



## **Sugarcane Crosses as Potential Forages for Ruminants: Nutrient Compositions Were Influenced by Season and Time of Harvest**

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### **Introduction**

Accessing the ability of tropical forages to use solar energy in combination with soil nutrients to produce high-quality feed for ruminants is one of the most efficient and sustainable forms of agriculture. In Hawai'i, we have a year-round growing season, with up to 365 days of sunshine and ample rainfall in many places. Total sunny days may vary by location, ranging from 168 to 276 days (The National Climate Center 2015).

Forages for livestock can be classified into three broad categories: a) legumes – generally high in protein and low in fiber, they constitute forage that is very digestible; b) cool- season grasses – these are grasses with the C3 photosynthetic pathway, e.g., Ryegrass, Timothy grass, Kentucky Bluegrass, etc., that generally have high digestibility due to lower fiber content; and c) warm-season grasses – these are the grasses that utilize the C4 photosynthetic pathway, e.g., corn, Guinea grass, California-grass, African Star-grass, Kikuyu-grass, etc. They can yield tremendous biomass, but they also contain higher fiber contents and some have silica. Hence, they are less digestible than cool-season grasses. Sugarcane crosses, the subject of this study, are C4 grasses.

Animal performance on forages, including meat and milk production, is tied closely to forage quality. Intake and digestibility are directly related to plants' fiber content, lignin, and indigestible components. Cooler temperatures result in better-quality forages; higher temperatures

negatively impact forage quality (Ball et al. 2001).

For several years, it was observed that cattle at the Cloverleaf Dairy in Hāwi, Kohala district, would go out to the pasture to graze in the mid-afternoon (1400h), when the heat was intense and the solar radiation load was high (Lee and Hillman 2007). Figure 1 shows yearling dairy heifers in Kohala grazing at 1430 when the temperature-humidity index was above 84. This THI is considered a severe heat stress condition. Why did these heifers compromise their homeostatic condition? The answer, as explained below, is due to the higher feed value in the afternoon.



**Figure 1. Holstein heifers grazing at 1430 h in Hāwi, Kohala, Hawai'i.**

The following were the objectives of this portion of our study on sugarcane crosses as potential forages for ruminants:

1. To determine if season (winter – November to March – or summer – June to September) affects feed quality, and
2. To determine if time of harvest within a season affects the nutrient composition of C4 forages.

## Materials and Methods

Forty sugarcane crosses from over 7,000 seedlings were selected for field evaluation of their potential for ruminant feed. The selection criteria were published (Lee et al. 2014). Each selection was vegetatively propagated in 3.05m (10') x 0.61m (2') rows and irrigated via drip irrigation.

For each season, there was a “cut-back” event, where the forages were cut to a height of 33–35 cm (13–14") from the ground. Cut-back took place in late October of 2013 for winter harvests and late June of 2014 for summer harvests. The plots were sampled three times per season at six-week intervals following the cut-back.

At harvest, total yield (kg) was recorded immediately and a sub-sample of 1 kg was bagged for drying at

65°C for 3 days. The forage was ground using a Thomas Wiley mini mill (model 4). The ground sample was then divided into 2 Ziploc plastic bags. One sample was held back in the laboratory for use in future *in vitro* digestibility studies. The other was shipped for analysis (Dairy One, 730 Warren Road, Ithaca, New York 14850; <http://dairyone.com/>).

Forage analysis at Dairy One utilizes the Near Infrared (NIR) spectroscopy. While a full analysis was ordered for the samples, this paper will examine only selected nutrients. The nutrients of interest are 1) Acid Detergent Fiber (ADF), 2) Nutrient Detergent Fiber (NDF), 3) Crude Protein (CP), 4) Non-Fibrous Carbohydrates (NFC), 5) Water-Soluble Carbohydrates, 6) Starch, and 7) Relative Feed Value (RFV).

## Statistical Analyses

For the effect of season on forage quality, a 2-way analysis of variance (ANOVA) was performed using Prism 6 software (Graphpad, CA, USA). For data reflecting time of harvest, a 3-way analysis of variance (ANOVA) was performed using the same software. Differences in values were depicted with different superscripts in the respective table or graphs.

