AN ABSTRACT OF THE THESIS OF

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Title: PHYSIOLOGICAL CHARACTERISTICS OF DIFFERENT FORAGE YIELDING TALL FESCUE (*Festuca arundinacea* Schreb.) SELECTIONS UNDER FIELD SWARD CONDITIONS

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The study of relationships of plant characteristics to forage yield in tall fescue has often been restricted to controlled environment or low competition field situations. There is need to better understand characteristics related to yield in this species under sward conditions. To this end, four tall fescue selections representing different yield potentials and growth habits were evaluated for leaf elongation, leaf width, leaf area expansion, leaf area per tiller, tiller number, tiller dry weight, leaf area index (LAI) and stem base water soluble carbohydrate over a two year period.

TFM 16 and TFM 26, tall fescue selections with low and high yielding characteristics respectively, exhibiting growth during late fall and winter months, and TFK 4 and TFK 12 early spring and summer month growing selections, high an low yielding respectively, were selected for this study.

Relationships among all independent variables and yield were analyzed by means of simple correlation coefficients. Path coefficient analysis was used to determine the direct and indirect effects of the various factors associated with forage yield.

Dry matter production among selections was significantly different only for the July harvest in 1976 and 1977. The September harvest yields were not significantly different although the yield trends were the same as in July.

The four selections did not differ in leaf elongation, but significant differences were found for leaf width. Leaf area expansion was statistically different for both years with the exception of the July harvest in 1976.

Multiple coefficients of determination showed that leaf width, tiller number, and tiller dry weight contributed most to forage dry matter yield.

The TFK selections displayed significantly wider leaves than TFM particularly in 1977. TFM 16, a low yielding selection displayed the narrowest leaves throughout the experiment. Leaf width was consistently related to forage yield across harvests and years, emphasizing the importance of width in describing leaf area expansion and its stability as a morphological characteristic.

The results of these investigations lead to the conclusion that forage yield in tall fescue under high competition situations is a complex system characterized by an inter-dependence of characteristics that can be changed for any particular environment. Caution must, therefore, be taken if selection of a single characteristic is to be used as a criterion in yield improvement.

Physiological Characteristics of Different Forage Yielding Tall Fescue (*Festuca arundinacea* Schreb.) Selections under Field Sward Conditions

by

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Typed by Opal Grossnicklaus for Julio Cesar Lhamby

DEDICATION

To my wife Dinaci, and my son Fabio, for their affection and love, I dedicate this thesis.

J. C. L.

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Muito obrigado.

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PHYSIOLOGICAL CHARACTERISTICS OF DIFFERENT FORAGE YIELDING TALL FESCUE (*Festuca arundinacea* Schreb.) SELECTIONS UNDER FIELD SWARD CONDITIONS

LITERATURE REVIEW

Forage yield, above ground biomass, is a function of solar energy captured by the crop's photosynthetic system and its partitioning into harvestable dry matter. Hunt and Cooper (1967), studying seven grass species, indicated that differences in productivity were closely associated with the size of the photosynthetic system. The rate of leaf elongation was recognized as an important factor in the selection of grass genotypes for yield improvement by Scott (1961). Horst (1973) reported that rate of leaf elongation was positively correlated with productivity in tall fescue genotypes grown under field environments. Nelson *et al*. (1977), studying forage yield in tall fescue under conditions of low competition, concluded that yield per plant was affected by tiller number and rate and that yield per tiller was also positively correlated with leaf area expansion. However, leaf area expansion was inversely related to tiller number. Ryle (1964), comparing leaf growth of several perennial grasses showed that even though tall fescue had a slower rate of leaf production and a smaller number of living leaves per tiller the larger leaves compensated for the lower number of leaves, thereby maintaining leaf area display. Tan *et al*. (1977), working with Bromegrass, found that tiller density and leaf area per tiller were major factors affecting spring yield. Robson (1968), however, found that an increase in shading due to large leaf area development could lead to an increased mortality of newly developed tillers which could not compete for light and other environmental factors.

Carbohydrate reserves were important in perennial plants for spring growth initiation and regrowth following defoliation (Alberda, 1966). Sullivan and Sprague (1943), identifying fructosans as the primary storage component in cool season grasses, found that the leaf sheath was the main site for storage. The importance of stored reserves and residual leaf area was investigated by Smith (1974) in Timothy. He agreed with the conclusion reached by Ward and Blaser (1961) that both components influenced regrowth, but residual and newly developed leaf area appeared to be somewhat more important than carbohydrate reserves in determining regrowth.

Since much of the work with canopy characteristics and yield in tall fescue has been done with spaced plants (low competition situations) or controlled environment conditions, a study of physiological characteristics and their variation under sward conditions was deemed desirable. The objectives of these studies were to evaluate different yielding tall fescue selections for variation in leaf width, leaf elongation, tiller number, tiller dry weight, leaf area index, and stem base carbohydrate content. By using low and high yielding tall fescue selections representing two growth habits, winter growth versus summer growth, it was hoped that important characteristics explaining yield differences could be elucidated and progress made toward identifying selection criteria for yield improvement in tall fescue.

MATERIALS AND METHODS

Experiments were conducted over a two year period using four tall fescue selections differing in their genetic background and dry matter production based on yield determinations in sward plots established in 1974. Yields in 1975 were used to identify those selections which were low and high yielding. (See Figure 1.) The plots were established in a randomized block design with four replications located at the Hyslop Agronomy Farm, Corvallis, Oregon, on June 24, 1974.

