Tall Fescue Mowing Height Effects under Simulated Athletic Field Traffic

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Abstract. Tall fescue (*Schedonorus arundinaceus*) offers an alternative to kentucky bluegrass (*Poa pratensis*) for use on athletic fields. Tall fescue has the ability to withstand athletic field traffic, but little is known about the best management practices such as optimal height of cut (HOC). A 2-year study was conducted on established 'Snap Back' tall fescue grown over a native soil root zone to determine optimal HOC under simulated athletic field traffic. Plots were maintained at various HOC treatments (1.5, 2, or 3 inches) for the duration of the growing season. Twenty-five simulated traffic events were applied each fall with a modified Baldree traffic simulator. The percentage of green cover (GC) loss per traffic event by HOC varied between years. In 2017, the 1.5-inch HOC improved traffic tolerance (–1.7% GC per event) compared with the other HOC treatments (–2.6% GC per event) in terms of percentage of GC. In 2018, the HOC did not have an impact on traffic tolerance. Differences in traffic tolerance between years could be a result of differences in precipitation (78 mm in 2017, 6 mm in 2018) during the period when traffic occurred, which suggest that the lower HOC performs better under wet conditions compared with the greater HOC. There were no differences among treatments for the safety variables measured (surface hardness, rotational resistance, and soil moisture).

Medium- to low-end athletic field managers often struggle with maintaining high-quality athletic fields because of high use rates and limited budgets to supply enough inputs. Athletic field turfgrass must survive frequent and damaging foot traffic (Minner et al. 1993). Many previous research projects have investigated traffic stress tolerance in turfgrass (Adams and Gibbs 1989; Bonos et al. 2001; Haselbauer et al. 2012; McNitt and Landschoot 2001; Minner et al. 1993; Thoms et al. 2011; Trappe et al. 2008; Williams et al. 2010), reporting differences between varieties of both cool- and warm-season grasses. Canaway (1981) and Shearman and Beard (1975a, 1975b) investigated seven different species of turfgrass under simulated traffic and determined significant traffic tolerance differences among species, with perennial ryegrass (*Lolium perenne*) and annual bluegrass (*Poa annua*) being the most traffic and wear tolerant. 'Kentucky 31' tall fescue [*Festuca arundinacea* (synonyms *Schedonorus arundinaceus* and *Lolium arundinaceum*)] was also considered a high-traffic–tolerant species in our study because it has greater amounts of sclerenchyma cells than other grass species, which are often associated with lignin. Previous research (Minner et al. 1993) indicated tall fescue can withstand the rigors of athletic field foot traffic.

In addition to traffic tolerance, tall fescue also requires fewer management inputs, such as irrigation and nitrogen, and less organic matter management than other cool-season turfgrasses (Christians et al. 2017). However, limitations exist with using tall fescue as a turfgrass playing surface. Traditionally, limitations included a bunch-type growth habit, lower cold tolerance, wide leaf blade, and susceptibility to brown patch [*Rhizoctonia solani* (Christians et al. 2017)], all of which have slowed the adaptation of athletic fields to tall fescue. Newer cultivars offer solutions such as improved disease resistance, improved cold tolerance, and more narrow leaf blades (Christians et al. 2017); however, management of tall fescue as an athletic field needs further research.

Coaches often want a shorter height of cut (HOC) maintained in a belief that players can run faster and there are improved ball-roll properties on a lower HOC. However, Gramckow (1968) reported that as the HOC was decreased, the peak deceleration (GMAX) on impact increased. Mooney and Baker (2000) reported that for perennial ryegrass, cutting heights between 18 and 30 mm decreased turfgrass cover, ball deceleration, and traction. Rogers and Waddington (1992) reported that kentucky bluegrass (*Poa pratensis*) cutting height did not change the GMAX with a Clegg impact soil tester (CIST; Turf Tec, Tallahassee, FL, USA) for various cutting heights of 19, 38, and 57 mm, when using the 0.5- or 2.25-kg hammers. When the CIST was equipped with the 0.5-kg hammer, which is often used on golf course putting greens, the GMAX on tall fescue was decreased as cutting height increased (Rogers and Waddington 1989).

