Chapter 2

THE EFFECTS OF TRINEXAPAC-ETHYL AND FOLIAR IRON ON SUPINA BLUEGRASS (*POA SUPINA* SCHRAD.) AND KENTUCKY BLUEGRASS (*P. PRATENSIS* L.)

INTRODUCTION

Commonly used cool-season turfgrasses are thought to have evolved near the margins of forests in Eurasia where light would not have been limited (Beard, 1973). Consequently, most commonly used cool-season turfgrass species have relatively poor shade tolerance with the exception of the fine fescues (e.g., *Festuca rubra* L., *F. rubra* var. *commutata* Gaud.). As a turf, fine fescues perform best in conditions of well-drained soil and low fertility but have poor traffic tolerance due in part to a slow recuperative rate (Beard, 1973). Kentucky bluegrass (*Poa pratensis* L.) is the most commonly used cool-season turfgrass but its growth can be severely limited in the shade due to insufficient light and enhanced disease susceptibility (Beard, 1973; Vargas and Beard, 1981). Rough bluegrass (*Poa trivialis* L.) has better shade tolerance than Kentucky bluegrass but lacks traffic tolerance. A relatively shade and traffic tolerant cool-season turfgrass species is desirable for golf courses, lawns, and athletic fields.

Supina bluegrass (*P. supina* Schrad.) has been cultivated as a cool-season turfgrass in Germany for over 20 years (Berner, 1984). Supina bluegrass is a stoloniferous turfgrass capable of forming a dense turf at low mowing heights suitable for lawns, athletic fields, and golf course fairways, tees, and putting greens (Berner, 1980; Nonn, 1994; Pietsch, 1989). The stolons are significantly more robust and have shorter internodes compared to rough bluegrass (personal observation). Supina bluegrass is found naturally in high traffic areas (e.g., human and cattle paths) and in moist, shaded areas in woods near the Alps (Berner, 1984; Pietsch, 1989). Supina bluegrass is well adapted to cold weather and is common even in the sub-alpine regions of the Alps (Berner, 1984; Köck and Walch, 1977; Skirde, 1971). In Germany, Supina bluegrass often encroaches and fills in high wear areas on sports fields (Köck and Walch, 1977); subsequent testing documented the high wear tolerance which is at least partly due to a rapid recuperative rate (Berner, 1980; Berner 1984). In addition, Supina bluegrass has been observed to have a high level of shade tolerance on golf courses, lawns, and in controlled tests in Germany although the actual data have not been reported (Pietsch, 1989). The ability to persist in moist, shaded, high traffic environments makes Supina bluegrass a suitable candidate for use as a turf for shaded golf course or athletic field situations (e.g., partially or wholly covered stadia). Drawbacks to the production and use of Supina bluegrass are its poor seed yield (hence, high cost), poor drought tolerance, undefined management schemes, and light green leaf color (Berner, 1980; Leinauer et al., 1991). The development of management schemes requires controlled investigation. While seed yield and drought tolerance are characteristics not easily altered, leaf color is an adjustable parameter which could increase the acceptablity of Supina bluegrass if a darker color can be easily obtained.

Plant growth regulators (PGRs) and foliar applications of iron have been used successfully to enhance (darken) turf foliage in normal field conditions (Brueninger et al., 1983; Freeborg, 1983; Glinski et al., 1992; Yust et al., 1984). Foliar applications of iron have also been useful to negate the transient phytotoxicity which can result from a PGR (Carrow & Johnson, 1990). Recent reports indicate PGRs can also significantly enhance turf color and quality in reduced light conditions (RLC) (< 30% full sunlight) (Rogers et al., 1996; Stier et al., 1994) although the effects of iron are relatively unknown. Although moderate RLC result in increased chlorophyll content, extreme RLC reduce chlorophyll content resulting in a lighter green color (Beard, 1973). In our research we have found chlorophyll levels in Kentucky bluegrass decline at less than approximately 10 mol photosynthetically active radiation (PAR) day^{-1}, equivalent to approximately 20% full summer sunlight (*unpublished data*).

The objectives of this research were to: 1) Compare the shade tolerance of Supina bluegrass and Kentucky bluegrass under a defined light regime, and 2) Determine the effects of multiple applications of trinexapac-ethyl (below label rates) and foliar applications of iron on the growth and quality of Supina bluegrass and Kentucky bluegrass in RLC.

MATERIALS AND METHODS

<u>Experimental environment</u>

The research was conducted inside the Covered Stadium Simulator Facility (CSSF) at the Hancock Turfgrass Research Center from Dec. 1994 through May 1996. Constructed initially in 1992 with a fiberglass fabric (Sheerfill IV, Chemical Fabrics Corporation, Buffalo, NY) which transmitted 11 ± 2% sunlight, the fabric was replaced in late October

1994. The new fiberglass fabric, Sheerfill IV®, transmitted approximately 10.5 ± 1.4% solar radiation from Nov. 1994 through April 1995. After being bleached by the sun in the spring and summer of 1995, the fabric transmitted approximately 15.5 ± 3.0 % solar radiation from Dec. 1995 through May 1996. Quality of the light transmitted through the Sheerfill IV® was equivalent to that transmitted by Sheerfill II® (Figure 1, Chapter 1). Temperature and relative humidity were recorded daily with a sling psychrometer. Temperature was maintained typically at 16.6 C using furnaces. Actual temperatures ranged from 12.2 to 24.4 C due to the inability of the furnaces to compensate for extremely low outdoor temperatures (e.g., -10 C) and due to the lack of an active cooling system as outdoor air temperatures rose during the spring. Relative humidity averaged 45.6 ± 12.5 % with a range of 28-63%.

Daily totals of photosynthetically active radiation (PAR) in the CSSF were determined based on the percent of PAR transmitted through the fabric onto the turf surface inside the CSSF. To determine percentage of light transmission, data were collected weekly from each plot inside the CSSF within one hour of the solar zenith using a Li-Cor 1800 portable spectroradiometer (Li-Cor, Lincoln, NE). Two to four measurements were collected outside the CSSF with the spectroradiometer immediately before and immediately after collecting data inside the CSSF. Daily solar radiation data outside the CSSF were collected with a Li-Cor PY 14226 pyranometer (Li-Cor, Lincoln, NE) located approximately 15 m away from the CSSF. Pyranometer data were integrated hourly and daily through a Maxi weather station (Rain Bird Sales, Inc., Glendora, CA). Radiometric units from the pyranometer were converted to quantum units using the following equation which was based on conversion units from Thimijan and Heins (1983):

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

The average percentage of light transmitted into the CSSF was used to determine the daily PAR inside the CSSF based on the data recorded outside with the pyranometer.

Plot construction and maintenance

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 85 and 90 kg ha^{-1}, respectively, in 1994. In 1995, the pH was 7.7 with initial P and K levels of 131 and 85 kg ha^{-1}, respectively. Sixteen holes (0.6 cm diam) were drilled in the bottoms of each box to provide drainage. The sand:peat mixture was compacted using hand-held tampers. Starter fertilizer (13-25-12 in 1994) was added to the sand:peat mixture surface prior to sodding to supply 66 kg P ha^{-1} and 58 kg K ha^{-1} in 1994. The plots were sodded 28 September 1994 and 28 August 1995. Additional fertilizer was applied twice in 1994 (24, 20, and 18.5 kg N, P, K ha^{-1}, respectively, on 29 Sept. and 36, 30, and 28 kg N, P, K ha^{-1}, respectively, 13 Oct.) and once in 1995 (24, 20, and 18.5 kg N, P, K ha^{-1}, respectively, on 29 Sept.) prior to moving the plots into the CSSF. Supina bluegrass 'Supranova' and Kentucky bluegrass 'Victa'/'Abbey' (50:50 v/v) were used both years. In 1994 the Supina bluegrass sod had been raised in a woody yard waste compost media while in 1995 washed Supina bluegrass sod grown in a sandy loam soil was used for establishment (sod raised in the woody compost was not available). In both 1994 and 1995 washed Kentucky bluegrass sod grown in an organic soil was used for establishment. Plots were mowed once to twice weekly depending on height of cut and growth rate. During establishment (approximately three weeks) plots were mowed with a rotary mower set at 5 cm height. The height was gradually lowered to 3 cm; a reel mower was used once a 3 cm cutting height was achieved. Plots were irrigated as necessary to prevent visible drought stress (bluish-green color, footprinting, wilting). Trinexapac-ethyl (0.19 kg ha^{-1}, approximately two-thirds the full label rate for Kentucky bluegrass) was applied to six plots each of Supina bluegrass and Kentucky bluegrass on 3 Oct. 1994 and 9 Oct. 1995. A CO_2-powered backpack sprayer with 8002 flat fan nozzles was used to apply the trinexapac-ethyl in 896 L H_2O ha^{-1}. Plots were moved into the CSSF for testing from 12 Dec. 1994 through 12 April 1995 and from 8 Dec. 1995 through 11 June 1996.

The plots were arranged in the CSSF in a completely randomized design with three replications per treatment. Two experiments were designed to determined treatment effects in both non-trafficked (Experiment I) and trafficked (Experiment II) conditions. Traffic was applied by having a person (approximately 70-75 kg) jog 50 passes each week. Traffic was applied 28 Dec. 1994 through 16 Mar. 1995 (total of 144 passes) and 26 Jan. 1995 through 26 Apr. 1996 (total of 168 passes). Additional trinexapac-ethyl (0.08 kg ha^{-1}, approximately one-quarter the full label rate for Kentucky bluegrass, diluted in 896 L H_2O ha^{-1}) was applied on 21 Dec. 1994, 20 Jan., 18 Feb., and 16 Mar. 1995 for the first year's testing and on 31 Jan., 15 Mar., and 26 Apr. 1996 for the second year's testing. Iron (1.14 kg ha^{-1} as $FeSO_4 \cdot 7H_2O$) was applied to foliage using Ferromec

AC (PBI Gordon Corp., Kansas City, MO) on the following dates: 10 Jan., 14 Feb., and 17 Mar. 1995; 28 Feb. and 13 May 1996.

Plots were fertilized monthly with 24, 2, and 20 kg ha^{-1} N, P, and K, respectively (18-3-18). Approximately 1.25 cm water was applied immediately following fertilizer application. Additional irrigation was applied as necessary to prevent drought stress (approximately 1.25 cm at seven to 14 day intervals). Industrial fans were occasionally used for 24-72 h periods to dry the turf surface following irrigation to discourage fungal pathogen activity. Iprodione (3-(3,5-Dichlorophenyl)-N-(1-methylethyl)-2,4-dioxo-1-imidazolidinecarboximide) was applied to all plots on 23 Dec. 1994 (3 kg ha^{-1}), 6 Mar. (6 kg ha^{-1}) and 14 Apr. (6 kg ha^{-1}), 1995 to control Microdochium patch (*Microdochium nivale*), primarily on the Supina bluegrass.

Data collection

A reel mower was used to maintain turf height at 3 cm. The turf was mowed once to twice weekly to prevent removal of more than one-third of the leaf tissue. Mowing was always performed immediately preceding data collection or fertilizer, trinexapac-ethyl, or traffic application. Clippings were generally collected for clipping yield determination except occasionally when time limits precluded clipping collection. Clippings were collected from a 41 x 117 cm strip through the center of each trafficked and non-trafficked plot. Clippings were dried in a forced-air oven at 60 C for 48 h then weighed.

Turf color and quality were evaluated visually on a one to nine scale. A one rating represented 100% necrotic turf/bare soil, while a nine rating represented dark green or ideal turf, respectively. A value of five was considered the minimum acceptable unit.

