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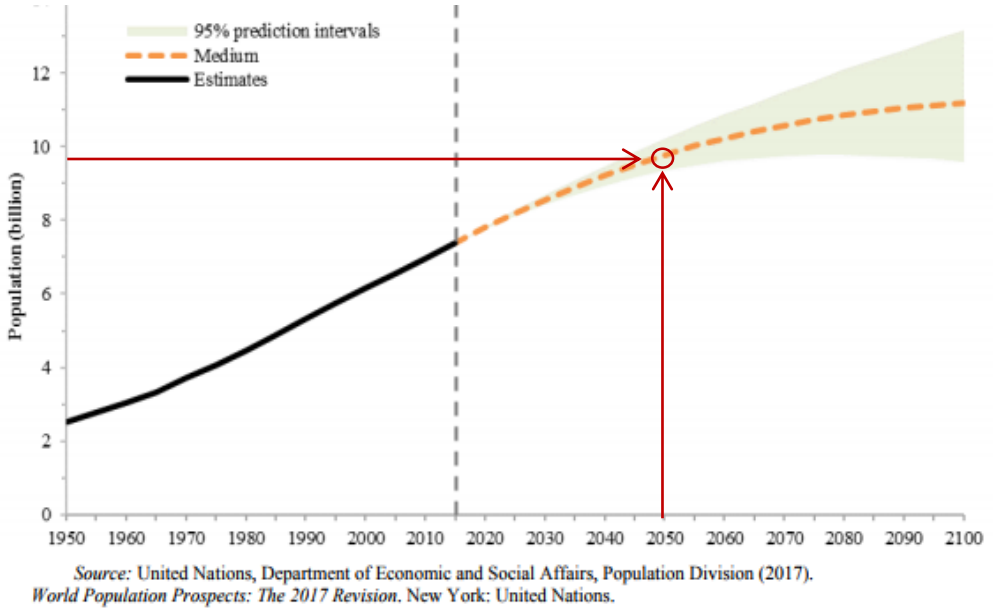
Cianobatteri e fissazione biologica dell'azoto per un'agricoltura sostenibile:

le prospettive per biofertilizzanti e biostimolanti

Elena Barbera
Lisa Borella
Nicoletta La Rocca
Eleonora Sforza
Alberto Bertucco

PAR lab

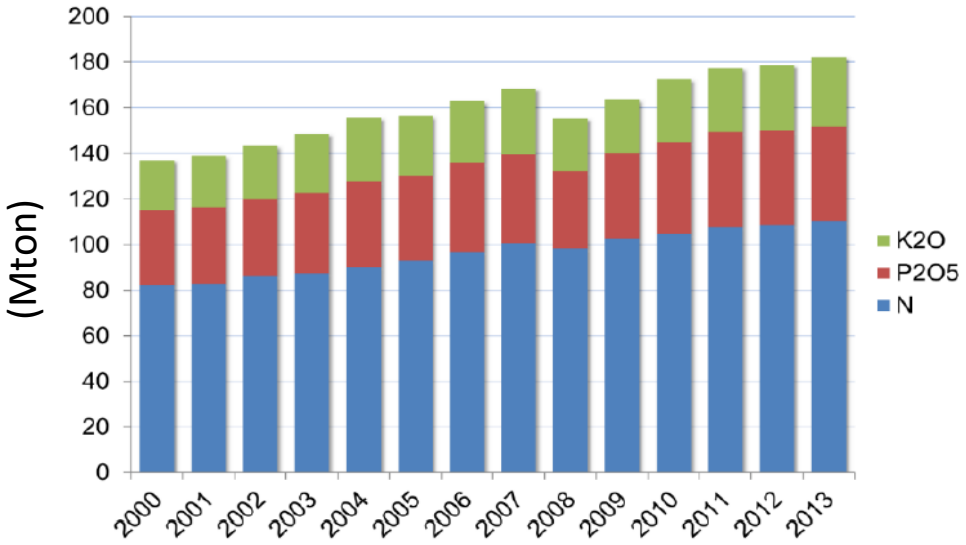
Global trends



Source: United Nations, Department of Economic and Social Affairs, Population Division (2017). *World Population Prospects: The 2017 Revision*. New York: United Nations.

