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Assessing the Optimum Harvesting Stage of *Tithonia diversifolia* as Climate Smart Soil Amendment for Coconut Plantations

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Abstract: *Tithonia diversifolia* is often grown as a cover crop or as a green manure crop in climate smart agriculture practices. This plant can be harvest at various growth stages, and the biomass can be incorporated into the soil. The decomposition of plant biomass enhances the soil nutrient, organic matter content and crop productivity. This study aimed to determine the best harvesting stage of *T. diversifolia* to be used as an efficient soil amendment for coconut plantations. Samples were collected at one, two, three, and four months of harvesting stages from an existing *T. diversifolia* field at Rathmalagara Research Station of the Coconut Research Institute of Sri Lanka. In the study, both plant growth parameters and nutrient composition of each plant part were individually evaluated for every section of the plant. Biochar was prepared from hardwood stems of *T. diversifolia* using them as the feedstock under five different temperatures 300 °C to 700 °C, and a proximate analysis was done for the characterization of produced biochar. The mean values of measured parameters of *T. diversifolia* and the properties of biochar were significantly different ($P<0.05$) at different growth stages and temperatures, respectively. Considering all the measured parameters of *T. diversifolia*, three months harvesting stage can be suggested as the best growth stage to be used as green manure. According to the proximate analysis results and by observing the half-burning of produced biochar, 500 °C can be proposed as the ideal temperature to produce biochar from hardwood stems.

Keywords: Biochar; Climate smart agriculture; Feedstock; Green manure; Growth stages

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1. Introduction

Tithonia diversifolia is a multipurpose shrub from the Asteraceae family, and known as the Mexican sunflower, Wild sunflower, or Tree marigold. Typically, this is a woody herb or succulent shrub that can reach up to 10 feet height [1]. *T. diversifolia* is popularly known for its large, bright orange or yellow flowers which resembles the sunflower. *Tithonia* is originated in Mexico and now extensively distributed throughout Central and South America, Asia and Africa. This species frequently grows along roadsides, farm boundaries, and native fallow systems [2]. It is a common plant in Sri Lanka in upcountry areas and is considered a weed [3]. *T. diversifolia* is frequently used as an ornamental plant. In addition, it has been used for various purposes around the globe, including as a source of fuel, a raw material to produce compost, for land demarcation, to control soil erosion, as building materials, as a shelter for livestock animals and fodder for ruminants [4]. *T. diversifolia* is important for its high nutrient content. It has a considerable amount of potassium (K) than nitrogeon (N) and Phosphorus (P) [5]. This high nutrient content is reported due to its cluster root-like formations, which allows it to scavenge for nutrients in the soil [6]. K is an essential plant macronutrient that is necessary for plant growth, development, metabolism, and yield [7]. Plants absorb K from the soil through their root system. In many agricultural systems, the supply of K from the soil is insufficient to fulfil the plant requirement. Also, coconut is a high K demanding crop, because nuts and husk of the coconut contain comparatively higher K content than other parts. Harvesting of nuts for processing or consumption causes removal of K from the field resulting in low K levels in the soils [8]. Therefore, the application of fertilizer is a must to meet the nutrient requirements. Even though the most common practice of providing nutrients is application of inorganic fertilizer, it has several limitations and negative impacts. In the current scenario, the main restrictions to access inorganic fertilizer are government regulations and high price of fertilizer. As a result, there is a huge trend for organic manure including compost and green manure. The K rich plant *T. diversifolia* has been identified as a K rich plant that has promising character for enhancing soil fertility [2]. Although K concentration in *T. diversifolia* has been mentioned in many literatures the best lopping stage with optimum nutrient content is still not clearly identified. Other than it is used as a green manure, *T.diversifolia* perform well if biochar can be produced using its mature stems. Biochar is a carbon rich product that can enhance soil productivity, carbon storage and possibly filtration of percolating soil water [9]. Therefore, this study was aimed at identifying the best stage of *T. diversifolia* with optimum nutrient content and also to evaluate the feasibility of using as a feedstock for biochar production.

2. Materials and Methods

2.1. Location and Sample Collection

The experiment was carried out between November 2022 and March 2023 at the Rathmalagara research station and the Agronomy Division of the Coconut Research Institute of Sri Lanka, Lunuwila (7 20^0 37N, 79 51^0 42E). This research site was situated within the North Western Province of Sri Lanka, specifically within the agro-ecological zone designated as the Low Country Intermediate Zone (IL1a).

