CHAPTER II

WEAR TOLERANCE OF SEVEN COOL-SEASON TURFGRASS SPECIES AND QUANTITATIVE METHODS FOR DETERMINING TURFGRASS WEAR INJURY

Abstract

The relative wear tolerance of seven cool-season turfgrass species was determined by four methods of evaluation for both sled (foot-like) and wheel (vehicular) wear injury. The four methods of evaluating wear tolerance differentials were (1) visual rating of wear injury, (2) percent total cell wall (TCW), (3) percent verdure, and (4) percent chlorophyll content per unit area remaining after wear treatment. Manhattan perennial ryegrass was the most tolerant to wheel wear; Kentucky 31 tall fescue and Merion Kentucky bluegrass ranked second; Pennlawn red fescue and Italian ryegrass were intermediate; while Cascade chewings fescue and rough bluegrass ranked lowest among the species examined. The relative ranking for sled (foot-like) wear was slightly different from that of the wheel. Visual ratings indicated that Manhattan, Kentucky 31, and Merion

were equally tolerant to sled wear. However, Merion was the most wear tolerant to sled injury, according to ratings based on the percent verdure remaining after treatment. Manhattan and Kentucky 31 ranked second and third, respectively; while, Cascade chewings fescue and rough bluegrass were essentially destroyed by the crushing and tearing action of the sled.

Percent verdure remaining after treatment was determined to be the preferred method for quantitatively evaluating wear tolerance differentials. It eliminated arbitrary decisions that were inherent in the visual rating system, and involved fewer procedural steps than either the percent TCW or chlorophyll content determinations.

Introduction

The injurious effects of foot or vehicular traffic on the above ground portions of turf are termed wear. Wear injury results from the weight and motion of traffic crushing and tearing the leaves, stems, and crowns of the turfgrass plant. Wear injury should be distinguished from the soil compaction aspects of traffic. Wear tolerance was reported by Beard (1973) to vary, according to the (a) turfgrass species, (b) intensity of turfgrass culture, and (c) intensity and type of traffic. Ferguson (1961), and Burton (1966), emphasized that proper traffic control is essential in minimizing the severity of wear injury and for recuperation of injured turfs.

Warm-season turfgrasses have been reported by Beard (1973) and Youngner (1961) to be more wear tolerant than cool-season turfgrasses. However, information concerning wear tolerance aspects of cool-season turfgrass species is limited. Morrish and Harrison (1948) found Kentucky bluegrass (Poa pratensis L.), Canada bluegrass (P. compressa L.), chewings fescue (Festuca rubra var. commutata Gaud.), sheep fescue (F. ovina L.), and tall fescue (F. arundinacea Schreb.) to be more wear tolerant of vehicular traffic than several common forage grass species. Shildrick (1971) and Wood and Law (1972) have reported wear tolerance variations among Kentucky bluegrass cultivars. Red fescue (Festuca rubra L.) was reported by Versteeg to not persist as well as chewings fescue on intensively trafficked areas. One basic limitation prevails throughout each of these studies. Evaluations of the persistence of cool-season turfgrasses under traffic is really not a measure of wear injury alone, but a composite of many effects including wear, compaction, and disease susceptibility.

Youngner (1961) conducted extensive investigations on the wear tolerance of warm- and cool-season turfgrass species. He used a wear simulator described by Perry (1958). The machine simulated two aspects of wear, scuffing feet, and a spiked roller. The spiked roller caused the most severe wear damage. Youngner's results indicated that zoysiagrasses (Zoysia japonica Steud., and Z. matrella L.), bermudagrass (Cynodon dactylon L.) and Alta tall fescue were the most wear resistant species tested. In general, the warm-season turfgrass species were more wear tolerant than the cool-season species. Tall fescue was the most wear tolerant of the cool-season species studied. Merion Kentucky bluegrass, common Kentucky bluegrass, and perennial ryegrass (Lolium perenne L.) were intermediate in wear tolerance, while Astoria and Highland colonial bentgrasses (Agrostis tenuis Sibth.) ranked lowest in wear tolerance among the species studied. In many cases, field observations have been the only basis for delineating the relative wear tolerance of cool-season turfgrass species.

