Pertanika J. Trop. Agric. Sci. 49 (4): 1629 - 1647 (2026)

PERTANIKA JOURNALS

TROPICAL AGRICULTURAL SCIENCE

Journal homepage: http://www.pertanika.upm.edu.my/

Agronomic Performance, Forage Yield, Nutritive Value and Forage Utilisation of Four *Urochloa* spp. to Repeated Cutting Cycles in Thailand

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ABSTRACT

Forage crops are fundamental for ruminant sustainable production, but Thailand's crop-livestock systems confront persistent feed shortages and low forage quality. Cultivating high-yield tropical grasses offers a practical solution, but selecting superior species requires detailed agronomic and nutritional evaluation. *Urochloa* grasses represent a promising resource for enhancing feed security. This study evaluated four *Urochloa* varieties (*U. ruziziensis*, *U. brizantha*, *U. decumbens*, and Mulato II) over three cutting cycles to assess growth performance, yield, nutritive value and silage quality under tropical conditions. The field study was conducted from July 2022 to April 2023 in Khon Kaen, Thailand, utilising a randomised complete block design with three replications. Grasses were harvested at 46-50 day regrowth intervals from third cutting, and fresh forage was ensiled in vacuum-sealed HDPE bags for 21 days without additives. In the third cutting, *U. brizantha* produced the highest fresh (16,670.83 kg ha^{-1}) and dry matter yields (4,520.83 kg ha^{-1}). *U. decumbens* showed the highest cell wall fraction, with NDF reaching 61.30% in the first cycle, whereas *U. ruziziensis* and Mulato II exhibited lower fibre contents and greater pre-ensiling digestibility (70.97% and 71.90% IVTDMD, respectively). In silage quality, *U. brizantha* maintained lower NH_3-N levels (0.15%), while *U. ruziziensis* and Mulato II demonstrated high digestibility. Therefore, *U. brizantha* showed exceptional yield potential, while Mulato II and *U. ruziziensis* exhibited desirable nutritional and fermentation characteristics. These findings provide practical guidance for selecting suitable *Urochloa* species for forage production and silage utilisation in tropical livestock production systems.

Keywords: Agronomic performance, forage yield, nutritive value, silage quality, *Urochloa* spp.

ARTICLE INFO

Article history:
Received: 06 October 2025
Accepted: 07 July 2026
Published: 24 July 2026

DOI: https://doi.org/10.47836/pjtas.49.4.04

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e-ISSN: 2231-8542

INTRODUCTION

Forage crops are essential as primary sources of roughage for ruminants, particularly beef and dairy cattle, which are key sources of meat and milk (Jayaneththi et al., 2026). In Thailand's crop-livestock mixed farming systems, year-round feed availability is often insufficient. This shortage, combined with poor feed quality, hinders the ability to meet the nutritional requirements of livestock throughout the year (Feyissa et al., 2022; Mottet et al., 2017). The introduction of enhanced forage varieties has been identified as a viable strategy to provide high-quality feed alternatives, thereby improving livestock productivity and addressing feed deficits within such systems (Feyissa et al., 2022). In addition to forage yield, digestibility, silage quality, and climate resilience are important considerations for tropical forage grasses, as these traits influence livestock productivity and adaptation to changing environmental conditions (Adepoju & Faniyi, 2025; Alves et al., 2025; Rodríguez et al., 2024)

The *Urochloa* genus is a tropical forage grasses, which has been cultivated in tropical and subtropical regions as pasture. The genus has about 100 species recognised in the world (Ferreira et al., 2021). At present, some species such as *U. brizantha*, *U. decumbens*, *U. humidicola* and *U. ruziziensis* have been important commercially because these species have many positive attributes, e.g., tolerance to acid soil, high productivity and high-quality forage (Ferreira et al., 2021; Hare, 2023; Masters et al., 2024). *U. ruziziensis* (Ruzigrass), is widely cultivated in Thailand due to its moderate drought tolerance, producing high seed yields, trampling resistance, high nutritional value, and palatability (Department of Livestock Development, 2002). However, limitations such as low seed germination (Usberti & Martins, 2007) and poor waterlogging tolerance (Department of Livestock Development, 2002). Mulato II (*U. ruziziensis x U. brizantha x U. decumbens*), developed by CIAT, is a hybrid forage grass widely cultivated in Thailand. It offers improved seed production and drought tolerance compared to Mulato I (Nakamanee et al., 2007) but remains limited by high seed costs and low waterlogging tolerance (Sithiwong et al., 2010). *U. decumbens* exhibits strong drought and grazing tolerance, while *U. brizantha* outperforms *U. ruziziensis* in drought resistance and dry matter yield (Hare et al., 2005).

However, due to limited seed availability and propagation, *U. brizantha* and *U. decumbens* have not yet been widely cultivated in Thailand. Several studies conducted in the temperate region of Japan by Nitthaisong et al. (2016) investigated the agronomic characteristics, growth, and influence on weeds of six *Urochloa* species. The results showed that *Urochloa* species exhibited stronger growth and higher dry matter yields compared to Rhodesgrass. In Thailand, *U. decumbens* has shown superior adaptability and yield compared to *U. ruziziensis*, producing 41.38% higher yields and 58.59% more during the dry season (Thinnakorn, 1988). It also adapts well to fertile soils, as demonstrated in Khon Kaen province (Wilailpol et al., 1989; Wilailpol et al., 1982). Additionally, *U. brizantha* outperformed other grasses in dry matter yield (Ernawati et al., 2023; Gatheru et al.,2017; Perini et al., 2023; Ponnampalam et al., 2024).