Turf rooting and strength were evaluated periodically using an Eijkelkamp shear vane apparatus (Eijkelkamp, Giesbeek, The Netherlands). The torque required to tear the turf with the shear vane was recorded as an average of two measurements per plot (Rogers and Waddington, 1990). On 24 March 1995 and 30 May 1996, plant densities were determined by counting the number of plants in eight random squares (32.7 cm^2 each) of a 0.4 m quadrat (Skogley and Sawyer, 1992). Leaf samples from 10 randomly selected plants were collected from each non-trafficked plot for chlorophyll analysis on 4 Apr. 1995 and 29 May 1996 (trafficked plots were not sampled because adequate plant material was often not available). A 10 mm segment from the youngest fully expanded leaf of each plant was excised starting 5 mm above the leaf collar. The leaf portion next to the shoot (< 5 mm distant) was avoided due to possible physiological differences compared to the more mature leaf region (Skinner and Nelson, 1995). Chlorophyll was extracted in three ml *N,N*-dimethlyformamide (DMF) incubated in the dark at 4 C for 48 h (Moran and Porath, 1980). A double-beam spectrophotometer was used to determine absorbances and the extinction coefficients described by Inskeep and Bloom (1985) were used to calculate levels of chlorophyll *a*, *b*, and total chlorophyll. On 12 Apr. 1995 and 31 May 1996 samples of ten randomly selected plants were collected from each plot for biomass assessments. Average leaf number $shoot^{-1}$, average shoot number $plant^{-1}$, and average oven-dry weight $plant^{-1}$ were determined for each sample.

Data were analyzed using MSTAT analysis of variance procedures. Data were analyzed as a 2x2x2 factorial in a completely randomized design with three replications.

RESULTS AND DISCUSSION

Temperature inside the CSSF averaged 16.6 C ± 1.5 C with a range of 12-24 C. Relative humidity averaged 46% ± 12% with a range of 28-63%. Photosynthetically active radiation inside the CSSF ranged from approximately 1 mol PAR day^{-1} during December 1994 to approximately 5 mol PAR day^{-1} in May 1996 (Table 27). The Supina bluegrass responded to the increased PAR in the spring more than did Kentucky bluegrass. In general, quality of the Supina bluegrass in 1995-96 was superior to that in 1994-95, probably largely due to the higher light transmittance of the Sheerfill IV fabric due to bleaching by the sun during the summer of 1995.

Turf color and quality

Experiment I: Turf not subjected to traffic

Turf color and quality was affected by both species and trinexapac-ethyl as soon as observations began once inside the CSSF (Tables 28 and 29). The turf was dormant when it was brought into the CSSF and recovered quickly the first year (1994) but slowly the second year (1995). In 1995 the weather had become quite cold in early November without an appropriate transition ("hardening-off") period between growing and non-growing conditions which probably caused the delay in recovery inside the CSSF. The extra N application in autumn 1994 may also have contributed to faster green-up of turf inside the CSSF. Turf treated with trinexapac-ethyl was particularly slow to recover inside the CSSF during the second year (Tables 30 and 31). Once recovered from

Table 27. Photosynthetically active radiation (PAR) at the Hancock Turfgrass Research Center, East Lansing, MI.

Location	Dec. 1994	Jan. 1995	Feb. 1995	Mar. 1995	Apr. 1995	
	---- mol PAR day^{-1} † ----					
average	8.4	9.4	19.2	24.8	26.9	
stnd deviation	3.9	6.5	6.6	10.4	12.8	
CSSF ‡, Ambient light						
average	0.9	1.0	2.0	2.6	2.8	
stnd deviation	0.4	0.7	0.7	1.1	1.4	
	Dec. 1995	Jan. 1996	Feb. 1996	Mar. 1996	Apr. 1996	May 1996
	---- mol PAR day^{-1} ----					
average	9.5	10.6	14.6	27.8	29.0	34.1
stnd deviation	4.4	4.7	7.6	10.2	14.6	14.5
CSSF, Ambient light						
average	1.5	1.6	2.3	4.3	4.5	5.3
stnd deviation	0.7	0.7	1.2	1.6	2.3	2.2

† 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 m^{-2} 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 level with a photometer (Greenlee Inc., Rockford IL) or a portable spectroradiometer (Li-Cor, model LI-1800, Lincoln NE).

Table 28. Mean squares and treatment effects on quality ratings of non-trafficked turfgrass in reduced light conditions, Hancock Turfgrass Research Center, East Lansing, MI.

		1994-1995						
Source of variation	df	20 Dec.	6 Jan.	26 Jan.	9 Feb.	24 Feb.	17 Mar.	6 Apr.
Species (S)	1	11.344	8.167**	7.594**	0.010	0.260	6.000**	27.094**
Trinexapac-ethyl (TE)	1	2.344	3.375**	25.010**	23.010**	27.094**	32.667**	44.010**
S x TE	1	0.260	2.667**	5.510**	12.760**	14.260**	9.375**	0.094
Iron (Fe)	1	0.844	0.667*	0.510	0.010	0.094	0.167	0.844*
S x Fe	1	0.844	0.042	0.260	0.844*	0.010	0.375	0.094
TE x Fe	1	0.010	0.167	0.844	0.010	0.260	0.042	1.260*
S x TE x Fe	1	0.094	0.042	0.094	0.010	0.510	0.000	0.260
Error	16	12.667	1.833	0.302	0.156	4.500	0.240	0.240
CV, %		14.38	5.05	9.26	7.81	11.21	12.37	10.63

		1995-1996									
Source of variation	df	20 Dec.	5 Jan.	26 Jan.	19 Feb.	8 Mar.	29 Mar.	26 Apr.	13 May	29 May	11 June
Species (S)	1	1.500	0.167	2.344	4.594**	7.594*	41.344**	58.594**	71.760**	104.167**	82.510**
Trinexapac-ethyl (TE)	1	12.042**	26.042**	3.760*	1.260**	8.760**	12.760**	38.760**	17.510**	15.042**	12.760**
S x TE	1	3.375**	28.167**	5.510**	0.010	3.760**	3.010	11.344**	14.260**	16.667**	21.094**
Iron (Fe)	1	0.042	0.167	0.010	1.260**	1.760*	0.510	0.844	0.510	0.000	0.844
S x Fe	1	1.042	0.042	0.094	0.510*	0.010	0.510	0.510	0.010	0.042	0.010
TE x Fe	1	0.000	0.167	0.010	0.010	0.010	0.094	1.260	0.010	0.000	0.510
S x TE x Fe	1	1.500	0.042	0.010	0.260	0.510	0.094	0.094	0.510	0.042	0.094
Error	16	0.313	0.146	0.500	0.115	0.396	0.760	0.615	0.427	0.135	0.396
CV, %		15.97	7.83	12.52	5.09	10.45	15.56	18.91	19.73	11.78	20.54

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

Table 29. Mean squares and treatment effects on color ratings of non-trafficked turfgrass in reduced light conditions, Hancock Turfgrass Research Center, East Lansing, MI.

Source of variation	df	1994-1995						
		20 Dec.	6 Jan.	26 Jan.	9 Feb.	24 Feb.	17 Mar.	6 Apr.
Species (S)	1	31.510**	12.042**	3.375*	2.344*	10.667**	7.594**	5.042**
Trinexapac-ethyl (TE)	1	5.510**	12.042**	28.167**	33.844**	57.042**	68.344**	40.042**
S x TE	1	4.594**	1.042**	1.500**	17.510**	3.375**	1.760**	0.375
Iron (Fe)	1	0.010	0.042	0.042	1.260*	2.042**	0.260	0.042
S x Fe	1	0.094	0.042	3.375**	0.510	0.042	0.010	0.042
TE x Fe	1	0.260	0.042	0.667*	0.260	0.167	0.844	2.042*
S x TE x Fe	1	0.094	0.042	0.000	0.510	0.667	0.844	2.042*
Error	16	0.104	0.115	0.115	0.229	0.146	0.125	0.302
CV, %		5.25	6.02	6.40	10.21	7.16	6.98	9.92

Source of variation	df	1995-1996										
		20 Dec.	5 Jan.	26 Jan.	19 Feb.	28 Feb.	8 Mar.	29 Mar.	26 Apr.	13 May	29 May	11 June
Species (S)	1	6.000**	0.094	5.510*	12.042**	21.094**	6.000*	14.260**	16.667*	100.042**	165.375**	119.260**
Trinexapac-ethyl (TE)	1	20.167**	38.760**	5.510**	5.042**	12.760**	6.000**	11.344**	32.667**	13.500**	8.167**	3.760**
S x TE	1	2.667*	36.260**	10.010**	0.000	0.260	0.000	0.260	0.667	13.500**	8.167**	3.760**
Iron (Fe)	1	0.667	1.260	0.260	0.667	3.760*	3.375**	0.510	1.500	0.167	0.667**	0.010
S x Fe	1	0.167	0.510	0.094	1.042	0.094	0.042	0.510	1.500	0.000	0.667**	0.010
TE x Fe	1	0.167	0.510	0.010	1.042	1.260	2.042*	0.260	1.500	0.042	0.375**	0.010
S x TE x Fe	1	0.667	0.010	0.510	0.667	1.260	0.042	0.010	0.167	0.042	0.375**	0.010
Error	16	0.396	0.490	0.302	0.333	0.469	0.271	0.240	0.552	0.073	0.021	0.104
CV, %		21.57	15.62	9.73	9.12	11.86	8.22	9.07	18.58	7.62	3.98	9.99

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

Table 30. Effect of species, trinexapac-ethyl, and iron on quality[†] of non-trafficked turfgrass in reduced light conditions, Hancock Turfgrass Research Center, East Lansing, MI.

	1994-1995						
Treatment	20 Dec.	6 Jan.	26 Jan.	9 Feb.	24 Feb.	17 Mar.	6 Apr.
Species							
Supina bluegrass	6.9	7.3	6.5	5.0	4.8	4.5	5.7
Kentucky bluegrass	5.5	6.1	5.4**	5.1	4.6	3.5**	3.5**
Trinexapac-ethyl							
no	5.9	6.3	4.9	4.1	3.7	2.8	3.2
yes‡	6.5	7.1	7.0**	6.0**	5.8**	5.1**	6.0**
Iron							
no	6.4	6.9	6.1	5.0	4.8	4.0	4.8
yes§	6.0	6.5	5.8	5.1	4.7	3.9	4.4*

	1995-1996									
Treatment	20 Dec.	5 Jan.	26 Jan.	19 Feb.	8 Mar.	29 Mar.	26 Apr.	13 May	29 May	11 June
Species										
Supina bluegrass	3.2	4.8	6.0	7.1	6.6	6.9	5.7	5.0	5.2	4.9
Kentucky bluegrass	3.8	5.0	5.3	6.2**	5.5*	4.3**	2.6**	1.6**	1.0**	1.2**
Trinexapac-ethyl										
no	4.2	5.9	6.0	6.4	5.4	4.9	2.9	2.5	2.3	2.3
yes¶	2.8**	3.8**	5.2*	6.9**	6.6**	6.3**	5.4**	4.2**	3.9**	3.8**

Table 30. Effect of species, trinexapac-ethyl, and iron on quality[†] of non-trafficked turfgrass in reduced light conditions, Hancock Turfgrass Research Center, East Lansing, MI.

	1994-1995						
Treatment	20 Dec.	6 Jan.	26 Jan.	9 Feb.	24 Feb.	17 Mar.	6 Apr.
Species							
Supina bluegrass	6.9	7.3	6.5	5.0	4.8	4.5	5.7
Kentucky bluegrass	5.5	6.1	5.4**	5.1	4.6	3.5**	3.5**
Trinexapac-ethyl							
no	5.9	6.3	4.9	4.1	3.7	2.8	3.2
yes‡	6.5	7.1	7.0**	6.0**	5.8**	5.1**	6.0**
Iron							
no	6.4	6.9	6.1	5.0	4.8	4.0	4.8
yes§	6.0	6.5	5.8	5.1	4.7	3.9	4.4*

	1995-1996									
Treatment	20 Dec.	5 Jan.	26 Jan.	19 Feb.	8 Mar.	29 Mar.	26 Apr.	13 May	29 May	11 June
Species										
Supina bluegrass	3.2	4.8	6.0	7.1	6.6	6.9	5.7	5.0	5.2	4.9
Kentucky bluegrass	3.8	5.0	5.3	6.2**	5.5*	4.3**	2.6**	1.6**	1.0**	1.2**
Trinexapac-ethyl										
no	4.2	5.9	6.0	6.4	5.4	4.9	2.9	2.5	2.3	2.3
yes¶	2.8**	3.8**	5.2*	6.9**	6.6**	6.3**	5.4**	4.2**	3.9**	3.8**

Table 31. Effect of species, trinexapac-ethyl, and iron on turfgrass color[†] in reduced light conditions under non-trafficked conditions, Hancock Turfgrass Research Center, East Lansing, MI.