World population

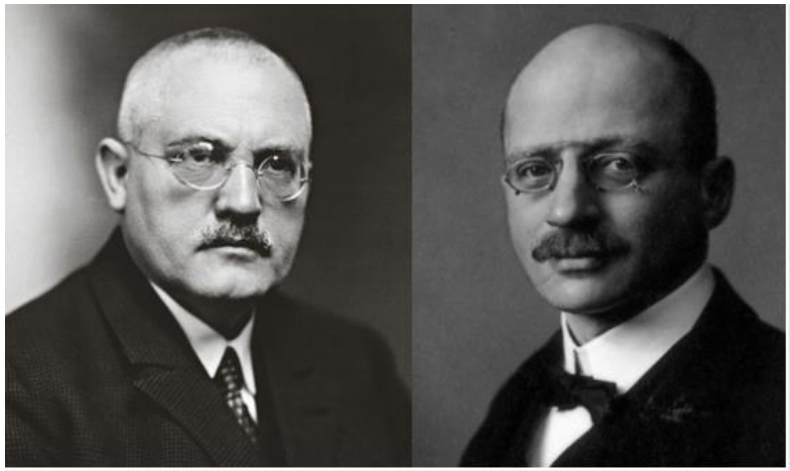
- Global population has been increasing
- It is expected to increase up to > 9 billion people by 2050 (and maybe > 11 billion people by 2100)
- Food production will have to increase by at least 60%



Fertilizers

- In 2013-2014 the N fertilizers demand was of 110 Mton/y
- Fertilizers demand is expected to increase by 1.6% per year until 2021

The Haber-Bosch process



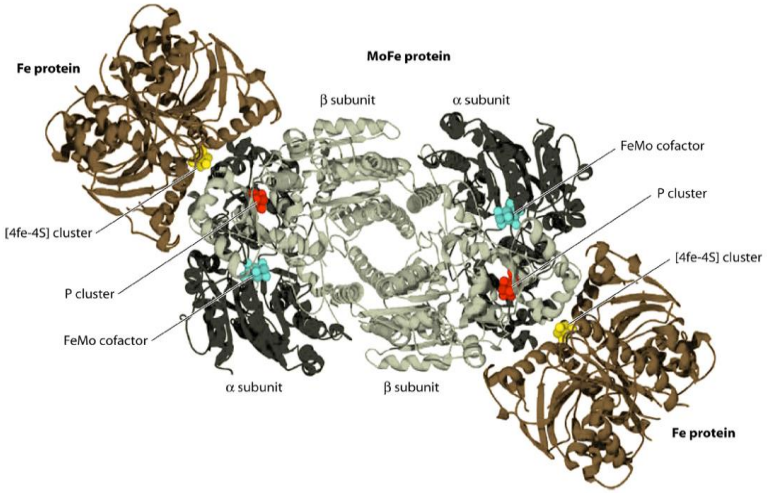
Chemical N fixation

$$N_2 + 3H_2 \rightarrow 2NH_3$$

- High temperatures (700K) and pressures (100atm);
- 300 Mt of CO_2 emissions each year;
- Exploits 2% of global natural gas reserves;
- Has reached its maximum energy efficiency

NOT SUSTAINABLE!

Can we find a greener process?

