Tropical Grasslands-Forrajes Tropicales (2024) Vol. 12(2):116–124
doi: 10.17138/TGFT(12)116-124

Research Paper

Farmers' evaluation and economic viability of *Urochloa* grasses grown on Nitosol and Vertisol in middle elevations in Ethiopia

Evaluación de los agricultores y viabilidad económica de los pastos Urochloa *cultivados en Nitosol y Vertisol en elevaciones medias en Etiopía*

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Abstract

This field study was carried out in the Ethiopian mid-elevations on Vertisol and Nitosol to determine effects of fertilizer use and identify more productive *Urochloa* grass varieties and cultivars based on farmers' variety evaluation and partial budget analyses. The study evaluated *Urochloa brizantha* cultivars 'La Libertad' and 'Marandu', *Urochloa* hybrid cultivars 'Mulato I' (Mulato I) and 'Mulato II' (Mulato II) and *Urochloa mutica* species. Data on farmers' variety selection were gathered at 45 and 90 days after planting. Pair wise preference ranking was used to record farmers' variety preferences and partial budgeting was used for economic analysis. Farmers selected *Urochloa* grass varieties or cultivars based on a variety of factors, including plant height, number of tillers, leafiness and smoothness. Mulato II, *U. mutica* and Mulato I were chosen in first, second and third rank, respectively, based on evaluation using farmers' criteria. *U. mutica* and Mulato II showed the highest gross benefit and benefit-cost ratio when fertilizer was applied at both sites. *U. mutica* produced the highest dry matter yield at both sites. *U. mutica* and Mulato II were selected as having superior production to meet requirements for fodder quantity in the research areas.

Keywords: Benefit-cost ratio, criteria, dry matter yield, fertilizer effects, partial budget analysis.

Resumen

Este estudio de campo se llevó a cabo en las elevaciones medias de Etiopía en suelos Vertisole y Nitosoles para determinar los efectos del uso de fertilizantes e identificar variedades y cultivares de pasto *Urochloa* más productivos basándose en la evaluación de variedades por los agricultores y análisis de presupuesto parcial. El estudio evaluó los cultivares de *Urochloa brizantha* 'La Libertad' y 'Marandu', los cultivares híbridos de *Urochloa* 'Mulato I' (Mulato I) y 'Mulato II' (Mulato II) y la especie de *Urochloa mutica*. Los datos sobre la selección de variedades por parte de los agricultores se recopilaron a los 45 y 90 días después de la siembra. Se utilizó una clasificación de preferencias por pares para registrar las preferencias de variedades por los agricultores y se utilizó la técnica de presupuesto parcial para el análisis económico. Los agricultores seleccionaron variedades o cultivares de pasto *Urochloa* en función de una variedad de factores, incluida la altura de la planta, el número de macollos, la frondosidad y la suavidad. Mulato II, *U. mutica* y Mulato I fueron elegidos en primer, segundo y tercer lugar, respectivamente, con base en la evaluación realizada con criterios de los agricultores. *U. mutica* y Mulato II mostraron el mayor beneficio bruto y la mejor relación beneficio-costo cuando se aplicó fertilizante en ambos sitios. *U. mutica* produjo el mayor rendimiento de materia seca en ambos sitios. Se seleccionaron *U. mutica* y Mulato II por tener una producción superior para cumplir con los requisitos de cantidad de forraje en las áreas donde se desarrolló la investigación.

Palabras clave: Análisis de presupuesto parcial, efectos de fertilizantes, relación costo-beneficio, rendimiento de materia seca.

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Introduction

Improved forages are crucial to supplement crop residues as feed. For the majority of ruminant livestock in the tropics, forage grasses serve as their primary source of nourishment. Higher herd densities on current pastures and increasing the yields of forage crops can both reduce strain on increasingly limited land resources and improve accessibility and reduce the cost of animal products (Fuglie et al. 2021). Although a wide variety of forages have been introduced in tropical regions, most attempts have overlooked farmers' preferences (Fuglie et al. 2021). Farmers have identified selection criteria through focus group discussions based on their extensive knowledge on forage production or feed resource identification (Misiko et al. 2008). Selection criteria, including drought tolerance, soil erosion control, plant height, growth habit, leaf color, disease and insect tolerance, and suitability for grazing and cut-and-carry have been used to select cultivars of *Urochloa* grass.

