2012

Dried distillers grains as a substitute for grazed forage

L. A. Stalker
West Central Research and Extension Center, University of Nebraska, stalkera@byui.edu

T. J. Klopfenstein
University of Nebraska-Lincoln, tklopfenstein1@unl.edu

Walter H. Schacht
University of Nebraska–Lincoln, wschacht1@unl.edu

J. D. Volesky
University of Nebraska-Lincoln, jvolesky1@unl.edu

The Professional Animal Scientist 28 (2012):612–617

Dried distillers grains as a substitute for grazed forage

L. A. Stalker,*[1] T. J. Klopfenstein,† W. H. Schacht,‡ and J. D. Volesky*
*West Central Research and Extension Center, University of Nebraska, North Platte 69101; and †Department of Animal Science, and ‡Department of Agronomy and Horticulture, University of Nebraska–Lincoln, Lincoln 68583

ABSTRACT

A 2-yr study evaluated effects of feeding dried distillers grains (DDG) to yearlings grazing native range at greater-than-recommended stocking rates on BW gain, grazed forage quality, and forage disappearance. Thirty-six paddocks were assigned randomly to 1 of 3 treatments: 1) control, stocked at a moderate stocking rate (1.48 animal unit months/ha in yr 1, 1.06 animal unit months/ha in yr 2) with no DDG; 2) double stocked, in which stocking rate was exactly twice the control with no DDG; and 3) double stocked with 2.27 kg/d (DM) of DDG per animal. Six paddocks per treatment replication were grazed in rotation. A total of 42 yearlings (242 ± 15 kg of BW) in yr 1 and 24 yearlings (229 ± 17 kg of BW) in yr 2 were stratified by BW and assigned randomly to treatment. Diet quality was assessed using esophageally fistulated cattle, and forage disappearance and standing crop were determined by clipping twenty 0.25-m^2 quadrats pre- and postgrazing. There was no difference ($P = 0.52$) in ADG between control and double-stocked-without-DDG yearlings (0.50 and 0.45 kg/d, respectively); however, those fed DDG gained more BW (1.14 kg/d; $P < 0.01$) than did yearlings not fed DDG. Forage disappearance was lower ($P < 0.01$) for the control treatment compared with the double-stocked treatments but was not different ($P > 0.05$) between the 2 double-stocked treatments. Diet in vitro OM disappearance did not differ ($P = 0.53$) among treatments. Feeding DDG was an effective means of increasing ADG of grazing yearlings when stocking rate was doubled but did not replace sufficient grazed forage to increase stocking rate 2-fold.

Key words: dried distillers grains, grazing, stocking rate, forage substitution

INTRODUCTION

Grazed forages have traditionally been considered the least expensive feedstuff in both cow-calf and backgrounding operations. However, ethanol production from corn grain has made dried distillers grains (**DDG**) an available feedstuff that improves growth rate of grazing cattle (Griffin et al., 2012). In addition to demonstrating an increase in animal performance, previous research has demonstrated a substitution effect on forage intake when DDG is fed in forage-based diets (Loy et al., 2007; MacDonald et al., 2007; Griffin et al., 2012). If the cost of DDG is less than the cost of replaced grazed forage on a per unit of energy basis, then cost of production could be decreased by feeding DDG. And if DDG acts as a substitute for grazed forage, then feeding DDG would allow increased stocking rates and greater production per unit of land. Potentially, this could be achieved without negatively affecting the forage resource because forage removal would be the same as at the lower stocking rate. Because measuring grazed forage intake is challenging, the NRC (1996) energetic equations have been used in several instances to estimate, rather than directly measure, grazed forage intake (MacDonald et al., 2007). This approach has indicated DDG may replace up to 1.6 kg of grazed forage for each kilogram of DDG fed (Morris et al., 2006). Increasing the stocking rate would allow a producer to realize an economic benefit from the substitution effects of DDG on grazed forage intake in addition to decreased cost per unit energy. The objective of this experiment was to evaluate the effect of feeding DDG in combination with greater-than-recommended stocking rates on BW gain, diet quality, and forage disappearance of cattle grazing native Sandhills range.

