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Seasonal pattern of photosynthetic rate and its relationship with chlorophyll content, ribulose-1,5-bisphosphate carboxylase activity and biomass production

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Abstract

Net photosynthetic rate (P_N), ribulose-1,5-bisphosphate carboxylase (RuBPC) activity, chlorophyll (Chl) content and biomass production were estimated at monthly intervals in *Chukrasia tabularis, Dolichandrone atrovirens, Eugenia jambolana, Gmelina arborea, Lannea coromandelica, Terminalia arjuna* and *Terminalia bellerica* from September 1990 to August 1991. The leaves of all the seven tree species showed significantly higher P_N during summer than in winter and these rates differed from one species to the other. A positive correlation was found between P_N of different tree species and their Chl content or biomass production. There was no significant correlation between ribulose-1,5-bisphosphate carboxylase activity and P_N when these were expressed on leaf area basis.

Key words: Chukrasia tabularis, Dolichandrone atrovirens, Eugenia jambolana, Gmelina arborea, Lannea coromandelica, Terminalia arjuna, Terminalia bellerica.

Introduction

Studies on seasonal changes in P_N and its relationship with Chl content and biomass production are scanty in tropical deciduous tree species. Therefore, we studied the seasonal changes in some selected tropical deciduous tree species which are widely used in afforestation, agroforestry and social forestry programmes in India.

Materials and methods

Plants: Seeds of selected forest tree species *Chukrasia tabularis* A. Juss. (*Meliaceae*), *Dolichandrone atrovirens* (Heyne ex Roth) Sprague (*Bignoniaceae*),

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Gmelina arborea Roxb. (*Verbenaceae*), *Lannea coromandelica* (Houtt.) Merr. (*Anacardiaceae*), *Terminalia arjuna* (Roxb. ex DC.) Wright & Arn. (*Combretaceae*) and *Terminalia bellarica* (Gaertn.) Roxb. (*Combretaceae*) were obtained from the Forest Department of Tirupati Division, India. Healthy seeds of uniform size were sown in polythene bags containing a mixture of three parts of red sandy loam soil and one part of farmyard manure. The saplings were grown in an open air under natural photoperiod in the experimental botanical garden. One-year-old saplings (200) were transplanted in a plot of 120 × 15 m and with a spacing of 3 × 3 m between the plants and rows and these were allowed to grow under natural photoperiod.The collection of data was initiated on plants at the age of two years and continued from September 1990 to August 1991. At the age of two years, all tree species were 1.4 to 2 m high, bearing 100 to 130 leaves. The tree species studied were broad-leaved and did not exhibit definite pattern of leaf fall at the age of 2 - 3 years.

Table 1. Seasonal variations in temperature, humidity, rainfall and sunshine hours. Each value represents monthly average.

Month	Temperature [°C]		Humidity [%]		Total rainfall	Sunshine
	maximum	minimum	maximum	minimum	[mm]	[h per d]
September 1990	35.0	24.6	71	50	143.6	6.0
October	30.9	23.0	84	66	230.5	4.9
November	30.3	20.4	81	61	307.7	6.4
December	29.0	18.5	80	63	26.8	7.9
January 1991	30.3	18.2	79	49	2.7	9.4
February	32.9	17.8	75	38	—	10.2
March	35.8	22.0	69	29	—	10.4
April	37.7	25.7	64	26	—	9.4
May	37.9	27.7	65	33	28.4	9.7
June	33.5	25.6	73	51	216.3	5.3
July	32.4	24.7	72	52	153.1	3.8
August	32.2	25.0	72	52	257.2	4.2

Twenty plants of each tree species were randomly selected at monthly intervals for the estimation of their biomass production. At the time of sampling, plants were well watered and carefully uprooted to avoid loss of root system. Plants were then separated into roots, stems and leaves. The plant samples were washed under tap water and dried in open air under sunlight. The air dried samples were then dried at 80 °C to a constant dry mass.

