Competition for light among summer planktonic species

Kompetice o světlo mezi druhy letního planktonu

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Abstract

The presented study aims to verify the hypothesis that *Planktothrix agardhii*, similarly to diatoms, can tolerate low light conditions; thus the changes in species composition of cyanobacterial blooms can be explained by light limitation. Its ability to occupy dominant position in the mixture with other planktonic species under low light conditions has been verified by experiments.

Introduction

Mass occurrence of cyanobacteria in summer months is considered as a symptom of eutrophication. *Planktothrix agardhii, Microcystis* sp. div., *Aphanizomenon* sp. div. and *Anabaena* sp. div. were found as dominant species creating cyanobacterial blooms. However, a shift from large-colonial cyanobacteria, such as *Aphanizomenon flos-aquae,* through *Microcystis aeruginosa* and small-colonial species of *Anabaena,* to single-filament species (*Planktothrix agardhii, Limnothrix redekei, Aphanizomenon gracile*) has been observed in shallow hypertrophic lakes (PECHAR 1995). Although centric diatoms dominate usually in spring and autumn, *Aulacoseira granulata* is a representative of summer phytoplankton. Its autecology differs from other centric diatoms and, in its inclination towards higher temperatures, is rather similar to the group of cyanobacteria (POULÍČKOVÁ, KRŠKOVÁ 2000). *A. granulata* has a very wide spectrum of environmental tolerance and may dominate in many lakes across the trophic gradient.

The presented study tried to verify the hypothesis that *P. agardhii*, similarly to diatoms, can tolerate low light conditions. Thus the changes in species composition of cyanobacterial blooms can be explained by light limitation (PECHAR 1995).

Material and methods

Planktothrix agardhii was observed in natural populations at fishponds of Central Moravia (Czech Republic) as well as in cultures. The natural material was cultured in Zehnder medium (STAUB 1961). Usually, a batch, synchronous culture (photoperiod L/D=16/8 hr.) in Erlenmayer 100 ml flasks with manual shaking was performed under the temperature of 19 - 23°C and different illuminations (26, 20, 15, 11 and 6 $\mu mol.m^{-2} . s^{-1}$). Since the species were tested for tolerance to shade at hypertrophic sites, the tested illumination intensities were deliberately low. White light (TUNGSRAM 36W) was used as a source of light.

The number of individuals (filaments, cells) in 1 ml was assessed in a counting chamber (Bürker chamber); each time, 400 individuals were counted. In the first experiment, natural material of *Microcystis aeruginosa* with an admixture of axenic culture of *Planktothrix agardhii* (GOM.)ANAGN. & KOMÁREK strain MEFFERT 1967/10 were used. Single species were cultured separately as control cultures. In the second experiment, natural material containing a mixture of *Aphanizomenon flos-aquae, Microcystis aeruginosa,* and *Aulacoseira granulata* was cultured. Large-colonial cyanobacteria disintegrate in cultures; that is why natural material was used in the case of *Microcystis* and *Aphanizomenon.* Every experiment was performed 3 times and the averages of these replicates were used for the construction of curves.

Results

Investigated strain of *P. agardhii* is able to tolerate very low light intensities (HAŠLER et al. 2003). Optimum growths of *P. agardhii* and *M. aeruginosa* in controls (single species cultures) were observed under the light intensities 6 and 26 $\mu mol.m^{-2} . s^{-1}$ (Fig. 1, control). Fig. 1 presents the results of experimental cultivation of the mixture of *P. agardhii* and *M. aeruginosa.* The representation of individual species changed during the 36-daygrowth experiment. While at the beginning of the cultivation, the suspension was dominated by *Microcystis,* several days later different representation was observed under different light intensities. *P. agardhii* dominated after 25 days under light intensities 6-15 $\mu mol.m^{-2} . s^{-1}$, while under higher light intensities *Microcystis* prevailed. Sequential disintegration of large colonies of *M. aeruginosa* was observed since the 15th day of cultivation. At the end of the experiment, *P. agardhii* was victorious in all variations. Since the species were tested for tolerance to shade at hypertrophic sites, all tested illumination intensities were deliberately low.

Fig. 2 presents competition of 3 planktonic species. The mixture was dominated by *Aphanizomenon flos-aquae.* The lowest light intensities were suitable for summer planktonic diatom *Aulacoseira,* while under the highest light intensities, competition between *Aphanizomenon* and *Microcystis* was observed.

