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Establishment and Fertility
Comparisons of Trafficked
Athletic Turf with Sand Based Rootzones

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Thomas Mark Krick

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ESTABLISHMENT AND FERTILITY
COMPARISONS OF TRAFFICKED
ATHLETIC TURF WITH SAND BASED ROOTZONES

By

Thomas Mark Krick

A THESIS

Submitted to
Michigan State University
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ABSTRACT

ESTABLISHMENT AND FERTILITY COMPARISONS OF TRAFFICKED ATHLETIC TURF WITH SAND BASED ROOTZONES

By

Thomas Mark Krick

Many newly constructed athletic fields are making use of sand based rootzones. These systems alleviate compaction and anaerobic conditions while simultaneously increase water infiltration and percolation and maximize rooting. When these fields are properly constructed and maintained they are highly regarded by athletes and fans alike. They provide for a superior surface on which to compete and are aesthetically pleasing. But if improperly built and established hastily they can be unsafe and unplayable.

Three studies were conducted at Michigan State University's Hancock Turfgrass Research Center in which common establishment methods and fertility requirements of trafficked athletic turfs in sand rootzones were evaluated. A simulated athletic field situation established with washed Kentucky bluegrass (*Poa pratensis*) provided significantly better color, density, quality, and shear measures compared to a turfgrass stand established with perennial ryegrass (*Lolium perenne*) seed. Complete fertilizers having 1-2-1 analysis ratios provided the best turf. Other than traction, significantly higher ratings were obtained with fertilizer treatments having the highest amounts of nitrogen and potassium. The final study indicated that a Kentucky bluegrass/perennial ryegrass sod mix grown initially on plastic provides a superior athletic surface when established on a sand based rootzone. The benefit of lateral topgrowth was observed in applying a plant growth regulator (PGR) to sod immediately after establishment with no detriment to root biomass.

ACKNOWLEDGMENTS

I would like to express my thanks to Dr. J.N. Rogers III, my advisor and graduate committee chair, for the opportunity to work with him and learn a great deal about turfgrass and people. His strong drive in attaining his goals motivated me to do likewise in reaching some of mine. I also thank Drs. J.R. Crum, P.E. Rieke, and J.M. Vargas for their insights and advice which maximized my graduate learning experience. I would also like to recognize the Michigan State University support staff for their time and efforts as well as the Institute of Agriculture Technology for providing me the position of graduate teaching assistant.

I extend my gratitude to my friends and family who have supported me in this endeavor. And most importantly to my wife Sarah, for all of her patience and love, and being my best friend.

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CHAPTER ONE

Establishment Methods and Nutrient Requirements of Athletic Turf in Sand Based Rootzones.

ABSTRACT

The establishment phase of athletic fields, especially high sand based rootzone systems like Prescription Athletic Turf (PAT) systems, is critical to their success. If established hastily and improperly these fields will likely fail due to poor and unsafe playing conditions. Athletic fields in cool season grass regions are commonly established by sodding with Kentucky bluegrass (*Poa pratensis*) or seeding with perennial ryegrass (*Lolium perenne*). The establishment method of Kentucky bluegrass sodding with soil removed had significantly higher color, density, quality, and shear ratings compared to the seeded perennial ryegrass method. Polypropylene fibers (VHAF), which were placed at the soil surface prior to establishment resulted in significant quality improvements late in the study. The fibers also increased shear measures and at no time were detrimental. Complete fertilizers (N-P-K) provided significantly higher turfgrass color, density, and quality ratings compared to slow release, single nutrient carriers. The slow release fertilizer treatments in combination with the perennial ryegrass seeding establishment method had significantly lower color and density ratings in comparison to fast release fertilizer treatments.

Establishment Methods and Nutrient Requirements of Athletic Turf in Sand Based Rootzones.

Introduction

As the interest in physical fitness and sports involvement continue to increase across the nation so to does the need for quality athletic fields. The challenge faced by today's field manager is to provide a high quality field usually under adverse conditions. This challenge is mainly due to a high use period immediately following establishment. The establishment stage of an athletic field is very critical. If done improperly the field will not perform up to its intended level and will not satisfy the needs of its users. Within the past two decades, athletic fields have been constructed with sand based rootzones. Sands are utilized because, even after frequent foot traffic and aggregation, they maintain their porosity thus allowing for sufficient water and air to plant roots (Bingaman and Kohnke, 1970). One design currently being implemented with sand media is the Prescription Athletic Turf (PAT) system. The PAT system was developed at Purdue University by Dr. W.H. Daniel in response to the need for a safe and consistent playing athletic surface (Daniel and Freeborg, 1979).

Sand rootzones can tolerate compaction and provide good water percolation and air infiltration (Cockerham et al., 1994). The ranges of sand shape and size are very important. A particle size analysis is the foundation on which the technical platform for a turf system assessment is built (Dixon, 1994). Size and distribution of sand particles also influence the porosity, infiltration rate and available water content of the mixture (Duble and Brown, 1976). Sand should be uniform in size distribution and its shape should have some angularity for increased stability (Baker, 1991). If only sand is used for sports field construction, one particle size distribution suggested is that the sands lie mainly within the range 0.10-0.60mm (Adams et al., 1971). However, sand does have some drawbacks. These include; little water and nutrient holding capacity, chemical inertness, and turfgrass establishment difficulties. Sand also lacks cohesiveness or binding ability (Gibbs, 1990). If or when a sand based athletic field's performance begins to fail it is often due to its instability. Irrigation and fertility can overcome most setbacks except for improved soil stability (Gibbs, 1990). Research has demonstrated that roots increased the shear resistance of sandy rootzones by a factor of 2-3, an effect which is much greater than could be achieved by increasing silt and clay content over an acceptable range (Adams et al., 1985). Related work indicated that greater turf cover leads to greater rooting, and consequently, an increase in resistance to shear (Rogers et al., 1988). This trend of traction decrease as above ground biomass deteriorated has been confirmed for warm season species as well (Dunn et al., 1994). Shear studies have also been conducted on media other than sand. Zebarth and Sheard (1985) stated that soil based mixes tend to have higher resistance to shear than do sands.

It is commonly held that the first key to ensuring turfgrass establishment success should be a soil test to obtain soil pH and phosphorus levels (Turner, 1992). After obtaining soil test results a decision must be made as to the turf species desired, for it is then that the information can be put to use. Athletic fields may be established through seeding, sodding, or sprigging. In cool season turfgrass regions seeding or sodding typically occurs. Sports field construction, particularly in major facilities, often incurs a heavy financial debt. The PAT system described earlier, for example, has an expense approximately five times that of a conventional field construction. For this reason sod installation occurs more often at major facilities to have them operating as soon as possible in order to gain profits (Cockerham et al., 1993). PAT fields are typically constructed in spring prior to fall use. This leaves approximately three months for establishment which also explains why sodding is used. Advantages to sodding include instant green color and aesthetic erosion control (Hall, 1984).

Rooting is critical to successful field performance. The quicker turfgrass rooting takes place the sooner the field can be put into use. For years, sod was typically grown on organic or mineral soils. Sods grown on organic soil rooted into underlying soil better than that produced on mineral soil (King and Beard, 1969). In their study the mineral sod was grown on a loam soil and placed on a loamy sand, which may have had a layering effect explaining the improved rooting of the organic grown sod treatment. Recent improvements in sod farming and harvesting have allowed for soil-less sod products. "Soil-less" sods may be grown on a shallow layer of organic mulch or compost underlain by plastic. When harvested, the plastic is removed and there is no loss of roots. Another method used in obtaining soil-less sod is to simply remove the soil by washing through use of high pressure water jets. Studies have confirmed a more rapid rate of rooting from washed sod in comparison to traditional sod with soil attached (Casimaty et al., 1993). Furthermore, washed sod also had reduced surface hardness and better lateral shear strength than unwashed sod. Finally, washed sod resulted in more favorable soil water infiltration rates.

The first criteria in selecting a turfgrass for heavily trafficked sites is its ability to withstand the wear or abrasion caused by cleats, foot, and mechanical traffic (Gaussoin, 1994). Gaussoin also indicated that warm season species are more wear-tolerant than cool season grasses, partly because of tougher leaves and wider blades. The second criteria is recuperative potential; rhizomatous and stoloniferous grasses have greater recuperative potential than bunch-type grasses. For cool season grass regions Kentucky bluegrass (KBG) and perennial ryegrass (PRG) as monostands or in mixtures are accepted athletic field turf species due to their wear-tolerance (Cockerham et al., 1989).

In recent years polypropylene fibers, also known as VHAF (Notts Sport Ltd., Leiccester, England) have been introduced in the soil sand profile with the intent of improving stability. VHAF is a needlepunched geotextile fabric comprised of *v*ertical, *h*orizontal, and *a*ngular *f*ibers of polypropylene. It was primarily designed to prolong turfgrass cover and stability within soccer field goalmouths (Dury, 1986). Adams and Gibbs (1989) found that VHAF maintains stability and traction on sand constructed fields even though the turf may be virtually destroyed. They also reported that sowing half of the seed under the VHAF had no significant effect on top growth but doubled the amount of root produced under the VHAF and that seeds germinating under the VHAF would have their roots protected from physical damage. Gibbs (1990) later suggested that VHAF does not prevent turf destruction but only maintains a firm stable surface. Other soil stabilizing products are on the market as well. Beard and Sifers (1993) researched an interlocking mesh element that provides a unique three-dimensional matrix for improving stabilization of high sand rootzones.

Three benefits were reported: a) increased root-zone turf stability b) improved field quality, and c) enhanced turfgrass rootzone environment.

Another concern of sand media is low cation exchange capacity. Quantitatively defined, cation exchange capacity (CEC) is the sum total of the exchangeable cations that a soil can adsorb (Brady, 1990). The CEC of a given soil is determined by relative amounts of different colloids and the CEC of these colloids. Because sands have such low CECs they do not hold nutrients well and thus must be tested often to check for nutrient levels. For this reason most sand media have little or no nutrient supplying power and therefore require a full spectrum of nutrients for turfgrass growth and development (Goss, 1987).

Organic soil amendments are frequently added to improve the physical and chemical performance of soils. It is suggested that organic sources having fiber contents greater than 45% may be excessively coarse and organic matter (O.M.) incorporation rates should be selected so the final mix does not exceed 3.5% O.M. by weight (McCoy, 1992). Peat is a widely used organic soil amendment often mixed with sand. Some of the benefits that it provides include:

- increased nutrient levels in soil
- improved aeration and moisture holding capacity
- assist in pH manipulation and
- expand microorganism populations (Kelly, 1989).

A turf not receiving adequate fertility will likely require annual renovation at a cost much higher than a properly scheduled fertilizer program. The higher the sand content of the rootzone the more frequently fertilizers will need to be applied. There is a need to understand the particular nutritional implications of sandy rootzones. Turfgrass performances do not only depend upon the physical and nutritional environment but also by the nature and quality of turfgrass tissue that soil supports (Adams, 1981). Certain elements are essential to plant growth, although each one is credited with specific functions, it is important to understand the intricate balance and interrelation of the entire plant growth process (Freeborg and Daniel, 1985).

The first objective of the study was to evaluate different establishment methods common to athletic field construction. The two most common methods of establishment in cool season regions are Kentucky bluegrass (sodding with) and seeding with perennial ryegrass. We wanted to see if there were any quantitative differences between the two establishment methods. This would be done through data collecting means. Since the athletic field established was strictly for research there was no time element in having the field ready for competition. This allowed for a one year growing season in which to allow both establishment methods to reach mature levels of growth.

Another objective of the study was to see how effective VHAF fibers were in improving stability of a newly established sand based athletic field. The primary means of doing this would be through visual observation and conducting shear vane measures. The objective was to determine if the fibers placed on the surface added more benefit rather than incorporating them into the rootmix as done by previous researchers. One thought that occurred after the study had initiated was that the fibers, when placed on the surface, might cause a layering effect albeit minimal. Based upon the literature though, the overriding hypothesis was that the fibers would significantly improve the overall turf system, particularly from the standpoint of stability.

The final objective of the study was to compare different fertilizers. The fertilizers used were chosen so as to provide a mixture of readily available and slowly available nitrogen sources as well as complete and incomplete fertilizers. It was hypothesized that the differing fertilizers along with their different N release rates would indicate specific differences of the turf stand in terms of color, density, and quality in relation to the establishment and fiber factors.

Materials & Methods

During the summer of 1992 a new athletic field facility was completed at the Hancock Turfgrass Research Center (HTRC) on the campus of Michigan State University. The site was constructed according to the Prescription Athletic Turf (PAT) design and is a self-contained system. A two-ply plastic sheet sealed the PAT system from surrounding soil contamination. Within this membrane a network of slitted drain tiles were spaced evenly at 1.5 m throughout the base of the field. The tiles (10 cm in diameter) are covered by a 30 cm rooting mixture. The rooting mixture at the HTRC was comprised of 20 cm of straight sand and the remaining top 10 cm being 80% sand and 20% peat by volume in composition. The sand separates are presented in Table 1.1.

Table 1.1: Sand content of PAT field rootmix at Michigan State University.

Description	Size (mm)	Weight(%)
Very coarse sand	1.00-2.00	5.5
Coarse sand	0.50-1.00	38.0
Medium sand	0.25-0.50	45.0
Fine sand	0.10-0.25	10.0
Very fine sand	0.05-0.10	1.5

The drainage tiles were connected to a vacuum pump which could extract water when conditions were too wet or subsurface irrigate when conditions were too dry. A PAT field profile is provided in Figure 1.1.

The study was initiated at the HTRC in August 1992. Two establishment methods were used, a washed Kentucky bluegrass (*Poa pratensis*) blend sod (KBG) and a blended perennial ryegrass (*Lolium perenne*) seed (PRG). Cultivars of the KBG blend included *Aspen, Kelly, Midnight, Rugby,* and *Trenton*. In the PRG seed blend were *Dandy, Delray,* and *Target*. Fiber treatments were laid on the soil surface prior to sod or seed establishment. There were six fertilizer treatments associated with the establishment and fiber treatments. The fertilizer treatments as well as the total N, P_2O_5 and K_2O applied for the duration of the study are summarized in Table 1.2.

Table 1.2: Fertilizer treatments for establishment and fertility study.

Treatment	Source	%WSN	%WIN	Total N, P2O5 and K2O applied (kg/ha)* N	P_2O_5	K_2O
1. Urea (46-0-0)	Maumee, OH	46	0	343	151	498
2. IBDU (31-0-0)	Fairview Hgts., IL	10	21	343	151	498
3. Lebanon (13-25-12)	Lebanon, PA	1	12	343	866	815
4. SC Urea (32-0-0)	Lebanon, PA	0	32	343	151	498
5. Nutri-Plus (10-3-4)	Saranac, MI	6	4	343	254	635
6. Milorganite (6-2-0)	Milwaukee, WI	0	6	343	265	498

Note: WSN and WIN = Water Soluble N and Water Insoluble N respectively.
* Supplemental P_2O_5 and K_2O applications included for total nutrients applied (10/26/92-10/11/93).

Urea, IBDU, Lebanon 13-25-12 and sulfur coated urea are all synthetic fertilizers. Nutri-Plus and Milorganite are both organic fertilizer sources. Nutri-Plus and Milorganite are comprised of chicken wastes and activated sewage sludge

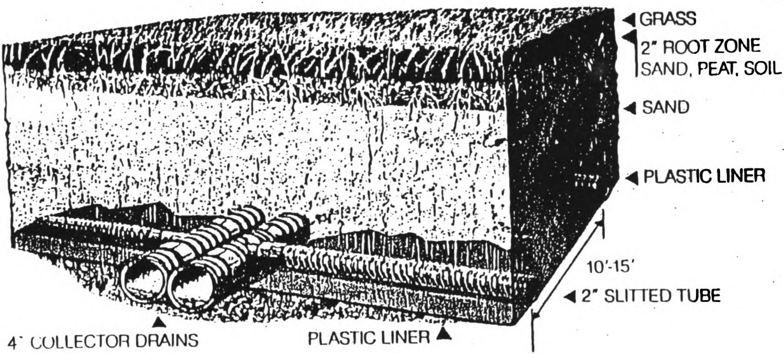

Figure 1.1:Prescription Athletic Turf (PAT) profile.

respectively. Nutri-Plus also has an additional 6 percent water soluble N in the form of ammonium nitrate.

The experimental design was a 2 X 2 X 6 split-plot randomized complete block design replicated three times. The establishment method and fiber treatments made up factors one and two. The fertility factor was a split-plot on the first two factors. Individual plots measured 1.5 m X 3 m. On 26 August 1992, 13-25-12 Lebanon was applied over the entire study area at a rate of 49 kg N/ha. Immediately prior to sodding or seeding VHAF fibers were laid on the soil surface for fiber treatments at a rate of 1.9 X 10^7 fibers/ha (1916/m^2). The washed Kentucky bluegrass sod, which had a thickness of approximately 2.5 cm, was laid 28 August. Perennial ryegrass was seeded 29 August at a rate of 245 kg seed/ha. On 4 and 16 September, 25-0-25 was applied at 24.5 kg N/ha per application on all plots. The first fertilizer applications were administered at a rate of 24.5 kg N/ha for each respective fertilizer treatment on 19 Sept. 1992. A composite soil test of the research field was conducted on 29 Sept. 1992 (Table 1.3). Soil pH was determined using the Schofield method (Schofield and Taylor, 1955). Soil phosphorus levels were determined by the Bray procedure (Bray and Kurtz, 1945). And K, Ca and Mg levels were obtained using a procedure slightly modified from the "NCR-13 Exchangeable Potassium Procedure" as reported by Carson (1980). The CEC was calculated based upon K, Ca and Mg levels. All soil tests were conducted at the Michigan State University Soil Testing Laboratory.

The first mowing of the study area was conducted 24 September using a Toro recycler mower (Toro Co., Minneapolis, MN) at a height of 7 cm. An application of

0-0-50 was applied at 49 kg K_2O/ha on 8 October. On 9 October fertilizer treatments were applied at the 24.5 kg N/ha rate. The grasses had began to harden off at this point as growth rates reduced considerably. Composite soil samples were again conducted on 29 October and in 1993 on 28 April and 27 May with results provided in Table 1.3. The samples for each respective date were comprised by a combination of random sampling from across the research field.

Table 1.3: Composite soil test results of PAT field rootmix at Michigan State University.

	Date			
Test Result	9/29/92	10/29/92	4/28/93	5/27/93
Soil pH	8.3	8.4	8.2	8.0
P (kg/ha)	62	17	16	15
K (kg/ha)	69	43	28	47
Ca (kg/ha)	2168	2261	1969	1960
Mg (kg/ha)	122	100	63	49
CEC (me/100g)	5.4	5.5	4.7	4.6

Fertilizer applications for all treatments resumed on 7 May 1993 at 24.5 kg N/ha rates. Supplemental K was applied in the form of soluble potash (K_2O), 0-0-50 at a rate of 49 kg K_2O/ha on; 7 May, 8 July, 15 Sept., and 11 Oct. 1993 to provide for acceptable soil potassium levels. At no time during the study did soil tests reveal potassium or phosphorous at inadequate levels for turfgrass growth.

