A new aspect of grassland vegetation dynamics: The presence of cyanobacterium colonies can affect establishment success of plants

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13th Eurasian Grassland Conference

20-24 September 2016, Sighişoara, Romania

Introduction

Cyanobacteria occur

- in most dry and astatic habitats
- in almost every saline habitat types – mostly *Nostoc* spp.

Alkali habitats (Pannonic salt steppes and salt marshes)

- Alkali meadows (*Agrostio stoloniferae – Alopecuretum pratensis*)
- Open alkali swards (*Puccinellietum limosae*; *Plantagini tenuiflorae – Pholiuretum pannonici*; *Camphorosmetum annuae*)
- Alkali marshes (*Bolboschoenetum maritimi*)

- Continental climate
- High ground water level
- Fluctuating moisture regime
- Moderate to high soil salt content

Introduction

***Nostoc* spp.**

- Filamentous cyanobacteria
- Aquatic or terrestrial
- Microscopic or macroscopic colonies
- Wide variety of toxins – cyanotoxins, e.g. microcystins

Alkali grassland with *Nostoc* colonies

Cyanotoxins

- Defence against planktivores
- Allelochemicals against aquatic plants?
- Adverse effects on various organisms
- Effects on plants: not well-studied

Introduction

Effects on terrestrial plants

- Irrigation with water containing cyanobacteria
- Studying its effects on crops: growth inhibition in several crop species
- Similar effect on the natural flora?

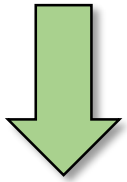
- It can have considerable impact on natural terrestrial habitats
- N-fixation ⇨ N-accumulation
- Can improve soil conditions
- Effects similar to that of litter

Positive effects (improving soil conditions, N-enrichment) ⇔ Negative effects (production of allelopathic compounds)

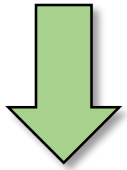
Introduction

Aims:

1. Gather the results of previous studies about the effects of toxic cyanobacteria on the germination and growth of terrestrial plants
2. Test the chemical effects of a *Nostoc* (Cyanobacteria) extract on the germination and seedling growth of species of alkali habitats



Affecting establishment success of plants?



Affecting community structure and diversity?

Materials & Methods

Literature search

- Google Scholar
- Search term: „cyanobacteria” AND „toxin” AND („plant growth” OR „germination”)
- 5720 hits
- First 500 papers: title and abstract, next 500 papers: by title

Inclusion criteria

1. Treatment with cyanotoxin or toxic cyanobacterial extract
2. Dealing with terrestrial vascular plant(s)
3. Measurement of the effects on seedling growth and/or germination
4. Comparison with untreated control

Materials & Methods

Nostoc extract preparation

- Colonies collected in the Hortobágy National Park (East-Hungary)
- Culturing in BG-11 medium (a medium optimised for cyanobacteria)
- Harvesting by centrifugation
- Ultrasonication till the cells lysed
- 20 g L^{-1} water extract

Detection of plant inhibitory metabolites

- Using plant test (*Sinapis* test)
- IC_{50} value (half maximal inhibitory concentration): 15 mg ml^{-1}

Materials & Methods

Germination experiment

Altogether 9 species

- 7 characteristic species of alkali habitats

  Agrostis stolonifera
  Aster tripolium ssp. *pannonicus*
  Beckmannia eruciformis
  Hordeum hystrix
  Lepidium ruderale
  Plantago schwarzenbergiana
  Puccinellia limosa

- + 1 adventive grass species recently invading alkali grasslands (*Hordeum jubatum*)
- + 1 easily germinating perennial forb (*Trifolium repens*)

Materials & Methods

Treatments

1. Watering with tap water containing *Nostoc* extract
2. Watering with tap water only (control)

Each tested on 3×100 seed for 9 species (54 pots, 5400 seeds)

Materials & Methods

At the end of the germination (after 5 weeks)

- All seedlings counted and removed
- Seedling fresh- and dry weight, seedling length measured
- Seedling dry matter content calculated

