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Nitrogen and Phosphorus Resorption Efficiencies of Selected Dipterocarp Tree Species in Two Reforestation Sites in Leyte

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ABSTRACT— This study was conducted at the Visayas State University Arboretum in Baybay City, Leyte, and a reforestation site in Ormoc City. It aimed to compare the N and P Resorption Efficiency (%) of four dipterocarp species; namely, Hagakhak (*Dipterocarpus validus*), White Lauan (*Shorea contorta*), Bagtikan (*Parashorea malaanonan*), and Yakal-Saplungan (*Hopea plagata*); and determine which nutrient is limiting based on such parameters. The mature leaves of Hagakhak had the highest N content while Yakal-Saplungan had the lowest. In the senesced leaves, all the four species had comparable amounts of N. Phosphorus contents in the mature leaves of all the four species were significantly highest in White Lauan, while Bagtikan, Hagakhak, and Yakal-Saplungan contained similar amounts. In the senesced leaves, Hagakhak and White Lauan had comparable P content which was higher than those in Bagtikan and Yakal-Saplungan. The four dipterocarp species had a Nitrogen Resorption Efficiency (NRE) of 32.2%-54.6% with a mean of 41.09%. Phosphorus Resorption Efficiency (PRE) ranged from 36.2% - 62.1%, with a mean of 50.7%, which were higher than the NRE values. This means that Yakal-Saplungan and Bagtikan are more efficient in recycling P in the leaves than Hagakhak and White Lauan, making them better adapted to P-deficient soils. The consistently high PRE compared to NRE suggests that P is more limiting than N in the soils of both sites.

KEYWORDS: P resorption efficiency, N resorption efficiency, senesced leaves, Bagtikan, White Lauan, Hagakhak, Yakal-Saplungan

1. INTRODUCTION

The two most important macronutrients that can regulate the growth and productivity of plants in the terrestrial ecosystem as given by [1] are Nitrogen (N) and phosphorus (P). Nitrogen is essential for carbon assimilation via photosynthetic proteins [2], whereas phosphorus is essential for the formation and production of energy rich compounds such as ATP, trios, pentose and hexose phosphates [3]. These macronutrients are essential in plants due to their functional links with photosynthetic absorption rates and growth [4].

Plants have a unique nutrient conservation technique known as nutrient resorption that occurs before senescence and leaf abscission. Nutrient resorption refers to the process by which nutrients are retranslocated from senescing to living or storage organs [5]. Prior to abscission, this system takes nutrients from the leaves for eventual redeployment or resorption in developing leaf tissues. This process can continue throughout the life of the leaf [6] and the resorbed nutrients are either used for plant growth or stored for the next growing season [7]. Nutrient resorption efficiency is calculated by comparing the nutrient contents in senesced leaves to those in fully expanded, mature green leaves [8].

Nutrient resorption enables plant to recycle nutrients [5], hence reducing the loss of nutrients and allows the plants not to fully rely on the nutrients from the soil [8]. Such process as [5] has been shown to influence a

number of ecological processes as it reduces plant competition, nutrient uptake and productivity rate. He added [22] that changes in nutrient resorption could influence stand-level biogeochemical cycling by influencing litter-fall quality, which influences litter decomposition and soil nutrient availability. The degree to which N and P are retranslocated and recycled is determined by the nutritional status of the plant [9]. In general, as nutrient availability decreases in an environment, the amount of N and P resorption increases [10] and this ratio can be used to determine which nutrient is the most limiting in an ecosystem [11].

According to [12], the variability in nutrient resorption can be influenced by both the supply (ie soil nutrient) and the sink (ie nutrient demand). Because nutrient resorption plays such a crucial role in plant nutrient conservation, it is hypothesized that species living in nutrient-poor settings will be more effective and proficient at resorbing nutrients [13]. However, the relationship between leaf nutrient resorption and soil nutrient availability is still unknown [14]. [5] for instance, found that soil nutrient availability controls nutrient resorption whereas [15] reported that nutrient resorption decreases as soil nutrient availability increases. Given these different responses in leaf nutrient resorption, dipterocarp tree species were selected in this study due to their ecological and economic importance. Moreover, this study was the first to investigate the difference if any, in the resorption of N and P in dipterocarp tree species found in the arboretum of VSU and a former sugarcane field which was converted into a rainforestation farm in Brgy. Catmon, Ormoc City.

2. Methodology

2.1 Study Area

The studies were conducted at the College of Forestry and Environmental Science (CFES) Arboretum of the Visayas State University (VSU) - Main Campus, Visca, Baybay City, Leyte and in a former sugarcane field converted into a rainforestation site found in Brgy. Catmon, Ormoc City (Figure 1).

