5TH INTERNATIONAL
STRAWBERRY CONGRESS

WELCOME

Connecting the dots in a complex world of strawberries

Antwerp – Belgium

17 – 20 September 2025

5TH INTERNATIONAL STRAWBERRY CONGRESS

Wednesday

Parallel Session 1: Strawberry Breeding & Physiology

The application of priming agents as a stress alleviation strategy to combat salinity conditions in strawberry

George Manganaris
Cyprus University of Technology
Department of Agricultural Sciences, Biotechnology & Food Science
Email: george.manganaris@cut.ac.cy
Website: www.fruitsciences.eu

Outline

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#1 **The strawberry sector in South Europe**
The case study of Greece

#2 **The concept of priming:**
a novel agricultural approach

#3 **The effect of priming agents on strawberry plants**
under salinity conditions (field experiment)

#4 **Exploring functionalized biopolymer prototypes** towards mitigation of salt stress in strawberry plants

The CUT Fruit Sciences Group

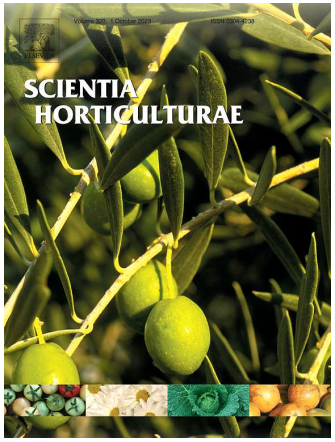
CUT FRUIT SCIENCES GROUP

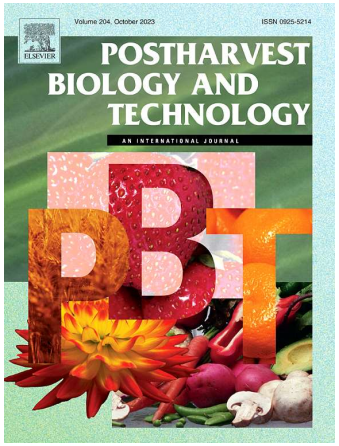
Cyprus University of Technology

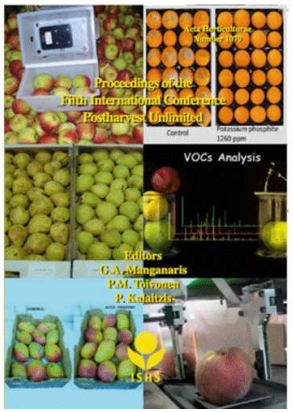
Full Professor (2024-),
Group leader of the www.frutsciences.eu group

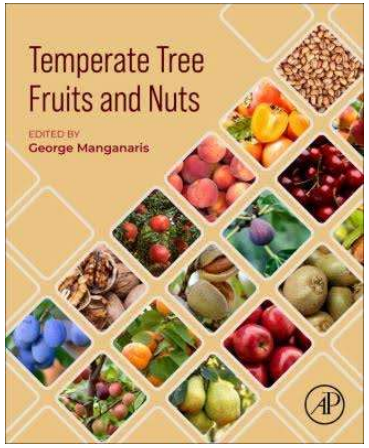
Post-doctoral Research Associate,
University of California at Davis, Department of Plant Sciences, USA

Post-doctoral Research Associate,
Recipient of an MC-IEF Fellowship, University of Padova, Italy









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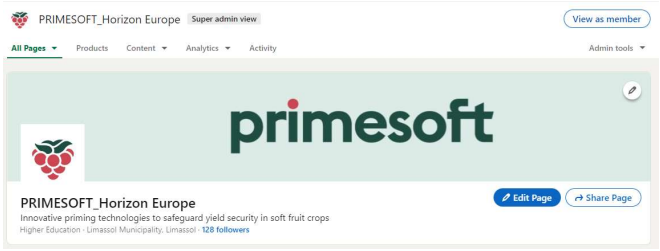
Home > ... > Horizon Europe > Development of innovative priming technologies safeguarding yield security in soft fruit crops through a cutting-edge technological approach

HORIZON EUROPE

Development of innovative priming technologies safeguarding yield security in soft fruit crops through a cutting-edge technological approach

Fact Sheet | Results



www.prime-soft.eu

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Germany

ETHNICON METSOVION POLYTECHNION
Greece

The strawberry production sector in South Europe

The case study of Greece

Strawberry:
a true success story of Greece

- ✓ More than 240 million € value from 300 growers
- ✓ From 160 ha in 2003->1000 ha in 2013-> to 2300 ha in 2024
- ✓ One of the earliest site in South Europe for production (mid November to late May)
- ✓ Exports (90% of production): West and East Europe+ Gulf countries
- ✓ A lot of young growers with Horticulture degree

Source: Tsormpatsidis

Strawberry production system:
the case of Greece

- ✓ Production in old beds (environmental friendly)
- ✓ Solarization
- ✓ Use of resilient varieties - High level of expertise
- ✓ Production based on measurements (analysis)

Fortuna

Total Production: 1 kg/plant
Ripening period: November-April
Plant material: 0.27 €/tray plant

- 💡 Early production: 3-fold ↑ price
- 💡 Excellent taste
- 💡 Skilled farmer

Victory

Total Production: 0.85 kg/plant
Ripening period: February-May
Plant material: 0.18 €/bare root plant

- 💡 Excellent postharvest performance
- 💡 No claims
- 💡 Inferior taste compared to 'Fortuna'

Source: Tsormpatsidis

Strawberry cultivation:

‘Fortuna’ production model

- ✅ Annual production cost: *ca.* 65,000€/ hectare
  65,000 plants per hectare
- ✅ Farm gate price (mid November – early January): 3,5€
  marketable yield per plant: 150 g
- ✅ Farm gate price (mid January – early May): 1,5€
  marketable yield per plant: 850 g

- 💡 Early production: 0,53€
- 💡 Mid-late production: 1,19 €
- 💡 Net profit: 46,800 €/ hectare

Source: Tsormpatsidis

The strawberry production sector

The reality:

- Labor cost and labor availability
- Royalties for high yield cultivars
- Highly perishable commodity

The challenges:

- High yield efficiency and availability throughout the year
- Extended storage potential
- Sustainable production models that meet consumers' expectations
- Exploitation of second class products for other uses

Towards reduced food loss

“Ugly Fruits” Movement towards reduced food loss

Source: Clarkson

The concept of priming:
a novel agricultural approach

Solutions to combat stress conditions

- **Genetic modification**

  CRISPR-Cas movement: Targeted Genome Editing Technology

  gene-edited plants remain under the strict GMO framework

  Lena Maas, Protoplast-CRISPR technology in strawberry

- **Selection of tolerant cultivars**

  Conventional breeding

  Capital intensive and time consuming

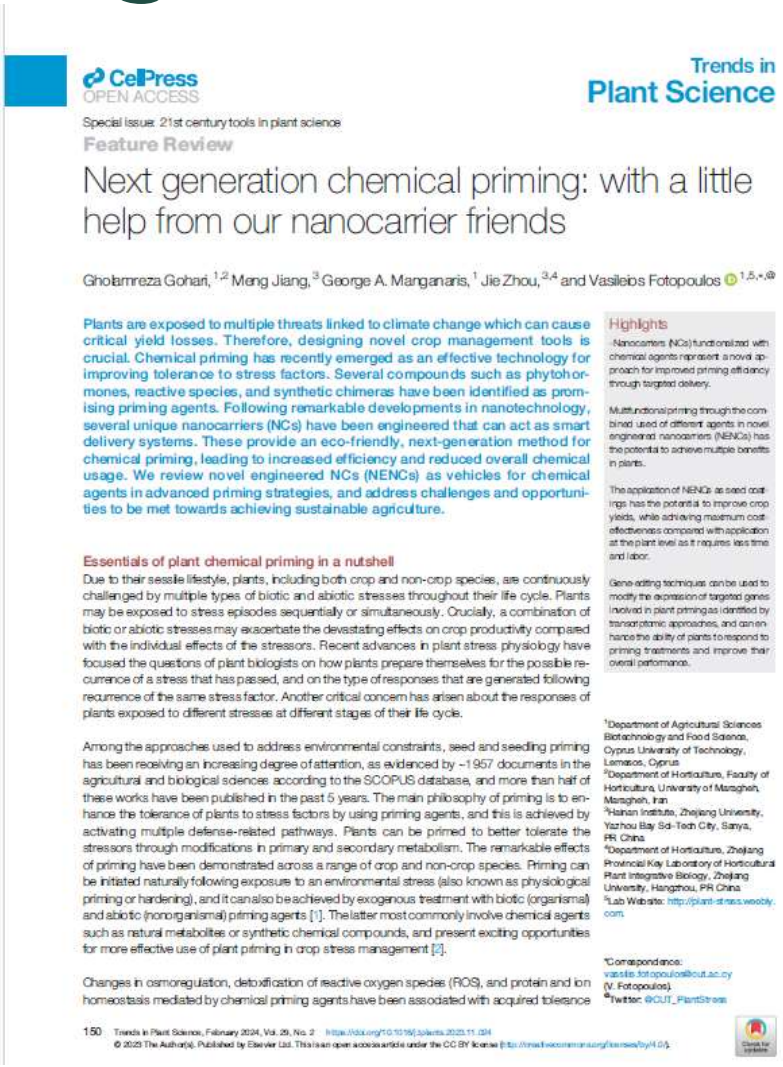
  Steven Knapp, Shaping the Next-Generation of Strawberry Cultivars

