# Case Study: Nutrient Values of Spring and Summer Annual Forages in a Single Cut Harvest1

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# Case Study: Nutrient Values of Spring and Summer Annual Forages in a Single Cut Harvest[1]

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## ABSTRACT

*The Central High Plains of the United States (western Nebraska and Kansas and eastern Wyoming and Colorado) is a major beef cattle production area, but it is subject to periodic droughts. Annual forages are an essential feed source for maintaining beef cattle herds during periods of drought and winter months. The objective of this study was to determine nutrient concentrations in annual forages, including barley, oats, triticale, forage sorghums, sudangrass, pearl millet, foxtail millet, field peas, soybeans, and vetch grown for hay in this region. The summer annuals—forage sorghums, sudangrass, pearl millet, and foxtail millet—were grown in replicated rain-fed and irrigated trials whereas the other forage species were grown in only rain-fed trials. Currently available cultivars of these forages species were included in the trials that were located primarily at Sidney and Scottsbluff, Nebraska. Results demonstrate that the harvested forage of many of these species approached or exceeded 10, 60, 0.4 and 0.2% of CP, TDN, Ca, and P, respectively, exceeding diet composition requirements for growing beef cattle and gestating beef cow classes listed by the NRC. Nitrate-N values exceeded safe feeding levels in pearl millet and irrigated foxtail millet forage, probably due to high soil N fertility levels. Feed testing of warm-season, summer annual forages grown in this region for nitrate-N would be a prudent management practice.*

**Key words:** annual forage, nutrient, cereal, legume, grass

## INTRODUCTION

Periodic droughts in the Central High Plains of the United States can adversely affect ruminant livestock feed supply from rangelands. This area, which includes western Nebraska and Kansas and eastern Wyoming and Colorado, is a major beef cattle production area. Annual forages are an essential feed source in this region for maintaining beef cattle herds during droughts and winter months. Moderate to severe droughts have occurred in this area during the last 7 yr. Annual forages that are adapted to this region include cool-season, spring-seeded cereals such as barley (*Hordeum vulgare* L.), oat (*Avena sativa* L.), triticale (*X Triticosecale rimpaui* Wittm.), annual legumes including field pea (*Pisum sativum* L.), soybean [*Glycine max* (L.) Merr.], vetch (*Vicia sativa* L.), and warm-season, annual summer forages including sorghum [*Sorghum bicolor* (L.) Moench], sorghum × sudan (*Sorghum bicolor* × *Sorghum sudanense*), sudangrass (*Sorghum bicolor sudanense*), pearl millet [*Pennisetum americanum* (L.) Leeke], and foxtail millet [*Setaria italica* (L.) Beauv.]. Data have been limited on the nutrient concentrations of dryland and irrigated annual forages in this region, although Weichenthal et al. (1998) reported initial nutrient concentrations for rain-fed or dryland summer annual forages grown at Sidney, Nebraska, during 1989 to 1991 and for irrigated summer annual

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forages grown at Scottsbluff, Nebraska, in 1991 and 1992.

The NRC (1996) has a feed library with RUP included in evaluating diets for meeting requirements for metabolizable protein. For example, estimated contents of CP in oat (dough stage) and sorghum silages, respectively, were 12.7 and 9.4%, and RUP as a percentage of CP were 15 and 17%. However, RUP has not been determined for many annual forages and is often estimated in nutrient composition tables. Mustafa et al. (2000, 2002) reported an effective RUP range of 18 to 19% of CP for pea, alfalfa, and barley silages grown in Quebec, Canada, which is a much more humid environment than the Central High Plains of the United States. Mustafa et al. (2004) also reported CP values of DM for brown midrib and normal pearl millet cultivars, respectively, of 18.7 and 17.9% and RUP averages of 26 and 29% of CP when harvested at vegetative maturity stages. In addition, the range in mean nutrient concentration that can occur in harvested annual forages due to differences in cultivars and environmental conditions often is not available.

This study was initiated to determine nutrient contents of annual forages harvested for hay in the Central High Plains of the United States as a reference base for producers and nutritionists when determining rations for various classes of cattle and their production levels. Another objective was to evaluate the nitrate-N contents of grass-type annual forages for potential toxicity problems. Finally, the macro- and microminerals were determined in these forages because this array of minerals has rarely been reported in the literature for the single cut annual forages tested in this study.

