Chapter 1

INTERACTION OF NITROGEN AND FLURPRIMIDOL ON KENTUCKY BLUEGRASS (*POA PRATENSIS* L.) IN REDUCED LIGHT CONDITIONS

INTRODUCTION

Turfgrasses in intense shade have weak tissues, reduced root to shoot ratio, and reduced tillering resulting in a reduced quality turf which cannot withstand traffic (Beard, 1973; Wilkinson and Beard, 1975). Minimal nitrogen inputs are recommended to maintain a balance between shoot and root growth and to minimize the growth of excessively succulent tissue. Traffic is to be minimized or avoided (Dudeck and Peacock, 1992). Consequently, current recommendations for turf in shade do not allow for management techniques in which traffic is a factor. Yet golf courses often have areas subjected to both shade and traffic. In addition, recent interest in the use of turfgrass systems for covered stadia requires the development of new management techniques for turf subjected to traffic under intensely shaded conditions (Anonymous, 1995; Kierle, 1995; Rogers, 1994; Tracinski, 1993).

Plant growth regulators (PGRs) which are gibberellic acid biosynthesis-inhibitors (GA-inhibitors) have been used successfully to decrease vertical growth (i.e., clipping yields) (Dernoeden, 1984; Diesburg and Christians, 1989; Johnson, 1988) by inhibiting cell elongation (Kaufmann, 1986a). Side effects of GA-inhibitors include darker green color and increased turf density due to enhanced tillering, often following a transient phytotoxic response resulting in tip die back (Dernoeden, 1984; Watschke, 1981). In shade, excessive turfgrass shoot elongation leads to weak, traffic-intolerant turf (Beard, 1973). Preliminary research has proven the potential of GA-inhibitors to control shoot elongation and provide a higher quality turf compared to untreated turf in reduced light conditions although phytotoxicity can occur (Rogers et al., 1996; Rogers and Stier, 1993). In normal light situations multiple applications of GA-inhibitors increase the level of suppression but also increase the potential for phytotoxicity, especially when turf is grown under a stress condition (Dernoeden, 1984; Johnson, 1988; Vitolo et al., 1990). Nitrogen fertilization in concert with PGR application has been reported to successfully minimize or overcome the short-term deleterious effects of PGRs in normal light situations (Devitt and Morris, 1988). The effects of nitrogen rate on PGR-treated turf in reduced light conditions are unknown.

The primary objective of this research was to determine the appropriate rate of nitrogen to apply to flurprimidol-treated Kentucky bluegrass turf in reduced light conditions. Secondary objectives included determining the amount of light required to maintain turf in an enclosed environment, the effects of traffic, and turf response to flurprimidol in reduced light conditions.

MATERIALS AND METHODS

The research was conducted inside the Covered Stadium Simulator Facility (CSSF) at the Hancock Turfgrass Research Center between Dec. 1992 and April 1994. The CSSF was constructed to simulate the conditions inside the Pontiac Silverdome, a covered stadium (Stier et al., 1993). The CSSF was a 600 m^2 air-supported structure constructed of Sheerfill II®, a fiberglass fabric (Chemical Fabrics Corporation, Buffalo, NY) which transmitted approximately 11 ± 2% sunlight. Temperature and relative humidity were recorded daily with a sling psychrometer. Furnaces on the endwalls of the facility were used to maintain the temperature typically at 16.8 ± 0.9 sd °C. Actual temperatures occasionally ranged from 3 to 23 ° C due to the poor insulating characteristics of the fiberglass fabric, the inability of the furnaces to compensate for excessively low outdoor temperatures (e.g., -10 C), and lack of an active cooling mechanism. Relative humidity (RH) averaged 44.8 ± 6.2 sd % with a range of 24-70% RH.

Portable plots were established in wood boxes (1.2 x 1.2 x 0.15m depth) filled with a sand:peat mix (80:20 v/v) (Table 78, Appendix). The pH was 7.3 with initial P and K levels of 63 kg ha^{-1} and 30 kg ha^{-1}, respectively. Holes were drilled in the bottoms of the boxes for drainage. The sand:peat mixture was compacted using hand-held tampers. Starter fertilizer (13-25-12) was applied to the soil which supplied 7.6 g N m^{-2}, 6.4 g P m^{-2}, and 5.8 g K m^{-2}. On 30 Sept. 1992 the plots were sodded with a washed Kentucky bluegrass blend (20% each of 'Trenton', 'Midnight', 'Aspen', 'Rugby', and 'Kelly'). The plots were moved into the CSSF for testing on 7 Dec. 1992 through 10 April 1993. The experiments were repeated a second year (season). In 1993, plots were sodded 10 Sept. using a washed Kentucky bluegrass blend (20% each of 'Trenton', 'Midnight', 'Aspen', 'Glade', and 'Parade'). These plots were moved into the CSSF on 10 Dec. 1993 and maintained until 8 April or 23 August 1994 depending on the experiment. In both years plots were mowed once to twice weekly at 3.8 cm during establishment and irrigated as necessary to prevent moisture stress. Urea (2.4 g N m^{-2}) was applied to aid establishment at three weeks after sodding in 1992 and at two and five weeks after sodding in 1993.

Two experiments were conducted to assess the effects of nitrogen rate in PGR-treated turf. Experiment I was conducted in the ambient light conditions of the CSSF. Experiment II was conducted in the CSSF under supplemental lighting. Supplemental light was supplied by 430 W high pressure sodium (HPS) lamps suspended 2.7 m above the turf surface. An automatic timer controlled the lamps to provide a 12 hr photoperiod (0700 to 1900 hr). Reflective (metallic) mylar sheets were suspended in parallel along the two long sides of the rectangular plot area to separate the lighted plots from the unlighted plots and to reflect light from the lamps for increased uniformity of irradiance.

Radiation data outside the CSSF were collected with a LI-PY14226 pyranometer and integrated daily. Radiometric units (Ly day^{-1}) were converted to quantum units using the following equation based on conversion units from Thimijan and Heins (1983):

$$\text{Equation 1:} \quad ((\text{Ly day}^{-1}/1.05)*3600*24)/\ 10^{6} = \text{mol PAR day}^{-1}.$$

Radiation data for plots in ambient light conditions of the CSSF were estimated based on the percent transmission of photosynthetically active radiation (PAR) through the fabric, measured at the turf surface. Radiation data inside the CSSF from Dec. 1992 through April 1993 were determined at the turf surface weekly within one hour of the solar zenith using a hand-held photometer (Greenlee Inc., Rockford, IL). Occasionally a portable spectroradiometer (Li-Cor, Lincoln, NE) was used from Dec. 1992 to April 1993 to determine only photosynthetically active radiation (PAR), 400-700 nm. Starting

Dec.1993 radiation data inside the CSSF were collected weekly using only the spectroradiometer.

For plots in supplemental light conditions in 1992-1993, photometeric units (lux) were converted to quantum units (μmol m^{-2} s^{-1}) by multiplying against a conversion factor (0.2215) derived from data collected concurrently with the photometer and the spectroradiometer. Starting Dec. 1993 radiation data inside the CSSF were collected weekly using only the spectroradiometer. Based on measurements collected when ambient PAR inside the CSSF was low (e.g., 10 μmol m^{-2} s^{-1} during rainstorms, pre-dawn, or evening), the HPS lamps supplied approximately 173 ± 22 μmol PAR m^{-2} s^{-1}. The metallic mylar curtains on both sides of the plot area blocked much of the light transmitted into the CSSF. Measurements at different times of the day under a range of sunlight conditions (sunny, cloudy) showed approximately 10% of the sunlight transmitted into the CSSF impinged on the plots under supplemental light in the morning and late afternoon; at midday approximately 80% of the light transmitted into the CSSF fell on the plots under supplemental light. Because ambient light levels peaked at midday, it was estimated that approximately 50% of the daily ambient PAR inside the CSSF contributed to the total daily PPFD of plots under supplemental light. The total daily photosynthetic photon flux density (PPFD) of plots in supplemental light conditions was estimated as follows using the average PPFD (μmol m^{-2} s^{-1}) from all plots:

Equation 2: $(((173\ \mu mol\ m^{-2}\ s^{-1}\ PAR*60\ sec\ min^{-1})*60\ min\ h^{-1})*12\ h)/1 \times 10^{6} =$

$mol\ PAR\ day^{-1}$ from HPS lamps + 0.5 $mol\ PAR\ day^{-1}$ ambient light =

$mol\ PAR\ day^{-1}$, supplemental light plots

The experiments were arranged as randomized complete block, split plot designs with three replications. Treatments were arranged in a 3 x 2 x 2 factorial with nitrogen rate and flurprimidol as main plots. Simulated soccer traffic was applied as a sub-plot treatment split over the main plots. Nitrogen rates were 24, 48, and 96 kg ha^{-1} per treatment date. Urea nitrogen was applied with a drop spreader on the same dates as flurprimidol. Flurprimidol was applied at the label rate of 1.12 kg ha^{-1} in 1168 L H_2O ha^{-1} using a CO_2-powered backpack sprayer; control plots received no flurprimidol. Nitrogen and flurprimidol were applied on the following dates: 16 Dec., 21 Jan., and 26 Feb. (supplemental light study only) 1992-93, and 17 Dec., 4 Feb., and 21 Mar. 1993-94. The turf was irrigated with approximately 1.25 cm water immediately following fertilization and flurprimidol applications. Additional irrigation was supplied as necessary to prevent visible drought stress symptoms (blue-green turf color, footprinting, wilting). Plots in ambient light conditions received approximately 1.25 cm water at 14-21 day intervals, while plots in supplemental light conditions received approximately 1.25 cm at seven to 10 day intervals. Traffic was applied to one-half of each plot by having a person (approximately 75-115 kg) walk 50 passes while wearing molded soccer cleats on each of the following dates: 29 Dec., 14 Jan., 21 Jan., 29 Jan., 6 Feb., 20 Feb., 10 Mar., and 24 Mar. (supplemental lighted study only on latter two dates) 1992-93, and 6 Jan., 11 Jan., 25 Jan., 1 Feb., 10 Feb., 22 Feb., 2 Mar., 17 Mar., 24 Mar., and 31 Mar. 1993-94. Traffic was applied immediately after mowing and prior to irrigation. Fungicides were applied at the onset of disease symptoms. On 9 Jan. 1993 and 14 Jan.

1994 chlorothalonil (tetrachloroisophthalonitrile; 16.5 kg ha^{-1}) was applied to control leafspot and melting out diseases caused by *Drechslera/Bipolaris* spp.

