Food and Agriculture Organization of the United Nations

Salt-affected soils: threats and potentials

Insight on how the halophyte *Tetragonia tetragonioides* deals with saline environments

Joint meeting of INSAS and SUSTAIN

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International Network of Salt-Affected Soils

Funded by the European Union

cost EUROPEAN COOPERATION IN SCIENCE & TECHNOLOGY

SUSTAIN

VNIVERSITAT DE VALÈNCIA

International Union of Soil Sciences

Valencia, Spain
May 27-31, 2024

GLOBAL SOIL PARTNERSHIP

Context

- water and food production nexus

Context

- water and food production nexus
- population growth

Context

- water and food production nexus
- population growth
- climate change

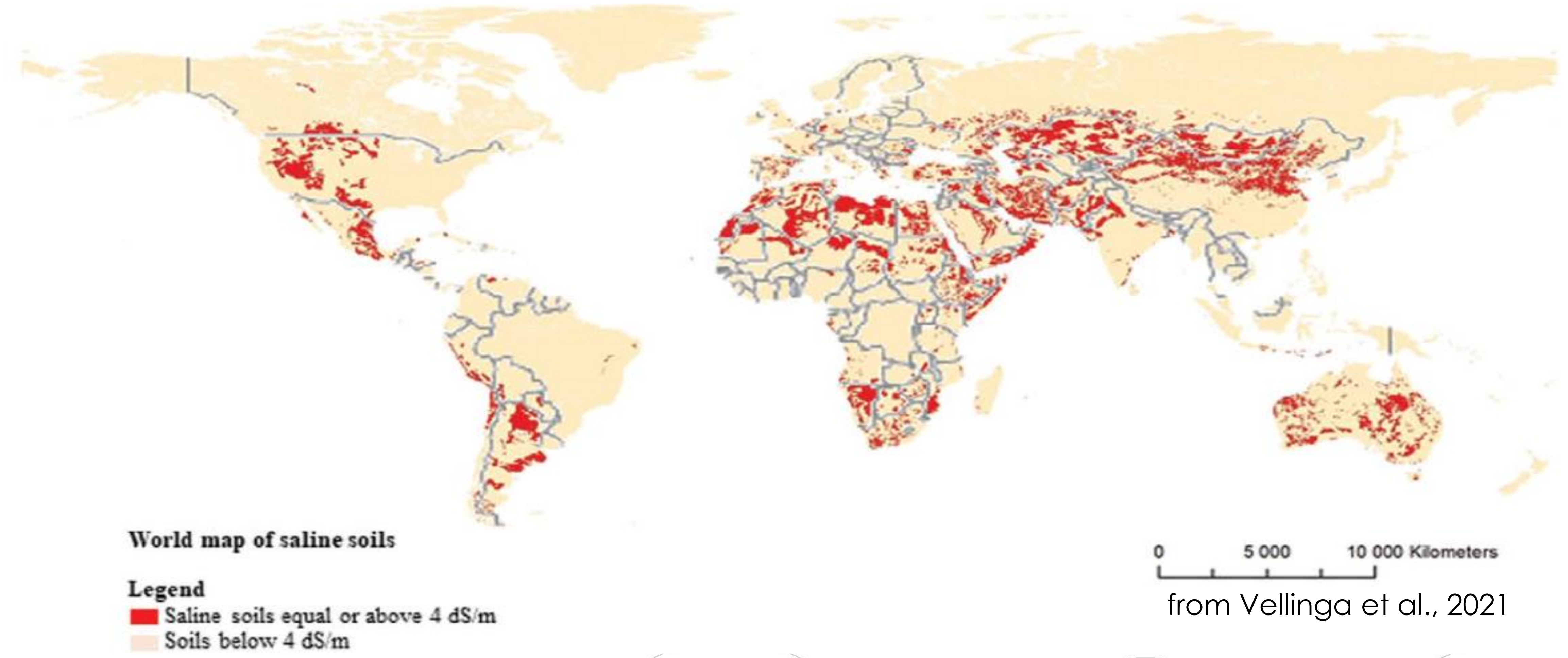
Context

- water and food production nexus
- population growth
- climate change
- impact on natural resources


from @AstroSamantha (June 2022)


Only 6 crops cover more than 60% of global agricultural production (FAOSTAT), all belonging to salt sensitive glycophytes

Global area of salinized soils: **11 million km²** (FAO Global Symposium on Salt-affected Soils 2021)
Every year up to 1.5 million hectares of agricultural land is lost due to **salinisation** (FAO, 2023)



from Vellinga et al., 2021

Over 5000 species of **halophytes** can grow and reproduce up to 200mM NaCl thanks to morphological, physiological and biochemical **adaptive traits**. Many of these species are edible and show crop potential in a **saline agriculture** context

Tetragonia tetragonioides (pallas) kunze

Family: Aizoaceae

Native to eastern Asia, Australia and New Zealand, then introduced in Africa, Europe, North and South America, ad already consumed in several world areas (South Italy)

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Salinity tolerance threshold: it withstands up to EC of 10 dS m^{-1} (Neves et al 2008, Wilson et al 2000), even higher (i.e., 18 dS m^{-1}) in hydroponics (Atzori et al 2020)

Salt-induced growth response at EC 5–10 dS m^{-1} (Yousif et al 2010, Atzori et al 2020)

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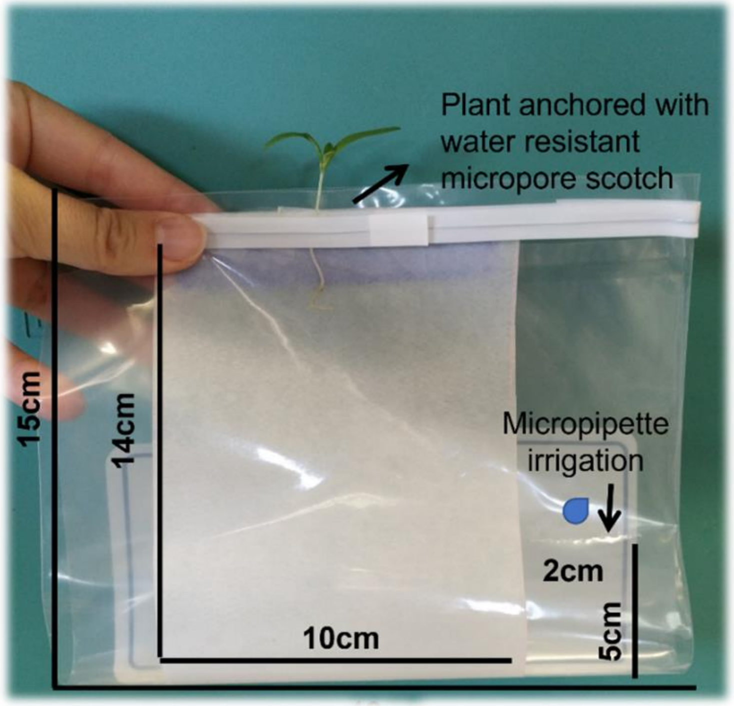
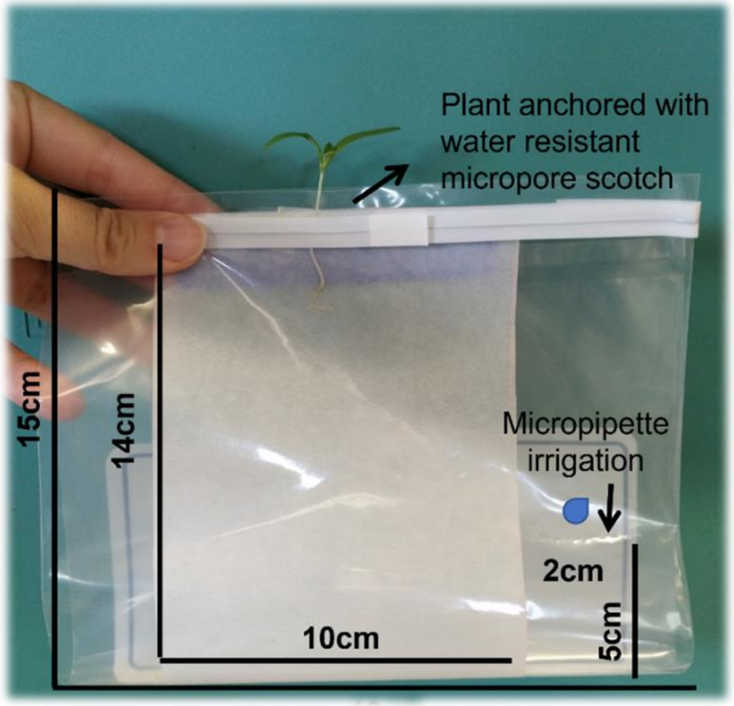
How do this plant deal with Na?



