# LEAF TENSILE STRENGTH, "IN VITRO" DIGESTIBILITY, AND FIBER COMPONENT RELATIONSHIPS IN TALL FESCUE[1]

F. BENI DE SOUSA[2], DAVID A. SLEPER, RONALD L. BELYEA, and ARTHUR G. MATCHES[3]

ABSTRACT - In a forage breeding program it is necessary to identify germplasms with high forage quality, able to positively influence animal performance. The interrelationships between leaf tensile strength (LTS) and chemical composition parameters may provide a useful criterion for screening tall fescue (*Festuca arundinacea* Schreb.) for herbage quality in a breeding program. Seventy-one genetically diverse genotypes of tall fescue were randomly selected from a broad-based population to evaluate LTS (leaf tensile strength), *in vitro* dry matter digestibility (IVDMD), acid detergent fiber (ADF), neutral detergent fiber (NDF), cellulose (CELL), lignin (ADL), hemicellulose (HEMI), ADL/ADF and ASH, to determine the associations among these traits with LTS, and the importance of LTS as a technique for screening tall fescue for herbage quality. Significant genetic variation was found in this gene pool for LTS. The majority of the correlations of LTS with IVDMD and with fiber components were not significantly different from zero while correlations of IVDMD with fiber components were highly significant and negative. As expected, character correlation repeatabilities between years were usually low. Path coefficient analysis showed that CELL and ADL were two important components with large direct effects on LTS and on IVDMD.

Index terms: acid detergent fiber, neutral detergent fiber, lignin, cellulose, hemicellulose, ash, path coefficient analysis.

## TENSÃO FOLIAR, DIGESTIBILIDADE "IN VITRO" E INTERRELAÇÕES DOS COMPONENTES DA PAREDE CELULAR EM FESTUCA-ALTA

RESUMO - Em um programa de de melhoramento de forrageiras, a identificação de plantas com elevado valor nutritivo, é um dos fatores importantes para melhorar o desempenho animal. Interrelações significativas entre características físicas e químicas talvez possam ser utilizadas como um critério para a seleção de novas cultivares de festuca-alta de maior valor nutritivo. Os objetivos deste experimento foram: a. avaliar a tensão foliar (TF) e a digestibilidade *in vitro* da matéria seca (DIVMS) e dos constituintes da parede celular; b. analisar as associações entre essas características com a TF e c. determinar a eficiência da TF como uma técnica para a seleção de novos germoplasmas de festuca-alta, com forragem de melhor qualidade. Setenta e um genótipos de festuca alta foram avaliados neste experimento. Foi encontrada uma variabilidade genética significativa para TF nesta população de festuca-alta. Geralmente, as correlações de TF com DIVMS e componentes da parede celular não foram significativas, enquanto que as correlações de DIVMS com os componentes da parede celular foram altamente significativas e negativas. Conforme esperado, houve baixa repetibilidade de correlações de caracteres nos dois anos. A "análise de coeficientes de trilha" demonstrou que a celulose e a lignina foram os caracteres com os maiores efeitos diretos na TF e na DIVMS.

Termos para indexação: fibra detergente ácida, fibra detergente neutra, lignina, celulose, hemicelulose, cinzas, análise de coeficientes de trilha.

## INTRODUCTION

Tall fescue (*Festuca arundianacea* Schreb.) is one of the most grown forage grasses in the United States, with the largest hectarage occurring in the Southern corn belt. Tall fescue has several problems such as low digestibility and high fiber composition especially during the summer and this may be responsible for reduced animal performance during this period. Digestibility and intake are probably the most important components of forage quality. However, several other factors such as fiber composition, leafiness, animal acceptability, leaf tensile strength (LTS) and leaf blade flexibility need to be assessed for their relationship to forage quality and animal performance. In this regard, the interrelationships between LTS and

1 Accepted for publication on August 18, 1982.
Part of a dissertation submitted by the senior author toward partial fulfillment of the M.Sc. Degree, University of Missouri, Columbia-Missouri.

2 Agronomist, M.Sc., Centro de Pesquisa Agropecuária dos Cerrados (CPAC) - EMBRAPA, Caixa Postal 70-0023, CEP 73300 - Planaltina, DF.

