"Ruolo dei biostimolanti per contrastare stress multipli: salinità e alte temperature"

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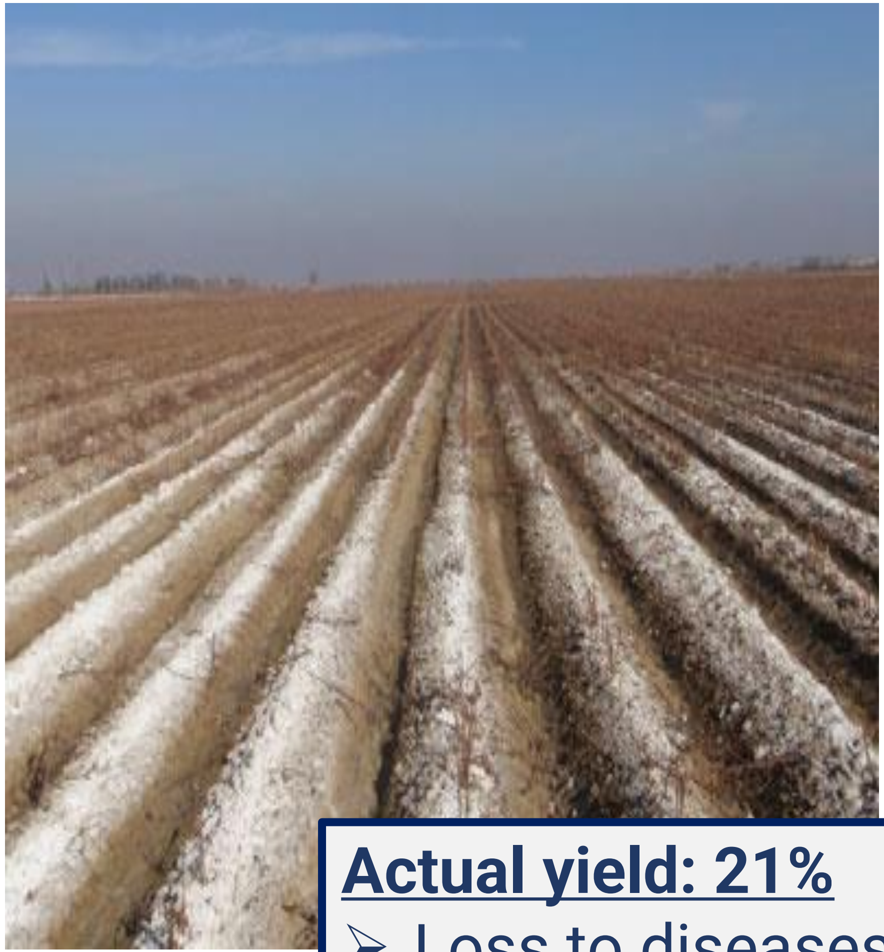
Environmental Stresses:
Major Factors for Yield Reduction

Salinity

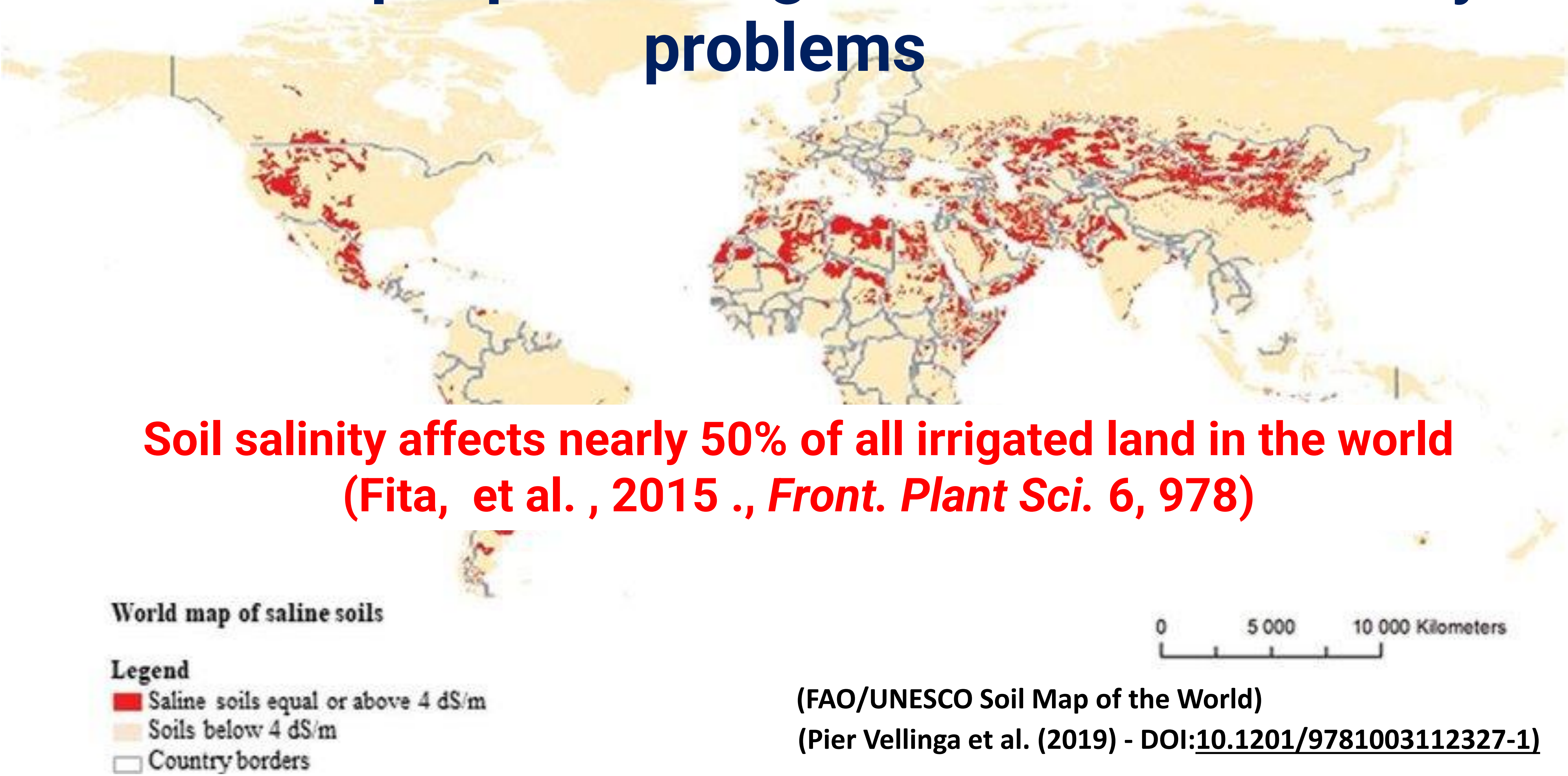


Heat Stress

Actual yield: 21%

- Loss to diseases, insects, weeds: 10%
- **Loss to environmental stresses: 69%**

World map representing countries with salinity problems



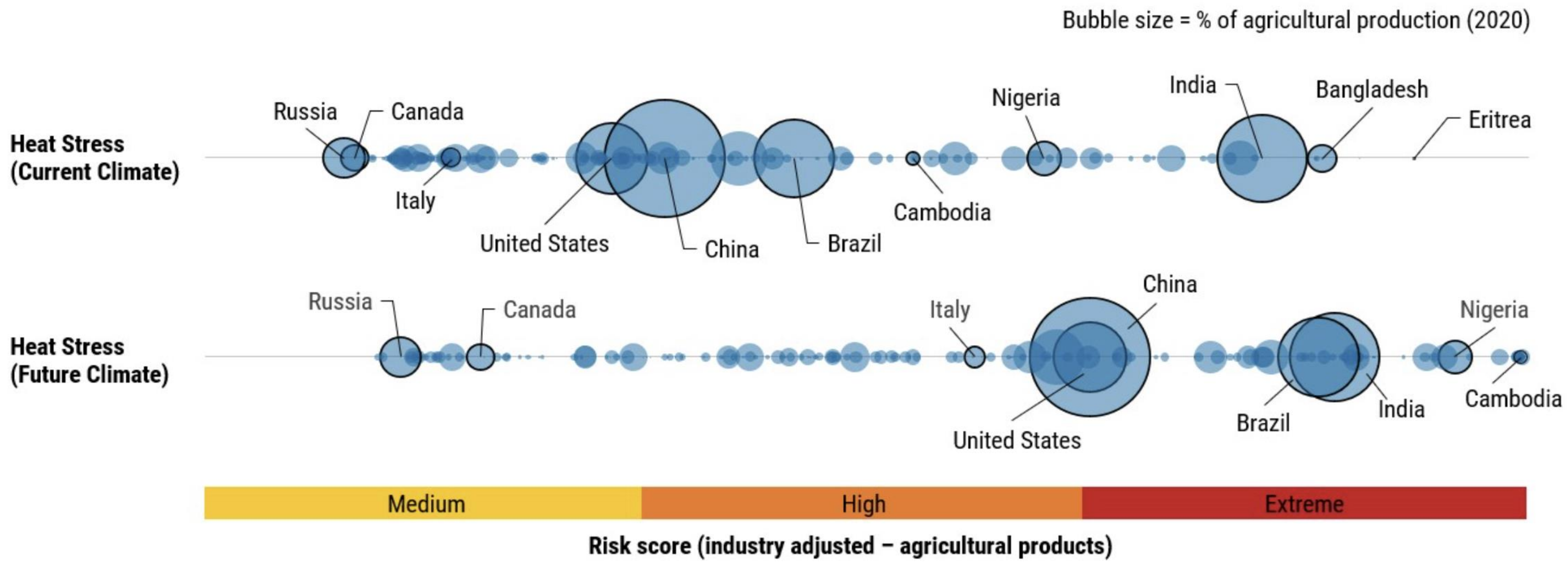
Soil salinity affects nearly 50% of all irrigated land in the world (Fita, et al. , 2015 ., *Front. Plant Sci.* 6, 978)

(FAO/UNESCO Soil Map of the World)

(Pier Vellinga et al. (2019) - DOI:10.1201/9781003112327-1)

