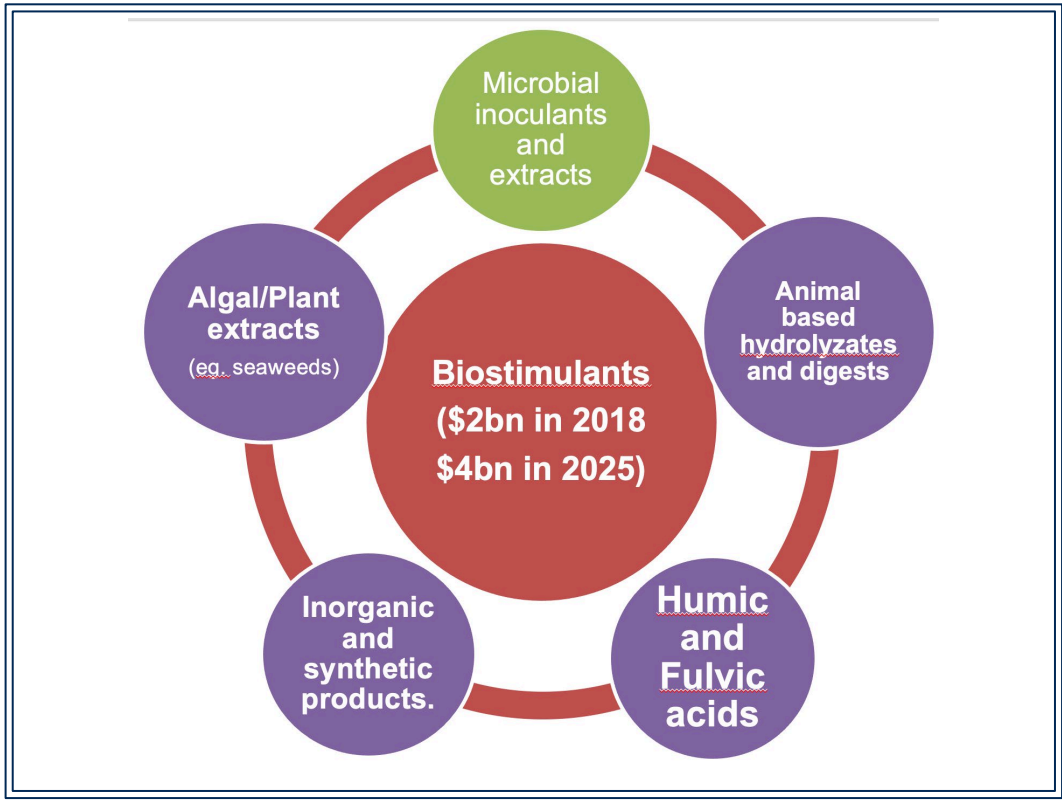
Biostimulants in Agriculture

Chair/co-Chair Biostimulants World Congress 2012, 2015, 2017, 2019, 2021, 2023

Editor/Author of book 'Biostimulants for Sustainable Production'

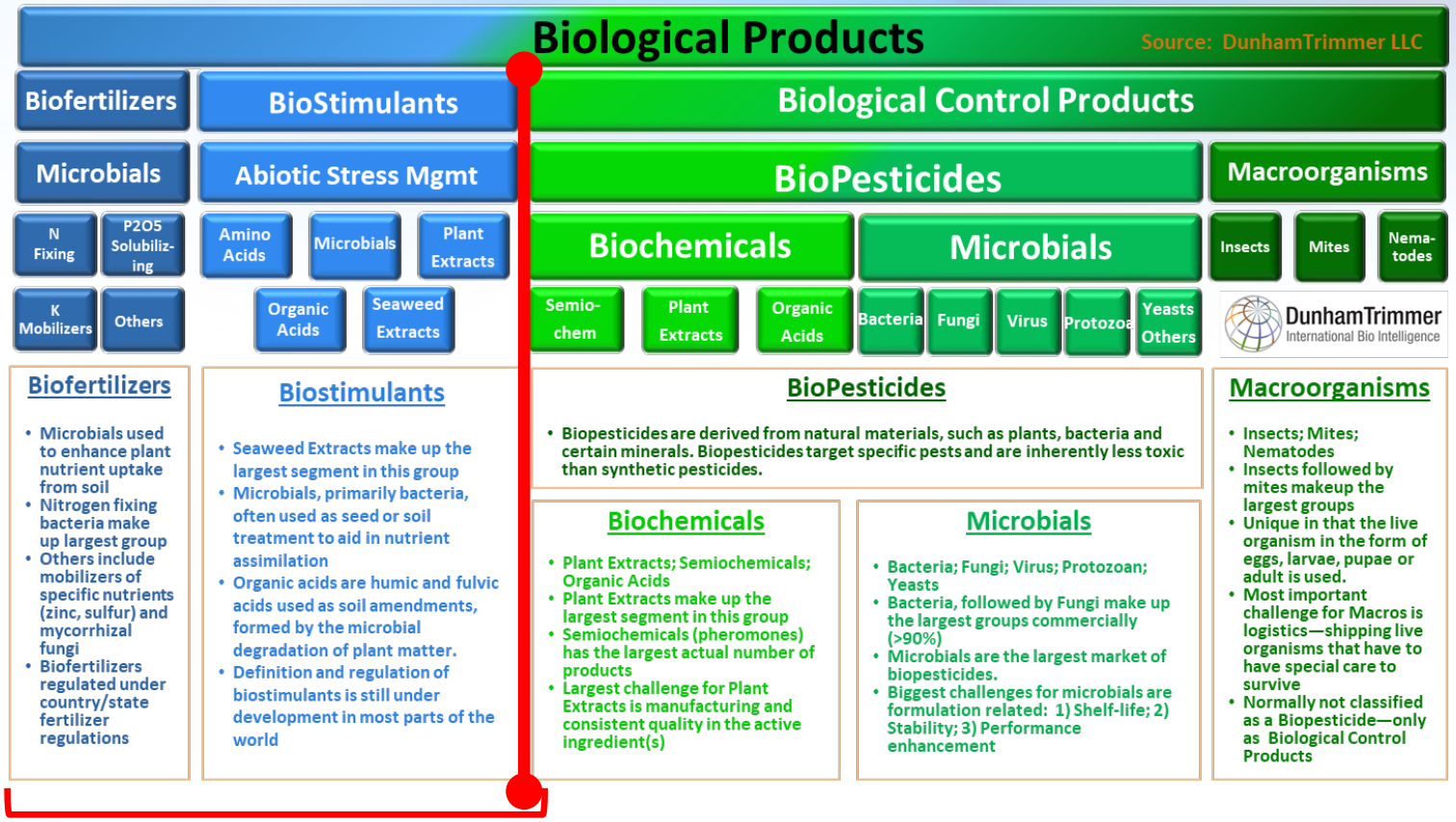
Top 5 cited author in the field. EPA/USDA biostimulants advisory role.

Professor Patrick Brown
Department of Plant Sciences
University of California-Davis
phbrown@ucdavis.edu



Biological Products Defined

Biostimulants $2bn 2018 ⟹ $4bn 2025



DunhamTrimmer
International Bio Intelligence

Merging?

What is the practical and legal definition of a Biostimulant?

In Europe (2019 Regulation): (and in pending US legislation)

A plant biostimulant shall be an EU fertilizing product the function of which is to stimulate plant nutrition processes independently of the product's nutrient content with the sole aim of improving one or more of the following characteristics of the plant or the plant rhizosphere:

(a) nutrient use efficiency,

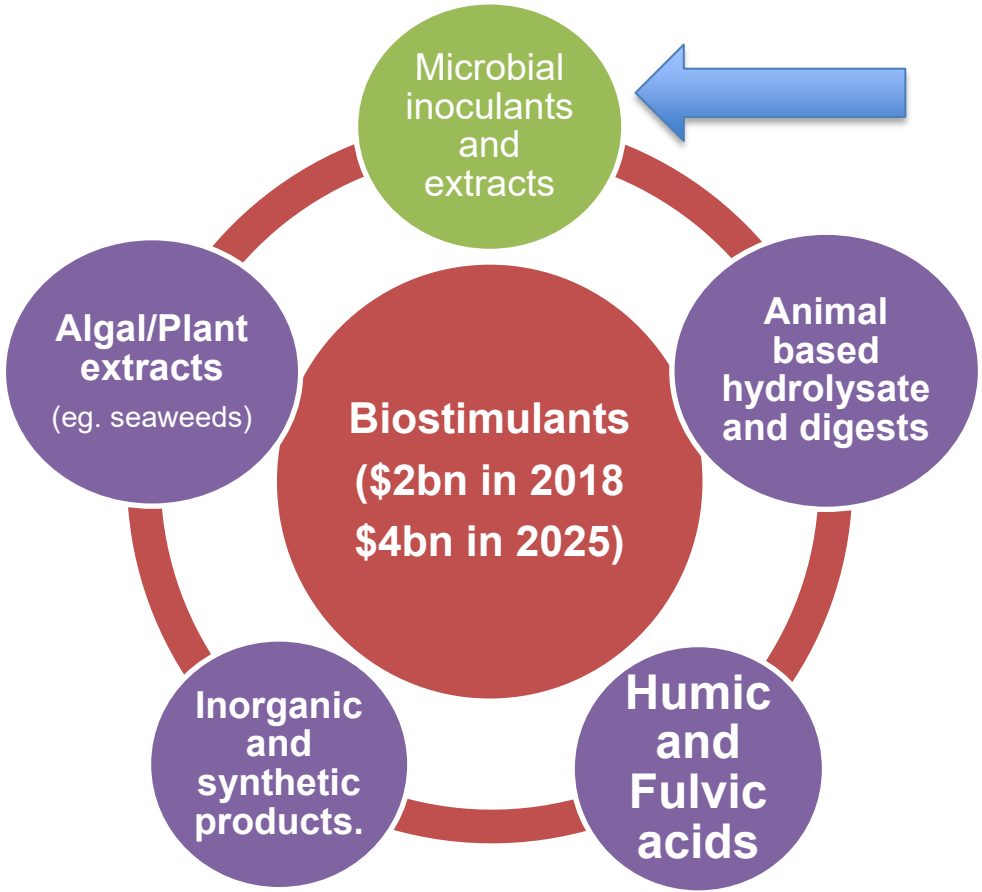
(b) tolerance to abiotic stress,

(c) quality traits, or

(d) availability of poorly soluble nutrients in the soil or rhizosphere

Why does this matter? If regulated as fertilizers, development of new products and use in the field is easy. If biostimulants are regulated as growth regulators/stimulators they will be treated like pesticides.

What are they and what do biostimulants do?



Calvo and Kloepper, 2014

Incredibly Diverse Origins:

Biological/Living: Algae/ plant/ animal/ microbial

Non living: Humates, synthetics, elements.

Complex mixes: Seaweeds, Humic, microbial fermentations

Simple molecules: Synthetic chemicals, elements, biochemicals

Understood/Not Understood.

No way they all work the same!

