International Research Journal of Biological Sciences ISSN 2278-3202
Vol. **3(6),** 73-82, June **(2014)** *Int. Res. J. Biological Sci.*

The Potentials of Nitrogen Fixing Tree Species for Forest Restoration in the Philippines

Combalicer M.S.[1*], Lee D.K.[2], Park Y.D.[3] and Bae K.K.[4]
[1]Department of Forest Biological Sciences, College of Forestry and Natural Resources, University of the Philippines Los Baños, College, Laguna 4031, PHILIPPINES
[2]Park Chung Hee School of Policy & Saemaul, Yeungnam University 280, Daehak-ro, Gyeongsan-si, Gyeongsangbuk-do, REPUBLIC OF KOREA
[3]Department of Forest Resources, College of Life & Environmental Science, Daegu University, Gyeongbuk 712-714, REPUBLIC OF KOREA
[4]Department of Forest and Natural Resources Management, SUNY College of Environmental Science and Forestry, Syracuse, NY 13210, USA

Available online at: www.isca.in, www.isca.me
Received 28th January 2014, revised 3rd March 2014, accepted 2nd April 2014

Abstract

A/C_i curve (net CO_2 assimilation rate, A, versus calculated internal CO_2 concentrations, C_i), foliage and soils for chemical properties were measured in some 20-year-old nitrogen fixing tree species for reforestation in the Philippines including Acacia auriculiformis, Acacia mangium and Pterocarpus indicus to determine their differences based on the derived parameters, maximum Rubisco carboxylation rate (V_{cmax}) and maximum capacity for electron transport rate (J_{max}). Results of the study showed that parameters, derived from the A/C_i curve (V_{cmax} and J_{max}), were significantly high in both A. mangium and A. auriculiformis. These species have the ability to survive in various conditions and could also serve as nurse species for other native species. This would eventually lead to subsequent succession by more site-demanding species in the future. The implication of this study is very crucial as it provided better insights about the nature of A. mangium and A. auriculiformis for reforestation purposes. Therefore, more attention should be given to ecophysiological researches by including a variety of species either exotic or native to provide greater understanding of their ecophysiological differences which would better aid forest restoration works.

Keywords: Assimilation rate, electron transport rate, internal CO_2 concentrations, Rubisco carboxylation.

Introduction

Deforestation in the Philippines has received considerable attention over the past several decades. Approximately 15.4 million of forest area disappeared by deforestation through illegal logging, shifting cultivation, fuel wood gathering, and forest fires in the Philippines[1]. Recently, at national and regional levels, trees have been planted for forest restoration in the degraded areas. At the same time, people have been interested in choosing appropriate tree species, which can survive and grow well in a barren area. For example, in tropical forests of Southeast Asia regions, in a broad perspective, studies recommended native, fast growing, and nitrogen (N) fixing tree species. However, the tree characteristics among the generally recommended tree species are not well known. Nitrogen fixing trees are well recognized for their contribution in restoring degraded areas and in improving the productivity of the land. There are various kinds of N fixing trees, either exotic or endemic, in the countries which are being used for reforestation activities needing appropriate breeding program[2].

Measurement of photosynthesis potential is one of the best ways to compare tree species to expect their growth rates during a short period. *A/C_i* curve (net CO_2 assimilation rate, *A*, versus calculated internal CO_2 concentrations, *C_i*) analysis has become a useful tool to estimate leaf photosynthesis under different environmental conditions[3]. The response function also represents the basis of using various plant physiology models[4]. Through the analysis of *A/C_i* curves the rates of carboxylation, ribulose biphosphate (RuBP) regeneration, triose phosphate export out of the chloroplast, maximum carboxylation capacity (V_{cmax}), maximum capacity for electron transport rate (J_{max}), and velocity for triose phosphate utilization can be determined[5]. This has also proven to be advantageous in developing prediction models of CO_2 assimilation for plants, to predict the effects of climate change on photosynthesis as a basis for scaling up from leaf to whole plant and/or ecosystem, and to assess the influence of occurring stresses, such as drought, salinity, extreme temperatures, and others on the photosynthetic capacity of the plant[6].

Aside from the photosynthesis capacity, it is also critical to understand the foliage and soil nutrientsto determine which tree species can continuously grow. Foliar nutrient content has been considered as an effective measure of the nutritional status of plants and has been frequently reported to be good indicator of photosynthetic rate and height and biomass increments in different types of species[7]. By absorbing nutrients from the soil, most plants grow in good condition.

While it is quick and easy to acquire the A/C_i response curves, and non-destructive, this has not been well documented in the Philippines due to unavailability of sophisticated equipment. Hence, in this study A/C_i curve, foliage and soil chemical properties were measured in three of the most frequently planted species for forest reforestation in the Philippines, including *Acacia auriculiformis*, *Acacia mangium* and *Pterocarpus indicus,* having similar age (20-year-old) to determine their differences based on the derived parameters, such as V_{cmax} and J_{max}, and leaf N and C concentration.

Material and Methods

Study sites: The study sites are in Mt. Makiling Forest Reserve (MMFR) and La Mesa Watershed in the Philippines (figure-1). MMFR is located in Los Baños, about 65 km away from Metro Manila (14^{o}08'14"N latitude, 121^{o}11'33"E longitude). It has two pronounced seasons: wet season (May to December) and dry season (January to April). The average annual precipitation, monthly temperature and monthly relative humidity measure ~2,700 mm, 20.9 to 25.9^{o}C, and 33% to 92%, respectively. The plots were establishedon the southwest slope of Mt. Makiling which is the Sitio Kay Inglesia having ~500 m asl. The area experienced cultivation and perennial forest fires until the 1990s.

La Mesa Dam Watershed (14^{o}45'N latitude and 121^{o}05'E longitude) (figure -1) is located in Metro Manila, 10 km away from Quezon City. It has two pronounced seasons: dry season (January to April) and wet season (May to December). January is the coolest month while March is the hottest. The average annual rainfall, monthly temperature and monthly relative humidity measures 2,700 mm, 24.2 to 26.6^{o}C and 22% to 94%, respectively. This study site has an elevation of ~110 m asl.

Field measurements were carried out in the 20-year-old plantations of *A. auriculiformis,A. mangium* and *P. indicus*in the MMFR, Philippines. These trees are all shade-tolerant, N fixing and fast growing species. *Acacia auriculiformis* is a well-known tropical species valuable for forestry especially in Southeast Asia and the Indian sub-continent. This species is rapidly growing with nicequality of wood and can tolerate a different climatic and soil condition[8]. Similarly, *Acacia mangium* has the same characteristics and it is well-known for its ability to compete with and suppress weedy species like *Imperata cylindrica* and *Eupatorium*. *Pterocarpus indicus* is known in Southeast Asia for its good quality of timber and is indigenous in the Philippines (called *Narra*).

