

Effect of Initial Cutting Age on Morphology, Biomass Production, Fiber Content, and In vitro Digestibility of Regrowth in Sunn Hemp (*Crotalaria juncea* L.)

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ABSTRACT

Sunn hemp (*Crotalaria juncea* L.) is a fast-growing leguminous plant widely used as a cover crop and green manure due to its high biomass yield and ability to improve soil fertility. However, its potential as a forage source remains underexplored, particularly during the regrowth phase, which is critical for sustainable feed production. This study was aimed to determine the effect of the first cutting age on morphology, biomass production, fiber content, and *in vitro* digestibility of regrowth in sunn hemp (*Crotalaria juncea* L.). A completely randomized design (CRD) with a unidirectional pattern was used, consisting of three cutting ages (6, 7, and 8 wk), each with three replications. The observed variables included morphological characteristics (leaf length, leaf width, stem diameter, and plant height), biomass production, fiber content (NDF and ADF), and *in vitro* dry matter (DM) and organic matter (OM) digestibility. Data were analyzed using analysis of variance (ANOVA), and mean differences were tested with Duncan's Multiple Range Test (DMRT). The results showed that cutting age had a significant effect ($p < 0.05$) on morphology, biomass production, and *in vitro* digestibility of DM and OM, but had no significant impact ($p > 0.05$) on fiber content of the first regrowth of sunn hemp. Cutting age of 6 weeks resulted in the highest values ($p < 0.05$) for leaf length (12.78 cm), leaf width (3.18 cm), plant height (133.76 cm), stem DM yield (2.77 tons/ha), leaf DM yield (2.39 tons/ha), stem DM digestibility (52.23%), leaf DM digestibility (82.45%), stem OM digestibility (47.26%), and leaf OM digestibility (77.61%). In conclusion, a cutting age of 6 weeks improved leaf length, leaf width, plant height, biomass production, and *in vitro* digestibility (DM and OM) of the first regrowth of sunn hemp.

KEYWORDS

Biomass production; *Crotalaria juncea* L.; first cutting age; regrowth; morphology; fiber content; *in vitro* digestibility

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1. Introduction

Sunn hemp (*Crotalaria juncea* L.), known locally in Indonesia as “orok-orok”, is a tropical and subtropical leguminous plant commonly found in Southeast Asia. Traditionally, sunn hemp has been utilized as cover crops due to their ability to improve soil fertility. However, it also possesses considerable potential as an alternative forage resource, attributed to its high nutritional content and strong adaptability to diverse environmental conditions. Despite these advantages, the use of sunn hemp as forage in Indonesia remains limited, primarily because of the lack of comprehensive information on its potential, particularly during the regrowth phase.

The nutritional composition of sunn hemp includes approximately 18.89–23.84% dry matter (DM), 12.23–25.76% crude fiber (CF), 6.37–7.97% ash, 23.36–54.33% neutral detergent fiber (NDF), and 21.25–47.19% acid detergent fiber (ADF) (Srisaikhram and Lounglawan, 2018). In addition, it contains

14–18% crude protein, 0.73–2.08% calcium (Ca), and 0.19–0.51% phosphorus (P) (Wanapat et al., 2021). Sunn hemp can produce large amounts of biomass within a short time, and its vegetative parts can serve as a nitrogen source for plants through symbiosis with *Rhizobium* spp., thereby enhancing soil nitrogen content. These attributes highlight the potential of sunn hemp not only as a soil-improving crop but also as a high-quality forage source (Rudiarto et al., 2014).