This study was conducted as part of an investigation to determine the influence of physiological, morphological, and anatomical characteristics of turfgrasses that are associated with wear tolerance. The objectives of this study were to (1) develop quantitative methods for differentiating wear tolerance among species, and (2) compare the relative wear tolerance of seven cool-season turfgrass species.

Materials and Methods

Seven cool-season turfgrass species were established in early May, 1972, on a sandy loam soil. A randomized complete block design with two blocks and seven treatments per block was used. The plots were 1.8 x 7.6 m. The turfgrasses utilized were (1) Pennlawn red fescue (*Festuca rubra* L.), (2) Cascade chewings fescue (*F. rubra* var. *commutata* Gaud.), (3) Kentucky 31 tall fescue (*F. arundinacea* Schreb.), (4) Manhattan perennial ryegrass (*Lolium perenne* L.), (5) Merion Kentucky bluegrass (*Poa pratensis* L.), (6) Italian ryegrass (*L. multiflorum* L.), and (7) rough bluegrass (*P. trivialis* L.). Each species was established from seed. The seeding rates were based on 15 seeds per 6.25 cm^2, or a rate equivalent to 0.454 kg per area of Kentucky bluegrass. The rates were adjusted for percent viable seed, according to the germination and purity percentages for each species.

Seedbed Preparation and Post-Germination Care. A complete fertilizer (12-12-12) was tilled into the upper 5.0 cm of the seedbed at a rate of 0.454 kg actual nitrogen (N) per are. The final seedbed was raked, the seed was applied with a Scotts' gravity spreader, and rolled to insure good seed-soil contact. An application of Tupersan (siduron) at a rate of 0.454 kg per hectare was applied to control annual weedy grasses. The plot area was mulched with straw at a rate of 27.2 kg per are. The mulch was removed three weeks after seedling emergence and an application of 0.225 kg actual N per are of ammonium nitrate (33-0-0) was applied. Subsequent fertilizations of 0.454 kg actual N (33-0-0) were applied on July 25, August 25, and September 15, 1972. The plots were mowed twice weekly at 5.0 cm with a reel mower and the clippings were removed. Irrigation was applied as needed throughout the growing season to prevent visual drouth stress. Broadleaf weeds were controlled by hand weeding the plots.

Determination of Turfgrass Wear Tolerance. On September 20, 1972, a preliminary wear study was conducted using the wear simulator previously described by Shearman et al. (1973) to develop standard operating procedures. Kentucky 31 tall fescue and rough bluegrass established in May were included in this study. A wear endpoint similar to that reported by Youngner (1961) was chosen to evaluate wear tolerance between turfgrass species. The wear tolerance was determined by the number of revolutions necessary to shred all leaf blades from the sheath with only stems and bare soil remaining.

Four alternate methods were chosen to measure wear injury in an attempt to achieve a greater degree of precision in wear testing procedures. The methods selected were (a) percent total cell wall, (b) percent verdure, (c) chlorophyll content on a per unit area basis, and (d) visual ratings. Each method was modified as needed for the specific evaluation of wear. Specific modifications are described in subsequent sections. A second wear study was conducted, utilizing these methods in early June, 1973. All seven turfgrass species were included. Each species was subjected to 600 machine revolutions (600 wear units) for both wheel and sled wear. No apparent disease activity was present at the time of wear treatment or when samples were taken. Samples for the quantitative determinations were made three days after the turf had been treated. The wear damaged tissues desiccated and turned a straw-color within this period of time.