RuBPC assay: Fully expanded leaves (second or third from the shoot tip) were extracted, unless otherwise specified, by 50 mM Tris-HCl buffer, pH 7.8, containing 1 mM EDTA, 2 mM $MgCl_2$, 5 mM dithiotreitol (DTT), and 10 mM 2-mercaptoethanol (Andrews *et al.* 1987). Freshly harvested leaves (1 g) were cut into small bits with a razor blade and ground vigorously in a pre-chilled mortar using four volumes of semi-frozen extraction medium. The homogenate was filtered through four layers of cheese cloth. An aliquot of the filtrate was assayed for total Chl content using the spectrophotometric method of Arnon (1949). The filtrate was centrifuged at 10 000 *g* for 15 min in a refrigerated centrifuge (*C-24, Remi Sales & Engineering*, Bombay, India). All the above operations were carried out 0 - 2 °C in a walk-incooler. The enzyme assays were performed at 30 ± 1 °C. The activity of RuBPC (E.C. 4.1.1.39) was assayed by observing the incorporation of radioactive bicarbonate into acid stable products (Raghavendra and Das 1977). The mixture (3.0 cm^3) contained 50 mM Tris-HCl buffer, pH 7.8, 3 mM DTT, 10 mM $MgCl_2$, 10 mM $NaH^{14}CO_3$ (11.1 GBq mol^{-1}), 0.5 mM RuBP, and the enzyme extract. After pre-incubation for 5 min, the reaction was started with the addition of 1 cm^3 of 4 M HCl. An aliquot was then examined for incorporated radioactivity, using the liquid scintillation counter *Beckman* model *170*.

Photosynthetic parameters: The leaf area of each plant species was estimated using a photoelectric area meter (*LICOR* model *LI-3100*, Lincoln, USA). Monthly variations in P_N were measured on three attached fully expanded leaves (second or third from the shoot tip) of three individual plants for each species. Ten observations were taken at monthly intervals for a period of one year. An open system with an infra-red CO_2 analyser (*LCA-2, Analytical Development Co.*, Herts, U.K.) was used. The chamber position after inserting the leaf was identical to the natural position of the leaf.

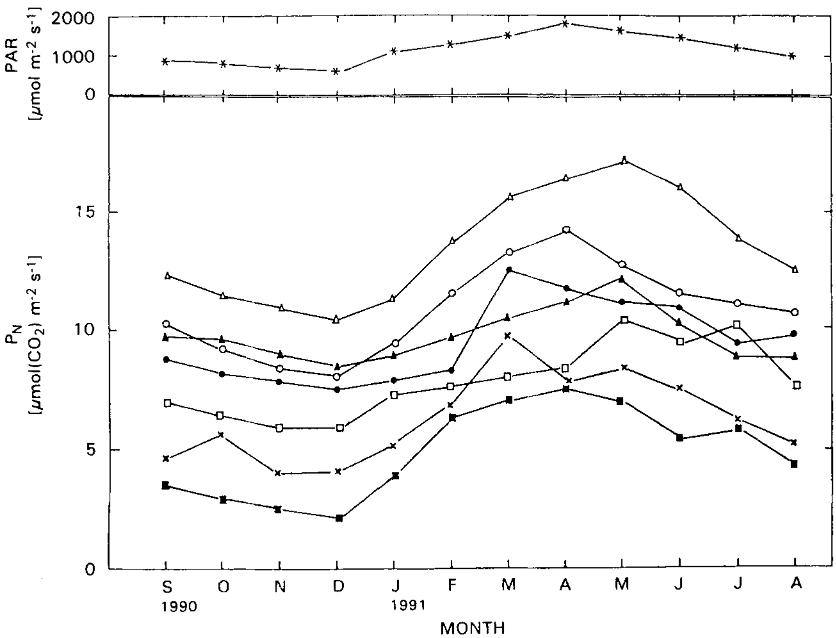


Fig. 1. Monthly changes in photosynthetic rates of leaves in seven tropical deciduous forest tree species. *Chukrasia tabularis* (*crosses*), *Dolichandrone atrovirens* (*open squares*), *Eugenia jambolana* (*closed squares*), *Gmelina arborea* (*closed circles*), *Lannea coromandelica* (*open circles*), *Terminalia arjuna* (*open triangles*), and *Terminalia bellerica* (*closed triangles*).

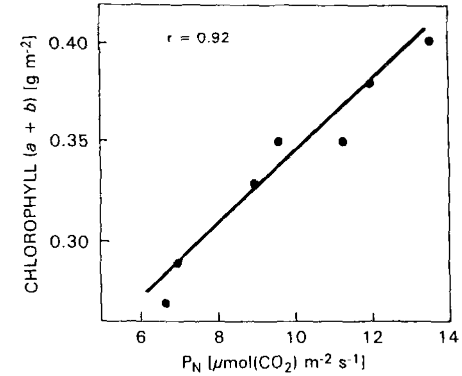
Measurements of P_N were made at an irradince of 1400 ± 50 and 850 ± 50 µmol (quantum) m^{-2} s^{-2} (direct sunlight) in summer and winter, respectively. At the time of P_N measurements, the atmospheric relative humidity and temperature were 40 ± 5 and 33 ± 2 °C in summer and 55 ± 10 and 27 ± 2 °C in winter, respectively. Monthly total Chl content, P_N and RuBPC activities were measured between 10.00 to 11.00 under full natural sunlight. The results were subjected to analysis of variance (*ANOVA*) and correlation statistical analysis.