Wear treatments were applied using the Brinkman Traffic Simulator (Cockerham and Brinkman, 1989) beginning 27 August 1993 (Figure 1.2). Two passes by the Brinkman Traffic Simulator (BTS) within the Zone of Traffic Concentration (ZOTC) is equivalent to one football game as researched by Brinkman

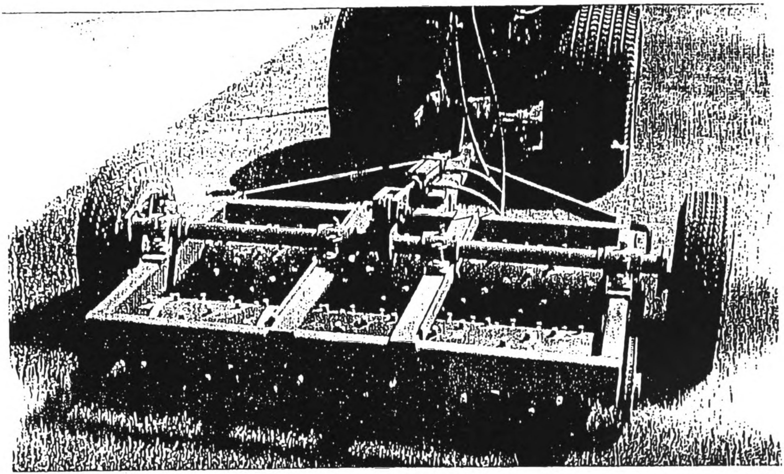

Figure 1.2: Brinkman Traffic Simulator.

and Cockerham (1989). The ZOTC is defined as the area at the 40 yard line between the hashmarks. The rate of traffic was 8 passes per week thus simulating 4 games per week. The BTS was pulled by a John Deere 5100 tractor (John Deere Inc., Moline, IL). Traffic simulation was conducted through 15 November at which point approximately 45 games had been simulated. Data collected included color, density, and quality ratings along with clipping yields, tissue analysis, root biomass, and shear vane measurements.

Color was rated on a scale of 1-9 with 1 being brown and 9 having a dark green color. The minimum acceptable color was 5. Density was rated on a percent coverage basis from 0-100. Visual observations were made of individual plots and the percent coverage for each plot was recorded. Since no individual quality ratings were conducted a manufactured quality rating was equated based upon the combination of both color and density ratings. Quality ratings for dates 28 Oct., 1992 through 26 Oct., 1993 were manufactured numbers. Ratings given within that time period were calculated by multiplying color and density ratings for the same dates and dividing by 90. This objective method provided the numerical data necessary to perform analysis for statistical purposes. The quality ratings equated by this method also represented the realistic trend of decreasing quality as traffic simulation continued. The quality rating scale was from 1-9; 1=bare ground, 9=ideal turf, with 4 being of minimum acceptable value.

Clippings were collected from an area approximately 0.23 m^2 (2.5 ft^2), dried at 55° C, and weighed for yield measurements for the growth periods of 28 May-2 June and 8-13 July 1993. On both dates clipping yields were taken 11 and 6 days after their most recent fertilizer treatment application respectively. Clippings were ground through a 40 mesh screen and ashed at 500 C for 5 hours. The ash was then digested for 1 hour in 3N nitric acid and analyzed for nutrient content.

At the end of traffic simulation (18 Nov. 1993) 6 soil samples were taken from each plot for root weight density determinations. The probe had a diameter of 3.5 cm and a depth 14 cm. Samples were separated into 0-7 cm and 7-14 cm depths. Roots were separated from the soil using the hydropneumatic system (Smucker et al., 1982).

Shear vane measurements were measured with an Eijkelkamp Type 1B shear vane apparatus (Eijkelkamp Equipment, Giesbeek, The Netherlands) shown in Figure 1.3. Measurements were conducted in Fall 1993 after traffic simulation began. The average of three measurements were taken and are presented in Newton-meters (Nm).

Analysis of variance was performed on all data and means were statistically separated using LSD procedures at the 0.05 level of probability.

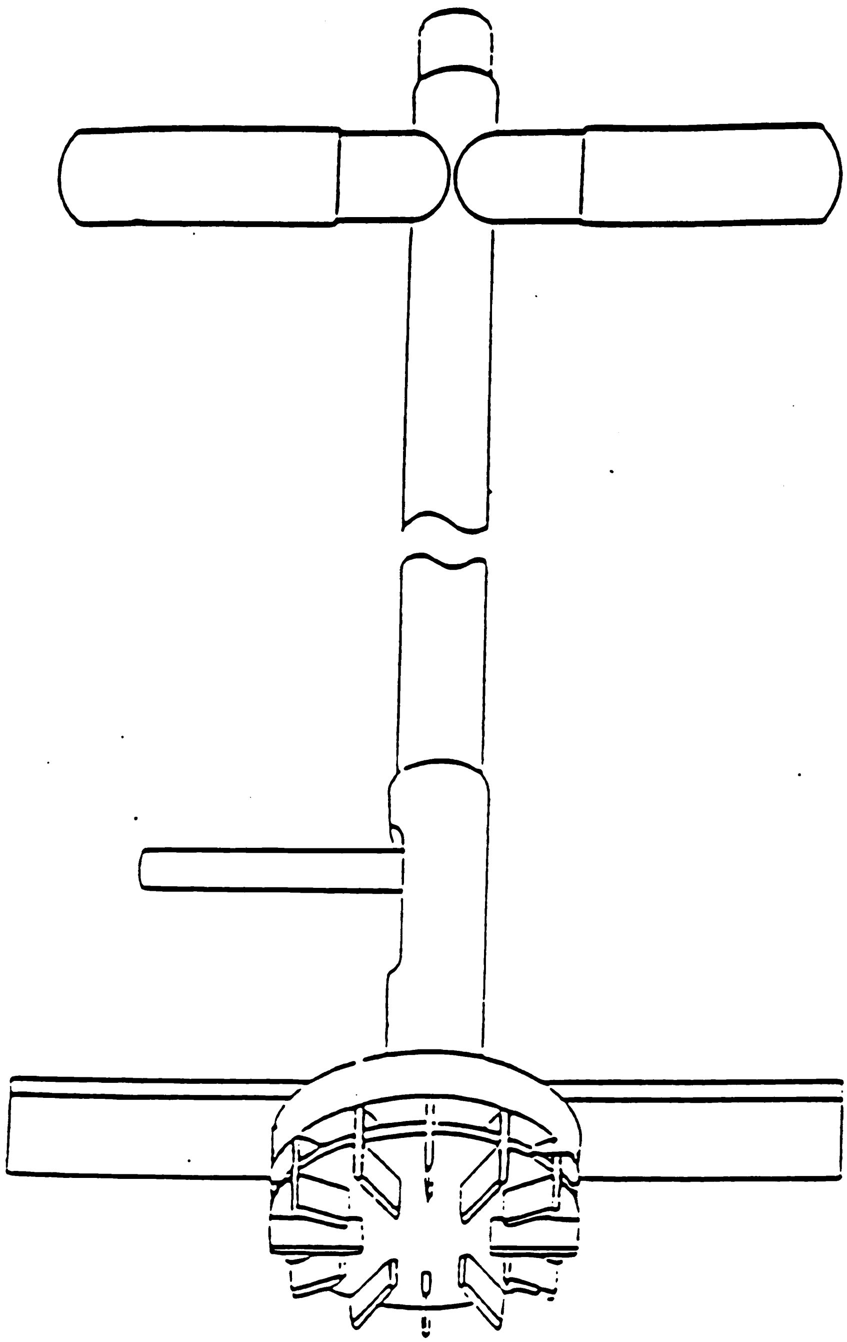

Figure 1.3: Eijkelkamp type 1B field shear apparatus.

Results and Discussion

Color

Color ratings were conducted in early, middle, and late season 1993 (Table 1.4). The washed KBG sod establishment method had significantly higher color ratings compared to the seeded PRG method. Not until the last rating date (23 November) late in the 1993 season did the color rating fall below an acceptable level (5) for the sodded KBG establishment method. No significant color differences were observed between the fiber treatments during the study. Significant color differences were noted for the fertilizer treatments. By taking the mean for all rating dates for each of the respective fertilizers, Urea rated highest followed by Lebanon 13-25-12. IBDU and Milorganite received the lowest color ratings.

On 12 May 1993 the establishment method factor had an interaction with the fertility factor (Table 1.5). Based upon this interaction, it is apparent that complete fertilizer treatments (N-P-K) or quick release N sources had better color ratings than slowly available N sources. It was also noted that IBDU had the highest color rating for sod but the lowest for seed treated plots. A similar interaction was observed for Milorganite. Figure 1.4 illustrates the color differences of the establishment and fertility factors. Release of nitrogen from IBDU is dependent on particle size as well as surrounding soil temperature, moisture, and pH levels. Coarse IBDU was used for the study, but it is believed that the particle size did not dictate the differences observed but rather the moisture levels. Although no moisture level data was collected, it appeared that the sod established treatments maintained higher moisture

Table 1.4: The effects of establishment method, fiber, and fertilizer treatment on trafficked and non-trafficked turfgrass color[1].

	Date						
Treatment	10/28/92	5/12/93	5/27/93	7/6/93	10/26/93	11/23/93	Mean
Washed KBG sod	7.7	6.8	6.8	7.2	7.6	4.9	6.8
Per. Rye seed	6.7	5.6	5.4	6.8	5.8	3.5	5.6
	*	*	*	*	*	*	
Fiber	7.1	6.1	6.1	7.0	6.5	3.8	6.1
No Fiber	7.3	6.3	6.0	7.1	6.9	4.5	6.4
	NS	NS	NS	NS	NS	NS	
Urea (46-0-0)	7.8	6.3	7.0	7.2	7.0	4.6	6.7
IBDU (31-0-0)	6.4	6.0	4.5	7.1	6.1	3.8	5.7
Lebanon 13-25-12	7.5	6.2	7.0	6.6	7.5	4.9	6.6
SCU (32-0-0)	7.3	6.3	6.5	7.8	6.8	4.1	6.5
Nutri-Plus (10-3-4)	7.7	6.6	6.4	6.4	7.3	4.6	6.5
Milorganite (6-2-0)	6.5	5.8	5.0	7.0	5.4	3.1	5.5
LSD at 0.05 α	0.4	NS	0.6	0.6	0.5	0.9	
Games Simulated	---	---	---	---	38	45	

[1]Scale 1-9; 1=brown, 9=dark green and 5 acceptable.

* Significant at 0.05 level.

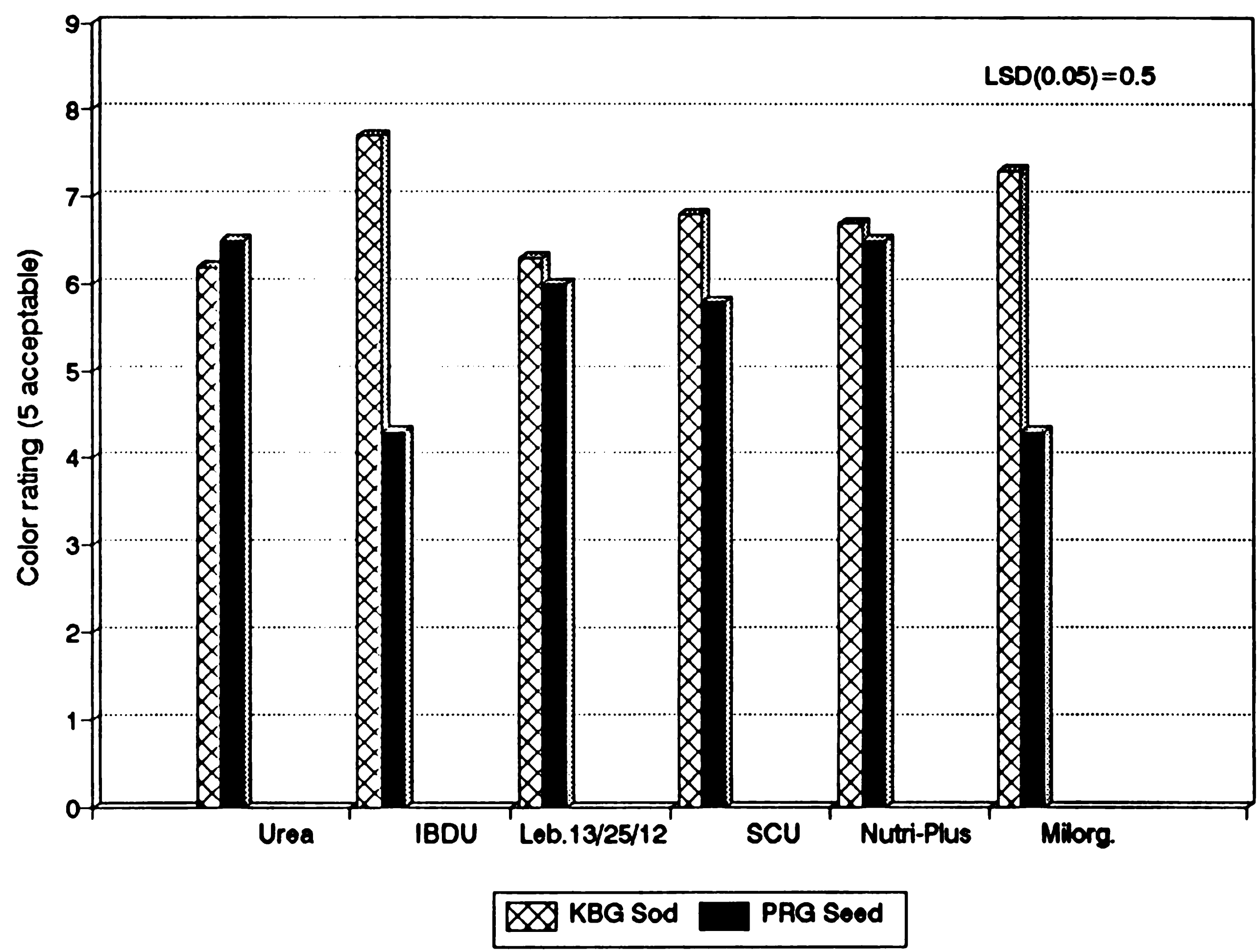

Figure 1.4: The effect of establishment method X fertility treatment interaction on non-trafficked turfgrass color, 12 May 1993.

levels for longer time periods than the seed established treatments. This likely allowed for greater N release and improved color. Milorganite showed similar results to that of IBDU, higher color ratings for sod established treatments and lower color for seeded treatments.

Table 1.6 shows the interactions that occurred between fiber and fertility factors on 12 May and 27 May 1993. Nutri-Plus and Lebanon 13-25-12 in combination with fiber provided for best color on each respective date. The other organic, Milorganite, with fiber had the lowest color rating. Both Nutri-Plus and Milorganite are natural organics but their methods of production differ. Sixty percent of Nutri-Plus' total N is water soluble where as Milorganite has no water soluble N.

An interaction between the establishment and fiber factor existed for color on 27 May 1993 (Table 1.7). Color ratings were highest for sodded treatments without fiber at the surface but this was the opposite for perennial ryegrass seed treatments as color was rated higher where fiber was present. Although the sod treatments with and without fibers had better color than the seed treatments, all treatments were at acceptable values. Interactions between all three factors took place on 28 Oct. 1992 and again almost a year later on 26 Oct. 1993 (Tables 1.8 and 1.9, respectively). The interactions on those dates indicated that sod established treatment, without VHAF and fertilized with urea had the highest color ratings and the seed establishment treatments combined with fiber and Milorganite were the lowest.

Table 1.5: The effect of establishment method X fertilizer treatment interaction on non-trafficked turfgrass color[1], 12 May 1993.

	Establishment Method	
Fertilizer Treatment	Washed KBG	Per. Rye Seed
Urea (46-0-0)	6.2	6.5
IBDU (32-0-0)	7.7	4.3
Lebanon 13-25-12	6.3	6.0
SCU (32-0-0)	6.8	5.8
Nutri-Plus (10-3-4)	6.7	6.5
Milorganite (6-2-0)	7.3	4.3
LSD at 0.05 α	0.5	

Table 1.6: The effect of fiber X fertilizer treatment interaction on non-trafficked turfgrass color[1], 1993.

	Date			
	12 May Fiber Factor		27 May Fiber Factor	
Fertilizer Treatment	w fiber	w/o fiber	w fiber	w/o fiber
Urea (46-0-0)	6.0	6.7	6.8	7.2
IBDU (32-0-0)	6.0	6.0	4.5	4.5
Lebanon 13-25-12	6.2	6.2	7.3	6.7
SCU (32-0-0)	6.0	6.7	6.3	6.7
Nutri-Plus (10-3-4)	7.0	6.2	7.0	5.8
Milorganite (6-2-0)	5.7	6.0	4.7	5.3
LSD at 0.05 α	0.5		0.8	

[1]Scale 1-9;1=brown, 9=dark green and 5 acceptable.

Table 1.7: The effect of fiber X establishment method interaction on non-trafficked turfgrass color[1], 27 May 1993.

Establishment Method	Fiber Factor: w fiber	Fiber Factor: w/o fiber
Washed KBG sod	6.6	7.0
Per. Rye seed	5.7	5.1
LSD at 0.05 α	0.7	

Table 1.8: The effects of establishment method, fiber and fertilizer treatment interaction on trafficked turfgrass color[1], 28 October 1992.

	Establishment and Fiber Factors			
	Washed KBG		Per. Rye seed	
Fertilizer Treatment	w fiber	w/o fiber	w fiber	w/o fiber
Urea (46-0-0)	7.7	8.7	7.7	7.3
IBDU (32-0-0)	7.0	7.0	6.0	5.7
Lebanon 13-25-12	8.0	7.7	7.3	7.0
SCU (32-0-0)	8.0	8.0	6.3	7.0
Nutri-Plus (10-3-4)	7.7	8.7	7.3	7.0
Milorganite (6-2-0)	7.0	7.3	5.7	6.0
LSD at 0.05 α	0.6			

[1]Scale 1-9;1=brown, 9=dark green and 5 acceptable.

Table 1.9: The effects of establishment method, fiber, and fertilizer treatment interaction on trafficked turfgrass color[1], 26 October 1993.

	Establishment and Fiber Factors			
	Washed KBG		Per. Rye seed	
Fertilizer Treatment	w fiber	w/o fiber	w fiber	w/o fiber
Urea (46-0-0)	7.3	8.7	6.0	6.0
IBDU (32-0-0)	6.7	7.7	5.3	4.7
Lebanon 13-25-12	8.0	8.3	6.7	7.0
SCU (32-0-0)	8.0	7.7	5.3	6.0
Nutri-Plus (10-3-4)	8.3	7.7	6.0	7.0
Milorganite (6-2-0)	6.0	6.3	4.0	5.3
LSD at 0.05 α		0.6		

[1]Scale 1-9; 1 = brown, 9 = dark green and 5 acceptable.

Density

Density is defined as the number of plants per unit area. For this study density ratings are given as percentages. The washed KBG sod establishment method was significantly better than the perennial ryegrass seeded establishment method in terms of density as defined above (Table 1.10). The fiber factor was of no significant benefit in turfgrass density. The fertility factor indicated that the Lebanon 13-25-12 treatment provided for the highest densities while IBDU and Milorganite were the lowest.

Significant interactions were noted on 28 Oct. 1992 and again on 27 May 1993 between establishment and fertility factors (Table 1.11). On 28 Oct. 1992 there were no significant differences among the sod establishment treatments but only for seed established treatments (Figure 1.5). On that date the seeded perennial ryegrass was approximately 3 months old. A plant is far from maturity at that stage of growth. Nutrient availability is critical at the above stage of growth and thus it is understandable why the slow release IBDU fertility treatment in combination with the perennial ryegrass seeded establishment method had significantly lower densities. The interaction on 27 May 1993 was comparable to that on 28 Oct. 1992. The seed establishment method had similar numbers on both dates but differences were more apparent with sod established treatments, particularly for IBDU and Milorganite.