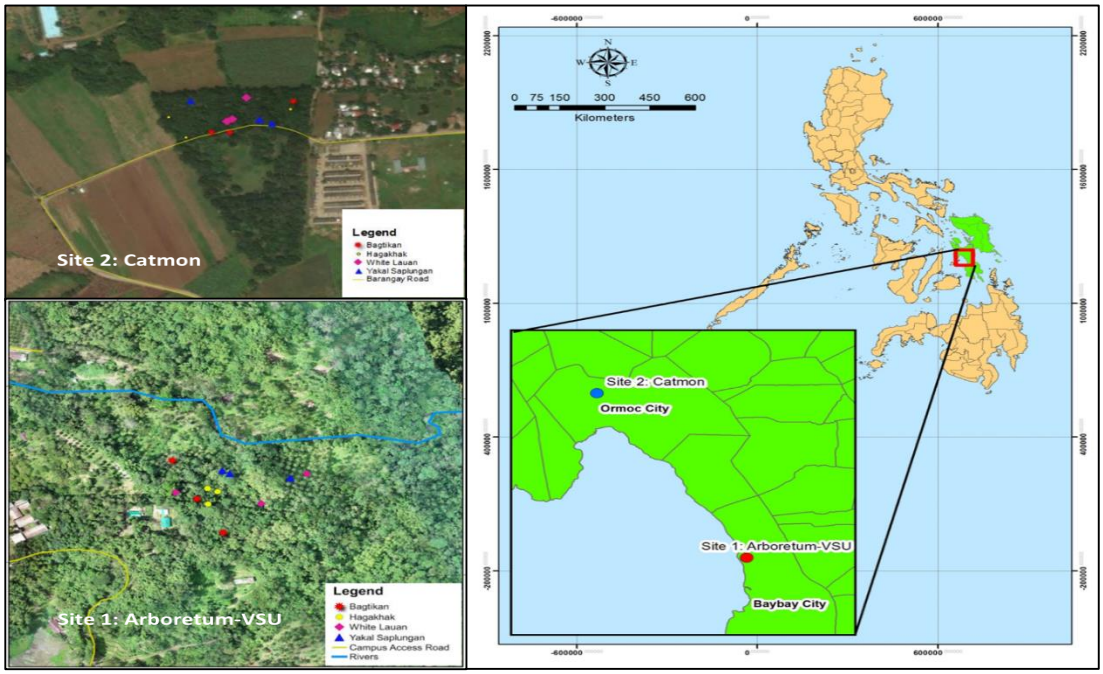

Figure 1. Map showing the location of the study sites at VSU and Ormoc Leyte

2.2 VSU Arboretum

The VSU arboretum has an altitude of approximately 50 meters above sea level. It is situated in the

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northeastern part of Leyte at N 10 °44' 38.4" E 124° 47' 31.2" with an area of about 0.83 hectare. This site was previously a cogonal area in the 1980s, and then it was converted into an agro-forestry farm and later developed into an arboretum planted with different native tree species. Family Dipterocarpaceae has the highest total number of tree species in the area consisting of Almon (*Shorea almon*), Bagtikan (*Parashorea malaanonan*), Guijo (*Shorea guiso*), Gisok-gisok (*Hopea philippinensis*) Hagakhak (*Dipterocarpus validus*), Mayapis (*Shorea palosapis*), Yakal-Saplungan (*Hopea plagata*), Tanguile (*Shorea polysperma)* and White Lauan (*Shorea contorta*). The VSU arboretum has no history of cultivation and soil fertilization.

The climate of VSU is classified as Type IV, characterized by more or less evenly distribution rainfall throughout the year [16]. The present climate of the western part of Leyte area is characterized as humid tropical monsoon with maximum rainfall of up to 300 mm per month (about 2600mm annually) based on the data from the PAG-ASA Meteorological Station, VSU, Visca, Baybay. The average atmospheric temperature of Baybay is about 25.5ºC.

2.3 Catmon Rainforest Site

In 1997, an area of approximately 1.2 hectares sugarcane field in Brgy. Catmon, Ormoc City (N 11º 04' 56.1" E 124º 34' 25.7") was converted into a rainforestation site. Among the native planted trees include Antipolo (*Artocarpus blancoi*), Philippine mahogany (*Toona ciliate*), White Lauan (*Shorea contorta*), Bagtikan (*Parashorea malaanonan*), Agoho (*Casuarina equisetlifolia* L.), Almaciga (*Agathis philippinensis*), Hagakhak (*Dipterocarpus validus)*, Narra (*Pterocarpus indicus*) and Yakal-Saplungan(*Hopea plagata*). For 45 years, it was a sugarcane plantation thus the field was subjected to intensive cultivation and intensive soil fertilization of commercial fertilizers especially ammonium (NH_4^+) like urea [7].

The climatic condition in this site is considered as Type 4, characterized by rainfall that is evenly distributed throughout the year and the annual average rainfall of about 1638 mm [16]. The soil moisture regime is udic which implies that the water is available year-round while the soil temperature regime is isohyperthermic indicating that the annual average temperature is above 30.86oC and it does not fluctuate above 5ºC [17].

2.4 Selection of Dipterocarp Tree Species

Selection of dipterocarp tree species in this study was based on the common dipterocarp tree species present in both sites. These consisted of Bagtikan (*Parashorea malaanonan* (Blco) Merr.), Hagakhak (*Dipterocarpus validus* Blume*)*, White lauan (*Shorea contorta* S. Vidal) and Yakal-Saplungan (*Hopea plagata* S. Vidal) Three (3) replicate sample trees per species per site or a total of 12 trees per site were randomly selected for the collection of leaf samples.

