

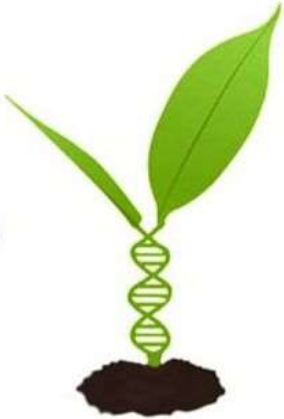


# **Plant and seed priming as ‘green’ tools for sustainable agriculture under conditions of global climate change**

**Vasileios Fotopoulos**

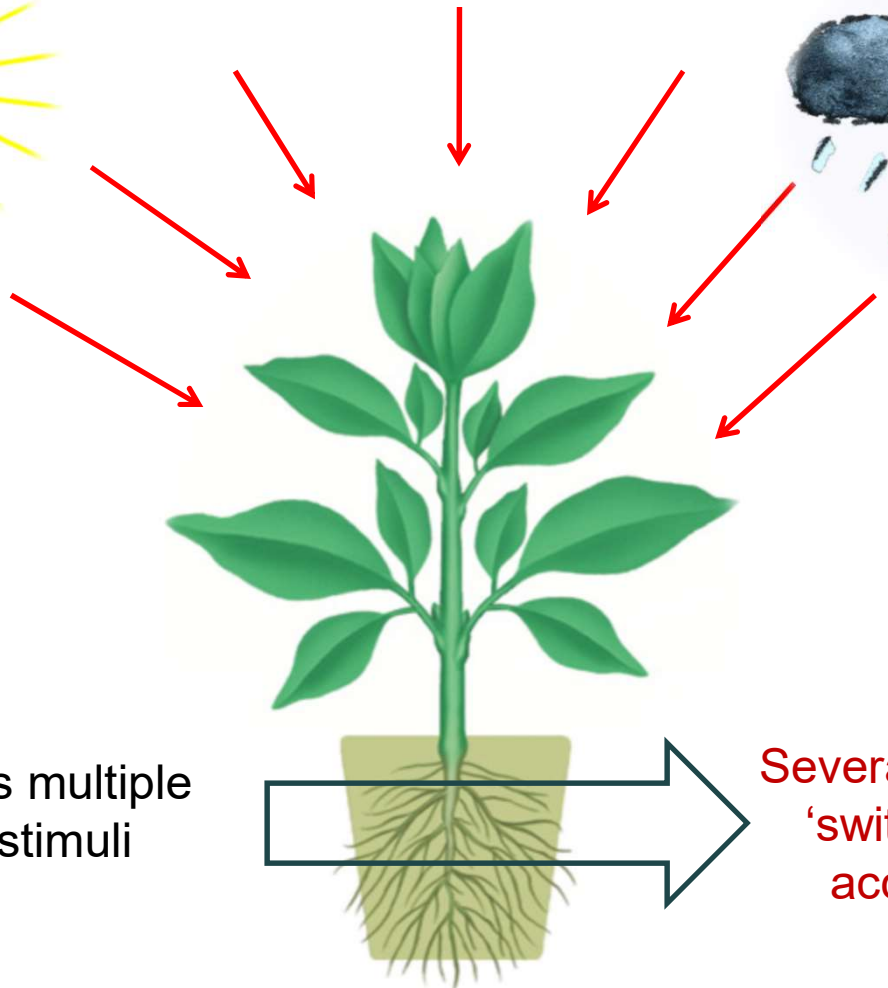
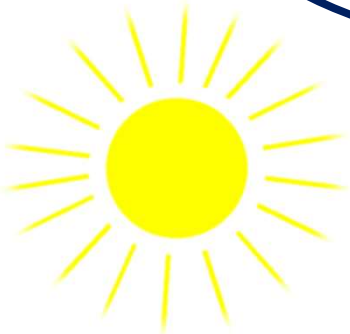
**PLANT STRESS  
PHYSIOLOGY GROUP**

**Cyprus University of Technology**





**Abiotic stress**  
(salinity, drought, heavy metals etc.)  
&  
**Biotic stress**  
(pathogenic microorganisms)



The plant receives multiple environmental stimuli

Several metabolic pathways are 'switched on' in response to accumulation of signaling molecules



# Potential solutions??

Examples include:

→ Genetic modification (**not so easy in countries such as Cyprus**)

→ Selection of tolerant cultivars (conventional breeding)

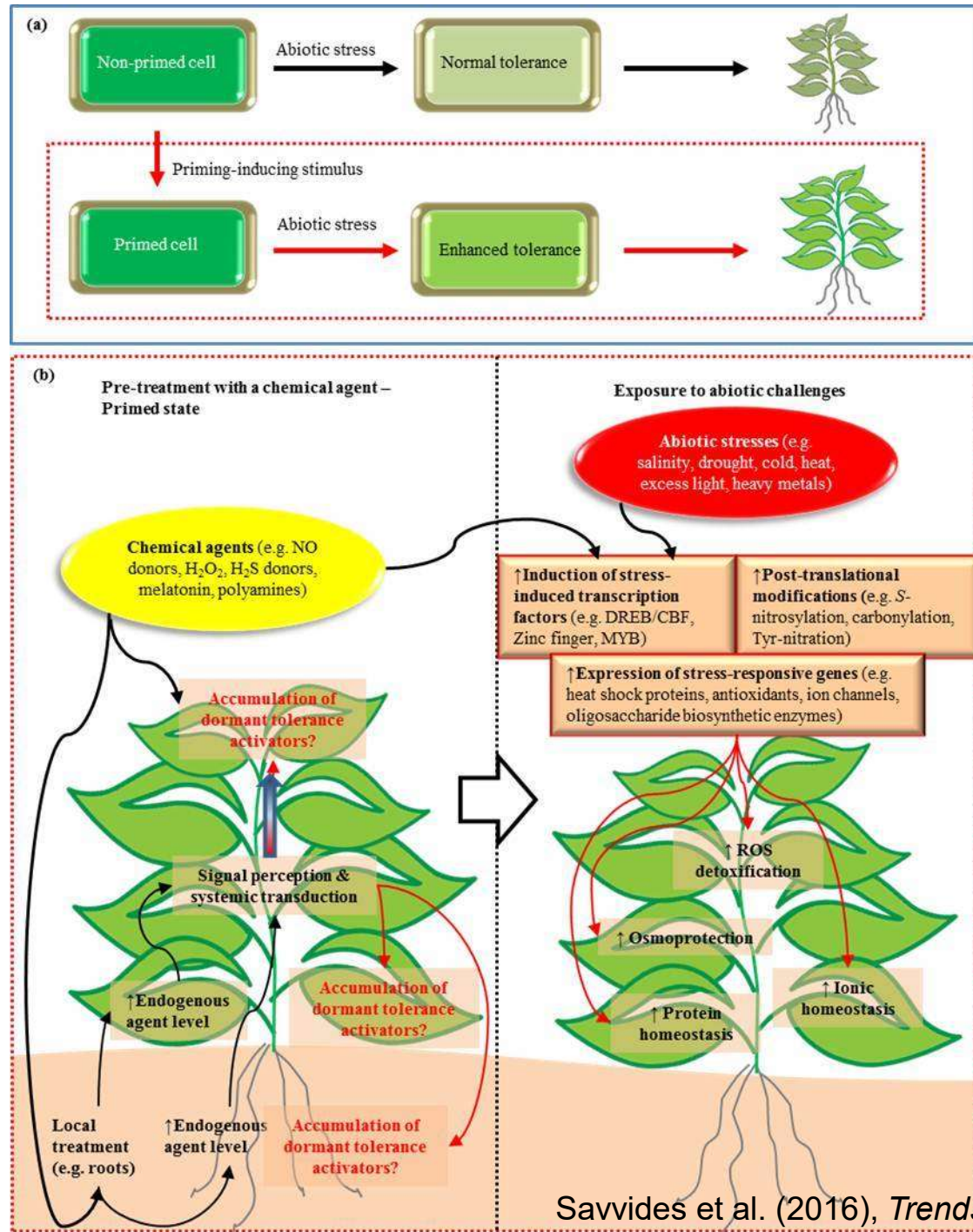
→ **Plant priming**



# Priming agents

What is priming?

