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Case Study: Yield and quality of traditional senescent and stay-green sorghum and in situ ruminal disappearance of respective crop residues

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ABSTRACT

Nutritional composition of sorghum before grain harvest and ruminal disappearance of crop residues were evaluated in traditional senescent and stay-green sorghum hybrids grown under restricted water conditions. Hybrids were seeded in a randomized complete block design (experimental unit = 2.63-ha plots; n = 12, 6 plots per treatment) in limited water conditions (330 mm/season). Plants were sampled 129 d after seeding and botanically fractioned for yield and nutrient composition (Exp. 1) and in vitro true digestibility (Exp. 2). Crop residues were baled and in situ ruminal disappearance was evaluated using a crossover design (Exp. 3). Ruminally cannulated steers (n = 6; BW = 722 ± 65 kg) were randomly assigned to treatments: hybrid (traditional senescent vs. stay-green) and supplement (0 or 0.68 kg/animal daily; cottonseed meal). Experimental periods (n = 4) included a 10-d adaptation phase before incubations of 0, 3, 6, 12, 24, 3, 48, and 72 h. Data were analyzed using GLIMMIX procedures of SAS. Greater ($P \leq 0.05$) whole-plant, grain, and stalk DM yields were observed with stay-green hybrid. Stay-green stalks contained less ash ($P = 0.04$) and greater fiber ($P \leq 0.03$) than the traditional senescent cultivar. Projected whole-plant, grain, and stalk digestible OM yield was greater ($P \leq 0.05$) with stay-green than the traditional senescent cultivar. Ruminal residue OM disappearance of both hybrids was increased ($P < 0.01$) with supplementation beyond 12 h of incubation. Under restricted water conditions, stay-green sorghum cultivar appears to better attend agronomic parameters for forage production compared with the traditional senescent cultivar.

Key words: cattle, residue, sorghum, stay-green, water

INTRODUCTION

Confined feeding operations across the Southern Plains have historically relied upon corn (*Zea mays* L.) due to energy density and feeding value of both grain and silage. However, corn production is a greater burden to increasingly scarce water resources relative to alternatives such as conventional sorghum [*Sorghum bicolor* (L.) Moench; Marsalis et al., 2010]. Continued reliance on the Ogallala Aquifer as a source of subsurface water warrants exploration of alternative fiber sources. Among viable considerations relevant to crop–livestock interaction are sorghum cultivars. Use of sorghum in production of alternative fuels yields a supply of residual fodder, which validates exploration of this residue as a feedstock. Further, some sorghum varieties express a stay-green phenotype that has demonstrated increased plant productivity after anthesis (increased grain yield and stalk mass) compared with conventional varieties. These characteristics are due, at least in part, to a reduced canopy and retarded senescence (Kholova et al., 2014). However, estimates of nutrient composition and ruminal degradation are needed to assess any applicable value to a beef production enterprise. Intuitively, variability in sorghum types and gene expression within similar type will influence these values. Therefore, these experiments evaluated forage and grain yield, nutrient composition, and in situ ruminal disappearance of respective residues of a traditional senescent and stay-green sorghum cultivar grown under restricted water conditions.

MATERIALS AND METHODS

All procedures involving the use of animals were approved by the Texas Tech University Institutional Animal Care and Use Committee (Protocol No. 13079–09). These experiments were conducted at the Texas Tech University Research Center located approximately 9.7 km east of New Deal, Texas.

Site Description

Two commercially sourced (Sorghum Partners, New Deal, TX) sorghum hybrid cultivars were evaluated: (a) NK7829 (traditional senescent); (b) NK8416 (stay-green). Sorghum received 100 mm of water from subsurface drip irrigation in addition to 230 mm of precipitation during a 147-d growing period. Hybrids were planted within a period of 3 d in June of 2013. Experimental units consisted

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of 2.63-ha plots (n = 12; 6 plots per treatment) arranged in 6 complete blocks.

Exp. 1: Yield and Nutrient Composition

Within plot and before grain harvest, samples of whole-plant structure were randomly collected in triplicate on d 129 after seeding by canvassing plots in a zig-zag pattern. Contents of one randomly spaced linear meter within plant lines were collected. The first linear meter collected in each plot was placed inside preweighed cotton bags and dried in a forced-air oven at 105°C for 24 h for extrapolation of DM yield. Samples of a second linear meter were botanically fractioned (grain, leaf, stalk, and shank), and contents of the third linear meter collected from each plot was left intact.