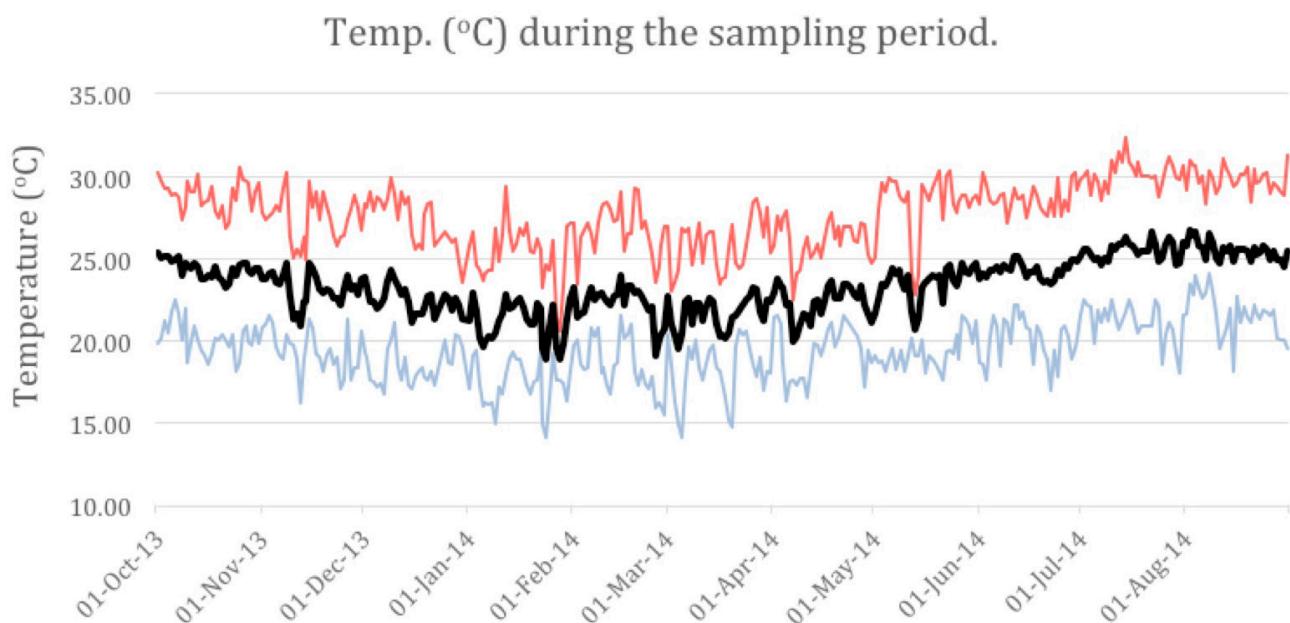


Figure 2. Ambient temperature of the field where the sugarcane forages were planted.

## Results and Discussion

**Weather data:** Figure 2 shows the temperatures (°C, max., average, and min.) for the field site where the 40 different selections of sugarcane forages were planted. The data were obtained from the closest weather station adjacent to the test field. In the winter months (October 15, 2013–March 31, 2014), the average temperature was  $22.35 \pm 0.10$  °C. In the summer months (May 15, 2014–August 31, 2014), the average temperature was  $24.94 \pm 0.08$  °C. Summer temperatures were 2.59°C higher.

Figure 3 shows the average daily solar load for the field site. This is the 24-hour solar load expressed in watts/m<sup>2</sup>. During the winter months, October 15 2013–March 31, 2014, the average solar load was  $170.8 \pm 3.21$  watts/m<sup>2</sup>. During the summer months, May 15, 2014–August 31, 2014, the average solar load was  $281.26 \pm 4.68$  watts/m<sup>2</sup>. The summer daily solar load was 110.46 watts/m<sup>2</sup> higher than the winter solar load.