Plots were mowed once to twice weekly as needed to prevent removal of more than one-third of the leaf tissue. Clippings were collected, oven-dried at 60 °C for 48 h, and weighed. Turf quality was rated visually at five to 14 day intervals; ratings were conducted more frequently at the beginning of each year to assess rapid changes in turf quality and became less frequent as turf quality fluctuated less abruptly. Visual turf quality was based on a one to nine scale, with one representing completely necrotic turf or bare soil and nine representing dense, uniform turf with good color. A value of five was considered the minimum value for acceptable turf. Turf and rooting strength were evaluated periodically using an Eijkelkamp shear vane apparatus (Eijkelkamp, Giesbeek, The Netherlands) (Rogers and Waddington, 1990). The amount of force (torque) required to tear the turf was collected in two locations from each plot on every measurement date. Treatment effects on the turf surface hardness were periodically evaluated using a Clegg Impact Soil Tester (CIT) (Lafayette Instrument Co., Lafayette, IN). The CIT provided surface hardness values by measuring maximum deceleration of a 2.25 kg hammer when dropped from a 0.46 m height (Rogers and Waddington, 1990). Impact values were collected from three locations in each plot on each measurement date. On 23 August 1994, one core (10 cm diam) was collected for plant biomass estimates from each plot which had received supplemental light. Plant density was evaluated by counting the number of live plants in each core. Verdure was removed from each core, and all living tissue was oven-dried at 60° C for 48 h then weighed. The number of shoots per plant was determined by averaging the number of shoots from five plants selected at random from each plot.

Data were analyzed using MSTAT analysis of variance procedures for a 3-by-2 factorial experiment in a randomized complete block, split-plot design with three replications. The three nitrogen rates and two flurprimidol levels were split into trafficked and non-trafficked turf.

RESULTS AND DISCUSSION

Experiment I

Turf quality, growth, and other attributes declined over time. To document the trends data are presented for individual dates throughout the course of the experiment. Data are presented for each year due to different results between years. Although some of the differences could have been due to different cultivars in the second year, the differences were probably due to a longer and more favorable establishment period during the autumn 1993. Average daily PAR values of ambient light in the CSSF increased steadily from December through April from, ranging from approximately 1 mol PAR day^{-1} in December to approximately 3 mol PAR day^{-1} in April, but the turf did not respond (Table 1). Light quality transmitted through the fiberglass fabric of the CSSF mirrored the light quality of sunlight but light quantity was reduced approximately 90% (Figure 1).

Table 1. Photosynthetically active radiation (PAR) at the Hancock Turfgrass Research Center, East Lansing, MI.

Location	Dec. 1992	Jan. 1993	Feb. 1993	Mar. 1993	
Outside			mol PAR day^{-1} †		
average	7.5	12.6	23.2	21.1	
stnd deviation	3.9	5.4	3.1	12.2	
CSSF, ambient light ‡					
average	0.8	1.4	2.5	2.3	
stnd deviation	0.4	0.6	0.3	1.3	
CSSF, Supplemental light §					
average	7.9	8.2	8.7	8.6	
stnd deviation	1.2	1.2	1.1	1.6	
	Dec. 1993	Jan. 1994	Feb. 1994	Mar. 1994	Apr. 1994
Outside			mol PAR day^{-1}		
average	9.5	10.8	19.3	24.3	31.7
stnd deviation	4.9	5.0	7.0	9.9	14.5
CSSF, ambient light					
average	1.0	1.2	2.1	2.7	3.5
stnd deviation	0.5	0.6	0.8	1.1	1.6
CSSF, Supplemental light					
average	8.0	8.1	8.5	8.8	9.2
stnd deviation	1.2	1.2	1.4	1.5	1.8

† PAR was collected with a pyranomter (Li-Cor, model PY 14226, Lincoln NE) and integrated daily. Radiation units (Ly day^{-1}) were converted to quantum units (mol PAR day^{-1}) based on the conversion methods in Thimijan and Heins (1983).

‡ CSSF = Covered Stadium Simulator Facility. Ambient PAR inside the CSSF was estimated by measuring the percent PAR transmitted into the CSSF at turf levels with a photometer (Greenlee Inc., Rockford IL) or a portable spectroradiometer (Li-Cor, Lincoln NE).

§ Supplemental lighting was supplied by 400 W high pressure sodium lamps. Because reflective mylar curtains on two sides of the plots blocked an estimated 50% of the ambient light from plots which received supplemental light, 50% of the total daily PAR was added to the total daily PAR supplied by the lamps (5.4 mol m^{-2} day^{-1}) to estimate the total daily PAR received by turf under the supplemental light.

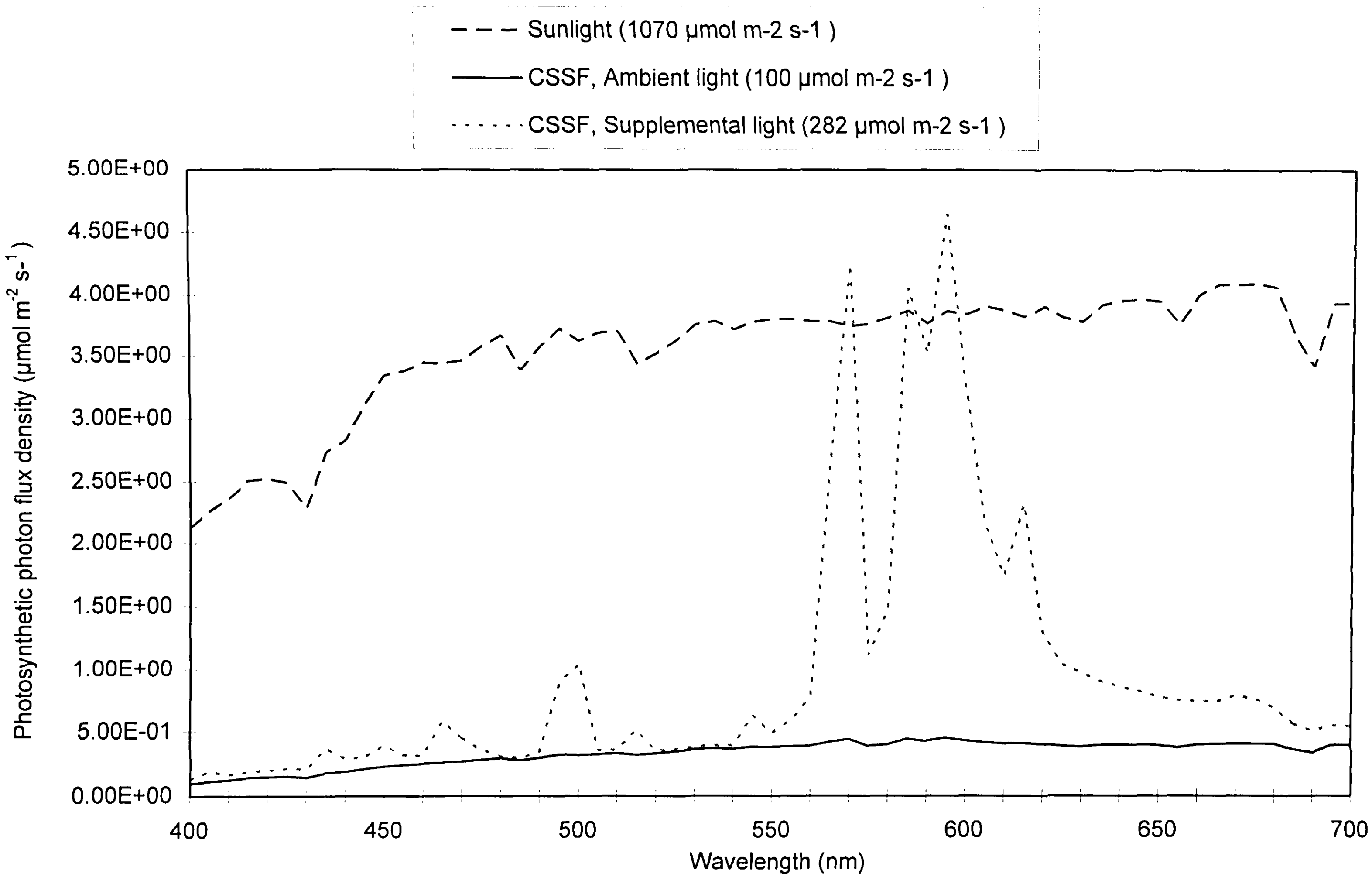

Figure 1. Photosynthetic photon flux density of sunlight, ambient light inside the Covered Stadium Simulator Facility (CSSF), and supplemental light inside the CSSF supplied by 400 W high pressure sodium lamps, 1515 h, 10 Feb. 1994.

Turf quality

Significant treatment effects on Kentucky bluegrass quality are shown in Table 2. In 1992-93 there were no interactions between treatments. In 1993-94 occasional interactions occurred between nitrogen-by-flurprimidol and nitrogen-by-traffic; a three-way interaction occurred on 22 Feb. 1994. In both 1992-93 and 1993-94 the turf recovered from winter dormancy once placed inside the CSSF, but did not survive well. Quality declined to unacceptable values (< 5.0) within 49 days after installation in the CSSF in 1993 and within 82 days in 1994 regardless of treatment. The turf became nearly completely necrotic within 72 days in 1993 although better quality was sustained for the entire trial (105 days) in 1994.

Traffic rapidly decreased turf quality and affected turf quality more often than nitrogen or flurprimidol (Table 2). Nitrogen rate did not affect turf quality in 1992-93; in 1993-94, the high rate (96 kg ha^{-1} $month^{-1}$) reduced turf quality within 74 days after installation in the CSSF (Table 3). High nitrogen rates are known to result in succulent tissues which render turf more susceptible to traffic and disease injury (Beard, 1973). High nitrogen rates have also been associated with decreased shoot density and root to shoot ratio in shaded conditions (Burton et al., 1959; Eriksen and Whitney, 1981; Schmidt and Blaser, 1967); flurprimidol did not alter this response at this level of light. Flurprimidol increased turf quality on two dates only after the second application in both seasons. Traffic began to decrease turf quality after one application (50 passes) in 1992 and after four applications (200 passes) in 1994. In 1993, the flurprimidol-by-traffic interaction on 3 Feb. showed flurprimidol increased turf quality in a non-trafficked

Table 2. Mean squares and treatment effects on the quality of Kentucky bluegrass maintained under ambient light conditions inside the Covered Stadium Simulator Facility, East Lansing, MI.

