

INTRA- AND INTERSPECIES VARIATION IN PHOTOSYNTHETIC ACTIVITY OBSERVED THROUGH OSP 5+ FLUOROMETER DURING LEAF FLUSHING PHASE IN DECIDUOUS FOREST SPECIES

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KEY WORDS: Photosynthesis Rate (Pn), Chlorophyll fluorescence, chlorophyll fluorescence decrease ratio (R_{Fd})

ABSTRACT: We investigated intra- and inter species variation in photosynthetic activity of three deciduous forest tree species viz., Kanju (*Holoptelea integrifolia*), Rohini (*Mallotus philipensis*) and Shisham (*Dalbergia sissoo*) during the leaf flushing phase. The experiment was carried out in Bhakra forest range, Terai Forest Plantation Division, Haldwani, India. *In-situ* measurements of leaves were taken during summer of 2016 and 2017. The observations were recorded during peak photoperiod 8 hrs to 10 hrs. Results show that photosynthesis rate (Pn) of species is significantly different while intra-species differences shows a smaller amount of differences. OS5p Multi-Mode Chlorophyll Fluorometer recorded higher level of variation than photosynthesis system (CI-340). Positive relationship was observed between photosynthetic rate and chlorophyll fluorescence decrease ratio (R_{Fd}). *Dalbergia sissoo* has higher rate of photosynthesis ($Pn=16 \pm 2.6$ and $Rd 3.72 \pm 0.20$) than other species.

1. INTRODUCTION

The diurnal and seasonal variation in photosynthesis activity have been well documented for many vegetation types. A well-marked seasonal variation as well as annual periodicity has been observed in deciduous species due to seasonal leaf flush and senescence (Bassow & Bazzaz, 1992). Eco physiological studies showed that leaf flushing in deciduous species controlled by many factors like shedding of old leaves, increasing day length, temperature and first significant rain (Rivera et al. 2002, Singh and Kushwaha, 2005a, Elliott et al., 2006). These forest plays significant role in maintain carbon balance in ecosystem (Rao & Rao 2015). Deciduous species regularly adding soil carbon by shedding their leaves. In fact, deciduous forest in India consist 3238.03 million tonnes of soil organic carbon from total soil organic carbon (4680.25 million tonnes) stock of India (Singh et al., 2016). Magnitude and capability of capturing CO₂ by vegetation is directly depends on the photosynthesis rate (Long et al., 2006). Photosynthesis process started with absorption of a quantum of light (Thomas & Govindjee, 1961), Whitmarsh & Govindjee, 1999).

Absorption of each quantum of light will rises a chlorophyll electron from its ground state to an excited state. Excited electron transferring these energy to photosynthesis system and back to its ground state. In course of energy transferring some part of energy (~3-5% *in vivo*) is dissipated as fluorescence (emission in red region). These chlorophyll fluorescence popularly used as indicator of photosynthesis activities of plant. It is complementary to photochemistry and heat dissipation of chlorophyll molecule during de-excitation of electron (Kautsky and Hirsh, 1931). The study also showed that gradual decline of the Chl fluorescence intensity from Fm (highest peak) to a much lower Fs (steady state). The greater the Chl fluorescence decrease (Fd) from Fm to Fs, the higher the net photosynthetic rate (Pn) of the leaf. (Lichtenthaler and Miehe, 1997, Lichtenthaler and Babani, 2004). It varies from species to species in fact from one leaf to another because of variability in chlorophyll content, light and raw nutrient supply. Quantifying the extent of variability in photosynthesis activities from species to species and within species will advance our understanding of forest carbon dynamics. It will also help to model forest carbon cycle and nutrient cycle.

2. METHODOLOGY

2.1. Study Site

The study area lies in Bhakra forest range (Lat. 29° 01' 30" N to 29° 16' 40"N, Long. 79° 13' 45" E to 79° 00' 31" E) of Tarai Central Forest Division, Uttarakhand state (India) (**Figure 1**). The area has categorized as moist deciduous forest (Champion and Seth, 1968) with sub-tropical monsoon climate. The mean annual temperature varies from 22°C to 26°C, with a dry summer. The area receives an average rainfall of 2076 mm/year. Study area has forest plantation of deciduous tree species.