## MATERIALS AND METHODS

Annual forages were grown in western Nebraska in 1998 and 1999 in field trials on research facilities of the University of Nebraska. Rain-fed or dryland plots were established at the High Plains Agricultural Laboratory near Sidney, Nebraska, where the elevation is 1,310 m above sea level and precipitation totals were 46 cm in both 1998 and 1999. Similar irrigated plots were grown at the Panhandle Research and Extension Center near Scottsbluff, Nebraska, where the elevation is about 1,200 m and precipitation totals were 44 and 43 cm for 1998 and 1999, respectively. Rain-fed soybean forage was grown in 1999 on a trial at the University of Wyoming Research and Extension Center at Archer, near Cheyenne, Wyoming, where the elevation is about 1,830 m and precipitation totaled 46 cm in 1999. Multiyear precipitation averages for Sidney, Scottsbluff, and Archer are 43, 39, and 37 cm, respectively.

Cool-season, spring-seeded forages included 2 triticale, 2 barley, 3 oat, and 6 field pea cultivars grown in replicated ($n = 4$) small plots (9.7 $m^2$). Similar practices were used for the soybean trial at Archer, Wyoming. Warm-season, summer annual rain-fed or irrigated forage trials included 9 forage sorghum, 6 sorghum × sudangrass, 1 sudangrass, 3 pearl millet, and 9 foxtail millet cultivars grown in replicated ($n = 7$ or 8 for irrigated and 4 for rain-fed trials) in small plots (13.7 $m^2$). Recommended agronomic practices for the region including seeding and fertilization rates were followed for all trials, except that N and P fertilizers were inadvertently not applied in 1998 for the spring-seeded trial. Irrigation water was applied to irrigated plots with a lateral move sprinkler system as needed during the growing season to maintain growth and maturity development of the forages. A single cut harvesting system was used to optimize forage yield. The forages were harvested after the heading or flowering maturity stages of growth with hay or green chop harvesters built or modified to harvest small research plots. Freshly harvested forage samples were collected from each plot and dried at 50°C to determine DM. Dried samples were then ground to pass a 1-mm screen for use in laboratory analyses.

Near infrared reflectance spectrophotometry (**NIRS**) analyses were used to predict composition of the summer annual rain-fed and irrigated forage samples for NDF, ADF, ADL, CP, nitrate-N, and IVDMD using the NIRS procedures described by Shenk and Westerhaus (1991). The NIRS calibration equations were based on laboratory means of a calibration set of subsamples that represented all species and environments and the spectral variation of all harvested, summer annual samples. The calibration samples for the summer annuals and all other forage samples including field peas and soybean forage were analyzed using the following laboratory procedures. Crude protein concentration (%N × 6.25) was determined by the Leco combustion method (Model FP 428 and FP 2000, Leco Corp., St. Joseph, MI; Watson and Isaac, 1990; Bremner, 1996). In vitro DM digestibility, NDF, ADF, and ADL were determined using the Ankom Fiber Analyzer (Ankom Technology Corp., Fairport, NY) using the procedures described by Vogel et al. (1999) and the Ankom ADL procedure (Ankom Technology−9/99, Method for Determining Acid Detergent Lignin in Beakers). Mineral compositions of the forage samples were determined in the University of Nebraska Agronomy and Horticultural Department's analytical laboratory using procedures described by Knudsen et al. (1981). Nitrate-N was determined in the same laboratory using the cadmium reduction method (Keeney and Nelson, 1982). The RUP was determined on frozen and freeze-dried forage samples at the Department of Animal Science, University of Nebraska in Lincoln, according to procedures described by Mass et al. (1999). The ADF values were used to calculate energy levels for TDN, ME, $NE_m$, $NE_g$, and $NE_l$ by using equations developed at Pennsylvania State University for sorghum and small grain and for legume forages as listed in the Dairy Reference Manual (1995). Composition means and SD for each class of annual forage were determined over years and cultivars by using SAS means procedures (SAS Institute, 1996).

