Szent István University

Ecophysiological investigations at species and stand levels in different terrestrial ecosystems affected by various desiccation influences

The main points of the thesis

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THE ANTECEDENTS AND AIMS OF THE WORK

Global climate change resulted by human effects which arranges the natural processes in large scale surrounding our environment. These processes comprise also ecological, economical and social crisis. Greenhouse effect will be probably increased and the average global temperature rising which lead to global changes. In the last decades, studies of role of global carbon cycle of grasslands and wetlands come to the front. These dynamic natural systems functioning as „key ecosystems" mostly exposed to external effects. Such kinds of ecosystems mark climatic and topographic zones, where the effects of climatic changes of weather expressly predominate. These ecosystems are vulnerable due to partly their simple structures, partly in these areas many species are living close to their survival barrier. Researchers agree that the global warming will affect the ecophysiological processes of plant systems, which lead to complex ecological interactions must be studied. Changes of spreading of species or associations may detect the most easily at the boundary of ecoton. During our research work we investigated the function of extreme ecosystems in different vegetation types which can help to put the expected prognosis for global and regional changes. Based on our present knowledge and prognosis it will be expected in climate change: temperature increasing, decreasing in expected precipitation quantity and irregular dispersion. Due to these processes, exploration of the mechanisms of desiccation tolerance will come to the front in all biological levels. Sensitivity, adaptation ability of earthly ecosystems for changes are variable, therefore their roles in the global climate system are different. That's why the role of the certain ecosystems in global carbon cycle and their parts from the atmosphere CO_2 circulation are determinative. Feed-back processes between climate and atmosphere in CO_2 concentration changes resulted increasing dried periods which will decrease the CO_2 uptake of vegetation at limited water supplied areas, while it will enhance (because of the increasing temperature) at frigid zones.

The objective of our research was to examine the ecophysiological characteristics of vegetations and their dominant plant species of two representative, extreme ecological systems which exist in different geographical environments and under different climatic conditions. Investigation of structure, function and the most characteristic features of the vegetations which surmount desiccation tolerant plants or drying tolerant/endure species (peat mosses) could be realized by integrated approach.

Aims of the study

The aim of the work was double: (1) investigation and comparison of production-destruction processes and interactions of different edaphic plant associations (peat bogs) under various weather-climatic conditions, (2) ecophysiological investigation of vegetation which specially adopted to extreme dried habitat.

(1)

- What are the differences in carbon balance of certain peatbog stands are composed same dominant plant species but living under different climatic conditions during the active vegetation period? Which relation can be showed among the heterogenity of the stand, presence of a certain species and net ecosystem gas exchange?
- Is it possible to predict the carbon balance of similar covered vegetation areas living under different climatic condition taking the results of Hungarian peat bogs consideration?
- Which environmental factors and what degree can be influenced the daily pattern and carbon balance of the investigated associations?
- Is it possible to test the changes of carbon balance during the natural dehydration and rehydration cycles based on the daily pattern of *in situ* field measurements?

(2)

- How can certain terrestrial ecosystems tolerate the permanent and long-term vegetative desiccation state besides this ability relatively rare among the vascular plants, particularly in case of dicotyledon plants?
- What are the key characteristics of vegetation structure and function surmounted by poilkiohydric desiccation tolerant plants and non-vascular communities?
- How can the cryptobiotic crusts of inselberg surfaces and the vascular desiccation tolerant plants regenerate which derive from similar ecological circumstances following different length of time desiccated period?
- Which kind of ecological and physiological adaptation responses are showed for global climate change by desiccation tolerant plants? The aim of our work was describe the relevant ecophysiological processes and their

characteristics (regeneration of photosynthesis during rehydration) which these plants are able to survive desiccation. Our aims were comparative investigation of the photosynthetical responses of different desiccation tolerant strategy applied vascular plants (PDT, HDT) and explore the background of long-term survival capability following desiccation.