The mature and senesced leaves of Bagtikan (*P. malaanonan*), Hagakhak (*D. validus)*, White lauan (*S. contorta*) and Yakal-Saplungan(*H. Plagata*) were used in this study (Figure 2). Bagtikan has a leaf size of 9-12.5 cm x 3.5-5 cm. The leaves are elliptical to ovate and with a petiole of 12-20 mm long. On the other hand, Hagakhak leaves have an elliptical-oblong to ovate shape with a leaf-size of 15-25 cm × 7.5-12 cm and has petiole of 3.5-5 cm long. On another note, White Lauan leaves are ovate to lanceolate shape and have a leaf size of 9-11.5 cm × 2-3.5 cm. Conversely, Yakal-Saplungan leaves are lanceolate-falcate in shape and with a 5-9 cm × 1.5-4 cm leaf size.

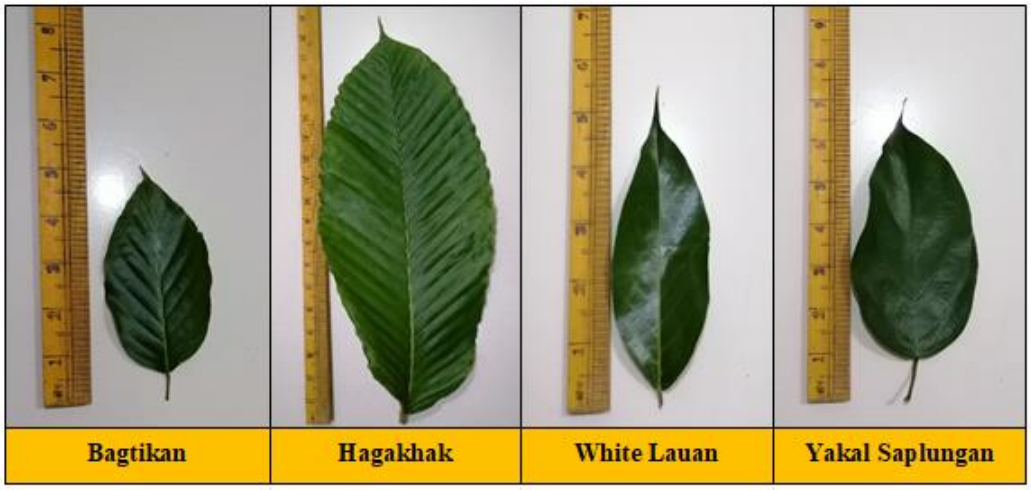

Figure 2. Leaf-size of the selected different dipterocarp tree species

2.5 Geotagging of Dipterocarp Tree Species

During the site visitation, a stable GPS signal was established and photos of the selected dipterocarp tree species were taken using a hand-held GPS receiver with geo-tagging capabilities. After the site visit, the consolidated geo-tagged photos were stored in the computer and the consolidated data were then imported using a GIS software. A map showing the locations and corresponding tree images was generated using this software.

2.6 Collection of Leaf Samples

Prior to collection of leaf samples, a two-week preliminary observation was done in the two sites to determine the timing and frequency of leaf abscission of the sample trees.

During collection, fifteen (15) leaves per sample tree were randomly collected; five (5) each from the top, middle and lower parts of the tree that were exposed to light. Moreover, the leaf samples gathered from each different part of the sample trees were separately placed in brown bags with the labels top, middle and lower parts respectively, for air drying.

2.7 Fresh Matured Leaves

For the fresh leaves, those that were deep green, mature, fully expanded and free from insect or pathogen damage were randomly collected using a modified pole clipper.

2.8 Senesced Leaves

Senesced leaves are those in which an abscission layer has formed at the base of the petiole, preventing further nutrient withdrawal [18]. These leaves are easily identified because their overall color (often yellow) differs from that of live, green leaves and can become detached by gently flicking the branch or leaf, those without an abscission layer cannot be removed in this way. To minimize the effect of leaf mass loss on the estimate of nutrient resorption efficiency, senesced leaves will be collected directly from the top, middle and lower layers of the trees rather than from the litter layer [18].

2.9 Laboratory Analysis

2.9.1 Oven-drying and Grinding of Leaf Samples

Both mature and senesced leaf samples were taken to the laboratory and carefully washed with tap water, rinsed with distilled water and cut into small pieces. They were air-dried in a well-ventilated room free from

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dust and contaminants for two days. After air drying, the leaf samples were placed inside an oven at 70°C for another 3 days. Moreover, after oven-drying the leaf samples were ground using a Willey Mill with No. 40 screen size and placed in pocket-sized paper envelopes and oven dried at the above-mentioned temperature for two (2) hours. The ground samples were stored inside a desiccator ready for analysis.

2.10 Plant tissue analysis for total N and P

2.10.1 Total Nitrogen

This was analyzed following the Kjeldahl Digestion method. A 0.20 g oven-dried and ground leaf sample was placed in a 30 mL Kjeldahl flask added with 1g of selenium reagent mixture and 3 mL of concentrated sulfuric acid. The flask was placed in the Buchi digestion unit inside the fume hood for digestion of dried sample. When the charring stops, a white precipitate was formed and the digested mixture was transferred to a Buchi distilling flask. A 20 mL NaOH was dispensed into the distilling flask and distillation process followed. The distillate was transferred in an Erlenmeyer flask containing 25 mL boric acid and 3 drops of mix indicator. Distillation of the mixture continued until 75 mL of distillate was obtained. Titration using a standard acid was done to the light pink endpoint. Total N was computed using the formula:

$$\% N = \frac{(A - B)(N)(0.014)(100)}{W}$$

where:
A = volume of standard acid used in sample, mL
B = volume of standard acid used in a blank, mL
N = Normality of standard acid
W = Oven-dry weight of the soil sample, g

$$0.014 = \frac{14\ (atomic\ weight\ of\ N)}{100} = meq.wt\ of\ N$$

2.10.2 Total Phosphorus

A 0.50 g oven-dried and ground leaf sample was placed into a 15 mL high-form porcelain crucible. Crucibles were placed in a rack, and subsequently into a muffle furnace set at 500oC for two hours until the samples turned into white ash. The ash samples were cooled down and then dissolved in 11.65 N hydrochloric acid and allowed to stand overnight. The collected clear liquid was used for the analysis of total Phosphorus content.