Repeated foot traffic will result in wear stress to turfgrass foliage as well as soil compaction (Carrow et al. 1992). A loss of turfgrass cover and increased soil compaction or bulk density can result in an increased chance of an athlete experiencing a brain trauma or lower

Units

To convert U.S. to SI, multiply by	U.S. unit	SI unit	To convert SI to U.S., multiply by
0.3048	ft	m	3.2808
0.0283	ft^3	m^3	35.3147
2.54	inch(es)	cm	0.3937
25.4	inch(es)	mm	0.0394
0.4536	lb	kg	2.2046
48.8243	lb/1000 ft^2	$kg \cdot ha^{-1}$	0.0205
1.1209	lb/acre	$kg \cdot ha^{-1}$	0.8922
1.3558	lbf ft	N·m	0.7376

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leg injury (Gadd 1966; Griffin et al. 2006; Gurdjian et al. 1966). A loss of cover will result in an increased GMAX as a result of soil compaction (Brosnan et al. 2014). Henderson et al. (1990) found greater surface hardness readings on bare soil as opposed to soil covered with kentucky bluegrass. Although there is a general belief that managing turfgrass at a shorter HOC will result in an increased loss of cover under repeated foot traffic, more research is needed on developing an optimum sports turf HOC for medium- to low-end tall fescue athletic fields.

Various cutting heights can also change the traction for an athlete, although the effects are not always consistent. Middour (1992) found no differences among three different cutting heights of four species of turfgrass, including tall fescue, on rotational traction. However, Middour (1992) did note that linear traction increased as cutting height decreased. Rogers and Waddington (1989) used an Eijkelkamp shear apparatus to evaluate traction of tall fescue maintained at different HOCs, and did not see any significant differences in traction. Verdure, or the amount of turfgrass foliage left after mowing (Beard et al. 1973), has been investigated to determine whether increased turfgrass density can improve traction. Verdure, either wet or dry, had no effect on traction of tall fescue according to McNitt (1994). However, Rogers and Waddington (1989) reported that with less verdure, there were lower traction values and that bare soil offered less traction after verdure had been removed. Based on the previous research cited, turfgrass cover can affect player-to-surface interactions. The objective of our study was to determine the optimum cutting height for tall fescue to maximize turfgrass performance and safety under simulated traffic conditions. The hypothesis was that the lower HOC would not be as traffic tolerant as the higher HOC.

Materials and methods

Research was conducted during the 2017 and 2018 growing seasons at the Iowa State University Horticulture Research Station on the Sports Turf Research Field at Ames, IA, USA. Plots were located on a disturbed native Clarion Loam soil (fine-loamy, mixed, superactive, mesic Typic Hapludolls containing 5.2% organic matter) with established 'Snap Back' tall fescue seeded in Fall 2015. The research was conducted to determine which HOC (1.5, 2, or 3 inches) performs best under simulated athletic field traffic. The same plots were used for both years of the study.

Plot maintenance. Turfgrass nutrients were supplied monthly from April to October with a 28N–0P–2.5K granular fertilizer (SiteOne, Roswell, GA, USA) at 0.5 lb/1000 ft^2 N. Preemergence herbicide (Barricade 65 WG; Syngenta Crop Protection, Greensboro, NC, USA) was applied at 0.5 lb/acre prodiamine in Apr 2017 and 2018. Irrigation was applied when soil moisture levels were less than 30% volumetric soil moisture, as determined by a time domain reflectance (TDR) sensor (TDR 350; Spectrum Technologies, Aurora, IL, USA) with 3-inch-long tines, with 0.3 inch of irrigation being applied each time. Plots were allowed to recover after the 2017 simulated traffic, with no addition of seed. The research area was hollow-tine (0.5 inch i.d.) aerified on 10 May 2018 to help with recovery from traffic the previous fall. Aeration was completed with an aerator (Procore 648; The Toro Co., Minneapolis, MN, USA) depth of 3 inches and set on a 2- × 2-inch spacing. Hollow-tine cores were left on the surface of the plots and incorporated into thatch with the next mowing. No topdressing material was applied at any time, to mimic typical Iowa, USA, high school athletic field management practices.

Treatments. The experimental design was a randomized complete block with three replications repeated in time in 2017 and 2018. Plots measured 4 × 8 ft. The mowing height treatments were 1.5, 2, and 3 inches. Treatments were applied three times per week throughout the growing season (1 May to 31 Oct) using a rotary push mower (Proline Commercial Mower, The Toro Co.), and clippings were returned to the plots.

