Biostimulants and Nutrient Use Efficiency

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What is the legal definition of a Biostimulant?

In Europe (2019 Regulation):

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, **(NUE)**

(b) tolerance to abiotic stress,

(c) quality traits, or

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

In USA (Proposed)

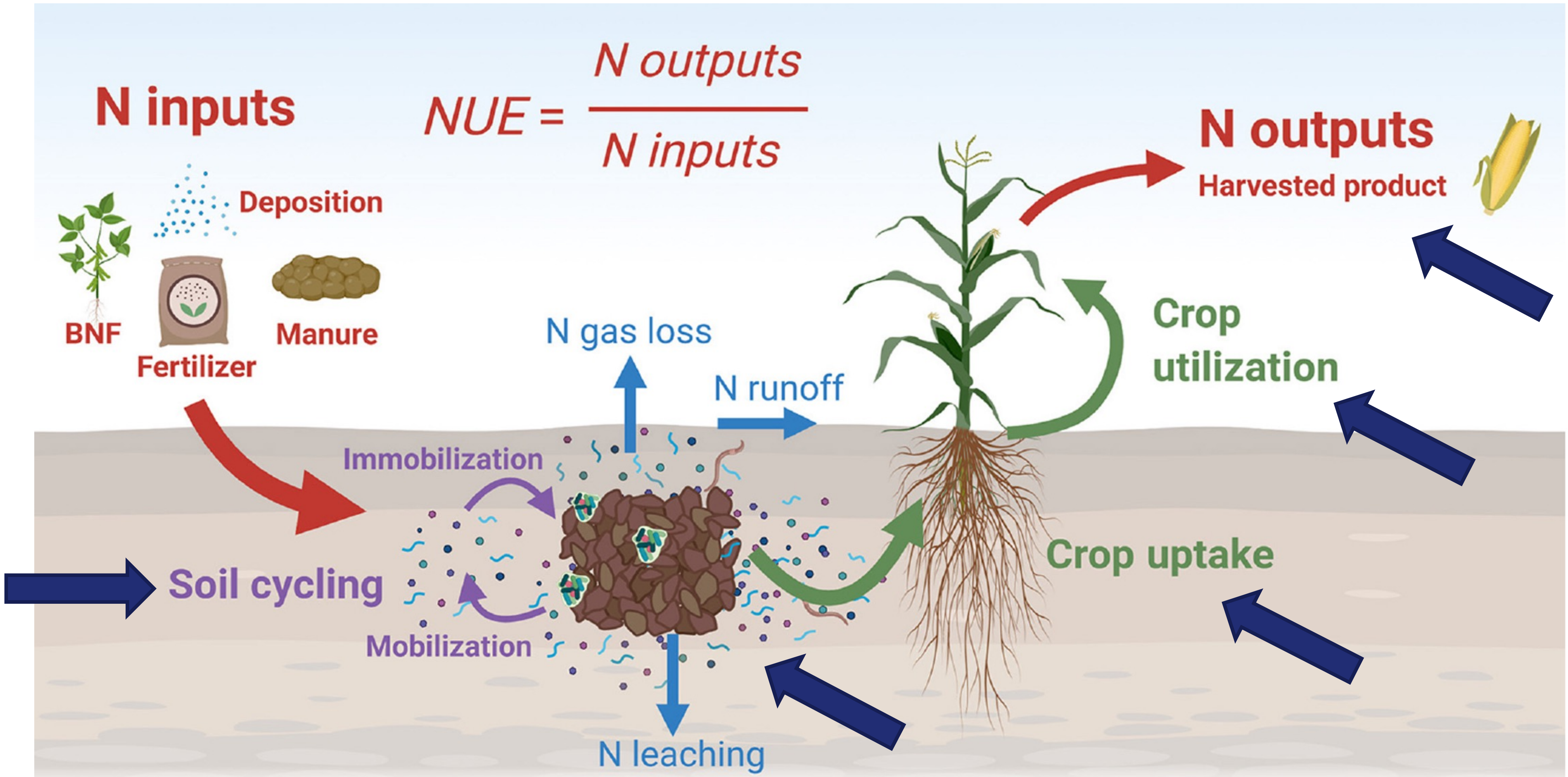
"a substance or micro-organism that, when applied to seeds, plants, soil or the rhizosphere, stimulates natural processes to enhance or benefit nutrient uptake, nutrient efficiency, tolerance to abiotic stress, or crop quality and yield."

There are Many Measures of NUE – Context Matters

<u>What are the Meanings and Uses of NUE?</u>

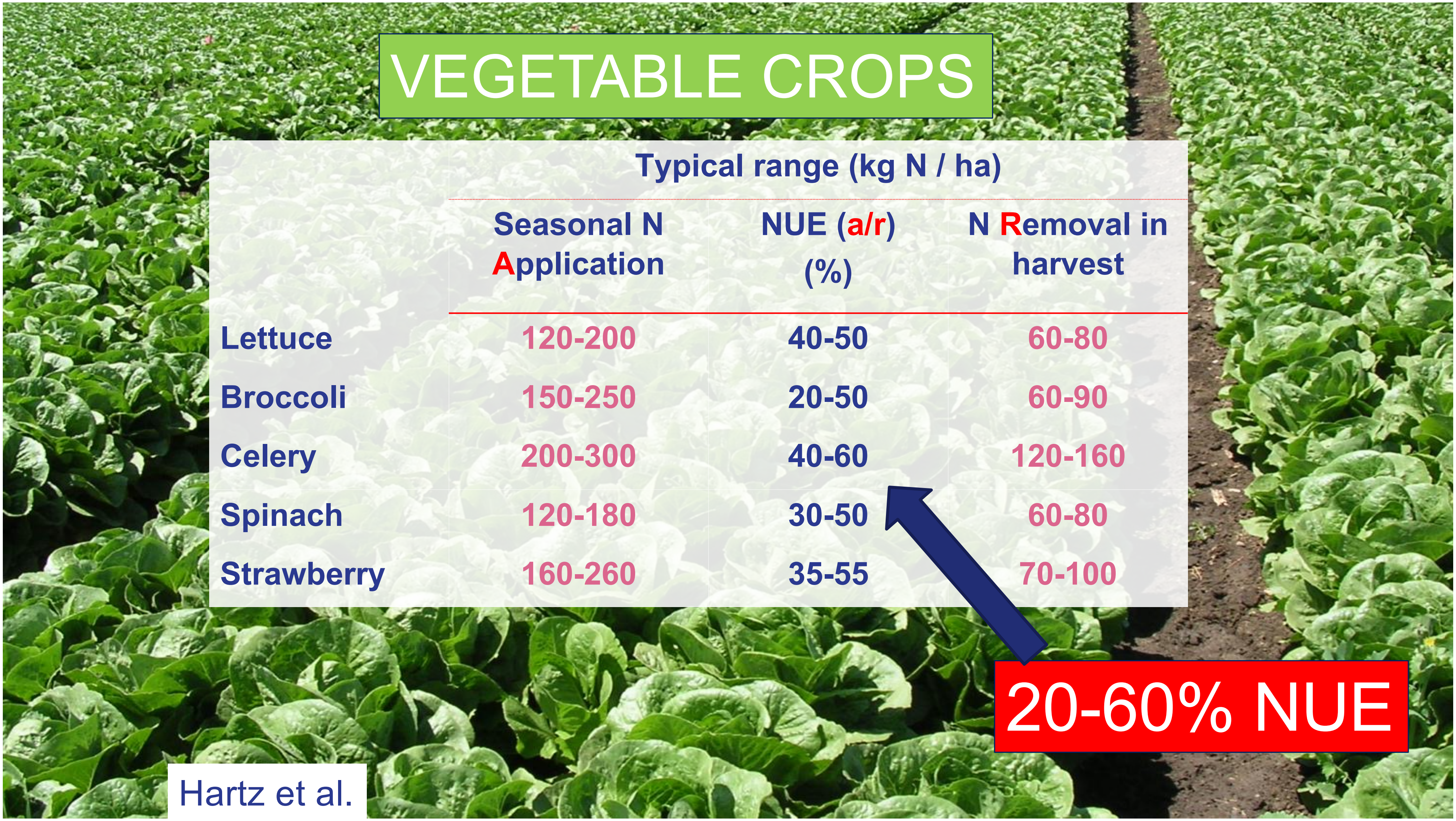
-Grower of low and mid-value crops: NUE goal is to minimize losses and enhance recovery of applied fertilizer (save $). NUE improvements derive from improved application technologies and protecting applied fertilizer from losses.

-Grower of high value crops: NUE is achieved by maximizing yield, optimizing quality and uniformity, while meeting environmental regulations. Focus is on production optimization and risk aversion. Nutrient cost is largely irrelevant.



A Research Road Map for Responsible Use of Agricultural Nitrogen 2019

Michael Udvardi[1*], Frederick E. Below[2], Michael J. Castellano[3], Alison J. Eagle[4], Ken E. Giller[5], Jagdish Kumar Ladha[6], Xuejun Liu[7], Tai McClellan Maaz[8], Barbara Nova-Franco[1], Nandula Raghuram[9], G. Philip Robertson[10], Sonali Roy[1†], Malay Saha[1], Susanne Schmidt[11], Mechthild Tegeder[12], Larry M. York[1] and John W. Peters[13*]



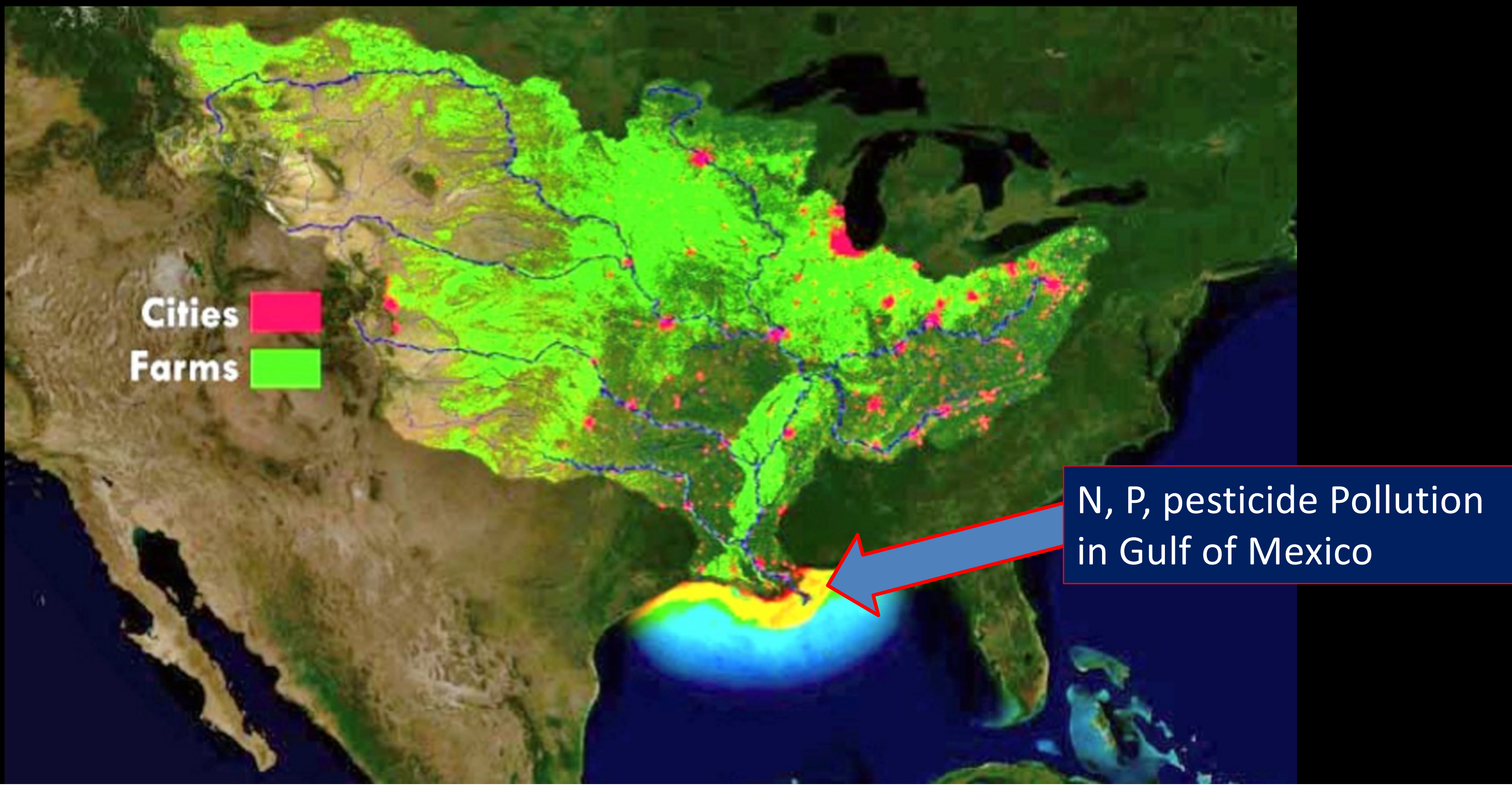
VEGETABLE CROPS

	Typical range (kg N / ha)		
	Seasonal N Application	NUE (a/r) (%)	N Removal in harvest
Lettuce	120-200	40-50	60-80
Broccoli	150-250	20-50	60-90
Celery	200-300	40-60	120-160
Spinach	120-180	30-50	60-80
Strawberry	160-260	35-55	70-100

20-60% NUE

Hartz et al.

Nutrient loss (N, P) is a major disruptor of the global environment



BIG DRIVER:
Consumer Demand for Sustainability and Low Environmental Footprint

How will we meet the demands of the consumer and food system?

Retailers

Brands

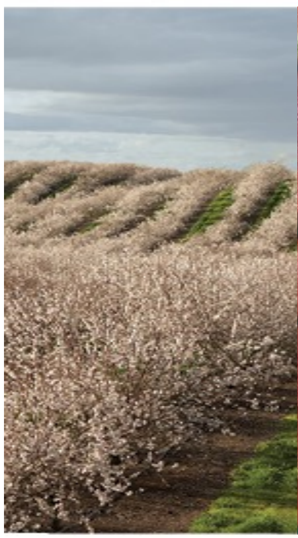
Ingredient Processors

Ag Service Providers

Plant Nutrition: Productivity, Economics and Environment.

