Acta Acad. Paed. Agriensis, Sectio Biologiae **XXIV** *(2003) 257–271*

Ecophysiological Screening of a Tropical Wet Evergreen Forest Vegetation in the Mishmi — Himalaya Range (Northeast India, Arunachal Pradesh): Preliminary Results

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Abstract. One of the main objectives of our study was to detect the actual ecophysiological state of species which use different habitats and life forms of the wet evergreen forest ecosystem within the boundary of Namdapha National Park (Arunachal Pradesh, India). The other goal was to test the usefulness of portable non-invasive chlorophyll fluorescence method for describing some ecophysiological processes in tropical rainforest. The measured plant species and their individuals grew either soliterly or in stand and there were stressed (high light-, heat- and water deficit stress) and non stressed speciesThe field chlorophyll fluorescence measurement can demonstrate the physiological differences of the various life forms of the tropical wet evergreen forest species and it is feasible to detect stress responses caused either by naturally occuring stress factors or anthropogenic perturbations in an early, non-visible state. Therefore the method can be very useful both for monitoring the status of the vegetation in the nature conservation areas of the tropical rainforest region and for managing a sustainable forestry and to follow the effects of tropical deforestation.

Keywords: chlorophyll fluorescence, ecophysiology, it in situ measurement, life forms, non-destructive, stress, tropical vegetation

Abbreviations: F_v/F_m: the maximal photochemical efficiency of PS II, R_{fd}: the variable chlorophyll fluorescence decrease ratio, NPQ: non photochemical quenching

Introduction

Many ecophysiological problems involving tropical ecophysiology and deforestation require some measure of the vitality or photosynthetic capacity of the plants. Concerning photosynthesis gas-exchange measurements in any case tend to be time-consuming, and are not always easy to carry out in the field. Uptake of $^{14}CO_2$ (e.g. Penny & Bayfield, 1982) is a very sensitive method and it can be used on even minute species, but scintillation counting is inherently destructive of the material. In recent years, chlorophyll fluorescence has become recognised as a powerful non-invasive technique in higher-plant physiology (Krause & Weis, 1991; Jones, 1992). It has been extensively used, both in fundamental studies of the photosynthetic mechanism in vivo, and in ecophysiology (Lichtenthaler, 1988). In particular, close relationships have been demonstrated between appropriate chlorophyll-fluorescence measurements and photosynthetic CO_2 uptake (Seaton & Walker, 1990). Seel, Baker & Lee (1992) used the ratio of variable to maximum fluorescence, F_v/F_m, in their analyses of photosynthesis (Tuba et al., 1997). The functioning of photosystem II (PS II) is the most sensitive indicator of the photosynthetic apparatus. Measurements of PS II activity provide a means of rapidly and non-destructively probing of photosynthetic characteristics in the field (Long et al., 1994; Ball et al., 1995; Dulay et al., 1998).

The majority of the field ecophysiological measurements are focused on the temperate vegetation while tropical areas are not widely represented in spite of possessing the highest species and vegetation diversity of the Earth. During the past 10 years, biodiversity has become a focal point of different natural and social sciences (Porembski & Barthlott, 2000). One of the major large scale disturbances to the worlds forest is timber harvesting and it is one of the most conspicuous aspects of contemporary global change. Deforestation occurs almost everywhere in the world but the highest rates (0.8–1.2 percent/year) can be observed in the tropical regions (Loreau et al., 2002). Trees are the dominant and essential elements of the forest ecosystems, especially in the wet evergreen forest where the trees consist the majority of the biomass and give habitats to thousands of species, but the diversity and abundance of mosses and liverworts (including epiphyllous liverworts) are also significant (Pócs, 1996). Because of the mentioned importance and there sensibility to any kind of disturbance wet evergreen forest trees are one of the best indicators of the tropical forest ecosystems. One of the most suitable method to detect the stress state of the plants in field "in situ" is the chlorophyll a fluorescence measurement (Hall et al., 1993; Lüttke, 1997).