Discussion

The occurrence of individual planktonic species is determined by their ecological requirements for light, temperature and nutrients (COLLIER et al.

1978, POULÍČKOVÁ, KRŠKOVÁ 2000). *P. agardhii* is a widely distributed species forming water blooms in eutrophic lakes (WUNDSCH 1940, GIBSON & FITZSIMONS 1982, HAŠLER & POULÍČKOVÁ 2002). Its occurrence is common especially in shallow lakes and fishponds, while deeper reservoirs are dominated by other species (Fig. 3). Although diatom maxima are often related to low water temperature, low irradiance and high turbulence, *A. granulata* is a summer species (WILLÉN 1991). *A. granulata*, a diatom species well distinguishable even in native preparation, is obviously one of the most frequent centric diatoms in the Czech Republic (POULÍČKOVÁ & KRŠKOVÁ 2000).

P. agardhii persists at a suitable locality throughout the whole year (SAS 1998, BERGER 1975, ROMO 1994). Its annual cycle in hypertrophic fishponds of the temperate zone starts in spring by germination of hormogonia. The abundance and biomass of *Planktothrix* increase during summer months with their maximum in August. The population overwinters near the bottom in the form of hormogonia.

The timing of cyanobacterial mass occurrence in late summer is often considered to be connected with their higher temperature optima (FOY et al. 1976), tolerance to different light intensities (SCHEFFER et al. 1997), tolerance to high pH (SHAPIRO 1984), or favoring a lower N:P ratio (SMITH 1983). Higher demand for phosphorus has been previously observed in our experiments with *P. agardhii* (HAŠLER et al. in press).

The growth of *P. agardhii* is possible, according to the previously published data, in shade of other algae (MUR 1983). Its mass occurrence in hypertrophic lakes and fishponds with low transparency is probably the result of such advantage (PECHAR 1995, SCHEFFER et al. 1997). In summer, light intensities at fishpond Bílá Lhota, where *P. agardhii* created a dense water bloom, were 136 $W.m^{-2}$ on the surface and 5 $W.m^{-2}$ in the depth of 20 cm below the surface. In spite of this fact, high biomass of *P. agardhii* occurred near the bottom (100 cm below the surface). Unlike other diatoms, *Aulacoseira granulata* is characterized by summer maxima, and tends towards higher temperatures (LUND 1962). Experiments in crossed light and temperature gradients produced similar results. The best growth of *A. granulata* was recorded at temperatures around 25° C within the range of light 5-50 $W.m^{-2}$ (POULÍČKOVÁ, KRŠKOVÁ 2000).

Optimum growth of *P. agardhii* strain was observed under light intensity 20 $\mu mol.m^{-2}.s^{-1}$. It was able to grow in lower intensities as well, but with longer time for adaptation (HAŠLER et al. 2003). The final crop was comparable to the crop at optimum illumination. Other experiments on Oscillatoriaceae species *Pseudanabaena galeata*, *Planktothrix agardhii* and *Limnothrix redekei* (ROMO 1994) revealed their better adaptation to lower light intensities. The best growth was noted at 25 – 60 $\mu mol.m^{-2}.s^{-1}$ while above this range of irradiance the growth was limited. ROMO (1994) found different light requirements in *Limnothrix redekei* isolated from various environments.

The ability to occupy dominant position in the mixture with other planktonic cyanobacteria under low light conditions was verified by the presented experiments. The changes in species composition of cyanobacterial blooms in shallow hypertrophic lakes are most likely influenced by their different tolerance to low irradiance.

