CHAPTER IV

PHYSIOLOGICAL, MORPHOLOGICAL, AND ANATOMICAL CHARACTERISTICS ASSOCIATED WITH TURFGRASS WEAR TOLERANCE

Abstract

This investigation was conducted to assess the relationship of various turfgrass physiological, morphological, and anatomical characteristics to wear tolerance. Comparisons were made among seven cool-season turfgrass species. No significant correlations between verdure, shoot density, leaf width, load bearing capacity, leaf tensile strength, percent moisture, or percent relative turgidity and species wear tolerance were noted, although significant differences in these factors were noted among species. An analysis of the combined relationship of these factors to wear tolerance indicated that leaf tensile strength and leaf width contributed significantly to the variation in turfgrass wear tolerance for the seven species studied.

Sclerenchyma tissues of Kentucky 31 tall fescue composed 18.6% of leaves and 23.4% of stems based on a percent of the total

cross-sectional area of leaf blades and stems. The contents for rough bluegrass were 8.9% and 10.3%, respectively. The percent of lignified cells of Kentucky 31 tall fescue were estimated as 49.8% based on total leaf cross-sectional area, while the estimate for rough bluegrass was 21.4%. Rough bluegrass showed very little affinity in the epidermal cells for the safranin stain indicating lignified cells compared to Kentucky 31 tall fescue. The percent sclerenchyma fibers and lignified cells were closely associated to the wear tolerance observed for the two species.

Introduction

Various physiological, morphological, and anatomical turfgrass characteristics have been proposed as factors contributing to turfgrass wear tolerance. Beard (1973) reported in a review of pertinent literature that turfgrass wear tolerance was influenced by (a) degree of tissue hydration, (b) quantity and location of sclerenchyma fibers, (c) lignin content, (d) coarseness of leaves and stems, and (e) shoot density. Most of these associations are based on field observations by various workers and not quantitative measurements.

Youngner (1962) found that cutting height affected turfgrass wear tolerance. He reported that turfs mowed at 1.3 cm for three years and then returned to 3.8 cm for 4 weeks prior to wear treatment had a significantly reduced wear tolerance compared to turfs maintained at 5.0 cm. The conclusion was that close mowing restricted the turfs ability to resist wear by affecting the development of the turfgrass plant.

The relative importance of cell wall constituents, influencing turfgrass wear tolerance was reported by Shearman and Beard (1973). Esau (1965) discussed the importance of sclerenchyma fibers as mechanical protectants for plants. Sclerenchyma fibers enable plants to withstand pressure from bending, stretching, and weight without undue damage to soft, thin-walled cells of the plant. Gramineae have sclerenchyma fibers that form prominent sheaths around the vascular bundles and the epidermis. Esau (1965) also reported the importance of lignin to plant structural strength and indicated that the lignification of leaf epidermal cells of grasses is common. The characteristics of these plant tissues leads one to conclude that they would be associated with wear tolerance in turfgrasses.

This investigation was conducted to determine the effect of various turfgrass morphological and anatomical characteristics on wear tolerance. The influence of verdure, shoot density, leaf width, load bearing capacity, leaf tensile strength, percent moisture, and percent relative turgidity were studied. Comparisons of percent sclerenchyma tissues and percent lignified cells were also related to turfgrass wear tolerance.

Materials and Methods

Plant materials for this investigation were grown under the same conditions and with the same cultural practices as those outlined previously by Shearman and Beard (1973). Seven cool-season turfgrass species were studied: a) Cascade chewings fescue (*Festuca rubra* var. *commutata* Gaud.), b) Pennlawn red fescue (*F. rubra* L.), c) Kentucky 31 tall fescue (*F. arundinacea* Schreb.), d) Manhattan perennial ryegrass (*Lolium perenne* L.), e) Italian ryegrass (*L. multiflorum* L.), f) Merion Kentucky bluegrass (*Poa pratensis* L.), and g) rough bluegrass (*P. trivialis* L.). The pots were seeded at a rate of 15 seeds per 6.25 cm^2. Seeding rates were adjusted according to percent viable seed based on percent germination and purity.