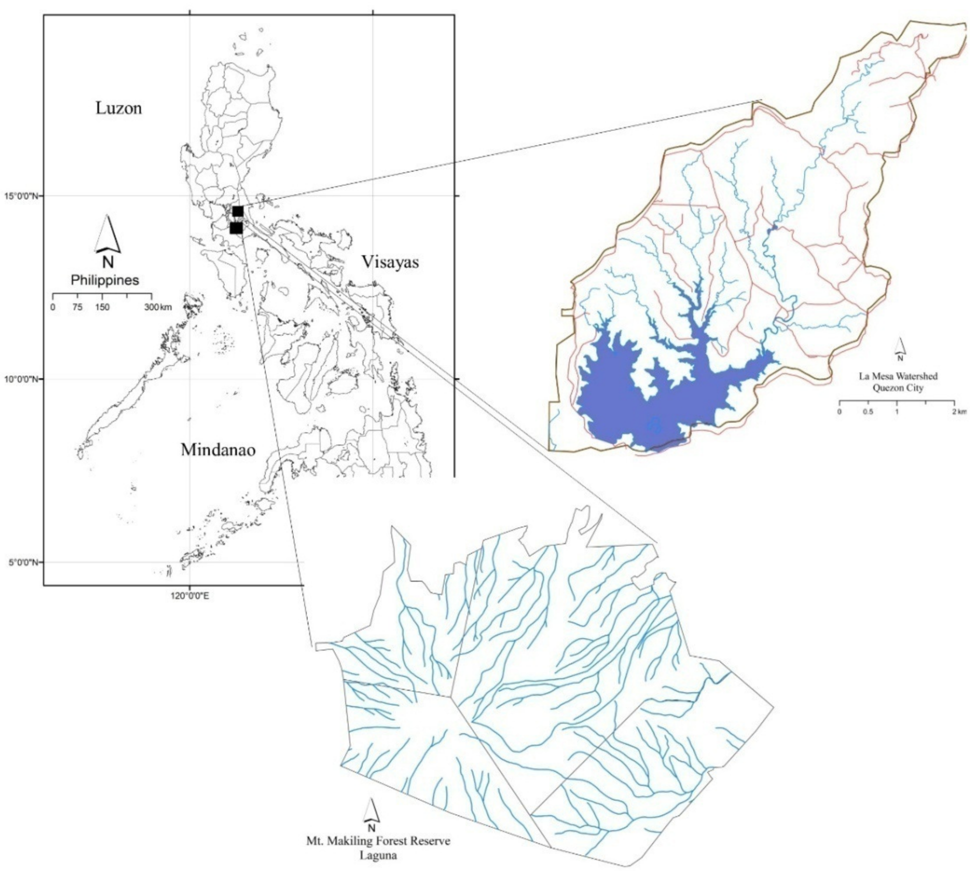


Figure-1
Location of the study site: Mt. Makiling Forest Reserve and La Mesa Watershed in the Philippines

Field layout: Three sampling plots (20 m x 20 m) were established in each of the 20-yr-old *A. auriculiformis,A. mangium*and *P. indicus* stand in MMFR, Lagunaand La Mesa Watershed in 2008 and data were gathered up to 2010.The sites have similar amount of rainfall, temperature and relative humidity. Diameter at breast height (DBH) was measured at 1.3 m aboveground of all the trees within each plot using a diameter tape while the basal area (BA) was calculated by getting the sum of individual trees' basal areas.

Leaf nitrogen and carbon concentrations: Five (5) discs wereobtained from each leaf sample (five leaf samples per plot per species) and were finely ground after oven-drying at 60°C for48 hr. To measure the leaf nitrogen, leaf samples were analyzed at the Analytical Services Laboratory of the Soils and Agro-ecosystems Division, College of Agriculture, UPLB, Laguna, Philippines. The leaf carbon concentration was analyzed at the National Instrumentation Center for Environmental Management, College of Agriculture and Life Sciences (CALS), Seoul National University (SNU), Republic of Korea.

Litterfall: Litterfall was collected monthly for one year (January 2009 to January 2010) for all three species in each plot. Four 0.25 m^2 litter traps made of fine nylon screen were mounted on wooden poles approximately 0.5 m from the ground and randomly distributed in each plot. In the laboratory, the litter was dried at 65°C for approximately 48 hr (or until constant weight was obtained) and ground to pass a 1-mm sieve. Samples were sorted into fractions, which included leaves, non-leaves (branches/twigs), and reproductive part (flowers and fruits). Total litter was obtained by adding their weights.

Foliage and soil analysis: Foliage and fresh litter samples (300 g) were combined to make a single sample as representative of each plot. Nutrients analyzed in the Analytical Services Laboratory of the Soils and Agro-ecosystems Division, College of Agriculture, University of the Philippines Los Baños, Laguna, Philippines included Ca, K, N, Mg, P, Cu, Fe, Mn and Zn. Nitrogen productivity was calculated as the ratio of the annual net primary productivity (ANPP) and the amount of foliage N.

At a depth of 0 - 30 cm using soil auger, soil samples were collected from four random positions in each plot. Samples were put into plastic bags and labeled. The fresh weight of the soils was obtained and were air-dried for 2 to 3 weeks, pulverized and sieved in 2-mm mesh wire. Thereafter, the samples were brought in the Laboratory of the Silviculture and Restoration Ecology, Department of Forest Sciences, CALS, SNU, Republic of Korea to estimate the organic matter using "loss-on-ignition" method. Soil samples (~250 g per plot) were oven-dried at 105˚C before being ignited in an electric muffle furnace at 600˚C for 4 hr. The weight of samples before and after ignition was measured. Calculation for the organic matter content (OM) is as follows:

$$\text{OM (\%)} = \frac{\text{Sample weight after ignition (g)}}{\text{Sample weight before ignition (g)}} \text{ x } 100$$

Other soil samples were then brought to the analytical services laboratory of the soils and agro-ecosystems division, College of Agriculture, UPLB, Laguna, Philippines. Soil properties, such as total N, K, P, Ca and Mg as well as pH and CEC were determined.