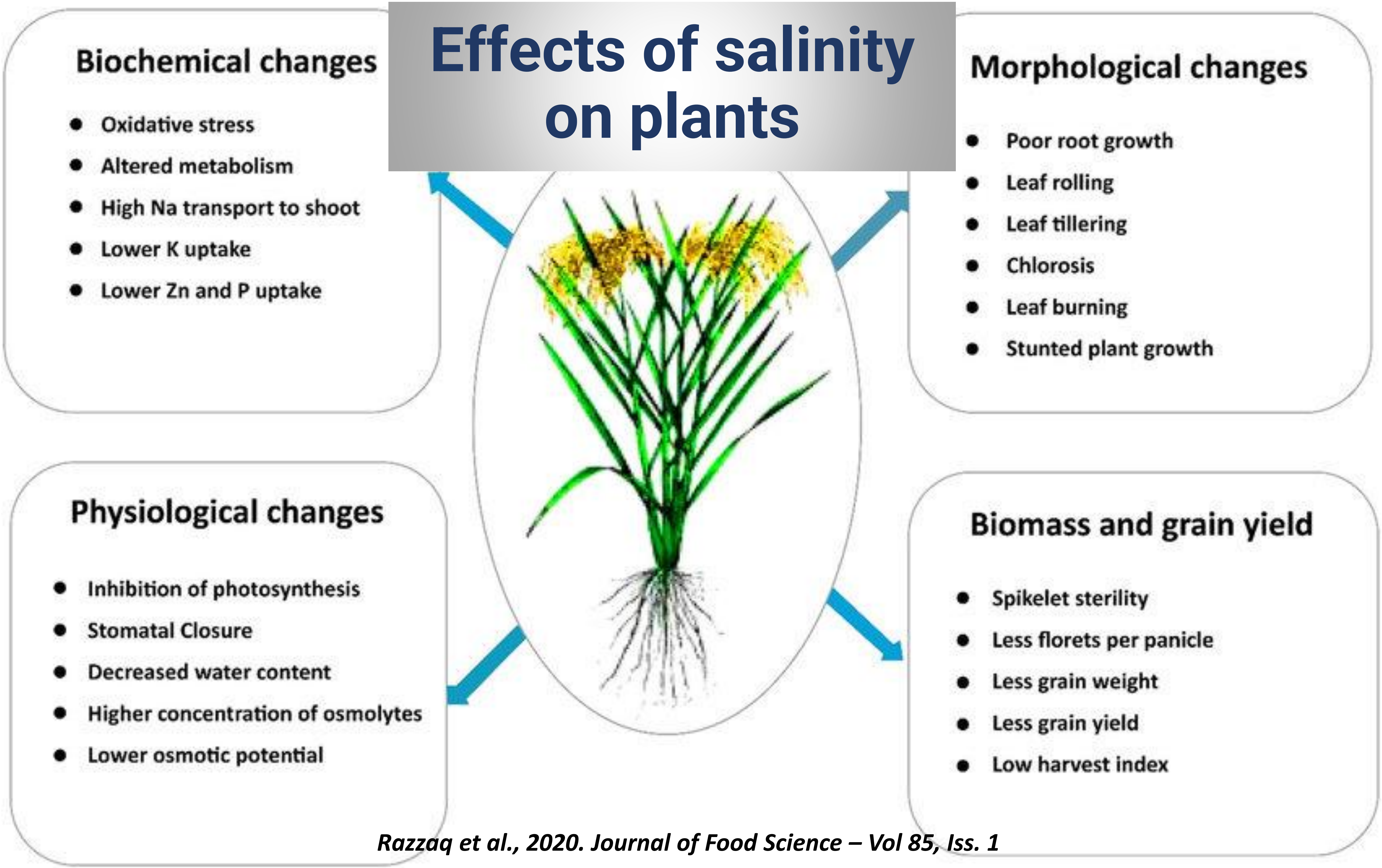
Heat Stress
(risk in Agriculture)

Industry adjusted (agriculture) heat stress risk scores for countries in current and future climate scenarios



Sources: The Heat Stress (Current Climate) and Heat Stress (Future Climate) indices use global temperature data extracted from the UK Met Office Hadley Centre Earth System model, HadGEM2-ES for the periods representing current (1980-2000) and future (2026-2045) climates; FAOSTAT; Verisk Maplecroft

Effects of salinity on plants



Razzaq et al., 2020. Journal of Food Science – Vol 85, Iss. 1

Effects of heat stress on plants

International Journal of *Molecular Sciences*

Review

Plant Responses to Heat Stress: Physiology, Transcription, Noncoding RNAs, and Epigenetics

Jianguo Zhao [1,2,†], Zhaogeng Lu [1,†], Li Wang [1] and Biao Jin [1,*]

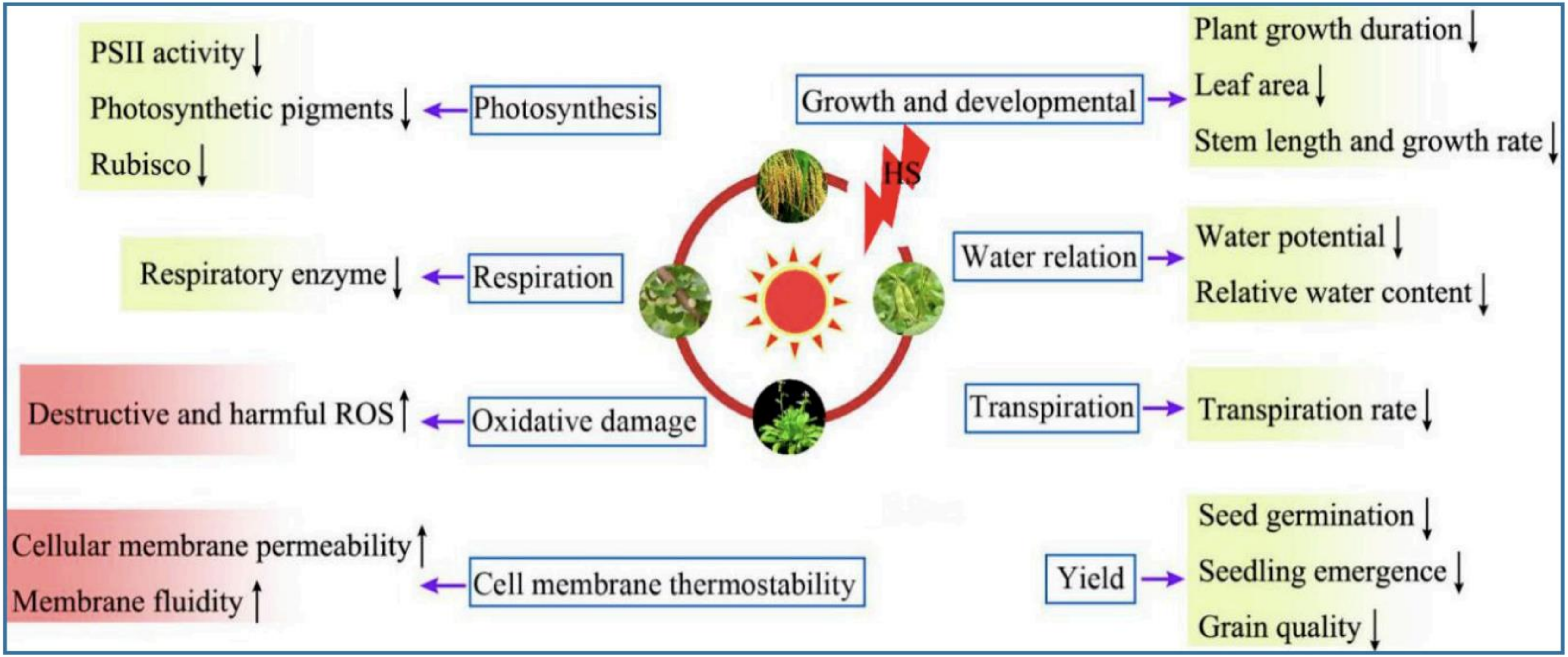


Table 1
Role of *DREBs* in transgenic plants and abiotic stress response tolerance on plants.

Target	Species	Technique	Stress	Findings	Reference
JfDREB1A	*Arabidopsis*	Overexpression	Cold	Enhanced survival	(Han et al., 2022)
AtCBF3	*Petunia hybrida*	Overexpression	Cold	Enhanced survival	(Walworth et al., 2013)
OsDREB1A	Rice	Overexpression	Cold	Retardated growth	(Ito et al., 2006)
AtDREB1A	Tomato	Heterologous expression	Cold,	Improved growth	(Karkute et al., 2019)
DREB2A	Wheat	Overexpression	Cold	Retardated growth	(Liu et al., 2022)
GhDREB	Cotton	Transcriptome analysis	Cold, Drought, Heat	132 cold-responsive, 63 drought-responsive, and 94 heat-responsive DREB genes were identified.	(Liu and Zhang, 2017)
CoDREB	*Camella Oleira*	Transcriptome analysis	Drought,Cold	*CoDREB1.2, 4.1, 4.4, 4.8, 4.12, 4.15, 5.1, 5.3, 5.5*, and *6.2* are responsive to long-term drought, *CoDREB1.2, 4.1, 4.4, 4.8, 4.12, 4.15, 5.1, 5.3, 5.5*, and *6.2* are responsive to short term drought.	(Wang et al., 2023b)
ScDREB2B-1	Tobacco	Overexpression	Drought	ABA signaling, increased ROS levels, and stress-related gene expression	(Chen et al., 2022)
tDREB2	Cotton	Overexpression	Drought	Improve biomass, gaseous exchange, increased ROS level, and stress-related gene expression.	(El-Esawi and Alayafi, 2019)
LbDREB6	Popular	Overexpression	Drought	Improve disease resistance	(Yang et al., 2020)
RcDREB1	Tobacco	Overexpression	Drought	Improve growth and pollen viability	(do Rego et al., 2021)
DREB1A	Soya bean	Overexpression	Drought	Enhanced water use efficiency	(Billah et al., 2021)
AtDREB1B	*Salvia militiorrhiza*	Overexpression	Drought	Modified water permeability in plant cells	(Lata and Prasad, 2011)
MsDREB6.2	Apple	Overexpression	Drought	Cytokinin-deficient developmental phenotypes	(Liao et al., 2017)
AtDREB1A	Chickpea, Peanut	Heterologous expression	Drought	Increase water absorption	(Anbazhagan et al., 2014)
ScDREB2B-1	Tobacco	Overexpression	Drought	Modified physiological and biochemical parameters and the expression of the stress response	(Chen et al., 2022)
StDREB1	Potato	Overexpression	Salt	Broad leaves, necrotic tumor	(El-Esawi and Alayafi, 2019)
GmDREB1	Wheat	Overexpression	Drought, Salt	Deeper roots, increased weight	(Jiang et al., 2017)
NnDREB2	Arabidopsis	Overexpression	Salt	High germination rates, improved root development	(Cheng et al., 2015)
LbDREB	Popular	Overexpression	Salt	Improve relative leaf water content, Membrane stability	(Zhao et al., 2018)
GhDBP1	Arabidopsis	Overexpression	Salt	Decreased expression of stress-induced gene	(Dong et al., 2010)
EcDREB2A	Tobacco	Overexpression	Heat	ROS scavenging	(Singh et al., 2021)
DREB2	Arabidopsis	Overexpression	Heat	Growth and development	(Sakuma et al., 2006)
SlDREBA4	Tomato	Overexpression	Heat	Osmolyte adjustment, expression of heat shock protein	(Mao et al., 2020)
CmDREB6	Chrysanthemum	Overexpression	Heat	Control the expression of genes involved in heat shock response.	(Du et al., 2018)
AtDREB1A	*Salvia miltiorrhiza*	Overexpression	Drought	Lower concentration of MDA, a higher concentration of CAT, POD, and SOD	(Muthurajan et al., 2021)

SlDREBA4 Tomato Overexpression Heat Osmolyte adjustment, expression of heat shock protein (Mao et al., 2020)
CmDREB6 Chrysanthemum Overexpression Heat Control the expression of genes involved in heat shock response. (Du et al., 2018)
AtDREB1A *Salvia miltiorrhiza* Overexpression Drought Lower concentration of MDA, a higher concentration of CAT, POD, and SOD (Muthurajan et al., 2021)