		1992-93								
Source	df	18 Dec.	23 Dec.	30 Dec.	8 Jan.	15 Jan.	20 Jan.	25 Jan.	3 Feb.	17 Feb.
Replication	2	0.167	1.764*	0.340	0.694	0.194	0.090	0.750	0.090	0.694
Nitrogen (N)	2	0.125	0.389	0.215	0.007	0.340	0.299	1.188	0.632	0.090
Flurprimidol (F)	1	0.056	0.056	0.250	1.174	0.174	1.361*	2.507	4.000**	0.340
N x F	2	0.097	0.056	0.271	0.090	0.132	0.340	1.715	0.542	0.090
Error	10	0.067	0.314	0.215	0.361	0.261	0.174	0.650	3.319	0.244
Traffic (T) †	1	--	--	4.694*	0.563	5.840**	5.444**	25.840**	38.028**	11.674
N x T	2	--	--	0.174	0.021	0.424	0.340	0.674	0.264	0.090
F x T	1	--	--	0.111	0.340	0.007	0.250	0.340	1.778*	0.174
N x F x T	2	--	--	0.090	0.049	0.049	0.021	0.340	0.097	0.090
Error	12	--	--	0.097	0.194	0.153	0.132	0.514	2.833	0.389
CV, %		5.00	9.70	5.79	8.04	7.09	7.11	16.70	18.41	39.04

		1993-94										
		28 Dec.	5 Jan.	12 Jan.	24 Jan.	3 Feb.	10 Feb.	22 Feb.	3 Mar.	11 Mar.	18 Mar.	25 Mar.
Replication	2	0.097	0.681*	1.715	4.465*	4.882*	0.194	0.194	0.396	2.382	0.813	1.399
Nitrogen (N)	2	0.097	0.181	0.132	1.965	2.840	3.028	22.215**	17.646**	15.924*	7.521	12.603
Flurprimidol (F)	1	0.014	0.000	0.340	0.444	1.778	18.778*	25.840**	10.563**	11.111	11.674	10.070
N x F	2	0.014	0.042	0.632	0.049	0.257	0.528	2.424*	3.271*	1.090	2.007	2.281
Error	10	0.031	0.164	0.465	1.024	1.065	2.111	0.494	0.688	2.540	4.771	3.207
Traffic (T) ‡	1	--	--	0.007	0.028	0.250	7.111**	22.563**	14.063**	17.361**	25.840**	24.933**
N x T	2	--	--	0.007	0.090	0.146	1.361	1.896*	3.063**	1.715*	0.632	1.021
F x T	1	--	--	0.007	0.000	0.000	0.694	0.174	0.563	0.694	0.563	1.346
N x F x T	2	--	--	0.007	0.062	0.062	0.694	2.549*	0.771	0.965	1.396	0.168
Error	12	--	--	0.049	0.056	0.090	0.403	0.375	0.319	0.278	0.389	0.333
CV, %		3.16	6.81	3.63	4.44	5.78	13.21	14.18	14.59	14.60	18.03	17.30

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

† Traffic was not started until 29 December 1992.

‡ Traffic was not started until 6 Jan. 1994.

Table 3. Main effects of nitrogen, flurprimidol, and traffic on the quality of Kentucky bluegrass maintained under ambient light conditions inside the Covered Stadium Simulator Facility (CSSF), East Lansing, MI. †

	1992-93‡								
Treatment	18 Dec.	23 Dec.	30 Dec.	8 Jan.	15 Jan.	20 Jan.	25 Jan.	3 Feb.	17 Feb.
Nitrogen (kg ha^{-1})§									
24	5.2	5.9	5.5	5.5	5.7	5.3	4.6	2.9	1.6
48	5.0	5.5	5.3	5.5	5.4	5.0	4.0	2.6	1.7
96	5.2	6.0	5.3	5.5	5.4	5.0	4.3	2.4	1.5
LSD (0.05)	ns	ns	ns	ns	ns	ns	ns	ns	ns
Flurprimidol (kg ha^{-1})¶									
0.00	5.1	5.7	5.3	5.3	5.4	5.0	4.0	2.3	1.5
1.12	5.2	5.8	5.5	5.7	5.6	5.3*	4.6	3.0**	1.7
Traffic#									
without	--	--	5.8	5.6	5.9	5.5	5.1	3.7	2.2
with	--	--	5.0**	5.4	5.1**	4.7**	3.4**	1.6**	1.0**

	1993-94 ††										
Treatment	28 Dec.	5 Jan.	12 Jan.	24 Jan.	3 Feb.	10 Feb.	22 Feb.	3 Mar.	11 Mar.	18 Mar.	25 Mar.
Nitrogen (kg ha^{-1})‡‡											
24	5.5	6.0	6.0	5.0	4.7	4.8	5.0	4.3	4.1	3.7	3.5
48	5.7	6.1	6.1	5.2	5.3	5.3	5.2	4.8	4.4	4.1	4.3
96	5.4	5.8	6.2	5.8	5.6	4.3	2.8	2.5	2.3	2.6	2.2
LSD (0.05)	ns	ns	ns	ns	ns	ns	0.6	0.7	1.4	ns	ns
Flurprimidol (kg ha^{-1})											
0.00	5.6	5.9	6.2	5.4	5.0	4.1	3.5	3.3	3.1	2.9	2.8
1.12	5.5	5.9	6.0	5.2	5.4	5.5*	5.2	4.4**	4.2	4.0	3.9
Traffic§§											
without	--	--	6.1	5.3	5.3	5.2	5.1	4.5	4.3	4.3	4.2
with	--	--	6.1	5.3	5.1	4.4**	3.5	3.2**	2.9**	2.6**	2.5**

Table 3 (cont'd.)

*,** Significant at the 0.05 and 0.01 probability levels, respectively.
† Quality was evaluated on a 1-9 scale, 1= dead turf/bare soil and 9=dark green, dense, uniform turf.
‡ Plots were sodded 30 Sept. 1992, established outside, and moved inside the CSSF on 7 Dec. 1992.
§ Nitrogen was applied as urea on 16 Dec. 1992 and 18 Jan. 1993.
¶ Flurprimidol was applied on the same day as nitrogen; control plots were untreated.
# Traffic was applied 29 Dec. 1992, 14 Jan., 21 Jan., 29 Jan., and 6 Feb. 1993.
†† Plots were sodded 10 Sept. 1993, established outside, and moved inside the CSSF on 10 Dec. 1993.
‡‡ Nitrogen was applied as urea on 17 Dec. 1993, 4 Feb., and 21 Mar. 1994.
§§ Traffic was applied 6 Jan., 11 Jan., 25 Jan., 1 Feb., 10 Feb., 22 Feb., 2 Mar., 17 Mar., and 24 Mar. 1994.

situation but did not affect turf quality in a trafficked situation (Table 3). Flurprimidol-by-nitrogen and nitrogen-by-traffic interactions occurred in the second season (Table 4). In the flurprimidol-by-nitrogen interaction, flurprimidol increased turf quality at the low and medium nitrogen rates but did not affect quality at the high nitrogen rate because the high nitrogen rate decreased turf quality regardless of flurprimidol application. In the nitrogen-by-traffic interaction, traffic decreased turf quality at the medium and high nitrogen rates, but did not significantly affect turf quality at the low nitrogen rate. For the three-way interaction on turf quality, traffic did not affect quality at low or medium nitrogen rates when treated with flurprimidol, but did significantly reduce turf quality at the medium and high nitrogen rates in the absence of flurprimidol (Table 5).

Clipping yields

Weekly clipping yields were affected by flurprimidol and traffic in 1992-93 and by all three treatment groups individually in 1993-94 (Table 6). Data presented are intended to describe trends of main effects and interactions therefore interactions occurring only once were not discussed. Flurprimidol and traffic significantly reduced clipping yields beginning immediately after their first application (Table 7). The second application of flurprimidol inhibited vertical growth nearly completely, causing clipping yields to be at or near zero for the duration of the studies. Zero vertical growth is undesirable if it prevents turf recovery following damage. In this study flurprimidol did not appear to prevent recovery any more than untreated turf because the low light level was the limiting factor for growth. In 1994, high nitrogen rates resulted in decreased yields compared to

Table 4. Quality ratings for the significant flurprimidol-by-nitrogen and nitrogen-by-traffic interactions in Kentucky bluegrass turf maintained in ambient light conditions in the Covered Stadium Simulator Facility, East Lansing, MI, 1994. †

Flurprimidol-by-nitrogen interaction

	22 Feb.		3 Mar.	
	Flurprimidol (kg ha^{-1}) ‡			
Nitrogen (kg ha^{-1})§	0.00	1.12	0.00	1.12
24	4.0	6.1	3.8	4.9
48	4.0	6.3	3.8	5.8
96	2.4	3.1	2.5	2.5
LSD (0.05)	0.9		1.1	

Nitrogen-by-traffic interaction

	22 Feb.		3 Mar.		11 Mar.	
	Traffic ¶					
Nitrogen (kg ha^{-1})	without	with	without	with	without	with
24	5.4	4.7	4.4	4.2	4.4	3.8
48	6.0	4.3	5.5	4.1	5.2	3.7
96	3.9	1.6	3.6	1.4	3.3	1.2
LSD (0.05)	0.8		0.7		0.7	

† Quality was evaluated on a 1-9 scale, 1= dead turf/bare soil and 9= dark green, dense, uniform turf.
‡ Flurprimidol was applied 21 Dec. 1993 and 4 Feb. 1994.
§ Urea was the nitrogen source and was applied the same day as flurprimidol.
¶ Traffic was applied 6 Jan., 11 Jan., 25 Jan., 1 Feb., 10 Feb., 22 Feb., and 2 Mar. 1994.

Table 5. Quality ratings for the significant nitrogen-by-flurprimidol-by-traffic interaction of Kentucky bluegrass turf maintained under ambient light conditions in the Covered Stadium Simulator Facility, 22 Feb. 1994.†

	Without traffic		With traffic‡			
	Flurprimidol (kg ha^{-1}) §					
Nitrogen (kg ha^{-1})¶	0.00	1.12	0.00	1.12	LSD (0.05)	
24	4.5	6.3	3.5	5.8		
48	5.3	6.7	2.7	6.0	between traffic	0.4
96	3.2	4.7	1.7	1.5	between N rate or flurprimidol	0.9

† Quality was evaluated on a 1-9 scale, 1= dead turf/bare soil and 9= dark green, dense, uniform turf.
‡ Traffic was applied 6 Jan., 11 Jan., 25 Jan., 1 Feb., and 10 Feb. 1994.
§ Flurprimidol was applied 21 Dec. 1993 and 4 Feb. 1994.
¶ Urea was the nitrogen source and was applied the same days as flurprimidol.

