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IDENTIFICATION OF THE OPTIMAL LOPPING STAGE OF *GLIRICIDIA SEPIUM* USED AS MANURE FOR COCONUT PLANTATIONS

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SUMMARY

In the light of the current fertilizer crisis in Sri Lanka, there has been a notable increase in the demand for organic fertilizers. Consequently, *Gliricidia sepium*, a nitrogen-fixing tree, has emerged as a viable option serving as green manure and soil amendment in coconut plantations. However, determining the most appropriate stage for lopping *Gliricidia* to obtain its optimal nutrient compositions remains uncertain. Therefore, the primary objective of this study is to identify the optimal lopping stage of *G. sepium* as soil amendment in coconut plantations. The experiment was conducted over three months in an established *Gliricidia* field, following a Randomized Complete Block Design with three replicates. Plant samples were collected at 4, 6, 8, 10, and 12 weeks after initial cutting, corresponding to different growth stages. The samples were further analyzed to measure various growth parameters and nutrient contents across the lopping stages. The collected data were statistically analyzed using one-way ANOVA at a 5% significance level on Minitab 17 software. The results revealed significant differences ($P < 0.05$) in the mean values of growth metrics and nutrient contents across the lopping stages. As the plant matured, the leaf biomass percentage showed a descending trend while the stem biomass percentage had an ascending pattern. At 10 weeks, leaves displayed the highest nitrogen content (3.43%), thus representing the optimal stage for fulfilling the nitrogen requirements of adult coconut palms, with minimal leaf biomass. These findings have identified the optimal lopping stage of *G. sepium* to maximize its efficacy as green manure for coconut cultivation. It is recommended that future studies further explore potential positive impacts of utilizing *G. sepium* as an intercropped green manure, thereby promoting sustainable agricultural practices within the coconut sector.

Key words:

green manure, growth parameters, growth stage, leaf biomass percentage, nutrient content

INTRODUCTION

Gliricidia sepium, a medium-sized leguminous tree belonging to the Fabaceae family, is recognized for its nitrogen-fixing capabilities and holds significant value as green manure for numerous crops (Solangi et al., 2010). *Gliricidia sepium* can be solitary or multi-stemmed, grows to a height of 2–15 m, and has a medium crown. The mature tree exhibits a well-developed root system (Alamu et al., 2023). Flowers are placed on visibly short, upward-curving to

upright inflorescences, typically pink in colour, but maturing into whitish-brown or pale purple tones. In many countries worldwide, *Gliricidia* is increasingly recognized as a promising and potentially beneficial long-term intercrop. According to Beedy et al. (2010), intercropping of *Gliricidia* with maize had significant and positive impacts on various soil quality parameters, including soil organic matter (SOM), particulate organic matter (POM), and different SOM fractions. Particularly noteworthy is the substantial enrichment of nitrogen in the POM fraction. Moreover, the *Gliricidia* intercrop displayed proportionally more pronounced benefits in enhancing soil fertility compared to carbon sequestration. Furthermore, this intercropping system notably improved the pools of POM, potentially leading to increased nitrogen availability for crop plants (Dissanayaka et al., 2023).

According to a study conducted in Ghana, combining *Gliricidia* and chicken manure significantly enhanced soil fertility by releasing more mineral nitrogen (Omari et al., 2016). Its extensive root system facilitates retention of leached nutrients within the soil profile, accumulating nutrients that would otherwise remain inaccessible to other crops. When the leaf biomass and other tree components start to decompose, these captured nutrients are gradually released at the soil surface, enhancing overall soil fertility (Tesfai et al., 2022).

Jadhao et al. (2019) carried out a field study to assess the impacts of managing potash nutrition in Vertisols via *Gliricidia* green leaf manuring under rainfed conditions. Their findings demonstrated that applying *Gliricidia* leaf manure at a rate of 15 kg potassium per hectare resulted in enhancement of various physicochemical and biological attributes of Vertisols. Another study was undertaken to investigate the mineral nitrogen buildup and nitrogen uptake in maize after application of fresh *Gliricidia* leaves to Ultisol. This research revealed that surface-applied *Gliricidia* leaves significantly increase nitrogen uptake by maize, supplying a significant portion of the total nitrogen in the stover and corn grain. Overall, the study highlights the immense potential of *Gliricidia* leaf mulch in improving productivity in tropical soils (Bah & Rahman, 2001).