Rhizoslides experiment

- Salt-coping strategies were investigated through a rhizoslide setup
- The rhizoslide system was developed as a 2D soil substitute to monitor salt accumulation, root architecture, and transpiration rate in young plant
- Plants were grown at increasing saline conditions: control, 100 mM NaCl and 200 mM NaCl



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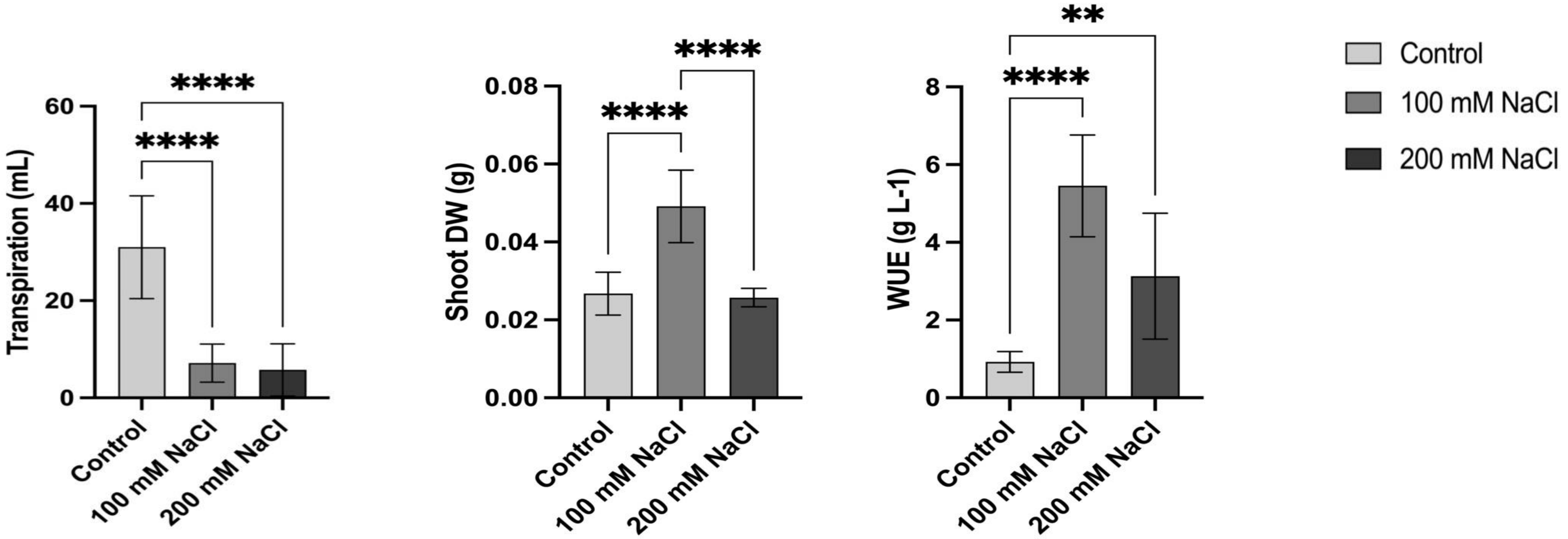
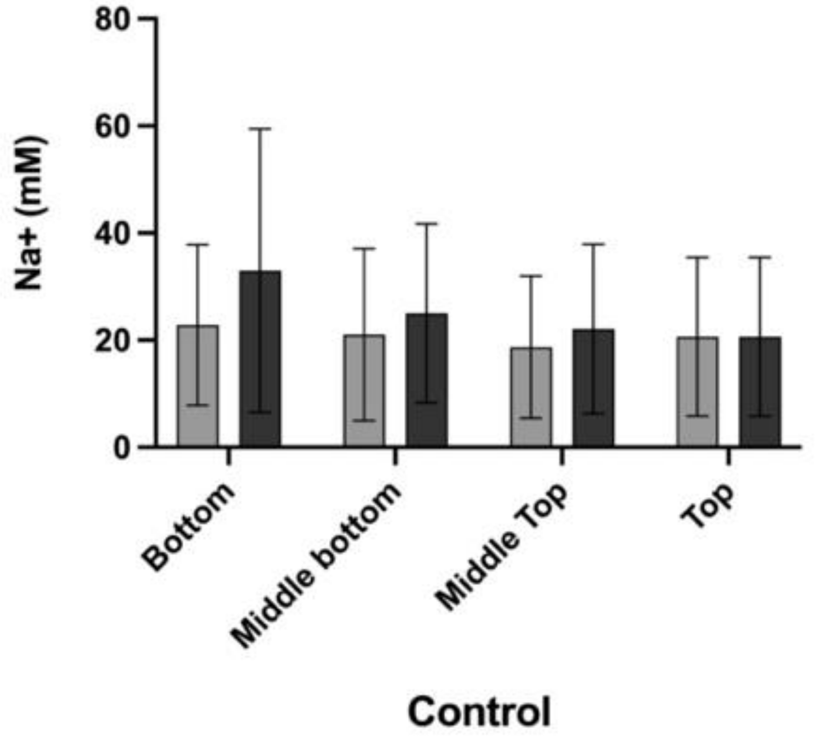
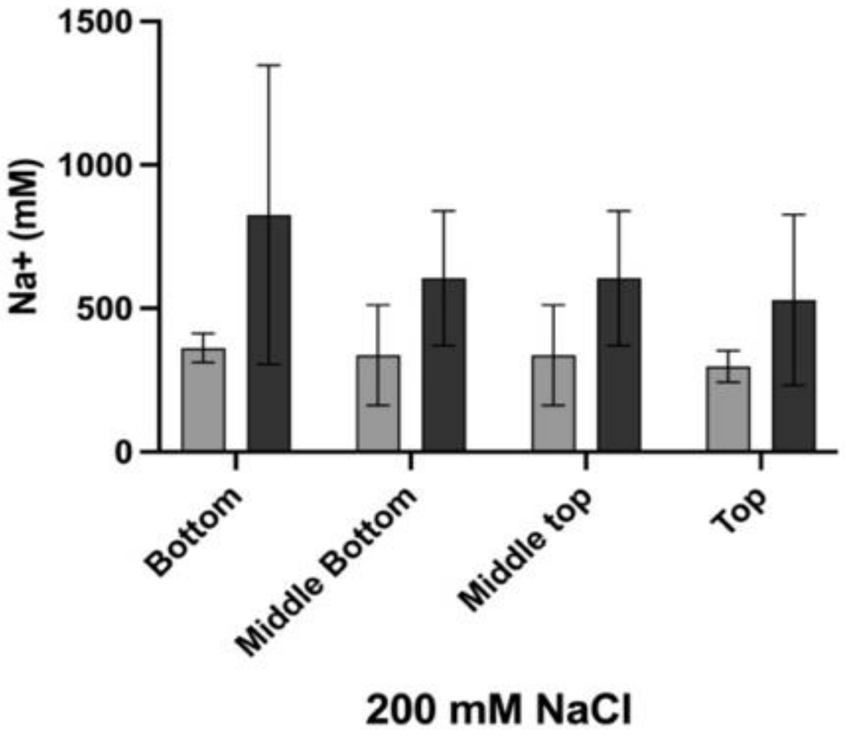
Comparini D.[1], Mozzo G.[1], Thiers L.[2, 3], Vanderborght J.[3], De Swaef T. [2], Mancuso S. [1,4], Garré S.[2], Atzori G.[5] (2024) **Exploring tolerance mechanisms and root morphological development of New Zealand Spinach and Quinoa across salinity levels. South African Journal of Botany** (under review).

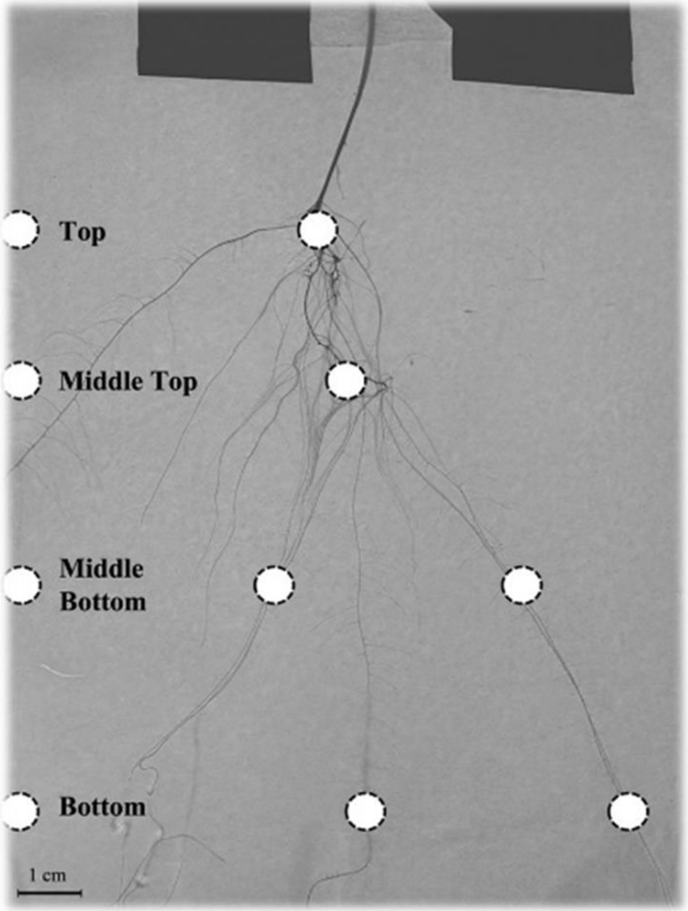
[1]Department of Agriculture, Food, Environment and Forestry (DAGRI), University of Florence, Viale delle Idee, 30, 50019 Sesto Fiorentino (FI), Italy; [2]Flanders Research Center for Agriculture, Fisheries and Food (ILVO), Caritasstraat 39, 9090 Melle, Belgium; [3]Department of Earth and Environmental Sciences, KU Leuven, Celestijnenlaan 200E, 3001 Leuven, Belgium; [4]Fondazione per il Futuro delle Città—FFC, 50125 Firenze, Italy; [5]National Research Council of Italy, Institute of Sustainable Plant Protection (CNR-IPSP), Via Madonna del Piano 10, 50019 Sesto Fiorentino (FI), Italy



- Transpiration decreased in saline conditions
- Plants growth followed the typical halophyte curve
- Significant increase in WUE







Under root

No root

Under saline conditions, [Na] in proximity of the root system was lower compared to far from the root system, suggesting Na uptake activity

Pot experiment

We studied how soil, climate, and salinity affect *T. tetragonioides* growth and productivity, alongside investigating ion accumulation in plant tissues to understand its salt stress adaptations.

