Reprinted from *Agronomy Journal*
Vol. 89, No. 4

Cattle Grazing Preference among Eight Endophyte-Free Tall Fescue Cultivars

Glenn E. Shewmaker,* Henry F. Mayland, and Susie B. Hansen

ABSTRACT

'HiMag' tall fescue (*Festuca arundinacea* Schreb.) was selected for high Mg concentration to reduce grass tetany risk to ruminants, but neither animal preference nor consumption of HiMag were known. The objectives were to evaluate methods of quantifying preference and to determine intake and preference by cattle (*Bos taurus* L.) of HiMag relative to seven other tall fescues. All entries were free of a fungal endophyte [*Neotyphodium coenophialum* (Morgan-Jones & Gams) Glen, Bacon & Hanlin] that reduces cattle performance. The experimental design was a randomized complete block with three replications of eight cultivars nested within each of three test pastures. Six heifers grazed the vegetative to boot-stage pastures for 48 h in May, June, August, and September of 1993 and 1994. The pastures, located at 1200 m elevation, were furrow irrigated. Pre- and postgrazed forage were clipped and weighed to determine yield and utilization (48-h utilization < 50%). Preference scoring of 0 to 10 (0 to 100% of forage eaten) was done by four trained observers at 24, 30, and 48 h. The heifers quickly learned to distinguish between cultivars, and their order of preference was Kenhy > KY 31 > HiMag = Barcel = C1 = Stargrazer > MO96 = Mozark. The cultivar × trial(year) interaction for preference indicated that cultivars responded differently to weather conditions, which in turn affected animal preference. Preference scoring had high repeatability and ranked cultivars similarly to the clip-and-weigh method of measuring utilization. Preference scoring was accomplished with 27% of the experimental error and only 6% of the time required for clip-and-weigh. Only 44% of the variation in preference score (PS) was explained by the model: PS = 8.8 − 1.1(Mg DM yield ha^{-1}). Estimated dry matter (DM) intake of HiMag was 6.4 kg (animal unit day)$^{-1}$. Consumption and preference of HiMag by cattle are satisfactory relative to other tall fescue cultivars.

A SELECTION PROGRAM at the University of Missouri using 'KY 31' and 'MO 96' clones produced a tall fescue breeding line with low grass tetany risk. This line, called HiMag, was selected from the second generation (Mayland and Sleper, 1993). HiMag had 20% higher levels of Mg and Ca in the forage, and lower K/(Mg+Ca) than populations of the parent cultivars. It is estimated that HiMag could reduce the risk of grass tetany from tall fescue, a $50 million annual loss, by 80% (Mayland and Sleper, 1993).

Grass cultivars are normally selected for yield and resistance to disease and pests. From a livestock production standpoint, however, dry matter intake must be at a level where the animal can meet physiological requirements and other production goals, such as milk production or weight gain. Few studies report intake and preference on endophyte-free tall fescue. Read and Camp (1986) reported that daily gains by cattle grazing high endophyte-infested Kenhy were reduced by 50% compared with those grazing non- or low-infested Kenhy. Our objectives were to evaluate methods of determining preference and to measure utilization and preference of HiMag by cattle relative to other tall fescues, all of which were free of the fungal endophyte *Neotyphodium coenophialum* (Morgan-Jones & W. Gams) Glenn, Bacon & Hanlin (syn. *Acremonium coenophialum* Morgan-Jones & W. Gams).

USDA-ARS, Northwest Irrigation and Soils Res. Lab., 3793 N. 3600 E., Kimberly, ID 83341. Received 5 Aug. 1996. *Corresponding author (shew@kimberly.ars.pn.usbr.gov).

Published in Agron. J. 89:695–701 (1997).

MATERIALS AND METHODS

Pasture Establishment and Maintenance

Endophyte-free seeds (4.7 kg ha^{-1}) of eight tall fescue cultivars were drilled in 7.6 m-long rows spaced at 0.56 m on 20 Sept. 1991. The soil was a surface-irrigated Portneuf silt loam (coarse-silty, mixed, mesic Durixerollic Calciorthid) near Kimberly, ID (42°30′ N, 114°8′ W; elevation 1200 m). Irrigation furrows were placed 1.1 m apart between every other forage row. Seedlings in the 0.4-ha nursery were successfully established by 21 Oct. 1991, when growth stopped for the winter. The tall fescue cultivars[1] seeded were 'Barcel', 'Mozark', 'Kentucky 31' (KY 31), 'Stargrazer' (Alderson and Sharp, 1995); 'Missouri 96' (MO 96), 'Kenhy' (Asay et al., 1979); and the first generation (C1) and second generation ('HiMag') selected for high Mg and Ca concentrations and reduced K/(Ca+Mg) (Mayland and Sleper, 1993).

Adequate soil water and fertility, and mechanical clipping promoted vigorous vegetative growth throughout the study. After each grazing period, forage on all pastures was flail-mowed to a uniform height (8 cm), fertilized with 50 kg N ha^{-1} as broadcast ammonium nitrate and immediately irrigated, or as liquid urea–ammonium nitrate applied in the irrigation water.