**Influence of temperature and solar load on nutrient composition of forages:** These differences in weather data seem to influence nutrient composition of the C4 sugarcane forages. Table 1 shows the influence of season (winter vs summer) on nutrient composition of

the forages. The average crude protein (CP) levels were lower in the summer harvests compared to the winter harvests (8.13 vs. 11.32%). Temperature has been known to reduce leaf-to-stem ratio in Timothy-grass (Buxton 1995) and Rye-grass (Ball et. al. 2001). Ohlsson (1991) found that a 10°C increase in temperature can lower digestibility for Red Clover and Timothy-grass by 5%. A University of Arkansas article on cool-season grasses for hay and silages suggested that for small cereals and Rye-grass, an early spring harvest yielded the best forage characteristics (Beck and Jennings 2013). In the current study, we observed a 3.19% decrease in CP for the summer months (see Table 1). Similarly, Beck et al. (2013) reported an 11.4% decrease in CP between November harvest and June harvest for the cool-season annual grasses. However, Buxton and Fales (1994) saw little change in CP levels. They suggested that each 1°C increase in temperature would result in a 0.3–0.7 % decrease in digestibility.

In the current study, we saw the influence of temperatures on non-fiber carbohydrates (NFC), starch, and percent of water-soluble carbohydrates (%WSC). The higher temperatures of summer months significantly increase the levels of NFC, starch, and WSC.

Daily Solar Radiation Load

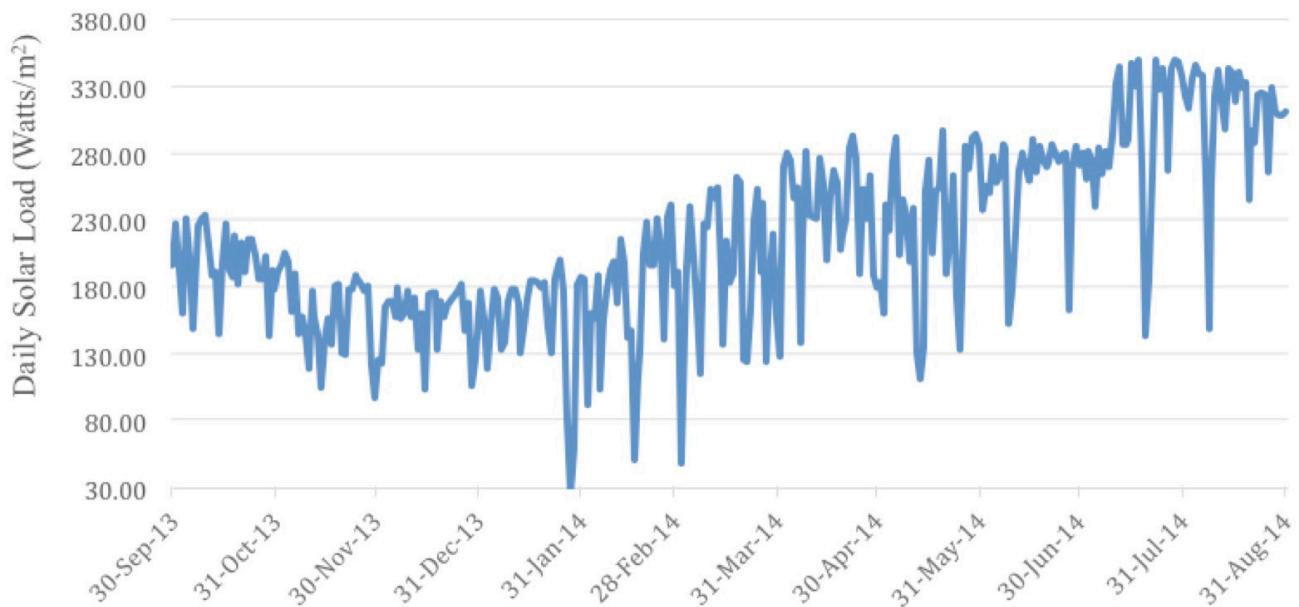


Figure 3. Average daily solar radiation load (24h) for the field where the sugarcane forages were planted.