	1994-1995						
Treatment	20 Dec.	6 Jan.	26 Jan.	9 Feb.	24 Feb.	17 Mar.	6 Apr.
Species							
Supina bluegrass	5.0	4.9	4.9	4.4	4.7	4.5	5.1
Kentucky bluegrass	7.3**	6.3**	5.7*	5.0*	6.0**	5.6**	6.0**
Trinexapac-ethyl							
no	5.7	4.9	4.2	3.5	3.8	3.4	4.2
yes‡	6.6**	6.3**	6.4**	5.9**	6.9**	6.8**	6.8**
Iron							
no	6.1	5.6	5.2	4.5	5.0	5.0	5.5
yes§	6.2	5.7	5.3	4.9	5.6	5.2	5.6

	1995-1996										
Treatment	20 Dec.	5 Jan.	26 Jan.	19 Feb.	28 Feb.	8 Mar.	29 Mar.	26 Apr.	13 May	29 May	11 June
Species											
Supina bluegrass	2.4	6.1	5.6	4.9	4.8	5.8	6.2	4.8	5.6	6.2	5.5
Kentucky bluegrass	3.4**	5.2**	6.8**	6.4**	6.7**	6.8*	4.6**	3.2*	1.5**	1.0**	1.0**
Trinexapac-ethyl											
no	3.8	6.1	5.7	5.0	5.0	5.8	4.7	2.8	2.8	3.0	2.8
yes¶	2.0**	5.2**	6.8*	6.4*	6.5**	6.8**	6.1**	5.2**	4.3**	4.2**	3.6**

Table 31 (cont'd.)

Iron											
no	2.8	4.7	5.5	6.2	5.4	6.0	5.2	3.8	3.5	3.5	3.2
yes#	3.1	4.2	5.8	6.5	6.2*	6.7**	5.5	4.2	3.6	3.8**	3.2

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

† Color was rated visually on a one to nine scale; one = 100% chlorotic turf/necrotic turf, nine=dark green turf.

‡ Trinexapac-ethyl was applied on the following dates; rates are shown in parentheses: 3 Oct. 1994 (0.19 kg ha^{-1}), 20 Jan., 18 Feb., 16 Mar. 1995 (0.08 kg ha^{-1} each date).

§ Iron (1.14 kg ha^{-1}) was applied as $FeSO_4$ on 10 Jan., 14 Feb., and 17 Mar. 1995.

¶ Trinexapac-ethyl was applied on the following dates; rates are shown in parentheses: 9 Oct. 1995 (0.19 kg ha^{-1}), 31 Jan., 15 Mar., 26 Apr. 1996 (0.08 kg ha^{-1} each date).

Iron (1.14 kg ha^{-1}) was applied as $FeSO_4$ on 28 Feb. and 13 May 1996.

dormancy, Supina bluegrass turf quality was superior to that of Kentucky bluegrass (Table 30). Turf density, uniformity, and overall appearance contributed to the quality ratings. Kentucky bluegrass turf density declined over time and the turf died in 1996 due in part to powdery mildew (*Erysiphe graminis*). No powdery mildew was observed on Supina bluegrass although Microdochium patch (*Microdochium nivale*) occasionally occurred. The Microdochium patch was controlled by using fans to dry the turf and with fungicide. Supina bluegrass had a lighter green color than Kentucky bluegrass except towards the end of the second year when the Kentucky bluegrass became necrotic (Table 31). Iron had negligible effect on either color or quality of turf in either year except for minor, transient (< 4 wks) increases in turf color which, while statistically significant, were not as dramatic as those caused by trinexapac-ethyl.

Interactions between species and trinexapac-ethyl occurred frequently (Tables 32 and 33). Supina bluegrass was more sensitive to trinexapac-ethyl than Kentucky bluegrass. Trinexapac-ethyl usually increased the turf quality and enhanced the color of Supina bluegrass compared to Kentucky bluegrass except at the beginning of the second year when trinexapac-ethyl delayed recovery from winter dormancy.

Experiment II: Turf subjected to traffic

Treatment effects on the quality and color of turf subjected to traffic were similar to those of untrafficked turf although actual values differed (Tables 34 and 35). Traffic treatments resulted in unacceptable turf quality and color (rating values < 5) two to three weeks after traffic applications began in 1994-1995 and three to five weeks after traffic applications began in 1996 (Tables 36 and 37). Traffic killed most of the turf within

Table 32. Quality rating values† for the significant species-by-trinexapac-ethyl interactions on non-trafficked turfgrass in reduced light conditions, Hancock Turfgrass Research Center, East Lansing, MI.

	1995									
	6 Jan.		26 Jan.		9 Feb.		24 Feb.		17 Mar.	
	trinexapac-ethyl ‡									
Species	no	yes	no	yes	no	yes	no	yes	no	yes
Supina bluegrass	6.6	8.0	5.0	8.0	3.3	6.8	3.0	6.7	2.7	6.2
Kentucky bluegrass	6.1	6.2	4.8	5.9	4.8	5.3	4.3	4.9	2.9	4.0
LSD (0.05)	0.4		0.7		0.5		0.6		0.6	

	1995-96													
	20 Dec.		26 Jan.		8 Mar.		26 Apr.		13 May		29 May		11 June	
	trinexapac-ethyl §													
Species	no	yes	no	yes	no	yes	no	yes	no	yes	no	yes	no	yes
Supina bluegrass	4.3	2.2	6.8	5.1	5.6	7.6	3.8	7.7	3.4	6.7	3.6	6.8	3.2	6.6
Kentucky bluegrass	4.1	3.4	5.2	5.4	5.2	5.7	2.0	3.2	1.5	1.7	1.1	1.0	1.4	1.0
LSD (0.05)	0.7		0.9		0.8		1.0		0.8		0.5		0.8	

† Quality was rated visually on a one to nine scale; 1=100% dead turf/bare soil, 9=dense, uniform turf; 5 was the minimum value for acceptable turf.

‡ Trinexapac-ethyl was applied on the following dates; rates are shown in parentheses: 3 Oct. 1994 (0.19 kg ha^{-1}), 20 Jan., 18 Feb., 16 Mar. 1995 (0.08 kg ha^{-1} each date).

§ Trinexapac-ethyl was applied on the following dates; rates are shown in parentheses: 9 Oct. 1995 (0.19 kg ha^{-1}), 31 Jan., 15 Mar., 26 Apr. 1996 (0.08 kg ha^{-1} each date).

Table 33. Color rating values† for the significant species-by-trinexapac-ethyl interaction on non-trafficked turfgrass in reduced light conditions, Hancock Turfgrass Research Center, East Lansing, MI.

	1994-1995											
	20 Dec.		6 Jan.		26 Jan.		9 Feb.		24 Feb.		17 Mar.	
	trinexapac-ethyl ‡											
Species	no	yes	no	yes	no	yes	no	yes	no	yes	no	yes
Supina bluegrass	4.1	5.9	4.0	5.8	3.6	6.2	2.3	6.4	2.8	6.6	3.1	5.9
Kentucky bluegrass	7.2	7.3	5.8	6.8	4.8	6.5	4.7	5.3	4.8	7.2	3.7	7.6
LSD (0.05)	0.4		0.4		0.4		0.6		0.5		0.4	

	1995-1996											
	20 Dec.		5 Jan.		26 Jan.		13 May		29 May		11 June	
	trinexapac-ethyl §											
Species	no	yes	no	yes	no	yes	no	yes	no	yes	no	yes
Supina bluegrass	3.7	1.2	6.9	1.9	7.2	5.0	4.1	7.1	1.8	6.4	4.7	6.2
Kentucky bluegrass	4.0	2.8	4.6	4.5	5.0	5.3	1.5	1.5	1.0	1.0	1.0	1.0
LSD (0.05)	0.8		0.9		0.7		0.3		0.2		0.4	

† Color was rated visually on a one to nine scale; one = 100% chlorotic turf/necrotic turf, nine=dark green turf.

‡ Trinexapac-ethyl was applied on the following dates; rates are shown in parentheses: 3 Oct. 1994 (0.19 kg ha^{-1}), 20 Jan., 18 Feb., 16 Mar. 1995 (0.08 kg ha^{-1} each date).

§ Trinexapac-ethyl was applied on the following dates; rates are shown in parentheses: 9 Oct. 1995 (0.19 kg ha^{-1}), 31 Jan., 15 Mar., 26 Apr. 1996 (0.08 kg ha^{-1} each date).

Table 34. Mean square and treatment effects on quality of turfgrass subjected to traffic in reduced light conditions, Hancock Turfgrass Research Center, East Lansing, MI.

		1995					
Source of variation	df	6 Jan.	26 Jan.	9 Feb.	24 Feb.	17 Mar.	6 Apr.
Species (S)	1	0.667	0.375	5.510*	0.000	0.167	2.667
Trinexapac-ethyl (TE)	1	9.375**	32.667**	2.344*	1.500**	2.042*	2.667*
S x TE	1	8.167**	18.375**	3.760**	0.667*	0.375	1.500
Iron (Fe)	1	0.167	0.167	0.010	0.042	0.042	0.375
S x Fe	1	0.042	1.042	0.010	0.042	0.042	2.042
TE x Fe	1	0.000	0.167	0.010	0.042	0.167	0.042
S x TE x Fe	1	0.375	0.042	0.260	0.042	0.167	0.375
Error	16	6.167	8.167	4.833	0.260	0.458	0.646
CV, %		10.28	15.04	21.80	34.02	42.76	40.18

		1996						
Source of variation	df	19 Feb.	8 Mar.	29 Mar.	26 Apr.	13 May	29 May	11 June
Species (S)	1	4.594*	3.010	2.344*	3.375**	25.010**	27.094**	25.010**
Trinexapac-ethyl (TE)	1	1.260*	7.594*	1.760*	3.375**	19.260**	15.844**	11.344**
S x TE	1	0.260	3.760	1.760*	2.667**	17.510**	15.844**	15.844**
Iron (Fe)	1	0.844	3.010	0.844	1.042**	0.844	0.844	0.260
S x Fe	1	0.010	0.260	0.010	0.667**	0.510	0.844	1.260
TE x Fe	1	0.094	0.010	0.094	0.667**	0.260	0.260	0.510
S x TE x Fe	1	1.260*	2.344	0.094	0.375*	0.094	0.260	0.010
Error	16	0.229	1.094	0.240	0.042	0.292	0.479	0.625
CV, %		7.69	25.48	29.74	14.41	26.18	33.56	36.84

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

Table 35. Mean square and treatment effects on color of turfgrass subjected to traffic in reduced light conditions, Hancock Turfgrass Research Center, East Lansing, MI.

Source of variation	df	1995 6 Jan.	26 Jan.	9 Feb.	24 Feb.	17 Mar.	6 Apr.
Species (S)	1	12.760**	4.568*	9.413*	0.680	0.010	0.844
Trinexapac-ethyl (TE)	1	12.760**	27.158**	4.192**	23.920*	1.260	1.260
S x TE	1	1.260**	1.274**	4.142**	0.000	1.260	1.260
Iron (Fe)	1	0.010	0.012	0.039	0.045	0.510	0.844
S x Fe	1	0.010	3.032**	0.044	0.038	0.510	0.844
TE x Fe	1	0.094	0.502*	0.000	0.045	0.844	1.260
S x TE x Fe	1	0.094	0.012	1.515*	0.045	0.844	1.260
Error	16	0.104	0.126	0.415	3.098	0.781	1.052
CV, %		5.25	6.78	21.78	78.17	58.12	60.78

Source of variation	df	1996 19 Feb.	28 Feb.	8 Mar.	29 Mar.	26 Apr.	13 May	29 May	11 June
Species (S)	1	8.760*	13.500*	0.510	1.500	9.375**	71.760**	57.042**	130.667**
Trinexapac-ethyl (TE)	1	6.510**	12.042**	7.594	2.667*	5.042**	38.760**	32.667**	2.667**
S x TE	1	0.094	1.042	1.260	2.667*	4.167*	36.260**	32.667**	2.667**
Iron (Fe)	1	0.844	2.042	3.010	2.042*	2.042	0.010	8.167	0.000
S x Fe	1	1.260	0.042	0.260	0.375	1.500	0.010	8.167	0.000
TE x Fe	1	1.760	4.167*	0.010	0.375	0.667	0.010	1.042	0.000
S x TE x Fe	1	1.260	2.667	3.760	0.375	0.375	0.010	1.042	0.000
Error	16	0.500	0.771	2.021	0.271	0.354	0.760	2.229	0.021
CV, %		11.35	15.49	31.44	32.87	35.71	31.47	58.74	4.33

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

Table 34. Mean square and treatment effects on quality of turfgrass subjected to traffic in reduced light conditions, Hancock Turfgrass Research Center, East Lansing, MI.

