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Management and Conservation Note

Effects of Mowing on Anthraquinone for Deterrence of Canada Geese

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ABSTRACT Anthraquinone (AQ)-based repellents have been shown to reduce Canada goose (*Branta canadensis*) use of turfgrass; however, impacts of frequent mowing on efficacy of AQ have not been studied. Our objective was to determine efficacy and longevity of a rain-fast AQ-based avian repellent, FlightControl® PLUS (FCP), as a deterrent of free-ranging resident Canada geese under 2 mowing frequencies. We conducted the study at 8 sites in the Triangle region (Raleigh, Durham, and Chapel Hill) of North Carolina, USA. We arranged our experiment in a randomized complete block design, with each of 8 sites containing 4 0.1-ha treatment combinations: 1) treated with FCP and mowed every 4 days (T4), 2) treated with FCP and mowed every 8 days (T8), 3) untreated and mowed every 4 days, and 4) untreated and mowed every 8 days. We conducted 4 37-day field sessions (Jun–Jul 2007, Sep–Oct 2007, Jun–Jul 2008, and Sep–Oct 2008), representing the summer molting phase and the full-plumage phase. Resident goose use (measured by daily no. of droppings) was 41–70% lower on treated plots than on untreated plots, but use was similar between T4 and T8. Average FCP coverage on grass blades decreased in coverage from approximately 95% to 10% over the 30-day posttreatment phase. Results indicate that resident Canada goose use of FCP-treated turfgrass areas was lower than untreated areas even when chemical coverage on grass was 10%. Further, mowing frequency did not have a clear impact on the efficacy of FCP as a Canada goose repellent.

KEY WORDS Anthraquinone, *Branta canadensis*, Canada geese, FlightControl® PLUS, mowing, repellents, turfgrass.

In the mid-20th century, restrictive waterfowl hunting regulations, increases in suitable habitat, and relocation programs contributed to a rise in resident Canada goose (*Branta canadensis*) populations in the United States, especially in suburban areas (Conover and Chasko 1985, Ankney 1996). Like many wildlife species, Canada geese have adapted to living near humans. Although there may be many stresses, hunting and often predation are reduced in suburban areas compared to more rural landscapes (Ditchkoff et al. 2006). Suburban areas (e.g., golf courses, parks, corporate facilities, and residences) typically contain ponds or lakes surrounded by managed turfgrass, which provide excellent habitat for geese (Conover and Chasko 1985). However, because of feces build-up, the aggressive behavior of Canada geese during nesting and flightless periods, and damage to turfgrass, novel approaches to goose reduction in suburban areas are needed (Ankney 1996, Loker et al. 1999).

Hunting can aid in controlling goose populations in rural areas but is illegal in most suburban and urban areas (Conover and Chasko 1985). Other lethal methods, including oiling or addling eggs and euthanizing birds captured during the summer molt stage, may be effective at reducing populations of geese in suburban and urban areas (Gosser et al. 1997). However, acquiring depredation permits and assistance for removals requires demonstrating that nonlethal methods of controlling geese have been attempted (U.S. Fish and Wildlife Service 2007). Further, lethal methods of goose control have different levels of opposition or support from the general public (Conover and Chasko 1985, Loker et al. 1999).

Nonlethal methods for goose management include habitat manipulation, visual and auditory disturbances, dog harassment, obstructions to water, and chemical deterrents (Gosser et al. 1997, Castelli and Sleggs 2000). Habitat manipulation and visual and auditory disturbances require maintenance and may be undesirable for aesthetic or functional reasons, and use of chase-dogs requires continuous oversight and may be cost-prohibitive (Conover 1992, Castelli and Sleggs 2000).

Previous studies have investigated efficacy of nonlethal chemical repellents as deterrents of nuisance geese (Conover 1985). For example, Methiocarb (Conover 1985), dimethyl and methyl anthranilate (Cummings et al. 1991, 1995; Belant et al. 1996), and lime (Belant et al. 1997) have had mixed results as Canada goose deterrents, depending on application method and active ingredients. Anthraquinone (AQ) has been shown to be an effective avian deterrent, especially when combined with a plant-growth suppressant (Avery et al. 1997, Dolbeer et al. 1998, Blackwell et al. 1999).