**Table 1. Feed analyses means and SD for cool-season, spring-seeded cereal and legume annual forages grown in 1998 to 1999 under rain-fed conditions in the Central High Plains of the United States[1,2]**

| | Protein | | | Nitrate | Fiber | | | Energy | | | | Digestibility |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | NDF | ADF | ADL | $NE_m$ | $NE_g$ | $NE_l$ | | |
| Forage maturity at harvest | DM, % | CP, % | RUP, %/CP | $NO_3N$, mg/kg | —— % —— | | | — Mcal/kg — | | | TDN, % | IVDMD, % |
| Spring cereal | | | | | | | | | | | | |
| Barley soft dough (1998, 1999) | 40 | 8.2 | 8 | 220 | 65 | 34 | 5.4 | 1.50 | 0.91 | 1.49 | 66 | 69 |
| n | 16 | 16 | 6 | 16 | 16 | 16 | 16 | 16 | 16 | 16 | 16 | 16 |
| SD | 6 | 0.9 | 3 | 380 | 2.3 | 2 | 0.4 | 0.02 | 0.01 | 0.02 | 0.6 | 3 |
| Oat headed (1998, 1999) | 30 | 9.5 | 8 | 360 | 65 | 34 | 5.1 | 1.49 | 0.90 | 1.49 | 66 | 73 |
| n | 24 | 24 | 9 | 24 | 24 | 24 | 24 | 24 | 24 | 24 | 24 | 24 |
| SD | 3 | 1.6 | 3 | 530 | 4 | 2.2 | 0.7 | 0.02 | 0.01 | 0.01 | 0.7 | 5.3 |
| Triticale headed (1998, 1999) | 38 | 9.3 | 6 | 130 | 66 | 36 | 5.5 | 1.48 | 0.89 | 1.48 | 65 | 70 |
| n | 16 | 16 | 6 | 16 | 16 | 16 | 16 | 16 | 16 | 16 | 16 | 16 |
| SD | 2.5 | 1.6 | 1 | 140 | 2.2 | 2.3 | 0.6 | 0.02 | 0.02 | 0.02 | 0.7 | 4.5 |
| Legumes | | | | | | | | | | | | |
| Pea early bloom (1999) | 26 | 17.1 | 9 | — | 40 | 33 | — | 1.43 | 0.85 | 1.44 | 64 | 75 |
| n | 32 | 32 | 4 | — | 32 | 32 | — | 32 | 32 | 32 | 32 | 4 |
| SD | 4 | 2.2 | — | — | 2.6 | 2.2 | — | 0.08 | 0.07 | 0.06 | 2.4 | 1.3 |
| Soybean early to mid pod-fill (1999) | 32 | 12.2 | 5 | 110 | 43 | 28 | 6.8 | 1.59 | 0.99 | 1.57 | 68 | 77 |
| n | 24 | 48 | 10 | 48 | 48 | 48 | 48 | 48 | 48 | 48 | 48 | 48 |
| SD | — | 1.4 | — | 120 | 2.6 | 2.3 | 0.7 | 0.09 | 0.07 | 0.07 | 2.4 | 1.9 |
| Vetch early bloom (1999) | 29 | 18.3 | 8 | — | 40 | 32 | — | 1.47 | 0.88 | 1.47 | 65 | 72 |
| n | 8 | 8 | 8 | — | 8 | 8 | — | 8 | 8 | 8 | 8 | 8 |
| SD | 4 | 1.8 | — | — | 2.9 | 2 | — | 0.07 | 0.06 | 0.05 | 2.1 | — |

[1]Rain-fed spring-seeded cereal, pea, and vetch forages were grown at the University of Nebraska High Plains Agricultural Laboratory near Sidney, where the altitude is about 1,310 m above sea level. Soybean forages were grown at the University of Wyoming Research and Extension Center near Cheyenne, where the altitude is about 1,830 m. All contents are expressed on a DM basis.

[2]SD values represent the variability that existed for harvested forage of these species with available cultivars.