Table 6. Mean squares and significance of treatment effects on clipping yields of Kentucky bluegrass maintained under ambient light conditions of Covered Stadium Simulator Facility, East Lansing, MI.

		1992	1993									
Source	df	29 Dec.	9 Jan.	15 Jan.	22 Jan.	29 Jan.	1 Feb.	8 Feb.	19 Feb.			
Replication	2	0.161	0.522	0.028	0.087	0.019	0.019	0.018	0.017	--†	--	--
Nitrogen (N)	2	0.293	0.340	0.136	0.045	0.006	0.069	0.023	0.019	--	--	--
Flurprimidol (F)	1	6.242**	36.603**	5.214**	4.658**	0.903**	1.210**	1.969**	4.767**	--	--	--
N x F	2	0.181	0.360	0.002	0.019	0.016	0.069	0.028	0.009	--	--	--
Error	10	0.152	0.410	0.062	0.106	0.022	0.052	0.086	0.077	--	--	--
Traffic (T) ‡	1	--	4.767**	4.340**	2.377**	0.934**	1.210**	1.203**	5.680**	--	--	--
N x T	2	--	0.120	0.005	0.019	0.010	0.069	0.019	0.030	--	--	--
F x T	1	--	2.834**	1.138**	1.342**	0.667**	1.210**	0.993**	3.868**	--	--	--
N x F x T	2	--	0.037	0.044	0.007	0.021	0.069	0.019	0.006	--	--	--
Error	12	--	0.036	0.039	0.057	0.025	0.047	0.034	0.037	--	--	--
CV, %		27.77	11.82	28.78	53.65	86.00	118.09	73.14	44.19	--	--	--

		1994										
		4 Jan.	11 Jan.	18 Jan.	24 Jan.	30 Jan.	10 Feb.	15 Feb.	22 Feb.	2 Mar.	16 Mar.	30 Mar.
Replication	2	1.062	0.432	0.588	0.024	0.754	0.151	0.521	0.896	0.198	1.646	0.029
Nitrogen (N)	2	3.022*	0.949	3.115	0.129	0.037	0.233*	1.059	4.648*	2.254**	3.327*	3.082**
Flurprimidol (F)	1	24.036**	55.007**	148.840**	3.967**	38.906**	14.440**	30.158**	95.714**	65.340**	77.001**	74.103**
N x F	2	0.284	0.293	3.115	0.003	0.087	0.233*	0.931	4.648*	2.342**	3.327*	3.082**
Error	10	0.555	0.552	1.039	0.174	0.456	0.044	0.333	0.635	0.109	0.549	0.322
Traffic (T) §	1	--	4.562**	0.810	0.051	1.059**	0.160	2.176**	2.300**	3.802**	1.891**	6.545**
N x T	2	--	0.211	0.143	0.023	0.007	0.006	0.004	0.094	0.051	0.404*	0.049
F x T	1	--	3.738**	0.810	0.051	0.788**	0.160	1.800**	2.300**	3.802**	1.891**	6.545**
N x F x T	12	--	0.163	0.143	0.070	0.015	0.006	0.006	0.094	0.051	0.404*	0.049
Error		--	0.089	0.194	0.030	0.054	0.036	0.041	0.052	0.036	0.101	0.106
CV, %		28.65	15.41	21.64	15.78	17.96	29.80	19.94	13.93	13.94	21.77	22.65

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

Table 7. Effect of nitrogen rate, flurprimidol, and traffic on clipping yields of Kentucky bluegrass maintained under ambient light conditions in the Covered Stadium Simulator Facility (CSSF), East Lansing, MI.†

Treatment	yield (g 0.5 m^{-2})							
	1992	1993						
Nitrogen (kg ha^{-1})‡	29 Dec.	9 Jan.	15 Jan.	22 Jan.	29 Jan.	1 Feb.	8 Feb.	19 Feb.
24	1.2	1.6	0.8	0.5	0.2	0.1	0.2	0.4
48	1.6	1.8	0.7	0.5	0.2	0.2	0.3	0.5
96	1.4	1.4	0.6	0.4	0.2	0.2	0.3	0.4
LSD (0.05)	ns	ns	ns	ns	ns	ns	ns	ns
Flurprimidol (kg ha^{-1})								
0.00	2.0	2.6	1.1	0.8	0.3	0.4	0.5	0.8
1.12 §	0.8**	0.6**	0.3**	0.1**	0.0**	0.0**	0.0**	0.1**
Traffic								
without	--	2.0	1.0	0.7	0.3	0.4	0.4	0.8
with ¶	--	1.2**	0.3**	0.2**	0.0**	0.0**	0.1**	0.0**

	1994										
Nitrogen (kg ha^{-1}) #	4 Jan.	11 Jan.	18 Jan.	24 Jan.	30 Jan.	10 Feb.	15 Feb.	22 Feb.	2 Mar.	16 Mar.	30 Mar.
24	1.8	1.7	1.8	1.0	1.3	0.8	1.2	2.1	1.8	2.0	1.9
48	2.8	1.9	1.6	1.1	1.2	0.6	1.1	1.9	1.4	1.4	1.6
96	3.2	2.2	2.6	1.2	1.4	0.5	0.7	0.9	0.9	1.0	0.9
LSD (0.05)	0.7	ns	ns	ns	ns	ns	ns	0.7	0.3	0.7	0.5
Flurprimidol (kg ha^{-1})											
0.00	3.8	3.2	4.1	1.4	2.3	1.3	1.9	3.3	2.7	2.9	2.9
1.12 ††	1.4**	0.7**	0.0**	0.8**	0.3**	0.0**	0.1**	0.0**	0.0**	0.0**	0.0**
Traffic											
without	--	2.4	2.2	1.1	1.5	0.7	1.3	1.9	1.7	1.7	1.9
with ‡‡	--	1.5**	1.9	1.1	1.1**	0.6	0.8**	1.4**	1.0**	1.2**	1.0**

*, ** Significant at the 0.05 and 0.01 probability levels, respectively; ns = not significant at p=0.05.

† Plots were established outside in the autumn and moved into the CSSF on 7 Dec. 1992 and 10 Dec. 1993.

Table 7 (cont'd.)

‡ Nitrogen was supplied as urea on 16 Dec. 1992 and 18 Jan. 1993.
§ Flurprimidol was applied on the same day as nitrogen.
¶ Traffic was applied 29 Dec. 1992, 14 Jan., 21 Jan., 29 Jan., and 6 Feb. 1993.
# Nitrogen (urea) was applied 17 Dec. 1993, 4 Feb., and 21 Mar. 1994.
†† Flurprimidol was applied on the same day as nitrogen.
‡‡ Traffic was applied 6 Jan., 11 Jan., 25 Jan., 1 Feb., 10 Feb., 22 Feb., 2 Mar., 17 Mar., and 24 Mar. 1994.

medium and low nitrogen rates. The adverse response to high nitrogen has been reported previously for bermudagrass and forage grasses in reduced light conditions (Burton et al., 1959; Eriksen & Whitney 1981). More importantly, nitrogen and flurprimidol interacted on clipping yields in the second season. Nitrogen did not affect clipping yields when flurprimidol was applied (which resulted in zero yield for all nitrogen rates) while clipping yields were decreased proprotionally to increased nitrogen rates in the absence of flurprimidol (Table 8). This is in contrast to Devitt and Morris (1988) who reported high nitrogen rates reduced the effects of GA-inhibitors, although Johnson (1988) found higher nitrogen rates (25 vs. 50 kg ha^{-1}) did not decrease the effectiveness of flurprimidol on bermudagrass in full sun. Traffic and flurprimidol also interacted in both seasons with flurprimidol decreasing clipping yields more than traffic (Table 9).

Surface characteristics

Shear resistance of turf was most affected by traffic and only minimally affected by nitrogen or flurprimidol. No interactions occurred (Table 10). Traffic consistently decreased shear resistance values. High nitrogen rates decreased shear resistance compared to low nitrogen rates (Table 11). Low shear resistance values due to traffic and high nitrogen rates were probably due to reduced turf cover and possibly reduced root structure although rooting was not measured. Flurprimidol had little effect, causing an increase on one date in 1994. Shear resistance declined over time regardless of treatment due to lack of sufficient light energy to sustain growth, particularly rooting.

Table 8. Values for the significant nitrogen-by-flurprimidol interaction on clipping yields of Kentucky bluegrass turf maintained under ambient light conditions in the Covered Stadium Simulator Facility (CSSF), East Lansing, MI. †

	1994									
	10 Feb.		22 Feb.		2 Mar.		16 Mar.		30 Mar.	
	Flurprimidol (kg ha^{-1}) ‡									
Nitrogen (kg ha^{-1})§	0.00	1.12	0.00	1.12	0.00	1.12	0.00	1.12	0.00	1.12
	yield (g 0.5 m^{-2})									
24	1.6	0.0	4.2	0.0	3.6	0.0	4.1	0.0	3.7	0.0
48	1.2	0.0	3.7	0.0	2.7	0.0	2.7	0.0	3.1	0.0
96	1.0	0.0	1.9	0.0	1.8	0.0	2.0	0.0	1.8	0.0
LSD (0.05)	0.3		1.0		0.4		1.0		0.7	

† Plots were established outside during autumn 1993 and moved into the CSSF on 10 Dec. 1993.
‡ Flurprimidol (1.12 kg ha^{-1}) was applied on 17 Dec. 1993, 4 Feb. and 21 Mar. 1994.
§ Nitrogen was applied as urea on the same dates as flurprimidol.