- **Plant priming**

Defining the term ‘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.



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Trends in
Plant Science

Special Issue: 21st century tools in plant science

Feature Review

Next generation chemical priming: with a little help from our nanocarrier friends

Gholamreza Gohari,[1,2] Meng Jiang,[3] George A. Manganaris,[1] Jie Zhou,[3,4] and Vasileios Fotopoulos[1,5,*,@]

Plants are exposed to multiple threats linked to climate change which can cause critical yield losses. Therefore, designing novel crop management tools is crucial. Chemical priming has recently emerged as an effective technology for improving tolerance to stress factors. Several compounds such as phytohormones, reactive species, and synthetic chimeras have been identified as promising priming agents. Following remarkable developments in nanotechnology, several unique nanocarriers (NCs) have been engineered that can act as smart delivery systems. These provide an eco-friendly, next-generation method for chemical priming, leading to increased efficiency and reduced overall chemical usage. We review novel engineered NCs (NENCs) as vehicles for chemical agents in advanced priming strategies, and address challenges and opportunities to be met towards achieving sustainable agriculture.

Highlights

Nanocarriers (NCs) functionalized with chemical agents represent a novel approach for improved priming efficiency through targeted delivery.

Multifunctional priming through the combined used of different agents in novel engineered nanocarriers (NENCs) has the potential to achieve multiple benefits in plants.

The application of NENCs as seed coatings has the potential to improve crop yields, while achieving maximum cost-effectiveness compared with application at the plant level as it requires less time and labor.

Gene-editing techniques can be used to modify the expression of targeted genes involved in plant priming as identified by transcriptomic approaches, and can enhance the ability of plants to respond to priming treatments and improve their overall performance.

Essentials of plant chemical priming in a nutshell

Due to their sessile lifestyle, plants, including both crop and non-crop species, are continuously challenged by multiple types of biotic and abiotic stresses throughout their life cycle. Plants may be exposed to stress episodes sequentially or simultaneously. Crucially, a combination of biotic or abiotic stresses may exacerbate the devastating effects on crop productivity compared with the individual effects of the stressors. Recent advances in plant stress physiology have focused the questions of plant biologists on how plants prepare themselves for the possible recurrence of a stress that has passed, and on the type of responses that are generated following recurrence of the same stress factor. Another critical concern has arisen about the responses of plants exposed to different stresses at different stages of their life cycle.

Among the approaches used to address environmental constraints, seed and seedling priming has been receiving an increasing degree of attention, as evidenced by ~1957 documents in the agricultural and biological sciences according to the SCOPUS database, and more than half of these works have been published in the past 5 years. The main philosophy of priming is to enhance the tolerance of plants to stress factors by using priming agents, and this is achieved by activating multiple defense-related pathways. Plants can be primed to better tolerate the stressors through modifications in primary and secondary metabolism. The remarkable effects of priming have been demonstrated across a range of crop and non-crop species. Priming can be initiated naturally following exposure to an environmental stress (also known as physiological priming or hardening), and it can also be achieved by exogenous treatment with biotic (organismal) and abiotic (nonorganismal) priming agents [1]. The latter most commonly involve chemical agents such as natural metabolites or synthetic chemical compounds, and present exciting opportunities for more effective use of plant priming in crop stress management [2].

Changes in osmoregulation, detoxification of reactive oxygen species (ROS), and protein and ion homeostasis mediated by chemical priming agents have been associated with acquired tolerance

[1]Department of Agricultural Sciences, Biotechnology and Food Science, Cyprus University of Technology, Lemesos, Cyprus
[2]Department of Horticulture, Faculty of Horticulture, University of Maragheh, Maragheh, Iran
[3]Hainan Institute, Zhejiang University, Yazhou Bay Sci-Tech City, Sanya, PR China
[4]Department of Horticulture, Zhejiang Provincial Key Laboratory of Horticultural Plant Integrative Biology, Zhejiang University, Hangzhou, PR China
[5]Lab Website: http://plant-stress.weebly.com

*Correspondence:
vassilis.fotopoulos@cut.ac.cy
(V. Fotopoulos).
@Twitter: @CUT_PlantStress

Classes of priming agents

Chemicals (including natural and synthetic molecules)

- Hormones (i.e. salicylic acid, jasmonic acid)
- Reactive Oxygen Nitrogen and Sulphur Species (RONSS: NO, H_2S, H_2O_2)
- Small organic molecules (i.e. melatonin, putrescine)

Microorganisms

- Arbuscular mycorrhizal fungi
- Plant growth-promoting bacteria

Nanomaterials

- Organic nanoparticles
- Inorganic nanoparticles
- Polymers (i.e., chitosan, sodium alginate)

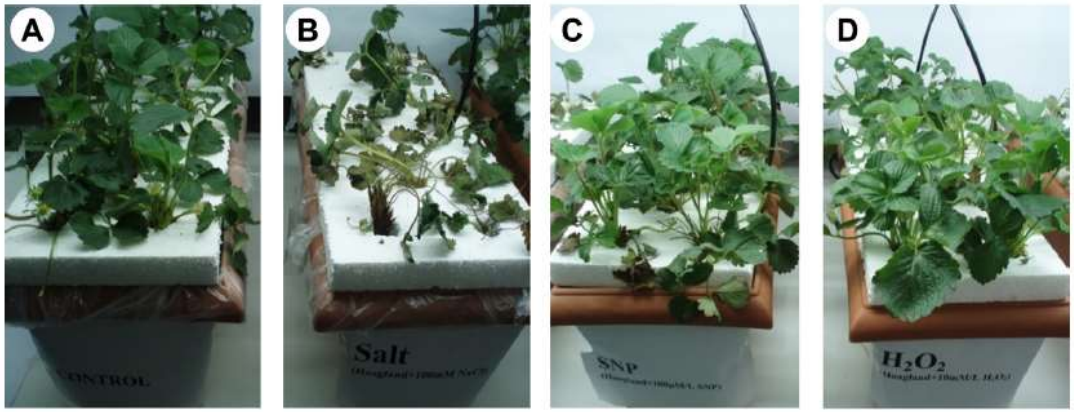
The effect of PAs on strawberry plants
Period: 2010-2013 (PhD project)


Plant priming with signaling molecules (H_2O_2, NO, H_2S):
a promising approach for alleviating abiotic stress devastating effects

Pretreatment was carried out in a hydroponic cultivation system and plants exposed to a multitude of abiotic stress factors and analyzed through a combinatorial physiological, biochemical and molecular approach

H_2S promotes NaCl and PEG stress tolerance in strawberry plants

A. Christou et al. / Environmental and Experimental Botany 107 (2014) 46–54



Exploring the mechanistic action of PAs

Journal of Experimental Botany, Vol. 64, No. 7, pp. 1953–1966, 2013
doi:10.1093/jxb/ert055 Advance Access publication 8 April, 2013
This paper is available online free of all access charges (see http://jxb.oxfordjournals.org/open_access.html for further details)