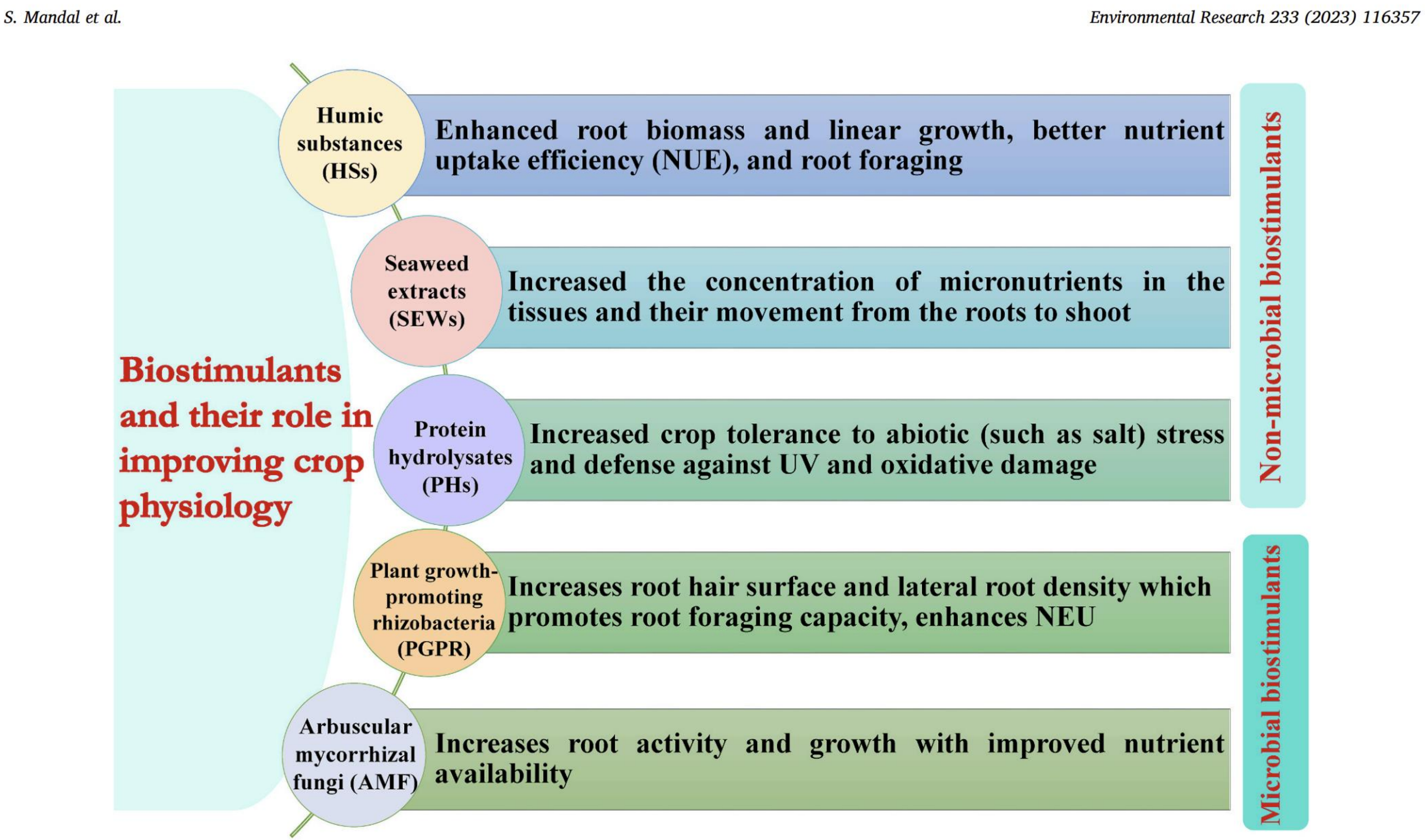
Various DREB gene targets, the plant species expressing these genes, and the stress mitigated are highlighted in the above table. The results achieved in these experiments are also shown along the references for more information.

Responses and
n Mechanisms

t stress: Pollen fertility
stress: Ion homeostasis

Role of biostimulants

Biostimulants Functions



BIOSTIMULANTS for SALT STRESS

Use of a Biostimulant to Mitigate Salt Stress in Maize Plants

by Roberto D'Amato * and Daniele Del Buono

Dipartimento di Scienze Agrarie, Alimentari e Ambientali, Università degli Studi di Perugia, Borgo XX Giugno 74, 06121 Perugia, Italy

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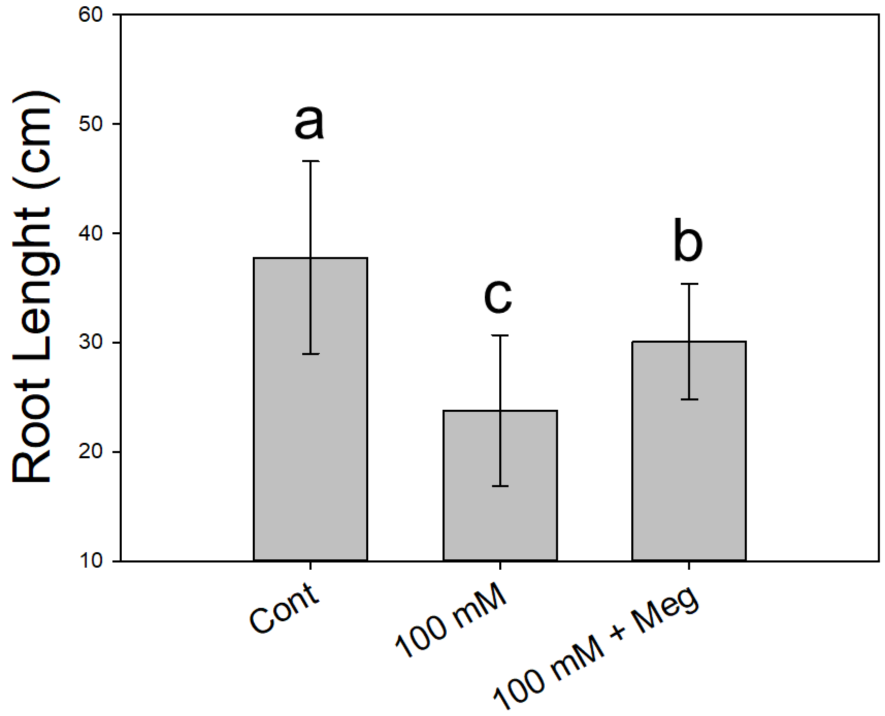
Agronomy **2021**, *11*(9), 1755; **https://doi.org/10.3390/agronomy11091755**

Received: 19 July 2021 / Revised: 24 August 2021 / Accepted: 28 August 2021 / Published: 31 August 2021



Effect of salinity and Megafol (biostimulant) on root length. Mean with different letters are statistically different according to Duncan's Post Hoc ($p < 0.05$).

- Reduced content of sodium in plant tissue
- Increased content of total chlorophyll
- Increased shoot biomass and root biomass
- Reduced content of hydrogen peroxide and malondialdehyde

complex of vitamines, aminoacids, proteins, betains and growth factors

Plant Soil (2013) 364:145–158
DOI 10.1007/s11104-012-1335-z

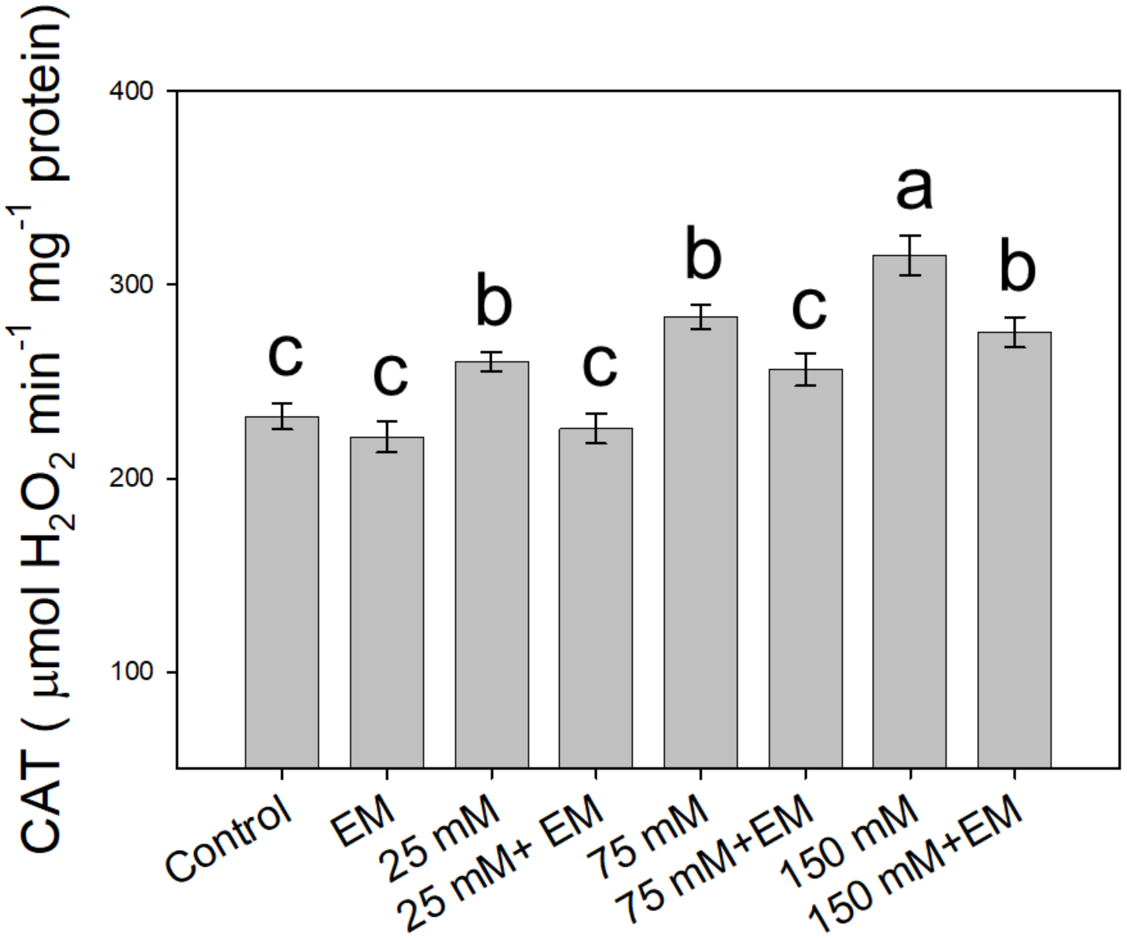
REGULAR ARTICLE

Alfalfa plant-derived biostimulant stimulate short-term growth of salt stressed *Zea mays* L. plants

Andrea Ertani · Michela Schiavon ·
Adele Muscolo · Serenella Nardi

Received: 29 March 2012 / Accepted: 25 June 2012 / Published online: 11 July 2012

- Decreased activity of antioxidant enzymes in leaves
- Increased plant biomass under salinity conditions
- Increase level of K^+



Catalase (CAT) activity in leaves of *Z. mays* plants under different salinity (0, 25, 75, 150) and bio-stimulant (EM) conditions. Mean with different letters are statistically different according to Duncan’s Post Hoc ($p < 0.05$).