Quality

Quality ratings are presented in Table 1.12. Highest quality ratings were given to the washed KBG sod establishment method. Quality ratings for the perennial

Table 1.10: The effects of establishment method, fiber, and fertilizer treatment on trafficked and non-trafficked turfgrass density[1].

	Date				
Treatment	10/28/92	5/12/93	5/27/93	7/6/93	10/26/93
			%		
Washed KBG sod	94	86	91	93	55
Per. Rye seed	81	75	78	88	42
	*	*	*	*	
Fiber	87	81	84	90	50
No Fiber	88	80	85	91	47
	NS	NS	NS	NS	NS
Urea (46-0-0)	89	85	87	91	46
IBDU (32-0-0)	81	73	78	87	50
Lebanon 13-25-12	90	84	88	92	56
SCU (32-0-0)	89	81	87	90	50
Nutri-Plus (10-3-4)	90	83	87	93	51
Milorganite (6-2-0)	86	75	80	89	39
LSD at 0.05 α	4	7	2	3	8
Games Simulated	---	---	---	---	38

[1]Density ratings based on % cover 0-100.
* Significant at 0.05 level.

Table 1.11: The effect of establishment method X fertilizer treatment interaction on non-trafficked turfgrass density[1].

	Date			
	10/28/92 Establishment Method		5/27/93 Establishment Method	
Fertilizer Treatment	Washed KBG	Per. Rye Seed	Washed KBG	Per. Rye Seed
Urea (46-0-0)	96	83	93	80
IBDU (32-0-0)	92	70	86	70
Lebanon 13-25-12	96	85	93	84
SCU (32-0-0)	96	82	93	81
Nutri-Plus (10-3-4)	94	86	90	82
Milorganite (6-2-0)	93	78	88	73
LSD at 0.05 α	5		3	

[1]Density ratings based on % cover 0-100.

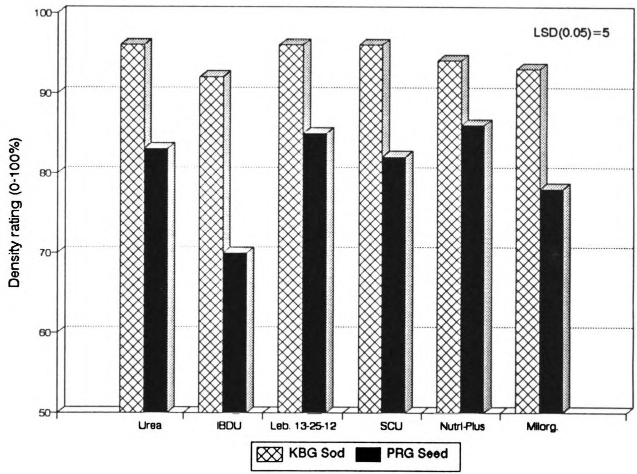

Figure 1.5: The effect of establishment method X fertility treatment interaction on trafficked turfgrass density, 28 Oct. 1992.

Table 1.12: The effects of establishment method, fiber, and fertilizer treatment on trafficked and non-trafficked turfgrass quality[1].

	Date								
Treatment	10/28/92	5/12/93	5/27/93	7/6/93	10/26/93	11/3/93	4/4/94	5/4/94	5/17/94
Washed KBG sod	8.1	6.5	6.8	7.5	4.6	3.9	4.8	4.6	4.7
Per. Rye seed	6.0	4.7	4.7	6.6	2.8	3.0	3.0	3.1	3.3
	*	*	*	*	*	*	*	*	*
Fiber	6.9	5.5	5.7	7.0	3.8	3.7	3.9	3.8	4.1
No Fiber	7.2	5.6	5.8	7.1	3.6	3.1	3.9	4.0	3.8
	NS	NS	NS	NS	NS	*	NS	NS	NS
Urea (46-0-0)	7.8	6.0	6.8	7.3	3.7	3.3	3.7	3.5	3.7
IBDU (32-0-0)	5.9	5.0	4.0	6.9	3.5	4.0	4.1	4.5	4.7
Lebanon 13-25-12	7.5	5.7	6.9	6.7	4.7	4.2	4.1	4.0	3.8
SCU (32-0-0)	7.3	5.7	6.3	7.9	3.9	3.2	3.8	4.2	4.5
Nutri-Plus (10-3-4)	7.7	6.1	6.1	6.6	4.1	3.8	4.0	3.5	3.7
Milorganite (6-2-0)	6.2	5.0	4.6	6.9	2.5	2.3	3.7	3.6	3.5
LSD at 0.05 α	0.5	0.5	0.5	0.6	0.7	0.9	NS	0.8	0.6
Games Simulated	---	---	---	---	38	40	---	---	---

[1]Quality rating 1-9; 1=bare ground, 9=ideal turf, and 4 acceptable.
* Significant at 0.05 level.

NOTE: Ratings for dates 10/28/92-10/26/93 are based on color and density ratings taken on those dates.

ryegrass seed establishment method were lower than the washed Kentucky bluegrass sod method and below acceptable levels late in the season as simulated traffic surmounted. Quality ratings conducted 3 November, after 40 simulated games of traffic, indicated that treatments having VHAF at the soil surface were significantly better than those treatments not having VHAF. The final fertilizer application was conducted 6 Oct 1993. SCU provided the best quality ratings followed by Urea, Nutri-Plus, Lebanon 13-25-12, and IBDU. Milorganite had the lowest quality ratings.

Table 1.13 shows the interaction between establishment and fertility factors for 12 May, 1993 quality ratings. Urea and sod establishment received the highest highest quality rating. All sodded treatments received higher quality ratings compared to any of the seed established treatments. The seeded plots with IBDU were the lowest rated which indicated the interaction. As was the case with color on 27 May, 1993, an interaction between the fiber and fertility factors occurred but relative to quality (Table 1.14). The fiber X fertility interaction stems from the ratings given to the Nutri-Plus treatment. All fertility treatments except the Nutri-Plus treatment had similar quality ratings with and without fibers. The Nutri-Plus treatment not having fibers had a significantly lower quality rating compared to the same fertility treatment with fibers (Figure 1.6). Quality was best for washed KBG sod established treatments not having fiber and the worst for seeded PRG establishment treatments not having fiber (Table 1.15). These interactions took place in May, four months before traffic simulation began.

Table 1.13: The effect of establishment method X fertilizer treatment interaction on non-trafficked turfgrass quality[1], 12 May 1993.

Fertilizer Treatment	Establishment Method	
	Washed KBG	Per. Rye Seed
Urea (46-0-0)	8.7	6.9
IBDU (32-0-0)	7.1	4.6
Lebanon 13-25-12	8.3	6.8
SCU (32-0-0)	8.5	6.1
Nutri-Plus (10-3-4)	8.5	6.8
Milorganite (6-2-0)	7.4	5.1
LSD at 0.05 α	0.7	

Table 1.14: The effect of fiber X fertilizer treatment interaction on non-trafficked turfgrass quality[1], 27 May 1993.

Fertilizer Treatment	Fiber Factor	
	w fiber	w/o fiber
Urea (46-0-0)	6.5	7.0
IBDU (32-0-0)	3.9	4.1
Lebanon 13-25-12	7.1	6.6
SCU (32-0-0)	6.2	6.5
Nutri-Plus (10-3-4)	6.7	5.6
Milorganite (6-2-0)	4.2	5.0
LSD at 0.05 α	0.8	

[1]Quality rating 1-9; 1=bare ground, 9=ideal turf, and 4 acceptable.

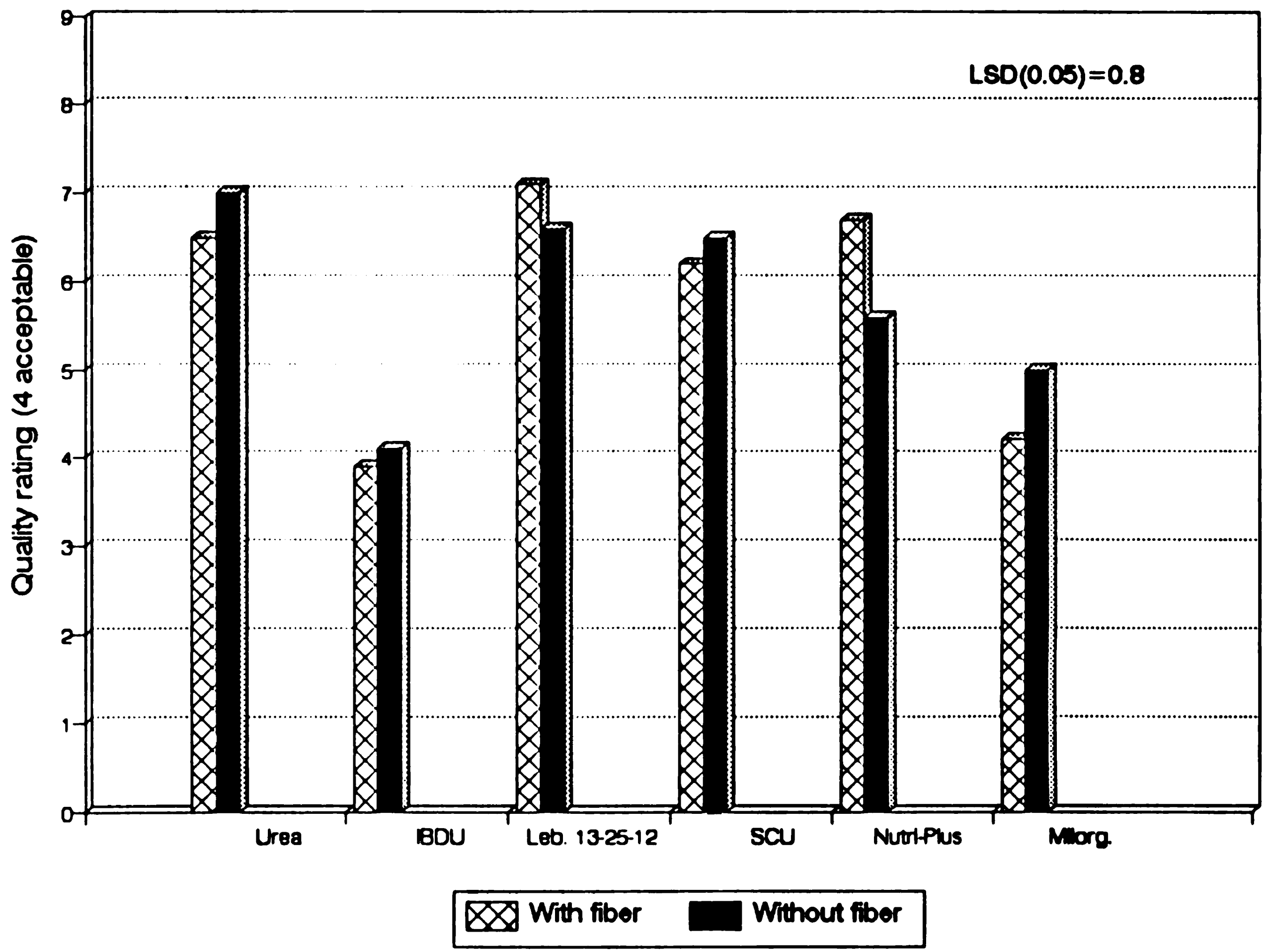

Figure 1.6: The effect of fiber X fertility treatment interaction on non-trafficked turfgrass quality, 27 May 1993.

Soil phosphorus and potassium levels were measured after fertility treatments were completed via soil sampling 16 November, 1993 and analyzed at Michigan State University's Soil Testing Laboratory. Significant phosphorus differences were noted among the fertilizer treatments. Plots receiving the Lebanon 13-25-12 averaged the most phosphorus at 44.2 kg/ha and SCU contained the lowest phosphorus amounts with a mean of 8.4 kg/ha. No significant differences were noted among the fertilizer treatments relative to potassium amounts (Table 1.16).

Root weight densities were also collected in late November 1993 (Table 1.17). Significant differences were noted amongst the establishment methods at the 7.6-15.2 cm depth. The washed Kentucky bluegrass sod established treatments received lower root biomass than the perennial ryegrass seed. No significant differences were seen at the 0-7.6 cm depth. Lastly, it should be noted that neither polypropylene fiber treatment nor fertility treatments had any significant differences on root biomass.

Clipping yields were obtained on 2 June and 13 July 1993 (Table 1.18). Sod established treatments had significantly higher clipping yields than seeded treatments on both dates. No differences were observed due to fiber treatment. As expected, differences were observed among fertility treatments. Complete and fast release N fertilizer treatments had relatively high clipping yields compared to Milorganite and slow release IBDU.

Nutrient content in the clippings was determined for both clipping dates in 1993 (Table 1.19). No significant differences in potassium were observed for either month. This was reassuring because it indicated that the supplemental soluble potash

Table 1.15: The effect of establishment method X fiber interaction on non-trafficked turfgrass quality[1], 27 May 1993.

	Fiber Factor	
Establishment Method	w fiber	w/o fiber
Washed KBG sod	6.5	7.2
Per. Rye seed	5.0	4.4
LSD at 0.05 α	0.7	

[1]Quality rating 1-9; 1 = bare ground, 9 = ideal turf, and 4 acceptable.

Table 1.16: The effect of fertilizer treatment on soil phosphorus and potassium levels, Nov. 1993.

	Soil Test Levels	
Fertilizer Treatment	kg P/ha	kg K/ha
Urea (46-0-0)	9.3	46.3
IBDU (32-0-0)	12.8	46.5
Leb. 13-25-12	44.2	52.9
SCU (32-0-0)	8.4	38.6
Nutri-plus (10-3-4)	15.6	49.5
Milorganite (6-2-0)	14.9	44.2
LSD at 0.05 α	4.9	NS

Table 1.17: The effects of establishment method, fiber, and fertilizer treatment on trafficked turfgrass root biomass[1], Nov. 1993.

	Sample Depth			
	Traffic g/L		Non-Traffic g/L	
Treatment	0-7 cm	7-14 cm	0-7 cm	7-14 cm
Washed KBG sod	17	3	19	3
Per. Rye seed	22	6	23	8
	NS	*	NS	*
Fiber	19	4	21	5
No Fiber	20	5	20	6
	NS	NS	NS	NS
Urea	21	4	19	6
IBDU	21	7	20	5
Leb. 13-25-12	16	5	18	5
SCU	20	4	22	7
Nutri-Plus	21	3	22	5
Milorganite	20	3	23	5
LSD 0.05 α	NS	NS	NS	NS

[1] Root biomasses given in g/L soil.
* Significant at 0.05 level.
NS: No significant differences.

Table 1.18: The effects of establishment method, fiber, and fertilizer treatment on non-trafficked turfgrass clipping yields[1].

Treatment	Date: June '93	Date: July '93
	g/m²	g/m²
Washed KBG sod	29.2	37.8
Per. Rye seed	16.8	18.3
	*	*
Fiber	22.6	27.5
No Fiber	23.4	28.6
	NS	NS
Urea (46-0-0)	31.5	34.3
IBDU (32-0-0)	11.7	22.7
Leb. 13-25-12	29.6	30.8
SCU (32-0-0)	27.5	32.8
Nutri-Plus (10-3-4)	25.2	25.5
Milorganite (6-2-0)	12.5	22.2
LSD at 0.05 α	3.9	4.9

[1] Clipping yields given in g/m^2.
* Significant at 0.05 level.
NS: No significant differences.

Table 1.19: The effect of fertilizer treatment on plant tissue nutrient levels[1].

June 1993

Fertilizer Treatment	Nutrients											
	Al	Zn	Fe	B	P	Cu	Mn	Mg	Ca	Mo	K	Na
	ppm											
Urea (46-0-0)	46.7	31.0	107.8	6.9	3065	4.2	51.1	1633	4922	2.31	22086	445
IBDU (32-0-0)	60.4	27.8	109.5	5.9	2769	3.3	48.9	1528	4690	2.48	18639	416
Leb. 13-25-12	41.5	31.2	114.9	5.5	5492	4.4	68.0	1579	4811	2.27	25100	393
SCU (32-0-0)	67.6	31.9	120.9	7.8	3057	4.3	54.1	1687	5215	2.35	22503	468
Nutri-plus (10-3-4)	47.9	33.0	107.2	11.4	3568	5.1	57.6	1607	4949	2.40	23854	456
Milorganite (6-2-0)	71.1	29.1	119.9	7.2	2992	4.9	50.9	1553	5044	2.57	19438	429
LSD at 0.05 α	NS	3.3	NS	2.4	465	NS	6.0	NS	NS	NS	NS	NS

July 1993

Fertilizer Treatment	Nutrients											
	Al	Zn	Fe	B	P	Cu	Mn	Mg	Ca	Mo	K	Na
	ppm											
Urea (46-0-0)	229.1	28.1	179.3	7.9	3119	5.3	91.4	2218	6047	3.42	25644	544
IBDU (32-0-0)	197.5	32.5	163.0	9.8	3183	6.1	97.5	2576	6687	3.78	25082	555
Leb. 13-25-12	231.1	32.1	175.4	8.6	5959	4.9	110.2	2076	5592	3.52	25713	544
SCU ((32-0-0)	385.7	33.3	239.4	8.3	3108	6.1	102.8	2234	6521	3.26	25348	544
Nutri-plus (10-3-4)	257.7	35.0	186.4	13.6	4242	8.2	97.5	2260	6387	3.86	24972	531
Milorganite (6-2-0)	309.1	37.0	233.4	9.0	4280	7.2	89.3	2541	7110	4.30	24655	552
LSD at 0.05 α	NS	NS	NS	1.9	426	2.0	13.0	168	719	0.3	NS	NS

[1]Nutrient levels given in parts per million (ppm).

applications were balanced across all fertility treatments in spite of low soil K levels. Lebanon 13-25-12 had significantly higher phosphorous levels than all other fertilizer treatments. This was expected and also explained why the Lebanon treated plots fared so well in most areas where data was collected. This information again stresses the importance of phosphorous nutrition within any turf establishment phase, be it sodded or seeded.

Shear vane measurements were taken after wear treatment had been initiated in Sept. 1993. Traffic was applied using the Brinkman Traffic Simulator. No differences were noted among the fertility treatments. The inclusion of the polypropylene fibers with sodded or seeded turf allowed investigation of the possibility of increased stability at the turf/soil interface. On 3 of the 6 dates when shears were taken, fibers provided a significant benefit. Shears were higher for treatments having VHAF compared to those that did not even though they were not significantly different. Sod established treatments obtained higher shear values than treatments established by seed for the duration of the study. Treatments not receiving traffic resembled those that did; a) no fertility differences, b) trend that fiber improves shear and c) sodded establishment sheared higher than seeded establishment. Both the trafficked and non-trafficked shear measure data are presented in Tables 1.20 and 1.21, respectively. One interaction took place between establishment and fiber factors relative to shear. The interaction occurred 17 Sept. 1993 and indicated the benefit fibers placed on the soil surface had in increasing shear strength for the seeded perennial ryegrass establishment method (Figure 1.7).

Table 1.20: The effects of establishment method, fiber and fertilizer treatment on trafficked turfgrass shear measures[1].