Three of the replications were used in the studies reported in this paper. Two winter growing types, TFM 16 and TFM 26, were selected to represent the low and high yield selections of tall fescue outstanding in vigor and production during the late fall and winter months. TFK 12 and TFK 4 were selections with apparent winter dormancy and exhibited low and high yield respectively in the forage harvest tests in 1975. The plot sizes were .75 meters by 4.3 meters with five rows planted per plot .15 meters apart and .3 meters between plots with a .9 meter alley between blocks. The experimental area received 448 kilograms per ha of 16/20 fertilizer at the time of seedbed preparation and an additional 168 kilograms per ha in the early fall of the establishment year. Additional nitrogen was supplied from January to October for a total of 308 kilograms per ha of the elemental N using ammonium nitrate as the nitrogen source. Plots were irrigated once in each year after the July harvest. In 1976 data gathered included dry matter yield, leaf elongation (Le), leaf width (Lw), leaf area expansion (La) and stem base water soluble carbohydrate content (WSC). In 1977 the data collection were expanded to include the previous year's parameters, plus leaf area index (LAI), tiller number (TN), tiller dry weight (TDW) and stem base water soluble carbohydrate content (WSC). In addition xylem water potential measurements using the Pressure Bomb technique (Boyer, 1967) were obtained at various times after harvest to determine if differences existed between selections and if leaf area display could be related to this variable. Attempts were also made to evaluate gas exchange characteristics using a porometer.

The harvesting regime involved three cuts per year to about seven centimeters stubble height in May, July, and September. Yield was recorded as metric tons per hectare of oven dry matter. The experimental sampling and data collection began after the May harvest. Results for the harvests in July and September are reported in this study with the physiological measurements made prior to a particular harvest.

Leaf elongation was determined by examining the last expanding leaf on an every-other-day basis for a period of eight days in each of the periods prior to harvest (prior to July and prior to September).

Ground level and the tip of the leaf blade were used as a reference point and 20 labeled tillers in each of the replications were observed over the eight day period. Leaf width was determined by measuring the width of the midpoint of each leaf blade. Leaf elongation x leaf width was used to provide leaf area expansion. In 1977 a point quadrat was utilized following the technique of Wilson (1959) to estimate the leaf area index of the various tall fescue selections. The mean number of contacts made by eight needles with leaves in each ten centimeter vertical segment of the sward using an inclination of 32.5 degrees was recorded and leaf area index was obtained by multiplying this number by the factor 1.1 as determined by Wilson (1959). Tiller dry weight accumulation and seasonal trends in water soluble carbohydrate samples were taken each week starting before the first harvest in 1977. Twenty to thirty fresh tillers were cut at ground level (below the growing point), microwaved for 30 seconds (Darrah et al., 1967), and then placed in a forced draft oven at 70 degrees C for approximately 24 hours. Dry tillers were weighed and the four centimeter base portion was utilized for chemical analysis following the method of Yemm and Willis (1954) for water soluble carbohydrate determination. The last tiller sample of each period was taken to the laboratory where leaf area per tiller, specific leaf weight, and leaf number were also measured. A portable area meter Licor Model number L13000 was used for leaf area determination. During 1977, tillers were counted within a 235 square centimeter area in three random locations within each plot three times following the May harvest. All the data were recorded on a plot mean basis. Statistical analyses were made on all of the variables measured and relationships to forage yield were evaluated by correlation and regression analysis (Steel and Torrie, 1960). Two missing plots were determined for the July harvest in 1977. Path coefficient analyses were also conducted to better understand relationships among variables and to determine direct and indirect effects of the various factors associated with forage yield (Li, 1956).

RESULTS AND DISCUSSION

Forage Yield

The patterns of forage yield for the two years of the study (1976 and 1977) and the yields for 1975 which served as a basis for choosing the four tall fescue selections are recorded in Figure 1. Forage yields in July 1976 were much lower than those in 1975 or 1977. In addition, September 1977 yields were very low. The temperature and rainfall patterns (Appendix Table 1) in these years provides some explanation for these differential yields. In 1975 the rainfall amounts for May and June were fairly normal, although August rainfall was high (28.7 millimeters above average precipitation), thus accounting for the recovery in September. In 1976 a particularly low rainfall pattern was recorded in April, May, and June (35.2 millimeters less than the normal), resulting in the low July yield. Irrigation was provided in July in each of the years and this followed by a higher than normal rainfall for July and August (53.4 millimeters above the normal) allowed recovery of yield to some extent. In 1977 during May above normal rainfall (40.2 millimeters) may have accounted for the high yields in the July harvest. The very low yields in September were the result of longer than normal periods of above average maximum and minimum temperatures during August.

