CHAPTER III

THE EFFECTS OF CELL WALL CONSTITUENTS ON TURFGRASS WEAR TOLERANCE

Abstract

The cell wall constituents of seven cool-season turfgrass species were quantitatively determined. The percent total cell wall (TCW), lignocellulose (ADF), cellulose, hemicellulose, and lignin were determined on a gram dry weight and mg per dm^2 basis. Species differed significantly in cell wall constituents for both methods of determination. The relative ranking of the species based on the content of the various cell wall constituents expressed on a gram dry weight basis was as follows: Cascade chewings fescue > Pennlawn red fescue and Kentucky 31 tall fescue > Manhattan perennial ryegrass > Merion Kentucky bluegrass > Italian ryegrass > rough bluegrass. However, this ranking was somewhat different when the cell wall components were expressed on mg per dm^2. The species ranked as follows: Kentucky 31 > Manhattan and Merion > Pennlawn and Italian ryegrass > Cascade > rough bluegrass. Cell wall constituents reported on a gram

per dry weight basis were not correlated individually to wear tolerance. However, the combined effects of TCW, ADF, cellulose, and lignin accounted for a high percentage of the variation of the observed wear tolerance among the seven turfgrass species studied. TCW, ADF, cellulose, and hemicellulose contents expressed as mg per dm^2 were significantly correlated to wear tolerance on an individual basis. Total cell wall content expressed on mg per dm^2 basis accounted for 78% of the variation in wear tolerance among the seven turfgrass species evaluated.

Cell wall constituents were found to increase significantly with plant maturity with the exception of hemicellulose. Hemicellulose content was quite variable among species. Total cell wall increased significantly during the period of July to September, but declined for all species in October. The cell wall constituents were compared between leaf blade and leaf sheath. Leaf blade contents of TCW, ADF, cellulose, hemicellulose and lignin were significantly less than leaf sheath contents for all species.

Introduction

Beard (1973), Shildrick (1971), Wood and Law (1972), and Youngner (1961) reported that turfgrass wear tolerance varies among turfgrass species and cultivars. Various physiological, morphological, and anatomical characteristics of the plant have been suggested to correspond with turfgrass wear tolerance differentials. Turfgrass wear tolerance was reported by Beard (1973) to be influenced by (a) degree of tissue hydration, (b) quantity and location of sclerenchyma fibers, (c) coarseness of stems and leaves, (d) shoot density, and (e) lignin content. However, little or no data have been reported in the turfgrass literature to verify these associations.

The objective of this investigation was to determine the relative importance of various turfgrass physiological characteristics that contribute to turfgrass wear tolerance. Major emphasis was placed on determining criteria upon which turfgrass wear tolerance could be based. This information would serve as a useful tool for selecting wear tolerant cultivars in turfgrass breeding programs.

Materials and Methods

Field study. Seven cool-season turfgrass species were established in early May, 1972, on a sandy loam soil, as reported by Shearman and Beard (1973) in an earlier paper. A randomized complete block design with two blocks and seven treatments per block was used.

The turfgrass species studied 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) Italian ryegrass (L. multiflorum L.), (6) Merion Kentucky bluegrass (Poa pratensis L.), and (7) rough bluegrass (P. trivialis L.). The turfs were fertilized with 2.1 kg of actual nitrogen (N) per are per growing season. A complete fertilizer (12-12-12) was applied at a rate of 0.454 kg actual nitrogen per are at establishment time. Three weeks after seedling emergence 0.225 kg N (33-0-0) per are was applied. Subsequent fertilizations of 0.454 kg N per are were applied on July 25, August 25, and September 15, 1972. The turfs were mowed twice weekly at 5.0 cm with the clippings removed. Irrigation was applied throughout the growing season as needed to prevent visual drouth stress.

Evaluation of changes in percent total cell wall content during the growing season were made. Cell wall constituents for each species were determined on a mg per dm^2 basis. Procedures for percent total cell wall content are explained in detail in the description of analytical procedures for cell wall constituents.