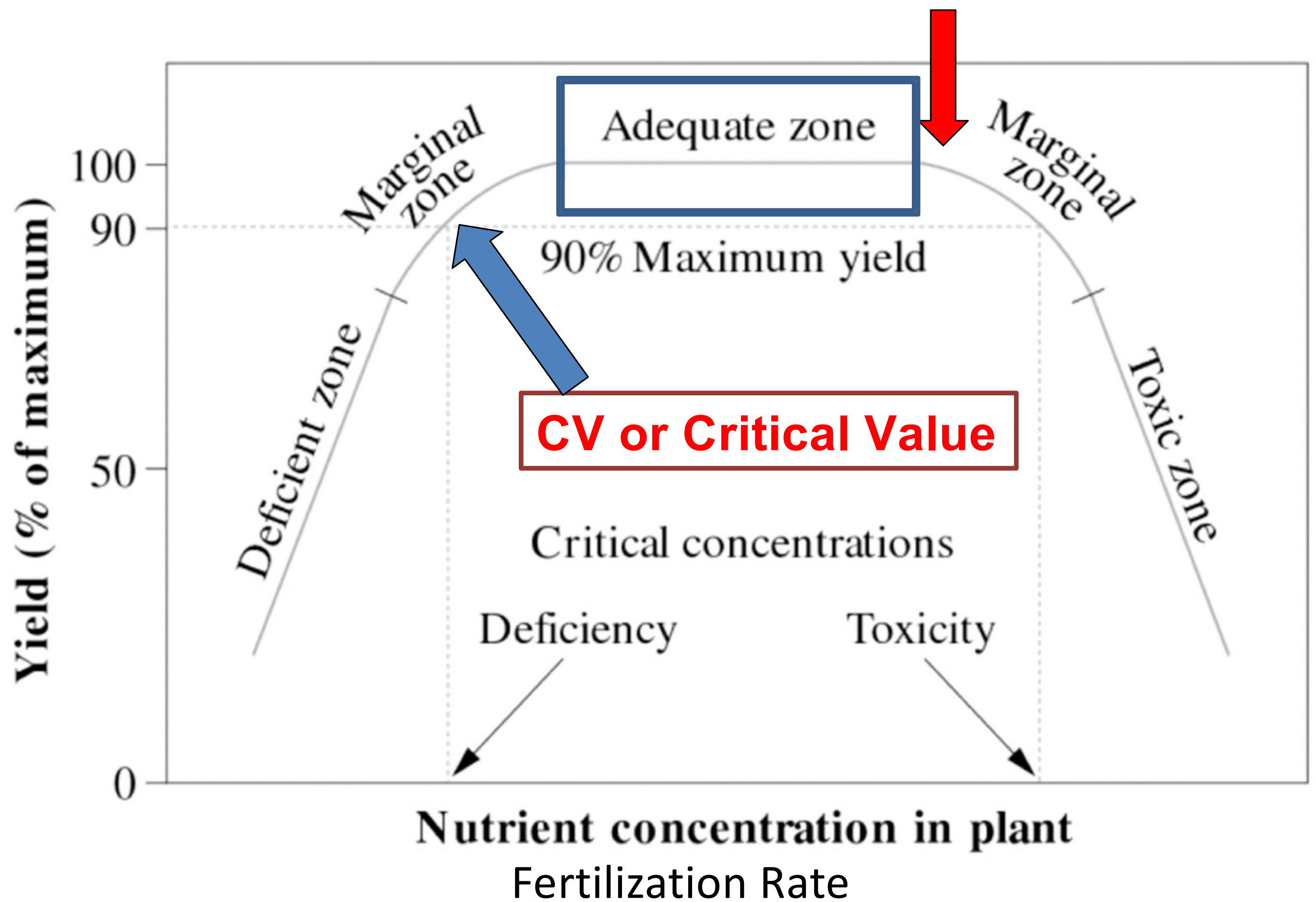
Why is there a NUE problem?

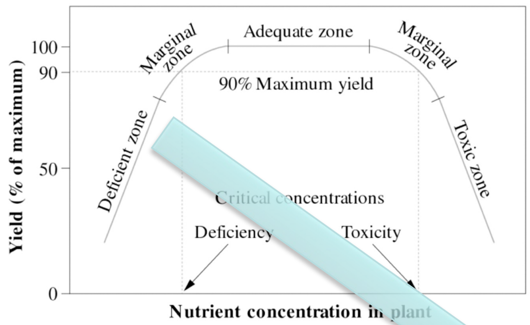
- Biophysical
- Behavioral
- Technical



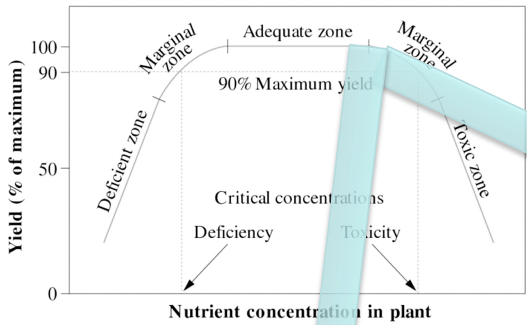

Nutrient Response Curve

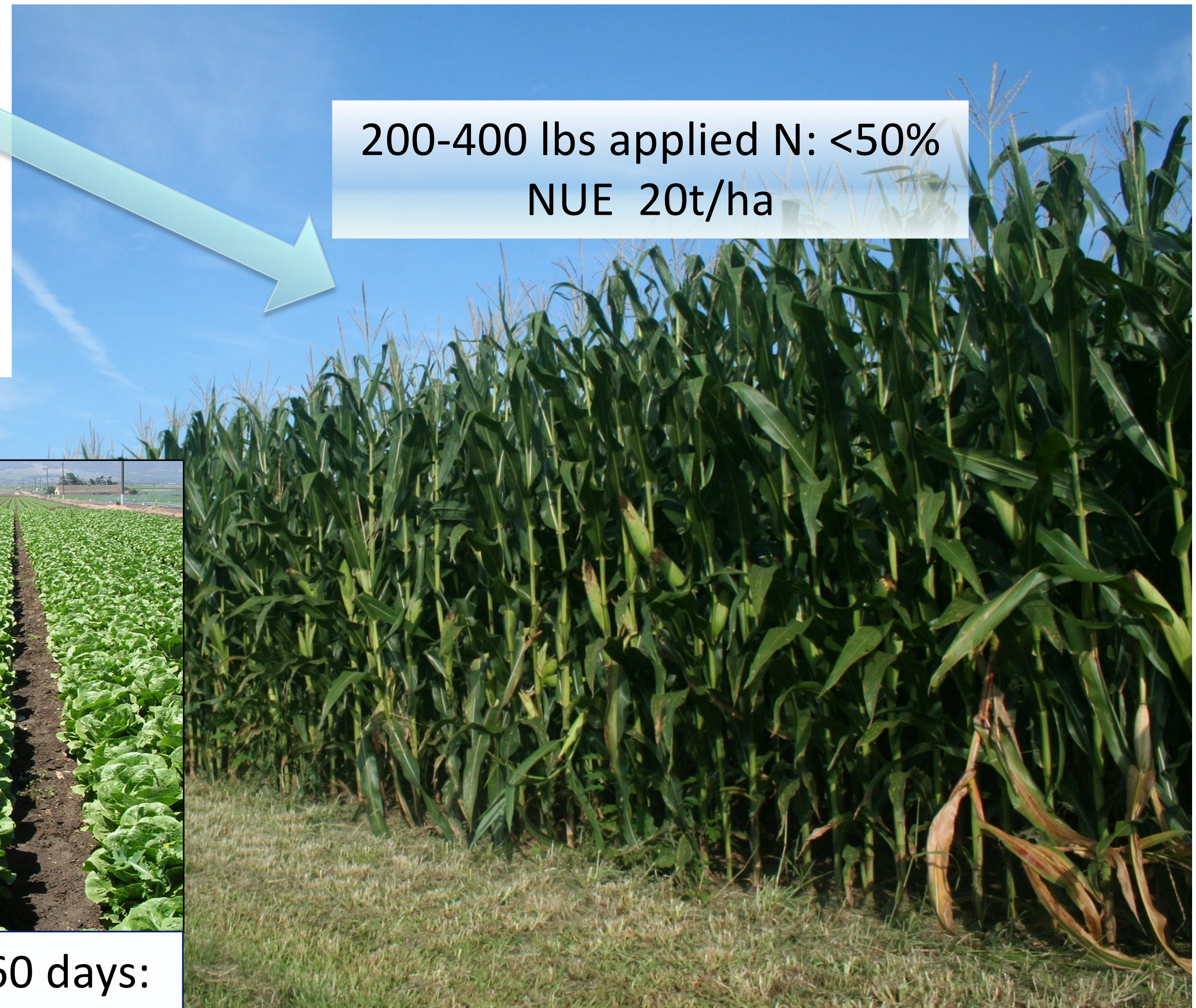
Diminishing Returns: Decreasing Risk





0-10 lbs applied N: >100% NUE and 1 t/ha

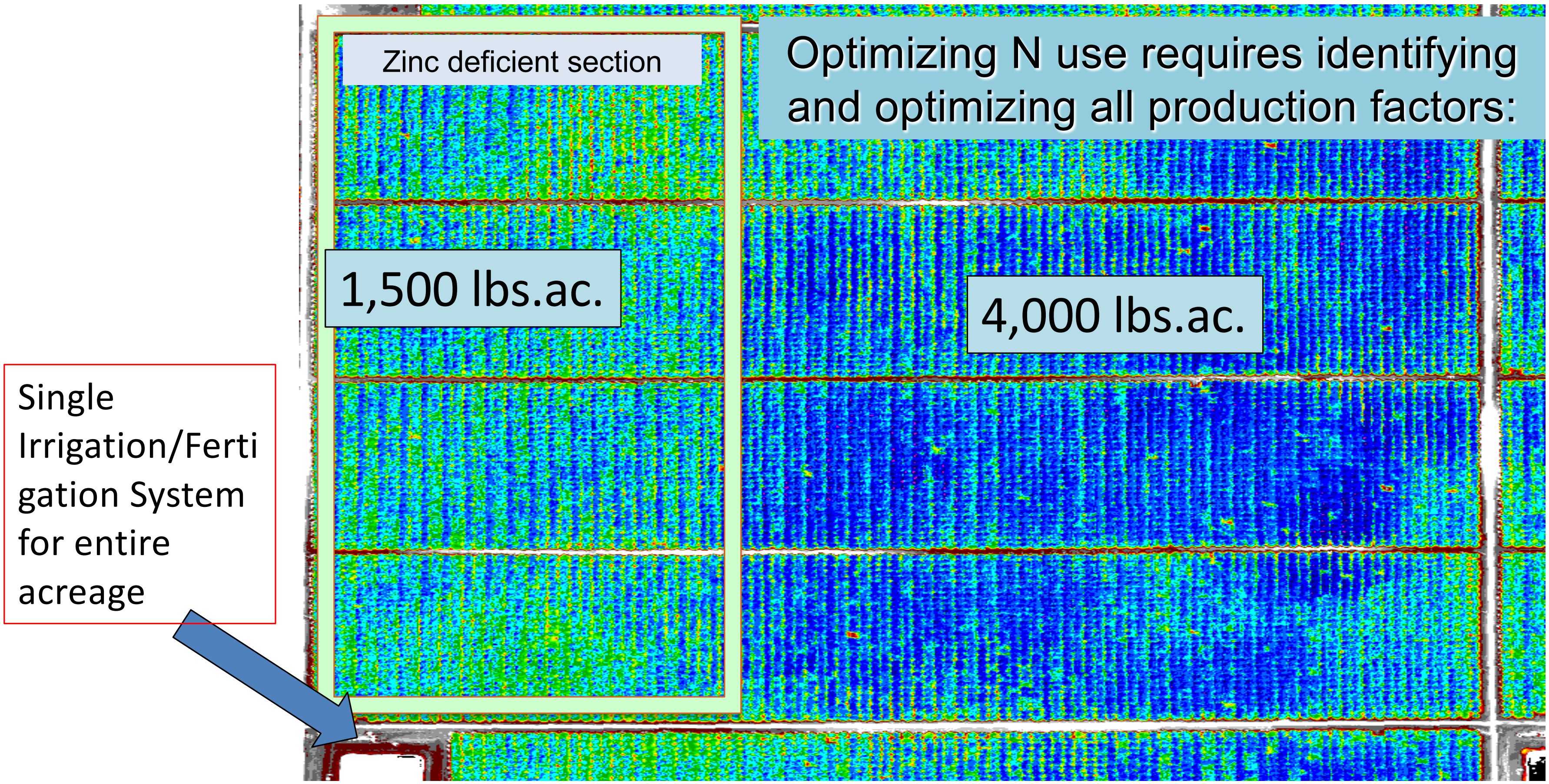




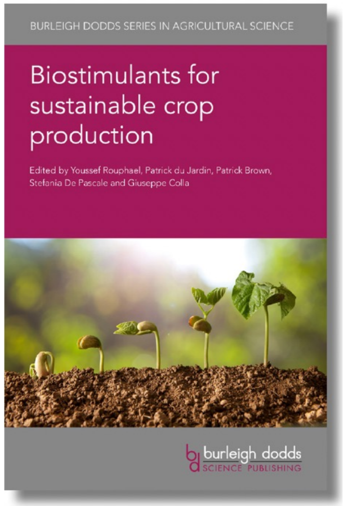
200-400 lbs applied N: <50% NUE 20t/ha

200-250 lbs applied N in 60 days: <50% NUE $20,000/ha

Optimizing N use efficiency requires Optimal Management of all Inputs: In this example Zinc Deficiency can limit crop response to N



GNDVI 29 April 2009: SmartImage (B,G, NIR only)1 m pixel (Britz Fert. Com.)