Total P was quantified from a 1-mL sample aliquot following the ascorbic acid color development described by [19].

The amount of P was calculated using the formula:

$$\% P = ODS\ x\ K\ (100/0.50)(1/10000)$$

where:
ODS = optical density of the sample
K = slope of the standard curve
100 = dilution ash sample
0.50 = weight of the plant tissue
1/1000 = factor to express in % basis

2.11 Nutrient Resorption

The concentrations of N and P in green and senesced leaves were used to calculate nutrient resorption efficiencies [24]. Nitrogen resorption efficiency (NRE) was calculated as:

$$NRE\ (\%) = [(Ngr-Nsen)/Ngr] \times 100$$

where Ngr and Nsen are the concentrations of N measured from mature green leaves and senesced leaves, respectively. Similar calculations were made for P, using values for P concentrations of green (Pgr) and senesced leaves (Psen) to compute P resorption efficiency (PRE).

2.12 Soil Analyses

The soil samples were collected from two reforestation sites for the determination of soil chemical properties. From each site, soil samples were collected approximately 200m distance from each 12 sample trees from 0-20 cm using soil auger. The soil samples were composited and placed in a properly labelled bag. A total of two composite soil samples from each reforestation sites were collected.

The soil samples were air-dried and then stones and plant roots from the soil samples were removed. After 3 days of air-drying, the soils were pulverized and passed through a 2.0-mm and 0.425-mm mesh sieves for the course and the fine samples, respectively. The soil samples were analyzed in the laboratory for chemical properties. Due to limited access in the university laboratories, the prepared soil samples were sent to Central for Analytical Soil Laboratory in VSU-PhilRootcrops (CASL) for the analyses. The following soil parameters were analyzed in order to identify the fertility status of the soil such as the following:

2.13 Soil pH

This was determined using a pH meter and analyzed potentiometrically at a ratio of 1:2.5 soil to water ratio.

2.14 Soil Organic Matter

This was analyzed using the Modified Walkley and Black method (Nelson & Sommer, 1982). A 0.5 g soil that has been passed through a 0.425-mm sieve (No. 40) was placed in a 500-mL Erlenmeyer flask. Using a volumetric pipette, the soil was added with 10 mL 1N potassium dichromate ($K_2Cr_2O_7$) and was gently swirled to disperse the solution. Under the fume hood, 10 mL of concentrated sulfuric acid (H_2SO_4) was added rapidly and the flask was swirled immediately until the soil and reagents were mixed. The mixture was allowed to stand under the fume hood for 1 hour before adding 200 mL of distilled water. Eight (8) drops of O-phenanthroline indicator was added, into the solution, was stirred using a magnetic stirrer and was titrated with 0.5 N $FeSO_4.7H_2O$ until the solution turned into a greenish cast to dark green with the latter color indication an endpoint of titration.

The organic matter was calculated using the formula:

$$\%\ SOC = 0.5\ N\ (FeSO_4.7H_2O) \times \frac{B-S}{W} \times 0.39 \times mcf$$

$$\%\ SOM = \%OC \times 2$$

where:
SOC = soil organic carbon,
SOM = soil organic matter,

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B = volume (mL) of $FeSO_4.7H_2O$ used in blank,
S = volume (mL) of $FeSO_4.7H_2O$ in sample,
w = weight (g) of soil used
mcf = moisture correction factor

2.15 Total Nitrogen

Total nitrogen was determined using the Micro-Kjeldahl method (ISRIC, 1995). A 1 g of the soil that was passed through a 0.425-mm sieve was added with about 1 g selenium mixture and 6 mL concentrated H_2SO_4 acid and was digested using Kjeldahl digestion heaters. After which, distillation was done using Buchi distiller apparatus (50 mL 40% NaOH was added), approximately 75 mL distillate was collected in a 125 mL Erlenmeyer flask with 2% Boric acid (H_3BO_3) and was titrated with standardized 0.05 N H_2SO_4 until the color changed from green to pink.