A/Ci curve and estimation of derived parameters (V_{cmax} and J_{max}): *A/C_i* response curves were obtained in the different portions of the sampled tree (upper, middle, and lower) between September and October 2010. One portion (*e.g.* upper) of a tree was measured in a day. Field measurements were conducted at day time (8:00 a.m. to 4:00 p.m.) under natural conditions using Li-Cor 6400 Portable Photosynthesis System (Li-Cor Inc., NE, USA) equipped with a leaf chamber (standard) and injection system (CO_2). Leaves were retained in their natural orientation. The condition of the cuvette was maintained at a photosynthetic photon flux density (PPFD), relative humidity and leaf temperature of 2000 µmol $m^{-2}s^{-1}$, 60-70%, 25°C, respectively. Cuvette's ambient CO_2 concentration (C_a) was controlled with a CO_2 mixer having a series of 30, 20, 10, 40, 50, 60, 80, 100, 160, and 200 Pa. After attaining a steady state, measurements were recorded with <2% coefficient of variation. At each C_a value, CO_2 leakage was determined into and out of the empty cuvette. The equations provided in the Li-Cor operator's manual was used[9].

The rate of maximum Rubisco carboxylation (V_{cmax}, µmol CO_2 $m^{-2}s^{-1}$) was derived by estimates of related to the initial slope of the A/C_icurve. The A/C_i curve was obtained by extrapolating the linear fitted model within 50-200 µmol^{-1}C_i using the linear equation, $A=k\ C_i + i$; where k is the initial slope of the A/C_i curve and may be described as carboxylation efficiency (*CE*), and $-i/k$ was equal to Γ* in the absence of mitochondrial respiration[10]. The rate of maximum Rubisco carboxylation (V_{cmax}) and the rate of dark respiration in µmol $m^{-2}s^{-1}$(R_d) were calculated using the following equations[11]:

$$V_{cmax} = \{k\ x\ K_c\ x\ (1 + O/K_o)]^2/[\Gamma^* + K_c\ x\ (1 + O/K_o)]\}$$

$$R_d = \{V_{cmax}\ x\ (C_i - \Gamma^*)/[C_i + K_c\ x\ (1 + O/K_c)] - (k\ x\ C_i + i)\}$$

Where K_c was 404.9 µmol mol^{-1}and K_o was 278.4 mmol mol^{-1} at 25°C, and O was 210 mmol mol^{-1}. PPFD saturated rate of maximum electron transport (J_{max}, µmol E $m^{-2}s^{-1}$) was calculated using the following equation[11,12]:

$$J_{max} = \{[4\ x\ (P'_{max} + R_d)\ x\ (C_i + 2\ x\ \Gamma^*)]/(C_i - \Gamma^*)\}$$

Weather data: Microclimate condition of the area, such as air temperature, relative humidity, and soil temperature, was measured using HOBO data logger from July 2007 up to February 2010.The data were downloaded in the field every six months. It was observed that the highest mean air temperature in

March and April in all the study sites ranged from 24.1°C to 26.6°C and 24.5°C to 26.6°C in 2007 and 2008, respectively.

Statistical analysis: Using a statistical software package (SPSS 16.0 program, SPSS Inc., Chicago, Illinois, USA), all statistical tests were performed. To estimate the derived parameters (V_{cmax}, R_d and J_{max}), regression analysis based on measured data was used. The means of variables among the stands were compared using paired t-test. Each variable was replicated into three. For multiple comparisons, Duncan's multiple range test (DMRT) was used.

Results and Discussion

Basal area: Basal area (BA) was determined by getting the total tree cross-sectional area in a stand at breast height which is 1.3 m from the ground. Among the stands, BA was significantly highest in the *A. mangium* (78.8 m^2 h^{-1}) followed by *A. auriculiformis* (75.4 m^2 h^{-1}) and *P. indicus* (15.4 m^2 h^{-1}) stand (figure-2). Stand BA is one of the quantitative measures of stand density along with other quantitative measures including the number of stems per acre and stand volume. Density also influences largely the yield and yield components of plants[13].

In terms of aboveground biomass estimation, simple linear relationship using BA was shown to be appropriate[14]. Basal area, a frequently calculated parameter in forest inventories, is certainly related to AGB, as may be realized from the fact that aboveground biomass is calculated out of the same data source - the DBH of all individual trees in the stand. In terms of species composition and other ecosystem activities, these are largely influenced by anthropogenic disturbances, climatic change among others[15].

Total leaf nitrogen and carbon concentrations: Nitrogen content of the leaves is one of the most important components that determine the important physiological processes in higher plants including respiration and photosynthesis[16]. Light is one of the major factors that regulates photosynthesis, and thereby influencing leaf characteristics such as carbon concentration and carbon/nitrogen ratio. It was found out that the total leaf nitrogen (N) and carbon (C) concentrations among the sampled tree species at different portions of the canopy and the stands were not significantly different (*p>0.05*) (figure- 3 and 4).The total N increases with shade treatment due to the changes in the specific leaf area[17]. In this study, it was found out in *A. auriculiformis* and *P. indicus* stands that total N increases with leaf area while total C was unaffected.

Species exposed under insufficient amount of light have the tendency to increase the splitting of N into chlorophyll in the thylakoids[18]. Plants also induce the adaptive mechanisms to available light condition at different levels, such as the fraction of biomass, the investment of N.

Litterfall: Annual litterfall (January 2009 to January 2010) of the study sites ranged from 2.30 to 5.72 tons ha^{-1} yr^{-1} (table - 1). It is shown in table - 1 and figure – 6 the monthly litterfall of the different sampled species. The values in this study is almost similar with the range of values obtainedin the tropical forests of Karnataka in India (3.4 to 4.2 tons ha^{-1} yr^{-1})[19]. The amount of litterfall was highest in the 20-yr-old *A. auriculiformis* and *A. mangium* (5.47 and 5.72 tons ha^{-1} yr^{-1}, respectively). When compared with other categories, the contribution of leaf litter to the total litter was higher while the contribution of barks/twigs and reproductive part was low.

