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Sugarcane Crosses as a Potential for Ruminants: Dry-Matter Yield and Nutrient Analysis of Selected Cultivars

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Introduction

In the United States, feed cost is a major contributor to cost of production for commercial livestock operations (Schnepf 2011). Schnepf (2011) reported that feed cost can account for as much as 70% of the cost of production for milk, 69.5% for cow–calf operations, and 70% for poultry. Winfield et al. (2016) cited 62% of production for pigs in the US, and Ibaburu (2015) indicated that 57.2% of the production cost for 1 dozen eggs was attributable to the cost of feed. In Hawai‘i, the importation of livestock feed increases the overall costs of production over other regions on the mainland.

In Hawai‘i, beef cattle farmgate value was estimated to be over $64m (NASS 2014). Hawai‘i's cattle industry is dominated by cow–calf operations, in which the weaned-off animals are usually shipped to the US mainland for growing and finishing. However, there is a growing focus on the potential for grass-finished beef production in Hawai‘i. The Islands are blessed with a year-round growing season, but this is dependent on rainfall. Several studies mapping out the best areas for grass-finished beef have been produced (Fukumoto et al. 2015, Fukumoto et al. 2016a, Fukumoto et al. 2016b). In spite of several years of drought (Mersereau 2015, Eversole and Andrews 2014), studies by Kim et al. (2015) have demonstrated that it is possible to produce tender grass-finished beef. Hence, the ability to grow forages that can meet the nutritional requirements of grass-finished beef is important to address issues of sustainability, including self-sufficiency of protein needs; create jobs in rural communities; ensure open space; and contribute an alternative economic tool to the Islands.

Figure 1. Variation in "green" yield at harvest between different cultivars of sugarcane crosses.

Objectives

This article is part of a series reporting our investigation of the potential of sugarcane crosses as forage for ruminants. Previous publications from our laboratory dealt with selection criteria (Lee et al. 2014) and the influence of season and harvest times on nutrient profiles (Lee et al. 2015). Pate et al. (2002) presented a good review on sugarcane as a forage for cattle.

In this current study, seventy-four cultivars were selected from over 30,000 lines from various sugarcane crosses. The objectives were to a) evaluate the nutrient profile of each of the 74 varieties that were selected, b) examine their yields (see Figure 1), and c) attempt to select the top 10 cultivars for further studies in other locations (and potentially, if funding is available, determine the forage–animal performance interactions).

Materials and Methods

Numerous crosses of sugarcane varieties were produced by Hawaiian Commercial and Sugar (HC&S) company for evaluation as potential sources for bio-fuel. It was recognized that there was some potential that these crosses could also be used for forage needs for livestock. Seventy-eight selections were made using the criteria previously discussed by Lee et al. (2014). Each of the selected varieties was vegetatively propagated in plots of 3.05m (10') x 0.61m (2') and drip irrigated. The land, field 601 of HC &S company in Maui, was 86 m (284ft.) above sea level (N20° 53'36.5", W156°24'04.2"). Planting were done in two phases: a) Phase I – 40 varieties were planted in July 2013 and data were collected from October 2013 to August 2014; b) Phase II – 38 varieties were planted in July 2014 and data were collected from October 2014 to August 2015.

Of the 78 varieties initially selected, 66 varieties were used in this study. Twelve varieties in Phase II were culled due to rust or smut development or poor growth. The first cut-back occurred in mid-October of each of the test years. Each cut/harvest was 33–35 cm above the ground. The forage samples were weighed and recorded. Then 1kg. wet weight of each variety was taken for oven drying and subsequent nutrient analysis. Samples were dried at 65^{0}C for 3 days. The samples were ground using a Thomas-Wiley mini mill (Model 4) and divided into equal portions, and the Ziploc plastic bags were appropriately labelled. One sample was held back in the laboratory for future *in vitro* digestibility studies and the other was sent to Dairy One Laboratory (Ithaca, NY 14850) for analysis by Near Infra-Red (NIR) spectroscopy.

