PASTURE MANAGEMENT

Forage Quality of Tall Fescue across an Irrigation Gradient

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ABSTRACT

Water available for irrigating pastures in the western USA is often limited and varies widely across sites and seasons. Objectives were to determine the trends in crude protein (CP), neutral detergent fiber (NDF), and in vitro true digestibility (IVTD) of 10 cultivars of tall fescue (*Festuca arundinaceae* Schreb.) at five levels of irrigation and three harvest dates (early, mid-, and late season). A secondary objective was to evaluate the effect of the endophytic fungus [*Neotyphodium coenophialum* (Morgan-Jones & Gams) Glenn, Bacon & Hanlin] on these trends. Cultivars differed significantly for CP, NDF, and IVTD, and differences were generally consistent across water levels (WLs). Concentration of CP increased in a near linear manner (154–189 g kg^{-1}) from the highest to lowest WL; however, total protein yield decreased from 611 to 447 kg ha^{-1} with less water, closely following the trend in forage yield. Forage quality at the late-season harvest, as indicated by lower NDF and higher IVTD values, was significantly higher at the lowest compared with the highest WL. Also, NDF was significantly lower and IVTD significantly higher at the late-season harvest at all WL. Presence or absence of the endophyte was not associated with CP; however, there was a tendency for the endophyte-free cultivar to have lower NDF and higher IVTD than its endophyte-infected counterpart at the higher WL. The magnitude of quality differences among the 10 cultivars indicates that forage quality should be a major consideration in the choice of cultivars for pastures of the Intermountain region.

RESTRICTIONS ON THE USE of public lands for livestock production has stimulated interest in improving the performance of animals grazing irrigated pastures in the Intermountain West. Perennial cool-season grasses are widely used in irrigated pastures of the Intermountain region; however, most cultivars of these species were developed for more humid areas (Alderson and Sharp, 1994). The USDA-ARS has initiated a breeding program to develop improved perennial grasses that are both productive and possess high quality for semiarid pasturelands, which are characterized by extreme temperature fluctuations and limited water resources.

Forage quality has been defined as the relative performance of animals when the forage is fed ad libitum (Buxton et al., 1996). It is influenced largely by nutrient concentration, intake potential, and digestibility of the forage. Constituents of cell walls (polysaccharides, lignin and phenolics, proteins, cutin, silica, and water) are the primary limitations to digestibility in forage grasses, whereas cell contents (organic acids, proteins, lipids, soluble minerals, and nonstructural carbohydrates) are usually highly digestible (Buxton et al., 1996). The detergent fiber system is widely used to estimate cell-wall concentrations in forage grasses. Neutral detergent fiber provides an estimate of the primary cell-wall components, such as hemicellulose, which is estimated as NDF minus acid detergent fiber (ADF), and cellulose, which is estimated as ADF minus lignin plus ash (Goering and Van Soest, 1970; Buxton et al., 1996).

Progress in breeding for improved quality in forages, including cool-season grasses, was reviewed by Casler and Vogel (1999). They concluded that genetic gains achieved in forages for in vitro dry matter digestibility (IVDMD) were comparable to those made for grain yield in many cereal crops. Heritable genetic variation was found in tall fescue for leaf tensile strength, NDF, ADF, and hemicellulose; however, no genetic variation was observed for IVDMD (Nguyen et al., 1982). In later studies with tall fescue, Bughrara et al. (1991) detected significant genetic variation for IVDMD, ADF, and NDF, and their results indicated that selection for improved IVDMD would be effective.

Poor animal performance and other disorders have been reported in animals grazing tall fescue (Schmidt and Osborn, 1993), and the presence of an endophytic fungus has been associated with these maladies (Bacon, 1995). Holstein dairy heifers (*Bos taurus*) produced 10% less average daily gain on endophyte-infected tall fescue hay compared with the endophyte-free forage of the same cultivar in trials conducted in northern Europe (Emile et al., 2000). However, no relationship was found between IVDMD or chemical composition and the presence of the endophyte in these trials. Bush and Burrus (1988) concluded in their review that CP, ADF, NDF, and IVDMD were not affected by the presence or absence of the endophyte. The endophyte did not consistently affect forage yield, IVDMD, or concentrations of N or NDF in tall fescue in Kentucky trials (Collins, 1991).