Experimental Design

The experimental area was divided into four pastures, each of which contained three replicates of eight plant cultivars in a randomized complete block design (Fig. 1). Pasture 4 was used at the beginning of each grazing trial to condition animals and experimenters to the test pastures and procedures. Pastures 1, 2, and 3 were used to test cattle preference. Each plot (cultivar) was composed of six rows 56 cm apart and 6.7 m long, having an area of 22.5 m^2. A 0.5-m bare alley existed between replicates and a 3-m bare alley between pastures. Two border rows of four additional cultivars occurred on each side of the pasture. Pastures (24 by 29 m) with three replicates nested within were enclosed by electric fence. Water was provided in 100-L plastic tubs located in each corner of each pasture and tubs were not refilled until almost empty. Plain salt blocks (NaCl) were placed at the middle of the two long edges of each pasture. The placement of salt and water minimized attraction of animals to any one location in the pastures.

Grazing Procedures

Six yearling heifers (four Hereford and two Angus × Hereford) with 286-kg average initial weight were used throughout

[1] Mention of a trade name does not imply an endorsement or recommendation by the USDA over similar companies or products not mentioned.

Abbreviations: AU, animal unit; AUD, animal unit day; DM, dry matter; PS, preference score: RMSE, root mean square error; SR, selection ratio.

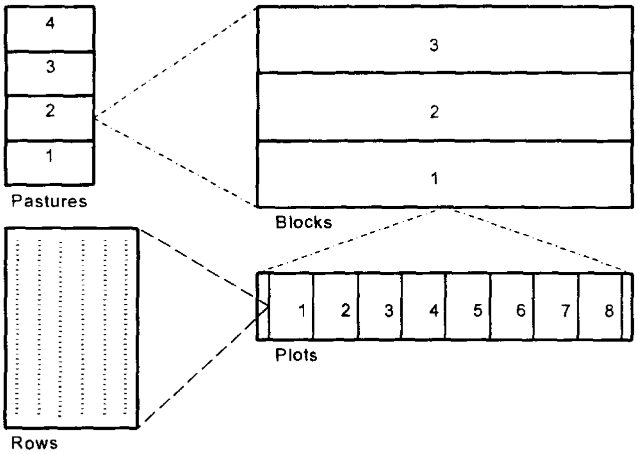

Fig. 1. Experimental plot design of tall fescue pastures at Kimberly, ID. Pasture 4 was used to precondition animals and Pastures 1, 2, and 3 were used in the tests.

1993. A second group of six yearling heifers (three Hereford and three Angus × Hereford), with an average initial weight of 281 kg, was used throughout 1994. The stocking density was 11 AU ha^{-1}. The forage allowance (Forage and Grazing Terminology Committee, 1992) ranged from 90 to 300 kg forage DM AU^{-1} (Table 1). The stocking rate was designed to remove an average of 50% of the forage in a 48-h period for optimum sensitivity of preference. Preference was defined as diet selection in the current environment—the interaction of the animal with its grazing environment.

Four grazing trials were conducted during each of two years (Table 1). Animals were conditioned for 48 h on Pasture 4 and then allowed to graze for 48-h periods on each of experimental Pastures 3, 2, and 1. Exceptions included a 30-h grazing of Pasture 3 during Trial 3 of 1994, and use of five rather than six animals in Trial 4 of 1994, because of low grass production. Each grazing period was initiated at 1000 h by opening the pasture cross fence. The heifers immediately and voluntarily traveled to the fresh pasture, regardless of forage remaining on the grazed pasture. Cross fences restricted the animals to the assigned pasture.

Between experimental periods, animals grazed irrigated pastures of endophyte-free HiMag and 'Martin' tall fescue. Individual animals were socially adjusted to the group before the experiment and were accustomed to humans in close proximity.

Forage Measurements

Forage yield was determined by clipping to an 8-cm stubble height on a randomly selected 60-cm length in each of Rows 3 and 4. The pregrazing clipping of two subplots was a compromise between reducing the sampling error and reducing the anticipated effect of the destructive sampling on grazing behavior. Reproductive tillers were counted in each of the clipped samples. Fresh samples were weighed, subsampled, and composited by plot. The composited subsamples were freeze-dried and weighed to determine DM concentration. Forage DM yield was calculated by correcting fresh weights for DM concentration and area. Perloline was analyzed on August 1994 samples composited within cultivars from pregrazing Replicates 1, 2, and 3 of Pasture 1 (Bush et al., 1970).

Postgrazing available forage was clipped to an 8-cm stubble height from three randomly selected 60-cm lengths in Rows 2, 3, and 4 or 3, 4, and 5 of each plot to determine postgrazing forage yield. After Trial 1 (May 1993) postgrazing available forage was clipped only from Rows 3 and 4. Postgrazing samples from Pastures 2 and 3 were dried in a forced-air oven (60°C), weighed, and discarded; those from Pasture 1 were freeze-dried, weighed, and stored.

Forage consumed (utilization) or estimated DM intake was calculated as the difference between pregrazing and postgrazing DM yields on Rows 3 and 4. Forage selection ratios (SR) were computed for each cultivar in each pasture and grazing season (Stuth, 1991). The selection ratios compared the proportion of a cultivar's forage in the test animals' diet with the proportion of forage of that cultivar available in the pasture. It was calculated as

$$\mathrm{SR} = \frac{\dfrac{\text{forage DM of cultivar consumed}}{\text{forage DM of all forage consumed}}}{\dfrac{\text{pregrazing forage DM of a cultivar}}{\text{pregrazing forage DM of all cultivars}}} \quad [1]$$

The ratios were based only on Rows 3 and 4 within a pasture and grazing period.