Growth Chamber Studies. Turfs of the seven cool-season turfgrasses used in the field wear study were established in a controlled environment chamber for comparison of the various cell wall constituents. The environmental conditions were (a) 32,280 lux light intensity, (b) a 20/15 C day/night temperature regime, and (c) a 14 hour photoperiod. The turfs were established in 10 cm diameter plastic pots in a sandy loam soil. They were seeded at a rate of 15 seeds per 6.25 cm^2 with numbers based on viable seed, according to percent germination and purity. The seedling turfs were grown for 14 days under an automatic sprinkling system in the greenhouse before being transferred to the growth chamber. A randomized complete block design with 4 blocks and seven treatments per block was used.

The turfs were mowed weekly at 5.0 cm with the clippings removed. A complete nutrient solution with a N-P-K ratio of 4:1:2 was applied biweekly. Micronutrients were supplied in concentrations comparable to a complete Hoagland's nutrient solution. The conductance of the nutrient solution was 0.875 mmhos cm^{-1}. Turfs were irrigated daily to prevent drouth stress.

Comparisons of cell wall constituents for the seven cool-season species, during the 10 week period after seedling emergence as well as between leaf blade and leaf sheath were the basic data collected in this study. Comparisons of leaf and sheath cell wall constituents were made 3 months after establishment when the study was terminated. Cell wall constituents were determined, according to the methods outlined in the analytical procedures section.

Analytical Procedures. Cell wall constituents were determined using the procedures outlined by Goering and Van Soest (1970). Determinations for each procedure were replicated four times. The neutral-detergent fiber (NDF) procedure was used to determine the percent total cell wall content on a dry weight basis. Lignocellulose was determined by the acid-detergent fiber (ADF) method. The difference between the NDF and ADF contents was used to estimate the percent hemicellulose. ADF was used as a preparatory step for lignin, and cellulose determinations.

The residue from the ADF was treated with the permanganate procedure described by Van Soest and Wine (1968) to determine lignin, and cellulose contents. The permanganate lignin determination is an alternative method to the acid-detergent lignin (ADL) procedure. It is a more rapid procedure for lignin determination than ADL and the residue can be reserved for cellulose, and silica determinations. In the permanganate procedure lignin is oxidized with an excess of acetic acid-buffered potassium permanganate solution, containing trivalent iron and monovalent silver as catalysts. Manganese and iron oxides formed in this process were dissolved with a demineralizing solution, containing ethanol, oxalic acid, and hydrochloric acid. The residue that remained consisted of cellulose and insoluble minerals (primarily silica). Lignin was measured as the weight lost after the potassium permanganate treatment. Cellulose was determined as the weight lost during ashing of the remaining residue. Silica was determined by treating the ash with hydrobromic acid and weighing the remaining residue. Unfortunately, silica contents obtained were not of a sufficient quantity to adequately use the silica determination procedure.

Permanganate lignin values are less affected by heat-damage artifacts than ADL, resulting in more valid lignin values. Van Soest (1964) reported that lignin and ADF content increased as temperature was increased above 50 C. Hemicellulose content tends to decrease while the lignin contents increase. This is possibly due to precipitation of a portion of the hemicellulose into the lignin fraction. Tissue samples in this study were dried in a forced-air oven at 50 C for 24 hours. The samples were ground through a 40 mesh screen in a Wiley mill.

Data Analysis. An analysis of variance was conducted on the data for each of the studies and means were separated with the Duncan's Multiple Range Test. The plant cell wall constituents were correlated to the wear tolerance of each species. A stepwise regression procedure, discussed by Draper and Smith (1966), was used to determine the plant characteristics that were most clearly related to the wear tolerance observed.

Results and Discussion

Comparison of Cell Wall Constituents for Species. The total cell wall content (TCW) expressed as mg per dm^2 are indicated in Table III.1. There were significant differences among species. Total cell wall contents in mg per dm^2 range from 414.8 to 805.6 mg. Kentucky 31 had the largest value per unit area. Manhattan and Merion ranked second. While, Pennlawn, Italian ryegrass, and Cascade ranked in an intermediate grouping. Rough bluegrass had the lowest value. TCW expressed on a weight per unit area basis was preferred to the TCW on a gram dry weight basis as a measure of turfgrass wear tolerance. TCW on a weight per unit area basis was significantly correlated ($r = 0.88$) to turfgrass wear tolerance.