MATERIALS AND METHODS

Study sites and plant species

Bereg-plain „peat bogs of Csaroda”: on two peat bogs of North-Plain of Hungary, seasonal ecophysiological investigations were carried out in the area of Báb and Nyíres lakes.
West-Siberian peat bogs: along Khanty – Mansysk – Tobolsk – Tomszk – Novoszibirszk transect (approx. 1200 km), in different kind of peat bogs were investigated.
Norvégia (Finse) mountain tundra or fjell vegetation: our research was carried out close to Finse (1222 m) on „Alpine Research Center” of Oslo University.
Desiccation tolerant plants of temperate and tropical zones: *Haberlea rhodopensis* Friv. From Bulgaria; desiccation tolerant cryptobiotic crusts and vasular plants from Tanzánia, Madagascar, Brasil, French Guiana, namely such as: *Xerophyta, Vellozia, Aftrotrilepis, Trilepis, Myrothamnus, Selaginella.*

Instrumentation

Chamber techniques in the field: Two types of infra red gas analysers (CIRAS-2 IRGA (PPSystems, Hitchin, UK) and ADC LCA-2; Hoddesdon, U.K) were carried out in the gas exchange measurements in open system. The chamber size (20 cm diameter) was the same in both systems.
During field or stand-level measurements micrometeorological data were continuously taken using HOBO-type micrometeorological station (MicroStation, Onset, Massachusetts, USA) which recorded the soil water content (m m^{-3}), air temperature (°C), canopy temperature (°C) and the photosynthetically active radiation (PAR) in the investigated areas.
The leaf level CO_2 gas exchange measurements were carried out using closed system infrared gas analyser (CIRAS-2, PP Systems, Hitchin, UK) and Li-6400 infrared gas analyser (Li-cor, Lincoln, NE, USA) which can calculate the net gas exchange of the leaves, intercellular CO_2 concentration, stomatal conductance and dark respiration. During the leaf-level measurements and measuring the cryptobiotic crusts the CIRAS-2 gas analyser were used in closed system. The root respiration measurements were taken by Li-6400 infrared gas analyser using the root respiration chamber.

The measurements of *in vivo* chlorophyll-*a* fluorescence were determined by portable fluorometers namely PEA-type (Plant Efficiency Analyser, Hansatech Ltd., UK) and FluorPen FP 100-type (Photon Systems Instruments Ltd., Czech Republic).

The photosynthetic pigments such as chlorophylls as well as total carotenoids were quantitatively determined in 100 % acetone extract solution by spectrophotometer using by methods of Lichtenthaler (1987).

The water content (WC, %) of the samples were measured and calculated by a direct thermogravimetric method using the fresh (FW) and dry (DW) weight of the samples.

Close to Finse Research Station in Norway, the biomass was determined using 10×10 cm quadrates which were taken photo by ADC Dycam camera calculating NDVI values.

Productivity and photosynthetic efficiency of vegetation were measured by reflectance determining the vegetation indexes. NDVI (Normalized Difference Vegetation Index) was measured by ADC (Dycam) digital camera pictures processing with Vegan–32 software.

The total content of carbon and nitrogen of the crusts were determined by flash combustion method using a Carlo-Erba (Fisons) NA 1500 elemental analyzer.

Statistical analysis: the data were analyzed by the Student's *t*-test. Differences are considered to be significant at a level of $P < 0.005$ or below. Treatments were statistically compared by analyses of variance (ANOVA). Used software's: Microsoft Excel 2003, SigmaPlot 8.0 (Systat Software Inc., San Jose, CA, USA) and Statistica 5.0 (StatSoft Inc., USA).

RESULTS

Methodological results

Measurements for rehydration of cyanobacterial cryptogamic crusts was build a special, continuous runing water assurance chamber which simulates the natural condition. At the bottom of the chamber there was a water pump under the water level which circulated the water through the crusts surfaces found on a stand. Illumination of the samples in the open top chamber was assured by external light resources.