Preference Scores

Preference scores were ocular estimates of utilization at 24, 30, and 48 h after initiating grazing. The 30 and 48-h scores provided more complete information than the 24-h scores, so the 24-h scores are not reported. Four observers without knowledge of cultivar location independently scored each row on a scale which ranged from 0 = no use to 10 = 100% use.

Table 1. Cattle grazing trial dates, elapsed days, average daily weather measurements during the trials, dry matter (DM) yield at beginning of trial, and forage allowance for tall fescue preference study in Kimberly, ID.

Trial	Dates	Elapsed time†	Avg. air temp.	Max. 10-cm soil temp.	Solar radiation	Pan evap.	Wind run	Thermal time	Forage DM yield	Forage allowance‡
		d	°C		MJ m^{-2}	mm	km	GDD§	kg ha^{-1}	kg AU^{-1}
1993										
1	08–16 May	127	15.2	19.3	26.3	8.7	346	467	3010	230
2	12–20 June	27	15.0	22.5	30.0	6.9	243	698	1840	130
3	07–15 Aug.	48	18.8	26.5	20.7	6.6	209	1233	4140	270
4	11–19 Sept.	27	13.2	18.9	18.4	5.7	240	794	2950	180
1994										
1	07–15 May	126	15.8	20.6	23.6	6.9	250	803	3890	300
2	11–19 June	27	16.1	21.4	28.2	8.6	283	664	1720	120
3	10–18 Aug.	52	21.1	27.1	23.0	7.3	245	1626	1700	110
4	17–25 Sept.	30	16.5	21.5	20.0	6.2	170	934	1300	90

† Days from beginning of calendar year to grazing Trial 1 or end of previous grazing trial to beginning of Trial 2, 3, or 4.
‡ Forage allowance (Forage and Grazing Terminology Committee, 1992) is the total forage DM available at the beginning of the trial divided by the standardized animal unit AU: [body weight in kg (500 kg)$^{-1}$]$^{0.75}$.
§ GDD, cumulative growing-degree days calculated for base 4.4 to 31.7°C.

The procedure was similar to that used by Johnston (1988a,b) and Rumbaugh et al. (1993) to assess palatability of a grass and grass plus forbs, respectively. The scores were averaged across observers for each of Rows 1 to 6.

Statistical Analyses

Data were confirmed to be normally distributed and were analyzed by the method of least squares to fit general linear models (SAS, 1990). Experimental units were the individual plots (cultivars) after reducing row data to plot means within replications, pastures, trials, and years. Year, year × cultivar, trial, and trial × cultivar effects were all significant; therefore, further analysis was done by year and by trial. The model assumed that cultivar and trial were fixed effects, and that pasture and replicate were random. Cultivar was tested by the pasture × cultivar interaction and pasture by the replicate within pasture mean squares. The LSD test was performed on cultivars only if mean squares for cultivars were significant. Preference scores on Rows 3 and 4 were regressed on selection ratios for the same rows.

We anticipated a border row effect on grazing preference; thus, orthogonal differences between sets of rows, as an effect, were assessed by single degree of freedom contrasts (data not shown). Occasionally, the variability in forage yield for both pre- and postgrazing and regrowth during a 48-h grazing period resulted in negative utilization values (17 and 7% of observations in 1993 and 1994, respectively). Such values were corrected to a small positive number (0.0001) prior to further calculations.

RESULTS

Preference Determinations

The preference rankings of cultivars were generally the same across years, although there were significant ($P < 0.05$) year, trial(year), cultivar × year, trial, and cultivar × trial(year) effects. The mean squares for 48-h preference scores as analyzed by trial and year are shown in Table 2. Table 1 lists some weather variables that may be associated with the year, trial, and cultivar interactions. Examination of mean 48-h preference scores by cultivar, trial, and year (Table 3) shows that much of the cultivar × trial interaction is caused by the inconsistent preference ranking of Barcel.

The cultivar effect was significant in every trial (Table 2). The pasture effect was significant in four of eight trials. Pastures served as blocks along an irrigation gradient and were expected to be different because of soil water content differences. Replicates nested within pastures were significant in three of the trials. Replicates were also serving as blocks along an irrigation gradient, which may explain the significant effect. The cultivar × pasture interaction was not significant in any trial. Therefore, the animals were generally consistent in preferring cultivars in the same order during the same environmental conditions.

Table 2. Analysis of variance by year and trial for cultivar effects on 48-h preference scores for cattle grazing tall fescue.†

		Preference score mean squares			
Source of variation	df	Trial 1	Trial 2	Trial 3	Trial 4
1993					
Cultivar	7	12.94***	12.18***	7.31***	19.19***
Cultivar × Pasture	14	1.07	0.41	1.26	0.50
Pasture	2	0.42	0.44	19.04***	10.77
Rep(Pasture)	6	1.22	1.78*	0.60	2.86
Residual	42	0.78	0.55	1.09	1.58
1994					
Cultivar	7	17.93***	8.21***	6.70***	8.87***
Cultivar × Pasture	14	0.31	0.72	0.45	0.38
Pasture	2	4.80***	6.24**	2.42	28.46**
Rep(Pasture)	6	0.17	0.51	2.15**	1.44*
Residual	42	0.54	0.46	0.41	0.59

*,**,*** Significant F-test by the Type III mean squares at the 0.05, 0.01, and 0.001 probability levels, respectively.

† Cultivar was tested with cultivar × pasture as an error term; pasture was tested by the rep(pasture) error.

Table 3. Mean preference scores for cattle grazing tall fescue cultivars by year, trial, and duration of grazing (30 and 48 h).