2.2. Treatments and Experimental Design

The experiment utilized an established mature field of *T. diversifolia* planted in a double-row system with inter-row spacing of 6 feet and intra-row spacing of 3 feet. Four distinct growth stages namely one, two, three, and four months of lopping were considered as treatment factors. These treatments were arranged following a randomized complete block design (RCBD) with three replicates.

2.3. Sampling Procedure and Data Collection

Before initiating the experiment, all the plants were cut at a height of one foot above the ground level and allowed to grow without carrying out agronomic practices. Then the regrown stems were harvested after one month, two months, three months and four months respectively, as four different lopping stages. Five random samples were taken from each plot. Height of the plant, number of stems, diameter of the stems, fresh weight of leaves and semi hardwood stems and dry weight of leaves and semi hardwood stems were recorded as growth parameters. All the samples were dried at a 60 ℃ of temperature until reached to a constant weight. Dried samples were analyzed for their nutrients: N, P, and K. N was determined by Kjeldhal digestion and distillation techniques and the P was determined by the colorimetric method. Atomic absorption spectrophotometer was used for determining the K [10]. Mature stems of *T. diversifolia* were subjected to five different temperatures to produce biochar. Stems were cut into small pieces and kept in a muffle furnace at 300 °C, 400 ℃, 500 °C, 600 °C and 700 °C for 01 hour. Produced biochar was analyzed for their conversion efficiency, pH, EC and available K contents [11].

2.4. Statistical Data Analyses

Statistical analyses was done using the Minitab 19 statistical software. Normality of all measured samples was checked using the normality and outlier test. The mean, minimum, maximum, standard deviation (SD), standard error (SE) and coefficient of variation

(CV) were calculated under descriptive statistics. Finally mean values of the data were compared statistically using the one-way analysis of variance (ANOVA) at 5% significance and the Tukey's pairwise comparison test.

3. Results and Discussion

3.1. Measuring of growth parameters

Table 01 shows the mean values of measured growth parameters. There is a significant effect ($p<0.05$) in the different lopping stages on height, number of stems, stem diameter, fresh weight and dry weight of semi hardwood stems and leaves. The maximum height and the stem diameter were recorded at three months lopping stage and the highest number of stems were recorded in one month lopping stage. The minimum height and stem diameter were recorded at one month lopping stage. The maximum number of stems were recorded at one month lopping stage while lowest was recorded at four months lopping stage. The highest fresh weight of semi-hardwood stems and leaves were recorded at three-month lopping stage and two-month lopping stage respectively, while both parameters were lowest at one-month lopping stage. In semi- hardwood stems, an increase was observed until three-month lopping stage, and it was decreased at the four-month lopping stage. No pattern was observed in the fresh weight of leaves. The dry weight of semi-hardwood stems has been increased with increasing maturity and the highest was recorded at four-month lopping stage while the lowest was recorded at one-month lopping stage. The highest dry weight of leaves was recorded in three-month loping stage and the lowest was recorded at one-month loping stage. Here also no trend was observed in the dry weight of the leaves with the increasing maturity. According to the findings presented in reference [2], cultivating *T. diversifolia* as a green manure crop can yield 5 t/ha^{-1} of dry matter.

Table 1. Mean values of growth parameters in *T. diversifolia* at different harvesting intervals.

Lopping stage	Height (Cm)	No of Stems	Stem Diameter (mm)	Fresh Weight (g)		Dry Weight (g)	
				SW	Leaves	SW	Leaves
1 month	74.56^{c}	61.87^{a}	7.65^{c}	289.20^{b}	408.40^{c}	22.66^{c}	38.73^{c}
2 month	135.73^{ab}	39.53^{b}	10.09^{b}	901.89^{a}	757.44^{a}	174.72^{b}	115.78^{ab}
3 month	151.73^{a}	36.33^{b}	12.02^{a}	1159.02^{a}	674.22^{ab}	319.37^{a}	135.82^{a}
4 month	135.73^{b}	29.73^{b}	11.40^{ab}	924.70^{a}	484.86^{bc}	327.79^{a}	80.78^{b}
P-Value	< 0.001	<0.001	<0.001	< 0.001	<0.001	<0.001	<0.001

Means that do not share a letter are significantly different ; (SW-Semi hardwood).