RESEARCH PAPER

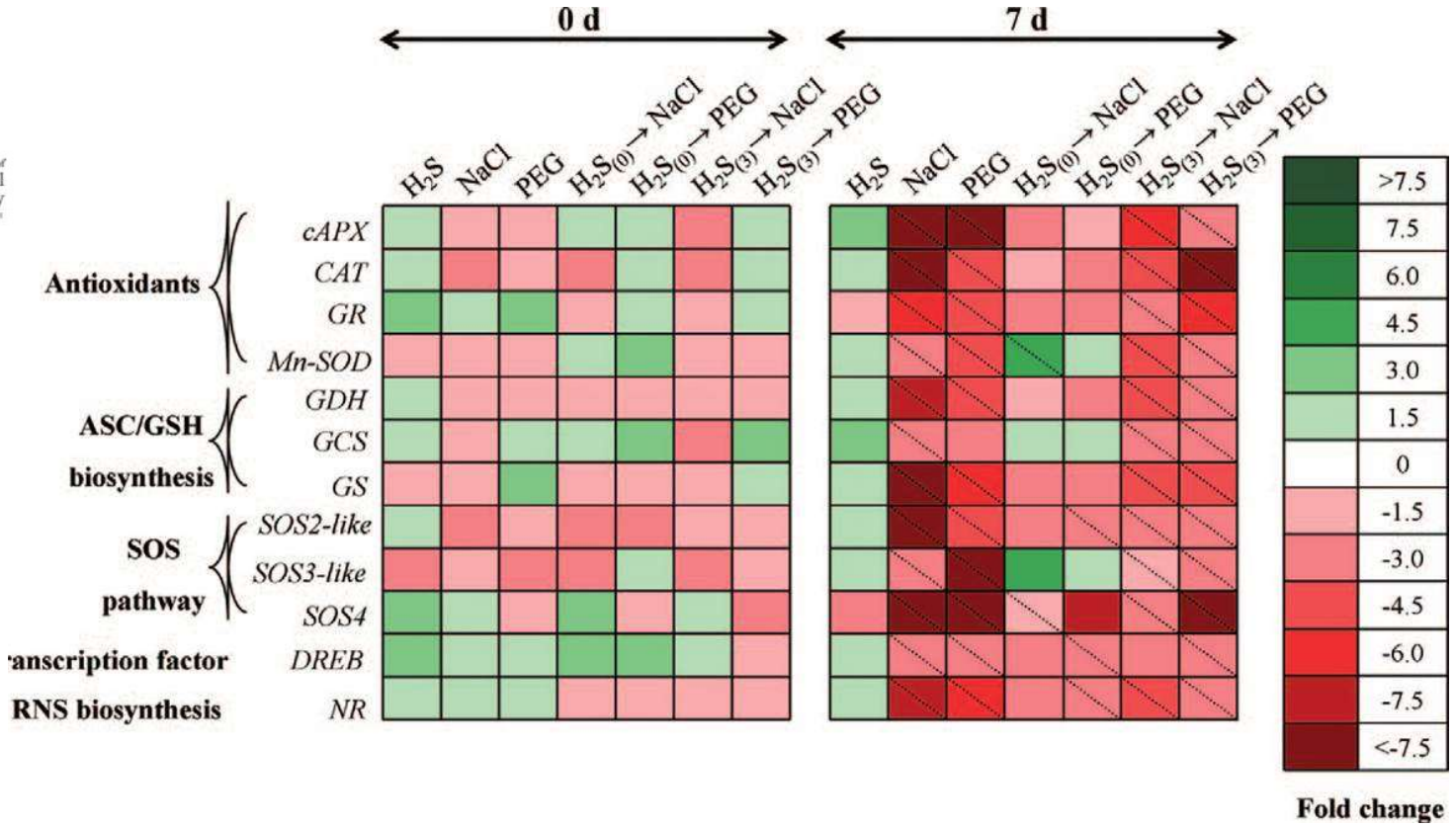
Hydrogen sulfide induces systemic tolerance to salinity and non-ionic osmotic stress in strawberry plants through modification of reactive species biosynthesis and transcriptional regulation of multiple defence pathways

Anastasis Christou[1,*], George A. Manganaris[2], Ioannis Papadopoulos[1] and Vasileios Fotopoulos[2,†]

Environmental and Experimental Botany 107 (2014) 46–54
Contents lists available at ScienceDirect
Environmental and Experimental Botany
journal homepage: www.elsevier.com/locate/envexpbot

Systemic mitigation of salt stress by hydrogen peroxide and sodium nitroprusside in strawberry plants via transcriptional regulation of enzymatic and non-enzymatic antioxidants

Anastasis Christou[a,1], George A. Manganaris[b], Vasileios Fotopoulos[b,*]



Defence-related genes are highly-expressed in primed plants

Source: Christou et al. (2013), *J Exp Bot 64*, 1953-1966

The effect of priming agents on strawberry plants under salinity conditions

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Plant material

“Red Sayama (1075)” fresh rooted plants that were subsequently transplanted in 6.5 L pots consisting of peat: perlite substrate (ratio 2:1).

Treatments

(1) Untreated
(2) Hydroprimed
(3) Melatonin
(4) Sodium alginate (NaA)
(5) Sodium alginate/Melatonin (NaA/Mel)
(6) Proline
(7) Sodium alginate/Proline (NaA/Proline)

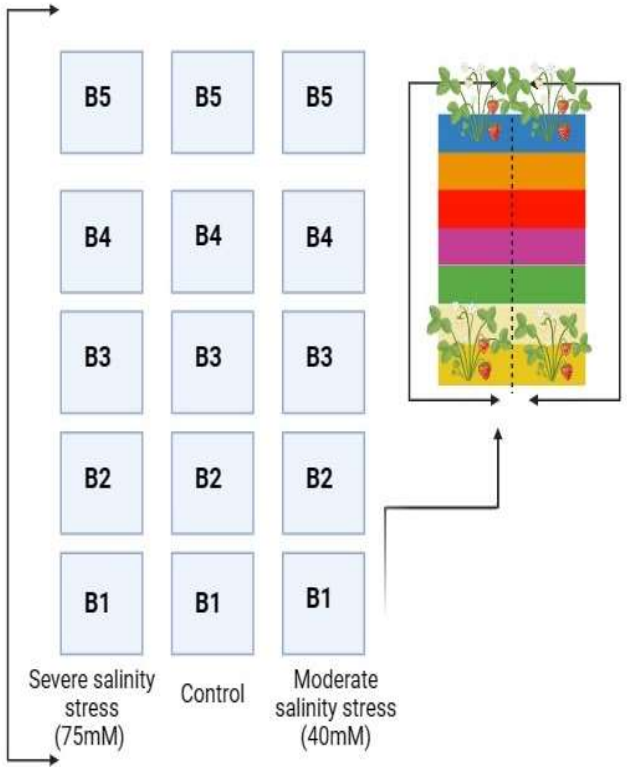
Applications:

- 2 days before transplantation
- 8 days after transplantation
- 15 days after transplantation

Salinity Stress levels:

✓ Moderate = 40 mM of NaCl
✓ Severe = 75 mM of NaCl

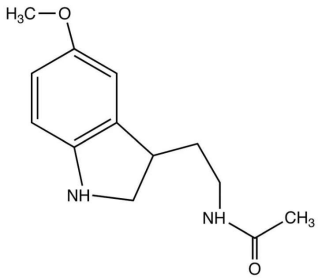
Experiment was set up: **factorial design** with 2 levels of salinity stress with 5 replicates and priming agent applications



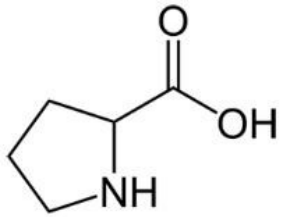
Duration: October 2023- February 2024.

Treatments justification

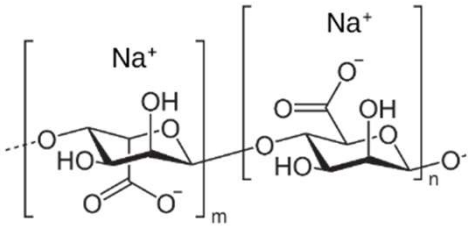
- **Melatonin:** a naturally occurring hormone in plants, animals, and humans that has been reported to enhance biomass production and resistance to water stress



- **Proline:** An amino acid, acting in plants as an osmoprotectant from various stresses and also helps plants to recover from stress more rapidly.