	Preference score†							
	Trial 1		Trial 2		Trial 3		Trial 4	
Cultivar	30 h	48 h	30 h	48 h	30 h	48 h	30 h	48 h
1993								
Kenhy	4.9	7.1	5.6	6.4	7.4	8.6	6.7	7.7
KY-31	2.5	5.3	3.0	3.9	5.2	7.1	4.0	5.2
HiMag	2.2	4.5	3.1	4.0	5.4	7.4	3.1	4.4
Barcel	4.5	6.6	2.9	3.9	3.9	5.6	4.3	5.3
C1	1.9	4.0	2.9	3.7	4.3	6.8	3.1	4.2
Stargrazer	1.9	4.5	2.4	3.3	4.7	6.4	2.7	4.0
MO-96	1.9	4.6	2.4	3.1	4.7	6.5	2.3	3.4
Mozark	1.5	3.9	1.6	2.4	4.0	6.1	1.7	2.9
LSD (0.05)	0.7	0.8	0.7	0.7	1.0	1.0	1.1	1.2
CV, %	29	17	24	19	22	15	32	27
1994								
Kenhy	5.4	6.8	7.3	8.8	8.1	8.6	7.8	8.2
KY-31	2.5	3.9	4.8	7.3	5.8	6.9	5.8	6.6
HiMag	2.7	3.8	4.3	6.6	5.3	6.6	5.6	6.5
Barcel	3.1	4.0	3.3	5.9	4.5	5.9	3.6	5.0
C1	2.5	3.7	4.2	6.4	5.3	6.5	5.6	6.8
Stargrazer	2.3	2.9	4.0	6.5	5.2	6.4	5.8	6.8
MO-96	2.1	2.9	3.3	5.8	4.2	5.7	4.0	5.4
Mozark	1.5	1.9	3.2	6.3	5.1	6.4	5.7	6.8
LSD (0.05)	0.7	0.7	0.6	0.6	0.8	0.6	1.0	0.7
CV, %	26	20	15	10	16	10	18	12

† Preference scores are rated from 0 = no evidence of grazing to 10 = all grazed to an 8-cm stubble height.

Table 4. Means of tall fescue forage dry matter (DM) yield before and after grazing by cattle, by year and trial.

Cultivar	Trial 1 Before	Trial 1 After	Trial 2 Before	Trial 2 After	Trial 3 Before	Trial 3 After	Trial 4 Before	Trial 4 After
	kg DM ha^{-1}							
1993								
Kenhy	3100	1740	1270	340	3330	1510	2190	560
KY-31	3030	2650	1710	670	3950	2240	2870	1680
HiMag	2800	2620	1650	650	3950	2930	2860	1780
Barcel	2700	2490	2130	1240	3950	2680	3080	1850
C1	3210	2780	1840	830	4050	3130	2770	1730
Stargrazer	2980	2610	2180	820	4640	3990	3270	1850
MO-96	2850	2830	2070	990	4730	3840	3140	2210
Mozark	3370	3450	1850	990	4500	4000	3380	3110
LSD (0.05)	NS	450	318	272	703	944	501	748
CV, %	14	18	18	35	18	33	18	43
1994								
Kenhy	3330	2050	1300	370	1300	230	1110	420
KY-31	3930	3160	1490	590	1670	830	1150	640
HiMag	4150	3040	1760	640	1850	600	1340	610
Barcel	3200	2730	1950	1040	2060	710	1320	930
C1	4400	3080	1720	890	1860	640	1340	630
Stargrazer	3880	3290	2050	780	1610	490	1280	650
MO-96	3710	3500	1990	880	1830	890	1530	850
Mozark	4550	4380	1530	570	1450	550	1300	430
LSD (0.05)	546	578	291	244	418	324	NS	272
CV, %	15	19	18	36	26	55	25	44

The general ranking of preference across years and trials (data not shown) was Kenhy > KY 31 = HiMag = Barcel = C1 = Stargrazer > MO 96 = Mozark. Preference ranking of cultivars (Table 3) was generally inverse to DM yields (Table 4). Kenhy was consistently the most preferred (Table 3) and was consumed to the 8- to 10-cm stubble height. Arias et al. (1990) suggested that steers avoided grazing Kenhy to a stubble height <10 cm because pseudostems were present and there was more senescent and dead material in that layer. Mozark was the least preferred of the eight tall fescues. Barcel was ranked second in preference during Trial 1 of both years, but decreased in rank during Trials 2, 3, and 4. Barcel and Mozark were the primary sources of the significant cultivar × trial interaction because their preference ranking changed between trials (Table 3). Preference ranking of Mozark changed from eighth in Trials 1 and 2 to midranking in Trials 3 and 4 of 1994.

The preference score method had high repeatability, with $r = 0.92$ between the independently determined 30- and 48-h scores. Moreover, the human eye and brain rapidly integrate estimates of forage weight for an entire row. Correlation coefficients of observer to observer preference scores ranged from a low of 0.83 to a high of 0.90 ($P = 0.0001$) with 3456 observations.

Forage DM Yield

Forage DM yields (Table 4) varied by trial and cultivar. For example, Mozark and C1 yielded high in Trial 1 of both years, but dropped in ranking during Trials 2, 3, and 4. Kenhy was the lowest-yielding cultivar. The additional 60-cm section of row clipped in Trial 1 of 1993 from either Row 2 or 5 was an attempt to reduce the postgrazing DM sampling error to the approximate pregrazing error level. However, the addition of a third row did not reduce the postgrazing DM error (2-row CV = 21% and RMSE = 19 vs. 3-row CV = 22% and RMSE = 20).