		1995					
Source of variation	df	6 Jan.	26 Jan.	9 Feb.	24 Feb.	17 Mar.	6 Apr.
Species (S)	1	0.667	0.375	5.510*	0.000	0.167	2.667
Trinexapac-ethyl (TE)	1	9.375**	32.667**	2.344*	1.500**	2.042*	2.667*
S x TE	1	8.167**	18.375**	3.760**	0.667*	0.375	1.500
Iron (Fe)	1	0.167	0.167	0.010	0.042	0.042	0.375
S x Fe	1	0.042	1.042	0.010	0.042	0.042	2.042
TE x Fe	1	0.000	0.167	0.010	0.042	0.167	0.042
S x TE x Fe	1	0.375	0.042	0.260	0.042	0.167	0.375
Error	16	6.167	8.167	4.833	0.260	0.458	0.646
CV, %		10.28	15.04	21.80	34.02	42.76	40.18

		1996						
Source of variation	df	19 Feb.	8 Mar.	29 Mar.	26 Apr.	13 May	29 May	11 June
Species (S)	1	4.594*	3.010	2.344*	3.375**	25.010**	27.094**	25.010**
Trinexapac-ethyl (TE)	1	1.260*	7.594*	1.760*	3.375**	19.260**	15.844**	11.344**
S x TE	1	0.260	3.760	1.760*	2.667**	17.510**	15.844**	15.844**
Iron (Fe)	1	0.844	3.010	0.844	1.042**	0.844	0.844	0.260
S x Fe	1	0.010	0.260	0.010	0.667**	0.510	0.844	1.260
TE x Fe	1	0.094	0.010	0.094	0.667**	0.260	0.260	0.510
S x TE x Fe	1	1.260*	2.344	0.094	0.375*	0.094	0.260	0.010
Error	16	0.229	1.094	0.240	0.042	0.292	0.479	0.625
CV, %		7.69	25.48	29.74	14.41	26.18	33.56	36.84

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

Table 36 (cont'd.)

Iron							
no	6.0	3.8	1.5	1.2	1.9	1.9	2.0
yes#	6.4	4.5	1.8	1.6**	2.2	2.2	2.2

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

† Quality was rated visually on a one to nine scale; 1=100% dead turf/bare soil, 9=dense, uniform turf; 5 was the minimum value for acceptable turf.

‡ Trinexapac-ethyl was applied on the following dates; rates are shown in parentheses: 3 Oct. 1994 (0.19 kg ha^{-1}), 20 Jan., 18 Feb., 16 Mar. 1995 (0.08 kg ha^{-1} each date).

§ Iron (1.14 kg ha^{-1}) was applied as $FeSO_4$ on 10 Jan., 14 Feb., and 17 Mar. 1995.

¶ Trinexapac-ethyl was applied on the following dates; rates are shown in parentheses: 9 Oct. 1995 (0.19 kg ha^{-1}), 31 Jan., 15 Mar., 26 Apr. 1996 (0.08 kg ha^{-1} each date).

Iron (1.14 kg ha^{-1}) was applied as $FeSO_4$ on 28 Feb. and 13 May 1996.

Table 37. Effect of species, trinexapac-ethyl, and iron on color[†] of turfgrass subjected to traffic in reduced light conditions, Hancock Turfgrass Research Center, East Lansing, MI.

	1995					
Treatment	6 Jan.	26 Jan.	9 Feb.	24 Feb.	17 Mar.	6 Apr.
Species						
Supina bluegrass	4.9	4.8	2.3	2.1	1.5	1.9
Kentucky bluegrass	6.3**	5.7*	3.6*	2.4	1.5	1.5
Trinexapac-ethyl						
no	4.9	4.2	2.5	1.3	1.3	1.5
yes‡	6.3**	6.3**	3.4**	3.2*	1.8	1.9
Iron						
no	5.6	5.2	3.0	2.2	1.7	1.9
yes§	5.6	5.2	2.9	2.3	1.4	1.5

	1996							
Treatment	19 Feb.	28 Feb.	8 Mar.	29 Mar.	26 Apr.	13 May	29 May	11 June
Species								
Supina bluegrass	5.6	4.9	4.4	1.8	2.3	4.5	4.1	5.7
Kentucky bluegrass	6.8*	6.4*	4.7	1.3	1.0**	1.0**	1.0**	1.0**
Trinexapac-ethyl								
no	5.7	5.0	4.0	1.2	1.2	1.5	1.4	3.0
yes¶	6.8**	6.4**	5.1	1.9*	2.1**	4.0**	3.7**	3.7**

Table 37 (cont'd.)

Iron								
no	6.0	5.4	4.2	1.3	1.4	2.8	2.0	3.3
yes#	6.4	6.0	4.9	1.9*	2.0	2.8	3.1	3.3

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

† Color was rated visually on a one to nine scale; one = 100% chlorotic turf/necrotic turf, nine=dark green turf.

‡ Trinexapac-ethyl was applied on the following dates; rates are shown in parentheses: 3 Oct. 1994 (0.19 kg ha^{-1}), 20 Jan., 18 Feb., 16 Mar. 1995 (0.08 kg ha^{-1} each date).

§ Iron (1.14 kg ha^{-1}) was applied as $FeSO_4$ on 10 Jan., 14 Feb., and 17 Mar. 1995.

¶ Trinexapac-ethyl was applied on the following dates; rates are shown in parentheses: 9 Oct. 1995 (0.19 kg ha^{-1}), 31 Jan., 15 Mar., 26 Apr. 1996 (0.08 kg ha^{-1} each date).

Iron (1.14 kg ha^{-1}) was applied as $FeSO_4$ on 28 Feb. and 13 May 1996.

eight to nine weeks in both years. Supina bluegrass showed signs of recovery, however, within three weeks after traffic treatments were ended; Kentucky bluegrass did not recover. Trinexapac-ethyl treatments resulted in superior recovery of Supina bluegrass compared to untreated turf (Tables 38 and 39) while Kentucky bluegrass was unaffected. As with non-trafficked turf, iron had little or no effect.

Clipping yields

Experiment I: Turf not subjected to traffic

Clipping yields of Kentucky bluegrass were significantly different compared to Supina bluegrass yields throughout the study (Table 40). Kentucky bluegrass clipping yields were greater than those of Supina bluegrass for the first two to three months inside the CSSF after which they were either no different (1995) or significantly less as the Kentucky bluegrass died (1996) (Table 41). In this study clipping yield data was only partly indicative of the turf's response to RLC; Supina bluegrass has a creeping growth habit which can be expected to result in less clipping yield compared to Kentucky bluegrass in even normal sunlight (Berner, 1980). Trinexapac-ethyl treatments significantly reduced clippings of both species on most dates. As with the effect on color and quality, Supina bluegrass was more sensitive to trinexapac-ethyl than Kentucky bluegrass in terms of clipping yield reduction (Table 42).

Lack of PGR efficacy after the first application and the rapid growth flushes following growth suppression commonly documented in non-RLC were not observed (Cooper et al., 1985; Shearing and Batch, 1982). The potential decline in turf color and quality observed due to the potential for retention of senescent foliage/suppression of new growth

Table 38. Quality ratings† for the significant species-by-trinexapac-ethyl interactions on turfgrass subjected to traffic in reduced light conditions, Hancock Turfgrass Research Center, East Lansing, MI.

	1995					
	6 Jan.		26 Jan.		9 Feb.	
	trinexapac-ethyl ‡					
Species	no	yes	no	yes	no	yes
Supina bluegrass	5.0	7.4	2.6	6.7	1.3	2.8
Kentucky bluegrass	5.8	5.9	4.6	5.1	3.1	2.9
LSD (0.05)	0.8		0.9		0.7	

	1996									
	29 Mar.		26 Apr.		13 May		29 May		11 June	
	trinexapac-ethyl §									
Species	no	yes	no	yes	no	yes	no	yes	no	yes
Supina bluegrass	1.4	2.5	1.1	2.5	3.4	6.7	1.5	4.8	1.7	4.7
Kentucky bluegrass	1.3	1.3	1.0	1.1	1.5	1.7	1.0	1.0	1.2	1.0
LSD (0.05)	0.6		0.3		0.7		0.9		1.1	

† Quality was rated visually on a one to nine scale; 1=100% dead turf/bare soil, 9=dense, uniform turf; 5 was the minimum value for acceptable turf.

‡ Trinexapac-ethyl was applied on the following dates; rates are shown in parentheses: 3 Oct. 1994 (0.19 kg ha^{-1}), 20 Jan., 18 Feb., 16 Mar. 1995 (0.08 kg ha^{-1} each date).

§ Trinexapac-ethyl was applied on the following dates; rates are shown in parentheses: 9 Oct. 1995 (0.19 kg ha^{-1}), 31 Jan., 15 Mar., 26 Apr. 1996 (0.08 kg ha^{-1} each date).

Table 39. Color ratins† for the signifcant species-by-trinexapac-ethyl interactions on turfgrass subjected to traffic in reduced light conditions, Hancock Turfgrass Research Center, East Lansing, MI.

	1995					
	6 Jan.		26 Jan.		9 Feb.	
	trinexapac-ethyl ‡					
Species	no	yes	no	yes	no	yes
Supina bluegrass	3.9	5.8	3.5	6.1	1.5	3.2
Kentucky bluegrass	5.8	6.8	4.8	6.5	3.6	3.6
LSD (0.05)	0.4		0.4		0.8	

	1996									
	29 Mar.		26 Apr.		13 May		29 May		11 June	
	trinexapac-ethyl §									
Species	no	yes	no	yes	no	yes	no	yes	no	yes
Supina bluegrass	1.2	2.5	1.4	3.2	2.0	7.0	1.8	6.4	5.0	6.3
Kentucky bluegrass	1.3	1.3	1.0	1.1	1.0	1.1	1.0	1.0	1.0	1.0
LSD (0.05)	0.6		0.7		1.1		2.2		0.2	

† Color was rated visually on a one to nine scale; one = 100% chlorotic turf/necrotic turf, nine=dark green turf.

‡ Trinexapac-ethyl was applied on the following dates; rates are shown in parentheses: 3 Oct. 1994 (0.19 kg ha^{-1}), 20 Jan., 18 Feb., 16 Mar. 1995 (0.08 kg ha^{-1} each date).

§ Trinexapac-ethyl was applied on the following dates; rates are shown in parentheses: 9 Oct. 1995 (0.19 kg ha^{-1}), 31 Jan., 15 Mar., 26 Apr. 1996 (0.08 kg ha^{-1} each date).

Table 40. Mean squares and significance of treatment effects on clipping yields of non-trafficked turfgrass in reduced light conditions, Hancock Turfgrass Research Center, East Lansing, MI.