Dry matter yield among the selections was significantly different

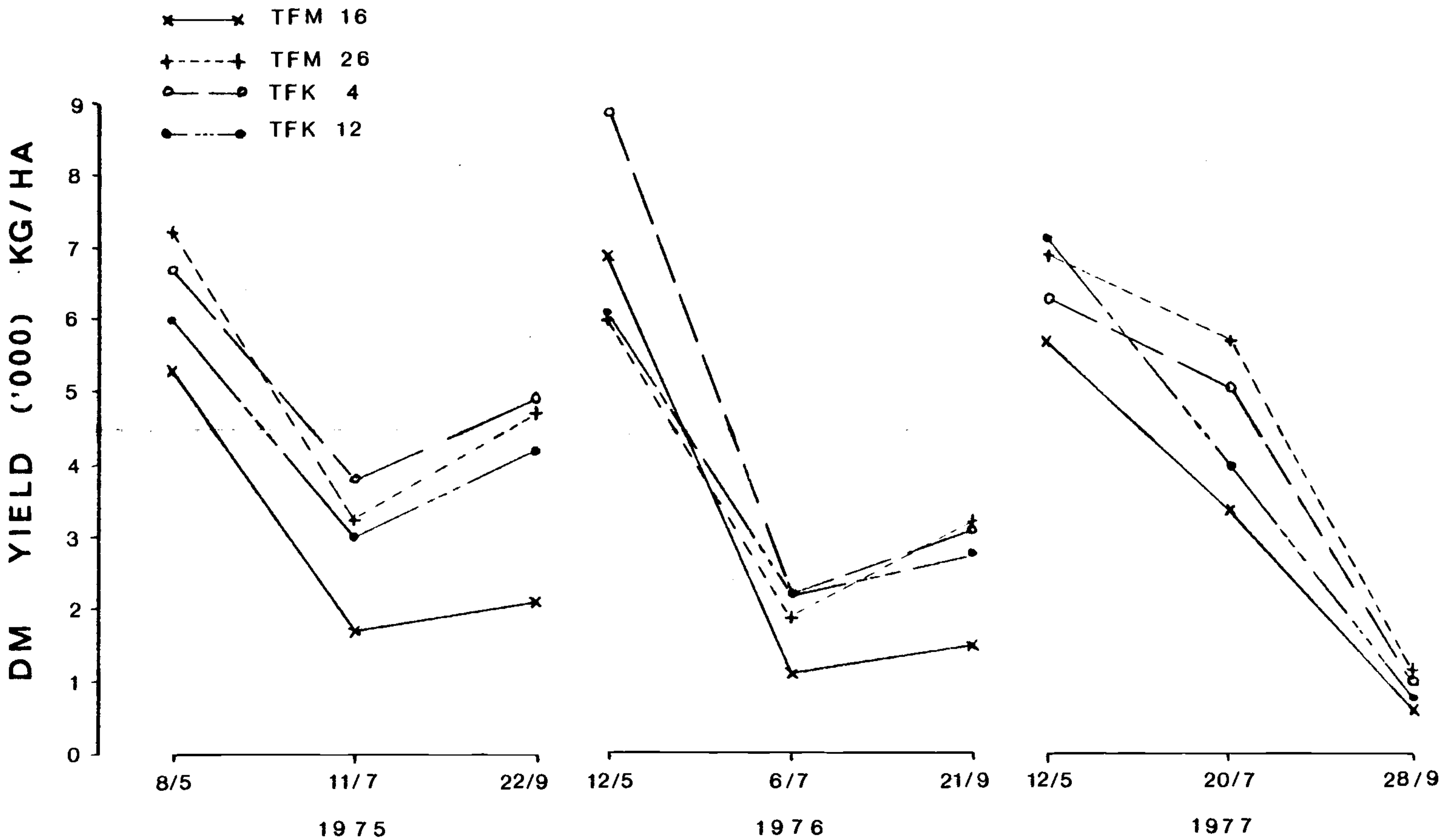

Figure 1. Dry matter forage yield of four tall fescue selections for three harvest dates over three different years.

only for the July harvest in both years of the study. In 1976 TFM 16 was significantly lower than the other three selections whereas in 1977 both TFM 16 and TFK 12 were significantly lower yielding. When totaled across harvests over the three years TFM 26 was the highest yielding selection followed by TFK 12, TFK 4, and TFM 16. TFM 16 was consistently lower than the other selections.

Since the objective of this study was to attempt to relate physiological characteristics to forage yield, emphasis was placed on the association of the various factors measured to forage yield. Although significant relationships were found only for the July harvest, September harvest results are presented to show the changes that occurred and relative consistency of the variables studied. Trends for yield and some other variables were similar to those in the July harvest; however, the lower yield of the September harvest in 1977 and the inherent variability in plot yields contributed to the lack of significant associations.

Leaf Area Development

Leaf area expansion is a function of leaf elongation and leaf width. Based on an eight day regrowth period in May 1976 (Figure 2), the four genotypes did not differ significantly in leaf elongation, but significant differences were found for leaf width. Although some differences in leaf area expansion were observed they were not

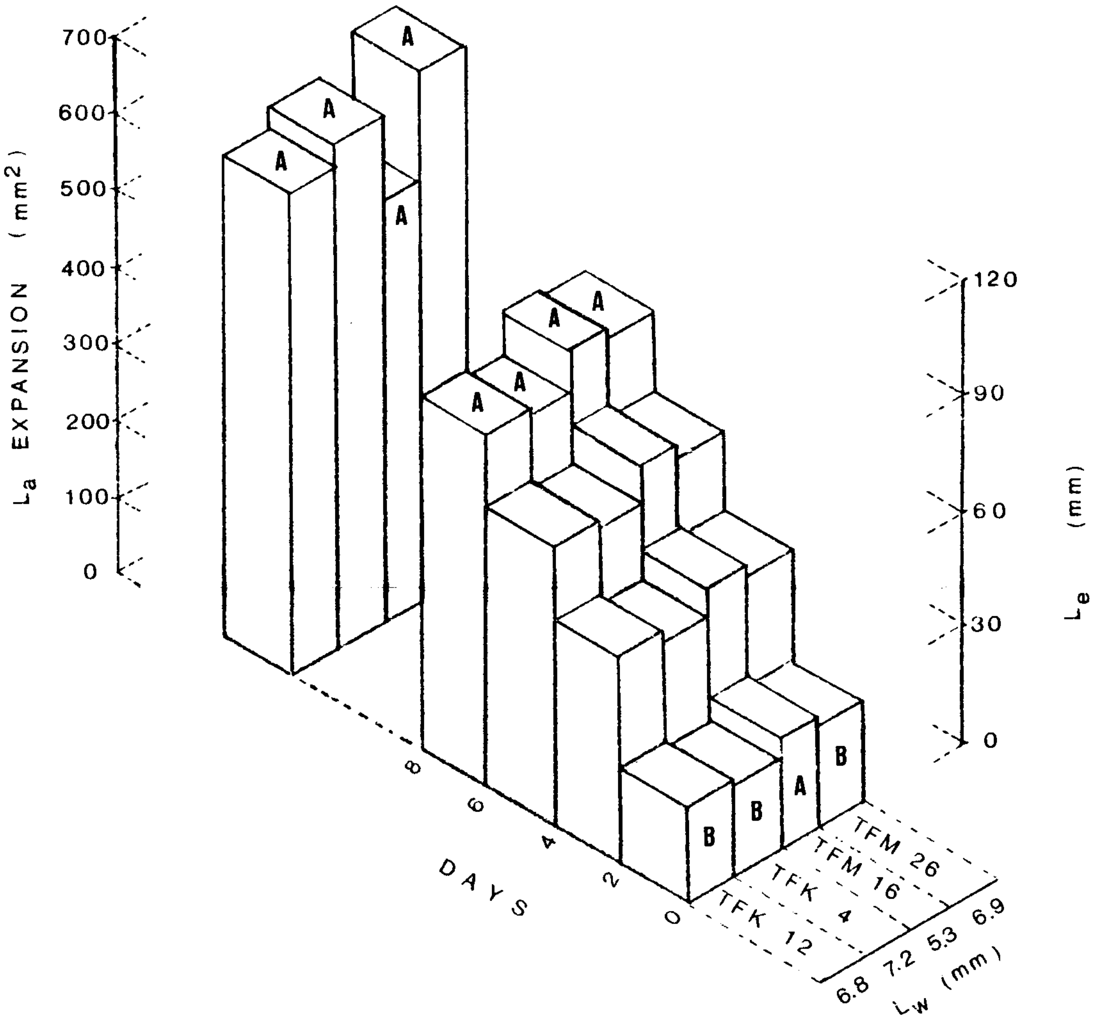

Figure 2. Leaf width (Lw), leaf elongation (Le), and leaf area expansion (La) of four tall fescue selections for an eight day regrowth period after harvest, beginning May 17, 1976.

