COMPARISON OF FORAGE YIELD AND NUTRIENT QUALITY OF HIGHLAND OAT VARIETIES IN BHUTAN

WANGCHUK[1] AND KARMA DORJI[2]

[1]National Development Center for Animal Nutrition, Department of Livestock, MoAL, Bumthang, Bhutan
[2]National Highland Development Center, Department of Livestock, MoAL, Bumthang, Bhutan

* Author for correspondence: wangchuk@moal.gov.bt

ABSTRACT: The on-farm experiments were conducted to evaluate forage yield and nutritional quality of two promising highland oat varieties namely Gansu 2 and Qingyin oats with stampede oats variety as control under the farmers' field management conditions in Bhutan. The experiment was laid out in randomized complete block design with three replications. The variety Gansu oat 2 produced significantly higher green forage yield than variety stampede. However, there was no significance difference in essential nutrient (Crude protein) content between new and existing oat varieties. The study concluded that variety Gansu oat 2 is suitable for forage production under temperate and sub-alpine climatic conditions and is a viable alternate oat variety to address winter fodder shortage in highland districts of Bhutan.

Keywords: Crude protein; dry matter yield; forage yield; highland; oat varieties

1. INTRODUCTION

Free ranching of native pasture is the dominant ruminant feeding system in most of the developing countries. It is grazed without proper management and as results native pasture in general are deteriorated and the quality is poor leading to poor performance of animal (Semman 2018). Poor livestock nutrition is the major factor affecting the development of viable livestock industries in developing countries (Sere et al. 2008). The success of livestock production and enterprise are highly dependent on the quantitative and qualitative adequacy of feed resources (Atumo et al. 2021) and timely availability (Dinkale et al. 2021). In Bhutan, various intervention such as promoting fodder conservation and winter fodder development have been made to address the feed shortage during lean seasons. One of the alternatives is intensive propagation of oat varieties for winter forage production in the country. Oat is used as succulent winter fodder crop with excellent growth habit, good quality herbage and palatability (Khanal et al. 2017). In highland areas, oat is normally harvested as hay and fed to grazing livestock as supplement during long and harsh cold season under traditional farming system (Zhang et al. 2007). The improved oat varieties produced three-fold green fodder yield and could feed twice the number of animals per unit as against the traditional fodder crop (Dinkale et al. 2020). Gyeltshen et al. (2017) reported that the Oat in in alpine region of Bhutan is used as conserved fodder in the form of hay and in temperate and subtropical regions as a fresh fodder managed under cut and carry system. As of now, the number of oat varieties with good forage yield, quality, and winter hardiness used in extension program remained limited to the dairy farmers. Currently, there are only two oat varieties namely Stampede Oat and Fodder Oat Bhutan (FOB) recommended for winter fodder production in Bhutan. Nonetheless, in 2017 five cold tolerant varieties of oat (Gansu oat 1, Gansu 2, Gansu oat 3, Lina oat and Qingying), known to provide high forage yield in high altitude areas in Tibetan plateau were introduced with support from the International Centre for Integrated Mountain Development (ICIMOD), Nepal. Of the five highland oat cultivars, two highland oat varieties namely Gansu oat 2 and Qingyin oat were found promising through initial variety screening trials. Therefore, the study was conducted to assess growth, forage dry matter production and nutritional quality of two promising highland oat varieties (Gansu oat 2 and Qingyin oat) under farmers' field conditions in Bhutan.

2. MATERIALS AND METHOD

2.1 Experimental sites

The field experiment was conducted from March to October 2021 at three locations, Naruth (Bumthang), Phobjikha (Wangdue) and Tsaluna (Thimphu). The experimental sites were located at an altitude range of 2600 to 3000 meters above sea level (masl). All the experimental sites fall under temperate environment characterized by cool wet summer and cold dry winter. The geographical locations of the sites were located between 27.54° North latitude and 90.75° East longitude.

2.2 Experiment design and treatment

A Randomized Complete Block Design (RCBD) was used with three replications and three treatments in each location. The treatments were Gansu oat 2, Qingyin oat and Stampede. Stampede was used as control. In each experimental site, individual plot measured 5 m^2 (2.5× 2 m) and there were total of 9 plots. Each replication had three plots. Spacing followed were 50 cm between plots and 70 cm between replications.