Although AQ has proven effective on captive geese, it has not been tested under natural environmental conditions in habitats occupied by free-ranging Canada geese. Because free-ranging geese are mobile, they have options for foraging locations, which may affect efficacy of turf-applied chemical deterrents. Additionally, longevity of turf-applied chemical repellents may be affected by mowing frequency

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because the chemical above mowing height will be removed. Blackwell et al. (1999) postulated that higher rates of mowing would remove turf-applied chemicals faster than less frequent rates of mowing; however, to our knowledge, mowing frequency has not been evaluated for its effect on turf-applied goose repellents. Therefore, our objective was to determine efficacy and longevity of a rain-fast AQ-based avian repellent, FlightControl® PLUS (FCP; Arkion® Life Sciences LLC, New Castle, DE), as a deterrent of free-ranging resident Canada geese under 2 mowing frequencies. FlightControl® PLUS is intended for use on managed turfgrass areas, and the manufacturer recommends reapplication after 2 or 3 mowings.

STUDY AREA

We conducted the study at 8 sites in the Triangle region (Raleigh, Durham, and Chapel Hill) of North Carolina, USA. Sites included corporate facilities, suburban neighborhoods, parks, a greenway, a college pond area, and a cattle facility. Two sites were dominated by bermudagrass (*Cynodon dactylon*), and 6 sites were dominated by tall fescue (*Schedonorus phoenix*). Each site had $\geq$0.4 ha of grass adjacent to or nearby a pond or lake with daily use by geese during early summer, early autumn, or both.

METHODS

We arranged a randomized complete block design, with 8 sites (i.e., blocks) each containing 4 0.1-ha treatment combinations (Ott and Longnecker 2001). At every site, we randomly assigned each 0.1-ha plot ($n = 4$) to 1 of 4 treatment combinations: 1) treated with FCP and mowed every 4 days (T4), 2) treated with FCP and mowed every 8 days (T8), 3) untreated and mowed every 4 days (U4), and 4) untreated and mowed every 8 days (U8). The schedules represent commonly used mowing frequencies on corporate, residential, and recreational sites during healthy growth stages (Christians 2004). We mowed the 2 sites dominated by bermudagrass at 5 cm and the 6 sites dominated by tall fescue at 9 cm as recommended by site managers. We conducted 4 37-day field sessions (Jun–Jul 2007, Sep–Oct 2007, Jun–Jul 2008, and Sep–Oct 2008), representing the summer molting phase and the full-plumage phase. We randomly rotated treatment combinations to each of the plots during the sessions.

Daily, we counted and removed goose droppings along a permanent 2 $\times$ 21-m transect in each plot. We chose those dimensions so that transects fit within each treatment plot in a central location to limit the influence of neighboring plots. We placed transects so they had a common orientation to water at each site.

We mowed all plots 8 days before repellent application and we maintained the 2 mowing schedules until the end of the postapplication observation phase. We recorded goose use (i.e., no. of droppings/transect) of all sites on each test plot for a 7-day baseline period prior to repellent application. We used the number of droppings/transect to represent goose use instead of number of geese or goose-hours because we could not continuously observe sites and droppings were used to estimate goose use in previous studies (Belant et al. 1996). Also, we used the number of droppings instead of dropping mass because roosting piles would contribute disproportionately compared to time spent grazing. Hence, we counted roosting piles as one dropping. We recorded the number of geese inside and outside all test plots upon daily arrival to each site and weighed all droppings from each transect each day.

After final baseline observations, we mowed all sites and applied FCP to the 2 treated plots at the maximum recommended rate of 9.5 L/ha using a CO_2-pressurized all-terrain-vehicle–mounted 3-m boom sprayer or a Solo® backpack sprayer (Solo®, Newport News, VA). We measured daily blade coverage of FCP visually in treated plots by estimating the proportion of live grass blade length that had FCP (i.e., spots) remaining in a random approximately 103-cm^2 patch. Because chemical coverage of each plot was homogenous, we considered one random location for measuring daily chemical coverage to be sufficient.