Table 9. Values for the significant flurprimidol-by-traffic interactions on clipping yields of Kentucky bluegrass turf maintained under ambient light conditions in the Covered Stadium Simulator Facility (CSSF), East Lansing, MI.†

	Yield (g 0.5 m^{-2})													
	1993													
	9 Jan.		15 Jan.		22 Jan.		29 Jan.		1 Feb.		8 Feb.		19 Feb.	
	Flurprimidol (kg ha^{-1})‡													
Traffic	0.00	1.12	0.00	1.12	0.00	1.12	0.00	1.12	0.00	1.12	0.00	1.12	0.00	1.12
without	3.2	0.7	1.6	0.4	1.3	0.2	0.6	0.1	0.7	0.0	0.8	0.0	1.5	0.1
with §	2.0	0.5	0.5	0.1	0.4	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.1	0.0
LSD(0.05)	0.2		0.2		0.2		0.2		0.2		0.2		0.2	
	1994													
	11 Jan.		30 Jan.		15 Feb.		22 Feb.		2 Mar.		16 Mar.		30 Mar.	
	Flurprimidol (kg ha^{-1})#													
Traffic	0.00	1.12	0.00	1.12	0.00	1.12	0.00	1.12	0.00	1.12	0.00	1.12	0.00	1.12
without	4.0	0.8	2.7	0.3	2.4	0.1	3.8	0.0	3.4	0.0	3.4	0.0	3.7	0.0
with ††	2.4	0.6	2.0	0.2	1.5	0.1	2.8	0.0	2.1	0.0	2.5	0.0	2.0	0.0
LSD (0.05)	0.3		0.2		0.2		0.2		0.2		0.3		0.3	

† Plots were established during autumn of both years and moved into the CSSF on 7 Dec. 1992 and 10 Dec. 1993.
‡ Flurprimidol (1.12 kg ha^{-1}) was applied 16 Dec. 1992 and 18 Jan. 1993.
§ Traffic was applied 29 Dec. 1992, 14 Jan., 21 Jan., 29 Jan., and 6 Feb. 1993.
# Flurprimidol (1.12 kg ha^{-1}) was applied 17 Dec. 1993, 4 Feb., and 21 Mar. 1994.
†† Traffic was applied 6 Jan., 11 Jan., 25 Jan., 1 Feb., 10 Feb., 22 Feb., 2 Mar., 17 Mar., and 24 Mar. 1994.

Table 10. Mean squares and significance of treatment effects on the shear resistance of Kentucky bluegrass maintained under ambient light conditions inside the Covered Stadium Simulator Facility (CSSF), East Lansing, MI.

		Shear resistance (N•m)				
		1992-93			1993-94	
Source of variation	df	22 Dec.	11 Jan.	3 Feb.	28 Dec.	8 Apr.
Replication	2	22.028	2.507	9.299	9.528	1.021
N rate (N)	2	5.778	21.049*	5.132	0.778	37.646*
Flurprimidol (F)	1	23.361	0.563	10.028	0.028	30.250*
N x F	2	0.444	5.063	1.799	8.778	3.771
Error	10	8.828	4.724	3.624	4.828	5.738
Traffic (T)†	1	-----	25.840*	40.111	-----	20.250*
N x T	2	-----	4.215	4.090	-----	2.146
F x T	1	-----	2.007	4.000	-----	0.250
N x F x T	2	-----	7.340	0.896	-----	0.187
Error	12	-----	3.993	1.681	-----	2.507
CV, %		0.00	10.74	8.38	0.00	15.97

* Significant at the 0.05 probability level.

† Traffic applications were not started until 29 Dec. 1992 and 6 Jan. 1994.

Table 11. Main effects of nitrogen, flurprimidol, and traffic on the shear resistance of Kentucky bluegrass turf maintained under ambient light conditions inside the Covered Stadium Simulator Facility (CSSF), East Lansing, MI.

	Shear resistance (N•m)				
	1992-93			1993-94	
Treatment	22 Dec.	11 Jan.	3 Feb.	28 Dec.	8 Apr.
Nitrogen (kg ha^{-1}) †					
24	20.9	20.1	16.2	22.6	11.7
48	19.9	18.2	15.0	22.8	10.0
96	21.2	17.5	15.2	22.5	8.1
LSD (0.05)	ns	2.0	ns	ns	3.1
Flurprimidol (kg ha^{-1})					
none	19.9	18.7	15.0	22.5	9.0
1.12 ‡	21.5	18.5	16.0	22.6	10.8*
Traffic					
without	----	19.4	16.5	22.5	10.7
with §	----	17.7*	14.4**	22.5	9.2*

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

† Nitrogen was applied as urea on 16 Dec. 1992, 18 Jan., 17 Dec. 1993, 4 Feb., and 21 Mar. 1994.

‡ Flurprimidol was applied on the same days as nitrogen.

§Traffic was applied 29 Dec. 1992, 14 Jan., 21 Jan., 29 Jan., and 6 Feb. 1993, and 6 Jan., 11 Jan., 25 Jan., 1 Feb., 10 Feb., 22 Feb., 2 Mar., 17 Mar., and 24 Mar. 1994.

Treatment effects on surface hardness were not consistent between years (Table 12). Relative differences in g_{max} values between years were probably due to the use of different accelerometers in the CIT equipment following a repair in 1993. In the first season (1992-93) traffic treatments appeared to reduce surface hardness, while in the second season traffic treatments increased surface hardness (Table 13). Generally traffic will increase surface hardness by compaction and reduction of thatch and turf cover (Rogers and Waddington, 1990). Surface hardness is also affected by soil moisture with higher soil moisture providing lower g_{max} values (Rogers and Waddington, 1992), however, soil moisture was not determined in this study. In Feb. 1993 most turf in trafficked areas was dead although a thick (approximately 1.5 cm) mat layer remained which may have retained sufficient moisture to cause a decrease in g_{max}. Compaction in the mat layer by the traffic may also have caused decreased water infiltration. Non-trafficked areas may have had lower soil moisture values due to water uptake by the turf and increased infiltration rates. In Feb. and Apr. 1994 turf cover was higher than in 1993 and soil moisture values may have been more equivalent between trafficked and non-trafficked turf.

Experiment II

Supplemental lighting supplied approximately 8.4 ± 1.4 mol PAR day^{-1} (Table 1). The HPS lamps emitted a significant portion of their light in the yellow, orange, and red wavelengths (Figure 1). Ambient light in the CSSF was minimal and contributed little to the PAR on plots under supplemental light.

Table 12. Mean squares and the significance of treatment effects on the surface hardness of Kentucky bluegrass turf maintained in ambient light conditions of the Covered Stadium Simulator Facility (CSSF), East Lansing, MI.

		1993	1994	
Source of variation	df	3 Feb.	3 Feb.	8 Apr.
Replication	2	99.750	398.401*	240.465
N rate (N)	2	1226.750	33.347	106.747
Flurprimidol (F)	1	205.444	31.923	30.988
N x F	2	196.861	143.191	37.814
Error	10	78.783	93.879	130.947
Traffic (T)	1	3211.111**	753.503**	1497.690**
N x T	2	206.194	57.341	116.328
F x T	1	225.000	9.714	124.695
N x F x T	2	37.750	6.930	45.859
Error	12	157.333	18.056	50.820
CV, %		9.09	6.23	9.48

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

Table 13. Effects of traffic on Clegg Impact Values of Kentucky bluegrass turf maintained in reduced light conditions inside the Covered Stadium Simulator Facilty (CSSF), East Lansing, MI.†

	g_{max}					
	Ambient light			Supplemental light ‡		
	1993	1994		1993	1994	
Treatment	Feb. 3	3 Feb.	8 Apr.	3 Feb.	3 Feb.	8 Apr.
Nitrogen (kg ha^{-1}) §						
24	141.3	66.5	72.2	156.0	74.4	83.5
48	134.8	69.8	75.4	146.6	69.2	79.0
96	134.8	68.2	78.1	147.2	71.0	79.2
LSD (0.05)	ns	ns	ns	ns	ns	ns
Flurprimidol (kg ha^{-1})						
0.00	139.8	67.2	74.3	144.3	72.6	82.9
1.12 ¶	134.1	69.1	76.2	155.6	70.5	78.2
Traffic						
without	147.4	63.6	68.8	154.9	66.4	73.8
with #	128.6**	72.8**	81.7**	145.0	76.7**	87.3**

*, ** Significant at the 0.05 and 0.01 probability levels, respectively; ns = not significant at p=0.05.

† Plots were established outside during autumn of each year and moved into the CSSF on 7 Dec. 1992 and on 10 Dec. 1993.

‡ Supplemental light was supplied from 400 W high pressure sodium lamps.

§ Nitrogen was applied as urea on 16 Dec. 1992, 18 Jan., 26 Feb., 21 Dec. 1993, and 4 Feb., 21 Mar. 1994.

¶ Flurprimidol was applied on the same dates as nitrogen fertilizer.

Traffic was applied on 29 Dec. 1992, 14 Jan., 21 Jan., 29 Jan., 6 Feb., 20 Feb., 10 Mar., 24 Mar. 1993, and 6 Jan., 11 Jan., 25 Jan., 1 Feb., 10 Feb., 22 Feb., 2 Mar., 17 Mar., 24 Mar., and 31 Mar. 1994.

Turf quality remained relatively stable under the supplemental light conditions. Traffic had more of an effect on the turf in the first year than in the second year for probably two reasons: 1) shorter period of establishment in the first year, and 2) a heavier person (approximately 115 kg) applied the traffic the first year while a lighter person (approximately 75 kg) applied the traffic the second year. The turf responded significantly to flurprimidol applications in most cases although surface characteristics (shear resistance, surface hardness) were not greatly affected.

Turf quality

Nitrogen rate and flurprimidol generated main effects on turf quality throughout the study in both seasons (Table 14). Turf quality increased in proportion to nitrogen rate (Table 15). Flurprimidol significantly enhanced turf quality in both seasons. Interactions between nitrogen and flurprimidol in both seasons showed higher nitrogen rates particularly enhanced turf quality when treated with flurprimidol (Table 16). Traffic decreased turf quality in season one but had little effect in season two. A three-way interaction occurred on turf quality 91 days after installation in the CSSF in both seasons: Traffic decreased turf quality of flurprimidol-treated turf only at the low nitrogen rate; otherwise traffic had no effect. Flurprimidol was responsible for most of the three-way interaction as it enhanced the effects of nitrogen at each successive nitrogen rate (Table 17).

Table 14. Mean squares for the effects of nitrogen rate, flurprimidol, and traffic on the quality of Kentucky bluegrass maintained under supplemental light conditions inside the Covered Stadium Simulator Facility, East Lansing, MI.