clay soil and sandy soil

Spring and Autumn

Control, 100 mM NaCl, 200 mM NaCl

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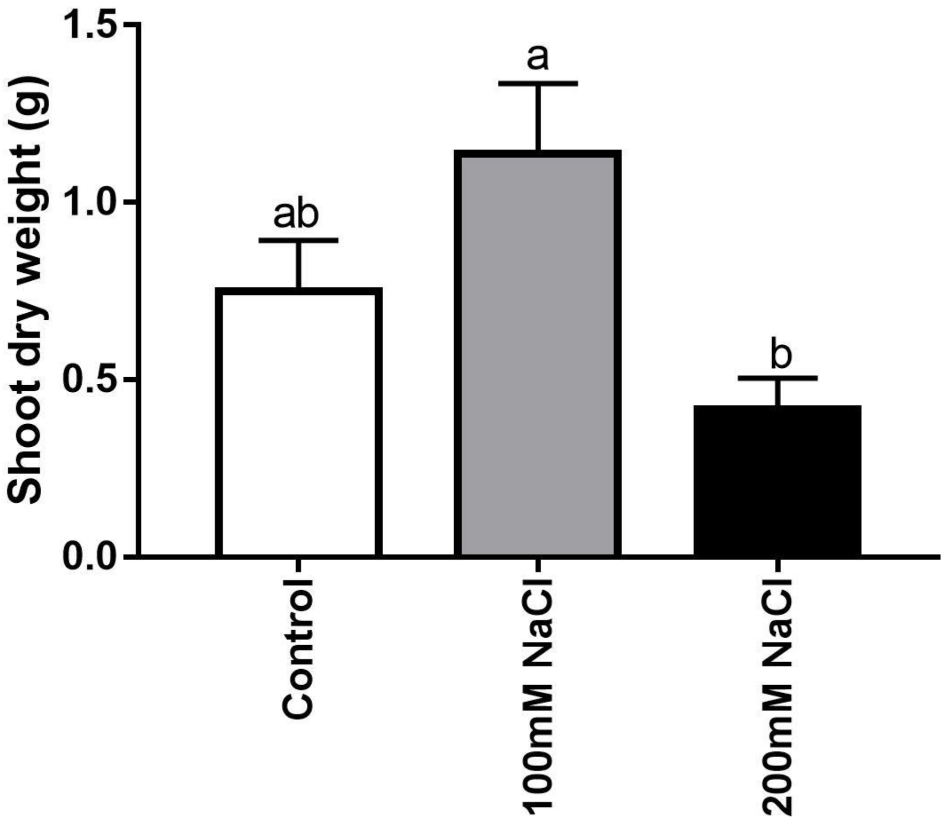
Petrillo M.[1], Mozzo G.[1], Bazihizina N.[2], Caparrotta S.[1], Bernardi S.[1], Masi E.[1], Atzori G.[3] (2024) **New Zealand Spinach Productivity under Salt Stress in different Pedoclimatic Conditions** (in preparation)

[1]Department of Agriculture, Food, Environment and Forestry (DAGRI), University of Florence, Piazzale delle Cascine 18, 50144 Florence, Italy; [2]Department of Biology, University of Florence, Via Micheli 1, 50121 Florence, Italy; [3]National Research Council of Italy, Institute of Sustainable Plant Protection (CNR-IPSP), Via Madonna del Piano 10, 50019 Sesto Fiorentino, Italy