		1995										
Source	df	13 Jan.	18 Jan.	25 Jan.	1 Feb.	8 Feb.	15 Feb.	22 Feb.	1 Mar.	8 Mar.	15 Mar.	22 Mar.
Species (S)	1	99.145**	21.376**	66.234**	15.089**	21.774**	16.401**	17.086**	10.760**	6.121*	0.360	6.334
TE	1	148.106**	11.999	19.929**	14.994**	14.727**	24.442**	44.363**	33.820**	24.321**	36.162*	9.464
S x TE	1	2.018	0.663	2.477**	0.502	3.227*	0.341	0.760	1.088	0.005	3.466	3.018
Iron (Fe)	1	0.976	0.293	0.048	0.172	0.002	0.000	0.909	0.158	0.141	4.699	5.235
S x FE	1	0.499	3.643	0.324	0.026	0.052	0.459	0.088	0.002	0.191	9.627	0.537
TE x FE	1	1.782	0.222	0.338	0.219	0.043	0.859	0.162	1.029	0.322	3.713	2.179
S x TE x FE	1	3.315	5.694	0.725	0.105	0.066	2.148*	1.122	2.106	2.458	0.004	1.922
Error	16	1.735	1.474	0.287	0.483	0.496	0.370	1.263	0.822	0.780	3.744	5.897
CV, %		18.96	37.86	16.48	28.34	34.75	27.64	47.19	55.14	42.18	46.70	53.12

		1996								
Source	df	8 Mar.	12 Mar.	24 Mar.	1 Apr.	15 Apr.	29 Apr.	3 May	8 May	17 May
Species (S)	1	12.630	156.417**	24.120	46.621**	129.596*	2.815	19.530	20.888*	24.080**
TE	1	5.539	45.733*	503.617**	108.758**	264.737**	12.702	24.261*	11.579**	11.620**
S x TE	1	5.539	48.082*	227.058	36.680*	60.579**	75.828**	25.113*	19.639**	14.727**
Iron (Fe)	1	4.395	100.409**	35.722	10.415	10.494	48.906*	13.878*	0.393	0.037
S x FE	1	0.980	20.739	31.740	0.158	0.005	1.530	0.044	0.081	0.056
TE x FE	1	1.990	3.519	90.171	0.644	0.105	12.702	4.762	0.435	1.017
S x TE x FE	1	0.803	35.893*	194.712	5.616	2.071	13.954	0.419	1.378	3.168*
Error	16	1.490	5.495	51.336	4.192	3.078	6.379	2.863	0.662	0.430
CV, %		28.07	18.55	54.11	29.59	19.35	29.67	40.19	38.98	36.64

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

Table 41. Effects of species, trinexapac-ethyl, and iron on clipping yields of non-trafficked turfgrass in reduced light conditions, Hancock Turfgrass Research Center, East Lansing, MI..

	1995										
Treatment	13 Jan.	18 Jan.	25 Jan.	1 Feb.	8 Feb.	15 Feb.	22 Feb.	1 Mar.	8 Mar.	15 Mar.	22 Mar.
Species	$g\ m^{-2}$										
Supina bluegrass	4.9	2.3	1.6	1.7	1.1	1.4	1.5	1.0	1.6	4.0	4.1
Kentucky bluegrass	9.0**	4.2**	4.9**	3.2**	3.0**	3.0**	3.2	2.3	2.6	4.3	5.1
Trinexapac-ethyl											
no	9.4	3.9	4.2	3.2	2.8	3.2	3.7	2.8	3.1	5.4	5.2
yes†	4.5**	2.5*	2.3**	1.7**	1.2**	1.2**	1.0**	0.5**	1.1**	2.9*	3.9
Iron											
no	6.7	3.1	3.2	2.4	2.0	2.2	2.2	1.6	2.0	3.7	4.1
yes‡	7.1	3.3	3.3	2.5	2.0	2.2	2.6	1.7	2.2	4.6	5.0

	1996								
Treatment	8 Mar.	12 Mar.	24 Mar.	1 Apr.	15 Apr.	29 Apr.	3 May	8 May	17 May
	$g\ m^{-2}$								
Species									
Supina bluegrass	3.6	10.1	12.2	5.5	6.7	8.2	5.1	3.0	2.8
Kentucky bluegrass	5.1	15.2**	14.2	8.3**	11.4*	8.8	3.3	1.2*	0.8**
Trinexapac-ethyl									
no	4.8	14.0	17.8	9.0	12.4	9.2	5.2	2.8	2.5
yes	3.9	11.3*	8.7*	4.8*	5.7*	7.8	3.2*	1.4**	1.1**

Table 41 (cont'd.)

Iron									
no	3.9	10.6	14.5	6.3	8.4	7.1	3.5	2.2	1.8
yes¶	4.8	14.6**	12.0	7.6	9.7	9.9*	5.0*	2.0	1.8

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

† Trinexapac-ethyl was applied on the following dates; rates are shown in parentheses: 3 Oct. 1994 (0.19 kg ha^{-1}), 20 Jan., 18 Feb., 16 Mar. 1995 (0.08 kg ha^{-1} each date).

‡ Iron (1.14 kg ha^{-1}) was applied as $FeSO_4$ on 10 Jan., 14 Feb., and 17 Mar. 1995.

§ Trinexapac-ethyl was applied on the following dates; rates are shown in parentheses: 9 Oct. 1995 (0.19 kg ha^{-1}), 31 Jan., 15 Mar., 26 Apr. 1996 (0.08 kg ha^{-1} each date).

¶ Iron (1.14 kg ha^{-1}) was applied as $FeSO_4$ on 28 Feb. and 13 May 1996.

Table 42. Values for significant interactions of trinexapac-ethyl and species on clipping yields of non-trafficked turfgrass in reduced light conditions, Hancock Turfgrass Research Center, East Lansing, MI.

	1995															
	18 Jan.		25 Jan.		1 Feb.		8 Feb.		15 Feb.		22 Feb.		1 Mar.		8 Mar.	
	trinexapac-ethyl†															
Species	no	yes	no	yes	no	yes	no	yes	no	yes	no	yes	no	yes	no	yes
	g m^{-2}															
Supina bluegrass	2.8	1.7	2.2	1.0	2.3	1.0	1.5	0.7	2.5	0.2	3.1	0.0	1.9	0.0	2.6	0.6
Kentucky bluegrass	5.0	3.3	6.1	3.7	4.2	2.3	4.1	1.8	3.9	2.1	4.4	2.0	3.7	0.9	3.6	1.6

	1996															
	12 Mar.		24 Mar.		1 Apr.		15 Apr.		29 Apr.		3 May		8 May		17 May	
	trinexapac-ethyl‡															
Species	no	yes	no	yes	no	yes	no	yes	no	yes	no	yes	no	yes	no	yes
	g m^{-2}															
Supina bluegrass	12.9	7.3	20.0	4.6	8.9	2.2	11.7	1.8	10.7	5.7	7.1	3.1	4.6	1.4	4.3	1.3
Kentucky bluegrass	15.2	15.2	15.8	12.7	9.2	7.4	13.1	9.7	7.8	9.9	3.3	3.3	0.9	1.4	0.7	0.9

† Trinexapac-ethyl was applied on the following dates; rates are shown in parentheses: 3 Oct. 1994 (0.19 kg ha^{-1}), 20 Jan., 18 Feb., 16 Mar. 1995 (0.08 kg ha^{-1} each date).

‡ Trinexapac-ethyl was applied on the following dates; rates are shown in parentheses: 9 Oct. 1995 (0.19 kg ha^{-1}), 31 Jan., 15 Mar., 26 Apr. 1996 (0.08 kg ha^{-1} each date).

resulting from long-term PGR applications was also not observed (Watschke, 1976; Kaufmann, 1986b). Apparently the successive low rate (0.08 kg ha^{-1}) applications of trinexapac-ethyl suppressed growth only to the point where carbohydrates may have been shifted to enhance tillering without causing growth cessation (Hanson and Branham, 1987). For practical use it may be important to be able to monitor the level of active PGR in the turf if PGRs are to be used on a continuous basis to maintain turf in RLC. Immunological techniques may prove to be the most expedient method for determining the amount of active ingredient in the plant.

Experiment II: Turf subjected to traffic

Treatment effects on the clipping yields of trafficked turf were similar to non-trafficked turf (Table 43) but actual yields were much lower than those from non-trafficked turf (Table 44). Trinexapac-ethyl continued to affect Supina bluegrass more significantly compared to Kentucky bluegrass (Table 45). In 1995 yields of Supina bluegrass were zero after Feb. 1 although turf yields in 1996 indicated continued growth throughout the trial. Since total inhibition of growth will slow or eliminate turf recovery it is important to match timing and rates of application of PGRs to maintain acceptable turf cover.

Turf shear resistance

Experiment I: Turf not subjected to traffic

Turf species and trinexapac-ethyl consistently affected turf shear resistance while other treatment effects were rare and inconsistent (Table 46). Shear resistance declined

Table 43. Mean squares and significance of treatment effects on clipping yields of turfgrass subjected to traffic in reduced light conditions, Hancock Turfgrass Research Center, East Lansing, MI.

		1995										
Source	df	13 Jan.	18 Jan.	25 Jan.	1 Feb.	8 Feb.	15 Feb.	22 Feb.	1 Mar.	8 Mar.	15 Mar.	22 Mar.
Species (S)	1	152.158**	40.951**	51.656**	24.020**	6.912**	9.920*	9.946*	1.233*	1.500	2.561	3.053
TE	1	88.974**	13.515**	4.887**	3.596**	1.826**	6.314**	6.500**	4.150**	2.600**	0.882	0.874
S x TE	1	7.718**	0.098	1.670*	1.184**	1.033*	5.088**	4.655**	1.233*	0.821**	0.331	0.459
Iron (Fe)	1	1.038**	0.158	0.000	0.000	0.056	0.100	0.020	0.002	0.003	1.344	0.844
S x FE	1	2.516	4.533	0.003	0.000	0.010	0.329	0.016	0.785	0.427*	2.030	1.144
TE x FE	1	1.515	1.071	0.041	0.189	0.094	0.293	0.732	0.002	0.070	1.033	0.010
S x TE x FE	1	14.586**	0.105	0.001	0.219	0.001	0.637	0.760	0.785	0.944**	0.564	0.602
Error	16	1.675	1.126	0.250	0.101	0.134	0.451	0.490	0.208	0.111	0.752	1.209
CV, %		22.12	38.72	25.48	27.33	60.41	96.61	96.76	109.68	84.39	136.36	122.72

		1996								
		8 Mar.	12 Mar.	24 Mar.	1 Apr.	15 Apr.	29 Apr.	3 May	8 May	17 May
Species (S)	1	0.002	66.334**	18.288	21.603	15.456	5.597	7.820	11.166**	6.668*
TE	1	4.043	0.029	50.489**	15.026**	12.877**	0.050	11.399	4.603	5.714**
S x TE	1	0.146	9.004	12.892	4.310	6.998**	8.202	16.500*	8.509	6.563**
Iron (Fe)	1	0.219	11.179	1.038	0.200	0.714	14.493	1.316	0.116	0.072
S x FE	1	0.525	0.118	0.175	0.000	0.073	3.060	0.829	0.008	0.009
TE x FE	1	0.657	0.184	0.111	0.168	1.685	3.368	0.647	0.186	0.061
S x TE x FE	1	1.140	30.106**	23.781	7.628*	2.344	2.768	0.213	0.739	0.580
Error	16	1.718	2.311	8.442	2.067	1.144	2.951	2.961	0.504	0.165
CV, %		77.57	31.94	53.02	43.06	42.11	45.95	74.14	53.41	41.39

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

Table 44. Effects of species and trinexapac-ethyl on clipping yields of turfgrass subjected to traffic in reduced light conditions, Hancock Turfgrass Research Center, East Lansing, MI.

	1995										
Treatment	13 Jan.	18 Jan.	25 Jan.	1 Feb.	8 Feb.	15 Feb.	22 Feb.	1 Mar.	8 Mar.	15 Mar.	22 Mar.
Species	$g\ m^{-2}$										
Supina bluegrass	3.3	1.4	0.5	0.2	0.1	0.1	0.1	0.2	0.1	0.3	0.5
Kentucky bluegrass	8.4**	4.0**	3.4**	2.2**	1.1**	1.3*	1.4*	0.6*	0.6	1.0	1.3
Trinexapac-ethyl											
no	7.8	3.5	2.4	1.6	0.9	1.2	1.2	0.8	0.7	0.8	1.1
yes †	3.9**	2.0**	1.5**	0.8**	0.3**	0.2**	0.2**	0.0**	0.1**	0.4	0.7
Iron											
no	5.6	2.7	2.0	1.2	0.6	0.8	0.7	0.4	0.4	0.4	0.7
yes ‡	6.1	2.8	2.0	1.2	0.7	0.6	0.8	0.4	0.4	0.9	1.1

	1996								
Treatment	8 Mar.	12 Mar.	24 Mar.	1 Apr.	15 Apr.	29 Apr.	3 May	8 May	17 May
Species	$g\ m^{-2}$								
Supina bluegrass	1.7	3.1	4.6	2.4	1.7	4.2	2.9	2.0	1.5
Kentucky bluegrass	1.7	6.4	6.4	4.3	3.3	3.3	1.8	0.6**	0.5*
Trinexapac-ethyl									
no	2.1	4.7	6.9	4.1	3.3	3.7	3.0	1.8	1.5
yes §	1.3	4.8	4.0**	2.5**	1.8**	3.8	1.6	0.9*	0.5**

Table 44 (cont'd.)