Physiological Rationale for Biostimulants

Stress Hypothesis

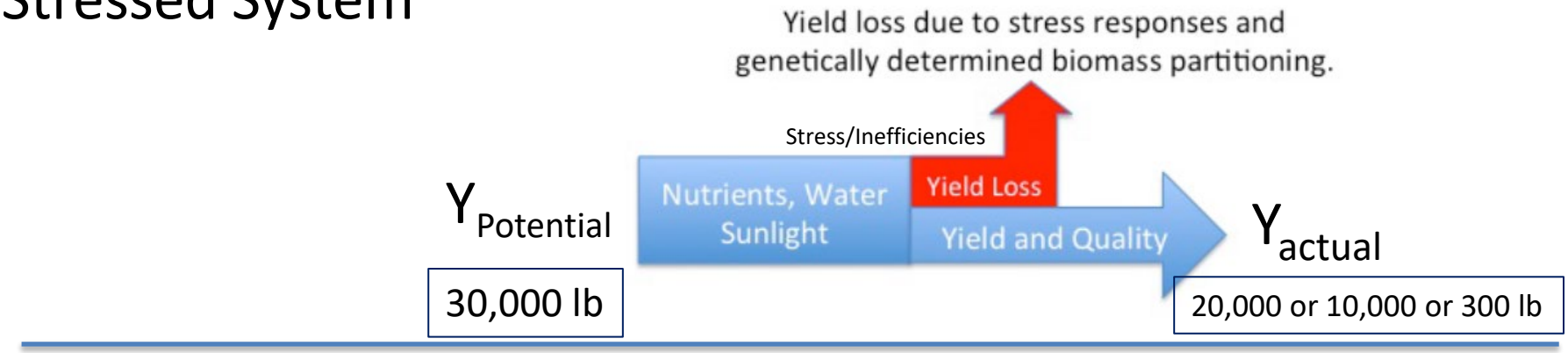
Abiotic 'stress' occurs in all environments and as a consequence yield rarely reaches full potential (abiotic stress = nutrients, drought, temperature, frost, deficiency, salinity, toxicity….)

<u>Biostimulants influence cropping system response to stress</u>

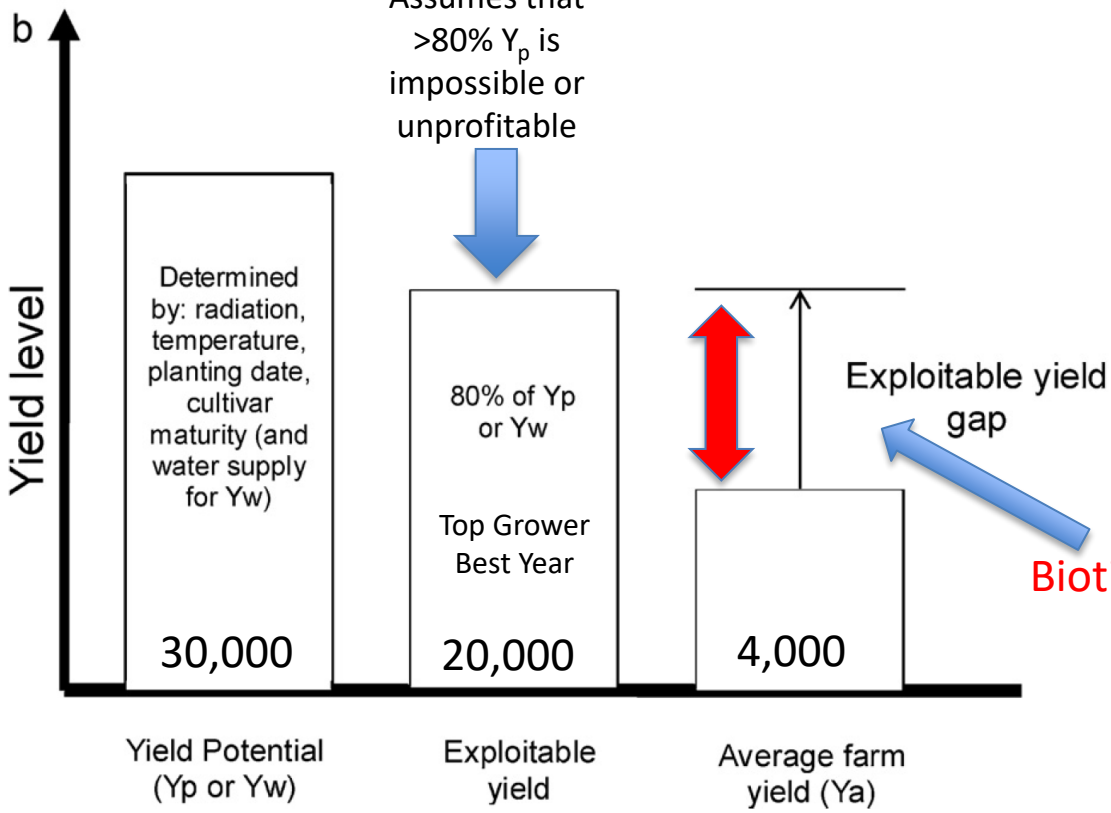
- Biostimulants enable plants to more effectively tolerate stress
- Biostimulants help plants access and utilize nutrients and water efficiently
- Biostimulants favorably alter the plant microbiome which in turn is essential for crop stress tolerance and nutrient uptake.

Brown and Saa, 2015 Frontiers Plant Sciences

Stressed System



Yield Gap Analysis



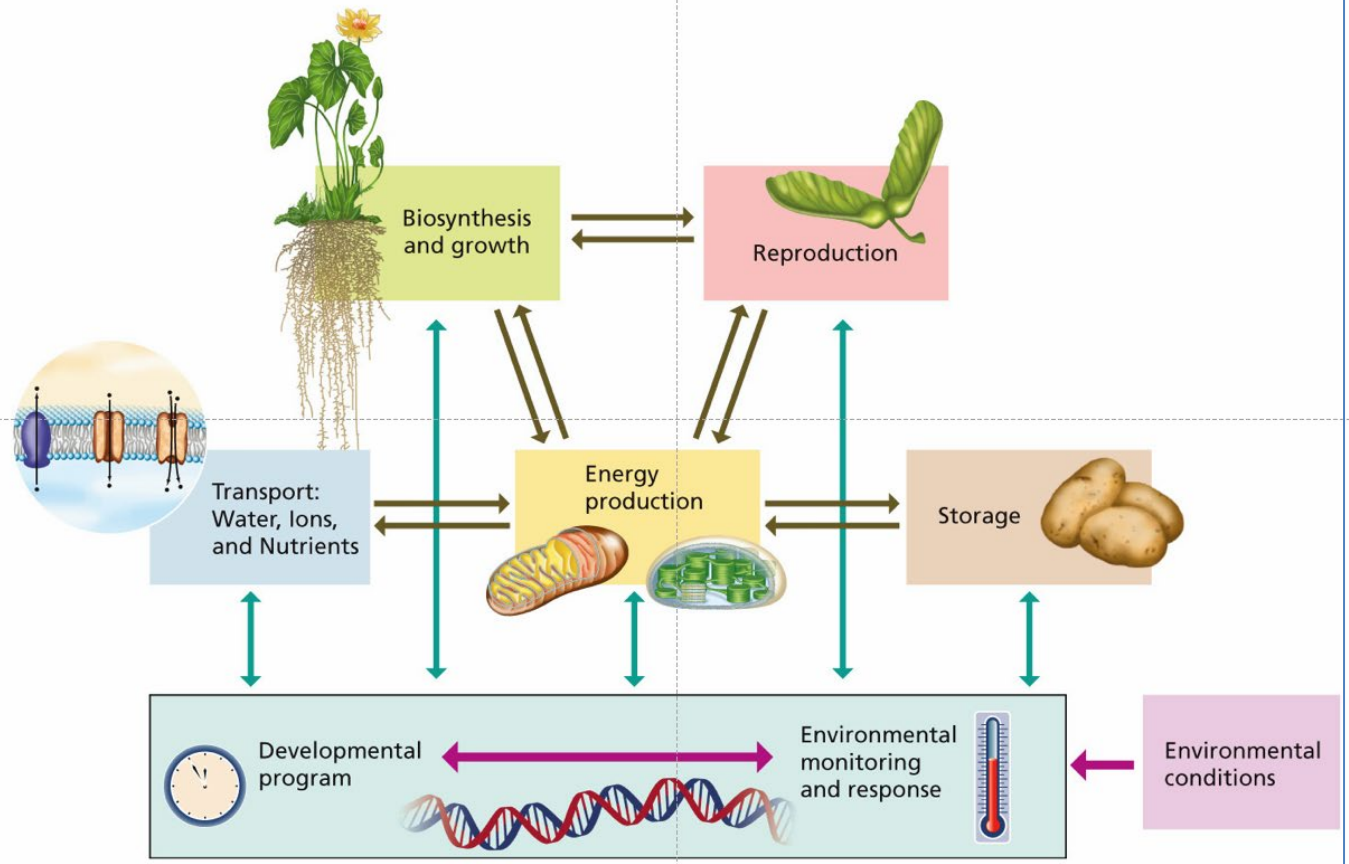
WARNING: Biostimulants supplement good farming, they don't replace it!

Biotic and Abiotic Stress

Biostimulants

M.K. van Ittersum et al. / Field Crops Research 143 (2013) 4–17

Interactions between environmental conditions and plant development, growth, energy production, and ion and nutrient balance and storage



PLANT PHYSIOLOGY AND DEVELOPMENT 6e, **Figure 24.1**

- Plants respond to the environmental stress by reducing reproduction to produce fewer but intact fruits/seeds and reducing vegetative growth
- How is the environment perceived and what determines how a plant reacts?
- In nature the tree cannot know that irrigation/fertigation will occur next week!

AND

- Can we manipulate these responses with biostimulants?

Are our Farming Systems Resilient?
Do they experience stress that compromises yield?

How Good Are We?

- 10-15 Ton Carbon captured per year.
- Three crops per year (330 day growing cycle)
- High level of inputs (fertilizer, water, pest and disease control)

Mid West USA Native pasture (200 day growing cycle)
20-45 Ton C – with no inputs.

The highest productivity, most resilient plant systems on earth are not agricultural crops, they are natural ecosystems.

How?:

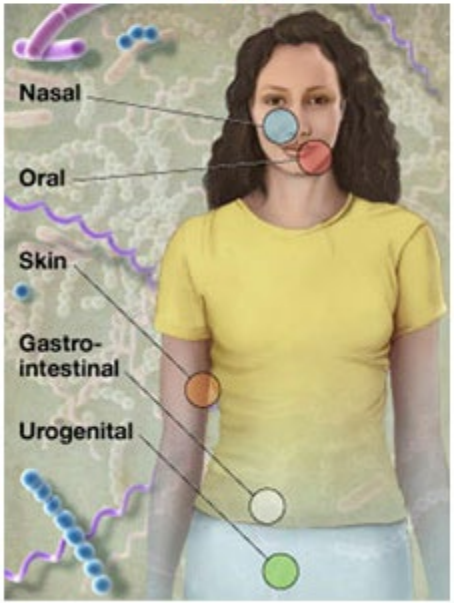
- Every resource is used efficiently in time and space
- Every change in the environment, opportunity or threat, has a species that can respond
- Partnerships (plant-microbiome) are formed for mutual benefit

PHOTOGRAPH BY JIM RICHARDSON, NATIONAL GEOGRAPHIC CREATIVE

Microbiome

The human microbiome, an initiative of the National Institute of Health

10X more microbial cells and 100X more microbial genes than human
(because microbial cells are 10-110 times smaller than human cells the human microbiome weighs only 7 ounces)



Human Microbiome Project

"We're not individuals, we're colonies of creatures."
Bruce Birren, Broad Institute

Diabetes, Parkinsons, Alzheimers, Obesity, Stress Perception and Health Responses

Skin bacteria affect how attractive we smell to malarial mosquitoes

http://commonfund.nih.gov/hmp/

http://blogs.discovermagazine.com/notrocketscience/category/bacteria/microbiome-bacteria/

The microbiome of a mouse influences how it can handle stress!