Simulated traffic. Simulated traffic was applied using a modified Baldree traffic simulator (Procore 648) with spring-loaded feet instead of core heads, similar to the device described by Dickson et al. (2018). These feet reciprocate and hit the turfgrass surface while the machine moves, simulating the dynamic forces of traffic stress (Thoms et al. 2011). Simulated traffic was initiated on 7 Aug 2017 and 10 Aug 2018, which was the same time as the start of the Iowa high school football season. The research area received one simulated traffic event per day three times per week for 8 weeks and one additional simulated event at week 9 for 25 events total. Typically, events were simulated on Monday, Tuesday, and Thursday.

Data collection. Traffic tolerance was accessed by measuring the percentage of green cover (GC) (Richardson et al. 2001) with digital image analysis before simulated traffic and after every five simulated traffic events, similar to previous studies (Brosnan et al. 2010; Thoms et al. 2016). Digital images were taken with a digital camera (G9X; Canon, Ota, Tokyo, Japan) using a light box as described by Thoms et al. (2011). Digital image analysis can provide quantitative measurements of turfgrass cover while removing observational bias (Karcher 2007). Digital images were taken in the same location of each plot to track changes over time and were analyzed using image analysis software (SigmaScan Pro ver. 5.0; Systat Software, San Jose, CA, USA) and converted image pixelation measurements to turfgrass cover ratings, according to the methods of Richardson et al. (2001). Green pixels were determined inside a hue range of 51 to 120 and saturation range from 0% to 100%. Turfgrass cover was calculated by dividing the number of green pixels by the total number of pixels in the image.

Surface hardness data were collected using a 2.25-kg CIST (Turf Tec, Tallahassee, FL, USA) released from a drop height of 45 cm. Surface hardness values were tested before simulated traffic and throughout the duration of simulated athletic traffic after every five simulated games. The CIST measures the GMAX (gravity), with the GMAX reported from deceleration of an accelerometer in the hammer contacting the surface. This device can give an indication of surface hardness and is commonly used to test athletic fields (Thoms et al. 2016). The harder the surface, the greater the deceleration. Each CIST reading was calculated from the average of three drops. A total of three CIST readings was determined per plot (i.e., nine individual drops per plot) based on random locations in the plot on every testing date.

Soil moisture data were collected with a TDR probe (TDR 350, Spectrum Technologies). The TDR probe was equipped with 3-inch-long tines. Soil moisture has been reported to have a high correlation with surface hardness, with low soil moisture correlating to high surface hardness (Rogers and Waddington 1992). Nine data points were collected in each plot next to the location where surface hardness data were collected. Soil temperature data and precipitation data were collected with a weather station (HMP45 and CS655; Campbell Scientific, Logan, UT, USA) at the Iowa State University Horticulture Research Station.

Rotational resistance is a measure of the force needed to tear the turfgrass tissue. Rotational resistance data were collected using a shear strength tester (Shear Vane, Turf Tec) with 0.5-inch cleats, as used by the National Football League (NFL) when testing the playing surface before each game. The Shear Vane was used by pushing the cleat at the bottom of the device into the ground and twisting the torque wrench until complete turf shearing was achieved. The peak resistance of the torque wrench (measured in Newton·meters) was recorded. Three different locations were tested in each plot.

Statistical analysis. Surface hardness, soil moisture, rotational resistance, and GC data were subjected to analysis of variance with repeated measures using statistical software (SAS ver. 9.3; SAS Institute Inc., Cary, NC, USA). Treatment means for surface hardness, rotational resistance, and soil moisture were separated using Fisher's least significant difference at the $P \leq 0.05$ level of significance. Surface hardness, rotational resistance, and soil moisture were combined across years and rating dates because of the lack of a significant interaction with treatment effect. A significant year × treatment × rating date interaction was present for GC, so linear regression analysis was conducted on GC over time for each year (2017: 1.5 inches, $R^2 = 0.82$; 2 inches, $R^2 = 0.90$; 3 inches, $R^2 = 0.92$; 2018: 1.5 inches, $R^2 = 0.81$; 2 inches, $R^2 = 0.90$; 3 inches, $R^2 = 0.93$). Nonlinear regression analysis was conducted, but the data had a better fit to linear regression. Estimates for the slopes and intercepts were obtained for each treatment through the linear regression analysis, and orthogonal contrast was conducted to compare slopes at the $P \leq 0.05$ level of significance (Lindsey et al. 2021).

Table 1. Effect of various mowing heights of 'Snap Back' tall fescue on percentage of green cover subjected to linear regression and orthogonal contrast under simulated athletic traffic using a modified Baldree traffic simulator, in Ames, IA, USA, in 2017 and 2018.