Comparisons of the percent total cell wall (TCW) content on a gram dry weight basis for seven cool-season turfgrass species, during the first 10 weeks after seedling emergence are given in Table III.2. Significant differences in percent TCW were found among species. Percent TCW ranged as high as 52.5% and as low as 40.4% in the tenth week after seedling emergence. Sullivan (1969) reported that TCW constituents composed 40-80% of the dry matter of forages with the higher percentages found in the grasses and the lower in legumes. The percent TCW in this study fell primarily in the lower portion of this expected range due to the fact that the tissues samples were relatively young. Sullivan (1969) also reported that the higher TCW percentages are common in mature forages. A trend of increasing percent TCW with increasing seedling maturity was noted among the species tested with the exception of Italian ryegrass and Merion Kentucky bluegrass. Italian ryegrass leveled off, during weeks 8 and 10. Merion Kentucky bluegrass showed a trend of increasing TCW content through week eight and then a significant drop in week 10. No causative effect was found to explain the decline for Merion. The percent TCW on a gram dry weight basis was not correlated ($r = 0.33$) to wear tolerance. Multiple correlation and regression analysis of TCW and the other cell wall constituents studied on a dry weight basis with wear tolerance will be discussed in a later section of this paper.

The cellulose contents expressed on a mg per dm^2 basis are given in Table III.1. Significant differences in cellulose content per unit area were noted among species. Values ranged from 393.9 mg for Kentucky 31 tall fescue to 208.7 mg for rough bluebrass. Kentucky 31 had the greatest content. Manhattan and Merion ranked second. While Cascade, Pennlawn, and Italian ryegrass were intermediate to low in ranking. Rough bluegrass had the lowest cellulose content. Cellulose content expressed on a per unit area was significantly (r = 0.85) associated with the observed wear tolerance reported by Shearman and Beard (1973) in an earlier paper.

Table III.3 compares the percent cellulose content on a gram dry weight basis of seven cool-season species and the effect of turfgrass maturity on cellulose content. Significant differences were found between species and within a species across harvest dates. Cellulose contents on a gram dry weight basis ranged from 26.9% for Cascade to 18.5% for rough bluegrass in the tenth week. Rough bluegrass was the only species that had a slight decline in cellulose content through the tenth week after seedling emergence. However, four species did level-off during the eighth and tenth weeks. The percent cellulose content did not correlate (r = 0.27) with the wear tolerance of the species. The relationship of cellulose and the other cell wall constituents to wear tolerance will be discussed later.

Fahn (1967) reported cellulose to be the largest component of the cell wall constituents. This was the case for all the species in this study. Armstrong, Cook, and Thomas (1950) reported cellulose contents to be higher in grasses than legumes. They also reported an increase in cellulose content with maturity of the forage. Sullivan (1969) found that cellulose may range from 20 to 40% of the dry weight of forages. Kentucky bluegrass was reported by Phillips et al. (1954) to increase from 22% to 30%, during progression from the vegetative stage to the time of flowering. Sullivan (1956) reported an average cellulose content of 23% for Kentucky bluegrass grown as a forage grass and cut successively over the summer. The cellulose content of tall fescue was reported by Patton (1943) to be 18.5% for immature plants and 46.8% for mature, dry plants.

The percent hemicellulose content expressed on a gram dry weight basis was the most variable cell wall constituent of those examined for both comparisons among species and within species across harvest dates (Table III.4). The variability noted was most likely due to the procedure for determining hemicellulose. Hemicellulose is determined indirectly as the difference between the total cell wall content and the lignocellulose complex. The percent hemicellulose values for this study varied from 21.5% to 17.5%. The wear tolerance of the species tested was not associated with the percent hemicellulose. The hemicellulose content expressed on a unit area basis was less variable than the gram dry weight basis (Table III.1) and was significantly correlated ($r = 0.88$) to wear tolerance. Kentucky 31 and Merion had the greatest hemicellulose content followed closely by Manhattan. Italian ryegrass and Pennlawn red fescue were intermediate, while Cascade and rough bluegrass had the lowest contents of the species studied. Fahn (1967) reported hemicellulose to be the second largest cell wall component. This was the case for the species tested in this study. Sullivan (1969) found that hemicellulose contents ranged from 12 to 20% on a dry weight basis with higher percentages common for grasses and lower for legumes. The results of this study agreed with Sullivan's findings.

