Journal of Agriculture and Rural Development in the Tropics and Subtropics
Vol. 125 No. 2 (2024) 159–165

https://doi.org/10.17170/kobra-2024070910495 ISSN: 2363-6033 (online); 1612-9830 (print) – website: www.jarts.info

Having inadequate roughages in cold areas in Tanzania? Consider forage oat and barley

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Abstract

Proper livestock feeding is key to improving the livestock sector in sub-Saharan Africa. Limited availability of well-performing forage technologies matched with production environment and context is often a constraint to increase forage quality and quantity for livestock productivity. To contribute towards forage technologies for cold areas, we selected four promising small grain varieties and evaluated them in 2020-21. They included two (Conway, Glamis) oat varieties and two (Rihane, Kounouz) barley varieties. In two village sites in Mufindi District in the southern highlands of Tanzania, we established trials in a randomised complete block design replicated three times. While the cultivars produced similar dry matter yields (t ha^{-1}), they returned significantly different crude protein (CP %), Neutral Detergent Fiber (NDF %) and in vitro organic matter digestibility. Digestibility was in the order Glamis > Conway > Kounouz > Rihane, while crude protein yield (t ha^{-1}) was in the order Glamis > Kounouz > Rihane > Conway. Based on dry matter and crude protein yields and digestibility, Glamis oat would be the most preferable in the study area and other similar ecologies.

Keywords: annual forage, forage quality, dry matter yield

1 Introduction

A significant portion of households in East Africa rear livestock, especially dairy (Baltenweck, 2010). Availability of feeds and forages that are of high quality is often a key challenge to smallholder dairy production systems (Maleko *et al*., 2018). Availing affordable well performing forage technologies can address this challenge, where the overreliance on low-quality crop residues (Mwendia *et al*., 2022) and low forage cultivation exacerbate the challenge (Maleko *et al*., 2018). Oats can be used for grazing, hay or silage (Barnhart, 2011). Oat forage harvested at boot stage (first grain heads appear) provides roughage with optimal energy and protein content unlike older plants with greater fiber concentration (Dochwat *et al*., 2020) leading to low digestibility. Oats are adapted to different soil types and can perform on acid soils. Importantly, oat has been used in cold areas and temperate environments for livestock feeding (Mwendia *et al*., 2017).

Comparing oat and barley intercrops with clover, forage quality indicators suggested that intercrops with barley were superior to those with oat (Ross *et al*., 2004a). Cutting barley at 45 and 55 days after sowing resulted in the production of greater forage yield with better quality- crude protein and low fiber content, compared to cutting 65 days after sowing (Salama, 2019). Barley/vetch rotations can enhance barley yields, improve soil quality, and provide valuable roughage (Ryan *et al*., 2012). Oat and barley are annual forages, thus allow crop rotation, in addition to good quality roughages for livestock. In the current study new oat and barley varieties in Tanzania were evaluated for roughage production under on-farm context, to identify which would be more beneficial in quality and forage production for cattle producers.

2 Materials and methods

2.1 Site and selection of test forages

The experiment was set in two locations, Lufuna and Sawala, in Mufindi district-southern highlands of Tanzania.

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Published online: 27 September 2024 – Received: 2 February 2024 – Accepted: 29 August 2024

At Sawala and neighboring Lufuna minimum temperature is usually below 10 °C, thus among coldest places in Mufindi (Getamap.net 2023). Sites for temperate forage evaluation were selected after a wider IFAD project (Notenbaert, 2017) that evaluated eleven tropical forages resulted in dismal forage production. A datalogger we set up at Sawala in 2020 recorded temperatures as low as 4.6 °C at night in the month of May. The logger malfunctioned and did not record temperatures (other than May-July), and rainfall as was expected. The area is at an altitude of 2028 meters (Getamap.net 2023) and receives average rainfall of 950 mm of rainfall annually (Jalango *et al.*, 2019).

