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Relationship between Stem Growth Variation and Soil Nutrients Levels in Selected Teak Plantations in Dry and Intermediate Zones in Sri Lanka

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ABSTRACT

Teak (*Tectona grandis*) is a popular tropical hardwood species, producing good quality timber products. However, productivity of timber is lower than their potential in most teak plantations. Investigating the relationship between stem growth variation and soil nutrient levels in Nikaweratiya and Kuliyapitiya sites is helpful to develop site specific management guidelines for each teak plantation. Stratified random sampling was carried out on both sites. Tree height and diameter of breast height (DBH) was measured as growth parameters. Organic carbon (OC) percentage, available phosphorous (AP), available nitrogen (AN) and exchangeable potassium (EP) were analyzed by obtaining soil samples. According to descriptive statistics of stem parameters, average height in Nikaweratiya plantation (4.98±1.09 m) was higher than Kuliyapitiya plantation (1.73±0.85 m). Organic carbon percentage in Nikaweratiya site (0.31±0.11) was lower than Kuliyapitiya site (0.56±0.06). However available phosphorus and exchangeable potassium in Kuliyapitiya site were greater than the Nikaweratiya site. Available nitrogen was similar in both plantations. Mutual relationship between soil parameters and the growth parameters was investigated using Pearson's correlation analysis. Relationship between stem parameters and soil parameters can be proven by regression equation, including site as an indicator variable. Adjusted R squared (R^2-adj) values for the model of height was 73.28% and R^2- adj value for the model of DBH was 75.29%.

KEYWORDS: Correlation analysis, Soil nutrient, Stem growth

INTRODUCTION

Establishment of forest plantations to cater global forest product demand has been a long standing tradition in the tropics (Evans, 1982). Globally, teak ranks third among the tropical hardwood species in the forest plantation area due to its timber qualities including attractiveness in color, grain, durability and lightness with strength (Panday and Brown, 2001).

However, productivity in most of the Teak plantations is generally below their potential. According to White, (1991). Teak prefers fertile deep riverine alluviums. Further, major determinants of soil productivity in the teak plantations are clay content, pH, moisture content, soil texture and root available depth (Hase and Falster, 1983; Balagopalan *et al.*, 2001).

Application of fertilizer is not common in forest plantations. Therefore, encouraging natural processes of restoring soil fertility status to release soil nutrients is important to gain optimum timber yield from teak monoculture plantations. Soil organic matter (SOM) is a virtual store house of nutrients. Moreover, SOM play a direct role in cation exchange, water retention, releases nutrients into the soil solution and production of acids that affect the fixation. Therefore, understanding nutrient dynamics and growth performances in monoculture teak plantations will assist forest managers to maintain considerable biomass throughout the rotational period. Studying the relationship between stem growth variations and soil nutrient levels in teak plantations provides multiple benefits such as understanding of stem growth performance of teak on different soil conditions in terms of soil chemical properties and reveal nutrient status and soil fertility levels in plantation sites. Therefore, this study provides valuable information to gain optimum timber yield from teak plantations by adapting the site specific conditions.

The main objective of this study was to investigate relationship between stem growth variation and soil nutrient levels in selected teak plantations in dry and intermediate zones of Sri Lanka. Further, modeling of stem growth with soil nutrients will be useful to develop site specific management guidelines for each teak plantation.

METHODOLOGY

Study Area

The study was carried out in monoculture teak plantations managed by the Forest Department of Sri Lanka located at Nikaweratiya and Kuliyapitiya which represent dry and intermediate zones respectively. Both plantations were established in year 2009 and the total extent is 10 ha in each plantation.

Data Collection

For the representation of entire plantation, stratified random sampling was carried out using five strata in Kuliyapitiya plantation and eight strata in Nikaweratiya plantation based on the topography of each site. Simple random sampling was carried out according to the rule of proportionality within strata (Kim, 2005). Altogether, fifty sampling locations were established for data collection. Soil samples were collected from each location for nutrient analysis. Height and DBH of the nearest two trees were measured as growth parameters.

Soil Analysis

Laboratory analysis was carried out at the Faculty of Agriculture and Plantation Management, Wayamba University of Sri Lanka from February to May 2016. Soil samples were air dried at room temperature and sieved using a 2 mm sieve. Soil samples were analyzed based on guidelines provided by Dharmakeerthi *et al.* (2007).