statistically significant. However, measurements in an eight day period following the July harvest showed significant differences in leaf width and leaf area expansion (Figure 3). In the July measurement period TFK 4 displayed the widest leaves although again leaf elongation was not different. Similar results were found in 1977 except that differences in leaf width and leaf area expansion were statistically significant in both sampling periods (Figures 4 and 5). In 1977 the TFK selections displayed significantly wider leaves than the TFM selections. TFM 16, a low forage yielding selection displayed consistently more narrow leaves in all periods in comparison to all other selections. This emphasizes the importance of leaf width in describing leaf area expansion and the relative stability of leaf width as a morphological characteristic.

Correlation coefficients showing the associations between the various measured physiological characteristics and forage yield per plot in 1976 are summarized in Table 1. A significant positive correlation was found for leaf width and yield in 1976 in both harvests. Leaf elongation and yield were negatively associated in the first harvest but positively associated in the second harvest. Leaf area expansion which was not significantly associated with yield in the first harvest (July) was significantly and positively associated with yield in the second harvest (September). The changes in association from harvest one to harvest two are difficult to explain, particularly

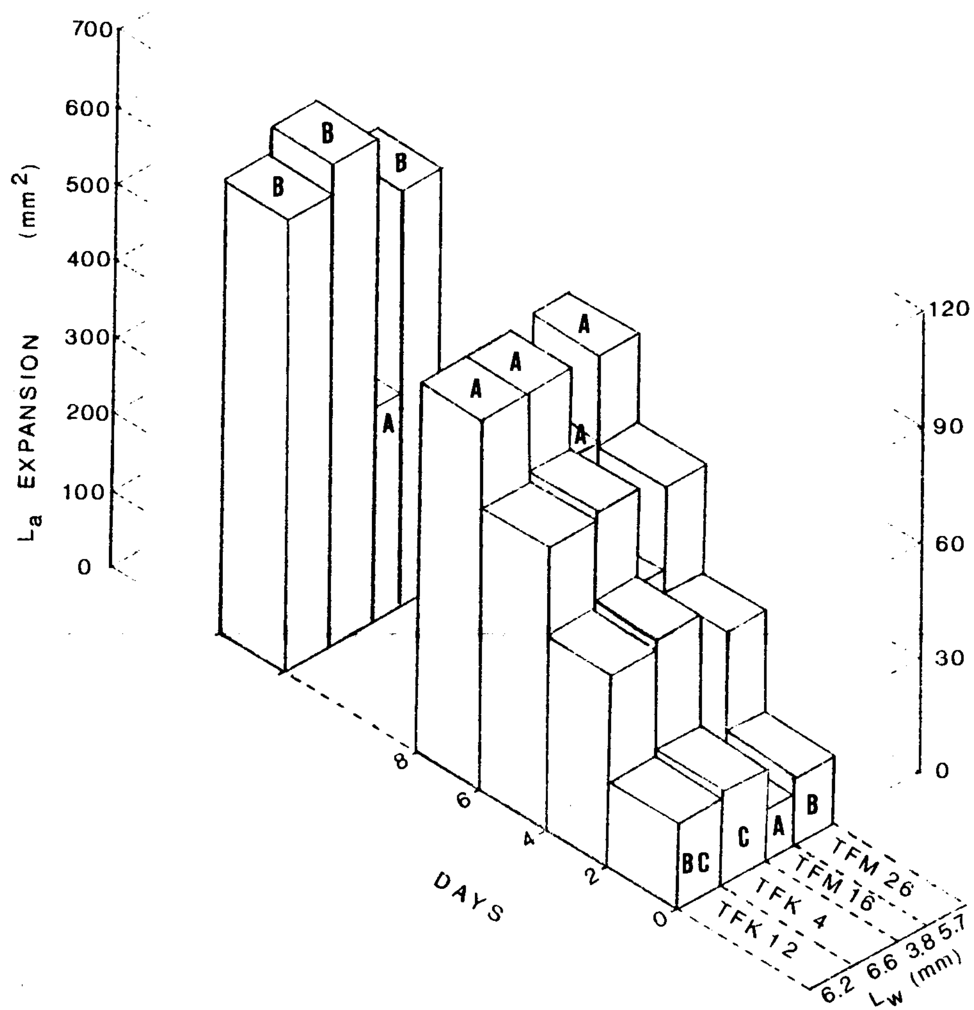

Figure 3. Leaf width (Lw), leaf elongation (Le), and leaf area expansion (La) of four tall fescue selections for an eight day regrowth period after harvest, beginning July 8, 1976.