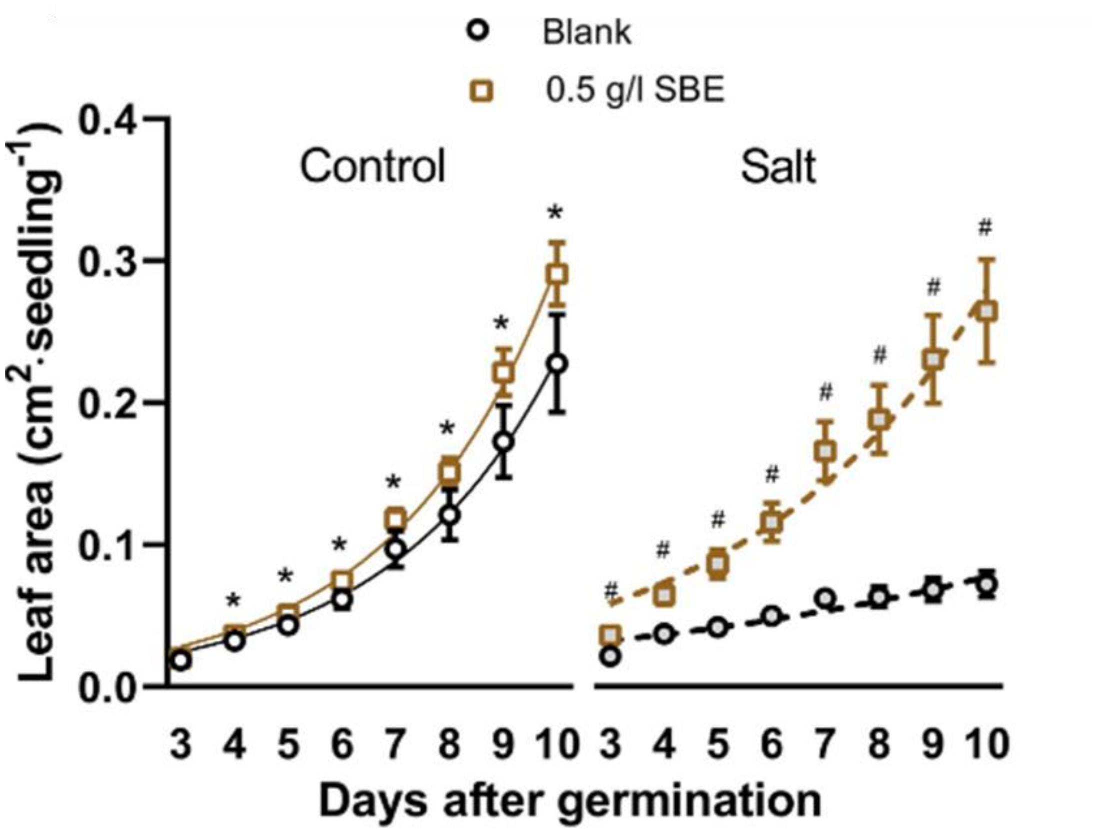
frontiers | Frontiers in Plant Science

ORIGINAL RESEARCH
published: 01 July 2022
doi: 10.3389/fpls.2022.837441

Check for updates

Sunflower Bark Extract as a Biostimulant Suppresses Reactive Oxygen Species in Salt-Stressed Arabidopsis

Jing Li[1], Philippe Evon[2], Stéphane Ballas[3], Hoang Khai Trinh[1,4], Lin Xu[1†], Christof Van Poucke[5], Bart Van Droogenbroeck[5], Pierfrancesco Motti[6], Sven Mangelinckx[6], Aldana Ramirez[1], Thijs Van Gerrewey[1] and Danny Geelen[1]*



- Reduced the production of ROS
- Preserved photosynthesis pigments
- Stabilized cell membrane
- Stimulated shoot growth

Salt stress alleviation of SBE treatment in the Arabidopsis true leaf assay. (A) The dynamic growth of leaf area from 3 DAG to 10 DAG..

Osmo-Priming with Seaweed Extracts Enhances Yield of Salt-Stressed Tomato Plants

by Emilio Di Stasio †, Valerio Cirillo *,†, Giampaolo Raimondi, Maria Giordano, Marco Esposito and Albino Maggio

Department of Agricultural Science, University of Napoli Federico II, Portici, 80055 Naples, Italy

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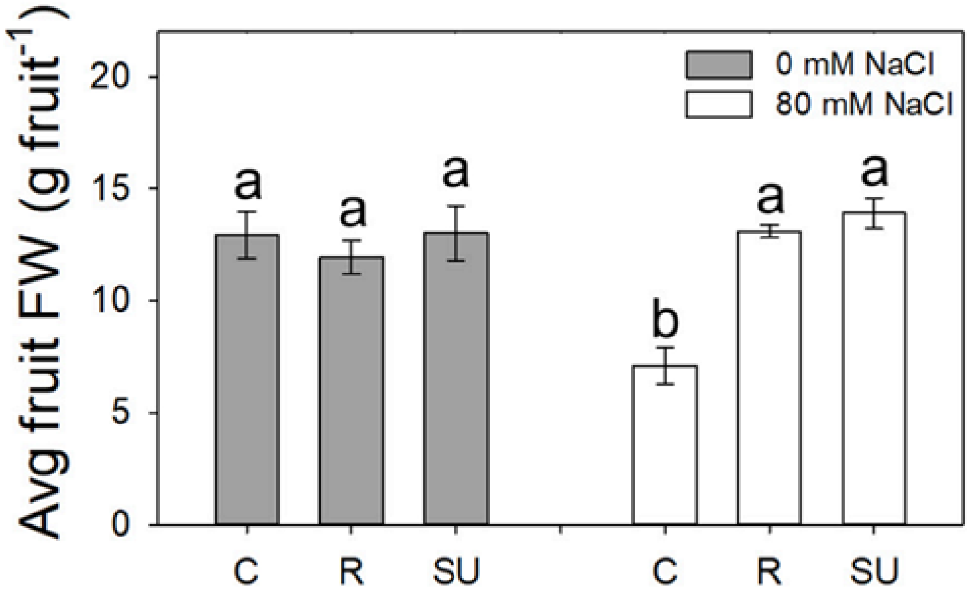
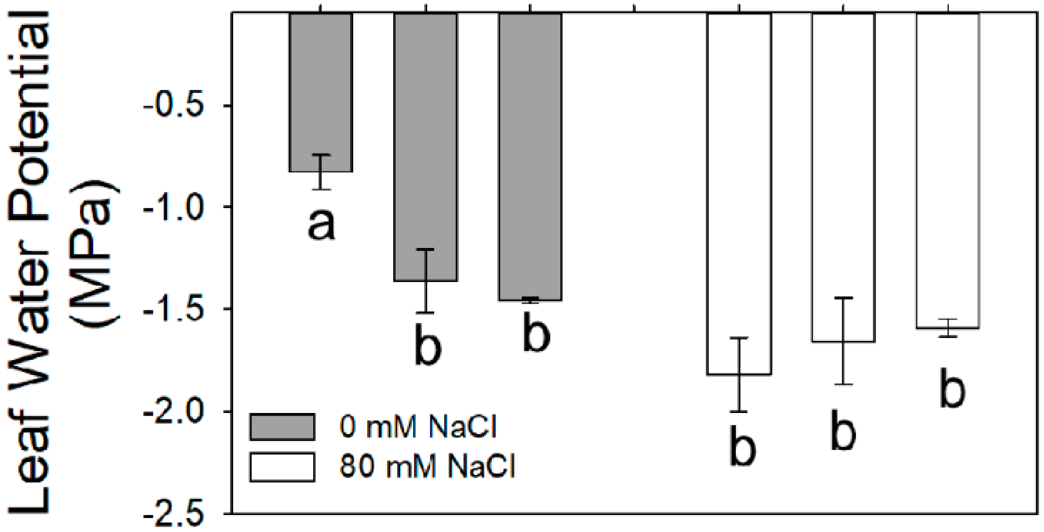
† These authors have contributed equally to this work.

Agronomy **2020**, *10*(10), 1559; https://doi.org/10.3390/agronomy10101559

Received: 9 September 2020 / Revised: 5 October 2020 / Accepted: 7 October 2020 / Published: 13 October 2020

- Osmolites content in both biostimulants (proline, mannitol, sorbitol)
- Higher allocation of biomass to roots
- Higher plant water use efficiency





The impact of biostimulants on the physiology and agricultural traits of crops under salt stress

Environmental Research 233 (2023) 116357

Contents lists available at ScienceDirect

Environmental Research

journal homepage: www.elsevier.com/locate/envres

Review article

Biostimulants and environmental stress mitigation in crops: A novel and emerging approach for agricultural sustainability under climate change

Sayanti Mandal[a,b,*,1], Uttpal Anand[c,1], José López-Bucio[d], Radha[e], Manoj Kumar[f], Milan Kumar Lal[g,h], Rahul Kumar Tiwari[g,h], Abhijit Dey[i,**]

Stenotrophomonas maltophilia BJ01	Peanut	low electrolyte leakage, lipid peroxidation, proline content, and H2O2. Hig[h] auxin and aa levels	Alexander et al. (2020) (hydroponics – no yield)
Arthrobacter woluwensis (AK1) and more	Soybean	Higher antioxidant activity and reduced endogenous ABA level	Khan et al. (2019) (pot? – no yield)
Acinetobacter bereziniae, Enterobacter ludwigii	Pea	Enhanced levels of chlorophyll, proline, and total soluble sugars.	Sapre et al. (2022) (pot – 3-6% yield increase)
Pseudomonas oryzihabitans AXSa06	Tomato	Positive effects on photosynthetic parameters. Upregulati[on] of genes implicated [in] ethylene/ ABA production.	Mellidou et al. (2021) (pot? - no yield)
Trichoderma reesei	Wheat	Increases chlorophyll, carotenoids. mineral absorption (Ca and [...] Reduction in ABA conc.	Ikram et al. (2019) (pot? – no yield)
Aneurinibacillus aneurinilyticus, Paenibacillus sp.	Bean	Increase of growth regulating hormones (IAA) water and nutrients absorption	Gupta and Pandey (2019) (rev – no yield)
Porostereum spadiceum AGH786	Soybean	Improved seedling daidzein and genistein endogenous levels [...] GAs and low ABA and JA	Hamayun et al. (2017) (pot – no yield)
Trichoderma longibrachiatum T6	Wheat	Decrease of malondialdehyde. In[...] of RWC, chlorophyll [...] proline	Zhang et al. (2016) (plastic boxes – no yield)
Protein hydrolysates	Lettuce	Improvement in plant nitrogen metabolism [...] Fv/Fm-ratio efficiency.	Lucini et al. (2015) (pot – yield unclear)