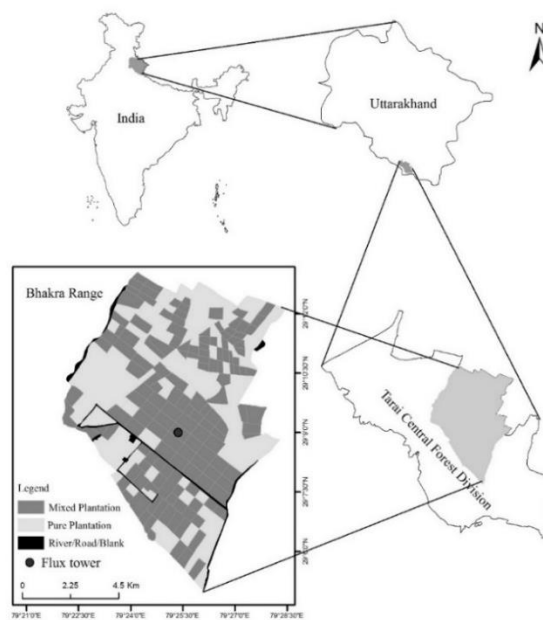


Figure 1. Location map of the study area

The dominant plantation species include Shisham (*Dalbergia sissoo*), Kanju (*Holoptelia integrifolia*), mixed Rohini (*Mallotus phillipensis*), Khair (*Acacia catechu*), Teak (*Tectona grandis*), and Poplar (*Populus deltoides*) etc.

2.2. Sampling and data acquisition

We collected *in-situ* data i.e. Photosynthesis rate (Pn) and Chlorophyll fluorescence (ChF) from well demarcated 30 plots following random sampling in the mixed forest plantations. The field measurements were taken during summer of 2016 and 2017. We selected three dominant species, Shisham (*Dalbergia sissoo*), Kanju (*Holoptelia integrifolia*) and Rohini (*Mallotus phillipensis*) for study their photosynthetic activity during leaf flushing. Photosynthesis was measured by using CI-340 portable photosynthesis meter (CID Biosciences, Inc.). It measures net photosynthesis rate (Pn) incorporating the IRGA (Infra-Red Gas Analyzer) measurements (CID bioscience). Data were taken for three times a day i.e. morning 7 - 9 am, afternoon 12-2 pm and in evening 5-6 PM on each operational day.

Chlorophyll fluorescence (ChF) was assessed by a pulse-modulated fluorometer (*OS5p*, *Opti-Sciences*, *Hudson, NH*, USA) during maximum photosynthesis time (8-10 am) of same individual tree. *In-situ* chlorophyll measurements were taken using CCM-200 hand-held chlorophyll meter (*Opti-Sciences*, *Massachusetts*, USA). Same leaf samples were used to measure CCI after Pn and ChF measurement.

2.3. Data analysis

All individual observations of each species were averaged for every single day. Daily photosynthetic rate were averaged for entire study period Pn_{avg} ($\mu\text{mol m}^{-2} \text{s}^{-1}$). All statistical analysis were carried in R Software (R Core Team, 2013). ANOVA (Analysis of Variance) is used for analysis of variation within and between groups (species). Relation between Chlorophyll decrease ratios (R_{Fd}) Vs Photosynthesis rate (Pn) (daily averaged (left) and during active period at 8-10 am (right)) is also tested. We analyses the correlation (Pearson correlation coefficient) between Chlorophyll content index (CCI) and different photosynthesis processes.

3. RESULT AND DISCUSSION

Dalbergia sissoo is has more young and mature leaves than *Holoptelia integrifolia* and *Mallotus phillipensis*. *Holoptelia integrifolia* and *Mallotus phillipensis* has old and very new leaflets with lower CCI value. We observed and fairly good co-relationship ($R^2 \sim 0.8-0.9$, $P > 0.05$) between Pn and R_{Fd} (Figure 2.). Lichtenthaler et al. (2005) found that chlorophyll fluorescence decrease ratio R_{Fd} of leaves is directly related to photosynthesis rate (Pn).

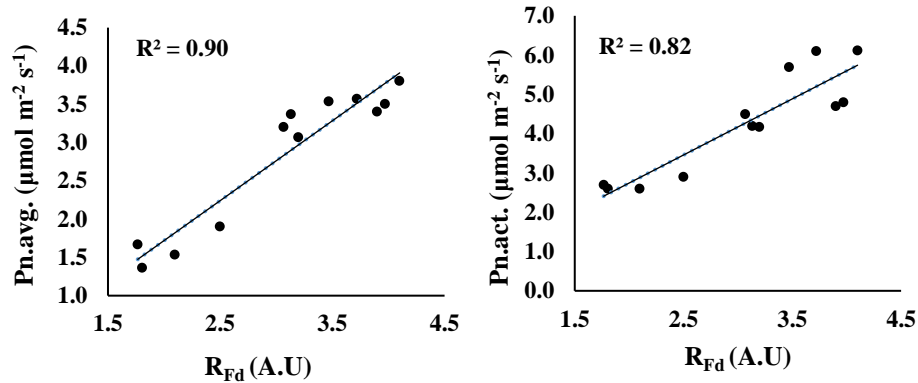


Figure 2. Relationship between Chlorophyll decrease ratios (R_{Fd}) Vs Photosynthesis rate (Pn) (daily averaged (left) and during active period at 8-10 am (right))

We obtain a good correlation between CCI and photosynthetic activities (0.65-0.74, $P > 0.05$) (**Figure 3**). CCI value is varies between ~ 12 to ~ 18 in young to mature leaves. Photosynthesis rate (Pn) and Chlorophyll decrease ratios (R_{Fd}) significantly differ from leaf to leaf. However, standard deviation of pn and R_{Fd} within species (± 0.15 & ± 0.29) is lower than between species (± 0.87 and ± 0.75). It indicates that photosynthetic activities varies species to species depends upon its chlorophyll concentration. However, chlorophyll content is not only factor for lower photosynthetic activities but it play a key role in photosynthetic activities.