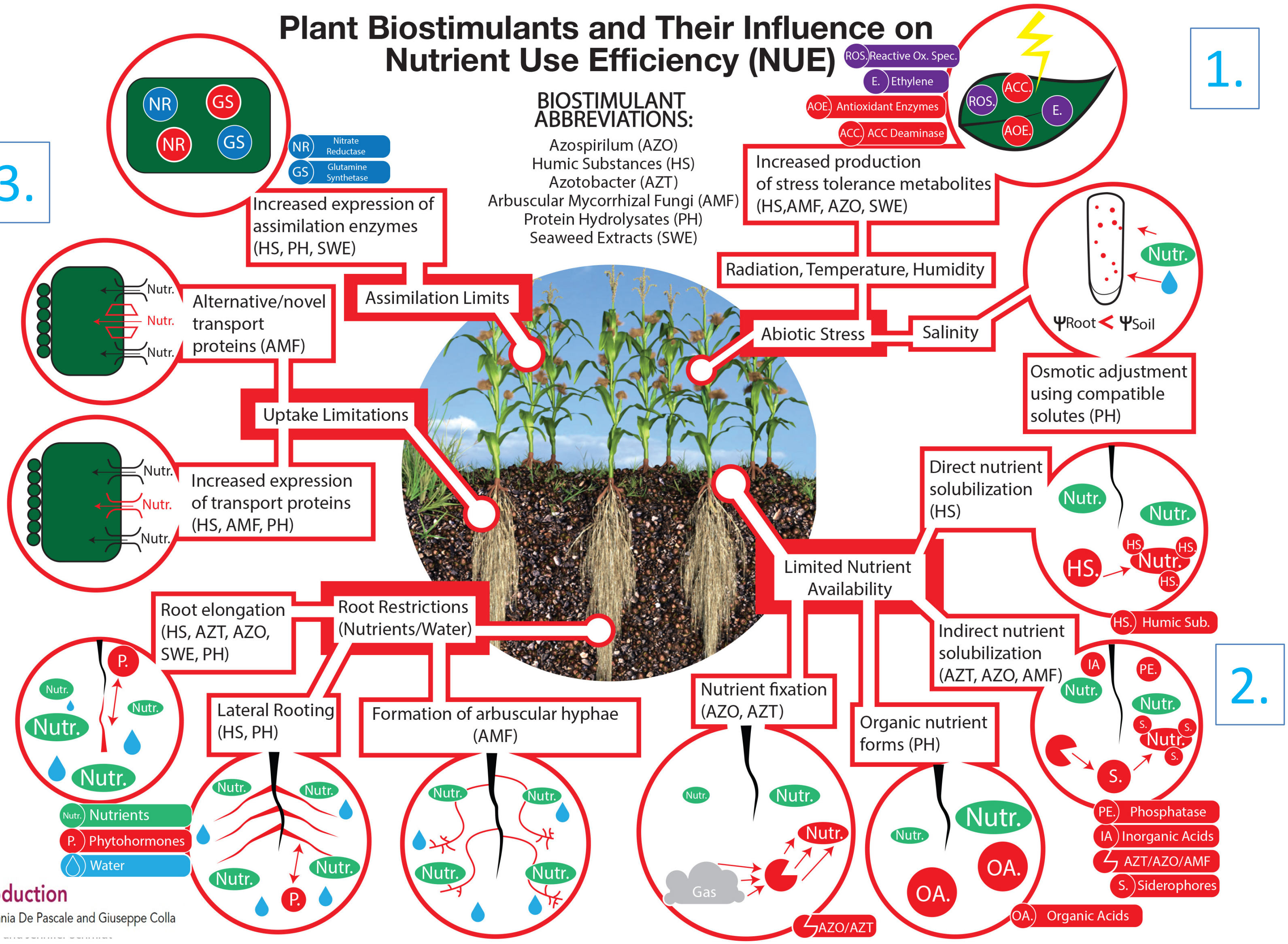
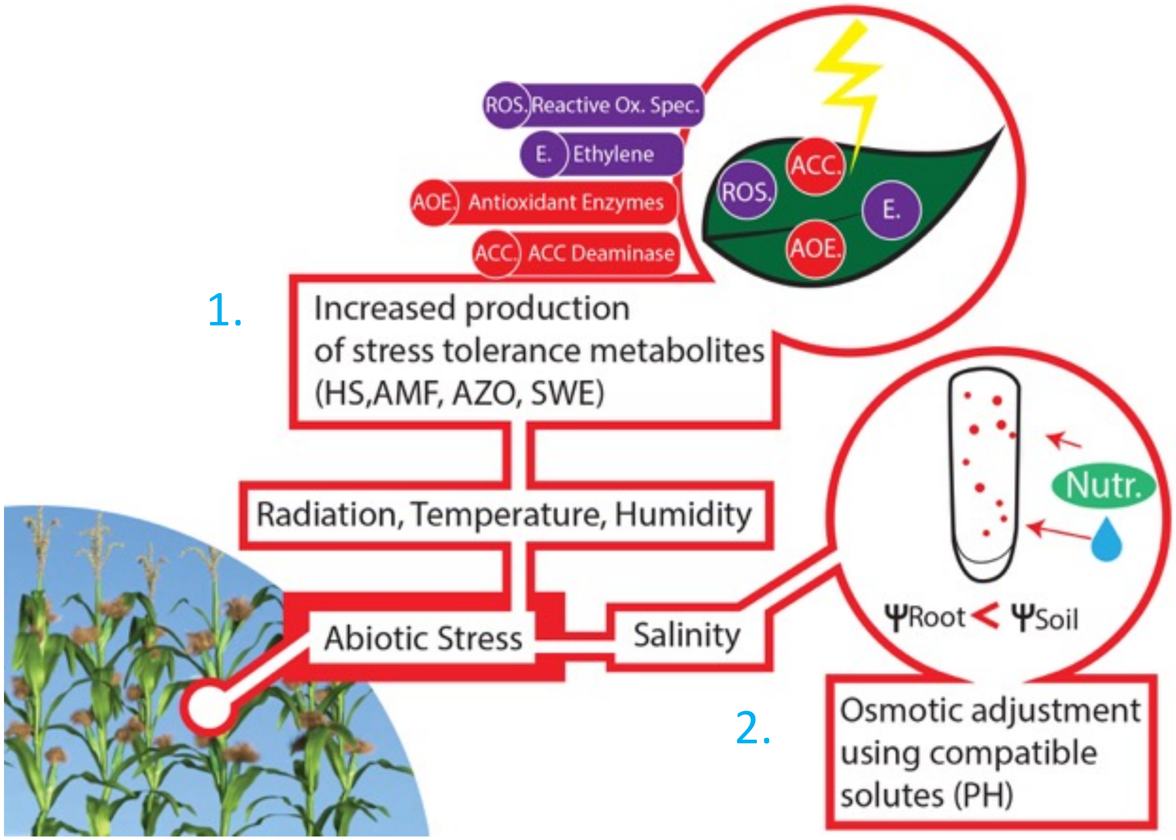


Figure Illustrated by Christopher Sisniegas, Meerae Park, and Jennifer Schmidt

Biostimulants for sustainable crop production

Edited by: Youssef Rouphael, Patrick du Jardin, Patrick Brown, Stefania De Pascale and Giuseppe Colla

1: Biotimulants and Nutrient Use Efficiency:
Overcoming Stress



Biostimulants for sustainable crop production
Edited by: Youssef Rouphael, Patrick du Jardin, Patrick Brown, Stefania De Pascale and Giuseppe Colla

Enhanced Agronomic NUE
(better use of soil and fertilizer nutrients)

1. Humic substances (HS), Mycorrhiza (AMF), Sea Weed Extracts (SWE) and Azospirilum (AZO) have been shown to stimulate stress tolerance allowing better growth and hence better use of available soil nutrients.

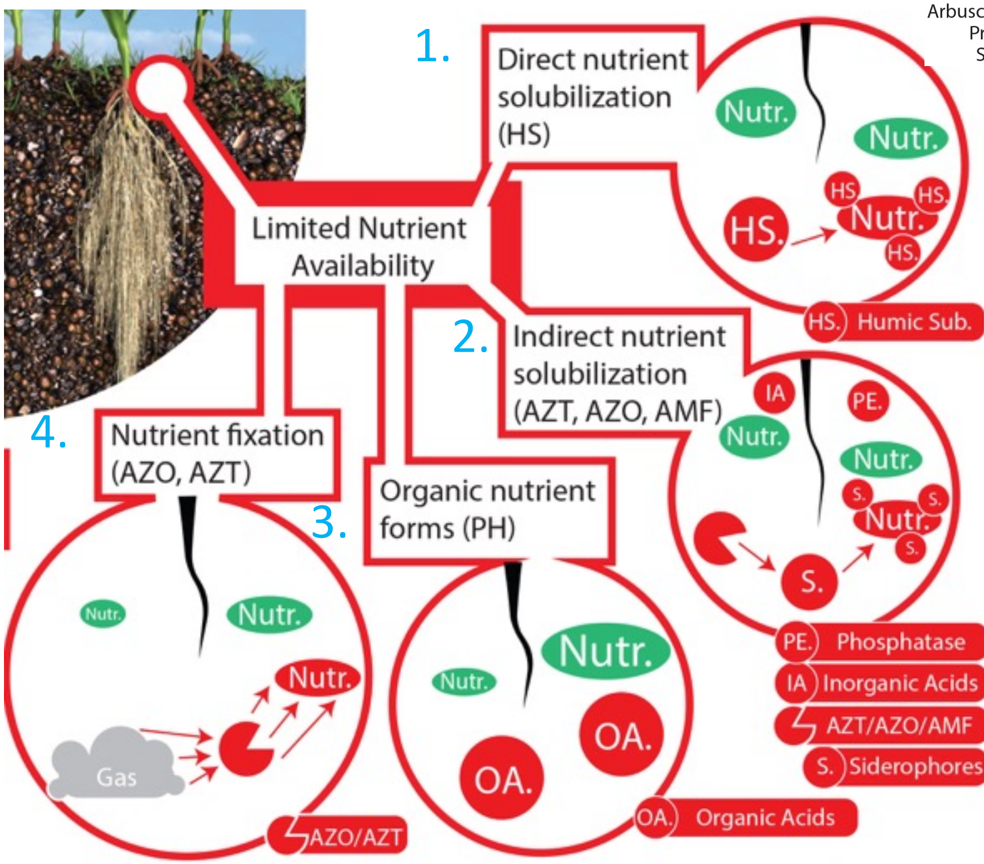
2. Protein Hydrolyzates (PH) contain organic and amino acids that help plants adapt osmotically to salinity and drought.

2: Biotimulants and Nutrient Use Efficiency:

Overcoming Limited Solubility

BIOSTIMULANT ABBREVIATIONS:

Azospirilum (AZO)
Humic Substances (HS)
Azotobacter (AZT)
Arbuscular Mycorrhizal Fungi (AMF)
Protein Hydrolysates (PH)
Seaweed Extracts (SWE)



Biostimulants for sustainable crop production

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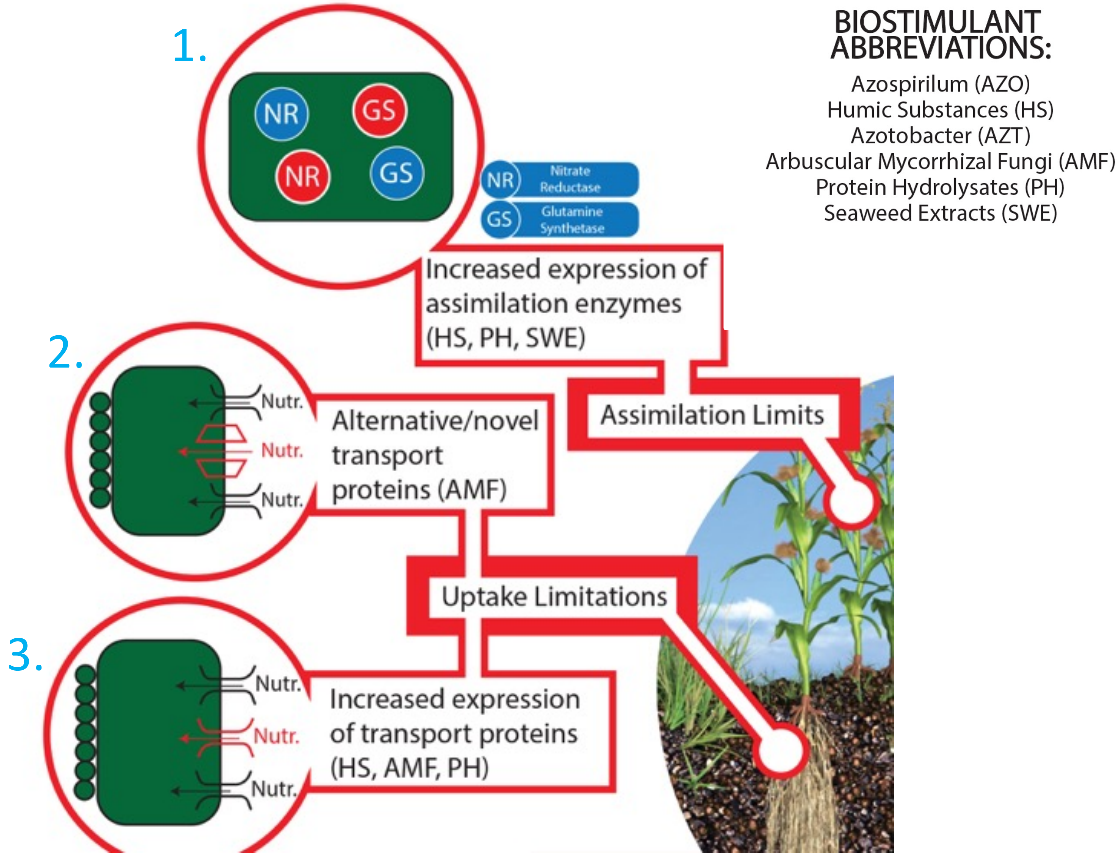
Enhanced Agronomic NUE (better use of soil and fertilizer nutrients)

1. Humic substances (HS) can directly solubilize soil minerals
2. Microbe containing or enhancing biostimulants (AZO, AZT, AMF) produce enzymes that solubilize minerals
3. Protein Hydrolyzates (PH) contain organic and amino acids that can bind minerals
4. Azotobacter (AZT) and azospirillum (AZO) can fix nitrogen.

3: Biostimulants and Nutrient Use Efficiency:

Upregulating transport and assimilation



Biostimulants for sustainable crop production

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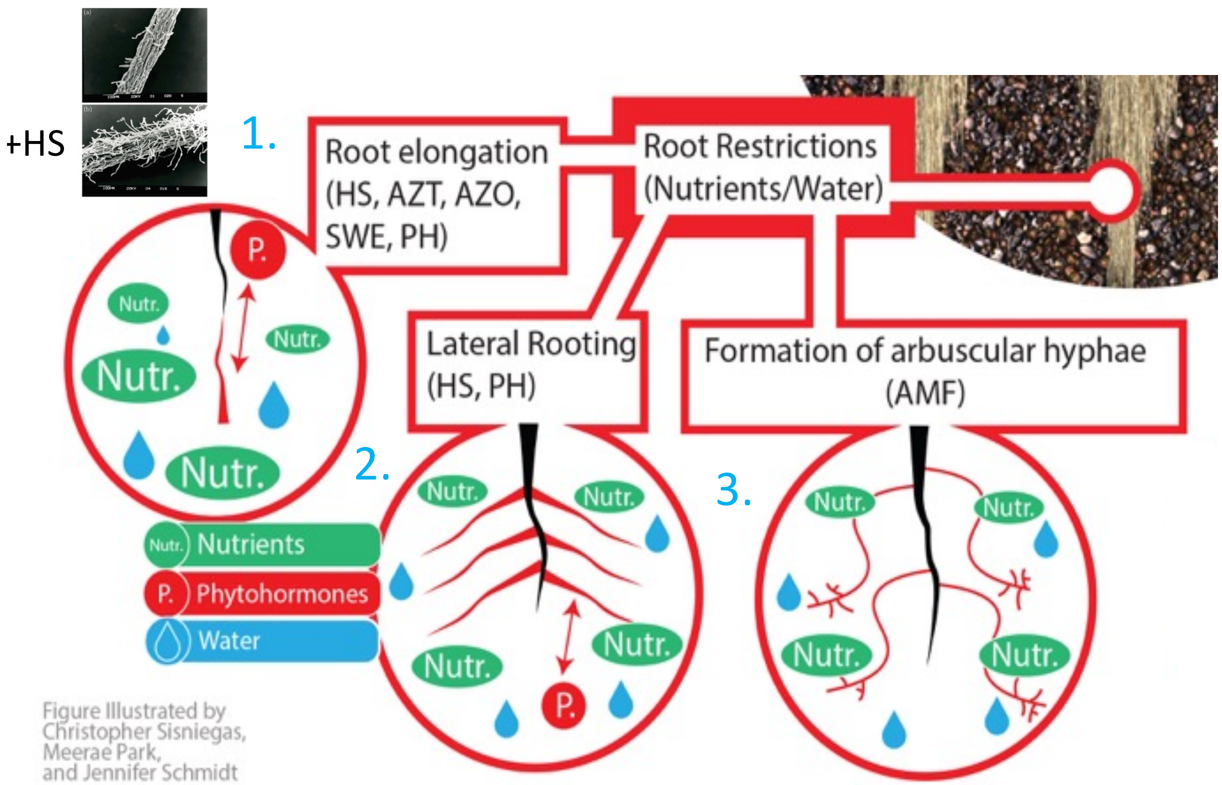
Enhanced Internal and Agronomic NUE

(better use of existing nutrients and more efficient use of internal nutrients)

1. Humic substances (HS), protein hydrolysates (PH) and Sea Weed Extracts (SWE) can increase expression of enzymes that regulate N use.
2. Mycorrhiza (AMF) express novel transporters that increase nutrient uptake.
3. HS, AMF and PH can induce the plant to produce new transporters.