- The process of priming involves **prior exposure to a biotic or abiotic stress factor** making a plant more resistant/tolerant to future exposure.
- Priming can also be achieved by **applying natural or synthetic compounds** which act as signaling transducers, 'activating' the plant's defense system.





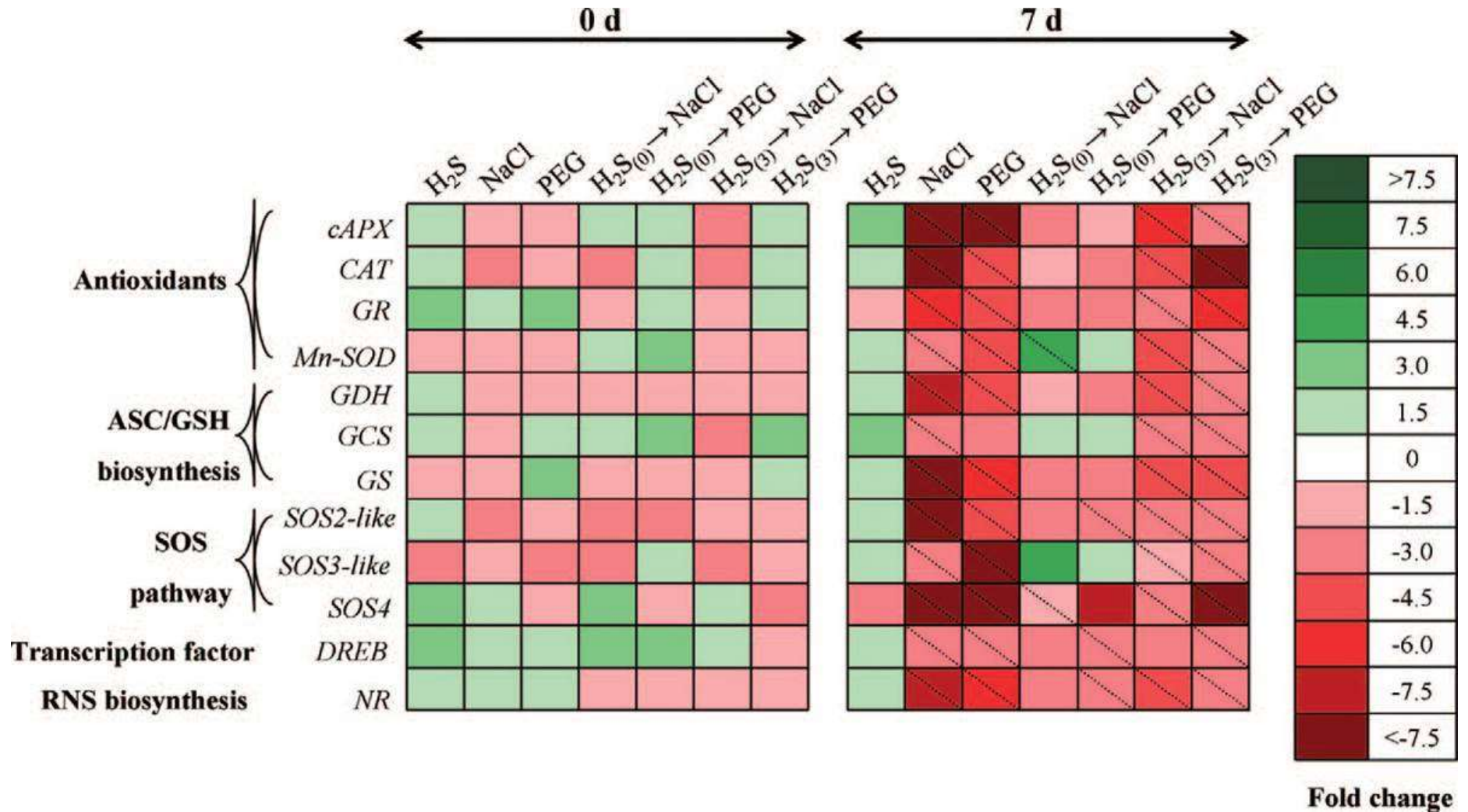
## Salt (100mM NaCl) and hyperosmotic (10% PEG6000) stress





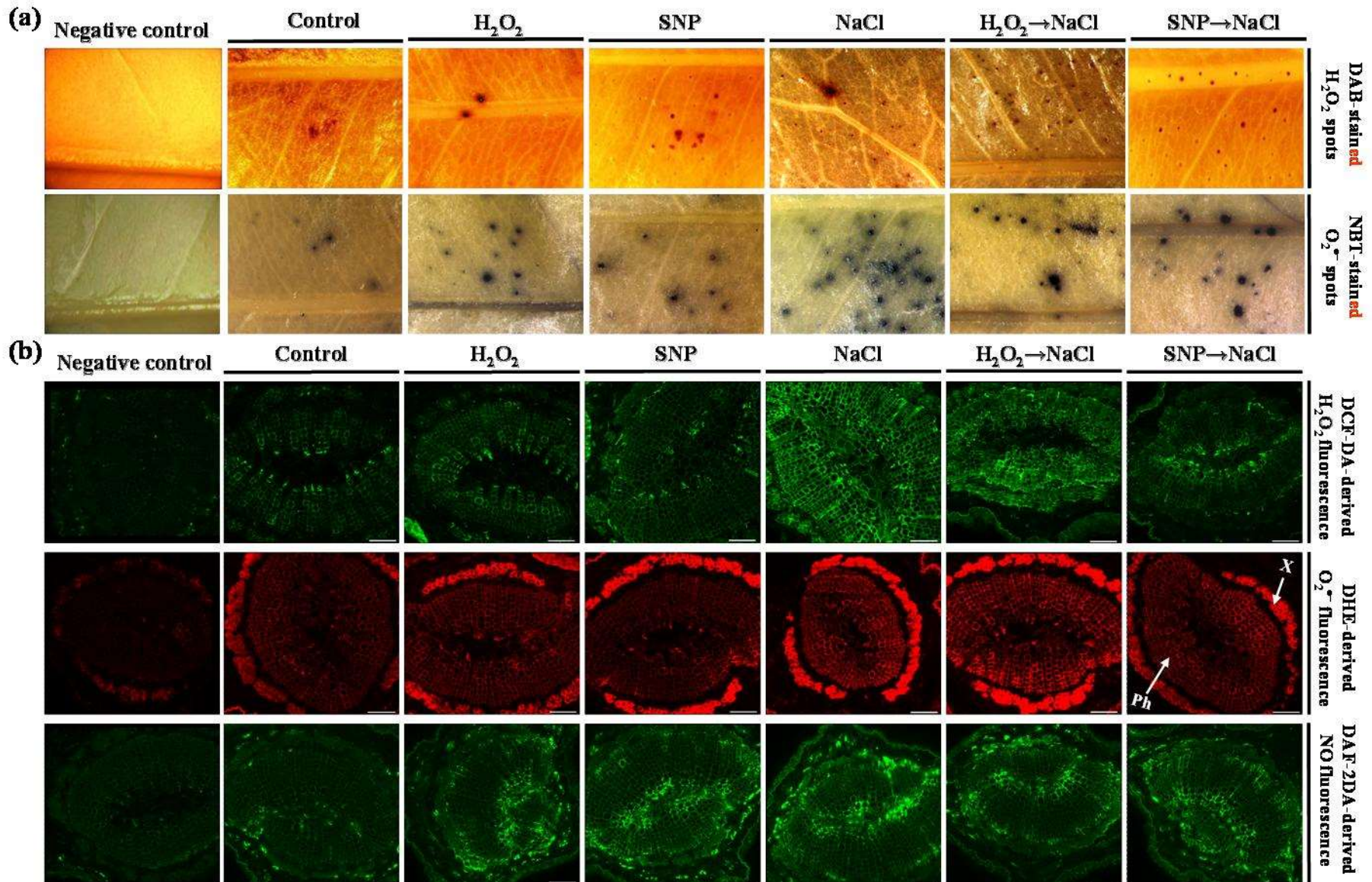
# Gene expression (RT-qPCR analysis)