In 1999 a botanical and ecophysiological expedition has been organized by the professor's assistants and PhD students of the Department of Botany and Plant Physiology of the Szent István University. Now we are presenting the ecophysiological part of the scientific results of this research trip. One of the main objectives of our study was to detect the actual ecophysiological state of species which occupy different habitats and use various life forms of the wet evergreen forest ecosystem like giant and medium size trees (indigenous, often endemic species), shrubs, perennials, epiphytes, lianas and even weeds. The other goal was to test the usefulness of portable non-invasive chlorophyll-a fluorescence method for describing ecophysiological processes in tropical rainforest.

Materials and methods

Site description

The area chosen is the richest one in species and habitats in Tropical Asia and situated in the Northeastern tip of India. Namdapha National Park and Tiger Reserve (Changlang district, Arunachal Pradesh) is spread in an area of 1,850 km^2 rugged terrain. Though located at 27 degrees north from the Equator hence being in the sub-tropical zone has tropical climate, the higher parts of the reserve, which are mountainous and rugged, experience cold and temperate conditions around the year. Concerning for the climatic characteristics the average minimum and maximum temperature is 17.7 °C and 29.5 °C in the tropical zone, while 2.4–21.4 °C in cold humid areas. Similarly, rainfall is very variable — excessive in the tropical part (3000 mm) and scanty (1900 mm) in the higher reaches. The park receives heavy rain almost throughout the year and practically without any dry months. Perhaps no other conservation area in the world has a wider altitudinal variation than the Namdapha National Park that rises from 200 m to 4,571 m in the snow-capped mountain. This variation rises the growth of diverse habitats of flora and fauna. Another unique feature of Namdapha is its location at the junction of the Indian sub-continental biogeographic region and the Indo-China biogeographic region. The vegetation can be broadly classified into tropical wet evergreen, temperate and alpine depends on the elevation (200–4571 a.s.l.), but the tropical and subtropical evergreen forest predominate the area. Among others the low-land tropical wet evergreen forests of Namdapha National Park holds the largest *Dipterocarpus* forests in India and give shelters to huge number of rare, endangered and threatened taxa as well as a rich gene pool of indigenous crop plants along with their wild relatives and ecological variants, such as the wild banana (*Musa sp.*), citrus (*Citrus sp.*) and mango (*Mangifera indica*) (Hajra et al., 1996a & b). Nomenclature follows "A Contribution to the Flora of Namdapha" (Hajra et al., 1996a).

Methods used

The 26 species were selected from a wet tropical forest in the territory of the national park, described above. The *in situ* field measurements were performed within two days (24th and 25th of November, 1999), in two different but close places (the distance is 20 kms) near Deban and Miao village. During the measurements climatic conditions (RH: 78–82%, temperature: 23–25 °C), elevation (250–260 m a.s.l.) and forest type (wet tropical evergreen forest) were similar. Ecophysiological measurement was carried out on species which occupy different life forms in the rainforest ecosystem like giant and medium size trees (indigenous, often endemic species), shrubs, perennials, epiphytes, lianas and even weeds. The observed plant individuals grew either soliterly or in stand and there were stressed and non stressed species.

The investigation was carried out by a portable chlorophyll-a fluorometer (PEA, Hansatech, UK), which could be used as an effective non-destructive, *in* vivo probe of photosynthetic performance in a wide range of species from the mosses to the flowering plants. All experiments were performed on intact leaves after a 20 minutes dark adaptation. At least three repetition have been done on the individuals' leaves selected for measurement with identical position and light environment. The maximal photochemical efficiency of PS II (F_v/F_m) and the variable fluorescence decrease ratio ($R_{fd} = (F_m - F_s)/F_s$) measured at 695 nm were calculated from the clorophyll-a fluorescence induction kinetics (Lichtentaler, 1988).