A top-down methodology has typically been used to evaluate and select varieties based on chemical composition and agronomic data. For variety selection, this kind of selection strategy is essential but insufficient. Participating farmers' opinions on variety evaluation and selection are required to increase acceptance (Roothaert et al. 2003). Most agriculture researchers have been trained in dissemination techniques that follow a clearly prescribed pattern. However, these techniques do not allow farmers to experiment or make decisions at every stage. Participatory approaches take time, while donors and national organizations may require quick results. The required flexibility of participatory approaches implies a lack of structure, which many new practitioners find difficult (Roothaert et al. 2003). Participatory selection of lablab (Hunegnaw et al. 2016), cowpea (Walie et al. 2016) and sweet lupin (Mekonnen et al. 2016) varieties for intercropping with maize was shown to be the successful choice of an individual farmer. The variety selection process uses a preference-ranking approach with pair-wise ranking to prioritize selection parameters (de Boef and Thijssen 2007). These approaches highlight the rationale for farmer's selection of feed. Since 1970, Ethiopian farmers have gradually been introducing improved forage species to complement the country's natural feed supplies, but adoption rates are still low owing to land scarcity, lack of improved forage seed/planting material, lack of awareness and poor extension services hindering forage technology adoption (EARO 2002; Gebremedhin et al. 2003; Beshir 2014).

Nitrogen fertilizer improves crude protein content, voluntary feed intake and digestibility, as well as dry matter yield (Aderinola 2007) but there is limited local economic information to encourage use of fertilizer for forage production (Sodeinde et al. 2006). Use of fertilizers to increase fodder productivity is restricted due to farmers' inability to afford them (Sodeinde et al. 2006). There is little information being made available to Ethiopian farmers on the economic impact of growing *Urochloa* cultivars and species in Ethiopia and use of inorganic fertilizer. This study was carried out to determine productivity, economic viability of fertilizer use and farmer perception of adaptation and productivity of these cultivars on Nitosol and Vertisol in Ethiopia.

Materials and Methods

The study was carried out concurrently on station at the Andassa Livestock Research Center (ALRC) at the Medabit Forage Trial Site and on farm at Ambo Mesk, North Mecha District (Mecha) West Gojam Zone, Amhara Region, Ethiopia. ALRC is located at 11°9' N and 37°9' E at an elevation of 1,730 masl. The soil in the area (Table 1) is Vertisol (Mekonnen et al. 2016). Ambo Mesk is situated between 11° 10′ to 11° 32′ N and 37° 04′ to 37° 17′ E at an elevation of 1,998 masl. The Mecha district primarily has Nitosol (Yeheyis et al. 2012). In both districts, the rainfall pattern is monomodal (Figure 1) (Hunegnaw et al. 2022). The duration of the experiment was during the rainy season from 1 June 2020 to 30 October 2020.

The experiment was established as root splits in a randomized complete block design with subplots (fertilizer and cultivar) and 3 replications at ALRC and Mecha districts. The study evaluated *Urochloa brizantha* cultivars 'La Libertad' (La Libertad) and 'Marandu' (Marandu), *Urochloa* hybrid cultivars 'Mulato I' (Mulato I) and 'Mulato II' (Mulato II) and *Urochloa mutica* grass with and without fertilizer (Table 2). Intra- and inter-row spacing was kept constant at 0.5 m and plots of 9 m^2 (3 m × 3 m) and blocks were separated by 0.5 and 1 m, respectively. Fertilizer was applied at planting at a rate of 100 kg nitrogen, phosphorus and sulfur (NPS)/ha and urea was applied 30 d after planting at a rate of 50 kg urea/ha. Two harvests (90 d after establishments for first harvest on 30 August 2020 and 60 d after first harvests for second cut on 30 October 2020) were carried out in the main rainy season and annual yield was estimated from them.

Plant height, tiller number, and yield were recorded at 90 d for first cut after establishment and 60 d later for second cut. Ten plants were chosen at random from the center 3 × 3 m of each plot. After measuring plant height and counting tiller number, plants were harvested at 10 cm height by cutting with a sickle. Farmers' perception was measured by variety selection at the vegetative stage (45 d after planting) and again at harvest at 90 d. Cost and benefit data were gathered for partial budget analysis at every production stage.

Farmer forage selection

Based on their interest in the technologies, willingness to take part in cultivar/variety evaluation, and prior experience with increased forage production, 20 farmers including 6 female farmers, representing community organizations were selected to participate in selection at both sites of ALRC and Mecha. Forage experts from the district agricultural office, researchers from the ALRC (focusing on feed, nutrition, and

Table 1. Soil chemical composition.