SCIENTIFIC REPORTS

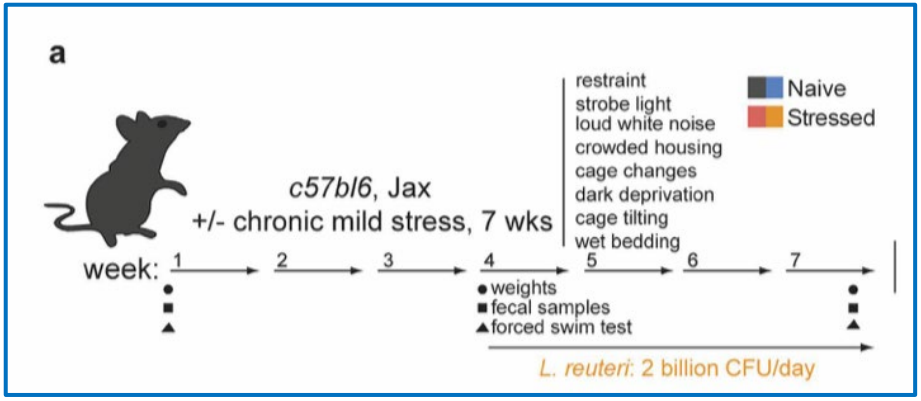
OPEN

Microbiota alteration is associated with the development of stress-induced despair behavior

Received: 11 October 2016
Accepted: 31 January 2017
Published: 07 March 2017

Ioana A. Marin[1,2,3], Jennifer E. Goertz[1,2], Tiantian Ren[4], Stephen S. Rich[5], Suna Onengut-Gumuscu[5], Emily Farber[5], Martin Wu[4], Christopher C. Overall[1,2], Jonathan Kipnis[1,2,3,*] & Alban Gaultier[1,2,3,*]

(Nature)

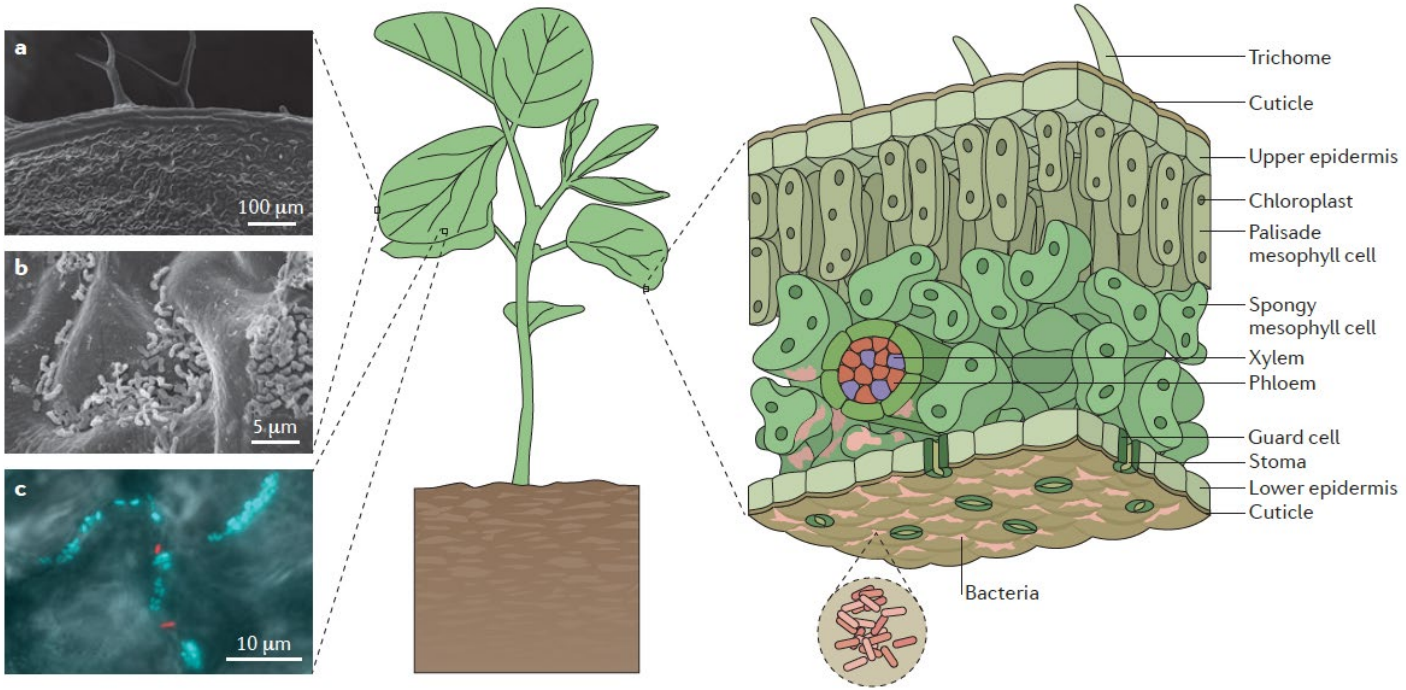


- Chronic stressed mice had lower Lactobacillus.
- Supplemental Lactobacillus decreased stress responses.
- Lactobacillus production of ROS in gut is protective against stress induced despair.

The Microbiome can mitigate stress.

The Microbiome of the Plant is the Most Diverse Biological Environment on Earth

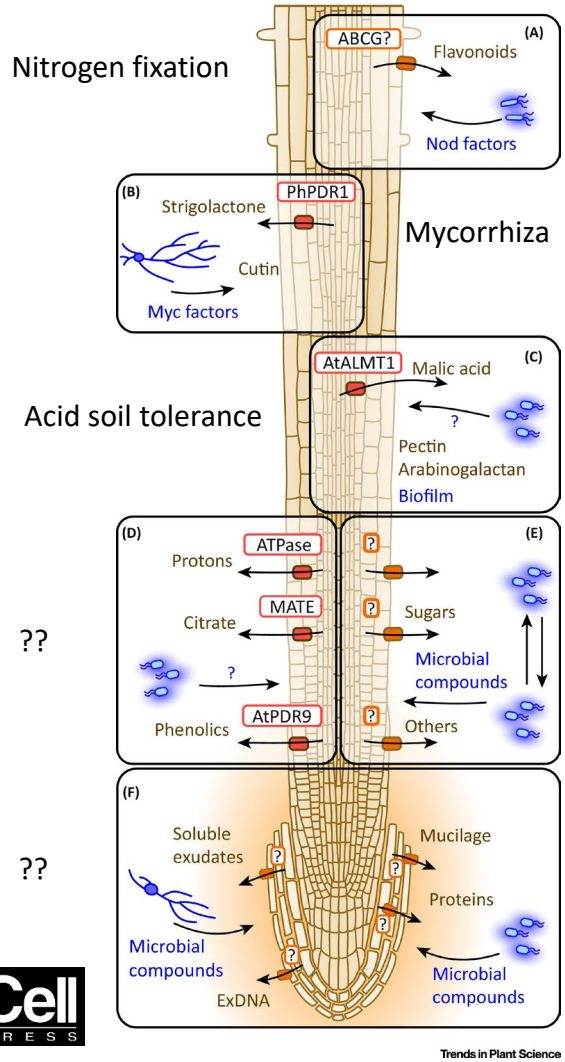
Why? Because plants and microbes have co-evolved for 1 Billion Years!
(Mammals have only been around 170 million years.)



We have learned a lot in the past decade.

But:

We probably only understand >.001% of the processes involved.



Flavonoids are exuded and sensed by rhizobia that in turn produce NOD factors that initiate nodule formation.

Strigolactones are exuded and sensed by mycorrhiza that in turn produce MYC factors that initiate mycorrhizal symbiosis

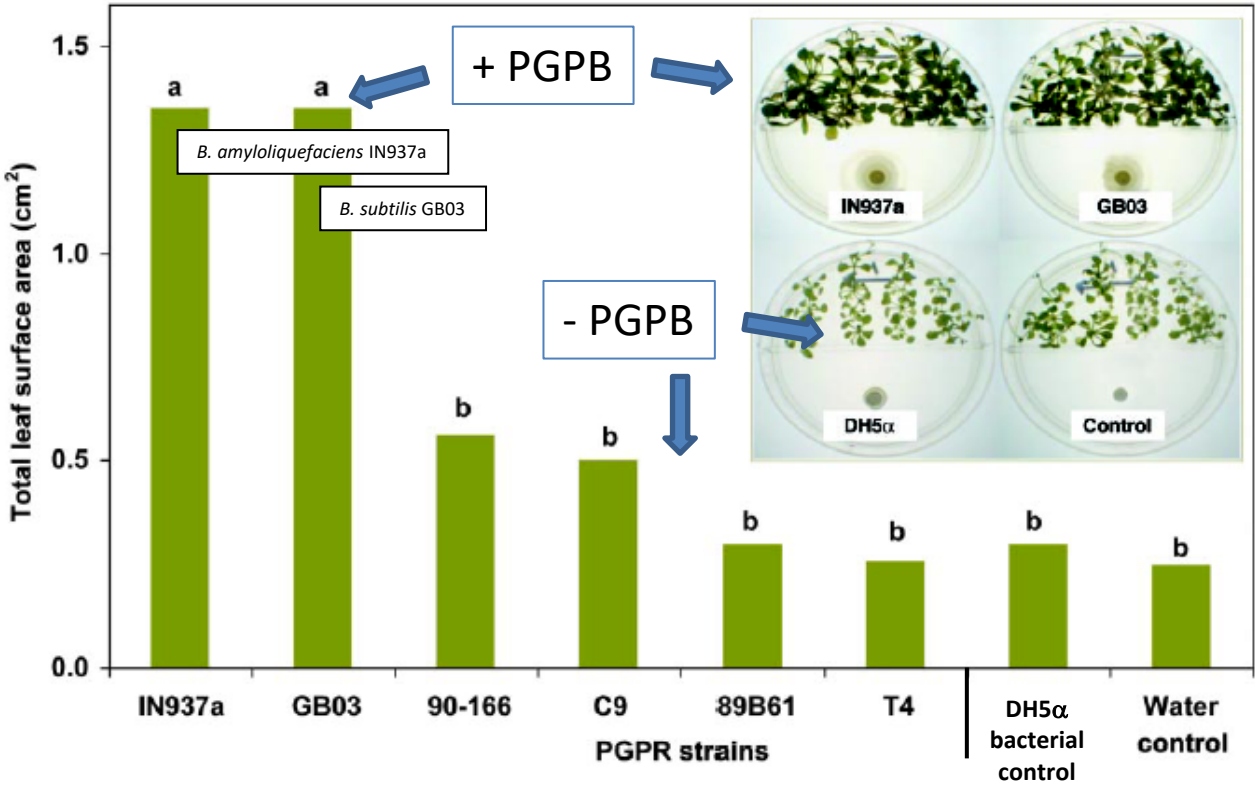
Malic acid exudation in *Pseudomonas*-infected *Arabidopsis thaliana*, which attracts *Bacillus subtilis* [80]. *B. subtilis* forms biofilms on roots and contributes to heavy metal homeostasis.