MATERIALS AND METHODS

This experiment was conducted at the University of Nebraska Gudmundsen Sandhills Laboratory near Whitman, Nebraska, (elevation of 1,073 m, lat 42°05′N, long 101°26′W) according to protocol approved by the University of Nebraska–Lincoln Animal Care and Use Committee. Precipita-

[1] Corresponding author: astalker3@unl.edu

Table 1. Monthly and long-term average precipitation (mm) at the Gudmundsen Sandhills Laboratory

Item	January–April	May	June	July	August
Yr 1	139.2	99.1	111.0	22.1	68.3
Yr 2	73.2	18.8	82.0	21.8	64.8
30-yr average	65.8	73.7	85.9	67.3	49.8

tion during the experiment and 30-yr average precipitation are shown in Table 1. Twelve 1-ha paddocks and twenty-four 0.5-ha paddocks were separated into 2 blocks because of minor differences in species composition and topography (Table 2). Six 1-ha paddocks and twelve 0.5-ha paddocks were included in each block. Before the start of the experiment, there were twelve 1-ha paddocks per block. Six paddocks per block were selected at random and divided in half, creating twelve 0.5-ha paddocks per block. Six paddocks of the same size within the same block were assigned randomly to 1 of 3 treatments: 1) control, stocked at a moderate stocking rate [1.48 animal unit months/ha in yr 1 and 1.06 animal unit months/ha in yr 2] with no DDG; 2) double stocked, in which stocking rate was exactly twice that of control with no DDG; and 3) double stocked with DDG, in which stocking rate was exactly twice that of control with 2.27 kg/d (DM) per animal of DDG. Number of animals, average initial BW, and grazing days were kept constant among treatments, and differences in stocking rate were achieved by providing exactly 50% less area to cattle in the double-stocked treatments. Six paddocks per treatment within each block were grazed in sequence once each year for 60 d from mid-June to mid-August, with grazing days per paddock adjusted for stage of plant growth (Table 3). The sequence in which pastures were grazed was altered between years to maximize recovery. The recommended stocking rate for the paddocks used in this experiment was 1.5 animal unit months/ha (Stubbendieck and Reece, 1992). Because of below-average spring precipitation in yr 2, stocking rate was reduced and put-and-take of yearlings was used to maintain constant percentage forage disappearance (Wheeler et al., 1973) between yr 1 and yr 2 in the control paddocks.

In yr 1, 42 summer-born yearling heifers (242 ± 15 kg of initial BW) that had been spayed and in yr 2, 24 summer-born yearlings (14 spayed heifers and 10 steers; 229 ± 17 kg of initial BW) were stratified by BW and assigned randomly to treatment paddocks. In addition, 6 similar yearlings were maintained in yr 2 for put-and-take. Yearlings were limit-fed grass hay at 2% of BW for 5 d and weighed on each of the last 3 d of the limit-feeding period at both the beginning and end of the experiment.

Paddock species composition was determined before grazing each year in all paddocks using step-point analysis (Owensby, 1973), and basal data are presented in Table 3. Standing crop and forage disappearance were determined by clipping twenty 0.25-m^2 quadrats per paddock pre- and postgrazing in late June, mid-July, and early August in 3 paddocks per treatment replication (the second, fourth, and sixth paddocks, respectively, in a 6-paddock rotation). Clipped samples were sorted into 4 categories: 1) live grass, 2) standing dead grass, 3) forbs, and 4) litter. These samples were dried in a forced-air oven for 48 h at 60°C and weighed. Forage disappearance was calculated by subtracting postgrazing forage (live grass, standing dead grass, and forbs) from pregrazing forage and then dividing the difference by pregrazing forage. In yr 1, all quadrat locations were selected randomly. In yr 2, contiguous pre- and postgrazing quadrat locations were selected randomly. The location of the selected postgrazing site was marked with a stake and subsequently located using GPS technology for postgrazing sampling. Nutrient content of clipped samples from yr 1 was evaluated from a composite of 6 randomly selected quadrats per pasture.