Moreover, the utilization of *Gliricidia* leaves holds promising potential in enhancing various soil attributes, including organic matter content, water-holding capacity, and overall physical condition (Raveendra et al., 2021). These improvements render the soil more suitable for agricultural development, particularly in instances of degraded or less fertile soil conditions. Additionally, the decomposition of *Gliricidia* leaf litter further contributes to enhancement of soil quality (Kumar & Mishra, 2013). On the other hand, over 90% of the population in Sri Lanka relies on wood energy for domestic use. *Gliricidia sepium* is a versatile option, suitable for diverse cultivation systems. Lopping branches can yield fuelwood, even when *G. sepium* serves other primary purposes like live fences and shade. Woodlots on underutilized land can meet the demand for wood energy, especially in locations such as tea factories (Atapattu et al., 2017a).

Gliricidia also serves as a sustainable cover crop in coconut plantations, with its optimal planting spacing contingent on available resources, size of the coconut plantation, palm maturity, and cultivation practices (Dissanayaka et al., 2022). Typically, two rows of *Gliricidia* are intercropped in a coconut avenue with 6 feet inter-row spacing and 3 feet intra-row spacing, accommodating 2400 trees per hectare (Nuwarapaksha et al., 2022).

Recently, the Coconut Research Institute of Sri Lanka investigated the potential use of *Gliricidia* as green manure for coconut plants (Nuwarapaksha et al., 2023). This research focused on utilizing *Gliricidia* loppings as green manure owing to its nutritional composition, containing 4.0% nitrogen, 2.0% potassium, and 1.4% calcium on a dry weight basis (La et al., 2018). Despite its potential benefits, farmers lack the knowledge required to identify the optimal lopping stage of *G. sepium* to attain the most favorable nutritional composition and yield as green manure (Atapattu et al., 2017b). In the light of the current fertilizer crisis in the country, there is a growing demand for organic fertilizers, with *Gliricidia* emerging as a suitable option for green manure and soil improvement in coconut plantations (Atapattu et al., 2017c).

By incorporating *Gliricidia* as green manure, farmers can mitigate their dependence on inorganic fertilizers, reduce production costs, and potentially increase their income. Applying *Gliricidia* leaves and branches to mature coconut palms can serve as a nitrogen substitute, reducing the need for inorganic fertilizers (Thomas et al., 2018). Therefore, this research aims to identify the optimal lopping stage of *G. sepium* used as soil amendment in coconut plantations, by assessing the growth performance of *G. sepium* at various lopping stages and evaluating the nutrient content of different plant parts (leaves, stems, and composite samples of leaves and stems) harvested at different lopping stages.

MATERIAL AND METHODS

Experimental Location

The research was conducted during the period from March to July 2023 at the Rathmalagara Research Station of the Coconut Research Institute of Sri Lanka, situated in Lunuwila within the North Western Province of Sri Lanka. The site is located within the agro-ecological region recognized as the Low Country Intermediate Zone.

Treatments and Experimental Design

The experimental site was established within a well-developed *G. sepium* field, arranged in a double-row system with 2 m inter-row spacing and 1 m intra-row spacing. The experiment was designed to assess five distinct lopping stages as treatment modalities, specifically at four, six, eight, ten, and twelve weeks of growth. These treatments were methodically arranged following a Randomized Complete Block Design (RCBD) with three replications.

Sampling Procedure and Data Collection

Before starting the experiment, all existing branches were uniformly pruned across the established *G. sepium* stands, ensuring comparable regrowth conditions. The pruned stems were allowed to regrow over 12 weeks without intervening agronomic treatments aside from scheduled harvests. Sample and data collection spanned five progressive lopping stages at 4, 6, 8, 10 and 12 weeks post-pruning. During each harvest, 5 random samples were taken as leaves, stems, and both stems and leaves together from each plant, and samples were collected from 6 plants from each block. The observed growth parameters included the number of branches, branch length, stem girth, biomass partitioning between leaves and stems, fresh weight, dry matter yield and moisture content.