However, despite their adaptability, previous studies in Thailand have primarily focused on the productivity of individual *Urochloa* species, while comprehensive comparative information on their agronomic performance, nutritional quality, seasonal response to repeated cutting, and silage potential remains limited. This indicated the essential need for comprehensive data on these study species. The study was based on the hypothesis that while top-performing *Urochloa* cultivars sustain high yields across repeated cuttings, their rising fibre content during regrowth poses a challenge for silage quality. Using this data to pinpoint the appropriate harvest time could solve the issue.

The primary significance of this study is that it introduces a multi-harvest selection process for livestock production in tropical conditions. Combining seasonal field performance directly with raw fermentation metrics provides a practical path for year-round sustainability for ruminant production in Thailand.

This study focuses on evaluating four distinct *Urochloa* species for agronomic performance, biomass yield, nutritive value, and the ensiling process of anaerobic fermentation post-harvesting without feed additive supplementation. The results revealed superior forage options suited for tropical conditions, thereby laying the groundwork for more resilient regional production systems.

MATERIALS AND METHODS

The field experiment was conducted at Tha Phra Subdistrict, Mueang District, Khonkaen, Thailand (latitude 16.20° N, longitude 102.49° E, and an elevation of 166.70 m above sea level). The study was carried out from July 2022 to April 2023. The soil type of the field was sandy soil, and rainfall data for the entire experimental period were obtained from the Khon Kaen Meteorological Station, Tha Phra, Mueang, Khon Kaen Province. Four tropical grasses, *U. ruziziensis*, *U. decumbens*, *U. brizantha* and Mulato II were used for comparison.

The field experiment utilized a Randomised Complete Block Design (RCBD) with three replications, while the post-harvest silage experiment followed a Completely Randomised Design (CRD) with four replications. Vegetative roots were transplanted using 2-3 splits per hole at a depth of 10 cm in July 2022 under supplementary irrigation. Each grass was planted in a 6 m^2 plot area (3× 2 m). A basal fertiliser consisting of nitrogen (15% N), double superphosphate (15% P_2O_5) and potassium chloride (15% K_2O) was applied to the plot area at a rate of 62 kg ha^{-1} at transplanting and immediately after each harvest. Weed management and regular monitoring of disease and insects were performed as appropriate.

Agronomic traits (plant height, stem diameter, leaf blade width, and leaf blade length, SPAD and tiller number) were investigated on four randomly selected grasses in each plot and were measured on the same days of cutting. For yield trait investigation, plants were cut 10 cm above ground level on 16 January, 7 March, and 22 April 2023 at approximately 46-50 days regrowth intervals. Plant materials were separated by hand into leaf blades and stems with leaf sheath to determine the leaf and stem ratio of whole plant dry samples for every yield sample. Plant materials were dried at 60 ºC for 72 hours prior to determining dry weight. Crop growth rate (CGR) was calculated by dividing dry matter yield by the regrowth period (days) between harvests and expressed as kg $m^{-2}d^{-1}$

Nutritive Value

Grass samples were dried at 105 °C overnight and ground to pass through a 1 mm sieve. The total ash content was determined in a furnace at 550 °C for 6 h. Neutral detergent fibre (NDF), Acid detergent fibre (ADF) and acid detergent lignin (ADL) were determined according to Van Soest et al (1991). Crude protein (CP) was determined using the Kjeldahl method. Ash and Ether extract (EE) were determined according to the Association of Official Analytical Chemists (AOAC) (2005).

Silage Quality

The experiment was a completely randomised design (CRD) with four treatments and four replications. Data collection was conducted during day zero (before fermentation) and 21 days after fermentation. Four grass was harvested from the third cutting on 22 April 2023. Then, it was chopped and packed into fermentation bags with HDPE (high-density Polyethylene) type. Air was removed using a vacuum machine, and the bag was sealed with a heat sealer. After that, the silage was stored under ambient warehouse conditions. Fresh forage was ensiled without moisture adjustment or additives. Moisture content was determined before ensiling and after 21 days of fermentation to evaluate changes during the ensiling process. In vitro true dry matter digestibility (IVTDMD) was analysed using an ANKOM Daisy II incubator (ANKOM Technology, 2017). The method has several steps; 0.3 g of samples were prepared in a filter bag (F57), buffer solutions and rumen inoculum mix were prepared, then the bags were incubated in a rumen fluid mix at 39±0.5 ºC for 48 hours. After 48 hours of incubation, bags were washed with the neutral detergent solution in an ANKOM-200 Fibre Analyser to remove rumen fluid particles and non-cell wall material. The bags were dried in a hot air oven, then weighed and recorded as the final weight (W3). The values of samples were used for energy and digestibility estimation. IVTDMD was calculated following ANKOM technology (2017), and *in vitro* Neutral detergent fibre digestibility (NDFD) was calculated following Muttoni et al. (2013).

Statistical analysis

All statistical analyses were carried out with the program R software (version 3.1.1, R Core Team 2021).