## RESULTS AND DISCUSSION

There was variation among and within species for all forage feed parameters that were evaluated (Tables 1, 2, 3, and 4). The SD represent the variation that exists about the mean for the composition value for the cultivars of a species evaluated in multiple plots in this study and clearly demonstrate that mean composition values should not be regarded as absolute values for ration formulation for the forages evaluated in this study. In general, CP concentrations (Tables 1 and 2) were similar among cereal and sorghum forages when they were harvested after the majority of the cultivars had headed, including sorghum cultivars grown in rain-fed or irrigated trials. Nitrate-N concentrations reached 2,000 mg/kg, a threshold level for toxicity in ruminants, in rain-fed and irrigated pearl millet and in irrigated foxtail millet that was fertilized with the high rate of N (134 kg/ha) used on the irrigated summer annual trials. Foxtail millet fertilized with N at 50 kg/ha grown in the rain-fed trials did not have significant nitrate accumulation. These results are supported by earlier reports of Weichenthal et al. (1998, 2001) and indicate that testing harvested forages of pearl millet and foxtail millet for nitrate-N levels when grown on soils with high N levels in this region would be prudent.

Crude protein concentrations were 12.2, 17.1, and 18.3% of DM for soybean, pea, and vetch forages, respectively, when harvested at early to mid pod-fill (soybean) and early bloom stages of maturity (pea and vetch). Similar CP levels were reported for pea (Carr et al., 2004), soybean (Seiter et al., 2004), and vetch (Alzueta et al., 2001). Crude protein levels in forage sorghum averaged about 10% of DM in this study, which was less than the level reported by Ward et al. (2000) when the sorghum was harvested in a vegetative stage. Pearl millet CP in this single cut trial averaged 11 to 15% of DM compared with an average of 17.9% in 2 harvests of pearl millet in a vegetative stage reported by Mustafa et al. (2004).

Laboratory analyses included RUP as a percentage of CP to indicate the RUP that bypasses to the intestinal tract. There was considerable variation in RUP for most of the cultivars,

**Table 2. Feed analyses means and SD for warm-season or summer annual forages grown in western Nebraska in 1998 to 1999 under rain-fed or irrigated conditions[1,2]**