**Table 1. Comparison of nutrients in sugarcane forages by season (winter = Oct. 15–March; summer=May 15–Sep.), 2013–2014.**

Season	N*	CP	ADF	NDF	NFC	Starch	WSC	RFV
Winter (avg.)	120	11.32	43.34	71.22	8.99	0.52	5.07	72.33
SE		± 0.12	± 0.16	± 0.35	± 0.25	± 0.06	± 0.18	± 0.46
Summer (avg.)	118	8.13	42.60	69.43	12.11	1.42	7.16	74.23
SE		± 0.16	± 0.23	± 0.23	± 0.35	± 0.06	± 0.16	± 0.68
P-value		<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01

\*Note: the lower sample size in summer was to due some forages' inability to recover from the harvest schedule; over time, they decreased in yield to the point that it was no longer viable to consider them.

N = sample size; CP = crude protein; ADF = Acid Detergent Fiber; RFV = Relative Feed Value; NFC = Non-Fibrous Carbohydrates; WSC = Water-Soluble Carbohydrates

**Influence of time of harvest on nutrient composition of forages:** Figure 4 shows the average nutrient composition of the 40 sugarcane grasses in the trial. The times of harvest were a) 830 h, b) 1230h, and c) 1500h. The times were selected for the following reasons: 1) sufficient daylight in the winter months to allow harvesting, sampling, etc. and 2) consideration given to the research field staff, who normally end their workday by 3pm. Each harvest and sampling took ~1h 15min. The nutrients presented in figure 4 are a) CP, b) ADF, c) NDF, d) NFC, e) starch, f) %WSC, and g) relative feed value (RFV).

In the winter season, CP was lowest at the 1500h harvest and highest at 1230h. In the summer months, CP was also lowest at the 1500h harvest but was highest at the 830h harvest (Fig. 4a). Kephart and Buxton (1993) found that imposing shade on forage grasses increased CP values but that this was often at the expense of yield and soluble carbohydrates.

The ADF was highest at 830h harvest for both winter and summer months (Fig. 4b). It was lowest in the harvests past noon. The summer ADF at the 1500h harvest was the lowest at 41%, compared to > 44% at the 830h harvest ( $p<0.01$ ). The winter months saw a lower NDF at 1230h and 1500h harvests compared to 830h harvest ( $p<0.01$ , Fig. 4c). However, no significant differences were observed in the levels of NDF in the summer har-