		1992-93										
Source	df	18 Dec	30 Dec	8 Jan	15 Jan	20 Jan	25 Jan	3 Feb	17 Feb	8 Mar	21 Mar	10 Apr
Replication	2	1.361	0.924	1.396*	1.188*	0.111	0.021	0.215	1.049	0.000	0.965	1.194
N rate (N)	2	0.861	1.924*	2.771**	0.438	1.215	0.813**	3.882*	4.715*	3.521*	5.715	6.361
Flurprimidol (F)	1	2.778*	0.028	0.063	10.028**	14.063**	24.174**	53.778**	14.694**	41.174**	30.250**	47.840**
N x F	2	0.028	0.007	0.271	0.132	0.146	1.215**	3.215*	6.674**	2.424*	1.271	1.361
Error	10	0.361	0.282	0.313	0.271	0.561	0.079	0.657	0.690	0.500	1.482	2.803
Traffic (T) †	1	-	1.778**	1.174**	0.250	0.063	3.063**	9.000**	18.778**	3.063**	11.111**	3.674*
N x T	2	-	0.090	0.049	0.063	0.021	0.063	0.188	0.715	0.146	0.090	0.111
F x T	1	-	0.028	0.007	0.111	0.174	0.174	0.111	0.250	0.063	0.111	0.174
N x F x T	2	-	0.007	0.132	0.007	0.007	0.049	0.299	1.562	0.438*	0.090	0.194
Error	12	-	0.042	0.090	0.063	0.069	0.056	0.347	0.597	0.111	0.243	0.493
CV, %		6.91	3.19	4.32	3.66	4.06	3.80	10.20	14.64	5.52	8.25	13.85
		1993-94										
		28 Dec	5 Jan	12 Jan	24 Jan	3 Feb	10 Feb	22 Feb	3 Mar	11 Mar	17 Mar	25 Mar
Replication	2	0.361	0.861*	0.111	0.632	0.861	0.146	0.090	0.396	1.674*	0.271	0.361
N rate (N)	2	0.444	0.528	7.694**	6.132**	14.111**	2.896**	2.299**	9.333**	7.528**	13.271**	1.340*
Flurprimidol (F)	1	0.000	1.000*	5.444*	7.111**	21.778**	41.174**	72.250**	87.111**	84.028**	62.674**	55.007**
N x F	2	0.333	1.750**	2.528	1.799	4.111**	3.340**	3.146**	1.694*	1.194*	1.132*	0.549
Error	10	0.161	0.161	0.811	0.524	0.228	0.313	0.157	0.229	0.240	0.229	0.178
Traffic (T) ‡	1	-	-	0.000	0.000	0.000	0.007	0.028	0.250*	0.028	0.174	0.063
N x T	2	-	-	0.000	0.021	0.000	0.049	0.049	0.083	0.028*	0.090	0.021
F x T	1	-	-	0.000	0.000	0.000	0.063	0.250*	0.111	0.028	0.174	0.007
N x F x T	2	-	-	0.000	0.021	0.000	0.021	0.063	0.028	0.028*	0.090	0.007
Error	12	-	-	0.000	0.014	0.000	0.035	0.021	0.035	0.007	0.097	0.042
CV, %		5.15	5.32	0.00	1.74	0.00	3.00	2.16	2.90	1.29	4.89	3.09

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

† Traffic was not started until 29 Dec. 1992

‡ Traffic was not started until 6 Jan. 1993.

Table 15. Main effects of nitrogen rate and flurprimidol on the quality of Kentucky bluegrass maintained under supplemental light conditions inside the Covered Stadium Simulator Facility (CSSF), East Lansing, MI.†

	1992-93 ‡										
Treatment	18 Dec.	30 Dec.	8 Jan.	15 Jan.	20 Jan.	25 Jan.	3 Feb.	17 Feb.	8 Mar.	21 Mar.	10 Apr.
Nitrogen (kg ha^{-1}) §											
24	5.3	6.0	6.4	6.7	6.2	6.1	5.9	4.9	5.5	5.2	4.5
48	5.8	6.8	7.0	6.8	6.4	6.0	5.2	5.0	6.0	6.0	4.9
96	5.7	6.5	7.4	7.0	6.8	6.5	6.3	6.0	6.6	6.6	5.9
LSD (0.05)	ns	0.5	0.5	ns	ns	0.3	0.7	0.8	0.6	ns	ns
Flurprimidol (kg ha^{-1})											
0.00	5.8	6.4	6.9	6.3	5.9	5.4	4.6	4.6	5.0	5.1	3.9
1.12 ¶	5.3*	6.4	7.0	7.4*	7.1*	7.0**	7.0**	5.9**	7.1**	6.9**	6.2**
Traffic											
without	--	6.6	7.1	6.9	6.5	6.5	6.3	6.0	6.3	6.5	5.4
with #	--	6.2*	6.8*	6.7	6.4	5.9**	5.3**	4.6**	5.7**	5.4**	4.8**

	1993-94 ††										
	28 Dec.	5 Jan.	12 Jan.	24 Jan.	3 Feb.	10 Feb.	22 Feb.	3 Mar.	11 Mar.	17 Mar.	25 Mar.
Nitrogen (kg ha^{-1})											
24	5.8	6.2	5.4	6.1	5.2	5.7	6.2	5.4	5.7	5.2	6.2
48	6.2	6.4	6.4	6.7	6.3	6.3	7.1	6.8	6.5	6.5	6.6
96	6.2	6.6	7.0	7.5	7.3	6.6	6.7	7.1	7.2	7.3	6.9
LSD (0.05)	ns	ns	0.8	0.7	0.4	0.5	0.4	0.4	0.4	ns	0.4
Flurprimidol (kg ha^{-1})											
0.00	6.1	6.3	5.9	6.3	5.5	5.1	5.3	4.9	4.9	5.1	5.4
1.12	6.1	6.6	6.7**	7.2**	7.1**	7.3**	8.1**	8.0**	8.0**	7.7	7.8**

Table 15 (cont'd.)

Traffic											
without	--	--	6.3	6.8	6.3	6.2	6.7	6.5	6.5	6.4	6.6
with §§	--	--	6.3	6.8	6.3	6.2	6.7	6.3*	6.4	6.3	6.5

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

† Supplemental lighting (approximately 8.4 mol PAR day^{-1}) was supplied by 400 W high pressure sodium lamps.

‡ Plots were established outside in the autumn (sodded 30 Sept.) and moved inside 7 Dec. 1992.

§ Nitrogen was supplied as urea at 24, 48, or 96 kg ha^{-1} at four to six week intervals.

¶ Plots were treated with flurprimidol (1.12 kg ha^{-1}) in conjunction with fertilizer applications.

Traffic was applied 29 Dec. 1992, 14 Jan., 21 Jan., 29 Jan., 6 Feb., 20 Feb., 10 Mar., and 24 Mar. 1993.

†† Plots were established outside in the autumn (sodded 10 Sept.) and moved inside 10 Dec. 1993.

§§ Traffic was applied 6 Jan., 11 Jan., 25 Jan., 1 Feb., 10 Feb., 22 Feb., 2 Mar., 17 Mar., and 24 Mar. 1994.

Table 16. Values for the significant interactions of nitrogen rate and flurprimidol treatment on the quality of Kentucky bluegrass maintained under supplemental light conditions inside the Covered Stadium Simulator Facility (CSSF), East Lansing, MI.†

	1993							
	25 Jan.		3 Feb.		17 Feb.		8 Mar.	
	flurprimidol							
Nitrogen (kg ha^{-1})	No	Yes	No	Yes	No	Yes	No	Yes
24	5.6	6.7	5.2	6.5	4.7	5.1	4.8	6.2
48	5.3	6.8	3.7	6.7	4.8	5.2	5.2	6.9
96	5.3	7.7	4.8	7.8	4.5	7.5	5.0	8.2
LSD (0.05)	0.4		1.0		1.1		0.9	

	1994													
	5 Jan.		3 Feb.		10 Feb.		22 Feb.		3 Mar.		11 Mar.		17 Mar.	
	flurprimidol													
Nitrogen (kg ha^{-1})	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
24	6.5	6.0	5.0	5.3	5.2	6.2	5.4	7.1	4.2	6.6	4.5	6.8	4.2	6.3
48	6.2	6.7	5.5	7.2	5.2	7.5	5.5	8.7	5.2	8.3	4.8	8.2	5.3	7.8
96	6.2	7.2	6.0	8.7	5.1	8.2	4.9	8.5	5.2	9.0	5.5	9.0	5.7	9.0
LSD (0.05)	0.5		0.6		0.7		0.5		0.6		0.6		0.6	

† Supplemental lighting (approximately 8.4 mol PAR day^{-1}) was supplied with 400 W high pressure sodium lamps.
‡ Nitrogen was supplied as urea at four to six week intervals.
§ Flurprimidol (1.12 kg ha^{-1}) was applied in conjunction with fertilizer applications.

Table 17. Quality ratings for the significant nitrogen-by-flurprimidol-by-traffic interactions in Kentucky bluegrass turf under supplemental light conditions inside the Covered Stadium Simulator Facility (CSSF), East Lansing, MI.†

	8 March 1993				11 March 1994			
	No Traffic		Traffic‡		No Traffic		Traffic§	
Nitrogen rate (kg ha^{-1})¶	No PGR	PGR#	No PGR	PGR	No PGR	PGR	No PGR	PGR
24	4.8	6.5	4.7	6.0	4.5	7.0	4.5	6.7
48	5.3	7.5	5.0	6.3	4.8	8.2	4.8	8.2
96	5.5	8.3	4.5	8.0	5.5	9.0	5.5	9.0
LSD (0.05)								
between traffic	0.2				0.1			
between N rates or flurprimidol	0.9				0.6			

† Supplemental lighting (approximately 8.4 mol PAR day^{-1}) was supplied from 400 W high pressure sodium lamps.
‡ Traffic was applied 29 Dec. 1992; 14 Jan., 21 Jan., 29 Jan., 6 Feb., 20 Feb., 10 Mar., and 24 Mar. 1993.
§ Traffic was applied 6 Jan., 11 Jan., 25 Jan., 1 Feb., 10 Feb., 22 Feb., 2 Mar., 17 Mar., and 24 Mar. 1994
¶ Nitrogen was supplied as urea at four to six week intervals.
# Flurprimidol (1.12 kg ha^{-1}) was applied in conjunction with nitrogen fertilizer.