| | Protein | | | Nitrate | Fiber | | | Energy | | | | Digestibility |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | NDF | ADF | ADL | $NE_m$ | $NE_g$ | $NE_l$ | | |
| Forage harvest stage | DM, % | CP, % | RUP, %/ CP | $NO_3N$, mg/kg | —— % —— | | | —— Mcal/kg — | | | TDN, % | IVDMD, % |
| Rain-fed | | | | | | | | | | | | |
| Forage sorghum boot (1998, 1999) | 26 | 9.6 | 10 | 1,170 | 59 | 30 | 3.6 | 1.54 | 0.95 | 1.52 | 67 | 78 |
| n | 24 | 72 | 24 | 58 | 72 | 72 | 72 | 72 | 72 | 72 | 72 | 72 |
| SD | 2.7 | 2.8 | 4 | 570 | 4.8 | 4.5 | 1.6 | 0.09 | 0.09 | 0.07 | 2.7 | 4.2 |
| Sorghum × sudan head exerted (1998, 1999) | 24 | 9 | 10 | 1,010 | 61 | 32 | 4.2 | 1.52 | 0.93 | 1.52 | 66 | 72 |
| n | 18 | 54 | 18 | 41 | 54 | 54 | 54 | 54 | 54 | 54 | 54 | 54 |
| SD | 1.9 | 2.9 | 4 | 450 | 4.3 | 4.3 | 1.2 | 0.11 | 0.09 | 0.09 | 3.3 | 3 |
| Sudangrass head exerted (1998, 1999) | 30 | 7.6 | 11 | 690 | 65 | 36 | 4.9 | 1.48 | 0.88 | 1.5 | 66 | 66 |
| n | 4 | 9 | 3 | 7 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 |
| SD | 1.8 | 2.3 | 1 | 380 | 4.4 | 4.5 | 1 | 0.18 | 0.15 | 0.13 | 5.2 | 2.4 |
| Pearl millet[3] head exerted and vegetative (1998) | 23 | 15.3 | 8 | 2,090 | 60 | 30 | 3.5 | 1.54 | 0.95 | 1.52 | 67 | 78 |
| n | 9 | 15 | 9 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 |
| SD | 1.7 | 2 | 2 | 920 | 1.9 | 1.3 | 0.3 | 0.02 | 0.02 | 0.02 | 0.4 | 3.2 |
| Foxtail millet[3] head exerted and vegetative (1999) | 32 | 8.9 | 9 | 320 | 61 | 32 | 3.5 | 1.52 | 0.93 | 1.5 | 66 | 73 |
| n | 27 | 36 | 27 | 36 | 36 | 36 | 36 | 36 | 36 | 36 | 36 | 36 |
| SD | 4 | 1.1 | 2 | 230 | 2.2 | 2 | 0.6 | 0.09 | 0.07 | 0.09 | 4 | 3.8 |
| Irrigated | | | | | | | | | | | | |
| Forage sorghum head exerted (1998, 1999) | 23 | 9.8 | 9 | 1,040 | 61 | 35 | 4.9 | 1.5 | 0.9 | 1.48 | 65 | 70 |
| n | 42 | 90 | 42 | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 |
| SD | 1.9 | 1.2 | 2 | 420 | 3.4 | 2.3 | 1.1 | 0.09 | 0.07 | 0.07 | 2.4 | 3.5 |
| Sorghum × sudan head exerted (1998, 1999) | 25 | 8.9 | 9 | 740 | 61 | 36 | 6.1 | 1.48 | 0.88 | 1.48 | 65 | 64 |
| n | 30 | 50 | 30 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 |
| SD | 2 | 0.9 | 3 | 390 | 2 | 2 | 0.8 | 0.07 | 0.07 | 0.04 | 2.2 | 3.2 |
| Sudangrass head exerted (1998, 1999) | 30 | 9 | 10 | 1,050 | 66 | 40 | 6.5 | 1.43 | 0.86 | 1.45 | 64 | 60 |
| n | 6 | 10 | 6 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 |
| SD | 3.8 | 1.4 | 3 | 880 | 3.5 | 3.5 | 0.8 | 0.18 | 0.15 | 0.11 | 5 | 4 |
| Pearl millet[3] head exerted and vegetative (1998, 1999) | 20 | 11.3 | 9 | 2,340 | 67 | 40 | 5.7 | 1.43 | 0.86 | 1.45 | 64 | 64 |
| n | 27 | 30 | 27 | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 30 |
| SD | 4.6 | 1.7 | 3 | 1,150 | 2.4 | 2.5 | 0.7 | 0.13 | 0.13 | 0.11 | 4.1 | 4 |
| Foxtail millet[3] head exerted and vegetative (1998, 1999) | 27 | 12.1 | 6 | 2,010 | 62 | 36 | 4.9 | 1.48 | 0.88 | 1.48 | 65 | 70 |
| n | 27 | 55 | 27 | 27 | 55 | 55 | 55 | 55 | 55 | 55 | 55 | 55 |
| SD | 4.8 | 0.9 | 3 | 770 | 2.9 | 2.5 | 0.6 | 0.02 | 0.02 | 0.02 | 0.8 | 3.4 |

[1]Rain-fed and irrigated summer annual forages were grown at the University of Nebraska High Plains Agricultural Laboratory near Sidney and the Panhandle Research and Extension Center near Scottsbluff, Nebraska, where the altitudes are about 1,310 and 1,200 m above sea level, respectively. All contents are expressed on a DM basis.

[2]SD values represent the variability that existed for harvested forage of these species with available cultivars.

[3]One pearl millet cultivar and one foxtail millet cultivar were genetic types that would remain vegetative and generally not produce seed heads in the environments tested.