RESULTS

Rainfall and Climate

The amount of rainfall was 281 mm in July 2022. The highest amount of rainfall was 455 mm in September (1.5 months after transplanting). The amount of rainfall from July to December in 2022 was 1,136 mm. In 2023, the maximum rainfall occurred in January (188 mm). The total amount of rainfall during the 10-month study period (July 2022 to April 2023) was 1,430 mm (Figure 1). The average temperature was 26.0 - 29.3 °C (Figure 1).

Agronomic Performance

The plant height of four *Urochloa* grasses in the 1st cutting ranged from 30.08 to 48.56 cm and did not show a significant difference. However, significant differences were observed in the 2nd and 3rd cutting, with *U. ruziziensis* (36.47 cm) exhibiting the lowest plant height in the 2nd cutting, while in the 3rd cutting, *U. brizantha* (85.76 cm) exhibited the highest plant height (Table 1). The range of tiller numbers in the 1st cutting was 121.22 to 160.44 and 180.44 to 231.44 tillers per plant in the 2nd cutting. The tiller number showed no significant difference among the varieties in both cuttings. However, there was a significant difference in the number of tillers in the 3rd cutting between *U. ruziziensis* (283.44) and

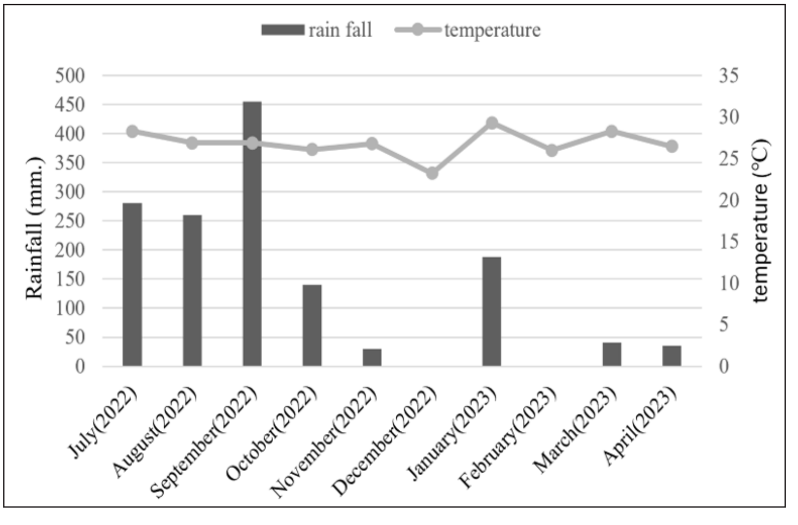

Figure 1. Average monthly rainfall and temperature from July 2022 to April 2023 at the Khon Kaen Meteorological Station, Tha Phra, Mueang, Khon Kaen Province, Thailand

U. decumbens (252.33) exhibiting the highest tiller number compared to Mulato II (Table 1). The stem diameter ranged from 2.58 - 4.33, 1.00 - 2.91 and 2.55 - 3.99 mm in the 1st, 2nd and 3rd cutting, respectively. Significant differences were observed among the varieties in all cutting cycles, with Mulato II and *U. brizantha* exhibiting the largest stem diameter in the 1st and 3rd cutting, and *U. brizantha* showing the highest stem diameter in the 2nd cutting (Table 1). There were significant differences in leaf width and leaf length among the varieties in all cuttings. Mulato II and *U. brizantha* exhibited the highest leaf width in 1st and 3rd cutting while in the 2nd cutting, only Mulato II exhibited the highest leaf width. In terms of leaf length, *U. brizantha* exhibited the highest leaf length in all cutting cycles, and Mulato II also exhibited the highest leaf length in the 2nd cutting (Table 1). The leaf greenness ranged from 35.35- 45.71 and 29.61 - 35.66 SPAD units in the 1st and 3rd cutting. Significant differences were observed among the varieties, with *U. ruziziensis* exhibiting the lowest leaf greenness in the 1st and 3rd cuttings, and *U. decumbens* also exhibited the lowest leaf greenness in the 3rd cutting (Table 1).

Table 1
The growth of U. ruziziensis, Mulato II, U. decumbens and U. brizantha after 1st cutting, 2nd cutting and 3rd cutting

Treatment	Height (cm)	Tiller per Plant	Stem Diameter (mm)	Leaf Width (cm)	Leaf Length (cm)	SPAD
1st cutting						
U. ruziziensis	30.08	160.44	2.62$^{b1/}$	1.64^{ab}	20.50^{b}	35.25^{b}
Mulato II	35.57	121.22	4.33^{a}	1.85^{a}	23.28^{ab}	45.71^{a}
U. decumbens	48.56	128.22	2.58^{b}	1.49^{b}	19.80^{b}	41.60^{a}
U. brizantha	41.50	137.55	3.99^{a}	1.81^{a}	27.78^{a}	45.52^{a}
F-test	ns	ns	*	*	*	*
C.V. (%)	21.32	18.71	19.55	8.24	11.61	6.28
2nd cutting						
U. ruziziensis	36.47^{b}	217.33	1.50^{bc}	1.50^{bc}	25.41^{ab}	nd
Mulato II	47.84^{a}	180.44	1.91^{b}	1.95^{a}	31.65^{a}	nd
U. decumbens	46.07^{a}	189.33	1.00^{c}	1.45^{c}	18.28^{b}	nd
U. brizantha	48.56^{a}	231.44	2.91^{a}	1.88^{ab}	35.51^{a}	nd
F-test	*	ns	*	**	**	-
C.V. (%)	10.43	24.06	14.90	8.02	14.36	-
3rd cutting						
U. ruziziensis	70.82^{bc}	283.44^{a}	2.55^{b}	1.28^{b}	22.01^{b}	29.61^{b}
Mulato II	76.03^{b}	175.33^{b}	3.99^{a}	1.90^{a}	26.53^{ab}	35.66^{a}
U. decumbens	66.18^{c}	252.33^{a}	3.48^{ab}	1.35^{b}	15.99^{c}	29.70^{b}
U. brizantha	85.76^{a}	246.78^{ab}	3.86^{a}	1.80^{a}	30.15^{a}	35.09^{a}
F-test	**	*	*	*	*	*
C.V. (%)	4.23	15.84	16.03	5.04	10.83	5.75