Prior to nutritional analyses, subsamples of leaves, stems and composite mixtures of leaves and stems underwent uniform drying at 60°C to a consistent weight (Kalra, 1998). Subsequently, dried materials were finely ground to pass through a 2 mm mesh screen before further processing. Total nitrogen content was estimated using micro-Kjeldahl digestion (Kjeltec™ 8200), distillation, and titration. Phosphorus content was determined colourimetrically using ammonium molybdate reagent (Olsen et al., 1954). The samples underwent wet digestion in nitric-perchloric acid (4:1) for potassium, calcium and magnesium quantification employing atomic absorption spectrophotometry (Shimadzu AA-7000) (Allen et al., 1974; Sahrawat et al., 2002). Total organic carbon content was measured by the Walkley-Black chromic acid oxidation method (Nelson & Sommers, 1996).

Statistical Data Analyses

The collected data were statistically analyzed using Minitab 17 software. Firstly, normality and outlier assessments were conducted on all growth and nutritional parameters to verify standard distributional assumptions. Subsequently, one-way ANOVA was performed at a 5% significance level to determine differences between lopping stages for each parameter. Finally, Tukey's pairwise comparison test was employed enabling precise quantification of growth and compositional variations across the lopping treatments.

RESULTS AND DISCUSSION

The effect of different lopping stages on the growth parameters

The present study investigated the influence of different lopping stages on various growth parameters of *G. sepium*. The mean values of the parameters which exhibited significant variations ($p > 0.05$) across different lopping stages included: the number of branches, branch length, stem diameter, percentage of leaves and stems within the total biomass, fresh biomass yield of plants and leaves, dry matter yield of plants, leaves and stems within the total biomass, and moisture content of leaves (Tab. 1).

Table 1. Comparison of growth parameters of *G. sepium* at different lopping stages

Lopping stage	Branch length (cm)	No. of branches	Stem diameter (cm)	Fresh weight (%)			Dry weight (%)		
				Plant	Stem	Leaves	Plant	Stem	Leaves
4 weeks	66.23 ^e	33.56 ^a	1.48 ^d	1.07 ^a	0.59	0.64 ^c	0.16 ^b	0.06 ^b	0.10 ^c
6 weeks	131.29 ^d	22.88 ^b	2.00 ^c	3.05 ^{ab}	1.59	1.63 ^b	0.54 ^a	0.30 ^{ab}	0.28 ^{bc}
8 weeks	161.44 ^c	22.14 ^b	2.03 ^c	3.87 ^{bc}	2.00	1.77 ^b	0.62 ^a	0.40 ^{ab}	0.31 ^b
10 weeks	214.41 ^b	19.88 ^b	2.42 ^b	4.27 ^c	2.49	2.68 ^a	0.97 ^a	0.56 ^a	0.60 ^a
12 weeks	242.57 ^a	18.13 ^b	4.5 ^a	4.67 ^d	2.67	2.37 ^{ab}	1.22 ^a	0.67 ^a	0.57 ^a
P-value	<0.001	0.002	<0.001	<0.001	0.053	<0.001	<0.001	0.003	<0.001

Means that do not share a letter are significantly different

The analysis revealed that the number of branches reached its peak during the 4-week lopping stage, whereas it was the lowest at the 12-week stage. In contrast, branch length extended to its maximum during the 12-week lopping stage, concurrently displaying its minimum value during the 4-week stage. Similarly, the stem diameter demonstrated its maximal dimension at the 12-week lopping stage, while its minimal value was observed at the 4-week stage. These observed growth parameters showed distinct trends aligned with the progressive maturation of *G. sepium* plants.

Regarding the fresh biomass and dry matter yield of the entire plant, the highest values were recorded at the 12-week lopping stage, while the lowest yields were at the 4-week stage. However, in the case of leaves, the maximum fresh biomass and dry matter yield were observed at the 10-week stage, whereas the minimal values were observed at the 4-week stage. A similar trend was noted for stems, with the highest fresh matter and dry matter yield recorded at the 12-week stage, while the lowest values were associated with the 4-week stage. This consistent pattern of increasing yield with the advancing maturity of *G. sepium* plants persisted throughout the study. According to the study conducted by Vennila et al. (2016), which evaluated the effect of lopping interval on growth and fodder yield of *Gliricidia sepium* trees, frequent lopping at 2 and 4-month intervals led to significantly higher numbers of branches, leaves, leaf weight, and leaf to branch ratio compared to less frequent lopping.