Statistical analyses

- SPSS 17.0
- Generalized Linear Models (GLMs): to test the effect of treatments and species identity on germination and seedling growth
- T-tests: to indicate significant differences in dependent variables between treatments within a species

Results

Results of the literature search

- 45 studies met the inclusion criteria
- 27 species from 8 plant families
- Mostly crop species
- Mostly concentration-dependent negative effects
- No effects or positive effects in a few studies

Species	Family	Number of studies
Allium cepa	Alliaceae	1
Brassica napus	Brassicaceae	3
Brassica narinosa	Brassicaceae	1
Brassica oleracea	Brassicaceae	2
Brassica rapa-chinensis	Brassicaceae	1
Eruca sativa	Brassicaceae	1
Festuca rubra	Poaceae	1
Lactuca sativa	Asteraceae	8
Lens esculenta	Fabaceae	2
Lepidium sativum	Brassicaceae	1
Lolium perenne	Poaceae	3
Lycoperiscon esculentum	Solanaceae	4
Malus pumila	Rosaceae	1
Medicago sativa	Fabaceae	3
Nasturtium officinale	Brassicaceae	1
Oryza sativa	Poaceae	9
Phaseolus vulgaris	Fabaceae	3
Pisum sativum	Fabaceae	3
Sinapis alba	Brassicaceae	7
Solanum tuberosum	Solanaceae	1
Spinacia oleracea	Chenopodiaceae	2
Trifolium repens	Fabaceae	1
Triticum aestivum	Poaceae	2
Triticum durum	Poaceae	2
Vicia faba	Fabaceae	3
Vigna radiata	Fabaceae	1
Zea mays	Poaceae	4

Results

Germination experiment

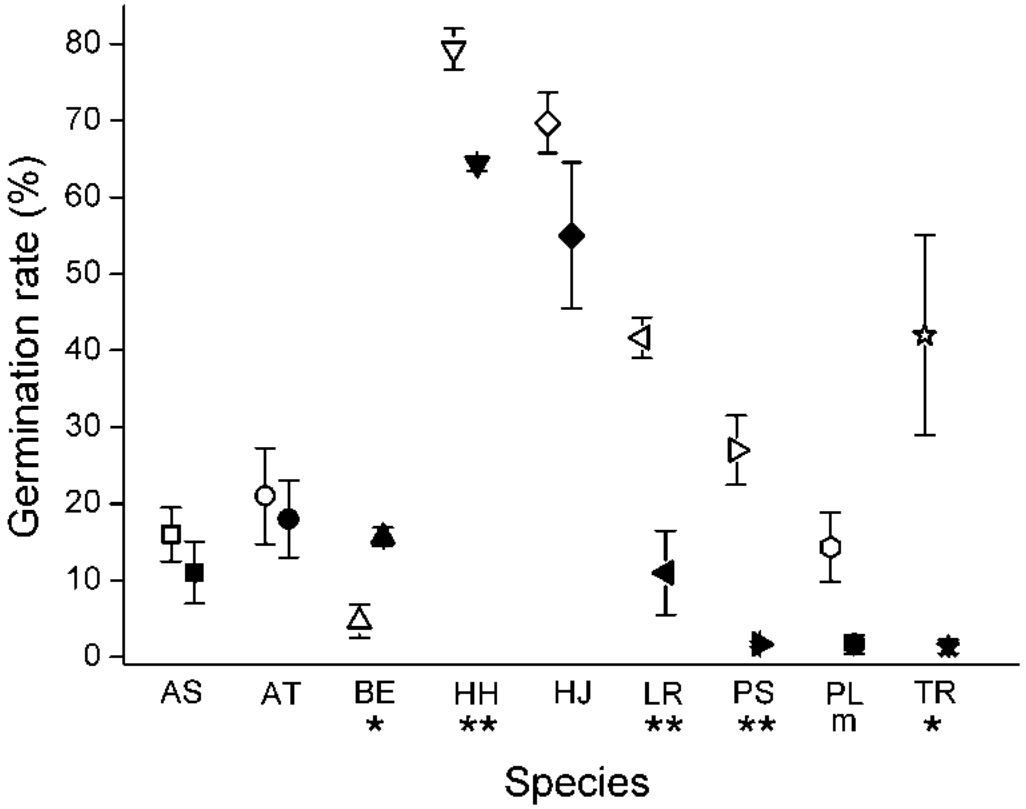
- Species identity had a significant effect on each measured variable except dry matter content
- *Nostoc* treatment had a significant effect on each variable except dry weight
- Their interaction had a significant effect only on germination rate and the fresh weight of seedlings