Although the analyses were comprehensive, the selected nutrients of interest here were a) crude protein (CP), b) acid detergent fiber (ADF), c) neutral detergent fiber (NDF), d) non-fibrous carbohydrate (NFC), e) starch (S), f) water-soluble carbohydrates (WSC), g) total digestible nutrient (TDN), and h) relative feed value (RFV). The dry-matter yield in kg. per ac. per yr. (DM/ac./yr.) was calculated from the harvest data per plot. The data were then sorted by Excel ranking methodology for respective nutrients.

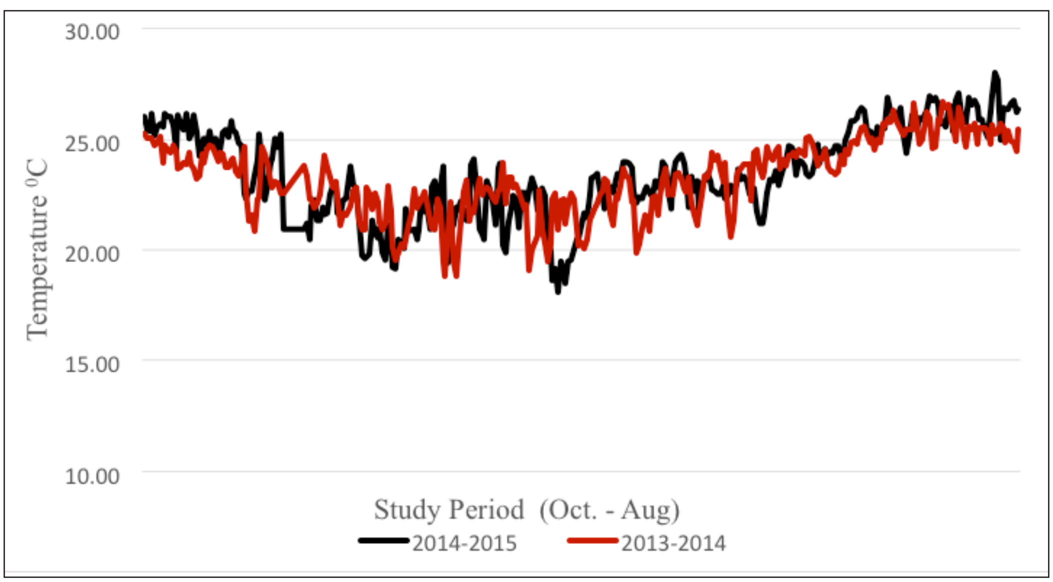

Figure 2. The average temperatures (^{0}C) in Field 601 of Hawaii Commercial and Sugar company, Maui, for October 2013 to August 2014 and October 2014 to August 2015.

Results and Discussion

Figure 2 shows the temperature for the growing seasons when samples were collected. There were no differences in the temperature between the two years. The average winter temperature (October–March) was 22.4^{0}C and the average summer temperature (May–August) was 24.1^{0}C. The average humidity was 72.1% and the average wind speed was ~15.6km/hr. The strongest winds in the field occurred between 1100 and 2100h, with the lowest wind speed of ~10.4 km/hr. occurring between 0000 and 1000h.

Table 1 shows the range of each of the specific parameters mentioned: DM, CP, ADF, NDF, NFC, S, WSC, TDN, and RFV. Initial selection of these cultivars was based solely on physical appearance and tactile (hand-feel) characteristics. The cultivars showed huge variation in nutrient composition. Similarly, there was a huge difference in yields. Some cultivars were able to withstand the harvests with hand machete at 6-week intervals and throve, increasing the growth of stolons or producing new shoots at crown, while others varieties showed reduced vigor and signs of demise. Figure 1 provides an example of yields from some cultivars. Figure 3 shows an example of those varieties that throve under the cultivation system, where new growth of 3.81 cm. occurred within 20h after harvesting. Rapid regrowth of biomass following harvesting is a desirable trait, as it would ensure availability of feed, enhance carrying capacity, and potentially yield more meat protein per acre. The DM yields for the selected cultivars ranged from 2,383 kg./ac./yr. to over 33,141 kg./ac./yr., a difference of over 30,000 kg.

However, dry-matter yields must be accompanied by desirable nutrient composition. Large variations exist in CP, ADF, NDF, NFC, S, and WSC, resulting in the observed differences in TDN and RFV. For each of the nutrients listed, the top 10 ranking yielded a different list of forage cultivars.

