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Optimizing Pruning Management of *Melochia umbellata* for Drought-tolerant Ruminant Feed

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Abstract

In semi-arid tropical regions, forage availability is the primary constraint to ruminant livestock production. *Melochia umbellata*, locally known as Busi, is a drought-tolerant indigenous shrubs in West Timor, Indonesia, with significant potential as supplementary feed during critical dry periods. However, scientific exploration on its agronomic management and nutritional dynamics remains limited despite of its potential. This study, for the first time, investigate the effect of pruning intervals on the biomass partitioning and nutritional profile of *M. umbellata* to understand effective management of the draught-tolerant plant for ruminant feeds. The experiment employed a randomized block design with three pruning interval treatments (8, 12 and 16 weeks) with four replications. The evaluated parameters included stem-to-leaf ratio, proximate composition, fiber fractions, and in vitro digestibility. Results demonstrated that extending the pruning interval did not significantly ($P > 0.05$) alter the stem-to-leaf ratio, dry matter, organic matter, ash, neutral detergent fiber, or acid detergent fiber content. Conversely, pruning interval exerted a significant influence on crude protein content ($P < 0.05$) and in vitro digestibility ($P < 0.01$), with shorter pruning interval (8 weeks) showed higher protein content. Furthermore, the stability of fiber fractions across maturity stages suggests that M. umbellata possesses a flexible harvest window suitable for dryland management, although protein its protein content declined at longer intervals (> 8 weeks). These findings support the integration of M. umbellata into silvo-pastoral systems as a resilient forage strategy for climate-vulnerable regions.

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1. Introduction

The sustainability of ruminant production systems in tropical drylands is intrinsically linked to the temporal stability of feed resources. In the semi-arid regions of the Indonesian archipelago, livestock farming is not merely an economic activity but a socio-cultural cornerstone of rural livelihoods (Suhartini et al., 2020). However, the productivity of these systems is severely constrained by extreme climatic seasonality (Tagang et al., 2025). The East Nusa Tenggara region, specifically West Timor, is characterized by a distinct unimodal rainfall pattern, where a short, intense wet season is followed by a prolonged dry season lasting eight to nine months, causing a drastic decline in the quantity and quality of the forage (Perdinan et al., 2024; Sulistijo & Rosnah, 2022). This climate creates a critical feed gap during the dry months, where the quality and quantity of available forage decline significantly. Moreover, the influence of global climate change and increasing El Niño-Southern Oscillation irregularity, these dry periods are becoming longer and more unpredictable, posing an existential threat to regional food security (Timmermann et al., 2018). Historically, the introduction of exotic tree legumes such as *Leucaena leucocephala* and *Gliricidia sepium* has transformed tropical livestock systems (de Macêdo Carvalho et al., 2024). These species are capable of accessing deep soil moisture and retaining green leaf biomass long into the dry season. However, the reliance on a narrow range of exotic species presents significant ecological and agronomic risks (Mastretta-Yanes et al., 2018). The establishment of exotic monocultures can be resource-intensive and ecologically unstable. On the other hand, utilizing indigenous forage will promote sustainable practice of the livestock farming (Antonio Pámanes-Carrasco et al., 2019; Sulistijo et al., 2021). Therefore, there is an urgent to identify, characterize, and utilize indigenous drought-tolerant shrub species that are already adapted to local environment and climatic stresses. One such promising but underutilized candidate is *Melochia umbellata*.

Melochia umbellata, locally known in West Timor as "Busi," is a pioneer shrub or small tree belonging to the family *Sterculiaceae*. This species exhibits exceptional physiological resilience, capable of thriving in nutrient-poor soils and enduring severe water stress (Starr et al., 2003). Despite this, scientific attention towards *M.*