Investigation of desiccation-rehydration cycles of desiccation tolerant plants was carried out a customized chamber system containing a modified desiccator and the rehydration chamber respectively.

Operation of customized desiccation chamber based on closed system in which an air-pump assumed the air flow inside the chamber. Air flowing out the chamber passes through the tank filled by silica gel then the air dried air flow inside the chamber again. An exiccator was reconstructed for rehydration processes: at the bottom of the exiccator were filled by water, the previously dried plants were placed in the centre of the exiccator. Using a water pump circulated the water in the chamber and the plants rehydrated fountain-like wetting.

Ecophysiological investigation of peat bogs

Species and stand levels ecophysiological investigations were carried out in three different vegetation zones. In the centre of our research was primarily to investigate the seasonal or the main season changes of net ecosystem gas exchange. In all three of studied areas, the non-vascular, lower plants dominated vegetations were typical, especially expanded the functional dynamics of peat mosses, their daily rhythms for environmental factors changes and their interactions within a certain associations. Peat bogs are important ecosystems which can form and store atmospheric CO_2 to significant amount of organic C. Otherwise, degree of these processes is influenced by regional factors, namely climate, local conditions and hydrological situation. Two most important factors influenced the biological and physicochemical processes of these ecosystems are: water conditions (including quantities, chemistry, fluctuation and flow system of water) and ratios of species composition (mainly peat mosses). Below ground layers of peat mosses dominated area have critical role in the carbon scale of peat bogs and the prevention of desiccation of above ground layers. Net primer production of peat bogs significantly determined by the water availability and the repeated desiccation-rehydration cycles, therefore supposed that carbon storage capacity of peat bogs may be in danger with decreasing water availability of above ground areas. Changes of present role of our studied areas are mainly effected by local environmental factors: in case of Bereg-plain bogs, the most important aim to assure of natural vegetation surrounding the bogs and the optimal water level; in case of Siberian bogs, thawing of permafrost can caused by global warming resulted northbound migration of peat bogs; in tundra vegetation, variety of population and diversity of species and ecotypes will be decreased by the effects of global climate change.

Comparative ecophysiological investigations of desiccation tolerant organisms

Both investigated cryptobiotic crusts had relatively high photosynthetic rates and showed active physiological function following rehydration. They took their functional activities at all applied light intensities beside sufficient water supply however degree of the recovery of photosynthetic apparatus was different. Presumably, the whole carbon scale of cryptobiotic crusts is influenced by frequency and duration of the precipitation: carbon loss of the crusts resulted by long-term arid periods just us long-term, continuous precipitation supply. Their desiccation tolerance based on their acclimation to periodic hydrated/dehydrated cycles. At the global scale significant occurrence of tropical/subtropical inselbergs covered by cryptobiotic crust and on the basis of their assimilation capacities it is likely to possess large amount of carbon storage hereby they significantly contribute to total carbon cycle of the Earth.
Physiological responses of having two different adaptation strategy of desiccation tolerant plants were investigated derived from three diverse geographical environments. Brazilian and African species have similar function in their own microclimates since they had to adopt to similar circumstances due to climatic conditions. However, there are some differences concerning the degree of regeneration following extreme long-term desiccation states among *Xerophyta* species which populate close to each other (Tanzania, Madagascar). The lowest regeneration capability was showed by *X. dasylirioides* in spite of the fact that this species has seemingly the most developed morphological adaptation feature, such as dense hairy leaf surface. In case of West-African *Afrotrilepis pilosa* has

also high degree of microclimatical adaptation ability. Higher photosynthetic productivity of savannas ecotype does not mean bigger carbon accumulation because the higher transpiration and stomatal conductance resulted in decreasing water use efficiency. Brazilian *Vellozia* species is equivalent to African *Xerophyta* species in ecological respect, following rehydration recovery of their viability was faster than African PDT species, which also due to spending shorter-term in desiccation state. Significantly high desiccation tolerance of *Haberlea rhodopensis* derives from temperate zone appeared not only at leaf but also at root level, although its degree reflects different adaptation between two organs during desiccation and rehydration.