BIOSTIMULANTS for HEAT STRESS

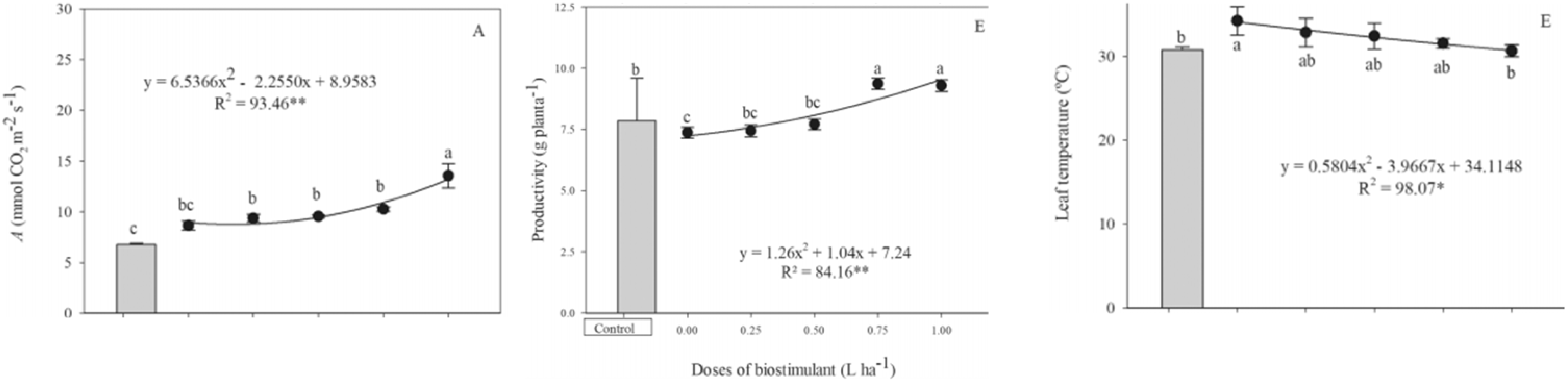
Increased soybean tolerance to high-temperature through biostimulant based on *Ascophyllum nodosum* (L.) seaweed extract

Rodrigo Alberto Repke[1,3] · Dayane Mércia Ribeiro Silva[2] · Jania Claudia Camilo dos Santos[2] · Marcelo de Almeida Silva[2]

Journal of Applied Phycology (2022) 34:3205–3218
https://doi.org/10.1007/s10811-022-02821-z

Received: 9 May 2022 / Revised and accepted: 11 August 2022 / Published online: 20 August 2022

- Increased productivity
- Increased the rate of CO_2 assimilation, stomatal conductance, the rate of transpiration and carboxylation efficiency
- Increased antioxidant enzymes activity
- Reduced temperature leaf



Average temperature of 40 °C throughout the cycle until harvest

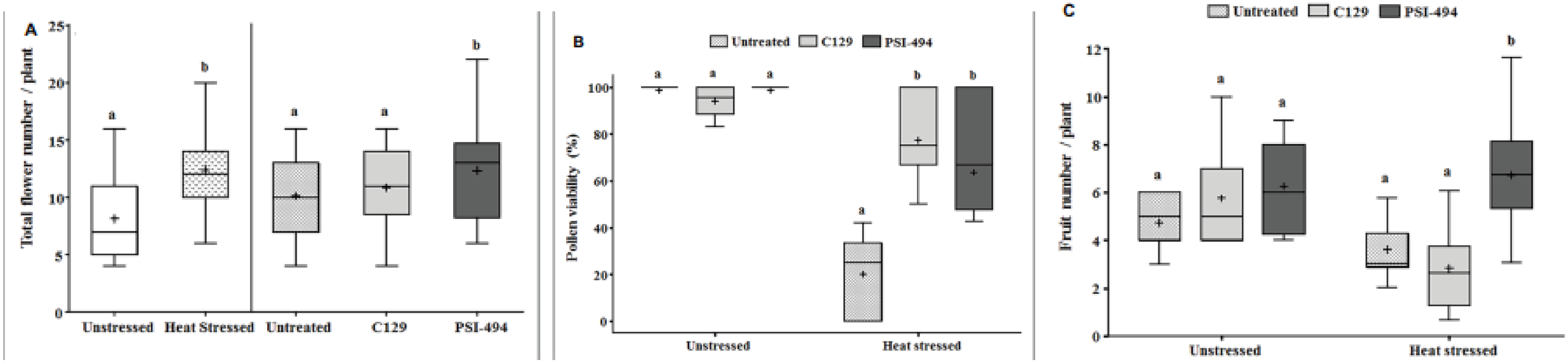
Ascophyllum nodosum Extract Biostimulant Processing and Its Impact on Enhancing Heat Stress Tolerance During Tomato Fruit Set

Nicholas Carmody[1], Oscar Goñi[1], Łukasz Łangowski[2] and Shane O'Connell[1]*

[1]Plant Biostimulant Group, Shannon Applied Biotechnology Centre, Institute of Technology Tralee, Tralee, Ireland, [2]Research and Development Department, Brandon Bioscience, Tralee, Ireland

Front. Plant Sci., 25 June 2020
Sec. Crop and Product Physiology
Volume 11 - 2020 | https://doi.org/10.3389/fpls.2020.00807

- Increased flower development
- Increased pollen viability and fruit production
- Enhanced carbohydrate metabolism and thermotolerance



Ascophyllum nodosum extracts (ANEs)
C129, an ANE obtained at low temperatures through a gentle extraction and the novel proprietary PSI-494 extracted under high temperatures and alkaline conditions.

plants

MDPI

Article

Transcriptome Analyses and Antioxidant Activity Profiling Reveal the Role of a Lignin-Derived Biostimulant Seed Treatment in Enhancing Heat Stress Tolerance in Soybean

Cristina Campobenedetto [1,2,†], Giuseppe Mannino [1,†], Chiara Agliassa [3], Alberto Acquadro [3], Valeria Contartese [2], Christian Garabello [2] and Cinzia Margherita Bertea [1,*]

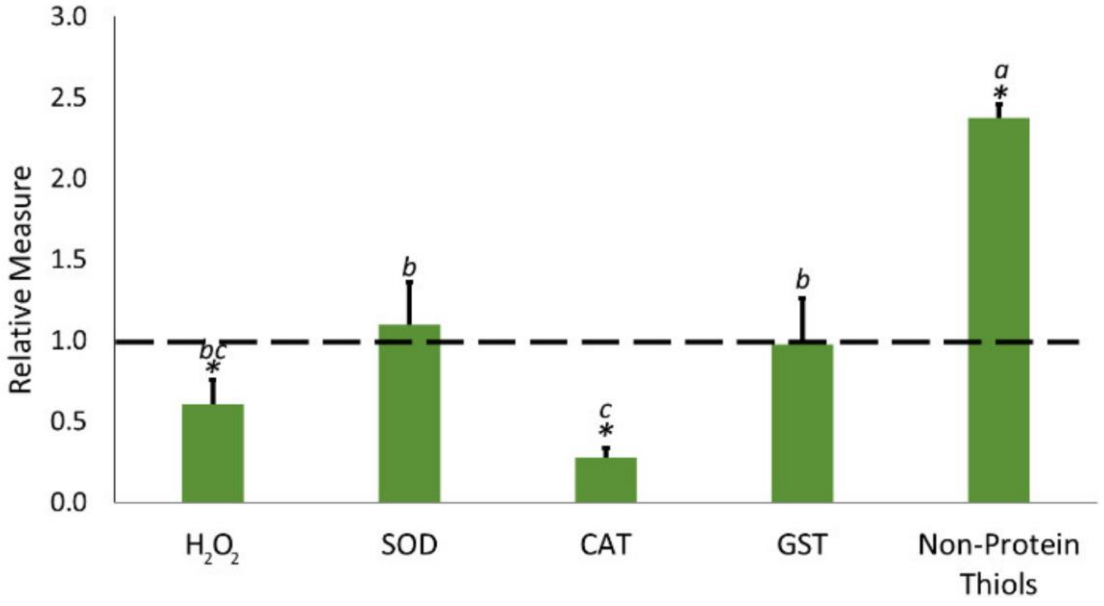
Received: 15 September 2020; Accepted: 30 September 2020; Published: 2 October 2020

check for updates

- Increase germination percentage;
- Few genes involved in stress response are upregulated;
- [H2O2] were significantly lower in the biostimulant-treated seeds.

	Untreated	Biostimulant-Treated	%Δ
24 h	n.d.	n.d.	-
48 h	68.80 ± 1.16 [a]	77.70 ± 0.58 [b]	12.95% ± 1.06%
72 h	82.22 ± 0.58 [a]	91.13 ± 0.55 [b]	10.84% ± 0.11%

Germination percentage of untreated and **biostimulant-treated soybean seeds incubated at 35°C** in the dark.



Effects of the application of the biostimulant on hydrogen peroxide (H_2O_2) level, superoxide dismutase (SOD), catalase (CAT), and glutathione S-transferase (GST) enzymatic activity and on non-protein thiol content. Dashed-line=related untreated sample.

Seed priming with seaweed extract mitigate heat stress in spinach: effect on germination, seedling growth and antioxidant capacity

Antônio Pereira dos Anjos Neto[1*], Gustavo Roberto Fonseca Oliveira[2], Simone da Costa Mell
Marcio Souza da Silva[4], Francisco Guilhien Gomes-Junior[3], Ana Dionisia da Luz Coelho Nove
Ricardo Antunes Azevedo[5]