umbellata has been lacking. Its agronomic potential remains obscured by a lack of quantitative data regarding its response to management practices, specifically pruning regimes, and the resulting impact on its nutritional profile. Optimizing the management of shrub legumes for forage requires a delicate balance between biomass production and nutritive value, a relationship largely governed by the harvest or pruning interval (Edvan & Bezerra, 2018). The pruning interval represents the physiological age of the regrowth at the time of defoliation. Theoretically, extending the interval between harvests allows the plant to intercept more light, restore root carbohydrate reserves, and maximize total dry matter yield (Vandermeulen et al., 2018). However, this biomass accumulation often comes at a nutritional cost. As plant tissue matures, the cell metabolic activity decreases, and structural components accumulate. The dilution effect occurs, where the synthesis of structural carbohydrates (cellulose, hemicellulose, and lignin) outpaces the uptake of nitrogen and minerals, leading to a reduction in crude protein concentration (Hatfield & Kalscheur, 2020). Furthermore, the process of maturation in tropical shrubs involves complex changes in cell wall architecture. Secondary thickening of the cell wall and increasing lignification reduce the accessibility of cellulose to rumen microbial enzymes, thereby depressing digestibility (Tedeschi et al., 2023; Anak-Dennis et al., 2025). The dynamic between fiber accumulation, protein dilution, and secondary metabolite activity defines the optimal pruning interval (Makhubedu et al., 2022). Short pruning interval may compensate the biomass yield, while longer interval may yield highly lignified and unpalatable shrubs, rendering it nutritionally useless despite high yields.

Currently, no specific guidelines exist for *M. umbellata* management. Establishing a standardized pruning interval is crucial for transforming this wild species into a managed crop. It is hypothesized that *M. umbellata*, as a woody pioneer, may possess a distinct maturation profile compared to herbaceous legumes. Understanding these specific morpho-physiological responses is essential for integrating Busi into the cut-and-carry feeding systems prevalent in West Timor. Therefore, this study aims to systematically evaluate the effect of varying pruning intervals (8, 12, and 16 weeks) on the agronomic and nutritional characteristics of *Melochia umbellata*. Specifically, this research seeks to: (1) determine the impact of regrowth age on biomass partitioning (stem-to-leaf ratio); (2) quantify the changes in chemical composition, particularly fiber fractions and crude protein; and (3) assess the bioavailability of nutrients through *in vitro* digestibility assays. The findings of this study will, for the first time, provide science-based management recommendations for smallholder farmers, facilitating the adoption of *M. umbellata* as a resilient, high-quality forage resource to bridge the dry season feed gap in the semi-arid tropics.

2. Materials and Methods

2.1 Site and Environmental Conditions

A field study involving the planting, pruning and observation of *M. umbellata* was conducted for six months (March to August 2024) in Oeletsala Village, Kupang Regency, West Timor, East Nusa Tenggara, Indonesia. The site is a semi-arid tropical zone characterized by a short, intense rainy season and prolonged dry season. During the experimental period, the weather was transitioned from late wet season (in March-April) to dry season (May-August). The average daily temperature ranged from 26.9 to 28.7 °C, with the highest temperature reached 33.4 °C. The average humidity ranged from 70 – 88%, total rainfall of approximately 417.4 mm, and a total rainy day of 21 days throughout the six months of the study. The soil at the experimental site is classified as rhodustalf with pH at 5.5 – 7.0.

2.2 Experimental Design

The study utilized an established stand of *Melochia umbellata* at the age of 1 year owned by local livestock farmer. The experiment was arranged in a randomized block design comprising three treatments based on pruning intervals (8-week, 12-week, and 16-week pruning interval). Each treatment was replicated four times, resulting in 12 experimental units. Blocking was based on the initial trunk diameter and canopy size of the shrubs to account for inherent variations in plant vigor.

2.3 Procedures and Sampling

Prior to the treatment period, a uniformization cut (pruning standardization) was performed on all plants at a height of 100 cm above ground level to ensure uniform regrowth. Samples were harvested at the end of each respective interval (8, 12, and 16 weeks). The harvested biomass was separated into edible fractions (leaves and

succulent stems) and woody stems. Fresh weights were recorded immediately to determine biomass production. A subsample of approximately 300 g from each plot was taken, seperated into leaf and stem components to calculate the stem-to-leaf rasio by drying both at fraction at approximately 70 °C for 3 days. Subsequently, the same stem and leaf fractions were further dried at 105 °C for 4 hours, and the weight of final drying is compared to the initial drying weight to calculate the percentage of dry matter (DM) content (AOAC, 2023). Finally, these dried samples were ground to pass through a 1-mm sieve using a Wiley mill for down-stream chemical analyses.

2.4 Chemical Analysis

Chemical composition was analyzed at the Nutrition and Feed Chemistry Laboratory, Faculty of Animal Husbandry, Universitas Nusa Cendana. Proximate composition, including dry matter (DM), organic matter (OM), and crude protein (CP) were determined according to the standards method of AOAC (2005). The CP was calculated as nitrogen *N x 6.25*. The neutral detergent fiber (NDF) and acid detergent fiber (ADF) were analyzed sequentially using the method described by Van Soest et al. (1991). *In vitro* dry matter digestibility (IVDMD) and *in vitro* organic matter digestibility (IVOMD) were determined using the two-stage technique of Tilley and Terry (1963). Rumen fluid was obtained from local slaughter house from a Bali cattle maintained on a standard forage diet.