Figure 1 showcases the distribution of stem percentage within the total biomass across distinct lopping stages. Significant differences ($p < 0.05$) in the mean stem percentage values were observed among the lopping stages. The highest stem percentage within the total biomass was observed following 12-weeks of lopping, reaching 54.98%. In contrast, the lowest stem percentage within the total biomass (28.53%) was identified at the 4-week lopping stage. The stem percentage within the total biomass exhibited an ascending pattern as the plant matured, with the sequence of proportions being 4 weeks < 6 weeks < 8 weeks < 10 weeks < 12 weeks.

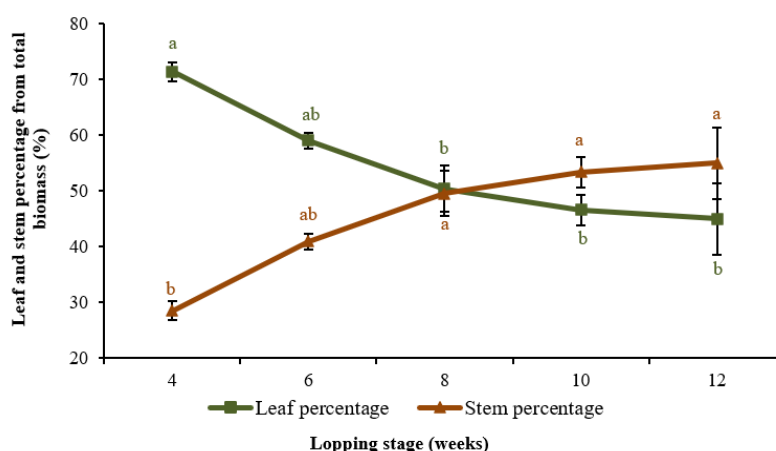


Figure 1. The effect of different lopping stages on leaf and stem percentage from total biomass
(Note: Means that do not share a letter are significantly different)

The moisture content of leaves and stems at different lopping stages is visually represented in Figure 2. Notably, no significant difference ($p > 0.05$) was observed in the mean values of moisture content for leaves. The highest moisture content in leaves (82.25%) was observed at the 4-week lopping stage, while the lowest content (73.9%) occurred at the 12-week stage. Additionally, the moisture content of leaves exhibited a decreasing trend with the advancing maturity of the plant, with the sequence being 4 weeks > 6 weeks > 8 weeks > 10 weeks > 12 weeks.

In contrast, a significant difference ($p < 0.05$) was observed in the mean values of moisture content for stems across different lopping stages. The highest moisture content in stems (88.09%) was recorded at the 4-week lopping stage, while the lowest content (73.4%) was noted at the 12-week stage. The moisture content of stems in relation to the total biomass also displayed a decreasing pattern with the maturation of the plant, following the sequence of 4 weeks > 6 weeks > 8 weeks > 10 weeks > 12 weeks.

It is worth highlighting that the moisture content variability observed in *Gliricidia* is influenced by factors such as plant age, season, and harvesting frequency. According to Melchor Marroquín et al. (2005), an increase in pruning frequency is associated with reduced moisture content in both foliage and stems.

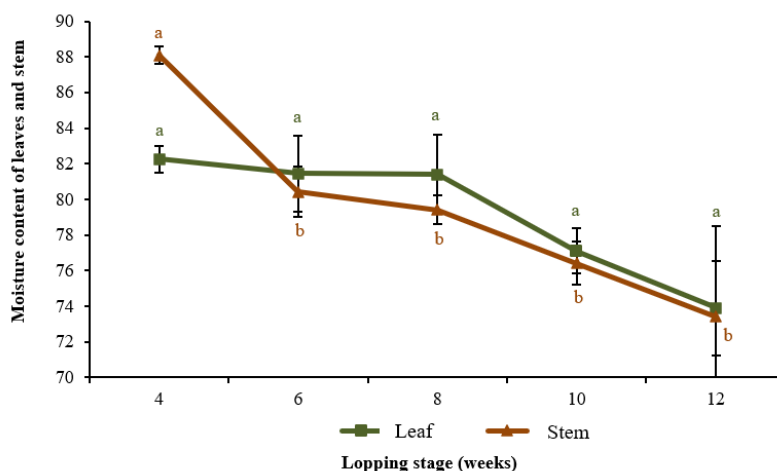


Figure 2. The effect of different lopping stages on the moisture content of leaves and stems from total biomass
(Note: Means that do not share a letter are significantly different)

The effect of different lopping stages on the plant nutrient content

The analysis indicated a significant effect ($p < 0.05$) of different lopping stages on N, K, P, Ca, Mg, and organic carbon contents of leaves, stems, and composite samples of leaves and stems.