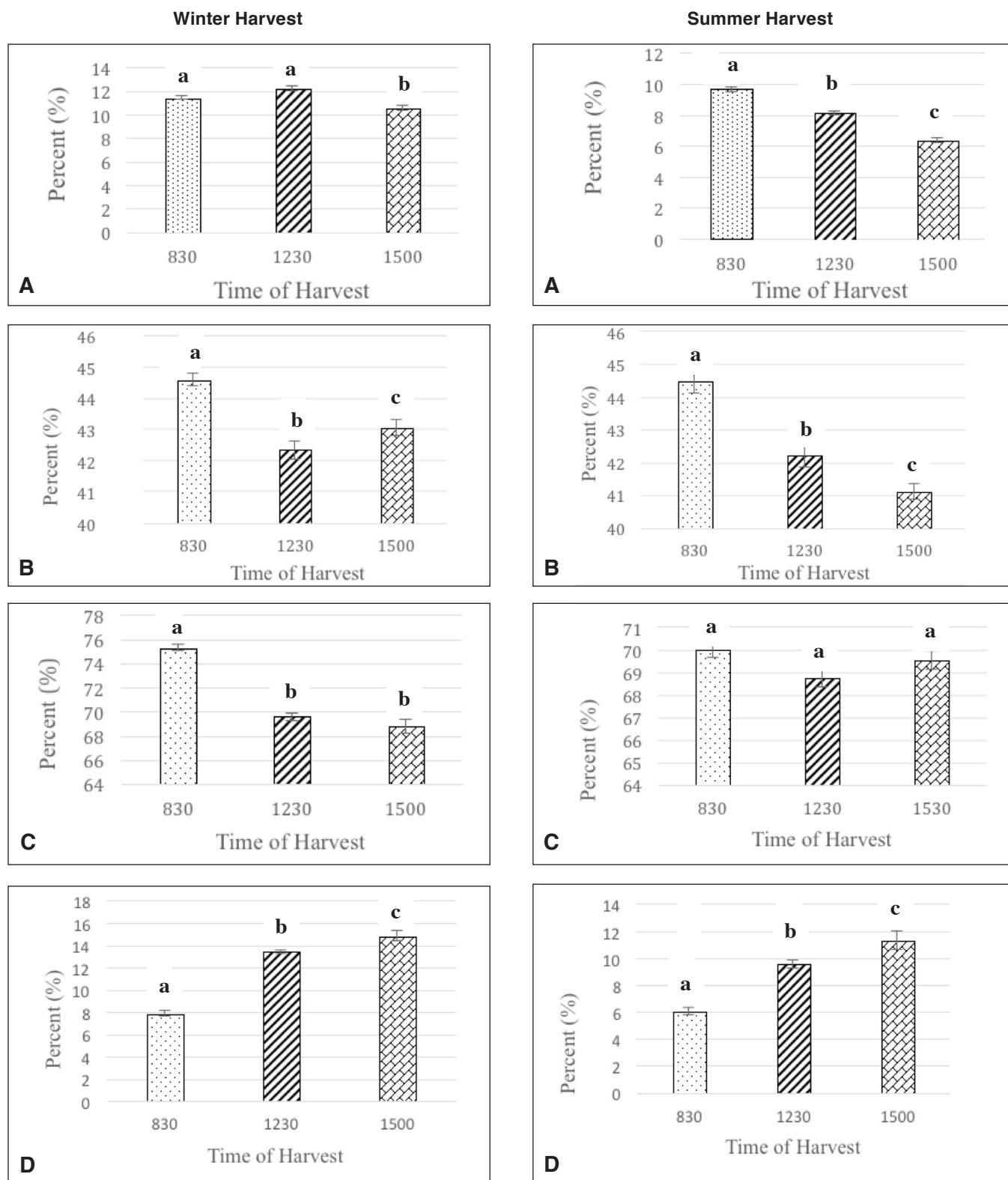
vest times, although the 1230h harvest was the lowest. Two factors probably played a role in these differences: the rapid growth rate due to higher ambient temperature and the intense solar radiation on the plant tissue, which may have contributed to the lack of difference in the NDF observed in the summer harvest.

High levels of NDF and/or ADF have negative effects on dry-matter intake. The high levels of NDF increased retention time in the gut, thus contributing the “gut fill” factor (Allen and Oba 1998, Belyea et al. 1993). Both NDF and ADF contribute to increase chewing time (Firkins 2010, Norgaard et al. 2011).