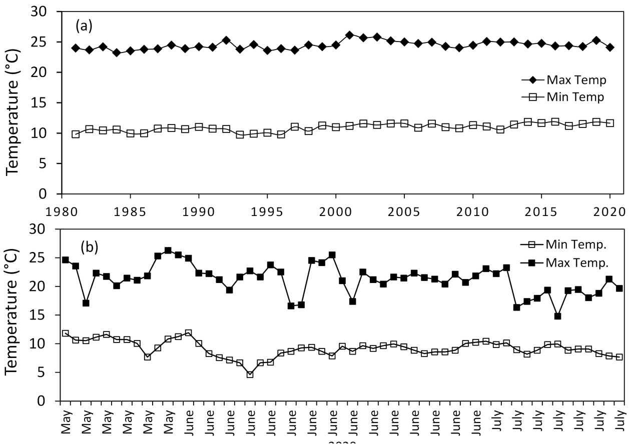

Fig. 1: *Mean minimum and maximum temperatures over 39 years from 1981 to 2020 (a) and (b) min-max temperatures during the cold season at Sawala primary school. The long-term data was obtained from https://ocp-power.larc.nasa.gov/data-access-viewer) while May- July 2020 data was downloaded from a data logger at Sawala Primary School near the oat-barley trials in 2020/21.*

Two spring oats *Avena sativa* L. varieties, Conway and Glamis, and two barley *Hordeum vulgare* L. varieties, Rihane and Kounouz, were selected. The oat varieties are breeding products from the Institute of Biological, Environmental and Rural Sciences-UK. Oats have rapid growth and are often suitable for forage production (Mwendia *et al*, 2017). Barley varieties were obtained from the International Center for Agricultural Research in the Dry Areas' breeding program. Rihane and Kounouz were registered in 1987 and 2009, respectively, in Tunisia. The International Center for Tropical Agriculture- Forages program had requested the institutes to select from their breeding program, materials that are leafy with best potential for forage production. While including a control was considered for comparison, we did not identify any annual forage cultivated in the area, as farmers rely on perennial native grasses for feeding.

2.2 *Land preparation trial design and establishment*

Twelve plots (1.8 × 2.5 m) were marked out using pegs and sisal twine running along the pegs after manually digging the land. Plots were laid across the slope in a randomized complete block design with three replicates. Forage treatments were randomly allocated to the plots by balloting and assigning a variety to a plot from left to right along the replicate/block. The process was repeated for the remaining replicates, and at the second site.

Shallow furrows 15 cm apart were made, and seeds placed along the furrows at about 1cm depth. The seed rate of 100 kg/ha was scaled back to fit each 4.5 m^2 plot. Inorganic fertiliser (NPK 23:23:0) was applied at rate of 50 kg N ha^{-1}. The seeds were covered with topsoil and the trial ran under rain-fed conditions. The experiment was conducted during the January-April season in 2020 and 2021. For 2021, a ratoon also was harvested (April-June) to gauge regrowth. Throughout the trials, the plots were kept weed-free by uprooting weeds.

2.3 *Data measurements*

Plant height was taken randomly from 5 plants within each plot before harvesting, from the ground to the topmost standing point of the plants. On tillering, 10 plants per plot were randomly selected, and counted the number of tillers. Ground cover was estimated by giving each plot a 'birds-eye-view' then assigned the proportion of visible biomass cover against ground/soil that could be seen within the plot.

Forage biomass was harvested from a 0.5 m × 0.5 m quadrat placed at the center of each 4.5m2 plot and weighed. A sample of about 150g was put in a sample bag and taken to Sokoine University Animal Science laboratory. Samples were oven dried at 65°C for 48 hours for dry matter determination before grinding to pass through a 1mm sieve for quality analysis. Following wet chemistry, the samples were analyzed according to AOAC procedure (1980) for Crude Protein (CP), Crude Fiber (CF), Neutral Detergent Fiber (NDF), Acid Detergent Fiber (ADF), invitro Organic Matter Digestibility (OMD), and Ash. Nitrogen content was analyzed following Kjeldahl method and converted to CP equivalent by multiplying by 6.25. Crude fiber was analyzed using a sulphuric acid and potassium hydroxide treatment according to methods of Goering and Van Soest (1970). Invitro organic matter digestibility followed Tilley and Terry (1963) and samples were ashed at 520°C. Crude protein yield (t/ha) was calculated from dry matter (DM) yield and CP content. The laboratory did not have the facility to analyse metabolizable energy.