Iron									
no	1.6	4.1	5.3	3.2	2.4	3.0	2.1	1.4	1.0
yes ¶	1.8	5.4	5.7	3.4	2.7	4.5	2.6	1.3	0.9

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

† Trinexapac-ethyl was applied on the following dates; rates are shown in parentheses: 3 Oct. 1994 (0.19 kg ha^{-1}), 20 Jan., 18 Feb., 16 Mar. 1995 (0.08 kg ha^{-1} each date).

‡ Iron (1.14 kg ha^{-1}) was applied as $FeSO_4$ on 10 Jan., 14 Feb., and 17 Mar. 1995.

§ Trinexapac-ethyl was applied on the following dates; rates are shown in parentheses: 9 Oct. 1995 (0.19 kg ha^{-1}), 31 Jan., 15 Mar., 26 Apr. 1996 (0.08 kg ha^{-1} each date).

¶ Iron (1.14 kg ha^{-1}) was applied as $FeSO_4$ on 28 Feb. and 13 May 1996.

Table 45. Values from significant interactions of trinexapac-ethyl and species on clipping yields of turfgrass subjected to traffic in reduced light conditions, Hancock Turfgrass Research Center, East Lansing, MI.

Treatment	1995															
	13 Jan.		25 Jan.		1 Feb.		8 Feb.		15 Feb.		22 Feb.		1 Mar.		8 Mar.	
	trinexapac-ethyl †															
Species	no	yes	no	yes	no	yes	no	yes	no	yes	no	yes	no	yes	no	yes
	g m^{-2}															
Supina bluegrass	4.7	2.0	0.7	0.3	0.3	0.0	0.1	0.0	0.1	0.0	0.2	0.0	0.4	0.0	0.3	0.0
Kentucky bluegrass	10.9	5.9	4.1	2.7	2.8	1.6	1.6	0.7	2.3	0.4	2.3	0.4	1.3	0.0	1.2	0.1
LSD (0.05)	1.0		0.6		0.4		0.5		0.8		0.8		0.6		0.3	

	1996															
	12 Mar.		24 Mar.		1 Apr.		15 Apr.		29 Apr.		3 May		8 May		17 May	
	trinexapac-ethyl ‡															
Species	no	yes	no	yes	no	yes	no	yes	no	yes	no	yes	no	yes	no	yes
	g m^{-2}															
Supina bluegrass	3.7	2.5	6.8	2.4	3.6	1.2	3.0	0.5	4.8	3.7	4.4	1.4	3.0	1.0	2.5	0.5
Kentucky bluegrass	5.8	7.1	7.1	5.6	4.6	3.9	3.5	3.2	2.6	3.9	1.6	1.9	0.5	0.8	0.4	0.5
LSD (0.05)	ns		ns		ns		0.8		ns		2.0		0.9		0.4	

† Trinexapac-ethyl was applied on the following dates; rates are shown in parentheses: 3 Oct. 1994 (0.19 kg ha^{-1}), 20 Jan., 18 Feb., 16 Mar. 1995 (0.08 kg ha^{-1} each date).

‡ Trinexapac-ethyl was applied on the following dates; rates are shown in parentheses: 9 Oct. 1995 (0.19 kg ha^{-1}), 31 Jan., 15 Mar., 26 Apr. 1996 (0.08 kg ha^{-1} each date).

Table 46. Mean square and significance of treatment effects on shear resistance of non-trafficked turfgrass in reduced light conditions, Hancock Turfgrass Research Center, East Lansing, MI.

		1994-1995			
Source of variation	df	20 Dec.	20 Jan.	22 Feb.	31 Mar.
Species (S)	1	369.094**	2.344	546.260**	240.667**
Trinexapac-ethyl (TE)	1	0.010	94.010**	0.260	20.167*
S x TE	1	3.760	10.010	1.760	3.375
Iron (Fe)	1	3.760	15.844	3.760	2.042
S x Fe	1	0.010	17.510	0.260	2.667
TE x Fe	1	0.010	36.260	1.260	32.667**
S x TE x Fe	1	7.594*	0.094	0.010	15.042*
Error	16	1.042	17.760	2.271	3.219
CV, %		5.57	25.77	10.17	14.08

		1996		
Source of variation	df	17 Jan.	12 Mar.	31 May
Species (S)	1	121.500**	48.167*	28.711**
Trinexapac-ethyl (TE)	1	1.500	18.375	5.753*
S x TE	1	7.042	15.042	6.773*
Iron (Fe)	1	4.167	5.042	0.023
S x Fe	1	2.042	30.375	0.315
TE x Fe	1	7.042	16.667	0.003
S x TE x Fe	1	0.667	32.667	0.065
Error	16	2.281	8.000	0.815
CV, %		7.29	16.80	10.31

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

over time in both years regardless of treatment (Table 47). The decline in shear resistance indicated a lack of sufficient turf growth and rooting probably due to insufficient light energy to sustain turf permanently. In the first year Kentucky bluegrass had higher shear resistance than Supina bluegrass probably due to the presence of rhizomes in Kentucky bluegrass which added stability to the turf (McNitt, 1994). Shear resistance values of Kentucky bluegrass were significantly lower than those of Supina bluegrass in 1996, perhaps due to increased root growth of Supina bluegrass during the longer establishment period in autumn of 1995 compared to autumn 1994. However the practical significance of such a difference in shear resistance may not be important as values were still relatively close. In addition, a desirable value for shear resistance using the Eijkelkamp shear vane has not been established despite previous attempts (Liesecke and Schmidt, 1978) . Shear resistance values are generally important for their ability to indicate relative turf strength and rooting differences. In 1996 the shear resistance of Supina bluegrass was significantly increased by trinexapac-ethyl while Kentucky bluegrass shear resistance was unchanged (Table 48). Trinexapac-ethyl enhanced Supina bluegrass growth and development more than Kentucky bluegrass, which resulted in more biomass aboveground which enhanced the shear resistance of the Supina bluegrass.

Experiment II: Turf subjected to traffic

Treatment effects on turf shear resistance were similar to those on non-trafficked turf (Table 49). Shear values declined over time due to loss of turf density and actual values were lower than for non-trafficked turf (Table 50). Supina bluegrass continued to be

Table 47. Effect of species, trinexapac-ethyl, and iron on shear resistance values (N•m) of non-trafficked turfgrass in reduced light conditions, Hancock Turfgrass Research Center, East Lansing, MI.

	1994-1995			
Treatment	20 Dec.	20 Jan.	22 Feb.	31 Mar.
Species	----------N m----------			
Supina bluegrass	14.2	16.0	10.0	9.0
Kentucky bluegrass	22.4**	16.7	19.6**	15.3**
Trinexapac-ethyl				
no	18.3	14.4	14.7	11.2
yes†	18.3	18.3**	14.9	13.0*
Iron				
no	18.7	15.5	15.2	12.4
yes‡	17.9	17.2	14.4	11.8

	1996		
Treatment	17 Jan.	12 Mar.	31 May
Species	----------N m----------		
Supina bluegrass	23.0	18.2	9.9
Kentucky bluegrass	18.5**	15.4*	7.7**
Trinexapac-ethyl			
no	20.5	16.0	8.3
yes§	21.0	17.7*	9.2*
Iron			
no	20.3	16.4	8.7
yes¶	21.1	17.3	8.8

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

†Trinexapac-ethyl was applied on the following dates; rates are shown in parentheses: 3 Oct. 1994 (0.19 kg ha^{-1}), 20 Jan., 18 Feb., 16 Mar. 1995 (0.08 kg ha^{-1} each date).

‡ Iron (1.14 kg ha^{-1}) was applied as $FeSO_4$ on 10 Jan., 14 Feb., 17 Mar 1995.

§ Trinexapac-ethyl was applied on the following dates; rates are shown in parentheses: 9 Oct. 1995 (0.19 kg ha^{-1}), 31 Jan., 15 Mar., 26 Apr. 1996 (0.08 kg ha^{-1} each date).

¶ Iron (1.14 kg ha^{-1}) was applied as $FeSO_4$ on 28 Feb. and 13 May 1996.

Table 48. Shear resistance values (N•m) for the significant species-by-trinexapac-ethyl interaction on non-trafficked turfgrass in reduced light conditions, Hancock Turfgrass Research Center, East Lansing, MI.

	31 May 1996	
	------------------------------ trinecapac-ethyl† ------------------------------	
Species	no	yes
	------------------------------------N m ------------------------------------	
Supina bluegrass	8.8	10.9
Kentucky bluegrass	7.7	7.6
LSD (0.05)	1.1	

† Trinexapac-ethyl was applied on the following dates; rates are shown in parentheses: 9 Oct. 1995 (0.19 kg ha^{-1}), 31 Jan., 15 Mar., 26 Apr. 1996 (0.08 kg ha^{-1} each date).

Table 49. Mean square and significance of treatment effects on shear resistance of turfgrass subjected to traffic in reduced light conditions, Hancock Turfgrass Research Center, East Lansing, MI.

		1994-1995		
Source of variation	df	20 Jan.	22 Feb.	31 Mar.
Species (S)	1	8.167	546.260**	152.510**
Trinexapac-ethyl (TE)	1	60.167	10.010	15.844**
S x TE	1	12.042	1.260	8.760*
Iron (Fe)	1	4.167	8.760	10.010*
S x Fe	1	18.375	6.510	4.594
TE x Fe	1	22.042	1.760	0.844
S x TE x Fe	1	1.500	0.260	25.010**
Error	16	15.010	3.083	1.948
CV, %		25.62	13.57	15.47

		1996	
Source of variation	df	12 Mar.	31 May
Species (S)	1	45.375*	19.260**
Trinexapac-ethyl (TE)	1	5.042	16.667**
S x TE	1	2.667	24.000**
Iron (Fe)	1	5.042	2.344
S x Fe	1	6.000	0.094
TE x Fe	1	6.000	0.667
S x TE x Fe	1	15.042	0.167
Error	16	6.667	1.255
CV, %		18.33	15.86

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

Table 50. Effect of species, trinexapac-ethyl, and iron on shear resistance values (N•m) of turfgrass subjected to traffic† in reduced light conditions, Hancock Turfgrass Research Center, East Lansing, MI.

Treatment	1994-1995		
	20 Jan.	22 Feb.	31 Mar.
Species	---------- N m ----------		
Supina bluegrass	14.5	8.2	6.5
Kentucky bluegrass	15.7	17.7**	11.5**
Trinexapac-ethyl			
no	13.5	12.3	8.2
yes‡	16.7*	13.6	9.8**
Iron			
no	14.7	12.3	9.7
yes§	15.5	13.5	8.4*

Treatment	1996	
	12 Mar.	31 May
Species	---------- N m ----------	
Supina bluegrass	15.5	8.0
Kentucky bluegrass	12.7	6.2**
Trinexapac-ethyl		
no	13.6	6.2
yes¶	14.5	7.9**
Iron		
no	13.6	7.4
yes#	14.5	6.8

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

† Traffic was applied by persons who jogged on the turf 50 passess each week while wearing molded soccer cleats on the following dates: 28 Dec. 1994 through 16 Mar. 1995 and 26 Jan. through 26 Apr. 1996.

‡ Trinexapac-ethyl was applied on the following dates; rates are shown in parentheses: 3 Oct. 1994 (0.19 kg ha^{-1}), 20 Jan., 18 Feb., 16 Mar. 1995 (0.08 kg ha^{-1} each date).

§ Iron (1.14 kg ha^{-1}) was applied as $FeSO_4$ on 10 Jan., 14 Feb., 17 Mar 1995.

¶ Trinexapac-ethyl was applied on the following dates; rates are shown in parentheses: 9 Oct. 1995 (0.19 kg ha^{-1}), 31 Jan., 15 Mar., 26 Apr. 1996 (0.08 kg ha^{-1} each date).

Iron (1.14 kg ha^{-1}) was applied as $FeSO_4$ on 28 Feb. and 13 May 1996.

more sensitive to trinexapac-ethyl applications in both 1995 and 1996 compared to Kentucky bluegrass (Table 51).