Verdure and Shoot Density. Webster defined verdure as the greenness of growing vegetation. The verdure in this study was measured utilizing the methods described by Madison (1962). The turfs were mowed at 5.0 cm with the clippings being removed immediately before sampling for verdure determinations. Four, 10 cm diameter pots of turf were sampled from each species studied. The living green plant tissues were harvested, including leaves, stems, and stolons. Verdure was expressed as grams fresh weight per dm^2. Shoot densities were determined by counting the number of shoots per pot and converting to numbers per dm^2. The treatments for verdure and shoot density determinations were replicated 4 times.

Load Bearing Capacity (LBC). A device was developed to determine the load bearing capacity of turf (Figure IV.1). It was constructed from a 10.5 x 25.0 cm plexiglass cylinder. A platform was designed (Figure IV.1A) to fit within the cylinder. The platform rested on the turf and was constructed to hold American standard, number-eight, lead shot. The lead shot was allowed to flow through a funnel with a 1.3 cm opening and onto the platform from a height of 20 cm until it was weighted and lowered to a predetermined point (Figure IV.1B). The weight necessary to reach this point was recorded in grams and reported as the LBC of the turf. The LBC of each of the seven cool-season turfgrass species studied was recorded. Determination of LBC was based on the average value of four replications.

Leaf Blade Tensile Strength. Leaf blade tensile strength was studied with procedures similar to those reported by Salmon (1931) and Coorts et al. (1970). A triple beam balance was modified so that leaf blades could be anchored to the base of the scale and the balance arm. A beaker was placed on the balance platform and number-eight lead shot was allowed to flow into the beaker from the funnel device with a shut-off valve described in the LBC study. The shot fell from a height of 20 cm into the beaker until sufficient weight was obtained to reach the breaking point of the leaves. Preliminary experiments indicated that leaf tensile strength was affected by leaf size and maturity. Therefore, leaves were selected from a size range of 1 to 2 mm and only the youngest, most-fully expanded leaves were chosen for testing. The leaf tensile strength was based on an average value for three leaves per determination and eight replications per treatment.

Percent Moisture and Relative Turgidity. Percent moisture of leaf blades and stems were determined on a wet weight basis for the seven cool-season turfgrass species studied. Relative turgidity measurements were made by procedures similar to those outlined by Weatherly (1950), and Namken and Lemon (1960). In this study 0.5 cm leaf sections were cut from the midportion of the youngest, most-fully expanded leaf. Seventy-five sections were cut and weighed for each determination, allowed to float for 4 hrs on distilled water, excess moisture removed by blotting with paper toweling, and weighed to determine the turgid weight. They were then oven dried to determine the dry weight. The percent relative turgidity was calculated as follows:

$$\% \text{ R. T.} = \frac{\text{fresh wt.} - \text{dry wt.}}{\text{turgid wt.} - \text{dry wt.}} \times 100$$

Anatomical Procedures. Leaf blade and stem cross-sections of Kentucky 31 tall fescue and rough bluegrass were prepared for anatomical studies. A microtome developed by Hooker (1967) for sectioning fresh plant tissues was used. The Hooker microtome was developed to section living tissues quickly and without extensive preparation. Thinness of cross-sections obtained with this procedure is limited only to the inherent ability of the plant tissues to hold together after cutting. Support for tissues was provided by placing the material on a thin slice of carrot during sectioning. The tissue sections were in the thickness range of 20 to 24 μ. Sections were fixed in an FAA (ethyl alcohol, glacial acetic acid, formaldehyde and water) solution and stained with safranin-fast green, according to procedures outlined by Sass (1966).

