all deer between the camera and the post in each picture. We then calculated the average deer per day for each camera during each week of the study.

Analysis

All data were tested for normality, equality of error, and independence before we conducted the analysis. For the mowing case study, we used a *t*-test in Program R to determine whether forage production during each collection period and total forage collection varied by treatment (R Core Team 2023). We used *t*-tests to determine whether crude protein, phosphorus, calcium, acid detergent fiber, or neutral detergent fiber varied during any collection period based on treatment. We also used *t*-tests to determine differences in the percent coverage of alfalfa and clover, grass, and broadleaf weeds by treatment period and average deer detections per day on camera traps. We considered each mowed treatment unit within the case study field as a replicate, for a total of three treatment and three control replicates for all analysis.

We used an ANOVA to determine whether herbicide applications influenced deer use of perennial forage plantings. We analyzed the average change in deer detections per day for each camera during the month before and after herbicide was applied. We also tested for differences in deer detections in the week before and after herbicide was applied to determine if the change in detections differed immediately following herbicide application. We included field as a fixed effect in all ANOVA analysis to control differences which might be attributed to the particular field. We set $\alpha = 0.05$ for all analyses.

Results

Biomass of alfalfa and clover prior to treatment implementation was similar between the treatment and control units ($P > 0.05$). Mowing reduced forage biomass during the early June, early August, and late August collection periods, and total forage biomass throughout all sampling periods was reduced by 879.7 (SE = 206.3) kg ha^{-1} ($P = 0.013$; Figure 1). Deer consumed 294.7 (SE = 240.4) kg ha^{-1} less forage in mowed treatments, but this was not statistically different from the control ($P = 0.288$). We did not detect any differences in crude protein, phosphorus, calcium, acid detergent fiber, or neutral detergent fiber following mowing (Table 1). Mowing reduced clover and alfalfa coverage during the early August ($P = 0.019$) and late August ($P = 0.002$) periods, but coverage was similar during the other periods (Table 2). Mowed treatments had 25.6% (SE = 13.9) grass coverage grass coverage during the late August sampling period compared to 1.1% (SE = 1.1) in the unmowed, but means were not statistically different ($P = 0.078$). We detected 1.6 (SE = 0.39) deer per day from our camera traps in mowed units and 2.4 (SE = 0.56) deer per day in control units, which did not vary significantly ($P = 0.211$).

For the herbicide spray trial, we did not detect differences between the change in deer detections in the month before and after treatments ($P = 0.54$; Figure 2). Compared to the week prior to treatment, deer detections decreased 9% in the control and 67% in the treated units the week after herbicide applications occurred, but the pattern of use was not statistically different ($P = 0.07$).

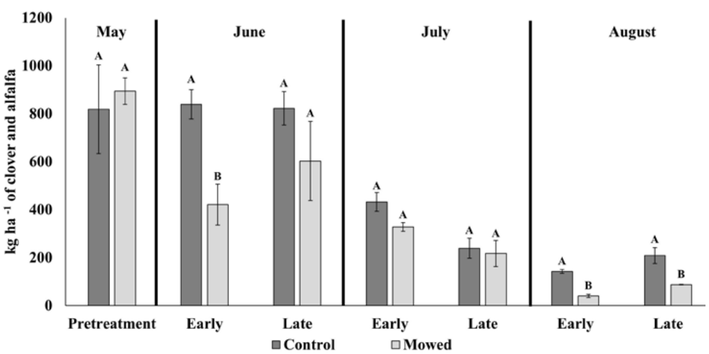

Figure 1. Standing biomass of perennial clover and alfalfa plantings with and without regular mowing during seven collection periods of May–August 2020. Vertical bars represent mowing events in the mowed treatment, and different letters in the same collection period were statistically different. The early sampling period occurred during the middle week of each month, and the late sampling period occurred during the last week of the month. Error bars represent standard error.

