Chapter 2

Impact of Cultural Practices and Traffic on a Native Soil Athletic Field

Introduction

The combination of grass, maintenance, and condition of the root zone are essential components in determining if an athletic field will hold-up under game traffic, or if it will fail. The root zone is the source of nutrient and water for turfgrass growth and it provides for the stability of the grass plants by anchoring their roots (Beard, 1973). The grass provides the cover of the field as well as adds stability. Consequently, even if the field has the highest standards for root zone and turf cover, if it is not properly managed, worn areas will occur, resulting in a lack of stability and decreased playing surface conditions. Worn areas and instability have been shown not only to reduce the playability and aesthetics of the field but also to increase field-related injuries (Harper *et al.,* 1984; Rogers *et al.,* 1988).

An athletic field must provide firm footing, adequate resiliency on impact, and resistance to tearing during play. It must also drain well and resist compaction from continuos severe traffic (Turgeon, 1996). This statement describes a combination of the two most commonly used athletic field root zones today. It describes the resistance to compaction of a sand based root zone and it describes the firm surface of an "existing" or native soil root zone-which is higher in silt + clay then a sand based field. Because both of these root zones represent the different types of root zones used in Michigan athletic fields and because both of these root zones have benefits for athletic traffic and may respond differently to treatments, this research was done on both types of root zones.

The pore spacing in a native soil root zone is primarily the result of aggregation from the cohesive nature of clay (Foth, 1990). There are benefits of using a native soil root zone for athletic field construction. Not only can native soil fields be cheaper to construct because the existing soil is used, but also, the smaller pore spaces provide for increased stability as well as increased nutrient and water holding capacity. In addition, because clay has a high cation exchange capacity, native soils are more fertile then sand based root zones on a regular basis (Beard, 1973). Unfortunately, native soil fields have less desirable characteristics as well. The clay aggregates in a native soil can be destroyed by intense traffic, which causes a reduction in pore space. Smaller pore spaces leave the stand more susceptible to compaction, and subsequently, a decrease in drainage and a decrease in air and water flow (Adams and Jones, 1979). Eventually, a decrease in root and shoot growth will occur, leaving the plant much weaker (Beard, 1973; Lee and Rieke, 1993; Nelson and Larson, 1994).

The native soil field was on existing Capac loam soil (Fine-loamy, mixed, mesic Aeric Ochradqualfs) with a *poa pratensis* blend cover. The maintenance practices for this research consisted of twelve different treatments, compromised of three treatment factors each; mowing, fertility, and cultivation. The mowing height (6 cm) was slightly higher then the mowing height chosen for the sand based field. This height was chosen because it is the optimal mowing height for a non-irrigated, *poa pratensis* stand, subjected to high traffic conditions (Rogers, pers. comm.). The increased mowing height is necessary for a native soil, non-irrigated field receiving intense traffic because it should result in increased root and rhizome growth, which will increase resistance to drought stress (Turgeon, 1996).

Fertilizer rate and frequency was slightly lower then the fertilizer rate and frequency for the sand based field. This is because of the increased nutrient holding capacity from the clay content. Fertilizer was applied at a rate of 5 g N m^{-2} two times per year for a total of 10 g N yr^{-1} (low infrequent), 2.5 g N m^{-2} applied 4 times per year for a total of 10 g of N yr^{-1}(low frequent), or 5 g N m^{-2} applied 4 times per year for a total of 20 g N yr^{-1} (high). These rates and frequencies were chosen because this was a native soil based root zone-which has high nutrient holding capacity, we looked at the same annual rate of nitrogen with varying frequencies within the low rate of nitrogen to see if fertilizing less frequently would provide the same quality turf stand as fertilizing more frequently. This would mean that less labor would be needed to maintain the field, which is typical for a native soil field. Differences in nitrogen rates were looked at to see if the growth and development of the grass would differ at different rates when subjected to traffic.

Similar to the sand based field, plots were cultivated zero or two times per year for the low and high rate, respectively. While the main reason for coring the sand based root zone field was to dilute the potential for layering from decomposing organic matter, the primary reason for core cultivating the native root zone study was to alleviate compaction from trafficking as well as to dilute the effects of decomposing organic matter.

With the results of this study we are going to quantify the relationship between cultural practices and turfgrass quality on a native soil athletic field.

Materials and Methods

The experimental design for this study was a 2 x 3 x 2 (mowing x fertilizing x cultivating) randomized complete block design with three replications. Individual plots were 2.7 m by 2.7 m. Plots were located on an existing, non-irrigated, Capac loam soil (Fine-loamy, mixed, mesic Aeric Ochradqualfs) on the campus of Michigan State University. The area was seeded 27 August 1997 with Kentucky bluegrass var Conventry (Scotts Co., Marysville, OH) at a rate of 7.5 g m^{-2}. Plots were prepared for this research on 18 October 2000 by fertilizing with 5 g N m^{-2} of Scotts 18-5-18 fertilizer (Scotts Co., Marysville, OH) and mowing to a height of 5 cm with a Toro zero turn mower (Toro Co., Minneapolis, MN). The only other maintenance procedure necessary was one spray application of Confront (Indianpolis, IN 33% triclopyr, 12.1% clopyralid, liquid formulation) on 8 May 2001 at a rate of .74 fl oz /1000ft^{-2} for control of broadleaf weeds.