Growth rate, leaf length, plant height, and stem diameter are indicators of plant regrowth performance. Cutting age and cutting height are among the key factors influencing regrowth. Cutting age, in particular, is closely related to the nutritional composition and biomass yield of forage crops. Tantalo et al. (2019) found that cutting age affects the proportion of leaves to stems. In addition, as plants mature, the proportion of stems increases relative to leaves, contributing to higher biomass yield and altering the nutrient composition. This shift is accompanied by increased fiber content, especially in stems, which reduces forage digestibility. Therefore,

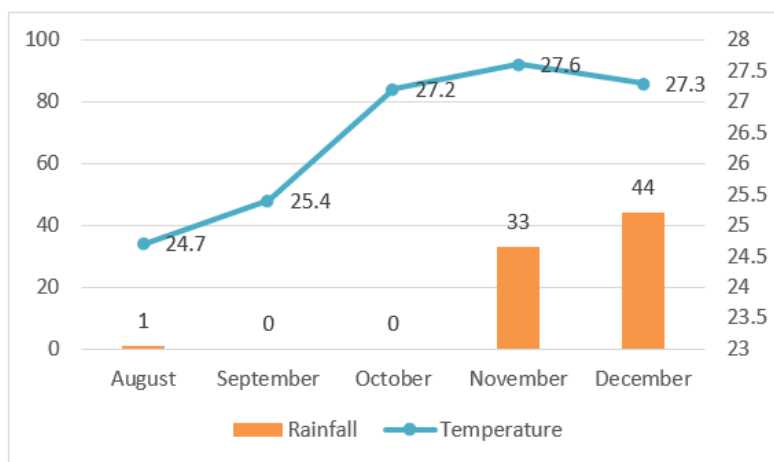


Figure 1. Average monthly agroclimatic data of Sleman Regency (BMKG, 2024)

Table 1. Soil characteristics at the experimental site

Soil parameter	Values
pH, H ₂ O	7.30
C-Organic, %	2.15
N-total, %	0.17
P, ppm	15.0
K, cmol/kg	0.48
C/N, %	12.65
Texture	
Sand, %	21.0
Silt, %	35.0
Clay, %	44.0

Note: (Dewanti et al., 2024)

identifying the optimal cutting age is essential to ensure high biomass yield and nutritional quality. Prolonged cutting intervals tend to increase the fiber content of sunn hemp, particularly in stems, thereby lowering digestibility in livestock (Savitri et al., 2012).

Previous studies on sunn hemp in Indonesia, such as those reported by Pratiwi et al. (2021) and Lubis (2023), have predominantly focused on its role as a cover crop and green manure, with limited attention given to its potential as forage. In particular, information regarding its morphology, biomass production, fiber content, and digestibility during the first regrowth phase at different cutting ages remains scarce. Hence, it is important to evaluate the effect of cutting age on these parameters in sunn hemp (*Crotalaria juncea* L.). The outcomes of this research are expected to provide valuable insights into the potential of sunn hemp regrowth as a promising forage source for livestock production in Indonesia.

2. Materials and Methods

2.1. Research location

This study was conducted from August 2023 to March 2024 at several locations. Sunn hemp was cultivated in the Forage Garden of the Faculty of Animal Science, Universitas Gadjah Mada (7°46'09.8" S and 110°23'11.4" E). Sample testing and *in vitro*

digestibility analysis were performed at the Forage and Pasture Laboratory, Faculty of Animal Science, Universitas Gadjah Mada. In contrast, fiber content analysis was conducted at the Poultry and Various Livestock Assembly and Testing Center (BRMP Unggas).

The experiment was conducted on regosol soil, whose characteristics (Table 1) classify it as low-fertility soil (Dewanti et al., 2024). During the study period, rainfall (Figure 1) was categorized as low (0–100 mm) because it occurred during the dry season. The average rainfall (Figure 1) at the beginning of the planting season in August was relatively low (1 mm), and no rainfall (0 mm) was recorded in September and October, during the harvesting period before regrowth. The stable temperature period (Figure 1) was characterized by a significant increase in air temperature from August (24.7°C) to its peak in November (27.6°C), coinciding with the harvesting of the first regrowth.