Kentucky 31 tall fescue and rough bluegrass were selected for study as representatives of wear tolerant and intolerant species, respectively. The combined areas of vascular bundles per total cross-sectional area of leaf and stem were calculated. Areas were determined from line drawings traced from photomicrographs of tissue sections by weighing the corresponding areas and relating them to the total cross-sectional area. Schank, Klock, and Moore (1973) used a similar procedure to study the relationship of forage digestibility to the combined areas of vascular bundles in leaf sheaths of the species studied. The percentages were determined by dividing the cross-sectional area of vascular bundles by that of the total cross-sectional area of the leaf or stem and multiplying by 100. The percentage of lignified cells was calculated in the same manner. All sections were examined at 40 X magnification.

Results and Discussion

Comparisons of verdure, leaf width (LW), shoot density, load bearing capacity (LBC), and leaf tensile strength (LTS) are shown in Table IV.1. Significant differences in verdure were noted among species. Rough bluegrass had the greatest verdure of the seven species studied. Kentucky 31 tall fescue and Merion Kentucky bluegrass ranked second. Manhattan perennial ryegrass was third. Italian ryegrass, Pennlawn red fescue, and Cascade chewings fescue ranked intermediate to low. Verdure was not correlated ($r = 0.14$) to wear tolerance. The species varied significantly in leaf width. Italian and Kentucky 31 had the coarsest textured leaves of the species tested. Manhattan, Merion, and rough bluegrass were intermediate in texture. Pennlawn and Cascade had the finest texture. Leaf width was not correlated ($r = 0.40$) to turfgrass wear tolerance. Shoot density was not associated ($r = -0.64$) with wear tolerance among the species studied. Rough bluegrass had the greatest shoot density and Italian ryegrass had the least. Species varied significantly in load bearing capacities. Kentucky 31 had the greatest LBC among the species. LBC was not correlated ($r = 0.69$) to species wear tolerance. Leaf tensile strength differences were also noted among species. Kentucky 31 and Italian ryegrass had the largest LTS among the species. Manhattan and Merion were second. Rough bluegrass was intermediate, while Pennlawn and Cascade ranked the lowest. LTS was significantly correlated ($r = 0.73$) at the 10% level.

The combined effects of LTS and LW accounted for 97% of the observed variation in turfgrass wear tolerance for the species examined. Beard (1973) reported that wear tolerance was related to coarseness of leaves and stems. These results indicated that the leaf coarseness was not simply related to wear tolerance. Esau (1965) indicated that tensile strength was a notable characteristic of mechanical cells of monocots, particularly those of extra-xylary fibers. This relationship between structural strength and tensile strength could result in the subsequent importance of this factor in contributing to the observed species wear tolerance.

Comparisons of percent moisture content for leaf blades and stems of the seven species studied are shown in Table IV.2. The species did vary significantly in moisture content. Leaf blades of all species had greater moisture contents than stems. Although the percent moisture contents varied significantly among species for leaves and stems, there was no significant correlation ($r = -0.51$, and $r = -0.26$) to wear for percent moisture of either leaves or stems. The same trend was true for relative turgidity measurements and wear tolerance among the species examined (Table IV.2). The species were bunched in two groups according to their percent relative turgidity measurements. Pennlawn red fescue, Manhattan perennial ryegrass, and Cascade chewings fescue had the greatest percent relative turgidities. While Merion Kentucky bluegrass, Italian ryegrass, and rough bluegrass ranked in a significantly lower group. Kentucky 31 was in between both groups. There was no correlation ($r = 0.25$) between percent relative turgidity and wear tolerance. The coefficients of determination did not account for a significant degree of the observed variation in species wear tolerance.