Selection Ratio and Utilization

Selection ratios were highly variable for Trial 1 in both years. The cultivar effect was not significant ($P > 0.05$) for Trials 2 and 4 in 1994 (Table 5). The utilization percentages are also shown in Table 5. Selection ratios were not highly correlated with the 48-h preference scores ($r = 0.25$). The preference scoring method is more sensitive and accurate than selection ratios and utilization percentages because the latter are based on clipped-weights of Rows 3 and 4 at pre- and postgrazing, and the CV were about twice the CV of preference scores (Shewmaker et al., 1995).

Factors Affecting Preference

Endophyte-free tall fescue seeds were planted, samples from the same seed packet tested negative one year later, and tests of random mature tillers from each cultivar in August 1995 were negative. Therefore, the confounding factor of reduced intake associated with the presence of the endophyte (*N. coenophialum*) was avoided.

There were no strong correlations between forage yield or dry matter concentration and cattle preference for tall fescue. The Pearson correlation coefficient ($P = 0.0001$) for the initial forage DM yield on 48-h preference scores was $r = -0.66$ (1993 and 1994 combined). The model to predict preference score (PS) by DM yield across years is

$$PS = 8.8 - 1.1(\text{Mg DM yield ha}^{-1}), \quad r^2 = 0.44 \quad [2]$$

The cattle preferred the lower-yielding cultivars; however, forage maturity was not a major factor in this

Table 5. Means of selection ratios (SR) and percent utilization (U) by year and trial for tall fescue cultivars grazed by cattle.

Cultivar	Trial 1		Trial 2		Trial 3		Trial 4	
	SR†	U	SR	U	SR	U	SR	U
		%		%		%		%
1993								
Kenhy	4.32	42.8	1.32	73.5	2.14	55.9	2.02	75.6
KY-31	0.86	16.2	1.08	60.9	1.54	45.3	1.14	44.0
HiMag	0.10	10.7	1.09	60.2	0.82	25.8	0.96	37.8
Barcel	−0.41	14.3	0.69	41.8	1.26	36.7	1.09	41.6
C1	0.60	16.6	0.96	55.1	0.63	26.1	0.97	40.0
Stargrazer	0.81	16.4	1.13	65.0	0.50	17.3	1.15	44.3
MO-96	−1.22	8.9	0.93	53.3	0.68	20.9	0.76	36.6
Mozark	−0.28	6.9	0.82	47.5	0.38	15.7	0.17	15.4
LSD (0.05)	2.61	10.7	NS	NS	0.74	16.5	0.61	19.1
CV, %	459.0	67.9	31.1	29.7	78.8	56.9	62.5	47.9
1994								
Kenhy	2.36	39.8	1.20	70.0	1.28	81.6	1.24	62.0
KY-31	0.39	23.8	1.03	60.0	0.79	50.8	0.76	46.3
HiMag	1.42	27.3	1.08	63.2	1.02	65.4	1.05	53.0
Barcel	0.54	14.8	0.78	46.0	0.96	63.5	0.60	36.7
C1	1.71	31.4	0.81	47.8	1.00	63.9	0.93	50.6
Stargrazer	0.54	15.9	1.03	60.4	1.05	67.6	0.92	49.8
MO-96	0.18	8.9	0.92	54.3	0.76	49.0	0.87	43.2
Mozark	−0.11	7.3	1.07	62.5	0.96	61.3	1.32	64.9
LSD (0.05)	1.17	10.3	0.21	11.9	0.22	13.4	NS	11.6
CV, %	140.0	51.1	22.8	21.6	24.0	22.1	39.3	24.0

† The selection ratio is proportion of a cultivar's forage in the test animals' diet with the proportion of forage of that cultivar available in the pasture. It is calculated as [(forage DM of cultivar consumed/forage DM of all forage consumed)/(pregrazing forage DM of a cultivar/pregrazing forage DM of all cultivars)].

study, because forage DM concentration had low correlation with 48-h preference score in 1993 ($r = -0.05$). In 1994, the r-value was 0.67 ($P = 0.0001$), which suggests that as DM concentration increased the preference increased. Barcel was lower ($P = 0.05$) in forage DM concentration (221 mg g^{-1}) than the other cultivars (234 mg g^{-1}).

Multiple linear regression analysis by year produced the following models to predict 48-h preference score. In 1993:

$$PS = 7.4 - 1.01(\text{Mg DM yield ha}^{-1}) + 0.0051(\text{DM conc.}), \quad R^2 = 0.31 \qquad [3]$$

And in 1994:

$$PS = 5.8 - 0.98(\text{Mg DM yield ha}^{-1}) + 0.011(\text{DM conc.}), \quad R^2 = 0.57 \qquad [4]$$

The models were significant ($P = 0.0001$) because of the large sample ($n = 576$), but they explained only 31 and 57% of the variation for 1993 and 1994, respectively. The prediction intervals are so large that using the models to predict preference is not practical.

There was a significant row effect. The preference scores for the set of rows on the edge of the plot (Rows 1 and 6) were lower ($P < 0.05$) than for the middle rows (3 and 4). The set of Rows 2 and 5 also had lower ($P < 0.001$) preference scores than the middle pair of rows (3 and 4) (Shewmaker et al., 1997).