Clipping yields

Treatments indicated significant main effects and two-way interactions between nitrogen and flurprimidol and between flurprimidol and traffic on clipping yields in both seasons (Table 18). Clipping yields were proportional to nitrogen rates while flurprimidol and traffic both significantly decreased clipping yields (Table 19). The nitrogen-by-flurprimidol interactions showed flurprimidol negated the effects of nitrogen on clipping yields while increasing nitrogen rates significantly increased clipping yields in the absence of flurprimidol (Table 20). The flurprimidol-by-traffic interaction showed traffic did not reduce clipping yields when flurprimidol was applied because flurprimidol acutely reduced clipping yields compared to traffic (Table 21).

Surface characteristics

Treatments affected turf shear strength in both seasons (Table 22). No interactions occurred. Traffic and higher nitrogen rates decreased turf shear strength. Unlike the results in experiment one, the lower shear resistance values were probably due to reduced rooting and increased turf succulence as turf cover was not significantly diminished by either treatment. Flurprimidol did not affect shear strength in season one but caused a slight decline in season two (Table 23).

Treatment effects on surface hardness (CIT values) were inconsistent between seasons. In season one only the flurprimidol-by-traffic interaction was significant, while in season two the nitrogen-by-flurprimidol interaction was significant plus flurprimidol and traffic main effects (Table 24). In season one, traffic apparently decreased surface

Table 18. Mean squares and significance of treatment effects on clipping yields of Kentucky bluegrass maintained under supplemental light conditions of Covered Stadium Simulator Facility, East Lansing, MI.

		Yield (g 0.5 m^{-2})									
		1992	1993								
Source	df	29 Dec.	9 Jan.	15 Jan.	22 Jan.	29 Jan.	1 Feb.	8 Feb.	19 Feb.	12 Mar.	27 Mar.
Replication	2	3.648	12.852	2.154	0.751	0.452	5.653	1.144	38.640	30.579	13.562
Nitrogen (N)	2	80.367*	132.253*	17.2240**	3.807**	0.886	7.538	0.838	38.494	12.366	5.763
Flurprimidol (F)	1	1386.889**	2370.067**	307.126**	149.247**	40.853**	74.837**	34.028*	280.004*	131.676**	82.810**
N x F	2	51.573*	98.574*	1.729	0.468	1.380	7.538	5.038	3.205	5.476	5.763
Error	10	12.228	18.119	1.335	0.494	1.424	3.512	6.381	45.224	8.197	5.655
Traffic (T)	1	--	31.174*	28.712**	9.507**	9.558**	10.568*	19.068**	35.204**	18.562**	0.034
N x T	2	--	1.670	1.707	0.225	0.227	0.885	0.558	7.179	2.474	0.102
F x T	1	--	15.867	7.067*	4.067**	3.516*	10.568*	1.103	11.111	0.627	0.034
N x F x T	2	--	0.227	0.205	0.075	0.407	0.885	0.046	4.160	1.761	0.102
Error	12	--	3.730	0.965	0.405	0.548	1.268	0.663	3.726	0.776	0.219
CV, %		31.07	18.71	19.94	22.05	34.49	78.09	34.68	38.35	30.51	30.87

		1994									
Source	df	4 Jan.	11 Jan.	18 Jan.	24 Jan.	2 Feb.	9 Feb.	15 Feb.	22 Feb.	16 Mar.	30 Mar.
Replication	2	26.968	6.341	8.297*	0.710	6.847*	1.600*	0.527	2.351	5.353	0.181
Nitrogen (N)	2	40.417*	32.744**	23.908**	12.054**	37.376**	4.827**	13.293**	7.552*	33.100**	22.555
Flurprimidol (F)	1	315.005**	454.400**	331.847**	148.028**	408.377**	84.334**	514.156**	802.778**	239.218**	1070.380**
N x F	2	8.847	20.596**	18.860**	10.455**	24.377**	3.040**	5.473**	7.552*	2.003	9.137
Error	10	8.299	2.293	1.283	0.701	1.614	0.374	0.347	1.543	3.434	5.930
Traffic (T)	1	--	15.210**	1.734	0.780	3.706	0.490	3.770**	0.250	0.234	12.250**
N x T	2	--	0.875	0.357	0.241	1.204	0.016	0.223	0.040	2.347	0.527
F x T	1	--	8.218**	0.250	0.047	0.856	0.063	2.176**	0.250	5.444	11.222**
N x F x T	2	--	0.283	0.136	0.068	0.758	0.126	0.056	0.040	0.301	0.332
Error	12	--	0.609	0.487	0.180	1.178	0.110	0.169	0.203	1.934	0.545
CV, %		32.94	12.95	14.67	14.47	22.50	15.60	9.06	9.53	34.74	12.01

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

Table 19. Effect of nitrogen rate, flurprimidol, and traffic on clipping yields of Kentucky bluegrass maintained under supplemental light conditions of the Covered Stadium Simulator Facility (CSSF), East Lansing, MI.†

	Yield (g 0.5 m^2)									
	1992 ‡	1993								
Treatment	29 Dec.	9 Jan.	15 Jan.	22 Jan.	29 Jan.	1 Feb.	8 Feb.	19 Feb.	12 Mar.	27 Mar.
Nitrogen rate (kg ha^{-1})§										
24	7.4	6.9	3.9	2.4	1.9	0.6	2.1	3.5	1.8	0.7
48	11.6	10.5	4.7	2.8	2.2	1.5	2.3	4.8	3.1	1.9
96	14.7	13.6	6.2	3.5	2.4	2.2	2.6	6.9	3.8	1.9
LSD (0.05)	4.5	3.9	1.0	0.6	ns	ns	ns	ns	ns	ns
Flurprimidol (kg ha^{-1})¶										
none	20.033	18.4	7.8	4.9	3.2	2.9	3.3	7.8	4.8	3.0
1.12	2.478**	2.2*	2.0**	0.8**	1.1**	0.0**	1.4*	2.2*	1.0**	0.0**
Traffic										
without	--	11.3	5.8	3.4	2.7	2.0	3.1	6.0	3.6	1.5
with #	--	9.4**	4.0**	2.4**	1.6**	0.9*	1.6**	4.0**	2.2**	1.5

	1994 ††									
Treatment	4 Jan.	11 Jan.	18 Jan.	24 Jan.	2 Feb.	9 Feb.	15 Feb.	22 Feb.	16 Mar.	30 Mar.
Nitrogen rate (kg ha^{-1})‡‡										
24	5.8	4.2	3.3	1.9	3.0	1.5	3.3	3.8	2.3	4.7
48	9.6	6.3	4.9	3.1	4.9	2.2	5.1	5.2	4.0	6.4
96	10.8	7.5	6.1	3.9	6.6	2.7	5.1	5.1	5.6	7.4
LSD (0.05)	3.7	1.4	1.0	0.8	1.2	0.6	0.5	1.1	1.7	ns
Flurprimidol (kg ha^{-1})										
none	12.9	9.6	7.8	5.0	8.2	3.7	8.3	9.4	6.6	11.6
1.12	4.6**	2.5**	1.7**	0.9**	1.5**	0.6**	0.8**	0.0**	1.4**	0.7**
Traffic										
without	--	6.7	5.0	3.1	5.1	2.2	4.9	4.8	4.1	6.7
with §§	--	5.4**	4.5	2.8	4.5	2.0	4.2**	4.6	3.9	5.6**

Table 19 (cont'd.)

*, ** Significant at the 0.05 and 0.01 probability levels, respectively; ns = not significant at p=0.05.
† Supplemental light was supplied by 400 W high pressure sodium lamps.
‡ Plots were established outside during autumn 1992 and moved into the CSSF on 7 Dec. 1992.
§ Nitrogen was applied as urea on 16 Dec. 1992, 18 Jan., and 26 Feb. 1993.
¶ Flurprimidol was applied on the same date as nitrogen in both years.
# Traffic was applied 29 Dec. 1992; 14 Jan., 21 Jan., 29 Jan., 6 Feb., 20 Feb., 10 Mar., and 24 Mar. 1993.
†† Plots were established outside during autumn 1993 and moved into the CSSF on 10 Dec. 1993.
‡‡ Nitrogen was applied as urea on 17 Dec. 1992; 4 Feb.,and 21 Mar. 1994.
§§ Traffic was applied 6 Jan., 11 Jan., 25 Jan., 1 Feb., 10 Feb., 22 Feb., 2 Mar., 17 Mar., and 24 Mar. 1994.

Table 20. Clipping yields for the significant nitrogen-by-flurprimidol interactions in Kentucky bluegrass turf maintained under supplementary light conditions in the Covered Stadium Simulator Facility (CSSF), East Lansing, MI.†

	Yield (g 0.5 m^{-2})																	
	1992 ‡		1993		1994§													
	29 Dec.		9 Jan.		11 Jan.		18 Jan.		24 Jan.		2 Feb.		9 Feb.		15 Feb.		22 Feb.	
	Flurprimidol ¶																	
Nitrogen (kg ha^{-1})#	no	yes	no	yes	no	yes	no	yes	no	yes	no	yes	no	yes	no	yes	no	yes
24	13.0	1.9	11.9	2.0	6.9	1.6	5.5	1.1	3.2	0.6	5.4	0.7	2.6	0.3	6.3	0.3	7.6	0.0
48	21.2	2.0	19.3	1.7	9.3	3.4	7.4	2.4	4.8	1.3	7.6	2.1	3.5	0.9	9.4	1.0	10.5	0.0
96	25.9	3.5	24.1	3.0	12.5	2.4	10.6	1.6	6.9	0.8	11.6	1.6	4.8	0.6	9.3	1.0	10.2	0.0
LSD (0.05)	6.4		5.5		1.9		1.5		1.1		2.1		0.8		0.8		1.6	

† Supplemental lighting was supplied from 400 W high pressure sodium lamps.
‡ Plots were established outside during autumn 1992 and moved into the CSSF on 7 Dec. 1992.
§ Plots were established outside during autumn 1993 and moved into the CSSF on 10 Dec. 1993.
¶ Flurprimidol (1.12 kg ha^{-1}) was applied on 16 Dec. 1992, 18 Jan., 26 Feb., and 21 Dec. 1993, 4 Feb., and 21 Mar. 1994.
# Nitrogen was applied as urea on the same dates as flurprimidol.