2.4 Data analyses

Analysis of Variance was according to the procedures of GenStat 21st Edition. Factors included site, season, and forage and variables were plant height, number of tillers, ground cover, DM yield, CP, CF, NDF, ADF, OMD and Ash. Correlation coefficients (r) between laboratory attributes and agronomic measurements were analyzed in GenStat and significance level determined from a Pearson's Correlation coefficient table with 11 degrees of freedom.

3 Results

There were a greater number of tillers in 2021 compared to 2020, as well as adequate tillering in the ratoon crop in 2021. Oats tended to have more tillers than barley varieties regardless of the site. Consequently, DM production (t ha^{-1}) ranged from 5.35–9.33 for 2020 harvest, 1.57–4.4 for 2021, and 0.73–1.49 in the ratoon crop. Forage DM yields (t ha^{-1}) were 0.82–7.11 (Conway), 0.94–9.33 (Glamis), 0.73–7.76 (Kounouz) and 1.0–6.27 (Rihane) with the least yields coming from the ratoon (Table 1).

Barley varieties had greater CP content than oats at the Lufuna site (Table 2.) but similar ($P > 0.05$) CP at the Sawala site. Overall, the four forages accumulated similar CP yields. Neutral detergent fiber concentration was greater for barley than oats regardless of the sites, with a similar pattern for ADF. Consequently, oat varieties had significantly greater OMD than barley.

There were significant positive and negative relationships, governed by forage type (Table 3). Conway had positive correlations ($P < 0.001$) for plant height with number of tillers, DM yield, NDF, ground cover and ash. Unlike the other forages, Glamis had a strong positive correlation between plant height and CP content, while Kounouz had strong correlations between number of tillers and plant height, DM yield (positive), and ground cover with ash (negative). In Rihane, positive correlations were between DM yields and number of tillers or plant height. The correlation between CP and NDF was positive for oats and significant for Glamis, while that relationship in barley was negative and significant for Rihane.

4 Discussion

Differences in forage production from selected oat and barley varieties in southern Tanzania were influenced by year, variety, and site, which in practice underscores the need to consider these attributes when planning roughage production from small grains (Table 1). The ratoon crop had less DM yield dropping by 85 % and 63 % compared to the main crops in 2020 and 2021 respectively. This implies that

Table 1: *Summary of treatment effects for the agronomic attributes of mean plant height, number of tillers, ground cover and dry matter yield for oat (Conway, Glamis) and barley (Kounouz, Rihane) varieties over 2 seasons and 1 ratoon crop - in Mufindi District southern Tanzania in 2020-21.*

		Harvest			
Site	*forage*	*2020*	*2021*	*Ratoon**	*LSD†*
Plant height (m)					
Lufuna	Conway	0.88	0.91	0.52	0.269
	Glamis	0.98	0.80	0.46	
	Kounouz	0.96	0.72	0.38	
	Rihane	0.79	0.70	0.41	
Sawala	Conway	0.90	0.61	0.36	
	Glamis	0.79	0.55	0.26	
	Kounouz	0.73	0.76	0.38	
	Rihane	0.77	0.65	0.41	
Number of tillers					
Lufuna	Conway	2.6	8.6	6.3	2.67
	Glamis	3.6	9.8	6.1	
	Kounouz	3.7	7.4	5.4	
	Rihane	2.8	4.9	5.3	
Sawala	Conway	3.3	11.0	8.6	
	Glamis	3.4	10.1	6.4	
	Kounouz	3.2	8.2	5.4	
	Rihane	2.8	6.5	5.3	
Ground cover (%)					
Lufuna	Conway	87.7	50.0	50.0	20.33
	Glamis	76.7	61.7	58.3	
	Kounouz	75.0	56.7	66.7	
	Rihane	70.0	27.3	61.7	
Sawala	Conway	85.0	78.3	78.3	
	Glamis	76.7	85.0	70.0	
	Kounouz	63.3	85.0	66.7	
	Rihane	60.0	61.7	61.7	
Dry matter yield (t ha^{-1})					
Lufuna	Conway	5.35	2.75	0.82	3.173
	Glamis	7.56	4.40	1.17	
	Kounouz	5.82	1.88	0.73	
	Rihane	6.27	1.57	1.00	
Sawala	Conway	7.11	3.23	1.29	
	Glamis	9.33	2.87	0.94	
	Kounouz	7.76	3.36	0.73	
	Rihane	6.03	2.33	1.49	

* in 2021; † least significant difference.