The effect of different lopping stages on the total nitrogen content

The study investigated the N content in leaves, stems, and composite samples at different lopping stages (Fig. 3). Significant differences ($p < 0.05$) were found in the mean total N content among these stages. The highest N content in leaves (3.43%) was recorded at 10 weeks of lopping, while the lowest content (2.44%) was at 6 weeks. The highest N content in stems (2.54%) was at 6-weeks, whereas the lowest content (1.18%) was at 12-weeks. Composite samples had the highest N content (2.73%) at 8 weeks and the lowest content (1.91%) at 4 weeks of the lopping stage. These results underscore the variations in N content during different lopping stages, with distinct trends observed in leaves, stems, and composite samples.

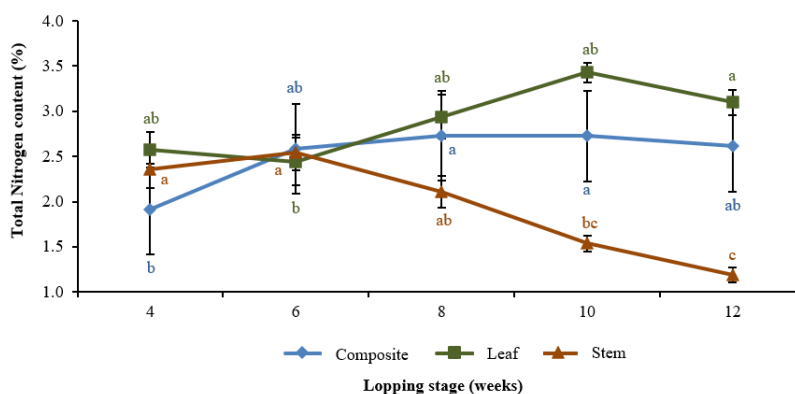


Figure 3. The effect of different lopping stages on the total nitrogen content in leaves, stems and composite samples of leaves and stems
(Note: Means that do not share a letter are significantly different)

As observed in studies by Dalling (1987) and Shantharam & Mattoo (1997), senescence accelerates the transfer of nitrogen and soluble compounds to growing or storage tissues, resulting in decreased nitrogen concentration within the foliage. Reduced pruning frequency can lead to leaf maturation, metabolic decline, and nutrient relocation, ultimately resulting in reduced nitrogen content in leaves, as posited by Tesfai et al. (2022).

The effect of different lopping stages on the total phosphorous and potassium content

The P content in leaves, stems, and composite samples at various lopping stages is presented in Figure 4. Significant differences ($p < 0.05$) in the mean P content were observed among these stages. The highest P content in leaves (0.41%) was recorded at 6 weeks of lopping, while the lowest content (0.10%) was at 4 weeks. The highest P content in stems (0.37%) was at 6 weeks, whereas the lowest content (0.17%) was recorded at 4 weeks. Composite samples of leaves and stems had the highest P content (0.43%) at 6 weeks and the lowest (0.15%) at 4 weeks of lopping. These results indicate variations in the P content during different lopping stages, with distinct trends observed in leaves, stems, and composite samples. A study by Anis et al. (2016) revealed a reduction of the phosphorous content in leaves of *G. sepium* with advancing maturity. However, the current study showed distinct patterns in the phosphorous content in leaves, stems, and composite samples.