Treatment	Date					
	9/10/93	9/17/93	9/24/93	10/1/93	10/11/93	11/5/93
	Nm					
Washed KBG sod	27.1	27.4	22.4	20.2	21.8	18.8
Per. Rye seed	18.7	19.6	15.0	14.5	15.4	14.1
	*	*	*	*	*	*
Fiber	23.8	24.3	19.4	18.3	19.7	17.7
No Fiber	22.0	22.8	18.0	16.4	17.5	15.3
	*	NS	NS	*	NS	*
Urea (46-0-0)	22.4	22.3	17.8	17.8	18.0	18.0
IBDU (32-0-0)	23.0	22.8	18.5	15.5	18.1	14.7
Lebanon 13-25-12	23.8	24.9	20.0	18.8	18.0	15.8
SCU (32-0-0)	23.3	24.5	18.9	18.0	21.3	16.7
Nutri-Plus (10-3-4)	23.2	24.0	19.2	17.9	18.6	18.3
Milorganite (6-2-0)	21.5	22.7	17.6	16.1	17.5	15.3
LSD at 0.05 α	NS	NS	NS	NS	NS	NS
Games Simulated	10	14	18	23	28	40

[1]Shears given in Newton meters (Nm).
* Significant at 0.05 level.

Table 1.21: The effects of establishment method, fiber and fertilizer treatment on non-trafficked turfgrass shear measures[1].

Treatment	Date 9/10/93	9/17/93	9/24/93	10/1/93	10/11/93
			Nm		
Washed KBG sod	35.0	27.3	32.4	33.3	26.2
Per. Rye seed	27.3	20.0	25.1	25.2	19.8
	*	*	*	*	*
Fiber	32.0	24.3	29.3	30.6	23.8
No Fiber	30.3	23.1	28.2	27.9	22.2
	*	NS	NS	NS	*
Urea (46-0-0)	32.0	23.8	28.7	29.0	22.5
IBDU (32-0-0)	30.9	23.8	28.7	29.3	22.1
Lebanon 13-25-12	32.0	25.5	28.6	30.5	24.2
SCU (32-0-0)	30.4	22.5	28.5	29.5	22.9
Nutri-Plus (10-3-4)	30.7	23.4	28.4	28.9	23.8
Milorganite (6-2-0)	31.0	23.0	28.6	28.1	22.5
LSD at 0.05 α	NS	NS	NS	NS	NS

[1]Shears given in Newton meters (Nm).
* Significant at 0.05 level.

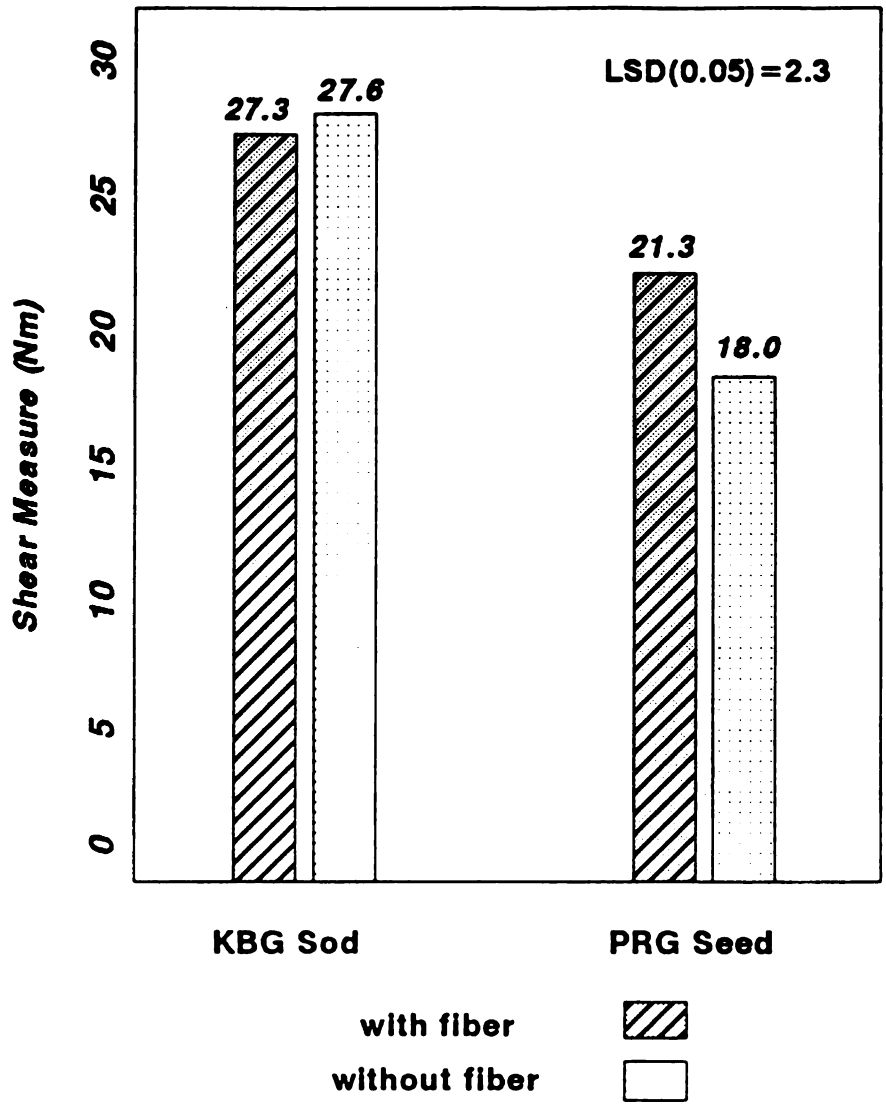

Figure 1.7: The effect of establishment method X fiber interaction on trafficked turfgrass shear resistance, 17 Sept. 1993.

Conclusions

The establishment phase of athletic fields, especially high sand based rootzone systems like PAT, is critical to their success. If established hastily and improperly these fields will likely fail due to poor and unsafe playing conditions. Sod establishment with washed KBG proved to be the more beneficial establishment method compared to seeding with PRG. Washed Kentucky bluegrass sod provided significantly higher color and quality ratings. The washed KBG sod receiving traffic had a 12% higher average density and 26% higher average shear measure relative to the seeded perennial ryegrass (also trafficked) over the 1993 growing season. When placed on the soil surface prior to establishment, VHAF treatments provided higher shear and quality measures in limited evaluations and at no time were detrimental. Polypropylene fibers (VHAF) added significant improvements to quality late in the study (after approximately 42 simulated games). An interesting observation was noted between shear vane measures and root weight densities. Literature indicates that higher root weight densities would correlate to higher shear vane measures (Adams et al., 1985) but rather the opposite was noted. Although the perennial ryegrass seed had higher root weight densities compared to the washed Kentucky bluegrass sod the shear vane measures were significantly higher for the washed Kentucky bluegrass sod. Shear vane measures with the Eijkelkamp apparatus are not necessarily an indication of root development but rather a measure of components which make up the turf system. These components include the mat and thatch layers, soil , water and air. Lastly, complete fertilizers, those having N, P, and K provided significantly higher color, density, and quality ratings. Some of the slow release and single nutrient carriers, if used, should be applied at higher rates in combination with soluble N sources to be effective during the establishment phase for sand based athletic fields.

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CHAPTER TWO

Nitrogen and Potassium Fertility of a Sand Based Rootzone Athletic Turf

ABSTRACT

Turfgrasses are dependent on nitrogen (N) and potassium (K) for their livelihood. The availability of N and K is a necessity for a turfgrass to function properly. Because nitrogen and potassium can readily leach in sandy soils (e.g. sand based athletic fields), monitoring of these nutrients at such sites is highly recommended. When N and K are made available, the concern becomes at what ratio should they be applied. Fertilizer treatments having higher amounts of nitrogen and potassium had significantly higher color ratings compared to lower levels. Turf quality and density ratings were also enhanced for those treatments where higher rates of nitrogen and potassium were applied. None of the treatments proved better in terms of shear vane measures (rotational force). The treatment receiving the highest amount of N (441 kg/ha) obtained the highest quality ratings yet did not provide high shear measures. As traffic simulation continued shear vane measures dropped for all treatments through the course of the study. Due to its growth habit, perennial ryegrass (*Lolium perenne*) has very little to no thatch and poor recuperative ability. Depending on soil conditions, the magnitude of nutrient output can substantially influence fertilizer requirements. They must also be applied more frequently and at environmentally appropriate levels.

Nitrogen and Potassium Fertility of a Sand Based Rootzone Athletic Turf

Introduction

Sand based fields are increasingly being used throughout the U.S. They provide for adequate drainage and maximum turf plant rooting. *Lolium perenne* grown on rootzones of pure sand or rootzone mixtures exceeding 90% sand gave the greatest wear tolerance under intensive wear compared to soil media having less than 90% sand (Baker and Isaac, 1987). Two drawbacks of athletic fields having sand rootzone mixes is their limited stability and low cation exchange capacities (CEC) (Gibbs, 1990). Sands do not hold nutrients readily, particularly nitrogen and potassium. Nitrogen (N) and potassium (K) are essential nutrients for turf plant survival. Some of the major turfgrass effects attributed to nitrogen include: shoot growth, shoot density, color, heat and cold tolerance, drought hardiness, wear tolerance, and disease proneness (Beard, 1984). Potassium regulates turf plant water relations, heat/cold/frost resistance, wear tolerance and rooting (Beard, 1973).

In greenhouse experiments, Waddington et al. (1994) compared sand and soil media and found macro and micronutrient deficiencies in *Lolium perenne* were more evident with sand. Cockerham et al. (1991) recognized that turf species having minimal thatch accumulation are more susceptible to traffic. Due to its bunch-type growth habit, *Lolium perenne* produces less thatch than rhizomatous grasses such as Kentucky bluegrass (*Poa pratensis*).

Canaway (1989) emphasized that permeable sand rootzones are usually lacking in nitrogen and contain low levels of other nutrients required for turfgrass establishment and growth. Considerable research has been conducted on N fertility as it relates to sand rootzone turf maintenance. The bulk of that work has dealt with sand based putting greens. Lodge et al. (1991), in research on sand based golf greens, found that with increasing N application rates, the cover of *Agrostis spp.* increased and that of *Festuca rubra* declined. Davidson and Hummel (1990) found that applications of low rates of Mn increased growth and quality of creeping bentgrass grown on acidic and calcareous sands. They also reported that turf growth and quality also increased when the N rate was 340 g N/m^2/year. Research conducted by Canaway (1985) indicated that *Lolium perenne* fresh weight, dry weight, moisture content and tiller numbers all increased with increasing nitrogen. Shearman (1988) suggested that increased moisture content of turf may contribute to poorer wear and tolerance of turf receiving high levels of N. He concluded that turfgrass wear tolerance increases with increasing plant maturity and that wear tolerance increases with N nutrition until it results in succulent growth.

The target value for N fertilization to maintain maximum turfgrass cover during wear as indicated by Canaway (1985) should be 225 kg/ha/yr. Clement et al. (1978) reported on the relationship of NO_3 concentration in flowing nutrient solution on *Lolium perenne*. At nitrate levels between 1000 and 2000 mg N/L there was a marked reduction in root length and tensile strength. The effect of traffic also affects the amount of nitrogen required for plant maintenance. Turf receiving high N levels deteriorates under traffic at a greater rate than turf receiving an intermediate level of N (Canaway and Hacker, 1988).

Without adequate levels of potassium, the health and recuperative potential of sports turf is severely reduced. Carroll et al. (1994) found that an increased Kentucky bluegrass (*Poa pratensis*) potassium tissue concentration appears to have a small but positive influence on leaf turgor and thus accumulation of solutes. Fry et al. (1989) said potassium had no effect on visual quality of creeping bentgrass on a sand medium. The amounts of K are not as apparent as that of N. Isaac and Canaway (1987) had conflicting reports on K amounts which may be due to modern use of free-draining sand-based rootzones for golf greens, from which potassium is readily leached. For this reason it is suggested that on sandy media to apply K in light, frequent applications, but only if the crowns are below the thatch (Shearman, 1988). He suggested that along with the K fertility applications, other good cultural practices and traffic-control procedures can help reduce immediate and chronic/long-term turf injury.

It is important to understand the intricate balance and interrelation of the entire plant growth process (Freeborg & Daniel 1985). Christians et al. (1981) found that effects of K on the quality and growth of Kentucky bluegrass (KBG) depend on the levels of the other applied nutrients. They also showed a positive growth response to K at lower N levels and a negative response to K at high levels of N. Lodge et. al. (1990) compared red fescue and creeping bentgrass on a sand rootzone with three levels of N-P-K. Perennial ryegrass (*Lolium perenne*) growing on a sand rootzone responded to N and K with nitrogen increasing the traffic tolerance of the top growth at the expense of root growth. Cockerham et al. (1994) reported a significant improvement in turfgrass rooting when K was applied with the nitrogen . Reactions and relationships other than between nitrogen and potassium have also been documented. Colclough and Canaway (1989) cited that ground cover and botanical composition were affected by the interaction of phosphorus and nitrogen. And lastly Yust et al. (1984) found that combining Fe and N can result in acceptable turfgrass color with lower rates of N.

Athletic field performance is dependent on the audience evaluating the field: fans, players, media etc. Turf managers, especially at higher levels of competition, are under the most scrutiny. Canaway and Baker (1993) indicated that plant factors affecting playing quality include turfgrass species, cultivar, biomass, density, ground cover, height of cut, and root biomass.

The objective of the study was to determine the effects of nitrogen and potassium rates and ratios on turfgrass color, quality and overall stability of a sand based athletic field.

Materials & Methods

A study began September 1993 at the Hancock Turfgrass Research Center (HTRC) on the campus of Michigan State University in which nitrogen and potassium fertilizers were applied to a one year old perennial ryegrass (*Lolium perenne*) grown on a sand based athletic field. The perennial ryegrass was a blend consisting of; *Dandy*, *Delray*, and *Target* cultivars (all in equal percentages) that had been seeded 14 August 1992 at 240 kg seed/ha. The experiment was conducted as a completely randomized design. Plot sizes measured 4.6 m by 3 m. The fertilizer products used in the study were; Anderson's (Maumee, OH) Nutralene (40-0-0); Turfgrass Greens and Tees Fertilizer (South Lyon, MI) (25-0-25); and soluble potash (0-0-60). The N sources in Nutralene were: 14.5% WIN, 5.0% urea N, and 20.5% slowly available WSN. The Greens and Tees fertilizer contained 17.6% urea N and 7.4% NO_3 and 25% soluble K_2O. The treatments were nitrogen/potassium ratios typical of common fertility programs used on athletic fields as shown in Table 2.1.

Table 2.1. Total N and K_2O applied, Sept.-Nov. 1993, May-Nov. 1994.

Fertilizer Treatment		kg/ha/1993 N	kg/ha/1993 K_2O	kg/ha/1994 N	kg/ha/1994 K_2O
1	0.5X/0	98	0	147	0
2	0.5X/0.5Y	98	98	147	147
3	0.5X/Y	98	196	147	294
4	X/Y (control)	196	196	294	294
5	X/1.5Y	196	294	294	441
6	1.5X/0.5Y	294	98	441	147

X=Nitrogen
Y=Potassium (K_2O)

Since the study began Fall 1993 and only 3 fertilizer applications were made a minimal amount of data was collected in 1993. Fertilizer applications were made on 2 Sept., 4 Oct., and 28 Oct. 1993. The rates were divided into equal applications reflective of the total amount applied for the year (1993). This same distribution was again followed for 1994. Six applications were made in 1994 on 5 May, 2 June, 5 July, 8 Aug., 2 Sept., and 6 Oct.. Treatments were watered in with overhead irrigation for approximately 5 minutes following application. Wear treatments were applied using the Brinkman Traffic Simulator (BTS) (Cockerham and Brinkman, 1989) beginning 2 September 1994. In two passes at an average of 14 cleats per square foot per roller, the BTS makes 56 cleat dents per square foot, the equivalent of one football game within the Zone of Traffic Concentration (ZOTC), (Cockerham and Brinkman, 1989). The BTS weighs 450 kg and was pulled by a John Deere 5100 tractor as discussed in Chapter 1. Traffic simulation was conducted from 28 Aug. through 16 Nov. 1993 for a total of 46 simulated games and from 2 Sept. to 9 Nov. at which time approximately 42 games had been simulated.

Data collected included turfgrass color, density, quality, traction, tissue analysis, clipping yields, root biomass, and susceptibility to red thread (*Laetisaria fuciformis*). Color was rated on the same scale as that presented in chapter 1 as well as density, quality, root biomass and tissue analysis. Traction was measured with the Eijkelkamp shear-vane (Chapter 1). Means of three measurements per plot were recorded and are given in Newton-meters (Nm). Clipping yields were collected from an area approximately 1.8 m^2 (19 ft^2), dried at 55°C, and weighed for yield measurements for the growth periods of 30 May to 2 June, 30 June to 5 July, and 30 July to 5 August. Tissue analysis was conducted as explained in Chapter 1. Total nitrogen was determined using the Kheldahl procedure (Schuman et al., 1973). Red thread (*Laetisaria fuciformis*) development became apparent in June 1994 and was measured visually by recording the number of infected areas per plot (14 m^2). Treatment means for all data collected were statistically compared through use of ANOVA analysis with LSD values at the $P=0.05$ level.

Results and Discussion

Color

Color ratings were conducted in Fall only, due to the simulation of wear and correlation of typical athletic field use periods (i.e. football/soccer seasons). Minimum acceptable color rating was 5. Color differences were significant among the fertilizer treatments for all dates in both 1993 and 1994 (Table 2.2). In 1993 significant color differences were noted as N amounts increased. Treatments receiving 0.5X annually had lower color ratings than the X and 1.5X treatments. There were no significant differences between the X and 1.5X treatments as color ratings were quite similar between the two. All three of the treatments having 0.5X showed significant color differences compared to the other treatments in 1993. Color ratings were higher for increased K amounts for all but one date (1 Oct.). Only the treatments receiving no potassium suffered a significant color loss. Results in 1994 provided a positive relationship between N rate and color. The 1.5X (441 kg N/ha/year) treatment received the highest color ratings for all dates and yet the control received acceptable color ratings. No significant difference were recognized for treatments having the same nitrogen amounts but different levels of potassium. The treatment receiving no potassium rated much better in 1994 than in 1993. Turfgrass color responses followed the nitrogen applied. Comparisons between different potassium levels at similar N levels showed little difference in turfgrass color in 1994.

Table 2.2: The effect of nitrogen and potassium fertility on trafficked perennial ryegrass color[1].

1993	Date			
Treatment	13 Sept.	20 Sept.	1 Oct.	16 Nov.
0.5X/0	5.5	5.3	4.8	4.3
0.5X/0.5Y	6.5	6.3	6.3	5.8
0.5X/Y	6.8	7.0	6.0	6.0
X*/Y (control)	8.5	8.5	8.0	8.3
X/1.5Y	8.5	8.5	8.5	8.3
1.5X/0.5Y	8.5	8.5	8.0	8.5
LSD at 0.05 level	1.1	0.7	1.1	1.3
Games simulated	12	16	22	46

1994	Date										
Treatment	28 Aug.	2 Sept.	9 Sept.	16 Sept.	23 Sept.	30 Sept.	7 Oct.	13 Oct.	21 Oct.	28 Oct.	9 Nov.
0.5X/0	6.5	6.1	5.5	5.5	5.0	6.0	5.5	5.3	5.1	3.4	4.8
0.5X/0.5Y	6.1	5.3	5.9	5.6	4.6	5.4	5.5	4.8	4.9	4.0	4.5
0.5X/Y	5.9	5.3	5.5	4.9	4.4	5.1	5.1	4.5	4.3	3.5	4.3
X**/Y (control)	7.3	7.1	7.6	6.9	6.3	6.9	7.3	6.9	7.0	6.3	5.8
X/1.5Y	7.1	6.8	7.3	6.9	6.4	6.9	7.0	6.9	6.8	6.3	6.1
1.5X/0.5Y	8.1	7.8	7.6	8.0	8.1	8.3	8.3	8.9	8.3	7.8	8.4
LSD at 0.05 level	1.0	0.8	0.6	0.8	0.9	0.9	0.7	1.0	0.6	0.9	0.9
Games simulated	---	---	4	10	14	18	24	29	34	39	42

[1]Color scale 1-9; 1=brown, 9=dark green and 5 acceptable.
*1993, X=196 kg N/ha and Y=196 kg K_2O/ha
**1994, X=294 kg N/ha and Y=294 kg K_2O/ha

Quality

No quality ratings were collected in 1993. In 1994 quality ratings were conducted prior to and during traffic simulation (Table 2.3). Quality ratings were based on a both color and density. Throughout the study the treatment receiving the highest amount of N (1.5X) also received the highest quality ratings. Again, the control received acceptable ratings. This trend was recognized for all dates other than the April and early May ratings when the field was still recovering from winter damage. Higher quality ratings were associated with high N treatments. Nitrogen is critical to turfgrass color and density. Potassium is important to wear tolerance. Wear tolerance is a function of turf density, which K provides for. This explains the higher quality ratings given to treatments receiving greater N amounts. The importance of K fertility became apparent mid-way through traffic simulation (7 Oct.) at which point 24 games had been simulated. Potassium did not appear to improve quality ratings for treatments that were low in nitrogen content (0.5X).