For each session, we conducted an analysis of covariance (ANCOVA) to compare goose use of plots, using PROC MIXED in SAS 9.1 (SAS Institute Inc., Cary, NC). We used the number of droppings each day after FCP application as the response variable and the baseline number of daily droppings for each transect as a covariate. We divided the 30-day posttreatment phase into 4 consecutive multiday (7-, 7-, 7-, and 9-day) periods. Predictor variables were FCP treatment, mowing frequency, site, and post-treatment phase. We used treatment, mowing frequency, and site as class variables and period as a continuous variable. We considered site a random effect because we randomly chose our study sites from a regional population of water bodies surrounded by turfgrass. Also, we included in the model the interaction between treatment and mow and the interaction between treatment and posttreatment period.

For all sessions combined, we conducted an analysis of variance to test chemical longevity on treated plots, using PROC MIXED in SAS 9.1 (SAS Institute Inc.). We defined chemical longevity as the number of days that spots of FCP were still evident on grass blades in treated plots. The response variable was percentage of grass blade length still containing FCP spots and the predictor variable was mowing schedule of the treated plot.

We removed daily records with zero fecal droppings at a site from the analysis because we assumed geese did not use those sites on those days. We did not include 2 of the 8 sites in the autumn 2007 ANCOVA analysis because there were no geese present. In autumn 2008, we did not use one site because of construction and another because no geese were present. All methods were approved by the North Carolina State University Institutional Animal Care and Use Committee (Protocol no. 08-012-O).

RESULTS

Plots treated with FCP had less goose use than untreated plots in summer 2007 ($F_{1,752} = 20.79$, $P < 0.001$), autumn 2007 ($F_{1,456} = 7.23$, $P = 0.007$), and summer 2008 ($F_{1,714}$

Table 1. Results from analysis of covariance of resident Canada goose use of 0.1-ha plots during 4 experimental sessions. Treatment indicates use of FlightControl® PLUS to deter goose grazing of turfgrass. Mowing indicates mowing every 4 days compared to every 8 days. Baseline indicates differences in goose use of plots before any plots were treated. Period is the 7- or 9-day period of the 30-day session during which droppings were collected. Estimate indicates effect of the variable on the number of goose droppings collected. The negative treatment effect indicates goose use on treated plots lower than goose use on untreated plots. The negative mowing effect indicates lower goose use on plots mowed every 4 days than on plots mowed every 8 days. We conducted testing during summer and autumn 2007 and 2008 at 8 sites in the Raleigh–Durham–Chapel Hill area of North Carolina, USA.

Session	Variable	Estimate	SE	Den_df[a]	*F*-value	*P*-value
Summer 2007[b,c]	Treatment	−16.609	3.643	1, 752	20.79	<0.001
	Mowing	−4.724	2.007	1, 752	5.54	0.019
	Baseline	0.376	0.118	1, 752	10.14	0.002
	Period	1.335	0.647	1, 752	4.26	0.040
Autumn 2007	Treatment	−7.948	2.956	1, 456	7.23	0.007
	Mowing	3.350	1.360	1, 456	6.06	0.014
	Baseline	0.219	0.171	1, 456	1.64	0.201
	Period	0.139	0.561	1, 456	0.06	0.805
Summer 2008[c,d]	Treatment	−15.860	2.971	1, 714	28.50	<0.001
	Mowing	2.525	1.313	1, 714	3.70	0.055
	Baseline	0.660	0.049	1, 714	185.00	<0.001
	Period	−0.093	0.554	1, 714	0.03	0.868
Autumn 2008[d]	Treatment	1.355	2.253	1, 404	0.36	0.548
	Mowing	1.989	0.854	1, 404	5.43	0.020
	Baseline	0.215	0.131	1, 404	2.68	0.102
	Period	1.635	0.400	1, 404	16.72	<0.001

[a] Den df = denominator degrees of freedom.
[b] Significant treatment × mow interaction ($P < 0.05$).
[c] Significant treatment × period interaction ($P < 0.05$).

= 28.50, $P < 0.001$; Table 1; Fig. 1). Averaged for all 4 sessions, goose use on treated plots in the first week posttreatment was 70% lower than use on untreated plots, 59% lower in week 2, 57% lower in week 3, and 41% lower in week 4 (Fig. 2). Although goose use was lower on treated than on untreated plots, geese continued to use treated plots at reduced levels (Fig. 2). Number of zero dropping days per site per session ranged from 0 to 32 with a mean of about 10.