Yield

The yield potential of the four *Urochloa* grasses in the 1st cutting demonstrated significant differences in both fresh and dry weights. *U. brizantha* showed the highest fresh and dry weights with a yield of 4,212.50 and 945.80 kg $ha^{-1,}$ respectively, with no significant difference compared to Mulato II and *U. decumbens*. However, no significant differences were observed in the dry matter contents (DM) among the varieties in the 1st cutting. In the 2nd cutting found that the fresh weight, dry weight, and DM of the four *Urochloa* grasses were significantly different. In terms of fresh weight, Mulato II exhibited the highest value at 7,560.89 kg ha^{-1}, with no significant difference observed compared to *U. decumbens* (6,781.94 kg ha^{-1}) and *U. brizantha* (6,359.65 kg ha^{-1}). For dry weight, *U. decumbens* (1,864.09 kg ha^{-1}) and Mulato II (1,794.21 kg ha^{-1}) gave the highest values, while *U. decumbens* had the highest DM. In the 3rd cutting, significant differences were observed in the fresh and dry weight of the four *Urochloa* grasses. *U. brizantha* exhibited the highest values, with fresh weight reaching 16,670.83 kg ha^{-1} and dry weight 4,520.83 kg ha^{-1}. While DM did not differ significantly among the groups (Table 2), evaluating the relative performance across consecutive cutting cycles underscored a dramatic acceleration in total biomass and structural maturity. Specifically, *U. brizantha* exhibited an exceptional +295.75% relative increase in fresh matter yield and a +377.99% relative increase in dry matter yield from the first to the third cutting cycle, outperforming the recovery velocity of all other varieties. Concurrently, plant maturation led to expected structural cell wall alterations, with *U. decumbens* demonstrating a relative NDF increase of +12.41% by the final harvest. The crop growth rate of the four *Urochloa* grasses, based on the growth rate among all three cutting cycles, indicated no significant difference in CGR1. However, a significant difference was observed in CGR2, which found that *U. brizantha* had the highest CGR value at 10.35 kg m^{-2} day^{-1}, followed by *U. ruziziensis*, *U. decumbens* and Mulato II (Table 3), respectively.

Table 2
Fresh matter yield (kg ha^{-1}), Dry matter yield (kg ha^{-1}) and Dry matter of U. ruziziensis, Mulato ll, U. decumbens and U. brizantha after 1st cutting, 2nd cutting and 3rd cutting

Treatment	Fresh Yield	Dry Yield	DM (%)
1st cutting			
U. ruziziensis	2,520.83$^{b1/}$	564.00^{b}	22.53
Mulato II	3,475.00^{ab}	713.48^{ab}	20.50
U. decumbens	3,716.66^{ab}	782.48^{ab}	21.03
U. brizantha	4,212.50^{a}	945.80^{a}	22.43
F-test	**	**	ns
C.V. (%)	14.60	10.58	6.41

Table 2 *(continued)*

Treatment	Fresh Yield	Dry Yield	DM (%)
2nd cutting			
U. ruziziensis	4,227.58^{b}	1,009.01^{b}	24.30^{cb}
Mulato II	7,560.89^{a}	1,794.21^{a}	23.76^{c}
U. decumbens	6,781.94^{ab}	1,864.09^{a}	27.47^{a}
U. brizantha	6,359.65^{ab}	1,607.21^{ab}	25.26^{b}
F-test	*	*	*
C.V. (%)	23.52	22.09	2.26
3rd cutting			
U. ruziziensis	9,679.16$^{b1/}$	2,700.90^{b}	27.91
Mulato II	12,141.67^{ab}	3,185.09^{b}	26.37
U. decumbens	11,558.33^{b}	3,319.35^{b}	28.84
U. brizantha	16,670.83^{a}	4,520.83^{a}	27.11
F-test	**	**	ns
C.V. (%)	12.19	9.60	5.46

Note. ns = non-significant, ** = highly significant ($p \leq 0.01$)
1/Means in a column with the same letter are not significantly different based on least significant difference (LSD)

Table 3
Crop growth rate (kg $m^{-2}d^{-1}$) of U. ruziziensis, Mulato II, U. decumbens and U. brizantha after cutting

Treatment	CGR (kg $m^{-2}d^{-1}$)	
	CGR 1	CGR 2
U. ruziziensis	1.58	6.01$^{b1/}$
Mulato II	3.84	4.94^{b}
U. decumbens	3.85	5.17^{b}
U. brizantha	2.35	10.35^{a}
F-test	ns	*
C.V. (%)	40.90	28.24

Note. ns = non-significant, * = significant ($p \leq 0.05$), ** = highly significant ($p \leq 0.01$)
1/Means in a column with the same letter are not significantly different based on least significant difference (LSD)