Percent total cell wall. Total cell wall content determinations were made using the method outlined by Goering and Van Soest (1970). The turfs were mowed at 5.0 cm and the clippings were removed. Four, 10 cm diameter plugs were sampled from trafficked (wheel only) and non-trafficked areas within each treatment. The percent total cell wall was determined for the wear injured and uninjured turfs. The total cell wall content for the wear-injured turf was determined after the straw-colored tissues were removed. The percent total cell wall per dm^2 value for the injured turf was divided by that obtained for the adjacent uninjured turf. This calculation was multiplied by 100 and converted to a percentage value based on the turf receiving no wear injury. Hence, the larger the calculated value, the greater the wear tolerance of the turf.

Percent verdure. Verdure measurements were made using the method described by Madison (1962). The plots were mowed at 5.0 cm and the clippings removed immediately before evaluations were made. Four, 10 cm diameter plugs were sampled from both the wear-injured (wheel and sled) and uninjured turfs, as described in the percent total cell wall determination procedures. Verdure was expressed in grams of fresh weight per dm^2. The value obtained for the wear-injured turf was divided by that obtained for the uninjured. The resultant calculation was multiplied by 100 to obtain a percentage value based on the verdure for the uninjured turf. A large calculated value indicated a great degree of wear tolerance.

Chlorophyll content per unit area. The chlorophyll content of turf has been correlated with visual quality ratings by Madison and Anderson (1963), Mantell and Stanhill (1966), and Wilkinson and Duff (1972). The chlorophyll content per dm^2 for wear-injured (wheel only) and uninjured turfs was determined spectrophotometrically using the procedures outlined by Wilkinson and Duff (1972). The turfs were mowed at 5.0 cm and the clippings were removed. Four, 10 cm diameter plugs were sampled from each treatment for both the wear-injured and uninjured turfs as previously described. Chlorophyll content was expressed as mg chlorophyll per dm^2. The value obtained for the wear-injured turf was divided by that obtained for the uninjured turf.

This value was multiplied by 100 and expressed as a percentage on an uninjured basis.

Visual rating. Visual ratings of turfgrass wear injury for both wheel and sled were determined. Ratings were based on a scale of 1 to 5. A rating of 1 indicated no injury, while 5 indicated bare soil exposed and only stems remaining. Intermediate ratings were based as follows: a) 2 indicated 25 percent of leaf blades shredded from sheaths, b) 3 indicated 50 percent of leaf blades shredded from sheaths, and c) 4 indicated 75 percent of leaf blades shredded from the sheaths and some exposed soil.

Data Analysis. A randomized complete block design with nested subsamples was used in this study. An analysis of variance was conducted and means were separated by the Duncan's Multiple Range Test. The usefulness of the methods evaluated for measuring wear tolerance differentials was based on correlations with visual quality ratings, and whether satisfactory differentials in wear tolerance could be achieved among species.

Results and Discussion

The results of a preliminary wear tolerance experiment conducted in the fall of 1972 are shown in Table II.1. Wear tolerance was based on the number of revolutions to reach the predetermined endpoint described in the Materials and Methods section. This procedure satisfactorily differentiated wear tolerance between the two species studied. However, considerable variability between runs existed, making it difficult to determine wear tolerance differentials among closely associated species. In addition, it was recognized that the wear endpoint was rather arbitrary and could be difficult to duplicate when attempted by other researchers. With these disadvantages in mind, alternative methods were sought for quantitatively determining wear tolerance.