Goose use was higher on plots mowed every 4 days than on plots mowed every 8 days in summer 2007 ($F_{1,752}$ = 5.54, $P = 0.019$) but lower on plots mowed every 4 days in autumn 2007 ($F_{1,456}$ = 6.06, $P = 0.014$), summer 2008 ($F_{1,714}$ = 3.70, $P = 0.055$), and autumn 2008 ($F_{1,404}$ = 5.43, $P = 0.020$; Table 1). However, mowing frequency did not affect treatment efficacy, because goose use of T4 and T8 plots was similar in all sessions (Fig. 1). Conversely,

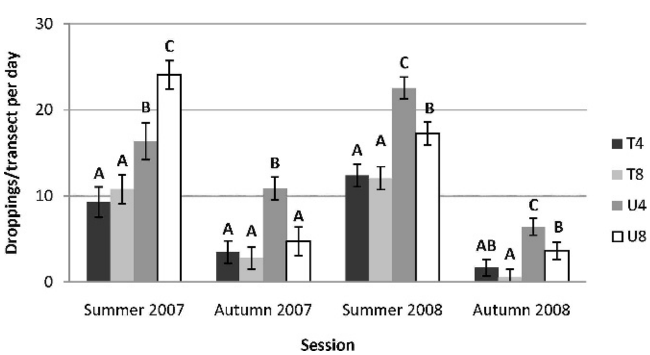

Figure 1. Daily Canada goose droppings on 4 2 × 21-m transects during the 30-day phase after application of FlightControl® PLUS (FCP) goose repellent. T = treated with FCP, U = untreated, 4 = mowed every 4 days, and 8 = mowed every 8 days. Different letters represent significantly different means at α = 0.05. We conducted testing during summer and autumn 2007 and 2008 at 8 sites in the Raleigh–Durham–Chapel Hill area of North Carolina, USA.

mowing frequency did affect goose use of untreated plots and number of droppings on U4 was 33% lower than on U8 in summer 2007, 120% higher in autumn 2007, 35% higher in summer 2008, and 86% higher in autumn 2008 (Fig. 1). Average daily rainfall was 0.30 cm in 2007 sessions and 0.48 cm in 2008 sessions (including 30 days prior to each session to account for soil moisture; Weather Underground 2009). Average FCP coverage on grass blades was similar between T4 and T8 plots during the posttreatment phase ($F_{1,1560}$ = 0.01, $P = 0.931$) and we observed a steady decrease in coverage from approximately 95% to 10% over the 30-day posttreatment phase (Fig. 3).

Goose use during the baseline period affected goose use during the posttreatment phase for the 2007 and 2008 summer sessions but not during the 2007 and 2008 autumn sessions (Table 1). Average daily numbers of geese observed at each site were 41 and 38 during summer 2007 and summer 2008, respectively, and 53 and 35 during autumn 2007 and autumn 2008, respectively, but the level of goose use at sites based on fecal counts was lower on all plots in autumn sessions than in summer sessions (Fig. 2). Our results indicate dropping concentrations in grazing areas at sites similar to ours with 42 geese per site per day and treated once per month would be approximately 0.26 droppings/m^2 per day in early summer and approximately 0.06 droppings/m^2 per day in early autumn.

DISCUSSION

One application of FCP consistently reduced use by free-ranging resident Canada geese for the 30-day posttreatment observation phase. Similarly, previous studies demonstrated that AQ was an effective avian repellent (Avery et al. 1997, Dolbeer et al. 1998, Blackwell et al. 1999). However, repellent efficacy lasted longer (≥30 days) in our study than