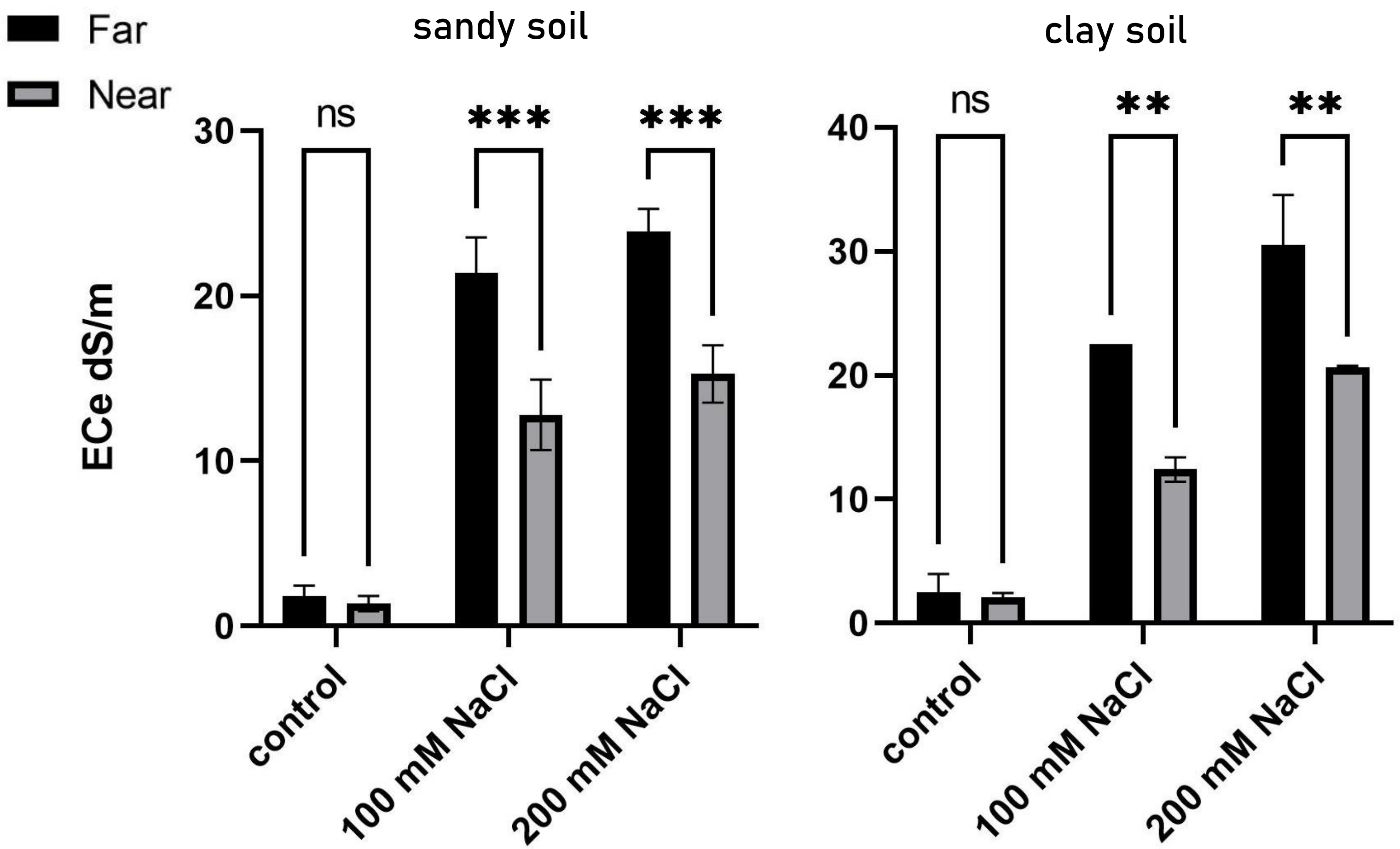


control

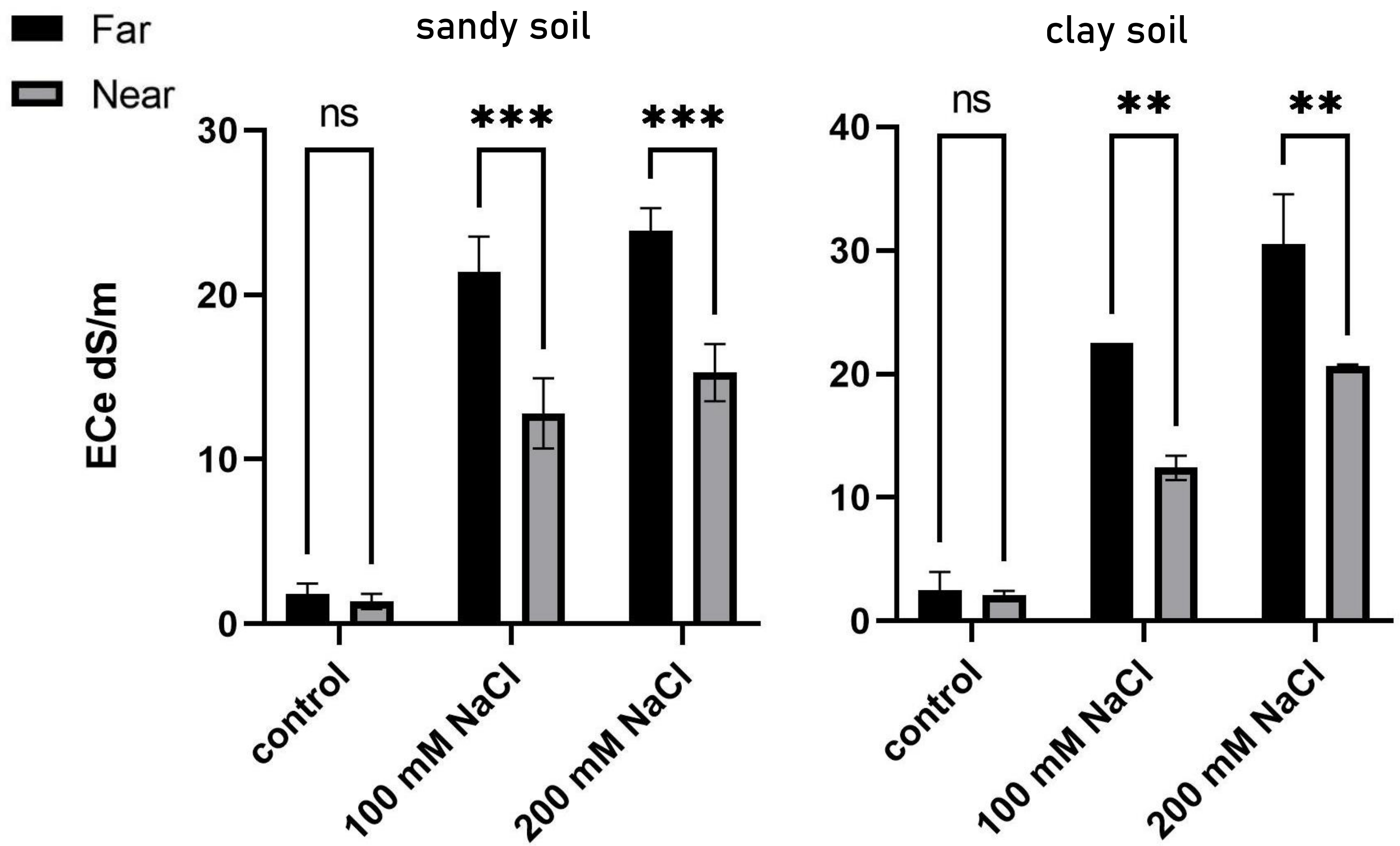
100mM NaCl

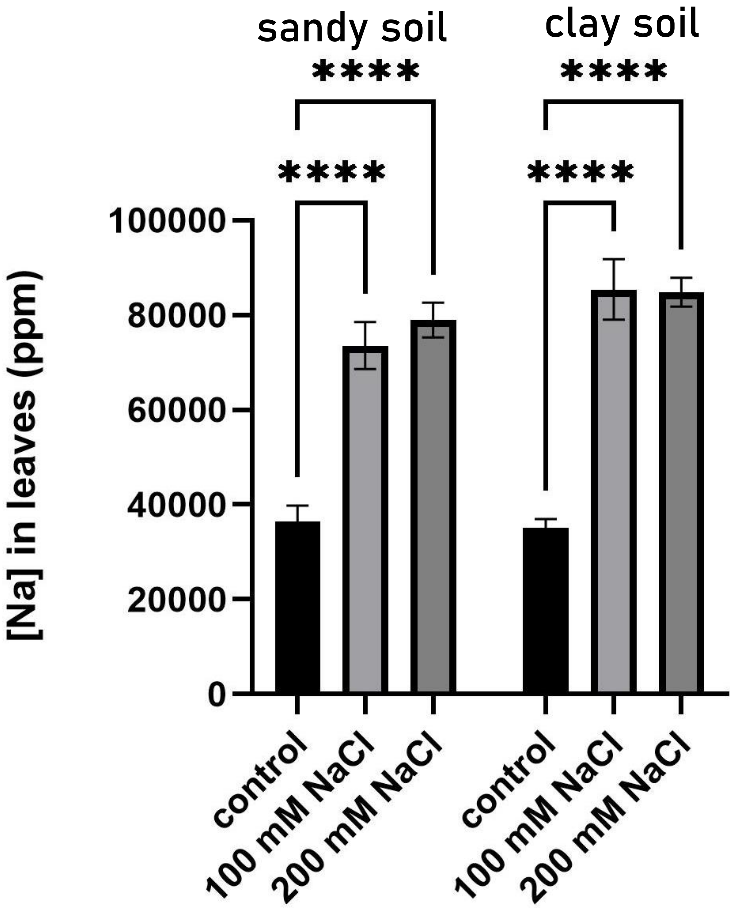
200mM NaCl

- Growth was enhanced in sandy soil at 100 mM NaCl compared to the control
- The 200 mM NaCl treatment was detrimental in both tested soils



Soil EC is lower near the rootzone compared to the pots borders: same pattern observed in rhizoslides experiment





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Na is translocated in the shoots

Hydroponics experiment

Investigation of plants growth and localization of Na in plants tissues
Plants grown in hydroponics using Hoagland solution (control), Hoagland solution + 100 mM NaCl and Hoagland solution + 200 mM NaCl

Leaves and roots analysed for Na concentration by means of ICP OES Optical Emission Spectrometer

Confocal imaging with Corona green dye and stereomicroscope

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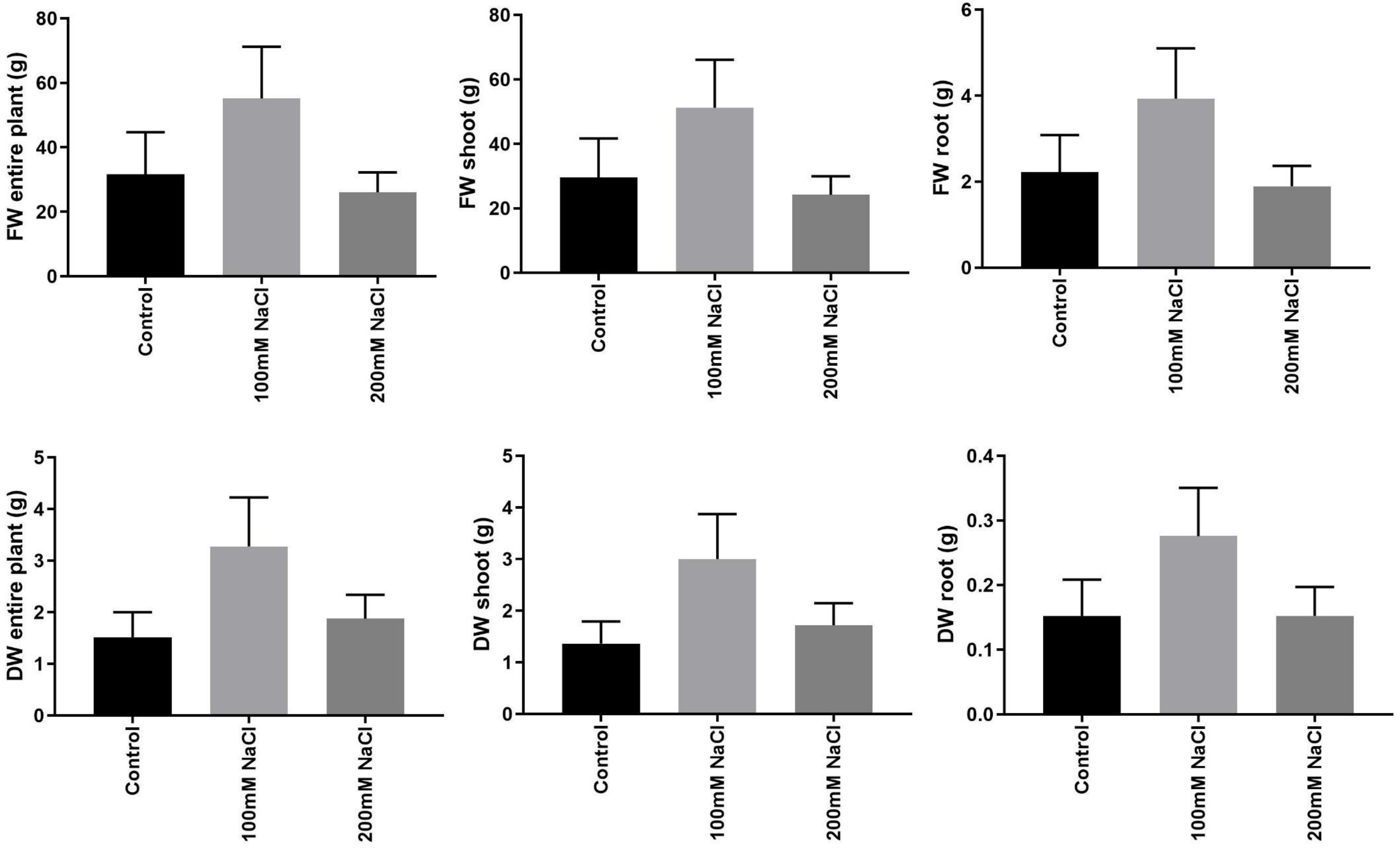
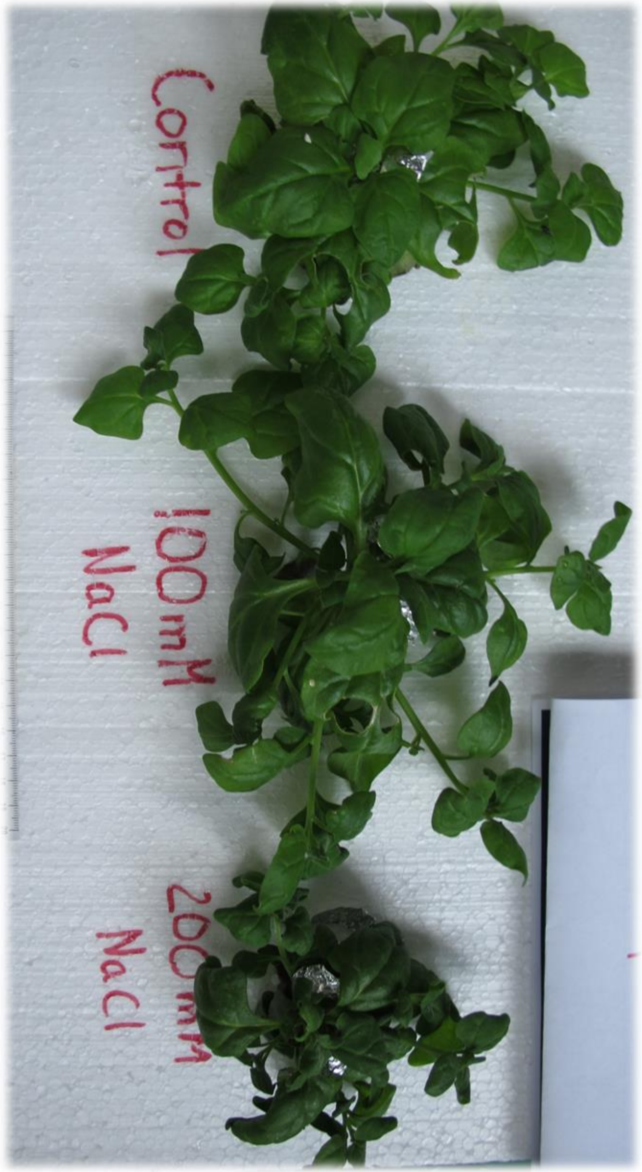
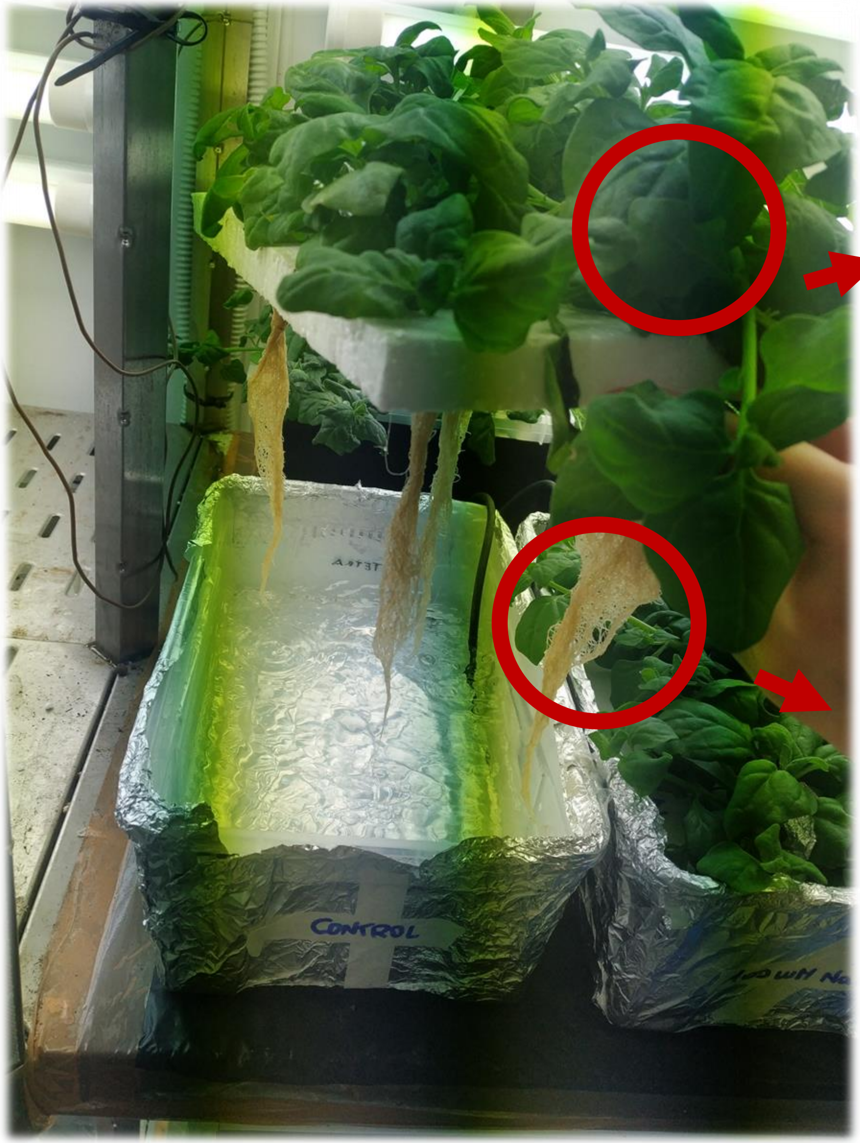
Emily Palm[1], Nadia Bazihizina[2], Luciana Renna[3], Elisa Masi[3] and Giulia Atzori[4] (2024) **Constitutive and adaptive salt tolerance mechanisms and their cumulative effect on biomass production in salt treated edible halophytes** (in preparation)