Nutritive Value

The nutritional analysis in the 1st cutting cycles of all four *Urochloa* grasses revealed that the crude protein concentration ranged from 10.36 to 11.00% (Table 4) and did not differ significantly among the four varieties. However, significant differences were observed in the levels of Ash, EE, NDF, ADF and ADL. *U. decumbens* exhibited the highest levels of NDF, ADF and ADL compared to other varieties. Regarding ether EE concentrations, *U. brizantha* demonstrated the highest values among the evaluated varieties. Meanwhile, *U. ruziziensis*, Mulato II and *U. brizantha* did not have significant differences in Ash level

(Table 4). In the 2nd cutting cycles, the range of CP and Ash levels was 7.40 to 8.40% and 11.00 to 14.26%, respectively, with no significant difference among the varieties (Table 4). In terms of EE, NDF, ADF, and ADL levels, *U. ruziziensis* and Mulato II showed the lowest significant differences in NDF levels when compared to other varieties. Significant differences were observed in the levels of ADF and ADL, with *U. decumbens* exhibiting the highest levels. However, no significant differences were found when compared to *U. ruziziensis* and *U. brizantha* in ADF levels, and only *U. ruziziensis* showed significant differences in ADL levels. At the same time, *U. ruziziensis* and Mulato II exhibited the highest significant EE levels when compared to *U. decumbens* (Table 4). In the 3rd cutting, CP, ADF and ADL were not significantly different among varieties. *U. ruziziensis* had the lowest significant NDF levels when compared to *U. decumbens* and *U. brizantha* (Table 4). Both *U. ruziziensis* and Mulato II showed the highest significant Ash levels when compared

Table 4
The chemical compositions of U. ruziziensis, Mulato II, U. decumbens and U. brizantha after 1st cutting, 2nd cutting and 3rd cutting

Treatment	**CP (%)**	**NDF (%)**	**ADF (%)**	**ADL (%)**	**Ash (%)**	**EE (%)**
1st cutting						
U. ruziziensis	10.73	55.26c1/	30.83c	5.13b	16.46a	1.93b
Mulato II	10.36	52.77d	29.50c	4.70b	16.30a	2.03ab
U. decumbens	11.06	61.30a	38.90a	7.03a	13.43b	1.83b
U. brizantha	11.00	58.73b	32.33b	5.60b	14.70ab	2.33a
F-test	ns	*	*	**	*	*
C.V. (%)	6.68	2.00	2.03	6.00	8.29	8.86
2nd cutting						
U. ruziziensis	7.76	56.93b	31.87ab	4.36ab	14.20	2.13a
Mulato II	7.40	57.26b	30.13b	3.57b	14.26	2.03a
U. decumbens	6.86	65.43a	33.97a	4.83a	11.00	1.56b
U. brizantha	8.40	62.90a	32.40ab	3.57b	11.43	1.93ab
F-test	ns	**	*	**	ns	*
C.V. (%)	13.35	3.16	5.08	9.58	12.67	9.64
3rd cutting						
U. ruziziensis	6.86	65.64b	35.14	6.62	9.55a	1.00b
Mulato II	5.60	67.43ab	36.46	6.61	10.93a	0.90b
U. decumbens	5.86	68.91a	35.53	4.93	8.12b	1.16a
U. brizantha	6.03	69.94a	36.51	4.31	8.68b	1.03ab
F-test	ns	**	ns	ns	*	*
C.V. (%)	11.25	1.27	2.83	22.88	9.75	6.70

Note. ns = non-significant, * = significant (p ≤ 0.05), ** = highly significant (p ≤ 0.01)
1/Means in a column with the same letter are not significantly different based on least significant difference (LSD)

to *U. decumbens* and *U. brizantha*. *U. decumbens* exhibited the highest significant EE levels, with no significant differences found when compared to *U. brizantha* (Table 4).

Silage Quality

The chemical composition of silage included DM contents and levels of CP, Ash, EE, NDF, ADF and ADL are presented in Table 5. *U. decumbens and U. brizantha* showed the highest significant DM contents compared to other varieties in both before and after fermentation. There were ranges in CP levels among the four varieties of grass before and after fermentation, 7.16 to 9.56 and 7.80 to 10.00% (Table 5), respectively, with no significant difference among the varieties. The range of Ash levels before fermentation was 10.36 to 12.17% and did not have significant differences among the varieties. However, Mulato II had the highest significant Ash concentrations after fermentation (Table 5). The fermentation profiles, including silage pH and NH_3-N concentrations, are shown in Table 5. Significant differences were observed in the silage pH before and after fermentation. Before the fermentation of silage, *U. brizantha* exhibited the highest pH compared to *U. ruziziensis*, whereas after fermentation, *U. decumbens* exhibited the highest pH in comparison to *U. brizantha*. For Ammonia nitrogen (NH_3N) concentrations, *U. brizantha* exhibited the lowest significant NH_3-N concentrations in both before and after fermentation. The digestibility of silage was indicated by IVTDMD and NDFD as shown in Table 5. *U. ruziziensis* and Mulato II exhibited the highest IVTDMD and NDFD compared to other varieties before fermentation, with no significant difference in NDFD observed between *U. brizantha*. However, no significant differences were observed in IVTDMD and NDFD after fermentation.