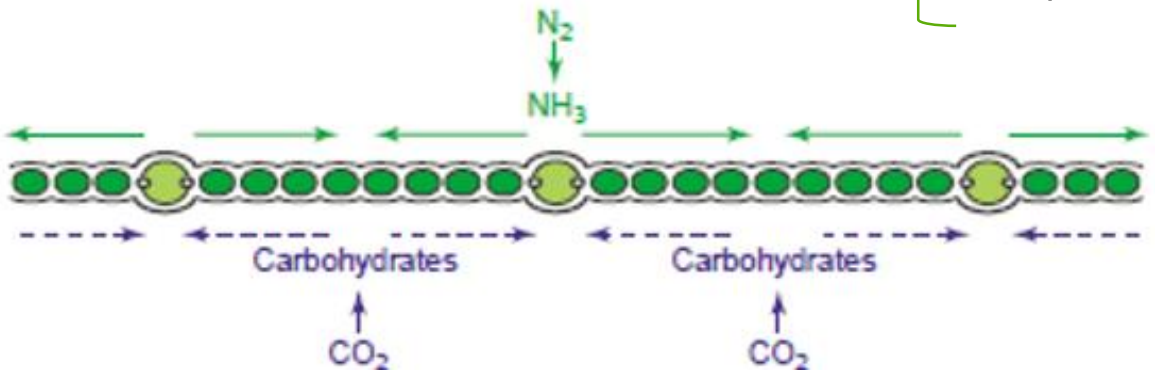


Biological N fixation

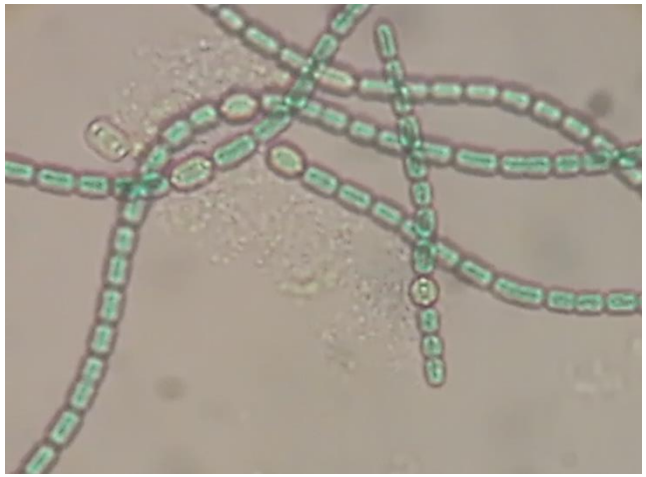
$$N_2 + 8\,H^+ + 8\,e^- \rightarrow 2\,NH_3 + H_2$$

N-FIXING CYANOBACTERIA

- Photoautotrophs
- Largely distributed in aquatic and terrestrial ecosystems
- Could be of interest for industrial exploitation!



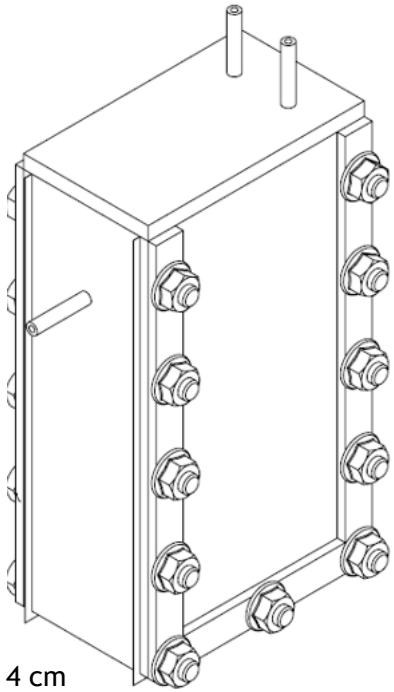
Anabaena PCC 7122



- Filamentous
- Heterocystous
- High specific growth rate (0.4 d^{-1} in batch systems) under different light intensities

- Can it be cultivated in continuous photobioreactors?
- What fixed N productivity can be achieved?
- What are possible applications towards a sustainable agriculture?