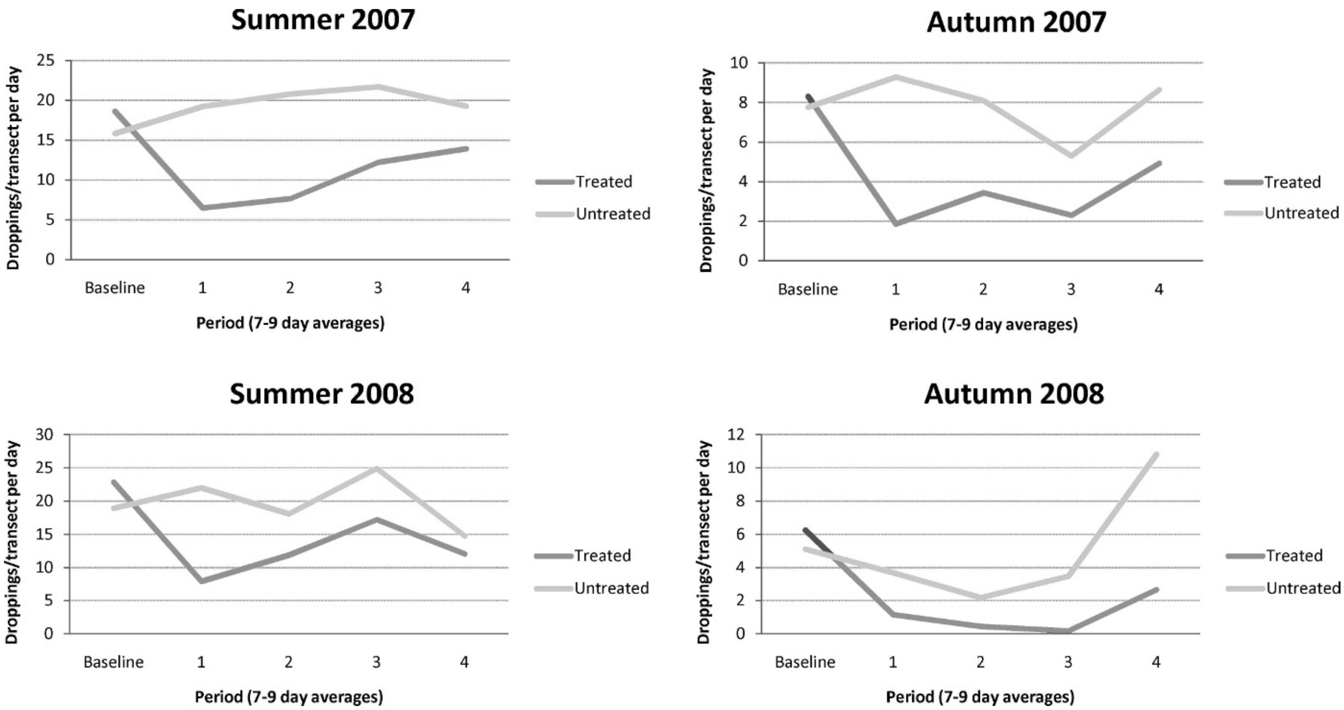

Figure 2. Average number of daily Canada goose droppings during 4 sessions before and 4 periods (30 days) after FlightControl® PLUS application. Period values are averages of daily values for that 7–9-day period. We conducted testing during summer and autumn 2007 and 2008 at 8 sites in the Raleigh–Durham–Chapel Hill area of North Carolina, USA.

the 6 days shown in Dolbeer et al. (1998). Blackwell et al. (1999) determined that a predecessor of FCP, which was not rain-fast, combined with a plant-growth suppressant was effective for their entire 22-day observation phase. Extended efficacy of the repellent was attributed to the growth suppressant, but the relationship was not directly tested (Blackwell et al. 1999). Application rates of AQ product used by Dolbeer et al. (1998) and Blackwell et al. (1999) were 4.5 L/ha and 2.3 L/ha, respectively, and were lower than the rate we used (9.5 L/ha). Because the current formula of FCP is rain-fast, the concentration of application should not affect the longevity on the plant but perhaps could have a stronger repellency effect on geese. In the

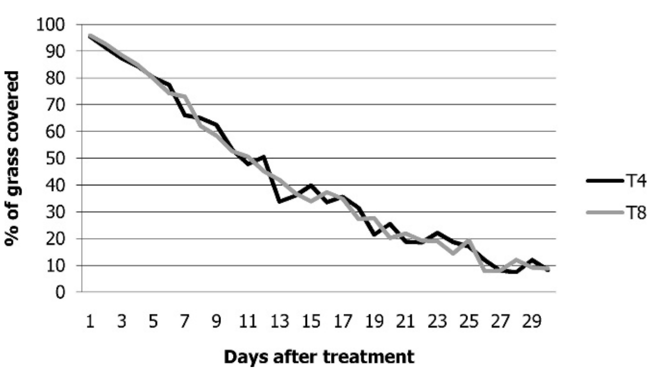

Figure 3. FlightControl® PLUS blade coverage on treated turfgrass plots mowed every 4 days (T4) and treated plots mowed every 8 days (T8) over a 30-day posttreatment phase. We conducted testing during summer and autumn 2007 and 2008 at 8 sites in the Raleigh–Durham–Chapel Hill area of North Carolina, USA.