(D) Protons are exuded altering rhizosphere pH, MATE transporters exude citrate which can be metabolized by microbes. Function is unknown. (E) Microbes exude compounds that are utilized by other microbes and sensed by plants.

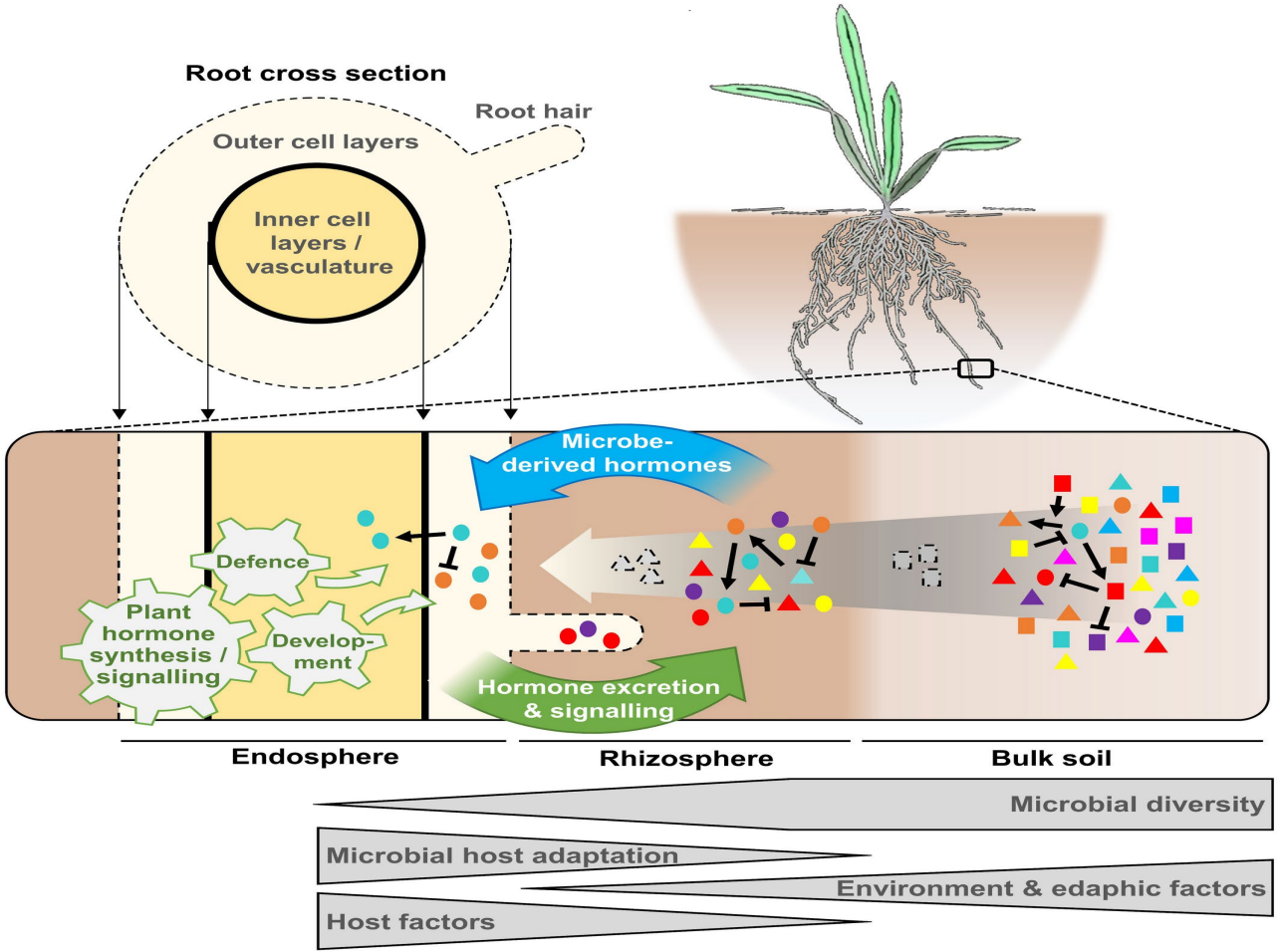
Border cells produce mucilage, exude proteins, extracellular DNA, as well as metabolites, all of which impact the microbial community . Currently, the function of these compounds is not known.

Trends in Plant Science 2018 23, 25-41DOI: (10.1016/j.tplants.2017.09.003)

Plants Grow Better in Presence of Certain Plant Growth Promoting Bacteria (PGPB) .
(pioneering work of Ryu *et al.*, 2003, *PNAS* 100: 4927)



Soil and Plant Associate Microbes Regulate Plant Growth



THE SOIL MICROBIOME IS A KEY PLAYER IN CROP PRODUCTIVITY

- Microbial abundance and diversity is a key measure of soil health.
- Plant development and tolerance to stress is strongly mediated by soil microbes.
- Both plant and the microbial community, produce and metabolize plant regulators in a mutually beneficial partnership.

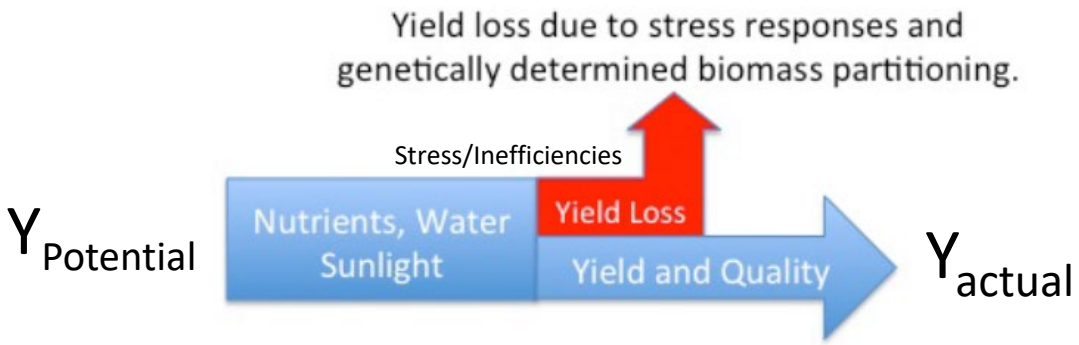
The Plant Journal, Volume: 105, Issue: 2, Pages: 518-541,
First published: 17 December 2020, DOI: (10.1111/tpj.15135)

Embrace your Biome!

BAD

GOOD!

Stressed System



Microbiome
Soil Health

Physiological Rationale for Biostimulants and Implications for Management

Hypothesis - Biostimulants enable plants to respond more effectively to stress or utilize nutrients more efficiently through increased plant vigor, preventing unproductive stress responses or enhancing nutrient availability. This effect may be direct or microbially mediated.

Big Questions!:

- How do we predict the occurrence of a stress?
- What process is the biostimulant targeting?
- Is there a 'yield penalty' or only a $$ penalty to biostimulant use if no stress event occurs?
- What is the relationship between cultivar, cropping system, the existing plant and soil microbiome and biostimulant efficacy?
- How persistent is the biostimulant and how does that affect application timing?
- How should biostimulant research and field testing be conducted?

UCDAVIS
DEPARTMENT OF PLANT SCIENCES
College of Agricultural and Environmental Sciences

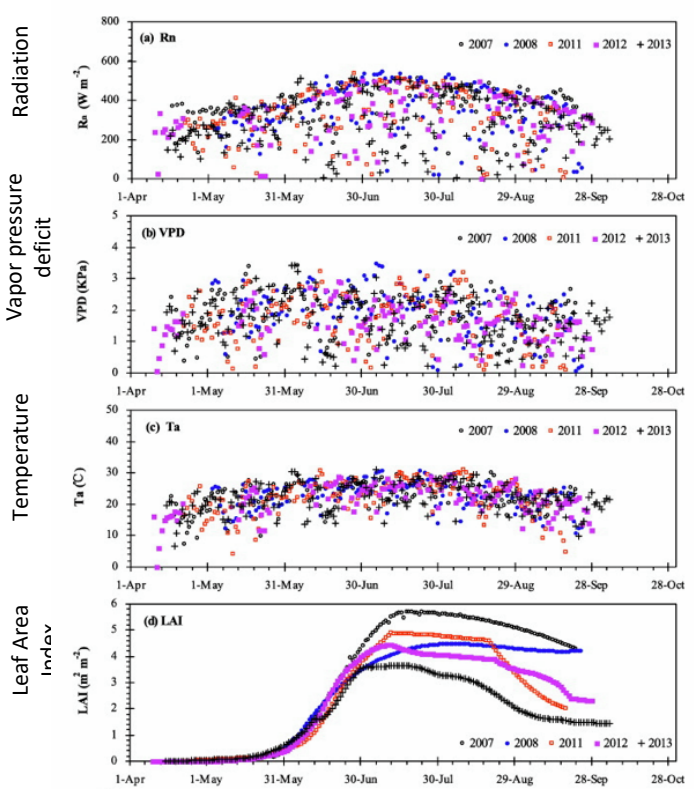
Stress varies with season and location.