Results and conclusions

Generally accepted that the species those F_v/F_m values higher than 0.800 have optimal photosynthesis (e.g. Lichtentaler & Rinderle, 1988), but species below this value probably are stressed. As *Fig.1* shows there is a significant difference between the F_v/F_m values of the stressed and non stressed species. For example this stressed plant is the epiphyte *Asplenium nidus* whose neighbour trees was cutted (except its host tree). This disturbance increased irradiation, decreased its photosynthetic activity and simultaneously caused higher evaporation. This noticeable separation between the species can be seen in *Fig.2* too where $(F_s - F_0)/F_0$ values below zero indicate adaptation to the changing environment like *Pterospermum acerifolium* and *Alangium chinense*. The above-mentioned two medium sized tree growing in stand naturally were seriously effected by clearing around them recently and during our measurement were at the beginning of adaptation. Another group contains the moderately stressed species with F_v/F_m values between 0.75–0.8 and those $(F_s - F_0)/F_0$ values are also low, around zero. Nevertheless the two third of the measured plants had normally high these two characteristic photosynthetic chlorophyll fluorescence values (Schreiber & Bilger, 1993). This clearly demonstrates that primary charge separation is more efficient in those plants which are growing in stand compare with solitary species of the rainforest. Further, the higher Fi values (data not shown) of the stressed specimens indicate a deceleration of the $Q_A \longrightarrow Q_B$ electron transfer within the photosynthetic electron transport. Consequently, the elevated proportion of Q_A^- (higher F_i) in the stressed group results in a larger fraction of closed reaction centres incapable of stable charge separation, and thus in a decrease in the light-limited quantum efficiency of the PS II photochemistry ((Schreiber et al., 1995).

Although R_{fd} parameter was previously interpreted clearly as "vitality-index" (characterises the potential photosynthetic activity of the leaves (Lichtentaler, 1988; Lichtentaler & Rinderle, 1988)) according to the *Fig. 3.* there is not so significant correlation between the R_{fd} parameter and the physiological state of the plants. Based on the R_{fd} values less species seems to be stressed than using F_v/F_m values. Additionally until the *Nephrolepis cordifolia, Dipterocarpus retusus* and *Bauhinia purpurea* species were part of the groups with optimal photosynthesis on the basis of F_v/F_m, according to the R_{fd} these species belongs to the seriously stressed group. Probably the F_v/F_m values reflect more accurately the physiological status of the plants furthermore R_{fd} value is not vitality, rather isolated fragment of non photochemical quenching (NPQ) during stress like in the mosses during desiccation (Csintalan et al., 1999).

The difference between the R_{fd} and F_v/F_m parameters is well noticeable in *Fig. 4.a* and *4.b* too. Comparing the taxonomically created groups in both case the *Dicotyledon* trees have the lowest values because amongs them were the most stressed species (this caused the great deviation). The only difference can be observed in the group of *Pteridophytes* but they contain the least stressed species therefore both photosynthetic parameters belong to optimal non-stressed physiological range.

Because of the importance, diversity and complexity of the tropical evergreen trees we have analyzed them separately (Fig.5). The species growing soliterly (the neighbour trees were cutted) have lower F_v/F_m and R_{fd} values, because they are just attending to adaptate for this stress. Amongs the soliter species the *Bauhinia* and *Dillenia* are widely distributed (in another vegetation types, too) and have stronger ecological tolerance so they can be adapted better to this stress and this can be seen in the higher F_v/F_m values. From the species growing in stand the *Magnolia* and *Aesculus* have the lowest F_v/F_m values because they did not reach their maximal size and therefore they not obtained optimal irradiance. The dominant species of this forest like *Dipterocarpus* and *Terminalia* had the highest F_v/F_m values.

Our field chlorophyll fluorescence measurements were able to demonstrate the physiological differences of the various life forms of the tropical evergreen forest and it seems to be feasible to detect stress responses caused either by naturally occuring stress factors or anthropogenic perturbations in an early, non-visible state. Therefore the chlorophyll a fluorescence method can be very useful both for monitoring the status of the vegetation in the nature conservation areas of the tropical region and for managing a sustainable forestry and to follow the effects of tropical deforestation.

Acknowledgements

This study was supported by grants from the SOROS Foundation Hungary (194-198/222/1999), the Hungarian-Indian Bilateral Intergovermental S&T Cooperation (TÉT, IND-11/2001), the MTA/INSA project, the Department of Botany and Plant Physiology of Szent István University and the Plant Ecology Research Group of Hungarian Academy of Sciences, at the Department of Botany and Plant Physiology, SZIE, Gödöllő.