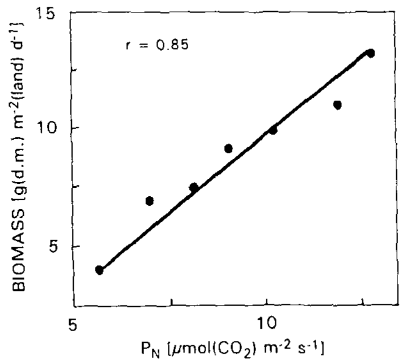
Results and discussion

High temperature, low humidity, long sunshine hours, scanty and erratic precipitation with minimum number of rainy days prevailed during the hot summer (February - July). But in winter season (August - January), the number of sunshine hours was decreased which was associated with an increase in humidity, precipitation and the number of rainy days. The P_N of different tree species varied from month to month and also from one tree species to the other. Further, the P_N of leaves did not reach maximum value during the same month in all tree species studied. The leaves of *G. arborea*, and *C. tabularis* showed maximum P_N in March, of *L. coromandelica* and *E. jambolana* in April, of *T. arjuna*, *T. bellerica* and *D. atrovirens* in May (Fig. 1). Among the different tree species studied, mean P_N was highest in *T. arjuna* [13.15 µmol(CO_2) m^{-2} s^{-1}] followed by *L. coromandelica* [11.27 µmol(CO_2) m^{-2} s^{-1}], *G. arborea* [10.11 µmol(CO_2) m^{-2} s^{-1}], *T. bellerica* [9.25 µmol(CO_2) m^{-2} s^{-1}], *D.atrovirens* [8.43 µmol(CO_2) m^{-2} s^{-1}], *C. tubularis* [6.16 µmol(CO_2) m^{-2} s^{-1}] and *E. jambolana* [5.41 µmol(CO_2) m^{-2} s^{-1}]. P_N was significantly higher during summer than in winter in all tree species studied. The decrease in P_N observed during winter season may be due to the decrease in temperature, irradiance and sunshine hours. The P_N showed a gradual increase in early spring until the summer which exhibited maximum temperature and irradiance. Similar results were reported in other broad-leaf tree species (Bhatt 1989). The *ANOVA* test showed significant differences in P_N between the season ($P < 0.01$) and species ($P < 0.05$). These results are in agreement also with the reports on coniferous tree species (Schulze *et al.* 1967, Drew and Leding 1981).

A clear positive correlation ($r = 0.92$; $P < 0.01$) was found between P_N and Chl content in all seven tree species studied on the basis of leaf area (Fig. 2). Similar correlation was observed earlier in *Quercus* species (Spyropoulos and Mavrommatis 1978). A significant positive correlation ($r = 0.85$; $P < 0.01$) was also found between P_N and biomass production (Fig. 3). However, there was no significant correlation ($r = 0.52$; $P > 0.05$) between RuBPC activity and P_N on leaf area basis among the tree species studied (Fig. 4). Earlier reports have indicated that the activities of this enzyme may not limit the P_N. For example, the very high activity of RuBPC in wheat leaves were not associated with high P_N (Sinha and Rajagopal 1980, Aggarwal and Sinha 1984).

According to the present results, P_N and Chl content in leaves of different tree species varied with the changes in the environmental factors, which in turn





Figs. 2 and 3. Relationship between net photosynthetic rate (P_N) and chlorophyll (Chl) content of seven tree species studied. Each point presents the mean of 12-month observations during the period of one year (Fig. 2), and between net photosynthetic rate (P_N) and biomass production (Fig. 3).

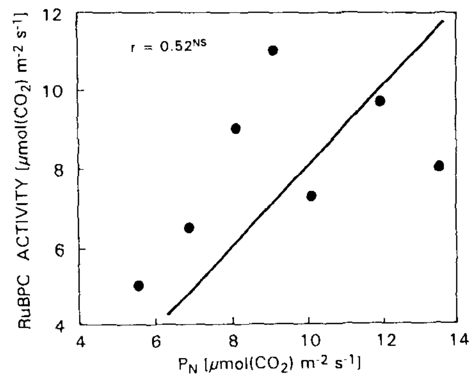


Fig. 4. Relationship between net photosynthetic rate (P_N) and ribulose-1,5-bisphosphate carboxylase (RuBPC) activity of seven tree species studied (*c.f.* Fig. 2 for details)

influenced the biomass production of tree species. Thus, measurement of P_N and/or Chl and biomass production at early stages of plant growth may be used as useful criteria for screening and selecting the right type of forest tree species for national developmental programmes such as afforestation, agroforestry and social forestry.

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