- Optimization of DNA/RNA extraction protocol (Christou et al. (2014), *Gene* 537, 169-173)





# RONS detection by *in situ* histochemistry and confocal microscopy

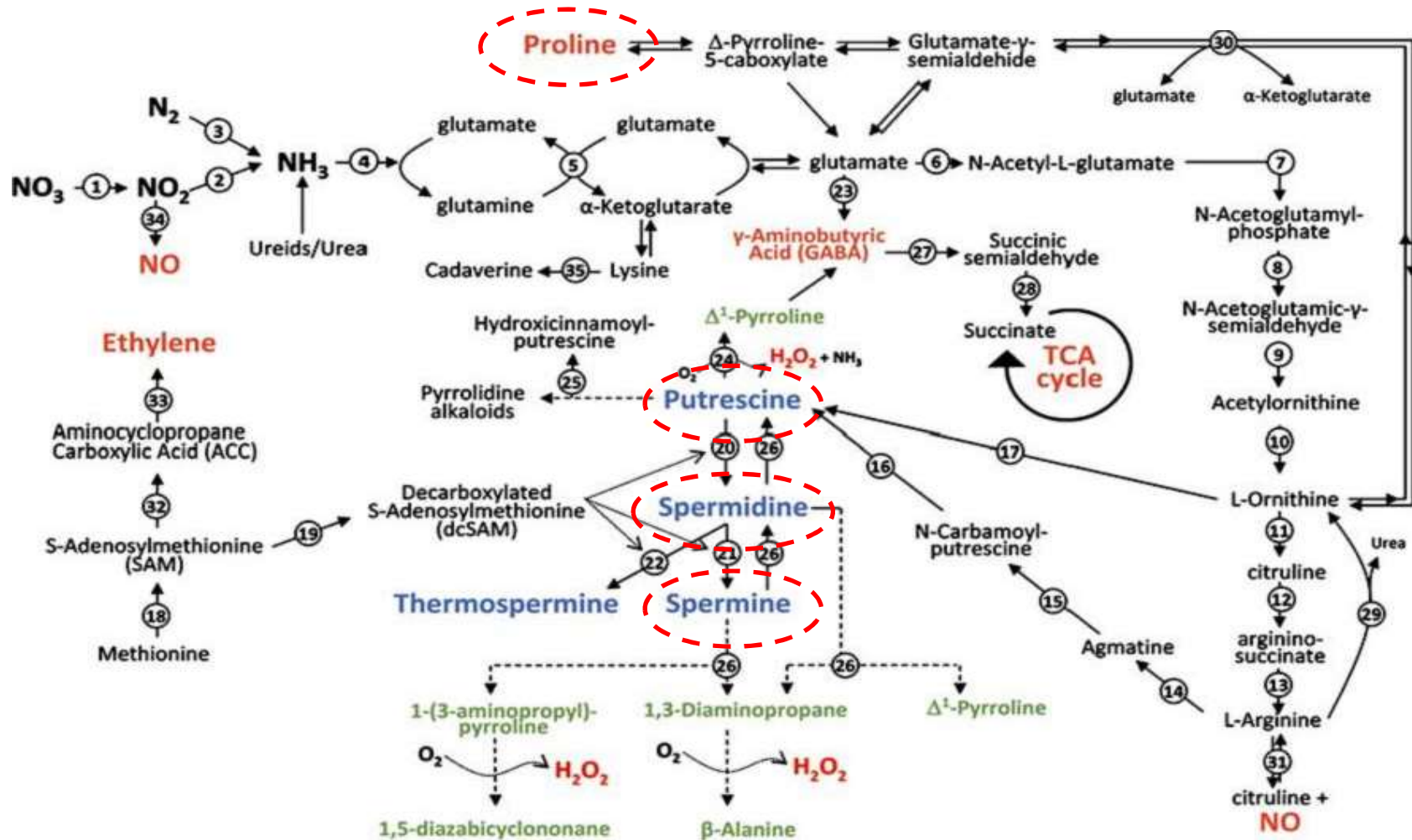


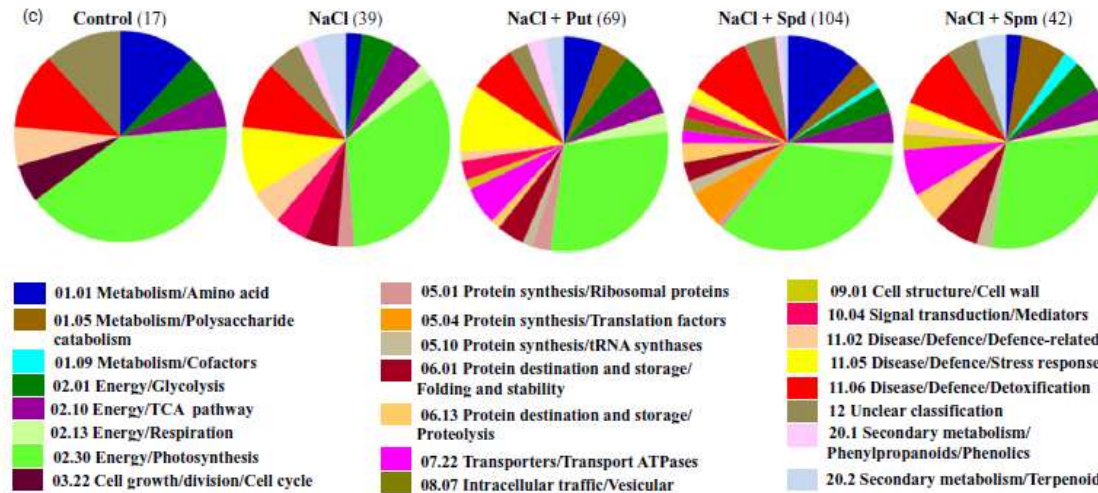
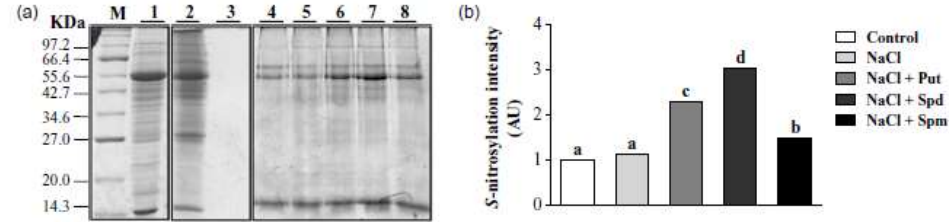
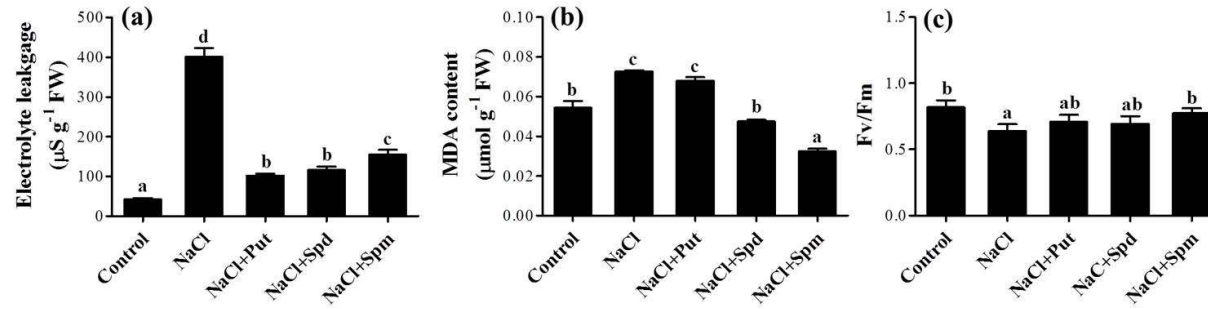