Continuous flat-panel PBR



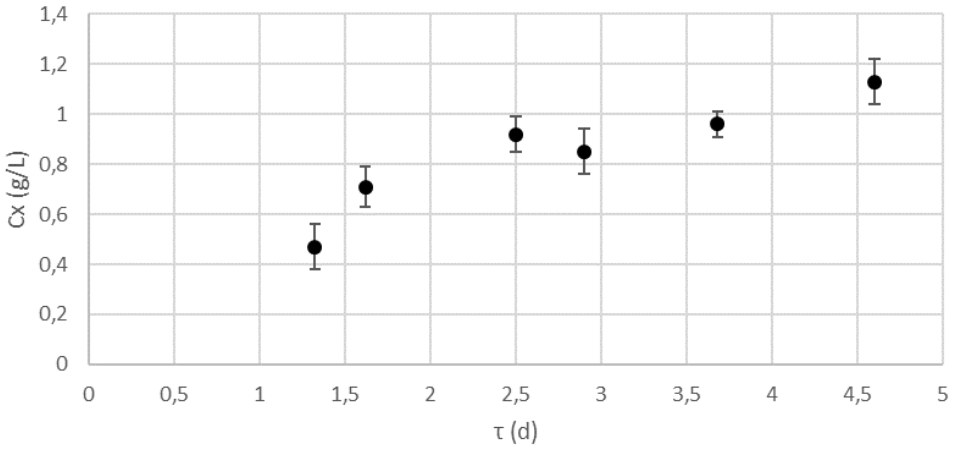
Experimental conditions

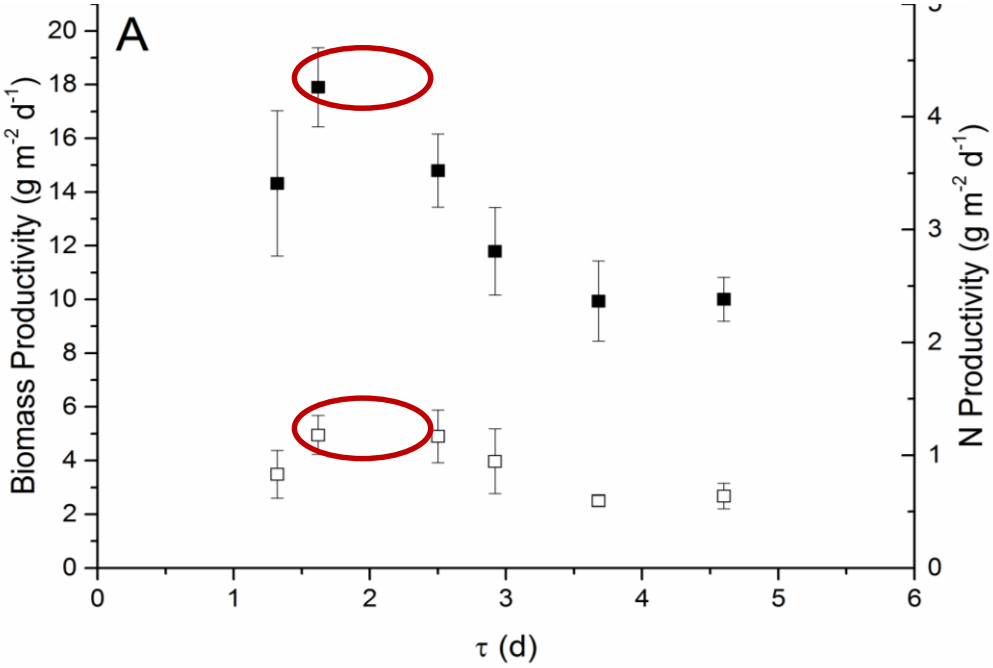
Cultivation medium: $BG11_0$ 2x
Air-CO_2 (5% v/v)
2.5 g L^{-1} $NaHCO_3$
T = 24°C

Effect of **residence time** and **light intensity** on biomass and N productivities