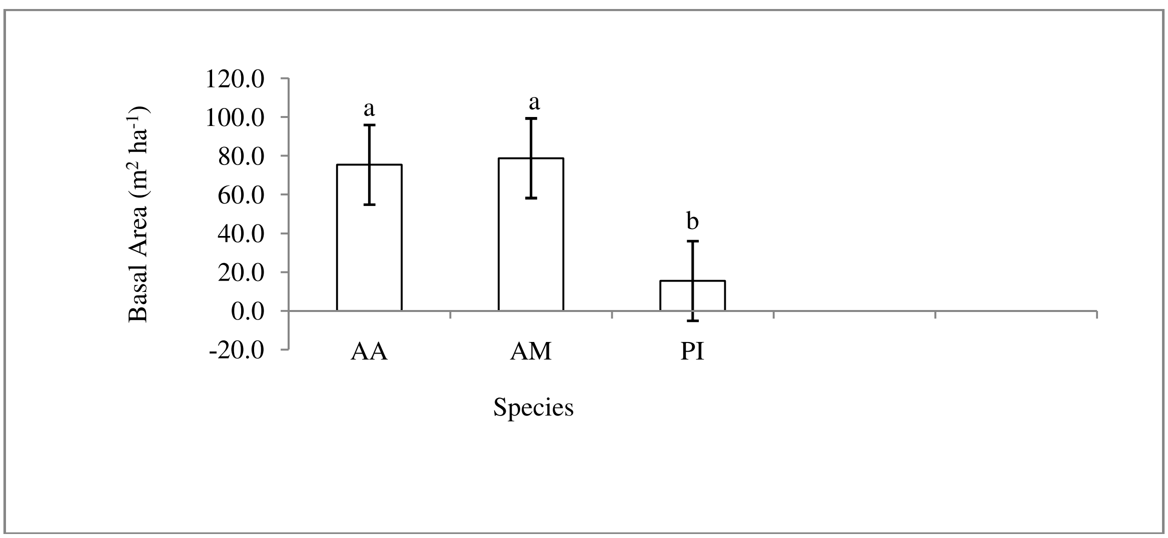


Figure-2

Species basal area observed in the study. Each bar represents the mean (with standard error). Means with the same letter are not significantly different at 5% level by DMRT (Note: AA – *Acacia auriculiformis*, AM – *Acacia mangium*, and PI – *Pterocarpus indicus*)

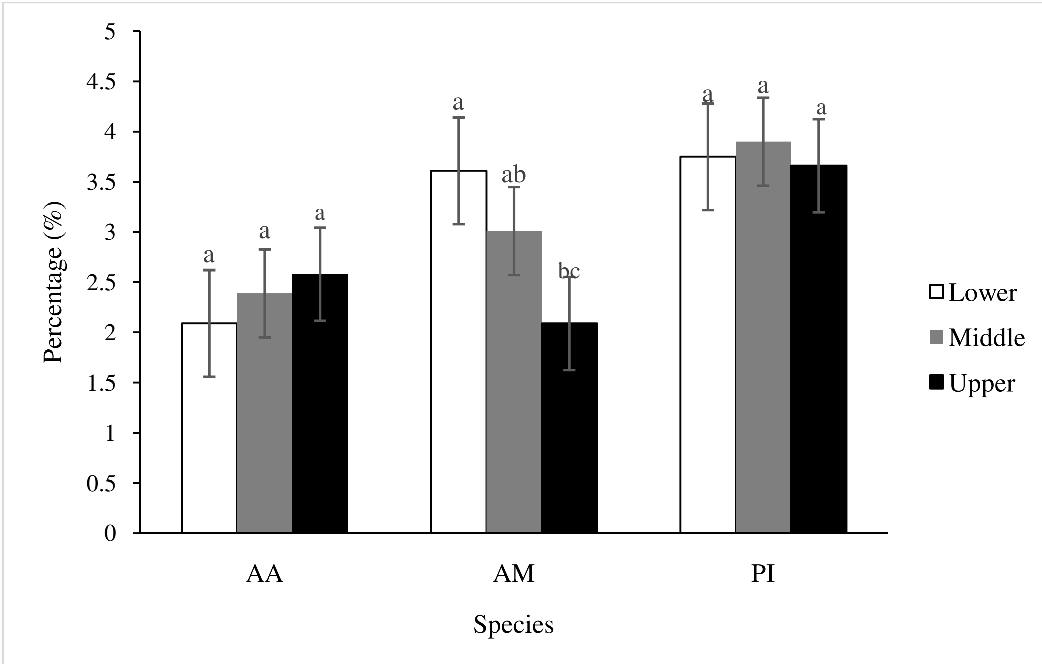


Figure-3
Leaf nitrogen concentration of the 20-yr-old stand of *Acacia auriculiformis* (AA)*, A. mangium* (AM) and *P. indicus* (PI)in the different portions of the canopy (lower, middle and upper). Each bar represents the mean (with standard error). Means with the same letter are not significantly different at 5% level by DMRT (Note: AA – *Acacia auriculiformis*, AM – *Acacia mangium*, and PI – *Pterocarpus indicus*)

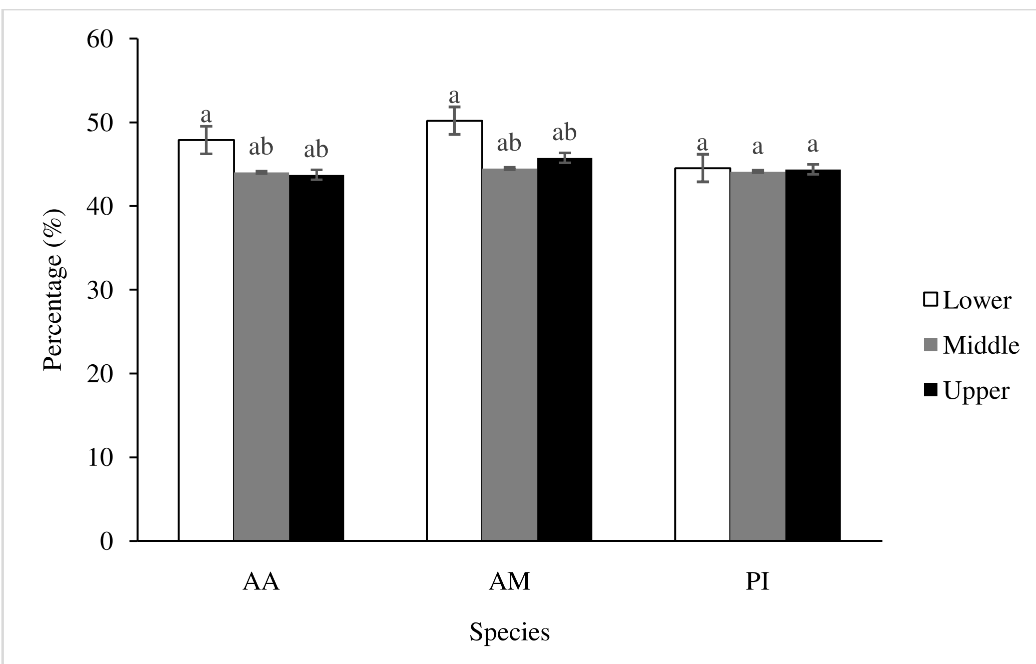


Figure-4
Leaf carbon concentration of the 20-yr-old stand of *Acacia auriculiformis* (AA)*, A. mangium* (AM) and *P. indicus* (PI)in the different portions of the canopy (lower, middle and upper). Each bar represents the mean (with standard error). Means with the same letter are not significantly different at 5% level by DMRT (Note: AA – *Acacia auriculiformis*, AM – *Acacia mangium*, and PI – *Pterocarpus indicus*)