A line-source sprinkler system was designed (Hanks et al., 1976) and used to study the responses of several crop species, including cool-season grasses, to controlled irrigation levels (Johnson et al., 1982; Rumbaugh et al., 1984; Asay and Johnson, 1990; Asay et al., 2001; Jensen et al., 2001). Some constraints must be considered in

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Abbreviations: ADF, acid detergent fiber; CP, crude protein; IVDMD, in vitro dry matter digestibility; IVTD, in vitro true digestibility; NDF, neutral detergent fiber; NIRS, near infrared reflectance spectroscopy; WL, water level.

statistical analyses and interpretation of results from line-source irrigation experiments (Hanks et al., 1980). Plots assigned to WL are not randomized within replications; therefore, a valid error term is not available for testing the main effects due to WL. The *F* tests for other main effects and their interactions with WL are valid, provided that they are randomized within replications.

Little information is available regarding the effects of irrigation level on the forage quality of tall fescue and other cool-season grasses. Objectives of this study were to determine the trends in CP, NDF, and IVTD for 10 cultivars of tall fescue across an irrigation gradient. A secondary objective was to evaluate the effect of the endophyte on any observed differences and trends in forage nutritive value across the irrigation gradient.

MATERIALS AND METHODS

The experiment was conducted at the Utah State University Evans Research Farm located approximately 2 km south of Logan, UT (41°45′ N, 111°8′ W; 1350 m above sea level). Soil type at the site was a Nibley silty clay loam series (fine, mixed, mesic Aquic Argiustolls). Ten cultivars and experimental lines of tall fescue, previously described by Asay et al. (2001), were included in the study. Individual plots, consisting of six rows that were 15 cm apart and 15 m long, were drilled perpendicular to and on both sides of a line-source irrigation pipe. The grass entries were established in the plots as a randomized complete block with four replications, two on each side of the irrigation pipe. Plots were divided into five 2-m-long subplots or WLs that were separated by 1-m alleys. Plots nearest to the sprinkler line, which received the most water, were designated as WL-1, and those most distant to the sprinkler line were designated as WL-5.

During the establishment year (1995), plots were irrigated as needed, and 112 kg N ha^{-1} was applied as a split application during midsummer and fall. Fertilizer applications (56 kg N ha^{-1}) were made before the first harvest and after Harvests 2, 4, and 6 in 1996 and 1997 and before the first harvest and after Harvests 2, 4, and 5 in 1998. Plots were harvested at the boot stage of plant development at the first harvest and thereafter when the regrowth height was 25 to 30 cm. A gradient of plant growth across WL was not achieved in 1996; therefore, only results from 1997 and 1998 are reported. Plots were harvested six times in 1997, and samples for determinations of forage quality were obtained at Harvests 2 (4 June), 4 (22 July), and 6 (23 September). Of the five harvests made in 1998, forage quality was determined at Harvests 2 (18 June), 4 (17 August), and 5 (1 October). These sampling dates were designated as early, mid-, and late season for each year, respectively.

Forage quality samples were dried at 60°C, double-ground with a Wiley and Cyclone mill to pass through a 1-mm screen, and scanned with a Model 6500 near infrared reflectance spectroscopy (NIRS) instrument (Pacific Sci. Instruments, Silver Spring, MD). NIRSystems software was used to calibrate an existing ISI Forage Equation, IS-0122FS (Infrasoft Int. LLC, Port Matilda, PA). Representative samples were selected from each year and harvest and used as a calibration data set for wet laboratory analyses. This data set for calibration consisted of 473 samples for NDF, 440 for CP, and 441 for IVTD. Validation of the new equation was determined from a different set of samples including 119 samples for NDF, 130 for CP, and 112 for IVTD. The r^2 values for validation, computed from the six combinations of year and harvest, ranged from 0.96 to 0.99 for CP, 0.82 to 0.93 for NDF, and 0.72 to 0.91 for IVTD. The low r^2 for IVTD was associated with apparent lower precision of determinations at the early-season harvest.

Table 1. Amounts of water applied to plots at early-, mid-, and late-season harvests during 1997–1998.