Table 2: *Means for laboratory nutrition attributes and metric (crude protein yield) for oat (Conway, Glamis) and barley (Kounouz, Rihane) varieties in Mufindi district, southern Tanzania 2020-21.*

		Varieties				
Yield attribute	*Site*	*Conway*	*Glamis*	*Kounouz*	*Rihane*	*LSD*
CP (%)	Lufuna	16.44	16.13	20.92	20.42	1.317***
	Sawala	14.11	14.34	14.48	15.16	
CP yield (t ha^{-1})	Lufuna	0.88	1.22	1.21	1.26	0.901^{ns}
	Sawala	1	1.35	1.13	0.89	
CF (%)	Lufuna	21.95	27.82	22.3	23.09	4.825**
	Sawala	22.46	19.41	24.62	26.43	
NDF (%)	Lufuna	47.3	46.3	52.6	56.9	5.903***
	Sawala	45.4	45.2	52.7	61.5	
ADF (%)	Lufuna	30.2	29.3	34.1	36.2	4.32***
	Sawala	31	28.9	35.5	37.3	
OMD (%)	Lufuna	54.7	52.9	44.7	38.9	17.32**
	Sawala	60	68.5	50.1	36.7	
Ash (%)	Lufuna	17.12	16.23	16.27	13.11	2.778**
	Sawala	20.99	19.21	17.23	11.9	

CP: crude protein; CF: crude fibre; NDF: neutral detergent fibre; ADF: acid detergent fibre; OMD: organic matter digestibility; ^{ns} means not significant, * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$, LSD: least significance difference.

Table 3: *Growth and nutritional correlation (r) coefficients for oat (Conway, Glamis) and barley (Kounouz, Rihane) varieties in Mufindi district, southern Tanzania 2020-21.*

	Correlation (r) coefficients					
Attributes	*GC**	*NT*	*PH*	*DMY*	*CP*	*NDF*
Number of tillers (NT)	−0.07				*Conway*	
Plant height (PH)	0.15	0.82***				
Dry matter yield (DMY)	−0.06	0.62	0.80***			
Crude protein (CP)	0.07	−0.38	−0.01	−0.31		
Neutral detergent fibre (NDF)	0.39	0.60*	0.93***	0.66**	0.23	
Ash (%)	−0.31	0.04	−0.38	0.03	−0.87***	−0.64**
Number of tillers (NT)	0.14				*Kounouz*	
Plant height (PH)	0.35	0.88***				
Dry matter yield (DMY)	−0.17	−0.24	−0.11			
Crude protein (CP)	0.54*	0.71**	0.70**	−0.68**		
Neutral detergent fibre (NDF)	−0.09	−0.04	−0.31	0.37	−0.15	
Ash (%)	−0.86***	−0.08	−0.38	−0.33	−0.24	−0.01
Number of tillers (NT)	−0.55*				*Glamis*	
Plant height (PH)	0.07	0.23				
Dry matter yield (DMY)	−0.38	0.63*	0.06			
Crude protein (CP)	−0.25	0.13	0.87***	−0.002		
Neutral detergent fibre (NDF)	−0.09	−0.54*	0.38	−0.15	0.63*	
Ash (%)	0.25	−0.001	−0.68**	0.38	−0.75**	−0.53*
Number of tillers (NT)	−0.09				*Rihane*	
Plant height (PH)	−0.59*	0.79**				
Dry matter yield (DMY)	−0.43	0.82***	0.93***			
Crude protein (CP)	0.75**	−0.01	−0.25	−0.17		
Neutral detergent fibre (NDF)	−0.61*	0.46	0.46	0.35	−0.74**	
Ash (%)	−0.01	0.74**	0.71**	0.73**	0.06	−0.01