Soil type	Soil chemical composition				
	pH	Organic carbon (%)	Organic matter (%)	Total nitrogen (%)	Available phosphorus (ppm)
Vertisol	6.94	1.41	2.42	0.22	4.57
Nitosol	5.45	1.64	2.86	0.23	7.49

Source: Hunegnaw et al. 2022

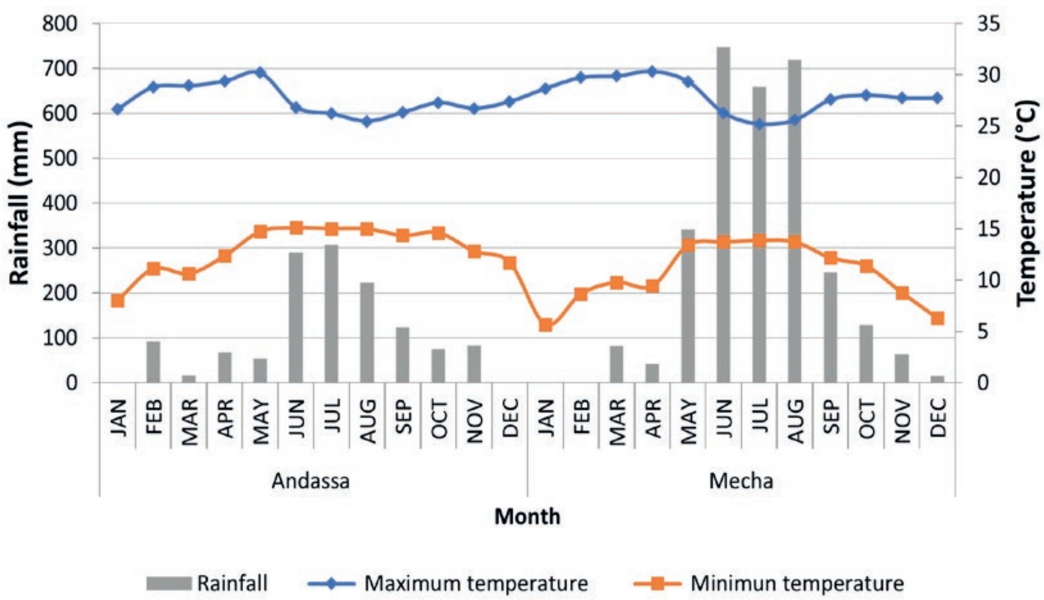

Figure 1. Monthly rainfall (mm) and maximum and minimum temperature (°C) of experimental sites (Hunegnaw et al. 2022).

Table 2. Grasses tested in treatment combinations.

Grasses	With fertilizer (WF)	Without fertilizer (WO)
Urochloa mutica (UM)	UMWF	UMWO
Urochloa Hybrid cultivar 'Mulato I'(UMI)	UMIWF	UMIWO
Urochloa Hybrid cultivar 'Mulato II' (UMII)	UMIIWF	UMIIWO
Urochloa brizantha cultivar 'Marandu' (UMU)	UMUWF	UMUWO
Urochloa brizantha cultivar 'La Libertad' (ULA)	ULAWF	ULAWO

extension), and kebele development agents (DAs) were also involved in recording farmers' perceptions in the field. Following an explanation of the study goals, farmers had the opportunity to visit all experimental plots and develop criteria for cultivar/varieties/species selection using their traditional knowledge.

Urochloa grass selection criteria were captured using pair-wise matrix ranking and preference ranking techniques. The pair-wise matrix ranking method was used to determine the weight of each criterion for farmers. Farmers voted for each criterion and rated the grasses using a preference ranking approach proposed by de Boef and Thijssen (2007). Selection criteria were scored and used to determine overall weighted ranking of *Urochloa* grasses. Comparisons of all *Urochloa* grasses were made using the sum of all selection criteria weighted values according to preference ranking.