In yr 1, grazed-forage IVDMD and CP were determined from masticate samples obtained from 2 esophageally fistulated cattle that were not part of the experiment. Masticate samples were collected in the same paddocks selected for standing crop and forage disappearance measures (the second, fourth, and sixth paddocks) halfway through the grazing period. Surgeries were performed on the 2 cows 2 yr before the beginning of the experiment. Fistulated cattle were held with access to water but not feed for 12 h, fitted with screen-bottom bags after removal of the esophageal plug, and then introduced to the paddock and allowed to graze for about 20 min. Samples collected from the bags were immediately frozen and stored at −20°C. They were then lyophilized, ground to pass a 1-mm screen in a Wiley Mill (Model-4, Thomas Scientific, Swedesboro, NJ), and composited by collection date within paddock. Compositing was accomplished by combining the material obtained from each of the 2 cows on an equal weight basis. Composited samples were analyzed for DM and ash following AOAC (1996) procedures.

Table 2. Grazing days and sequence for the 6 paddocks (A–F)

Item	Mid-June	Late June	Early July	Mid-July	Late July	Early August
Grazing days	7	9	11	11	11	11
Yr 1 sequence	A	B	C	D	E	F
Yr 2 sequence	E	F	A	B	C	D

Table 3. Species composition of paddocks at the initiation of the experiment

Species, %	Block West	Block East
Sedge (*Carex* spp.)	25	23
Prairie sandreed (*Calamovilfa longifolia*)	19	19
Needleandthread (*Stipa comata*)	10	15
Little bluestem (*Schizachyrium scoparium*)	8	6
Switchgrass (*Panicum virgatum*)	7	6
Prairie junegrass (*Koeleria macrantha*)	3	4
Sand dropseed (*Sporobolus cryptandrus*)	3	3
Blue grama (*Bouteloua gracilis*)	5	4
Hairy grama (*Bouteloua hirsuta*)	4	3
Sand bluestem (*Andropogon hallii*)	2	3
Western ragweed (*Ambrosia psilostachya*)	6	6
Stiff sunflower (*Helianthus pauciflorus*)	3	3
Other	5	5

Nitrogen content was measured using a Leco FP 2000 combustion nitrogen analyzer (Leco Corp., St. Joseph, MI), which was converted to CP by multiplying by 6.25. In vitro DM disappearance was measured using the procedure of Tilley and Terry (1963), with the modification of adding 1 g of urea to the McDougall's buffer (Weiss, 1994). Residue remaining following in vitro incubation was analyzed for ash content (AOAC, 1996) and used to convert IVDMD to in vitro OM disappearance (**IVOMD**). For in vitro analysis, ruminal fluid was collected from 2 steers maintained on smooth brome (*Bromus inermis*) grass hay (9.8% CP, 58% TDN) delivered once daily at 1.5% of BW. Ruminal fluid from the 2 steers was combined on an equal volume basis. Five forage standards with known in vivo digestibility were included in triplicate in the in vitro run (L. A. Stalker, B. G. Lorenz, N. A. Ahern, and T. J. Klopfenstein, unpublished data). The IVOMD of the masticate samples were adjusted to in vivo values according to a formula derived by regressing the observed IVOMD of each forage standard against its known in vivo digestibility within each run (Weiss, 1994; L. A. Stalker, B. G. Lorenz, N. A. Ahern, and T. J. Klopfenstein, unpublished data).