**Table 3. Feed analyses means and SD for mineral concentrations in forage of cool-season, spring-seeded cereal and legume annual forages grown under rain-fed conditions in 1999 in the Central High Plains of the United States[1,2]**

| Forage | Ca, % | P, % | K, % | Mg, % | S, % | Na, % | Cl, % | Si, % | Mn, mg/kg | Fe, mg/kg | Cu, mg/kg | Zn, mg/kg | Ti, mg/kg | Ni, mg/kg |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Spring cereals | | | | | | | | | | | | | | |
| Barley | 0.3 | 0.2 | 2.3 | 0.09 | 0.13 | 0.17 | 0.18 | 4.3 | 45 | 460 | 5 | 10 | 30 | 25 |
| n | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 |
| SD | 0.04 | 0.03 | 0.5 | 0.02 | 0.02 | 0.08 | 0.05 | 0.8 | 12 | 230 | 1.1 | 2.2 | 19 | 10 |
| Oat | 0.35 | 0.24 | 3.5 | 0.11 | 0.19 | 0.09 | 0.2 | 4.7 | 110 | 470 | 6 | 15 | 60 | 30 |
| n | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 4 | 12 | 12 | 12 | 12 |
| SD | 0.05 | 0.04 | 0.4 | 0.02 | 0.03 | 0.09 | 0.09 | 0.8 | 29 | 120 | 0.9 | 3.8 | 28 | 14 |
| Triticale | 0.27 | 0.24 | 2.7 | 0.09 | 0.16 | 0.07 | 0.14 | 4.5 | 70 | 350 | 7 | 16 | 25 | 20 |
| n | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 |
| SD | 0.05 | 0.02 | 0.3 | 0.02 | 0.02 | 0.06 | 0.03 | 0.14 | 23 | 120 | 0.6 | 3 | 7 | 7 |
| Legumes | | | | | | | | | | | | | | |
| Pea | 1.2 | 0.33 | 2.8 | 0.26 | 0.19 | 0.06 | 0.06 | 3.9 | 105 | — | 8 | 23 | — | — |
| n | 32 | 32 | 32 | 32 | 32 | 4 | 4 | 4 | 4 | — | 4 | 4 | — | — |
| SD | 0.2 | 0.04 | 0.4 | 0.04 | 0.02 | 0.06 | 0.01 | 1.6 | 23 | — | 2.4 | 5.8 | — | — |
| Soybean | 1.75 | 0.24 | 1.9 | 0.48 | 0.21 | 0.37 | 0.07 | 0.63 | 45 | 220 | 5 | 20 | 25 | 6 |
| n | 48 | 48 | 48 | 48 | 48 | 48 | 48 | 48 | 48 | 48 | 48 | 48 | 48 | 48 |
| SD | 0.2 | 0.03 | 0.3 | 0.06 | 0.03 | 0.05 | 0.02 | 0.06 | 10 | 150 | 1.1 | 4.8 | 6 | 1.9 |
| Vetch | 1.5 | 0.31 | 2.9 | 0.26 | 0.2 | — | — | — | — | — | — | — | — | — |
| n | 8 | 8 | 8 | 8 | 8 | — | — | — | — | — | — | — | — | — |
| SD | 0.3 | 0.04 | 0.3 | 0.03 | 0.02 | — | — | — | — | — | — | — | — | — |

[1]Rain-fed spring–seeded cereal, pea, and vetch forages were grown at the University of Nebraska High Plains Agricultural Laboratory near Sidney, where the altitude is about 1,310 m above sea level. Soybean forages were grown at the University of Wyoming Research and Extension Center near Cheyenne, where the altitude is about 1,830 m. All contents are expressed on a DM basis. Mineral contents were determined with the use of x-ray analysis.

[2]SD values represent the variability that existed for harvested forage of these species with available cultivars.

but RUP generally ranged from 5 to 10% of CP for the fresh-cut, annual forage maturities tested. These values were slightly less than the RUP levels suggested in the NRC (1996) for fresh grass and legume forages and reported by Mustafa et al. (2000, 2002, 2004) for pea, alfalfa, barley, and pearl millet forages.

Calculated energy levels for $NE_m$, $NE_g$, $NE_l$, and TDN were in a similar range for the grass-type forages under both irrigated and dryland management, using the ADF equation for sorghum and small grain forages. The ADF for dryland summer annuals ranged from 30 to 32% of DM except for 36% for sudangrass, and 35 to 36% for irrigated forage sorghum, sorghum × sudan, and foxtail millet and 40% for sudangrass and pearl millet. The irrigated ADF values are comparable to the 38% reported by Ward et al. (2000) for forage sorghum and pearl millet and to 36.5% for pearl millet reported by Mustafa et al. (2004), all harvested in vegetative stages.