Light intensity varies dramatically

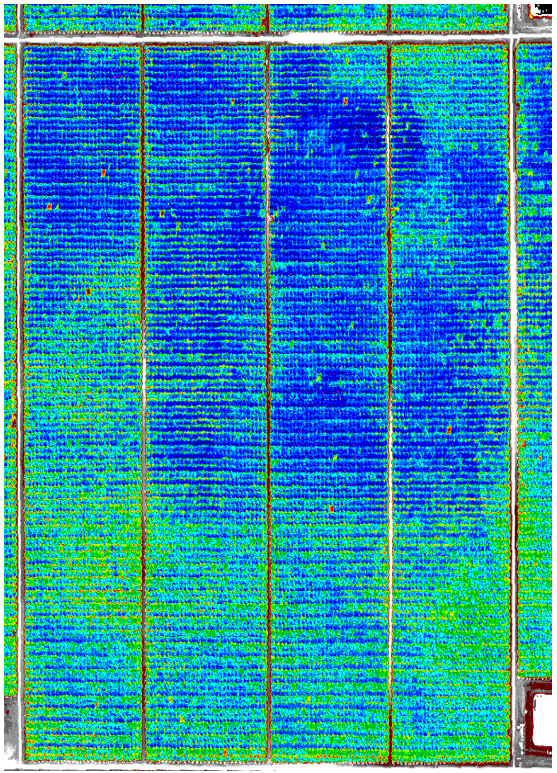
Evapotranspiration varies dramatically

Temperature varies dramatically

Plant growth varies dramatically



Seasonal Variability in Environment



Spatial Variability in Environment

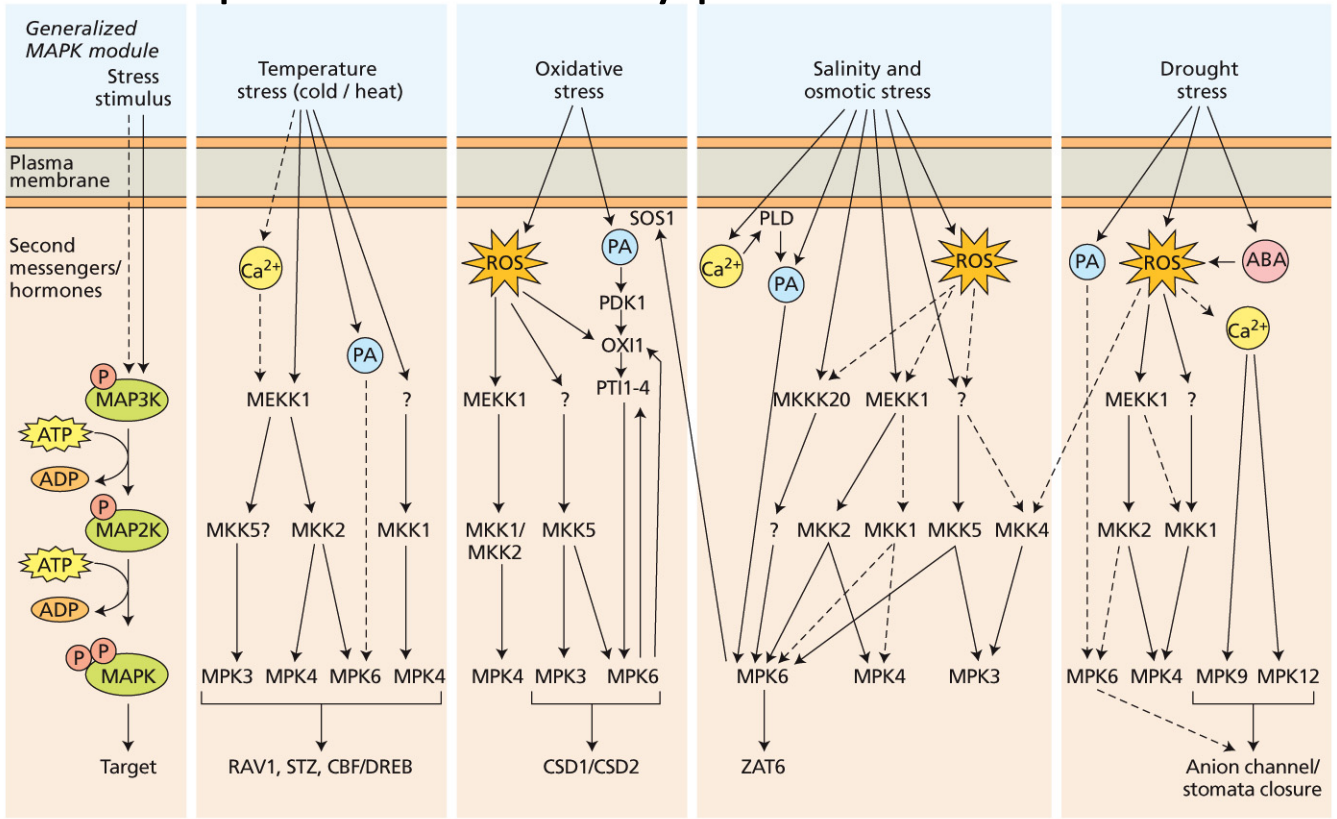
(RGB image of leaf Area)

Understanding of the mechanisms of plant growth and stress response has exploded but is only part of the solution

Stress detection

Molecular Response

Crop Response



***PLANT PHYSIOLOGY AND DEVELOPMENT 6e*, Figure 24.12**

Microbial Complexity is not understood

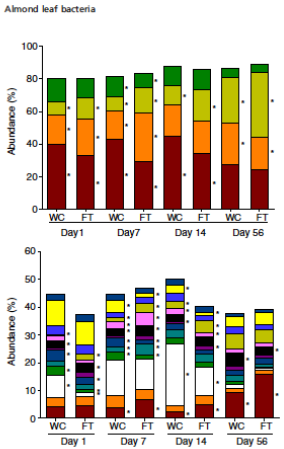
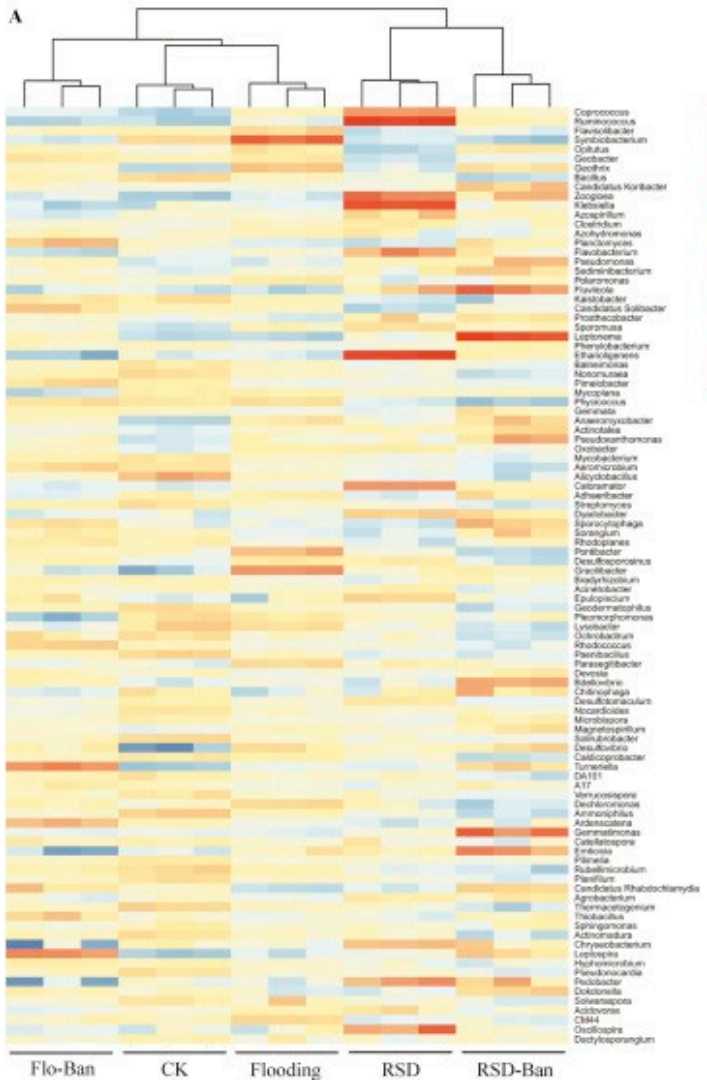
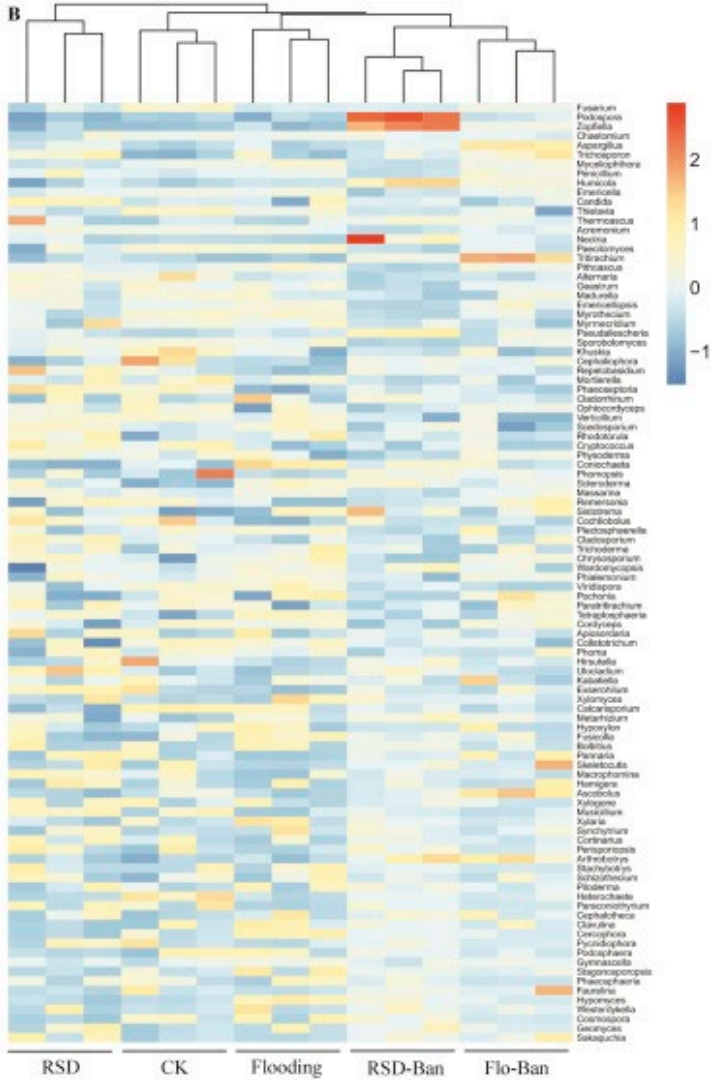


Figure 2 (a) Distribution of bacterial 16S rRNA gene sequences representative of the four predominant bacterial phyla in the foliar fertilization (FT) and water control (WC) libraries; ■ – Bacteroidetes, ■ – Firmicutes, ■ – Actinobacteria, ■ – Proteobacteria. (b) Distribution of bacterial 16S rRNA gene sequences representative of the 13 predominant bacterial families in the foliar fertilization (FT) and water control (WC) libraries; ■ – Sphingomonadaceae, ■ – Rhodospirillaceae, ■ – Rhodobacteraceae, ■ – Planococcaceae, ■ – Nocardioidaceae, ■ – Micrococcaceae, ■ – Microbacteriaceae, ■ – Methylobacteriaceae, ■ – Intrasporangiaceae, ■ – Flavobacteriaceae, ■ – Enterobacteriaceae, ■ – Cytophagaceae, ■ – Bacillaceae. *$P < 0.01$. [Colour figure can be viewed at wileyonlinelibrary.com]

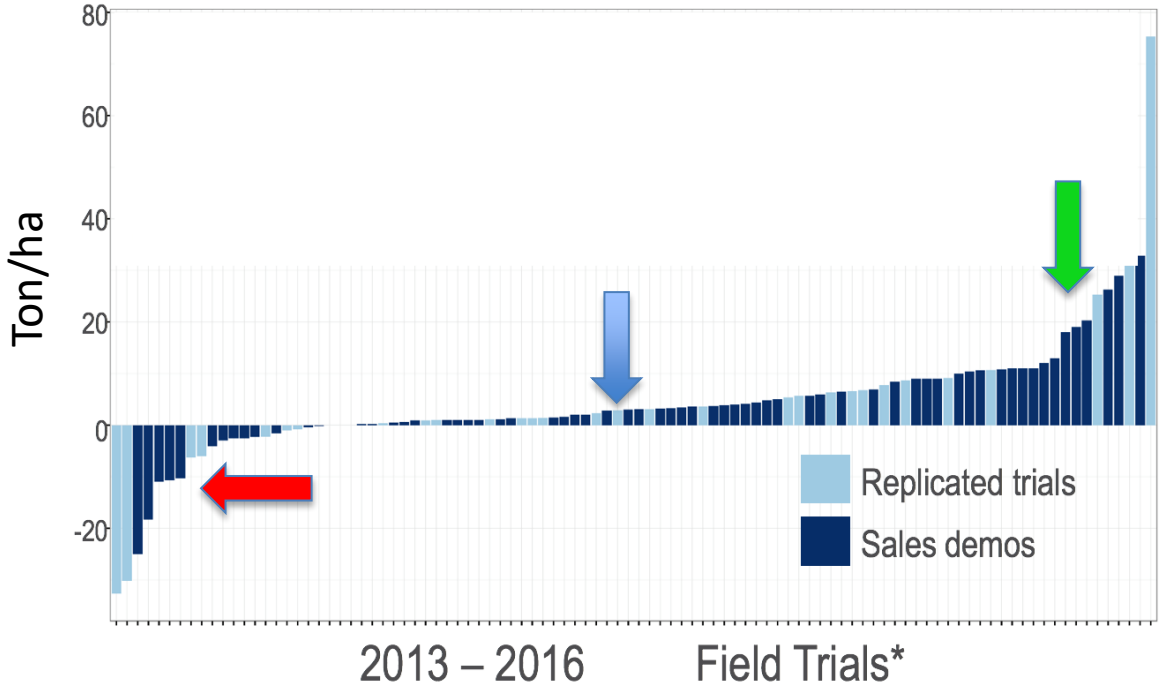




Testing Biostimulants

150 Trials and Demos

Variability in the crop and environment causes variability in response.