4: Biostimulants and Nutrient Use Efficiency:
Increased Root Growth and Soil Exploration



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Enhanced Agronomic NUE
(better use of soil and fertilizer nutrients)

1. All classes of biostimulants have been shown to increase root elongation.

2. Humic Substances (HS) and Protein Hydrolyzates can increase lateral root formation.

3. Mycorrhiza (AMF) extend very fine hypha into the soil and increase soil exploration.

4. More roots is not always a good thing, particularly in nutrient and water rich systems.

Context Specific Role for Biostimulants to Improve Nutrient Use Efficiency

Rainfed, sprinkler or furrow irrigated row crops (Corn, sugarcane, soybean, beans..)

- Access to field for in-season fertilization impractical
- Early, deep and well branched root systems are valuable
- Retention/protection of early season nutrients is critical
  - Protection of applied N through soil carbon/health optimization to provide buffering
  - Mitigation of immobilization processes
- Growth rate and seasonal demand curves define demand
  - Stress mitigation is critical
  - Low volume foliar biotimulants/micro-nutrients are possible

Context Specific Role for Biostimulants to Improve Nutrient Use Efficiency

Fertigated High Value Crops (orchard, berry, vegetable, nursery)

- In season fertigation timed with demand and optimized for formulation is possible
- Protection of nutrients from leaching with irrigation is highly critical
- Root exploration is less critical in fertigated crops.
- Highest priority is to optimize plant growth and mitigate any stress induced yield delay or quality compromise and increase field uniformity.
- In short season rotational vegetables, organic matter and crop residue protection/management is also critical to avoid off-season N release.

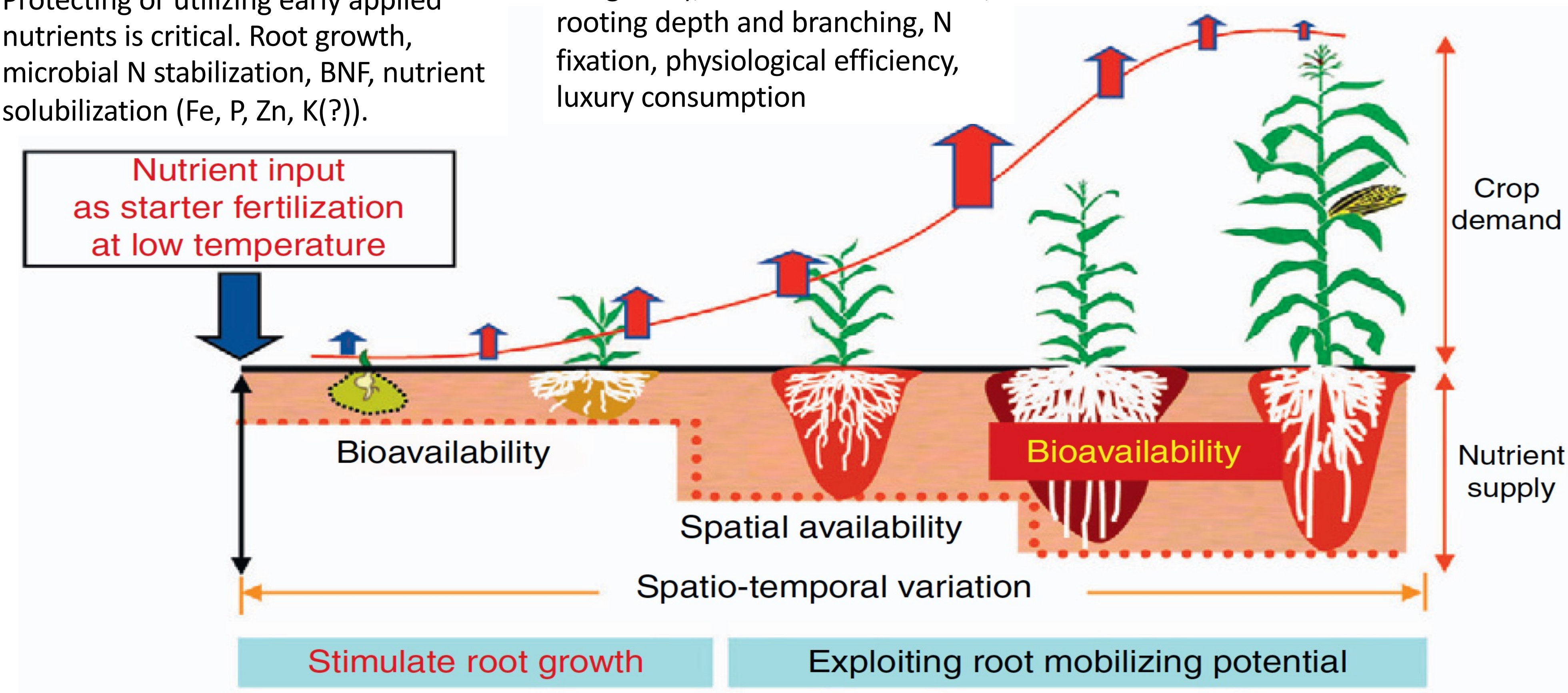
Cropping System with Limited in-season fertilization (sugarcane, maize etc..)

Zhang et al. 2010
Advances in Agronomy, Volume 107

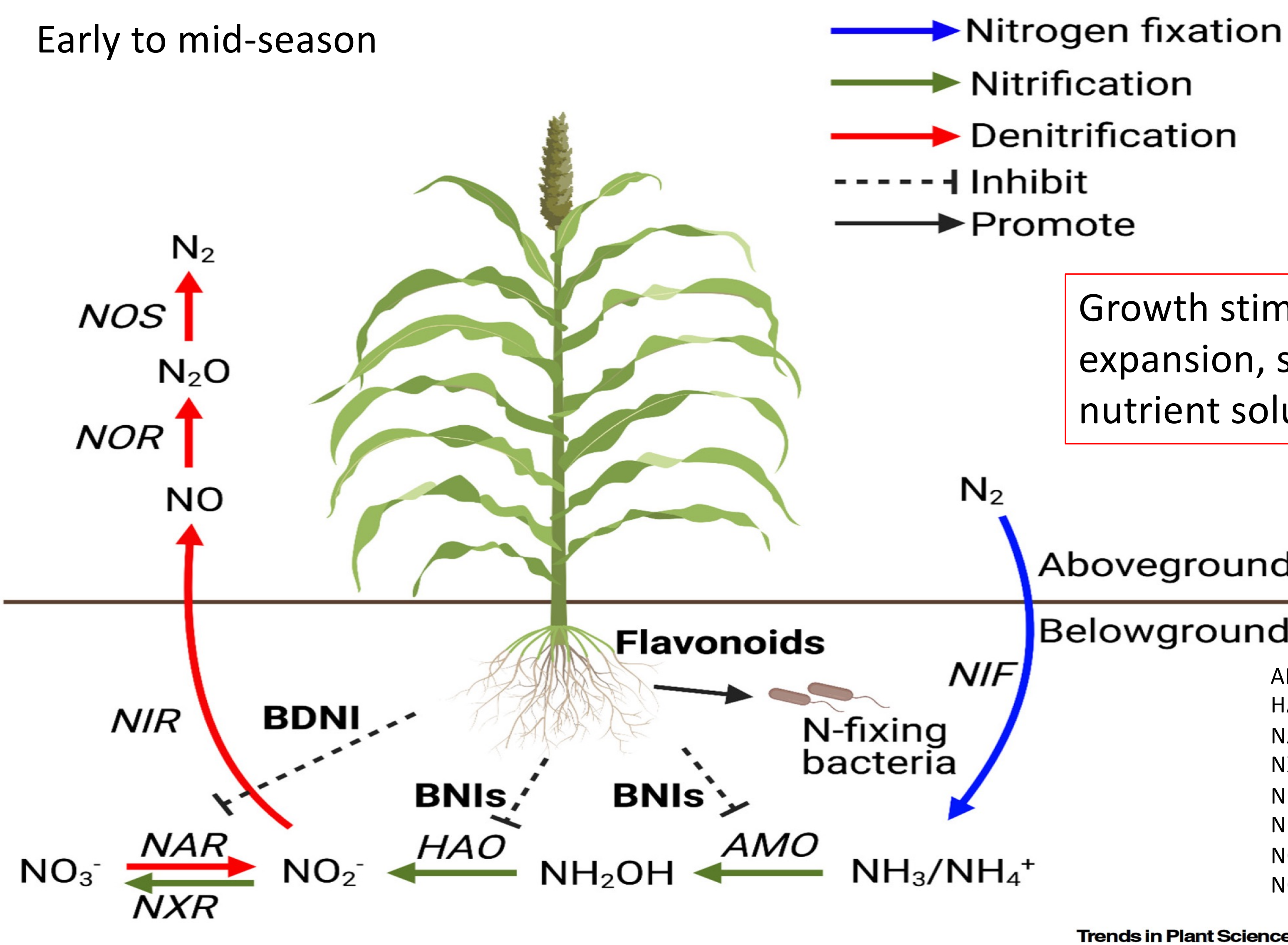
Protecting or utilizing early applied nutrients is critical. Root growth, microbial N stabilization, BNF, nutrient solubilization (Fe, P, Zn, K(?)).

Maximize growth (stress mitigation), nutrient solubilization, rooting depth and branching, N fixation, physiological efficiency, luxury consumption

To minimize residual soil N, P – internal remobilization, delayed senescence, nutrient scavenging.



Early to mid-season



Trends in Plant Science

CellPress

Review

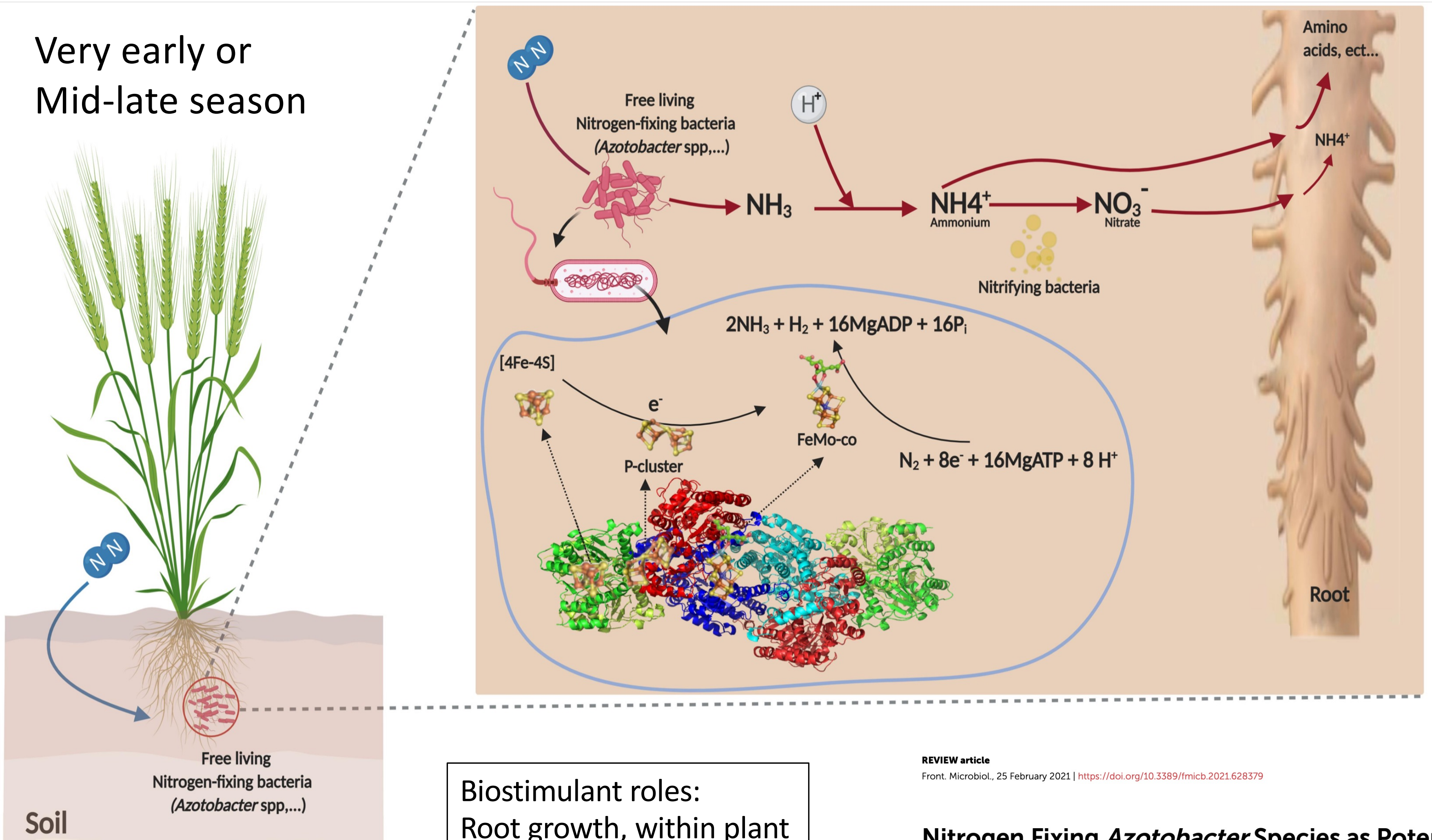
Root exudates impact plant performance under abiotic stress

Yen Ning Chai[1,2] and Daniel P. Schachtman[1,2,*]

Growth stimulation, root expansion, stress mitigation, nutrient solubilization.