Anatomical studies were conducted on Kentucky 31 tall fescue and rough bluegrass. The cross-sectional area of vascular bundles, sclerenchyma tissues and lignified cells were compared to the total cross-sectional area for stems and leaves. The comparisons were expressed as a percent of the total cross-sectional area. Vascular bundles of leaves of Kentucky 31 tall fescue comprised 10.6% of its cross-sectional area, and 8.4% of rough bluegrass (Figures IV.2 and IV.3). Leaves of Kentucky 31 had 18.6% sclerenchyma tissues and rough bluegrass had 8.9%. The total lignified cells were also estimated for both species. Kentucky 31 tall fescue had 49.8% lignified cells based on total cross-sectional area. Total lignified cells for rough bluegrass were estimated at 21.4%. Sclerenchyma fibers composed 23.4% of the total stem cross-sectional area of Kentucky 31 tall fescue, while rough bluegrass had 10.3%. The epidermal cells of the abaxial and adaxial leaf surfaces of Kentucky 31 were more extensively lignified that those for rough bluegrass (Figures IV.2a and IV.2b). Rough bluegrass showed a very low affinity for safranin stain, indicating low lignin content in tissues. Sclerenchyma fibers were associated extravascularly on the uppermost surface of the veins on the Kentucky 31 tall fescue, contributing to strengthening and stiffness of the leaves. This characteristic was not true for rough bluegrass. The results of these anatomical studies and the wear tolerance studies previously conducted indicated that there was an excellent association between turfgrass wear tolerance and the percent sclerenchyma and lignified tissues. However, more extensive investigations are needed, involving a comparison of a number of species before more representative conclusions can be made among species.

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TABLE IV.1.--Comparisons of original verdure, leaf width (LW), shoot density, load bearing capacity (LBC), and leaf tensile strength (LTS) of seven cool-season turfgrass species grown in controlled environment chamber.

Turfgrass species	Verdure (gm dm^{-2})	LW (mm)	Shoot density (number dm^{-2})	LBC (gm dm^{-2})	LTS (gm $leaf^{-1}$)
Manhattan perennial ryegrass	5.46 c*	2.0 b	234 c	874 b	635 b
Merion Kentucky bluegrass	5.84 b	2.0 b	239 c	687 d	635 b
Kentucky 31 tall fescue	5.98 b	2.6 a	160 d	990 a	722 a
Italian ryegrass	5.12 d	2.9 a	151 e	843 c	696 a
Pennlawn red fescue	4.58 e	1.0 c	317 a	625 e	305 d
Cascade chewings fescue	4.43 e	1.0 c	318 a	636 e	269 e
Rough bluegrass	6.64 a	2.0 b	306 b	635 e	412 c

*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 for 4 replications with the exception of LTS that are averages of 8 replications.

TABLE IV.2.--Comparison of percent moisture content of leaf blades and stems, and percent relative turgidity of leaf tissues for seven cool-season turfgrass species grown in a controlled environment chamber.

Turfgrass species	Percent moisture content		Percent relative turgidity
	Leaves	Stems	
Manhattan perennial ryegrass	76.0 b*	69.2 d	90.3 a
Merion Kentucky bluegrass	75.4 b	70.9 c	87.2 b
Kentucky 31 tall fescue	77.3 b	74.5 b	88.2 ab
Italian ryegrass	83.1 a	77.9 ab	83.8 b
Pennlawn red fescue	76.8 b	68.3 d	93.1 a
Cascade chewings fescue	75.0 b	65.6 d	90.2 a
Rough bluegrass	84.9 a	80.5 a	83.6 b
LSD .05 = 1.54**			

*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.