3 Associate professor of Agronomy, Associate professor of Animal Science, professor of Agronomy, SEA, USDA, University of Missouri, Columbia, respectively, Mo 65211, USA.

fiber components may be important. It may be possible to use LTS measurements, which are comparatively rapid, simple, accurate, and inexpensive, as a reliable indication of the nutritive value of a forage crop.

Leaf tensile strength is a physical trait which may be related to forage quality and/or animal performance. The earliest studies on LTS of forage grasses as related to palatability were reported by Beaumont et al. (1933). Leaf strength differences of grasses were later related to fiber content by Archibald et al. (1943). They found that animals tended to select plants with lower fiber content and lower breaking strength. Kneebone (1960) reported quantitative measurements of LTS obtained with a tensilgraph in weeping lovegrass (*Eragrostis curvula* (Schrad.) Nees.) and certain other grasses. He found significant differences in LTS among lines of weeping lovegrass, among clones of bermudagrasses (*Cynodon dactylon* Pers.), sideoats grama (*Boutelouna curtipendula* Torr.) and sand bluestem (*Andropogon hallii* Hack). He also pointed out that age or growth stage of individual leaves tested was the principal source of nongenetic variation. Hides (1977) studied herbage quality in two Italian ryegrass (*Lolium multiflorum* Lam.) populations and reported that LTS appeared to be a more sensitive indication of differences in leaf quality than either fibrosity index or dry matter digestibility. Wilson (1965) successfully utilized a high genetic correlation ($r_g = 0.93$) between LTS and cellulose (CELL) content in the backcross of *L. perenne L.* with L. *multiflorum* Lam., x *L. perenne L.* to produce selected lines with high and low CELL content. He also found that differences among plants in both LTS and CELL were maintained from season to season and from one year to the next. Cell wall substances such as cellulose (CELL), hemicellulose (HEMI), lignin (ADL), and silica have been reported by several authors (Kneebone 1960, Evans 1964, 1967a, b; Theron & Booysen 1968a, b; Martens & Booysen 1968, and Wilson 1965) as factors affecting LTS. Leaf tensile strengths of successive leaves on a tiller have been reported by Kneebone (1960) and Evans (1967a). They indicated that LTS was higher at the base and lower at the trip.

On the other hand, Nguyen et al. (1982) studied the inheritance of forage quality and its relationship to LTS in tall fescue. They found that selection would be effective for changing the mean level of LTS, ADF, and NDF in that forage species. Narrow sense heritability estimates for LTS were high and heritability estimates for fiber ranged form medium to high. Correlations between fiber content and IVDMD were low. They suggested that additional plant materials should be collected for the purpose of broadening the genetic base for improving IVDMD in tall fescue.

There are few reports showing the relationship between LTS and animal performance. Evans (1967b) and Wilson (1965) found that sheep performance was negatively associated with leaf cellulose which was positively correlated with LTS in ryegrass. The results were consistent with differences in weight gains in sheep grazing the pastures; higher gains occurred on the pasture with the lowest LTS. Anderson (1976) noticed that a new cultivar of tall fescue 'G 4710', which was selected for low LTS, appeared to be more acceptable to both sheep and cattle, than 'S 170'. Theron & Booysen (1968b) reported that the breaking tension was the most important single factor influencing the preference shown by sheep for ten indigenous grasses. However, Voigt et al. (1970) reported no relationship between palatability and LTS from selecting within the curvula-type of weeping lovegrass (*E. curvula* (Schrad) Nees.). Two of the four most palatable strains were second and third in LTS. They also pointed out that the lower cellulose content in weeping lovegrass was associated with a higher lignin content which resulted in lower animal gains. An intensive review of literature on LTS and palatability was released by Voigt (1975).

The objectives of this experiment were:

a. to evaluate LTS, IVDMD, and fiber composition in a broad-based tall fescue gene pool;

b. to ascertain the associations among these traits with LTS, and

c. to determine the importance of LTS as a technique for screening tall fescue for nutritive quality in a breeding program.