The following formula was used to calculate the N concentration.

$$\% N = \frac{(a-b)}{S} \times N\ H_2SO_4 \times 1.4 \times mcf$$

where:
a = volume (mL) of standardized H_2SO_4 for titration of sample,
b = volume (mL) of standardized H_2SO_4 for titration of blank,
s = weight (g) of soil samples,
N = normality of standardized H_2SO_4
mcf = moisture correction factor

2.16 Available Phosphorus

Available P was analyzed according to Bray method No.2 (Jackson 1958). Exactly 2.5 g soil sample that passed through a 2-mm sieved was weighed, a 25-mL extracting solution was added (0.1 N HCl and 0.03 N NH_4F) mixture was shaken for 5 mins using a reciprocating shaker at 180 oscillations per min. Filtrate was collected by filtering the solution through Whatman # 42 filter paper. Two (2) mL aliquot of the filtrate was added with 10 mL Reagent C (mixture of ascorbic acid and ammonium molybdate) it was mixed through the vortex mixer, and allowed to stand for 1 hour for the blue color development [19]. Absorbance was read using spectrophotometer (Spectronic $20D^+$) at 880 nm wavelength.

Available P was calculated using the formula:

$$\text{ppm P in solution} = Ods \times K$$

$$\text{ppm P in soil} = \text{ppm P in solution} \times \frac{25}{2.5} \times \text{dilution} \times mcf$$

where:
Ods = optical density of samples and
K = slope of standard curve (average)
25 = volume (mL) of extracting solution
1.5 = weight of soil used

2.17 Statistical Analysis

Analysis of Variance (ANOVA) was used to determine if there are significant effects of leaf state, canopy level, and site location on the N and P content, and N and P Resorption Efficiency. Mean comparison was done using Least Significant (LSD) test at $p<0.05$ level of significance. All statistical analyses were carried out using Statistics software version 8.1.

3. RESULTS AND DISCUSSION

3.1 Soil Chemical Properties of the Study Sites

The soils in the VSU Arboretum and the Ormoc Reforestation had pH values of 4.85 and 5.03, respectively; which are very strongly acidic. The [19] Soil Science Society of America classifies soil pH values ranging from 4.5 to 5.0 as very strongly acidic. The soil organic matter in both soils were low at 1.26% (VSU) and 1.56% (Ormoc), respectively. The moisture content of the Ormoc soil was also lower (26.19%) than that of the VSU Arboretum (31.03%). In addition, the total nitrogen content was also low in both sites 0.19% (VSU) and 0.20% (Ormoc). Moreover, the available phosphorus contents of the soils were 0.95 ppm (VSU) and 1.49 ppm (Ormoc) which can be interpreted as very low according to [20]. Based on the chemical analysis, the soils in both sites have comparable fertility status which can be considered infertile or nutrient-poor (Table 1).

Table 1. Soil chemical properties of the study sites

Location	pH (H_2O)	OM (%)	Total N (%)	Available P (ppm)	Moisture Content (%)
VSU	4.85	1.26	0.19	0.95	31.03
Ormoc	5.03	1.56	0.20	1.49	26.19

3.2 Nitrogen and Phosphorus Content in Leaves of Dipterocarp Tree Species

The total nitrogen and phosphorus contents of senesced leaves in all the four species of dipterocarp trees used in the study were significantly lower than those in fully mature leaves in both VSU Arboretum and Ormoc Reforestation Site. Total nitrogen content in the mature leaves ranged from 1.57 – 1.76% and 0.91 – 1.02% in the senesced leaves prior to abscission. For phosphorus, mature leaves contained 0.11 - 0.13% while the senesced leaves had only 0.05 - 0.07% (Fig. 3).

Figure 3 shows the combined analysis of the N and P contents of mature and senesced leaves in the two sites. Mature leaves of Hagakhak had the highest N content of 1.76% although it did not differ significantly with that of Bagtikan and White Lauan having 1.63% and 1.69%, respectively. Yakal-Saplungan contained the significantly lowest N (1.57%) in the mature leaves among the four dipterocarp species. For the senesced leaves all the four species had comparable amounts of N which ranged from 0.91 – 1.02% (Fig. 3).

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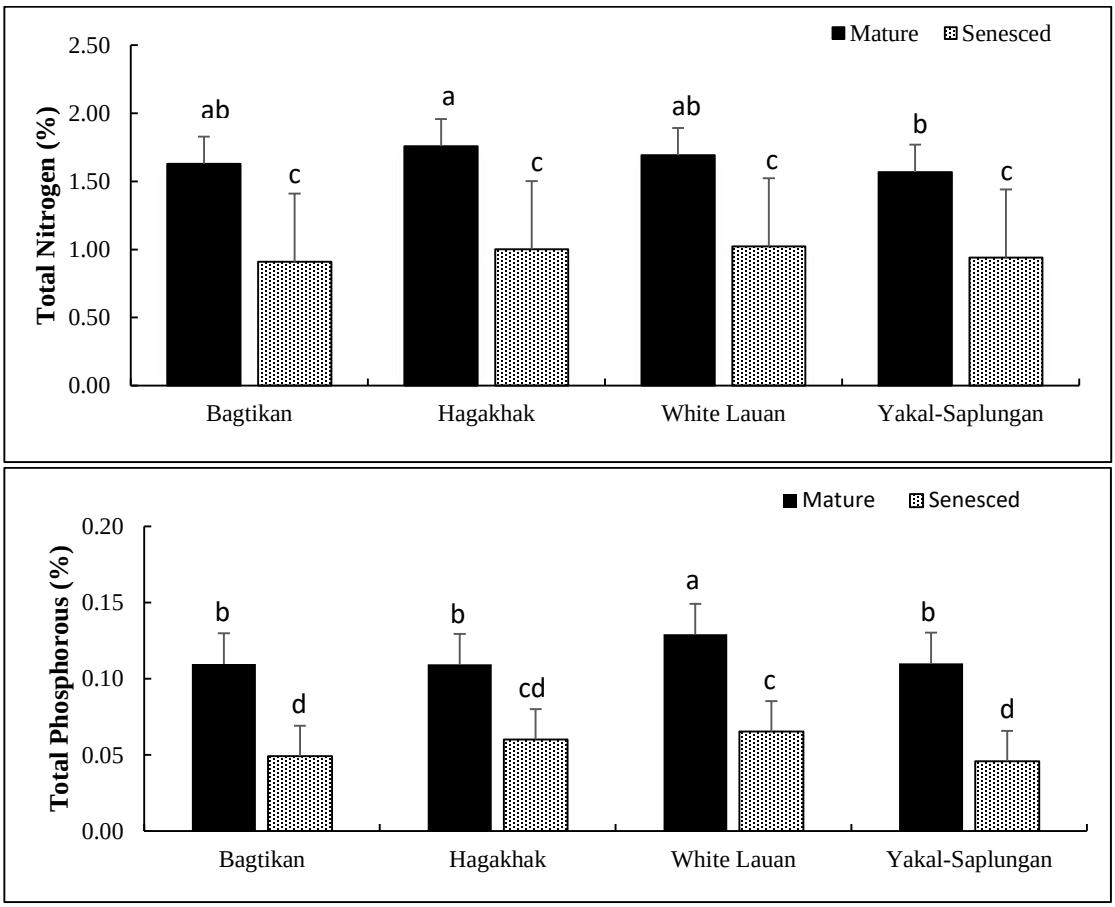