Plot maintenance

Twelve different treatments, with three treatment factors each, (mowing, fertility, and cultivation) were used in this study. Plots were mown either once or twice per week for the low and high treatment, respectively. Fertilizer was applied at a rate of 5 g N m^{-2} two times per year for a total of 10 g N m^{-2} yr^{-1} (low infrequent), 2.5 g N m^{-2} applied 4 times per year for a total of 10 g of N m^{-2} yr^{-1}(low frequent), or 5 g N m^{-2} applied 4 times per year for a total of 20 g N m^{-2} yr^{-1} (high). Plots were core cultivated zero or two times per year for the low and high rate, respectively. These treatments are outlined in Table 29.

Table 29. Treatment applications for the native soil athletic field study, 2000, 2001.

Treatment	Mowing† (times/week^{-1})	Fertilizer‡ (g N m^{-2} year^{-1})	Cultivation§
1	1	10(LIF)	No
2	1	10(LIF)	No
3	1	10(LF)	Yes
4	1	20(LF)	Yes
5	1	10(High)	Yes
6	1	20(High)	No
7	2	10(LIF)	No
8	2	10(LIF)	Yes
9	2	10(LF)	No
10	2	10(LF)	Yes
11	2	20(High)	No
12	2	20(High)	Yes

† **The native soil study was mown at 5 cm, respectively.**

‡ The fertilizer treatments consisted of low infrequent, low frequent, and high levels. LIF = 10 g N m^{-2} year^{-1} with four applications; LF = 10 g N m^{-2} year^{-1} with eight applications; High = 20 g N m^{-2} year^{-1} with six applications.

§ Cultivation consisted of spring and fall core cultivation.

Mowing treatments began the first week of May 2001. All plots were mown to a height of 5 cm using a Toro zero turn mower (Toro Co., Minneapolis, MN) once per week. Plots mown at the high level were mown an additional time each week with a rotary mower set at 5 cm.

Fertilizer treatments began for all plots on 18 October 2000. On 18 November 2000, a 10 g N m^{-2} of urea (46-0-0) dormant feeding was given to all plots. For 2001, Scotts 18-5-18 fertilizer (Scotts Co., Marysville, OH) was applied two or four times (Table 30). Fertilizer was applied with a drop spreader unless all plots were to receive at least 2.5 g of N m^{-2}. In such cases, a rotary spreader was used to apply the 2.5 g of N m^{-2} and a drop spreader was used to apply the additional 2.5 g of N m^{-2}.

Plots were cultivated 28 November 2000 and 9 May and 05 December 2001 using a 1.2 m Toro walking greens aerator with 7.6 x 0.64 cm tines (Toro Co., Minneapolis, MN). These plots were not irrigated, unless by nature.

Traffic Simulation

For traffic simulation, each 2.7 x 2.7 m plot was split in half; one half received traffic using the Brinkman Traffic Simulator (BTS) during late fall season 2000 and spring and fall seasons 2001, the other half received no traffic simulation. The BTS imposes both compactive and tearing forces on the turf by using full rollers with metal cleats. Two passes with the BTS equal the cleat marks between the hash marks and between the 40 yard lines during one NFL football game (Cockerham and Brinkman, 1990). For this research, 2 passes

Table 30. Annual fertilizer† schedule for native soil athletic field study, 2000-2001.

Year	Date	Low Infrequent	Medium Frequent	High
		------------ g N m^{-2} application^{-1} ------------		
2000	18 October	5.0	5.0	5.0
	18 November‡	5.0	5.0	5.0
	Total g N m^{-2}/yr.	10.0	10.0	10.0
2001	3 May	--	2.5	--
	22 May	5.0	2.5	5.0
	12 June	--	2.5	5.0
	3 September	5.0	2.5	5.0
	19 October	--	--	5.0
	Total g N m^{-2}	10	10	20

† Scotts® ProTurf fertilizer 18-5-18

‡ Dormant fertilization using urea (46-0-0).

were made 2 times/week 23 October through 16 November 2000, 17 April through 24 May and 27 August through 19 November 2001.

Data Collection

Turfgrass density, color, quality, shear strength, and surface hardness ratings were made in October and November of 2000, and monthly from May through November of 2001. The density ratings were based on a visual percent cover scale (0-100%). Beginning in 2001, density was also measured quantitatively by plant counts 100 cm^{-2}. Quality and color were rated on a visual (1-9) scale. For quality ratings, a rating of one was given for dead or no turf, six for acceptable turf, and nine for excellent turf. For color, a rating of one was given for yellow or brown turf, six for acceptable turf color, and nine for dark green. Beginning in July of 2001, color was assessed using the Spectrum™ FieldScout chlorophyll meter (Spectrum Technologies, Inc., Plainfield, IL). Shear strength was measured using an Eijelkamp shear vane (Eijkelkamp, Giesbeck, The Netherlands) and beginning in August of 2001, shear strength was also assessed using the Shear Clegg (Dr. Baden Clegg Pty Ltd., Perth, Australia) Surface hardness was measured using a Clegg Impact Hammer (Lafayette Instrument Co., Lafayette, IN).

Results and Discussion

Results and discussion are divided by maintenance practice and then subdivided by the effect each practice had on the evaluation criteria. Interaction results and discussion are at the end. We designated surface hardness measurements between treatments to be inconclusive if differences were less then 5 g_{max}. A cost analysis for each treatment is also listed in Appendix C.