- **Sodium alginate:** A natural anionic polysaccharide being exploited in nano-smart delivery systems.



Leaf analysis

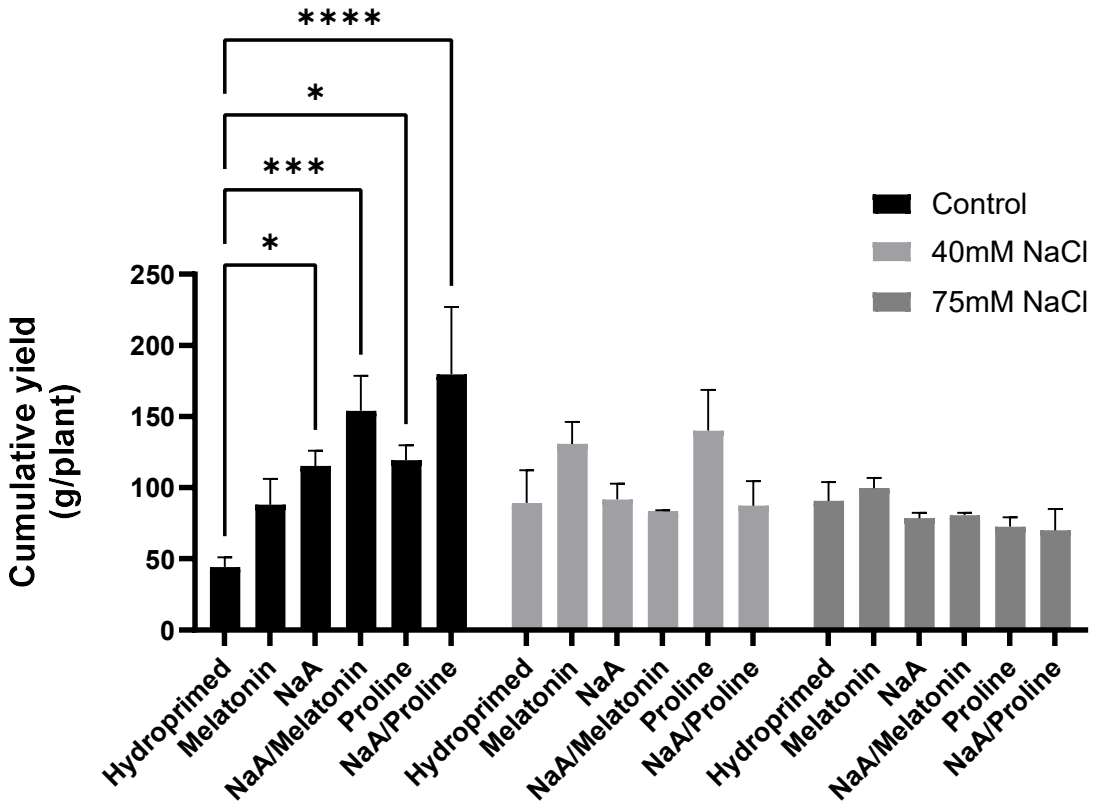
- Malondialdehyde (MDA) - a key biomarker for oxidative stress H_2O_2
- Nitric oxide (NO) - mitigate the damaging effects of ROS
- Proline - a precursor molecule of poyamines with osmoprotective effect
- Melatonin content

Fruit analysis

- Phytochemical analysis (reduced ascorbic acid, anthocyanins, flavonoids, phenolics)
- Metabolomic analysis
- Melatonin content

Cumulative Yield

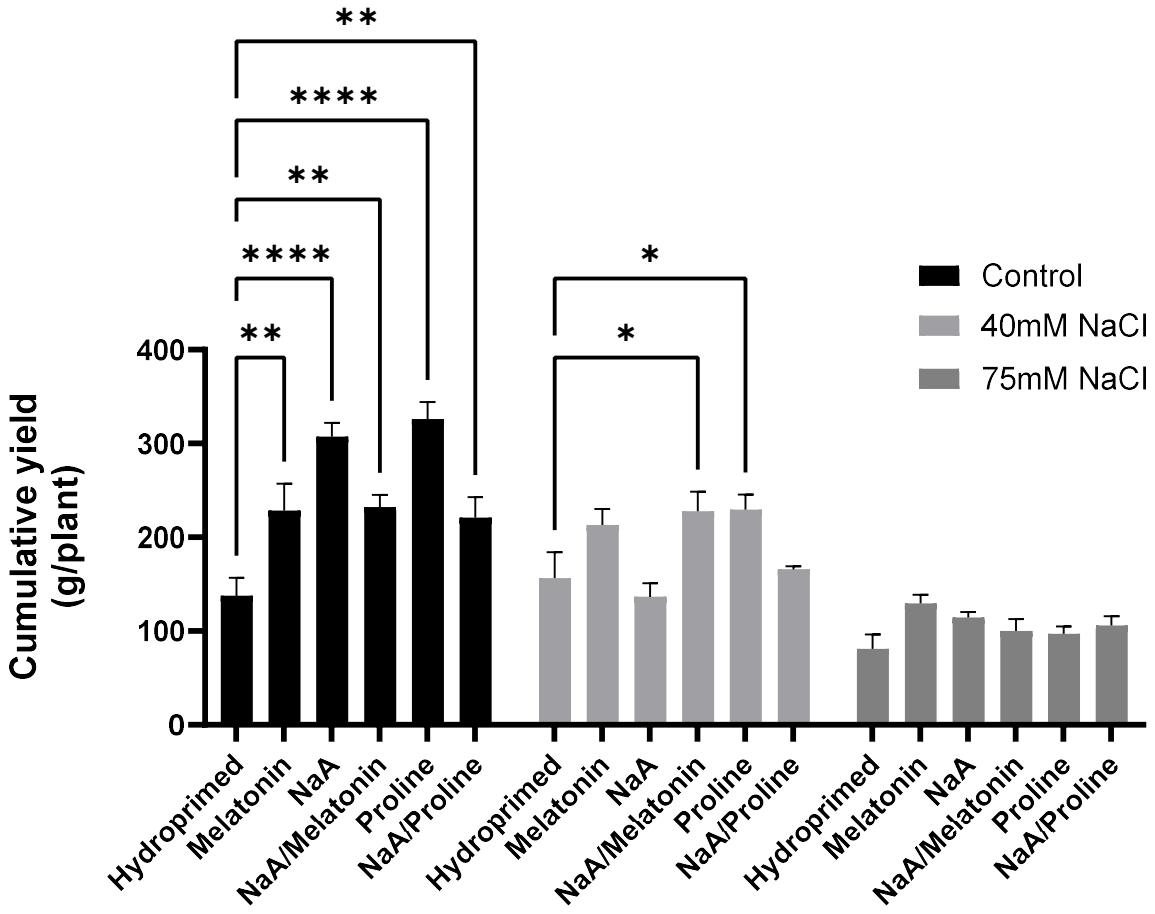
Harvest: 1-5



NaA/Proline (p-value<0.0001) and NaA/Melatonin (p-value<0.001) conjugates had the most significant effect in the absence of stress.