AMO: ammonia monooxygenase
HAO: hydroxyamine oxidoreductase
NAR: Nitrate Reductase
NXR: Nitrite oxidoreductase
NIF: Nitrogenase
NIR: Nitrite reductase
NOR: Nitric oxidase reductase
NOS: Nitrous oxide reductase

Very early or
Mid-late season



Biostimulant roles:
Root growth, within plant NUE and remobilization to grain.

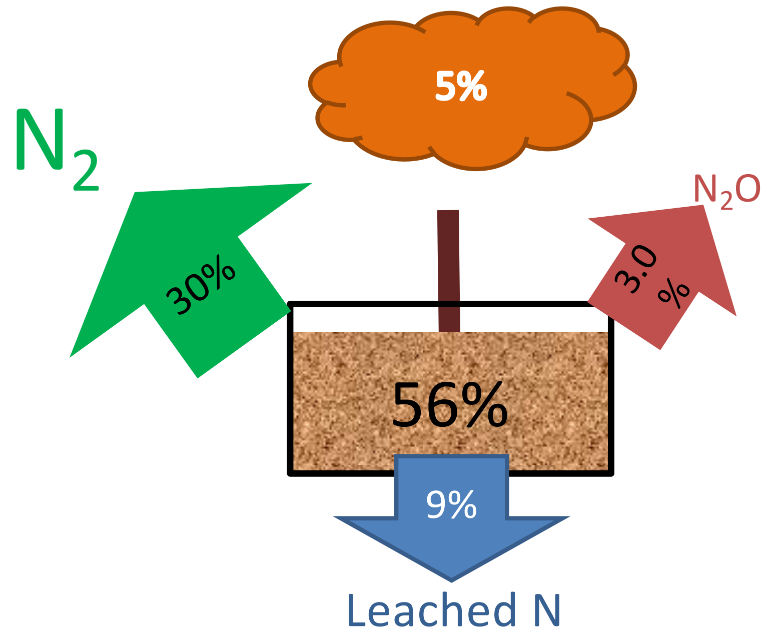
REVIEW article
Front. Microbiol., 25 February 2021 | https://doi.org/10.3389/fmicb.2021.628379

Nitrogen Fixing *Azotobacter* Species as Potential Soil Biological Enhancers for Crop Nutrition and Yield Stability

Abderrahim Aasfar[1,2*], Adnane Bargaz[3], Kaoutar Yaakoubi[1], Abderraouf Hilali[2], Iman Bennis[1], Youssef Zeroual[4] and Issam Meftah Kadmiri[1,3*]

How does the use of biostimulants to enhance NUE in fertigated, high value systems?

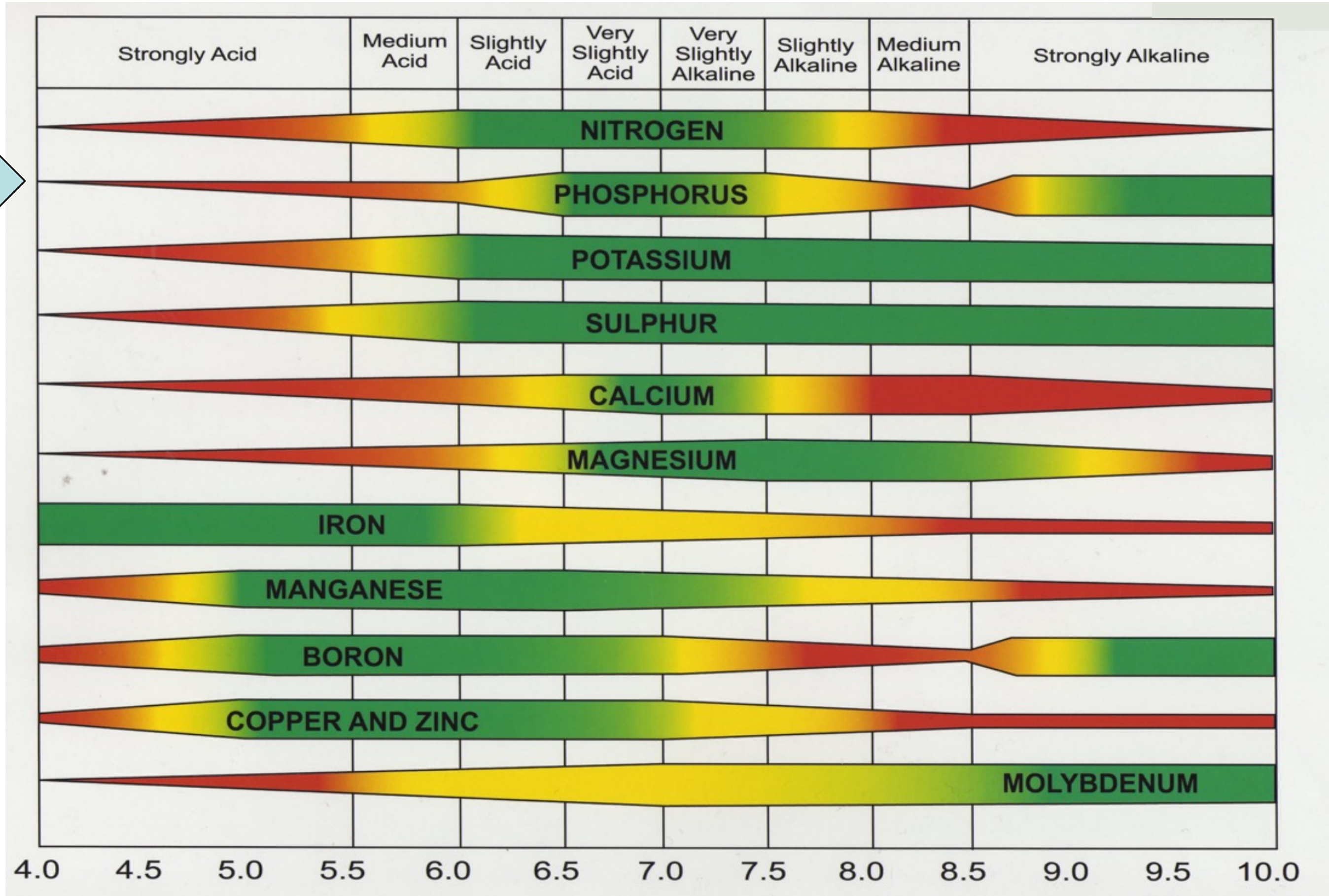
Different Crops, Different Challenges

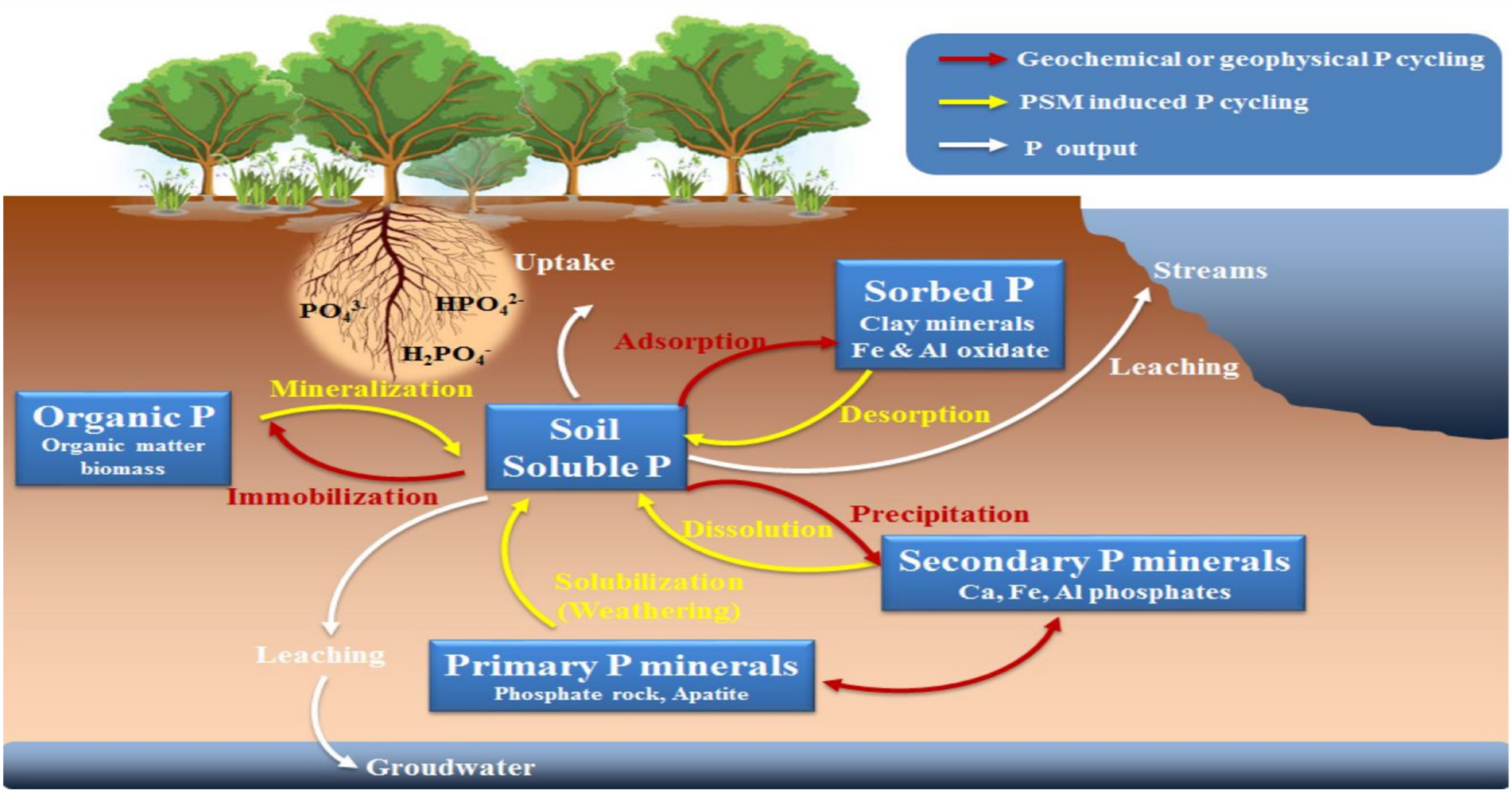


NUE benefits will come from minimizing GHG N losses.

Pitton, et al 2022. Agricultural Science & Technology

Focus on Phosphorus





Biology **2021**, *10*, 158. https://doi.org/10.3390/biology10020158

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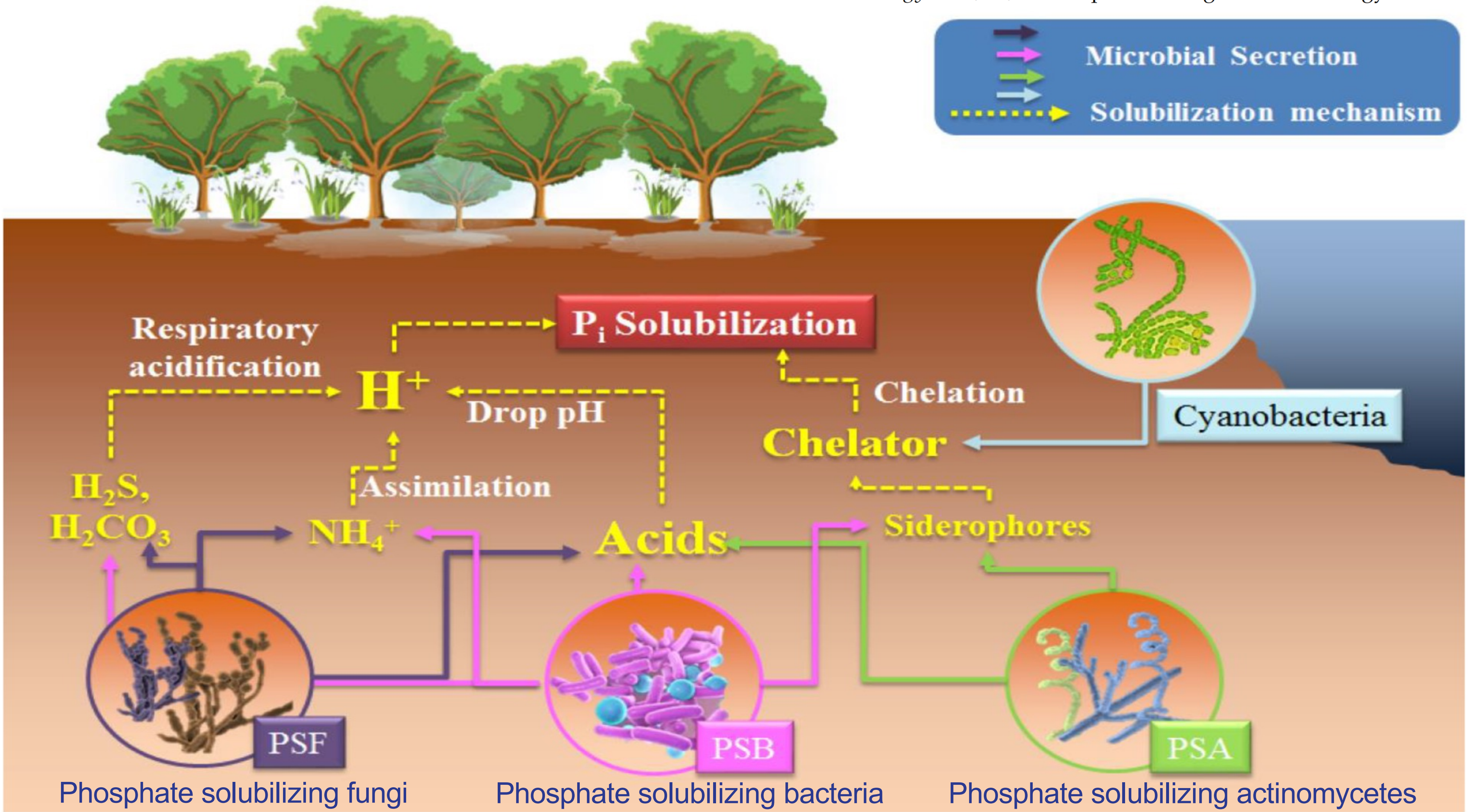
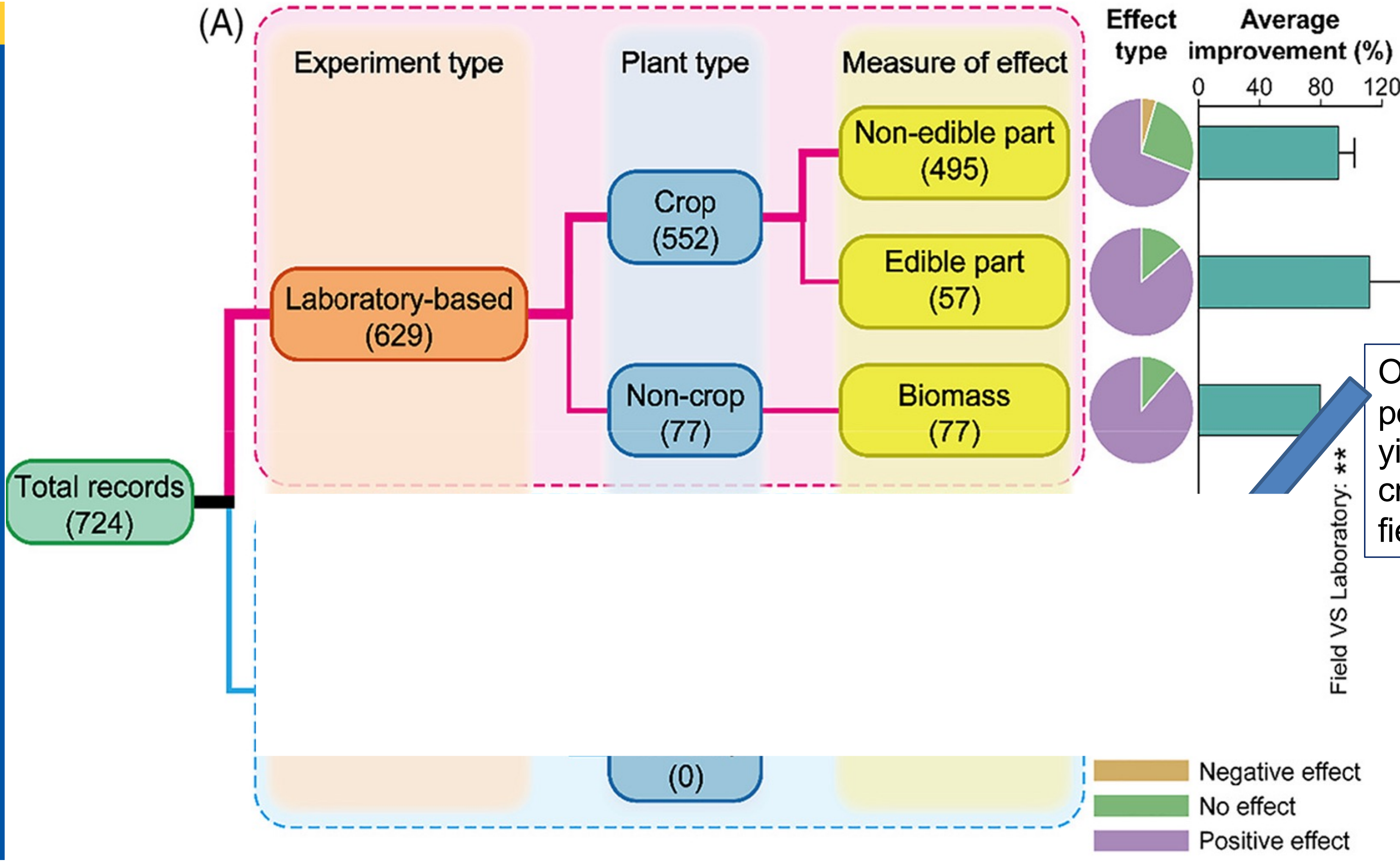