Mowing

Plant counts

Plots mown twice per week gave a 31 % increase in plant counts over plots mown once per week in June and a 25 % increase over plots mown once per week in 01 October 2001 (Table 31). This effect was also seen on the sand based root zone. Once traffic simulation began, the root systems of the plants mown once per week may not have been as strong as the root systems of the plants mown twice per week, because all of their energy was being put towards shoot development. Therefore, when put under stress, these plants were removed from the ground much more easily causing a decrease in plant counts. The reason this effect only occurred on these two dates could be because the entire plot area was dormant, due to water and heat stress, throughout the month of July and part of August. Therefore, mowing and fertilizer treatments could not have much of an effect because the grass was not growing and the fertilizer could not be absorbed because of a lack of rain. Thus, although the grass was

Table 31. Significance of treatment effects and traffic on plant counts (plants 100cm^{-2})†, East Lansing, MI. 2000-01

	5/08	6/15	7/12	8/25	10/01	10/15	10/29	11/09	11/16
Mowing									
1x/week	35.3	128.0	88.7	75.5	68.1	67.1	73.6	76.4	67.8
2x/week	39.0	185.4	97.5	81.9	91.4	78.7	71.5	84.5	70.0
Significance	ns	**	ns	ns	**	ns	ns	ns	ns
Fertilization‡									
Low infrequent	34.6	179.5	95.1	76.0	78.1	69.1	66.0	78.5	64.6
Low frequent	44.0	144.8	89.9	83.3	76.7	73.3	77.8	77.4	60.4
High	32.8	146.2	94.1	76.7	84.4	76.4	74.0	85.4	81.6
Significance	ns	ns	ns	ns	ns	ns	ns	ns	*
Cultivation									
0 x/yr^{-1}	39.7	181.7	97.9	85.7	87.3	75.7	70.6	81.3	73.4
2 x/yr^{-1}	34.6	131.9	88.2	71.8	72.2	70.1	74.5	79.6	64.4
Significance	ns	*	ns	ns	ns	ns	ns	ns	ns
# of Passes	6	-	-	-	10	14	18	22	25

*,**,*** Significant at the 0.10, 0.05, and 0.01 probability levels, respectively.
Ns Not significant at the 0.10 probability level.
† Plants were hand counted using three subsamples per treatment.
‡ Low infrequent = 10 g N m^{-2} year^{-1} with two applications; Low frequent = 10 g N m^{-2} year^{-1} with four applications; High = 20 g N m^{-2} year^{-1} with four applications.

almost entirely out of summer dormancy by the time traffic simulation began, it is unclear how much of the treatments were able to have an effect on the plants. As a result, although this data implies that plots mown twice per week maintained higher plant count ratings for an additional two games, given the environmental factors, more research is warranted.

Turfgrass cover

Plots mown twice per week yielded at least a 4% increase in turfgrass cover over plots mown once per week on 15 October through 16 November 2001 (Table 32). This effect was only seen on these dates because in June, plant growth was fairly slow because growing conditions were not optimal and, in July and August plant growth was minimal because the plants were in summer dormancy. Therefore, mowing frequency effects on turfgrass cover really did not begin to show until turfgrass growth slowed and traffic simulation continued. At this time, the results indicate that mowing frequency has the potential to maintain increased turfgrass cover for a longer period of time under traffic simulation. This could be because the mowing at the proper height and frequency stimulates shoot growth and tillering (Juska, 1961; Crider, 1955). However, if more then 30% of the leaf blade of a plant is removed in a single mowing, all or nearly all of the plants energy goes into shoot production and negligible amounts, if any go into root, rhizome, or tiller initiation (Crider, 1955). The negative effect of the apparent weakened root system becomes obvious once traffic simulation begins because these plants are torn from the ground more easily, causing a decrease

Table 32. Significance of treatment effects and traffic on turfgrass cover†, East Lansing, MI. 2000-01

	2000	2001									
	10/27	5/15	6/15	7/12	8/25	9/13	10/01	10/15	10/26	11/09	11/16
Mowing											
1x/week	100	51	57	20	35	38	34	35	37	35	18
2x/week	100	54	61	18	31	38	36	41	45	43	22
Significance	ns	ns	ns	ns	ns	ns	ns	**	***	***	*
Fertilization‡											
Low infrequent	100	53	60	18	31	39	36	39	40	38	20
Low frequent	100	50	60	20	34	37	33	36	41	37	17
High	100	55	58	19	34	38	36	39	43	41	24
Significance	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	**
Cultivation											
0 x/yr^{-1}	100	56	59	24	41	40	36	39	43	40	22
2 x/yr^{-1}	100	49	60	14	25	36	34	37	40	38	19
Significance	ns	*	ns	***	***	**	ns	ns	ns	ns	ns
# of Passes	-	6	-	-	-	5	10	14	18	22	25

*,**,*** Significant at the 0.10, 0.05, and 0.01 probability levels, respectively.

Ns Not significant at the 0.10 probability level.

† Turf cover was visually estimated on a percent (0-100%) scale.

‡ Low infrequent = 10 g N m^{-2} $year^{-1}$ with two applications; Low frequent = 10 g N m^{-2} $year^{-1}$ with four applications; High = 20 g N m^{-2} $year^{-1}$ with four applications.

in visual density (Table 31). Hence, this data shows that mowing twice per week will result in higher turfgrass cover ratings for an additional ten games.

Surface hardness

Mowing frequency did not have an effect on surface hardness. This is likely because mowing effects plant physiology, not soil conditions (Table 33).

Shear vane and Shear/clegg

Plots mown twice per week gave higher shear strength ratings then plots mown once per week on 16 November 2001 (Table 34 and 35). This effect may have been seen because at the time of data collection, there was a significant difference in turfgrass cover (18 and 22%); thus yielding a significant difference in shear vane ratings (6.2 and 7.1) and shear/clegg ratings (17.0 and 20.1) for plots mown once per week versus plots mown twice per week. However, because the turfgrass cover in plots mown twice per week was only 4% greater then in plots mown once per week, getting an accurate rating with the Eijelkamp shear vane was nearly impossible. In addition, because this was the only date that mowing frequency had an effect on shear strength, the difference may have occurred as a result of chance by sampling location.