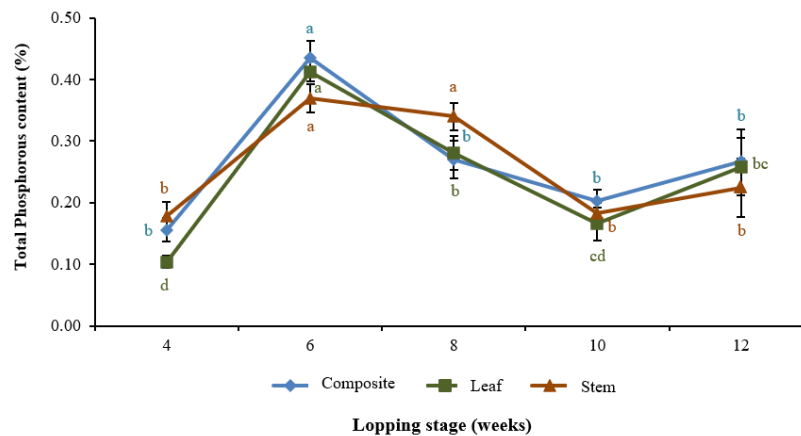


Figure 4. The effect of different lopping stages on the total phosphorous content of leaves, stems, and composite samples of leaves and stems

(Note: Means that do not share a letter are significantly different)

The study analyzed the K content in leaves, stems, and composite samples at various lopping stages, revealing significant variations in the mean K values among these stages. Specifically, the highest K content in leaves (6.19%) was observed at 6 weeks, while the lowest content (1.24%) was recorded at 8 weeks. The highest K content in stems (7.31%) was noted at 6 weeks, with the lowest content (1.46%) occurring at 8 weeks. Composite samples, comprising both leaves and stems, exhibited the highest K content (6.11%) at 6 weeks and the lowest content (1.22%) at 8 weeks (Fig. 5). These findings illustrate fluctuations in the K content across different lopping stages, highlighting notable differences in the K levels among leaves, stems, and composite samples.

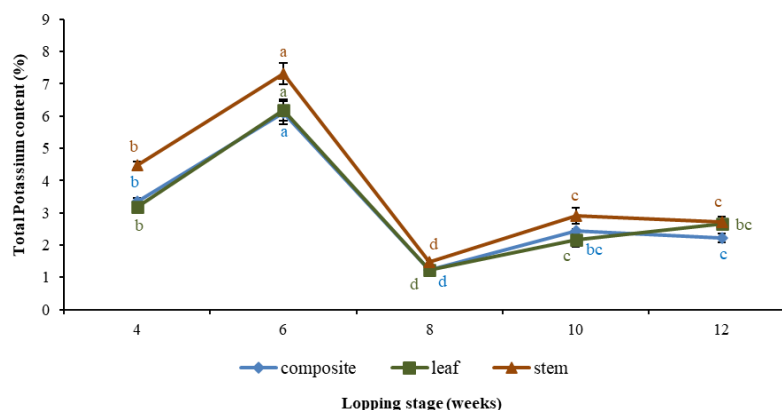


Figure 5. The effect of different lopping stages on the total potassium content of leaves, stems, and composite samples of leaves and stems

(Note: Means that do not share a letter are significantly different)

Potassium content was increased with age intervals from two to six months, as reported by Tesfai et al. (2022). Kabaija (1985) revealed lower potassium levels in *Gliricidia* leaves during dry seasons across ages (3-12 weeks) compared to wet seasons.

The effect of different lopping stages on the total calcium and magnesium content

The study examined the Ca content in leaves, stems, and composite samples across different lopping stages. Significant variations ($p < 0.05$) were noted in the mean Ca values among stages. The highest Ca content in leaves (2.68%) was recorded at 10 weeks, while the lowest content (0.44%) was at 4-weeks. The highest Ca content in stems (2.89%) was at 12 weeks, whereas the lowest content (0.28%) was at 4 weeks. Composite samples of leaves and stems exhibited the highest Ca content (2.99%) at 6 weeks and the lowest content (0.60%) at 4 weeks (Fig. 6). These results underscore fluctuations in the Ca content during the lopping stages, with notable differences observed in leaves, stems, and composite samples.