Effect of residence time τ

I: 190 µmol m^{-2} s^{-1}





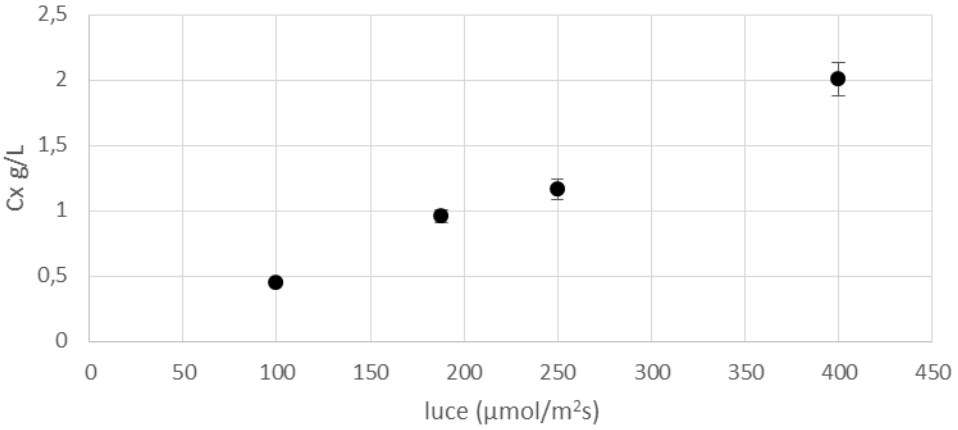
$$\tau = V_R/Q$$

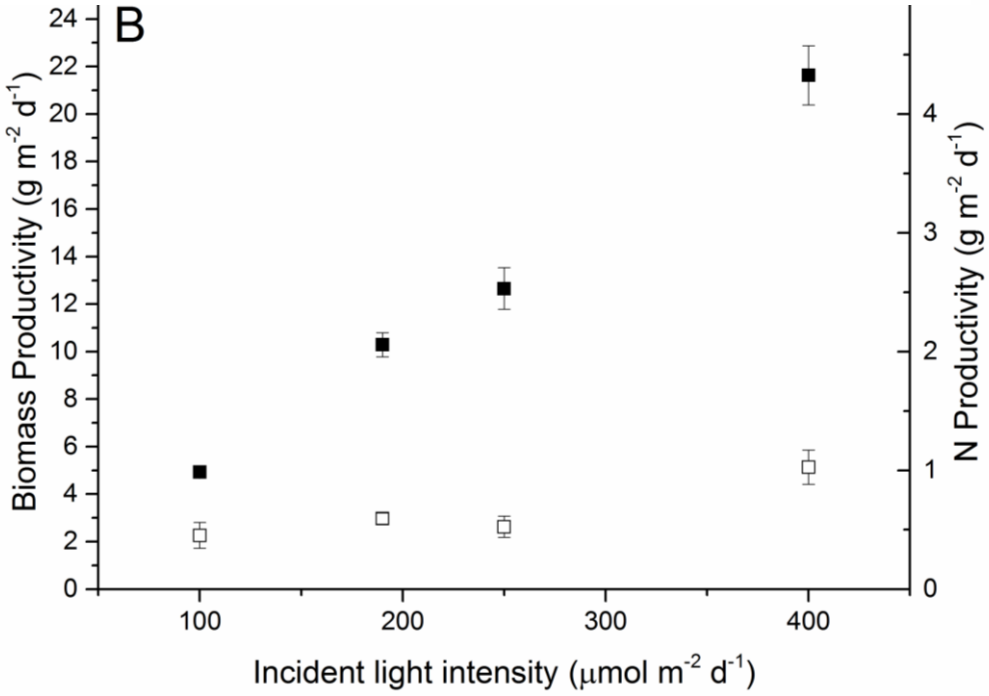
- N content in the biomass between 5. 73 ± 0.82 e 7.88 ± 0.85 wt%, not influenced by τ
- Optimum value of τ around **1.7 d**
- Maximum biomass productivity achieved: 0.45 g L^{-1} d^{-1} / **18 g m^{-2} d^{-1}**
- Maximum N productivity: 30 mg L^{-1} d^{-1} / **1.2 g m^{-2} d^{-1}**