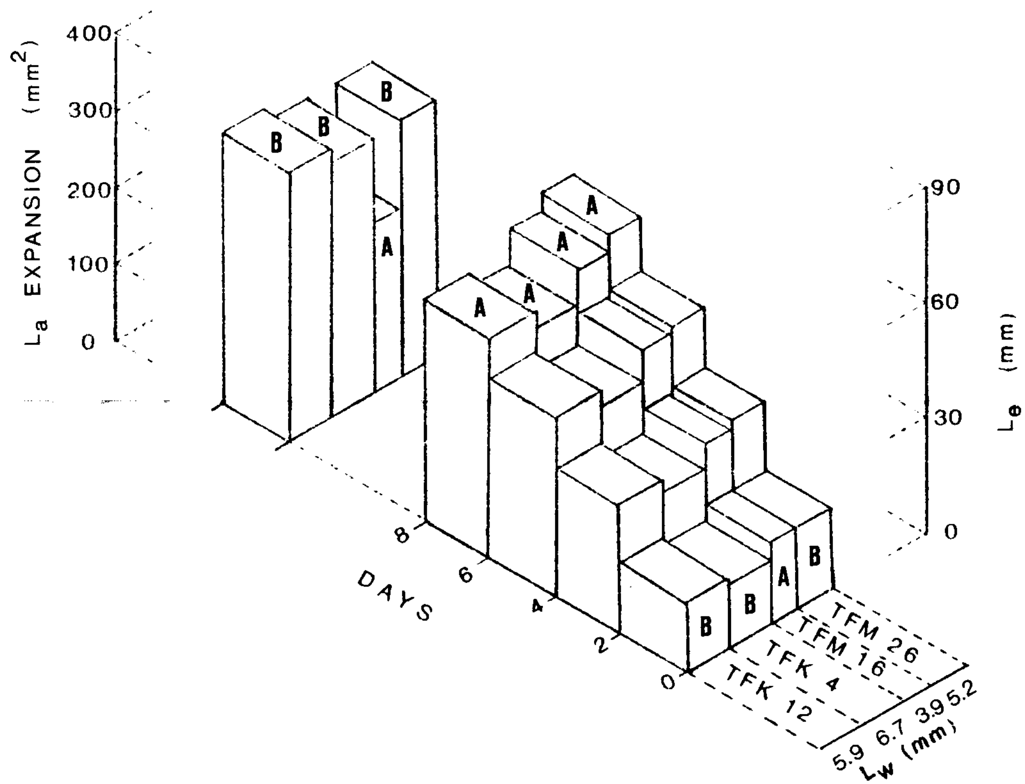

Figure 4. Leaf width (Lw), leaf elongation (Le), and leaf area expansion (La) of four tall fescue selections for an eight day regrowth period after harvest, beginning June 18, 1977.

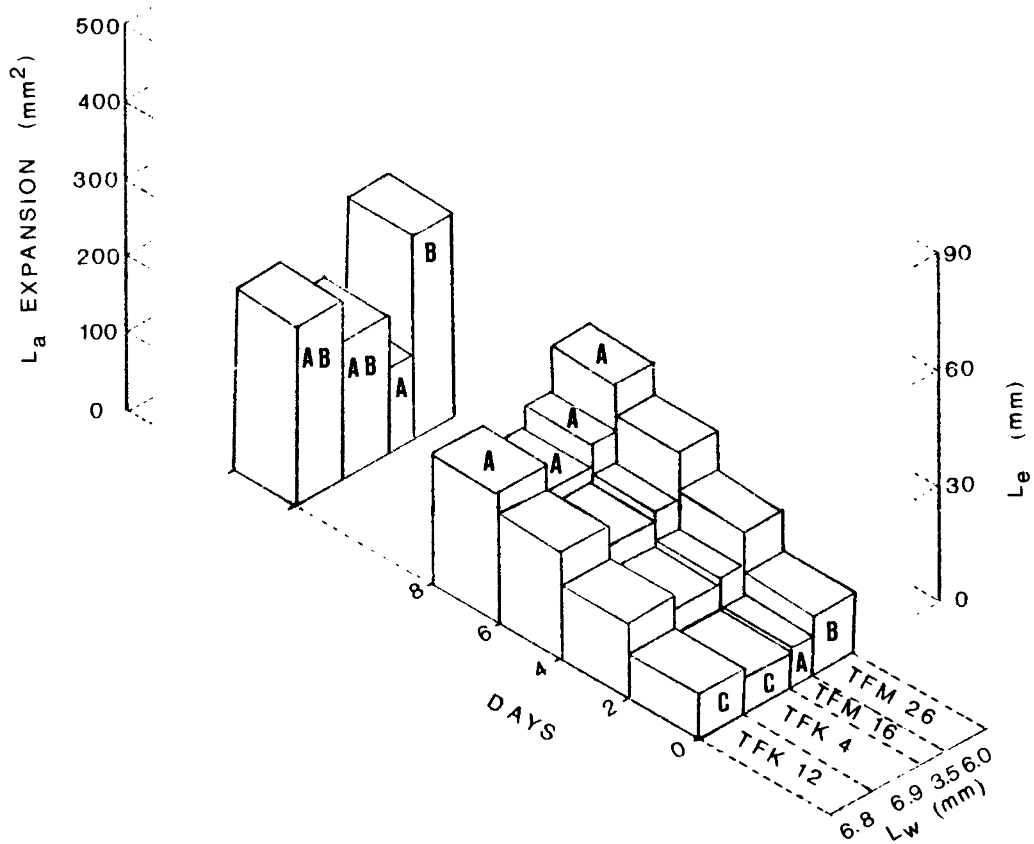

Figure 5. Leaf width (Lw), leaf elongation (Le), and leaf area expansion (La) of four tall fescue selections for an eight day regrowth period after harvest, beginning August 8, 1977.

Table 1. Simple correlation coefficient for leaf characteristics and forage yield in two harvests for four tall fescue selections during 1976.[1]

	Characters	Harvest 1st (1)	Harvest 2nd (1)	Harvest 1st (2)	Harvest 2nd (2)	Harvest 1st (3)	Harvest 2nd (3)
(1)	Yield/plot (g)	--	--				
(2)	Leaf elongation (mm/day)	-.65	.77	--	--		
(3)	Leaf width (mm)	.89	.72	-.50	.73	--	--
(4)	Leaf area expansion (mm^2/day)	.38	.80	.33	.93	.65	.94

[1] d.f. = 10, n = .576 and .708 are significant at .05 and .01 level of probability respectively.

since forage yields among selections were not significantly different in the second harvest in 1976. The decreased yield in the September harvest along with greater variability may have contributed to this anomaly.

The association of leaf area characteristics and yield for 1976 was further evaluated via path coefficient analysis (Li, 1956). As noted in Table 2 both leaf elongation and leaf width had a positive direct effect on forage dry matter yield in both harvests although the direct effect was much smaller in the second harvest. The negative direct effect of leaf area expansion was primarily offset by the positive indirect effect via leaf width.

