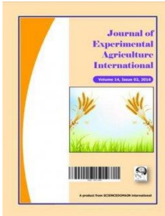

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Preference and Forage Quality of 13 Cultivars of Forage Barley and 2 Cultivars of Oats when Grazed by Sheep

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Authors' contributions

This work was carried out in collaboration between all authors. Author ECG designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors ECG, DMS and DF were responsible for data collection. Author DMS managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Annual forages are an increasingly important feed source for ruminants in the western region of the U.S. However, little information is available on the grazing value and forage quality of many cultivars. The objectives of this project were to evaluate sheep grazing preference and forage quality of thirteen forage barley cultivars and two oat cultivars. Eight Rambouillet rams were used in a randomized complete block design. Rams were allowed to graze a single replication of all fifteen entries for a 24-h period before being moved to another replication. Quadrats were hand-harvested from each plot immediately before and after grazing to evaluate herbage mass production and herbage mass removal. Subsamples were collected and sent to a commercial lab for quality analysis. Visual scores of herbage mass removal were taken from each plot post-grazing. No differences were observed between herbage mass production or herbage mass removal, although there were differences in visual pre- and post-grazing assessment scores ($P < 0.001$). Significant differences were observed amongst cultivars for acid detergent fiber (25.9-35%, $P = 0.011$) and

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nitrate concentrations (2.1-2.5% NO_3; $P < 0.002$), with the oat varieties having the highest nitrate. Other forage quality parameters evaluated were not significantly different among cultivars. Based on nutrient quality, without accounting for nitrate concentrations, these cultivars are a high-quality forage source. This research shows that these annual forage cultivars can be utilized as a high-quality grazing source to meet animal requirements; however, care must be taken to avoid elevated nitrate levels.

Keywords: Annual forages; sheep; grazing; grazing preferences.

1. INTRODUCTION

Small grains are highly-ranked commodities contributing to the Montana economy. Barley for grain is one of the top crop items (in acres) produced in Montana [1], and forage barley acres are increasing as grain prices decrease. Barley and oat production has risen in Montana since the last census conducted in 2012. The Montana State Agriculture Overview (2015) reported a total of 860,000 acres of barley and 22,000 acres of oats harvested in 2015. Although there has been a rise in small grain production, overall cereal grain prices in 2016 have caused concern among producers. A combination of a declining livestock market, lower international/domestic corn prices, and an adequate supply of eastern and western feed grains has reduced small grain prices. Concerned producers have begun looking for an alternative market for their small grains, sparking an interest in the use of annual cereal crops as forage.

The economic value of feeding cereals as forage to livestock depends on both yield and quality. The inverse relationship between yield and forage quality influences the extent to which a forage can produce a desired animal response [2]. Factors that influence year-to-year variability in forage quality are species composition, plant maturity, and environment [3]. Grazing animals avoid certain components of vegetation based on chemical characteristics and “anti-quality” factors. Grazing preference is usually influenced by nutritive characteristics and the proportion of indigestible components present in forage [4]. Thomas et al. [4] reported that the grazing strategy for sheep allowed them to respond to changing vegetation characteristics. The sheep in this study preferred to consume forage that did not limit nutrient availability and allowed for increased intake of digestible dry matter. The authors of this study suggest that grazing strategy and preference by sheep allows them to maintain nutrients essential for optimal rumen function.

Variation in yield and quality of cereal forages depends on cultivar, stage of growth, year, and planting location [5]. Oats used as forage are generally higher yielding than other cereal crops such as barley, wheat, triticale, and rye [5,6]. However, yields comparable to oat have been reported in the literature in both barley and triticale [7]. The nutritional forage value of oat is generally lower than that of other cereals. Reports in the literature show lower in vitro dry matter (IVDM) and organic matter (OM) digestibility for oat than for barley [7-9]. Baron et al. [8] reported that in vitro dry matter digestibility (IVDMD) and crude protein (CP) was highest for wheat and triticale, intermediate for barley, and lowest for oat.

Utilizing cereal crops as forage is a potential alternative market option for producers during times when cereal grain prices are low. Cereal forages have high yield potential; however, producers need to be mindful of the trade-off between yield and forage quality. Grazing preference varies due to differences in quality between cultivars. Research regarding grazing selection and preference between different cereal forages may be useful for producers during cultivar selection. Selection will vary based on environmental conditions, the goals of the producer, and the type of animal being used.