## MATERIAL AND METHODS

Seventy-one genetically diverse genotypes of tall fescue (*Festuca arundinacea* Schreb.) were used to study LTS and its relationship to IVDMD, ADF, NDF, ADL, HEMI, ash and ADL/ADF. The genotypes, grown as single spaced plants were randomly chosen from approximately 3000 plants which had been established in 1974 at the Agronomy Research Center, Columbia, Missouri. This type of random evaluation is common in a forage grass breeding program when making initial selections from a breeding nursery. On 31 August 1979 and 1980 the genotypes were cut a stubble height of 10 cm and 40 kg/ha of nitrogen ($NH_4NO_5$) applied to the experimental area. During September in both years the experimental area was irrigated.

Leaf samples for LTS were taken in 1979 and 1980. In each year the genotypes were sampled twice, once at the "late-boot" stage (May) and once at a vegetative stage (October). After obtaining leaf samples for LTS, the remaining herbage of each genotype was harvested to a stubble height of approximately 5 cm with hand clippers. The herbage was dried at 50°C, ground through a 1 mm screen and analysed for IVDMD, ADF, NDF, CELL, HEMI, ADL, and ash.

Leaf samples for LTS in the first season (May 1979) consisted of 50 randomly selected leaf blades per genotype; 25 were the first fully collared leaf blade and the other 25 were the second fully collared leaf blade below the flag leaf, respectively. For the second season (Fall 1979) and for 1980 (May and October) only 25 leaf blades (first fully collared leaf) per genotype were taken for LTS measurements. Leaf samples for LTS were sampled on the basis of similarity in physiological age (full collared leaves). Leaf samples for LTS consisted of approximately 7 cm lengths of leaf blades taken from the midpoint. The 7 cm leaf blade sections were placed in glass vials that contained water. The glass vials were held in an ice chest while in the field and later were stored at 4°C in a refrigerator.

Leaf breaking load measurements were obtained with a transilmeter, which has a spring tension gauge with a dial indicator, an eletric motor and two clamps. Five cm sections of 25 leaves/genotype were measured for LTS. Leaf tensile strength was calculated according to Evans (1964), as follows:

LTS = Breaking load (g)/dry weight (mg) of a 5 cm leaf section.

*In vitro* dry matter digestibility was determined by the two-stage *in vitro* technique of Tilley & Terry (1963), as modified by Barnes (1967). Acid detergent fiber, NDF, CELL, ADL and ash were determined by procedures outlined by Goering & Soest (1970). Hemicellulose was calculated as NDF minus ADF. The ratio ADL/ADF was estimated since lignin is best expressed as a percentage of ADF according to Goering & Soest (1970).

A completely randomized analysis of variance was used to estimate the variation among and within genotypes. The data for LTS were analyzed a splitplot design in time with genotypes as main plots, and seasons as subplotes, according to Steel & Torrie (1980).

Simple correlation analysis for LTS, IVDMD, ADF, NDF, CELL, ADL, HEMI, and ash were made according to Snedecor & Cochran (1980). A path coefficient analysis (Wright 1921) was performed on the data to estimate cause and effect relationships.

## RESULTS AND DISCUSSION

The range, mean, and standard error of leaf tensile strength (LTS), *in vitro* dry matter digestibility (IVDMD) and fiber composition of 71 tall fescue genotypes at the "late-boot" stage (spring), at regrowth (fall) and combined over years within seasons are shown in Table 1. The data indicated that LTS at the "late-boot" stage was 81% higher than LTS at regrowth. Leaf tensile strength values ranged from 61 to 232 g/mg and from 53 to 127 g/mg for the "late-boot" stage (spring) and regrowth (fall), respectively. Fall LST values were similar to those reported by Nguyen et al. (1982) in some forage species. Although these genotypes had similar leaf anatomy within a season, significant ($p < 0.01$) variation for LTS was found among the genotypes tested. Evans (1964, 1967a) and Theron & Booysen (1968a) found similar results in ryegrass and in ten indigenous grasses, respectively.

*In vitro* dry matter digestibility values ranged from 41.93 to 65.21% and from 51.38 to 72.82% for the spring and fall, respectively. *In vitro* dry matter digestibility averages in the spring (57.02%) were significantly lower than those recorded in the fall (65.13%). Matches (1979), Asay et al. (1975) and Nguyen et al. (1982) reported similar IVDMD values for different tall fescue selections.