Partial budget analysis

The method documented by CIMMYT (1988) was used to perform the partial budget analysis considering only variable costs across experimental treatments to determine the economic viability of fertilizer application. This method was selected because of easy applicability to on farm participatory research conditions. Data on all variable expenses associated with fertilizer costs (including the cost of NPS and urea) were recorded from farmers. At each site, the average yield of each treatment in the trial was recorded. The average cost of purchasing 100kg of NPS at cooperatives was USD 41/100kg and the average cost of purchasing urea was USD 34.7/100kg. There was no field price or market price for *Urochloa* hay at the sites but the price of 1kg *Urochloa* hay has been valued at up to USD 0.12/kg (Walie et al. 2018). In the current study, the market price estimate for *Urochloa* hay was set at USD 0.09/kg. Adjusted yield was used to reflect the yield that farmers can achieve on their farms, estimated at 10% less than yields recorded in these replicated trials with and without fertilizer using identical methods (CIMMYT 1988). Gross benefit (GB) was calculated from the predicted market price and adjusted dry matter yield. Gross profit (GP) for each cultivar was determined by deducting the total expenditures from the gross field benefit and the benefit-cost ratio calculated as gross benefit divided by total variable cost that was incurred in the experiment.

Data Analysis

Analysis of variance (ANOVA) was used to analyze data on plant height, tiller number and total dry matter yield. The F test was used for analysis of variance and Duncan's multiple range test (DMRT) ($P<0.05$) was used to compare treatment means for the variables for which the F test was significant. Reductions were deemed statistically significant at a level of ($P<0.05$).

Results

The interaction effects between fertilizer application, cultivar and soil type had significant ($P<0.001$) effect on plant height, number of tillers per plant and dry matter yield of *Urochloa* grasses (Table 3). Plant height increased with fertilizer application at both sites for all cultivars and species. Plant height of grasses grown on Vertisol was higher than for plants grown on Nitosol. All parameters increased with application of fertilizer with the highest yields being obtained from UMWF and UMIIWF grown on both soils.

Farmers' selection criteria

Farmers' selection criteria were ranked pair wise to determine which trait was considered most crucial for forage selection on Vertisol (Table 4) and Nitosol (Table 5). Plot cover, leafiness (number of leaves per plant), plant height (visible observation of the growing condition) and smoothness/softness (feeling leaves with fingers) were determined as criteria for selection on both soils.

Farmers' variety evaluation of Urochloa grass

Farmers' preference ranking for *Urochloa* grass showed Mulato II was preferred, followed by Mulato I and *U. mutica* (Table 6). Farmers considered plot cover, linked to tiller number, and plant height as significant factors influencing forage productivity.

Table 3. Effect of fertilizer, cultivars and soil type on plant height, number of tillers per plant and dry matter yield of *Urochloa* grasses.

Soil type	*Urochloa*	Plant Height (m)	NTPP (count)	Dry matter yield (t/ha)
Vertisol	UMWF	1.55a	40bc	20.37a
	UMIIWF	0.82d	46a	18.61b
	UMIWF	0.52fg	36.3efg	11.07e
	UMUWF	0.51fg	29.8j	7.13g
	ULAWF	0.49fg	26.2k	5.7jkl
	UMWO	1.12c	32.2hi	6.95gh
	UMIIWO	0.55f	36.3efg	6.5hi
	UMIWO	0.37ij	31.03ij	5.33kl
	UMUWO	0.32jk	26.67k	3.85n
	ULAWO	0.35jk	24.9k	2.75o
Nitosol	UMWF	1.45b	41.67b	17.19c
	UMIIWF	0.62e	45.27a	13.29d
	UMIWF	0.52fg	39cd	11.55e
	UMUWF	0.5fg	37.67de	6.02ij
	ULAWF	0.46gh	36.03efg	5.87jk
	UMWO	0.85d	20.33l	5.27l
	UMIIWO	0.42hi	34.8fg	8.2f
	UMIWO	0.36ij	31.17ij	5.65jkl
	UMUWO	0.38ij	37.0def	4.44m
	ULAWO	0.3k	34.0gh	3.47n
	SEM	0.04	0.86	0.63
	CV	5.6	3.74	3.78
	SL	***	***	***

NTPP=number of tillers per plant; SEM=standard error of mean; CV=coefficient of variation; SL=significance level. Means within columns with different letter are significant at P<0.001

Table 4. Pair-wise ranking matrix of selection criteria for grasses grown on Vertisol.

Criteria	Plot cover	Plant height	Leafiness	Tiller number	Smoothness/ leaf softness	Score/ Frequency	Rank
Plot cover		1	1	1	1	4	1
Plant height			2	4	2	2	3
Leafiness				4	5	1	4
Tiller number					4	3	2
Smoothness/leaf softness						0	5

Table 5. Pair-wise ranking matrix of selection criteria for grasses grown on Nitosol.