Mowing ht (inches)[i]	2017: Slope[ii] and GC (%/event)[iii]	2018: Slope and GC (%/event)
1.5	−1.7	−3.9
2	−2.6	−3.9
3	−2.6	−3.9
	Orthogonal contrast	
1.5 vs. 2	***	NS
1.5 vs. 3	***	NS
2 vs. 3	NS	NS

[i] Mowing height treatments were applied using a rotary push mower applied three times per week during the growing season; 1 inch = 2.54 cm.
[ii] Slope and intercept values were determined using linear regression analysis.
[iii] Percentage of green cover (GC) was determined using digital image analysis.
NS, *, **, *** Nonsignificant or significant at $P \leq 0.05$, 0.01, or 0.001, respectively.

Results and discussion

Traffic tolerance in terms of GC varied between years (Table 1, Figs. 1 and 2). In 2017, the 1.5-inch HOC maintained more GC after each traffic event compared with the higher HOC. In 2018, there were no differences between HOC in terms of GC loss per traffic event. Differences in traffic tolerance between years could be the result of differences in precipitation (78 mm in 2017 and 6 mm in 2018) during the period when traffic occurred. This suggests that the lower HOC performs better under wet conditions compared with the higher HOC; under drier conditions, the HOC did not have an impact on traffic tolerance. In 2017, the 1.5-inch HOC had a greater GC after 10 simulated traffic events (Fig. 1) than the other HOCs. This is different from previous studies on common bermudagrass (*Cynodon dactylon*) at a 2.2-cm HOC in Tennessee, USA, that reported greater turfgrass cover loss when soil moisture was elevated as opposed to lower soil moisture readings (Dickson et al. 2018). Dickson et al. (2018) evaluated soil moisture from just above the permanent wilting point ($0.06\ m^3 \cdot m^{-3}$) to high levels ($0.30–37\ m^3 \cdot m^{-3}$) of soil moisture on a silt loam soil with bermudagrass and found that the greatest levels of soil moisture resulted in a loss of turfgrass cover four times faster than lower levels of soil moisture. In our study, greater precipitation rates in 2017 could have resulted in a greater loss of turfgrass cover. It appears that

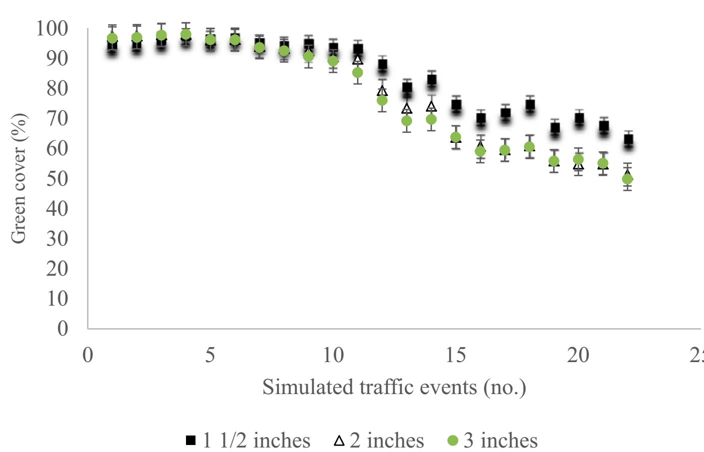

Fig. 1. Effect of various mowing heights of 'Snap Back' tall fescue on percentage of green cover under simulated athletic traffic using a modified Baldree traffic simulator at Ames, IA, USA, in 2017. Error bars represent the standard error of the mean; 1 inch = 2.54 cm.

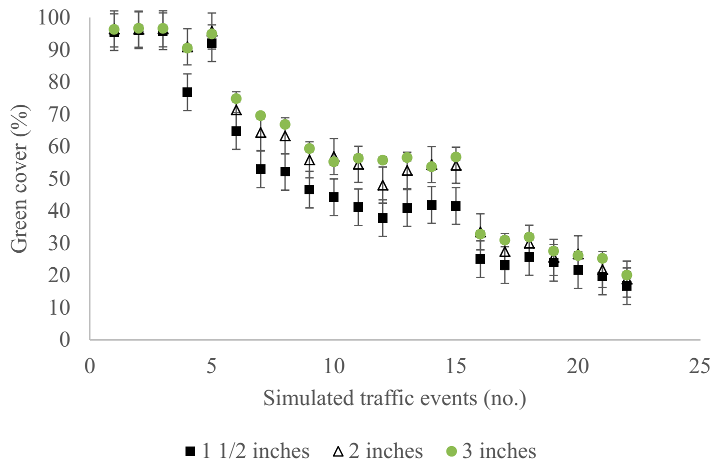

Fig. 2. Effect of various mowing heights of 'Snap Back' tall fescue on percentage of green cover under simulated athletic traffic using a modified Baldree traffic simulator at Ames, IA, USA, in 2018. Error bars represent the standard error of the mean; 1 inch = 2.54 cm.

the optimal HOC for a tall fescue athletic field varies depending on precipitation amounts during traffic.