Figure 3. Total Nitrogen (%) and Total Phosphorus (%) in the leaves of different dipterocarp species in both sites

Phosphorus contents in the mature leaves of all the four species were significantly highest (0.13%) in White Lauan, while Bagtikan, Hagakhak and Yakal-Saplungan contained similar low amount of 0.11%. In the senesced leaves, Hagakhak and White Lauan had comparable P content of 0.06 – 0.07% which were significantly higher than those in Bagtikan and Yakal-Saplungan 0.046 – 0.049%, respectively (Fig. 3).

The low amounts of N and P in the senesced leaves can be due to resorption or retranslocation of some of these nutrients to the living organs especially strong sinks like young developing leaves and storage organs as a nutrient conservation strategy making them less dependent on the nutrient availability of the soil. According to [21] nutrient elements in the leaves are redistributed to the different parts of the plant prior to abscission. N and P are mobile in the plant [5] so they can easily be retranslocated from senescing leaves to the living parts.

Of the four species, Hagakhak, White Lauan and Bagtikan had consistently high N and P content in the mature leaves, whereas Yakal-Saplungan had low N but high in P. This could mean that Hagakhak, White Lauan and Bagtikan are more efficient in absorbing N from the soil. Yakal-Saplungan, on the other hand, is more efficient in absorbing P but not N (Fig. 3). These results maybe attributed to the species characteristics of these trees, such as root mass, root architecture or their ability to form mycorrhizal association with fungi in the root zone. It may also be due to leaf characteristics like leaf size or thickness. In the study of [23] some dipterocarp species such *P. malaanonan*, *Shorea* and some *Hopea* species have mychorrhizal associations in the plant roots which enhance the trees nutrient absorptive capacity from the soil.

3.3 Effect of Location of the Study Sites on N and P Contents

There was a significant effect of location (site) on the N and P contents of the leaves of the tree species. Figure 4 shows that the trees in Ormoc had significantly higher leaf nitrogen and phosphorus than those in the VSU Arboretum. This could be explained by the difference in environmental conditions such as light intensity, temperature and soil moisture content in the two sites. The Ormoc site is an open area as it is surrounded by sugarcane plantations on all sides (Fig. 1), while the VSU Arboretum has the College of Forestry and Environmental Science building on its northern side and many more forest trees on the other sides (Fig 1). The average temperature in the Ormoc site was much higher (30.86oC) than that in VSU (25.5oC) during the period of the study (weather.com). The moisture content of the Ormoc Rainforestation site was lower (26.19%) than that of VSU Arboretum (31.03%). According to Yan Zhu and Yang (2017) plants grown in higher temperature regions have higher potential evapotranspiration, thus plants have higher transpiration rates to cool the leaves, which in turn trigger faster absorption of water and nutrients from the soil.