DISCUSSION

The study evaluated the agronomic performance of four *Urochloa* varieties with three cutting cycles under Thailand conditions, with a particular focus on identifying optimal candidates for sustainable forage production (Dereje et al., 2024). Considering the rainfall prior to each cutting cycle, it was found that a dry spell in February 2023 negatively affected the growth of all four *Urochloa* varieties, resulting in reduced plant height and stem diameter. However, *U. brizantha* continued to demonstrate superior plant height and stem diameter relative to the other varieties, which is attributable to its greater adaptability to environmental conditions (Perini et al., 2023). Enhanced tillering constitutes a key adaptive mechanism that enables plants to endure recurrent harvesting by effectively restoring their photosynthetic capacity and sustaining the integrity of the basal region. A higher number of tillers reduces apical dominance, which in turn encourages the growth of shoots from the plant's base (Ernawati et al., 2023). Therefore, the observed increase in tiller numbers during the second and third cutting cycles, especially in *U. ruziziensis,* can be attributed to

Table 5
The chemical compositions of U. ruziziensis, Mulato II, U. decumbens and U. brizantha before and after fermentation

Treatment	DM (%)	CP (%)	Ash (%)	EE (%)	NDF (%)	ADF (%)	ADL (%)	IVTDMD (%)	NDFD (% NDF)	pH	NH3-N (%)
Before fermentation											
U. ruziziensis	$24.06^{b1/}$	9.56	10.53	1.60^{ab}	67.00^{ab}	31.73^{c}	4.03^{ab}	70.97^{a}	54.97^{a}	5.56^{b}	0.006^{a}
Mulato II	24.00^{b}	6.93	12.17	1.63^{a}	64.30^{b}	32.03^{bc}	3.90^{b}	71.90^{a}	61.40^{a}	5.76^{ab}	0.006^{a}
U. decumbens	29.53^{a}	7.60	10.80	1.43^{b}	68.40^{ab}	34.07^{ab}	4.20^{a}	60.23^{b}	45.57^{b}	5.81^{ab}	0.006^{a}
U. brizantha	27.67^{a}	7.16	10.36	1.50^{ab}	69.53^{a}	34.96^{a}	4.13^{a}	64.57^{b}	52.87^{ab}	5.90^{a}	0.004^{b}
F-test	**	ns	ns	*	**	*	**	**	**	**	*
C.V. (%)	4.04	15.56	11.65	6.02	2.14	3.38	1.78	2.98	5.45	0.84	10.18
After fermentation											
U. ruziziensis	18.47^{b}	10.00	14.43^{b}	2.90^{ab}	60.87^{bc}	36.47^{b}	5.03^{b}	71.09	38.41	4.56^{ab}	0.13^{ab}
Mulato II	18.67^{b}	9.77	20.17^{a}	3.23^{a}	57.10^{c}	34.73^{b}	4.47^{b}	71.75	38.64	4.57^{ab}	0.16^{ab}
U. decumbens	23.07^{a}	8.33	15.33^{b}	2.17^{c}	67.00^{a}	42.73^{a}	6.33^{a}	70.03	37.79	4.67^{a}	0.17^{a}
U. brizantha	22.23^{a}	7.80	14.16^{b}	2.30^{bc}	64.00^{ab}	38.97^{ab}	5.07^{b}	69.18	35.72	4.46^{b}	0.15^{b}
F-test	**	ns	*	*	*	**	*	ns	ns	**	*
C.V. (%)	4.49	14.47	7.93	12.11	3.05	4.62	10.51	2.96	12.60	1.06	11.86

Note. ns = non-significant, * = significant ($p \leq 0.05$), ** = highly significant ($p \leq 0.01$)
[1/]Means in a column with the same letter are not significantly different based on least significant difference (LSD)

an adaptive response aimed at enhancing resilience to recurrent harvesting. *U. brizantha* and Mulato II exhibited a reduction in tiller numbers during the third cutting cycle, potentially because of harvesting-induced damage sustained in the preceding cycle.

The variation in leaf greenness via SPAD values further suggests the importance of nutrient management strategies to optimise photosynthetic efficiency within *Urochloa* species (Pinho Costa et al., 2014). Silva et al. (2018) reported that chlorophyll content declines with increasing plant age, in contrast to other agronomic traits that generally exhibit a positive correlation with plant maturity. This observation is consistent with the findings of the present study, which demonstrated a decline in leaf greenness during the third cutting cycle relative to the first, suggesting a reduction in chlorophyll content with plant maturation. However, *U. brizantha* and Mulato II maintained significantly higher levels of leaf greenness, suggesting a greater capacity for chlorophyll retention within the leaf tissues. *U. decumbens* displayed intermediate agronomic traits, underperforming *U. brizantha* and Mulato II in most parameters while exhibiting slightly superior traits to *U. ruziziensis*. These findings indicated the potential of *U. brizantha* as a high-yield, resilient forage crop for Thailand, while Mulato II is identified as a viable alternative under specific management practices to mitigate regrowth limitations (Hare et al., 2005; Hare et al, 2015). However, in terms of consistency from the first to third cutting, *U. brizantha* exhibited higher agronomic traits and some traits and significant differences compared to Mulato II. Agronomic performance showed the potential of *U. brizantha* utilisation in Thailand conditions.