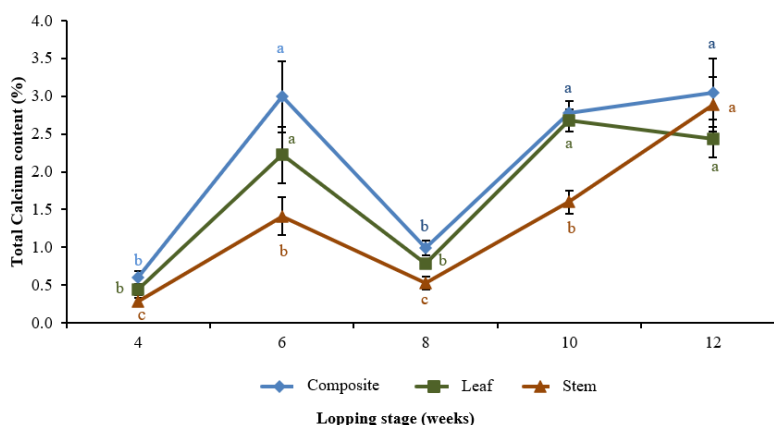


Figure 6. The effect of different lopping stages on the total calcium content of leaves, stems, and composite samples of leaves and stems

(Note: Means that do not share a letter are significantly different)

The study analyzed the Mg content in leaves, stems, and composite samples across various lopping stages, revealing significant differences ($p < 0.05$) in the mean Mg values among the stages. The highest Mg content in leaves (0.84%) was observed at 8 weeks, while the lowest content (0.28%) occurred at 6 weeks. The highest Mg content in stems (0.68%) was noted at 12 weeks, whereas the lowest content (0.18%) was observed at 6 weeks. Composite samples, with both leaves and stems, exhibited the highest Mg content (0.98%) at 8 weeks and the lowest content (0.34%) at 6 weeks of lopping (see Fig. 7). These findings emphasize the variations in the Mg content across different lopping stages, highlighting distinctions in the Mg levels among leaves, stems, and composite samples.

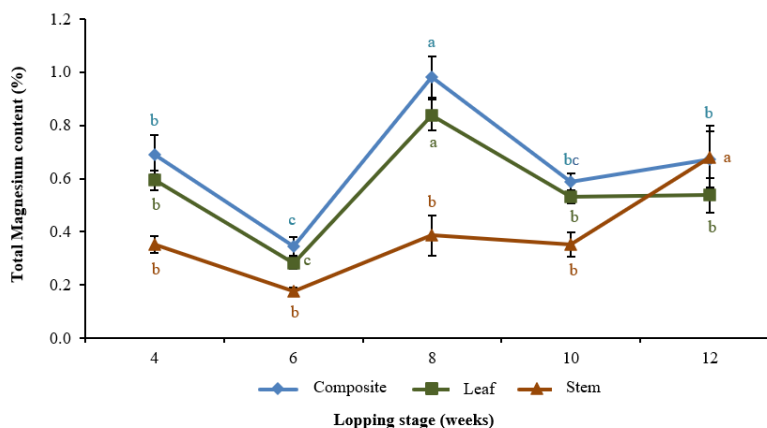


Figure 7. The effect of different lopping stages on the total magnesium content of leaves, stems, and composite samples of leaves and stems

(Note: Means that do not share a letter are significantly different)

Chadhokar & Lecamwasam (1982) observed that as *Gliricidia* leaves matured over a span of two to six months, their crude protein, ether extract, calcium, manganese, and zinc levels decreased. Leaf age and season influenced ash and mineral content. Young leaves (6 weeks) exhibited lower mineral content during the dry season (8.8%) compared to the wet season (10%). Conversely, older leaves (12 weeks) displayed higher dry season mineral content (9.0% vs. 7.9% in the wet season) (Smith & Van Houtert, 1987).

The effect of different lopping stages on the organic carbon content

Significant differences ($p < 0.05$) were found in the mean organic carbon values across different lopping stages. The highest organic carbon content in leaves (33.22%) occurred at 4 weeks while the lowest content (26.33%) was observed at 8 weeks. The highest organic carbon content in stems (27.26%) was at 6 weeks, whereas the lowest content (22.24%) was at 12 weeks. Composite samples of leaves and stems showed the highest organic carbon content (29.20%) at 4 weeks and the lowest content (22.35%) at 12 weeks of the lopping stage (Fig. 8). These findings emphasize the fluctuations in the organic carbon content across different lopping stages, with distinct trends observed in leaves, stems, and composite samples.