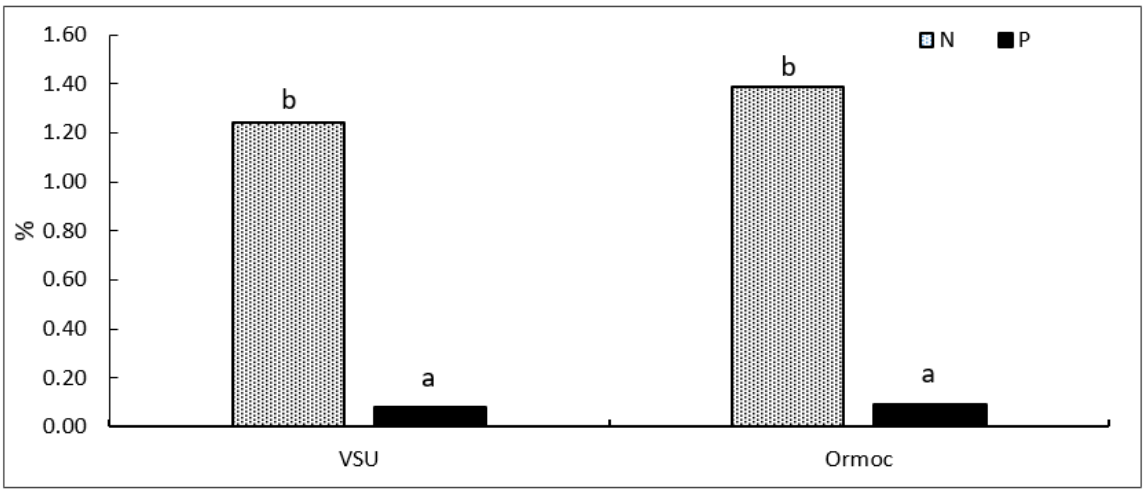

Figure 4. Total Nitrogen (%) and Phosphorus (%) content of the different dipterocarp species in both sites

There were significant differences in nitrogen and phosphorus concentrations among the dipterocarp trees in both Ormoc and VSU sites. In Ormoc, White Lauan, Bagtikan, and Yakal-Saplungan had comparably higher N and P and Hagakhak had the lowest. In VSU, N and P were higher in Hagakhak and White Lauan but low in Bagtikan and Yakal-Saplungan (Fig. 5-6). As earlier mentioned, the results could be attributed to the differences in species characteristics of the trees as well as the variation in the environmental conditions in the two sites.

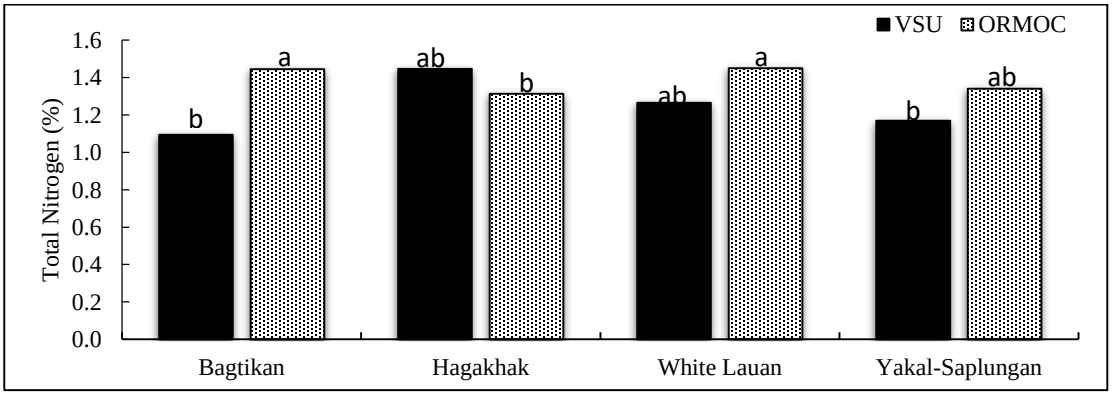

Figure 5. Total Nitrogen (%) content of the different dipterocarp species in both sites

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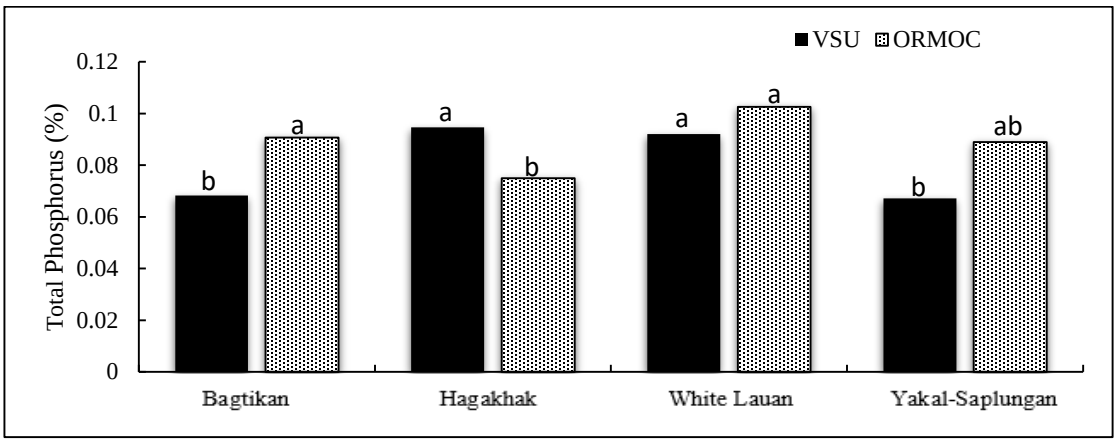

Figure 6. Total Phosphorus (%) content of the different dipterocarp species in both sites

3.4 Nitrogen and Phosphorus Resorption Efficiency

Results 2 show that the four dipterocarp species were able to resorb or retranslocate as low as 32.2% to as high as 54.6% with a mean of 41.09% of nitrogen from the senesced leaves prior to abscission (App. Table 7). Previous studies have shown that the proportion of N withdrawn from senesced leaves by resorption varies widely with species and life forms. In the study of [27] the NRE of species belonging to different species ranged from 29.8% (N-fixers) to 76.1% (herbs). [25] found in their study that trees had moderate NRE of 40-46%. Terrestrial plants in China had an average of 46.9% while Amazonian rain forest trees growing on nutrient-poor soils had an average of 48% NRE. [9], on the other hand reported NREs of as low as 5% to as high as 80% in wild plants.