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List & acronyms of investigated species (authors listed in the "A Contribution to the Flora of Namdapha" [Hajra et al., 1996]):

Pteridophytes
Asplenium nidus, ASP (Aspleniaceae)
Cyathea spinulosa, CYA (Cyatheaceae)
Nephrolepis cordifolia, NEP (Nephrolepidaceae)
Tectaria polymorpha, TEC (Tectariaceae)
Selaginella hookeri, SEL (Selaginellaceae)

Dicot trees
Aesculus assamica, AES (Hippocastanaceae)
Alangium chinense, ALA (Alangiaceae)
Bauhinia purpurea, BAU (Caesalpiniaceae)
Dillenia indica, DIL (Dilleniaceae)
Dipterocarpus retusus, DIP (Dipterocarpaceae)
Magnolia hodgsonii, MAG (Magnoliaceae)
Pterospermum acerifolium, PTE (Bombacaceae)
Terminalia myriocarpa, TER (Combretaceae)

Dicots:
Ageratum conyzoides, AGE (Asteraceae)
Bidens pilosa, BID (Asteraceae)
Boehmeria glomerulifera, BOE (Urticaceae)

Clerodendrum colebrookianum, CLE (Verbenaceae)
Lantana camara, LAN (Verbenaceae)
Laportea terminalis, LAP (Urticaceae)
Mikania macrantha, MIK (Asteraceae)
Oxyspora paniculata, OXY (Melastomataceae)

Monocots
Bambusa tulda, BAM (Poaceae)
Colocasia fallax, COL (Araceae)
Commelina paludosa, COM (Commelinaceae)
Costus speciosus, COS (Costaceae)
Musa velutina, MUS (Musaceae)

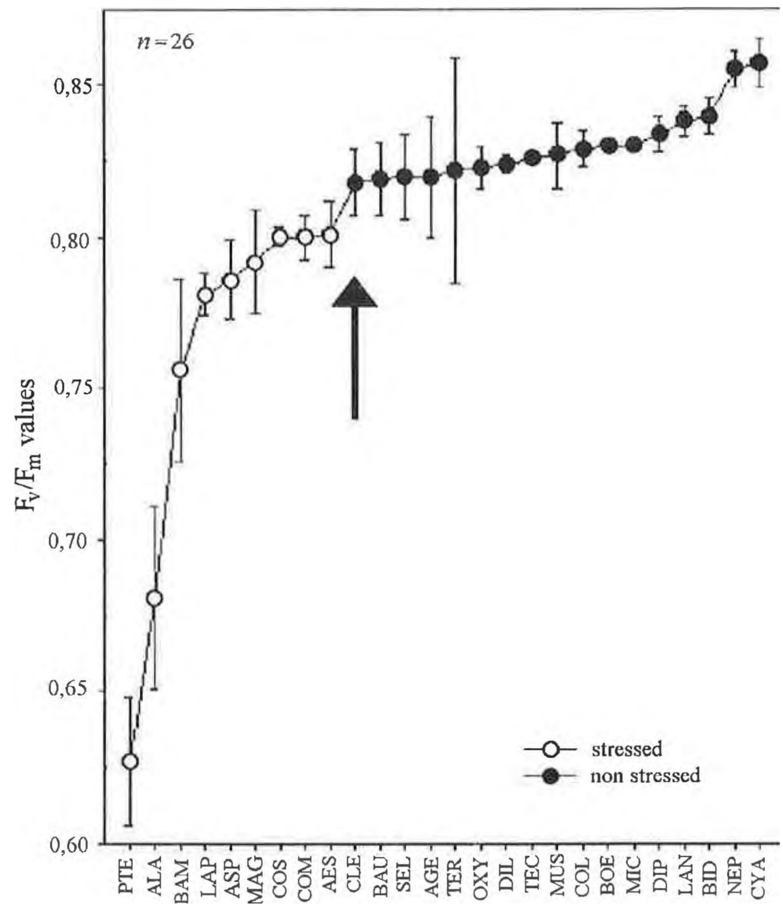

Fig.1 Chlorophyll fluorescence F_v/F_m ratios measured at 695 nm of the investigated species in the wet evergreen forest (24–25/11/1999; Deban & Miao, Arunachal Pradesh, India)