BIOCONTROL MARKET IS CREATING HUGE EXCITEMENT AND BIG COMPANIES ARE MAKING BIG INVESTMENTS

Nutrien/Agrichem 2018
Tradecorp/Idai Nature 2018
UPL/Arysta LifeScience 2018
Valagro/Grabi Chemical 2018
Nutrien/Actagro 2019
Marrone Bio/Pro Farm Technologies 2019
Syngenta/Valagro 2020
Biobest/Beneficial Insectary 2020
Rovensa/Grupo Agrotecnologia 2020/
..Oro Agri/Cosmocel/ Redox 2022
AMVAC/Agrinos 2020

Verdesian / Cytozyme 2021
Lesaffre /Advanced Bio Marketing 2021
Bioceres /Marrone Bio 2022
FMC/ BioPhero 2022
J.M. Huber/ Biolchim 2022
Corteva/ Symborg 2022
Mosaic/Plant Response 2022

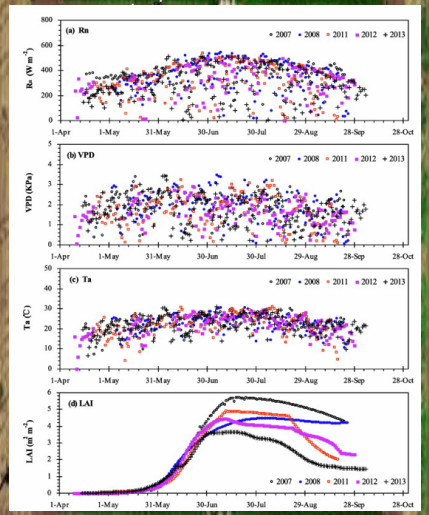
It is hard to ignore this!

Field screening approaches for monitoring **whole-plant** response modulated by biostimulants

Meerae Park, Zhehan Tang, and Patrick H. Brown
University of California, Davis
Department of Plant Sciences

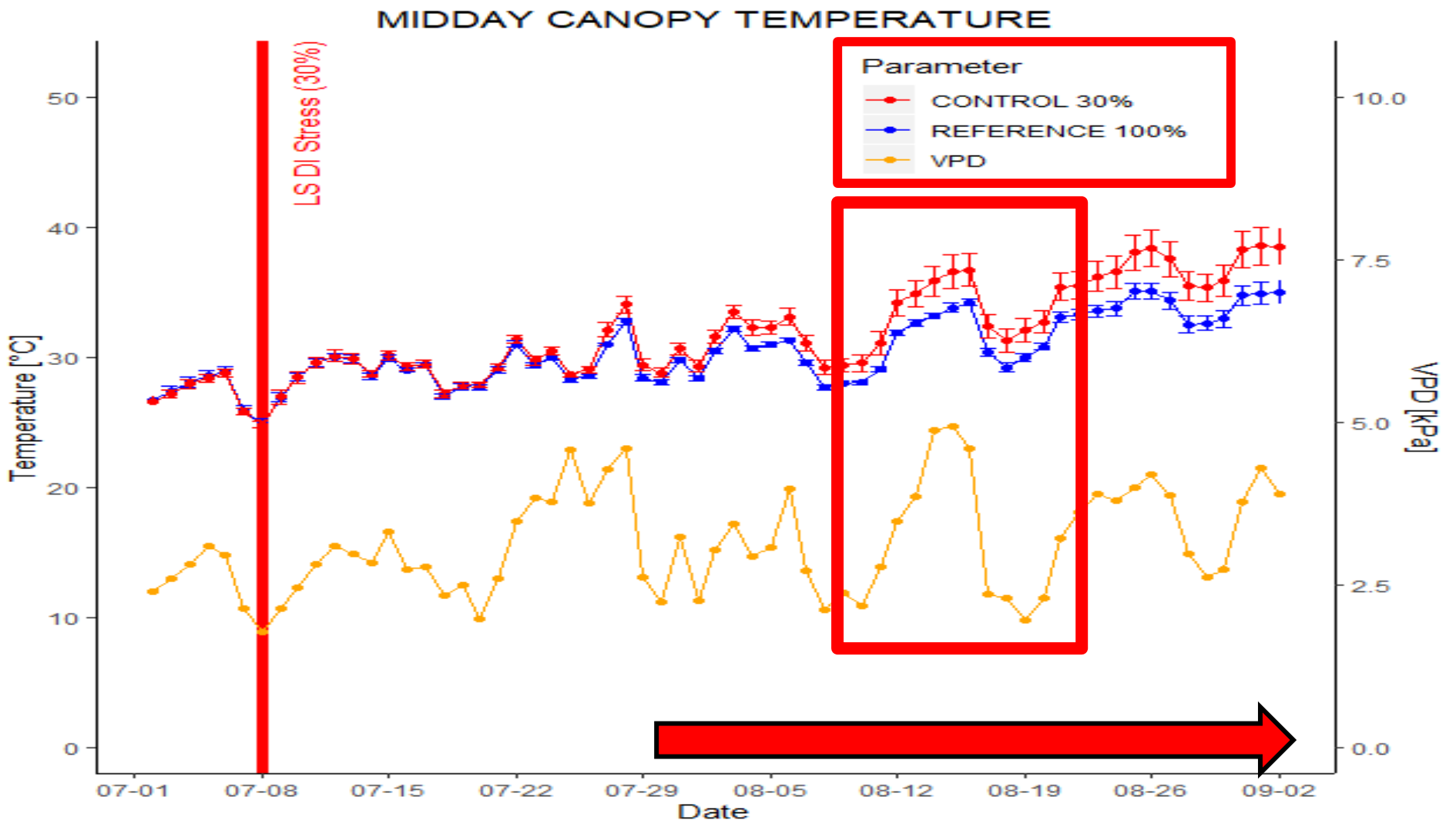

Image Credits: Lance Cheung


Image Credits: Lance Cheung



Under what conditions do plants experience stress?

Which biostimulants work and when.

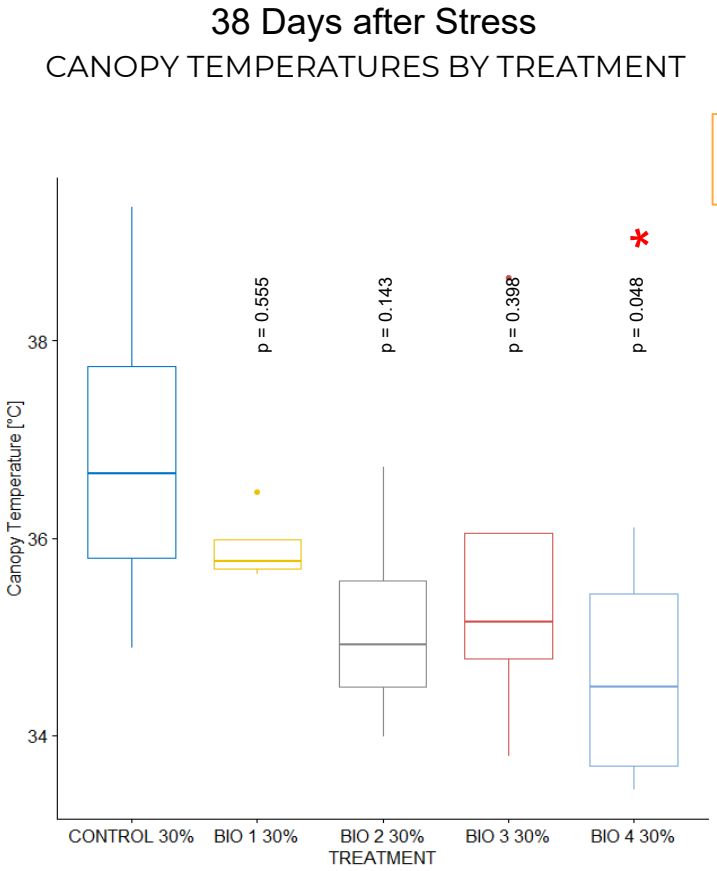

MIDDAY CANOPY TEMPERATURE
LS DI Stress (30%)
Parameter
CONTROL 30%
REFERENCE 100%
VPD
Temperature [°C]
VPD [kPa]
Date
0
10
20
30
40
50
0.0
2.5
5.0
7.5
10.0
07-01
07-08
07-15
07-22
07-29
08-05
08-12
08-19
08-26
09-02

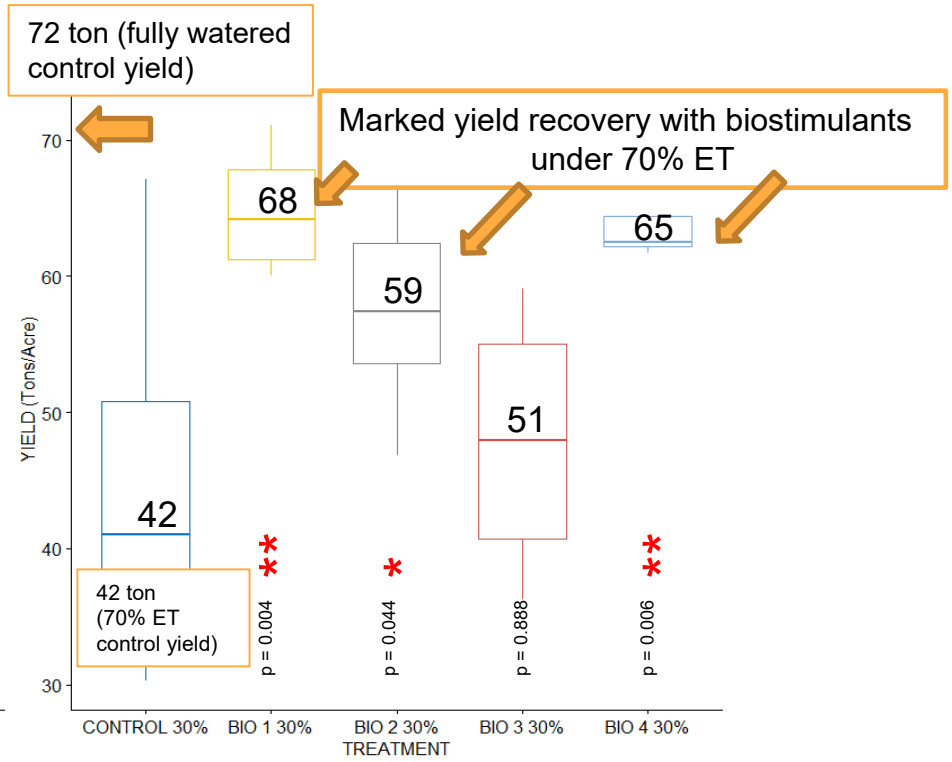
Effect of Biostimulants on Canopy Temperature and Yield (Processing tomato)