2.3 Field management and sowing

The experimental plots located within the farmland of the participating farmers were properly ploughed, harrowed and fenced for forage research purpose. The plots were divided into blocks and each block comprised of three sub-plots. The seed was sown at the rate of 50 kg per acre. Farmyard manure was applied at the rate of 5000 kg per acre during the establishment period. Sowing was done in spring season, and manual irrigation was done at early stage. The periodic weeding was carried out to maintain the field. Plants along the border of plots were cut and disposed off at the time of data collection and excluded from measurement.

2.4 Field measurement and data collection

The crop was harvested at booting stage after sowing. The second harvest was done at 60 days after first cut. The data on fresh and dry matter yield, number of tillers, plant height, number of leaves per plant and leaf to stem ratio were recorded; similar measurements were carried out in the second and third cut. For the fresh yield, the entire plot was harvested and fresh plant materials were weighed using weighing scale (Spring balance). For the plant height, ten plants were randomly selected from each plot and plant heights were measured with measuring scale. Ten plants were selected at random and plants parts were segregated into leaf and stem and then weighed separately to calculate leaf to stem ratio. The tiller numbers per plant were counted from ten plants randomly selected from each plot and recorded.

2.5 Laboratory analysis

Plant materials were thoroughly mixed after harvesting and a representative sample weighing 250 gm was collected from each plot.

A total of 27 samples were collected from the three experimental sites. These samples were used to estimate dry matter (DM) content, crude protein (CP), crude fat (CF) and total ash contents. The laboratory tests for dry matter and nutrient contents were performed at the Animal Nutrition Laboratory, NDCAN, Bumthang. Samples were dried in a hot air oven at 65°C for 48 hours. After drying, samples were chopped into small pieces, ground into to fine powder and stored in sealed bag before chemical analysis. The dry matter was calculated based on following formula.

$$\% \text{ DM} = \frac{\text{W3} - \text{W}}{\text{W2} - \text{W1}}\ X\ 100$$

Where W_1 is the weight of the pan, W_2 is the weight of pan + weight of fresh sample and W_3 is the weight of the pan + weight of the dried sample.

The proximate analysis was performed to determine CP, CF and total ash content. A factor of 6.25 was used for converting total nitrogen to CP content (i.e., % CP = % N x 6.25).

2.6 Data analysis

The data for biomass and DM yield from each cut in respective experimental site was added and converted to acreage to obtain total yield. For morphological traits, data was averaged from three cuts. The data was entered in Microsoft Excel and exported to IBM SPSS version 26 for statistical analysis. The data sets were checked for outliers followed by Shapiro Wilk's and Leven's tests for normality and homogeneity of variance respectively.

The Generalized Linear Model with one-way MANOVA was performed to compare the mean differences on various parameters between new and existing oat varieties. Differences in means were considered significant when p-value was less than 0.05.

3. RESULTS AND DISCUSSION

3.1.1 Plant height

The data for morphological traits for mean plant height, tiller number, leaf number and leaf to stem ratio are represented as PH, TN, LN and LSR respectively in Table 1. Plant height is a major factor contributing towards forage yield of different crops (Ansar et al. 2010). The tallest plant recorded among three oat varieties in Naruth was Gansu oat 2 (93.58 ± 8.74 cm) followed by Stampede oat (83.65 ± 13.97 cm) and Qingyin oat (79.78 ± 7.73 cm). Similarly, in Phobjilka and Tsaluna, plant height measured for Gansu oat 2 were 103.66 ± 4.04 cm and 84.33 ± 7.02 cm which were taller than stampede oat of 86.00 ± 10.00 cm and 78 ± 1.73 cm, respectively. Plant height recorded for Qingyin oat in Phobjikha was 94.33 cm and Tsaluna was 82.33 cm. The plant height of Gansu oat 2 was significantly ($p < 0.05$) higher than stampede oat in Phobjikha. However, there was no significance ($p > 0.05$) difference between two highland oat varieties and stampede oat in Naruth and Tsaluna. The significant effect of variety on plant height in the present study is in agreement with the previous findings (Lodhi et al. 2009 and Beyene et al. 2015). The main cause of difference in plant height is due to variation in environmental conditions and genetic makeup of the varieties (Singh et al. 2018).