2.5 Statistical Analysis

Data were subjected to analysis of variance. The statistical model for a randomized complete block design is as follow:

$$Yij = \mu + Bi + tj + \epsilon ijj \quad (1)$$

where Y_{ij} indicates the observed numerical value (dependent variable) for treatment j occurring in block i; μ indicates the overall mean of all observations in the experiment; B_i indicates the effect of the i-th block; t_j indicates the effect of the j-th treatment being tested; and ϵ_{ij} indicates the random variation or experimental errof for the observation Y_{ij}. Significant treatments effect were detected at $P < 0.05$, while means were compared using Duncan's multiple range test

3. Results and Discussion

3.1 Effect of Pruning Intervals on Stem-to-Leaf Ratio and Fiber Compositions

The analysis of variance revealed that extending the pruning interval from 8 to 16 weeks did not give a statistically significant effect ($P > 0.05$) to the stem-to-leaf ratio of *Melochia umbellata*. Although not statistically distinct, an upward trend was observed as the plant matured, with the highest stem-to-leaf ratio of 0.22 was recorded at the 16-week interval. This indicates that while structural tissue accumulation marginally increased with age, it was insufficient to constitute a genuine treatment effect. The chemical composition of *M. umbellata* forage harvested at different pruning intervals is presented in Table 1. The statistical analysis revealed a distinct divergence in how different nutrient fractions responded to maturation. The pruning interval did not significantly influence ($P > 0.05$) the contents of dry matter (DM), organic matter (OM), ash, neutral detergent fiber (NDF), or acid detergent fiber (ADF). In contrast, a significant effect ($P < 0.05$) was observed on crude protein (CP) content, which exhibited a linear decline as the interval extended from 8 to 16 weeks.

Table 1. Proximate and fiber components of *M. umbellata* at different pruning interval

Parameters	Pruning interval (week)			p-value
	8	12	16	
Dry matter (%)	27.88 ± 0.28[a]	30.52 ± 0.87[a]	33.27 ± 1.02[a]	0.10
Organic matter (%)	92.81 ± 0.30[a]	92.77 ± 0.35[a]	92.63 ± 0.29[a]	0.97
Ash (%)	7.19 ± 0.30[a]	7.23 ± 0.35[a]	7.37 ± 0.29[a]	0.97
Crude protein (%)	18.07 ± 0.30[b]	13.76 ± 0.35[a]	12.94 ± 0.29[a]	0.02
Neutral detergent fiber (%)	34.88 ± 0.50[a]	35.62 ± 0.63[a]	35.60 ± 0.60[a]	0.88

Acid detergent fiber (%)	16.59 ± 0.36[a]	17.41 ± 0.52[a]	18.85 ± 1.07[a]	0.55

[a,b]Different superscripts between pruning intervals indicate significant difference ($P < 0.05$)

The stem-to-leaf ratio serves as a fundamental morphological index of forage quality, directly influencing voluntary intake and nutrient accessibility. In ruminant nutrition, a lower ratio is preferable as it indicates a biomass dominated by leaves, which typically contain higher concentrations of protein and lower lignified fiber compared to stems (Castro-Montoya & Dickhoefer, 2020). The finding that *M. umbellata* maintained a stem-to-leaf ratio as low as 0.22 even with 16 weeks pruning interval is a significant deviation from the typical agronomic behaviour of tropical shrub legumes. For context, rapidly growing species such as *Indigofera zollingeriana* or *Leucaena leucocephala* often exhibit ratios approaching or exceeding 1.0 (equal parts stem and leaf) as they mature, driven by the plant's priority to lignify stems for vertical support (Elfeel & Elmagboul, 2016; Hassen et al., 2006). In contrast, the ratio of 0.22 observed here implies that for every kilogram of leaf biomass produced, only 220 grams of stem tissue is accumulated, ensuring that the edible fraction remains overwhelmingly dominant.