The average CP for the 66 cultivars was 9.5 + 0.1%.

Figure 3. An example of sugarcane crosses capable of withstanding the harvest by machete, showing regrowth of 3.8 cm 20h after cutting.

Table 1. The average and range of dry matter (DM), acid detergent fiber (ADF), neutral detergent fiber (NDF), non-fibrous carbohydrates (NFC), starch (S), water-soluble carbohydrates (WSC), total digestible nutrients (TDN), and relative feed value (RFV).

	DM kg/ac/yr.	CP %	ADF %	NDF %	NFC %	S %	WSC %	TDN %	RFV %
Average	10,848.0	9.49	42.86	70.30	9.95	0.85	5.54	56.0	73.7
±	929.3	0.09	0.14	0.17	0.16	0.04	0.14	0.24	0.3
Range	2,383.4 to 33,141.7	7.68 to 11.18	39.93 to 45.43	66.52 to 74.10	7.33 to 12.55	0.30 to 2.08	3.08 to 7.82	48.7 to 60.3	68.2 to 79.8

The top 10 cultivars have CP values from 10.4 to 11.2%. The CP level for these cultivars is sufficient to meet the requirements for mature lactating beef cows, first-calf heifers, and bulls (Hall 2016, Moore et al. 1991). Newport (2014) suggested that CP may be the wrong indicator for forage quality and that degradable intake protein (DIP) may be a more useful reflector of forage quality. The DIP is the fraction of protein that can be degraded in the rumen and becomes available to the animal.

Table 2 shows the top 10 cultivars of sugarcane crosses for each of the respective nutrients. The highest DM cultivar, C12, did not make the top 10 for CP, ADF, NDF, NFC, etc. Similarly, high-CP cultivars like F3 and A6 did not make the top 10 in DM yield. In short, no single nutrient measurement is sufficient as a tool for forage selection.

Forage Indices

Relative Feed Value (RFV) is a commonly used forage index. The RFV is based on the nutrients provided by alfalfa forage in full bloom, which is considered 100%. For this forage, other nutrient values are CP – 16%, ADF – 41%, and NDF – 53% (Jeranyama and Garcia 2004).

Table 2. The top 10 cultivars of sugarcane crosses in terms of selected nutrients

Sample #	DM Kg./ac./yr.
C12	33141.7
B11	28521.5
D9	27320.4
C11	24852.0
D7	24232.9
A10	23621.6
D11	23485.9
D10	22164.1
D12	20045.3
B3	19025.0

Sample #	CP (%)
F3	11.18
A6	11.10
B6	10.78
J1	10.77
A11	10.68
D7	10.55
B5	10.50
B1	10.42
B13	10.38
A2	10.38

Sample #	ADF (%)
F3	39.93
A7	40.75
A3	40.77
A6	41.10
D8	41.15
A11	41.33
G4	41.37
J1	41.52
C9	41.65
H3	41.68

Sample #	NDF (%)
A6	66.52
A11	66.57
B1	67.17
F3	67.78
J1	67.93
B2	68.47
I1	68.53
D9	68.95
G5	69.10
C9	69.12

Sample #	NFC (%)
A7	12.55
A8	12.48
A9	12.32
D9	12.13
C9	11.98
A6	11.93
G5	11.80
B9	11.73
F2	11.58
A11	11.52

Sample #	Starch (%)
B1	2.08
A5	1.62
A1	1.37
B7	1.32
D9	1.27
A4	1.23
A7	1.23
A11	1.20
B10	1.17
C7	1.17

Sample #	WSC (%)
A9	7.82
D8	7.82
A6	7.43
A1	7.27
A8	7.27
C8	7.17
D9	7.17
A3	7.05
C9	7.05
A7	6.83

Sample #	TDN (%)
A3	60.33
F3	59.67
A6	59.00
B9	58.33
G4	58.17
I6	58.17
B10	58.00
A7	57.83
A13	57.83
C10	57.83

Sample #	RFV (%)
A6	79.83
F3	79.83
A11	79.33
B1	77.67
J1	77.67
C9	76.50
B2	76.17
G4	76.00
G5	76.00
A3	75.83

The RFV is more reflective of fiber digestion, with the assumption that dry-matter intake is a constant for all forages. It further ignores the value of CP in the forages, and DM yield is not factored into the equation either. Despite these limitations, this index is widely used.