Table 21. Clipping yields for the significant flurprimidol-by-traffic interactions in Kentucky bluegrass turf maintained under supplementary light conditions in the Covered Stadium Simulator Facility (CSSF), East Lansing, MI.†

	Yield (g 0.5 m^{-2})													
	1993 ‡								1994 §					
	15 Jan.		22 Jan.		29 Jan.		1 Feb.		11 Jan.		15 Feb.		30 Mar.	
	Traffic ¶													
Flurprimidol ($kg\ ha^{-1}$) #	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
0.00	9.2	6.5	5.7	4.1	4.0	2.4	4.0	0.0	10.7	8.4	8.9	7.8	12.7	10.5
1.12	2.5	1.6	1.0	0.7	1.3	0.9	1.8	0.0	2.6	2.3	0.8	0.7	0.7	0.7
LSD (0.05)	1.0		0.6		0.8		1.2		0.8		0.4		0.8	

† Supplemental light was supplied with 400 W high pressure sodium lamps.

‡ Plots were established outside during autumn 1992 and moved into the CSSF on 7 Dec. 1992.

§ Plots were established outside during autumn 1993 and moved into the CSSF on 10 Dec. 1993.

¶ Traffic was applied 29 Dec. 1992, 14 Jan., 21 Jan., and 29 Jan. 1993 and 6 Jan., 11 Jan., 25 Jan., 1 Feb., 10 Feb., 22 Feb., 2 Mar., 17 Mar., and 24 Mar. 1994.

Flurprimidol (1.12 $kg\ ha^{-1}$) was applied 16 Dec. 1992, 18 Jan., 26 Feb., 21 Dec. 1993, and 4 Feb., 21 Mar. 1994.

Table 22. Mean squares and significance of treatment effects on the shear resistance of Kentucky bluegrass maintained under supplemental light conditions inside the Covered Stadium Simulator Facility, East Lansing, MI.

		Shear resistance (N•m)					
		1992-93				1993-94	
Source	df	22 Dec.	11 Jan.	3 Feb.	20 May	28 Dec.	8 Apr.
Replication	2	50.361**	10.896	10.882	5.027	23.083	5.090
N rate (N)	2	0.528	6.813	12.340	127.823**	5.250	281.757**
Flurprimidol (F)	1	1.000	16.000	16.000	15.867	8.028	20.250*
N x F	2	19.083	10.146	3.271	3.151	0.861	6.896
Error	10	5.828	6.929	8.315	3.643	9.083	3.599
Traffic (T)†	1	------	12.250	4.000	125.814**	------	20.250*
N x T	2	------	2.021	4.146	2.014	------	10.021
F x T	1	------	0.694	0.111	1.914	------	2.778
N x F x T	2	------	1.882	1.549	0.034	------	0.632
Error	12	------	4.604	7.271	2.537	------	3.764
CV, %		0.00	9.61	12.87	12.82	0.00	10.95

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

† Traffic was not started until 29 Dec. 1992 the first year and 6 Jan. 1994 the second year.

Table 23. Effects of nitrogen, flurprimidol, and traffic on the shear resistance of Kentucky bluegrass maintained under supplemental light conditions inside the Covered Stadium Simulator Facility (CSSF), East Lansing, MI.†

	Shear resistance (N•m)					
	1992-93				1993-94	
Treatment	22 Dec.	11 Jan.	3 Feb.	20 May	28 Dec.	8 Apr.
Nitrogen (kg ha^{-1}) ‡						
24	21.8	23.1	22.0	16.1	23.7	22.2
48	21.5	22.2	20.0	11.5	24.7	18.4
96	21.9	21.6	20.8	9.7	24.9	12.6
LSD (0.05)	ns	ns	ns	1.7	ns	2.4
Flurprimidol (kg ha^{-1})						
none	21.9	21.7	20.8	11.8	24.9	18.5
1.12 §	21.6	23.0	21.6	13.1	23.9	17.0*
Traffic						
without	----	22.9	21.3	14.3	----	18.5
with ¶	----	21.8	20.6	10.6	----	17.0*

* Significant at the 0.05 probability level; ns=not significant at p=0.05.

† Supplemental light (approximately 8.4 mol day^{-1}) was supplied by 400 W high pressure sodium lamps.

‡ Nitrogen was applied as urea on 16 Dec. 1992, 18 Jan., 17 Dec. 1993, 4 Feb., and 21 Mar. 1994.

§ Flurprimidol was applied on the same days as nitrogen.

¶ Traffic was applied 29 Dec. 1992, 14 Jan., 21 Jan., 29 Jan., and 6 Feb. 1993, and 6 Jan., 11 Jan., 25 Jan., 1 Feb., 10 Feb., 22 Feb., 2 Mar., 17 Mar., and 24 Mar. 1994.

Table 24. Mean squares and significance of treatment effects on the surface hardness of Kentucky bluegrass turf maintained under supplemental light conditions in the Covered Stadium Simulator Facility, East Lansing, MI.

		1993	1993-94	
Source	df	3 Feb.	3 Feb.	8 Apr.
Replication	2	2762.861**	85.343	146.551*
N rate (N)	2	331.361	84.010	77.048
Flurprimidol (F)	1	1156.000	37.414	198.810*
N x F	2	245.583	109.471	214.666**
Error	10	316.228	35.931	23.308
Traffic (T)	1	880.111	945.563**	1653.778**
N x T	2	525.194	2.843	0.564
F x T	1	2177.778**	0.122	17.921
N x F x T	2	739.528	9.880	41.792
Error	12	195.889	19.469	30.086
CV, %		9.33	6.17	6.81

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

Table 25. Clegg Impact Values (g_{max}) for the flurprimidol-by-traffic interaction (3 Feb. 1993) and flurprimidol-by-nitrogen interaction (8 Apr. 1994) in Kentucky bluegrass turf maintained under supplemental light conditions in the Covered Stadium Simulator Facilty, East Lansing, MI.†

	g_{max}				
	3 Feb. 1993		8 Apr. 1994		
	flurprimidol (kg ha^{-1})‡			flurprimidol (kg ha^{-1})§	
Traffic¶	0.00	1.12	Nitrogen (kg ha^{-1})#	0.00	1.12
	g			g	
without	157.0	152.8	24	83.2	83.8
with	131.6	158.4	48	86.3	71.8
			96	79.3	79.0
LSD (0.05)	14.4			6.2	

† Supplemental light (approximately 8.4 mol day^{-1}) was supplied by 400 W high pressure sodium lamps.
‡ Flurprimidol was applied 16 Dec. 1992 and 18 Jan. 1993
§ Flurprimidol was applied 21 Dec. 1992 and 4 Feb. 1993.
¶ Traffic was applied 29 Dec. 1992, 14 Jan., 21 Jan., and 29 Jan. 1993
# Nitrogen was applied on the same dates as flurprimidol.

hardness in the absence of flurprimidol; traffic did not affect surface hardness of turf treated with flurprimidol (Table 25). Untreated turf was flaccid and traffic caused a prostrate growth (grain), forming a cushion on the surface which absorbed the impact of the CIT hammer. Turf treated with flurprimidol remained rigid and had an upright growth which resulted in similar amounts of foliage removal during mowing, thus providing similar cushioning, regardless of traffic. The flurprimidol-by-nitrogen interaction was more difficult to decipher. CIT values were inconsistent among treatments and did not indicate an orderly or meaningful response (Table 25).

Plant density

By August 1994 all turf was maintaining fair to excellent quality and had completely recovered from traffic. Plant biomass data showed flurprimidol significantly affected turf growth five months after the final treatment had been applied. While the number of plants per unit area was less in plots treated with flurprimidol compared to control plots, the number of shoots per plant was nearly double, and verdure mass was approximately 25% greater (Table 26).

CONCLUSIONS

Kentucky bluegrass turf in the early stages of winter dormancy recovered sufficiently within two weeks at approximately 1 mol PAR m^{-2} day^{-1} and temporarily provided acceptable quality. However, this level of light was insufficient to maintain acceptable Kentucky bluegrass turf for periods of longer than eight weeks. At 1-3 mol m^{-2} day^{-1} PAR the best nitrogen rates were a low or medium rate (24 and 48 kg ha^{-1} $month^{-1}$).

Table 26. Plant density, shoot density, and verdure weight of Kentucky bluegrass maintained under supplemental light in the Covered Stadium Simulator Facility, 10 Dec. 1993 to 23 August 1994.†

Treatment	No. of plants m^{-2} ‡	No. of shoots $plant^{-1}$ §	Verdure ($g\ m^{-2}$) ¶
Nitrogen rate ($kg\ ha^{-1}$) #			
24	8885	2.8	60.8
48	8144	3.2	60.7
96	7095	3.5	49.1
LSD (0.05)	ns	ns	ns
Flurprimidol rate ($kg\ ha^{-1}$) ††			
0.00	9474	2.2	49.7
1.12	6609 **	4.0 *	64.1

*,** Significant at the 0.05 and 0.01 probability levels, respectively.
† Supplemental light, approximately 8.4 mol PAR day^{-1}, was supplied from 400 W high pressure sodium lamps.
‡ Plants were counted from a 10 cm diam core extracted from each plot.
§ Five randomly selected plants from each plot were used for analysis.
¶ Verdure was collected from a 10 cm diam core extracted from each plot and included all living above ground
plant tissue.
Nitrogen was applied as urea on 21 Dec. 1993, 4 Feb. 1994, 21 March 1994.
†† Flurprimidol was applied on the same dates as nitrogen fertilizer.

Traffic and high nitrogen rates (e.g., 96 kg ha^{-1}) hastened demise of the turf, while flurprimidol extended the period of acceptable quality for a short period (e.g., two weeks). Two or more full rate applications of flurprimidol at four to six weeks halted the turf vertical growth rate which may have reduced the potential for recovery from damage (Stier et al., 1994), although lack of sufficient light would probably have been the limiting factor for recovery.

Kentucky bluegrass turf recovered from winter dormancy within two weeks when placed in supplemental light conditions. Reduced light of approximately 8.4 mol PAR m^{-2} day^{-1} was sufficient to maintain high quality turf indefinitely, even in trafficked conditions. The medium nitrogen rate (48 kg ha^{-1} mo^{-1}) was considered optimal as it provided the most desirable combination of quality, yield, hardness, and shear resistance. Flurprimidol significantally improved turf quality throughout the study and was paramount for maintaining high turf quality. Timing of flurprimidol applications and rates need to be further assessed as turf vertical growth was nearly totally halted following the second application. Flurprimidol rates and application intervals should be determined that allow a steady suppression of growth without inhibiting turf recovery from traffic and other damages. Diesburg and Christians (1989) reported the combination of growth phase and season affected turf response to PGRs. Since the environment of indoor stadia is moderated, long-term or permanent use of turf in covered stadia or other reduced light conditions may require unique rates and application intervals due to the lack of seasonal changes.