Throughout the duration of the study, there were no treatment differences in the safety variables measured (Table 2). Surface hardness varied from 72.9 to 74.1 GMAX, which is well under the 100 GMAX threshold for NFL synthetic turf (Jastifer et al. 2022). Soil moisture ranged from 44.3% to 44.7% volumetric water content, as measured with each surface hardness measurement. Although precipitation varied between years, there were no differences in volumetric water content between treatments or years. This could be because volumetric water content was measured only after every five simulated traffic events, which may not have captured differences while simulated traffic was being applied. Rotational resistance varied from 20.1 to 20.4 N·m. Findings in this experiment supported those by Rogers and Waddington (1992), who reported that, in general, kentucky bluegrass turfgrass HOC did not affect the impact absorption characteristics with either the 0.5- or 2.25-kg hammers. Similarly, Rodgers and Waddington (1989) found no differences in surface hardness with the 2.25-kg hammer on 'Kentucky 31' tall fescue at a 2.5-, 5.1-, and 2.5-cm HOC. The use of a lighter hammer may have detected differences in surface hardness in our study, as Rodgers and Waddington (1989) reported differences with the 0.5-kg hammer, but that hammer was not used in our study and newer tall fescue cultivars were used that could better handle different HOCs. Soil moisture would vary more with different soil types than with different cutting heights, so results in our study are not unexpected. The rotational resistance results were similar to findings from Rogers and Waddington (1989) on tall fescue; they reported no differences in shear resistance (measured in Newton meters) between cutting heights. Dickson et al. (2018) suggested a shear strength threshold of 18 N·m for bermudagrass to avoid poor stability conditions at a 2.2-cm HOC; in our study, all tall fescue HOCs offered more than 18 N·m of resistance. Overall, the HOC did not have an effect on the safety variable measured.

Turfgrass HOC performance data varied by year in terms of GC. In the first year of the study, the lower HOC maintained greater GC per traffic event throughout the season, whereas the higher HOC did not perform as well. Those results changed in 2018, with all the HOCs having the same loss of GC per traffic event. Perhaps environmental conditions, other than soil temperature (which did not differ between years), such as increased rainfall, resulted in the differences in treatment performance. It appears that during wet conditions, the lower HOC maintains greater GC per traffic event compared with the higher HOC. There were no differences among treatments for the other variables measured (surface hardness, rotational resistance, and soil moisture). Future research needs to investigate different root zones, cultivars, optimal fertility, a comparison with kentucky bluegrass and soil moisture for tall fescue athletic fields, as well as how much seed to add back to tall fescue stands to limit the loss of turfgrass cover during the athletic season.

Table 2. Effect of various mowing heights of 'Snap Back' tall fescue on surface hardness, soil moisture, and rotational resistance under simulated athletic traffic using a modified Baldree traffic simulator, in Ames, IA, USA, in 2017 and 2018.

Mowing ht (inches)[i]	Surface hardness (GMAX)[ii]	VWC (%)[iii]	Rotational resistance (N·m)[iv]
1.5	73.2[v]	44.3	20.4
2	72.9	44.7	20.1
3	74.1	44.5	20.3
$LSD_{0.05}$[vi]	NS	NS	NS

[i] Mowing height treatments were applied using a rotary push mower applied three times per week during the growing season; 1 inch = 2.54 cm.
[ii] Peak surface hardness values were collected using a 2.25-kg (4.960-lb) Clegg Impact Soil Tester in peak deceleration (GMAX).
[iii] Volumetric water content (VWC) values were collected using a time domain reflectance sensor with 3-inch-long tines.
[iv] Rotational resistance values collected using a shear vane with 0.5-inch cleats; 1 N·m = 0.7376 lb ft.
[v] Means were pooled over years and rating dates because of a nonsignificant interaction with treatment effect.
[vi] Means were separated using Fisher's protected least significant difference at the $P \leq 0.05$ level of significance ($LSD_{0.05}$). NS = nonsignificant at $P > 0.05$.

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