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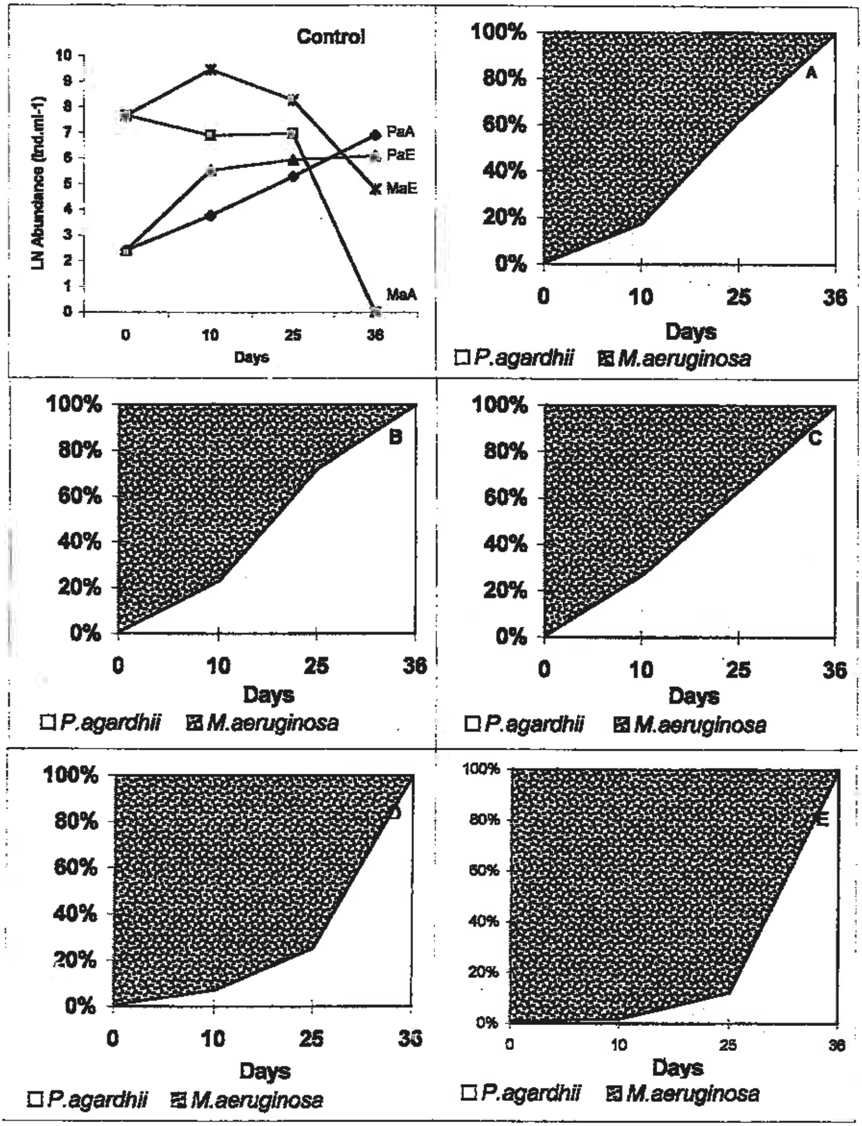

Fig. 1. Control: growth of *Planktothrix agardhii* (Pa) and *Microcystis aeruginosa* (Ma) under light conditions A=6; E=26 $\mu mol.m^{-2}.s^{-1}$. A-E: Competition among *P. agardhii* and *M. aeruginosa* under light limited conditions. (A=6; B=11; C=15; D=20; E=26 $\mu mol.m^{-2}.s^{-1}$).