There was no significant effects of site and species on the nitrogen resorption efficiency of the four dipterocarps species used in this study (Table 2, App. Table 7a). Mean NRE of the dipterocarps in the VSU Arboretum ranged from 40.18 – 43.11%, while that in Ormoc was 40.06 – 43.28%). According to [27] plants with higher N concentration in green leaves are capable of withdrawing a higher percentage of N from the senescing leaves resulting in a lower N content in the leaf litter. However, in this study, the four dipterocarp tree species did not differ significantly in their NRE both in VSU and in Ormoc despite the fact that the N contents of the mature leaves of Hagakhak, Bagtikan and White Lauan were higher and that of Yakal-Saplungan was lower, and the amount of N in the senesced leaves of all the species were comparable. Aerts [5] also found no relationship between green leaf nutrient status and resorption efficiencies. [18] reported that nutrient resorption efficiency is positively correlated with phloem transport efficiency, thus it may be possible that all the dipterocarp species used in this study possess comparable capacity for phloem transport. Resorbed nutrients like N is actively transported via phloem through abscission zones (Williams, 1955; Chapin, 1980; Hill, 1980), activated by kinetin proteins (Dela Fuente and Leopold, 1968) and recycled for the biosynthesis of lignin, which is required for the growth of new tissues (Canton et al 2005).

Table 2. Nitrogen Resorption Efficiency (NRE) in different dipterocarp species in VSU Arboretum and Ormoc Reforestation Site

Dipterocarp trees	**Nitrogen Resorption Efficiency (NRE, %)**	
	VSU	**ORMOC**
Bagtikan	40.53	42.83

Hagakhak	43.11	40.06
White Lauan	40.18	43.28
Yakal-Saplungan	41.96	41.36

Phosphorus Resorption Efficiency (PRE) of the tree species were found to be higher than their NRE. Values ranged from a PRE of as low as 36.2% - 62.1%, with a mean of 50.7% (App. Table 8). This is similar to the finding of [18] that plants resorbed more P than N. Reid et al (2012) reported that in Costa Rica, lowland tropical forests in highly weathered soils resorbed P more strongly than N. As earlier mentioned, nutrient resorption is a nutrient strategy in nutrient-poor soils. In this study the mature leaves of the four species contained higher N than P which means P was more limiting than N in the soil, thus, P resorption was higher. Nutrient resorption is higher for the scarcer nutrient than the more available one.

There was no significant effect of site but significant effect of species on PRE. Figure 6 shows that across sites, PRE was significantly highest in Yakal-Saplungan (57.46%) and lowest in Hagakhak 44.6%, although Bagtikan did not vary significantly with Yakal-Saplungan and White Lauan (47.33%) was comparable to Hagakhak. This means that Yakal-Saplungan and Bagtikan are more efficient in recycling P in the leaves compared to the other 2 species, which make them better adapted in P-deficient soils.

Table 3. Phosphorus Resorption Efficiency (%) of different dipterocarps species in the VSU Arboretum and Ormoc Reforestation Site

Dipterocarp Species	**Phosphorus Resorption Efficiency (PRE, %)**		
	VSU	**ORMOC**	**Both Sites**
Bagtikan	52.21 cc	54.71 a	53.46 ab
Hagakhak	47.32 a	42.02 bc	44.67 c
White Lauan	42.15 a	52.20 a	47.18 bc
Yakal Saplungan	62.47 cc	62.50 ab	62.48 a

3.5 N and P Resorption Efficiency of Leaves from Different Canopy Layers

Analysis of variance reveals that NRE and PRE of the four tree species did not differ significantly in the top, middle and bottom layers of the canopy. However, in all canopy layers, PRE was consistently higher than NRE (Table 3). This was corroborated by the study of Huett [26] in macadamia leaves, wherein PRE was unaffected by canopy layer. However, for NRE, the same researchers found that NRE increased with canopy height most probably due to higher photosynthetic rate as well as nutrient transport as a result of exposure to higher irradiance.

Table 4. Combined NRE (%) and PRE (%) of the different dipterocarp species at different canopy levels

Canopy Level	**NRE (%)**	**PRE (%)**
Bottom	40.05	51.64
	41.38	51.22

Middle		
Top	41.82	49.21

4. Conclusion

Based on the results of the study, N and P contents of the four dipterocarp species were consistently higher in the Ormoc Rainforestation Site than in the VSU Arboretum. Despite this, Nitrogen Resorption Efficiency (NRE) of the species were just comparable in the two sites and along the different layers of the canopy. Similarly. Phosphorus Resorption Efficiency (PRE) was likewise similar in both sites and canopy levels. This implies that nutrient content in the mature leaves does not influence NRE and PRE. However, Yakal-Saplungan and Bagtikan had significantly higher PRE which implies that they are more efficient in the recycling of P compared to Hagakhak and White Lauan. Thus, these two dipterocarp species are better adapted in P-deficient soils. The consistently high PRE compared to NRE suggests that P is more limiting than N in the soils of both sites.

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