Walkey and Black method (Walkey and Black, 1934) was used to determine the SOC. The exchangeable potassium (K) in soil samples were extracted and estimated using Flame Photometry method using JENWAY PEF 7 Flame Photometer (Jackson, 1958). The available phosphorus (P) in soil samples were extracted and described by Olsen *et al.* (1954). Available P in the extract was measured using a calorimetric method by using the UV- 160A UV-visible recording spectrophotometer (Murphy and Riley, 1962). Available nitrogen (N) in soil samples were detected using nitrate and nitrite by Extraction-Distillation method (Bremner and Keeney, 1966).

Model Construction

Regression equation was used to investigate relationship between stem growth variation and soil nutrients levels in Nikaweratiya and Kuliyapitiya teak plantations. Minitab 17 statistical package was used for analysing.

RESULTS AND DISCUSSION

Table 1 illustrates the descriptive statistics of both stem parameters and soil nutrient variables in both Nikaweratiya and Kuliyapitiya plantations. The average height in Nikaweratiya teak plantation (4.9±1.0 m) was higher than the average height of Kuliyapitiya plantation (1.7±0.8 m). Furthermore, average DBH in Nikaweratiya site (6.2±1.4 cm) was higher than that of Kuliyapitiya site (1.5±1.1 cm). Therefore, the mean values of growth parameters were higher in Nikaweratiya site compared to those in Kuliyapitiya site.

According to the results in the Table 1, organic carbon, available P and exchangeable K in Kuliyapitiya site were comparatively greater than the Nikaweratiya site. However, available N was almost similar in both sites.

Correlation between Variables

The correlation analysis was carried out to find the mutual relationship between soil parameters and the growth parameters of Kuliyapitiya and Nikaweratiya sites separately. Results of correlation of variables are presented in the Table 2. According to the results, there was a significant correlation between DBH and height of teak trees. Organic carbon showed a significant correlation between the height and DBH of teak plants. Further, available P had a significant correlations each with height, DBH and the organic carbon. In addition, there was a significant correlation between available N and the organic carbon, while there was no significant correlation each with height, DBH and the available P (Table 2).

Exchangeable K, showed correlations with available N, organic carbon and available P. However, K did not show a significant correlation each with average height and average DBH (Table 2).

Fitted Models for Two Plantation Sites

According to the R^2-adj values of the regression analysis, two types of model structures were tested for height and DBH of teak trees in both Nikaweratiya and Kuliyapitiya plantations. Altogether four models were selected as the best models to exemplify the relationship between growth variables of Teak trees and soil variables in each plantation. Equation 1 and 2 represents the height of teak trees in Kuliyapitiya and Nikaweratiya respectively. DBH of Kuliyapitiya and Nikaweratiya were shown in equation 3 and 4 respectively. R^2-adj value for the model which examined the height of teak trees was 73.28% and R^2-adj values for the model which describes DBH of teak trees was 75.29% respectively. Table 3 represents generated co-efficient for the factors and their respective p values for the two models.

R^2-adj values were very good for the selected models. Further, Figure 1 and Figure 2 represent the standard residual distribution and normality of distribution of model residuals. Therefore, selected models were fitted to the data properly. Based on the two fitted models for height and DBH of the teak trees,

Table 1. Descriptive statistics of growth parameters and soil nutrient variables

Parameters	Kuliyapitiya site			Nikaweratiya site		
	Min	Max	Mean (±SD)	Min	Max	Mean (±SD)
Average height (m)	0.40	4.05	1.73 ±0.85	2.55	7.45	4.98 ±1.09
Average DBH (cm)	0.50	5.00	1.56 ±1.18	3.00	8.50	6.24 ±1.41
Organic carbon (%)	0.42	0.66	0.56 ±0.06	0.10	0.51	0.31 ±0.11
Available phosphorus (ppm)	0.60	17.40	8.94 ±3.61	0.20	11.70	4.66 ±2.85
Available nitrogen (%)	0.05	0.58	0.29 ±0.12	0.04	0.60	0.29 ±0.13
Exchangeable potassium (ppm)	44.00	104.00	82.05 ±12.76	50.00	98.00	79.00 ±11.61

Min- Minimum, Max-Maximum, SD- Standard deviation, DBH- Diameter of breast height

Table 2: P values of Pearson's correlation between experimental variables

Parameters	Average height	Average DBH	Organic carbon	Available phosphorus	Available nitrogen
DBH	0.000*				
Organic carbon	0.000*	0.000*			
Available phosphorus	0.000*	0.000*	0.000*		
Available nitrogen	0.551	0.565	0.000*	0.480	
Exchangeable potassium	0.225	0.376	0.002*	0.025*	0.000*