Harvest	Water level	1997	1998	Mean
		mm d^{-1}		
Early season†	1	3.00	3.30	3.15
	2	2.80	3.16	2.98
	3	2.59	3.04	2.81
	4	2.44	2.97	2.70
	5	2.21	2.88	2.54
Midseason	1	4.35	4.59	4.47
	2	3.79	3.99	3.89
	3	3.13	3.30	3.21
	4	2.72	2.93	2.83
	5	2.16	2.25	2.20
Late season	1	5.03	4.72	4.88
	2	4.35	4.06	4.21
	3	3.47	3.47	3.47
	4	2.98	2.88	2.93
	5	2.12	2.02	2.07
Seasons combined	1	4.13	4.20	4.16
	2	3.64	3.74	3.69
	3	3.06	3.27	3.17
	4	2.71	2.93	2.82
	5	2.16	2.38	2.27

† See Materials and Methods section for harvest dates.

Samples used for calibration were analyzed for N using a LECO CHN-2000 Series Elemental Analyzer (LECO Corp., St. Joseph, MI). The first stage of the IVTD procedure consisted of a 48-h in vitro fermentation in the ANKOM Daisy II incubator (ANKOM Technol. Corp., Fairport, NY). Analyses for NDF and for the second stage of IVTD procedure were made with an ANKOM-200 Fiber Analyzer (ANKOM Technol. Corp., Fairport, NY).

Data were analyzed within and across years and WLs using the GLM procedure with a random statement (SAS Inst., 1999). Effects due to grass entry, WL, and year were considered as fixed and replications as random. Although the main effect for WL should be evaluated with caution, it was tested with the replication × WL mean square. Mean separations were made on the basis of Fisher's protected least significant difference (LSD) at the 0.05 level of probability. Linear, quadratic, and cubic trends of CP, NDF, and IVTD across WLs were determined for each cultivar using orthogonal polynomials with unequal intervals (Gomez and Gomez, 1984). Amounts of water (mm d^{-1}) received by the plots from 1 April until the harvest date were used in the computation of the coefficients (Table 1).

RESULTS AND DISCUSSION

Crude Protein

Differences among the tall fescue cultivars were significant for CP at the early- ($P < 0.05$) and midseason ($P < 0.01$) harvests and in the analysis of data combined across harvests ($P > 0.01$; Table 2). Differences among cultivars were relatively consistent across the 2 yr of the study for CP, as indicated by the nonsignificant cultivar × year interactions at each of the three harvests and in the analyses combined across harvests.

Relative differences among cultivars for CP were consistent across WLs; the WL × cultivar interaction was significant ($P < 0.05$) only at the early-season harvest. For example, the cultivars Advance and MO-HDII were consistently in the high-CP tier of cultivars across WLs (Table 3, data not shown for individual WLs). Other

Table 2. Mean squares from analyses of variance for crude protein (CP), neutral detergent fiber (NDF), and in vitro true digestibility (IVTD) of 10 tall fescue cultivars at five water levels (WLs), three harvest dates, and 2 yr.

Source	df	Harvest Early	Mid	Late	Combined
		$g^2\ kg^{-1}$			
		CP			
Cultivar (C)	9	1 235*	1 063**	484	2 031**
Water level†	4	2 043**	12 381**	34 375**	38 455**
C × WL	36	220*	119	129	152
Harvest (H)	2				34 443**
C × H	18				316*
WL × H	8				6 111**
C × WL × H	72				153**
Year (Y)	1	54 709*	1 067	23 826**	41 799*
C × Y	9	485	277	61	211
WL × Y	4	2 605**	1 960**	1 654**	1 400**
H × Y	2				18 845**
C × WL × Y	36	85	99	58	80
C × H × Y	18				304
WL × H × Y	8				2 384**
C × WL × H × Y	72				81
		NDF			
C	9	3 150**	1 940**	2 329**	2 614**
WL	4	80	978*	7 782**	3 572**
C × WL	36	484*	156	111	253
H	2				21 2534**
C × H	18				2 314**
WL × H	8				2 561**
C × WL × H	72				237*
Y	1	2 025	503	436	699
C × Y	9	766	424	263	426
WL × Y	4	2 192*	710*	1 791**	517
H × Y	2				1 138
C × WL × Y	36	221	155	64	108
C × H × Y	18				473
WL × H × Y	8				2 102**
C × WL × H × Y	72				155
		IVTD			
C	9	3 545**	2 693**	1 749**	7 063**
WL	4	263	709**	1 511**	1 783**
C × WL	36	145	68	77	134
H	2				40 852**
C × H	18				430**
WL × H	8				311**
C × WL × H	72				74
Y	1	27 044*	18 358**	21 705**	5 066
C × Y	9	257	367*	58	239*
WL × Y	4	1 161**	877**	150	264
H × Y	2				30 792**
C × WL × Y	36	117	82	44	93
C × H × Y	18				198
WL × H × Y	8				857**
C × WL × H × Y	72				72