Trials 1 and 2 in both years occurred when most plants were at the boot stage; however, some reproductive tillers emerged, primarily on the sides of the rows. The highest mean stem density was 70 m^{-2} during Trial 2 of 1993. Correlation analyses (data not shown) indicated no relationship between stem density and utilization; therefore, the number of stems was not used as a covariate in this analysis. At that density, the animals simply avoided the stem but could easily obtain the leafy forage.

DISCUSSION

Sampling Techniques

The ranking of cultivars by the selection ratio, utilization, and preference score methods were generally similar (Tables 3 and 5). The preference score method provided more statistical mean separation because of less experimental error. Since the preference scores are arithmetic means of four observers and six rows, one would expect less variation because of the central-limit theorem (Mood 1950; see also Snedecor, 1956). The selection ratio method theoretically is good because it should normalize the quantity of forage ingested based on its relative abundance. In this study, the selection ratio had a high CV because of a large experimental error and variation of DM yield. The consequence was less mean separation of the cultivars, although cultivar ranking was similar to the preference score method.

Subjective scoring is nondestructive and more flexible and rapid than clipping and weighing. Destructive clipping decreases available forage, and may influence animal grazing behavior. Preference scoring took about 1.3 min per plot (all six rows) vs. 17 min per plot (only two rows) for clipping and weighing. Technicians also preferred scoring, as the technicians remained an order of magnitude cleaner than when clipping the after-grazing plots. The local area around a fresh dung pat can be consciously ignored in the observational scoring technique.

Buckner and Burrus (1962) recognized greater precision in subjective scoring compared with the clip-and-weigh technique. They also acknowledged that consciously ignoring dung pat effects increases the precision of the observational technique over the clipping technique. Their observational technique, which used a 9-point scale, was more precise than the before- and after-clipping technique. They reported CV of 19 and 20% for the two years, which is similar to the values we observed. There were significant entry × year interactions for both the observational and clipping techniques, as was observed in our study. Their preference ratings were correlated with the clipped weight data, $r = -0.85$ and -0.75 for the two years. Correlation coefficients for percent composition and DM yields, and for preference rating and DM yields, were low in both years (Buckner and Burrus, 1962).

Similarly, O'Donovan et al. (1967) reported that observing the grazing habits of sheep (*Ovis aries*) at 5-min intervals gave a more reliable measure of preference than did clipping before and after grazing (CV = 107%). Burns et al. (1978) reported that a defoliation score (1 = not grazed to 10 = grazed to stubble) produced a CV of 29%, slightly higher than in our study, vs. a CV of 87% for an occupancy score that recorded the position of the steers in the plots.

There were some instances of estimating negative values of forage consumption by the before and after-clipping technique in our study. This phenomenon was also reported by Petersen et al. (1958), who attributed it to large error (CV = 70 to 443%) even in homogeneous stands of forage. Negative utilization values in our study may be explained in part by continued forage growth during the grazing period, but we think the negative values were largely a result of variation in forage mass measurements.

Cultivar Effects

Weather factors (Table 1), probably temperatures, during 1993 and 1994 may have affected the plant physiology of cultivars and consequently cattle preference for tall fescues. The preference ranking of Barcel (Table 3) was 2, 3, 8, and 2 for Trials 1, 2, 3, and 4, respectively in 1993, and 2, 7, 7, and 8 during 1994. Barcel appears to be more preferred when grown at air temperatures <16°C (Tables 1 and 3). The smooth leaves of Barcel appeared to roll during heat stress before other cultivars. Tall fescue preference appears to have been affected by temperature or other weather conditions as indicated by the significant year and trial interactions with cultivar. Barcel was selected in the Netherlands, whereas the others were selected in Missouri and Indiana. Buckner (1960) also found significant grazing trial effects and significant grazing trial × entry interaction for seven tall fescue entries, most of which were closely related.

Animal Selection of Forage

Within an hour after grazing initiation, one plot in each replicate could be distinguished as being significantly utilized. The 24- or 30-h preference scores were adequate to distinguish the two or three most preferred tall fescues by the protected LSD test. Ranking of all eight cultivars did not change from the 30-h to the 48-h score. Animals used a selection process that is rapid, repeatable, but dynamic. Diet selection may have involved interplay between taste and postingestive feedback from nutrients (e.g., soluble carbohydrates), as discussed by Provenza (1995). Provenza describes postingestive feedback as effects of nutrients and toxins of a unique food on chemo-, osmo-, and mechanoreceptors of an animal. Animals can associate positive feelings obtained from eating and digesting a food with the taste and/or smell of that food. Aversions may be formed from foods with toxicants, foods with nutrient deficiencies, or from nutritionally adequate foods eaten in excess (causing the animals to experience malaise). Aversions diminish preference and cause animals to seek a variety of foods (Provenza, 1995). Postingestive feedback calibrates a food's taste with its homeostatic utility.

We hypothesize that cattle may receive mixed sensory input (especially olfactory) when selecting forage at outer edges of the plot, whereas in the center of the plot the senses should more distinctly identify palatability. It is also possible that the clipped area influenced cattle to utilize center rows disproportionately; however, Rows 2 and 5 also had higher preference scores than Rows 1 and 6. The heifers grazed substantially after dark, although we did not quantify the time. We observed that heifers did not necessarily taste the forage to select their diet, but merely passed their muzzles over the canopy, then decided to eat or move on. We interpret the results as evidence for selection by olfactory senses (Mayland et al., 1997).