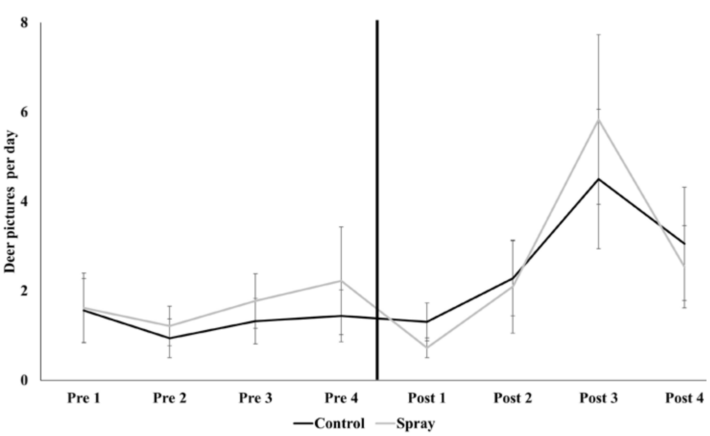

Figure 2. Average deer pictures per camera per day in the four weeks before and after clethodim and imazethapyr were applied to four perennial forage plantings in Tennessee and North Carolina in September, October, and November 2021. Dates represent the start of each sampling week. The black line represents timing of the herbicide treatment, and error bars represent standard error.

Table 1. Number of samples (*n*), percent crude protein (CP), phosphorus (P), calcium (Ca), acid detergent fiber (ADF) and neutral detergent fiber (NDF) of perennial forages collected during June–August 2020 with and without regular mowing. No significant differences between treatments were detected for these measures.

	n	CP	P	Ca	ADF	NDF
Young alfalfa						
Control	17	30.5	0.42	1.47	14.9	20.9
Mow	17	31.4	0.44	1.35	14.6	20.1
Old alfalfa						
Control	18	28.2	0.38	1.69	15.8	21.6
Mow	17	29.8	0.35	1.52	14.4	20.5
Young red clover						
Control	7	26.4	0.35	1.58	16.3	23.9
Mow	9	27.5	0.40	1.27	15.4	22.1
Old red clover						
Control	11	26.7	0.32	1.70	14.2	20.8
Mow	12	28.1	0.29	1.67	13.3	19.6
Young white clover						
Control	13	28.0	0.34	1.38	13.8	17.8
Mow	10	29.7	0.33	1.51	12.6	18.5

Table 2. Percent coverage of clover and alfalfa, grass weeds, and broadleaf weeds during seven collection periods in May–August 2020. Pre-treatment data (PRE) were collected in late May prior to treatment implementation. Mowing events occurred in early June, July, and August, with sampling occurring approximately 2 and 4 wk after mowing. Significant differences between treatments were detected for clover/alfalfa in early and late August (bold).

	PRE	Early June	Late June	Early July	Late July	Early August	Late August
Clover/Alfalfa							
Control	100	100	100	95.6	100	**97.3**	**98.9**
Mow	100	95.6	100	86.7	100	**72**	**77.8**
Grass							
Control	0	0	0	0	0	2.7	1.1
Mow	0	1.1	1.1	2.2	1.1	6.7	25.6
Broadleaf							
Control	0	2.2	2.2	7.7	18.9	12	7.7
Mow	3.3	6.7	8.9	5.5	11.1	1.3	22.2

Discussion

Mowing decreased forage availability for deer and did not improve nutritional quality or weed control in perennial forage plantings. Additionally, regular mowing resulted in decreased coverage of planted forages by August. We failed to detect significant differences in deer use following mowing or herbicide applications given our limited sample size, but our results suggest deer use may decrease for a week following selective herbicide applications.