In the current study, oat varieties were evaluated in three different locations. Guenni et al. (2008) mentioned that availability of light plays a major role in influencing plant growth and survival. Plant height is also affected by status of soil fertility and positive effect of application of organic and inorganic fertilizer on plant height was reported by Tripathi et al. 2016).

3.1.2 Number of tillers per plant

Tillering in forage grass is an important trait for the productivity and sustainability of the grazing system (Silva 2015). Number of tillers per plant plays vital role in increase or decrease of crop yield (Shah et al. 2015). As shown in Table 1, the tiller numbers counted for Gansu oat 2, Qingyin oat and Stampede in Naruth were 5.67 ± 0.57, 5.33 ± 0.57 and 5.00 ± 0.45. In Phobjikha, Gansu oat 2 variety recorded 4.34 ± 0.57 tillers per plant, followed by Qingyin oat and Stampede which produced tiller numbers of 4.33 ± 0.58 and 4.31 ± 0.57, respectively. The tiller numbers per plant recorded in Tsaluna for variety Gansu oat, Qingyin oat and Stampede were 8.33 ± 1.15, 8.30 ± 1.52 and 7.33 ± 1.15. The number of tillers per plant was not significantly ($p > 0.05$) affected by different oat varieties in three different locations. This finding is in agreement with the result reported by Zaman et al. (2006). However, in contrast, Arif et al. (2002) and Naeem et al. (2002) observed significant variation among oat varieties in numbers of tiller per plant. Differences in number of tillers among the varieties may be attributed to genetic variation of oat varieties (Muhhamad et al. 2011). Tillering process in the plant is also affected by amount of rainfall it received and sufficient amount of rainfall make faster plant growth, triggering more tiller per plant which are responsible for more dry matter yield (Kebede et al. 2016).

3.1.3 Numbers of leaves per plant

The number of leaves play a vital role in growth of the plant. Over all, the development and growth of the plant depends on total number of leaves as it acts as the basic factory for food production in growing plants (Wada et al. 2019). The maximum number of leaves was recorded for variety Gansu oat 2 (5.00 ± 1.00) and Stampede (5.00 ± 0.98) followed by variety Qingyin oat (4.33 ± 1.15) in Naruth. In Phobjikha, Gansu oat 2 (6.00 ± 0.00) produced maximum number of leaves per plant followed by Qingyin oat (5.67 ± 0.57) and Stampede (5.33 ± 0.58). The numbers of leaves counted per plant at Tsaluna were 4.67 ± 0.57, 4.33 ± 0.58 and 4.00 ± 0.00 for variety Gansu oat 2, Qingyin oat and Stampede. However, significant differences ($p > 0.05$) were not observed on the number of leaves per plant among oat varieties across three locations. Yield of the forage crops depend on increase or decrease in number of leaves per plant (Khan et al. 2014). According to Tessema and Getinet (2020), plant leaves play greater role in influencing forage yield. The number of leaves per plant was also affected by soil fertility stage and application of nitrogen fertilizer (Ali et al. 2017). Irfan et al. (2016) reported higher and lower numbers of leaves of forage oat with highest and lowest N application. The fertilizer was applied on initial stage and only organic farmyard manure was used for soil fertility improvement in current study.