The lignin content of the seven cool-season species studied was expressed on a weight per unit area basis (Table III.1). There were significant differences among species. Kentucky 31 tall fescue had the greatest quantity of lignin per unit area with 97.7 mg dm^{-2}. Rough bluegrass was the lowest with 30.3 mg dm^{-2}. The lignin values obtained on the weight per unit area basis more closely agreed to the wear tolerance observed than those determinations based on a gram per dry weight basis. Lignin was significantly correlated ($r = 0.76$) to wear tolerance at the 10% level but not the 5%.

The lignin contents expressed as a percentage on a dry weight basis are indicated in Table III.5. There were significant differences in lignin content between species. Cascade chewings fescue had the highest lignin content with 6.2% and rough bluegrass had the lowest with 2.6%. Bonner and Varner reported that lignin is a major component of woody plants with values ranging from 22-34% on a dry weight basis. Sullivan (1969) reported lignin to be the least abundant of the cell wall constituents. The lignin content in leaves, stems, and heads of orchardgrass (<u>Dactylis glomerata</u> L.), bromegrass

(<u>Bromus inermis</u> Leyss.) and wheatgrass (<u>Agropyron</u> spp.) reported by Soluski, Patterson, and Law (1960) were 5.3, 7.8, and 8.9%, respectively. Phillips et al. (1954) reported the percentage of lignin in Kentucky bluegrass ranged from 3.4% to 7.1% as the plants matured. Patton (1943) reported lignin in tall fescue to increase from 4 to 20% as the plant matured under forage conditions. A composite sample of Kentucky bluegrass, red fescue, and colonial bentgrass was reported by Ledeboer and Skogley (1967) to have a lignin content of 14.8%. Van Soest (1964) questioned the validity of large lignin values due to the possibility of heat damage and the potential for reporting heat artifacts rather than true lignin values. He found that lignin values could be increased as much as three times for plant tissues dried between 80-100 C compared to those dried at 50 C or lower. Lignin values in this study agree with those reported by individuals previously cited, working with forage grasses. Wear tolerance of the species studied was not correlated (r = 0.23) to the lignin content expressed on a dry weight basis.

<u>Comparison of Cell Wall Constituents for Leaf vs. Sheath</u>. Comparisons of percent total cell wall (TCW), lignocellulose (ADF), cellulose, hemicellulose, and lignin contents of leaf blades and leaf sheaths of seven cool-season turfgrass species are shown in Table III.6. Leaf blades consistently had lower levels of the various cell

wall constituents than did the leaf sheaths. The relative rankings of the species within blade and sheath determinations were the same. Martin (1970) reported similar results comparing cell wall constituents of leaf, sheath, and root for Kentucky bluegrass, and red fescue. However, he reported no difference between leaf blades and leaf sheaths TCW for creeping bentgrass (Agrostis palustris, Huds.). He also reported hemicellulose to exceed cellulose in the blades and sheaths of creeping bentgrass and Kentucky bluegrass, but not for red fescue. This was not the case in this investigation. There was not a good association between cell wall constituents and wear tolerance of the species tested for either leaf blade or sheath tissues when expressed on the gram dry weight basis.