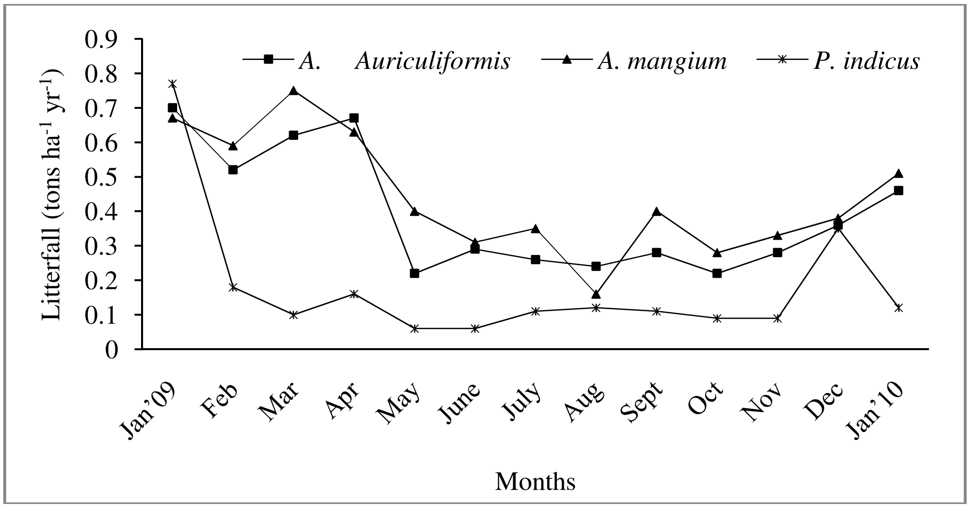


Figure-5
Monthly litterfall of the different stands from January 2009 to January 2010

Table – 1
Litter production (tons ha^{-1} yr^{-1}) in the 20-yr-old *Acacia auriculiformis, Acacia mangium* and *Pterocarpus indicus* stands

Stands	Foliar litter	Branches/ Twigs	Reproductive parts	Total litterfall
A. auriculiformis	2.68±0.5	1.93±0.2	0.86±0.1	5.47±0.6
A. mangium	4.10±0.4	1.19±0.1	0.44±0.1	5.72±0.6
P. indicus	2.45±0.2	0.83±0.1	0.81±0.2	4.08±0.1

As the amount of litterfall becomes higher the productivity in the stand also increases[20]. Different factors are affecting the patterns of litterfall in a forest ecosystem, including species composition, successional stage in its development and other microclimatic factors[21]. Hence, disparity in the patterns of litterfall is observed in this study as shown by the three species. The average amount of annual litterfall was greater in the 20-yr-old *A. auriculiformis* and *A. mangium* stands. The observed deviation in litterfall pattern may possibly be influenced bythe species composition. *Gliricidia sepium*, *Leucaena leucocephala*, *Ficus septica*, *Gmelina arborea*, *Pterocarpus indicus*, *Syzigium nitidum*, *Swietenia macrophylla*, *Calliandra calothyrsus*, and *Arthocarpus heterophyllus*are the other species that contribute greatly in addition to the common species (*A. auriculiformis*) to the total litter production. Likewise, in the *A. mangium* stand, *L. leucocephala*, *F. septica*, *P. indicus*, *S. nitidum*, *S. macrophylla* and *C. calothyrsus*greatly contributed in the total litter production. Consequently, it can be infer in this study that the composition of the species and their contribution to litter production are crucial in determining the total litter of the community as demonstrated by*A. auriculiformis* and *A. mangium* stands.

Yearly cycle of environmental parameters largely affects the periodicity of litterfall. The highest amount of litterfall (0.45 to 0.77 tons ha^{-1} yr^{-1}) happened from January to April, which is dry season in the Philippines (figure-5). This is also the same with the results of other studies having higher yield during summer, *e.g.* deciduous plantations. Climate change could also be a contributory factor in the changes that is occurring in the forest[22].

Foliage and soil analyses: The analysis of foliage is important in determining the nutrient status of the plant and for appropriate application of fertilizers. The level of nutrients in the plant often varies. However, in this study the foliage nutrients did not much vary among the species (*p>0.05*) (table - 2). The important factor controlling the growth of plantation is the nutrients which can be made available to the plant through fertilizer application. This amount of nutrients could vary depending on the species, age and the productivity of the stand[23].

Overall, the 20-yr-old *A. auriculiformis* (267.23 kg kg^{-1} yr^{-1}) and *A. mangium* (221.72 kg kg^{-1} yr^{-1}) had the highest increase in plant dry mass per unit plant N per unit time(NP).The N deposition effect, CO_2 level increase in the atmosphere, and forest management practices can contributeto the increase in NP[24]. The role of nitrogen fixing species is important in enriching the nitrogen content in the soil. It was suggested in earlier studies the use of N fixing species could improve quality and quantity of litters as well as increase the above and belowground productivity[25].

Soil analysis: In terms of soil pH and N, insignificant difference (*p>0.5*) was observed in all the stands while other nutrients exhibited significant difference ($p<0.03$) (table - 3). The soil organic matter (SOM), K, Ca, Mg and CEC were high in the 20-yr-old *A. auriculiformis* stand (6.25% and 2.53 cmol(+)/kg, 10.7 cmol(+)/kg, 5.2 cmol(+)/kg, and 38.3 cmol (+)/kg, respectively) and *A. mangium* stand (5.79%, 2.03 cmol(+)/kg, 8.9 cmol(+)/kg, 4.7 cmol(+)/kg, and 32.3 cmol(+)/kg, respectively). The higher soil nutrients in MMFR could be attributed to its quite low soil temperature and elevation.

A/Ci curve and estimation of derived parameters (V_{cmax} and J_{max}): In all the studied species, strong relationship ($R^2=0.81$ to 0.92) was observed between A and C_i. Based on the analysis, it was found out that, upper portion of the canopy of*A. mangium* stand had the highest A/C_irate with peak value of 12.78 µmol CO_2 $m^{-2}s^{-1}$ under 600 µmol mol^{-1} C_i, while the lowest peak rate was obtained by *P. indicus* stand in the lower portion of the canopy with value of 8.87 µmol CO_2 $m^{-2}s^{-1}$ under 600 µmol mol^{-1} C_i (figure - 6).