[1] Department of Biotechnology and Biosciences, University of Milan-Bicocca, Italy; [2] Department of Biology, University of Florence, Via Micheli 1, 50121 Florence, Italy; [3] Department of Agriculture, Food, Environment and Forestry (DAGRI), University of Florence, Piazzale delle Cascine 18, 50144 Florence, Italy; [4] National Research Council of Italy, Institute of Sustainable Plant Protection (CNR-IPSP), Via Madonna del Piano 10, 50019 Sesto Fiorentino, Italy

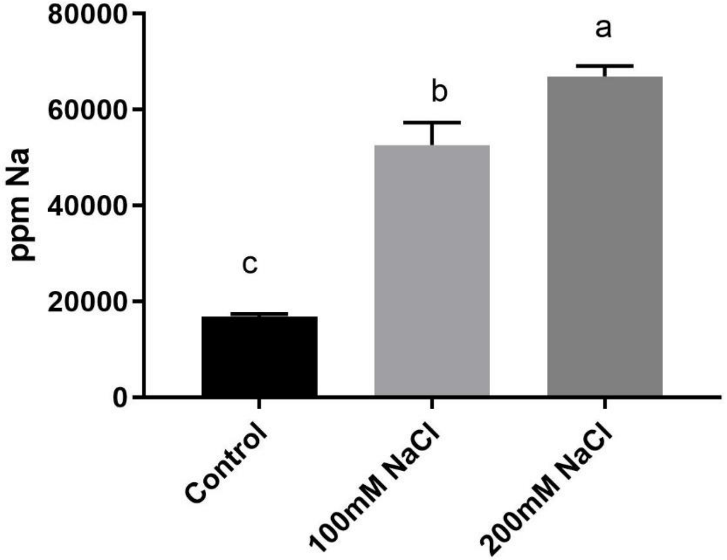




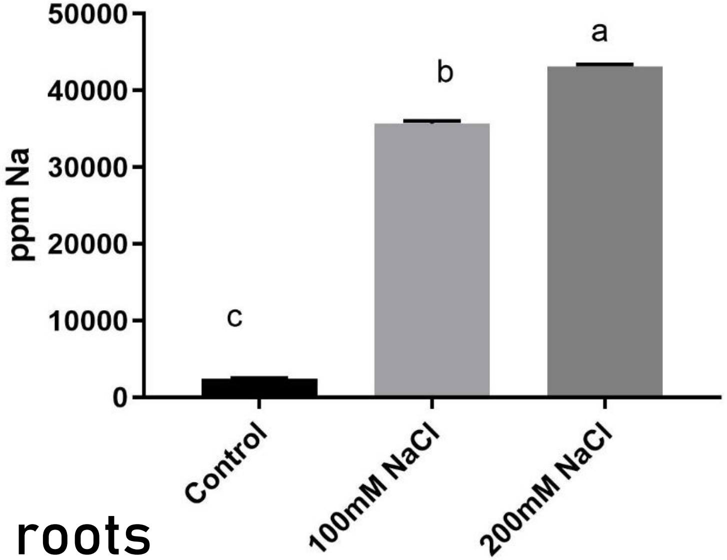
- Growth was enhanced at 100 mM NaCl
- 200 mM NaCl treatment did not prove to be detrimental as in soil