Relative Feed Quality (RFQ) is another index that is available but not as commonly known to the lay reader. This formula was developed by Wisconsin researchers (Undersander et al. 2010). This equation takes into account the TDN of the forage and thus more accurately accounts for the digestibility of the forage. However, it does not account for production data. Under the RFQ index, dry cows and heifers of 18mo. or older would need forages between 100 and 120 RFQ (Newport 2014). Younger animals would need forages with RFQ over 115, and dairy animals would need forages of RFQ 125 or higher. Like RFV, RFQ focuses on feed-quality factors and does not account for yields. For a greater understanding of forage quality, check Robinson et al. (1998), Putnam et al. (2008), and Undersander et al. (2010). Quality Index (QI) is also another index used to quantify the quality of forages that was reported by Moore et al. (1991). QI is based on the ratio of TDN:CP.

Total Digestible Nutrients (TDN) can also be used to evaluate a forage, although this measure is more commonly used for grains. For most beef cattle operations, a minimum of 55% TDN would meet the needs in terms of DMI. A higher TDN would result in higher intake and hence higher gains (Lalman 2015, Moore et al. 1991). Younger animals would require forages with lower ADF (<42%) and higher TDN (60% or higher). Our results indicate that the top 10 cultivars would provide 57% TDN, 41.7% or lower ADF, and NDF values below 70. The TDN values would meet the needs of cow–calf operators. However, the fiber values of sugarcane crosses, which use C4 photosynthetic pathways, are high compared to hay made from alfalfa, a C3 plant.

The formula for the calculation of TDN includes the NFC value of forages. Several studies have shown that forages with higher NFC would result in greater weight gain (Mayland et al. 2005, Burns et al. 2005, Huntington et al. 2005) or higher milk production (Kim et al. 1995, Berthiaume et al. 2013). Undersander (2015) showed the relationship of NFC and RFQ for alfalfa. As the NFC values increase, the RFQ value for that forage also increases ($r^2 = 0.61$).

Hence, a challenge arises for ranchers or those producers who have land constraints and a desire to produce more feed per acre/hectare. This is especially true in many developing nations where farmers own small plots of land and at the same time face a rapidly rising demand for ruminant protein (Thorton 2010). The income of such smallholders is limited by the amount of space on which they can grow feed for their animals. High nutrient values in forages do not mean the plants can withstand the stress of grazing or cutting; conversely, high yields may not equate to digestible feed for the ruminants.

Thus, there may be a need to develop a theoretical forage index that would accommodate all the important nutrients including DM yield for C4 forages, which have higher fiber content than many traditionally researched forages. McDowell and Hernandez-Urdaneta (1975) highlighted the challenges of producing beef in the tropics where producers have limited land area. Moore and Undersander (2002) presented the relationships between fiber, energy, and intake for forages and proposed the use of a new index, the relative feed quality, for evaluation of the quality of temperate and tropical forages. Intake is generally lower with tropical forages (Moore and Mott 1975, Vendramini 2010) due to structures and composition of cell walls and differences in forages. In the next publication, we will make an attempt to do this. Ultimately, more field studies that evaluate the NFC, CP, NDF, and ADF content from these cultivars or other C4 forages would help to provide greater insights on the relationship between yield and nutrients and animal performance in the tropical regions.

Impact

This study demonstrates that no single nutrient composition can be used as a selection tool for tropical forages. Along with our previous publications on the potential of sugarcane crosses as ruminant feed, one must take into account DM yield, fiber digestibility, and time of harvest to ensure better animal performance.

Summary

There are wide variations in the nutrient compositions of sugarcane crosses. In addition, there were huge differences in DM yields. Data in the literature suggest that a minimum of 10% CP combined with TDN greater than 55% is necessary for desirable DMI for most cow–calf operations. Several of the sugarcane cultivars meet this requirement, but a robust tool for evaluation of tropical forages must be developed to gain a better understanding of nutrients in tropical forages and animal performance.

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