Density

Density ratings were not collected in 1993. Similar trends were apparent for density as was seen with quality. Density ratings were conducted in the Fall 1994 and significant differences were noted among the treatments (Table 2.4). Potassium had little effect at low N levels. It is thought that N may have been limiting for these treatments since only three pounds had been applied through the course of the growing season. It was noted that when K is held steady and N is increased higher densities were obtained.

Table 2.3: The effect of nitrogen and potassium fertility on perennial ryegrass quality prior to and under trafficked conditions[1].

1994 (pre-traffic)	Date									
Treatment	19 Apr.	4 May	16 May	31 May	13 June	30 June	14 July	1 Aug.	16 Aug.	2 Sept.
0.5X/0	5.5	5.8	4.3	5.4	4.9	5.6	5.8	5.4	7.4	5.5
0.5X/0.5Y	4.6	4.5	4.5	5.9	5.5	5.6	5.9	5.6	7.0	4.8
0.5X/Y	4.0	3.8	4.6	5.6	5.3	5.5	6.1	5.8	7.1	5.3
X**/Y (control)	4.0	3.9	5.8	6.0	7.1	6.6	7.1	6.6	7.8	7.0
X/1.5Y	4.4	4.6	5.8	6.4	7.0	6.6	7.1	7.1	7.8	7.0
1.5X/0.5Y	6.4	7.3	7.4	7.1	8.5	7.3	8.1	7.9	8.4	8.4
LSD at 0.05 level	NS[2]	NS	1.1	1.0	1.2	0.9	0.7	0.8	1.1	1.0

1994 (traffic)	Date								
Treatment	9 Sept.	16 Sept.	23 Sept.	30 Sept.	7 Oct.	13 Oct.	21 Oct.	28 Oct.	9 Nov.
0.5X/0	6.0	5.3	5.0	5.0	5.0	4.4	3.8	4.3	3.9
0.5X/0.5Y	6.5	5.3	4.8	4.8	5.0	5.1	4.1	4.4	4.9
0.5X/Y	6.0	5.0	4.4	4.0	4.4	4.8	3.8	3.6	4.4
X**/Y (control)	7.1	6.6	6.6	6.6	7.0	6.5	6.0	6.1	5.9
X/1.5Y	6.9	6.5	6.6	6.4	6.8	6.4	6.1	6.3	6.3
1.5X/0.5Y	8.1	7.9	8.0	8.0	7.3	6.9	7.0	6.4	6.6
LSD at 0.05 level	0.8	1.0	0.9	0.8	1.2	1.3	1.0	0.8	1.0
Games simulated	4	10	14	18	24	29	34	39	42

[1]Quality rating 1-9; 1=bare ground, 9=ideal turf and 5 acceptable.
**1994, X=294 kg N/ha and Y=294 kg K_2O/ha
[2]NS=Not significant at 0.05 alpha level.

Table 2.4: The effect of nitrogen and potassium fertility on trafficked perennial ryegrass density[1].

1994	Date								
Treatment	9 Sept.	16 Sept.	23 Sept.	30 Sept.	7 Oct.	13 Oct.	21 Oct.	28 Oct.	9 Nov.
0.5X/0	83	68	59	54	47	43	46	42	34
0.5X/0.5Y	87	67	61	56	49	42	54	44	36
0.5X/Y	85	54	52	46	42	39	54	40	33
X**/Y (control)	92	79	76	71	66	62	78	71	58
X/1.5Y	92	78	74	69	69	67	80	70	62
1.5X/0.5Y	97	90	86	85	80	70	88	79	74
LSD at 0.05 level	5	14	11	12	14	15	13	11	13
Games simulated	4	10	14	18	24	29	34	39	42

[1]Density rating % coverage, 0-100.
**1994, X=294 kg N/ha and Y=294 kg K_2O/ha

Shear Measures

In 1993 shear measures were collected on three dates (Table 2.5) for both trafficked and non-trafficked treatments. No noticeable shear differences were noted in 1993. For 1994 there were no significant shear differences observed on trafficked areas among fertilizer treatments for all dates (Table 2.6). Perennial ryegrass has a bunch-type growth habit and a minimal thatch layer. The combination of growth habit and very low thatch levels likely explains the low shears recorded.

Treatments not receiving traffic did show significant shear differences on 6 of 9 fall rating dates in 1994. Potassium did not appear to be the nutrient that caused the shear measure differences but rather nitrogen. Shears were lowest for the treatments receiving the highest N. The 1.5X treatment left the turf extremely succulent which explains the lower shear values. The control provided adequate shears as well as the 0.5X treatment in combination with Y (294 kg K_2O/ha/year) (Table 2.6).

Tissue Analysis

Plant tissue analysis was conducted in the months of June, July, and August 1994. Nutrients which exhibited significant differences across fertilizer treatments are given in Table 2.7. Significant N differences were noted in June and July. Significant differences in potassium levels were noted in June but not in July and August. A possible explanation for this is that the cool-season turf plant grows at slower rate in the months of July and August. Plant uptake in these months is lower than spring and fall periods due to lower root respiration rates (Beard, 1973). Other

Table 2.5: The effect of nitrogen and potassium fertility on 1993 perennial ryegrass shear measures[1].

Treatment	Traffic			Non-Traffic		
	20 Sept.	1 Oct.	11 Oct.	20 Sept.	1 Oct.	11 Oct.
0.5X/0	22.6	17.1	19.9	19.9	20.1	19.1
0.5X/0.5Y	20.4	18.9	21.9	19.6	19.1	19.3
0.5X/Y	22.6	20.3	18.5	18.9	19.6	18.4
X*/Y (control)	20.9	21.5	17.1	19.8	19.1	18.9
X/1.5Y	21.8	19.6	19.0	19.4	18.6	16.3
1.5X/0.5Y	22.5	17.4	18.9	20.1	19.1	17.9
LSD at 0.05 level	NS	NS	NS	NS	NS	NS
Games simulated	16	22	28	16	22	28

[1]Shears given in Newton meters, Nm.
*1993, X=196 kg N/ha and Y=196 kg K_2O/ha

Table 2.6: The effect of nitrogen and potassium fertility on 1994 perennial ryegrass shear measures[1].

Traffic

Treatment	9 Sept.	16 Sept.	23 Sept.	30 Sept.	7 Oct.	13 Oct.	21 Oct.	28 Oct.	9 Nov.
0.5X/0	13.4	13.0	12.1	14.8	14.0	14.8	14.1	12.5	11.1
0.5X/0.5Y	12.8	12.9	13.2	14.9	14.0	14.0	14.3	13.9	13.0
0.5X/Y	12.9	13.6	12.4	14.7	13.6	12.9	12.9	13.0	12.9
X**/Y (control)	13.6	12.3	13.7	12.8	13.2	13.9	13.5	13.9	12.8
X/1.5Y	13.5	13.3	12.4	13.4	14.1	14.0	13.2	12.7	12.0
1.5X/0.5Y	13.2	13.1	10.7	13.8	13.5	14.2	12.7	12.7	9.9
LSD at 0.05 level	NS[2]	NS	NS	NS	NS	NS	NS	NS	NS
Games simulated	4	10	14	18	24	29	34	39	42

Non-traffic

Treatment	9 Sept.	16 Sept.	23 Sept.	30 Sept.	7 Oct.	13 Oct.	21 Oct.	28 Oct.	9 Nov.
0.5X/0	16.3	17.9	16.3	18.3	19.4	20.4	19.8	23.7	25.5
0.5X/0.5Y	15.7	17.8	17.0	18.7	19.2	19.4	18.9	23.6	23.4
0.5X/Y	16.8	18.0	16.7	19.0	19.0	20.0	20.0	24.3	24.3
X**/Y (control)	16.4	17.2	16.6	17.7	18.3	19.9	19.8	22.6	24.5
X/1.5Y	16.6	17.3	15.8	17.2	18.8	20.1	19.4	22.0	23.5
1.5X/0.5Y	13.7	15.0	14.2	17.6	17.2	18.1	17.4	20.5	20.3
LSD at 0.05 level	1.5	1.5	1.2	NS	NS	NS	1.4	1.7	2.1

[1]Shears given in Newton meters Nm.
**1994, X=294 kg N/ha and Y=294 kg K_2O/ha
[2]NS=Not significant at 0.05 alpha level.

Table 2.7: The effect of nitrogen and potassium fertility on perennial ryegrass tissue nutrients.

Month 1994	June					July				August				
Treatment	N	B	Mn	Mo	K	N	Cu	Ca	Mo	N	Zn	Fe	Cu	Ca
0.5X/0	3.0	6.9	49.4	5.7	22281	3.2	13.1	6646	5.8	3.7	33.8	121	15.0	4815
0.5X/0.5Y	2.7	5.3	45.4	5.2	23516	3.0	13.9	5692	5.1	3.5	34.3	100	16.5	4738
0.5X/Y	2.2	8.2	49.1	5.4	24042	3.2	14.5	5724	5.3	3.5	35.2	98	16.9	4427
X**/Y (control)	3.0	5.4	33.6	4.7	24525	3.5	14.6	4981	4.4	3.6	44.6	101	18.6	4058
X/1.5Y	3.1	4.8	27.1	4.3	25128	3.8	14.2	4801	4.3	4.1	44.9	97	18.1	3760
1.5X/0.5Y	4.2	4.9	28.6	5.3	27843	4.3	10.4	4241	4.3	3.9	36.4	133	14.1	5122
LSD at 0.05 level	0.8	2.3	17.6	0.8	2464	0.5	0.9	1019	0.9	NS[z]	4.2	23	1.6	582

Nutrient levels expressed in parts per million (ppm)
**1994, X=294 kg N/ha and Y=294 kg K_2O/ha
[z]NS=Not significant at 0.05 alpha level.

nutrients that exhibited differences included molybdenum, copper, and calcium.

Clipping Yields

Clipping yields were taken 2 June, 5 July, and 5 August. As expected treatments receiving the highest N amount had the greatest amount of clippings (Table 2.8). Both the X and 0.5X treatments had correspondingly lower yields, respectively. Potassium levels did not indicate any apparent trends.

Root Biomass

No significant differences were noted although a trend was recognized. Observations showed that treatments having 0.5X/0 and 0.5X/0.5Y treatments had higher root biomass than higher K amount treatments (Table 2.9).

Red Thread

The data presented in Table 2.10 reconfirms previous research. Perennial ryegrass is known to be quite susceptible to red thread (*Laetisaria fuciformis*), particularly on nitrogen deficient turfs (Smiley, 1983). Although no significant red thread differences were observed, it was noted that treatments receiving lower N amounts had higher incidents of red thread presence.

Conclusions

Nitrogen (N) and potassium (K) are extremely important for turfgrass survival. Fertilizer treatments having higher amounts of nitrogen and potassium had

Table 2.8: The effect of nitrogen and potassium fertility on perennial ryegrass clipping yields[1].

Treatment	1994		
	June	July	August
0.5X/0	5.8	19.3	15.5
0.5X/0.5Y	8.3	25.4	17.2
0.5X/Y	11.3	31.9	13.9
X**/Y (control)	15.2	36.6	31.3
X/1.5Y	15.0	48.3	23.4
1.5X/0.5Y	32.1	52.4	32.2
LSD at 0.05 level	11.5	11.5	5.5
# days growth	5	10	7

[1] Clipping yields given in g/m^2.

**1994, X=294 kg N/ha and Y=294 kg K_2O/ha

Table 2.9: Root biomass[1] for respective fertility treatments in Nov. 1994.

Treatment	Sample Depth	
	0-5cm	5-10cm
0.5X/0	4.8	2.2
0.5X/0.5Y	4.3	2.1
0.5X/Y	2.9	1.5
X**/Y (control)	4.0	1.1
X/1.5Y	3.3	1.5
1.5X/0.5Y	2.7	1.6
LSD at 0.05 α	NS	NS

[1] Root biomasses given in g/L of soil.
**1994, X=294 kg N/ha and Y=294 kg K_2O/ha
NS: No significant differences.

Table 2.10: The effect of nitrogen and potassium fertility on red thread (*Laetisaria fuciformis*) susceptibility in perennial ryegrass.

1994	Date					
	30 June	14 July	1 Aug.	16 Aug.	26 Aug.	2 Sept.
Treatment	infected areas per $14m^2$					
0.5X/0	2.5	1.3	1.8	1.3	2.8	1.8
0.5X/0.5Y	2.3	2.3	2.8	2.0	3.3	3.3
0.5X/Y	1.8	1.5	1.5	1.3	3.5	2.5
X**/Y (control)	0.3	0.3	0.3	0.0	1.8	0.5
X/1.5Y	0.3	0.0	0.0	0.0	0.0	0.0
1.5X/0.5Y	0.0	0.0	0.0	0.0	0.0	0.0
LSD at 0.05 α	NS[1]	NS	NS	NS	NS	NS

[1]NS = Not significant at 0.05 alpha level.
**1994, X = 294 kg N/ha and Y = 294 kg K_2O/ha

significantly higher color ratings compared to lower levels. Turf quality and density were also enhanced for those treatments containing more nitrogen and potassium. No treatment proved better than another in terms of shear vane measures (rotational force). The treatment receiving the highest amount of N (441 kg N/ha/year) obtained the highest quality ratings yet did not provide high shear measures. As traffic simulation continued, shear vane measures dropped for all treatments through the course of the study but no differences among fertility regimes were detected. Due to its growth habit, perennial ryegrass has very little to no thatch and poor recuperative ability. Tissue analysis indicated a significant potassium difference amongst treatments for only one of three months. Overall, the control (X/Y) provided the best turf conditions. Nitrogen appeared to be more of a controlling factor than potassium based upon low quality ratings for those treatments low in nitrogen but having moderate levels of potassium. Depending on soil conditions, the magnitude of nutrient output can substantially influence fertilizer requirements. Nitrogen and potassium are readily leached in sandy soils (Turgeon, 1991), and for this reason these nutrients should be monitored either by tissue or soil testing. They must also be applied more frequently and at environmentally appropriate levels.

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CHAPTER THREE

Sod Strategies for Establishing Athletic Turf with Sand Based Rootzones

ABSTRACT

Sodding is the preferred establishment method for newly constructed sports fields with sand based rootzones. This method of establishment is done primarily to assure availability for use due to time constraints. Numerous grass species and sod types are currently available for cool season sites. The need to determine which of these sod species performs best for sand based athletic field establishment was needed. A study was conducted at Michigan State University's Hancock Turfgrass Research Center in which different sod types were evaluated when established on a sand-base athletic research field and subsequent athletic type traffic simulated. The Kentucky bluegrass (KBG), *Poa pratensis*, blend/perennial ryegrass (PRG), *Lolium perenne*, blend sod treatment grown initially on plastic performed significantly better than other sod treatments when established on the research field. The *Poa supina* sod treatment reared on plastic had lower quality ratings within the first two months of the study but maintained adequate quality ratings as traffic simulation continued. The washed KBG blend had the lowest quality ratings in months of October and November. Shear vane measures were highest for the KBG/PRG sod mix treatment followed by the KBG blend grown on plastic. Application of the plant growth regulator (PGR) trinexapac-ethyl one week after sodding improved both color and quality with the added benefit of reduced mowing. Density ratings were also higher for PGR treatments as the plant growth regulator promoted lateral topgrowth.

Sod Strategies for Establishing Athletic Turf with Sand Based Rootzones

Introduction

Public and athlete attitudes are shifting the use of artificial turf surfaces for athletic fields back towards the use of natural turfgrass (Cockerham, 1989; Canaway, 1990). Newly constructed athletic fields, as discussed in Chapter 1 are making use of sand based root mixtures. These fields are often used intensely and when renovation is needed are commonly sodded for quick availability. Following two years of research at Michigan State University's Hancock Turfgrass Research Center (HTRC), data indicated significantly higher color, density, quality, and shear vane measurements for the washed Kentucky bluegrass establishment method compared to the perennial ryegrass seeding establishment method for sand based athletic fields. That study confirmed the importance of sod establishment particularly if the turf is subjected to heavy use in its first year, which typically is the case.

Different sod types, particularly in regard to how they are raised and on what medium, influences the extent of subsequent rooting. Earlier studies indicated that sod grown on organic soil rooted better than that grown on mineral soil (King and Beard, 1969). Recently, soil-less sods are being made available to the consumer. Davis and Pratt (1982) determined that rooting from a washed sod was more than twice that of the unwashed sod averaged across different growing media. Washed sod also had reduced surface hardness and better lateral shear strength than unwashed sod (Casimaty et al., 1993). Washed sods also provided more favorable water infiltration rates. Sods, in general, are more strongly knitted than seeded turf areas. Beard (1973) defines this "knitting" as the inter-twining of rhizomes, stolons, and/or roots. The more strongly knit a sod is, the less likely it is to tear if harvested and replanted. Root initiation and mass are two factors that influence the overall traffic tolerance of sod. Ross et al. (1991) determined that sod tearing strength was related to the mass and orientation of roots. Their research indicated that two *Poa* cultivars had higher sod tearing strengths followed by *Festuca, Lolium,* and *Agrostis* cultivars. Recent developments have allowed for turf to be reared on soil-less mediums, most notably compost that is placed on top of plastic sheeting. These types of sods have shown greater root mass binding as well as quicker rooting (Decker, 1989). Sods grown in that manner also save valuable topsoil.

Typical sod species used on athletic fields in cool-season climates include Kentucky bluegrass and perennial ryegrass. Gaussoin (1994) indicated that grasses with tougher leaves and wider leaf blades are more wear resistant and that rhizomatous and stoloniferous grasses recuperate quicker than bunch grasses. Another turfgrass used on athletic fields in cool season regions, particularly Northern Europe, is *Poa supina*. *P. supina* was discovered in the Alps and a German plant breeder developed the cultivar 'Supranova' (Lundell, 1994). Although its vertical growth is slow, it is quite wear tolerant. Mixes containing up to 20% *P. supina* produce excellent results on athletic field when mixed with species of similar color (Lundell, 1994). *P. supina* also prefers moist to very moist soils (Köck and Walch, 1977). Its use within the United States is minimal due to the fact that other, more desirable, turf species are available. It has been used in small amounts at various locations around the country (Mrock, 1995). Besides its high seed cost, which is the result of minimal breeding work, *Poa supina* has a very light green color relative to Kentucky bluegrass and perennial ryegrass species. One advantage of *Poa supina* is a strong stoloniferous growth habit. Athletic field managers residing in colder regions lack a turf species of such a growth habit and for this reason *Poa supina* may show promise in gaining acceptance in cool-season grass regions of the United States.