**LSD for comparison between column values only.

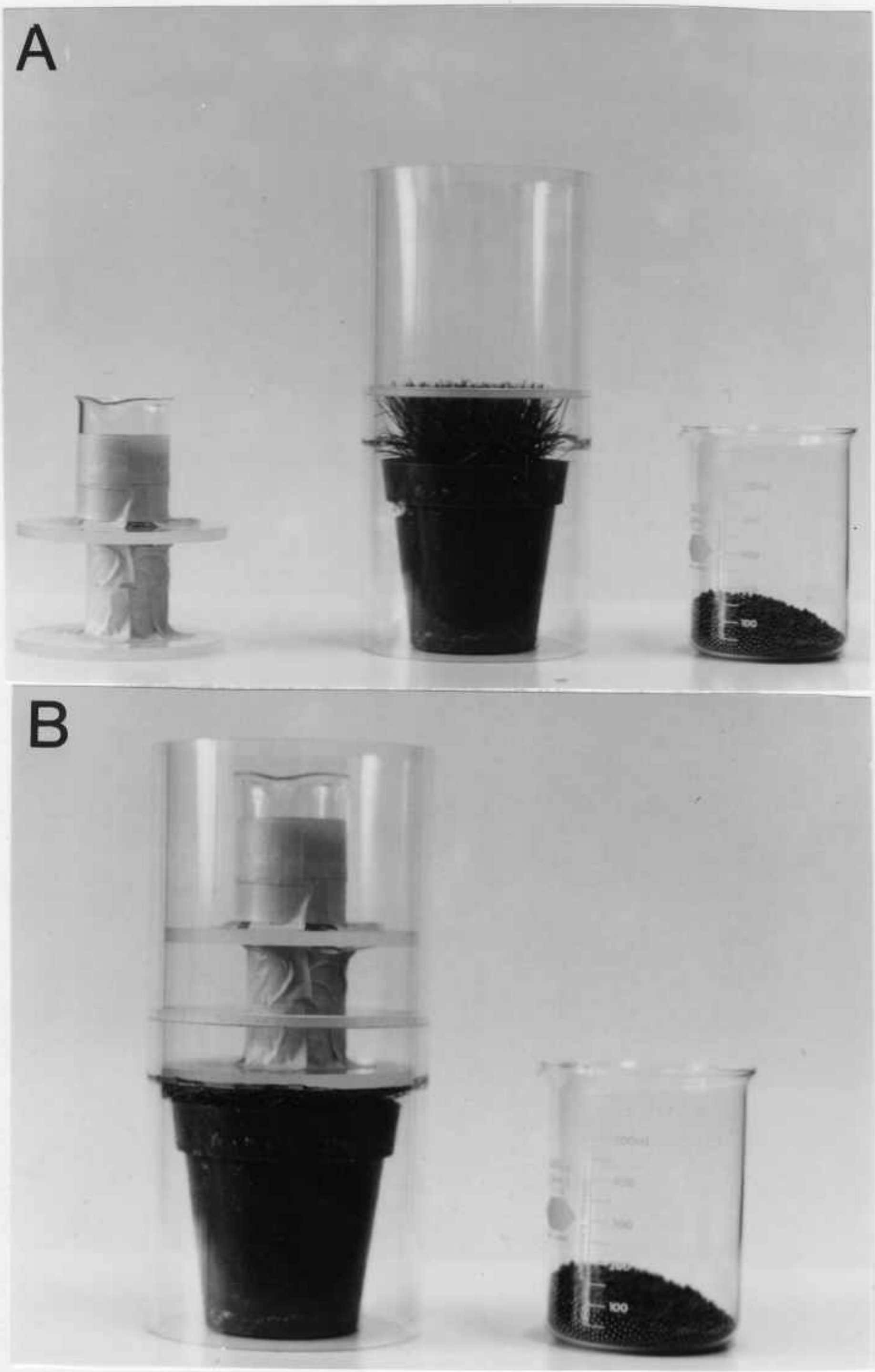

Fig. IV.1.--A device to evaluate the load bearing capacity (LBC) of turfs: (A) shows the platform, plexiglass cylinder, potted turf, and lead weights; (B) Shows the weighted platform resting on the turf at the predetermined endpoint for LBC determinations.

