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Research Article

Impacts of Teak Defoliator (*Hyblaea puera)* in Carbon Accumulation in Teak (*Tectona grandis*) Plantation Forest

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Abstract

Among the insects attacking teak well-known pests of the teak tree (*Tectona grandis*) i.e., *Hyblaea puera* (Lepidoptera: Hyblaeidae), popularly known as the teak defoliator is the most widespread and serious pest causing a loss in increment volume of plants. Having a high economic timber value, *Tectona grandis* has also played an important role in storing carbon. Hence, the present investigation has attempted to study the impacts of teaks defoliator *Hyblaea puera* on carbon stocks accumulation and overall growth in plantation forests and make acomparison with healthy teak plantation forests without the impacts of teak defoliator. Remaining all other factors constant, the study conducted on tropical regions of eastern Nepal has shown an 18% increase in carbon stocks in 2 years in the teak defoliator infected patch whereas it's 38% in the healthy patch. Similarly, a highly positive correlation was found between diameter and height in a healthy patch in both the measurement i.e., 0.88 and 0.89. Whereas there is less positive correlation i.e.,0.64 and 0.69 in the infected patch.The mean height increment of the healthy plot was 1.1, while it was 0.5 in the case of the infected plot. Furthermore, the Mean DBH Increment of the Healthy plot was 2.1; however, it was 1.0 in the case of the infected plot. To sum up, this study at tropical regions has presented the impacts of teak defoliator (*Hyblaea puera)* on growth(height and diameter) and carbon accumulation on Teak plantation area.

Keywords: Teak defoliator, carbon stocks, plantation forest

1. INTRODUCTION

The Species Teak (*Tectona grandis*) is considered to be one of the most valuable timber trees in Southeast Asia due to its outstanding wood properties which rank third among the tropical hardwood species in plantation areas and constitute about 8 percent of the plantations worldwide [1]–[3]. This relatively fast-growing species of the family *Lamiaceae* has an attractive natural color and is valuable for high-quality furniture and interior finishing [4]–[6]. The incidence of teak defoliator affected trees ranged from 5 to 10% across all inspected commercial fields in the world [7]. Carbon sequestration and storage may be increased significantly if tree growth increases without any external disturbance and infection [8]. In the context of Nepal, *T. grandis* was introduced in 1960 in Chiliya, Rupendehi followed by some block plantations in Sagarnath, Sarlahi, and Ratuwamai by Forest Product Development Board [9]. The range and scale of teak (*Tectonagrandis*) plantation on private land has tremendously increased in the Terai region of Nepal [10]. With the increase in plantation, diseases and infection from teak defoliator and root rot have also been increased [10]. From preliminary surveys conducted in plantation areas, teak defoliators i.e. *Hyblaea puera* (Lepidoptera: Hyblaeidae) have greatly affected teak growth and development. So far, many studies have been conducted related to the growth pattern and distribution of *Tectona grandis* in Nepal but very few studies have been concentrated on the impacts of teak defoliator on carbon accumulation [10][11]. Therefore, this research was objectively carried out to assess how teak defoliators make an impact on carbon accumulation quantitatively, and to study the intensity of infection and correlation between diameter and height growth in infected plantation areas and infection-free plantation area.

2. MATERIALS AND METHODS

2.1. Study Area

This study was conducted in the eastern tropical region of Nepal in the Letang municipality of Morang district; the Terai region of Nepal as shown in Fig. 1. The figure also depicts the research plots (both healthy and infected). In the study area, the mean annual temperature is higher than 16 °C and