All data were analyzed as a randomized complete block design using the MIXED procedure of SAS (SAS Institute Inc., Cary, NC). Animal performance was analyzed with block and treatment included in the model as fixed effects and year as a random effect using group of yearlings in the same paddock rotation as the experimental unit. Masticate and standing crop sample CP and IVOMD were analyzed with block, treatment, date paddocks were grazed, and their interaction included in the model as fixed effects using paddock as the experimental unit. Forage disappearance was analyzed with block, treatment, date grazed, and their interaction as fixed effects, with year and paddock included as random effects using paddock as the experimental unit.

Table 4. Body weight, ADG, and BW gain/ha of yearlings grazing Sandhills upland range[1]

Item	CON	SUP	2X	SE[2]	*P*-value
Initial BW, kg	236	236	234	7	0.95
Final BW, kg	267[b]	306[a]	262[b]	8	0.03
ADG, kg/d	0.50[b]	1.14[a]	0.45[b]	0.05	0.003
BW gain, kg/ha per animal	5.2[c]	23.3[a]	9.3[b]	0.8	0.01

[a–c]Within a row, means lacking a common superscript letter differ ($P < 0.05$).

[1]Control stocking rate of 1.48 animal unit months/ha in yr 1 and 1.06 animal unit months/ha in yr 2 (CON), double control stocking rate plus 2.27 kg/d per animal (DM) of dried distillers grains (SUP), and double control stocking rate without supplement (2X).

[2]Standard error of the least squares means (n = 4).

RESULTS AND DISCUSSION

There was no difference ($P = 0.52$) in ADG between yearlings assigned to the nonsupplemented treatments (Table 4). However, yearlings assigned to the double-stocking rate with DDG treatment gained 0.67 kg/d more ($P < 0.01$) than did the nonsupplemented groups. When expressed on a per unit land area basis, BW gain was greatest ($P = 0.01$) for the double-stocking rate with DDG, intermediate for the double-stocking rate without DDG, and least for the control. Because stocking rate differed between the control and double-stocked treatments, forage quality, and therefore energy intake, would logically be expected to be lower for the double-stocking-rate treatment. This is because the ability of an individual animal to select better-quality plants and plant parts is reduced as stocking rate increases because of competition. A lack of difference in ADG between the control and double-stocked-without-DDG treatments suggests energy was not the first limiting nutrient. This conclusion is supported by the masticate quality data presented in Table 5. There was no difference ($P = 0.53$) among treatments in IVOMD of masticate samples, although IVOMD tended ($P = 0.08$) to decrease as the growing season progressed. The CP content of masticate samples decreased ($P = 0.001$) as the grow-

Table 5. Nutrient content of masticate samples collected in yr 1 using esophageally fistulated cattle[1]

	June			July			August				*P*-value		
Item	CON	SUP	2X	CON	SUP	2X	CON	SUP	2X	SE[2]	Month (M)	Treatment (T)	M × T
IVOMD,[3] %	60.7	57.3	54.2	54.5	53.5	54.1	51.2	47.4	54.7	2.9	0.08	0.53	0.42
CP, % DM	11.2	10.1	9.3	8.8	8.2	7.7	8.2	7.9	8.0	0.5	<0.01	0.06	0.51

[1]Control stocking rate of 1.48 animal unit months/ha (CON), double control stocking rate plus 2.27 kg/d per animal (DM) of dried distillers grains (SUP), and double control stocking rate without supplement (2X).

[2]Standard error of the least squares means (n = 4).

[3]IVOMD = in vitro OM disappearance.