# Regulation of polyamines by NO

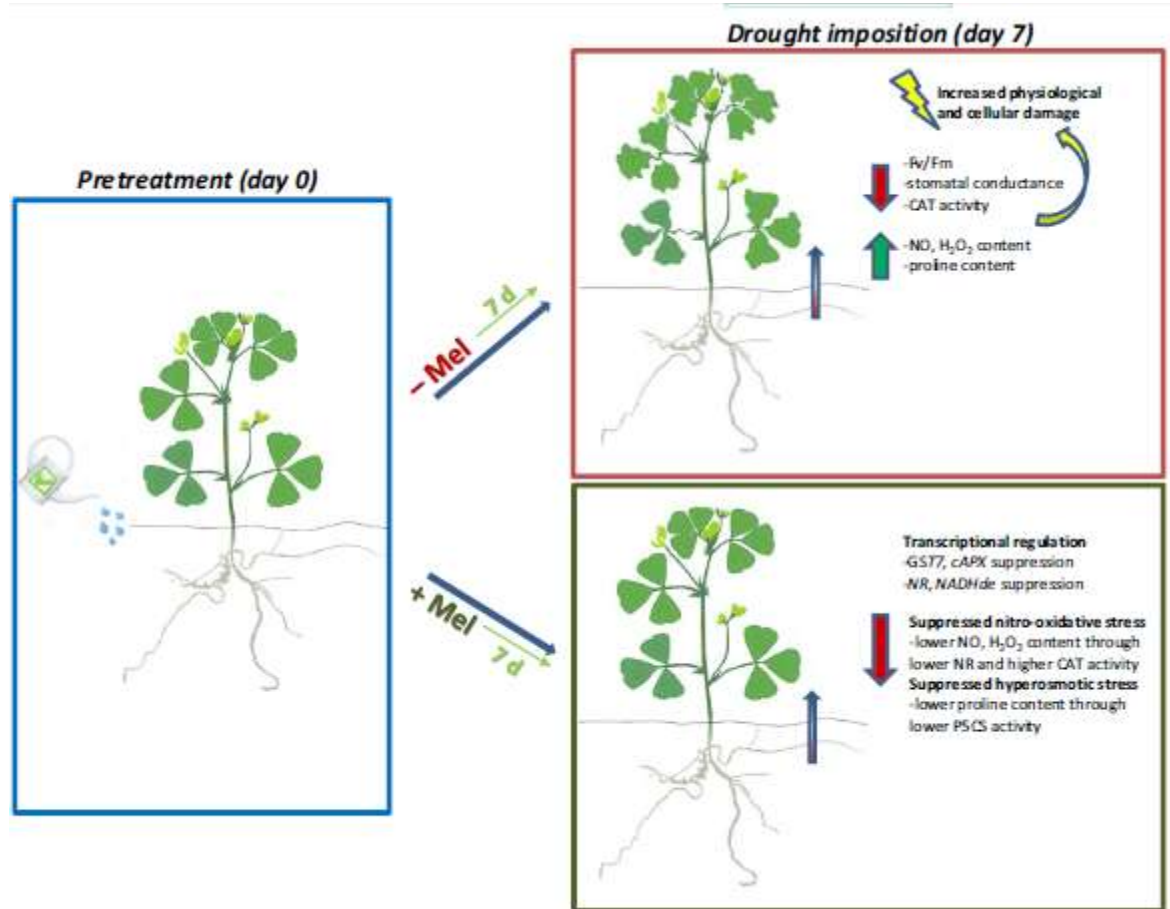
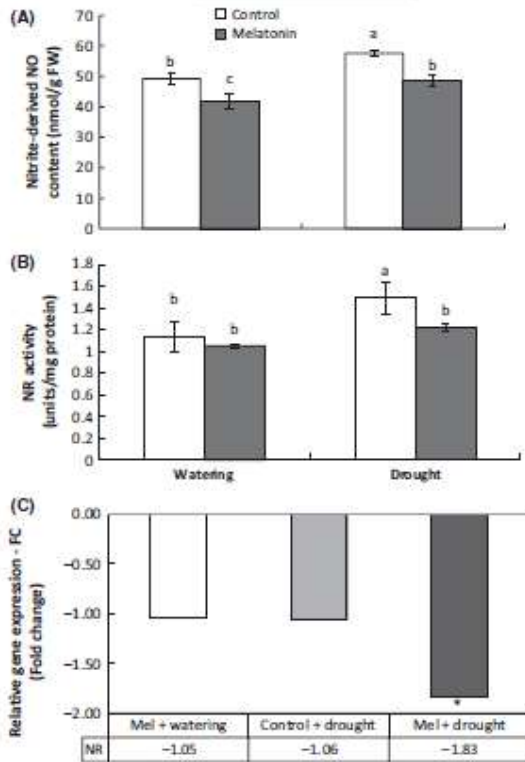
- Low MW N-containing compounds
- Protective to stress conditions