* Significant at the 0.05 level.
** Significant at the 0.01 level.
† *F* tests for mean squares due to WL should be interpreted with caution because plots assigned to WL are not randomized within replications.

cultivars such as Ky31e−, Ky31e+, Himag, and MO-96 tended to be in the low-CP group. Although the cultivar × harvest date interaction was significant ($P < 0.05$), the rankings among the cultivars were relatively consistent across harvest dates, and correlation coefficients (r) among harvest dates (based on cultivar × harvest × WL means) were all positive and significant ($P < 0.01$), ranging from 0.54 to 0.85. The significant interaction was apparently associated with changes in magnitude of variation among cultivars at each harvest.

Although statistical interpretations of the WL main effect should be evaluated with caution, substantial differences in CP were found among WLs (Table 2). Most noteworthy was that mean CP for all cultivars increased almost linearly from the wettest (WL-1) to driest (WL-5) WL. Linear trends in CP across WLs, based on orthogonal polynomials with unequal spacings, were significant ($P < 0.01$) for all cultivars and in the analysis of the data combined across cultivars (Table 3). The nonlinear trends were significant only for the quadratic effect in the analysis combined across cultivars and for the cultivars Advance and MO-96. Regression coefficients (b) based on data combined across cultivars, harvests, and years showed that CP decreased 20 g kg^{-1} for each millimeter per day increase in water received by the plots. The rate of decline was relatively consistent across cultivars, with b values ranging from −18 to −22 (data not shown).

The significant ($P < 0.01$) WL × harvest date interaction suggests that the trends in CP across WLs were affected by harvest date (Fig. 1). Values of CP increased at a slower rate with decreased water for the early-

Table 3. Means and orthogonal trends across five water levels for in vitro dry matter digestibility (IVTD) of 10 tall fescue cultivars combined across three harvests and 2 yr.

	Crude protein				Neutral detergent fiber				In vitro true digestibility			
Cultivar	Mean	Linear†	Quadratic	Cubic	Mean	Linear	Quadratic	Cubic	Mean	Linear	Quadratic	Cubic
	g kg^{-1}	%			g kg^{-1}	%			g kg^{-1}	%		
Advance	176	94**	6*	0	461	65	12	23	880	88	0	11
Alta	171	99**	1	1	468	42	0	57	856	19	2	75**
Fawn	171	97**	4	0	473	83**	0	0	855	27	68	1
Forager	170	96**	1	1	466	60**	1	5	855	25	31	7
Himag	164	97**	1	2	459	24	72	2	858	38*	41*	18
Ky31e−	163	98**	3	0	468	10	73**	16	862	1	92**	3
Ky31e+	165	96**	2	0	472	53	1	32	859	41	22	21
MO-96	166	88**	12**	0	470	14	6	25	859	79**	18	0
MO-HDII	173	96**	0	1	474	10	46*	42*	862	0	64**	30*
Martin	173	100**	0	0	470	67**	24*	8	852	49*	45*	4
LSD$_{(0.05)}$	7.1	–	–	–	5.4	–	–	–	3.3	–	–	–
Mean	169	98**	2**	0	468	51**	21*	27**	860	38*	45**	15*

* Significant at the 0.05 level.
** Significant at the 0.01 level.
† Orthogonal trends expressed as percent of water level sums of squares due to linear, quadratic, and cubic effects, based on orthogonal polynomials with unequal spacings.