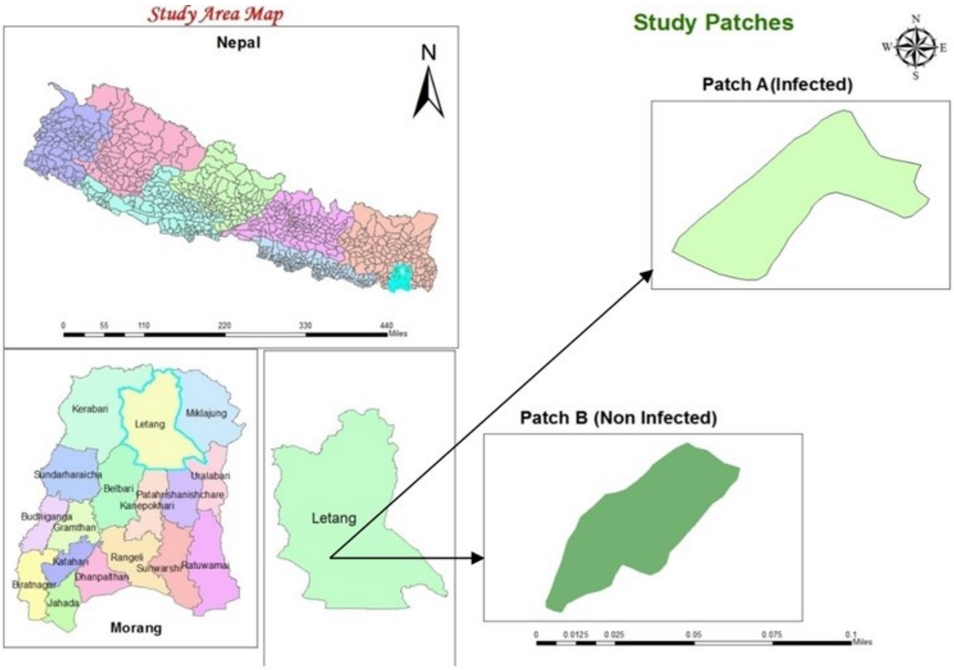

Figure 1. Study area map on Country, district and Municipality Map.

means annual rainfall is over 1500 mm [12]. The study area consists of two patches of 2 ha (i.e., 1 ha each): A (Infected) and B (Healthy) of almost 800 teaks (*Tectona grandis*) species each of which are separated by a buffer area of 300m between the patches. Both the patches of teak (*Tectona grandis*) were planted in 2013 A. D. These areas are registered as private forests by the division forest office.

2.2. Methods

2.2.1. Research plot establishment and design

Two plantation forest patches (research plots) of 1 ha each and 800 trees per plot were taken for research purposes. Patch A consisted of the infected poles, whereas patch B was of healthy (none-infected) ones. In both patches, the growth of the individual sample trees was assessed with the help of the two variables: Height and DBH. These variables were considered appropriate for the study because they are easily. Two plantation plots of the same locality, which were about 300 meters apart from each other's, were chosen for the research purpose. These sites were previously used as agricultural land and were converted into the private forest by the plantation of the *Tectona grandis* species in the same year and number with prescribed methodology in the equal area of 1 ha each. Furthermore, soil factors were not significantly distinct as they were under the same land-use system. Additionally, physiographical factors such as slope, and elevation were also similar if not the same. Hence, herbivorous (*Hyblaea puera*) attack was the exclusively contrasting factor among the plots.

With the help of GPS, the boundary of the patches was delineated and the shape of the patches was not taken into consideration for the research work because the sites were taken in a readily available state and a total (1 ha) plantation area was used as a single patch.

2.2.2. Sampling (selection of the sample tree)

Out of 800 teak species in each patch, 5% trees (40 trees) were taken as a sample tree which was selected based on a systematic method with the help of Fishnet (Arc GIS tool). 40 random equidistance points (Geo-coordinates) each were generated inside both patches A and B. Then, GPS was used to locate the aforementioned Geo-coordinates in the field within3-meter accuracy. Once the point was located, the next step was to select the sample tree for further measurement. To be biased-free, 4 nearby trees were selected in a clockwise direction from four cardinals (N,W,S, and E) with the help of a compass. After this, one sample tree was selected among the 4 trees according to the personal judgments regarding the representativeness of the individual trees in terms of health, DBH, and height.

2.2.3. Measurement

2.2.3.1. Growth of the individual tree

The first measurement was carried out in 2019 January, when DBH (diameter at breast height) was measured at 1.3m with the help of a diameter tap, and height was measured with the help of clinometers (sunto). The Measured trees were marked and numbered from 1 to 40 in each patch. The second measurement was carried out in 2021 December when the same 40 marked trees in each patch were again measured and height and diameter were measured and recorded.