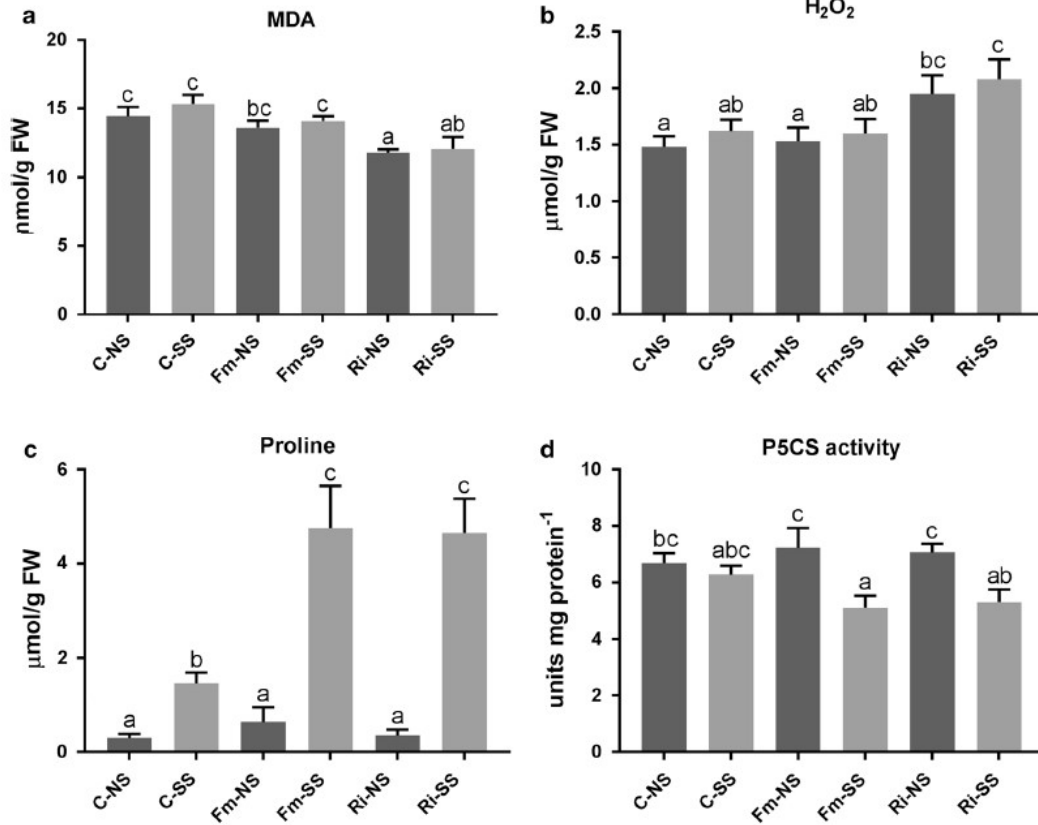


# Water stress – Melatonin!!!





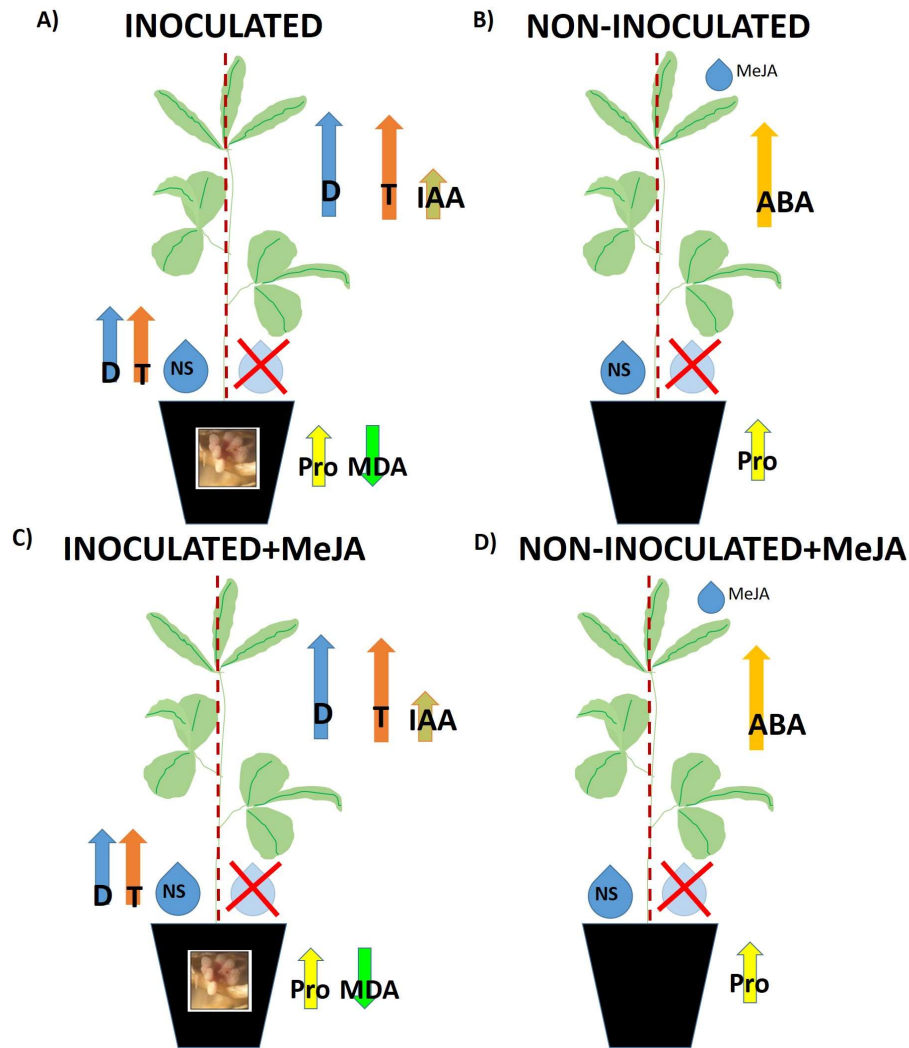
# Biological priming – microbes to the rescue!



Plant protection with AMF  
(*Funneliformis mosseae*,  
*Rhizophagus irregularis*)



# Mixing it up – what happens when we combine chemical priming agents with biological ones??



AM-fungal inoculum +  
MeJA priming



## Jumping on the biostimulant train...

- A plant biostimulant is any substance or microorganism applied to plants with the aim to enhance nutrition efficiency, abiotic stress tolerance and/or crop quality traits, regardless of its nutrients content (Du Jardin, 2015, *Sci Horti* 196, 3-14)
- Plant biostimulants are defined as products obtained from different organic or inorganic substances and/or microorganisms, that are able to improve plant growth, productivity and alleviate the negative effects of abiotic stresses (Rouphael and Colla, 2018, *Front Plant Sci* 9, 1655)
- Mineral elements, vitamins, amino acids, poly- and oligosaccharides, trace of natural plant hormones are the most known components.



# Jumping on the biostimulant train...





# Advanced nanomaterials: another way to the future?

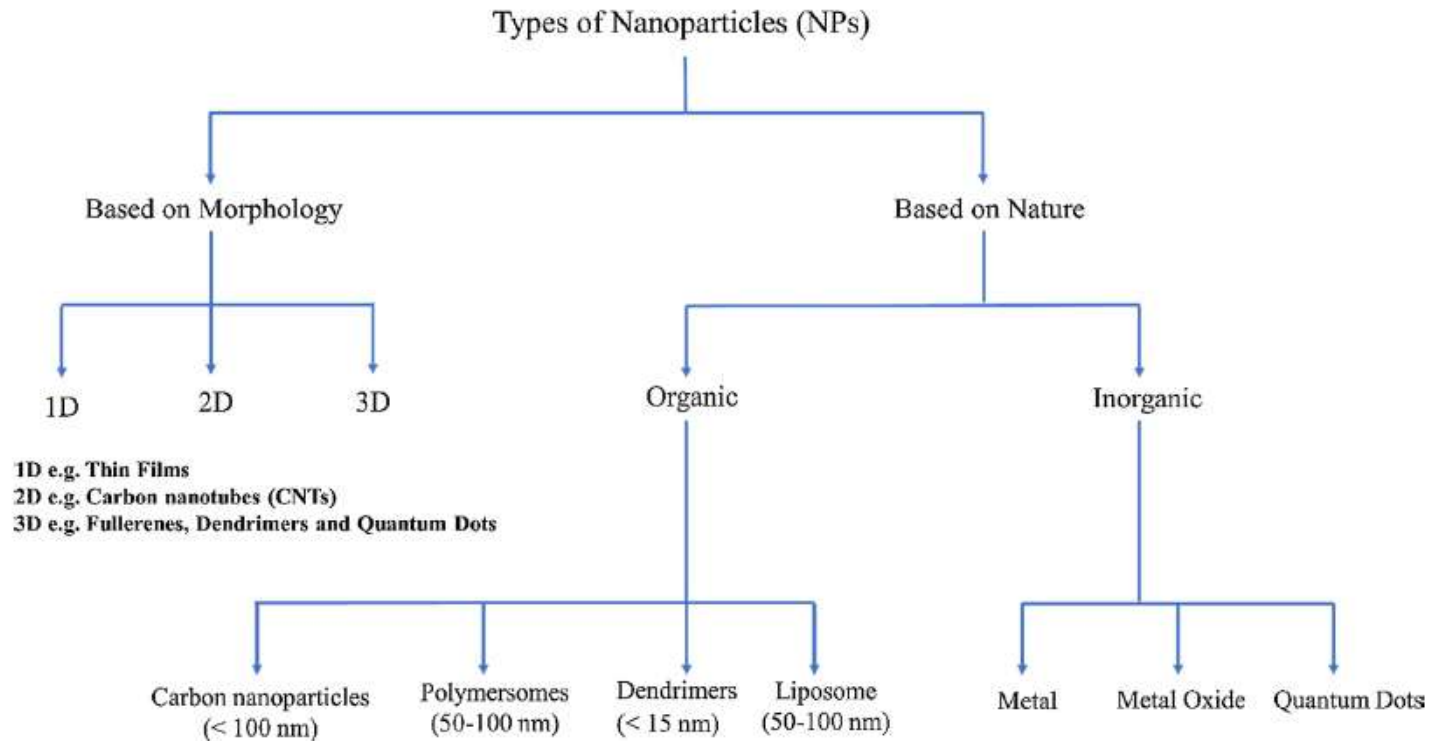
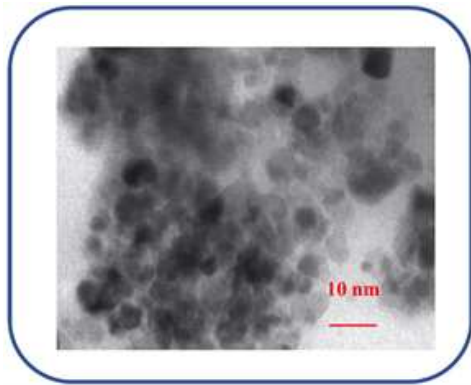
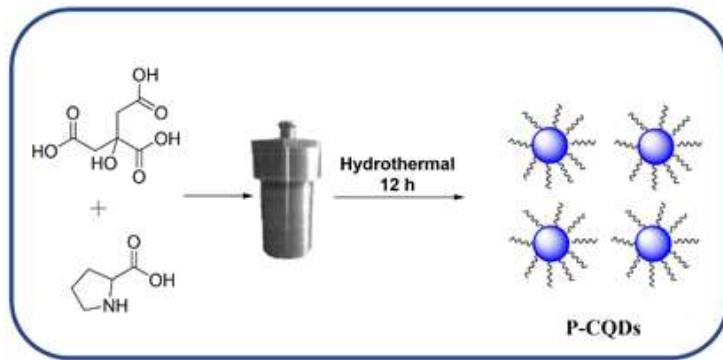