Quality

Plots mown twice per week gave higher quality ratings then plots mown once per week on 09 November 2001 (Table 36). This effect probably occurred

Table 33. Significance of treatment effects and traffic on surface hardness†, East Lansing, MI. 2000-01

	2000	2001									
	10/27	5/15	6/15	7/12	8/25	9/13	10/01	10/15	10/26	11/09	11/16
Mowing											
1x/week	70.3	88.2	60.1	130.5	88.0	82.7	69.5	55.2	77.3	78.7	61.9
2x/week	68.9	87.6	62.8	114.7	86.3	84.9	67.6	52.7	64.4	79.7	63.9
Significance	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Fertilization‡											
Low infrequent	71.0	91.1	62.8	146.5	89.1	87.8	68.1	55.1	66.1	79.9	64.3
Low frequent	70.2	85.9	61.6	112.9	86.4	80.1	67.2	54.0	64.3	78.7	60.8
High	67.6	86.7	60.9	108.5	86.0	83.6	70.4	52.7	82.2	78.9	63.6
Significance	ns	ns	ns	ns	ns	**	ns	ns	ns	ns	ns
Cultivation											
0 x/yr^{-1}	68.6	87.4	61.8	122.7	92.8	89.7	71.6	55.1	79.6	81.7	64.0
2 x/yr^{-1}	70.6	88.4	61.8	122.5	81.5	77.9	65.5	52.8	62.0	76.6	61.8
Significance	ns	ns	ns	ns	***	***	***	ns	ns	**	ns
# of Passes	-	6	-	-	-	5	10	14	18	22	25

*,**,*** Significant at the 0.10, 0.05, and 0.01 probability levels, respectively.
Ns Not significant at the 0.10 probability level.
† Surface hardness was measured using the Clegg Impact Soil Tester in gravity deceleration (G_{max}).
‡ Low infrequent = 10 g N m^{-2} year^{-1} with two applications; Low frequent = 10 g N m^{-2} year^{-1} with four applications; High = 20 g N m^{-2} year^{-1} with four applications.

Table 34. Significance of treatment effects and traffic on turfgrass Eijelkamp shear strength†, East Lansing, MI. 2000-01

	2000	2001									
	10/27	5/15	6/15	7/12	8/25	9/13	10/01	10/15	10/26	11/09	11/16
Mowing											
1x/week	30.9	19.6	22.2	20.6	15.3	16.0	14.9	15.6	15.3	10.9	6.2
2x/week	31.0	19.0	22.1	20.4	15.5	17.3	16.1	15.6	15.6	10.8	7.1
Significance	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	***
Fertilization‡											
Low infrequent	31.0	19.1	21.1	20.1	15.6	16.0	15.7	16.1	15.1	11.0	6.5
Low frequent	31.3	19.3	23.2	20.8	14.7	16.5	15.1	15.5	14.8	10.7	6.8
High	30.5	19.4	22.1	20.6	15.9	17.4	15.8	15.2	16.5	10.9	6.5
Significance	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Cultivation											
0 x/yr^{-1}	30.1	19.8	22.4	21.7	16.0	17.4	15.3	15.4	15.6	10.4	6.4
2 x/yr^{-1}	31.1	18.8	21.9	19.3	14.8	15.8	15.8	15.8	15.4	11.3	6.8
Significance	ns	ns	ns	***	ns	**	ns	ns	ns	**	ns
# of Passes	-	6	-	-	-	5	10	14	18	22	25

*,**,*** Significant at the 0.10, 0.05, and 0.01 probability levels, respectively.
Ns Not significant at the 0.10 probability level.
† Shear strength was measured using the Eijelkamp Shear vane in Newton meters (Nm).
‡ Low infrequent = 10 g N m^{-2} year^{-1} with two applications; Low frequent = 10 g N m^{-2} year^{-1} with four applications; High = 20 g N m^{-2} year^{-1} with four applications.

Table 35. Significance of treatment effects and traffic on turfgrass Clegg/shear strength†, East Lansing, MI. 2001.

	9/13	10/01	10/15	10/26	11/09	11/16
Mowing						
1x/week	16.3	19.9	15.6	19.4	22.6	17.0
2x/week	18.6	19.8	16.6	19.1	23.4	20.1
Significance	ns	ns	ns	ns	Ns	**
Fertilization‡						
Low infrequent	15.5	20.5	17.1	17.6	24.0	20.0
Low frequent	19.5	19.8	14.7	20.4	22.0	18.8
High	17.3	19.2	16.5	19.6	23.0	16.9
Significance	ns	ns	ns	ns	ns	ns
Cultivation						
0 x/yr^{-1}	17.9	19.1	16.2	18.8	22.4	19.1
2 x/yr^{-1}	16.9	20.5	16.0	19.7	23.6	18.0
Significance	ns	ns	ns	ns	ns	ns
# of Passes	5	10	14	18	22	25

*,**,*** Significant at the 0.10, 0.05, and 0.01 probability levels, respectively.
Ns Not significant at the 0.10 probability level.
† Shear strength was measured using the shear/clegg in Newton meters.
‡ Low infrequent = 10 g N m^{-2} $year^{-1}$ with two applications; Low frequent = 10 g N m^{-2} $year^{-1}$ with four applications; High = 20 g N m^{-2} $year^{-1}$ with four applications.