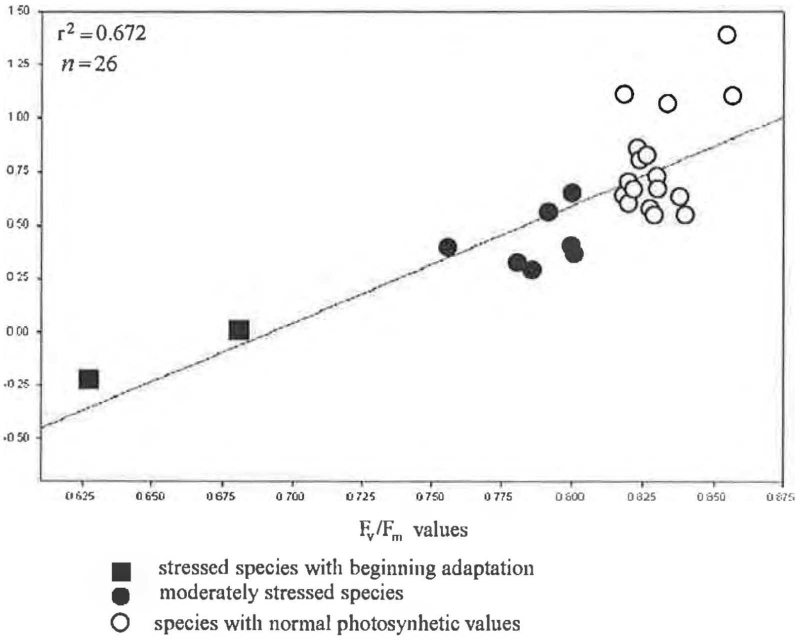

Fig.2 Correlation between the chlorophyll fluorescence F_v/F_m ratios and the chlorophyll fluorescence decrease ratio (R_{fd}) values measured at 695 nm of the investigated species in the wet evergreen forest (24–25/11/1999; Deban & Miao, Arunachal Pradesh, India)

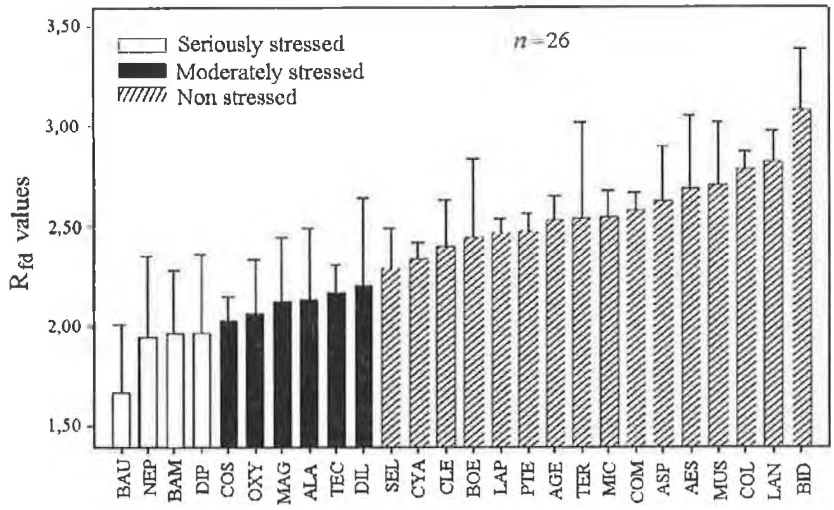

Fig.3 The average values of chlorophyll fluorescence decrease ratios measured at 695 nm (R_{fd}) of the investigated species in the wet evergreen forest (24–25/11/1999; Deban & Miao, Arunachal Pradesh, India)