Cumulative Yield

Harvest: 1-10

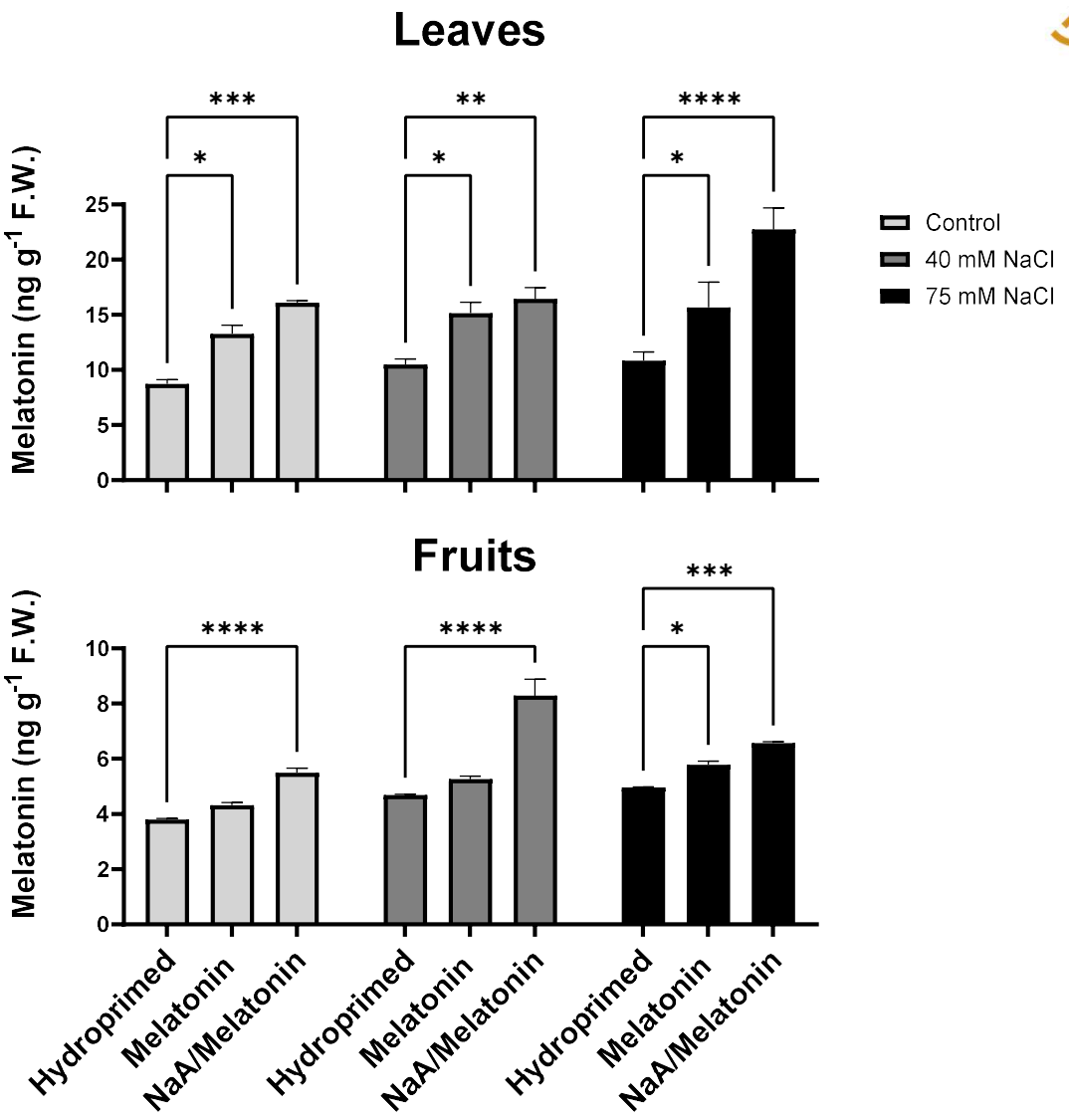


- PAs significantly increased plant productivity by more than 50% compared with hydroprimed
- Under mild salinity, NaA/Melatonin conjugate and proline showed an increment in cumulative yield (p-value<0.05).

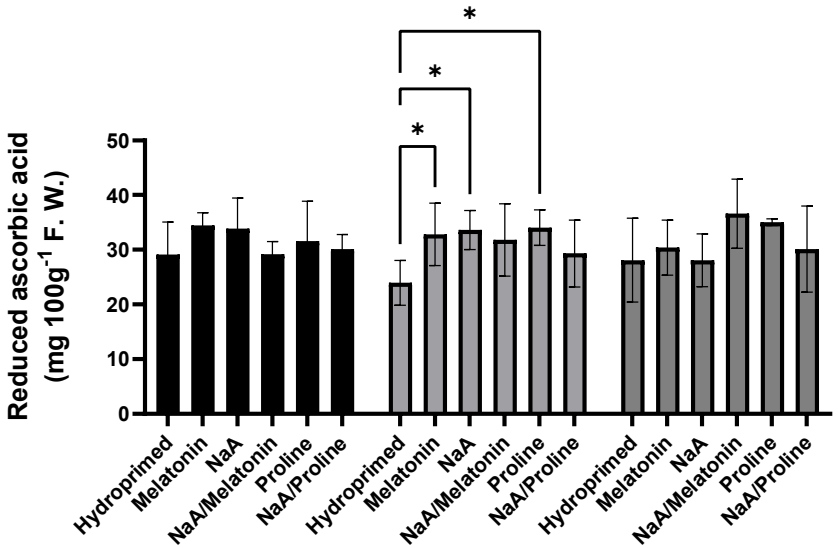
Melatonin content

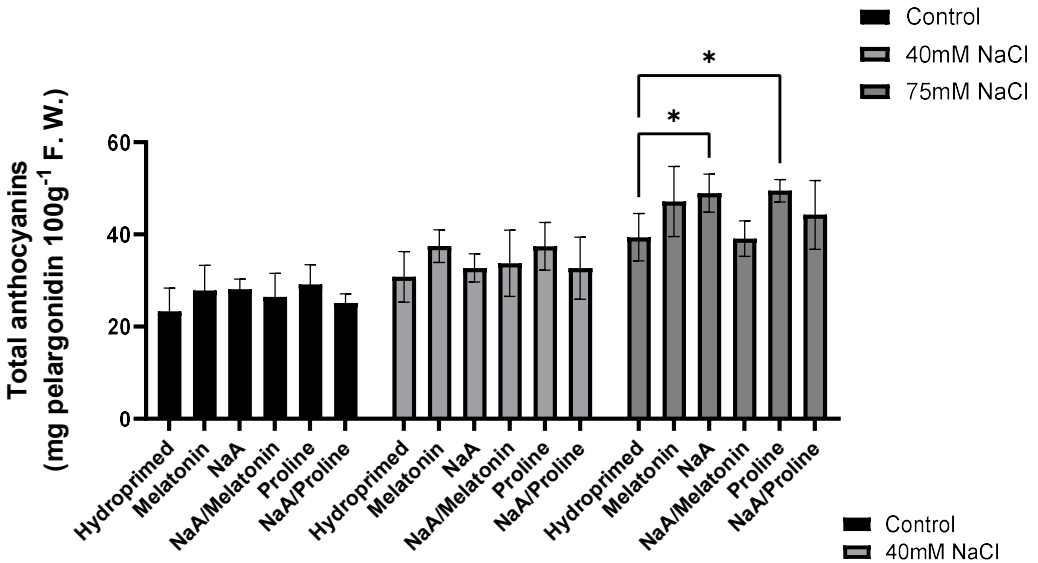
Successful donation

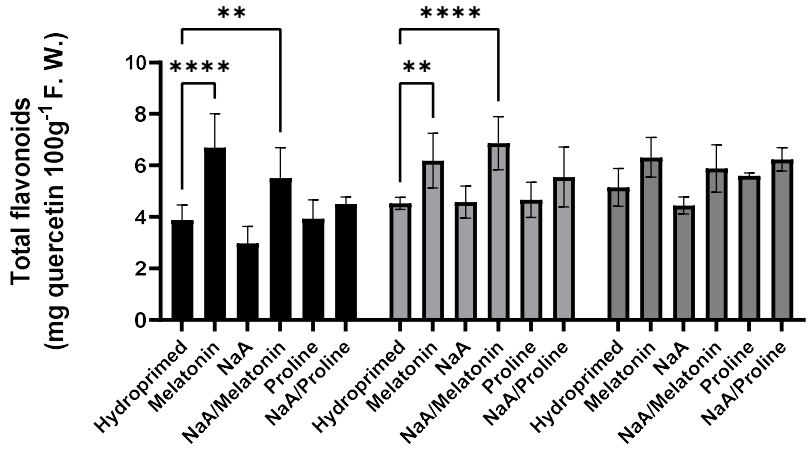
Mel and NaA/Melatonin displayed significantly higher endogenous Melatonin content compared with hydroprimed.