Table 2. Leaf and stem nutrient content (% DM) of *Crotalaria juncea* L. (Sunn hemp)

Nutrient content	Leaf	Stem
Dry matter	15.45	15.15
Organic matter	85.43	90.65
Crude protein	28.37	7.66
Crude fiber	16.16	52.82
Ether extract	4.54	1.63

Note: (Dewanti et al., 2024)

2.2. Experimental design

The study employed a Completely Randomized Design (CRD) with a unidirectional pattern, consisting of three cutting age treatments (6, 7, and 8 wk). Each treatment was replicated three times.

2.3. Preparation and planting

The experimental preparation began by soaking sunn hemp seeds for 12 h, followed by seed germination to ensure uniform growth. The seeds were sown in pot trays filled with Ganong[®] planting media composed of a mixture of cotton residue, manure, soil, or sand. Each pot tray hole was filled with 2–3 seeds and maintained for two weeks.

Table 3. Morphology of regrowth in Sunn hemp (*Crotalaria juncea* L.) at different initial cutting ages

Variable	Cutting age (wk)		
	6	7	8
Leaf length (cm)	12.78 ± 0.77 ^b	13.04 ± 0.67 ^b	10.47 ± 1.70 ^a
Leaf width (cm)	3.18 ± 0.33 ^b	3.52 ± 0.08 ^b	2.26 ± 0.11 ^a
Stem diameter (cm)	0.91 ± 0.18 ^a	1.16 ± 0.12 ^{ab}	1.34 ± 0.16 ^b
Plant height (cm)	133.76 ± 3.65 ^c	124.60 ± 3.38 ^b	102.21 ± 5.26 ^a

^{a,b,c} Different superscripts show significant results ($p < 0.05$).

2.4. Land preparation and planting

The field was prepared using a tractor without the application of either organic or inorganic fertilizers. The experimental area was divided into nine plots, each measuring 1 × 1.5 m, with 30 cm spacing between plots and a planting distance of 15 × 15 cm. Sunn hemp seedlings that had been germinated for two weeks were then transplanted into the field, with 48 plants placed in each plot at a planting depth of 2–3 cm.

2.5. Crop management

Crop management included watering and weed control. Watering was done twice daily, in the morning (07:00–08:00) and afternoon (16:00–17:00). Weed control was conducted when weed growth became abundant. Maintenance was carried out from the initial planting until the first regrowth phase. No fertilization was applied to the sunn hemp throughout the study period.

2.6. Preliminary cutting

Sunn hemp plants were harvested according to the treatments at 6, 7, and 8 wk after planting, with a cutting height of ± 30 cm above the ground. After the first cutting, the remaining stubble was allowed to regrow under similar management conditions until the plants reached the first regrowth stage.

2.7. Morphological measurements

The morphological characteristics measured included leaf length, leaf width, stem diameter, and plant height of sunn hemp, starting from 6 wk after the first regrowth. Measurements were taken at 6, 7, and 8 wk of the first regrowth. Leaf length and width were measured using a ruler. Five fully expanded leaves from each sampled plant were selected for measurement. Stem diameter was measured on the main stem at 2–5 cm above the soil surface using a calliper. Plant height was measured using a tape from the soil surface or the base of the main stem to the highest part of the plant. Morphological characteristics of sunn hemp during the first regrowth were recorded by sampling five plants from each treatment.

It is important to note that all morphological and yield measurements in this study were conducted during the first regrowth phase following the initial cutting, rather than during the continuous growth of the primary crop. Therefore, the variations in leaf length, leaf width, stem diameter, and plant height observed among harvested treatments represent differences in regrowth performance rather than cumulative growth. Plants cut at older initial ages generally have lower regrowth capacity due to reduced carbohydrate reserves and lower meristematic activity, which may result in smaller morphological values during regrowth.

2.8. Cutting and yield measurement

Sunn hemp plants were harvested 6 wk after the first regrowth by cutting the main stem at ± 30 cm above the soil surface. The harvested plants were then separated into stems and leaves. Leaf

samples were directly placed in paper sheets, while stems were chopped into 5–10 cm pieces using a chopper. Samples were then wrapped in pre-weighed paper sheets, labelled, and dried in an oven at 55°C for 3–5 d until a constant weight was obtained to determine dry weight.