studies by Dolbeer et al. (1998) and Blackwell et al. (1999), geese were captive and remained near treated areas. Conversely, geese in our study were free-ranging and able to move away from areas treated with FCP, especially during autumn sessions when full plumage allowed flight. Upon moving to alternative feeding locations, geese may avoid treated sites for longer lengths of time than in captive studies.

Mowing frequency had no effect on treatment efficacy or coverage of FCP on grass blades in treated plots. We suggest that mowing removed more untreated grass than treated grass and that most treated grass was removed by senescing of leaves. Mowing reduced foliage on a given plant; less foliage reduced the shading and subsequent senescing of lower blades (Emmons 2008). Because new untreated blades of grass grow above older treated blades, FCP likely was removed by the senescing and shedding of older treated blades that remained in the shade of newer blades for an extended length of time (Emmons 2008). Conversely, re-exposure of older treated blades by the mowing removal of younger untreated blades allows sunlight to reach the treated blades, which could grow above mowing height, depending on leaf growth angle and growth rate (Emmons 2008).

To maximize longevity of FCP efficacy, treated blades need to stay alive but remain below the mowing height as long as possible. Hence, a plant growth regulator can be used to limit the amount of treated grass growth above mowing height and reduce the shading of treated grass by untreated blades (Blackwell et al. 1999). Also, methods of encouraging horizontally growing grass blades may reduce the amount of treated blade removed by mowing (Emmons

2008). Sheffer et al. (1978) noted that lower mowing height (range = 1.3–5.1 cm) resulted in more horizontal leaf angles, but less is known about the effect of mowing frequency on blade angle.

Inconsistent differences between goose use of U4 and U8 plots may have resulted from several random effects, including lower rainfall amounts during 2007 sessions compared to 2008 sessions. Blackwell et al. (1999) detected no preference by geese for short grass (4.2 ± 0.7 cm) over tall grass (17.4 ± 3.3 cm); however, we documented higher use on U4 plots than on U8 plots for 3 of the 4 sessions, possibly indicating goose selection of the shorter grass in the more frequently mowed plots. During the dry summer of 2007, use on U8 was higher than use on U4. Slower grass growth during the dry session may have allowed other factors (e.g., turf damage or disturbance from excessive mowing) to influence goose use of untreated plots, whereas remaining sessions were wetter, allowing grass to become taller and less palatable in U8 plots (Conover 1991).

We accounted for heterogeneity among sites as a random effect in the ANCOVA. Characteristics that contributed to differences among sites may include dominant grass type, total amount of turf available for grazing, proximity of shoreline to turfgrass, and amount of human disturbance to grazing. Conover (1991) determined that geese select grass based on ash content and ease of severing blades from the plant and that Kentucky bluegrass (*Poa pratensis*) was preferred over tall fescue. We did not evaluate the difference between treatment effect on sites dominated by tall fescue and those dominated by bermudagrass, but we speculate that different morphology and water tolerances of these grasses may affect chemical longevity.

Management Implications

Managers must determine whether 40–70% reduction in goose use each month is a sufficient reduction in fecal nuisance. Although FCP application reduced feces concentrations in treated areas, additional goose presence following treatment may not be acceptable. Goose numbers and environmental conditions will vary from site to site, leaving managers to identify an application rate and total treated area that is economically feasible. Prior to treatment, we recommend that site managers and homeowners identify areas and times of year of highest goose use so that applications can be made when most effective. Also, seasonal changes in goose mobility may create differences in efficacy of FCP applications during different times of year. Many of the molting geese that used our study sites during the summer sessions likely did not nest there, so deterrence efforts may need to span the nesting and molting periods at areas where geese congregate during the molt period. Also, mowing more frequently than every 4 days, as is the case in some parts of golf courses, may affect FCP efficacy. However, if the growth rate and angle of grass blades can be regulated to limit growth of treated blades above mowing height, then more frequent mowing should not have negative effects on FCP longevity.

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