3.1.4 Leaf to stem ratio

Leaf to stem ratio is an important trait in the selection of appropriate forage cultivar as it is strongly related to forage quality (Befekadu and Yunus, 2015). Leaf to stem ratio represents leaf weight divided by stem weight. As shown in Table 1, the variety Gansu oat 2 (0.44 ± 0.11, 0.68 ± 0.07, 0.71 ± 0.10) recorded the highest leaf to stem ratio followed by Qingyin oat (0.38 ± 0.02, 0.64 ± 0.04, 0.66 ± 0.07) and Stampede (0.35 ± 0.04, 0.63 ± 0.04, 0.65 ± 0.16) in three locations. But there was no significant difference ($p > 0.05$) for leaf to stem ration among oat varieties. The result obtained was in conformity with those reported by Mengistu et al. (2021). The leaf to stem ratio has important effect on the quality of the forage and edible plant preferred by animals. Location wise, leaf to stem ratio was recorded higher in Tsaluna in all three oat varieties. The variation in leaf to stem ratio in three locations may be attributed to soil fertility status and environmental conditions in different agroecological zones including effect of temperature. Stage of harvest including cutting regime also affected the leaf to stem ratio. According to Sharma et al. (2019). reduction in leaf to stem ratio with delay in fodder cut could be due to increase in stem biomass owing to more dry matter accumulation in stem than leaves. In the present study, forage harvesting was maintained uniformly at 60 days cutting intervals throughout the experimental period. Yiberkew et al. (2020) mentioned that type of soil fertilizer applied and plant spacing also affect the leaf to stem ratio and the highest leaf to stem ratio was observed at manure and wider spacing.

3.2 Yield parameter

3.2.1 Fresh fodder biomass and dry matter yield

Fodder yield is the most important trait and ultimate product of fodder variety which indicates the total biomass attained by the plant during its life cycle. As illustrated in Table 2, variety Gansu oat 2 (12.62 ± 1.49, 25.78 ± 4.53 MT/acre) recorded significantly ($p < 0.05$) higher forage biomass yield than existing oat variety Stampede (8.78 ± 2.25, 19.12 ± 7.53 MT/acre) at Naruth and Phobjikha, respectively. However, there was no significant difference observed among three varieties on forage dry matter yield although Gansu oat 2 yielded numerically higher dry matter yield than stampede. The significant effect of variety on green forage yield in present study is in line with the previous findings of (Khanal et al. 2017; Semman et al. 2018; Dinkale and Semman, 2019). Variation in forage yield among oat varieties may be attributed to differences in environmental conditions, sowing seasons, soil fertility and genetic makeup of varieties (Desta 2022). Moreover, genotype interactions with the environment and environmental factors over year have an impact on yield performance of forage species (Hidosa and Kibiret 2019). The previous study reported by Molla et al. (2018) demonstrated that warmer climatic condition and better distribution of rainfall are the major reasons for getting better forage yield and other growth parameters in forage species. In present study, the evaluation was carried out in temperate environment during summer and autumn seasons. Forage yield was also affected by harvesting management and dry matter yield was recorded higher by cutting forage oat at 65 days than at 45 days (Patel et al. 2022). Minimum harvesting period of 60 days was maintained in present study for subsequent fodder cuts. Higher yields of fodder in oat cultivars can also be possibly attributed to their greater leaf area, responsible for more photosynthetic activities having high capacity to store assimilative products of photosynthesis (Amanullah et al. 2004). Yield is a complex quantitative character and is mainly influenced by environmental fluctuations. Thus, the selection for superior genotypes based on yield parameter at a single location may not be very

Table 1: Morphological traits (Mean ± SD) of highland oat varieties at three experimental sites

Location	Oat varieties	PH (cm)	TH	LN	LSR
Naruth	Gansu oat 2	93.58 ± 8.74^{ns}	5.67 ± 0.57^{ns}	5.00 ± 1.00^{ns}	0.44 ± 0.11^{ns}
	Qingyin oat	79.78 ± 7.73^{ns}	5.33 ± 0.57^{ns}	4.33 ± 1.15^{ns}	0.38 ± 0.02^{ns}
	Stampede	83.65 ±13.97^{ns}	5.00 ± 0.45^{ns}	5.00 ± 0.98^{ns}	0.35 ± 0.04^{ns}
Phobjika	Gansu oat 2	103.66 ± 4.04*	4.34 ± 0.57^{ns}	6.00 ± 0.00^{ns}	0.68 ± 0.07^{ns}
	Qingyin oat	94.33 ± 9.29^{ns}	4.33 ±0.58^{ns}	5.67 ± 0.57^{ns}	0.64 ± 0.04^{ns}
	Stampede	86.00 ± 10.00^{ns}	4.31 ± 0.57^{ns}	5.33 ± 0.58^{ns}	0.63 ± 0.04^{ns}
Tsaluna	Gansu oat 2	84.33 ± 7.02^{ns}	8.33 ± 1.15^{ns}	4.67 ± 0.57^{ns}	0.71 ± 0.10^{ns}
	Qingyin oat	82.33 ± 4.16n	8.30 ± 1.52^{ns}	4.33 ± 0.58^{ns}	0.66 ± 0.07^{ns}
	Stampede	78.00 ± 1.73^{ns}	7.33 ±1.15^{ns}	4.00 ± 0.00^{ns}	0.65 ± 0.16^{ns}