Chemical analysis for fiber composition (ADF, NDF, ADL, CELL, HEMI, and ash) were carried out for both years. Acid detergent fiber, NDF, CELL, HEMI, and ADL/ADF values followed a similar trend as LTS over seasons, i.e., high contents in the spring and low in the fall, ash content being slightly higher for the fall. Henderson & Robinson (1980) reported increased concentrations of ADF, NDF, CELL, ADL, and silica with increasing temperatures on coastal

**TABLE 1. Range, mean and standard error of LTS, IVDMD and fiber composition of 71 genotypes of tall fescue composition of 71 genotypes of tall fescue combined over two years.**

| Trait | Statistic | Spring | Fall |
|---|---|---|---|
| LTS 1 | Range | 61 232 | 53 - 127 |
| (g/mg) | Mean | 146.70 ± 3.03 | 81.47 ± 1.38 |
| IVDMD | Range | 41.93 - 65.21 | 51.38 - 72.82 |
| (%) | Mean | 57.02 ± 0.37 | 65.31 ± 0.32 |
| ADF | Range | 32.40 - 50.61 | 21.54 - 34.71 |
| (%) | Mean | 39.71 ± 0.23 | 26.33 ± 0.12 |
| NDF | Range | 57.38 - 79.22 | 40.54 - 61.63 |
| (%) | Mean | 67.80 ± 0.27 | 50.44 ± 0.34 |
| HEMI | Range | 19.40 - 35.07 | 14.92 - 32.31 |
| (%) | Mean | 28.01 ± 0.23 | 24.11 ± 0.33 |
| ADL | Range | 2.48 - 12.61 | 1.35 - 5.85 |
| (%) | Mean | 6.78 - 0.12 | 3.21 ± 0.06 |
| CELL | Range | 22.03 - 38.19 | 17.49 - 24.62 |
| (%) | Mean | 30.79 ± 0.22 | 20.46 ± 0.14 |
| ASH | Range | 0.68 - 4.82 | 1.01 - 5.32 |
| (%) | Mean | 2.31 ± 0.07 | 2.68 ± 0.06 |
| ADL/ADF | Range | 7.32 - 28.19 | 5.61 - 19.16 |
| (%) | Mean | 16.82 ± 0.25 | 12.14 ± 0.20 |

bermuda-grass. They also pointed out that ADF was more sensitive to changes in temperature than NDF. Similar results were found by Stratton et al. (1979) in orchardgrass (*Dactylis glomerata* L.) for ADF and NDF. Matches (1979) reported ADF and NDF spring values lower than the summer values, but higher than fall concentrations in five tall fescue cultivars. Nguyen et al. (1982) also reported similar ADF and NDF concentrations during the fall in tall fescue.

Estimated LTS mean squares for genotypes, seasons, years, and their first and second order interactions are given in Table 2. Significant genotype season year interaction indicated the possible inconsistence of genotype responses in the fall and spring during the two years. Nguyen et al. (1980) reported similar genotype x environment interactions in tall fescue for herbage yield as well as Stratton et al. (1979) for IVDMD and ADF in orchard-grass.

The relationship among the traits under study are important to forage breeders. The correlations between LTS, IVDMD, and fiber components are shown in Table 3. Correlations between LTS and IVDMD were generally low, the highest significant correlation occuring between LTS and IVDMD ($r = 0.28$) for the fall of 1979. Similar poor correlations between those two characters were also reported for tall fescue by Nguyen et al. (1982). On the other hand, there were no significant correlations between ADF, NDF, and CELL and LTS. These results are in disagreement with those obtained by Evans (1964), who reported a significant relationship between the leaf tensile strength and leaf cellulose content of four ryegrass cultivars. However, Theron & Booysen (1968b)

TABLE 2. Estimates of mean squares, and coefficients of variation for $LTS_1$ in the spring ("late-boot" stage) and fall (regrowth) combined over years in tall fescue.