2.2.3.2. Intensity of pest attack

Visible symptoms of the pest (teak defoliator) such extensive areas of plantations being defoliated, and the ground is littered with fallen leaf skeletons. Partially eaten leaves wither and fall off later were taken into the account for the evidence of the infection. Analysis of the intensity of the pest attack in an individual tree was done instantly in the field by the analytical view of the observer. The intensity was categorized into three categories: 0, 1, 2, and 3. The intensity of the pest attack increases with the number from 0 to 3 [13].

2.2.4. Data analysis

The obtained height and diameter data were used to obtain basal area and above-ground growing stocks of each tree from both measurements and a Summation was done to obtain total above-ground stocks in 2 different periods of measurement shown in Equation 1.

Above Growing Stocks ($G.S_{above}$) = Basal Area (B.A.) x Height (H) x Form Factor (0.5) **(1)**

The obtained growing stocks were used to calculate above-ground biomass (Equation 2).The conversion factor adopted in this study is influenced by the contents of studies by Pukkala [14], MD is Mean Wood Density i.e., 0.712.

Above ground biomass = above ground Growing Stocks x MD **(2)**

On the other hand, below-ground biomass was calculated considering 15% of the above-ground biomass [15].

Total biomass (B) =Above ground biomass + 15% of above-ground biomass **(3)**

The obtained biomass was then converted into total carbon content assuming 48% of total biomass as carbon content [16]. Change in carbon content in this 2-year study period was then calculated.

Change/addition of carbon stocks = obtained carbon stocks at 2021 measurement — obtained carbon stocks at 2019 measurement **(4)**

Similarly, total CO_2 sequestration in 2 different times period in two different patches was also calculated and differences in CO_2 sequestration in two different patches were obtained as shown in Equation 5 [17].

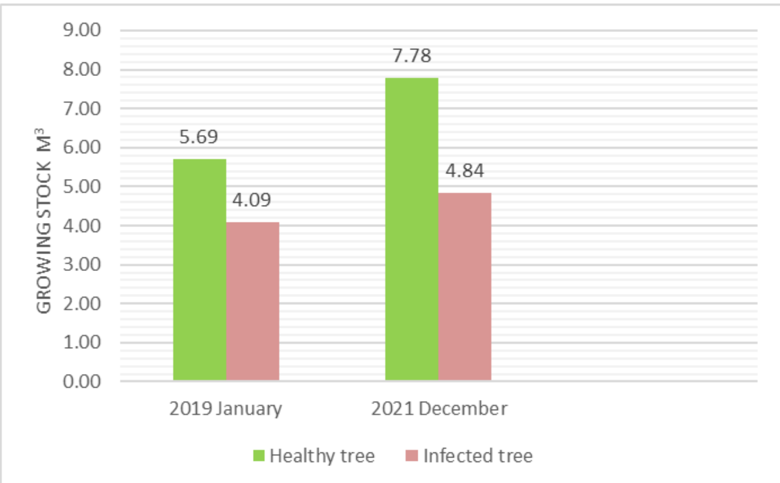

Figure 2. The growing stock of the patches.

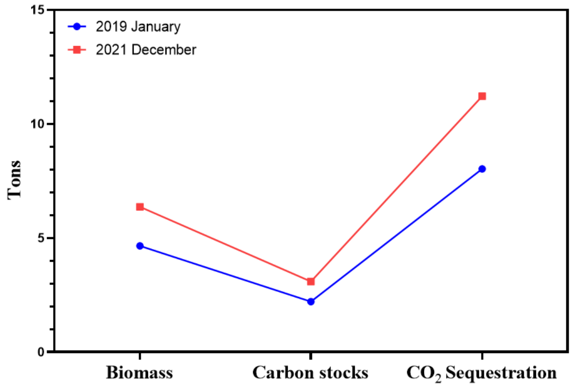

Figure 3. Total biomass and carbon content in two different measurement (health patch).

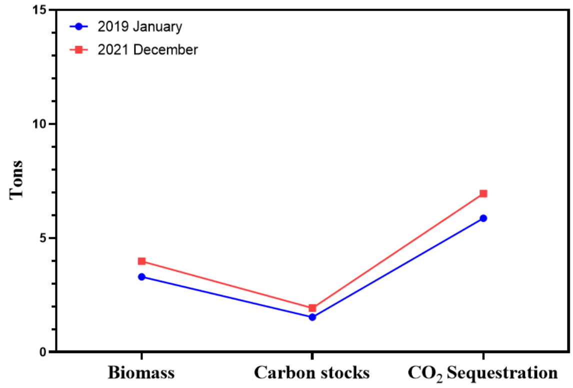

Figure 4. Total biomass and carbon content in two different measurements (infected patch).

$$W (CO_2) = 3.67 \times W(carbon) \quad \textbf{(5)}$$

The Obtained data and results were analyzed and presented using statistical tools, graphs, and charts.