The dried samples were ground using a Wiley Mill with a 1 mm sieve to obtain fine material, which was subsequently used for DM, OM, fiber content (NDF and ADF), and *in vitro* digestibility (DM and OM) analyses, then stored in plastic bags according to treatment. Contents of DM and OM were determined following the **AOAC International (2005)** method, while DM and OM digestibility were assessed using the **Tilley and Terry (1963)** method, involving incubation of samples with rumen fluid and buffer solution for 48 h at 39°C, followed by 48 h of pepsin–HCl digestion. Fiber content consisting of NDF and ADF were analysed using the **Soest (1982)** method.

2.9. Data analysis

The data were statistically analyzed using Analysis of Variance (ANOVA) based on a Completely Randomized Design (CRD) with a unidirectional pattern, followed by Duncan's Multiple Range Test (DMRT) (**Steel and Torrie, 1995**). Statistical analyses were performed using the Statistical Product and Service Solutions (SPSS) software, version 25.0.

3. Results and Discussion

3.1. Plant morphology

The morphological characteristics of sunn hemp included leaf length, leaf width, stem diameter, and plant height. Cutting age significantly affected ($p < 0.05$) sunn hemp leaf length and width (**Table 3**) during the first regrowth. Leaf length and width (**Table 3**) at 6 wk of cutting age (12.78 cm; 3.18 cm) and 7 wk (13.04 cm; 3.52 cm) were significantly higher ($p < 0.05$) compared to 8 wk (10.47 cm; 2.26 cm). Increasing cutting age resulted in reduced leaf length and width. This response may be attributed to photosynthetic processes and nutrient uptake. According to **Sitorus et al. (2014)**, soil nutrients such as N, P, and K are essential in developing meristematic tissues responsible for cell elongation, increasing leaf length and width, and ultimately affecting leaf area. In addition, these nutrients function as activators of essential enzymes involved in photosynthesis and respiration. **Tantalo et al. (2019)** reported that prolonged cutting age reduces leaf size. The reduction in leaf length, width, and plant height observed with increasing cutting age does not reflect a reversal of growth but rather a decrease in regrowth vigor. Since the parameters were measured during the first regrowth phase, the lower values in plants initially cut at older ages (7–8 wk) are likely due to reduced carbohydrate reserves and slower meristematic activity after cutting. Older plants tend to allocate more assimilates to structural tissues and reproductive development before cutting, leaving fewer resources for regrowth initiation. **Mulatsih (2003)** further

Table 4. Dry matter production of regrowth in Sunn hemp (*Crotalaria juncea* L.) at different initial cutting ages

Variable	Cutting age (wk)		
	6	7	8
Stem dry matter yield (ton/ha)	2.77 ± 0.63 ^b	1.97 ± 0.75 ^{ab}	1.12 ± 0.50 ^a
Leaf dry matter yield (ton/ha)	2.39 ± 0.52 ^b	1.74 ± 0.19 ^{ab}	1.25 ± 0.38 ^a

^{a,b,c} Different superscripts show significant results ($p < 0.05$).

Table 5. Fiber content (%) of regrowth in Sunn hemp (*Crotalaria juncea* L.) at different initial cutting ages

Variable	Cutting age (wk) ^{ns}		
	6	7	8
Stem NDF (%)	64.16 ± 5.44	68.61 ± 2.76	71.28 ± 1.34
Leaf NDF (%)	28.73 ± 3.12	28.61 ± 1.69	28.65 ± 1.37
Stem ADF (%)	55.01 ± 4.19	56.85 ± 4.23	60.17 ± 2.89
Leaf ADF (%)	23.52 ± 0.44	24.17 ± 1.96	25.49 ± 1.12

^{ns} superscripts show non-significant results ($p > 0.05$).