| Source | d.f. | | Mean square |
|---|---|---|---|
| Among genotypes (G) | 70 | | 21053.28 ** |
| Error (a) | 1704 | | 577.55 |
| Season (S) | 1 | | 7554576.11 ** |
| Year (Y) | 1 | | 3808.56 ** |
| S x Y | 1 | | 2108.4 * |
| G x S | 70 | | 16289.48 ** |
| G x Y | 70 | | 11519.23 ** |
| G x S x Y | 70 | | 11429.67 ** |
| Error (b) | 5112 | | 561.23 |
| CV (%) from error (a) | | 21.06 | |
| CV (%) from error (b) | | 20.76 | |

* Significant at the 0.05 and 0.01 level of probability.
** Significant at the 0.01 level of probability.

reached the conclusion that cellulose did not emerge as a determinant factor as did other factors when mature and immature stages of the forage were taken into account. Our experimental data showed low but significant correlations between HEMI, ADL, ash, ADL/ADF and LTS, confirming Theron & Booysen's data (1968b), which indicated that the intensity of lignification was more important than any other factor affecting breaking tension when only the immature herbage was considered.

As expected, correlations between IVDMD and fiber components were all highly significant and negative, in close agreement with those found in tall fescue by Anderson (1980) and Nguyen et al. (1982). Associations between ADF and the other fiber components were highly significant and positive except for HEMI. Correlations between NDF and ADF, NDF and HEMI, NDF and CELL were highly significant and positive. The magnitude of these correlations suggested that effective selection for lower NDF would decrease ADF, HEMI, and CELL. These relationships were expected and are in agreement with the results of Nguyen et al. (1982) in tall fescue, Stratton et al. (1979) in orchardgrass, and Marum et al. (1979) in reed canarygrass (*Phalaris arundinacea* L.). Associations between ADF and IBDMD and between NDF and IVDMD were highly significant and negative. These results suggested that ADF would be the best parameter to predict digestibility of tall fescue herbage.

In general, correlations between chemical characteristics and LTS were usually low, suggesting that there would be little or no adverse effect on LTS after selecting for lower fiber components or higher IVDMD.

Tables 4 and 5 show the results of a path coefficient analysis performed to determine the influence of four characters on LTS and on IVDMD, respectively. Simple correlation and direct and indirect effects are given in Table 4 for four characters on LTS. Significant correlation coefficients were recorded only between ADL, HEMI, ash and LTS. The largest direct effect on LTS was for ADL and it was negative (- 0.50) in the fall of 1979. Other important direct effects on LTS were recorded for CELL (0.34) and ash (0.32). Direct effects in the remainder of Table 4 were small as were all indirect and correlation coefficients. An examination of the correlation components revealed that CELL, ADL, and ash were the three factors that exerted the greatest influence directly upon LTS. Hemicellulose had no direct or indirect effect on LTS. This analysis gave a somewhat different picture than did the simple correlation analysis. For example, the correlation between CELL and LTS, r = 0.88 (fall 1979)

TABLE 3. Simple correlations among LTS, IVDMD and fiber components of tall fescue.