Table 36. Significance of treatment effects and traffic on turfgrass quality†, East Lansing, MI. 2000-01

	2000	2001									
	10/27	5/15	6/15	7/12	8/25	9/13	10/01	10/15	10/26	11/09	11/16
Mowing											
1x/week	7.5	6.7	7.0	1.3	5.0	3.7	2.9	3.4	4.0	3.6	3.6
2x/week	7.5	6.7	7.1	1.5	5.2	3.8	2.8	3.5	4.3	4.1	3.8
Significance	ns	ns	ns	ns	ns	ns	ns	ns	ns	**	ns
Fertilization‡											
Low infrequent	7.5	6.7	7.1	1.4	5.1	3.7	2.9	3.5	4.3	3.8	3.6
Low frequent	7.5	6.7	7.0	1.5	5.3	3.8	2.6	3.3	3.9	3.6	3.3
High	7.5	6.8	7.0	1.4	5.0	3.8	3.0	3.6	4.2	4.1	4.2
Significance	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	***
Cultivation											
0 x/yr^{-1}	7.5	6.8	7.0	1.7	5.2	3.9	3.1	3.6	4.2	4.0	3.8
2 x/yr^{-1}	7.5	6.6	7.1	1.1	5.0	3.6	2.6	3.3	4.0	3.7	3.5
Significance	ns	ns	ns	**	ns	ns	*	ns	ns	ns	**
# of Passes	-	6	-	-	-	5	10	14	18	22	25

*,**,*** Significant at the 0.10, 0.05, and 0.01 probability levels, respectively.
Ns Not significant at the 0.10 probability level.
† Quality was rated visually on a 1-9 scale: 1=necrotic turf/bare soil, 9=dense, uniform turf with acceptable color (color $\geq$ 5).
‡ Low infrequent = 10 g N m^{-2} $year^{-1}$ with two applications; Low frequent = 10 g N m^{-2} $year^{-1}$ with four applications; High = 20 g N m^{-2} $year^{-1}$ with four applications.

because the increased mowing frequency caused the older leaf tissue to be removed and newer leaf tissue to emerge, as a result plants appeared to be more vibrant and healthy. In addition, plots mown twice per week were not put under "mowing stress." Plots mown once per week were having more then 30% of their leaf tissue removed with each mowing. This may have caused less energy to go towards the root system and much more to go towards the shoots (Crider, 1955). When the plants were not under additional stress, the effects of this physiological change went unnoticed. However, when the plants were put under the additional stress of traffic, the effects become discernable. This resulted in less turfgrass cover (Table 32) in plots mown once per week, thereby causing individual plant damage (i.e. necrosis) to be less noticeable and the quality to appear lower. In addition, this effect appeared after traffic simulation began; thus, this data implies that mowing, in combination with traffic, stimulated higher wear tolerance and more growth, which resulted in greater turfgrass quality. However, because the plants were just recovering from drought and heat stress when time traffic simulation began, it is unclear how much of the treatments were able to have an effect on the plants.

Color

Plots mown twice per week had higher color ratings on 09 and 16 November 2001 then plots mown only once per week. This effect may have occurred as a result of increased mowing frequency, which caused the older leaf tissue to be removed and newer leaf tissue to emerge. This caused the plants to appear healthier and more vibrant (Table 37). In addition, plots mown twice per week were not put under "mowing stress." Plots mown once per week were having more then 30% of their leaf tissue removed with each mowing. This may have caused less energy to go towards the root system and much more to go towards the shoots (Crider, 1955). When the plants were not under additional stress, the effects of this physiological change went unnoticed. However, when the plants were put under the additional stress of traffic, the effects became discernable. This resulted greater turfgrass cover (Table 32) in plots mown twice per week, thereby causing individual plant damage (i.e. necrosis) to be less noticeable and the color to appear darker.

Fertilization

Plant counts and Turfgrass cover

Fertilizer rate and frequency had an effect on plant counts and turfgrass cover ratings on 16 November 2001 when the high (HF) rate of fertilizer yielded at least a 21% increase in plant counts and at least a 4 % increase in turfgrass cover over plots fertilized at either the LIF (LIF) or the low frequent (LF) rate (Tables 31 and 32). This effect was seen because, within one month of this rating date, plots fertilized at the HF level were the only plots to receive a fertilizer application. Plots maintained at either of the other two levels did not have a fertilizer application since 3 September 2001. Because the plants in these regimes were most likely low in nitrogen, they did not recuperate or generate growth as rapidly, therefore they had a lower number of plant counts (Kussow,

Table 37. Significance of treatment effects and traffic on turfgrass color†, East Lansing, MI. 2000-01

	2000	2001									
	10/27	5/15	6/15	7/12	8/25	9/13	10/01	10/15	10/26	11/09	11/16
Mowing											
1x/week	7.0	8.0	8.5	3.3	6.4	5.0	5.5	6.0	6.5	4.8	4.3
2x/week	7.0	8.0	8.5	3.4	6.5	5.2	5.7	6.4	7.1	5.2	4.7
Significance	ns	ns	ns	ns	ns	ns	ns	ns	ns	**	**
Fertilization‡											
Low infrequent	7.0	8.0	8.5	3.3	6.2	5.1	5.3	6.2	7.0	4.8	4.3
Low frequent	7.0	8.0	8.5	3.3	7.0	5.1	5.5	6.1	6.7	4.8	4.3
High	7.0	8.0	8.5	3.5	6.3	5.1	6.0	6.4	6.8	5.4	4.9
Significance	ns	ns	ns	ns	ns	ns	ns	ns	ns	**	**
Cultivation											
0 x/yr^{-1}	7.0	8.0	8.5	3.6	6.7	5.2	5.7	6.3	6.8	5.0	4.6
2 x/yr^{-1}	7.0	8.0	8.5	3.1	6.3	5.0	5.5	6.2	6.8	5.0	4.4
Significance	ns	ns	ns	***	ns	*	ns	ns	ns	ns	ns
# of Passes	-	6	-	-	-	5	10	14	18	22	25

*,**,*** Significant at the 0.10, 0.05, and 0.01 probability levels, respectively.