Fig. 1. Types of nanoparticles.



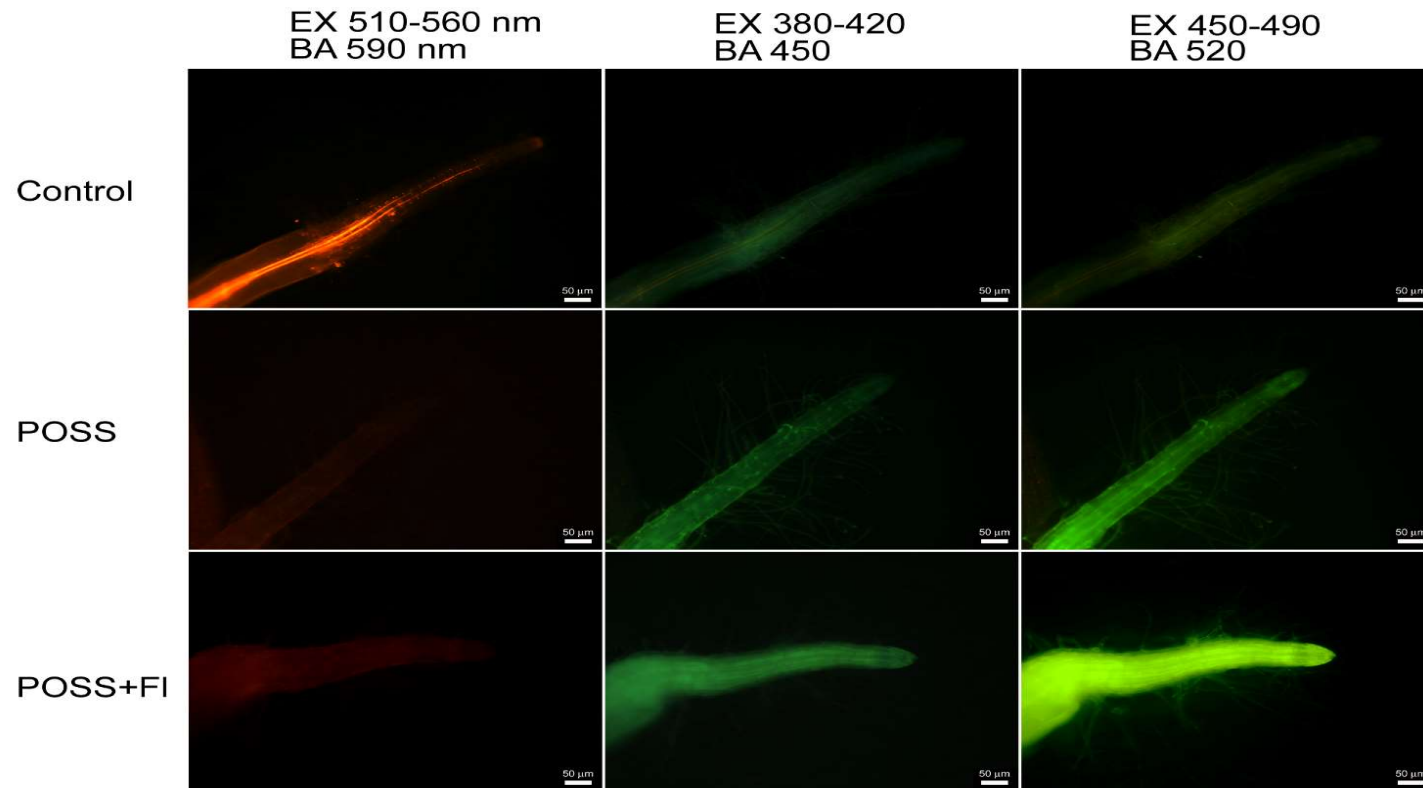


# Functionalized carbon nanotubes + Putrescine





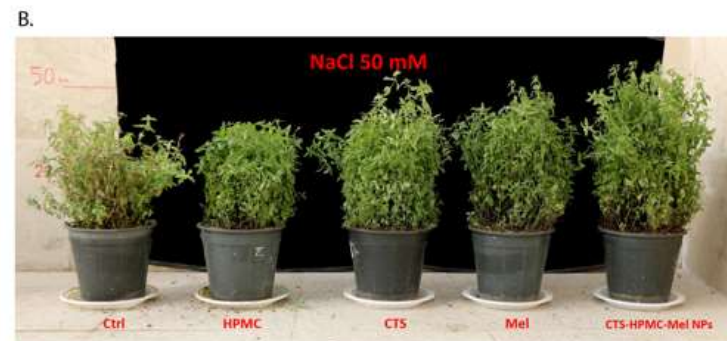
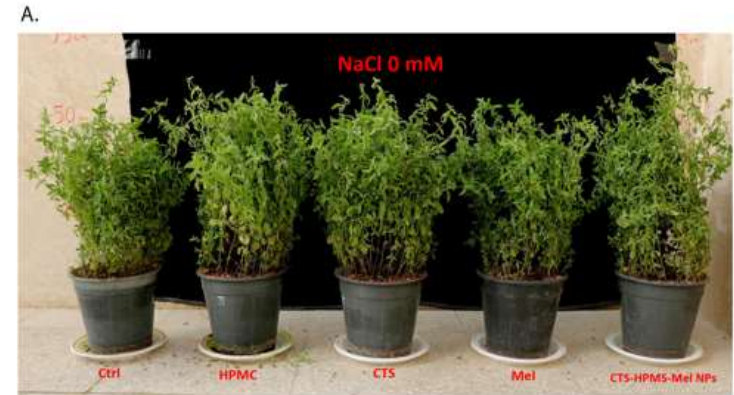
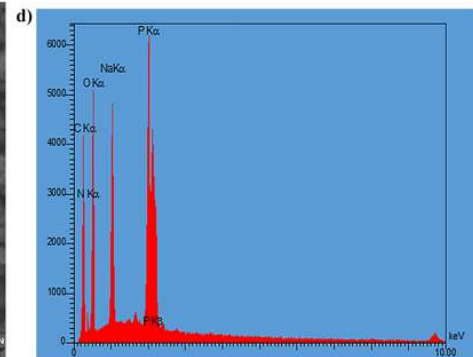
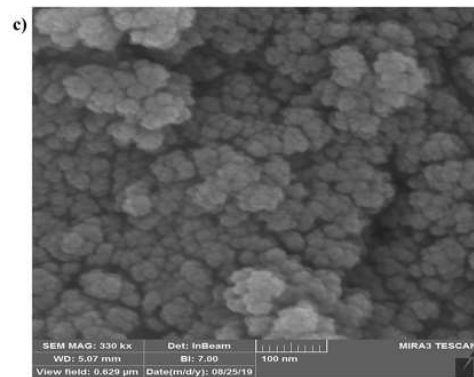
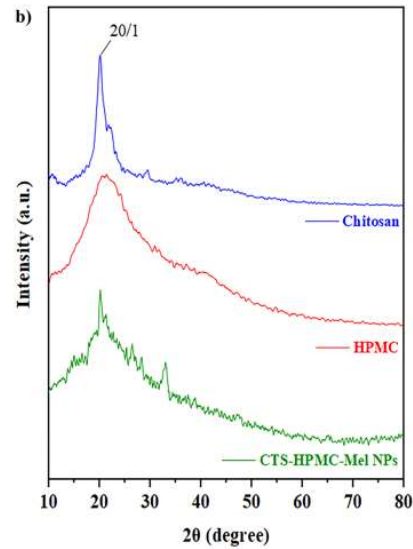
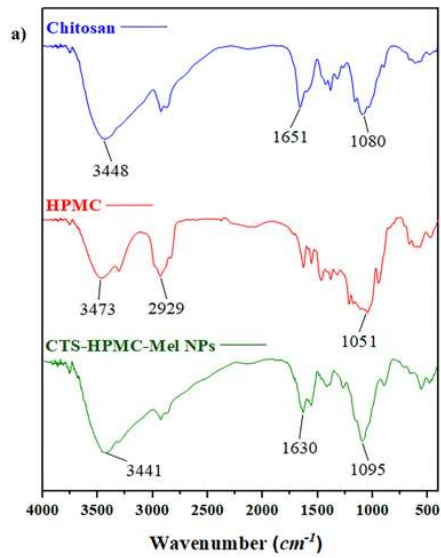
✓ POSS as new polyamine and silica base nano particles  
Nano-particles conjugated with fluorescence dyes in order to monitor smart delivery *in planta*