100 F

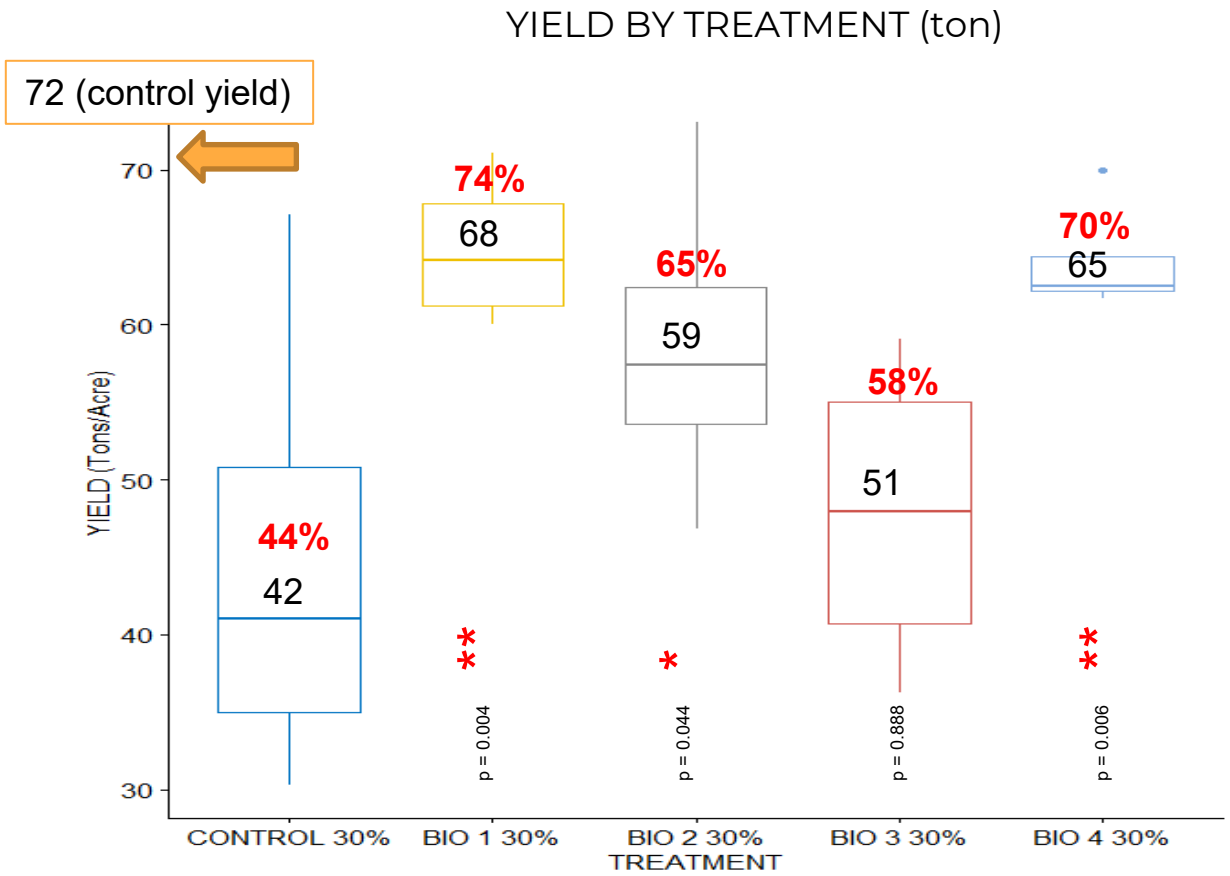
96 F

93 F





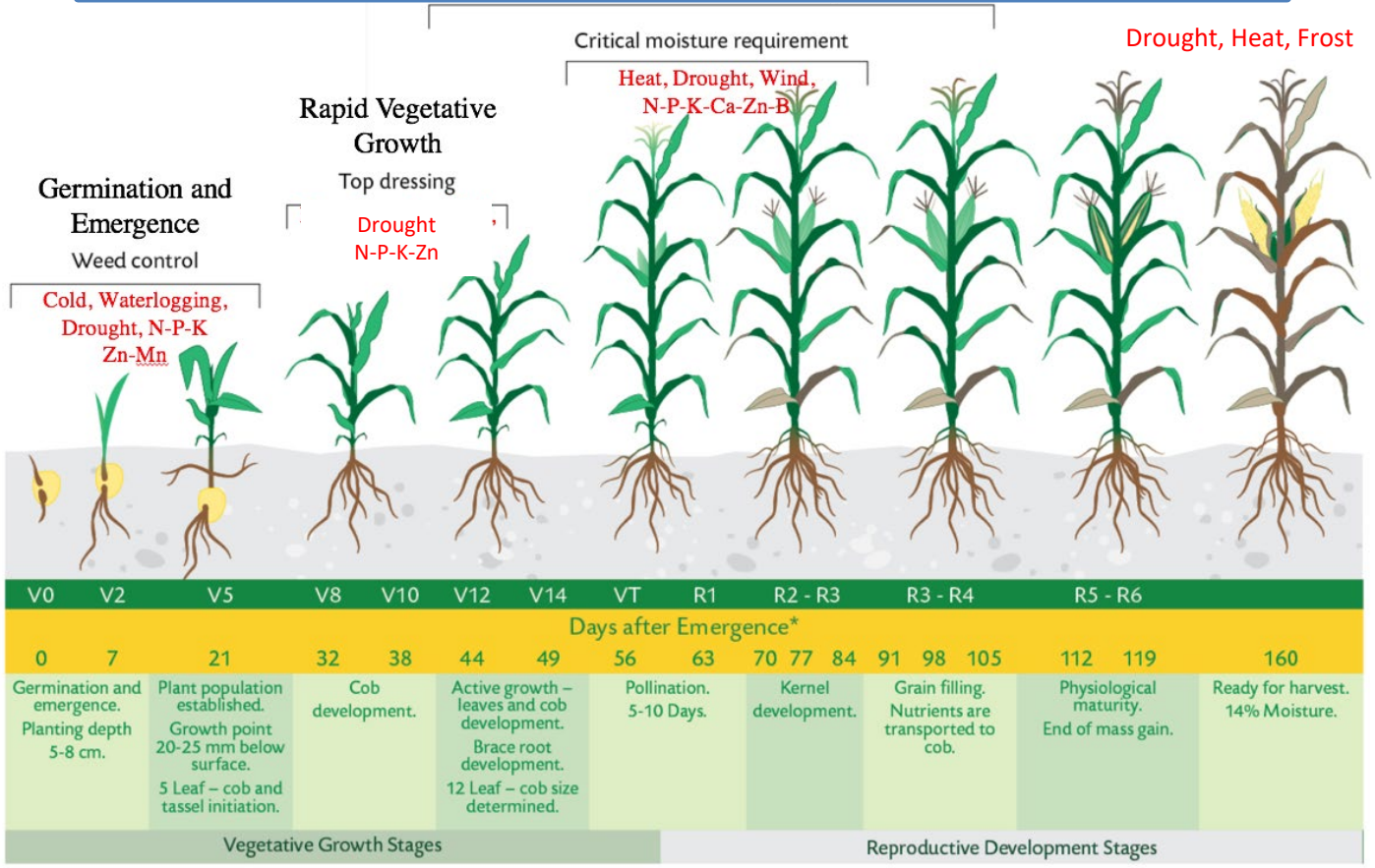
Effect of Biostimulants on Yield and NUE $_{PNB}$ (Processing tomato)



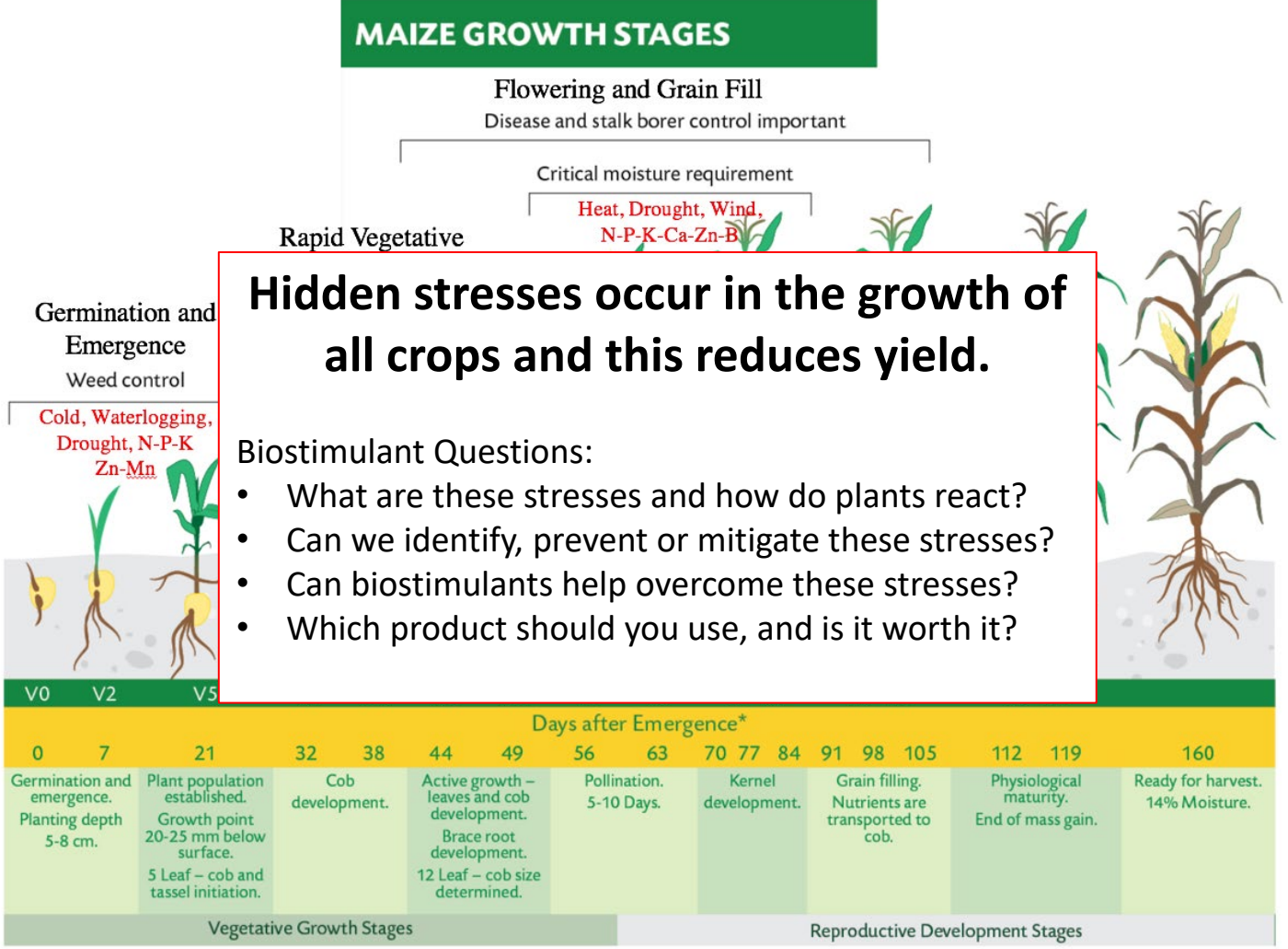
Nutrient use efficiency increases entirely due to stress mitigation.