Wear tolerance differentiation among the four methods studied was quite significant (Tables II.2-II.6). Manhattan perennial ryegrass was the most wear tolerant species under wheel traffic. Kentucky 31 tall fescue and Merion Kentucky bluegrass ranked second. Pennlawn red fescue and Italian ryegrass were intermediate, while Cascade chewings fescue and rough bluegrass ranked lowest for the species examined. The relative wear tolerance differential based on the percent verdure remaining after sled wear injury differed slightly from that found for the wheel (Table II.2). Sled damage was more severe in all cases. Visual ratings indicated that Manhattan perennial ryegrass, Kentucky 31 tall fescue, and Merion Kentucky bluegrass were equally tolerant of sled wear. Merion was the most wear tolerant to sled injury, according to ratings based on the percent verdure remaining after treatment (Table II.5). Manhattan and Kentucky 31 ranked second and third, respectively. Pennlawn red fescue and Italian ryegrass ranked intermediate to low. While, Cascade chewings fescue and rough bluegrass were completely destroyed by the abrasive, tearing action of the sled wear. Sled injury appeared to be most severe on the stoloniferous and bunch-type species than on the rhizomatous species. Youngner (1961) found Alta tall fescue to be more wear tolerant than Merion Kentucky bluegrass or perennial ryegrass. However, this study was conducted under growing conditions more suitable for warm-season species. Therefore, tall fescue, being a more transitional species, was better suited to these growing conditions than the other cool-season species studied. No statistical comparisons were indicated in Youngner's study.

The relative agreement among the four methods tested was significant. Visual ratings were significantly correlated to percent TCW remaining (r = -0.98), percent verdure remaining (r = -0.97), and percent chlorophyll content per unit area (r = -0.97). The visual ratings were negatively correlated to the other methods due to the fact that larger values for visual ratings indicated more severe wear injury, while the other methods were based on the fact that larger values indicated less severe wear injury. Percent TCW remaining was significantly correlated to the percent verdure (r = 0.98) and percent chlorophyll content per unit area (r = 0.95). Percent verdure was significantly correlated (r = 0.98) to the percent chlorophyll content remaining after wear treatment.

The correlation coefficients indicated satisfactory agreement between the methods tested. Any of the methods used could satisfactorily evaluate wear tolerance differentials among species. However, certain advantages and disadvantages for each method must be weighed. The visual rating system is the least involved procedure of those studied. It has a basic disadvantage in that it relies on arbitrary decisions for determining wear injury as well as the experience and biases of the evaluator. The percent verdure remaining after wear treatment was second to the visual rating method in its simplicity. It was the preferred method for quantitatively determining wear differentials. It eliminated the arbitrary decisions involved in the visual rating system, and involved fewer procedural steps and calculations per determination than either percent TCW or percent chlorophyll content methods.

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TABLE II.1.--Comparison of turfgrass species wear tolerance utilizing the wear machine operated until a comparable endpoint was achieved.

Turfgrass species	Number of machine revolutions to reach the endpoint				
	Replication				Avg.
	I	II	III	IV	
Kentucky 31 tall fescue	785	770	725	703	745.75a*
Rough bluegrass	365	425	395	418	400.75b

*Values with the same letter are not significantly different at the 5% level using Duncan's Multiple Range Test.

TABLE II.2.--Visual ratings of wheel and sled wear injury of seven cool-season turfgrass species made 3 days after wear treatment.

Turfgrass species	Visual ratings of injury*	
	Wheel	Sled
Manhattan perennial ryegrass	2.1a**	2.9a
Merion Kentucky bluegrass	2.5b	2.9a
Kentucky 31 tall fescue	2.4b	2.9a
Pennlawn red fescue	3.4c	4.0b
Italian ryegrass	3.6d	4.5c
Cascade chewings fescue	4.0e	5.0d
Rough bluegrass	4.6f	5.0d
LSD .05 = 0.21***		

*Visual ratings based on 1--no injury and 5--stems only with exposed soil. Values are averages of 8 replications.

**Values with the same letter in a column are not significantly different at the 5% level, using Duncan's Multiple Range Test.

***LSD for comparisons between column values only.

TABLE II.3.--Percent total cell wall content for wheel wear injured and uninjured turfs of seven cool-season turfgrass species, and a comparison of percent total cell wall content of green tissues, remaining 3 days after wear treatment.