2. MATERIALS AND METHODS

All protocols were approved by the Montana State University Agriculture Animal Care and Use Committee (Protocol 2016-AA12).

Fifteen cultivars were established on May 18, 2016 on Meadowcreek loam soils at the Bozeman Agricultural Research and Teaching Farm. The seedbed was prepared a year prior, and was rolled once more immediately prior to seeding. Species were established into a prepared seedbed, previously disked and harrowed, using a no-till drill, and seeded at a rate of approximately 73 kg ha^{-1}. Fertilizer amounts were based off of soil samples taken prior to establishment. All species were grown in a dryland environment, with no supplemental irrigation.

The study was planted as a randomized complete block design, with a total of three reps per cultivar. Each block contained all fifteen cultivar entries. Individual plots measured 1.8 m x 4.6 m. Initial plant heights were taken in three locations within each plot across the diagonal using a meter stick. Initial herbage mass samples for all plots were taken on July 13, 2016, after a majority of the cultivars had begun heading. All cultivars were within 5-10 days of heading at harvest. As all plots were uniform in growth, a 0.3 m x 0.3 m quadrat was randomly thrown into the middle of each plot, and samples were cut to a 5 cm height using a hand-held electric shears (Black and Decker, New Britain, CT). Samples were immediately weighed for initial fresh herbage mass, and placed in a 60°C oven for 72 hours for drying. Upon drying, samples were immediately reweighed to determine initial dry matter herbage mass. Density of each plot was determined by taking the initial dry matter herbage mass divided by the area harvested. The density was then extrapolated to the entire plot to determine whole plot dry matter production, as well as dry matter production in kilograms per hectare.

Each replication was fenced off individually using mesh nylon fencing. A solar-powered charger was used to electrify the fence. On July 18, 2016 at 0800, eight Rambouillet rams (47.0 ± 8.3 kg) were placed into block 1 for a 24-h grazing period. Sheep were removed after 24-h and placed into block 2 for the second day of data collection. On day 3, sheep were moved into block 3 for the final 24-h grazing period. Sheep had ad libitum access to water.

Residual herbage mass samples were taken each day immediately after sheep removal. Due to uneven grazing, two 0.3 m x 0.3 m quadrats were harvested to a 5 cm height from each plot to more accurately depict residual herbage mass. These samples were placed in a 60°C oven for 72 hours for drying. Herbage mass removal was calculated using Equations 1 and 2.

Herbage mass removal (g) = initial DM herbage mass – residual DM herbage mass (1)

Herbage mass removal (%) = (initial DM herbage mass – residual DM herbage mass) / initial DM herbage mass (2)

Samples were ground using a Wiley mill (Thomas Scientific) with a 2-mm screen. Ground samples were thoroughly mixed, and subsamples were submitted to Midwest Laboratories (Omaha, NE) for nutrient analysis. Acid detergent fiber (ADF), total digestible nutrients (TDN), crude protein (CP), crude fat (CF), net energy for maintenance (NEm), and nitrate levels were evaluated.

Data were analyzed using the Proc GLM procedure of SAS Version 9.4 (SAS Institute, Cary, NC). Plots were the experimental unit, and statistical significance was set at $P \leq 0.05$. Means are the least square means of the GLM procedure. Cultivar and replication were set as fixed effects. No interactions between cultivar and replication were found to be significant, or have a trend for significance ($P \geq 0.10$), and so those data are not shown.

3. RESULTS AND DISCUSSION

No differences were observed between cultivars in initial herbage mass (HM) production (P = 0.38; Table 1), residual HM production (P = 0.11), initial plant height (P = 0.38), or residual plant height (P = 0.15), while a trend was estimated for HM removal (P = 0.06). There were cultivar differences ($P < 0.0002$) observed in visual estimation of HM removal, with 'Stampede' showing considerably more HM removed by the grazing animals than any other cultivar entered. There were also differences noted in the forage barley varieties, with the new forage barley entries being significantly more preferred over some of the older varieties.

There was no significant difference in the measured herbage mass removal of the plots (P = 0.19), and it is believed that this difference is due to sampling method. Only two quadrats were removed and weighed per plot. This may have caused a significant portion of the plots to be missed and the analysis to be altered. Sampling a larger portion of the plot may have been more reflective of the visual observations. However, it was noted that each day the animals were turned into a new set of plots, all sheep went to the oat plots first before moving to the forage barley plots.