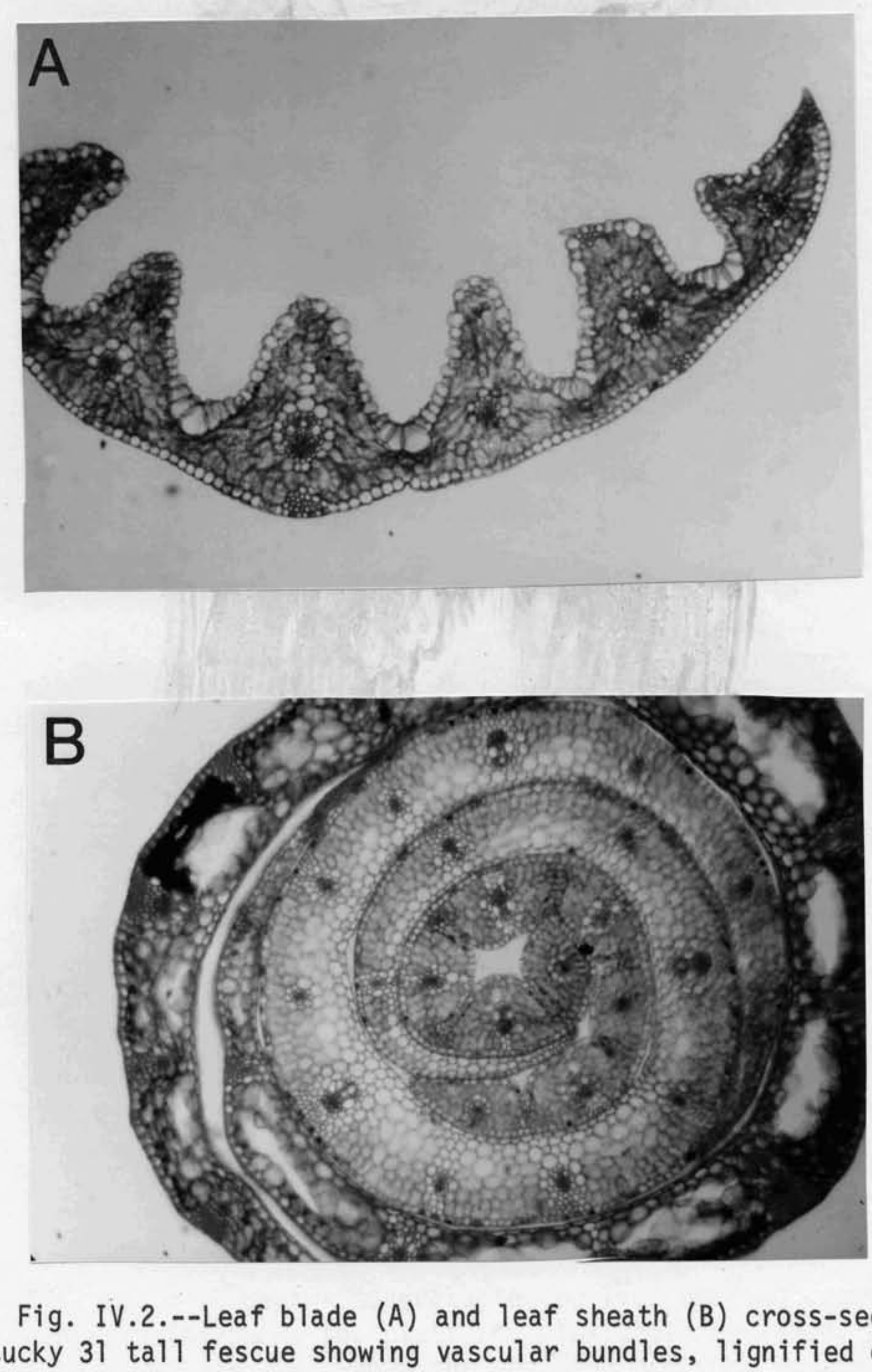

Fig. IV.2.--Leaf blade (A) and leaf sheath (B) cross-sections of Kentucky 31 tall fescue showing vascular bundles, lignified cells, and extravascular sclerenchyma fibers.