The fresh ginger roots used for this research (201 g) were obtained from the Lafia main market, in Nasarawa State. It was transported in a polyethylene bag to the Department of Chemistry Laboratory, Federal University of Lafia. It was washed and rinsed severally with deionized water to remove dust and adhering soil particles. The thin outer covers were carefully peeled using stainless steel knife. The sample was washed again and sliced into bits and pounded using a ceramic mortar. The pounded sample was placed in a stainless basin, and 2 L of deionized water was added. The mixture was allowed to stand for 10 min, stirred and then filtered. The residue obtained after the juice extraction was re-soaked in 2 L of deionized water for another 10 min. This process was repeated for further three consecutive times and filtered after each soaking. The chaff obtained after this series of extraction is referred to as the ginger root waste. The waste was air-dried for 24 h and then oven-dried for 72 h at 80 °C. The dried sample was ground into fine powder using ceramic mortar and pestle and sieved to less than 1 mm fine particle size with a sieve and stored in a plastic sealable bag ready for the chemical analysis.

3. RESULTS AND DISCUSSIONS

3.1. Change in Growing *stocks in these two years of measurements*

The growth stocks (as shown in Fig. 2) in the first year of measurement (i.e. 2019) in the healthy patches were found to be 5.69 m^3 which increased to 7.78 m^3 (i.e. 36.73 %) in the second measurement in 2021. Where, in the context of the infected patch, first-year growing stocks were found at 4.09 m^3 which increased to 4.84 m^3 (i.e. 18.34 %).

3.2. Change in biomass, carbon content, and CO_2 sequestration in the healthy patch

The total biomass and carbon content in the healthy patch was found to be 4.65 tons and 2.2 tons respectively which increased to 6.35 tons and 3.04 tons in the second measurement (Fig. 3). The change in carbon content in these two years of the study periods was found to be 38 %. Whereas total carbon sequestration in these two years of the period was found to be 3.09 tons which shows a 38 % increase in respect to the previous measurement.

3.3. Change in biomass, carbon stocks, and CO_2 sequestration in the infected patch

As shown in Fig. 4, total biomass and carbon content in the infected patches were found to be 3.33 tons and 1.6 tons respectively which increased to 3.94 tons and 1.89 tons in the second measurement. The change in carbon content in these two years of the study period was found to be 18%. Whereas total carbon sequestration in these two years of the period was found to be 1.07 tons which shows an 18.23 % increase in respect to the previous measurement.

3.4. Correlation between height and diameter

Correlations between DBH and the height of individual trees were established for both healthy and infected patches during the years 2019 and 2021 (Fig. 5 to 8). A highly positive correlation was found between diameter and height in a healthy patch in both the measurement i.e., 0.88 and 0.89. Whereas less positive correlation as compared to a healthy patch was found between diameter and height in an infected patch in both the measurements i.e.,0.64 and 0.69.

3.5. Mean difference between the variables

DBH and height data from 2019 and 2021 of the infected and healthy plots have been plotted in the scattered diagram which is illustrated in fig 9. The result from the scattered graph provides information about the difference between the two plots (Healthy & Infected) regarding the aforementioned variables. The trend line of the healthy plot depicts the consistent and steep rise from 2019 to 2021, whereas the trend line of the infected plot illustrates an inconsistent and slow rise. Additionally, trend lines of infected plots lag behind that of healthy plots, during both years. All in all, the healthy plot showed a satisfactory result in comparison with the infected plot for the two variables: height and DBH.

This increment of two variables was also evident in the mean difference of variables in two plots during the given period. The mean height increment of the healthy plot was 1.1, while it was 0.5 in the case of the infected plot. Furthermore, the Mean DBH Increment of the Healthy plot was 2.1; however, it was 1.0 in the case of the infected plot. So, the Growth rate was high in the healthy plot in comparison with the infected plot.