NUE_{PNB} = Biomass N/Applied plus Nmin

Challenge: How to prevent plant stress and deliver cost effective solutions.



* The number of days varies between different growth classes and environments.

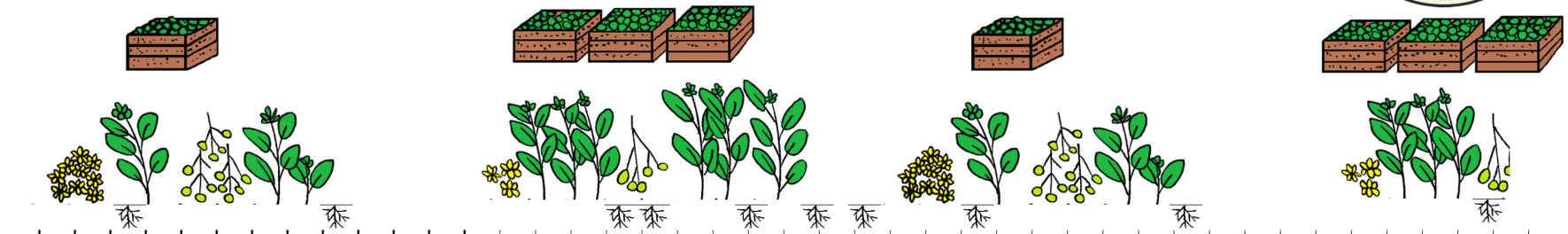


Hidden stresses occur in the growth of all crops and this reduces yield.

Biostimulant Questions:

- What are these stresses and how do plants react?
- Can we identify, prevent or mitigate these stresses?
- Can biostimulants help overcome these stresses?
- Which product should you use, and is it worth it?

THE TWO YEAR ALTERNATE BEARING CYCLE: This is a general diagram only and does not describe accurately any individual grove or growing district in California.
Sink strength changes each year, in an "off-crop" year it is mostly to flowers and fruit, in an "on-crop" year it is mostly to growth



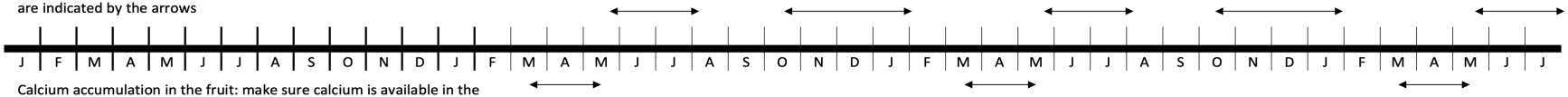
MULTIPLE SHOOT GROWTH CYCLES HAPPEN AT THE SAME TIME:

- there can be several happening at the same time
- the challenge is to get these in balance with one another
- each year only looks like one series of events but are a combination of different stages of the growth cycle

SHOOT LIFE CYCLES: Each growth flush takes two years from bud break until fruit set on the flush are harvested

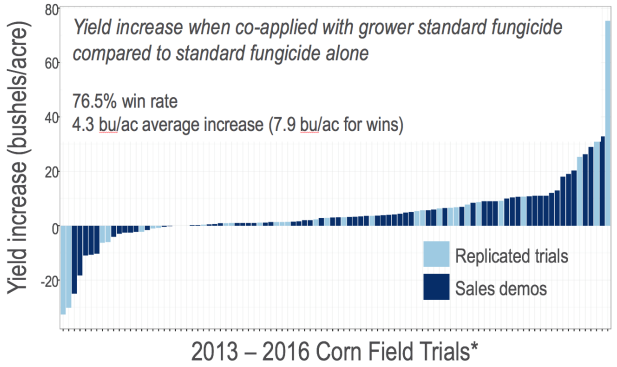
EXAMPLES OF CRITICAL TIMES FOR:

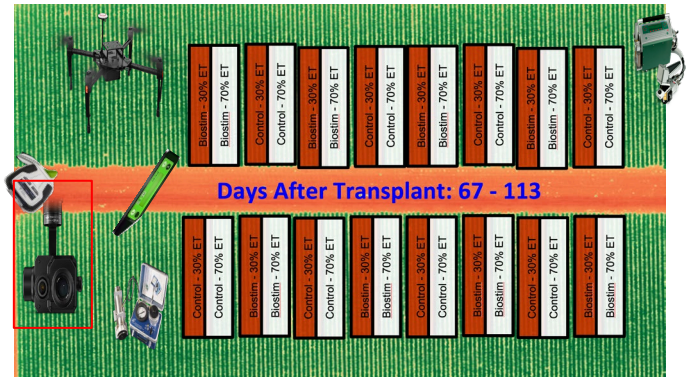
Phytophthora control: apply control measures when the roots are the primary sink; the best application times are indicated by the arrows

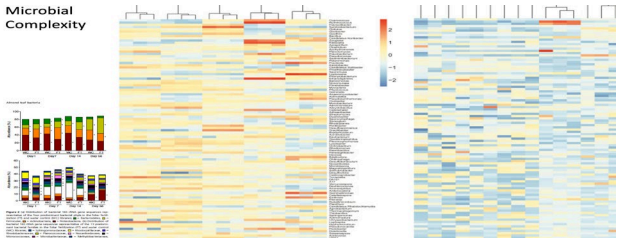


Calcium accumulation in the fruit: make sure calcium is available in the soil water in the first 6-8 weeks after fruit set as indicated by the arrows.

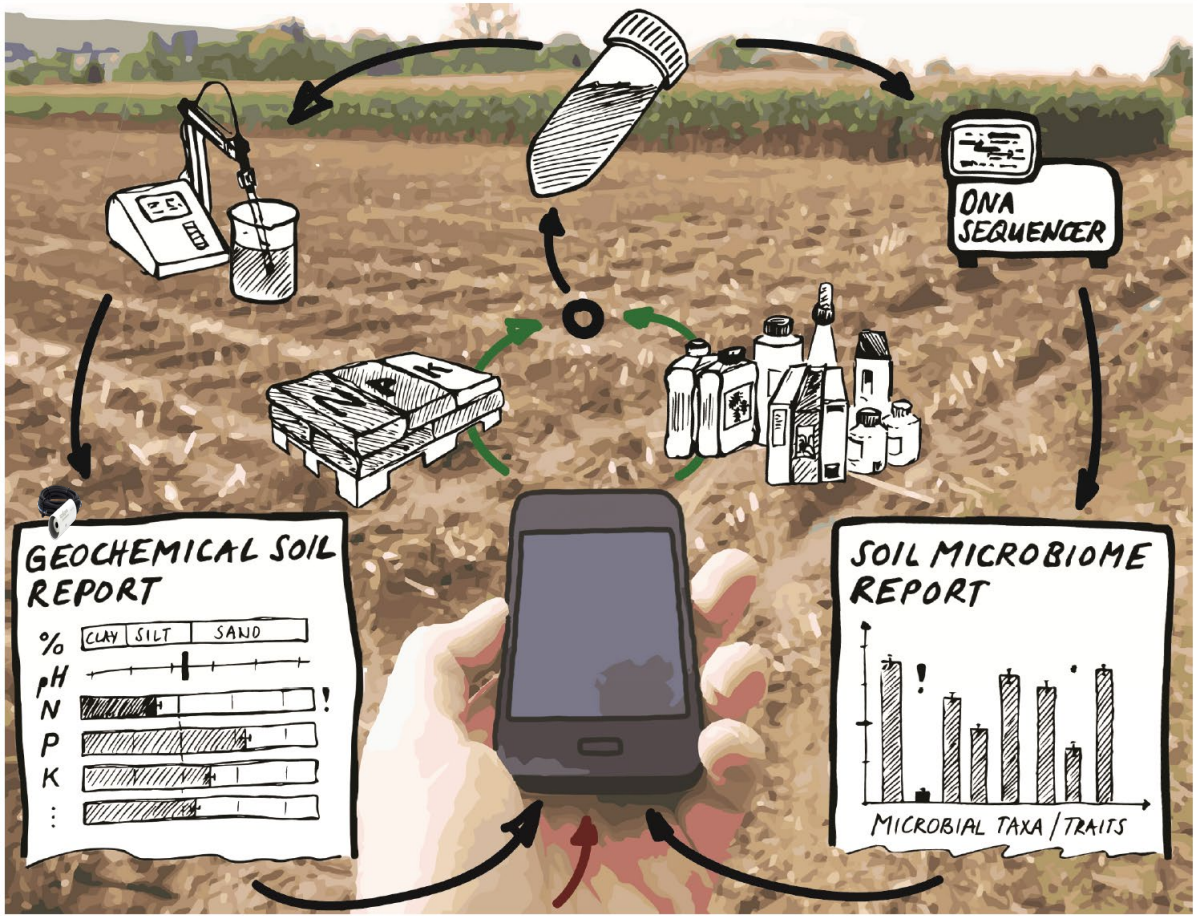
Roots | Bud break | Shoot growth | Flower development | Flowering and shoot growth | Fruit set | Fruit ready to harvest







The Plant Microbiome at Work 2015
Schlaeppi and Bulgarelli. MPMI 28:212



Our Goal – A Resilient Cropping Systems

Q: Can Biostimulants Contribute?

A: Potentially

PHOTOGRAPH BY JIM RICHARDSON, NATIONAL GEOGRAPHIC CREATIVE

Best Practices to Effectively Utilize Biostimulants

- Research on stress biology and the microbiome suggest the yields are often constrained by subtle environmental stress.
- Biostimulants MAY (!) have a significant potential to increase yields by mitigating the negative effects of these stress events.
- Modern agriculture has ignored and compromised the plant microbiome, system resilience and soil ‘health’
- Know your crops and understand the production weaknesses
  - What are the critical phenology and stress events that limit your productivity
  - What is the ‘function’ of the biostimulant
  - What are the environmental and phenological drivers
- Test biostimulants under field conditions using careful experiments, good statistics and detailed environmental monitoring. (Or have the company prove they did!)

Thank You!