Ns Not significant at the 0.10 probability level.

† October 2000 through June 2001 color was rated visually on a 1-9 scale: 1 = dead/no turf, 9 = uniform dark green turf. July through November 2001 color was rated using the Spectrum™ FieldScout chlorophyll meter (Spectrum Technologies, Inc., Plainfield, IL).

‡ Low infrequent = 10 g N m^{-2} $year^{-1}$ with two applications; Low frequent = 10 g N m^{-2} $year^{-1}$ with four applications; High = 20 g N m^{-2} $year^{-1}$ with four applications.

2000 and Carrow *et al.,* 2001). Fertilizer level may not have had an effect on plant counts at any of the other dates because the actual rates of annual nitrogen applied were in the range of what is recommended for Poa pratensis on a native soil root zone. Therefore, differences were less likely to occur. In addition, differences may not have shown in the summer months because there was very little water to dissolve the fertilizer for plant uptake (Appendix B).

Surface hardness

Fertilizer rate and frequency did not have an effect on surface hardness ratings except in September when the LIF rate of fertilizer gave a higher surface hardness rating then the LF rate of fertilizer (Table 33). Fertilizer rate and frequency may have had an effect on this date because the higher or more frequent nitrogen applications caused a greater accumulation of thatch; thus yielding significant differences in surface hardness. The reason this effect did not continue might be because the effects of continued traffic eliminated further differences in thatch accumulation. However, because no thatch measurements were collected, this is only a speculation as to why significant differences occurred on this date.

Shear vane and Shear/clegg

Fertilizer rate and frequency did not have an effect on turfgrass shear strength or shear/clegg ratings (Tables 34 and 35). Fertilizer rate and frequency may not have effect shear ratings because from June through August, plants only got 6.5 inches of rain. Because this was the only water these plants received, absorption of fertilizer was probably very minimal. Therefore, fertilizer regime may have not had an effect on shear strength because plants were unable to absorb enough fertilizer to effect on tensile strength.

Quality

Fertilizer rate and frequency did not have an effect on turfgrass quality except on 16 November when the HF rate of fertilizer gave a higher quality rating then either of the other two treatments (Table 36). This effect was seen because, within one month of this rating date, plots fertilized at the HF level were the only plots to receive a fertilizer application. Plots maintained at either of the other two levels did not have a fertilizer application since 3 September 2001. Because the plants in these regimes were most likely low on nitrogen, they did generate growth or recuperate from traffic as rapidly, therefore the plants did not appear to be as healthy and the quality ratings were lower (Carrow *et al.,* 2001). Fertilizer level may not have had an effect on plant counts at any of the other dates because the actual rates of annual nitrogen applied were in the range of what is recommended for Poa pratensis on a native soil root zone. Therefore, differences were less likely to occur. In addition, differences may not have shown in the summer months because there was very little water to dissolve the fertilizer for plant uptake (Appendix B).

In addition, similar to other results from this study, because the plants were just recovering from drought and heat stress when time traffic simulation began, it is unclear how much of the treatments, particularly mowing and fertilizing, were able to have an effect on the plants. As a result, although this data implies that plots fertilized at the HF level maintained higher turfgrass quality ratings for an additional two games, given the environmental factors, more research is warranted.

Color

Plots fertilized had the HF rate of fertilizer had higher color ratings then plots fertilized at either of the other two levels on 09 and 16 November as well (Table 37). This effect was seen because, within one month of this rating date, plots fertilized at the HF level were the only plots to receive a fertilizer application. Plots maintained at either of the other two levels did not have a fertilizer application since 3 September 2001. Because the plants in these regimes were most likely low in nitrogen, the color appeared lighter and less vibrant (Carrow *et al.,* 2001). In addition, plant counts and percent cover ratings were higher in plots mown twice per week, (Table 31) causing more plants per unit area. This resulted in individual plant damage (i.e. necrosis) to be less noticeable and the color to appear darker for plots receiving the HF level of nitrogen. Fertilizer effects may not have been seen earlier in the season because there was no water to dissolve the fertilizer for plant uptake (Appendix B).

Cultivation

Plant counts and Turfgrass cover

It can be ascertained that cultivating had a negative effect on plant counts and percent turfgrass cover (Tables 31 and 32). This may be because the effects of cultivating, although intended to be beneficial, may have actually been detrimental. Because plots were not irrigated the aerification holes allowed the soil to dry out faster. This added an additional stress to the turf, which possibly caused a reduction in plant counts and turfgrass cover.

Surface hardness

Cultivation frequency had an effect on surface hardness ratings in August through 01 October 2001 and again on 09 November 2001 when plots not cultivated yielded higher surface hardness ratings then plots cultivated twice per year (Table 33). This result was also seen on *Poa pratensis* and *Festuca arundinacea* in a study done by Rogers in 1990. This effect was probably seen because cultivation directly affects soil conditions, therefore it has the potential to greatly influence surface characteristics, as it did in August through 01 October and again on 09 November 2001. Although surface hardness ratings were not significantly lower for plots cultivated twice per year on 15 and 26 October, the ratings on these dates continued with the trend that surface hardness ratings are lower on cultivated versus non-cultivated plots. Therefore, it can be determined that cultivation, done twice per year on a native soil root zone, decreases surface hardness for at least an additional 13 games. By 16 November cultivation frequency may have not had an effect on surface hardness because when the final surface hardness ratings were taken, the effects of traffic simulation were severe. Therefore, the chances of variability between treatments had become reduced.