There are many underlying assumptions in the analysis of A/C_i curves or net photosynthesis. By estimating V_{cmax} on the A/C_i curve the influence of the C_i value on the Rubisco and electron transportwas examined. There's a considerable variability among the species in terms of A, in which environment explains part of this variation and therefore produces different patterns of response[26]. Also, at the species level, A varied in concert with assimilation capacity and stomatal conductance. At community level, there is no seasonal influence over A.

V_{cmax} and J_{max} are key parameters of the A/C_i model and they vary by species. These parameters also vary with temperature[27]. Analysis of the V_{cmax} and J_{max} gives us insight into the potential to photosynthesize at a given CO_2 concentration that is independent of stomatal limitations[28]. For instance, highly productive herbaceous species were reported to have consistently higher rates of both V_{cmax} and J_{max} than slower growing woody species. In this study, it was observed that V_{cmax} and $J_{max}$are significantly different ($p<0.01$) among the studied species (figure - 7). The highest V_{cmax} and J_{max} observation was obtained by 20-yr-old *A. mangium* with an average value of 72.24 µmol CO_2 $m^{-2}s^{-1}$ and 210.15 µmol E $m^{-2}s^{-1}$, respectively.

Table - 2
Foliar nutrients and nitrogen productivity (NP) of 20-yr-old *Acacia auriculiformis*, *Acacia mangium* and *Pterocarpus indicus* stands

Species/Age class	Ca(%)	K (%)	Mg (%)	N (%)	P (%)	Cu (ppm)	FeCu (ppm)	Mn (ppm)	Zn (ppm)	NP (kg $kg^{-1}yr^{-1}$)
Acacia auriculiformis										
	2.44^{a} (0.20)	0.25^{ab} (0.10)	0.32^{ab} (0.02)	2.84^{ab} (0.02)	0.06^{ab} (0.10)	1.1^{a} (0.17)	332^{c} (0.48)	208^{b} (0.04)	44^{b} (0.42)	267.23^{a} (0.31)
Acacia mangium										
	1.85^{ab} (0.02)	0.05^{ab} (0.10)	0.41^{ab} (0.03)	3.18^{a} (0.50)	0.05^{ab} (0.10)	1.3^{a} (0.12)	1220^{a} (0.39)	272^{a} (0.11)	39^{b} (0.54)	221.72^{ab} (0.29)
Pterocarpus indicus										
	2.39^{a} (0.50)	0.35^{a} (0.10)	0.65^{a} (0.06)	3.19^{a} (0.50)	0.16^{a} (0.10)	0.9^{ab} (0.23)	2985^{b} (0.25)	233^{ab} (0.13)	86^{a} (0.21)	143.80^{bc} (0.41)

Standard errors of the means are given in parentheses. Means within a column with the same letter are not significantly different at 5% level by DMRT

Table - 3
Soil characteristics of 20-yr-old *Acacia auriculiformis*, *Acacia mangium* and *Pterocarpus indicus* stands in Mt. Makiling Forest Reserve, Philippines

Age class	pH	OM (%)	N (%)	P (ppm)	K (cmol(+)/kg)	Ca (cmol (+)/kg)	Mg (cmol (+)/kg)	CEC (cmol (+)/kg)
Acacia auriculiformis								
	4.9^{a} (0.30)	6.25^{a} (0.10)	0.35^{a} (0.08)	0.6^{b} (0.19)	2.53^{a} (0.61)	10.7^{a} (2.18)	5.2^{a} (2.67)	38.3^{a} (2.68)
Acacia mangium								
	4.6^{a} (0.10)	5.7^{a} (0.2)	0.33^{a} (0.04)	1.3^{ab} (0.23)	2.03^{ab} (0.52)	8.9^{ab} (2.44)	4.7^{a} (2.44)	32.3^{ab} (2.71)
Pterocarpus indicus								
	4.7^{a} (0.10)	3.55^{b} (0.2)	0.25^{ab} (0.03)	3.1^{a} (0.77)	0.35^{b} (0.08)	7.9^{ab} (1.92)	2.8^{ab} (0.23)	13.6^{b} (0.53)

Standard errors of the means are given in parentheses. Means within a column with the same letter are not significantly different at 5% level by DMRT