| Trait | Season | IVMD | | ADF | | NDF | | HEMI | | ADL | | CELL | | ASH | | ADL/ADF | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1979 | 1980 | 1979 | 1980 | 1979 | 1980 | 1979 | 1980 | 1979 | 1980 | 1979 | 1980 | 1979 | 1980 | 1979 | 1980 |
| LTS | Spring | -.07 | -.21 | -.08 | .20 | .04 | .17 | .13 | -.02 | .03 | .08 | .01 | .16 | 00 | .12 | .06 | 00 |
| (g/mg) | Fall | .28 ** | .07 | -.09 | .13 | .07 | -.17 | -.01 | -.24 | -.33 ** | -.19 | .08 | .09 | .08 ** | -.33 ** | -.28 ** | -.29 |
| IVDMD | Spring | | | -.44 ** | -.74 ** | -.50 ** | -.60 ** | -.24 ** | -.13 | -.30 ** | -.52 ** | .28 ** | -.56 ** | -.12 | -.03 | -.21 | -.25 * |
| (%) | Fall | | | -.73 ** | -.52 ** | -.62 ** | -.33 ** | -.13 | -.09 | -.53 ** | -.27 ** | -.62 ** | -.46 ** | -.36 ** | -.08 | -.31 ** | -.10 |
| ADF | Spring | | | | | .65 ** | .67 ** | -.08 | -.33 * | .51 ** | .60 ** | .59 ** | .81 ** | -.05 | -.02 | .25 * | .22 * |
| (%) | Fall | | | | | .59 ** | .30 ** | -.14 | -.17 | .60 ** | .57 ** | .91 ** | .83 ** | .52 ** | .23 * | .30 ** | .24 * |
| NDF | Spring | | | | | | | .70 ** | .46 ** | .35 ** | .26 * | .65 ** | .68 ** | -.33 ** | -.21 | .20 | -.02 |
| (%) | Fall | | | | | | | .71 ** | .88 ** | .24 * | .17 | .57 ** | .32 ** | .35 ** | -.09 | .03 | .06 |
| HEMI | Spring | | | | | | | | | -.01 | -.37 ** | .29 ** | -.10 | -.38 ** | -.25 * | -.02 | -.29 ** |
| (%) | Fall | | | | | | | | | -.23 * | -.09 | -.08 | -.04 | -.01 | -.22 * | -.21 | -.07 |
| ADL | Spring | | | | | | | | | | | .33 ** | .07 | -.12 | -.52 ** | .95 ** | .91 ** |
| (%) | Fall | | | | | | | | | | | .40 ** | .27 ** | -.06 | .08 | .94 ** | .93 ** |
| CELL | Spring | | | | | | | | | | | | | -.43 ** | -.32 ** | .18 | -.31 ** |
| (%) | Fall | | | | | | | | | | | | | .29 ** | .21 | .11 | .04 |
| ASH | Spring | | | | | | | | | | | | | | | -.12 | .11 |
| (%) | Fall | | | | | | | | | | | | | | | -.30 ** | -.21 |

* Correlation coefficient was significantly different from zero at the 0.05 level of probability.
** Correlation coefficient was significantly different from zero at the 0.01 level of probability.

indicated that CELL had little or no effect on LTS, whereas the path analysis showed CELL as a major influence.

Simple correlations and direct/indirect effects between four quality components on IVDMD are given in Table 5. All correlation coefficients between CELL, ADL and IVDMD were highly significant, while for HEMI and ash only one out of four was found to be significant. The largest direct on IVDMD was for CELL (- 0.60), followed by ADL (- 0.53), both in the spring of 1980. All direct effects on IVDMD were negatively associated with CELL, ADL, HEMI, and ash.

TABLE 4. Simple correlations and path coefficients showing direct and indirect effects of several traits on LTS.

| Traits | Season | Effects via[a] | | | | | | | | Correlation with LTS | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | (1) Cellulose | | (2) Lignin | | (3) Hemicellulose | | (4) Ash | | | |
| | | 1979 | 1980 | 1979 | 1980 | 1979 | 1980 | 1979 | 1980 | 1979 | 1980 |
| (1) | Spring | **- 0.02** | **0.24** | - 0.01 | 0.02 | 0.01 | - 0.02 | - 0.06 | - 0.08 | 0.01 | 0.16 |
| | Fall | **0.34** | **0.24** | 0.14 | 0.06 | - 0.03 | - 0.01 | 0.10 | - 0.05 | 0.08 | 0.09 |
| (2) | Spring | 0.02 | 0.00 | **0.06** | **0.08** | - 0.01 | - 0.03 | 0.01 | 0.00 | 0.03 | 0.08 |
| | Fall | - 0.21 | - 0.08 | **- 0.50** | **- 0.30** | 0.12 | 0.03 | 0.03 | - 0.03 | - 0.33 ** | - 0.19 |
| (3) | Spring | 0.04 | - 0.01 | - 0.01 | - 0.03 | **0.16** | **0.09** | - 0.01 | - 0.02 | 0.13 | - 0.02 |
| | Fall | 0.01 | 0.00 | 0.02 | 0.02 | **- 0.10** | **- 0.19** | 0.01 | 0.04 | - 0.01 | - 0.24 * |
| (4) | Spring | - 0.03 | - 0.07 | 0.01 | 0.01 | - 0.01 | - 0.06 | **0.06** | **0.22** | 0.00 | 0.12 |
| | Fall | - 0.06 | - 0.07 | 0.01 | 0.03 | - 0.06 | - 0.07 | **- 0.22** | **0.32** | - 0.08 | 0.28 ** |

[a] Direct effects in bold face.
* Significant at the 5% level.
** Significant at the 1% level.