Density of reproductive tillers was low and did not affect preference at these forage allowances. Vecellio et al. (1995) suggested that leaf-to-stem ratios did not limit preference by ewes grazing endophyte-free tall fescue as long as grazing pressure allowed for selection of leaf material.

Heifers gained 0.66 and 0.79 kg head^{-1} d^{-1} during Trials 1 through 4 in 1993 and 1994, respectively. In a more typical production situation, Sleper et al. (1994) reported steer gains of 0.45, 0.40, and 0.42 kg d^{-1} on HiMag, KY 31, and Mozark, respectively. Estimated DM intake in their study was 6.1 kg head^{-1} d^{-1} averaged across cultivars for both years. Essig et al. (1993) reported heifer gains of 0.48 kg d^{-1} on endophyte-free KY 31 pastures rotationally grazed to an 8- to 10-cm stubble height.

In our study, estimated DM intakes of HiMag were 5.4 and 7.4 kg head^{-1} d^{-1} in 1993 and 1994, respectively. Estimated DM intake rate (2.2% of body weight) in 1994 should be acceptable for cattle maintenance requirements. Estimated intake rates for 1993 seem low, but were based on clipping weights having large errors (15 to 55% CV). Nutrient concentration of herbage (data not shown) is another important factor affecting animal performance. Since the heifers gained weight and HiMag was ranked third in preference overall, intake of HiMag should be adequate.

Presence of perloline, an alkaloid, may also affect intake of tall fescue. Perloline can inhibit cellulose digestion by rumen microorganisms (Bush et al., 1970). In this study, perloline concentration was 343 (Kenhy), 207 (KY 31), 358 (HiMag), 98 (Barcel), 255 (C1), 257 (Stargrazer), 606 (MO 96), and 225 μg g^{-1} (Mozark) in August 1994 samples. These are below levels associated with animal aversion (L.P. Bush, personal communication; Bush et al., 1970). Kenhy, a perennial ryegrass × tall fescue backcrossed hybrid, had lower perloline concentration than KY 31 (Asay et al., 1979); however, the nutritive value index of Kenhy was not different from KY 31.

Herbivores grazing tall fescue discriminate between cultivars (Buckner and Burrus, 1962) and between different fertilizer treatments (Reid and Jung, 1965). In this experiment, pastures were well fertilized to avoid possible forage quality differences beyond genetic effects. Craigmiles (1964) reported that calves selected clones of tall fescue with broad, thick leaves over narrow-leaved clones. We did not measure leaf dimensions; however, we observed that rolling of Barcel leaves during heat or water stress may have affected grazing use (though by what factors is unknown).

Some authors suggest the hypothesis that Si may decrease animal selection of grasses. Silicon reduces digestibility of grass (Van Soest and Jones, 1968). Although we did not analyze Si in this study, Shewmaker et al. (1989) reported no relationship of sheep preference to Si concentration for 22 grasses, including 'Alta' tall fescue.

CONCLUSIONS

Observational scoring of preference was more precise and more easily obtained than utilization data determined by the clipping method. Preference scoring, utilization, and selection ratio methods were all successful in ranking preference of eight tall fescue cultivars. There was more variation, and hence less mean separation, of cultivar preference with the clipping method than the subjective preference scoring method. Preference scoring is probably the best method to determine palatability in forage breeding programs.

The overall ranking of preference was Kenhy > KY 31 > HiMag = Barcel = C1 = Stargrazer > MO 96 = Mozark. However, preference in tall fescue cultivars is dynamic and may be affected by weather factors and interactions. The DM yield and concentration, although related to preference, would be poor predictors of cattle preference among tall fescue cultivars. The HiMag cultivar has acceptable preference and DM intake by cattle.

ACKNOWLEDGMENTS

The authors thank B.E. Mackey (USDA-ARS, Albany, CA) for his suggestions in statistical analysis; D.A. Sleper (Univ. Missouri, Columbia, MO), Bret Winsett (FFR Coop., Lafayette, IN), G. van't Klooster (Barenburg Res., Rotterdam, The Netherlands), and C.W. Edminster (Int. Seeds, Halsey, OR) for endophyte-free seed; and L.P. Bush (Univ. of Kentucky, Lexington) for perloline analysis.

REFERENCES

Alderson, J., and W.C. Sharp. 1995. Grass varieties in the United States—USDA. (Rev. ed. of A.A. Hanson. 1972. Agric. Handb. 170.) Lewis Publishers, CRC Press, Boca Raton, FL.

Arias, J.E., C.T. Dougherty, N.W. Bradley, P.L. Cornelius, and L.M. Lauriault. 1990. Structure of tall fescue swards and intake of grazing cattle. Agron. J. 82:545–548.

Asay, K.H., R.V. Frakes, and R.C. Buckner. 1979. Breeding and cultivars. p. 111–139. *In* R.C. Buckner and L.P. Bush (ed.) Tall fescue. Agron. Monogr. 20. ASA, CSSA, and SSSA, Madison, WI.

Buckner, R.C. 1960. Performance of inbred lines, polycross progenies, and synthetics of tall fescue selected for improved palatability. Agron. J. 52:177–180.

Buckner, R.C., and P. Burrus. 1962. Comparison of techniques for evaluating palatability differences among tall fescue strains. Crop Sci. 2:55–57.