These growth patterns confirm the strong potential of *U. brizantha* for cultivation in Thailand. These results suggest that mechanical cutting drops apical auxin levels, triggering basal bud growth to rebuild the canopy. The varieties handle this stress differently through distinct resource allocation strategies: *U. brizantha* prioritises rapid vertical growth and upper-leaf chlorophyll retention to maximise light capture, whereas *U. ruziziensis* invests its carbohydrate reserves into horizontal tiller expansion rather than height. This may be explained by the fact that these diverse structural pathways illustrate how internal resource routing dictates the regeneration speed of tropical perennial grasses. (Ernawati et al., 2023; Perini et al., 2023).

The fresh and dry weight yields of *Urochloa* grasses varied significantly in three cutting cycles. In the first cutting, *U. brizantha* showed the highest fresh and dry weight yields (4,212.50 and 945.80 kg ha^{-1}, respectively); there were no significant differences compared to Mulato II and *U. decumbens* (Table 2). This suggests that these varieties exhibit comparable early growth potential. The dry matter (DM) did not show significant differences among the varieties in the first cutting, indicating similar forage quality at this stage. In the second cutting, fresh weight and dry weight differed significantly among the varieties. Mulato II exhibited the highest fresh weight (7,560.89 kg ha^{-1}), with no significant difference compared to *U. decumbens* (6,781.94 kg ha^{-1}) and *U. brizantha* (6,359.65 kg ha^{-1}). For dry weight, *U. decumbens* (1,864.09 kg ha^{-1}) and Mulato II (1,794.21 kg ha^{-1}) give the highest dry weight, while *U. decumbens* exhibited the highest DM content (Table 2). This highlights *U. decumbens* as an excellent candidate for forage conservation methods like silage or hay production. (Singh & Singh, 2017).

By the third cutting, significant differences were observed in both fresh and dry weights among the varieties. *U. brizantha* exhibited the highest fresh weight (16,670.83 kg ha^{-1}) and dry weight (4,520.83 kg ha^{-1}) (Table 2), demonstrating superior regrowth potential and biomass accumulation. However, no significant differences in DM were observed, suggesting that all varieties maintained relatively stable dry matter proportions, which is a crucial aspect of forage nutritional quality (Jank et al., 2014). Crop growth rate is an important factor influencing overall forage yield. The results indicated no significant difference in CGR during the first phase (CGR1), suggesting that the initial growth rates of the varieties were comparable. However, in the second phase (CGR2), significant differences emerged, with *U. brizantha* exhibiting the highest CGR (10.35 kg m^{-2}day^{-1}), followed by *U. ruziziensis*, *U. decumbens*, and Mulato II (Table 3). This suggests that *U. brizantha* has a higher biomass accumulation rate under sustained cutting, making it a suitable option for intensive forage production systems (Thaiana Rueda da Silva et al., 2020).

The rapid recovery and superior daily growth rates of *U. brizantha* under continuous harvesting stem from its deep root system and robust non-structural carbohydrate reserves. After defoliation, this bunchgrass relies on energy stored in its stem base to drive new vegetative shoots. Its extensive root framework extracts moisture and minerals from deeper sandy soil layers even during surface dry spells, maintaining the cellular turgor necessary for continuous cell division. This sustained metabolic activity prevents post-harvest stagnation, matching recent field trials where deep root depth and quick energy mobilisation directly sustained tropical pasture regrowth speeds (Dereje et al., 2024; Thaiana Rueda da Silva et al., 2020).

The nutritional analysis of the four *Urochloa* grass varieties within three cutting cycles provides implications for livestock feed management. In the first cutting, crude protein was consistent among the four varieties, ranging from 10.36% to 11.36% (Table 4) and decreased in the second and third cutting, which corresponds to the study conducted by Rodríguez et al. (2024), which reported a decline in crude protein content with advancing plant maturity across six *Urochloa* hybrids. Moreover, the reduction in crude protein content may be associated with the decline in leaf greenness, as the SPAD index has been shown to serve as a reliable indicator of protein levels in plants (Silva et al., 2018). This study revealed that the concentrations of NDF and ADF increased with plant maturity due to the progressive development and thickening of cell wall structures (Jung & Allen, 1995).

However, *U. decumbens* exhibited the highest levels of NDF, ADF, and lignin, indicating that it is more fibrous and potentially less digestible than other varieties (Vinhas Itavo et al., 2022). On the other hand, *U. brizantha* provided the highest EE levels, suggesting it may offer higher fat content, which can contribute to energy intake in livestock diets (Ponnampalam et al., 2024). Ash levels were similar among *U. ruziziensis*, Mulato II, and *U. decumbens*, indicating a comparable mineral composition in these varieties.

During the second cutting, CP levels declined to a range of 7.4% to 8.4% (Table 4) with no significant differences among varieties. This reduction in protein content is associated with the expected decline in nutrient concentration as grasses mature (Bantihun et al., 2022). Similarly, ash content increased to a range of 11.00% to 14.26% (Table 4) without significant differences among varieties, suggesting consistent mineral content despite the decline in protein levels. The most notable differences during this cycle were observed in the fibre components. *U. ruziziensis* and Mulato II had significantly lower NDF levels than other varieties, indicating higher digestibility (Dereje et al., 2024). In contrast, *U. decumbens* maintained the highest levels of ADF and ADL, reinforcing its more fibrous nature. Furthermore, *U. ruziziensis* and Mulato II exhibited higher EE levels, suggesting a potential advantage in energy content during this growth phase. In the third cutting, CP, ADF, and ADL levels remained statistically similar among varieties, indicating that nutrient composition may stabilise as the grass matures. Nevertheless, *U. ruziziensis* demonstrated the lowest NDF levels, suggesting its potential for higher digestibility in later stages (Dereje et al., 2024). Ash content was significantly higher in *U. ruziziensis* and Mulato II, suggesting greater mineral availability in these varieties (Bantihun et al., 2022). Notably, *U. decumbens* gave the highest EE levels, indicating a relatively high fat content that may enhance its energy contribution to livestock feed (Ponnampalam et al., 2024).