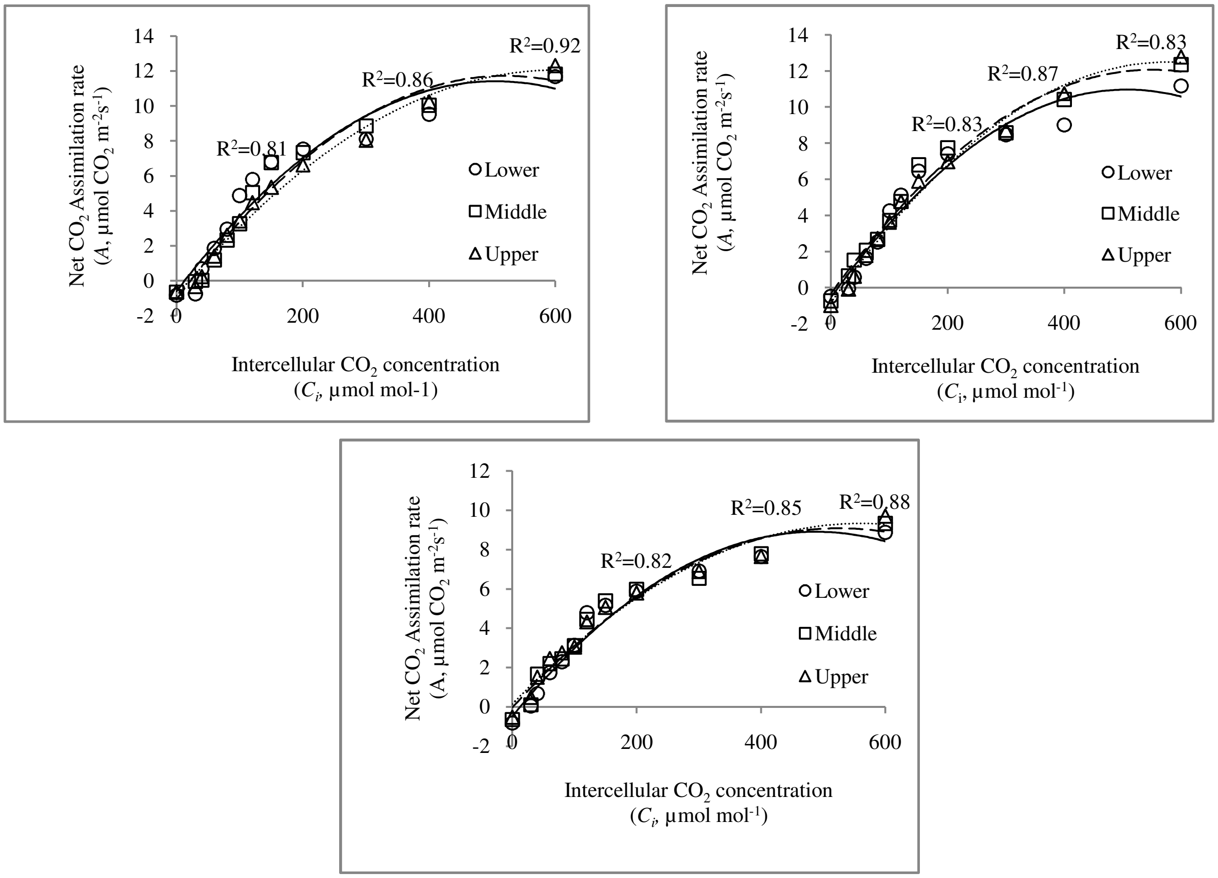
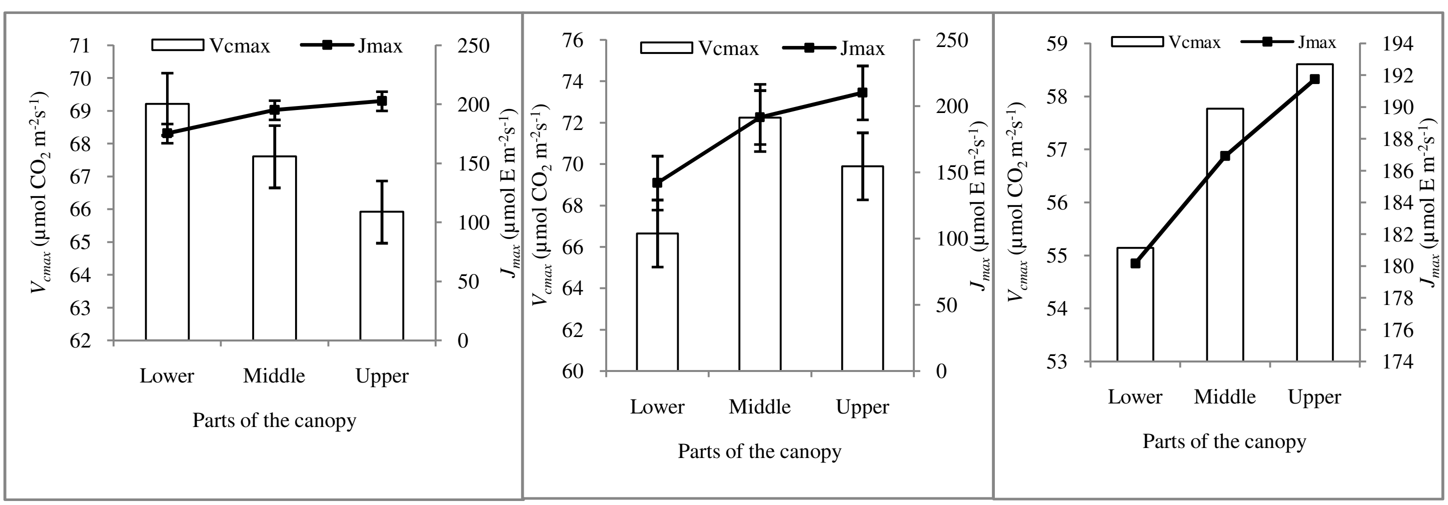


Figure – 6

A/C_icurves of 20-yr-old (A) *Acacia auriculiformis*, (B) *Acacia mangium,* and (C) *Pterocarpus indicus* stands in the lower, middle and upperportions of the canopy, Values are the mean ± S.D. (n = 3)



(a) (b) (c)

Figure-7

Estimated $V_{cmax}$and J_{max} of the 20-yr-old (A) *Acacia auriculiformis*, (B) *Acacia mangium* and (C) *Pterocarpus indicus* stands in the lower, middle and upper portions of the canopy

V_{cmax} parameter is important to describe precisely the Rubisco activity which describes the efficiency of the Calvin cycle. Based on the A/C_i curve analysis, it is assumed that C_i is nearly equal to chloroplast CO_2 concentrations. The lower V_{cmax} is influenced by the reduced amount of resource allocation to photosynthetic processes (*i.e.* Rubisco and chlorophyll per unit N), high amount of inactivated Rubisco, or lower stomatal conductancevalues[29].

As a whole, A/C_i, V_{cmax} and J_{max} were found highest in the *A. auriculiformis* and *A. mangium* stands than *P. indicus*. A/C_i declined due to high temperature that reduces the capacity for electron transport and increases the rate of CO_2 evolution from other sources and photorespiration[30].

Conclusion

The study revealed that parameters derived from the A/C_i curve (V_{cmax} and J_{max}), were high in both *A. mangium* and *A. auriculiformis* that gives us insight of the potential of these species to photosynthesize at a given CO_2 concentration. Also, based on the results obtained, *A. auriculiformis* and *A. mangium* exhibited better performance as they had the highest value in terms of NP as influenced by their higher leaf area, biomass accumulation and N inputs. Since *A. auriculiformis* and *A. mangium* species are fast growing and could easily develop their growth and coverage, they had an advantage of gaining more height and DBH over the native species.

The implication of this ecophysiological study is very crucial as it provided a great degree of generalization about the nature of *A. mangium* and *A. auriculiformis* in choosing them for reforestation purpose. It is also about high time to include ecophysiological studies in doing species trial for forest plantations in the country. With the results obtained in this study, it is therefore recommended toconsider physiological research with the inclusion of a variety of tree species and age classes so that the pattern and ecological features of each species can be clearly understand.

Acknowledgement

Acknowledgement is given to the staff of the Makiling Center for Mountain Ecosystems (MCME) in UPLB and the ABS-CBN *Bantay Kalikasan* in La Mesa Watershed for their assistance during field works. Gratitude is also given to the ASEAN-Korea Environmental Cooperation Project (AKECOP) for their financial support in this endeavor.