It is not surprising that there was no difference between the initial heights and HM production of the entries, as all entries appeared to have fairly similar growth patterns. Some of the cultivars, particularly the two oat entries, did mature a little faster than the other entries in the trial, but the height was fairly similar among all plots.

Table 1. Morphological attributes of the fifteen cereal forage cultivars tested

Cultivar	Species	Initial plot DM herbage mass[1] (kg)	Initial DM herbage mass (kg ha^{-1})	Residual DM herbage mass (kg)	Herbage mass removal (%)	Initial plant height (cm)	Residual plant height (cm)	Visual removal estimation (%)
Haybet	Barley	1857.9	11665.0	1096.9	50.6	70.4	41.7	31.7^{a}
Hays	Barley	1605.2	10078.4	758.9	50.5	51.1	40.1	50.0^{bc}
Haymaker	Barley	1765.9	11088.2	874.4	50.0	59.2	32.3	36.7^{acde}
Lavina	Barley	2013.9	12645.8	1016.6	48.7	65.3	41.4	33.3^{ade}
MT103083	Barley	1542.0	9681.7	848.8	45.8	53.6	31.5	48.3^{bcd}
Haxby	Barley	1934.1	12144.0	915.7	52.5	62.2	36.3	55.0^{b}
Horsford	Barley	1689.7	10609.1	806.8	51.2	56.4	42.4	48.3^{bcd}
Pronghorn	Barley	1817.4	11410.5	831.0	53.4	89.4	66.3	21.7^{e}
MT10397-1	Barley	1896.9	11910.9	1023.6	44.9	68.6	41.0	45.0^{abcd}
MT103038-6	Barley	1809.5	11362.0	818.6	54.3	45.0	25.7	56.7^{b}
MT103038-4	Barley	1878.5	11796.0	1070.7	42.2	52.3	33.0	48.3^{bcd}
MT103089-3	Barley	1806.6	12044.1	813.9	57.0	61.0	34.8	$41.7a^{bcd}$
MT103101-5	Barley	1461.1	9173.8	1000.0	38.3	64.3	40.6	$46.7a^{bcd}$
Otana	Oats	1822.3	11441.6	776.6	57.0	76.5	38.6	55.0^{b}
Stampede	Oats	1276.5	8014.1	586.6	53.6	43.4	14.5	86.7^{f}

[a,b] Means without a common superscript within a column differ (P ≤ 0.05)

[1] DM: Dry matter

There was an impact of replication on residual DM herbage mass ($P < 0.001$) and measured herbage mass removal ($P < 0.001$), with rep 1 being significantly lower than reps 2 and 3 in both measurements. This likely indicates that the sheep were not properly acclimated to the species, as they had previously been grazing annual forage hay and not fresh forage, which probably contributed to this difference.

There was no significant difference amongst cultivars in CP ($P = 0.43$; Table 2), and CF ($P = 0.97$). There was an effect of cultivar on ADF ($P = 0.011$), TDN ($P = 0.036$), NEm ($P = 0.045$), and nitrates ($P = 0.002$). There was also a significant effect of replication on NEm ($P < 0.001$), and TDN ($P < 0.001$), with all reps being significantly different from one another, and rep 3 having the highest values for both nutrients and rep 1 the lowest. This was unexpected, as all soils were fertilized similarly, and the field was quite level. The data show no differences in initial herbage mass ($P = 0.79$) or initial height ($P = 0.53$), so it is unlikely that the growing conditions were different amongst replications.

The cultivar (MT103101-5) with the highest TDN and NEm is part of a program that breeds and selects for improved digestibility and energy availability, so it is not surprising that it outranked some of the older varieties of forage barley and oats. The cultivar quality rankings found in this study are similar to another study conducted in Montana and Wyoming in 1994, where 'Horsford' and 'Haybet' barley were both found to have higher TDN and CP than 'Otana' and 'Stampede' oat varieties [10]. The CP appears to be much greater than other reported values for similar cultivars, with our values ranging from 17.3-21.5%, while other reports have CP values ranging from 8.6-15.3% when annual forages were grown in similar environments [11-13]. However, in these studies, the annual forages were being harvested for silage or hay, and were harvested at a later maturity than those harvested in our study. This is supported by our lower ADF values, which ranged from 26.5- 35%, while those in the aforementioned studies ranged from 18-46%. ADF is an indicator of digestibility in the forage, and as a forage matures, more fiber is accumulated and the digestibility is decreased. Also, many of our entries are newer varieties which have been bred for lower fiber and increased digestibility, resulting in the lower fiber values and elevated protein and energy values.