Plant growth regulators (PGRs) came into use in the 1950s in attempts to minimize labor by reducing time required to mow turf settings on a daily basis. In some cases mowing has been reduced by as much as 50% (Harlow, 1994). Mowing can be extremely difficult to conduct on a newly harvested sod because rooting is not immediate. Although there is a risk of some phytotoxicity, PGRs have been shown to improve turfgrass quality and enhance uptake efficiency for most macro-elements and some micro-elements at lower fertility levels (Yan et al., 1993). PGRs are typically classified into one of two types. Type I PGRs, such as paclobutrazol and flurprimidol, work by blocking the plant hormone gibberellic acid. Type II PGRs inhibit growth as well as suppress seed head development (e.g. mefluidide) (Harlow, 1994). The most recent PGR now on the market is trinexapac-ethyl and with it another classification group. So now PGRs may be classified into one of three classes. Class A PGRs interfere with gibberellic production (e.g. trinexapac-ethyl). Class B PGRs also disrupt gibberellin productivity but earlier in the biosynthetic pathway compared to Class A growth regulators. Paclobutrazol and flurprimidol are examples of class B PGRs. And Class C plant growth regulators are mitiotic inhibitors. Class C PGRs work by preventing cell division which provides excellent seed head control. Mefluidide is an example of a Class C PGR (Watschke and DiPaola, 1995).

Literature indicated that minimal research in using PGRs to improve sod rooting and strength has been conducted. However, the research that has been done in this area shows that PGRs can be of definite benefit. Brown and White (1974) illustrated that *Poa pratensis* var. 'Baron' treated with growth regulator and supplemental potassium produced twice the root growth compared to grass treated with growth regulators. Within the past two years Hall and Bingham (1993) demonstrated that certain growth regulators had no negative impact on sod strength or sod installation rooting. Research done by Elam (1993) indicated that cimetacarb (*Primo 2EC*), now known as trinexapac-ethyl, produced no significant differences in the dry root weight and thus no differences in root biomass. Johnson (1993) reported that trinexapac-ethyl injured centipedegrass (*Eremochloa ophiuroides*) aboveground parts and suppressed some seed head development.

Canaway and Baker (1993) stated that soil moisture content and water movement are key variables in determining playing quality of sports surfaces. They went on to say that aesthetic quality is measured by color, density, and uniformity with playing quality being measured by ball rebound, roll, traction, and hardness. The objective of this study was to evaluate and determine the most efficient sodding strategy for establishing a high quality sports turf in a sand based rootzone given the parameter that the field will be subjected to use shortly after establishment. The factors utilized in determining this included three sod species either as mixtures or monostands. The sod species used were also raised on differing mediums. The foliar absorbed PGR trinexapac-ethyl (*Primo*) was also used. The objective in using the PGR was to see how effective its use would be in slowing the growth of the sodded turfgrass so mowing would not be necessary and to determine if it would improve turfgrass color, density, wear tolerance, etc.

Materials & Methods

The experimental design of this study was a two factor strip-plot randomized complete block design (RCBD) with three replications. Plot size was 3 m X 6 m. Six sodding regimes comprised the first factor, and two levels of plant growth regulator (PGR) were stripped over the first factor. The sod treatments were; Kentucky bluegrass/ perennial ryegrass mixture grown on plastic, perennial ryegrass (PRG) blend grown on plastic, Kentucky bluegrass (KBG) blend grown on plastic, washed KBG blend, KBG blend grown on a Rensselaer soil series (Fine-loamy, mixed, mesic, typic Argiaquoll), and *Poa supina* grown on plastic. The sod treatments defined as being grown on plastic had a medium of yard waste compost in which to grow. The KBG treatments defined as grown on plastic had the following cultivars; *1757*, *Columbia*, *Trenton*, *New-Blue*, and *Rugby*. *Palmer II*, *Dandy*, and *Citation II* made up treatments having perennial ryegrass. The *Poa supina* treatment contained both *Supra* and *Supranova* varieties. Both the washed and mineral grown sod treatments contained the Kentucky bluegrass cultivars; *Aspen*, *Kelly*, *Midnight*, *Rugby*, and *Trenton*.

Starter fertilizer (Scott's 16-25-12 at a rate of 150 kg P/ha) was applied just prior to the laying of sod. Mineral grown sod treatments were laid 6 July 1994 and those treatments grown on plastic were laid 2 August. The sod treatments were laid on the same PAT field as described in Chapter 1. All sod treatments were rolled twice following laying using a Jacobsen Greens King triplex roller (Jacobsen Div. of Textron Inc., Racine, WI). PGR treatments were applied 9 August, one week after the last sod treatment was applied. Trinexapac-ethyl (*Primo*) was applied at labeled rates (0.4 kg a.i./ha).

The plot was topdressed on 16 August, 23 August, and 30 August using a Turfco machine powered topdresser (Turfco, St. Paul, MN). The 80 sand/20 peat mix was used for the topdressing applications to maintain a uniform soil profile thus preventing any layering problems. The sand component of the topdress medium was 60% (by weight) within the coarse-medium range, 20% in the fine sand range, and the remainder within the very coarse, fine, and silt size ranges. The rate of soil applied per topdressing was approximately 97 tons/ha. Sod treatments were initially hand watered to ensure viability, rooting, and prevent desiccation. On 22 August and 12 September, 18-3-18 was applied at a rate of 24 kg N/ha. 18-4-10 was put down at 24 kg N/ha rate on 6 October. A final fertilizer application consisting solely of soluble potash (0-0-50) was distributed 14 October at a 75 kg K_2O/ha rate.

Athletic field type traffic simulation began in late August and continued through early November using the Brinkman Traffic Simulator (BTS) as presented in Chapter 1. Data collected included turfgrass color, density, quality, root biomass, verdure, and traction. Color was rated on a weekly basis until 9 Nov. 1994. A scale of 1-9 was used: 1=brown, 9=dark green, and 5 was an acceptable color. Density was reported as stated in Chapter 1. Quality ratings were assigned on a scale of 1-9 and were based upon both color and density characteristics. Plant density was determined by recording the mean of above-ground plants from two plugs per plot. The mean is presented as the number of plants per 10 cm^2. Samples were collected 20 November using a golf course cup cutter having a cup diameter of 10.4 cm and were taken from trafficked plot areas only. One more plug was collected 16 December 1994 in order to determine root biomass. Root biomass was determined for 0-5 cm and 5-10 cm depths. Roots were separated from soil with the hydropneumatic elutriation system (Smucker et al., 1982). Traction was measured weekly from 2 Sept. to 9 Nov. on both trafficked and non-trafficked plots with a field shear vane apparatus as discussed in Chapter 2. Means of three measurements per plot were recorded and are given in Newton-meters (Nm). Treatment means for all data collected were statistically compared through use of ANOVA analysis with LSD values at the 0.05 alpha level.

Results & Discussion

Color

Turfgrass color was significantly higher for the KBG/PRG plastic grown and KBG mineral grown sod treatments (Table 3.1). Treatments receiving trinexapac-ethyl had significantly darker green color than treatments not receiving the PGR. Numerous interactions between the sod treatments and PGR factor took place. The interactions stemmed from some sod treatments responding more dramatically to the PGR than others. Trinexapac-ethyl enhanced color by an average of 0.7 across all sod treatments for dates when interactions took place (Table 3.2). The perennial ryegrass blend grown initially on plastic had less color response to the trinexapac-ethyl than did the plastic grown Kentucky bluegrass sod treatments. The *Poa supina* without PGR did not receive acceptable color ratings throughout the study. Although trinexapac-ethyl enhanced turfgrass color significantly there were some phytotoxic effects. These effects were recognized for approximately a two week period following its application in early August. The sod treatment X PGR interaction for 2 Sept. is shown in Figure 3.1. The phytotoxic symptoms of the *P. supina* sod treatment to the trinexapac-ethyl may have

Table 3.1: The effect of sod treatment and plant growth regulator on trafficked and non-trafficked turfgrass color[1].

1994	Date											
	8/19	8/26	9/2	9/9	9/16	9/23	9/30	10/7	10/13	10/21	10/28	11/9
Sod Treatment												
KBG/PRG mix grown on plastic	7.7	7.5	7.2	7.5	7.4	7.4	7.6	7.1	7.2	7.6	7.0	6.9
P. Ryegrass blend grown on plastic	7.2	7.3	6.8	7.3	7.6	7.5	7.5	6.1	6.0	6.7	7.2	6.0
KBG blend grown on plastic	6.7	6.7	6.5	6.9	6.6	6.8	6.7	7.1	7.1	6.9	6.1	5.6
Washed KBG blend	7.0	7.3	7.7	8.2	7.5	7.1	7.4	6.5	6.5	7.0	5.5	5.7
KBG blend grown on mineral soil	7.6	7.6	7.7	8.0	7.8	7.7	8.1	7.2	7.0	7.8	6.4	6.3
Poa supina grown on plastic	5.0	5.2	5.0	5.7	5.3	5.5	5.5	5.9	4.8	5.0	5.2	5.5
LSD at 0.05 level	0.4	0.5	0.3	0.5	1.1	0.9	1.0	NS	1.2	0.5	0.5	NS
PGR Treatment												
Trinexapac-ethyl	7.3	7.5	7.4	7.8	7.6	7.4	7.6	7.0	6.9	7.3	6.6	6.5
No trinexapac-ethyl	6.5	6.4	6.3	6.8	6.5	6.6	6.7	6.3	6.0	6.3	5.8	5.5
*=Significant at 0.05 level	*	*	*	*	*	*	*	*	*	*	*	*
Games simulated via Brinkman Simulator	---	---	---	4	10	16	16	18	20	20	22	24

[1]1-9 scale; 1=brown, 9=dark green and 5 acceptable.
NS=Not Significant

Table 3.2: The effect of sod treatment X plant growth regulator interaction on trafficked and non-trafficked turfgrass color[1].

1994	Date											
	8/19		8/26		9/2		10/13		10/21		10/28	
PGR Treatment	PGR	None	PGR	None	PGR	None	PGR	None	PGR	None	PGR	None
Sod Treatment												
KBG/PRG mix grown on plastic	8.8	6.7	8.2	6.8	8.0	6.3	7.5	6.8	8.2	7.0	7.4	6.6
P. Ryegrass blend grown on plastic	7.5	6.9	7.6	7.1	7.1	6.6	6.4	5.7	7.1	6.3	7.3	7.0
KBG blend grown on plastic	7.3	6.1	7.3	6.1	7.2	5.9	8.0	6.2	8.0	5.8	7.0	5.2
Washed KBG blend	6.8	7.2	7.6	6.8	8.3	7.2	6.8	6.3	7.3	6.8	5.6	5.5
KBG blend grown on mineral soil	7.8	7.4	8.3	6.8	8.5	6.9	7.3	6.8	8.1	7.5	6.7	6.1
Poa supina grown on plastic	5.4	4.7	5.7	4.7	5.4	4.7	5.3	4.3	5.4	4.7	5.7	4.7
LSD at 0.05 level	0.5		0.4		0.4		0.3		0.7		0.5	
Games simulated via Brinkman Simulator	---		---		---		20		20		22	

[1]1-9 scale; 1=brown, 9=dark green and 5 acceptable.

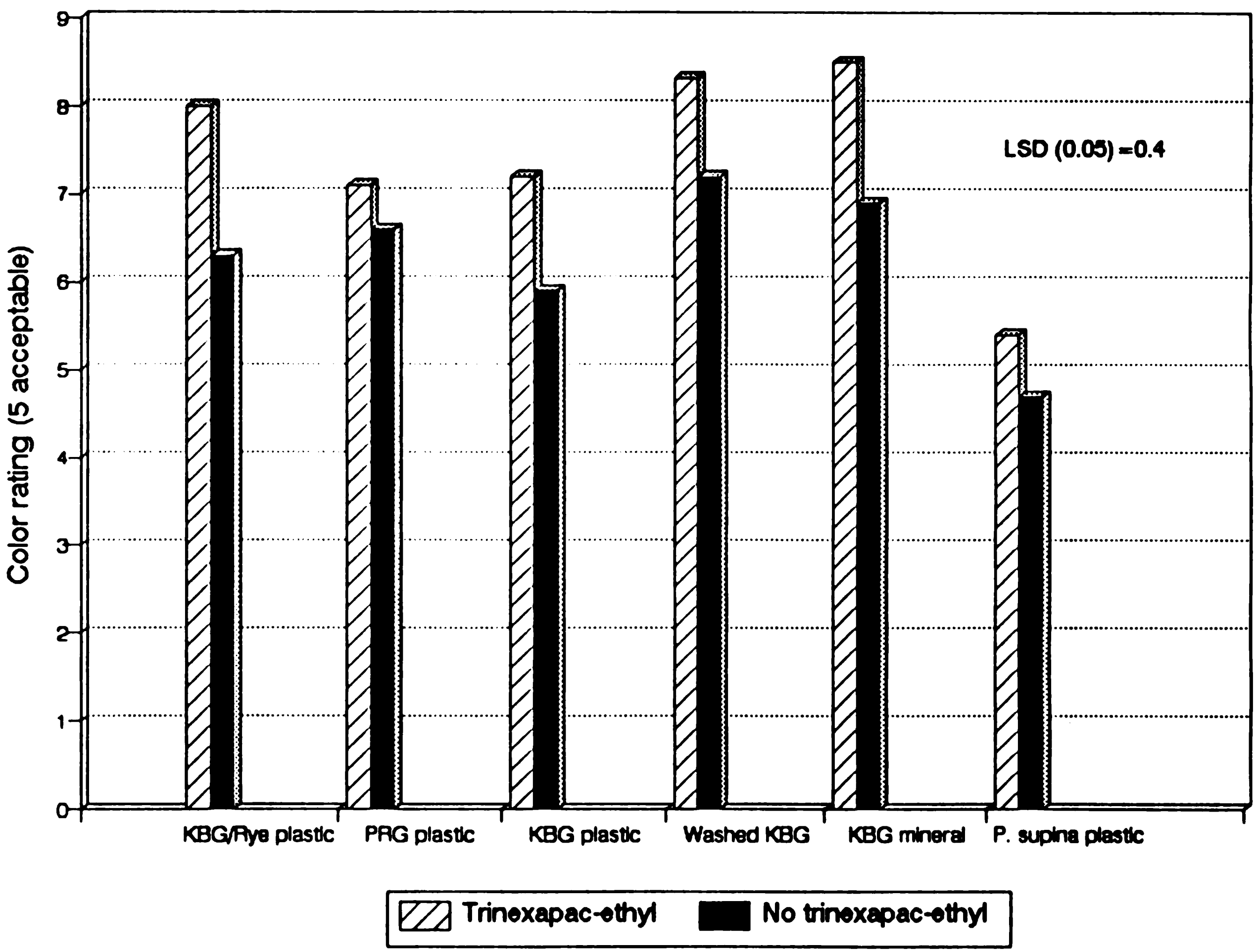

Figure 3.1: The effect of sod treatment X plant growth regulator interaction on non-trafficked turfgrass color, 2 Sept. 1994.

resulted because of its stoloniferous growth habit, which likely increased the amount of foliar absorbed PGR. Turfgrass color is relative and does not reflect turfgrass performance, yet the PGR did provide a darker green color thus improving aesthetics.

Density

Turfgrass densities were highest for *Poa pratensis* and *Poa supina* sod treatments grown on plastic (Table 3.3). This was likely due to the respective growth habits and the extensive root knitting of those treatments. Both the mineral grown and washed KBG blend sod treatments did not have the extensive root knitting which the plastic grown sod treatments possessed. The knitted root mass of the plastic grown sod treatments resulted in increased wear tolerance compared to the mineral grown sod treatments. PGR treatments received a slightly lower density rating prior to traffic initiation, but were significantly higher in density after traffic application began. Some phytotoxicity was evident for approximately a two week period after growth regulator application. This phytotoxic effect explains the initially low density ratings but the sod treatments recovered within two weeks. Although the effects of the PGR application were not as apparent by mid-September, the lateral growth allowed for higher densities after traffic simulation. This trend was consistent for all sod treatments.

Table 3.4 shows interactions between the sod and PGR factors. The largest differences in density were noted for the *P. supina* and the smallest for washed Kentucky bluegrass blend treatments. The sod treatment X PGR interactions occurred on; 19 Aug., 16 Sept., and 23 Sept., all of which were within the first month following the PGR application. The effect of the PGR after a months time was still noticeable but no sod

Table 3.3: The effect of sod treatment and plant growth regulator on trafficked and non-trafficked turfgrass density[1].

1994	Date												
	8/19	8/26	9/2	9/9	9/16	9/23	9/30	10/7	10/13	10/21	10/28	11/9	12/2
Sod Treatment													
KBG/PRG mix grown on plastic	99	99	99	96	94	89	89	89	88	90	87	88	88
P. Ryegrass blend grown on plastic	99	99	95	91	89	88	88	81	78	86	78	76	85
KBG blend grown on plastic	98	99	98	97	93	91	91	91	92	92	89	85	86
Washed KBG blend	88	92	93	92	88	80	84	71	74	77	68	69	75
KBG blend grown on mineral soil	94	97	96	94	92	82	86	78	79	83	76	75	83
Poa supina grown on plastic	92	95	97	96	91	89	90	82	82	88	78	78	79
LSD at 0.05 level	3	2	NS	3	NS	NS	6	9	7	9	10	12	NS
PGR Treatment													
Trinexapac-ethyl	94	96	96	96	93	89	91	84	84	88	81	81	85
No trinexapac-ethyl	94	98	96	93	89	84	85	80	80	84	78	76	81
* = Significant at 0.05 level	*	*	NS	*	*	*	*	*	*	*	*	*	*
Games simulated via Brinkman Simulator	---	---	---	4	10	16	16	18	20	20	22	24	24

[1] Density rating % coverage, 0-100.
NS = Not Significant

Table 3.4: The effect of sod treatment X plant growth regulator interaction on trafficked and non-trafficked turfgrass density[1].

1994	Date					
	8/19		9/16		9/23	
PGR Treatment	PGR	None	PGR	None	PGR	None
Sod Treatment						
KBG/PRG mix grown on plastic	99	99	96	92	91	87
Ryegrass blend grown on plastic	99	99	92	87	90	86
KBG blend grown on plastic	97	98	96	90	94	89
Washed KBG blend	87	88	89	89	82	79
KBG blend grown on mineral soil	93	95	93	91	83	81
Poa supina grown on plastic	90	94	94	89	94	84
LSD at 0.05 level	1		3		3	
Games simulated via Brinkman Simulator	---		10		16	

[1]Density rating % coverage, 0-100.

treatment X PGR interactions were noted. The first interaction date indicates that densities were lower for treated plots on 4 of the 6 sod treatments. The final interaction date between the sod and PGR factors is shown in Figure 3.2.

Quality

Turfgrass quality ratings are presented in Table 3.5. Overall, the KBG/PRG mix grown on plastic provided higher quality ratings compared to the other sod treatments. One note of interest was the washed KBG blend treatment quality ratings. The initial quality ratings for the washed KBG blend treatment were very high but as traffic simulation continued, its quality ratings began to drop steadily. This was likely due to the knitted root mass of which the washed Kentucky bluegrass treatment lacked. The other sod treatment of note was the *Poa supina* sod treatment. The *Poa supina* treatment had lower quality ratings through the study but they did not decline like the washed KBG blend treatment. The growth habit of *Poa supina* is strongly stoloniferous and for this reason was able to maintain adequate quality. Near the end of the study the quality ratings for *P. supina* were similar to those of the highest rated. Although *P. supina* received low color ratings, its quality ratings reflect the component of higher density. Trinexapac-ethyl enhanced quality significantly for all rating dates. Their were several PGR and sod treatment interactions through the study (Table 3.6). The PGR's phytotoxic effect to *P. supina* on 19 and 26 August allowed for the interactions to occur. Figures 3.3 and 3.4 also show the sod treatment X PGR interactions for 16 Sept. and 9 Nov. respectively.