Table 2: Total forage yield (Mean ± SD) per acre for highland oat varieties at three experimental sites

Location	Oat varieties	Fresh forage biomass (MT)	DM yield (MT)
Naruth	Gansu oat 2	12.62 ±1.49*	1.68 ± 0.35^{ns}
	Qingyin oat	13.00 ± 4.36*	1.62 ± 0.56^{ns}
	Stampede	8.78 ± 2.25	1.06 ± 0.25^{ns}
Phobjika	Gansu oat 2	25.78 ± 4.53*	2.69 ± 0.48^{ns}
	Qingyin oat	19.99 ± 7.22^{ns}	2.14 ±0.57^{ns}
	Stampede	19.12 ± 7.53^{ns}	2.09 ± 0.92^{ns}
Tsaluna	Gansu oat 2	26.40 ± 3.60^{ns}	3.72 ± 0.17^{ns}
	Qingyin oat	22.59 ± 7.24^{ns}	3.56 ± 0.93^{ns}
	Stampede	24.29 ± 2.32^{ns}	3.26 ±0.14^{ns}

** p < 0.05; ns: not significant*

effective (Shrestha et al. 2012).

3.3 Fodder quality parameter

3.3.1 Crude protein content

The quality of fodder plants is largely determined by their nutritional value (Jakubus and Graczyk 2022). Crude protein is one of the vital factors affecting quality of fodder and represents important criteria for evaluating forage quality (Lithourgidis et al. 2007). From the point of nutritional value, Crude Protein is an essential nutrient for livestock and its content not only affects the economic benefits but also affects the milk yield and protein yield of livestock (Li et al. 2022). Table 3 presents the nutrient content mainly crude protein, crude fat and total ash of three oat varieties across different experimental locations. Variety Gansu oat 2 (11.92 ± 4.39 %, 13.91 ± 0.44 %, 12.52 ± 0.99 %) recorded higher crude protein content than existing oat variety stampede (10.19 ± 1.26 %, 12.78 ± 2.26 %, 11.24 ± 0.91 %) in all three experimental sites. Statistically no significant ($p>0.05$) difference was observed among three oat varieties. This finding is in line with that of Habib et al. (2003) and Devkota et al. (2015). However, these findings are contradictory to those of Wada et al. (2019) and Adeel et al. (2014) who reported that crude protein content varied significantly among oat varieties. These conflicting results can be attributed to variation in soil fertility status and climatic conditions in different agro-ecological zones. The crude protein content is also influenced by maturity stage of the forage plant and crude protein content in leaves and stem decreases as the growth stage of plant advances (Abdelraheem et al. 2022). Harvesting intervals of 60 days were maintained for subsequent cuts in present study in all locations. The crude protein content in Gansu oat 2 in current study is comparable to those reported by Wayou et al. (2019). The level of crude protein content recorded in all three oat varieties in the current study is above the recommended minimum level (7%) of CP by Van Soest (1994) in the diet of ruminants for optimum rumen function.

3.3.2 Crude fat content

As shown in Table 3, variety Gansu oat 2 (2.83 ± 2.83 %, 2.00 ± 0.00 %, 2.00 ± 0.00 %) recorded numerically higher crude fat content than stampede oat (2.66 ± 0.57 %, 1.83 ± 0.28 %, 2.00 ± 0.00 %) in Naruth and Phobjikha. However, there was no significant different observed among three varieties on crude fat content. These findings are in agreement with those of Staudenmeyer et al. (2017). But Saleem et al. (2015) reported significant difference in crude fat content among oat varieties. This variation could be due to genetic and environmental factors. Nutrient content of the plant depends on stage of maturity and as plant ages, reduce the digestible nutrients due to increase in percentage of cellulose and hemicellulose content (Ribeiro et al. 2014). The best time to harvest oat for forage is in the late milk to early dough or mid-dough growing stage (Gardner and Wiggans 1961). According to CSIRO (2007), crude fat level of 2% or below in forage are considered low while level of 5% or above are considered high. In this study, crude fat level obtained in variety Gansu oat 2 was below 5% in three experimental sites. These variations could be due to soil fertility status and stage of defoliation.