References

1. Lasco R.D. and Pulhin F.B., The mountain ecosystems of the Philippines: opportunities for mitigating climate change, University of Oxford, UK, December **(1997)**

2. Dhabhai R. and Prakash A., Production and Applications of Artificial seeds: A Review, *Int. Res. J. Biological Sci.,* **1(5),** 74-78 **(2012)**

3. Sharkey T.D., Bernacchi C.J., Farquhar G.D. and Singsaas E.L., Fitting photosynthetic carbon dioxide response curves for C_3 leaves, *Plant Cell Environ*., **30**, 1035-1040**(2007)**

4. Díaz-Espejo A., Walcroft A.S., Fernández J.E., Hafidi B., Palomo M.J. and Girón I.F, Modeling photosynthesis in olive leaves under drought conditions, *Tree Physiol.,***26,** 1445 – 1456 **(2006)**

5. Flexas J., Diaz-Espejo A., Berry J.A., Cifre J., Galmes J., Kaldenhoff R., Medrano H. and Ribas-Carbo M., Analysis of leakage in IRGA's leaf chambers of open gas exchange systems: quantification and its effects in photosynthesis parameterization. *J. Exp. Bot*.,**58(6),** 1533-1543 **(2007)**

6. Woodward I., Smith T.M. and Emmanuel W.R., A global land primary productivity and phytogeography model, *Global Biogeochem Cy*., **9,** 471-490**(1995)**

7. Ansari A., Biomass: Energy and Environmental Concerns in Developing Country, *Int. Res. J. Biological Sci.,* **1(1),** 54-57 **(2012)**

8. Eldoma A. and Awang K.,*Site adaptability of Acacia mangium, Acacia auliculiformis, Acacia crassicarpa and Acacia aulacocarpa*. APAFRI Publication Series **No. 3**. Asia Pacific Association of Forestry Research Institutions, Kuala Lumpur, Malaysia **(1999)**

9. Bernacchi C., Singsaas E., Pimentel C., Portis Jr. A. and Long S., Improved temperature response functions for models of Rubisco-limited photosynthesis, *Plant Cell Environ*., **24,** 253-259 **(2001)**

10. Laisk A.K.,*Kinetics of photosynthesis and photorespiration in C_3 plants*. Nauka, Moscow **(1977)**

11. Kwak M.J.,*Growth and physio-biochemical parameters changes in response to water and light intensity on Cork Oak (Quercus suber L.) Seedlings*, M.Sc. Thesis. Department of Environmental Horticulture, Graduate School, University of Seoul, 137 **(2010)**

12. Loustau D., Brahim M.B., Gaudillere J.P. and Dreyer E., Photosynthetic responses to phosphorus nutrition in two-year-old maritime pine seedlings. *Tree Physiol*.,**19,** 707-715**(1999)**

13. Srivastava N. and Kumar G., Biomass productivity of Green Manure crop *Sesbania cannabina* Poir (Dhaincha) in different Planting Density Stress, *Int. Res. J. Biological Sci.,* **2(9)**, 48-53**(2013)**

14. Chiba Y., Architectural analysis of relationship between biomass and basal area based on pipe model theory, *Ecol. Model.,* **108 (1-3)**, 219-225**(1998)**

15. Dangwal L.R. and Singh T., Comparative Vegetational Analysis and *Pinus roxburghii* Sarg regeneration in relation to their disturbances in some Chirpine forest of block Nowshera, district Rajouri, J and K, India, *Int. Res. J.*

Biological Sci., **1(1),** 47-54 **(2012)**

16. Makino A. and Osmond B., Effects of nitrogen nutrition on nitrogen partitioning between chloroplasts and mitochondria in pea and wheat. *Plant Physiol.,***96,** 355-362 **(1991)**

17. Aranda I., PardosM., PuertolasJ., JimenezM.D.and Pardos J.A. Water use efficiency in cork oak (*Quercus suber*) is modified by the interaction of water and light availabilities. *Tree Physiol*.,**27**, 671-677 **(2007)**

18. Evans J.R., Photosynthesis and nitrogen relationships in leaves of C_3 plants. *Oecologia*,**78**, 9-19**(1989)**

19. Rai, S.N. and Proctor, J., Ecological studies on four forests in Karnataka, India. Environment, structure, floristics and Biomass.*J. Ecol*.,**74**, 439–454**(1986)**

20. Forrester D.I.,*Mixed-species plantations of nitrogen-fixing and non-nitrogen-fixing trees*. Ph.D. Dissertation. Australian National University **(2004)**

21. Sundarapandian S.M. and Swamy P.S., Litter production and leaf-litter decomposition of selected tree species in tropical forests at Kodayar in the Western Ghats, India. *Forest Ecol. Manag.*, **123,** 231-244. **(1999)**

22. Suryavanshi P., Babu S. and Baghel J.K., Impact of Climate Change on Agriculture and their Mitigation Strategies for Food Security in Agriculture: A Review. *Int. Res. J. Biological Sci.,* **1(3)**, 72-77**(2012)**

23. Turner J. and Lambert M.J., Nutrient cycling in age sequences of two Eucalyptus plantation species. *Forest Ecol. Manag*., **255,** 1701–1712 **(2008)**

24. Jandle R., Neumann M. and Eckmüllner O., Productivity increase in Northern Austria Norway spruce forests due to changes in nitrogen cycling and climate. *J. Plant Nutr. Soil Sc.,***170 (1),** 157-165**(2007)**

25. Liu S. Effects of seabuckthorn on tree growth and biomass production of poplar plantations in a sub-humid-arid area of China. *Acta Phytoecol. Sin.*,**24 (2),** 169-174**(2000)**

26. Domingues T.F., Meir P., Lloyd J., Grace J. and Ishida F.Y.,*Unravelling the role of leaf nitrogen and phosphorus over photosynthetic capacity*. 23rd New Phytologist Symposium. Carbon Cycling in Tropical Ecosystems. Yanling Hotel, Guangzhou, China 17–20 November **(2009)**

27. Medlyn B.E., Dreyer E., Ellsworth D., Forstreuter M., Harley P.C., Kirschbaum M.U.F., Le Roux X., Montpied P., Strassemeyer J., Walcroft A., Wang K. and Loustau D. Temperature Response of parameters of a biochemically based model of photosynthesis. II. A review of experimental data. *Plant Cell Environ*.,**25**,1167-1179**(2002)**

28. Wullschleger S.D., Biochemical limitations to carbon assimilation in C_3 plants—a retrospective analysis of the A/C_icurves from 109 species. *J. Exp. Bot.,***44**, 907–920**(1993)**

29. Manter D.K. and Kerrigan J., A/C_i curve analysis across a range of woody plant species: influence of regression analysis parameters and mesophyll conductance. *J. Exp. Bot.,* **55(408)**, 2581–2588 **(2004)**

30. Farquhar G. and Sharkey T., Stomatal conductance and photosynthesis. *Ann. Rev. Plant Physio.,* **33,** 317-345**(1982)**