> 10x the global N fixing capability estimated in the ecosystem

Effect of incident light intensity

τ: 3.68 d

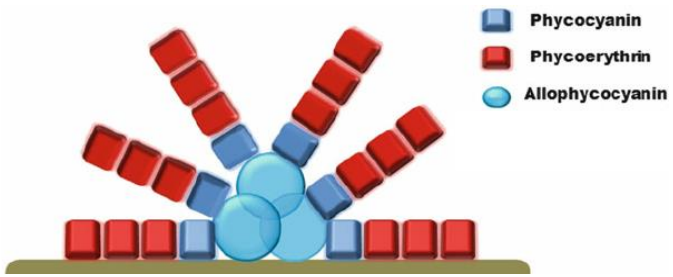




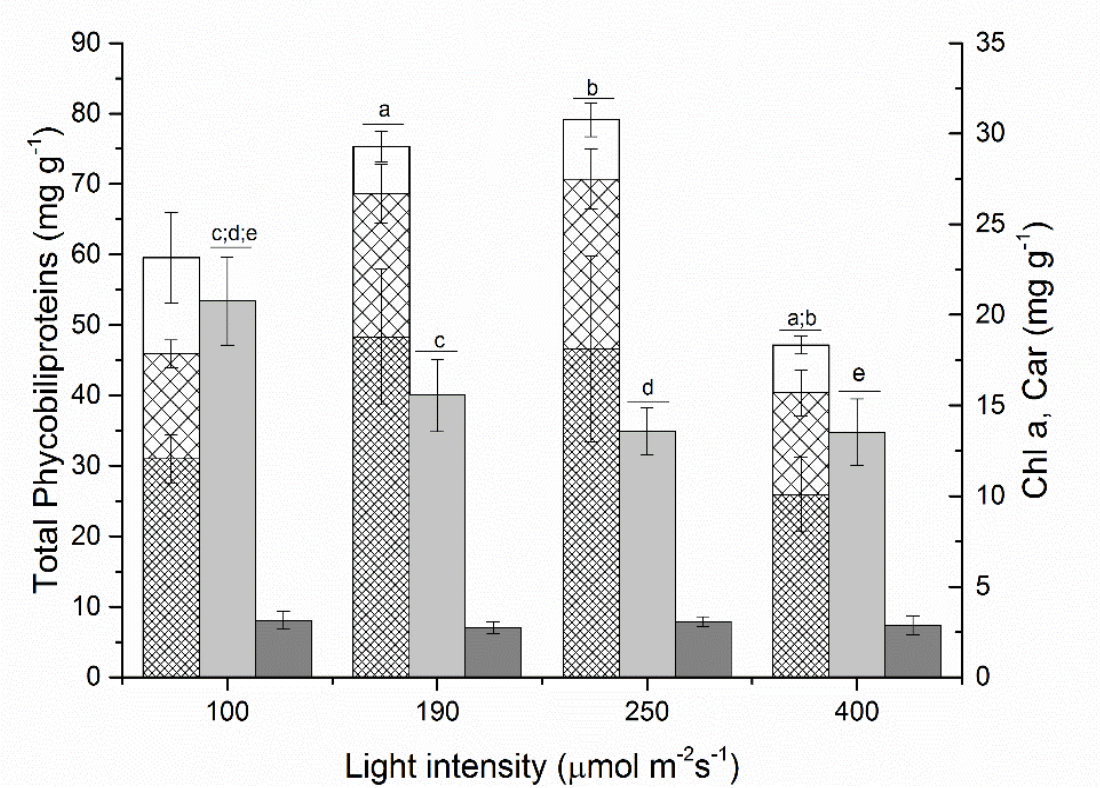
- No photosaturation/ photoinhibition effect up to 400 µmol m^{-2} s^{-1}
- Biomass productivity achieved: 0.54 g L^{-1} d^{-1} / **21 g m^{-2} d^{-1}**
- N wt% in the biomass appears negatively affected by the light intensity, but overall productivity increases