	Species		Treatment		Species×Treatment	
	F	*p*	F	*p*	F	*p*
Germination rate	41.966	**<0.001**	39.853	**<0.001**	4.694	**0.001**
Fresh weight	34.094	**<0.001**	21.417	**<0.001**	2.317	**0.042**
Dry weight	35.583	**<0.001**	3.398	*0.074*	1.671	0.142
Dry matter content	1.756	0.121	10.947	**0.002**	2.192	*0.053*
Seedling length	135.020	**<0.001**	22.650	**<0.001**	1.290	0.281

Significant effects are marked with **boldface**, marginally significant effects are marked with *italics*.

Results

- Germination rate of five species was significantly lower in the *Nostoc* treatment compared to the control
- Dry matter content significantly increased in case of four species (*A. stolonifera*, *H. jubatum*, *H. hystrix* and *T. repens*)
- Seedling fresh and dry weight and seedling length significantly decreased in *Hordeum jubatum*



AS – *Agrostis stolonifera*
AT – *Aster tripolium* ssp. *pannonicus*
BE – *Beckmannia eruciformis*
HH – *Hordeum hystrix*
HJ – *Hordeum jubatum*
LR – *Lepidium ruderale*
PS – *Plantago schwarzenbergiana*
PL – *Puccinellia limosa*
TR – *Trifolium repens*

Discussion

Literature search

- 45 papers dealing with the effects of toxic cyanobacteria on the germination and growth of terrestrial plants
- Dealing with crop plants and another few economically important grassland species (*Festuca rubra*, *Lolium perenne* and *Trifolium repens*)
- Focusing on sites and species contaminated by cyanotoxins via spray irrigation with cyanobacteria-containing water
- Effects on the natural flora and plant communities remained unclear

Discussion

- The presence of *Nostoc* colonies can affect the establishment of grassland species
- Species-specific effect: an indirect driver of competition between plants
- Important role in biotic filtering?

Beckmannia eruciformis tolerated the allelopathic effects ⇨ it can even benefit from N-fixation

The most severe adverse effects: the adventive species *Hordeum jubatum* ⇨ probably not adapted to the effects of *Nostoc*

Discussion

Similar results in aquatic ecosystems

- Concentration-dependent negative effects on a number of macrophytes (e.g. *Chara* spp., *Nitella* spp., *Myriophyllum variifolium*, *Spirodela oligorrhiza*, *Phragmites australis*)
- Stronger negative effects by shading than by allelopathic compounds?

Substantial impact on the composition and structure of aquatic macrophyte communities

Conclusions

- Effects of cyanobacteria on grasslands have been largely overlooked
- Primarily aquatic organisms should also be taken into account in terrestrial ecosystems
- Important role in shaping the structure, species composition and diversity of natural plant communities

Thank you for your attention!

The research was supported the TÁMOP 4.2.1./B-09/1/KONV-2010-0024 project and by the SROP-4.2.2.B-15/1/KONV20150001 project.

The authors were supported by the National Research, Development and Innovation Office (OTKA K116639; NKFIH K119225).

JS, SR, OV and MR were supported by the NTP-EFÖ-P-15 project by the Human Capacities Grant Management Office and the Hungarian Ministry of Human Capacities.

This project was supported by the János Bolyai Research Scholarship of the Hungarian Academy of Sciences (OV, DB).

AK was founded by the MTA's Post Doctoral Research Program.