Table 6. In vitro digestibility (%) of regrowth in Sunn hemp (*Crotalaria juncea* L.) at different initial cutting ages

Variable	Cutting age (wk)		
	6	7	8
Stem DM digestibility (%)	52.23 ± 0.90 ^c	47.19 ± 0.95 ^b	43.50 ± 1.33 ^a
Leaf DM digestibility (%)	82.45 ± 0.99 ^c	77.67 ± 1.92 ^b	72.75 ± 1.08 ^a
Stem OM digestibility (%)	47.26 ± 1.48 ^b	45.85 ± 1.01 ^{ab}	43.79 ± 0.76 ^a
Leaf OM digestibility (%)	77.61 ± 0.29 ^b	77.75 ± 0.26 ^b	74.43 ± 0.58 ^a

^{a,b,c} Different superscripts show significant results ($p < 0.05$).

noted that regrowth performance is influenced by carbohydrate reserves stored in the roots after cutting, soil fertility, climate, light reception, cutting age, and cutting height.

The results presented in (Table 3) show that cutting age had a significant effect ($p < 0.05$) on the stem diameter of sunn hemp during the first regrowth. Stem diameter at 8 wk of cutting age (1.34 cm) was significantly higher ($p < 0.05$) compared to 6 wk (0.91 cm), but not significantly different from 7 wk (1.16 cm). This indicates that older cutting age resulted in a larger stem diameter. The increase in stem diameter may be attributed to internal and external plant factors. Cutting of the main stem has been reported to stimulate stem thickening (Baki et al., 2001). Moreover, (Table 3) also shows that the stem diameter in the present study was higher than the findings reported by Baki et al. (2001). It was stated that cutting the main stem can reduce plant height, increase stem diameter, decrease apical dominance, enhance the number and size of primary and secondary branches, and promote the development of more new leaves on the emerging branches, which may consequently lead to greater flower production.

The results demonstrated that cutting age had a significant effect ($p < 0.05$) on the plant height of sunn hemp during the first regrowth. Plant height at 6 wk cutting age (133.76 cm) was significantly higher ($p < 0.05$) than at 7 wk (124.60 cm) and 8 wk (102.21 cm), while plants cut at 7 wk were taller than those cut at 8 wk. These findings indicate that increasing cutting age led to lower plant height during regrowth. According to Schabarum et al. (2017), the average plant height of *Crotalaria juncea* planted in October and cut at different ages showed substantial variation, with 39.84 cm at 40 d, 75.93 cm at 48 d, 203.58 cm at 83 d, and 234.76 cm at 90 d.

3.2. Biomass production

Cutting age significantly affected ($p < 0.05$) the stem and leaf dry matter (DM) yield of sunn hemp at the first regrowth. The highest DM yields were recorded at 6 wk (2.77 and 2.39 t/ha for stem and leaf, respectively), which were significantly greater than those at 8 wk (1.12 and 1.25 t/ha), but not different from 7 wk (1.97 and 1.74 t/ha).

The production of DM declined with increasing cutting age, likely due to reduced carbohydrate reserves. Consistently, Dewanti et al. (2024) demonstrated that cutting *C. juncea* at 8, 10, and 12 wk significantly reduced DM yield, with the lowest production observed at 12 wk. Similarly, Udumann et al. (2023) reported that maximum productivity occurred before 8 wk, as older plants exhibited reduced DM accumulation efficiency due to slower growth rates and the shift from vegetative to reproductive development, ultimately limiting biomass production.

3.3. Fiber content

The fiber fractions of NDF and ADF in the first regrowth of sunn hemp are presented in (Table 5). The results indicate that cutting age had no significant effect ($p > 0.05$) on NDF and ADF contents. The NDF content of stems ranged from 64.16% to 71.28%, while leaves ranged from 28.61% to 28.73%. These values were lower than those reported by Cristobal-Santiago et al. (2024), who observed an NDF content of 72.76% at 56 days of regrowth. Higher values were also reported for the same species, with NDF concentrations of 64.25% and 71% across regrowth periods of 43 to 98 days (Balseca et al., 2015; Lagunes-Rivera et al., 2019). According to Fariani and Akhadiarto (2012), factors influencing NDF concentration include cellulose, hemicellulose, lignin, silica, plant age, and plant parts. The variation in fiber content of forages is an important indicator of forage quality.