NEW SCIENTIFIC RESULTS

- We constructed custom-developed chambers for measuring photosynthetic yields of lower and vascular plants of different type of vegetation stands.
- Open system chamber gas flux measurements are suitable for comparison to similar structural stands which living in different climatic conditions in the area of Hungarian and Siberian peat bogs.
- Measuring values of net ecosystem gas exchange derive from vegetations of three different climatic zones are reconcilable with the productivity of dominant stand composer species in certain association.
- On Hungarian investigated bogs in positive carbon balance (sink) respect the most characteristic periods are springs and autumns independently the different microclimatic circumstances. On the other hand, decomposition rate is basically influenced by climate, in case of native bogs showed higher decomposition rates than in the north areas.
- Diversity relations of different peat mosses depend on significantly macroclimate also in association and microgeographical scales, which simultaneously determine degree of their productivity hereby their roles in carbon scale.
- Productivity, daily gas exchange pattern of investigated peat moss associations are mostly influenced by the radiation under optimal water condition.
- More closed forest peat bog stands are considerable CO_2 resources while open bogs are CO_2 sinks in the main vegetation period.
- Inside the formation of ridge-hollow complex two parts are also different each other in their activities: species of ridge showed higher CO_2 fixation rate than the dominant peat mosses of hollow formation.
- We described the relations of different production-biomass of lower plants and vascular plants in mountain tundra associations. Lichens adopted to long and unfavourable periods from the point of view of physiological activities can took their positive carbon balance with fast and dynamic reactivity during daily natural and changeable desiccation-rehydration cycles.

- Degree of desiccation tolerance of cryptobiotic crusts of inselbers is significantly influenced by length of spending period under dry state, confined microclimate of provenance just as species composition and diversity of the crusts.
- In case of tropical cryptobiotic crusts following spending long-term desiccated period the physiological activity of the crusts are appeared immediately under short-term rehydration.
- Photosynthetic activities of cyanobacteria dominated cryptobiotic crusts are also influenced by the period of water supply.
- Photosynthetic productivities of desiccation tolerant plants adopted to extreme arid habitats showed significant differences among ecotypes and species pertain to the same genus (*Xeropyta* species) just as different desiccation strategies (PDT, HDT).
- All investigated *Xerophyta* species were able to revive following extreme long-term desiccation period but its degree was different among species.
- Desiccation tolerance ability of roots of HDT strategy *Haberlea rhodopensis* reflected different adaptation mechanisms compared to leaves.
- Differences of various desiccation tolerance strategy (PDT-HDT) plants adapted to longer-shorter desiccated periods appeared in their carbon and nitrogen contents.

CONCLUSIONS AND PROPOSITIONS

Novelty of our research in part to combined measurements in natural habitats and laboratory conditions on lower and vascular desiccation tolerant plants, on the other hand we would like to integrate our knowledge derive from different levels (leaf, shoot, whole plant, stand) in a common model. In the long-term, it is expected that the results of present research will increase our available knowledge of the effects of drought stress for cultivated plants hereby it will help drought tolerance works of molecular biologists and plant breeders. Direct practical benefits offer for plant cultivation and agricultural sciences. Understanding of the molecular mechanisms and features allow of viability of vegetative photosynthesise plant tissues in desiccated state will be a significant criterion to selection of cultivated plants and its cross breeding. All climate models deal with global climate change predict to increase the frequency of drought hereby the importance of the desiccation tolerant plants in the natural conditions will be increase in the future.

Our results also important from the point of view of ecology after all derived from investigations of natural ecosystems therefore it can provide useful information to conservation biology. One part of the results origin from protected natural ecosystems represents significant values, which insure their wide range applicability in the practice of natural and environmental protection.

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