Criteria	Plot cover	Plant height	Leafiness	Tiller number	Smoothness/ leaf softness	Score/ Frequency	Rank
Plot cover		2	3	4	1	1	4
Plant height			3	4	2	2	3
Leafiness				4	3	3	2
Tiller number					4	4	1
Smoothness/leaf softness						0	5

Economic viability of fertilizer application

The overall partial budget analysis is presented in detail in Table 7 and 8. The highest gross profit in the Vertisol was obtained from UMWF (USD 856) followed by UMIIWF (USD 763.4) (Table 7). Similarly, the highest gross profit in the Nitosol soil was obtained from UMWF (USD 750) followed by UMIIWF (USD 589.6) (Table 8). The gross profit among cultivars, fertilizer, and soil type differed with dry matter yield differences among experimental *Urochloa* grasses cultivars for both fertilizers and soil type. The benefit-cost ratio obtained from Mulato II and *U. mutica* (2.2 on Nitosol and 2.1 on Vertisol) implies that growing *Urochloa* grasses with fertilizer is profitable for farmers.

Table 6. Farmers' preference ranking.

	Selection criteria	Weighted value	*Urochloa* grasses and weighted score values				
			UMI	UMII	UM	UMU	ULA
Vertisol (ALRC)	Plot cover	5	125	120	120	65	70
	Tiller number	4	72	88	80	64	56
	Plant height	3	60	60	69	51	15
	Leafiness	2	30	60	24	56	30
	Leaf Smoothness	1	15	30	20	20	10
	Total score	-	302	358	313	256	181
	Rank	-	2	1	3	4	5
Nitosol (Mecha)	Plot cover	2	24	44	52	16	24
	Tiller number	5	70	110	85	75	45
	Plant height	3	48	48	60	36	18
	Leafiness	4	56	104	60	48	52
	Leaf Smoothness	1	16	22	16	16	10
	Total score	-	214	328	273	191	149
	Rank	-	3	1	2	4	5

Table 7. Partial budget analysis *Urochloa* grass cultivars and species grown on Vertisol with and without fertilizer.

Description	*Urochloa* grass cultivars/varieties (Treatments)									
	ULAWO	UMUWO	UMIWO	UMIIWO	UMWO	ULAWF	UMUWF	UMIWF	UMIIWF	UMWF
DMY (Kg/ha)	2,750	3,850	5,330	6,500	6.950	5,700	7,130	11,070	18,610	20,370
ADMY (Kg/ha) (A)	2,475	3,465	4,797	5,850	6,255	5,130	6,417	9,963	16,749	18,333
Cost of NPS/ha (100kg)	0	0	0	0	0	41	41	41	41	41
Cost of Urea/ha (50kg)	0	0	0	0	0	17.4	17.4	17.4	17.4	17.4
Harvesting cost/ha	128.5	160.8	270.3	310.5	350.4	270.4	370.1	448.3	660.5	708.1
(TVC) (B)	128.5	160.8	270.3	310.5	350.4	328.8	428.5	506.6	718.8	766.5
Price (USD/kg) (C)	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09
Gross benefit (USD) (A*C)(D)	219.0	306.6	424.5	517.7	553.56	454	567.9	881.7	1,482.3	1,622.5
Gross profit (D-B) (USD)	90.5	145.8	154.2	207.2	203.2	125.2	139.4	375.1	763.4	856
Benefit-cost ratio (B/C)(USD)	1.7	1.9	1.6	1.6	1.6	1.38	1.32	1.7	2.1	2.1

USD=US dollar; DMY=Dry matter yield; ADMY=Adjusted dry matter yield; NPS=Nitrogen, phosphorous and sulfur; TVC=Total variable cost.

Table 8. Partial budget analysis *Urochloa* grass cultivars and species grown on Nitosol with and without fertilizer.