A comprehensive synthesis unveils the mysteries of phosphate-solubilizing microbes

Jin-tian Li, Jing-li Lu, Hong-yu Wang, Zhou Fang, Xiao-juan Wang, Shi-wei Feng, Zhang Wang, Ting Yuan, Sheng-chang Zhang, Shu-ning Ou, Xiao-dan Yang, Zhuo-hui Wu, Xiang-deng Du ... See all authors

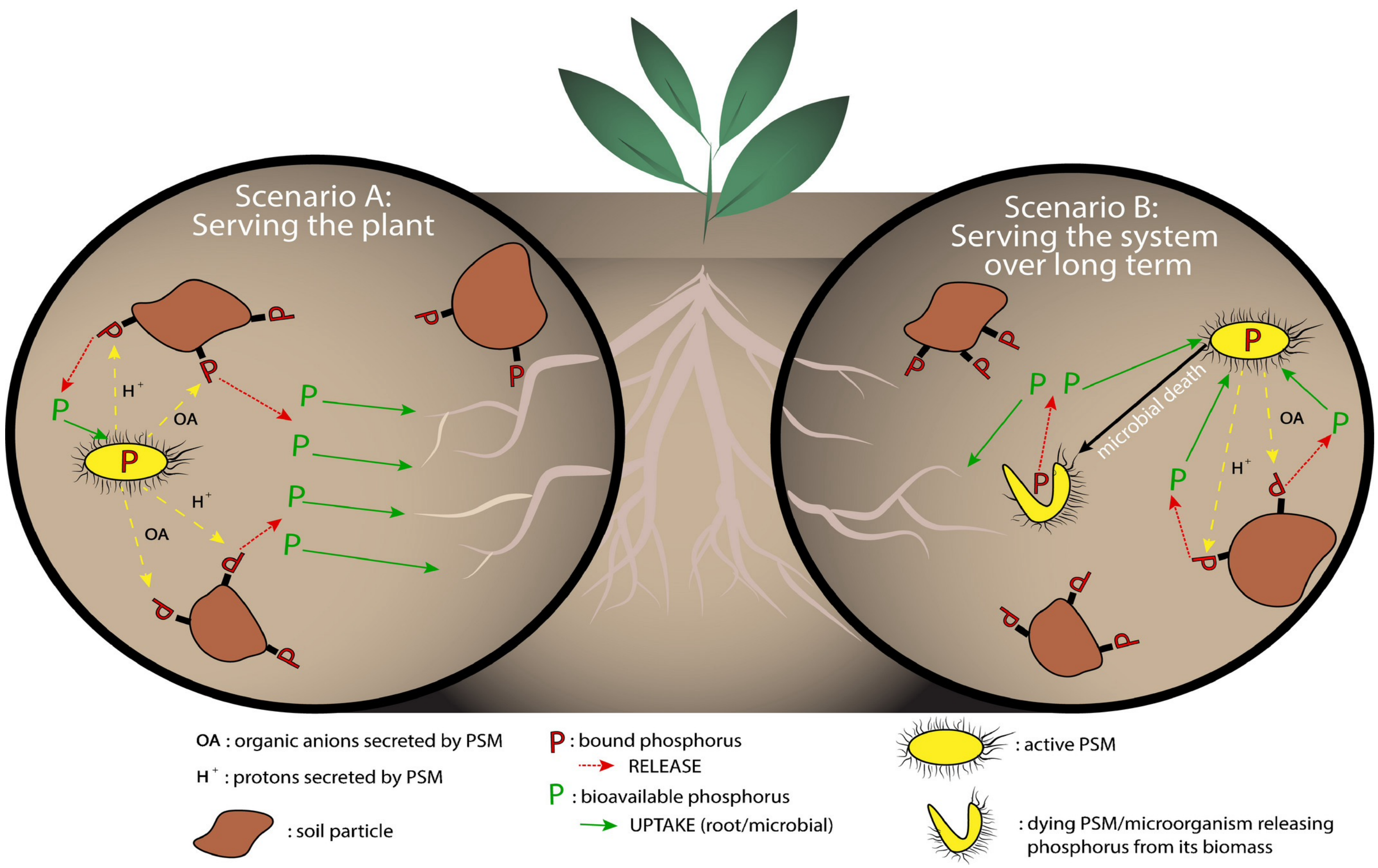
First published: 21 July 2021 | https://doi.org/10.1111/brv.12779 | Citations: 1

Results of 724 research studies.



Of 724 studies only 5 positive records of a yield benefit in cropping plants in field.

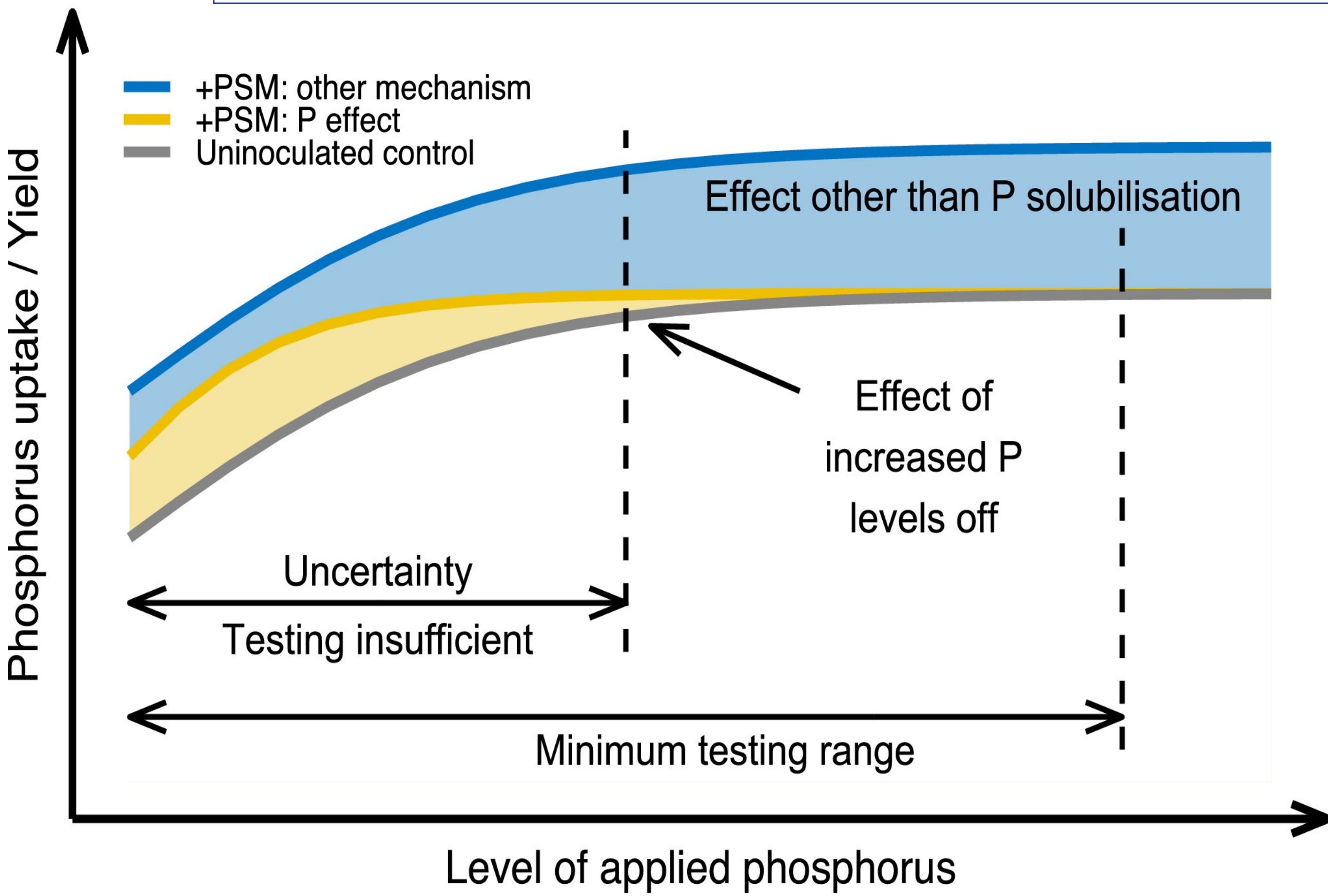
Reason 1: P Solubilizing Microorganism (except mycorrhiza) are selfish!



Phosphate-solubilising microorganisms for improved crop productivity: a critical assessment

New Phytologist, Volume: 229, Issue: 3, Pages: 1268-1277, First published: 14 September 2020, DOI: (10.1111/nph.16924)

Under most Ag circumstances the benefit of PSM is not a consequence of P release



Raymond et al. New Phytologist, Volume: 229, Issue: 3, Pages: 1268-1277, First published: 14 September 2020, DOI: (10.1111/nph.16924)