Food plots are intended to improve diet quality for deer beyond what is naturally occurring, especially during periods of nutritional stress such as lactation and antler growth (Hewitt 2011). Nutritional requirements of deer peak during the growing season, and forage quality may be limited in some regions (Short 1975, Hewitt 2011). Additionally, supplemental forage that exceeds the nutritional requirements of deer may allow deer to benefit from availability of lower-quality natural forages in a mixed diet to meet their nutritional requirements (Hobbs and Swift 1985, Timmons et al. 2010). Thus, the primary goal of food plots should be to provide maximum biomass of forage that is sufficiently high-quality to meet the nutritional demands of deer. Mowing has been promoted as a way to increase forage quality of both native and planted forages (Kirk et al. 1974, Kallenbach et al. 2002, Smith et al. 2018). Forbs and grasses typically produce fresh regrowth following mowing. However, most forbs continue to produce fresh new leaves at the tips of stems through the growing season. Thus, mowing may reduce the overall amount of fresh growth available. The leaves of the planted forages remained palatable and digestible for deer through the growing season, and both the old and young tissue of the planted forages remained similar with regards to the nutritional requirements of deer through the growing season (National Research Council 2007). The lack of change in nutritional quality relative to deer selection is further demonstrated by deer consumption and detections numerically greater in control units, indicating deer were not selecting the mowed units over the control units. Mowing failed to change the quality or use of three perennial agronomic forages in our case study, and we do not recommend regular mowing to change nutrient levels or attractiveness for deer.

The timing of planted forage availability in relation to natural forage availability and physiological requirements is also important to consider. Peak parturition occurs during early June throughout most of the South, which is when we conducted our first mowing treatment with a corresponding decrease in planted forage availability. Declines in natural forage quality in August also occur throughout the South despite ongoing nutritional demands for lactation, but regular mowing decreased planted forage availability during this time. Overall, our mowing treatments resulted in a 37% decrease in biomass during a time when food plots should be managed to provide additional forage to meet nutritional demands.

Frequent mowing may provide an opportunity for weeds to establish in perennial forage plantings, which may lead to decreased production of planted forages and necessitate additional herbicide treatment. Weed coverage was relatively low during June and early July because of the selective herbicides we applied prior to treatment initiation, but grass weed coverage during late August in the mowed units increased to 25.6%. In contrast, grass weed coverage was only 1.1% in the control units. More than 25% coverage of grass weeds is problematic given deer do not select grass during the growing season (Hewitt 2011, Harper et al. 2021). Maintaining a dense stand of forage plants is one of the primary strategies to reduce weed pressure (Légère and Schreiber 1989, Hoy et al. 2002), and coverage of clover and alfalfa was less during August in the mowed treatments. Frequent mowing likely stresses perennial forages and provides an opportunity for weeds to establish (Tesar and Ahlgren 1950), and our results do not indicate it benefits weed control at any period.

Herbicide applications to control weeds are often needed to maintain perennial food plots, but few data exist on deer response to these treatments. Several studies have documented the effects of herbicide treatments on vegetation for wildlife (Lashley et al. 2011, Harper et al. 2021, Turner et al. 2023), but the immediate response of deer following herbicide treatments is scant in the literature. Our limited sample size of four sites prevented detecting significant differences based on treatments, but we believe a 67% reduction in deer detections during the week following herbicide applications is relevant if there is concern about reduced deer activity in food plots soon after herbicide application. Given the selective herbicides we applied, the short-term avoidance was likely related to taste or smell and not changes in forage quality or quantity. Decreased use could not be attributed to disturbance of the field because the treated unit was immediately adjacent to the untreated unit at each site. There appeared to be an increase in use three to four weeks following herbicide applications in both treated and control units, but this likely was a result of decreasing availability of other forages during our sampling period (Pekins and Mautz 1987). Further research should investigate wildlife response to herbicide applications in food plots, as we believe these are among the first results demonstrating a potential behavioral response of a mammal immediately after an herbicide application.

We suggest managers avoid regular mowing of perennial food plots, and instead use selective herbicide applications early in the growing season (i.e., April–May) to reduce weed competition. A single mowing in late summer when perennial forage production is at its lowest (i.e., August or September) is sufficient to maintain perennial plantings, and an additional application of various selective herbicides can be applied to control incoming cool-season weeds if needed following mowing in the fall. This approach increases deer forage availability while maintaining quality of forage plantings. Consideration should be given to the timing of herbicide application to ensure deer do not avoid forage plantings during nutritional stress periods, but our results indicate deer only avoid treated fields for a short period after treatment.

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