3.6. Infection intensity of teak defoliator (Hyblaea puera) in the infected patch

Analysis of the intensity of the pest attack in an individual tree was done instantly in the field by the analytical view of the observer. Among those 40 sampled trees; 5 trees have an infection intensity of 0. 16 trees with intensity 1, 11 trees with intensity 2, and 7 trees with intensity 3. Trees under category

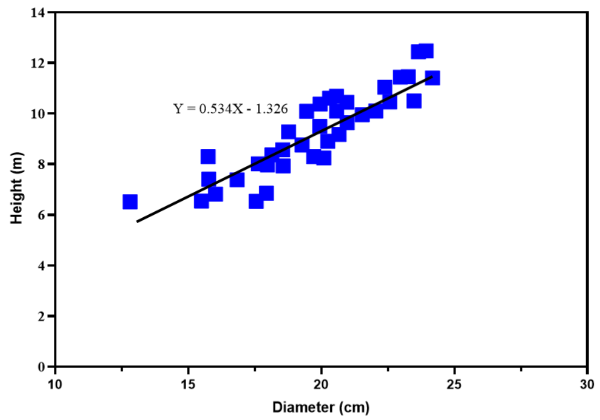

Figure 5. Diameter and height of healthy patch in 2019.

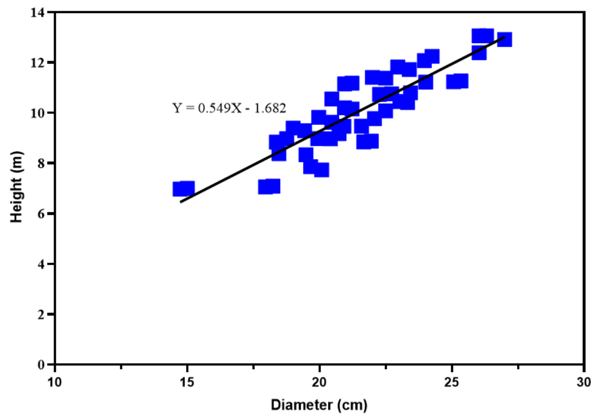

Figure 6. Diameter and height in the healthy patch in 2021.

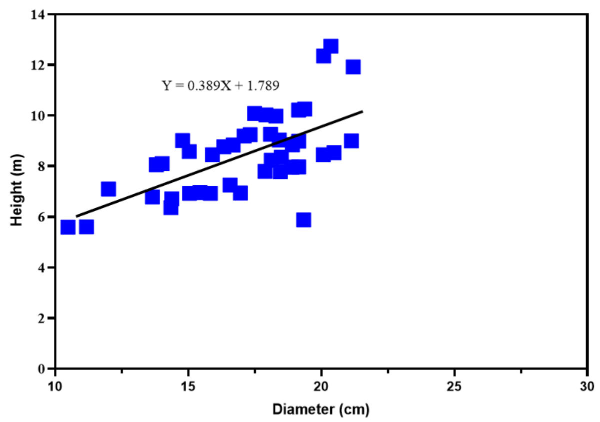

Figure 7. Diameter and height in the infected patch in 2019.

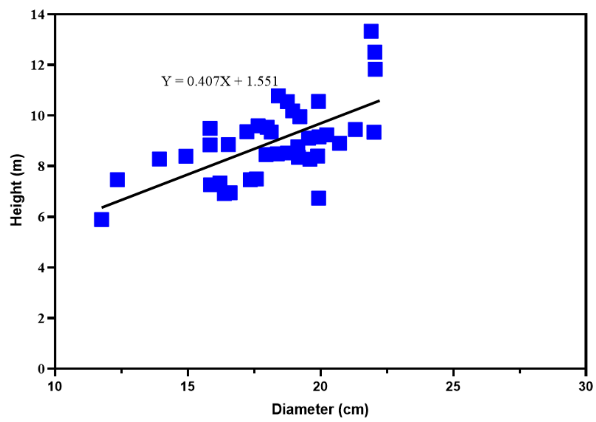

Figure 8. Diameter and height in the infected patch in 2021.