Table 6. Standing crop and forage disappearance from paddocks[1]

	June			July			August				*P*-value		
Item	CON	SUP	2X	CON	SUP	2X	CON	SUP	2X	SE[2]	Month (M)	Treatment (T)	M × T
Live grass, kg/ha													
Pregraze	956	917	910	1,111	989	923	1,103	1,027	1,016	50	0.01	0.02	0.66
Postgraze	737	519	503	653	390	276	549	315	329	34	<0.01	<0.01	0.01
Standing dead grass, kg/ha													
Pregraze	577	432	456	480	368	367	550	422	454	54	0.01	<0.01	0.98
Postgraze	354	257	244	359	233	192	379	256	219	34	0.31	<0.01	0.73
Forbs, kg/ha													
Pregraze	81	88	95	138	175	124	180	187	170	30	<0.01	0.62	0.88
Postgraze	67	57	32	129	12	14	149	71	36	34	0.11	<0.01	0.14
Litter, kg/ha													
Pregraze	1,159	829	964	1,274	1,041	1,148	1,677	1,726	1,407	50	<0.01	0.04	0.14
Postgraze	1,344	1,274	1,332	2,034	1,866	1,641	1,834	1,608	1,348	107	<0.01	0.003	0.20
Disappearance,[3] %	28[c]	42[b]	47[b]	34[b]	59[a]	66[a]	41[b]	61[a]	64[a]	5	<0.01	<0.01	0.48

[a–c]Within a row, means lacking a common superscript letter differ ($P < 0.05$).

[1]Control stocking rate of 1.48 animal unit months/ha in yr 1 and 1.06 animal unit months/ha in yr 2 (CON), double control stocking rate plus 2.27 kg/d per animal (DM) of dried distillers grains (SUP), and double control stocking rate without supplement (2X).

[2]Standard error of the least squares means (n = 20).

[3]Difference between pregraze and postgraze live grass, standing dead grass, and forbs divided by pregraze amount.

Table 7. In vitro OM and CP content of live grass, forbs, and standing dead grass clipped in June, July, and August in yr 1 both before and after grazing

	June		July		August			*P*-value		
Item	Pregraze	Postgraze	Pregraze	Postgraze	Pregraze	Postgraze	SE[1]	Month (M)	Graze (G)	M × G
IVOMD,[2] %										
Live grass	58.8[a]	55.4[b]	54.9[b]	54.6[b]	53.8[b]	51.3[c]	0.9	<0.01	<0.01	0.06
Forb	57.6[ab]	57.3[ab]	60.5[a]	54.3[bc]	56.7[ab]	50.6[c]	2.2	0.11	0.02	0.26
Standing dead	43.5	44.0	43.2	44.9	45.3	43.3	1.2	0.87	0.94	0.25
CP, %										
Live grass	10.7[a]	9.3[b]	8.2[c]	7.9[c]	7.0[d]	6.5[d]	0.2	<0.01	<0.01	0.03
Forb	13.3[a]	12.6[ab]	11.5[ab]	10.3[bc]	10.3[bc]	8.5[c]	1.0	0.01	0.08	0.76
Standing dead	5.5[b]	6.4[a]	5.7[b]	5.7[b]	5.7[b]	6.0[ab]	0.3	0.39	<0.01	0.08

[a–d]Within a row, means lacking a common superscript letter differ ($P < 0.05$).

[1]Standard error of the least squares means (n = 10).

[2]IVOMD = in vitro OM disappearance

ing season progressed and tended ($P = 0.06$) to be greatest for yearlings in the control treatment, intermediate for double stocked with DDG, and least for double stocked without DDG. Gain of yearlings assigned to control and double-stocked-without-DDG treatments was likely limited by a metabolizable protein deficiency. Young, lightweight cattle have a relatively high metabolizable protein requirement compared with other classes of cattle (NRC 1996). When IVOMD and CP content of the diet samples were used as inputs in the NRC (1996) model, control yearlings were deficient in metabolizable protein by 147 g/d but had an energy-allowable ADG of 0.77 kg. In contrast, the double-stocked-with-DDG yearlings had a 145 g/d metabolizable protein excess, and energy-allowable ADG of 1.17 kg, which was very near their actual BW gain. This further supports the hypothesis that digestible RUP was the first limiting nutrient in these yearlings, and some of the response to DDG supplementation was likely a response to RUP. Under conditions similar to the present experiment, Creighton et al. (2003) reported increased ADG when summer-born yearlings were supplemented with RUP during summer grazing. Hafley et al. (1993) also reported increased ADG in response to RUP supplementation in calves grazing summer pastures dominated by warm-season grasses.