TABLE 5. Simple correlations and path coefficients showing direct and indirect effects of several traits on IVDMD.

| Traits | Season | Effects via[a] | | | | | | | | Correlation with IVDMD | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | (1) Cellulose | | (2) Lignin | | (3) Hemicellulose | | (4) Ash | | | |
| | | 1979 | 1980 | 1979 | 1980 | 1979 | 1980 | 1979 | 1980 | 1979 | 1980 |
| (1) | Spring | **- 0.27** | **- 0.60** | - 0.09 | - 0.06 | - 0.08 | - 0.06 | 0.12 | 0.20 | - 0.28 ** | - 0.56 ** |
| | Fall | **- 0.37** | **- 0.48** | - 0.15 | - 0.13 | 0.03 | 0.02 | - 0.11 | 0.11 | - 0.62 ** | - 0.46 ** |
| (2) | Spring | - 0.09 | - 0.04 | **- 0.28** | **- 0.53** | 0.01 | 0.20 | 0.03 | - 0.04 | - 0.53 ** | - 0.27 ** |
| | Fall | - 0.19 | - 0.04 | **- 0.46** | **- 0.14** | 0.11 | 0.02 | 0.03 | 0.01 | | |
| (3) | Spring | - 0.10 | 0.02 | 0.01 | 0.06 | **- 0.33** | **- 0.17** | 0.12 | 0.04 | - 0.24 * | 0.13 |
| | Fall | 0.03 | 0.01 | 0.06 | 0.02 | **- 0.28** | **- 0.18** | 0.01 | 0.04 | 0.13 | 0.09 |
| (4) | Spring | 0.18 | 0.06 | 0.05 | - 0.01 | 0.16 | 0.04 | **- 0.41** | **- 0.17** | - 0.12 | 0.03 |
| | Fall | - 0.09 | 0.05 | 0.02 | - 0.02 | 0.01 | 0.05 | **- 0.29** | **- 0.22** | - 0.36 ** | - 0.08 |

[a] Direct effects in bold face.
* Significant at the 5% level.
** Significant at the 1% level.

## CONCLUSIONS

As a conclusion, the results indicated that cellulose and lignin had a major influence on leaf tensile strength (LTS) while the *in vitro* dry matter digestibility was negatively associated with cellulose, hemicellulose, lignin and ash.

A tall fescue breeding program aimed at high quality forage, to be effective, should take into account those relationships, i.e., better forage quality may be achieved in tall fescue by selecting genotypes with proper leaf tensile strength (LTS).

## REFERENCES


ANDERSON, B.E. Herbage sampling and intake estimation techniques for evaluating relationships among forage composition, rumen process, and gains of sheep grazing tall fescue fertilized with three rates of nitrogen in summer and fall. Columbia, University of Missouri, 1980. Tese Mestrado.

ANDERSON, L.B. Grasslands G4710 tall fescue (*Festuca arundinacea* Shreb.). N.Z. Grassl. Assoc. Proc., 36: 198-9, 1976.

ARCHIBALD, J.G.; BENNETT, E. & RITCHIE, W.S. The composition and palatability of some common grasses. J. Agric. Res., 66:341-7, 1943.

ASAY, K.H.; MINNICK, T.R.; GARNER, G.B. & HARMON, B.W. Use of crickets in a biossay of forage quality in tall fescue. Crop Sci., 15:585-8, 1975.

BARNES, R.F. Brief outline of the two-stage *in vitro* rumen fermentation technique. Washington, USDA, 1967.

BEAUMONT, A.B.; STITT, R.E. & SNELL, R.S. Some factors affecting the palatability of pasture plants. J. Amer. Soc. Agron., 25:123-8, 1933.

EVANS, P.S. A study of leaf strength in four ryegrass varieties. New Zealand J. Agric. Res., 7:508-13, 1964.