Leaf area expansion in 1977 for the July harvest was significantly correlated with yield (Table 3), although individually leaf elongation and leaf width associations were not significant. In the second harvest leaf area expansion was not significantly associated with yield perhaps because other variables were having a greater effect on yield. The components of leaf area expansion for harvest in 1976 and 1977 were evaluated via path coefficient analysis. As noted in Table 4, there is a positive direct effect of both leaf elongation and leaf width on leaf expansion in both 1976 and 1977. However, the indirect effect of leaf elongation via leaf width and the indirect effect of leaf width via leaf elongation is negative. This results in a lack of correlation for leaf elongation with leaf area expansion in the

Table 2. Path coefficient analysis for relationship between yield and leaf characteristics in four tall fescue selections in two harvest periods for 1976.

	Variables correlated and pathways of association		1st period	2nd period
I.	Yield and Leaf Elongation	r=	-.645	.755
	a. Direct Effect		.822	.454
	b. Indirect via Leaf Width		-1.062	.187
	c. Indirect via Leaf Area Expansion		-.405	.134
II.	Yield and Leaf Width		.886	.725
	a. Direct Effect		2.106	.256
	b. Indirect via Leaf Elongation		-.415	.332
	c. Indirect via Leaf Area Expansion		-.805	.137
III.	Yield and Leaf Area Expansion		.383	.803
	a. Direct Effect		-1.246	.146
	b. Indirect via Leaf Elongation		.268	.417
	c. Indirect via Leaf Width		1.361	.240
	$1 - R^2$		.141	.354

Table 3. Simple correlation coefficients for leaf characteristics, leaf area per tiller, tiller number, tiller dry weight, and LAI and forage yield in two harvests for four tall fescue selections during 1977.[1]

Characters	Harvest (1)		Harv[illegible] (2)		Harvest (3)		Harvest (4)		Harvest (5)		Harvest (6)		Harvest (7)	
	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd
(1) Yield/plot (g)	--	--												
(2) Leaf elongation (mm/day)	.44	.36	--	--										
(3) Leaf width (mm)	.44	.31	-.31	.12	--	--								
(4) Leaf area expansion (mm^2/day)	.70	.44	.36	.83	.77	.65	--	--						
(5) Leaf area/tiller (mm^2)	.42	.43	-.20	.47	.88	.86	.74	.84	--	--				
(6) Tiller number (235 cm^2)	.52	.89	.17	.57	-.01	.11	.06	.48	.28	.38	--	--		
(7) Tiller dry weight (mg)	.59	.29	.31	.27	.38	.94	.59	.72	.66	.94	-.26	.20	--	--
(8) LAI	.71	.77	.21	.31	.74	.72	.84	.62	.53	.80	.51	.70	.22	.74

[1] d. f. = 10, n = .516 and .708 are significant at .05 and .01 level of probability respectively.

Table 4. Path coefficient analysis for components of leaf area expansion rate, in four tall fescue selections in four harvest periods for 1976 and 1977.

Pathways of Association		1976 1st period	1976 2nd period		1977 1st period	1977 2nd leriod
Leaf Area Expansion vs. Leaf Elongation	r=	.33	.92	r=	.36	.85
Direct Effect		.87	.50		.66	.76
Indirect via Leaf Width		-.55	.42		-.30	.09
Leaf Area Expansion vs. Leaf Width	r=	.65	.94	r=	.77	.62
Direct Effect		1.09	.57		.97	.55
Indirect via Leaf Elongation		-.44	.36		-.20	.07
$1 - R^2$		.01	.00		.01	.00

first harvest in both years. Leaf width is apparently having a greater effect on leaf area expansion and the negative association with leaf elongation may indicate an inverse relationship between leaf length and leaf width. The dramatic change in the second harvest is difficult to explain. However, the inconsistency observed suggests caution in using these parameters as a yield criteria applied to sward conditions.

Path coefficient analysis for leaf area characteristics in 1977 (Table 5) show a negative direct effect of leaf area expansion on forage yield for the first harvest. Leaf area expansion is a product of leaf elongation and leaf width both of which have positive direct effects. Thus the positive correlation of leaf area expansion and yield exists but indirectly via these two components, leaf elongation and leaf width. Leaf width shows the greatest direct effect on yield and is the largest positive indirect factor of the leaf area expansion path coefficient analysis. The change in relationships for harvest two is apparently related to other factors which have a greater effect on yield than leaf area expansion components.

The evaluation of leaf characteristics and yield in both years shows leaf width as a predominant factor related to forage yield. This is consistent with work reported by Asay et al. (1977) where forage yield increased significantly in tall fescue genotypes as leaf width increased.

Table 5. Path coefficient analysis for relationship between yield and leaf characteristics, leaf area per tiller, tiller number, tiller dry weight, and LAI in four tall fescue selections in two harvest periods for 1977.

	Variables correlated and pathways of association		1st period	2nd period
I.	Yield and Leaf Elongation	r=	.443	.356
	a. Direct Effect		.937	-.300
	b. Indirect via Leaf Width		-.354	.084
	c. Indirect via Leaf Area Expansion		-.115	.127
	d. Indirect via Leaf Area/Tiller		-.082	.079
	e. Indirect via Tiller Number		.167	.579
	f. Indirect via Tiller Dry Weight		.071	-.196
	g. Indirect via LAI		-.181	-.017
II.	Yield and Leaf Width	r=	.436	.314
	a. Direct Effect		1.156	.700
	b. Indirect via Leaf Elongation		-.287	-.036
	c. Indirect via Leaf Area Expansion		-.245	.099
	d. Indirect via Leaf Area/Tiller		.359	.143
	e. Indirect via Tiller Number		-.007	.115
	f. Indirect via Tiller Dry Weight		.086	-.668
	g. Indirect via LAI		-.626	-.039
III.	Yield and Leaf Area Expansion	r=	.699	.443
	a. Direct Effect		-.318	.154
	b. Indirect via Leaf Elongation		.340	-.248
	c. Indirect via Leaf Width		.891	.452
	d. Indirect via Leaf Area/Tiller		.300	.141
	e. Indirect via Tiller Number		.065	.491
	f. Indirect via Tiller Dry Weight		.134	-.513
	g. Indirect via LAI		-.713	-.034
IV.	Yield and Leaf Area/Tiller	r=	.422	.432
	a. Direct Effect		.408	.167
	b. Indirect via Leaf Elongation		-.189	-.142
	c. Indirect via Leaf Width		1.018	.601
	d. Indirect via Leaf Area Expansion		-.234	.130
	e. Indirect via Tiller Number		-.279	.390
	f. Indirect via Tiller Dry Weight		.149	-.670
	g. Indirect via LAI		-.451	-.044