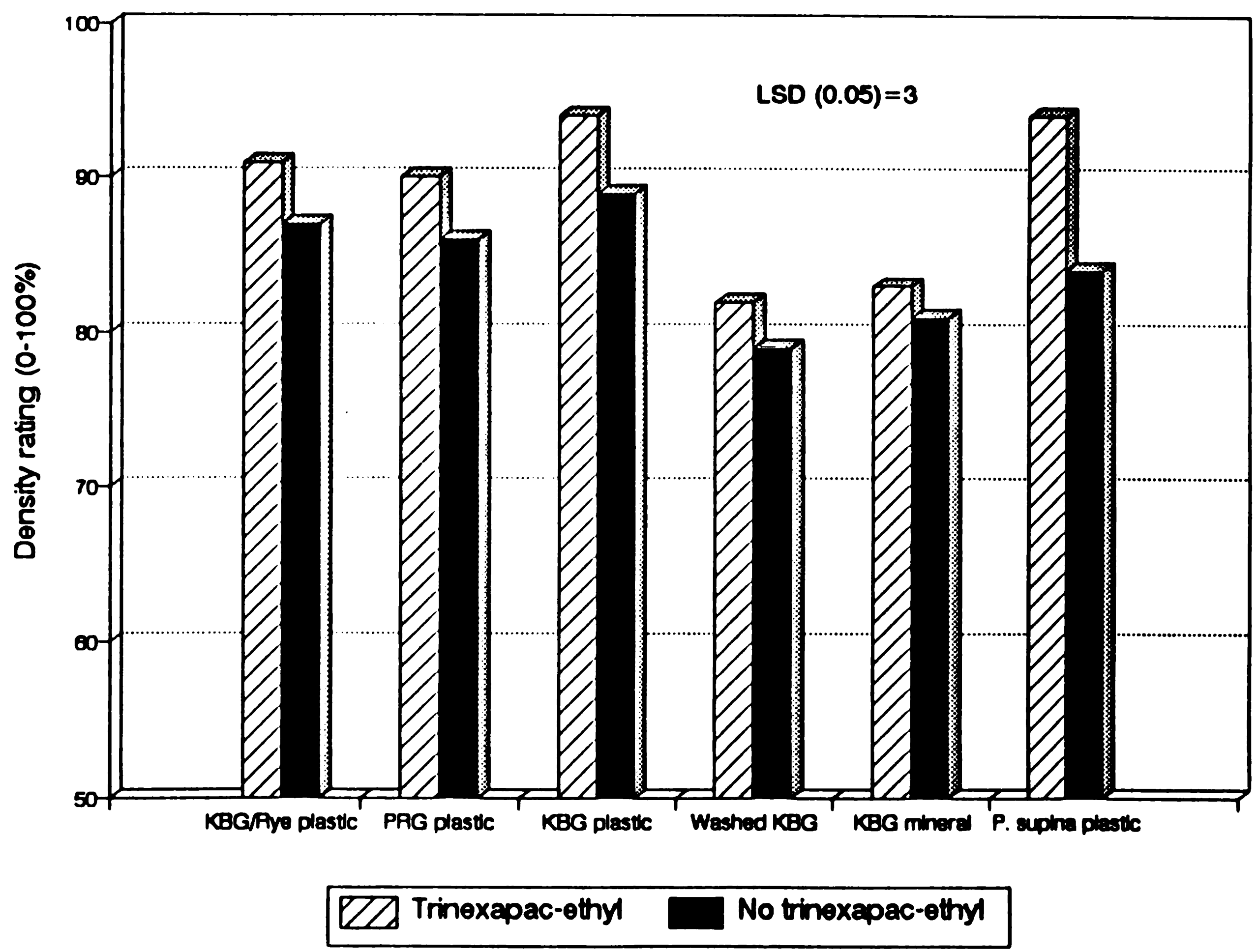

Figure 3.2: The effect of sod treatment X plant growth regulator interaction on trafficked turfgrass density, 23 Sept. 1994.

Table 3.5: The effect of sod treatment and plant growth regulator on trafficked and non-trafficked turfgrass quality[1].

1994	Date												
	8/19	8/26	9/2	9/9	9/16	9/23	9/30	10/7	10/13	10/21	10/28	11/9	12/2
Sod Treatment													
KBG/PRG mix grown on plastic	8.1	8.1	7.8	7.8	7.8	7.8	7.5	7.3	7.3	7.5	6.7	7.3	5.9
P. Ryegrass blend grown on plastic	8.1	8.0	6.9	6.9	7.5	6.7	7.0	6.2	6.3	6.9	6.5	6.5	5.8
KBG blend grown on plastic	7.5	7.4	7.4	7.2	6.9	7.0	7.4	7.5	7.3	6.5	6.2	6.5	5.4
Washed KBG blend	4.6	7.2	7.2	7.1	7.2	7.2	7.3	6.2	6.2	6.8	5.5	5.3	4.8
KBG blend grown on mineral soil	6.8	8.1	7.8	7.9	7.7	7.5	7.5	6.9	7.0	7.3	5.8	6.4	5.5
Poa supina grown on plastic	5.0	5.6	6.2	6.3	6.1	5.8	7.5	6.9	7.0	7.3	6.1	6.3	6.4
LSD at 0.05 level	0.5	0.5	0.9	0.8	0.6	0.8	NS	0.6	0.8	NS	0.7	1.0	0.8
PGR Treatment													
Trinexapac-ethyl	6.7	7.5	7.6	7.6	7.6	7.5	7.7	7.2	7.2	7.5	6.6	6.9	6.1
No trinexapac-ethyl	6.6	7.3	6.8	6.7	6.8	6.4	6.9	6.4	6.4	6.2	5.7	5.8	5.2
* = Significant at 0.05 level	NS	*	*	*	*	*	*	*	*	*	*	*	*
Games simulated via Brinkman Simulator	---	---	---	4	10	16	16	18	20	20	22	24	24

[1]1-9; 1 = bare ground, 9 = ideal turf and 5 acceptable.
NS = Not Significant

Table 3.6: The effect of sod treatment X plant growth regulator interaction on trafficked and non-trafficked turfgrass quality[1].

1994	Date											
	8/19		8/26		9/16		10/13		10/28		11/9	
PGR Treatment	PGR	None	PGR	None	PGR	None	PGR	None	PGR	None	PGR	None
Sod Treatment												
KBG/PRG mix grown on plastic	8.7	7.5	8.7	7.6	8.5	7.2	7.8	6.8	7.2	6.2	7.8	6.9
P. Ryegrass blend grown on plastic	8.3	7.8	8.3	7.8	7.8	7.1	6.6	6.1	6.8	6.3	7.0	6.0
KBG blend grown on plastic	7.8	7.2	7.6	7.2	7.5	6.3	8.1	6.5	7.3	5.2	7.2	5.8
Washed KBG blend	4.5	4.8	7.2	7.3	7.3	7.1	6.5	5.8	5.8	5.2	5.8	4.9
KBG blend grown on mineral soil	6.5	7.1	8.4	7.8	8.1	7.3	7.2	6.8	5.9	5.8	6.8	6.0
Poa supina grown on plastic	4.6	5.5	5.1	6.2	6.5	5.7	7.1	6.2	6.6	5.6	7.2	5.5
LSD at 0.05 level	0.6		0.5		0.5		0.5		0.8		0.4	
Games simulated via Brinkman Simulator	---		---		10		20		20		22	

[1]1-9; 1=bare ground, 9=ideal turf and 5 acceptable.

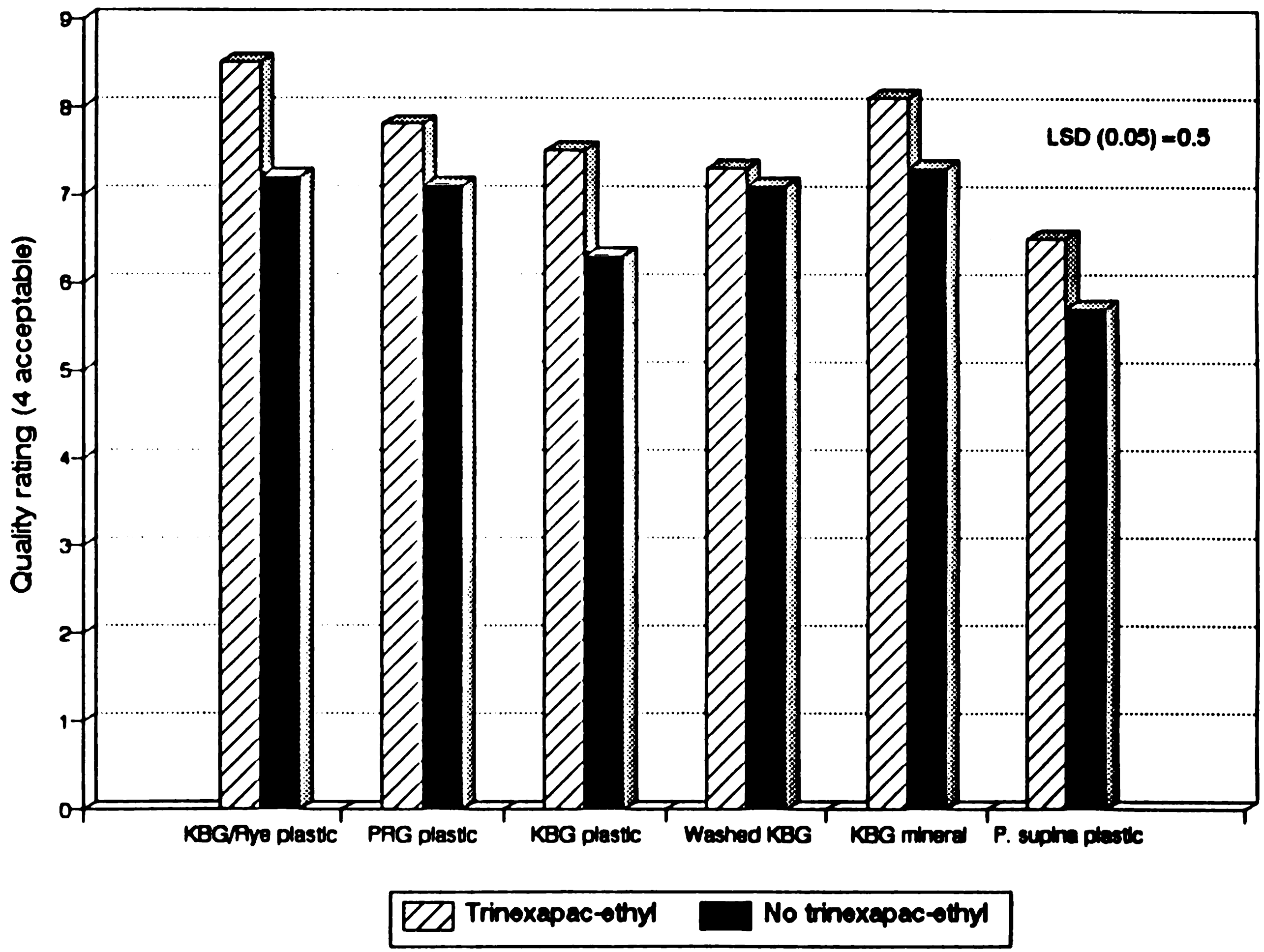

Figure 3.3: The effect of sod treatment X plant growth regulator interaction on trafficked turfgrass quality, 16 Sept. 1994.

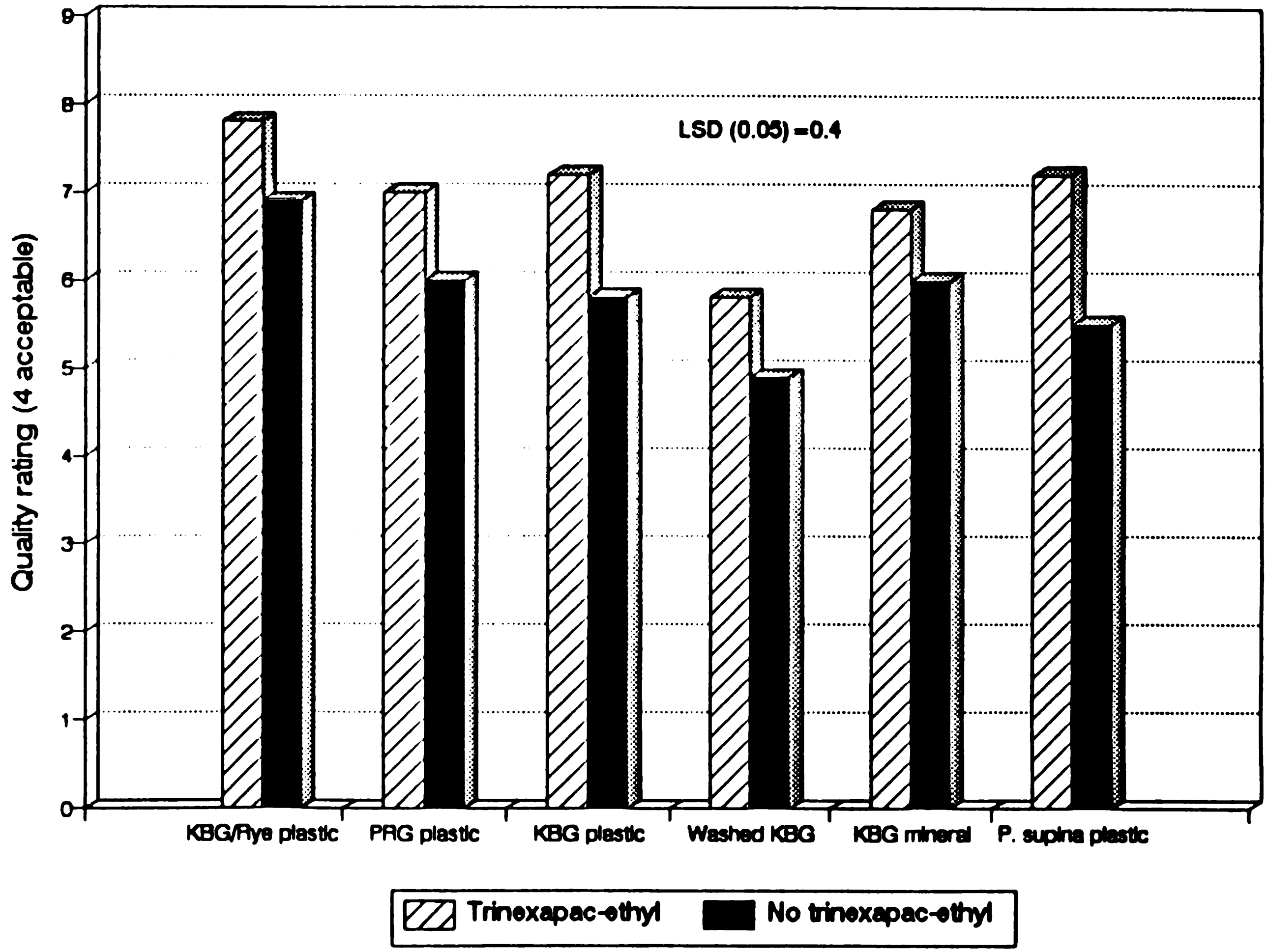

Figure 3.4: The effect of sod treatment X plant growth regulator interaction on trafficked turfgrass quality, 9 Nov. 1994.

Shear vane Measures

Non-traffic shears are presented in Table 3.7. Both plastic grown sod treatments containing Kentucky bluegrass had the highest shear values for treatments not receiving any traffic. There were small fluctuations amongst the sod treatments through the course of the study but no large differences from one measurement date to another were recognized. No significant shear differences were noted for the PGR factor.

For treatments that received traffic the Kentucky bluegrass sod treatments grown on plastic received the highest shear vane measures. The KBG/PRG mix treatment grown on plastic had the highest shears on all dates (Table 3.8). Growth habit differences along with mat layer thickness are the likely factors that allowed for these differences. Dunn et. al. (1994) stated that traction will decrease as thatch and above-ground biomass also deteriorate. As mentioned previously, both the mineral grown and washed KBG blend sod treatments did not have the extensive mat layer which the plastic grown sod treatments possessed. The perennial ryegrass treatment grown on plastic had a bunch-type growth habit which explains its lower shear measures. No shear vane differences were noted amongst the plant growth regulator factor and the PGR had no shear interactions with sod treatments.

Root Biomass

No differences were noted for either the 0-5 cm or the 5-10 cm depths. The lack of differences between PGR treatments in both root biomass and shear vane measurements indicates that a PGR application does not adversely affect turfgrass rooting. The ability of the turf manager to apply a growth regulator to reduce mowing

Table 3.7: The effect of sod treatments and plant growth regulator on non-trafficked turfgrass shear measures[1].

1994	Date									
	9/2	9/9	9/16	9/23	9/30	10/7	10/13	10/21	10/28	11/9
Sod Treatment										
KBG/PRG mix grown on plastic	30.3	33.8	37.0	35.0	36.3	28.6	34.0	30.1	31.7	30.4
P. Ryegrass blend grown on plastic	23.4	22.8	27.9	25.2	24.2	21.5	23.1	23.1	24.3	24.3
KBG blend grown on plastic	25.5	28.5	33.4	32.5	33.8	28.9	29.2	30.9	29.9	29.0
Washed KBG blend	24.2	25.5	28.2	28.8	28.0	24.8	26.0	24.7	25.1	28.7
KBG blend grown on mineral soil	22.3	24.1	28.9	26.3	26.0	23.0	25.3	24.8	24.8	25.5
Poa supina grown on plastic	23.8	26.1	29.0	29.6	28.7	25.2	29.0	26.5	26.0	28.1
LSD at 0.05 level	4.8	3.0	3.5	5.1	3.8	3.4	4.1	4.0	3.8	3.7
PGR Treatment										
Trinexapac-ethyl	24.7	26.7	31.2	29.2	28.7	25.3	27.9	26.9	27.0	27.4
No trinexapac-ethyl	25.0	26.6	30.2	30.0	30.3	25.4	27.6	26.5	26.9	27.9
*=Significant at 0.05 level	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Games simulated via Brinkman Simulator	---	4	10	16	16	18	20	20*	22	24

[1] Shears given in Newton meters Nm.
NS=Not significant

Table 3.8: The effect of sod treatments and plant growth regulator on trafficked turfgrass shear measures[1].