and midseason harvests than for the late-season harvest. This trend was likely associated with seasonal precipitation levels. Because of the abnormally high precipitation received by the plots early in the season for the 2 yr that data were collected, a distinct gradient in plant growth did not occur until later in the season. This explanation was supported by the trends observed in dry matter yield at these harvest dates (Fig. 2a). Dry matter yield, which was determined earlier by Asay et al. (2001), remained relatively uniform across WLs at the early-season harvest. Less forage was produced at the two later harvests, and a curvilinear trend was evident across WLs, with little or no response between WL-1 and WL-3 and a nearly linear decrease thereafter.

Although CP (g kg^{-1}) increased at low irrigation levels (Fig. 1), more CP was produced per hectare at higher levels of irrigation because dry matter yield was much higher at these WLs (Fig. 2b). These observations suggest that more N was taken up from the soil at the higher WLs but was allocated over a larger amount of plant mass compared with the low WLs. In contrast, water-limited plants growing at the low WLs were able

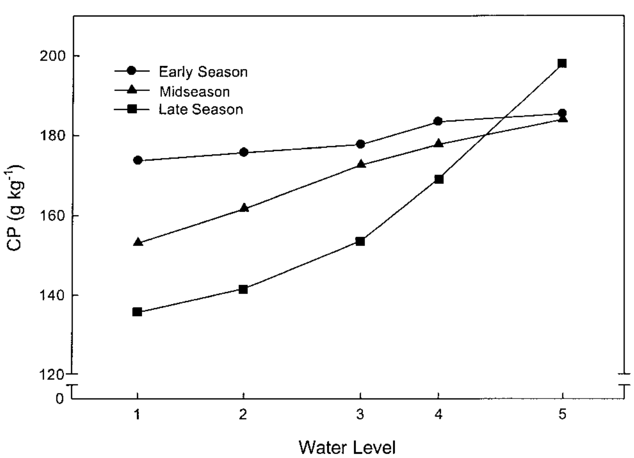

Fig. 1. Trends in crude protein (CP) of 10 tall fescue cultivars across five water levels (WLs) at three harvests. The LSD$_{(0.05)}$ values for differences among harvests were 4.6, 9.2, 5.7, 7.9, and 8.4 g kg^{-1} at WL-1 through WL-5, respectively.

to take up N from the soil but were unable to produce high yields because of limited water. This observation suggests that higher CP (g kg^{-1}) under low WL was likely induced by water limitations on growth.

Neutral Detergent Fiber

Cultivars differed significantly ($P < 0.01$) for NDF at each harvest date and in the analyses combined across harvests (Table 2). Moreover, differences among cultivars for NDF were consistent across years, and the cultivar × WL interaction was significant ($P < 0.05$) only at the early harvest. However, the cultivar × harvest interaction was significant ($P < 0.01$), and the correlations (r) among harvests were all nonsignificant (data not shown). For example, cultivars Fawn and Martin were in the low-NDF group at the early harvest and in the high group at the mid- and late harvests, and MO-96 had relatively high NDF values at the early and midharvests and low NDF at the late harvest (data not shown).

Although the F tests for WL were significant in all analyses except the early-season harvest (Table 2), no consistent trend in NDF across WLs was detected among the tall fescue cultivars (Table 3). In the analyses combined across cultivars, harvests, and years, 51, 21, and 27% of the sums of squares for WL were due to linear, quadratic, and cubic effects, respectively. Although the cultivar × WL interaction was nonsignificant for the midseason, late-season, and combined harvests, these trends were highly variable among cultivars. For example, highly significant linear trends were detected for the cultivars Fawn, Forager, and Martin, whereas nonlinear trends were predominant for Ky31e− and MO-HDII.