**There is a correlation between variable for significant at 0.05 level. DBH- Diameter of Breast Height*

Table 3: P values for model variable in regression analysis

Growth parameter	P values	Co-efficient
Height		4.880
Constant	0.000	2.980
Organic Carbon	0.049	0.024
Available Nitrogen	0.483	0.090
Available Phosphorous	0.941	-0.013
Exchangeable Potassium	0.200	
DBH		5.653
Constant	0.000	3.550
Organic Carbon	0.082	0.009
Available Nitrogen	0.839	0.450
Available Phosphorous	0.779	-0.008
Exchangeable Potassium	0.524	

DBH- Diameter of breast height

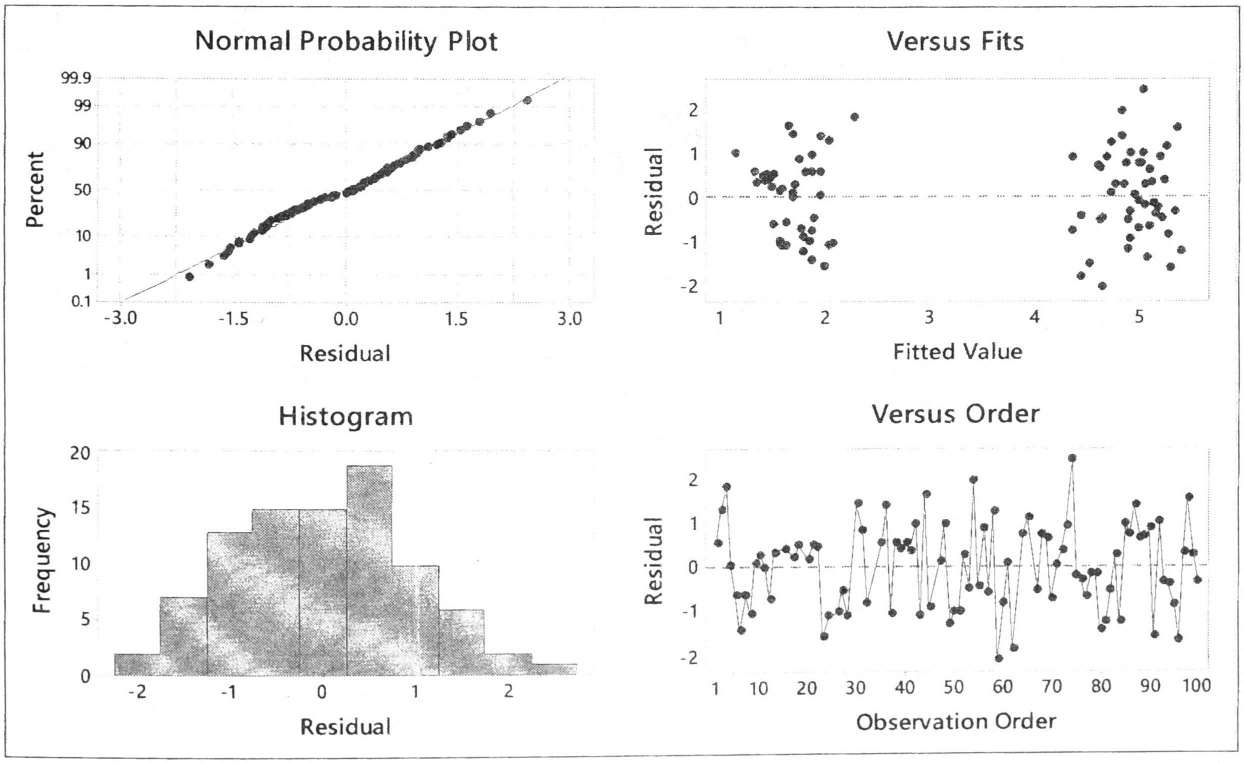

Figure 1: Standard residual distribution and normality distribution of model residuals

$$\text{Height (m)} = 0.824 + 2.98\text{OC (\%)} + 0.0242\text{AP (ppm)} + 0.09\sqrt{\text{AN}}\text{ (ppm)} - 0.0130\text{ EP (ppm)} \quad (1)$$

$$\text{Height (m)} = 4.880 + 2.98\text{OC (\%)} + 0.0242\text{AP (ppm)} + 0.09\sqrt{\text{AN}}\text{ (ppm)} - 0.0130\text{ EP (ppm)} \quad (2)$$