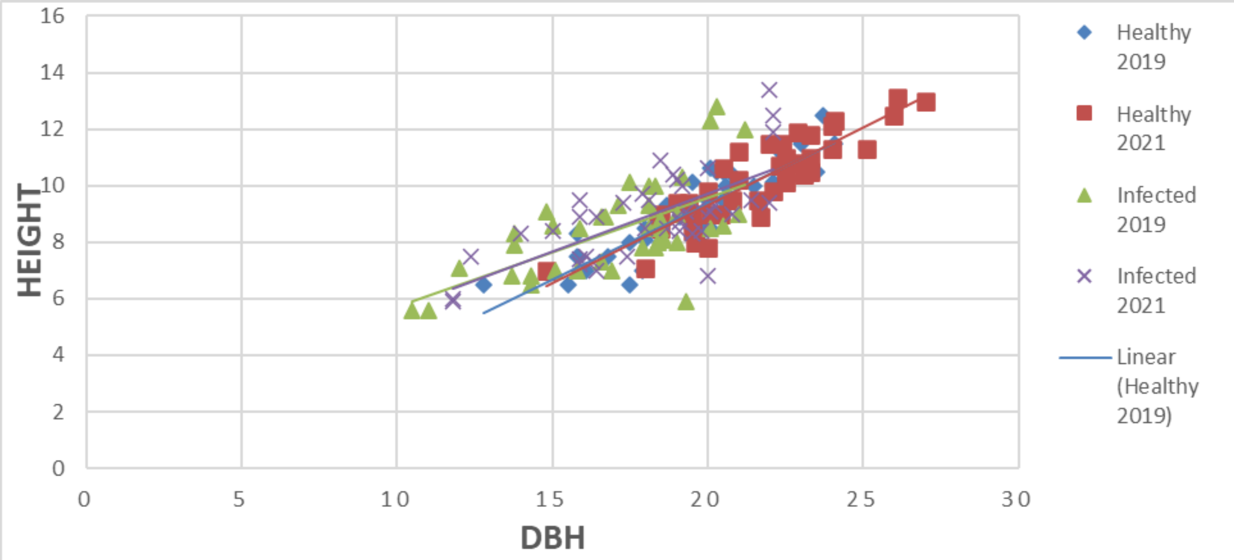

Figure 9. DBH and height of all trees.

o had a 29 % increment in growth stocks in these 2 years, similarly, Teak trees under categories 1, 2,3 had 21 %, 16 %, and 10 % respectively.

3.7. Discussions

This study has shown how infection and diseases in teak affect overall carbon accumulation in the plantation area. During these two years of the study period, we observed a 38% of increment in carbon stocks in healthy patches and only 18% in teak defoliator infected patches. The defoliation by *H. puera* in the infected patch was epidemic, with a decrease in growth percentage and carbon accumulation. A similar kind of observation was also found by Camarero et al. [18]. Several studies have evaluated the effects of insect defoliators on the plantation. Wu et al. [19] has mentioned outbreak on older (6-12 years old) plantations with defoliation up to 90 % resulting in high mortality and significant diameter and height reductions. Similarly, a highly positive correlation was observed in healthy patches in these two measurements between height and diameter (i.e., 0.88 and 0.89) whereas the correlation between height and diameter in infected patches was only 0.64 and 0.69. The effect and impacts of teak defoliator in teak have been seen in mean height and DBH increment in infected patches. Mean height and DBH increment are observed in half of the healthy patches. A similar observation was observed by Callister [20] where defoliation of teak leaves reduces the capability of producing plant food reserve which hampers the annual increment in girth and height. According to Islam et al. [21], the population outbreak of *H. puera* and *E. machaeralis* has effectively suppressed the incidence of teak defoliator and leaf skeletonizer and subsequently triggered early leaf flushing in teak forests. The present finding of this research closely matches the past research, finding, and observation.

4. CONCLUSIONS

The growth of a healthy patch surpassed the growth of an infected one. Growth was measured in terms of height, DBH, growing stock, and change in biomass. In all aspects, healthy patch showed better performance. Hence, the present investigation has shown that the teaks defoliator *Hyblaea puera* hurts carbon stocks accumulation and overall growth in plantation forests while making a comparison between healthy teak plantation forests without the impacts of teak defoliator and the infected teak plantation forest with visible symptoms of teak defoliator.

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