I_{in} (µmol m^{-2} s^{-1})	N wt%
100	9.16 ± 1.89
190	6.09 ± 0.18
250	4.15 ± 0.42
400	4.75 ± 0.39

Pigments (phycobiliproteins)



Light harvesting antennae: content is reduced when the light intensity increases, as a phtoprotection system



High-value product (food/cosmetic industry):

Productivity of about

1 g m^{-2} d^{-1}

Agricultural applications

BIOFERTILIZERS

- Average N fertilization rate:

  160 kg N ha^{-1} y^{-1}

- Lab-scale experimental productivity achieved:

  4380 kg N ha^{-1} y^{-1} ✓

(Need to assess the actual efficiency)

BIOSTIMULANTS

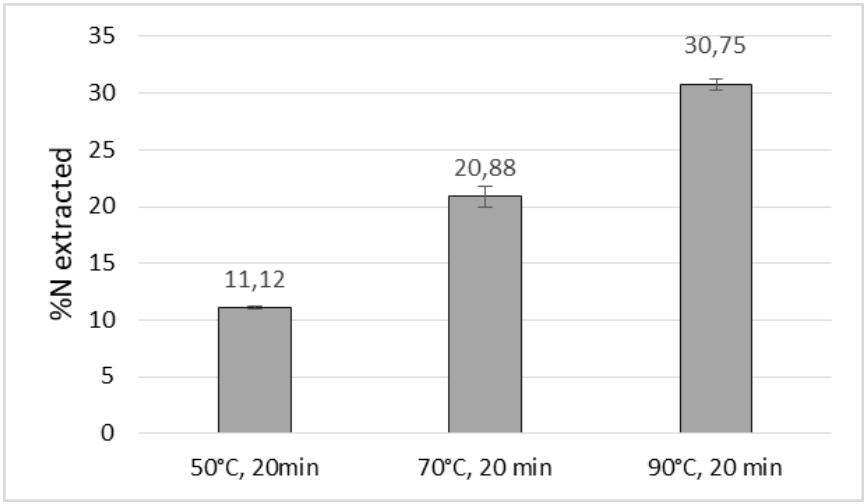
Different compounds of various origins and complex composition,

characterized by some *hormon-like* activites, which increase crop productivity

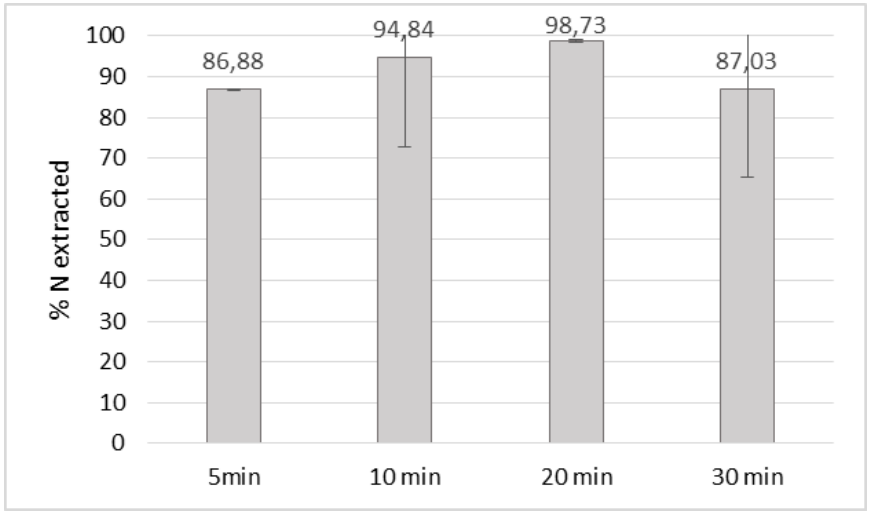
Biostimulants

Three different pre-treatments to break the cell wall and extract compounds of possible interest