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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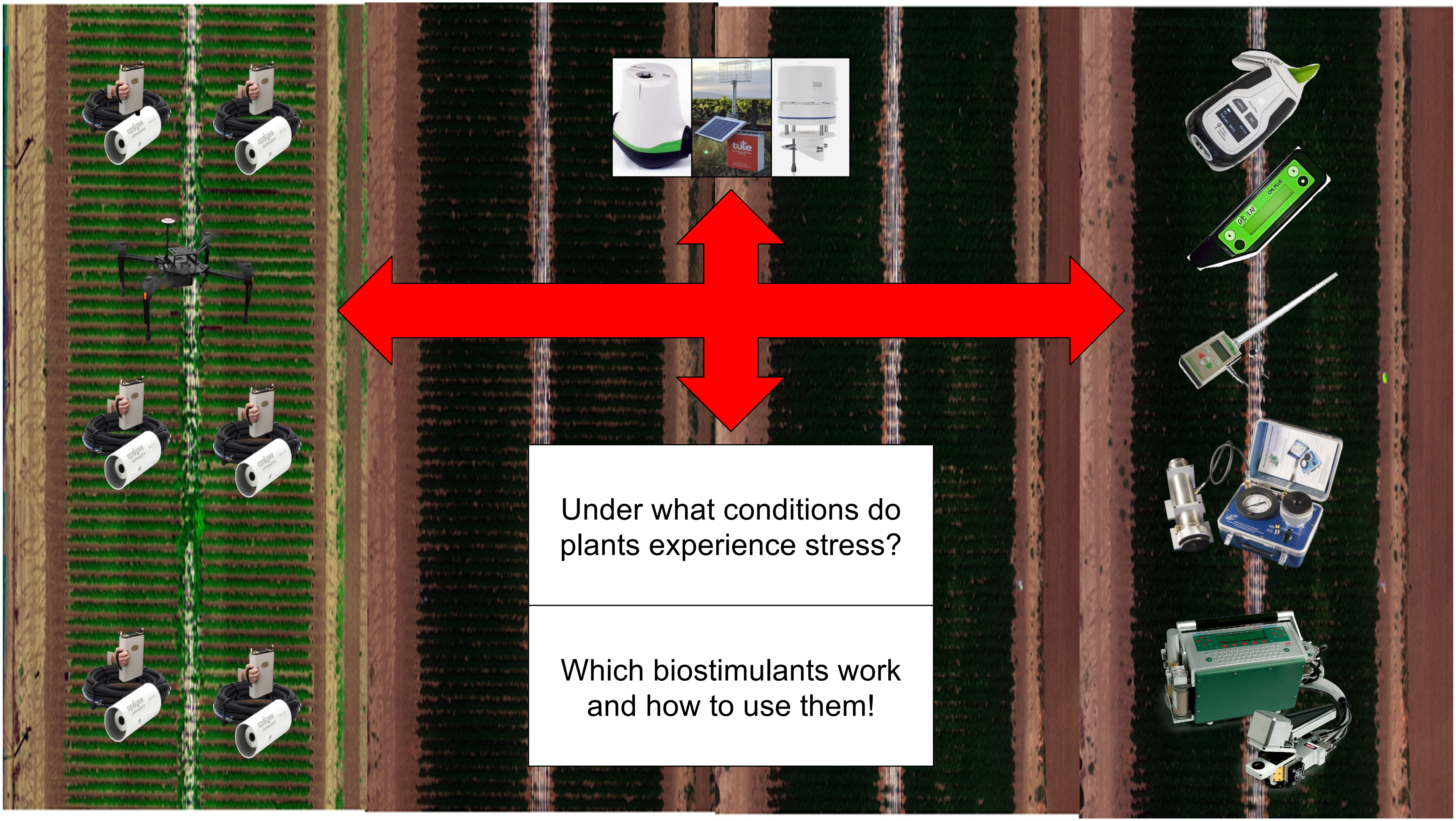
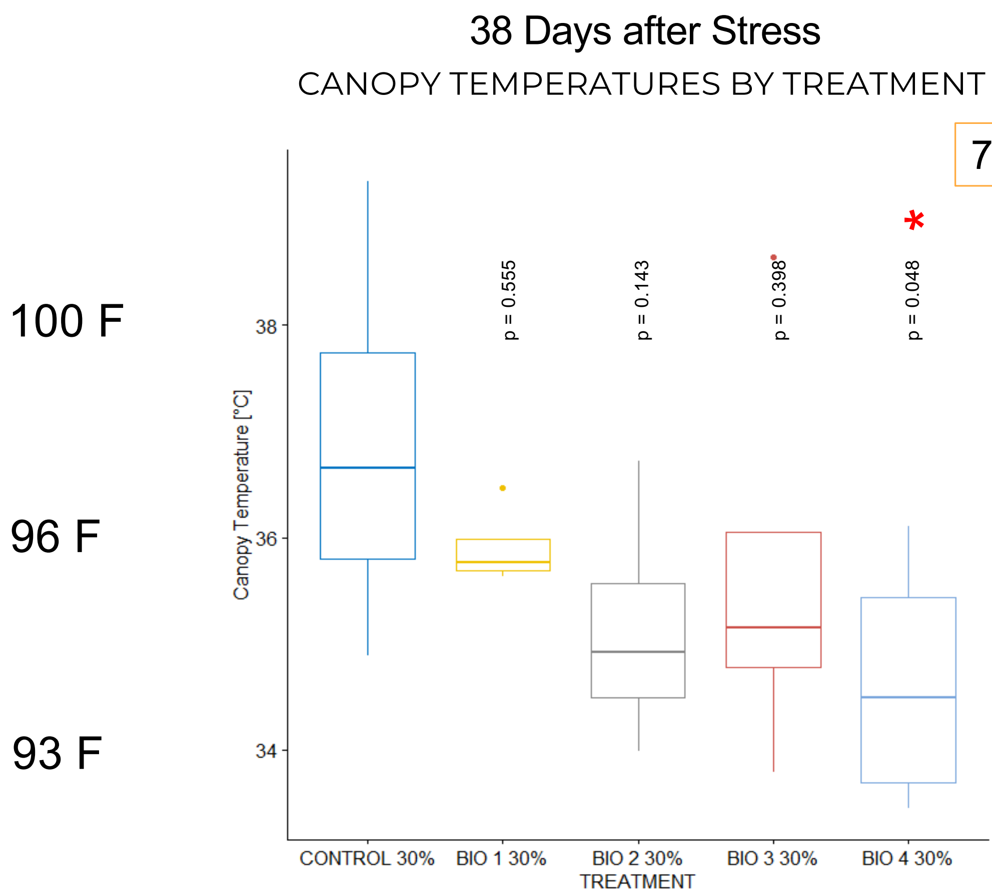
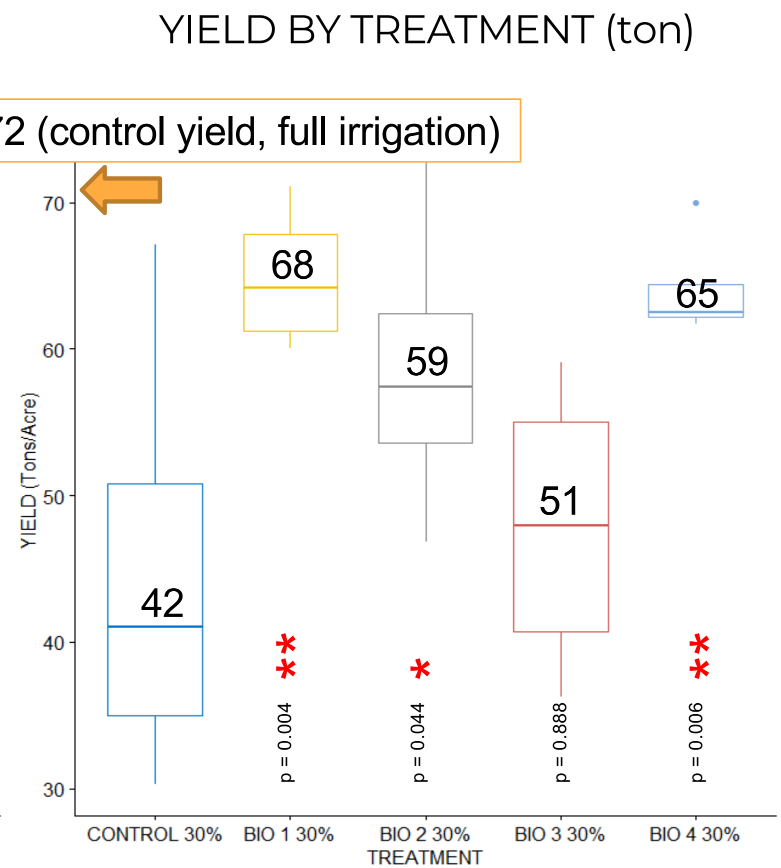
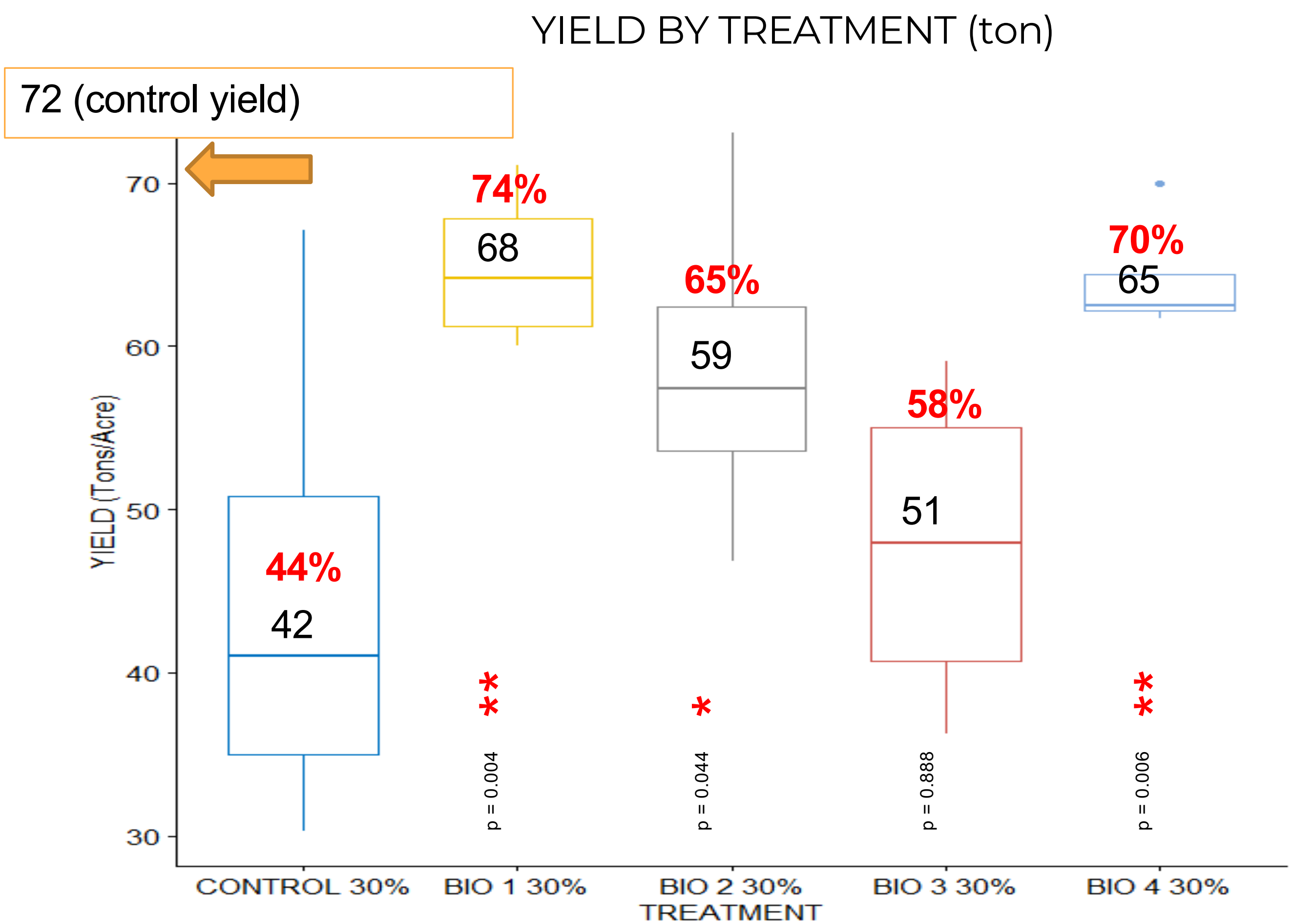

tule
Under what conditions do plants experience stress?
Which biostimulants work and how to use them!

Effect of Biostimulants on Canopy Temperature and Yield under 30% Water deficit (Processing tomato)





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



NUE_{PNB} = Biomass N/Applied plus Nmin

NUE_{PNB} (%) = Biomass N/Applied plus Nmin x100%

No significant difference in tissue N%

Nutrient use efficiency increases entirely due to stress mitigation.

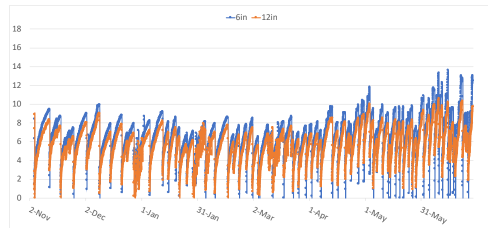
Assessing the Impact of Biostimulants on Strawberry Yield

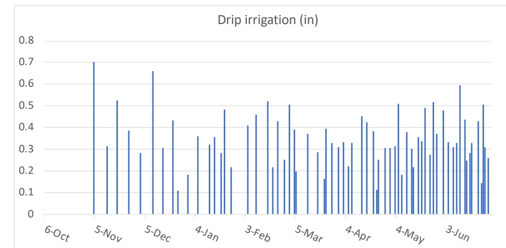
Andre Biscaro,
Irrigation and Water Resources Advisor
University of California Cooperative Extension

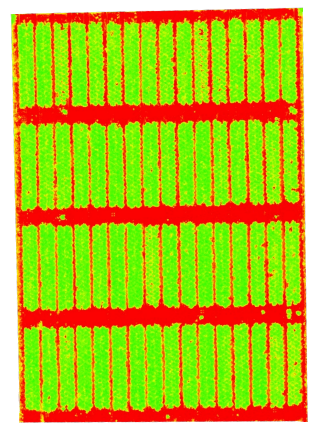
Patrick Brown,
Distinguished Professor, UC Davis

Collaborators:
Chris Greer, UCCE
Oleg Daugovish, UCCE

High Input Highly Managed and Monitored







Blue = 100% N budget
Green = 60% N budget
Red = 20% N budget
Purple = 80% N budget

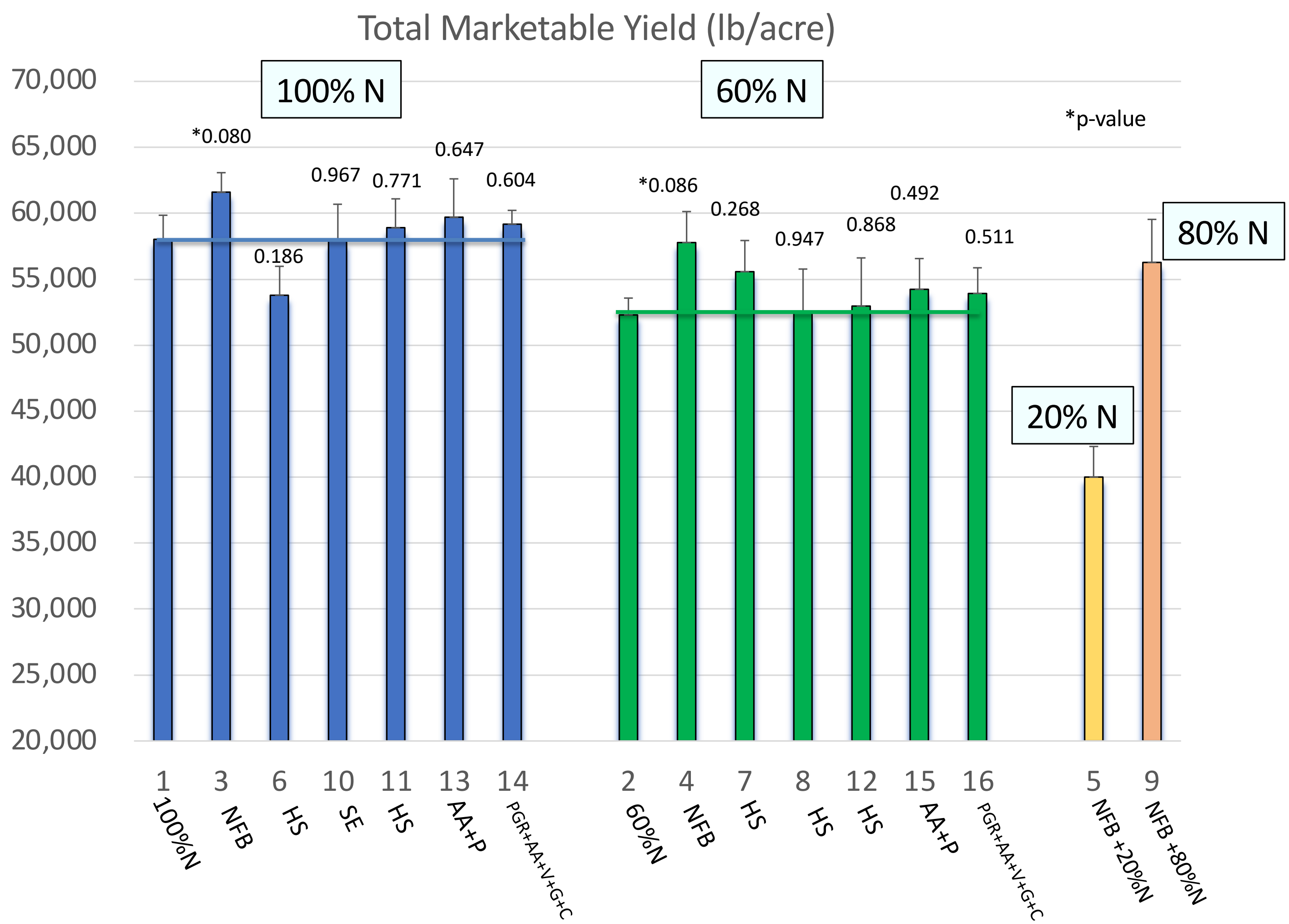
<u>Treatments:</u>

1) Control A: 100% of expected N uptake* applied as AN20
2) Control B: 60% of expected N uptake applied as AN20
3) Control A + N fixing bacteria
4) Control B + N fixing bacteria
5) 20% of expected N uptake + N fixing bacteria
6) Control A + Humic substance (lignite reacted with nitric acid) applied at 0.0625gpa/week
7) Control B + Humic substance (lignite reacted with nitric acid) applied at 0.0625gpa/week
8) Control B + Humic substance (leonardite + NPK fertilizers) applied at 0.5gpa/week
9) 80% of expected N uptake + N fixing bacteria
10) Control A + seaweed extract applied at 0.5gpa/week
11) Control A + humic substance (K extracted from leonardite) applied at 0.5gpa/week
12) Control B + humic substance (K extracted from leonardite) applied at 0.5gpa/week
13) Control A + monthly spray of amino acids and peptides
14) Control A + bi-monthly spray of of PGR, amino acids, vitamins, GABA and choline chloride
15) Control B + monthly spray of amino acids and peptides
16) Control B + bi-monthly spray of PGR, amino acids, vitamins, GABA and choline chloride

*100% expected N uptake: 4 and 9 lb N/acre/week for early (Oct-Mar) and late (Mar-Jun) stages, respectively.