The dominance of leafy tissue suggests that *M. umbellata* maintains a high proportion of metabolically active parenchyma cells (mesophyll) relative to sclerenchyma or lignified vascular tissues (xylem) throughout this growth phase. In typical plant maturation, the transition from vegetative growth to structural hardening involves secondary cell wall thickening, a metabolically expensive process where carbon skeletons are diverted from protein synthesis to the deposition of cellulose and lignin (Cosgrove, 2024). The stability of the stem-to-leaf ratio implies a delayed onset of this secondary thickening. Consequently, the plant maintains a favourable cytoplasm-to-cell wall ratio, ensuring that metabolic activity remains focused on photosynthesis and protein synthesis in the leaf rather than structural rigidification in the stem. This delayed lignification strategy is crucial for forage quality, as it preserves the accessibility of cell contents to rumen microbes (Silva et al., 2021). Furthermore, this morphological stability likely reflects a specific adaptation of *M. umbellata* to the semi-arid environment of West Timor. Many crops exhibit stress-induced growth during water deficit, where internode elongation and apical dominance are restricted to conserve resources (Li et al., 2023). Instead of investing energy into expanding structural woody biomass (stems), the plant prioritizes the maintenance of existing photosynthetic organs (leaves) to maximize survival. Although the numerical increase to 0.22 at 16 weeks suggests the onset of inevitable physiological maturation, the lack of statistical significance confirms that this process is remarkably slow. Furthermore, this trait implies that *M. umbellata* possesses an exceptionally wide harvest window. Farmers are afforded significant management flexibility, as biomass can be accumulated on the plant for extended periods (up to 4 months) without the rapid morphological deterioration that renders other forages unpalatable during the dry season. This persistence of leafiness ensures that even at delayed harvests, the harvested biomass remains a high-quality, leaf-rich feed resource rather than a fibrous, woody residue.

3.2 Effect of Pruning Intervals on In Vitro Digestibility

The biological value of the forage, evaluated through *in vitro* dry matter digestibility (IVDMD) and organic matter digestibility (IVOMD), was highly significantly influenced ($P < 0.01$) by the pruning interval. The data demonstrated a distinct inverse relationship between plant maturity and nutrient bioavailability: the highest digestibility coefficients were observed at the 8-week interval, followed by a significant progressive decline at 12 and 16 weeks. In our study, the dry matter of *M. umbellata* was ranging from 27.88% at 8-week pruning interval to 33.27% at 16-week pruning interval (Table 1). The absence of a significant increase in DM content across the 8 to 16-week period contradicts the typical maturation trajectory of tropical forages, where DM content usually rises due to cell wall thickening and reduced tissue hydration. In *M. umbellata*, the stability of DM implies that the plant maintains a relatively constant level of tissue hydration even as it ages into the dry season. This phenomenon is indicative of a drought-related strategy, commonly found in deep-rooted shrubs (Brum et al., 2017). This stable DM content is advantageous for silage making or direct feeding, as it ensures consistent nutrient density per kilogram of fresh feed offered, reducing the bulk-density constraints often associated with very young, high-moisture forages.

Similarly, the OM and ash (mineral) contents remained statistically unchanged across treatments (Table 1). The stability of the mineral fraction suggests that mineral uptake and accumulation kept pace with biomass production. In many fast-growing tropical legumes, rapid biomass accumulation can sometimes dilute mineral concentrations (Tiemann et al., 2009). However, *M. umbellata* appears to maintain a balanced mineral profile throughout this growth phase. While mineral speciation (Ca, P, Mg) was not analyzed in our study, the total ash

consistency indicates that the plant continues to actively mine soil nutrients even at 16 weeks of regrowth. This persistence supports the potential role of *M. umbellata* not just as a protein supplement, but as a reliable source of minerals for grazing cattle, which often suffer from mineral deficiencies when relying solely on senescent savanna grasses, such as previously reported by (Barbosa et al., 2014) and Baijukya et al. (2021). Furthermore, the significant decline in CP represents the most critical nutritional change observed in this study. As the plant matures, the rate of carbon fixation and structural carbohydrate synthesis (cellulose and hemicellulose) accelerates and volumetrically outpaces the rate of nitrogen uptake from the soil (Liu et al., 2025). Consequently, the concentration of nitrogen per unit of DM decreases. Despite this decline, it is important to contextualize the CP values within the requirements of ruminant physiology at 7 - 8% by DM basis. Below this threshold, rumen ammonia levels become insufficient to support microbial population growth, depressing fiber digestion and voluntary intake. Comparing these results to native grasses in West Timor, which often plummet to approximately 5% CP during the dry season (Hartutik et al., 2012), even the 16-week *M. umbellata* likely offers a superior nitrogen profile.