Burns, J.C., D.H. Timothy, R.D. Mochrie, D.S. Chamblee, and L.A. Nelson. 1978. Animal preference, nutritive attributes, and yield of *Pennisetum flaccidum* and *P. orientale*. Agron. J. 70:451–456.

Bush, L.P., C. Streeter, and R.C. Buckner. 1970. Perloline inhibition of *in vitro* ruminal cellulose digestion. Crop Sci. 10:108–109.

Craigmiles, J.P., L.V. Crowder, and J.P. Newton. 1964. Palatability differences in tall fescue using leaf and plant type. Crop Sci. 4:658–660.

Essig, H.W., B. Aremu, C.E. Cantrell, F.T. Withers, Jr., and D.J. Lang. 1993. Grazing management of endophyte-free fescue pastures. Prof. Anim. Sci. 9:107–113.

Forage and Grazing Terminology Committee. 1992. Terminology for grazing lands and grazing animals. J. Prod. Agric. 5:191–201.

Johnston, W.H. 1988a. Palatability to sheep of the *Eragrostis curvula* complex: I. Methods of assessing palatability. Aust. J. Exp. Agric. 28:41–45.

Johnston, W.H. 1988b. Palatability to sheep of the *Eragrostis curvula* complex: II. Selection of palatable taxa. Aust. J. Exp. Agric. 28:47–51.

Mayland, H.F., R.A. Flath, and G.E. Shewmaker. 1997. Volatiles from fresh and air-dried tissues of tall fescue (*Festuca arundinacea* Schreb.): Relationship to cattle preference. J. Agric. Food Chem. (in press).

Mayland, H.F., and D.A. Sleper. 1993. Developing a tall fescue for reduced grass tetany risk. p. 1095–1096. *In* M.J. Baker et al. (ed.) Proc. Int. Grassl. Congr., 17th, Palmerston North, NZ. 13–16 Feb. 1993. NZ Grassl. Assoc., Palmerston North.

Mood, A.M. 1950. Introduction to the theory of statistics. McGraw-Hill, New York.

O'Donovan, P.B., R.F Barnes, M.P. Plumlee, G.O. Mott, and L.V. Packett. 1967. *Ad libitum* intake and digestibility of selected reed canarygrass (*Phalaris arundinacea* L.) clones as measured by the fecal index method. J. Anim. Sci. 26:144–1152.

Petersen, R.G., P.H. Weswig, and J.R. Cowan. 1958. Measuring palatability differences in tall fescue by grazing sheep. Agron. J. 50: 117–119.

Provenza, F.D. 1995. Postingestive feedback as an elementary determinant of food preference and intake in ruminants. J. Range Manage. 48:2–17.

Read, J.C., and B.J. Camp. 1986. The effect of the fungal endophyte *Acremonium coenophialum* in tall fescue on animal performance, toxicity, and stand maintenance. Agron. J. 78:848–850.

Reid, R.L., and G.A. Jung. 1965. Influence of fertilizer treatment on the intake, digestibility, and palatability of tall fescue hay. J. Anim. Sci. 24:615–625.

Rumbaugh, M.D., H.F. Mayland, B.M. Pendery, and G.E. Shewmaker. 1993. Utilization of globemallow (*Sphaeralcea*) taxa by sheep. J. Range Manage. 46:103–109.

SAS Institute. 1990. SAS/STAT user's guide. Vol. 2. GLM-VAR-COMP. Version 6, 4th ed. SAS Inst., Cary, NC.

Shewmaker, G.E., H.F. Mayland, and S.B. Hansen. 1995. Determining animal preference for grasses: Methods and error analysis. p. 508. *In* N.E. West (ed.) Proc. Int. Rangeland Congr., 5th, Salt Lake City, UT. 14–28 July 1995. Vol. 1. Soc. Range Manage., Denver, CO.

Shewmaker, G.E., H.F. Mayland, and S.B. Hansen. 1997. Border effects on cattle grazing preference. p. 13–14. *In* B.R. Christie (ed.) Proc. Int. Grassland Congr., 18th., Winnipeg, MB, and Saskatoon, SK, Canada. 9–19 June 1997. Vol. 1, session 5. Int. Grassl. Congr., Calgary, AB, Canada.

Shewmaker, G.E., H.F. Mayland, R.C. Rosenau, and K.H. Asay. 1989. Silicon in C-3 grasses: Effects on forage quality and sheep preference. J. Range Manage. 42:122–127.

Sleper, D.A., H.F. Mayland, R. Crawford, R. Joost, B.J. Alabaugh, and M. Massie. 1994. Experimental high magnesium tall fescue. p. 22–24. *In* Southwest Missouri Ctr. 1994 Res. Rep. Univ. of Missouri, Columbia.

Snedecor, G.W. 1956. Sampling from a normally distributed population. p. 66–84. *In* Statistical methods. 5th ed. Iowa State Univ. Press, Ames.

Stuth, J.W. 1991. Foraging behavior. p. 65–83. *In* R.K. Heitschmidt and J.W. Stuth (ed.) Grazing management: An ecological perspective. Timber Press, Portland, OR.

Van Soest, P.J., and L.H.P. Jones. 1968. Effect of silica in forages upon digestibility. J. Dairy Sci. 51:1644–1648.

Vecellio, L.C., G.A. Jung, H.W. Harpster, J.A. Shaffer, C.E. Engle, and J.R. Everhart. 1995. Endophyte-free tall fescue cultivars grazed by sheep: Forage quality and sward characteristics. Agron. J. 87:1169–1175.