Using a separate ADF equation for legumes, soybean forage TDN averaged 68% of DM and pea and vetch TDN averaged 64 and 65% of DM, respectively. However, the soybean crop was the only forage grown near Cheyenne, Wyoming, at an altitude of about 1,830 m, where maturity is slower to develop, especially in late summer when nighttime temperatures are cooler. The soybean ADF averaged 28% of DM at mid pod-fill in this study, which was less than the averages for soybean forages at 42.7 and 42.1% at 2 locations in Minnesota (Sheaffer et al., 2001). Seiter et al. (2004) reported soybean ADF at 30% in a 2-yr study when harvested at the beginning pod-fill stage of maturity in New Hampshire with 'Donegal', a forage soybean.

The means for IVDMD were generally in ranges of 72 to 78% for dryland and 64 to 70% for irrigated summer annuals at separate locations. In a 2-yr study, Ward et al. (2000) reported that in vitro apparent digestibilities of silages were similar for forage sorghum and tropical corn but less for pearl millet. Mean IVDMD values comparable to those for several forage crops in this study were also reported by Soder (2005) for some grass-legume pasture forages, depending on the forage mixture and the individual donor cow for the artificial rumen inoculum source.

Forage mineral levels (Tables 3 and 4) are shown for most of the annual forages harvested in 1999. Spring cereal Ca and P averaged about 0.3 and

**Table 4. Feed analyses means and SD for mineral concentrations for dryland and irrigated summer annual forages grown in western Nebraska in 1999 under rain-fed or irrigated conditions[1,2]**