1. Universidade Federal da Paraíba – Centro de Ciências Agrárias – Programa de Pós-Graduação em Agronomia - Areia
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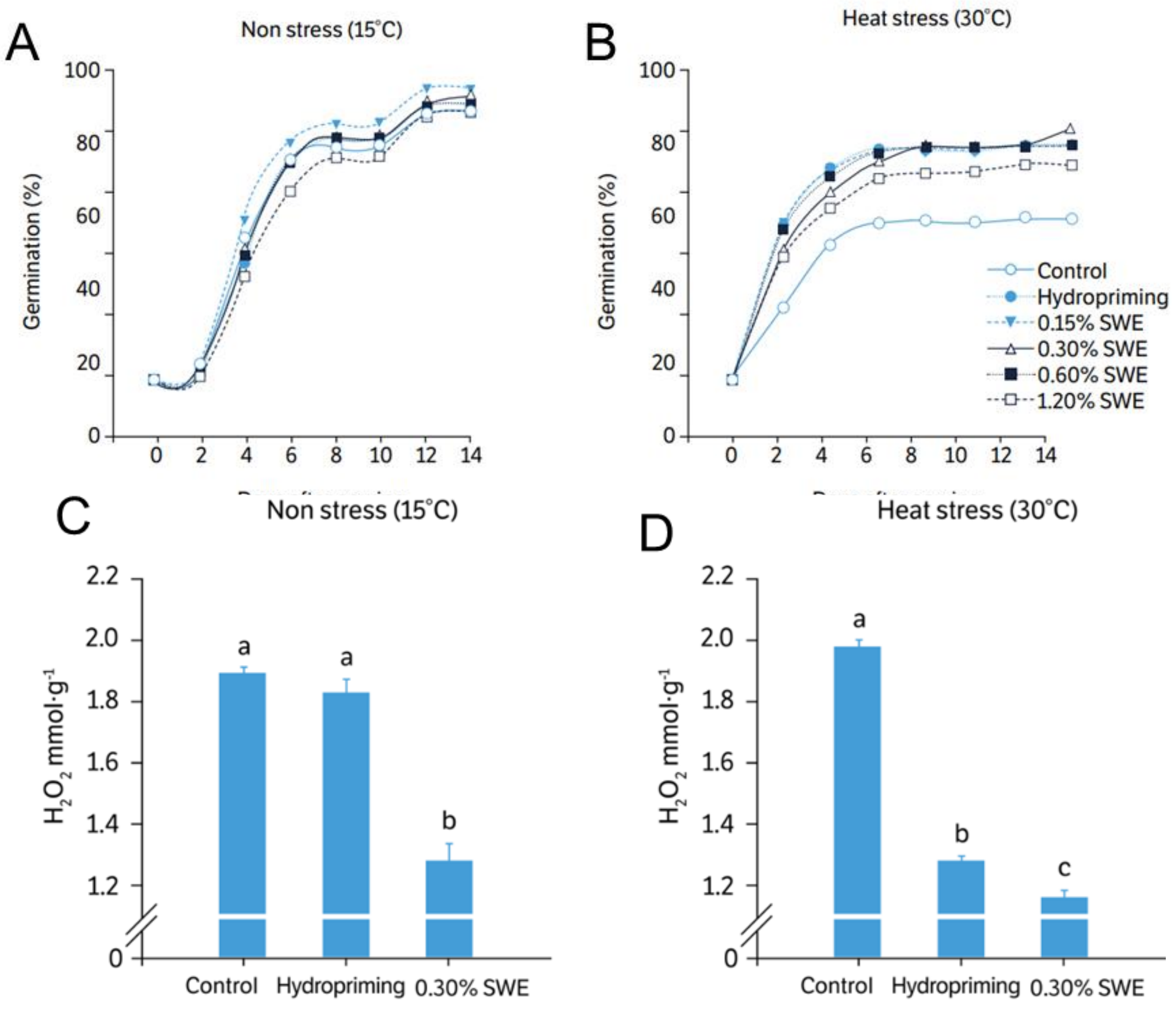


- Seaweed extract increase germination speed and germination percentage
- Seaweed extract decrease H2O2 levels

Plant Soil (2014) 379:337–350
DOI 10.1007/s11104-014-2063-3

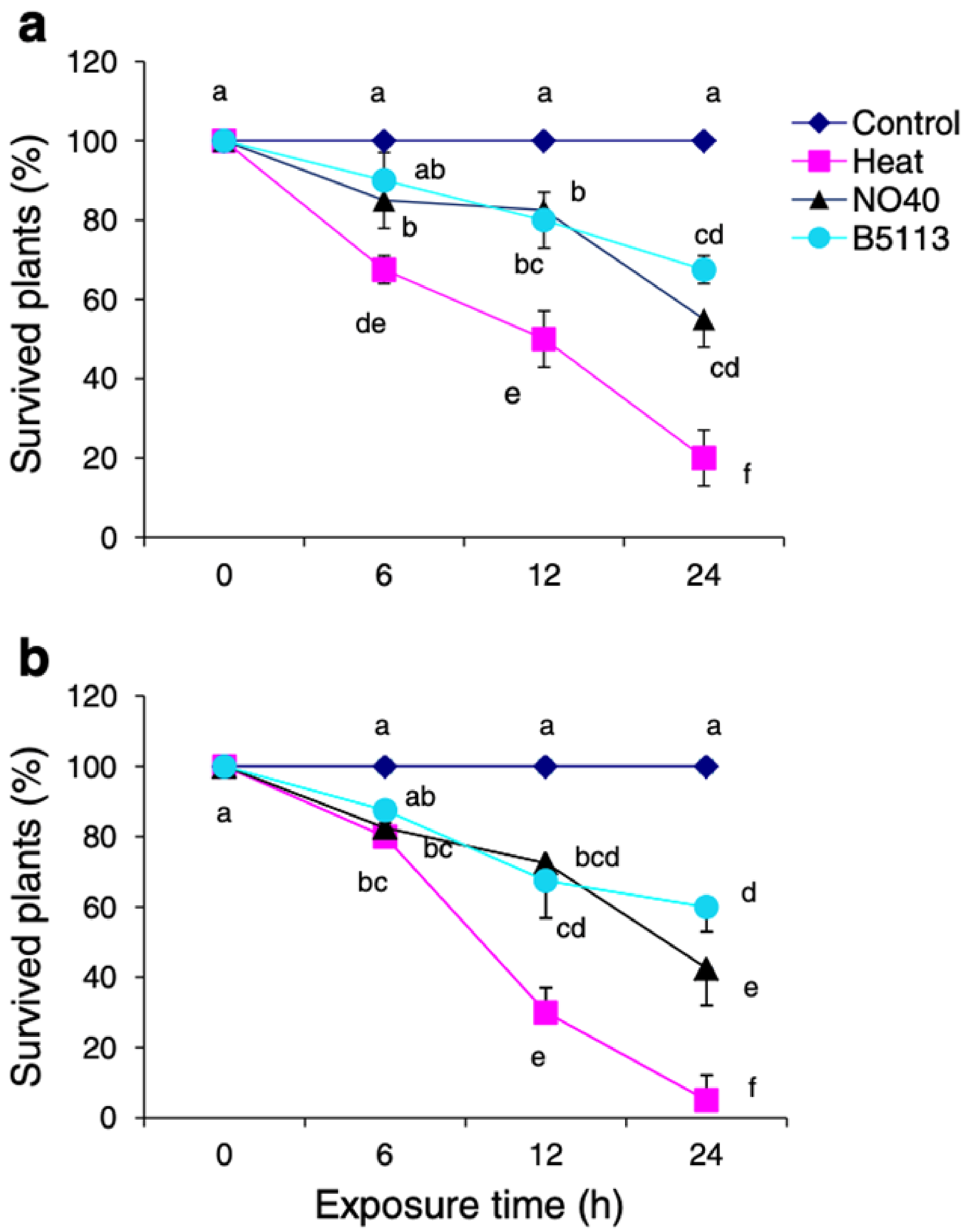
REGULAR ARTICLE

Improved heat stress tolerance of wheat seedlings by bacterial seed treatment

Islam A. Abd El-Daim · Sarosh Bejai · Johan Meijer

Heat stressed plants were exposed to a temperature of 45 °C.

- Bacterial treated plant showed higher survival rate.
- The expression of stress marker genes was lower in treated plants.
- Treatment with bacterial strains decreased Ascorbate peroxidase activity after heat exposure.
- Heat stress resulted in increased Dehydroascorbate reductase activity and Gluthatione reductase activty.



A second generation of biostimulant-based products with synergistic biostimulatory activity has been proposed

agronomy

Article

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RESEARCH ARTICLE

A plant bios
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L. R. Gunupuru, J. S. Pa

Published: September 1

frontiers | Frontiers in Plant Science

TYPE Original Research
PUBLISHED xx xx 2023
DOI 10.3389/fpls.2023.1304627

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Q3 *CORRESPONDENCE
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†These authors have contributed equally to this work and share

Inoculation with a microbial consortium increases soil microbial diversity and improves agronomic traits of tomato under water and nitrogen deficiency Q1

Valerio Cirillo[1†], Ida Romano[1†], Sheridan L. Woo[2,3,4], Q2 Q11
Emilio Di Stasio[1], Nadia Lombardi[1], Ernesto Comite[1], Q4
Olimpia Pepe[1,4], Valeria Ventorino[1,4*] and Albino Maggio[1]

New Approaches/ Tools in Plant Biotech

biology
MDPI

Review

Genetic, Epigenetic, Genomic and Microbial Approaches to Enhance Salt Tolerance of Plants: A Comprehensive Review

Gargi Prasad Saradadevi [1,†], Debajit Das [2,†], Satendra K. Mangrauthia [3,†], Sridev Mohapatra [1,†], Channakeshavaiah Chikkaputtaiah [2,†], Manish Roorkiwal [4,5,†], Manish Solanki [3], Raman Meenakshi Sundaram [3], Neeraja N. Chirravuri [3], Akshay S. Sakhare [3], Suneetha Kota [3,*], Rajeev K. Varshney [4,5,6,*] and Gireesha Mohannath [1,*]