The significant ($P < 0.01$) WL × harvest interaction provides some insight into the response of NDF in tall fescue to WL (Table 2). At the early- and midseason harvests, NDF remained relatively constant across WLs although a decline in NDF at WL-3 contributed to a significant quadratic component at the midseason harvest (Fig. 3a). Concentrations of NDF were significantly

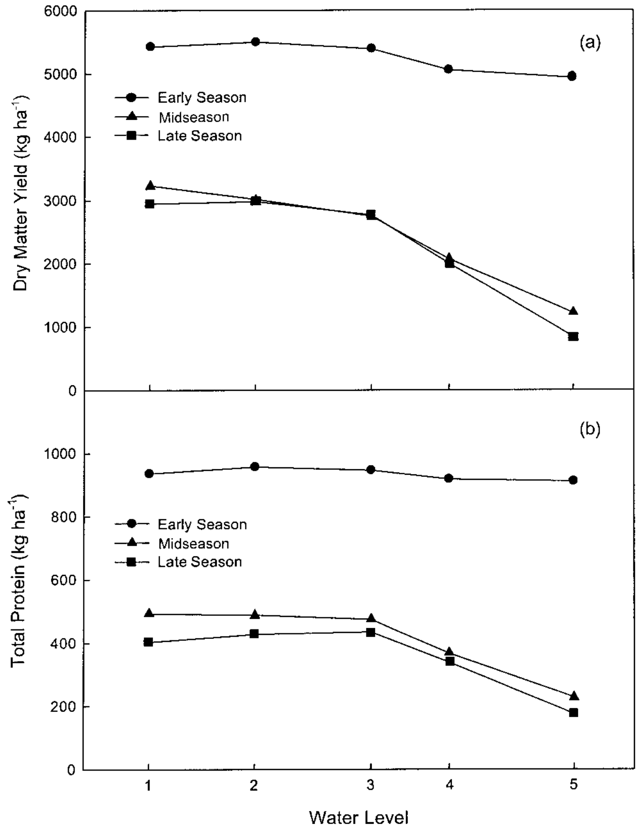

Fig. 2. Trends in (a) dry matter yield and (b) total protein yield for 10 tall fescue cultivars across five water levels (WLs) at three harvests. The $LSD_{(0.05)}$ values for differences among harvests for dry matter yield were 456, 415, 533, 313, and 491 kg ha^{-1} at WL-1 through WL-5, respectively. Corresponding $LSD_{(0.05)}$ values for total protein were 80, 84, 97, 73, and 82 kg ha^{-1}.

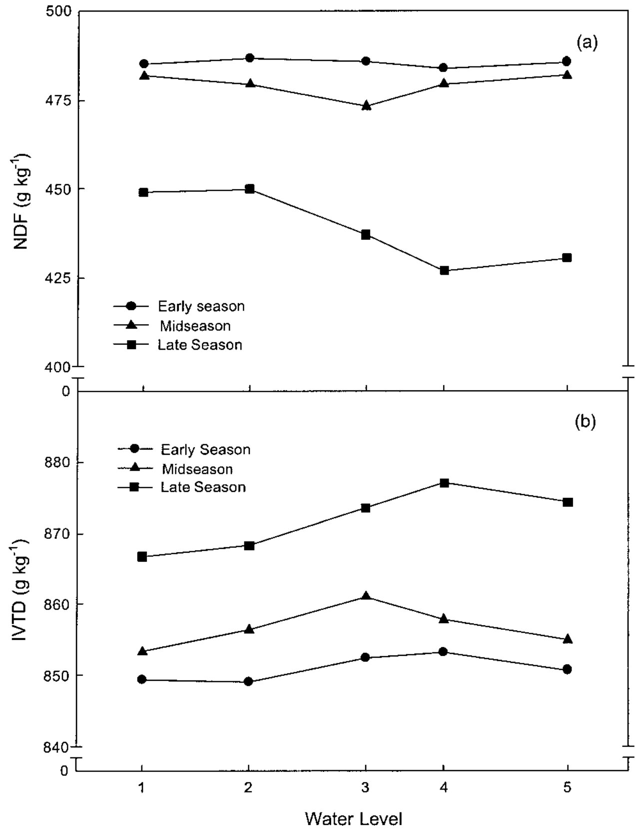

Fig. 3. Trends in (a) neutral detergent fiber (NDF) and (b) in vitro true digestibility (IVTD) for 10 tall fescue cultivars across five water levels (WLs) at three harvests. The $LSD_{(0.05)}$ values for differences among harvests for NDF were 11.1, 9.7, 6.9, 7.4, and 9.5 g kg^{-1} at WL-1 through WL-5, respectively. Corresponding $LSD_{(0.05)}$ values for IVTD were 2.8, 6.1, 2.9, 4.1, and 5.4 g kg^{-1}.