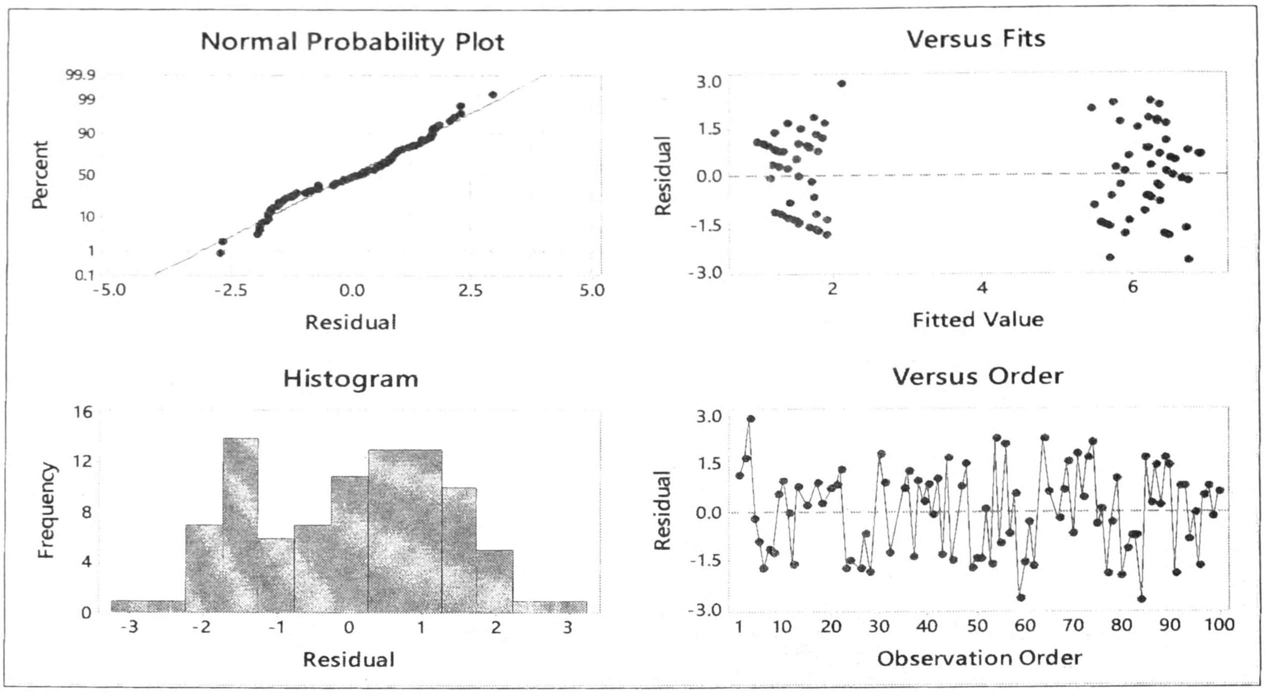

Figure 2. Standard residual distribution and normality of distribution of model residuals

DBH (cm) = 0.040 + 3.55 OC (%) + 0.0096P (ppm) +0.45 AN (ppm) – 0.0088 EP (ppm) (3)
DBH (cm) = 5.653 + 3.55 OC (%) + 0.0096P (ppm) + 0.45 AN (ppm) – 0.0088 EP (ppm) (4)

site specific conditions are highly influenced for the stem growth. According to the P values of model factors, the effect of macro nutrients to the stem parameters of teak trees was not considerable. That may due to both plantations were semi matured and seven years of aged. Further, macro nutrients DBH of the teak trees, site specific conditions are highly influenced for the stem growth. According to the P values of model factors, the effect of macro nutrients to the stem parameters of teak trees was not considerable. That may due to both plantations were semi matured and seven years of aged. Further, macro nutrients are essential for the early physiological development of teak plants. However, the nutrient requirements of teak trees reduce with the age of the trees (Moya et al., 2013). Nevertheless, soil physical parameters were different in the studied teak plantations. The growths of semi matured teak trees highly depend on the soil physical parameters. Therefore, stem growth performances in Nikaweratiya plantation were comparatively higher than that of the Kuliyapitiya site although it has relatively better soil nutrient status (chemical) compared with the Nikaweratiya site.

CONCLUSIONS

On the basis of the results of this study, it is clear that, the stem growth of semi matured teak plantation is not highly depend on nutrient levels of the soil in each plantation. Further, based on the regression analysis, soil organic carbon significantly affect the tree height in both plantations. In addition, the co-relation analysis proved that, there is a co-relation between stem growth variables (height and DBH) and organic carbon. Therefore, in order to obtain optimum tree height, it is recommended to maintain the status of soil organic carbon in semi matured and matured teak plantations rather than maintaining higher N, P, K levels by adding inorganic fertilizer.

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