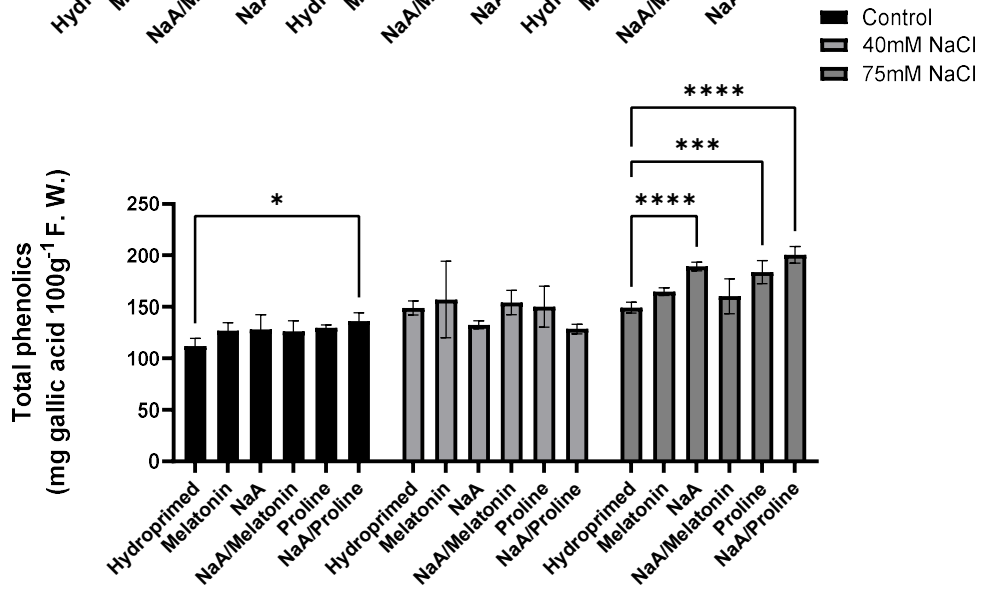


Phytochemical analysis

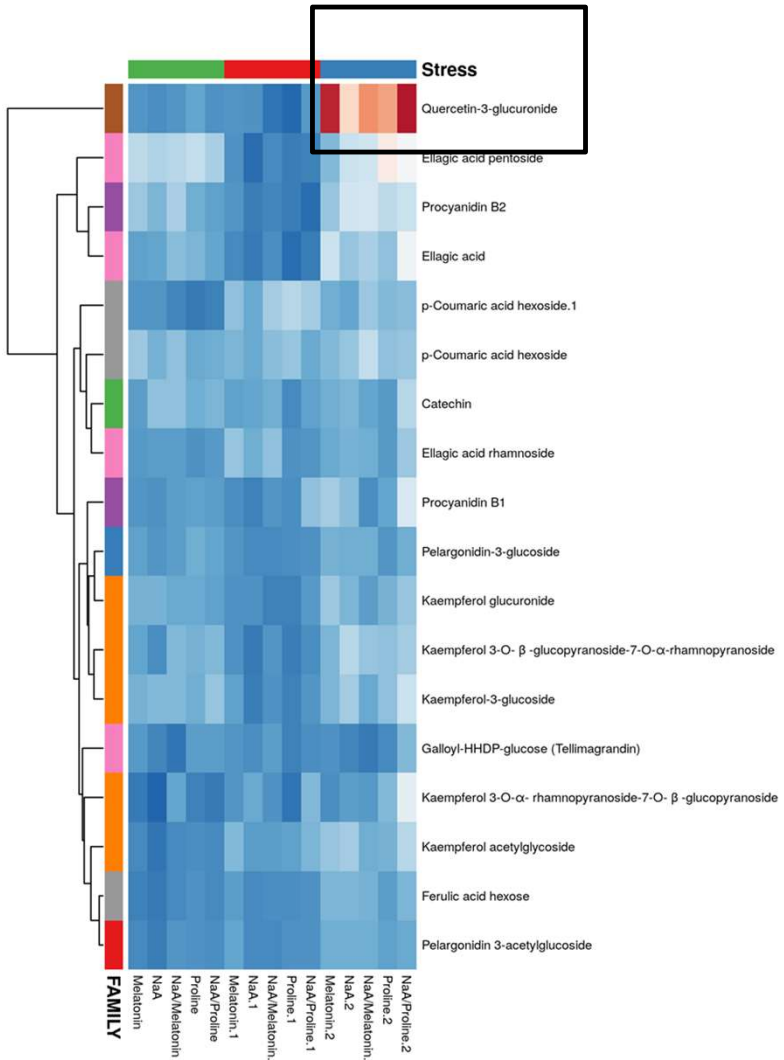


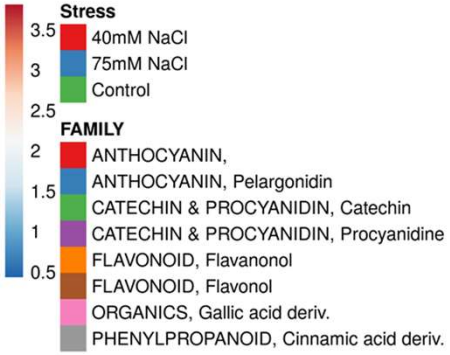






Metabolomic analysis





- Pre-treatments of melatonin and NaA/proline significantly increased the quercetin-3-glucuronide compound of the flavonoid family under severe stress conditions.

- A widely consumed flavonoid, that has been shown to inhibit the induction of inflammatory markers and its having a protective role against oxidative damage.

What's next

Novogene

Dissect the mechanistic action and *modus operandi* of the priming solutions

- Interpretation of RNAseq data (81 samples) from leaves
- Interpretation of RNAseq data (63 samples) from fruits
- Target journal: Horticultural Research

Exploring functionalized biopolymer prototypes towards mitigation of salt stress in strawberry plants

Methodological approach

Aim: Test the efficacy of encapsulated material

Collaboration with material scientists

National Technical University of Athens

University of Cyprus

- **Encapsulation of salicylic acid in zein nanoparticles**
- **Development of graphene oxide-functionalized hydrogels**

1	Hydroprimed
2	0,25 mM salicylic acid (SA)
3	0,5 mM SA
4	1 mM SA
5	2 mM SA
6	5 mM SA
7	5 mg/L Zein
8	10 mg/L Zein
9	25 mg/L Zein
10	50 mg/L Zein
11	5 mg/L Zein-SA
12	10 mg/L Zein-SA
13	25 mg/L Zein-SA
14	50 mg/L Zein-SA
15	6,25 mg/mL sodium alginate (NaA)
16	0,01 mg/mL Graphene oxide (GO)
17	0,02 mg/mL GO
18	0,03 mg/mL GO
19	0,04 mg/mL GO
20	6,25 mg/mL NaA/0,01 mg/mL GO
21	6,25 mg/mL NaA/0,02 mg/mL GO
22	6,25 mg/mL NaA/0,03 mg/mL GO
23	6,25 mg/mL NaA/0,04 mg/mL GO

Plant material

How it started, 03/04/2025

Plant material

How it progressed

Methodology: Three successive foliar applications in 230 strawberry plants prior to its imposition to salinity stress conditions (100 mM).

Plant material

Implementation phase

At first glance, this new cultivar selection (cv. Aethra) is apparently particularly resistant to extreme abiotic stress conditions