Variations in Total Cell Wall Content over a Growing Season. The total cell wall contents of seven cool-season turfgrass species were compared during four months within a growing season under field conditions (Table III.7). Significant differences in percent TCW on a gram dry weight basis were noted among species within harvest dates. The trends in terms of relative ranking of species were consistent across harvest dates. Cascade chewings fescue consistently ranked highest in percent TCW and rough bluegrass ranked the lowest. There were significant differences within species across harvest dates. The general trend for the species was to increase in percent

TCW during the months of July, August, and September and then decrease in October. The decrease in October cannot be readily explained. Perhaps the decline in TCW was due to hardening-off and decrease in moisture content of the turfgrass tissues during this period. Barth, McLaren, and Lane (1972) reported on monthly changes in cell wall constituents for grass-legume forage mixtures. They noted no differences among months for either orchardgrass-clover or tall fescue-lespedeza mixtures. However, they did note differences in lignin content for both mixtures, with orchardgrass-clover increasing from 4.8 to 5.9% during the period of May to August, and fescue-lespedeza increasing from 3.7 to 5.2% during May to August. They also reported a decline in the acid-detergent fiber (lignocellulose) and lignin contents during September, indicating similar trends to those found in this study.

Multiple Correlation and Regression Analysis of Cell Wall Constituents to Wear Tolerance. A stepwise least squares program was used to estimate the best relationship between wear tolerance (dependent variable) and the cell wall constituents (independent variables). The total cell wall content (TCW) expressed on a mg per dm^2 basis accounted for 78% of the variation in observed wear tolerance among the species studied. The coefficient of determination with all five variables present accounted for 97% of the variation. Procedures for determining all five variables involved more procedural steps and calculations than simply determining TCW on a mg per dm^2 basis. Therefore, TCW expressed on a mg per dm^2 basis would be a potential tool for selecting wear tolerance differentials among cultivars. Total cell wall constituents on a gram dry weight basis could also be used as a selection tool. However, determination of TCW, lignocellulose, cellulose, and lignin would be necessary to give the best relationship between cell wall constituents and turfgrass wear tolerance.

The objective of this investigation was to determine the importance of various physiological characteristics of turfgrass plants that contribute to wear tolerance. Emphasis was placed on determining criteria upon which turfgrass wear tolerance could be based. Cell wall constituents based on a mg per dm^2 basis gave the best relationship to wear tolerance. TCW content expressed as mg per dm^2 accounted for 78% of the variation in observed wear tolerance. Percent total cell wall, lignocellulose, cellulose, hemicellulose, and lignin on a gram dry weight basis were not correlated to wear tolerance on an individual basis. These cell wall constituents expressed on the weight per unit area basis were correlated. However, the combined relationship of percent TCW, lignocellulose, cellulose and lignin were significantly related. The relative ranking of cell wall constituents among species was quite consistent across harvest dates as the species developed into mature turfs.

The results of this investigation indicated that the best criteria based on the relationship between cell wall components and turfgrass wear tolerance was the combined effects of all cell wall components expressed on a mg per dm^2 basis. The combined relationship of TCW, lignocellulose, cellulose, and lignin reported on percent dry weight basis was the next best criteria. However, TCW expressed as mg dm^{-2} accounted for a significant portion of the observed variation in turfgrass wear tolerance. TCW would be the preferred method for utilization. It is a more simple and rapid determination, involving fewer procedural steps and calculations than the others discussed. A rapid procedure of this nature is essential for efficiently screening large numbers of selections or cultivars in turfgrass breeding programs.

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TABLE III.1.--A comparison of total cell wall (TCW), lignocellulose (ADF), cellulose, hemicellulose, and lignin content based on mg dm^{-2} for seven cool-season turfgrass species grown in a controlled environment chamber.

Turfgrass species	TCW	ADF	Cellulose	Hemi-cellulose	Lignin
Manhattan perennial ryegrass	726.1 b*	421.3 b	350.5 b	304.9 b	68.4 b
Merion Kentucky bluegrass	739.4 b	418.7 b	351.5 b	320.6 a	68.9 b
Kentucky 31 tall fescue	805.6 a	489.6 a	393.9 a	316.0 ab	97.7 a
Italian ryegrass	499.5 cd	301.2 d	239.6 d	198.3 c	62.8 c
Pennlawn red fescue	506.7 c	303.7 d	249.7 cd	210.7 c	60.9 c
Cascade chewings fescue	482.0 d	322.2 c	257.5 c	177.2 d	61.1 c
Rough bluegrass	414.8 e	238.6 e	208.7 e	176.2 d	30.3 d

*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 4 replications.