This drop in crude protein combined with rising NDF and ADF values stems from plant maturation and a shifting leaf-to-stem ratio. As the grass ages, it redirects resources from producing soluble cell contents, like metabolic proteins and enzymes, toward structural stem growth. To support this vertical weight, the plant builds thick layers of cellulose, hemicellulose, and complex lignin within its cell walls. *U. decumbens*, for example, exhibits rapid stem lignification, accumulating structural carbohydrates into vascular bundles at the expense of nitrogenous leaf proteins. This trend mirrors classic forage studies where advancing maturity accelerates cell wall development while diluting overall crude protein content. (Jung & Allen, 1995; Rodríguez et al., 2024).

U. decumbens and *U. brizantha* demonstrated significantly higher DM content relative to the other grass varieties, both before and after ensiling. The sustained DM content in these grasses indicates a superior capacity to retain dry matter throughout the fermentation process, a critical factor in preserving nutrient integrity in silage. However, CP levels showed no significant variation among all varieties, suggesting that the ensiling process had a minimal effect on protein retention. This observation aligns with prior research indicating negligible CP alterations post-ensiling in tropical grasses (Sath et al., 2013). Interestingly, the ash content of Mulato II significantly increased after fermentation, indicating a potential accumulation of mineral components during the fermentation process. These results may be attributed to the mineral composition levels of the substrates and indicate the effectiveness of the microbial consortium in improving the mineral composition of the substrates (Ntuli et al., 2013). Such a finding is consistent with reports on tropical forages, where fermentation processes can influence ash concentrations (Ogodo et al., 2017).

The pH and NH_3-N concentrations exhibited significant variations among the grass varieties, suggesting that the impact of grass species on fermentation quality. *U. brizantha* demonstrated the highest pre-fermentation pH, suggesting lower fermentable carbohydrate availability or a higher buffering capacity before ensiling. On the other hand, *U. decumbens* showed the highest post-fermentation pH, potentially indicating suboptimal fermentation efficiency. The observed NH_3-N concentrations in *U. brizantha* were significantly lower in both pre- and post-fermentation stages, suggesting better protein preservation and reduced proteolytic activity in this grass variety. Assessment of digestibility through IVTDMD and NDFD revealed that *U. ruziziensis* and Mulato II demonstrated superior fibre digestibility before ensiling, consistent with findings reported in other tropical forage studies (Jayasinghe et al., 2022). However, after fermentation, analysis indicated no significant differences in digestibility among the grass varieties, suggesting that the fermentation process may attenuate initial variations in fibre composition and digestibility (Zhang et al., 2017). The lack of significant NDFD differences after ensiling is particularly significant, as it emphasises the potential of the fermentation process to homogenise digestibility traits throughout ensiled forages, effectively minimising variability in fibre degradability. Previous studies indicate that ensiling can mitigate initial differences in fibre composition through microbial degradation and structural breakdown (Oba & Allen, 2000).

The excellent protein protection in *U. brizantha* results from a fast drop in pH caused by early organic acid accumulation under anaerobic conditions. This rapid acidification blocks plant proteases, stopping the breakdown of true proteins into ammonia and volatile nitrogen. Concurrently, during the 21-day storage period, lactic acid bacteria carry out natural microbial hydrolysis to partially break down structural hemicellulose bonds across all varieties. This cellular breakdown erases the natural differences between the species to create a uniform fibre product. This aligns with findings that effective fermentation standardises dry matter digestibility in tropical silage. (Alves et al., 2025; Ponnampalam et al., 2024).

In conclusion, the four *Urochloa* species exhibited distinct agronomic and nutritional characteristics under Thailand's tropical conditions. Among the evaluated species, *U. brizantha* showed the greatest potential for intensive forage production and repeated cutting systems due to its superior biomass yield and growth performance. *U. ruziziensis* demonstrated favourable digestibility characteristics, indicating its suitability for silage production, while *U. decumbens* exhibited relatively high dry matter content and stable performance, suggesting potential for forage production under drought-prone conditions. These findings indicated the importance of selecting forage species according to specific production objectives and provide practical guidance for forage management, year-round feed production, and silage utilisation in Thai livestock production systems. Future research should further investigate the effects of seasonal variability and ensiling practices on forage quality and fermentation characteristics to optimise sustainable livestock feeding strategies in tropical environments. The study indicated the significance of selecting grass varieties with superior agronomic performance, high yield and digestibility potential to enhance the nutritional quality of silage. Future research should explore the interaction between ensiling conditions and grass variety, particularly in tropical regions where climatic variability can significantly affect fermentation dynamics and nutrient preservation. This approach will provide important information for optimising forage management strategies and promoting sustainable livestock feeding systems.

ACKNOWLEDGEMENT

This work was financially supported by King Mongkut's Institute of Technology Ladkrabang [grant number: 2565-02-04-004].

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