EVANS, P.S. Leaf strength studies of pasture grasses. I. Apparatus, techniques, and some factor affecting leaf strength. J. Agric. Sci. Camb., 69:171-4, 1967a.

EVANS, P.S. Leaf strength studies of pasture grasses. II. Strength, cellulose content and schlerenchyma tissue proportions of eight grasses grown as single plants. J. Agric. Sci. Camb., 69:175-81, 1967b.

GOERING, H.K. & SOEST, P.T. van. Forage fiber analysis. Washington, USDA, 1970. (USDA. Handbook, 379).

HENDERSON, M.S. & ROBINSON, D.L. The influence of temperature, light and soil moisture stress on fiber component concentrations of Coastal Bermudagrass. Agron. Abstr. 125, 1980.

HIDES, D.H. Breeding for improved herbage quality in Italian ryegrass. Annual Rep. Welsh Plant Breed. Sta. for 1976. 1977. p.16-8.

KNEEBONE, W.R. Tensile strength variation in leaves of weeping lovegrass (*Eragrostis curvula* Nees.) and certain other grasses. Agron. J., 52:539-42, 1960.

MARTENS, P.O. & BOOYSEN, P.V. A tensiometer for the measurement of tensile strength of grass leaf blades. Proc. Grassland. Soc. Sth. Afric., 3:51-6, 1968.

MARUM, P.; HOVIN, A.W.; MARTEN, G.C. & SHENK, J.S. Genetic variability for cell wall constituents and associated quality traits in reed canarygrass. Crop Sci., 19:355-60, 1979.

MATCHES, A. Management. In: BUCKNER, R.C. & BUSH, L.P., eds. Tall fescue, Madison, American Society of Agronomy, 1979. p.171-99. (ASA. Monography, 20).

NGUYEN, H.T.; SLEPER, D.A. & HUNT, K.L. Genotype x environment interactions and stability analysis for herbage yield of tall fescue synthetics. Crop. Sci., 20:221-4, 1980.

NGUYEN, H.T.; SLEPER, D.A. & MATCHES, A.G. Inheritance of forage quality and its relationship to leaf strength in tall fescue. Crop Sci., 22(1):67-72, 1982.

SNEDECOR, W.G. & COCHRAN, W.G. Statistical methods. 7.ed. Ames, The Iowa State Univ. Press, 1980.

STEEL, R.G.D. & TORRIE, J.H. Principles and procedures of statistics. 2.ed. New York, McGraw-Hill, 1980.

STRATTON, S.D.; SLEPER, D.A. & MATCHES, A.G. Genetic variation and interrelationships of *in vitro* dry matter disappearance and fiber content in orchardgrass herbage. Crop Sci., 19:329-33, 1979.

THERON, E.P. & BOOYSEN, P.V. The tensile properties of ten indigenous grasses. Proc. Grassland. Soc. Sth. Afri., 3:57-61, 1968a.

THERON, E.P. & BOOYSEN, P. de V. A study of factors influencing the breaking tension of the leaves of various grasses. Proc. Grassland. Soc. Sth. Afri., 3: 63-6, 1968b.

TILLEY, T.M.A. & TERRY, R.A. A two-stage technique for *in vitro* digestion of forage crops. J. Br. Grassland. Soc., 18:104-11, 1963.

VOIGT, P.W. Improving palatability of range plants. In: CAMPBELL, R.S. & HERBEL, C.N., ed. Improved range plants. Denner Society for Range Management. 1975. p.23-49. (Range Symposium Series, 1).

VOIGT, P.W.; KNEEBONE, W.R.; MCILVAIN, E.H.; SHOOP, M.C. & WEBSTER, J.E. Palatability, chemical composition, and animal gains from selections of weeping lovegrass, *Eragrostis curvula* (Schrad.). Nees. Agron. J., 72:673-6, 1970.

WILSON, D. Nutritive value and the genetic relationship of cellulose content and leaf tensile strength in *Lolium*. J. Agric. Sci., 65:285-92, 1965.

WRIGHT, S. Correlation and causation. J. Agric. Res., 20:557-87, 1921.