Plant density and biomass

Experiment I: Turf not subjected to traffic

Species, trinexapac-ethyl, and species-by-trinexapac-ethyl interactions existed for specific plant weight, plant density, tiller, and leaf counts (Table 52). The turf density of Supina bluegrass was much greater than Kentucky bluegrass and positively influenced quality ratings. Supina bluegrass had more tillers and leaves per plant plus a higher specific plant weight (Table 53). Plant density (number plants per unit area) was either the same or greater than Kentucky bluegrass.

Trinexapac-ethyl increased turf density by increasing the plant density, number of tillers and leaves per plant, and specific plant weight. Apparently trinexapac-ethyl was effective at repartitioning carbohydrates in the plant to produce axillary tillers and more leaves per plant similar to the effects of paclobutrazol and flurprimidol (Hanson and Branham, 1987). Turf left untreated, particularly Kentucky bluegrass, exhibited a spindlier, more upright growth habit and may have exhausted carbohydrate reserves by cell and shoot elongation without benefitting from an increased leaf area index (LAI) resulting from the trinexapac-ethyl application. As with color, quality, and clipping yields, Supina bluegrass was more sensitive to trinexapac-ethyl than Kentucky bluegrass and exhibited a strong positive response while Kentucky bluegrass was largely unaffected (Table 54).

Table 51. Shear resistance values (N•m) for the significant species-by-trinexapac-ethyl interactions on turfgrass subjected to traffic† in reduced light conditions, Hancock Turfgrass Research Center, East Lansing, MI.

	31 March 1995		31 May 1996	
	trinexapac-ethyl			
Species	no	yes‡	no	yes§
	N m			
Supina bluegrass	5.1	7.9	6.1	9.8
Kentucky bluegrass	11.3	11.8	6.3	6.0
LSD (0.05)	1.6		1.0	

† Traffic was applied by persons who jogged on the turf 50 passess each week while wearing molded soccer cleats on the following dates: 28 Dec. 1994 through 16 Mar. 1995 and 26 Jan. through 26 Apr. 1996.

‡ Trinexapac-ethyl was applied on the following dates; rates are shown in parentheses: 3 Oct. 1994 (0.19 kg ha^{-1}), 20 Jan., 18 Feb., 16 Mar. 1995 (0.08 kg ha^{-1} each date).

§ Trinexapac-ethyl was applied on the following dates; rates are shown in parentheses: 9 Oct. 1995 (0.19 kg ha^{-1}), 31 Jan., 15 Mar., 26 Apr. 1996 (0.08 kg ha^{-1} each date).

Table 52. Mean squares and treatment effects on plant density and biomass of non-trafficked turfgrass in reduced light conditions, Hancock Turfgrass Research Center, East Lansing, MI.

		12 April 1995			
Source of variation	df	Plant density (No. plants m^{-2})	Tillers $plant^{-1}$	Leaves $plant^{-1}$	Specific plant weight (mg)
Species (S)	1	1695697.630	15.360**	180.950*	94.169**
Trinexapac-ethyl (TE)	1	13834140.784**	2.667*	34.800*	143.277**
S x TE	1	749137.231	3.227*	33.844*	48.053*
Iron (Fe)	1	4924.957	0.202	3.300	1.242
S x Fe	1	60.805	0.135	1.170	0.814
TE x Fe	1	102207.627	0.375	13.650	14.291
S x TE x Fe	1	572082.701	0.482	3.920	2.857
Error	16	610266.411	0.400	4.872	7.807
CV, %		13.71	33.27	30.82	29.72
		31 May 1996			
Source of variation	df	Plant density (No. plants m^{-2})	Tillers $plant^{-1}$	Leaves $plant^{-1}$	Specific plant weight (mg)
Species (S)	1	20665817.941**	10.402**	388.815**	2061.277**
Trinexapac-ethyl (TE)	1	832314.080**	0.807**	12.042*	10.010
S x TE	1	1208798.011**	0.807**	1.500	2.306
Iron (Fe)	1	26813.528	0.240	2.282	58.033
S x Fe	1	32164.085	0.240	8.167	191.648
TE x Fe	1	1520.039	0.082	1.500	198.490
S x TE x Fe	1	547.217	0.082	0.015	220.584
Error	16	28759.193	0.087	2.187	66.212
CV, %		15.79	17.84	20.17	33.78

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

Table 53. Effect of species, trinexapac-ethyl, and iron on plant density and biomass of non-trafficked turfgrass in reduced light conditions, Hancock Turfgrass Research Center, East Lansing, MI.

	12 April 1995			
Treatment	Plant density (No. plnts m^{-2})	Tillers $plant^{-1}$	Leaves $plant^{-1}$	Specific plant weight (mg)
Species				
Supina bluegrass	5430.8	2.7	9.9	11.4
Kentucky bluegrass	5962.4	1.1**	4.4*	7.4**
Trinexapac-ethyl				
no	4937.4	1.6	6.0	7.0
yes†	6455.8**	2.2*	8.4**	11.9**
Iron				
no	5710.9	1.8	6.8	9.2
yes‡	5682.2	2.0	7.5	9.6

	31 May 1996			
Treatment	Plant density (No. plnts m^{-2})	Tillers $plant^{-1}$	Leaves $plant^{-1}$	Specific plant weight (mg)
Species				
Supina bluegrass	1990.	2.3	11.4	33.4
Kentucky bluegrass	134**	1.0**	3.3**	14.8**
Trinexapac-ethyl				
no	875	1.5	6.6	23.4
yes§	1248**	1.8**	8.0*	24.8
Iron				
no	1028	1.6	7.0	22.5
yes¶	1095	1.8	7.6	25.6

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

†Trinexapac-ethyl was applied on the following dates; rates are shown in parentheses: 3 Oct. 1994 (0.19 kg ha^{-1}), 20 Jan., 18 Feb., 16 Mar. 1995 (0.08 kg ha^{-1} each date).

‡ Iron (1.14 kg ha^{-1}) was applied as $FeSO_4$ on 10 Jan., 14 Feb., 17 Mar 1995.

§ Trinexapac-ethyl was applied on the following dates; rates are shown in parentheses: 9 Oct. 1995 (0.19 kg ha^{-1}), 31 Jan., 15 Mar., 26 Apr. 1996 (0.08 kg ha^{-1} each date).

¶ Iron (1.14 kg ha^{-1}) was applied as $FeSO_4$ on 28 Feb. and 13 May 1996.

Table 54. Plant density and biomass values for the significant species-by-trinexapac-ethyl interactions on non-trafficked turfgrass in reduced light conditions, Hancock Turfgrass Research Center, East Lansing, MI.

12 April 1995

	Plant density (no. plants m^{-2})		Tillers $plant^{-1}$		Leaves $plant^{-1}$		Specific plant weight (mg)	
	trinexapac-ethyl†							
Species	no	yes	no	yes	no	yes	no	yes
Supina bluegrass	49370	6366	2.0	3.4	7.5	12.3	7.5	15.2
Kentucky bluegrass	5379	6544	1.1	1.1	4.4	4.4	6.4	8.4
LSD (0.05)	ns		0.8		2.7		3.4	

31 May 1996

	Plant density (no. plants m^{-2})		Tillers $plant^{-1}$		Leaves $plant^{-1}$		Specific plant weight (mg)	
	trinexapac-ethyl‡							
Species	no	yes	no	yes	no	yes	no	yes
Supina bluegrass	1579	2400	2.0	2.7	10.4	12.3	33.0	33.7
Kentucky bluegrass	172	96	1.0	1.0	2.8	3.8	13.9	15.8
LSD (0.05)	208		0.4		ns		ns	

† Trinexapac-ethyl was applied on the following dates; rates are shown in parentheses: 3 Oct. 1994 (0.19 kg ha^{-1}), 20 Jan., 18 Feb., 16 Mar. 1995 (0.08 kg ha^{-1} each date).

‡ Trinexapac-ethyl was applied on the following dates; rates are shown in parentheses: 9 Oct. 1995 (0.19 kg ha^{-1}), 31 Jan., 15 Mar., 26 Apr. 1996 (0.08 kg ha^{-1} each date).

Experiment II: Turf subjected to traffic

Trinexapac-ethyl had less effect on the biomass of turf subjected to traffic compared to non-trafficked turf (Table 55). Supina bluegrass continued to exhibit a higher plant density, more tillers and leaves per plant, and higher specific plant weight compared to Kentucky bluegrass (Table 56). In addition, both species exhibited a higher specific plant weight compared to untrafficked turf apparently due to less competition for light and perhaps water and nutrients. Unlike non-trafficked turf, trinexapac-ethyl had little effect on response to traffic between species (Table 57).

Chlorophyll concentration

Experiment I: Turf not subjected to traffic

Species and trinexapac-ethyl significantly affected chlorophyll *a* and *b* levels and total chlorophyll (Table 58). The greater levels of chlorophyll *a*, *b*, and total chlorophyll in Kentucky bluegrass compared to Supina bluegrass were consistent with the darker green color of Kentucky bluegrass but were not effective in providing superior shade tolerance (Table 59). Trinexapac-ethyl also enhanced chlorophyll concentration (leaf area basis) in both turf species probably due to decreased cell enlargement. Trinexapac-ethyl cannot be expected to affect chlorophyll synthesis directly since its known modes of action have been described as blocking gibberellic acid (GA) biosynthesis only at the end of the pathway, primarily by preventing 3-β hydroxylation of the biologically inactive GA_{20} to the biologically active GA_1 (Rademacher, 1991). Since carotenoids and GA_1 have a common precursor, geranylgernalypyrophosphate (GGPP), it is possible GA inhibition

Table 55. Mean squares and treatment effects on plant density and biomass of turfgrass subjected to traffic in reduced light conditions, Hancock Turfgrass Resarch Center, East Lansing, MI.

		12 April 1995			
Source of variation	df	Plant density (No. plnts m^{-2})	Tillers $plant^{-1}$	Leaves $plant^{-1}$	Specific plant weight (mg)
Species (S)	1	1368037.471	15.844**	301.750**	193.007**
Trinexapac-ethyl (TE)	1	5113419.885*	0.260	9.004	9.805
S x TE	1	107254.135	0.304	3.450	1.540
Iron (Fe)	1	8755.448	0.000	0.120	4.200
S x Fe	1	190673.985	0.020	2.100	1.101
TE x Fe	1	117712.025	0.004	0.454	1.224
S x TE x Fe	1	78798.975	0.000	2.220	1.325
Error	16	689430.079	0.293	4.807	8.944
CV, %		39.94	26.78	25.16	21.78

		31 May 1996			
Source of variation	df	Plant density (No. plnts m^{-2})	Tillers $plant^{-1}$	Leaves $plant^{-1}$	Specific plant weight (mg)
Species (S)	1	5545355.292**	6.934**	320.470**	2058.869*
Trinexapac-ethyl (TE)	1	818147.252**	0.350	6.720	110.039
S x TE	1	934886.447**	0.510	4.420	98.537
Iron (Fe)	1	41101.925	0.070	1.450	5.482
S x Fe	1	107254.140	0.020	0.400	31.763
TE x Fe	1	35021.756	0.034	0.634	0.196
S x TE x Fe	1	0.000	0.004	0.034	224.298
Error	16	94729.003	0.125	2.390	125.984
CV, %		50.62	22.59	22.95	39.29

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

Table 56. Effect of species, trinexapac-ethyl, and iron on plant density and biomass of turfgrass subjected to traffic† in reduced light conditions, Hancock Turfgrass Research Center, East Lansing, MI.

	12 April 1995			
Treatment	Plant density (No. plnts m^{-2})	Tillers $plant^{-1}$	Leaves $plant^{-1}$	Specific plant weight (mg)
Species				
Supina bluegrass	1840	2.8	12.3	16.6
Kentucky bluegrass	2317	1.2**	5.2**	10.9**
Trinexapac-ethyl				
no	1617	1.9	8.1	13.1
yes‡	2540*	2.1	9.3	14.4
Iron				
no	2098	2.0	8.8	14.1
yes§	2060	2.0	8.6	13.3

	31 May 1996			
Treatment	Plant density (No. plnts m^{-2})	Tillers $plant^{-1}$	Leaves $plant^{-1}$	Specific plant weight (mg)
Species				
Supina bluegrass	1089	2.1	10.4	37.8
Kentucky bluegrass	127**	1.0**	3.1**	19.3**
Trinexapac-ethyl				
no	423	1.4	6.2	26.4
yes¶	793**	1.7	7.3	30.7
Iron				
no	649	1.5	6.5	28.1
yes#	567	1.6	7.0	29.0

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

† Traffic was applied by persons who jogged on the turf 50 passes each week while wearing molded soccer cleats on the following dates: 28 Dec. 1994 through 16 Mar. 1995 and 26 Jan. through 26 Apr. 1996.