Turfgrass species	Total cell wall (g dm^{-2})		% total cell wall remaining
	Injured	Uninjured	
Manhattan perennial ryegrass	0.91 a*	1.06 ab	85.6 a
Merion Kentucky bluegrass	0.90 ab	1.17 a	76.3 b
Kentucky 31 tall fescue	0.83 ab	1.12 ab	75.2 b
Italian ryegrass	0.71 b	0.94 bc	66.2 c
Pennlawn red fescue	0.35 cd	0.61 d	57.3 d
Cascade chewings fescue	0.48 c	0.98 b	48.3 e
Rough bluegrass	0.25 d	0.78 cd	33.4 f
LSD 0.5 = 0.20**			

*Values with the same letter in a column are not significantly different at the 5% level, using Duncan's Multiple Range Test. Values are averages of 8 replications.

**LSD for comparison between column values only.

TABLE II.4.--Verdure for wheel wear injured and uninjured turfs of seven cool-season turfgrass species, and a comparison of percent verdure remaining 3 days after wear treatment.

Turfgrass species	Verdure ($g\ dm^{-2}$)		% Verdure remaining
	Injured	Uninjured	
Manhattan perennial ryegrass	4.73 a*	5.46 c*	87.0 a*
Merion Kentucky bluegrass	4.41 b	5.84 b	75.5 b
Kentucky 31 tall fescue	4.48 b	5.98 b	75.0 b
Italian ryegrass	3.13 c	5.12 d	61.0 c
Pennlawn red fescue	2.32 d	4.58 e	50.5 d
Cascade chewings fescue	1.64 e	4.43 e	36.8 e
Rough bluegrass	1.37 f	6.64 a	20.3 f
LSD .05 = 0.22**			

*Values with the same letter in a column are not significantly different at the 5% level, using Duncan's Multiple Range Test. Values are averages of 8 replications.

**LSD for comparison between column values only.

TABLE II.5.--Verdure for sled wear injured and uninjured turfs of seven cool-season turfgrass species, and a comparison of the percent verdure remaining 3 days after wear treatment.

Turfgrass species	Verdure ($g\ dm^{-2}$)		% Verdure remaining
	Injured	Uninjured	
Merion Kentucky bluegrass	4.50 a*	5.90 c	76.2 a
Manhattan perennial ryegrass	3.82 b	5.89 c	65.0 b
Kentucky 31 tall fescue	3.66 b	7.30 a	50.2 c
Pennlawn red fescue	2.51 c	5.36 d	46.8 d
Italian ryegrass	2.11 d	4.64 e	45.5 d
Cascade chewings fescue	1.23 e	4.44 e	27.6 e
Rough bluegrass	0.35 f	6.86 b	5.1 f
LSD .05 = 0.13**			

*Values with the same letter in a column are not significantly different at the 5% level, using Duncan's Multiple Range Test. Values are averages of 8 replications.

**LSD for comparison between column values only.

TABLE II.6.--Chlorophyll content (mg dm^{-2}) for wheel wear injured and uninjured turfs of seven cool-season turfgrass species and a comparison of percent chlorophyll remaining 3 days after wear treatment.

Turfgrass species	Chlorophyll Content (mg dm^{-2})		% Chlorophyll remaining
	Injured	Uninjured	
Manhattan perennial ryegrass	8.90 a*	11.02 bc	80.3 a
Kentucky 31 tall fescue	7.32 b	11.63 b	63.3 b
Merion Kentucky bluegrass	7.51 b	11.86 a	63.2 b
Italian ryegrass	2.98 c	6.74 e	44.2 c
Pennlawn red fescue	2.95 c	8.57 d	34.6 d
Cascade chewings fescue	0.94 d	4.28 f	21.9 e
Rough bluegrass	1.26 d	10.93 c	11.4 f
LSD .05 = 0.26**			

*Values with the same letter in a column are not significantly different at the 5% level, using Duncan's Multiple Range Test. Values are averages of 8 replications.

**LSD for comparisons between column values only.