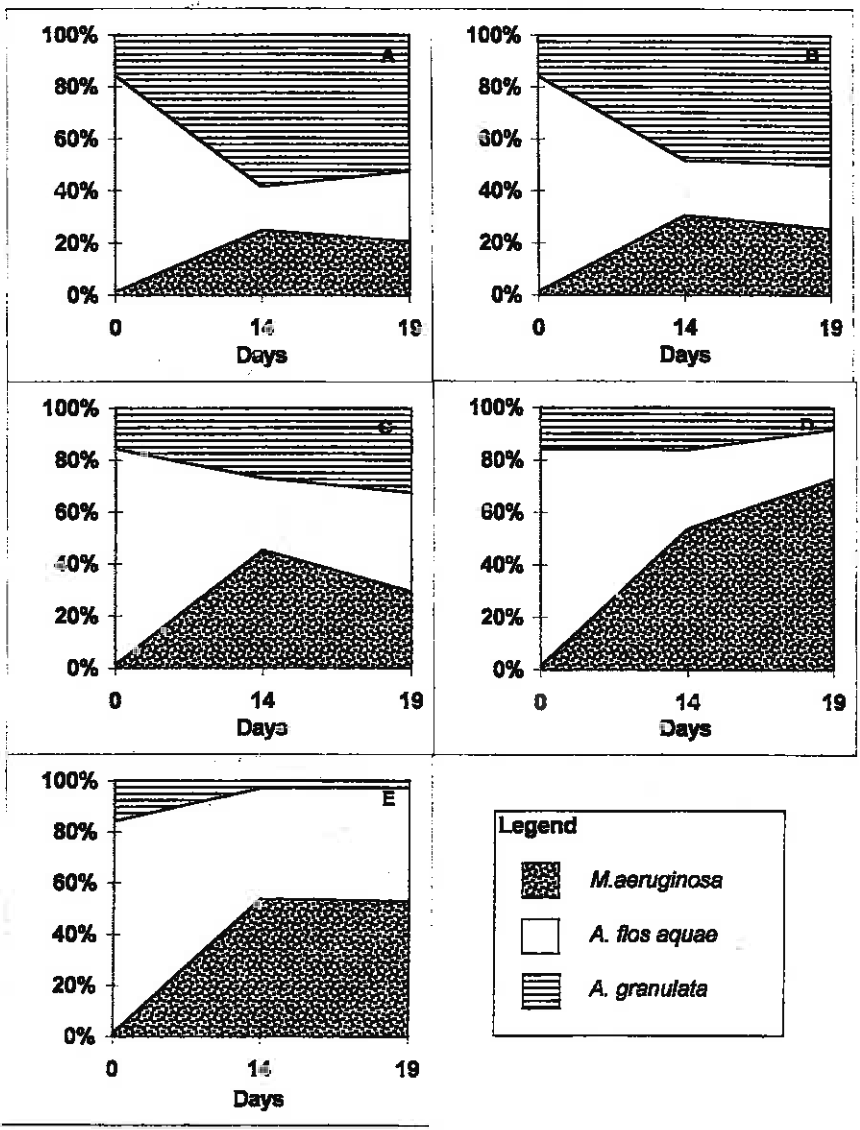

Fig. 2. A-E: Competion among *Microcystis aeruginosa*, *Aphanizomenon flos-aquae* and *Aulacoseira granulata* under light limited conditions. (A=6; B=11; C=15; D=20; E=26 $\mu mol.m^{-2}.s^{-1}$).

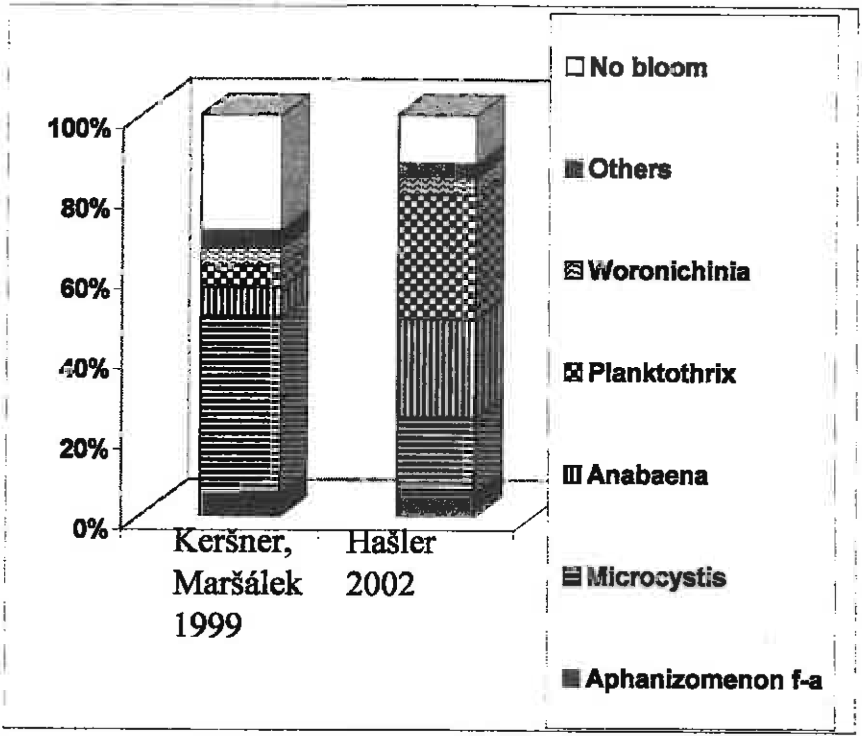

Fig. 3: Dominant species of planktonic cyanobacteria in deep reservoirs according to KERŠNER & MARŠÁLEK (1999) and in shallow fishponds (HAŠLER, POULÍČKOVÁ 2002)