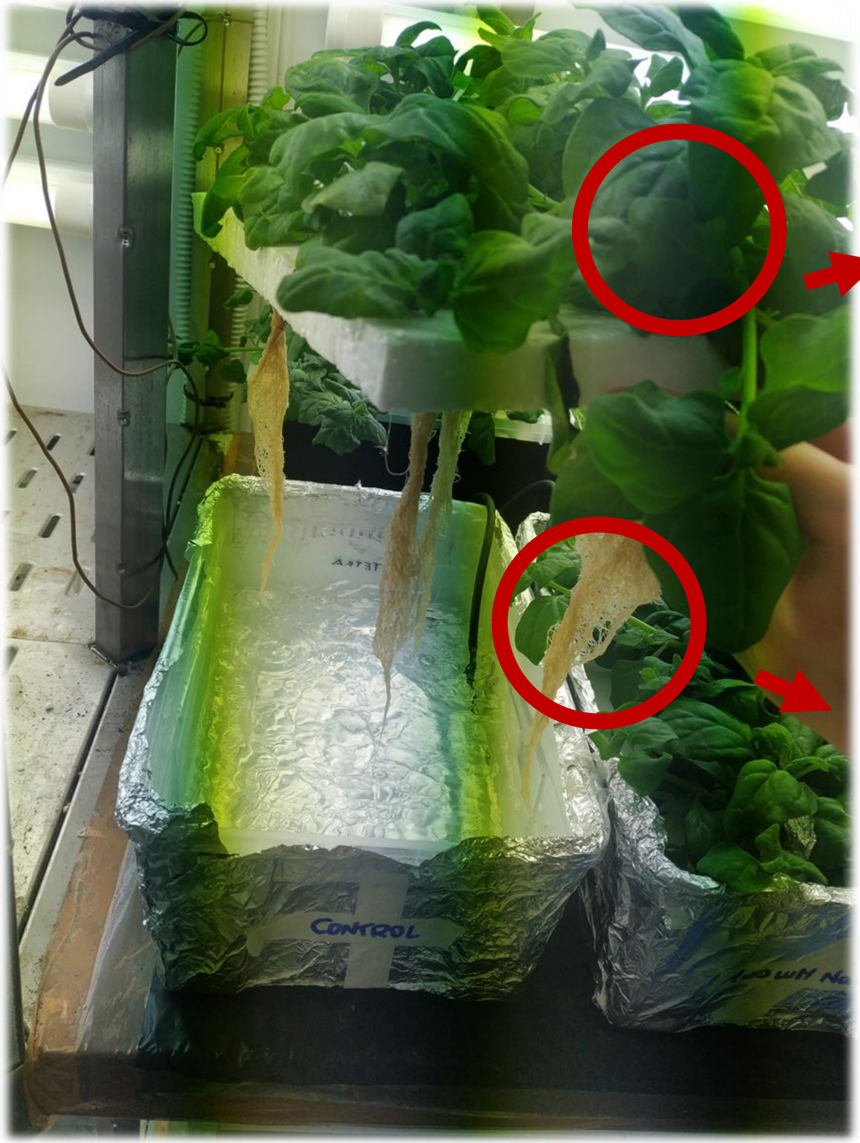
leaves

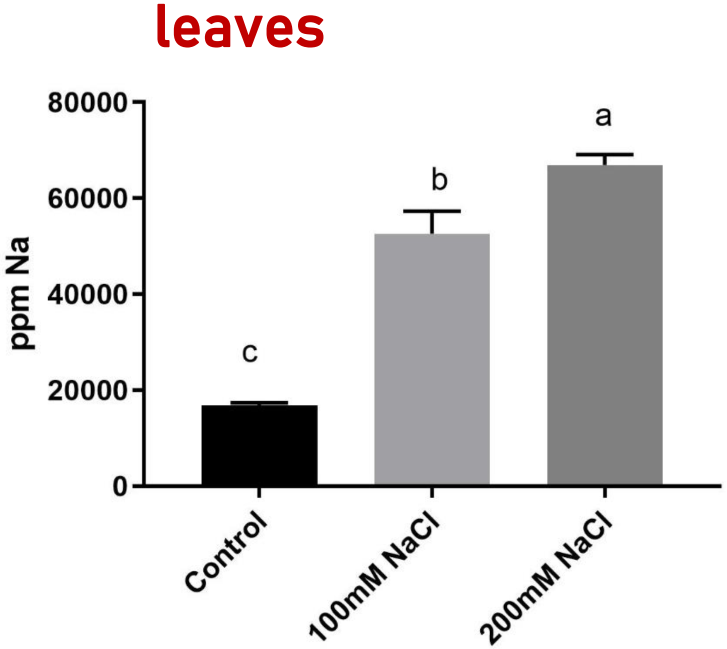


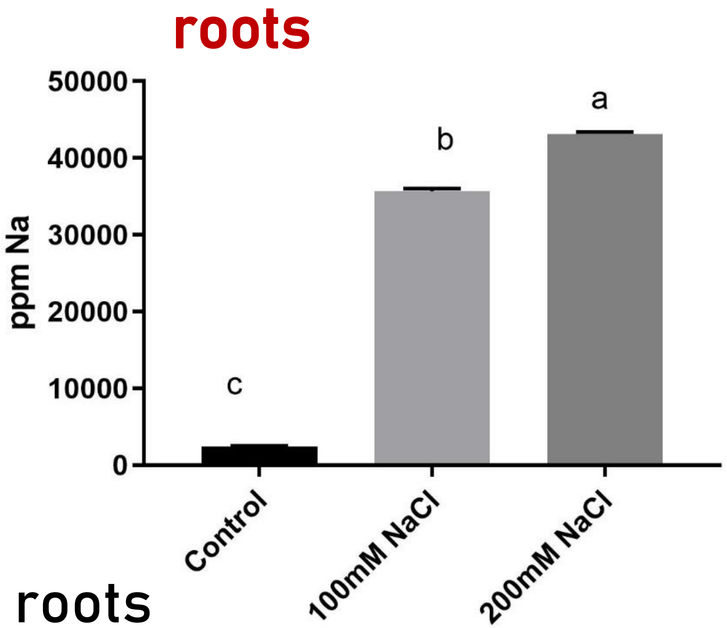
roots



Higher [Na] in leaves compared to roots







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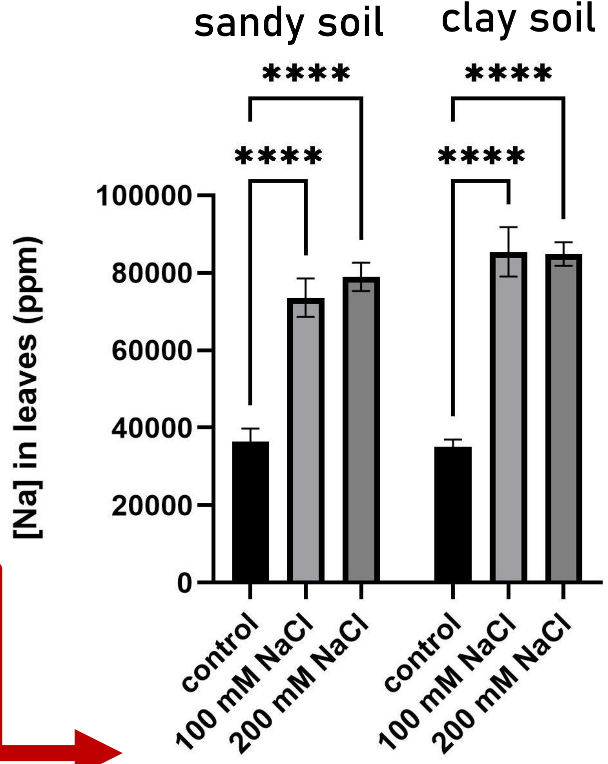
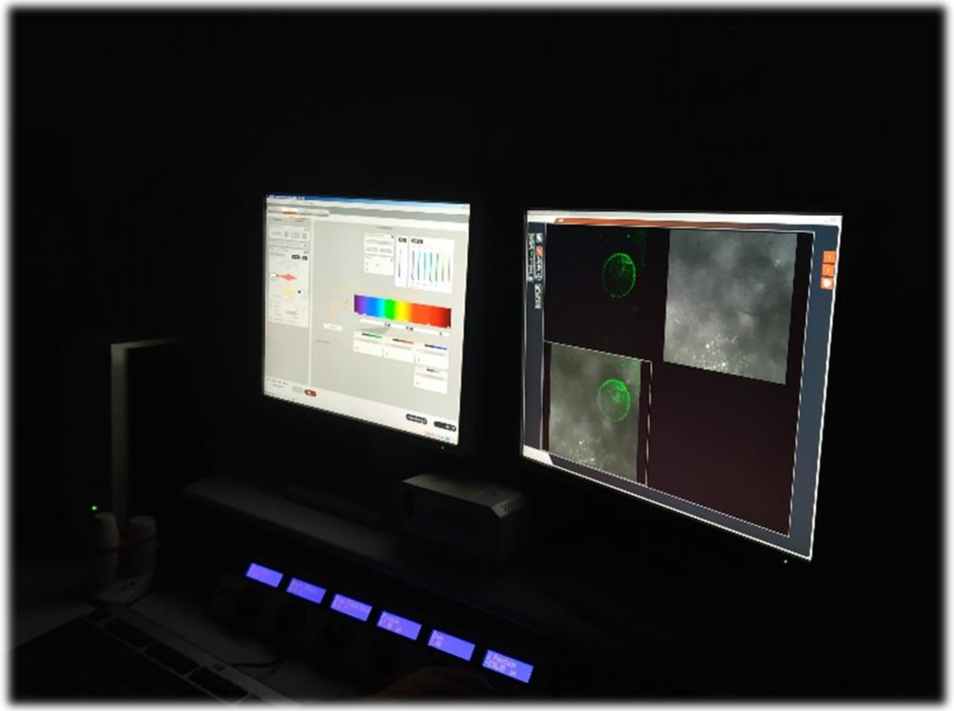


pot experiment data

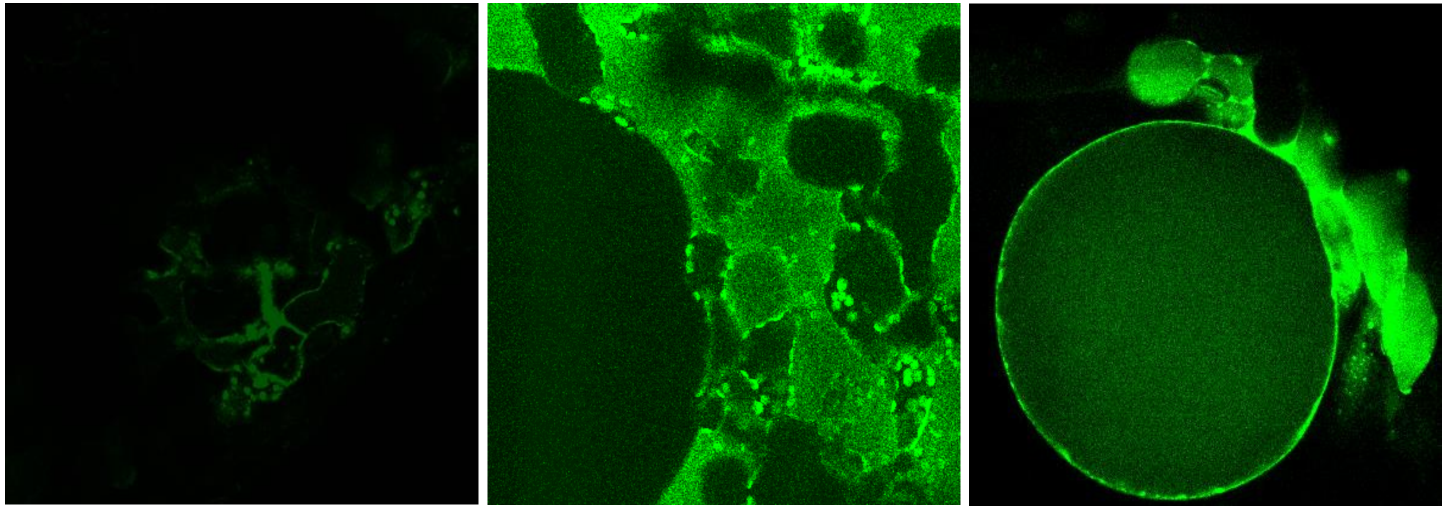
Comparable results in hydroponics versus soil for Na uptake and translocation to shoots



Leaf tissue samples collected after 4 weeks salt treatment;
Excitation wavelength: 488 nm; Emission wavelength: 510-522 nm