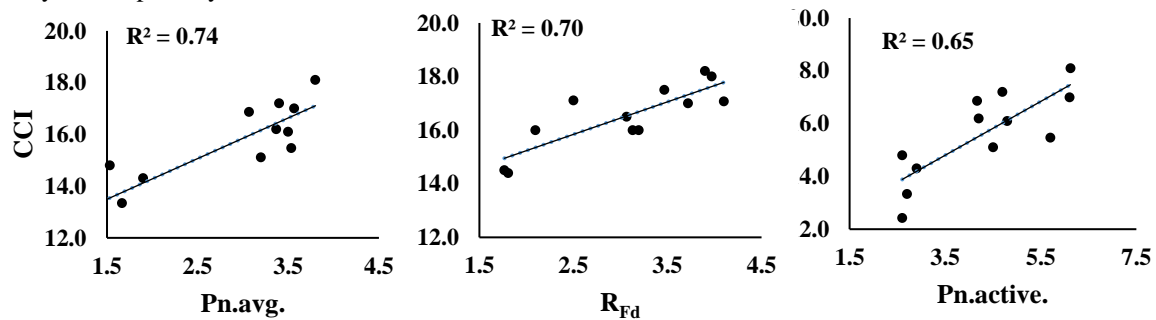


Figure 3. Comparative analysis between Chlorophyll content index (CCI) and different photosynthesis processes.

Dalbergia sissoo shows higher Pn value 16 (individual leaf) and ~ 3.5 (averaged) $\mu\text{mol m}^{-2} \text{s}^{-1}$ during leaf flushing (summer) than *Holoptelia integrifolia* and *Mallotus philipensis* (**figure 4**). *Mallotus philipensis* shows lower Photosynthetic activities with lowest CCI due to very young and old senescent leaf.

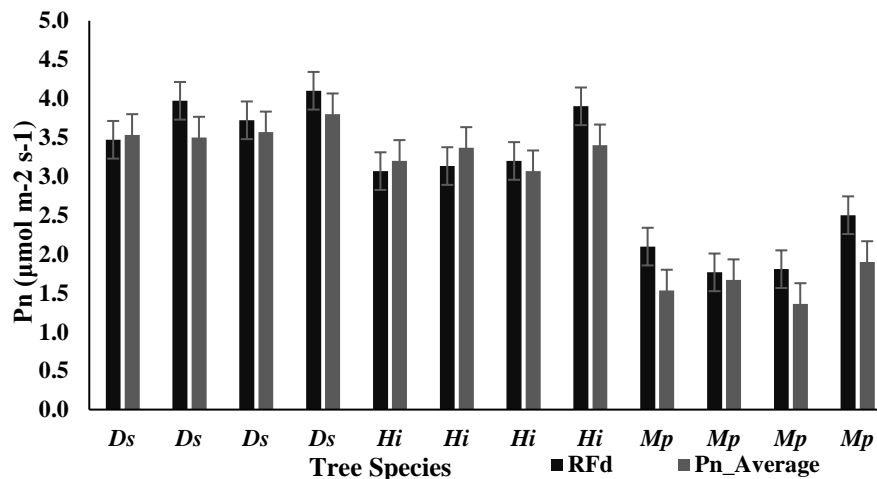


Figure 4. Inter-species variation of Photosynthesis rate (Pn) and Chlorophyll decrease ratios (R_{Fd})

4. CONCLUSION

Present study highlighted the potential and sensitivity of R_{Fd} to capturing the variability in photosynthetic activities (P_n). We observed significant Intra- and interspecies variation in photosynthetic activity during leaf flushing phase in deciduous forest species. Use of R_{Fd} information may give an precise estimation and variability of photosynthetic activities (P_n) in different species.

ACKNOWLEDGEMENT

Authors are grateful to Dr. Parag Madhukar Dhakate, Chief Conservator of Forest for permission to collect field data in the study area. I would also like to show my gratitude to Director, IIRS and Dean IIRS for providing support to conduct this study. I am thankful to University Grants Commission (UGC) to provide scholarship under National Eligibility Test-Junior Research Fellowship (NET-JRF) scheme.

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