*Ground cover.

the potential Tropical Livestock Units that can be supported from these roughages would need to be reduced in an equal measure. Therefore, relying on forage regrowth from these forages in this region may not be advisable. Elsewhere a ratoon crop is recommended for certain varieties e.g., Meliane and Fretissa oats in Tunisia, which produced a significant amount of dry matter (Youssef *et al.*, 2000). Plant height obtained for oats (Table 1) was comparable to the 0.95m reported by Hussain *et al.* (1995) at boot stage, but a bit lower for barley- 0.86m. Similarly, ground cover that is good for the environment, in particular carbon accumulation for oat (Li *et al.*, 2020), tended to be greater for oats than barley (Table 1), especially for Conway in 2020. This was likely corroborated by the greater tillering ability observed for Conway and Glamis, especially in 2021 and the ratoon.

Glamis's greater digestibility compared to the other forages, especially from the Sawala site, is quite desirable given the importance of roughage quality. Although leafiness was not assessed in the study, most likely Glamis was leafier than the others, resulting in lower fiber content and likely greater digestibility. Depending on growth habit, e.g. leafy or stemmy, varieties may accumulate similar nutrient yields of crude protein (CP) and metabolizable energy (ME), which are paramount in animal production. While we did not measure ME in the study, measuring CP enabled us to derive CP yield. The four forages yielded similar CP per ha (Table 2) despite differences observed in plant growth attributes (Table 1). Varieties with low CP content compensated with greater DM yield. Although the four forages studied could provide similar CP yields in the system, digestibility allows gauging the extent to which the nutrients in a roughage are available to the animals. As such, despite the four varieties accumulating similar CP yields, the oat varieties had significantly greater digestibility regardless of the site, suggesting better access of nutrients to the animals for oats compared to barley varieties, corroborating the observations of Chapko *et al.* (1991).

It is notable that differences between oat and barley in growth and nutritional attributes can be quite variable with even contrasting correlations (Table 3). While CP generally decreases with increasing plant height (Govintharaj *et al.*, 2018), this was not observed for Glamis or Kounouz, since both had positive correlations (Table 3). Most likely these two varieties sustained a high leaf:stem proportion, further supported by no significant increase in NDF as plant height increased (Table 3), traits that are desirable for forage quality. Moreover, for Glamis, CP and NDF were positively correlated, unlike Conway and Kounouz which did not have a correlation, while Rihane had a negative correlation. Annual forages, unlike perennials, allow crop-rotation which could fit the study area characterized with mixed farming, growing maize, beans, and potatoes (Sauth, 2021) and rearing cattle (Mwambene *et al.* 2014). The desire to increase livestock productivity cannot be met by use of crop residues, typically of low quality (Mwendia *et al.*, 2022), or the low-quality native forages in Tanzania (Rubanza *et al.*, 2005). The forementioned food crops can be rotated with the annual forages considered in this study. By so doing, co-benefits that go with crop-rotation practices including weeds, pests, diseases control and increasing plant diversity would be tapped (Zhao *et al.*, 2020), and this system should apply to other similar agro-ecologies in East Africa and beyond.

5 Conclusion

Use of annual forages presents a realistic option of producing good quality forage in the study area and other similar production systems. Owing to its better DM production coupled with increased CP yield and greater digestibility, Glamis oat was the best choice among the four forages considered. Promoting the advantages of annual forages for crop rotation may hasten adoption and use.

Conflict of interest

The authors declare that they have no conflict of interest.

Acknowledgements

The authors appreciate the farmers who willingly participated in the trials. Special thanks for the financial support from the International Fund for Agricultural Development (IFAD), through the Climate Smart Dairy Project grant number D180 in Tanzania. Equally, the Sustainable Animal Productivity (SAP) initiative under the Consultative Group of International Agricultural Research (CGIAR) that has continued to support livestock improvement in Africa, Tanzania included.

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