Standing crop and forage (live grass, standing dead grass, and forbs) disappearance is presented in Table 6. Some differences in pregrazing standing crop components existed even though paddocks were blocked, assigned randomly to treatments within block, and none of the paddocks had been grazed for 8 yr before the start of the experiment. Because there were pregrazing differences, forage disappearance (proportion of pregrazing forage still remaining postgrazing) is the most appropriate way to compare treatments. Within each month, forage disappearance was lower ($P < 0.01$) in the control treatment than in either of the double-stocked treatments, but there was no difference ($P > 0.15$) between the double-stocked-without-DDG and double-stocked-with-DDG treatments. A lack of difference in forage disappearance between the 2 double-stocked treatments suggests the DDG did not replace forage. MacDonald et al. (2007) found a forage replacement rate of almost 50% when DDG was supplemented to heifers grazing smooth brome pastures at rates ranging from 0.75 to 2.25 kg/d. Extrapolating the finding of MacDonald et al. (2007) to the present experiment suggests feeding 2.27 kg/d per animal of DDG would only replace 1.14 kg/d per animal of forage. If this is accurate, forage replacement may have indeed occurred but not at a level that could be detected by the sampling procedure used in this experiment. Furthermore, if DDG did replace forage, it was not a level sufficient to result in forage removal equal to the recommended stocking rate. These results demonstrate the NRC (1996) model does not accurately predict replacement of forage with DDG in grazing situations.

Most researchers who have studied effects of stocking rate on standing crop have reported a decrease in standing crop with increasing stocking rates (Willms et al., 1986; Ralphs et al., 1990; Gillen et al., 1998). Long-term experiments, such as that conducted by Willms et al. (1986), show the difference in standing crop between pastures stocked at greater rates compared with lesser rates continues to increase over time. The relatively short duration (2 yr) of the present experiment limits inference about the sustainability of the treatments. However, because the control paddocks were stocked at the recommended, sustainable level and feeding 2.27 kg of DDG did not result in equivalent forage utilization, doubling the stocking rate with DDG at this rate is expected to result in decreased range condition over time and is not recommended.

Month the paddocks were grazed affected forage disappearance ($P < 0.01$). This was expected and is a result of plant growth stage. These paddocks were primarily composed of warm-season grasses, which reach peak yield late in the summer (Stubbendieck and Reece, 1992). Because the length of grazing was shorter in the initial 2 paddocks, forage disappearance within treatment was not as great in June compared with July and August.

The IVOMD and CP content of the standing crop components were not affected ($P > 0.15$) by treatment; therefore, data were pooled among treatments and are shown in Table 7. There was a tendency ($P = 0.06$) for an interaction between month and whether or not paddocks had been grazed for IVOMD of live grass. Live grass IVOMD was greatest ($P < 0.05$) in June before grazing occurred and was least ($P < 0.05$) in August after grazing occurred but not different ($P > 0.05$) at any other time. Similarly, month and whether or not paddocks had been grazed interacted ($P = 0.03$) for CP content of live grass; CP content was greatest ($P < 0.05$) in June before grazing occurred and least ($P < 0.05$) in August. Forb IVOMD was lower ($P < 0.05$) after grazing compared with before grazing in July and August but not in June. Forb CP was not affected ($P > 0.05$) by grazing within month. In vitro OM disappearance of the standing dead grass was not affected ($P > 0.87$) by month or grazing status. There was a tendency ($P = 0.08$) for an interaction between month and grazing for CP content of standing dead grass, in which pregrazing and postgrazing samples contained similar amounts of CP in each month except June.