Gohari et al. (under revision)



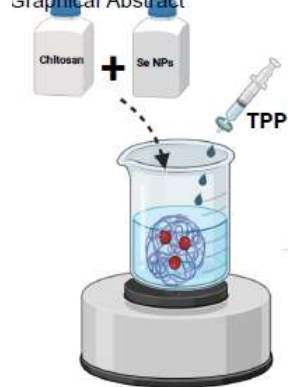
# Engineered chitosan-melatonin conjugates (CTS-mel NPs)



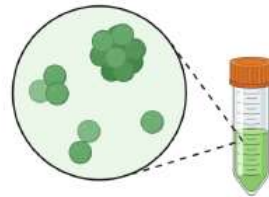


# Nanofertilisation with chitosan-selenium nanoparticles

Graphical Abstract

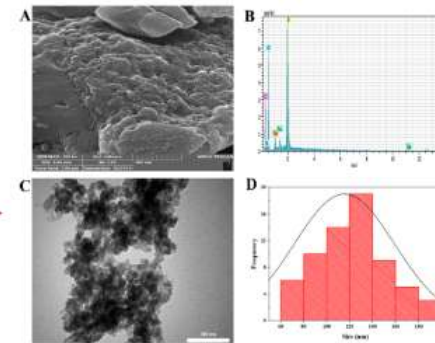


Synthesize



CS-Se NPs

characterization



(A) SEM micrograph, (B) EDS spectra, (C) TEM image, and (D) Particle size distribution of CS-Se NPs.



*Momordica charantia*

Salinity Stress  
(50 and 100 mM NaCl)

mitigate the adverse effects of salt stress

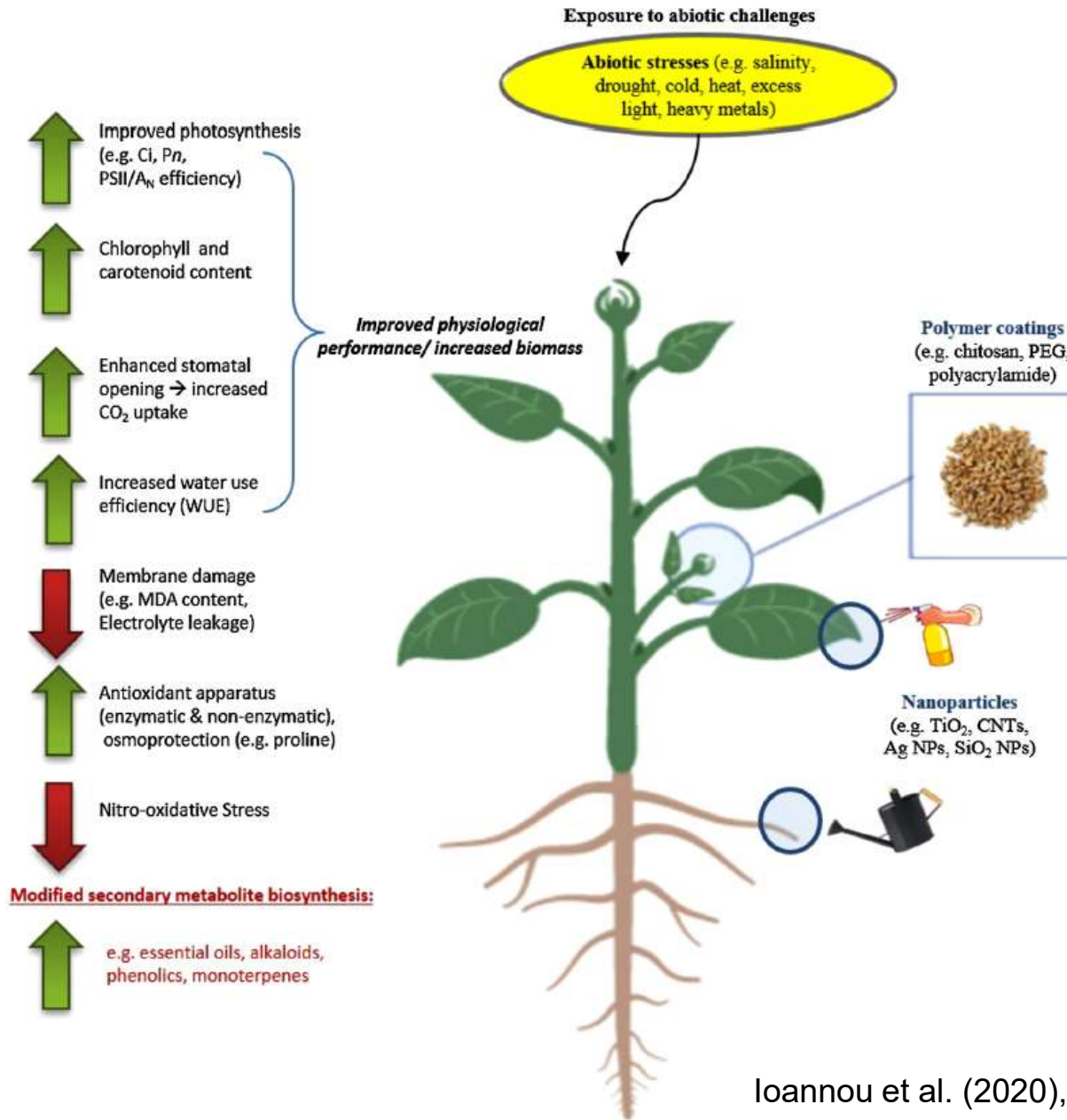


- Growth and photosynthesis parameters (SPAD, Fv/Fo and Y(II))
- Proline and RWC, Ca<sup>2+</sup>, P
- Antioxidant enzyme activities (SOD, CAT, POD)
- Expression of: *WRKY1*, *SOS1*, *PM H<sup>+</sup>-ATPase*, *SKOR*, *Mc5PTase7*, and *SOAR1*, *MAP30*,  $\alpha$ -*MMC* and *polypeptide-P*
- (YNO), Y(NPQ)
- Na<sup>+</sup>/K<sup>+</sup>, Cl
- H<sub>2</sub>O<sub>2</sub> and MDA