The oat entries had the highest levels of nitrates, which is in agreement with many other published reports [14-16]. The values found in this study are in agreement with those found by Gul and Kolp [16], although they were much higher

Table 2. Nutrient quality analysis of the fifteen cultivars of cereal forage cultivars tested

Cultivar	Species	CP	ADF	CF	TDN	NEm	Nitrate
				%			% NO_3
Haybet	Barley	18.7	30.2^{a}	2.6	63.4^{acd}	0.64^{abd}	1.02^{ab}
Hays	Barley	21.4	26.7^{b}	3.5	63.3^{a}	0.64^{a}	1.19^{a}
Haymaker	Barley	20.1	28.0^{ab}	2.5	62.9^{a}	0.64^{ab}	0.98^{ab}
Lavina	Barley	18.7	29.3^{ab}	3.4	64.1^{abc}	0.65^{abde}	0.82^{b}
MT103083	Barley	21.5	29.3^{ab}	2.9	60.5^{cd}	0.61^{cb}	1.11^{ab}
Haxby	Barley	17.8	26.9^{ab}	4.3	64.3^{a}	0.66^{d}	0.89^{b}
Horsford	Barley	16.2	30.4^{a}	2.8	62.1^{abcd}	0.63^{abcde}	0.77^{b}
Pronghorn	Barley	18.5	33.4^{ac}	3.9	63.0^{ac}	0.64^{ab}	0.46^{b}
MT10397-1	Barley	20.0	29.6^{ab}	2.9	62.7^{acd}	0.64^{abcd}	1.19^{ab}
MT103038-6	Barley	20.8	25.9^{b}	2.7	62.8^{ac}	0.64^{abd}	1.23^{ab}
MT103038-4	Barley	19.1	26.5^{ab}	3.2	62.6^{abc}	0.63^{abd}	1.09^{ab}
MT103089-3	Barley	18.6	31.3^{a}	3.1	61.4^{acd}	0.62^{abc}	0.97^{b}
MT103101-5	Barley	17.3	27.8^{abc}	3.0	65.0^{b}	0.66^{e}	0.76^{b}
Otana	Oats	18.5	35.0^{c}	2.7	62.3^{c}	0.63^{b}	2.53^{c}
Stampede	Oats	20.3	27.0^{ab}	3.7	60.3^{d}	0.60^{c}	2.10^{c}

^{a,b} Means without a common superscript within a column differ ($P \leq 0.05$)
CP: crude protein, ADF: acid detergent fiber, CF: crude fat, TDN: total digestible nutrients, NEm: net energy for maintenance

than those found by Stamm et al. [11], and Todd et al. [13]. This is likely due to the fact that our forages were harvested at an earlier maturity (within five days of heading), compared to the other studies where they were harvested at soft dough.

Oats tend to be the highest nitrate accumulators, more so than wheat and barley, as they generally convert lower amounts of NO_3-N to organic N [14]. It has also been anecdotally reported that barley and wheat varieties that have been bred for forage production tend to have lower nitrate risks than their grain-producing counterparts. While all of the entries tested reached at least a cautionary level of nitrates in which they would need to be limit-fed to pregnant animals, none of the forage barley entries reached a level close to the oat entries. However, we did not see any adverse effects in the grazing animals, and none of the eight animals exhibited any signs of nitrate toxicity. This may be due to the short duration of grazing, as well as the fact that sheep appear to be slightly more resistant to elevated nitrate levels compared to other species of livestock and horses.

4. CONCLUSION

Overall, the results of this study suggest that these forage barley and oat cultivars are an acceptable grazing source for livestock. In exception to the high nitrate levels found in both oat entries, the nitrate levels found in the forage barley entries are safe for non-pregnant animals, although they should be dilute-fed to pregnant animals. The high protein, energy, and fat, as well as low fiber values illustrate that these are forages that will allow for adequate animal gains and productivity. The relatively high production of each entry, even in a dryland setting, demonstrates that these can also be an economical forage source, with high dry matter production per acre.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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