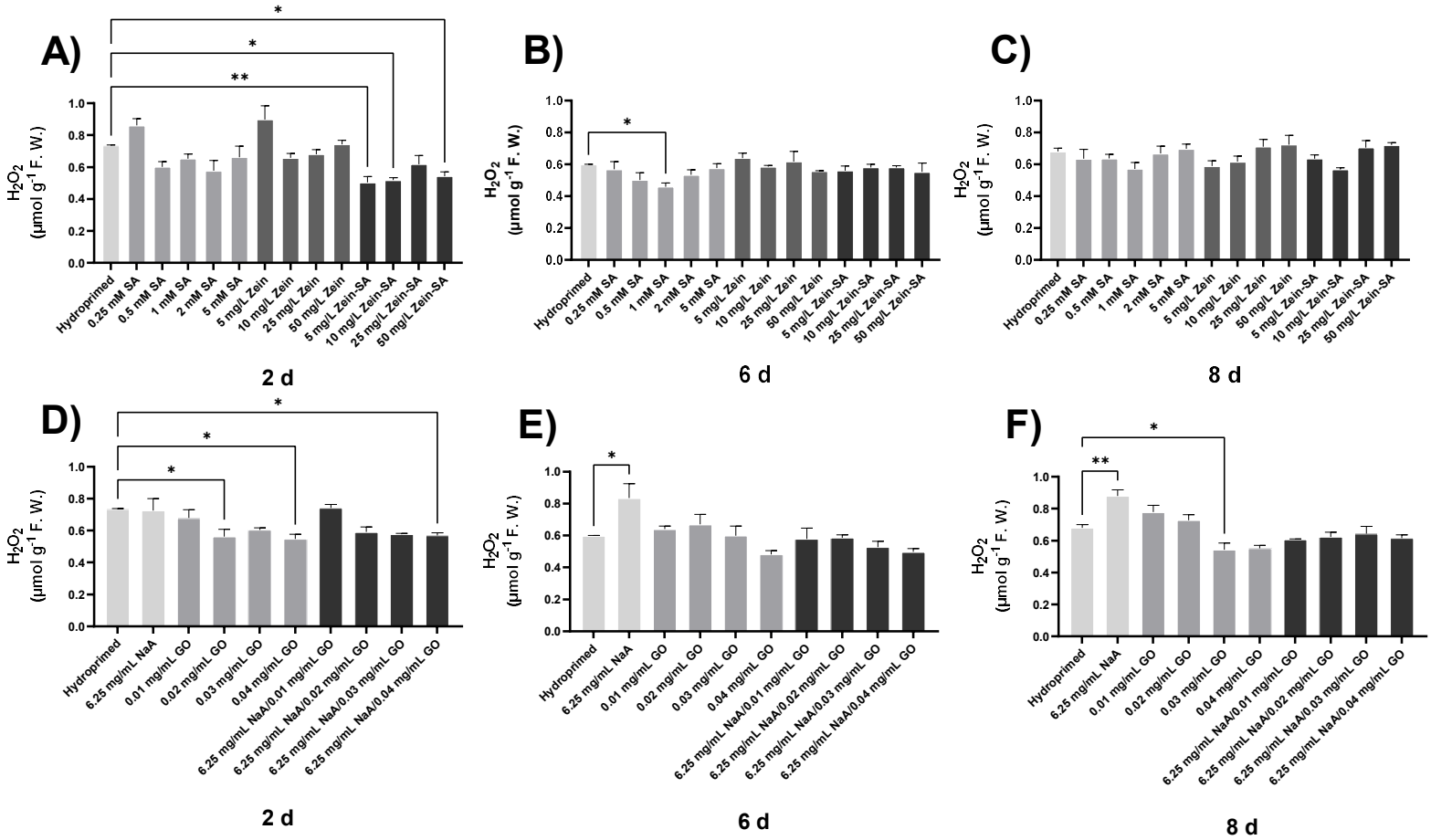
Cellular damage indicators

- Malondialdehyde (MDA)
- Nitric oxide (NO)
- Proline
- Hydrogen peroxide

Hydrogen peroxide

Zein

GO

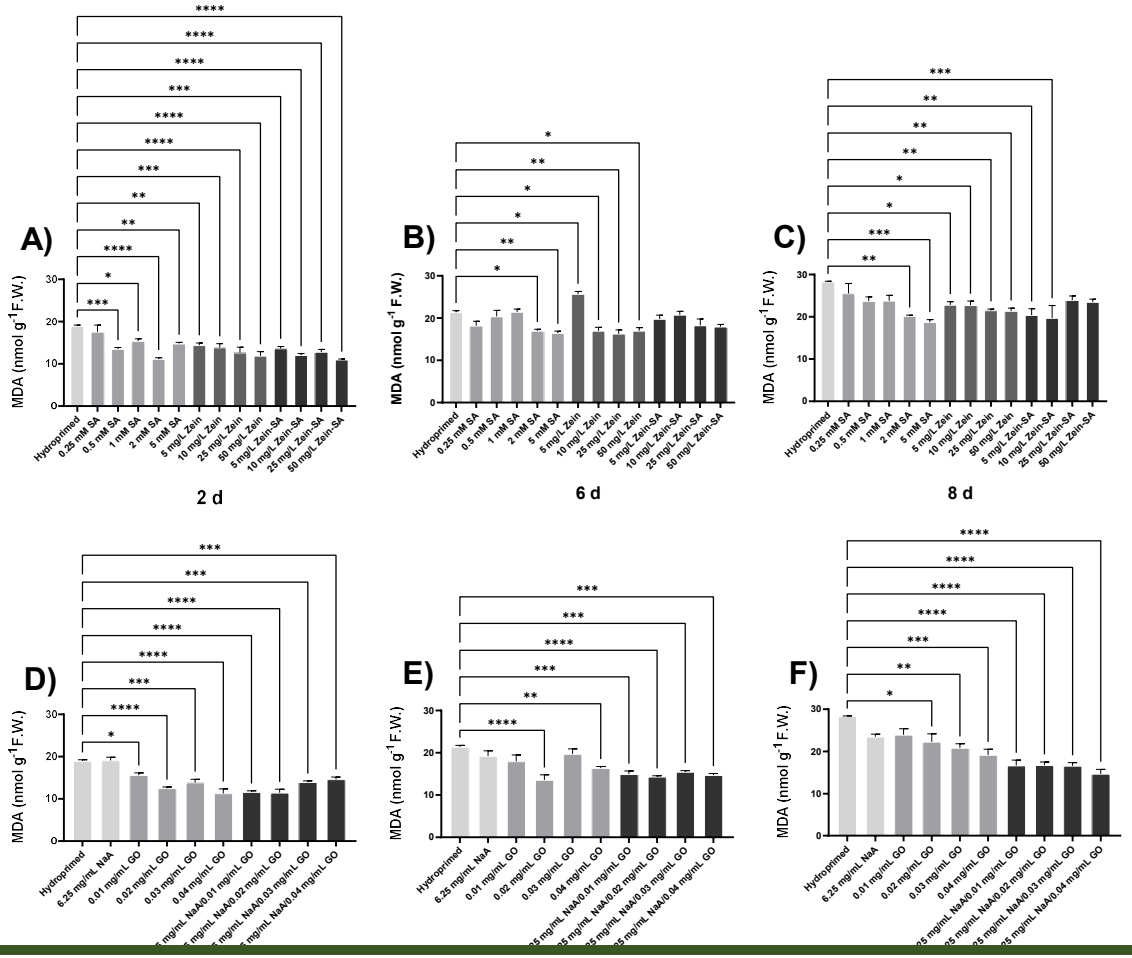


Malondialdehyde (MDA)