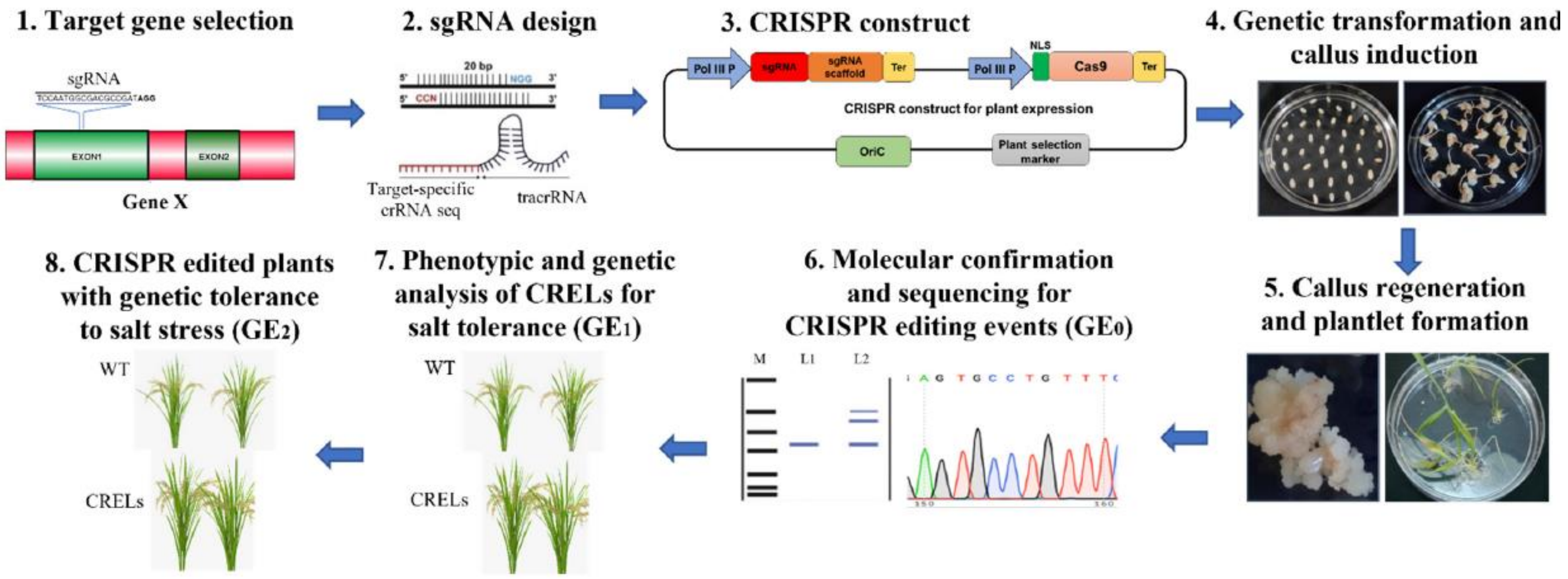


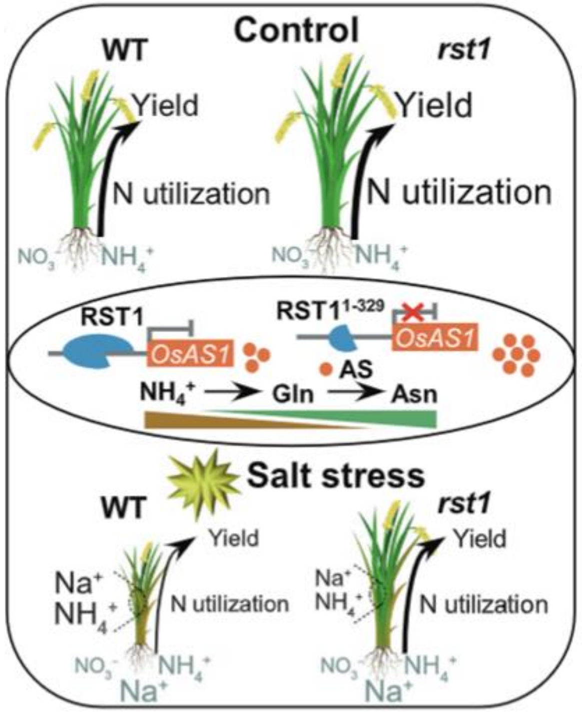
Figure 1. A scheme of CRISPR/Cas mediated genome editing for salt tolerance in plants. CRELs: CRISPR Edited Lines. NLS: Nuclear Localization Signal (NLS can also be at the end of Cas9), OriC: Origin of Replication C, Ter: Terminator, Pol III P: Polymerase III promoter, GE0: Genome Edited Generation 0, GE1: Genome Edited Generation 1, GE2: Genome Edited Generation 2.

PNAS RESEARCH ARTICLE | AGRICULTURAL SCIENCES

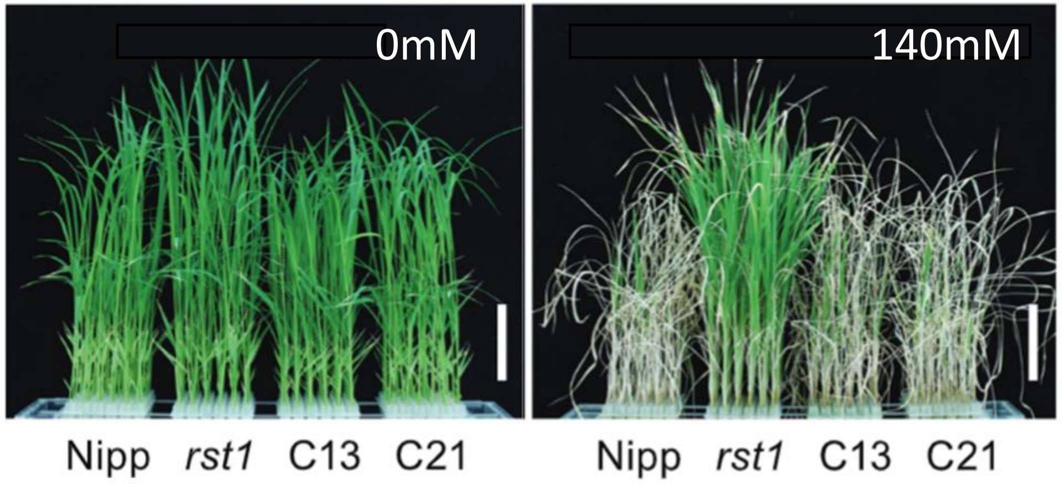
Transcriptional repressor RST1 controls salt tolerance and grain yield in rice by regulating gene expression of asparagine synthetase

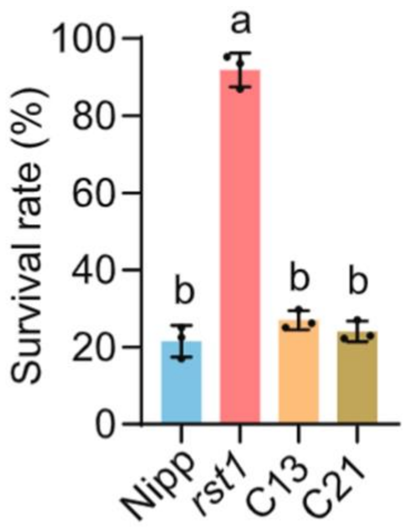
Ping Deng[a], Wen Jing[a,1], Chengjuan Cao[a], Mingfa Sun[b], Wenchao Chi[c], Shaolu Zhao[b], Jinying Dai[b], Xingyu Shi[a], Qi Wu[a,d], Baolong Zhang[d], Zhuo Jin[e], Chunxia Guo[a], Quanxiang Tian[a], Like Shen[a], Jun Yu[c], Ling Jiang[c], Chunming Wang[c], Joong Hyoun Chin[e], Jingya Yuan[a], Qun Zhang[a,1], and Wenhua Zhang[a,1]

Edited by Julian Schroeder, University of California San Diego, La Jolla, CA; received June 17, 2022; accepted October 13, 2022



- Loss of *RST1* Function Enhances Stress Tolerance by Improving Nitrogen Use and Na^+/K^+ homeostasis
- Loss of *RST1* function increases the expression of *OsAS1* and improves nitrogen (N) utilization by promoting asparagine production and **avoiding excess ammonium (NH_4^+) accumulation**





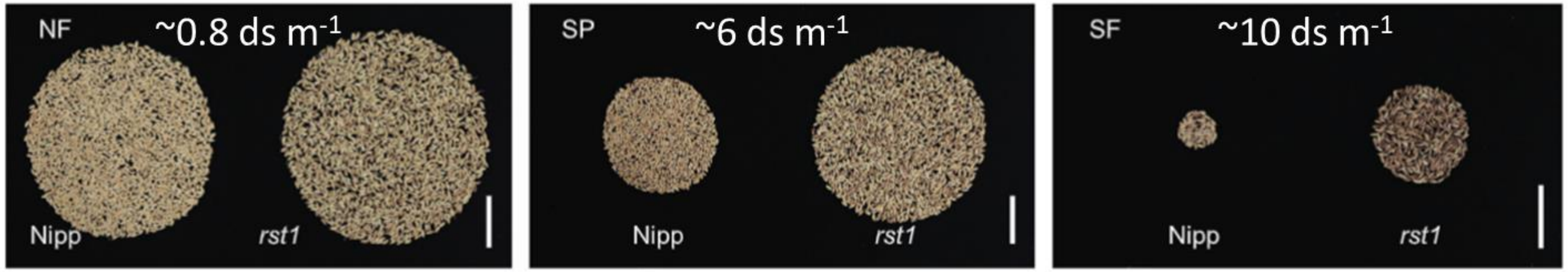


TABLE 1 Functions of conversed miRNAs in plant growth, development, and abiotic stresses.

miRNAs	Targets	Functions in growth and development	Functions in abiotic stresses (heat, cold, drought and salt)
miR156*	*SPLs*;	Plant architecture (Jiao et al., 2010);	Heat stress memory (Stief et al., 2014);

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Czech University of Life Sciences Prague, Czechia
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CSIR-National Institute of Science Communication and Policy Research, India

Non-coding RNAs fine-tune the balance between plant growth and abiotic stress tolerance

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Improving plant multiple stress tolerance *wrap-up*

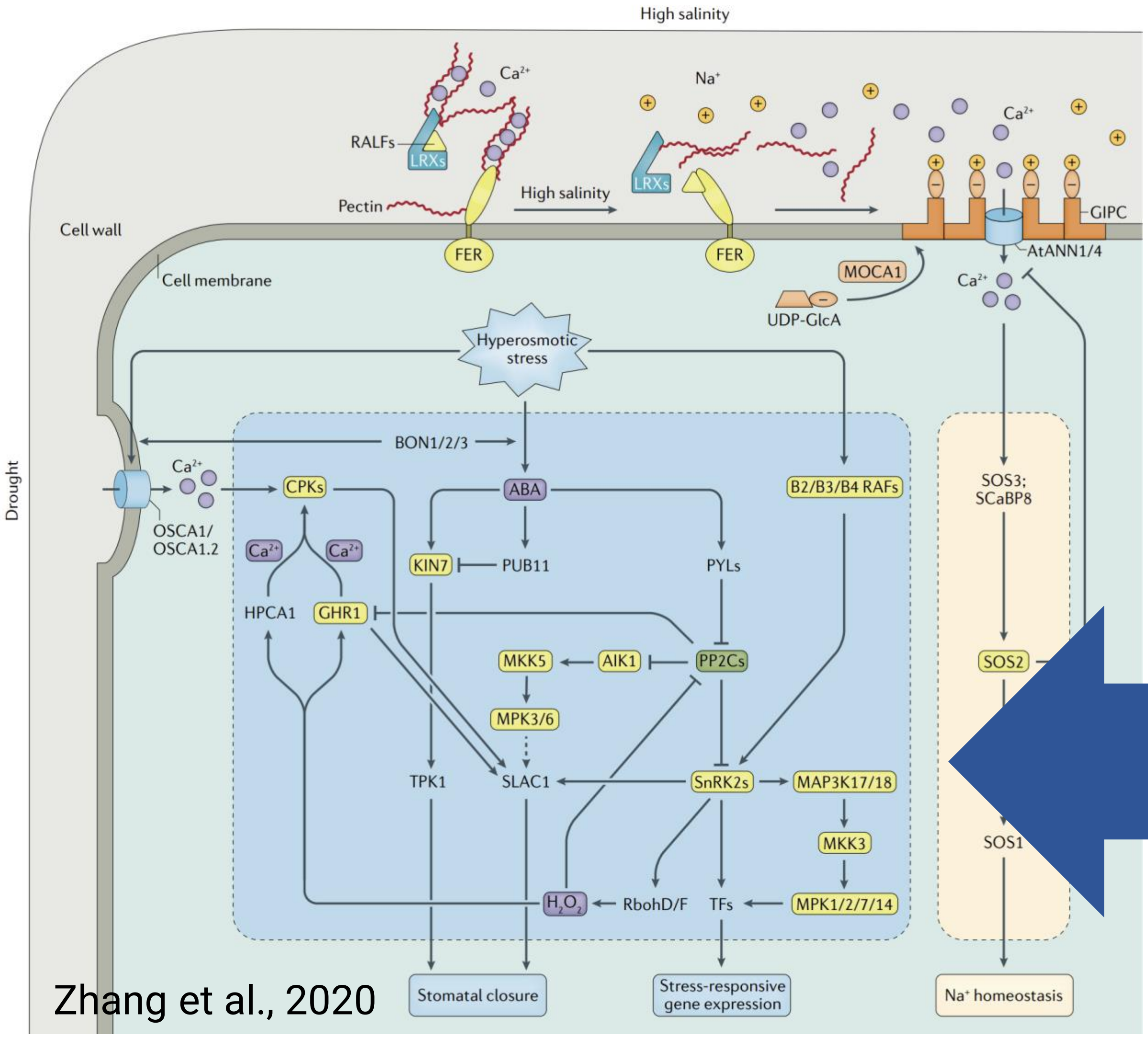
1) Biostimulants success has capitalized on the gap left by transgene technology