Description	*Urochloa* grass cultivars/varieties (Treatments)									
	ULAWO	UMUWO	UMIWO	UMIIWO	UMWO	ULAWF	UMUWF	UMIWF	UMIIWF	UMWF
DMY (Kg/ha)	3,470	4,440	5,270	5,660	8,200	5,870	6,020	11,550	13,290	17,190
ADMY (Kg/ha) (A)	3,123	3,996	4,743	5,085	7,380	5,283	5,418	10,395	11,961	15,471
Cost of NPS/ha (100kg)	0	0	0	0	0	41	41	41	41	41
Cost of Urea/ha (50kg)	0	0	0	0	0	17.4	17.4	17.4	17.4	17.4
Harvesting cost/ha	140.5	240.8	270.5	280.5	320.2	290.5	280.1	390.4	430.5	560.8
(TVC) (B)	140.5	240.8	270.5	280.5	320.2	348.8	338.5	448.7	488.8	619.2
Price (USD/kg) (C)	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09
Gross benefit (USD) (A*C)(D)	276.4	353.6	419.7	450.0	653.1	467.5	479.5	919.9	1,058.5	1,369.2
Gross profit (D-B) (USD)	135.9	112.8	149.2	169.5	332.9	118.7	141	501.2	589.6	750
Benefit-cost ratio (B/C)(USD)	1.9	1.4	1.5	1.6	2.0	1.3	1.4	2	2.2	2.2

USD=US dollar; DMY=Dry matter yield; ADMY=Adjusted dry matter yield; NPS=Nitrogen, phosphorous and sulfur; TVC=Total variable cost.

Discussion

Plant height increases with fertilizer could be associated with increased root development and efficient nutrient uptake, allowing the plant to continue to increase in height (Berihun 2005). Taller plants on Vertisol could indicate lower adaptation to soil acidity of the red soil (pH 5.45). Tiller number increases the chances of survival and forage yield (Laidlaw 2005) and is an indicator of efficient utilization of nutrients. Kizima et al. (2014) reported that application of optimal levels of nitrogen fertilizer significantly increased tiller number of *Cenchrus ciliaris* grass. The highest yield of *Urochloa* grass could be attributed to the formation of additional tillers which conveyed an increase in leaf formation, leaf elongation and stem development from application of fertilizer (Crowder and Chheda 1982). The highest yield was recorded on cultivars with fertilizer at both sites. The overall evaluation found that *U. mutica* and Mulato II provided sufficient biomass to address forage shortages and enhance livestock production and productivity in the study areas.

Farmers selected grasses based on plant height, leafiness, smoothness, number of tillers and plot cover. Cheruiyot et al. (2020) reported that farmers often preferred cultivars with smooth leaves since they were easier to cut and handle because the hairs on the leaves cause skin irritation. Additionally, farmers believe that Mulato II is superior because the animals prefer softer leaves. The results of this investigation are consistent with other reports (Cheruiyot et al. 2020) on *Urochloa* grasses and the opportunity cost of adopting improved planted forages (Maina et al. 2022). In order to promote and multiply cultivars in future, farmers would need to increase the availability of planting materials through use of root splits or cuttings (Ramadhan et al. 2015).

Assessment of plot cover and plant height as significant factors influencing forage productivity was supported by Zewdu et al. (2006), who found a direct correlation between increased foliage and plant height.

The benefit-cost ratio for all treatments was found to be higher than the lowest acceptable rate of return (CIMMYT 1988) with fertilizer application increasing gross benefits and benefit-cost ratios of *U. mutica*, Mulato II and Mulato I on both soils. The partial budget analysis accounts for costs that vary over the course of the experiment period and is easy to apply in on farm participatory research conditions. The limitation of this approach is not considering the fixed costs so that net benefits and net profits from each experimental unit cannot be calculated. Application of fertilizer to La Libertad grown on Nitosol and Marandu grown on Vertisol in the current study was not economically profitable, indicating there is no benefit to apply fertilizer to *Urochloa* cultivars with low yields. The current study confirms that applying fertilizer to more productive *Urochloa* grasses, such as *U. mutica* and Mulato II was profitable. Maina et al. (2022) reported that the production of different *Urochloa* cultivars under farmer's field conditions resulted in higher gross benefit than growing Napier grass.

Conclusions

The farmers' selection criteria ranked tiller number and plant height as important traits for forage development and Mulato II and *U. mutica* as preferred forages. *U. mutica* and Mulato II had the highest gross benefit and benefit-cost ratio at both sites. Studies on availability of planting materials from farmers will be essential to promote and multiply cultivars in the future for further adoption. Additional adaptation and feeding studies are needed in a range of environments to fully test the potential of these grasses under farmers' management strategies.

Acknowledgments

The authors would like to express their gratitude to farmers who took part in the selection of *Urochloa* grasses and ARARI (Amhara Agricultural Research Institute) for their financial support, which was important in the success of the study.

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(Note of the editors: All hyperlinks were verified 24 May 2024).

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(Received for publication 26 December 2021; accepted 24 April 2024; published 31 May 2024)

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