Table 2. *In vitro* dry matter and organic matter digestibility of *M. umbellata*

Parameters	Pruning intervals (week)			p-value
	8	12	16	
IVDMD	64.78 ± 0.21^{b}	62.10 ± 0.31^{a}	61.25 ± 0.19^{a}	0.00
IVOMD	63.03 ± 0.20^{b}	60.11 ± 0.26^{ab}	58.86 ± 0.19^{a}	0.00

[a,b]Different superscripts between pruning intervals indicate significant difference ($P < 0.05$). IVDMD: *In vitro* dry matter digestibility; IVOMD: *In vitro* organic matter digestibility

Interestingly, our finding revealed the non-significant difference in NDF and ADF between 8 and 16 weeks (Table 1). NDF represents the total cell wall (cellulose, hemicellulose, and lignin) and is the primary regulator of voluntary feed intake due to its physical fill effect in the rumen. In typical tropical grasses (C4 species) and many herbaceous legumes, fiber fractions increase rapidly with maturity as the plant stiffens to support height growth. For instance, *Pennisetum purpureum* can see NDF levels rise from 66.8% to 78.6% in a matter of weeks (Islam et al., 2024), drastically reducing intake potential. The stability of fiber content in *M. umbellata* suggests that this could be an adaptive response to the semi-arid environment where rapid vertical growth is metabolically risky due to water costs, such as found in *Brachiaria* spp. (Rodrigues et al., 2023) and *Medigaco sativa* L. (Tlahig et al., 2024). Our finding thus suggests the possibility of utilizing *M. umbellata* as a living haystack, in a sense that farmers can defer harvesting without the penalty of handling highly fibrous and unpalatable material. This flexibility is crucial in West Timor's farming systems, where labor availability fluctuates and the ability to store feed "on the stump" is a valuable risk management strategy.

The *in vitro* digestibility analyses of our study revealed that while the fiber fractions of *M. umbellata* were not significantly different across the pruning intervals (Table 2), the *in vitro* digestibility exhibited a significant reduction with prolonged interval. Feed digestibility is typically negatively correlated with cell wall content, as an increase in NDF generally linked with reduced digestibility (Raffrenato et al., 2017). In our study, declined digestibility with stable fiber content in *M. umbellata* suggests that the reduction in nutrient bioavailability is affected by qualitative changes within the cell wall matrix rather than a simple accumulation of structural mass. Furthermore, the IVDMD values of *M. umbellata* at the 8-week interval in our study is higher compared to those of commonly forage feed, such as *Leucaena leucocephala*, which typically exhibit IVDMD and IVOMD of 50–55% (Piñeiro-Vázquez et al., 2017). This indicates that the foliage of young *M. umbellata* is highly fermentable, capable of providing rapid energy release to rumen microorganisms. In the dry season of West Timor, indigenous grasses such as *Heteropogon* or *Graminiae* typically experience a decline in digestibility to levels below 50% due to extensive lignification (Hayashi et al., 2021; Sio & Iswoyo, 2021). A digestibility below 50% generally restricts voluntary intake due to the rumen fill effect, as the feed requires prolonged retention times for degradation. Provided *M. umbellata* maintains digestibility above 55% at 16 weeks, it offers a superior alternative to the basal grass diet, sufficient to support maintenance energy requirements without the severe intake limitations associated with low-quality crop residues.

4. Conclusion

This study demonstrates the distinct physiological response of *Melochia umbellata* to varying harvest intervals under semi-arid conditions, revealing a unique trait of quality persistence characterized by morphological and fibrous stability. Unlike many tropical forages that undergo rapid lignification during the dry season, *M. umbellata* revealed to maintain a constant stem-to-leaf ratio and stable cell wall fractions (NDF and ADF) up to 16 weeks of regrowth. However, a notable nutritional uncoupling was observed, where *in vitro* digestibility significantly declined despite the absence of quantitative fiber accumulation. This dissociation is attributed to qualitative changes in the cell wall matrix (cryptic lignification) and the likely accumulation of secondary metabolites, such as tannins, which reduce nutrient bioavailability with age. Consequently, while the plant offers a wide harvest window, the optimal management strategy involves a trade-off between biomass accumulation and nutrient density. Our findings demonstrate the potential of *M. umbellata* not merely as a survival feed, but as a resilient, flexible basal forage capable of supporting sustainable ruminant production in climate-vulnerable silvopastoral systems.

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