Table 5. (Continued)

	Variables correlated and pathways of association		1st period	2nd period
V.	Yield and Tiller Number	r=	.520	.886
	a. Direct Effect		1.000	1.018
	b. Indirect via Leaf Elongation		.156	-.171
	c. Indirect via Leaf Width		-.008	.079
	d. Indirect via Leaf Area Expansion		-.021	.074
	e. Indirect via Leaf Area/Tiller		-.114	.064
	f. Indirect via Tiller Dry Weight		-.059	-.139
	g. Indirect via LAI		-.434	-.039
VI.	Yield and Tiller Dry Weight	r=	.585	.285
	a. Direct Effect		.226	-.714
	b. Indirect via Leaf Elongation		.293	-.082
	c. Indirect via Leaf Width		.439	.655
	d. Indirect via Leaf Area Expansion		-.189	.111
	e. Indirect via Leaf Area/Tiller		.269	.157
	f. Indirect via Tiller Number		-.262	.199
	g. Indirect via LAI		-.191	-.041
VII.	Yield and LAI	r=	.711	.771
	a. Direct Effect		-.851	-.055
	b. Indirect via Leaf Elongation		.200	-.092
	c. Indirect via Leaf Width		.851	.502
	d. Indirect via Leaf Area Expansion		-.266	.096
	e. Indirect via Leaf Area/Tiller		.216	.134
	f. Indirect via Tiller Number		.510	.716
	g. Indirect via Tiller Dry Weight		.051	-.530
	$1 - R^2$		.084	.090

Tiller Number

After the May harvest in 1977 the tiller number decreased in all selections and by the end of July, tiller populations were reduced by 12.5 percent. Langer (1959) showed in Timothy that an early cut designed to prevent flowering led to a temporary increase in tiller number. However, if the sward was allowed to flower before harvest an opposite effect was noted. The results in this experiment follow the latter response, since flowering did occur in late April. Apparently, the tillers formed during the early summer during flowering were less vigorous and after harvest did not survive the effects of defoliation, supporting the findings of Robson (1968). Differences in tiller populations among selections were not significant throughout the experiment. The magnitude of the association between yield and tiller number is shown in Table 2. Although the correlation coefficient for the July harvest is not significant, it is positive, supporting in principle the concept of Nelson et al. (1977) that tiller number is an important component of yield in tall fescue. In the second harvest tiller number became a significant factor in forage yield.

Path coefficient analysis (Table 5) shows that tiller number has primarily a direct effect on forage yield with some negative indirect effects via LAI. The reduction in tiller number during July may explain the increased importance of this component in forage yield in the second harvest.

Tiller Dry Weight

All selections showed a decrease in tiller dry weight during the first week following defoliation. This reduction was also concomitant with a reduction in stem base carbohydrate. Tiller dry weight was significantly correlated with yield for the July harvest of 1977 (Table 2), but not for the second harvest where tiller number became more important. No significant correlation was noted for the association between tiller number and tiller dry weight; however, the association was negative in the first harvest, suggesting that these two variables may be inversely related under some conditions. The path coefficient analysis (Table 5) shows that most of the association with yield is through an indirect effect via leaf width which was true for both harvests.

Leaf Area per Tiller

No significant correlation between leaf area per tiller and yield were observed in either harvest. There was also no differences in leaf number per tiller or in specific leaf weight among the selections. Path coefficient analysis showed a high positive indirect relationship to yield through leaf width. As noted in Table 2 a high correlation between leaf width and leaf area per tiller existed in both harvests.

Leaf Area Index

Leaf area index was positively and significantly associated with yield in both harvests as determined by correlation analysis (Table 2). The differences between the various selections in LAI and the distribution of the leaf area index over the canopy height are illustrated in Figures 6 and 7 for harvest 1 and harvest 2, respectively. TFM 16 had the lowest leaf area index in the first harvest followed by TFK 12 and TMK 26 which were similar and TFK 4 which showed the greatest leaf area index. The distribution of the leaf area is also of interest. In the lowest yielding selection (TFM 16) both the upper and the basal area contained a smaller portion of the total leaf area. Selections with either a large basal leaf area or a large amount of leaf area in the upper part of the canopy were higher yielding. In the second harvest TFM 16 was again significantly lower in leaf area index, but there were no statistical differences among the other selections. Basal leaf area again seemed to be related to superior forage yield. This would be logical considering the importance of current photosynthate in regrowth. Path coefficient analysis (Table 5) showed LAI to have its effect on yield primarily indirectly through leaf width and tiller number.

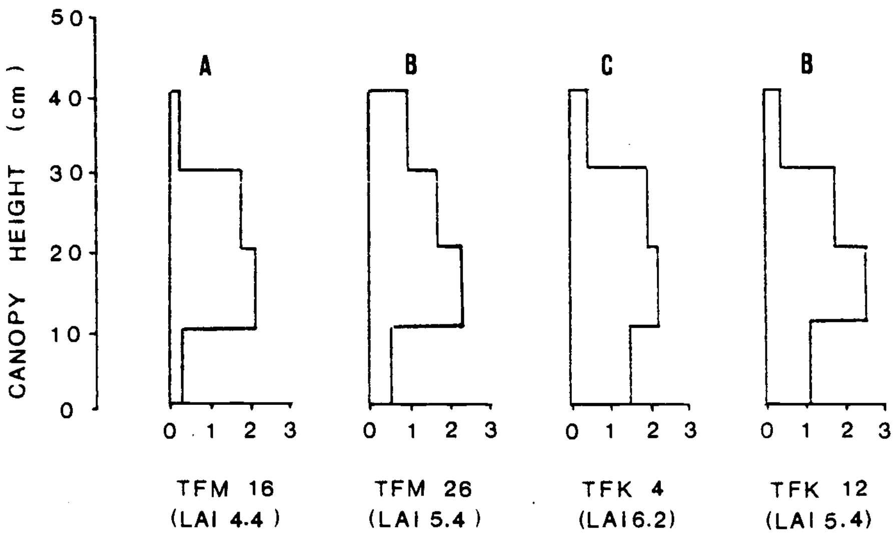

Figure 6. Leaf area indices and distribution with canopy height (10 cm segments) for four tall fescue selections in July 1977.