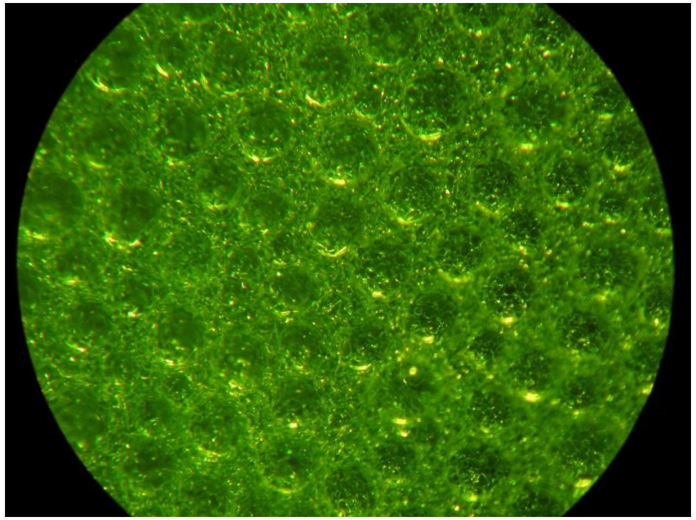
CoroNa™ Green 5uM

Control 0mM NaCl | 100mM NaCl | 200mM NaCl

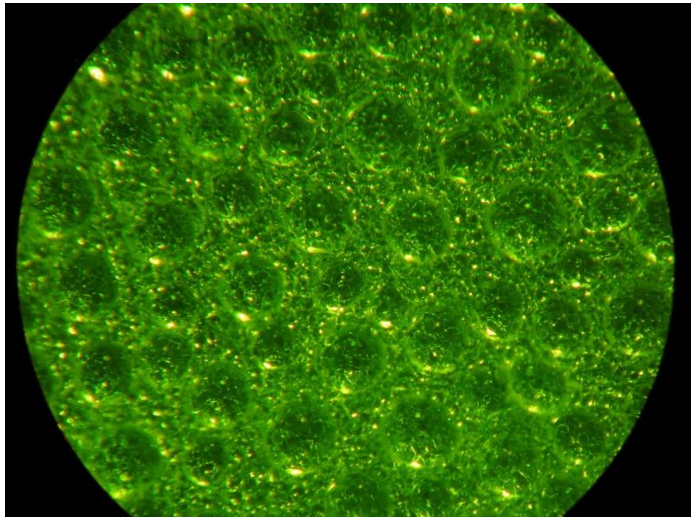


Scale bar 20 um; valid for all panels
40x; transversal sections

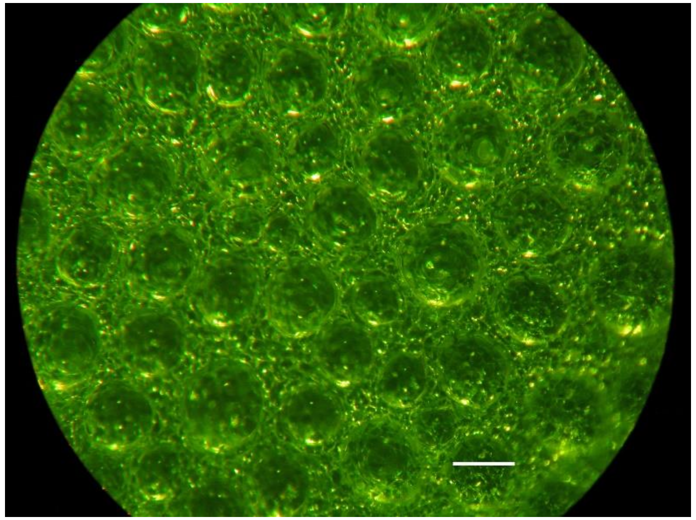
Confocal imaging shows Na localization in *Tetragonia tetragonioides* **epidermal layer**, in particular **bladder cells** and **apoplast,** away from the metabolically active tissues



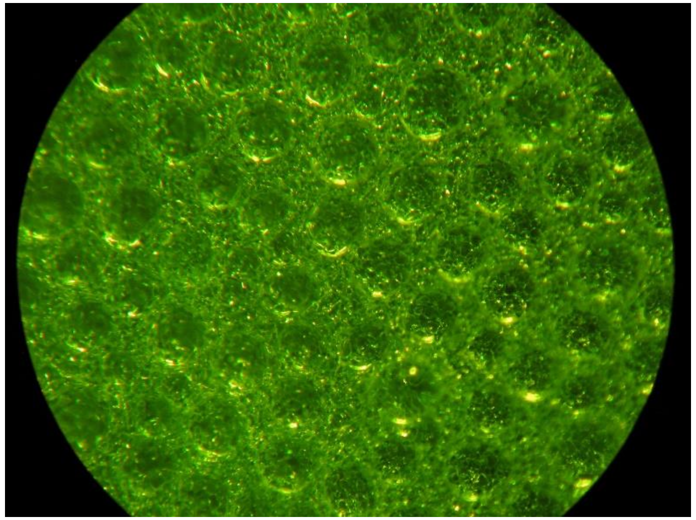
Control 0mM NaCl



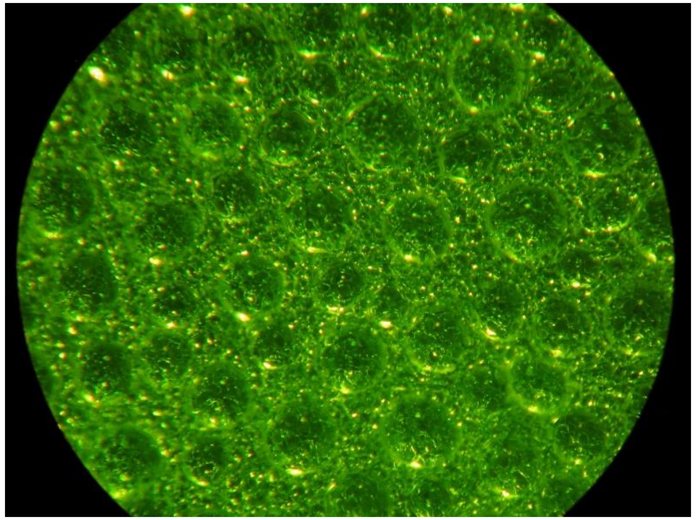
100 mM NaCl



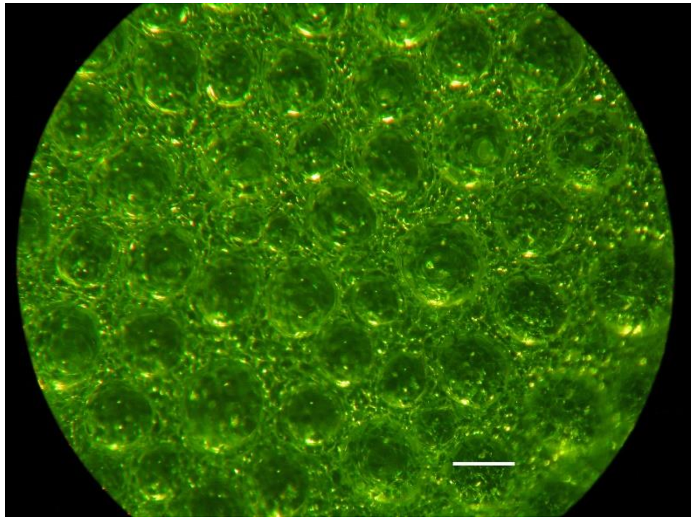
200 mM NaCl



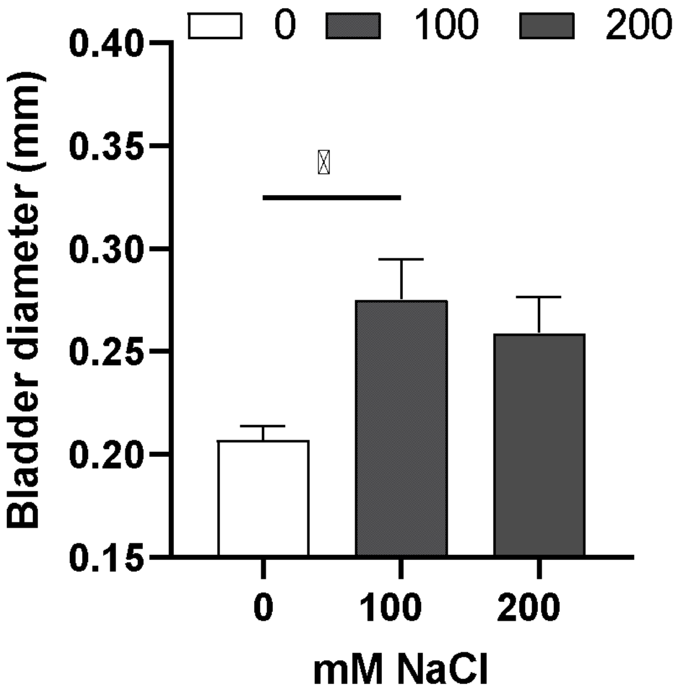
Control 0mM NaCl

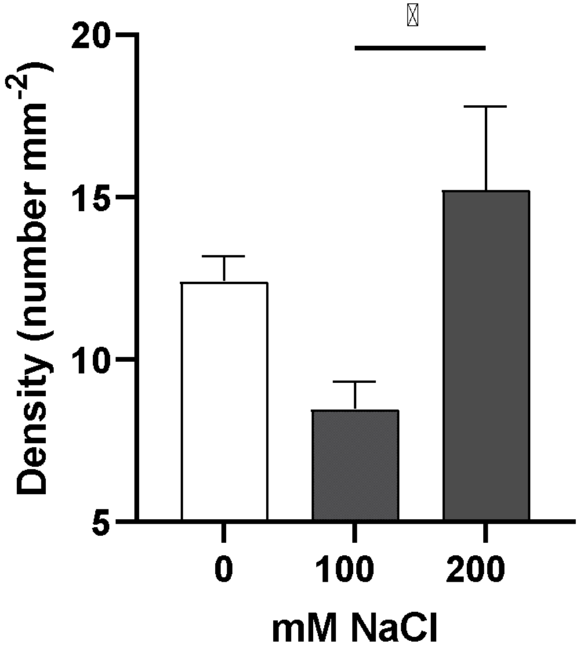


100 mM NaCl



200 mM NaCl





- At 100 and 200 mM, bladder cells resulted bigger in diameter
- At 200 mM, bladder cells resulted in higher density

Taste Test

Plants were grown in hydroponics at 100 mM NaCl.
A group of 125 people, 18 to 80 years old, tested the steamed leaves and filled a questionnaire investigating the overall appreciation of the product