30 Harvests with price range from $2.50 lb in early season, $1 lb at season end

Results



All statistics represent contrast to grower practice

Control A = 11.0% higher than Control B (p=0.041)

Cost Analysis $

Trt	N%	fruit sale ($)	AN20 cost	BS cost	Sale - fert - BS	Trt vs control A
1	100	107,064	179	-	106,885	
3	100	113,693	179	215	113,335	6,450*
6	100	99,777	179	NA	99,598	(7,287)
10	100	107,245	179	595	106,471	(414)
11	100	109,361	179	NA	109,182	2,297
13	100	110,323	179	NA	110,144	3,259
14	100	109,161	179	NA	108,982	2,097
2	60	97,182	107	-	97,074	
4	60	107,404	107	215	107,082	197
7	60	101,956	107	NA	101,849	(5,036)
8	60	98,077	107	931	97,039	(9,846)
12	60	98,693	107	NA	98,585	(8,300)
15	60	100,491	107	NA	100,384	(6,501)
16	60	100,105	107	NA	99,998	(6,887)
5	20	78,792	36	358	78,398	(28,487)
9	80	104,258	143	270	103,845	(3,040)

Total Nitrogen Cost

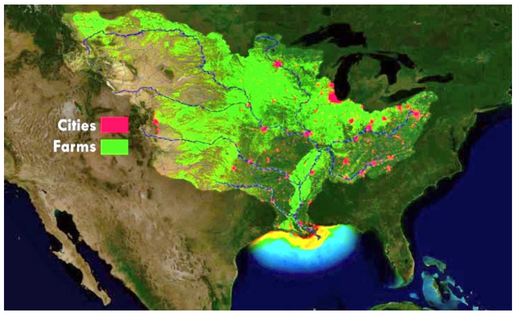
100% = $179
60% = $107
20% = $36

Total Loss
60% = - $14,000
20% = - $28,000

Full cost of Production = $85,000

Biostimulants and Nutrient Use Efficiency

PROBLEM

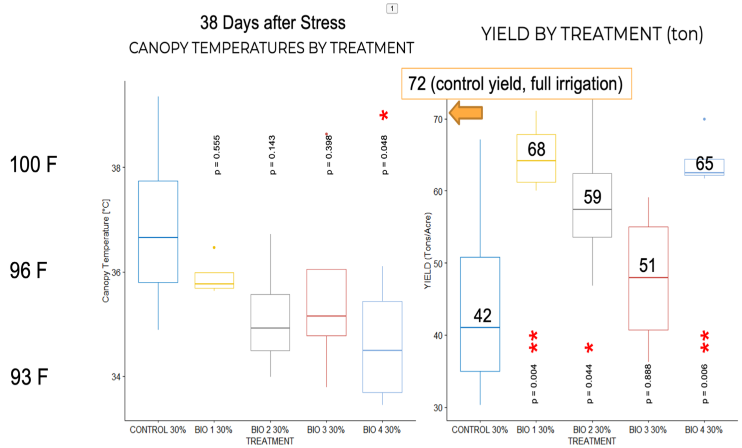


BIG DRIVER:
Consumer Demand for Sustainability and Low Environmental Footprint

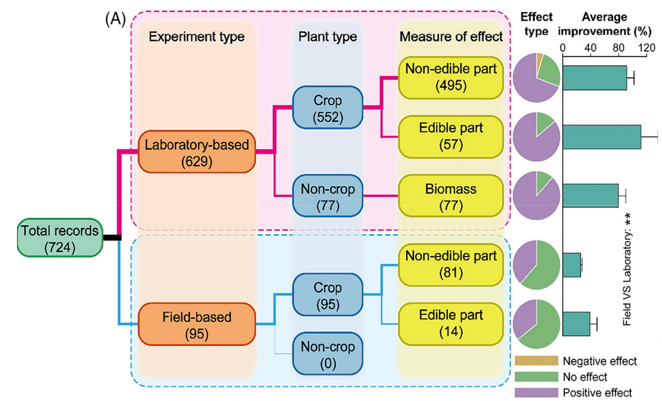
How will we meet the demands of the consumer and food system?

Retailers
Brands
Ingredient Processors
Ag Service Providers

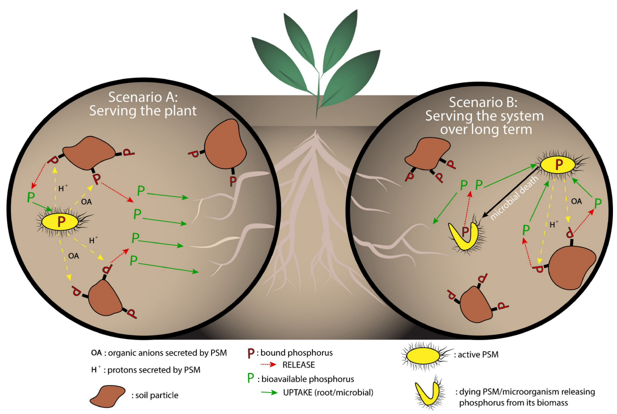
Stress Compromises NUE

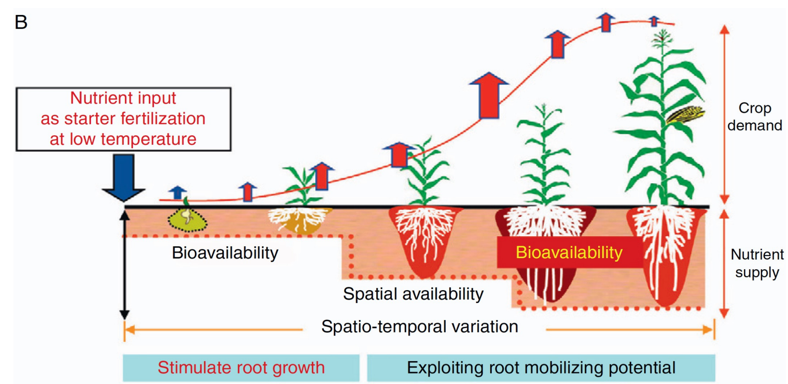


Effects are Inconsistent



CONTEXT MATTERS

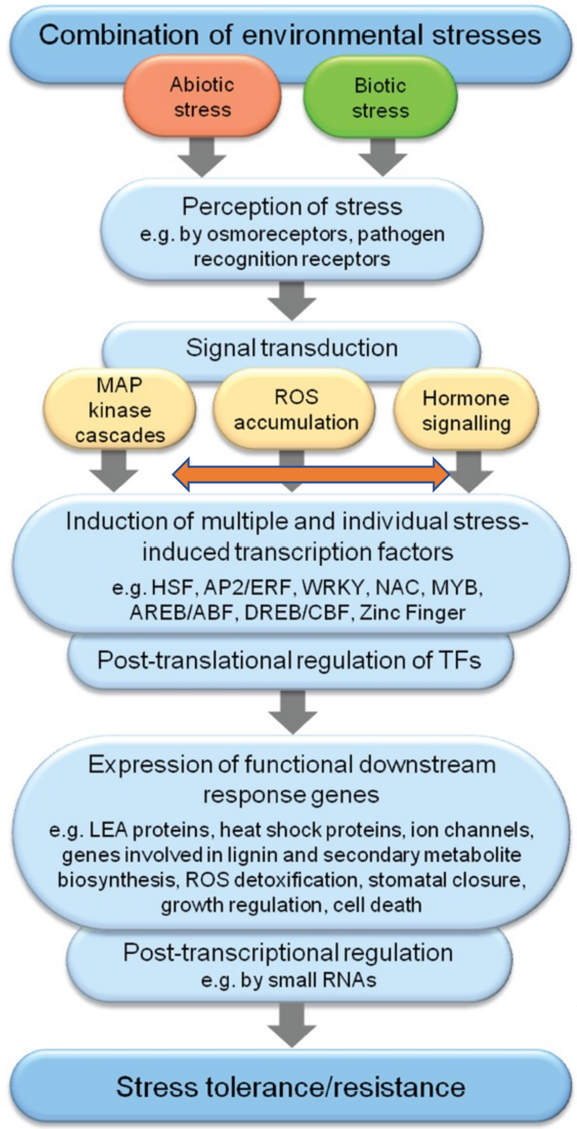




Applying biostimulants to achieve these goals = ‘Fertilizing Product’

Applying hormones/PGR’s to achieve these goals = Pesticide

Demonstrated biostimulant mediated responses.



Cytokinin, ABA, Eth, Brassinoteroids

Hormone and peptide mediated processes (Cyt, GA, IAA, SL..)

UC DAVIS
DEPARTMENT OF PLANT SCIENCES
College of Agricultural and Environmental Sciences

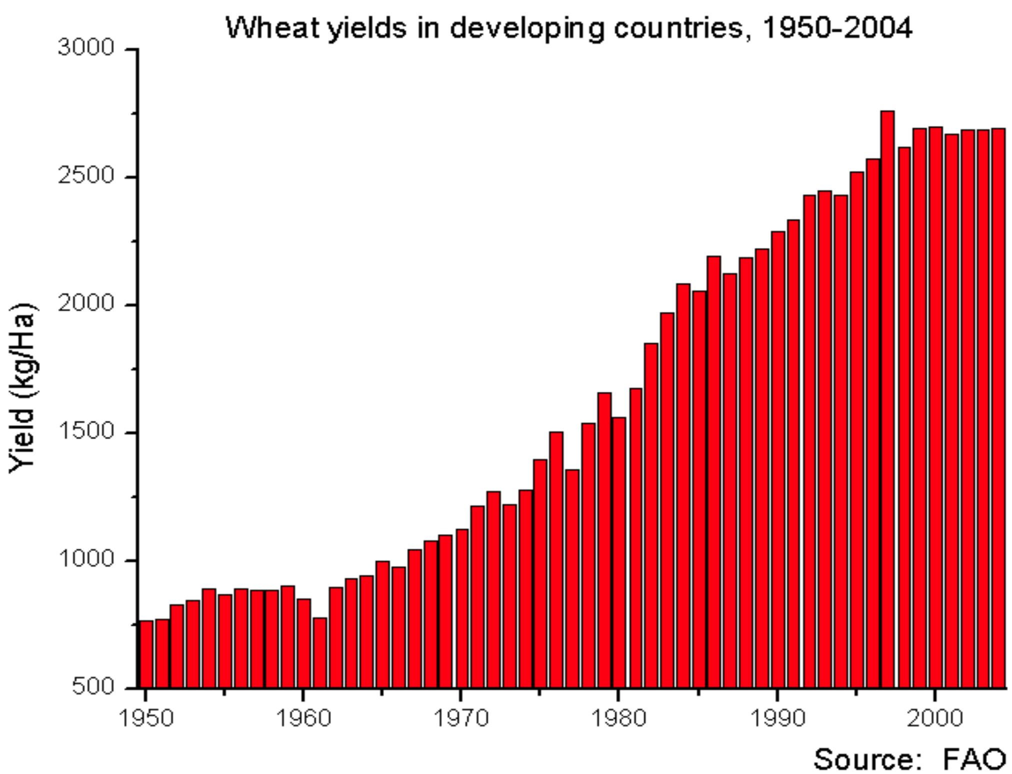
Zinc fertilization response is largely a auxin metabolism effect.

Application of Zn stimulates auxin metabolism, enhancing plant growth and altering architecture.

Is Zn therefore a PGR?

Gibberellin Manipulation was the Foundation of the Green Revolution

500% Increase in wheat, rice and corn yield



The semidwarf varieties that increase productivity 500% and fed the world, did so by changing the plant hormone gibberellic acid.

Hormone Metabolism and Signaling in Plants.
http://dx.doi.org/10.1016/B978-0-12-811562-6.00004-9
Jiayang Li, Chuanyou Li and Steven Smith. Published by Elsevier


Thank You!
Miles Hermann '07

Biostimulants: A quick history

Biogenic Stimulators… "biological materials derived from various organisms, including plants, that have been exposed to stressors …and effect the metabolic and energetic processes in humans, animals, and plants" Filatov, Blagoveshchensky (1951-1956). Coincident with the early work on plant differentiation and hormones discovery.

Biostimulant…compounds increase plant growth and vigor through increased efficiency of nutrient and water uptake" (Russo and Berlyn, 1991), "Materials of little or no fertilizer value that accelerate plant growth, usually when used at low concentrations." (Goatley and Schmidt, 1991),

Plant hormone-containing substances that can stimulate growth when exogenously applied (Schmidt, 1992), Materials that, in minute quantities, promote plant growth (Zhang and Schmidt, 1999)

'Biostimulants act on plant physiology through different pathways than nutrients to improve crop vigour, yields, quality and post-harvest shelf life/conservation." EBIC 2011

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

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Check for updates

Biostimulants in Plant Science: A Global Perspective

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