Shear vane

Statistical significance occurred between the shear vane ratings in July (21.7 and 19.3), September (17.4 and 15.8) and 09 November (10.4 and 11.4), for the low and high cultivation frequencies respectively. However, because the difference between ratings was so small, it is inconclusive as to whether or not cultivation frequency had an effect on shear vane ratings. Previous research has shown that for treatment effects to be truly significant, the difference between ratings should be at greater then five (Stier, 2001). Furthermore, when these ratings were taken turfgrass cover and plant count ratings were very low (Table 31 and Table 32), therefore the differences for these dates is most likely due to chance by sampling location (Table 34).

Shear clegg

Cultivation rate and frequency had no effect on shear/clegg ratings. Cultivation did not have an effect on shear/clegg ratings because the field was probably not compacted enough to show differences in shear/clegg ratings. The rooting amount and depth between plants probably did not differ enough to effect lateral shear ratings. Therefore, any long-term cultivation benefits were not attained for an increase in shear/clegg (Table 35).

Quality

Although statistical significance occurred between quality ratings for July (1.1 and 1.7), 01 October (3.1 and 2.6), and 16 November ratings (3.8 and 3.5), for the low and high cultivation frequencies respectively, the ratings did not differ enough to warrant discussion of cultivation effects on turfgrass quality (Table 36). Because the ratings were qualitative, and the actual ratings between treatments differed by less then one, the statistical difference that showed for quality ratings was likely incidental.

Color

Although statistical significance occurred between color ratings in July (3.6 and 3.1), and September (5.2 and 5.0), for the low and high cultivation frequencies respectively, the ratings did not differ enough to warrant discussion of cultivation effects on turfgrass color (Table 37). Because the ratings were qualitative, and the actual ratings between treatments differed by less then 0.5, the statistical difference that showed for color ratings was likely incidental.

Mowing x Fertilization Interaction

Plots fertilized at the LIF level had greater turfgrass cover if they were mown twice per week. However, if plots were mown once per week, then turfgrass cover and plant counts were greater if plots were fertilized at the HF level (for the 10/29 rating date plots fertilized at the LF rate also yielded higher turfgrass cover ratings). An interaction also occurred for shear vane and shear/clegg ratings. However, the differences between the ratings was minimal and each of the observations were isolated, thus, no trend could be drawn (Table 38).

Fertilization x Cultivation Interaction

Plots fertilized at the HF level had higher turf cover ratings if they were not cultivated then if they were cultivated both prior to and during traffic simulation. In addition, in May, plots fertilized at the HF level yielded higher surface hardness ratings if they were cultivated then if they were not. This effect was changed in late summer when plots fertilized at either the LIF or the LF level had lower surface hardness ratings if they were cultivated twice per year then if they were not cultivated. An interaction also occurred for quality and shear vane ratings. However, the differences between the ratings was minimal and each of the observations were isolated, thus, no trend could be drawn (Table 39).

Mowing x Fertilization x Cultivation Interaction

Cultivation increased quality and turfgrass cover ratings if plots were mown once per week and fertilized at the HF level. Cultivation also increased quality ratings if plots were mown twice per week and fertilized at the LIF level. This interaction shows that cultivation by itself does not lead to increased turfgrass quality or cover. However, cultivation does act as a catalyst for mowing and/or fertilizing applications to increase turfgrass quality or cover. Thus,

Table 38. Significance of the interaction of mowing frequency, fertilizing rate and frequency and traffic on turfgrass cover[†], plant counts[‡], and Eijelkamp and Clegg/shear shear strength[§¶], East Lansing, MI. 2001

	Turf Cover	Plant Counts (plants 100cm^{-2})		Shear Vane (Nm)			Shear/Clegg (Nm)
	5/15	10/29	11/16	6/15	7/15	11/16	10/01
Mowing x Fertilizing[#]							
1x/week, Low infrequent	45.8	50.0	59.7	20.1	19.7	5.6	20.2
1x/week, Low frequent	49.2	83.3	51.4	25.7	20.1	6.7	21.7
1x/week, High	59.2	87.5	92.4	20.8	22.1	6.3	17.8
2x/week, Low infrequent	60.0	81.9	69.4	22.2	20.6	7.5	20.8
2x/week, Low frequent	51.7	72.2	69.4	20.7	21.4	6.9	17.9
2x/week, High	50.8	60.4	70.8	23.4	19.1	6.8	20.6
$LSD_{(0.10)}$	11.2	31.9[††]	22.3	4.6[‡‡]	2.2	0.9	3.3
# of Passes	8	18	25	-	-	25	10

[†] Turf cover was visually estimated on a percent (0-100%) scale.
[‡] Plants were hand counted using three subsamples per treatment.
[§] Shear strength was measured using the Eijelkamp Shear Vane in Newton meters (Nm).
[¶] Shear strength was also measured using the shear/clegg in Newton meters.
[#] Low infrequent = 10 g N m^{-2} $year^{-1}$ with two applications; Low frequent = 10 g N m^{-2} $year^{-1}$ with four applications; High = 20 g N m^{-2} $year^{-1}$ with four applications.
[††] Significant at the 0.05 level.
[‡‡] Significant at the 0.01 level.