| Forage | Ca, % | P, % | K, % | Mg, % | S, % | Na, % | Cl, % | Si, % | Mn, mg/kg | Fe, mg/kg | Cu, mg/kg | Zn, mg/kg | Ti, mg/kg | Ni, mg/kg |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Rain-fed | | | | | | | | | | | | | | |
| Forage sorghum | 0.49 | 0.03 | 2.7 | 0.18 | 0.11 | 0.04 | 0.07 | 4.2 | 50 | 240 | 7 | 15 | 20 | 14 |
| n | 32 | 32 | 32 | 32 | 32 | 32 | 32 | 32 | 32 | 32 | 32 | 32 | 32 | 32 |
| SD | 0.09 | 0.03 | 0.4 | 0.03 | 0.02 | 0.05 | 0.05 | 0.7 | 12 | 170 | 1.6 | 3.5 | 13.0 | 8.9 |
| Sorghum × sudan | 0.43 | 0.12 | 2.6 | 0.15 | 0.1 | 0.04 | 0.07 | 4.1 | 50 | 180 | 6 | 15 | 16 | 12 |
| n | 24 | 24 | 24 | 24 | 24 | 24 | 24 | 24 | 24 | 24 | 24 | 24 | 24 | 24 |
| SD | 0.06 | 0.02 | 0.3 | 0.02 | 0.01 | 0.05 | 0.03 | 0.6 | 7 | 80 | 1.2 | 2.4 | 5.7 | 4.7 |
| Sudangrass | 0.41 | 0.1 | 2.5 | 0.17 | 0.06 | 0.01 | 0.06 | 3.3 | 40 | 180 | 6 | 13 | 17 | 9 |
| n | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 |
| SD | 0.04 | 0.02 | 0.2 | 0.02 | 0.05 | 0.01 | 0.04 | 1.6 | 5 | 28 | 1 | 3.5 | 3.5 | 0.8 |
| Foxtail millet | 0.35 | 0.12 | 3.2 | 0.23 | 0.14 | 0.06 | 0.03 | 3.9 | 60 | 100 | 6 | 13 | 12 | 7 |
| n | 36 | 36 | 36 | 36 | 36 | 36 | 36 | 36 | 36 | 36 | 36 | 36 | 36 | 36 |
| SD | 0.09 | 0.03 | 0.9 | 0.03 | 0.01 | 0.07 | 0.01 | 0.7 | 14 | 18 | 1.4 | 3.6 | 4.3 | 1.5 |
| Irrigated | | | | | | | | | | | | | | |
| Forage sorghum | 0.44 | 0.22 | 2.6 | 0.29 | 0.14 | 0.16 | 0.5 | 4.8 | 90 | 140 | 7 | 25 | 10 | 10 |
| n | 63 | 63 | 63 | 63 | 63 | 63 | 63 | 63 | 63 | 63 | 63 | 63 | 63 | 63 |
| SD | 0.05 | 0.05 | 0.36 | 0.04 | 0.02 | 0.09 | 0.08 | 0.8 | 20 | 50 | 1.6 | 5.6 | 5.7 | 4.0 |
| Sorghum × sudan | 0.43 | 0.2 | 2.5 | 0.29 | 0.13 | 0.13 | 0.48 | 4.7 | 100 | 110 | 8 | 26 | 9 | 9 |
| n | 35 | 35 | 35 | 35 | 35 | 35 | 35 | 35 | 35 | 35 | 35 | 35 | 35 | 35 |
| SD | 0.04 | 0.03 | 0.4 | 0.03 | 0.02 | 0.1 | 0.07 | 0.4 | 11 | 19 | 1.2 | 4.4 | 5.3 | 2.9 |
| Sudangrass | 0.47 | 0.19 | 2.8 | 0.31 | 0.15 | 0.15 | 0.52 | 4.7 | 90 | 110 | 7 | 24 | 9 | 7 |
| n | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 |
| SD | 0.05 | 0.04 | 0.5 | 0.02 | 0.02 | 0.13 | 0.06 | 0.6 | 11 | 28 | 1.3 | 3.7 | 4.9 | 2.6 |
| Pearl millet | 0.51 | 0.24 | 4.3 | 0.33 | 0.23 | 0.26 | 0.7 | 4.1 | 80 | 150 | 8 | 25 | 9 | 8 |
| n | 42 | 42 | 42 | 42 | 42 | 42 | 42 | 42 | 42 | 42 | 42 | 42 | 42 | 42 |
| SD | 0.07 | 0.04 | 0.9 | 0.06 | 0.04 | 0.09 | 0.15 | 0.7 | 14 | 38 | 1.7 | 5 | 6.2 | 4.7 |
| Foxtail millet | 0.48 | 0.22 | 4.7 | 0.31 | 0.21 | 0.14 | 0.43 | 5.1 | 105 | 170 | 9 | 35 | 12 | 8 |
| n | 35 | 35 | 35 | 35 | 35 | 35 | 35 | 35 | 35 | 35 | 35 | 35 | 35 | 35 |
| SD | 0.07 | 0.03 | 0.6 | 0.05 | 0.02 | 0.09 | 0.06 | 1 | 19 | 40 | 1.4 | 4.6 | 5.3 | 2.3 |

[1]Rain-fed and irrigated summer annual forages were grown at the University of Nebraska High Plains Agricultural Laboratory near Sidney and the Panhandle Research and Extension Center near Scottsbluff, Nebraska, respectively. All contents are expressed on a DM basis.

[2]SD values represent the variability that existed for harvested forage of these species with available cultivars.

0.22% and pea Ca and P averaged 1.2 and 0.33% of DM, respectively, which are similar to values reported by Carr et al. (2004). In the dryland and irrigated summer annuals, Ca was generally in a range of 0.4 to 0.5% of DM, but P levels in these dryland annuals were about half of those in the irrigated trials. However, these 2 systems were at different locations in the region with differences in soils, cropping history, and soil fertility management. For these dryland summer annuals, supplemental feeding with a source of P would be advised if they were the primary component of the diet and no other supplement was fed.

## IMPLICATIONS

Annual forages may be the only reasonable option for many farmers and ranchers to produce supplemental feed for beef cattle in the Central High Plains during drought years. This study showed that the composition of many of the annual forages approached or exceeded 10, 60, 0.4 and 0.2% of CP, TDN, Ca and P, respectively, exceeding dietary composition requirements for growing beef cattle and gestating beef cow classes listed by the NRC. Livestock producers can use these values for formulating rations for specific classes of livestock but should recognize that variation exists among forages of these species because of differences in cultivars and environmental effects. Feed testing of warm-season summer annual forages should include the potential for nitrate toxicity so producers can manage their use by either diluting them with other feeds or by avoiding them.

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