1994	Date								
	9/9	9/16	9/23	9/30	10/7	10/13	10/21	10/28	11/9
Sod Treatment									
KBG/PRG mix grown on plastic	30.8	34.8	35.8	33.2	29.6	33.4	29.3	29.7	30.9
P. Ryegrass blend grown on plastic	22.3	23.8	21.0	22.5	19.0	21.0	19.8	20.2	21.3
KBG blend grown on plastic	26.7	28.2	30.6	29.8	26.5	29.9	27.3	27.8	29.0
Washed KBG blend	25.1	27.9	23.1	26.6	23.4	24.3	21.8	21.8	25.3
KBG blend grown on mineral soil	21.6	22.6	22.3	21.5	19.7	20.5	19.2	21.0	21.6
Poa supina grown on plastic	22.0	22.5	22.0	22.9	20.1	21.6	21.8	22.5	23.1
LSD at 0.05 level	4.4	4.2	3.7	3.1	3.5	4.2	3.5	4.0	1.9
PGR Treatment									
Trinexapac-ethyl	24.7	26.7	26.0	26.1	22.8	24.8	23.2	24.2	25.0
No trinexapac-ethyl	24.8	26.6	25.6	26.0	23.3	25.4	23.2	23.5	26.0
*=Significant at 0.05 level	NS	NS	NS	NS	NS	NS	NS	NS	NS
Games simulated via Brinkman Simulator	4	10	16	16	18	20	20	22	24

[1]Shears given in Newton meters Nm.
NS=Not significant

and increase density 4-5 weeks prior to a high traffic situation could be beneficial in terms of season long management strategies. Root biomasses are presented in Table 3.9.

Verdure

Verdure refers to the layer of aboveground, green, living tissue following mowing (Turgeon, 1991). The final mowing was conducted 15 Oct. Table 3.10 shows the means of the two plugs in terms of plants per 10 cm^2. *Poa supina* along with the remaining sod treatments grown on plastic had significantly higher plant counts per unit area than the washed or mineral grown sod treatments. This information, again emphasizes the importance of a knitted rootmass in maintaining turf density and resilience to traffic. No verdure differences were noted for the PGR factor.

Conclusions

The Kentucky bluegrass (*Poa pratensis*) blend/perennial ryegrass (*Lolium perenne*) blend sod treatment grown on plastic performed significantly better under trafficked conditions compared to other treatments. In terms of color, the aforementioned sod treatment, along with the KBG grown on mineral soil, received the highest ratings with *Poa supina* rated the lowest. The plastic grown sod treatments had significantly higher densities while the washed KBG blend was lowest. The higher densities recorded for the plastic grown sod treatments was the result of the greater root knitting they had in comparison to washed and mineral grown Kentucky bluegrass sod treatments. Again, the quality ratings were highest throughout the study for the Kentucky bluegrass/perennial

Table 3.9: The effect of sod treatments and plant growth regulator on trafficked turfgrass root biomass, 15 Dec. 1994.

Sod Treatment	Sample Depth 0-5cm	g/L	5-10cm
KBG/PRG mix grown on plastic	1.2		1.1
P. Ryegrass blend grown on plastic	2.1		1.0
KBG blend grown on plastic	1.8		0.8
Washed KBG blend	2.3		1.0
KBG blend grown on mineral soil	1.5		1.2
Poa supina grown on plastic	1.1		0.9
LSD at 0.05 level	NS		NS
PGR Treatment			
Trinexapac-ethyl	1.6		1.0
No trinexapac-ethyl	1.8		1.0
*=Significant at 0.05 level	NS		NS
Games simulated via Brinkman Simulator	24		24

NS=Not significant

Table 3.10: The effect of sod treatments and plant growth regulator on trafficked turfgrass verdure, 25 Oct. 1994.

Sod Treatment	Plant Verdure plants/10 cm^2
KBG/PRG mix grown on plastic	18.8
P. Ryegrass blend grown on plastic	18.2
KBG blend grown on plastic	17.4
Washed KBG blend	11.1
KBG blend grown on mineral soil	10.2
Poa supina grown on plastic	20.2
LSD at 0.05 level	4.1
PGR Treatment	
Trinexapac-ethyl	15.6
No trinexapac-ethyl	16.3
*=Significant at 0.05 level	NS
Games simulated via Brinkman Simulator	22

NS=Not significant

ryegrass mixture grown initially on plastic. *Poa supina* had lower quality ratings within the first two months of the study but maintained adequate quality ratings as traffic simulation continued. This may be due to its better response to cooler temperatures (Lundell, 1994) and stoloniferous growth habit as compared to the other treatments. The washed KBG blend had the lowest quality ratings in months of October and November. Shear vane measures further promoted the KBG/Rye mix treatment followed by the KBG blend grown on plastic. The application of a plant growth regulator (PGR) such as trinexapac-ethyl shortly after sodding takes place can further maximize the overall surface, particularly in terms of color and quality. Sod densities were lower initially on treatments where PGR was applied but received significantly higher densities for the remainder of the study. Many benefits were observed in applying a PGR to sod. Although no root biomass differences were noted, lateral rather than vertical growth was enhanced. Trinexapac-ethyl, when applied, increased turf densities through making the turfgrass grow laterally which promoted better wear tolerance. Overlooking the short-term phytotoxic effect of trinexapac-ethyl, which was very minimal for Kentucky bluegrass and perennial ryegrass sod treatments, the product does promote better quality turf and reduced mowing during the establishment stage.

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APPENDIX

Table A: Statistically significant effects of establishment method, fiber, and fertilizer treatment on trafficked and non-trafficked turfgrass color, chapter 1.

Source of Variation	Date					
	10/28/92	5/12/93	5/27/93	7/6/93	10/26/93	11/23/93
Replication	NS	NS	NS	**	NS	NS
Estab. Method, A	**	**	**	**	**	**
Fiber Treatment, B	NS	NS	NS	NS	NS	NS
A X B	NS	NS	*	*	NS	NS
Error	0.35	0.36	0.80	0.11	0.88	1.67
Fertility, C	**	NS	**	**	**	**
A X C	NS	**	NS	NS	NS	NS
B X C	NS	*	*	NS	NS	NS
A X B X C	*	NS	NS	NS	*	NS
Error	0.20	0.36	0.46	0.53	0.43	1.16
CV (%)	6.2	9.7	11.2	10.4	9.9	25.8

*,** Significant at 0.05 and 0.01 levels, respectively.
NS = Not significant at 0.05 level.

Table B: Statistically significant effects of establishment method, fiber, and fertilizer treatment on trafficked and non-trafficked turfgrass density, chapter 1.

Source of Variation	Date				
	10/28/92	5/12/93	5/27/93	7/6/93	10/26/93
Replication	NS	NS	NS	NS	**
Estab. Method, A	**	**	**	**	*
Fiber Treatment, B	NS	NS	NS	NS	NS
A X B	NS	NS	NS	NS	NS
Error	167	92	16	31	261
Fertility, C	**	**	**	**	**
A X C	**	NS	**	NS	NS
B X C	NS	NS	NS	NS	NS
A X B X C	NS	NS	NS	NS	NS
Error	18.2	63.3	8.3	13.2	95.2
CV (%)	4.8	9.9	3.4	4.0	20.1

*,** Significant at 0.05 and 0.01 levels, respectively.
NS=Not significant at 0.05 level.

Table C: Statistically significant effects of establishment method, fiber, and fertilizer treatment on trafficked and non-trafficked turfgrass quality, chapter 1.

	Date								
Source of Variation	10/28/92	5/12/93	5/27/93	7/6/93	10/26/93	11/3/93	4/4/94	5/4/94	5/17/94
Replication	NS	NS	NS	NS	**	*	NS	NS	NS
Estab. Method, A	**	**	**	**	**	*	**	**	**
Fiber Treatment, B	NS	NS	NS	NS	NS	*	NS	NS	NS
A X B	NS	NS	*	NS	NS	NS	NS	NS	NS
Error	1.8	0.4	0.8	0.2	2.5	1.4	1.6	2.1	0.6
Fertility, C	**	**	**	**	**	**	NS	*	**
A X C	NS	**	NS	NS	NS	NS	NS	NS	NS
B X C	NS	NS	NS	NS	NS	NS	NS	NS	NS
A X B X C	NS	NS	NS	NS	NS	NS	NS	NS	NS
Error	0.3	0.4	0.4	0.6	0.7	1.3	---	0.9	0.6
CV (%)	8.3	11.9	11.4	11.1	22.9	33.5	19.7	24.5	19.5

*,** Significant at 0.05 and 0.01 levels, respectively.
NS=Not significant at 0.05 level.

NOTE: Ratings for dates 10/28/92-10/26/93 are based on color and density ratings taken on those dates.

Table D: Statistically significant effects of establishment method, fiber, and fertilizer treatment on soil phosphorus and potassium levels, chapter 1.

Source of Variation	Nov. 1993	
	kg P/ha	kg K/ha
Replication	NS	*
Estab. Method, A	NS	NS
Fiber Treatment, B	NS	NS
A X B	NS	NS
Error	---	514
Fertility, C	**	NS
A X C	NS	NS
B X C	NS	NS
A X B X C	NS	NS
Error	31.3	---
CV (%)	35.8	40.3

*,** Significant at 0.05 and 0.01 levels, respectively.
NS=Not significant at 0.05 level.

Table E: Statistically significant effects of establishment method, fiber, and fertilizer treatment on trafficked turfgrass root biomass, chapter 1.

	November 1993			
	Sample Depth			
	Traffic		No-Traffic	
Source of Variation	0-7cm	7-14cm	0-7.6cm	7.6-15.2cm
Replication	NS	NS	NS	NS
Estab. Method, A	NS	*	NS	**
Fiber Treatment, B	NS	NS	NS	NS
A X B	NS	NS	NS	NS
Error	---	0.05	---	0.02
Fertility, C	NS	NS	NS	NS
A X C	NS	NS	NS	NS
B X C	NS	NS	NS	NS
A X B X C	NS	NS	NS	NS
Error	---	---	---	---
CV (%)	43.5	97.8	47.3	70.1

*,** Significant at 0.05 and 0.01 levels, respectively.
NS=Not significant at 0.05 level.

Table F: Statistically significant effects of establishment method, fiber, and fertilizer treatment on non-trafficked turfgrass clipping yields, chapter 1.

1993	Date	
Source of Variation	June	July
Replication	*	NS
Estab. Method, A	**	**
Fiber Treatment, B	NS	NS
A X B	*	NS
Error	21.7	158
Fertility, C	**	**
A X C	**	NS
B X C	NS	NS
A X B X C	NS	NS
Error	22.4	65.7
CV (%)	20.6	21.3

*,** Significant at 0.05 and 0.01 levels, respectively.
NS=Not significant at 0.05 level.

Table G: Statistically significant effects of establishment method, fiber, and fertilizer treatment on plant tissue nutrient levels, chapter 1.

June 1993

Source of Variation	Nutrients											
	Al	Zn	Fe	B	P	Cu	Mn	Mg	Ca	Mo	K	Na
Replication	NS	NS	NS	NS	NS	**	**	NS	NS	NS	NS	NS
Estab. Method, A	NS	**	NS	NS	**	*	**	NS	NS	**	**	NS
Fiber Treatment, B	NS	NS	NS	NS	NS	NS	NS	NS	NS	*	NS	NS
A X B	NS	NS	NS	NS	*	NS	*	NS	NS	NS	NS	NS
Error	---	51	---	---	$1.3x10^5$	2.1	60	---	---	0.1	$9.3x10^6$	---
Fertility, C	NS	**	NS	**	**	NS	**	NS	NS	NS	**	NS
A X C	NS	NS	NS	NS	NS	NS	NS	NS	**	**	NS	NS
B X C	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
A X B X C	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Error	---	16	---	8.3	$3.2x10^5$	---	52	---	$3.2x10^5$	3.1	$5.2x10^6$	NS
CV (%)	82	13	34	39	16	43	13	10	11	11	10	23

July 1993

Source of Variation	Nutrients											
	Al	Zn	Fe	B	P	Cu	Mn	Mg	Ca	Mo	K	Na
Replication	NS	NS	NS	NS	NS	**	NS	NS	NS	NS	**	*
Estab. Method, A	*	NS	NS	*	**	NS	**	**	**	NS	**	NS
Fiber Treatment, B	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
A X B	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Error	50000	---	---	---	$1.6x10^5$	5.6	589	$1.8x10^5$	$3.3x10^6$	---	$2.1x10^6$	40000
Fertility, C	NS	NS	NS	**	**	**	*	**	**	NS	NS	NS
A X C	NS	NS	NS	NS	**	NS	NS	**	**	**	NS	NS
B X C	NS	NS	NS	NS	NS	NS	NS	NS	NS	*	NS	NS
A X B X C	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Error	---	---	---	5.4	$2.7x10^5$	5.6	249	41000	$7.6x10^5$	0.15	---	---
CV (%)	79	23	57	24	13	38	16	9	14	10	9	26

*,** Significant at 0.05 and 0.01 levels, respectively. NS=Not significant at 0.05 level.

Table H: Statistically significant effects of establishment method, fiber and fertilizer treatment on turfgrass shear measures, chapter 1.

Trafficked	Date					
Source of Variation	9/10/93	9/17/93	9/24/93	10/1/93	10/11/93	11/5/93
Replication	NS	NS	*	*	NS	**
Estab. Method, A	**	**	**	**	**	**
Fiber Treatment, B	*	NS	NS	*	NS	**
A X B	NS	*	NS	NS	NS	NS
Error	6.5	8.2	11.3	10.9	30.1	7.5
Fertility, C	NS	NS	NS	NS	NS	NS
A X C	NS	NS	NS	NS	NS	NS
B X C	NS	NS	NS	NS	NS	NS
A X B X C	NS	NS	NS	NS	NS	NS
Error	---	---	---	---	---	---
CV (%)	15.7	16.3	14.9	16.7	21.0	23.0

Non-trafficked	Date				
Source of Variation	9/10/93	9/17/93	9/24/93	10/1/93	10/11/93
Replication	*	NS	*	NS	**
Estab. Method, A	**	**	**	**	**
Fiber Treatment, B	*	NS	NS	*	**
A X B	NS	NS	NS	NS	NS
Error	9.5	7.0	4.2	21.0	1.8
Fertility, C	NS	NS	NS	NS	NS
A X C	NS	NS	NS	NS	NS
B X C	**	NS	NS	NS	NS
A X B X C	NS	NS	NS	NS	NS
Error	6.9	---	---	---	---
CV (%)	8.4	14.1	12.1	14.3	15.8

*,** Significant at 0.05 and 0.01 levels, respectively. NS=Not significant at 0.05 level.

Table I: Statistically significant effects of sod treatment and plant growth regulator on trafficked and non-trafficked turfgrass color, chapter 3.

1994	Date											
Source of Variation	8/19	8/26	9/2	9/9	9/16	9/23	9/30	10/7	10/13	10/21	10/28	11/9
Replication	NS	NS	**	**	NS	NS	NS	NS	NS	NS	NS	NS
Sod Treatment, S	**	**	**	**	**	**	**	NS	**	**	**	NS
Error	0.1	0.2	0.6	0.1	0.7	0.5	0.6	---	0.8	0.2	0.2	0.8
PGR Treatment, P	**	**	**	**	**	**	**	**	**	**	**	**
S X P	**	*	**	NS	NS	NS	NS	NS	**	*	**	NS
Error	0.08	0.05	0.04	0.05	0.10	0.17	0.25	0.36	0.02	0.15	0.09	0.14
CV (%)	4.0	3.1	3.0	3.2	4.4	5.8	7.0	9.0	2.3	5.6	7.4	3.7

Table J: Statistically significant effects of sod treatment and plant growth regulator on trafficked and non-trafficked turfgrass density, chapter 3.

1994	Date												
Source of Variation	8/19	8/26	9/2	9/9	9/16	9/23	9/30	10/7	10/13	10/21	10/28	11/9	12/2
Replication	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Sod Treatment, S	**	**	NS	**	NS	NS	NS	**	**	*	**	*	NS
Error	6.2	2.2	---	5.2	---	---	---	50.5	31.0	44.8	57.0	82.7	---
PGR Treatment, P	**	**	NS	**	**	**	**	*	**	**	**	**	**
S X P	**	NS	NS	NS	*	*	NS	NS	NS	NS	NS	NS	NS
Error	0.57	1.16	---	1.92	2.83	2.67	6.80	16.5	9.29	3.93	13.3	18.3	4.17
CV (%)	0.8	1.1	1.4	1.5	1.9	1.9	3.0	5.0	3.7	2.3	5.6	5.8	2.5

*,** Significant at 0.05 and 0.01 levels, respectively.
NS=Not Significant at 0.05 level.

Table K: Statistically significant effects of sod treatment and plant growth regulator on trafficked and non-trafficked turfgrass quality, chapter 3.

1994	Date												
Source of Variation	8/19	8/26	9/2	9/9	9/16	9/23	9/30	10/7	10/13	10/21	10/28	11/9	12/2
Replication	*	*	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	*
Sod Treatment, S	**	**	**	**	**	**	NS	**	*	NS	*	*	*
Error	0.14	0.14	0.46	0.39	0.20	0.35	0.37	0.24	0.34	0.36	0.29	0.61	0.43
PGR Treatment, P	NS	*	**	**	**	**	**	**	**	**	**	**	**
S X P	**	**	NS	NS	*	NS	NS	NS	*	**	*	*	NS
Error	0.10	0.09	0.06	0.06	0.07	0.11	0.19	0.12	0.08	0.07	0.21	0.06	0.07
CV (%)	4.8	4.1	3.4	3.3	3.6	4.7	5.9	5.2	4.1	3.9	4.9	6.2	4.8

*,** Significant at 0.05 and 0.01 levels, respectively.
NS=Not Significant at 0.05 level.

Table L: Statistically significant effects of sod treatments and plant growth regulator on non-trafficked turfgrass shear measures, chapter 3.

1994	Date									
Source of Variation	9/2	9/9	9/16	9/23	9/30	10/7	10/13	10/21	10/28	11/9
Replication	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Sod Treatment, S	*	**	**	**	**	**	**	NS	**	*
Error	14.2	5.36	7.56	15.5	8.51	6.98	9.92	---	8.74	8.31
PGR Treatment, P	NS	NS	NS	NS	*	NS	NS	NS	*	NS
S X P	NS	*	NS	NS	NS	NS	NS	NS	NS	NS
Error	4.64	3.72	2.41	2.24	3.67	2.19	2.77	3.63	2.31	2.58
CV (%)	8.7	7.2	5.1	5.1	6.5	5.8	6.0	7.1	4.6	5.4

Table M: Statistically significant effects of sod treatments and plant growth regulator on trafficked turfgrass shear measures, chapter 3.

1994	Date								
Source of Variation	9/9	9/16	9/23	9/30	10/7	10/13	10/21	10/28	11/9
Replication	NS	NS	NS	NS	NS	NS	NS	NS	**
Sod Treatment, S	**	**	**	**	**	**	**	**	**
Error	11.7	10.8	8.46	5.76	7.53	10.8	7.36	9.57	2.13
PGR Treatment, P	NS	NS	NS	NS	NS	NS	NS	NS	NS
S X P	NS	NS	NS	NS	NS	NS	NS	NS	NS
Error	---	---	---	---	---	---	---	---	---
CV (%)	6.4	6.2	7.2	4.8	7.3	7.8	6.6	7.0	5.4

*,** Significant at 0.05 and 0.01 levels, respectively.
NS=Not Significant at 0.05 level.

Table N: Statistically significant effects of sod treatments and plant growth regulator on trafficked turfgrass root biomass, chapter 3.

15 Dec. 1994

Source of Variation	Sample Depth 0-5cm	5-10cm
Replication	NS	NS
Sod Treatment, S	NS	NS
Error	---	---
PGR Treatment, P	NS	NS
S X P	NS	NS
Error	---	---
CV (%)	66.5	61.5

Table O: Statistically significant effects of sod treatments and plant growth regulator on trafficked turfgrass verdure, chapter 3.

25 Oct. 1994

Source of Variation	Plant Verdure plants/10 cm^2
Replication	NS
Sod Treatment, S	**
Error	10.0
PGR Treatment, P	NS
S X P	NS
Error	---
CV (%)	7.5

*,** Significant at 0.05 and 0.01 levels, respectively.
NS=Not Significant at 0.05 level.