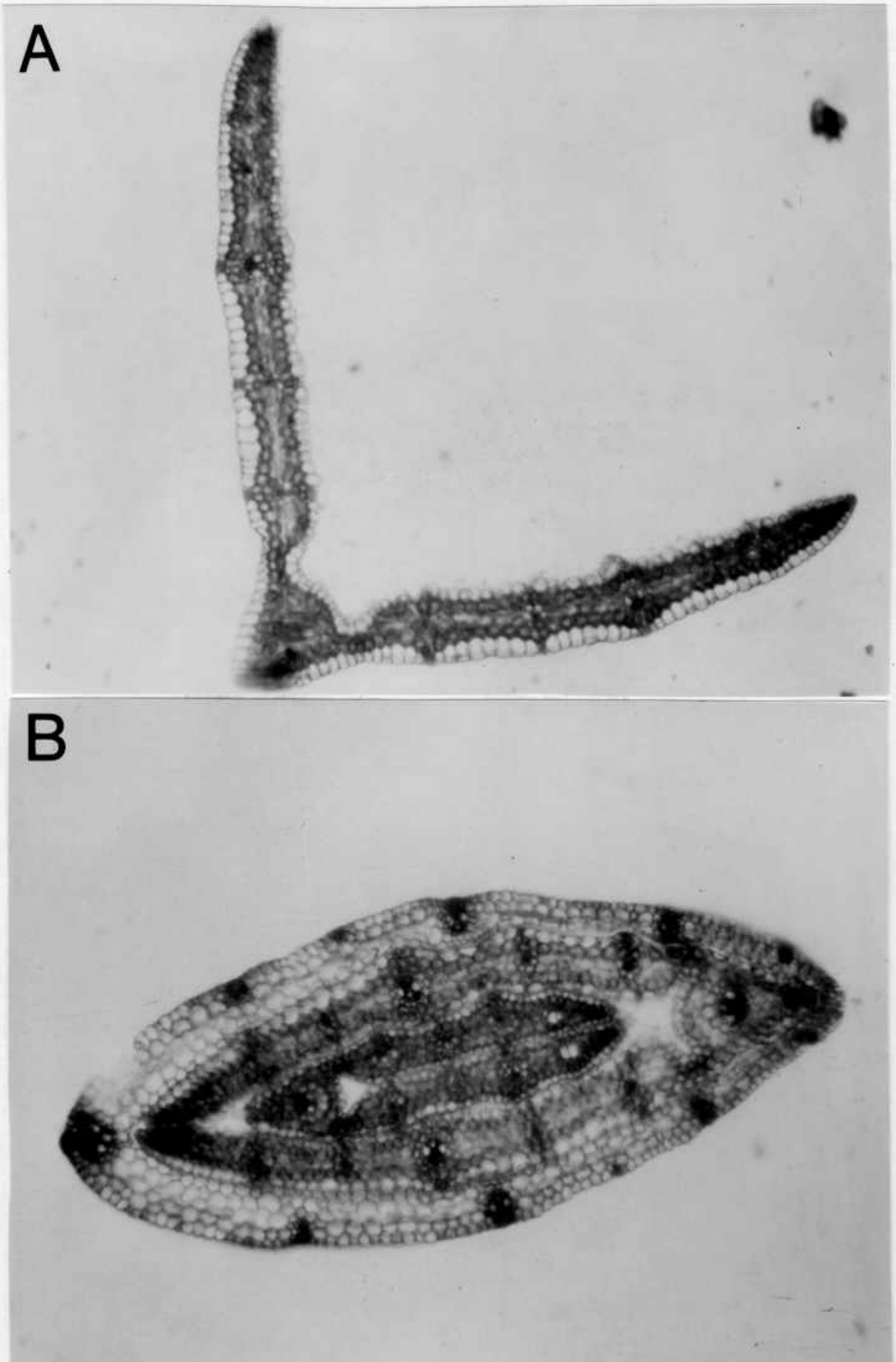

Fig. IV.3.--Leaf blade (A) and leaf sheath (B) cross-sections of rough bluegrass, showing vascular bundles, lignified cells, and extravascular sclerenchyma fibers.