lower at the late harvest than at the mid- and early harvests for all five WLs (Fig. 3a), and both linear and nonlinear effects were significant in the analysis across cultivars (Table 3). At the late harvest, no change in NDF occurred at the two wettest levels (WL-1 to WL-2), but NDF decreased in a linear manner from WL-2 to WL-4 and leveled off from WL-4 to WL-5 (Fig. 3a).

In Vitro True Digestibility

Similar to NDF, cultivars also differed significantly ($P < 0.01$) for IVTD at all three harvests and in the analyses combined across harvests (Table 2). Differences among cultivars were consistent across WLs as shown by the nonsignificant cultivar × WL interaction at the three harvests and in the combined analysis. Correlation coefficients among WLs, based on cultivar × harvest × WL means, were all positive and significant ($P < 0.01$), ranging from 0.88 to 0.94. In the analyses of data combined across years and harvests, IVTD for the cultivar Advance was significantly higher than that of other entries at all five WLs (Table 3, data not shown for individual WLs). Endophyte-free Ky31 and MO-HDII (with the exception of WL-5) also were in the upper tier of cultivars. Martin, Forager, and Fawn were consistently in the low-IVTD group of cultivars.

Although the cultivar × harvest interaction for IVTD was significant (Table 2), correlation coefficients among harvest dates, based on harvest × cultivar × WL means, were all significant ($P < 0.01$) and ranged from 0.67 to 0.79. As with the means across WLs, the cultivar Advance had significantly higher IVTD than all other cultivars at each of the harvest dates, and other rankings were relatively consistent and similar to that observed among WLs (data not shown). One exception that likely contributed to the significant interaction between cultivars and harvests was the cultivar Fawn, which had relatively high IVTD at the first harvest and low levels at the mid- and late-season harvests.

As with NDF, no consistent trends were detected in the analyses of data combined across harvests (Table 3). Analyses based on orthogonal polynomials showed that 38% of the variation due to WL was associated with linear effects and 45 and 15% with quadratic and cubic effects, respectively. As with NDF, orthogonal trends varied widely among cultivars.

The significant WL × harvest interaction for IVTD was apparently due to differences in magnitude of the WL effect at each harvest (Table 2; Fig. 3b). As with NDF, which was significantly lower (better forage quality) at the late harvest, forage quality as determined by IVTD was significantly higher at the late harvest than the other two harvests at all WLs. The trends were similar for the three harvest dates although IVTD at the two wettest levels (WL-1 and WL-2) was significantly lower than that at the two drier levels (WL-4 and WL-5) for the late harvest. Also, for the late harvest, 67% of the variation attributed to the effect of WL was associated with a linear trend ($P < 0.01$), 15% with a quadratic trend ($P < 0.05$), and 14% with a cubic trend. A significant quadratic trend was found at the midharvest; however, no trends were detected at the early harvest (Fig. 3b).

Endophyte Effects

Differences between Ky31e− and Ky31e+ for CP were not significant in the analyses of data combined across years, harvests, and WLs or at any of the WLs when combined across years and harvests (data not shown).

A relatively weak relationship was detected between the presence or absence of the endophyte and NDF and IVTD. The NDF content of Ky31e+ (473 g kg^{-1}) was significantly higher than that of Ky31e− (463 g kg^{-1}) at WL-3 in the analysis combined across harvests and years (Fig. 4a). Ky31e+ also had higher NDF than Ky31e− at WL-3 (505 vs. 489 g kg^{-1}) for the early harvest and for the late harvest at WL-1 (452 vs. 435 g kg^{-1}), WL-3 (439 vs. 428 g kg^{-1}), and WL-4 (428 vs. 418 g kg^{-1}).