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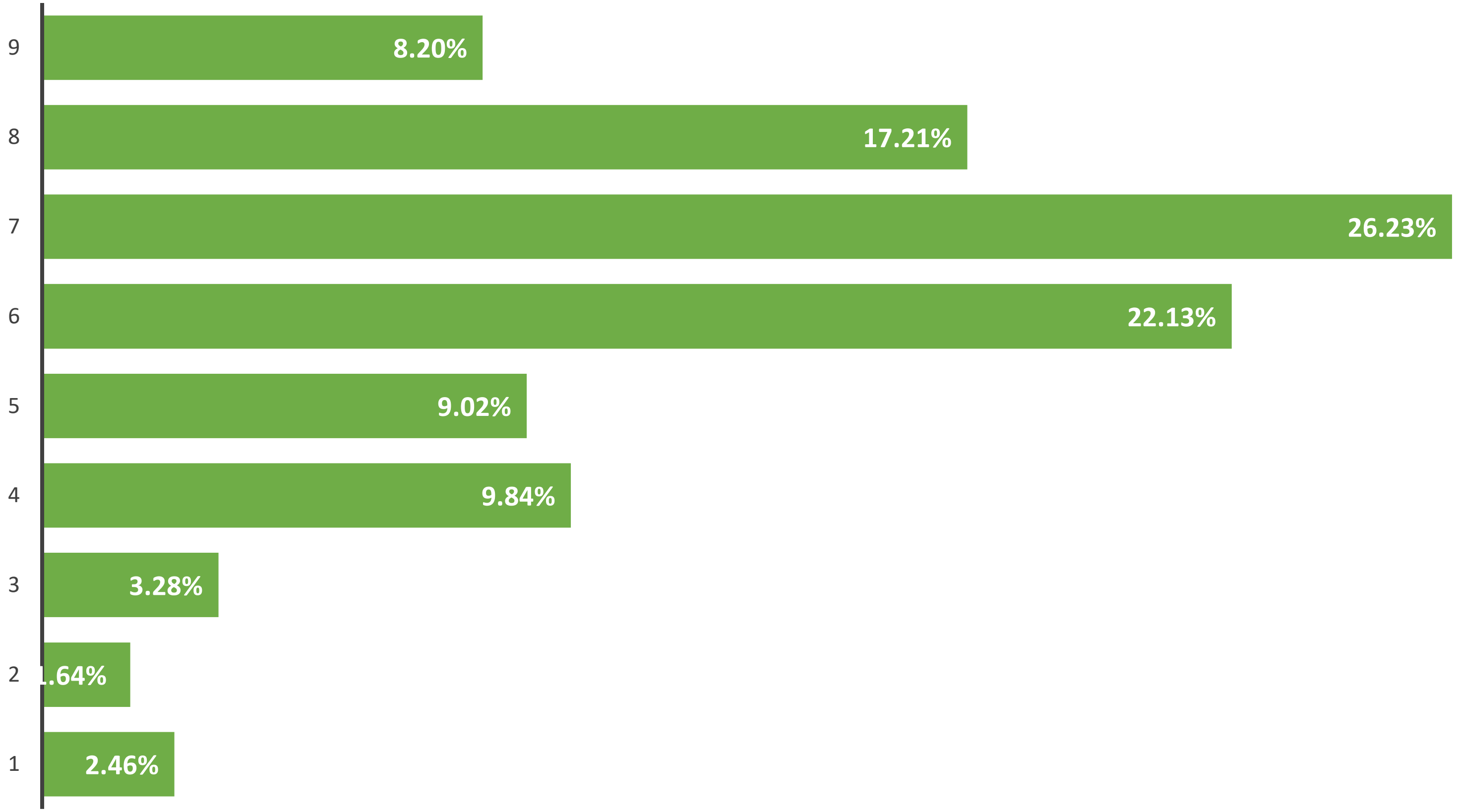
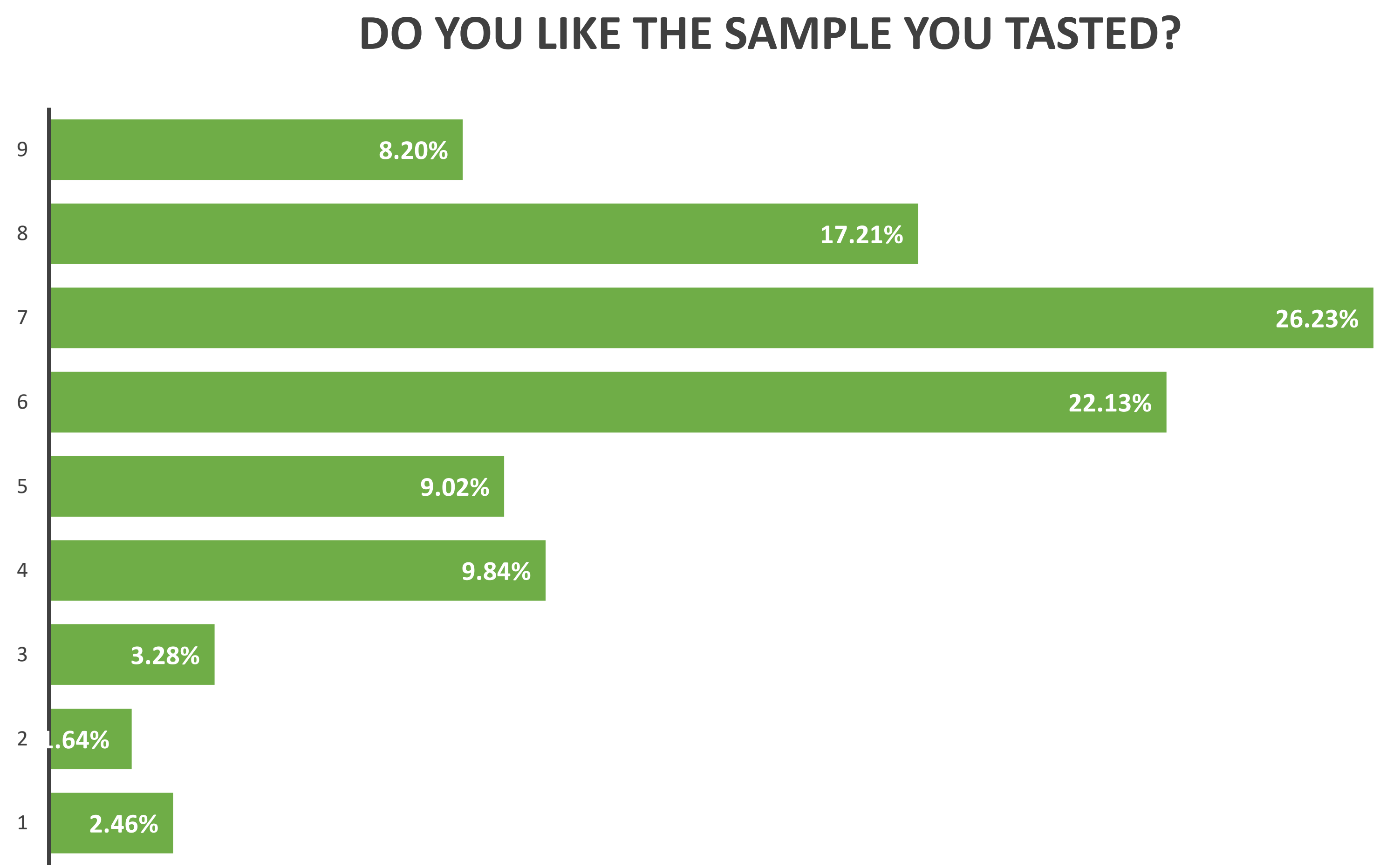
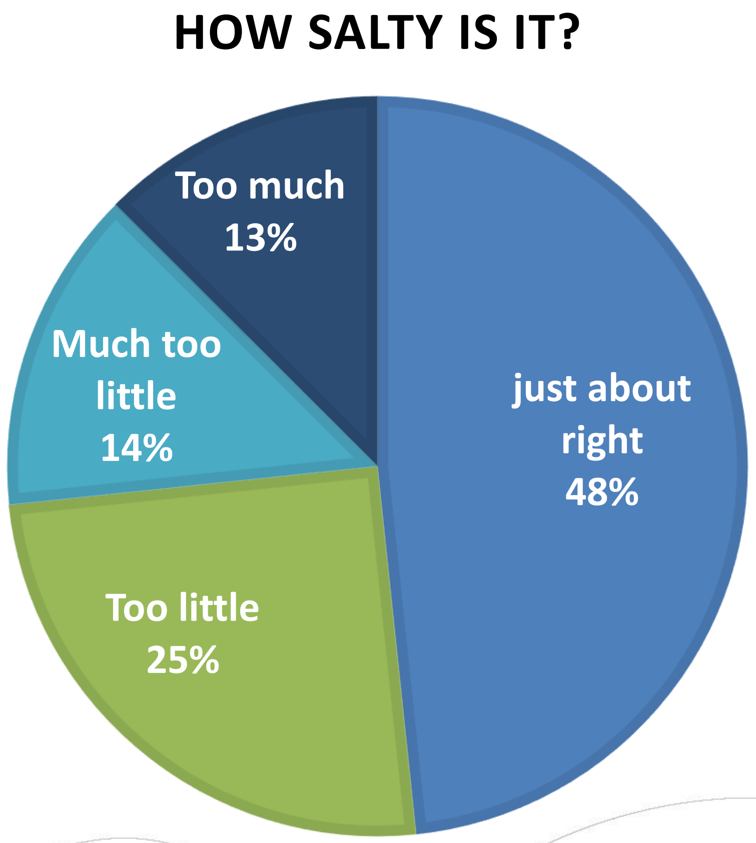
G. Mozzo[1], G. Atzori[2] and M. Petrillo[1] (2024) **Expanding food options with Tetragonia tetragonioides: a solution to soil salinization challenges** (in preparation)

[1]Department of Agriculture, Food, Environment and Forestry (DAGRI), University of Florence, Piazzale delle Cascine 18, 50144 Florence, Italy; [2]Department of Biology, University of Florence, Via Micheli 1, 50121 Florence, Italy; [3]National Research Council of Italy, Institute of Sustainable Plant Protection (CNR-IPSP), Via Madonna del Piano 10, 50019 Sesto Fiorentino, Italy

DO YOU LIKE THE SAMPLE YOU TASTED?




DO YOU LIKE THE SAMPLE YOU TASTED?
9
8.20%
8
17.21%
7
26.23%
6
22.13%
5
9.02%
4
9.84%
3
3.28%
2
.64%
1
2.46%


HOW SALTY IS IT?
Too much
13%
Much too
little
14%
just about
right
48%
Too little
25%

Conclusions

- *Tetragonia tetragonioides* shows a remarkable potential for cultivation in a **saline agriculture** context

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- People show **appreciation** and, beyond **local producers**, also **companies** are starting producing and selling it

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- People show **appreciation** and, beyond **local producers**, also **companies** are starting producing and selling it
- Its **salt uptake activity** do not seem to negatively affect people appreciation + important role for **phytodesalination**

Food and Agriculture Organization of the United Nations

Thank you

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Australian Government
Department of Agriculture, Water and the Environment

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra
Swiss Confederation

Funded by the European Union

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EUROPEAN COOPERATION IN SCIENCE & TECHNOLOGY

SUSTAIN
Sustainable use of salt-affected lands

Vniversitat de València

International Union of Soil Sciences

GLOBAL SOIL PARTNERSHIP

Ministry of Agriculture, Nature and Food Quality of the Netherlands