†Trinexapac-ethyl was applied on the following dates; rates are shown in parentheses: 3 Oct. 1994 (0.19 kg ha^{-1}), 20 Jan., 18 Feb., 16 Mar. 1995 (0.08 kg ha^{-1} each date).

‡ Iron (1.14 kg ha^{-1}) was applied as $FeSO_4$ on 10 Jan., 14 Feb., 17 Mar 1995.

§ Trinexapac-ethyl was applied on the following dates; rates are shown in parentheses: 9 Oct. 1995 (0.19 kg ha^{-1}), 31 Jan., 15 Mar., 26 Apr. 1996 (0.08 kg ha^{-1} each date).

¶ Iron (1.14 kg ha^{-1}) was applied as $FeSO_4$ on 28 Feb. and 13 May 1996.

Table 57. Plant density and biomass values for the species-by-trinexapac-ethyl interactions on turfgrass subjected to traffic† in reduced light conditions, Hancock Turfgrass Research Center, East Lansing, MI.

	12 April 1995							
	Plant density (no. plants m^{-2})		Tillers plant^{-1}		Leaves plant^{-1}		Specific plant weight (mg)	
	trinexapac-ethyl‡							
Species	no	yes	no	yes	no	yes	no	yes
Supina bluegrass	1445	2234	2.6	3.0	11.3	13.2	16.2	17.0
Kentucky bluegrass	1789	2846	1.2	1.2	4.9	5.4	10.0	11.8
LSD (0.05)	ns		ns		ns		ns	

	31 May 1996							
	Plant density (no. plants m^{-2})		Tillers plant^{-1}		Leaves plant^{-1}		Specific plant weight (mg)	
	trinexapac-ethyl§							
Species	no	yes	no	yes	no	yes	no	yes
Supina bluegrass	707	1471	1.8	2.4	9.4	11.4	33.7	42.0
Kentucky bluegrass	140	114	1.0	1.0	3.0	3.2	19.2	19.4
LSD (0.05)	377		ns		ns		ns	

† Traffic was applied by persons who jogged on the turf 50 passes each week while wearing molded soccer cleats on the following dates: 28 Dec. 1994 through 16 Mar. 1995 and 26 Jan. through 26 Apr. 1996.

‡ Trinexapac-ethyl was applied on the following dates; rates are shown in parentheses: 3 Oct. 1994 (0.19 kg ha^{-1}), 20 Jan., 18 Feb., 16 Mar. 1995 (0.08 kg ha^{-1} each date).

§ Trinexapac-ethyl was applied on the following dates; rates are shown in parentheses: 9 Oct. 1995 (0.19 kg ha^{-1}), 31 Jan., 15 Mar., 26 Apr. 1996 (0.08 kg ha^{-1} each date).

Table 58. Mean squares and treatment effects on chlorophyll of non-trafficked turfgrass in reduced light conditions, Hancock Turfgrass Research Center, East Lansing, MI.

		4 April 1995			
Source of variation	df	Chlorophyll *a*	Chlorophyll *b*	Total chlorophyll	Chlorophyll *a:b*
Species (S)	1	238.644**	30.173**	435.968**	0.029
Trinexapac-ethyl (TE)	1	314.071**	47.124**	601.301**	0.163*
S x TE	1	1.815	0.008	2.227	0.000
Iron (Fe)	1	5.587	0.980	10.921	0.000
S x Fe	1	4.267	0.022	5.125	0.035
TE x Fe	1	11.289	1.701	21.263	0.001
S x TE x Fe	1	19.802	1.071	30.759	0.009
Error	16	13.265	2.285	26.225	0.027
CV, %		15.21	19.45	16.16	5.25

		29 May 1996			
Source of variation	df	Chlorophyll *a*	Chlorophyll *b*	Total chlorophyll	Chlorophyll *a:b*
Species (S)	1	32.109	2.734	55.937*	0.029
Trinexapac-ethyl (TE)	1	121.590**	10.935**	200.797**	0.020
S x TE	1	8.592	0.680	15.360	0.029
Iron (Fe)	1	19.911	2.257	33.844	0.032
S x Fe	1	13.681	1.344	22.042	0.000
TE x Fe	1	0.341	0.070	1.033	0.022
S x TE x Fe	1	0.928	0.109	1.288	0.034
Error	16	4.710	0.470	7.887	0.043
CV, %		10.03	9.78	9.79	6.70

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

Table 59. Effect of species, trinexapac-ethyl, and iron on chlorophyll content of non-trafficked turfgrass in reduced light conditions, Hancock Turfgrass Research Center, East Lansing, MI.

Treatment	Chlorophyll *a*	Chlorophyll *b*	Total chlorophyll	Chlorophyll *a:b*
	4 April 1995			
	---μg cm^{-2} leaf tissue---			
Species				
Supina bluegrass	20.8	6.7	27.4	3.1
Kentucky bluegrass	27.1**	8.9**	36.0**	3.1
Trinexapac-ethyl				
no	20.3	6.4	26.7	3.2
yes†	27.6**	9.2**	36.7**	3.0*
Iron				
no	24.4	8.0	32.4	3.1
yes‡	23.5	7.6	31.0	3.1
	29 May 1996			
	---μg cm^{-2} leaf tissue---			
Species				
Supina bluegrass	20.5	6.7	27.1	3.1
Kentucky bluegrass	22.8*	7.3	30.2*	3.1
Trinexapac-ethyl				
no	19.4	6.3	25.8	3.1
yes§	23.9**	7.7**	31.6**	3.1
Iron				
no	20.7	6.7	27.5	3.1
yes¶	22.5	7.3*	29.9	3.1

*, ** Significant at the 0.05 and 0.01 probability levels, respectively.
†Trinexapac-ethyl was applied on the following dates; rates are shown in parentheses: 3 Oct. 1994 (0.19 kg ha^{-1}), 20 Jan., 18 Feb., 16 Mar. 1995 (0.08 kg ha^{-1} each date).
‡ Iron (1.14 kg ha^{-1}) was applied as $FeSO_4$ on 10 Jan., 14 Feb., 17 Mar 1995.
§ Trinexapac-ethyl was applied on the following dates; rates are shown in parentheses: 9 Oct. 1995 (0.19 kg ha^{-1}), 31 Jan., 15 Mar., 26 Apr. 1996 (0.08 kg ha^{-1} each date).
¶ Iron (1.14 kg ha^{-1}) was applied as $FeSO_4$ on 28 Feb. and 13 May 1996.

could cause a feedback mechanism to shunt additional GGPP to carotenoid production. Current evidence does not support the existence of such a feedback mechanism as typically non-active gibberellins(GA_1 precursors) continue to accumulate in the presence of a (GA_1) biosynthetic inhibitor (Rademacher, 1991).

Iron application caused only minor, temporary darker green turf color. Chlorophyll levels were relatively unaffected within two weeks following an application of iron. This result suggests the plants were already at their maximum capacity for using iron for chlorophyll production or else energy levels within the turfgrass plants were too low to utilize the iron. Auxiliary studies showed that while foliar applications of iron failed to enhance turf color or chlorophyll levels in Kentucky bluegrass, iron levels in plant tissues were increased threefold following an application of iron sulfate at the same rate used in the current study (*unpublished data*). Another possible explanation for the inconsistency between color enhancement and lack of effect on chlorophyll content is that the leaves used for chlorophyll analysis might have been partially unexpanded at the time of the iron application thus the effect would have been seen particularly on older leaves.

Chlorophyll *a:b* ratios were relatively unaffected by any treatment. Chlorophyll *a:b* ratios were approximately 3:1 which is equivalent to the ratio of approximately 3:1 observed for sun plants (Nobel, 1991). This indicates Supina bluegrass is not a "shade" plant *per se* but apparently has mechanisms for shade tolerance which are lacking in Kentucky bluegrass.

Experiment II: Turf subjected to traffic

Treatment effects on chlorophyll quality and quantity were similar between trafficked and untrafficked turf in 1995 (Table 60). As expected, data from 1995 indicated traffic did not affect chlorophyll content (Table 61). Data were not collected in 1996 due to insufficient plant material (the youngest fully matured leaves were consistently too short from mowing to use in analysis).

CONCLUSIONS

Supina bluegrass was more tolerant of RLC than Kentucky bluegrass. The light conditions tested were too low to sustain Supina bluegrass permanently in a trafficked conditions and were marginal for non-trafficked conditions. The enhanced growth of Supina bluegrass due to increasing light levels and photoperiod in the spring indicated the actual light requirement to sustain Supina bluegrass under traffic was greater than the test conditions generally provided.

Iron had negligible effect on any characteristic of either turfgrass species. Trinexapac-ethyl treatments provided superior enhancement of color and quality compared to iron. In addition, iron did not provide the enhanced biomass associated with trinexapac-ethyl treatments.

Supina bluegrass was consistently more responsive to trinexapac-ethyl than Kentucky bluegrass. Trinexapac-ethyl may have helped to increase the turf quality in RLC by shifting carbohydrate partitioning away from primary shoots to stimulate tillering with a subsequent increase in the LAI in addition to promoting a more prostrate

Table 60. Mean squares and treatment effects on chlorophyll of turfgrass subjected to traffic in reduced light conditions, Hancock Turfgrass Research Center, East Lansing, MI.

		4 April 1995			
Source of variation	df	Chlorophyll *a*	Chlorophyll *b*	Total chlorophyll	Chlorophyll *a:b*
Species (S)	1	104.125**	14.774**	278.734**	0.077*
Trinexapac-ethyl (TE)	1	179.252**	23.108**	328.486**	0.027
S x TE	1	0.017	0.134	4.708	0.010
Iron (Fe)	1	5.636	0.485	12.600	0.007
S x Fe	1	0.956	0.002	5.180	0.020
TE x Fe	1	24.990	3.190	52.896*	0.000
S x TE x Fe	1	13.395	3.046	4.797	0.056
Error	16	7.701	1.048	11.416	0.013
CV, %		10.98	12.94	10.18	3.54

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

Table 61. Effect of species, trinexapac-ethyl, and iron on chlorophyll content of turfgrass subjected to traffic in reduced light conditions, Hancock Turfgrass Research Center, East Lansing, MI. †

	4 April 1995			
Treatment	Chlorophyll *a*	Chlorophyll *b*	Total chlorophyll	Chlorophyll *a:b*
	µg cm^{-2} leaf tissue			
Species				
Supina bluegrass	23.2	7.1	29.8	3.3
Kentucky bluegrass	27.4**	8.7**	36.6**	3.2*
Trinexapac-ethyl				
no	22.5	6.9	29.5	3.3
yes‡	28.0**	8.9**	36.7**	3.2
Iron				
no	24.8	7.8	32.5	3.2
yes§	25.8	8.1	33.9	3.2

*, ** Significant at the 0.05 and 0.01 probability levels, respectively.
† Traffic was applied by persons who jogged on the turf 50 passes each week while waring molded soccer cleats from 28 Dec. 1994 through 16 May 1995.
‡ Trinexapac-ethyl was applied on the following dates; rates are shown in parentheses: 3 Oct. 1994 (0.19 kg ha^{-1}), 20 Jan., 18 Feb., 16 Mar. 1995 (0.08 kg ha^{-1} each date).
§ Iron (1.14 kg ha^{-1}) was applied as $FeSO_4$ on 10 Jan., 14 Feb., 17 Mar 1995.

and compact growth. These attributes could be expected to enhance net photoassimilation on a turf area basis, creating a favorable cycle as more carbohydrates can be produced to regenerate tissues damaged by traffic or disease.

Supina bluegrass was superior to Kentucky bluegrass in RLC due in part to an apparent resistance to powdery mildew. Supina bluegrass was more susceptible to pink snow mold in RLC compared to Kentucky bluegrass. This problem was partly controlled by providing wind movement over the turf with portable fans although occasional fungicide applications were still necessary to prevent noticeable disease damage.