IMPLICATIONS

Feeding DDG to yearlings grazing native Sandhills range is an effective method of increasing ADG even when stocking rate exceeds recommended levels. However, when stocking rate is doubled, reduction in voluntary forage intake of yearlings receiving 2.27 kg/d per animal (DM) of DDG is not sufficient to result in forage disappearance rates comparable to recommended stocking rates and may have detrimental effects on range condition over extended periods of time.

LITERATURE CITED

AOAC. 1996. Official Methods of Analysis. 16th ed. AOAC, Arlington, VA.

Creighton, K. W., C. B. Willson, T. J. Klopfenstein, and D. C. Adams. 2003. Undegradable intake protein supplementation of compensation spring-born steers and summer-born steers during summer grazing. J. Anim. Sci. 81:791–799.

Gillen, R. L., F. T. McCollum III, K. W. Tate, and M. E. Hodges. 1998. Tall prairie response to grazing system and stocking rate. J. Range Manage. 51:139–146.

Griffin, W. A., V. R. Bremer, T. J. Klopfenstein, L. A. Stalker, L. W. Lomas, J. L. Moyer, and G. E. Erickson. 2012. A meta-analysis evaluation of supplementing dried distillers grains plus solubles to cattle consuming forage based diets. Prof. Anim. Sci. 28:306–312.

Hafley, J. L., B. E. Anderson, and T. J. Klopfenstein. 1993. Supplementation of growing cattle grazing warm-season grass with proteins of various ruminal degradabilities. J. Anim. Sci. 71:522–529.

Loy, T. W., J. C. MacDonald, T. J. Klopfenstein, and G. E. Erickson. 2007. Effect of distillers grains or corn supplementation frequency on forage intake and digestibility. J. Anim. Sci. 85:2625–2630.

MacDonald, J. C., T. J. Klopfenstein, G. E. Erickson, and W. A. Griffin. 2007. Effects of dried distillers grains and equivalent undegradable intake protein or ether extract on performance and forage intake of heifers grazing smooth bromegrass pastures. J. Anim. Sci. 85:2614–2624.

Morris, S. E., J. C. MacDonald, D. C. Adams, T. J. Klopfenstein, R. L. Davis, and J. R. Teichert. 2006. Effects of supplementing dried distillers grains to steers grazing summer Sandhill range. Nebraska Beef Cattle Report, MP 88-A:30. Univ. Nebraska, Lincoln.

NRC. 1996. Nutrient Requirement in Beef Cattle. 7th ed. Natl. Acad. Press, Washington, DC.

Owensby, C. E. 1973. Modified step-point system for botanical composition and basal cover estimates. J. Range Manage. 26:302–303.

Ralphs, M. H., M. M. Kothmann, and C. A. Taylor. 1990. Vegetation response to increased stocking rates in short-duration grazing. J. Range Manage. 43:104–108.

Stubbendieck, J., and P. E. Reece. 1992. Nebraska Handbook of Range Management. EC-92–124-E. Univ. Nebraska, Lincoln.

Tilley, J. M. A., and R. A. Terry. 1963. A two-stage technique for the in vitro digestion of forage crops. J. Br. Grassl. Soc. 18:104–110.

Weiss, W. P. 1994. Estimation of digestibility of forages by laboratory methods. Pages 644–681 in Forage Quality, Evaluation, and Utilization. G. C. Fahey Jr., ed. Am. Soc. Agron., Crop Sci. Soc. Am., Soil Sci. Soc. Am. Inc., Madison, WI.

Wheeler, J. L., J. C. Burns, R. D. Mochrie, and H. D. Gross. 1973. The choice of fixed or variable stocking rates in grazing experiments. Exp. Agric. 9:289–302.

Willms, W. D., S. Smoliak, and G. B. Schaalje. 1986. Cattle weight gains in relation to stocking rate on rough fescue grassland. J. Range Manage. 39:182–187.