Sheikhalipour et al. (under review)



# Working model



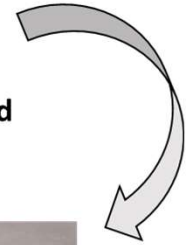
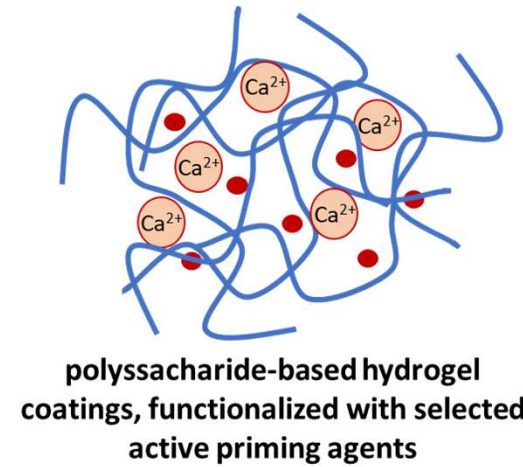
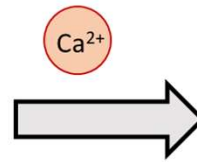
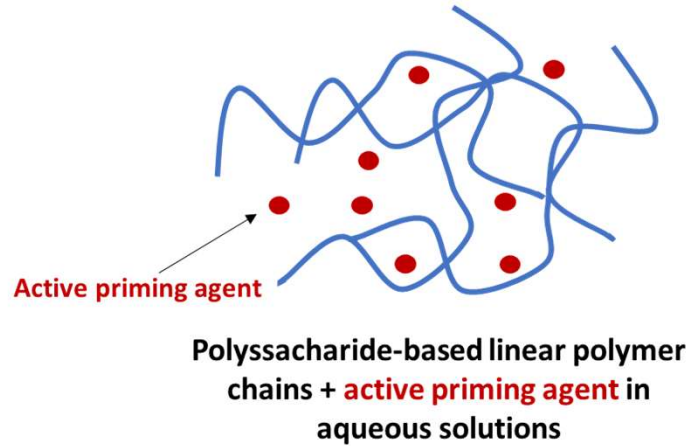


## Where to next?

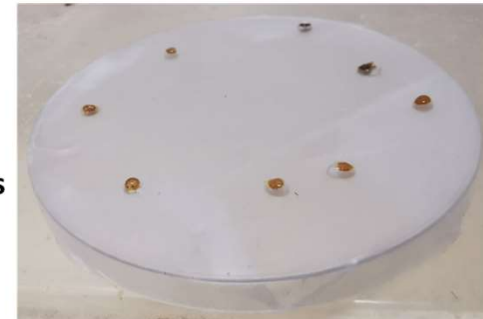
- There is a need for new cost-effective means of promoting plant growth from the time of seeding throughout the maturity of a plant.
- New approaches should steer away from using agrochemicals in their “free” form, since they require frequent application to plants and crops, while leaching phenomena result to severe environmental and economic issues.
- Treatment of seeds prior sowing would be practically much easier and economically more efficient than treatments at later developmental stages.
- The global market for seed was valued at **\$63 Billion** in 2021 and is projected to reach **\$86.8 Billion** by 2026, at a CAGR of 6.6% from 2021 to 2026.



# Our Solution – Biodegradable hydrogel coatings



Hydrogel-coated seeds



Provisional patent filed in USPTO  
(US Serial No. 63/284,167)



# Prototype field trials in process for TRL 7: 5 crops, 3 climates, 3 conditions



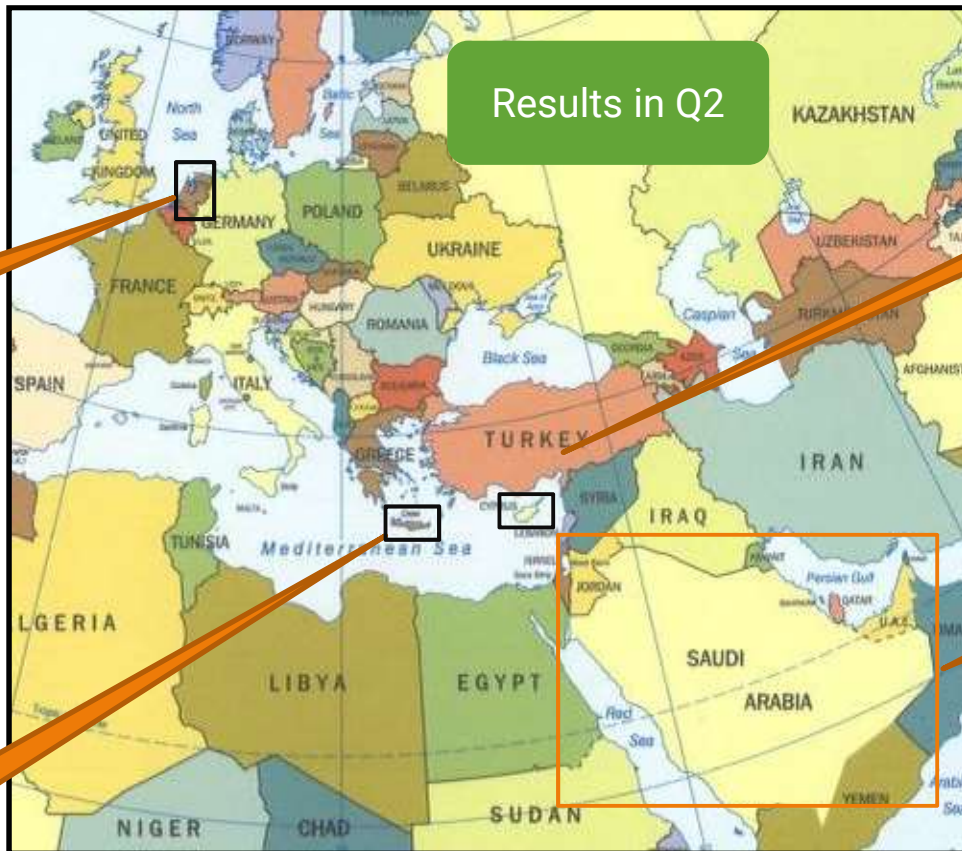
Growth enhancement

Stress protection

Results in Q2

Musk melon and gherkin  
*unstressed*  
(ongoing)

Baby spinach  
*Heat stress*  
(scheduled)



Tomato & pepper  
17 commercial sites  
*unstressed*  
(ongoing)

Tomato plants  
*Salt stress*  
(ongoing)





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## Collaborators:

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**UCY [CY]**  
- Theodora Krasia-Christoforou

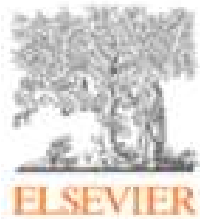


**CCNY [USA]**  
-Khosrow Kashfi



## Funding:





# Plant Stress

We are delighted to introduce *Plant Stress*, a new gold open access journal dedicated to plant research.

*Plant Stress* focus on plant or other photoautotrophs, such as algae, cyanobacteria and lichens responses to abiotic and biotic stress factor that can result in limited growth and productivity.



The journal is welcoming original, high-quality manuscripts related (but not limited) to interactions between plants and:

- Lack of water (drought) and excess (flooding),
- Salinity stress,
- Elevated temperature and/or low temperature (chilling and freezing),
- Hypoxia and/or anoxia,
- Mineral nutrient excess and/or deficiency,
- Heavy metals and/or metalloids,
- Plant priming (chemical, biological, physiological, nanomaterial, biostimulant) approaches for improved stress protection,
- Viral, phytoplasma, bacterial and fungal plant-pathogen interactions.