3.2. Measuring of nutrient level

Table 2 shows the mean values of nutrients in semi-hardwood stems and leaves. The mean values were significantly different ($p<0.05$) at different lopping stages. N content of semi-hardwood stems has been reduced with the maturity. Therefore, the highest N was recorded in one-month lopping stage and the lowest was recorded at the four-month lopping stage. Also previous study was found the nutrient concentration tends to be lower in senesced than green leaves [2]. There was no trend observed in the P content of semi-hardwood stems with increasing maturity. The highest P was recorded at three-month lopping stage and the lowest was recorded at four-month lopping stage. Similar to N content, the K content of semi-hardwood stems has been decreased with increasing maturity. The highest K was recorded at one-month lopping stage while the lowest was recorded at four-month lopping stage. No trend was observed in the N and K contents of leaves with plant maturity. However the highest N content in leaves was observed in two-month lopping stage and the lowest in one-month lopping stage. The highest K content in leaves was recorded at four-month lopping stage while the lowest was recorded at one-month lopping stage. The highest P content was recorded at three-month lopping stage in leaves while the lowest was recorded at one-month lopping stage. According to reports by [2, 5], the average nutrient concentrations in the green leaves of *T. diversifolia* were 3.5% N, 0.37% P, and 4.1% K on a dry weight basis.

Table 2. Mean values of mutrient contents in *T. diversifolia* at different harvesting intervals .

Lopping stage	Semi Hardwood			Leaves		
	N %	P %	K %	N %	P %	K %
1 month	0.96^{a}	0.17^{b}	8.02^{a}	2.37^{b}	0.20^{b}	3.59^{b}
2 month	0.66^{b}	0.19^{ab}	4.96^{b}	3.55^{a}	0.31^{a}	4.81^{ab}
3 month	0.53^{bc}	0.25^{a}	2.70^{c}	2.39^{b}	0.42^{a}	4.18^{ab}
4 month	0.36^{c}	0.15^{b}	1.96^{c}	3.04a^{b}	0.40^{a}	5.09^{a}
p-value	<0.001	<0.004	<0.001	<0.001	<0.001	<0.021

Means that do not share a letter are significantly different.

3.3. Properties of Biochar

Table 3 shows the pH, electrical conductivity available K% and conversion efficiency of biochar. The mean values of the measured property parameters were significantly different (p<0.05). The pH, and electrical conductivity have been increased with increasing temperature. The highest available K content was recorded at 600 °C, and the lowest at 300 °C. The conversion efficiency has been decreased with increasing temperature. However, half burned and low-quality biochar was observed at 3000C and 4000C. Therefore, considering the proximate composition, other properties, energy consumption and cost of production of produced biochar 5000C can be proposed as the optimum temperature to produce biochar using mature stems of *T. diversifolia* as the feedstock.

Table 3. Mean values of properties of biochar in *T. diversifolia* at different temperatures .

Temperature	pH	Electrical conductivity (µs/cm)	Available K%	Conversion efficiency %
300°C	7.51^{c}	535.30^{b}	1.23^{b}	53.75^{a}
400°C	8.47^{b}	590.70^{b}	3.47^{ab}	38.33^{b}
500°C	8.76^{b}	699.30^{b}	3.42^{ab}	28.73^{c}
600°C	9.20^{a}	1042.00^{a}	4.20^{a}	23.95^{d}
700°C	9.28^{a}	1042.40^{a}	4.04^{a}	23.74^{d}
p-value	<0.001	<0.001	<0.018	<0.01

Means that do not share a letter are significantly different.

4. Conclusion

In conclusion, this study was established the potential of *T. diversifolia* as a valuable multipurpose shrub for soil improvement in coconut plantations within the Sri Lankan context. The investigation revealed that the three-month lopping stage yields the highest nutrient content and biomass production, making it the optimal choice for sustainable soil amendment. Moreover, for the production of biochar from mature *T. diversifolia* stems, a temperature of 500 °C has been identified as the most suitable. These findings hold significance for the sustainable management of soil fertility in coconut plantations, not only in Sri Lanka but also in other tropical and subtropical regions where *T. diversifolia* is prevalent. Future research endeavors could delve deeper into the potential utility of *T. diversifolia* as a green manure crop, exploring its effects on crop yields and soil health. Such investigations could further enhance our understanding of its practical applications in coconut sector, thereby contributing to the development of environmentally friendly and sustainable climate smart agriculture practices .

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