TABLE III.2.--Comparison of percent total cell wall content of seven cool-season turfgrass species, during the first 10 weeks after seedling emergence.

Turfgrass species	Percent total cell wall content			
	week 4	week 6	week 8	week 10
Cascade chewings fescue	48.48 b*z**	49.62 ay	50.72 ax	52.55 aw
Pennlawn red fescue	49.76 axy	49.01 ay	50.01 abx	51.10 bw
Kentucky 31 tall fescue	46.42 cz	47.62 by	49.50 bx	50.46 bw
Manhattan perennial ryegrass	43.22 dy	45.13 cx	45.25 dx	48.38 cw
Merion Kentucky bluegrass	26.08 gz	38.22 ey	46.53 cw	44.72 ex
Italian ryegrass	39.97 ey	41.63 dx	45.42 dw	46.18 dw
Rough bluegrass	34.96 fz	37.73 ey	38.34 exy	40.36 fw

*Values with the same letter (a, b, c . . . f) in a column are not significantly different at the 5% level, using Duncan's Multiple Range Test. Values are averages of 4 replications.

**Values with the same letter (w, x, y, z) across dates are not significantly different at the 5% level, using Duncan's Multiple Range Test.

TABLE III.3.--Comparison of percent cellulose content of seven cool-season turfgrass species, during the first 10 weeks after seedling emergence.

Turfgrass species	Percent cellulose content			
	week 4	week 6	week 8	week 10
Cascade chewings fescue	26.20 a*xy**	25.94 ay	26.23 awx	26.86 aw
Pennlawn red fescue	23.47 bx	24.34 bw	24.97 bw	24.74 bw
Kentucky 31 tall fescue	23.36 bx	24.12 bw	24.27 cw	24.52 bw
Manhattan perennial ryegrass	22.34 cx	22.82 cwx	23.07 dw	23.02 cw
Merion Kentucky bluegrass	17.26 fz	18.25 ey	22.34 ex	24.22 bw
Italian ryegrass	20.44 dy	22.01 cx	22.04 ex	22.84 cw
Rough bluegrass	18.45 ex	19.16 dw	19.41 fw	18.48 dx

*Values with the same letter (a, b, c . . . f) in a column are not significantly different at the 5% level, using Duncan's Multiple Range Test. Values are averages of 4 replications.

**Values with the same letter (w, x, y, z) across dates are not significantly different at the 5% level, using Duncan's Multiple Range Test.

TABLE III.4.--A comparison of percent hemicellulose content of seven cool-season turfgrass species, during the first 10 weeks after seedling emergence.

Turfgrass species	Percent hemicellulose content			
	week 4	week 6	week 8	week 10
Cascade chewings fescue	20.56 a*w**	20.64 aw	18.27 cy	19.95 bx
Pennlawn red fescue	18.98 bx	18.52 cx	18.95 bx	21.54 aw
Kentucky 31 tall fescue	19.36 bx	19.18 bx	19.19 bx	21.05 aw
Manhattan perennial ryegrass	17.53 cy	18.81 bcx	17.80 cdy	21.48 aw
Marion Kentucky bluegrass	17.44 cx	17.54 dx	19.84 aw	17.45 ex
Italian ryegrass	16.72 dy	15.76 ez	17.53 dx	19.26 cw
Rough bluegrass	14.19 ey	16.25 ex	16.12 ex	19.41 bcw

*Values with the same letter (a, b, c . . . e) in a column are not significantly different at the 5% level, using Duncan's Multiple Range Test. Values are averages of 4 replications.

**Values with the same letter (w, x, y, z) across dates are not significantly different at the 5% level, using Duncan's Multiple Range Test.

TABLE III.5.--A comparison of percent lignin content of seven cool-season turfgrass species, during the first 10 weeks after seedling emergence.