Cutting age had no significant effect ($p > 0.05$) on stem ADF and leaf ADF contents of sunn hemp at the first regrowth. The ADF content of stems ranged from 55.01% to 60.17%, while that of leaves ranged from 23.52% to 25.49%. A study by Romero et al. (2013) on *Clitoria ternatea* reported a similar trend, although with lower ADF values of 18%, 25%, and 25% at 30, 60, and 75 days of growth, respectively. Likewise, Valles-De la Mora et al. (2014) reported that the average ADF content of *Crotalaria argentea* was 37.35% during the rainy season. In general, stem ADF values are higher than those of leaves, as stems contain greater structural fibers such as lignin and cellulose. Elevated ADF concentrations are associated with reduced forage digestibility.

3.4. In vitro digestibility

The *in vitro* digestibility of sunn hemp at the first regrowth is summarized in (Table 6). Cutting age significantly affected both dry matter (DM) and organic matter (OM) digestibility ($p < 0.05$). The highest digestibility values were obtained at 6 wk of regrowth, with stem and leaf DM digestibility of 52.23% and 82.45%, respectively, and OM digestibility of 47.26% and 77.61%. These values declined progressively at 7 and 8 wk, indicating that increasing plant maturity reduces digestibility.

The decline in digestibility with advancing cutting age is consistent with the changes in chemical composition observed in this study (Table 2 and Table 5). At 6 wk, sunn hemp leaves contained higher crude protein (28.37%) and lower CF (16.16%) and ADF (23.52%) compared to stems, which had 7.66% crude protein and 52.82% CF. These results confirm that younger plants are richer in soluble nutrients and have less lignified tissue, which facilitates microbial breakdown and nutrient absorption during fermentation. In contrast, older plants showed higher concentrations of NDF (71.28%) and ADF (60.17%), indicating greater structural fiber accumulation that restricts enzymatic access to cell wall carbohydrates and reduces rumen degradability.

The strong relationship between nutrient composition and digestibility has been widely reported. According to Telleng et al. (2017), increased lignin and cellulose contents in older forages inhibit microbial colonization and fermentation activity in the rumen. Similarly, Daning and Foekh (2018) demonstrated that the degradation of OM closely follows the degradation of DM, since most digestible organic compounds such as crude protein and soluble carbohydrates decline with plant age. Therefore, the high digestibility observed at 6 wk in the present study can be attributed to the higher crude protein and lower fiber fractions at this stage.

These findings suggest that chemical composition, particularly the balance between structural and soluble nutrients, is the key determinant of digestibility in sunn hemp regrowth. Harvesting at 6 wk optimizes both the nutritional quality and microbial utilization efficiency, confirming its potential as a high-quality forage source for ruminant feeding systems.

4. Conclusion

Based on the results of this study, it can be concluded that the first cutting at 6 wk produced greater leaf length, leaf width, plant height, and DM yield compared to cuttings at 7 and 8 wk. The highest DM and OM digestibility values were also obtained at 6 wk, with a progressive decline observed at later cutting ages. Therefore, harvesting sunn hemp at the first regrowth at 6 weeks is recommended to obtain high-quality forage as an alternative ruminant feed source.

5. Conflict of interest

No potential conflict of interest relevant to this article was reported. All authors have agreed with the contents of the manuscript.

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8. Author's contribution

The authors confirm their contribution to the paper as follows: study conception and design: BS, DH, HA; data collection: DH, HA; analysis and interpretation of results: DH, HA, YSP, NF, BS; draft manuscript preparation: DH, HA, YSP, NF, BS.

9. Ethics approval

This article does not involve animal subjects, so ethical approval for animal studies is not necessary in the present study.

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