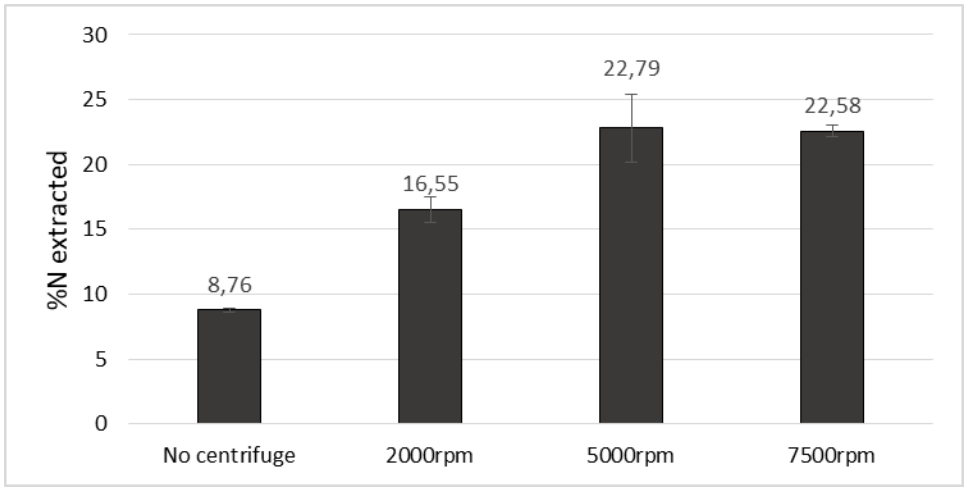
Thermal



Sonication

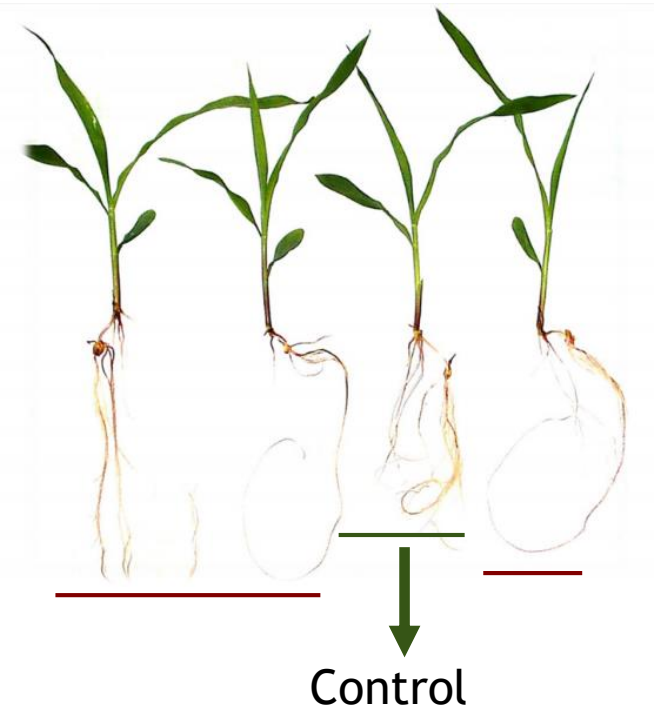


Freeze/thaw + centrifuge



Biostimulants

- Whole biomass: no *hormon-like* activity ✗
- Surnatant after freeze/thaw + centrifuge treatment: *auxin*- and *giberellin-like* activity ✓
- Surnatant after thermal treatment
- Surnatant after sonication treatment



*Biostimulation trials (Audus test) were carried out in collaboration with DAFNAE, UniPD

Conclusions

- Anabaena PCC 7122 was cultivated diazotrophically in continuous systems
- Nitrogen productivity achieved of 12 kg N ha^{-1} d^{-1}
- N content in the biomass is reduced under higher light intensity (phycobiliproteins)
- Potential for application in biofertilizers production
- Promising preliminary results for application as biostimulants

Acknowledgments

- Prof. Serenella Nardi and Dr. Andrea Ertani
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Thank you for your attention