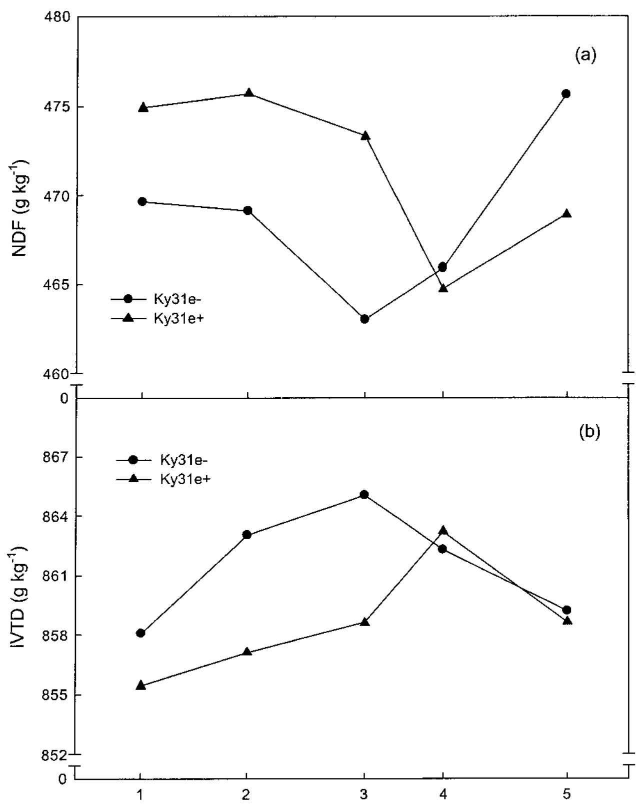

Fig. 4. Trends in (a) neutral detergent fiber (NDF) and (b) in vitro true digestibility (IVTD) for endophyte-free (Ky31e−) and endophyte-infected (Ky31e+) tall fescue across five water levels (WLs). The difference between cultivars was significant ($P < 0.05$) only at WL-3 for NDF [$LSD_{(0.05)}$ = 7.8 g kg^{-1}]. Differences between cultivars were significant at WL-2 [$LSD_{(0.05)}$ = 5.4 g kg^{-1}] and WL-3 [$LSD_{(0.05)}$ = 4.9 g kg^{-1}].

Forage from Ky31e− tended to have higher IVTD concentrations than that from Ky31e+. The difference (863 vs. 857 g kg^{-1}) was significant ($P < 0.05$) at WL-2 and at WL-3 (865 vs. 859 g kg^{-1}) in the analyses combined across years (Fig. 4b). In the analyses within harvests and WLs, Ky31e− had significantly higher IVTD than Ky31e+ for the early harvest at WL-2 (855 vs. 845 g kg^{-1}), the midharvest at WL-3 (864 vs. 859 g kg^{-1}), and the late harvest at WL-3 (879 vs. 872 g kg^{-1}). Although Ky31e− tended to have better forage quality (i.e., lower NDF and higher IVTD) than its endophyte-infected counterpart at the higher WLs, these associations were not consistent enough nor of sufficient magnitude to make conclusive inferences. Until a more definitive association is established, we concur with earlier findings (Bush and Burrus, 1988; Collins, 1991; Emile et al., 2000) that the presence of the endophyte does not consistently affect CP, NDF, or IVTD in tall fescue.

CONCLUSIONS

Based on the magnitude of differences for CP, NDF, and IVTD found among cultivars included in our studies and the consistency of these differences across WLs, we conclude that forage quality should be a major consideration in the choice of cultivars for use on irrigated pastures in the Intermountain West. The most notable trend in forage quality across WLs was the near linear increase in CP with decreasing levels of irrigation, particularly at the late-season harvest. The impact of this trend, however, would be negated by the associated negative trend in dry matter yield across WLs. We were unable to detect a consistent trend in NDF and IVTD across WLs although forage quality, as indicated by these parameters, tended to be higher at the drier WLs at the late-season harvest. Forage quality in these tall fescue cultivars was consistently higher at the late-season harvest, but this effect also was largely offset by decreased dry matter yield. A strong association was not found between the presence or absence of the endophyte and CP; however, the endophyte-free cultivar tended to have lower NDF and higher IVTD than its endophyte-infected counterpart at the wettest WLs. The effect of WL and other environmental factors on the relationship between forage quality and the endophyte merits further study.

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