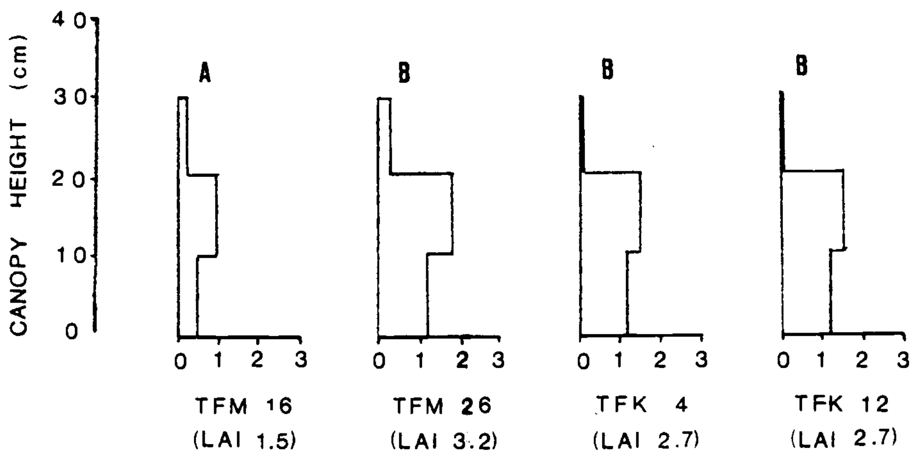

Figure 7. Leaf area indices and distribution with canopy height (10 cm segments) for four tall fescue selections in September 1977.

Stem Base Water Soluble Carbohydrates

The concentration of water soluble carbohydrates in the stem bases was not significantly different among selections in either year. In addition there was no relationship between water soluble carbohydrate and leaf area display. This is in agreement with the findings of Nelson et al. (1977). There was a reduction in the water soluble carbohydrate content after each harvest and thereafter a similar increase was observed in all selections. This suggests that current photosynthate was adequate for regrowth in all of the selections.

Xylem Water Potential and Porometer Measurements

Selections did appear to adapt to the ability of the root system to provide moisture. Pressure bomb analysis of the xylem pressure potential in the selections at various times during the day and across the season showed no significant differences in the xylem water pressure potential. Reduction in tillers and leaf area were apparent as stress increased, indicating a limitation by the plant in producing new tissue. Preliminary observation of root growth and crown depth showed that depth of the crown in TFM 16 was shallow in comparison to the other tall fescue selections. Root biomass also appeared smaller in TFM 16. The significance of this remains to be elucidated. Porometer measurements did not show significant differences among selections and were highly variable.

CONCLUSIONS

The results of these investigations lead to the conclusion that forage yield in tall fescue under high competition situations is a complex system characterized by an inter-dependence of characteristics that can change for any particular environment. Caution must, therefore, be taken if selection of a single characteristic is to be used as a criterion in yield improvement. However, certain yield related factors were identified in these studies. Multiple coefficients of determination showed that leaf width, tiller number, and tiller dry weight contributed most to forage dry matter yield and the combination of the eight factors studied in 1977 accounted for 92% of the variation in forage yield (Appendix Table 2). The leaf width contribution was especially evident and may be particularly significant if as cited in Asay _et al_. (1977), wide leaf plants have a greater sink capacity for energy accumulation and thus greater potential for growth. Further studies are needed to identify the variability and inheritance of leaf width in tall fescue and to further elaborate the significance of this factor in forage yield.

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APPENDIX

Appendix Table 1. Average monthly temperature and precipitation from March-September, 1975/76/77.

Month	Average temperature °C Mean max.	Mean min.	Monthly avg.	Precipitation, mm Total	Departure from normal
			1975		
March	11.17	2.11	6.64	24.89	-81.8
April	12.50	1.72	7.11	60.96	+ 8.9
May	18.83	5.78	12.13	52.58	+ 7.6
June	22.00	8.17	15.09	28.96	- 0.3
July	26.56	10.61	18.59	15.75	+ 7.4
Aug.	24.44	10.22	17.33	42.67	+28.7
Sept.	27.00	8.11	17.56	0.00	-33.3
			1976		
March	11.22	1.50	6.36	113.03	+ 6.4
April	14.06	3.22	8.64	50.29	- 1.8
May	19.48	5.11	12.29	28.96	-16.0
June	21.06	6.91	13.98	11.94	-17.3
July	26.17	10.22	18.19	22.86	+14.5
Aug.	24.50	11.22	17.89	52.83	+38.9
Sept.	24.72	9.61	17.17	32.26	- 0.8
			1977		
March	11.39	1.50	6.45	129.29	+22.6
April	17.17	3.11	10.14	25.91	-26.2
May	16.56	5.33	10.94	87.12	+42.2
June	23.67	8.72	16.22	28.70	- 0.5
July	26.00	9.50	17.78	3.05	- 5.3
Aug.	29.78	12.00	20.89	48.01	+34.0
Sept.	21.56	8.78	15.17	90.93	+57.7

Appendix Table 2. Correlation coefficient and coefficient of determination for yield and leaf characteristics, leaf area per tiller, tiller number, tiller dry weight, and LAI in four tall fescue selections, July harvest of 1977.

	Characters	df	R^2	r
	Leaf Elongation Rate	10	.2019	.4493 (NS)
plus	Leaf Width	9	.5555	.7453 *
plus	Leaf Area Expansion Rate	8	.5814	.7625 (NS)
plus	Leaf Area per Tiller	7	.5829	.7635 (NS)
plus	Tiller Number	6	.8410	.9171 *
plus	Tiller Dry Weight	5	.9054	.9510 *
plus	LAI	4	.9208	.9596 (NS)