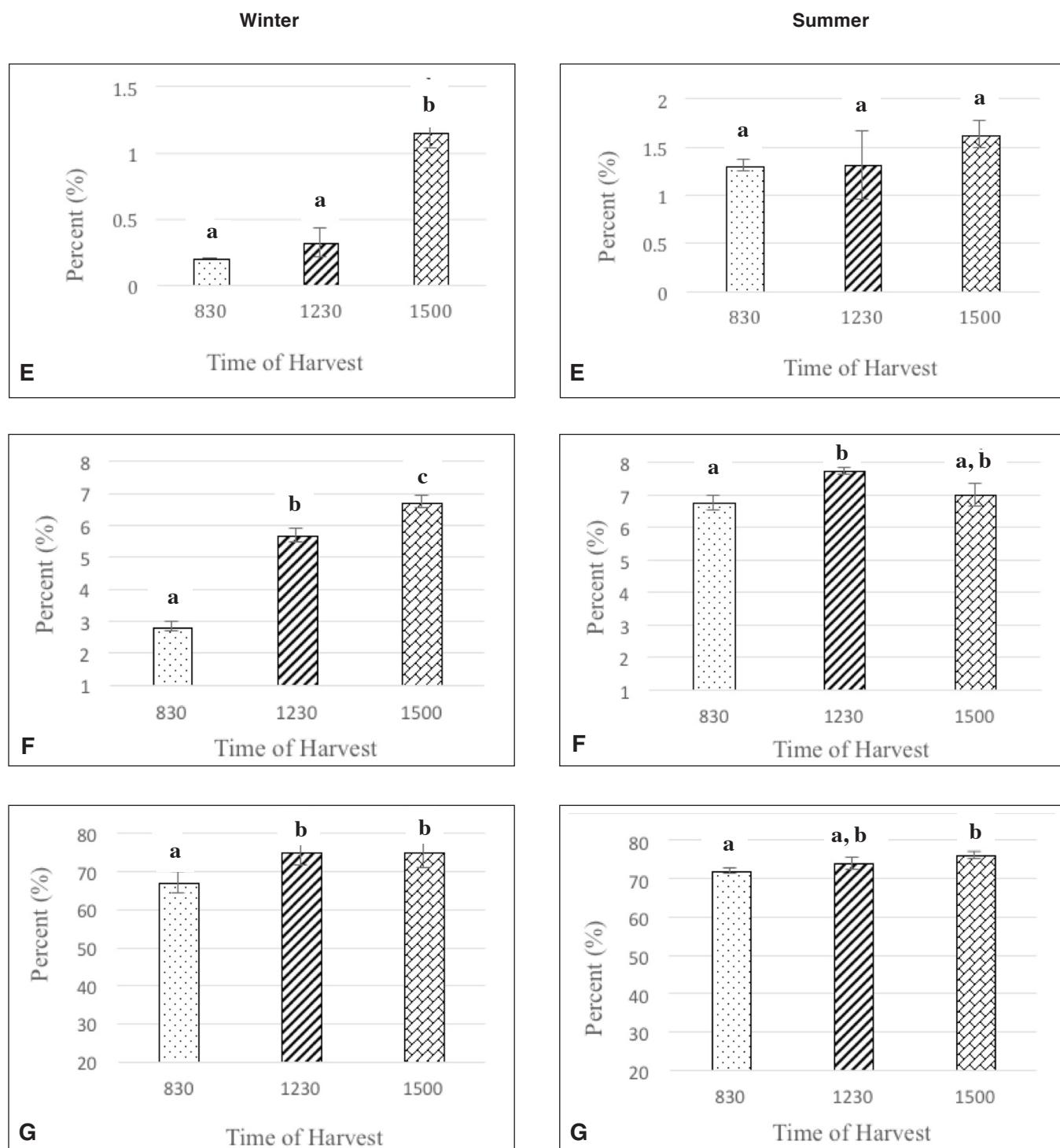
The NFC content for summer (Fig. 4d) showed increasing values with respect to harvest time, with the 1500h harvest having 2x the NFC values compared to 830h harvest (14.83 vs 7.84%.  $P<0.01$ ). Similarly, this was true for the winter harvest where the 1500h harvest time yielded 2x NFC content compared to the 830h harvest (11.83 vs 6.08 %,  $P<0.01$ ).

In the winter months, the starch concentrations increased in the plants over the course of the day. The 1500h harvest had 5x the starch level compared to the 830h harvest (1.16 vs 0.2,  $p<0.01$ , Fig. 4e). This could be due to the influences of temperature, solar radiation, and/or the genetics of the plant. In the summer months the variations in the starch concentrations were not as great,

**Figure 4. The influence of harvest time on nutrient compositions: 4A. Crude Protein (CP), 4B. Acid Detergent Fiber (ADF), 4C. Neutral Detergent Fiber (NDF), 4D. Non-Fibrous Carbohydrates (NFC). Note: Different superscripts differ significantly ( $P<0.01$ ).**



**Figure 4, continued. The influence of harvest time on nutrient compositions: 4E. Starch, 4F. Water-Soluble Carbohydrates (%), WSC), 4G. Relative Feed Value (RFV).**



although a higher level was observed at the 1500h harvest compared to the 830h harvest (1.63 vs 1.31, P<0.01). The level of starch was higher in the summer months vs the winter months. Again, this can be attributed to the higher temperatures, the higher solar load, and the genetic makeup of the forage in this project.