Table 3: Forage quality parameters (Mean ± SD) for highland oat varieties at three experimental sites

Location	Oat varieties	CP (%)	CF (%)	Total ash (%)
Naruth	Gansu oat 2	11.92 ± 4.39^{ns}	2.83 ± 2.83^{ns}	5.86 ± 2.54^{ns}
	Qingyin oat	9.65 ± 1.10^{ns}	2.84 ± 1.25^{ns}	4.86 ± 1.44^{ns}
	Stampede	10.19 ± 1.26^{ns}	2.66 ± 0.57^{ns}	5.61 ± 2.76^{ns}
Phobjika	Gansu oat 2	13.91 ± 0.44^{ns}	2.00 ± 0.00^{ns}	8.12 ± 1.49^{ns}
	Qingyin oat	12.89 ± 1.16^{ns}	1.84 ± 0.29^{ns}	9.51 ± 1.97^{ns}
	Stampede	12.78 ± 2.26^{ns}	1.83 ± 0.28^{ns}	8.87 ± 0.90^{ns}
Tsaluna	Gansu oat 2	12.52 ± 0.99^{ns}	.00 ± 0.00^{ns}	28.23 ± 0.71^{ns}
	Qingyin oat	11.37 ± 1.40^{ns}	1.66 ± 0.57^{ns}	8.23 ± 0.16^{ns}
	Stampede	11.24 ±0.91^{ns}	2.00 ± 0.00^{ns}	8.18 ± 0.31^{ns}

** $p < 0.05$; ns: not significant*

3.3.3 Total ash

Ash is the total mineral content of forage. The total ash content recorded for variety Gansu oat 2 were 5.86 ± 2.54, 8.12 ± 1.49, 8.23 ± 0.71 percent and Qingyin oat were 4.86 ± 1.44, 9.51 ± 1.97, 8.23 ± 0.16 percent in three locations. Variety stampede recorded total ash content of 5.61 ± 2.76, 8.87 ± 0.90 and 8.18 ± 0.31 percent. But statistically significant differences ($p > 0.05$) were not observed among oat varieties, a similar observation was recorded by Ayub et al. (2011).

Variation in concentration of minerals in forage can be influenced by various factors such as varieties, plant development stage, morphological fractions, soil characteristics and fertility regime (Juknevicius and Sabiene 2007). The mineral content is also affected by the stage of maturity and leaf to stem ratio of the forage plant (Kebede et al. 2021). In present study, only farmyard manures were used for soil fertility improvement and management. According to Kebede et al. (2020), higher ash content in forage could be an indication of high mineral concentration. The oat varieties also varied in efficiency to absorb nutrients which may be due to variable rooting depth and pattern.

3.4. Farmers' preference for three tested oat varieties

As per the visual evaluation carried out with farmers during on-farm trial, the farmers of the three regions preferred Gansu oat 2 variety over Qingyin oat and Stampede oat variety. The oat variety was ranked based on the criteria like forage yield, standing vigor, leafiness, plot cover and absence of lodging.

5. CONCLUSION & RECOMMENDATION

Maintaining a constant supply of green forage throughout the year is a major constraint in livestock production. Substantial efforts have been made so far to address the fodder shortage during lean seasons in the country. The oat cultivars have promising potential to be promoted as annual fodder crops for winter feeding with desirable attributes such as palatability and nutritive value that will address fodder shortage during lean seasons. The variety Gansu oat 2 performed better than Qingyin oat and existing oat variety (stampede) under farmer's field management conditions in Bhutan. Considering its yield performance and suitability for winter forage production Gansu oat 2 is recommended for the extension program in highland districts of Bhutan.

CONFLICT OF INTEREST

The authors declared that there is no conflict of interest.

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