Turfgrass species	Percent lignin content			
	week 4	week 6	week 8	week 10
Cascade chewings fescue	4.62 a*y**	4.64 ay	5.74 ax	6.22 aw
Pennlawn red fescue	4.67 ay	4.54 ay	5.48 bx	6.15 aw
Kentucky 31 tall fescue	3.79 bz	4.32 by	4.89 cx	6.05 aw
Manhattan perennial ryegrass	3.35 cy	3.50 cy	3.87 dx	4.37 cw
Merion Kentucky bluegrass	2.38 ey	2.42 ey	3.05 ex	4.33 cw
Italian ryegrass	2.81 dy	2.85 dy	4.08 dx	5.85 bw
Rough bluegrass	2.33 ex	2.31 ex	2.47 fwx	2.63 dw

*Values with the same letter (a, b, c, . . . f) in a column are not significantly different at the 5% level, using Duncan's Multiple Range Test. Values are averages of 4 replications.

**Values with the same letter (w, x, y, z) across dates are not significantly different at the 5% level, using Duncan's Multiple Range Test.

TABLE III.6.--A comparison of cell wall constituents of leaf blade and leaf sheath for seven cool-season turfgrass species grown for 3 months in a controlled environmental chamber.

Turfgrass species	% Total cell wall		% Lignocellulose		% Cellulose		% Hemicellulose		% Lignin	
	Leaf	Sheath	Leaf	Sheath	Leaf	Sheath	Leaf	Sheath	Leaf	Sheath
Cascade chewings fescue	50.72 a*	64.79 a	32.46 a	45.8 a	26.23 a	35.14 a	18.27 bc	18.94 c	6.22 a	10.71 a
Pennlawn red fescue	50.01 a	65.67 a	31.12 b	42.85 b	24.97 b	32.35 bc	18.95 ab	22.48 b	6.15 a	10.50 a
Kentucky 31 tall fescue	49.50 a	58.62 b	30.32 c	41.90 c	24.27 c	32.49 b	19.19 ab	16.72 e	6.05 ab	9.41 b
Manhattan perennial ryegrass	45.25 c	55.32 c	27.45 d	38.94 e	23.07 d	30.74 e	17.80 c	16.38 e	4.37 c	8.20 c
Merion Kentucky bluegrass	46.53 b	55.75 c	26.68 e	39.56 de	22.34 e	31.74 cd	19.84 a	16.21 e	4.33 c	7.83 d
Italian ryegrass	45.42 bc	57.77 b	27.89 d	39.83 d	22.04 e	31.64 d	17.53 c	17.94 d	5.85 b	8.19 c
Rough bluegrass	38.34 d	51.67 d	22.23 f	27.91 f	19.41 f	21.58 f	16.12 d	23.76 a	2.63 d	6.33 e
LSD .05 =**	1.38		0.613		0.617		0.757		0.275	

*Values in columns with the same letter are not significantly different at the 5% level, using Duncan's Multiple Range Test. Values are averages of 4 replications.

**LSD values for comparisons between column values only.

TABLE III.7.--Determination of changes in total cell wall content (TCW) for seven cool-season turfgrass species during four months of the growing season (field study).

Turfgrass species	Percent TCW (dry weight basis)			
	July	August	September	October
Cascade chewings fescue	48.43 ab*z**	57.58 aw	52.55 ax	50.59 ay
Pennlawn red fescue	47.96 bz	55.39 bw	51.11 abx	49.97 axy
Kentucky 31 tall fescue	49.76 aw	50.31 cw	50.80 bw	45.80 bx
Manhattan perennial ryegrass	47.49 bcw	48.46 dw	48.71 cw	45.13 bx
Merion Kentucky bluegrass	42.77 ey	45.47 fx	48.05 cdw	41.97 cy
Italian ryegrass	45.37 dwx	46.74 ew	44.57 ex	39.08 dy
Rough bluegrass	39.87 fx	45.34 fw	40.69 fx	36.55 ey

*Values in columns with the same letter (a, b, c, . . . f) are not significantly different at the 5% level, using Duncan's Multiple Range Test. Values are averages for 4 replications.

**Values across harvest dates with the same letter (w, x, y, z) are not significantly different at the 5% level, using Duncan's Multiple Range Test.