The percentage of WSC for winter months reflects that of the starch concentration (Fig. 4f). The 1500h harvest yielded 2x more WSC than the 830h harvest (6.7 vs 2.8%, P<0.01). The WSC levels were very similar at all harvest times in the summer months.

Fermentation of starch and carbohydrates in the rumen affects the bacteria population and subsequently the flow of microbial protein to the small intestine (Ferguson 2015). Microbial proteins are “by-pass” proteins; they provide solid protein for animal growth and milk production. Shenkoru et al. (2006) showed that afternoon (PM)-harvested alfalfa yielded higher butyrate acid and greater microbial nitrogen flow to the duodenum in ruminants when compared to morning (AM)-harvested alfalfa.

Several studies have shown that dry-matter intake and milk yield increased when dairy animals were fed afternoon-harvested feed (Kim et al. 1995, Berthiaume et al. 2013). Kim et al. (1995) reported 8% more dry-matter intake and 8% more milk. Berthiaume et al. (2013) showed 1.6 kg/day more energy-corrected milk and lower milk urea nitrogen, suggesting better utilization of N by the microbes in the rumen.

The influence of harvest time on carbohydrate composition has been noted in Switch grass (a C4 plant), tall fescue, and alfalfa harvested in the afternoon (PM) vs the morning (AM) (Maryland et al. 2000). In the study, using steers, sheep, and goats, the researchers suggested that the animals showed a preference for afternoon-harvested grass hay. There was an indication that some animals were able to differentiate between the PM- and AM-harvested forages by smell. This preference seems to be associated with the higher concentration of total nonstructural carbohydrates. In another study, Huntington et al. (2004) concluded that PM-harvested Gamagrass hay prompted a 7% greater dry-matter intake in goats and a 17% greater dry-matter intake in steers than AM-harvested Gamagrass. They attributed this to the higher total non-fibrous carbohydrates in forages in the PM harvest.

Studies suggest that genetic contribution may enhance starch and carbohydrates by ~13% for alfalfa but time of harvest contributes 46% higher values for these components (Chouinard-Michaud et al. 2010). Tremblay et al. (2011) demonstrated that PM harvest had higher NSC than AM harvest for spring, summer, and fall. The higher concentrations of sugars were not affected during the wilting process.

The above studies may help to explain the earlier observation that the dairy heifers were going out to graze at mid-afternoon. The sun and solar radiation might be high, but the forages on the pasture offered the best nutrition due to photosynthesis. The plants had low fiber and high sugar and starch contents (high energy) at that time of the day. Energy is one of the limiting factors for high milk production and better weight gains. Similar grazing behavior was observed by Gregorini et al. (2006), where dusk grazing was observed to be of greater intensity and duration. Griggs et al. (2004) confirmed higher soluble carbohydrates in PM vs AM forage. This suggests that cattle are driven to maximize intake based on energy needs.

The relative feed value (RFV) within a season also showed that PM-harvested forages had higher RFV (Fig. 4g). In the winter months, early harvest at 0830 yielded the lowest RFV (67.05) compared to the 1500h harvest, which had an RFV of 75.05. The RFV for the forages was 72.15 for the 830h harvest, and this value was higher than that of winter harvests, probably due to higher solar load and temperature for the season. The 1500h harvest RFV was 76.25, and this was higher than the 830h harvest (P<0.01).

## Impact

The cumulative information from this study and others available in the literature explains why cattle grazed with such concentration and vigor in the late afternoon. It would be worthwhile to identify the forages in this study with the higher starch and NFC content and plant some fields for grazing trials in future for local forage-finished beef. The data further suggest that for those making hay or bio-fuel from forages, PM harvests will yield a higher-quality product.

## Summary

This study demonstrated that season and time of harvest can influence the nutrient composition of forages. The

time of harvest has the greatest influence on the starch, NFC, WSC, and ADF values, and all these factors will impact animal performance.

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