2) The role of biostimulants as growth enhancers has been now established – products are available on the market

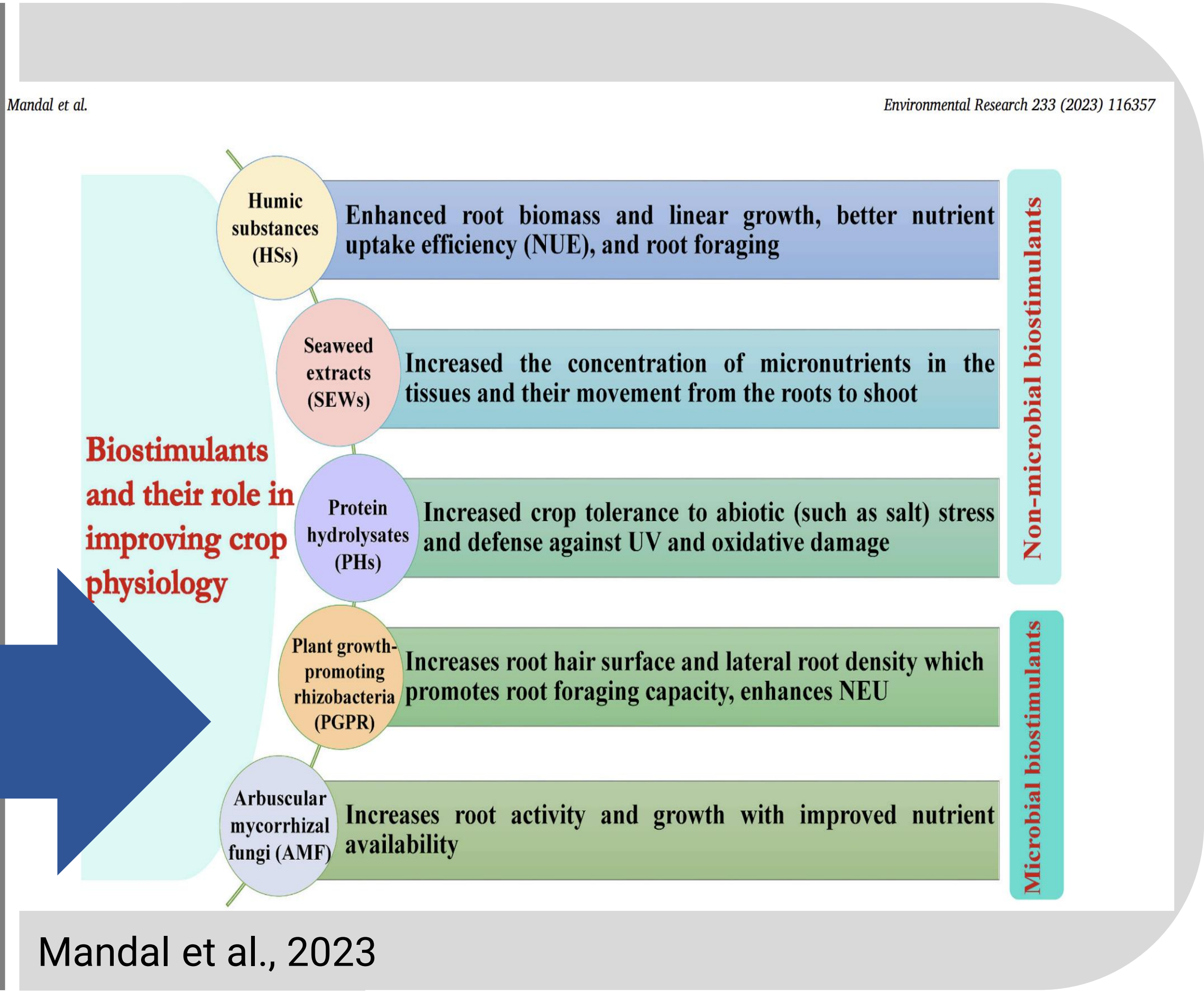
3) More can be done to elucidate the role of biostimulants as stress protectants (and growth enhancers)

4) Gene editing of regulatory molecules (epigenetics) can likely lead to a new wave of technical solutions for improving plant multiple stress tolerance

Matching Biostimulants Mode of Action With Key Mechanisms of Salt Stress Tolerance



Zhang et al., 2020



Mandal et al., 2023

Matching Biostimulants Mode of Action With Key Mechanisms of Heat Stress Tolerance

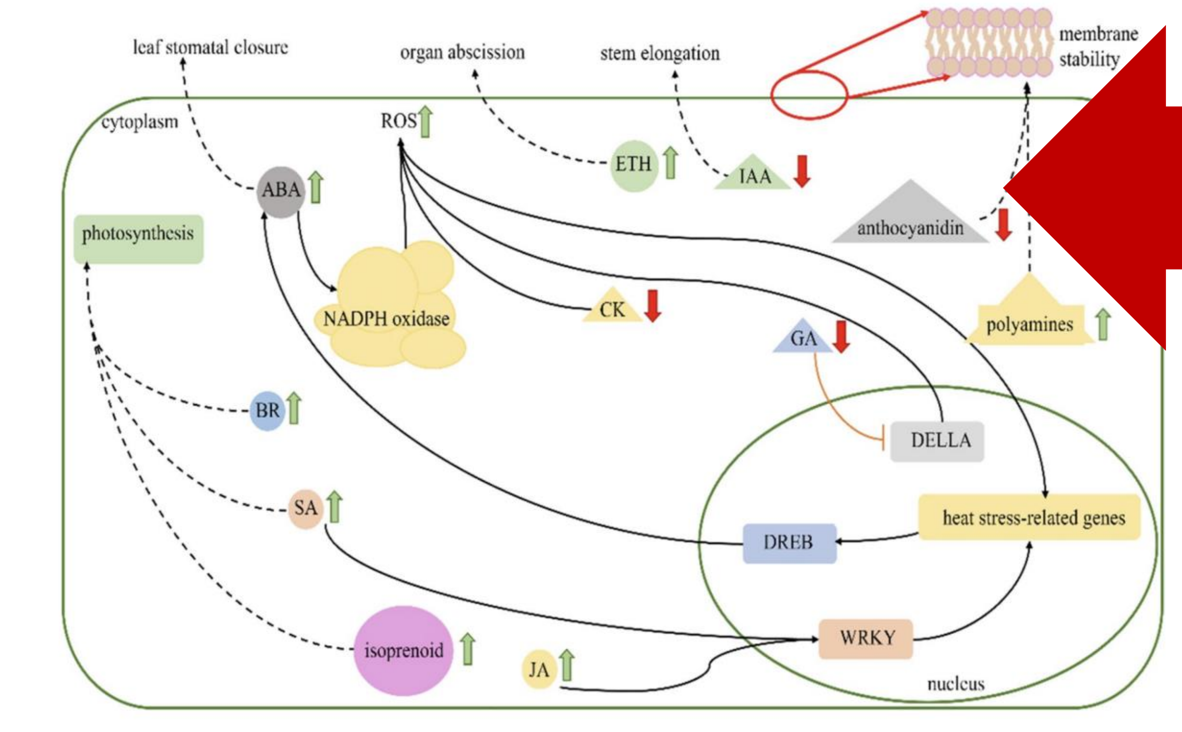
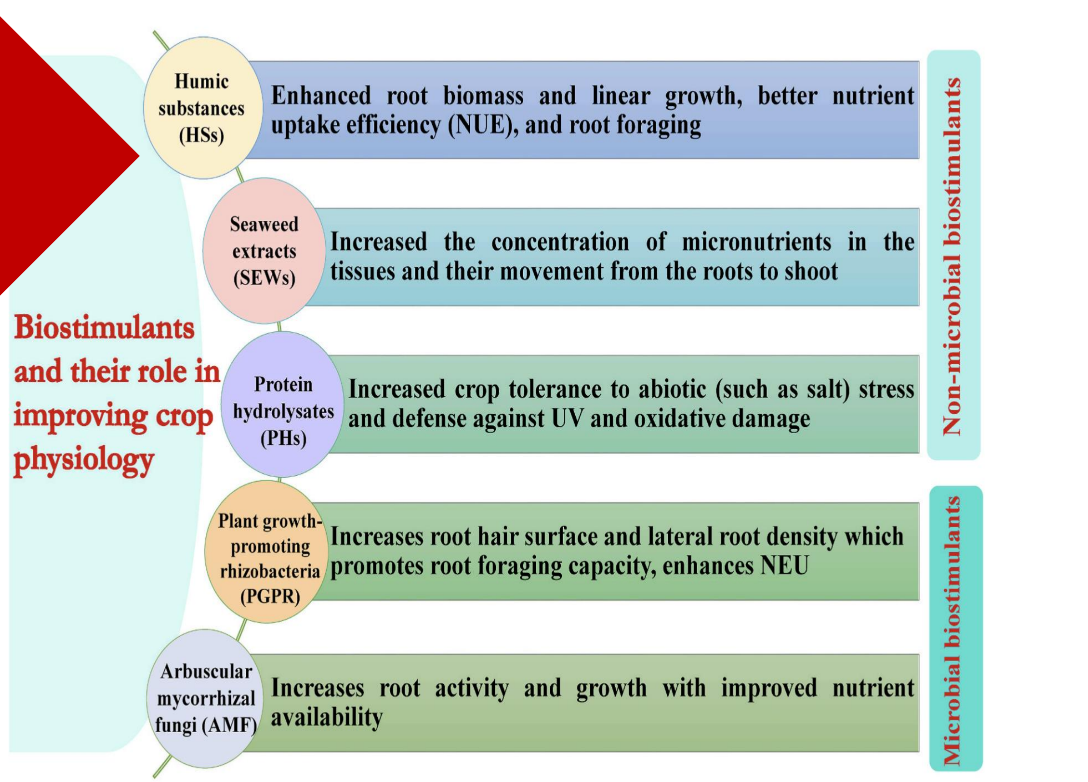


Fig. 2 The regulatory network of different metabolites at high temperature. The solid line represents the influence of metabolites on the omics level at high temperatures. The dashed line represents the specific effects of metabolites on plant cells or plants under high temperature



Conclusions

- **Biostimulants are an important turning point in crop stress protection**
- **We have learned a lot from research on plant stress adaptation and first-generation GM plants and modern biotech**
- **Biostimulants have great(er) potential compared to other technologies**
- **A systematic scientific approach to understand the mechanism of action of biostimulants is deemed necessary to define and fully exploit the potential value of promising eco-compatible molecules**
- **Modelling can help for a reasoned selection of most performant biostimulants**

Thank you

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