a key biomarker for oxidative stress H_2O_2

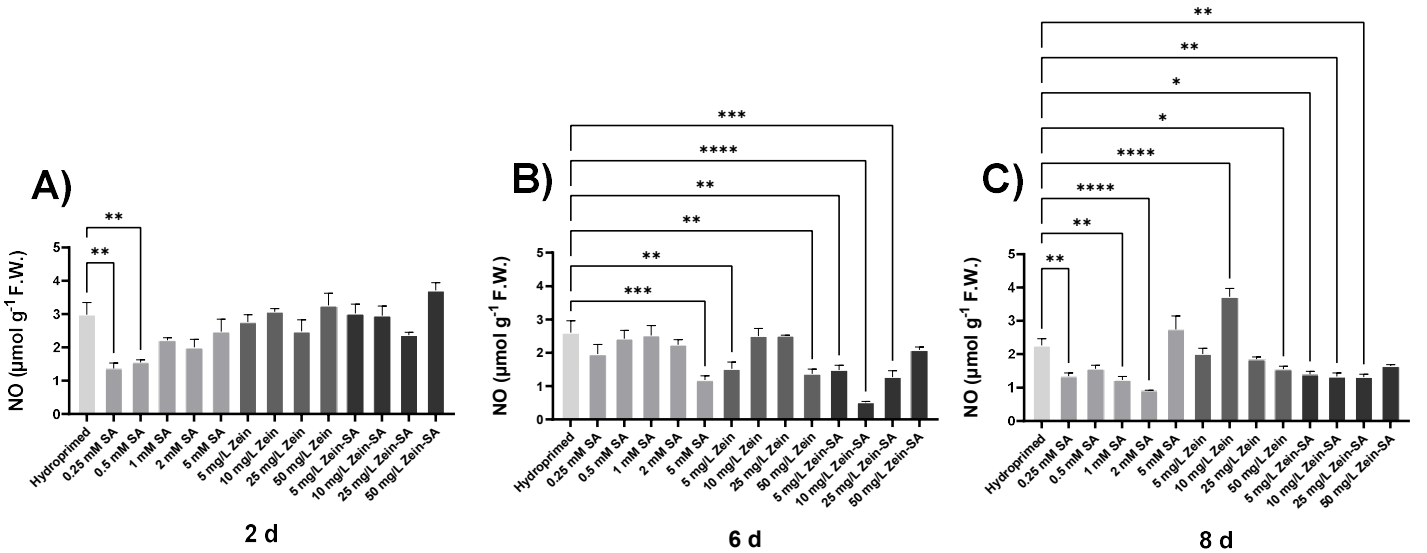
Zein

GO

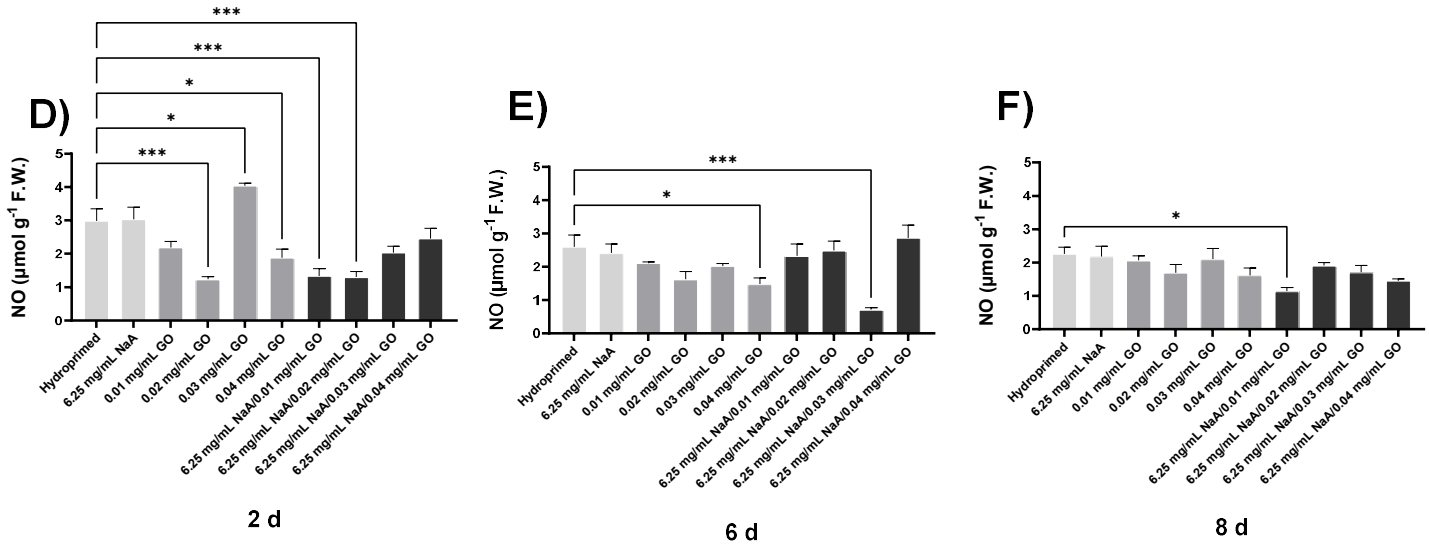


Nitric oxide

Zein



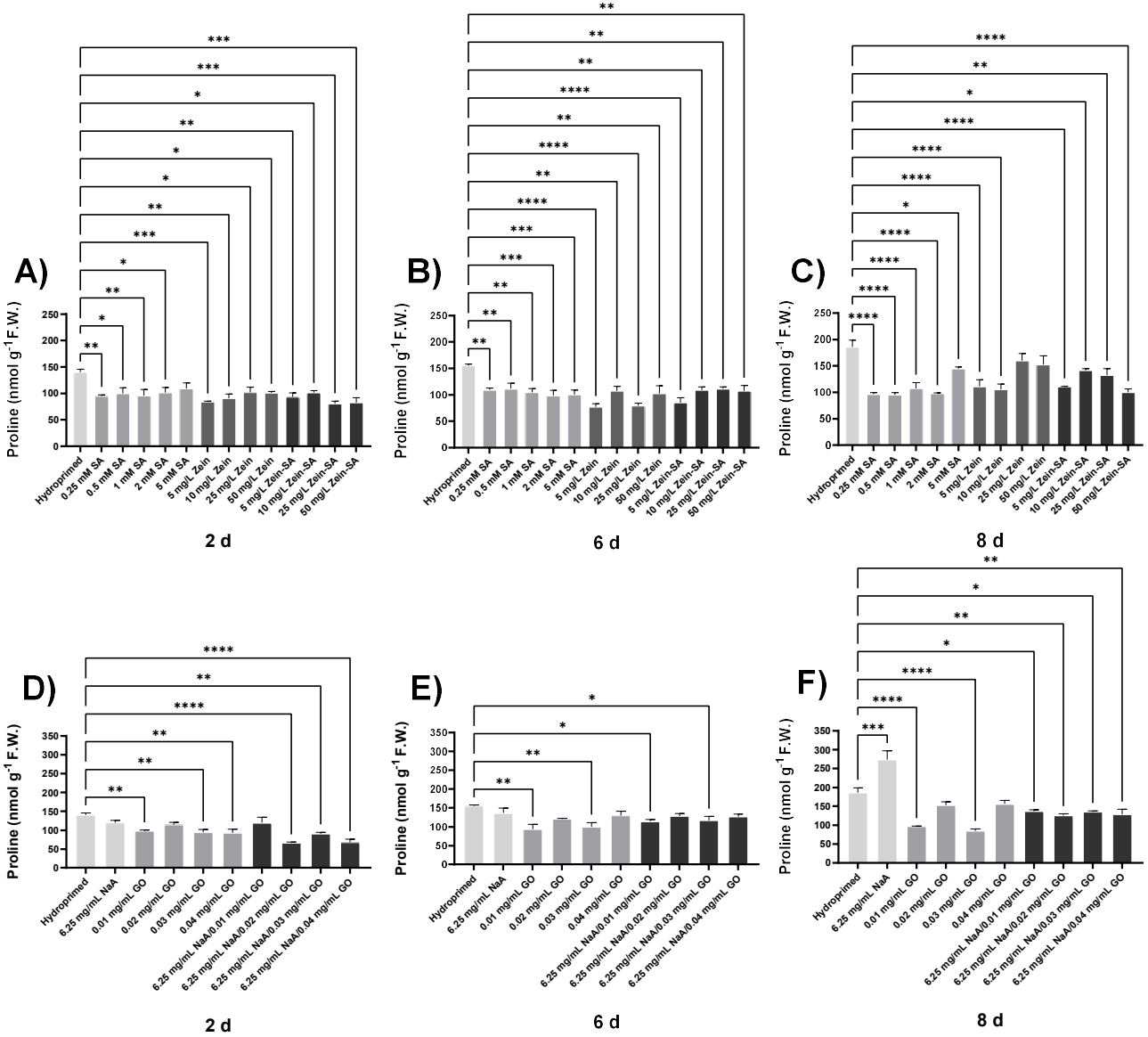
GO



Proline

Zein

GO



What's next

Dissect the mechanistic action and *modus operandi* of the priming solutions

- Interpretation of RNAseq data (63 samples) from leaves
- Target journal: Plant Nanobiology

Novogene

Contributors

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George Manganaris

Vasileios Fotopoulos

Fransisco Tomas-Barberan

Post-doctoral researcher

Egli Georgiadou

PhD Student

Nicolas Valanides

Post-doctoral researcher

Elena Myrtsi

Research Assistant

Sofia Torrado

PhD student

Anna Maria Taliadorou

Take home message

Priming agents is a step forward to enhance strawberry yield efficiency

Open invitation

To join forces towards integration of priming technology in strawberry cultivation under adverse climatic conditions

Any questions?

George Manganaris
Professor
george.manganaris@cut.ac.cy
www.fruitsciences.eu

SCAN ME

5TH INTERNATIONAL STRAWBERRY CONGRESS

Wednesday

Networking Break

- Sponsors & Exhibitors Fair
- Poster Sessions

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