Table 39. Significance of the interaction of fertilizing, cultivating and traffic on turfgrass quality[†], cover[‡], Eijelkamp shear strength[§], and surface hardness[¶], East Lansing, MI. 2001

	Quality			Turf cover		Shear vane (Nm)		Surface Hardness (G_{max})	
	6/15	10/26	11/12	6/15	10/26	5/15	8/15	5/15	8/15
Fertilizing[#] x Cultivating									
Low infrequent, Low	7.0	3.9	3.9	55.8	36.7	20.0	15.0	93.5	96.4
Low frequent, Low	6.9	3.9	3.4	56.7	41.7	18.0	14.6	89.4	93.5
High, Low	7.2	4.8	4.6	63.3	49.2	21.2	18.4	79.4	88.6
Low infrequent, High	7.3	4.6	3.7	63.3	42.5	18.2	16.2	88.8	81.8
Low frequent, High	7.1	3.9	3.8	63.3	40.8	20.7	14.8	82.5	79.3
High, High	6.8	3.6	3.7	52.5	35.8	17.6	13.5	94.0	83.4
$LSD_{(0.10)}$	0.3	0.9	0.7[††]	10.5	9.3[††]	3.0	3.1	11.3[††]	5.5
# of Passes	-	17	23	-	17	8	-	8	-

[†] Quality was rated visually on a 1-9 scale: 1=necrotic turf/bare soil, 9=dense, uniform turf with acceptable color (color $\geq$ 5).
[‡] Turf cover was visually estimated on a percent (0-100%) scale.
[§] Shear strength was measured using the Eijelkamp Shear Vane in Newton meters (Nm).
[¶]Surface hardness was measured using the Clegg Impact Soil Tester in gravity deceleration (G_{max})
[#] Low infrequent = 10 g N m^{-2} $year^{-1}$ with two applications; Low frequent = 10 g N m^{-2} $year^{-1}$ with four applications; High = 20 g N m^{-2} $year^{-1}$ with four applications.
[††] Significant at the 0.05 level.

cultivation, in combination with either the low mow/HF fertilizer treatment or the high mow/LF or HF fertilizer treatment, did increase turfgrass quality and cover. Furthermore, if both mowing and fertilizing are applied at the HF rate, there is not an increase in turfgrass quality or cover. This is likely a result of the environmental and plant limitations. Conversely, if plots were mown twice per week and fertilized at the LF level, cultivation decreased turfgrass cover. However, this was an isolated finding so the actual significance is inconclusive. A three-way interaction also occurred for plant count ratings. Plots maintained at low mow and LIF fertilizer had lower plant counts if they were cultivated then if they were not. However, again this was an isolated finding so the actual significance is inconclusive (Table 40).

* The Spring traffic applications did not yield any significant differences probably because treatments had not been applied for a long enough period of time.

Table 40. Significance of the interaction of mowing, fertilizing, cultivating and traffic on turfgrass quality†, cover‡ and plant counts§, East Lansing, MI. 2001

	Quality	Turf cover		Plant counts (plants $100cm^{-2}$)
	7/15	5/15	6/15	7/19
Mowing x Fertilizing¶ x Cultivating				
1x/week, Low infrequent, Low	1.2	46.7	51.7	112.5
1x/week, Low infrequent, High	1.2	45.0	56.7	63.9
1x/week, Low frequent, Low	1.8	45.0	56.7	87.5
1x/week, Low frequent, High	1.2	53.3	70.0	80.6
1x/week, High, Low	1.8	71.7	66.7	81.9
1x/week, High, High.	0.8	46.7	40.0	105.6
2x/week, Low infrequent, Low	2.0	60.0	60.0	98.6
2x/week, Low infrequent, High	1.2	60.0	70.0	105.6
2x/week, Low frequent, Low	1.7	60.0	56.7	104.2
2x/week, Low frequent, High	1.2	43.3	56.7	87.5
2x/week, High, Low	1.5	53.3	60.0	102.8
2x/week, High, High	1.3	48.3	65.0	86.1
$LSD_{(0.10)}$	0.6	15.8	15.0	34.0#

† Quality was rated visually on a 1-9 scale: 1=necrotic turf/bare soil, 9=dense, uniform turf with acceptable color (color ≥ 5).
‡ Turf cover was visually estimated on a percent (0-100%) scale.
§ Plants were hand counted using three subsamples per treatment.
¶ Low infrequent = 10 g N m^{-2} $year^{-1}$ with two applications; Low frequent = 10 g N m^{-2} $year^{-1}$ with four applications; High = 20 g N m^{-2} $year^{-1}$ with four applications.
# Significant at the 0.05 level.

Conclusions

Native soil

The objectives of this study were ascertained, as we were able to quantitatively define differences between treatment applications. We are confident that this research, coupled with continued research will set a foundation for which the future expectations of athletic fields based on cultural inputs of mowing, fertilizing, and cultivating can be determined. However, due to drought, the turf was in summer dormancy through much of the experiment. This may have caused the effects of the treatments to be lessened.

Mowing

The object of this experiment was defined and it was determined that mowing twice per week was generally better then mowing once per week. Although not always significant, mowing twice per week increased plant counts. Unlike the sand soil study, differences between mowing treatments were not as evident in terms of other data collection measurements. This is likely because the mowing treatments were not in place long enough (October 2000 - November 2001) to produce a significant effect.

Fertilizing

It was determined that fertilizing did not produce significant trends for any of the data collected.

Cultivating

Core cultivating had a negative effect on turfgrass cover and shear vane ratings. This negative effect was likely a result of the core aerification holes remaining open during the hot and dry summer months and the lack of irrigation. Conversely, cultivation did decrease surface hardness ratings during traffic simulation as anticipated in a native soil root zone.