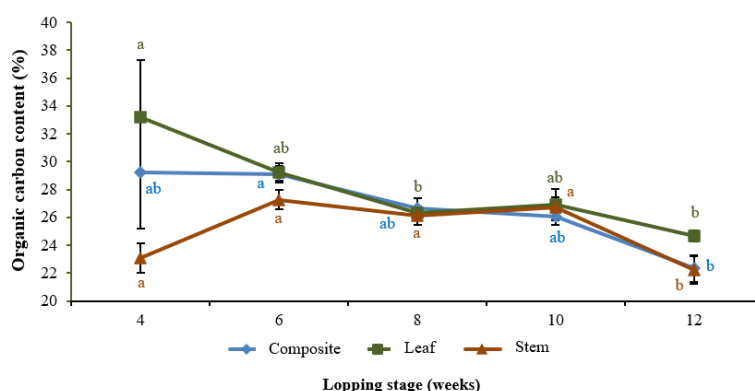


Figure 8. The effect of different lopping stages on the organic carbon content of leaves, stems, and composite samples of leaves and stems
(Note: Means that do not share a letter are significantly different)

Decline in reserve carbohydrates is evident during regrowth subsequent to cutting, burning, or defoliation in woody plants. These findings corroborate previous research indicating that repeated defoliation at frequent intervals reduces reserve carbohydrates (Tesfai et al., 2022).

Figure 9 provides a visual representation of the *Gliricidia* biomass necessary to meet the nitrogen demand of an adult palm. In order to adequately address the nitrogen requirement of an adult coconut palm, 800g of urea, containing 368g of nitrogen, is needed (Abeygunawardana, 2005). Considering the nitrogen content of *Gliricidia* biomass at various lopping stages, the lopping stage at which the lowest biomass content is required to meet this nitrogen demand is the 10-week stage.

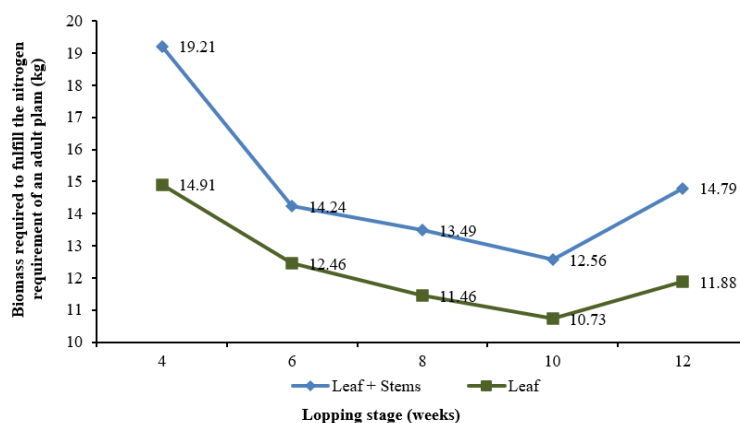


Figure 9. The biomass required to fulfill the nitrogen requirement of an adult palm (kg) at different lopping stages

CONCLUSION

In summary, the primary objective of this study was to identify the optimal lopping stage of *Gliricidia sepium* for provision of green manure in coconut plantations in Sri Lanka. The findings demonstrate significant variations in both growth parameters and nutritional composition of *G. sepium* across different lopping stages. The later lopping stages, particularly 10-12 weeks, displayed superior growth in terms of branch length, stem diameter, and biomass yield. However, an earlier lopping stage of 6-8 weeks exhibited optimal nutrient content, with higher levels of nitrogen, phosphorus, and potassium.

Considering both the growth performance and nutritional quality, the results suggest that lopping *G. sepium* at 10 weeks represents the best compromise. During this stage, plants show reasonably robust growth alongside a favorable nutritional profile to meet the nitrogen demand per coconut palm when applied as green manure. The study thus highlights the potential of *G. sepium* as a substitute for organic fertilizers, when the lopping stage is appropriately determined to optimize crop performance. Further research can refine the optimal lopping frequency and biomass application rates to sustain coconut yield. Overall, integration of *Gliricidia* intercropping demonstrates ecologically sustainable means to enhance coconut cultivation amidst changing fertilizer scenarios.

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Conflict of interest: The authors declare that they have no conflict of interest.

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