Analysis procedures of samples from the second and third meter collections were identical. First, samples were dried at 55°C for 72 h and subsequently ground to pass a 2-mm (entire sample) then a 1-mm (one-half of homogenized sample) screen in a Wiley Mill (Model 4, Thomas Scientific, Swedesboro, NJ). Further nutritional evaluation of 1-mm samples included quantification of ash, CP, NDF, and ADF. Ash concentration was determined from combustion in a 550°C muffle furnace for 4 h (AOAC, 1990) and CP from the Kjeldahl method (AOAC, 1990). Detergent fiber fractions were analyzed in sequence using an Ankom 200 Fiber Analyzer (ANKOM Technology Corp., Freeport, NY) by methods previously described by Van Soest et al. (1991) with both heat-stable α-amylase and sodium sulfite used during NDF analysis.

Exp. 2: Digestibility and Extrapolated Yield

With the remaining sample portion (2 mm), plant fractions within each plot were evaluated for in vitro true DM and OM digestibility (Tilley and Terry, 1963) using a Daisy-Incubator (ANKOM Technology Corp.). Ruminal fluid inoculum was collected from ruminally cannulated Holstein and Jersey steers (n = 1 each; BW = 718 ± 82 kg). Diets of the ruminal fluid donors consisted of an equal part combination of evaluated crop residues, a cottonseed meal (**CSM**) supplement (0.68 kg/animal per d), and a standard vitamin–mineral package formulated for grazing steers. Following in vitro procedures, estimates of digestible yield within plot were calculated from yield projections (Exp. 1).

Exp. 3: In Situ Ruminal Disappearance

Following the harvest of grain, crop residue within plot was baled. Subsamples from bales within plot were dried in a forced-air oven at 55°C for 72 h. Subsamples were then composited by weight to form treatment samples, which were ground to pass a 2-mm screen in a Wiley Mill. Residues were analyzed for in situ ruminal DM, OM, CP, NDF, and ADF disappearance. Treatments included hybrid (traditional senescent vs. stay-green) alone (**NSP**; no supplement) or in combination with CSM (0 or 0.68 kg/animal per d). Ruminally cannulated steers (3 Holsteins and 3 Jerseys; BW = 722 ± 65 kg) were used in a crossover design. Collection periods (n = 4) consisted of a 10-d adaptation followed by 72 h of in situ incubations. Steers were provided only the sorghum hybrid treatment in periods 1 and 2; CSM supplementation treatments were incorporated for periods 3 and 4. In all periods, steers were provided the respective crop residue ad libitum.

Duplicate hybrid composite samples were weighed (5 g, as-is basis) into 10 × 20 cm Dacron bags (ANKOM Technology Corp.). Samples were incubated in reverse sequential order in the respective adapted rumens for 0, 3, 6, 12, 24, 36, 48, or 72 h. Immediately before placement into the rumen, sample bags (including 0 h) were soaked in tap water for 5 min. Subsequently, bags were placed into 30 × 30 cm nylon mesh bags submersed in the cranial ventral sac (mesh bags also contained a 454-g weight plastic bottle aiming to keep the mesh bag in the allocated position). Following incubation, in situ bags were rinsed by hand with gentle agitation in running tap water until rinse was transparent, as described by Caton et al. (1988), and then dried in a forced-air oven at 55°C for 72 h. Subsequently, bags were individually opened and the contents homogenized. Analysis procedures to determine DM, ash, CP, and detergent fiber concentrations were identical to those described previously in Exp. 1.

Statistical Analyses

Data were analyzed using the GLIMMIX procedure of SAS (SAS Institute Inc., Cary, NC). Nutrient composition and in vitro true digestibility (plant fractions and whole plant) data were analyzed as a randomized complete block design with hybrid (n = 2) as the fixed effect and block (n = 6) as a random effect in the model. Plot (n = 12) served as the experimental unit. Analysis of in situ data included hybrid (n = 2), supplement (n = 2), time (n = 8), and their interactions as fixed effects in the model and steer as random effect. Steer (n = 6) within period (n = 4) served as the experimental unit. In both models, df were adjusted using the Kenward-Rogers method, and least squares means were compared using Tukey's test. Significance was declared at $P \leq 0.05$ and tendencies discussed at $P \leq 0.10$.

RESULTS AND DISCUSSION

Exp. 1. Yield and Nutrient Composition

Total mass and botanical fraction yields (kg of DM/ha) are presented in Table 1. Stay-green cultivars have demonstrated increased grain yields relative to senescent lines when subjected to both late-stage water restriction as well as adequate water (Borrell et al., 2000b). In the current experiment, greater grain production ($P = 0.02$) and whole-plant mass ($P < 0.01$) were observed with the stay-green hybrid relative to the traditional hybrid. Borrell et al. (2000a) previously described increased root