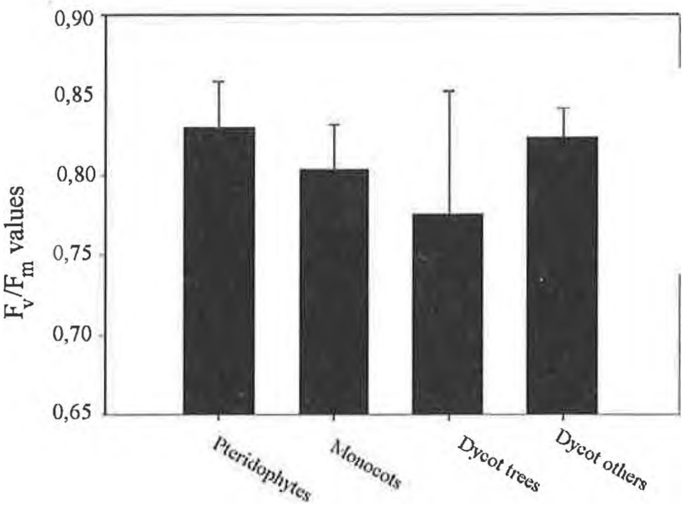

Fig.4.a The average values of chlorophyll fluorescence F_v/F_m ratios of various ecological groups of the measured species in the wet evergreen forest (24–25/11/1999; Deban & Miao, Arunachal Pradesh, India)

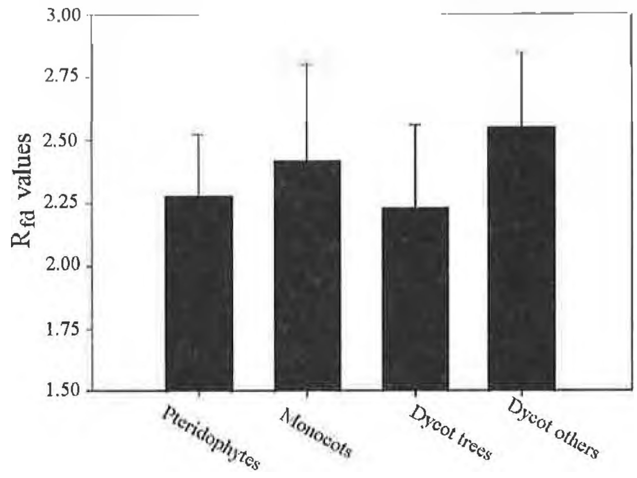

Fig. 4.b The average values of chlorophyll fluorescence decrease ratios measured at 695 nm (R_{fd}) of various ecological groups in the wet evergreen forest (24–25/11/1999; Deban & Miao, Arunachal Pradesh, India)

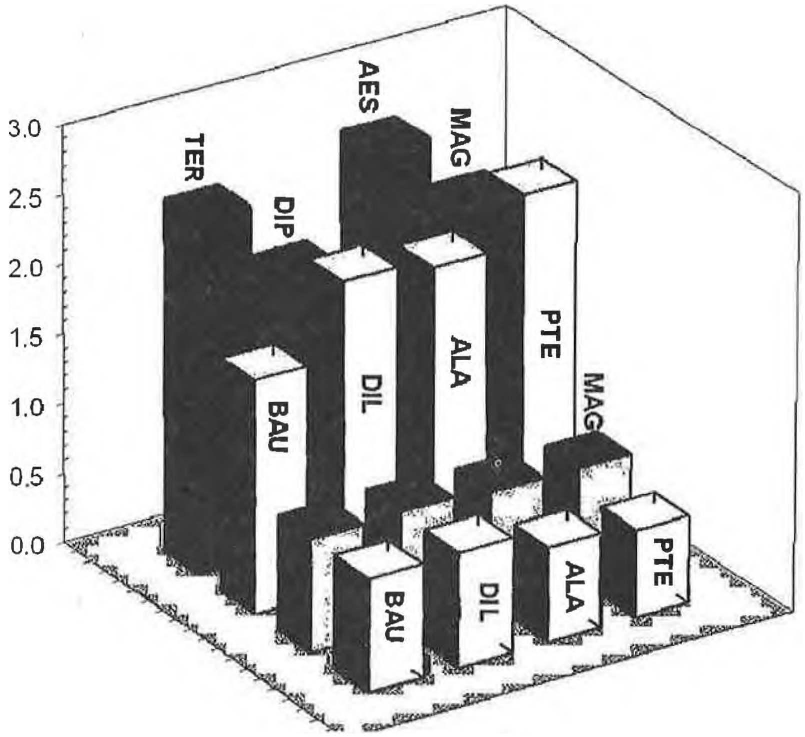

Fig.5 The average values of chlorophyll fluorescence F_v/F_m ratios and chlorophyll fluorescence decrease ratio (R_{fd}) values measured at 695 nm of the investigated tree species in the wet evergreen forest (24–25/11/1999; Deban & Miao, Arunachal Pradesh, India)