Role of Mineral Fertilizers in Climate-resilient Agriculture

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14+ crop nutrients. But much ado about nitrogen

Well……….

- ✓ Half of the global human population is fed by nitrogen fertilizers (Erisman et al. 2008)

- ✓ If Erisman et al. is right, then half of us in this room would be dead

- ✓ But that's only one-half of the story

Nitrogen is both a foe and a friend

Nitrogen as a foe: Nitrogen fertilizers contribute to:

- **Climate change** – atmospheric nitrogen losses – low NUE – GHG (N_2O)

- **Loss of aquatic life** – soil nitrogen loss – water pollution – eutrophication (NO_3)

- **Soil degradation and crop susceptibility to biotic stress** –intensive use of nitrogen + imbalanced fertilizer composition – nutrient mining – weakened tolerance to pests and diseases

Nitrogen as a friend: Balanced nutrient fertilizers (N + others) contribute to:

- **Improved crop performance** – better growth - greater biomass - more CO_2 capture (photosynthesis) = improved yield, and improved GHG (CO_2) removal
- **Improved SOM** - better microbial growth, activity, and rhizosphere functions
- **Resilient production systems** - suppressed disease incidence - improved drought tolerance - improved tolerance to salinity – improved tolerance to logging (rice)
- **Agronomic fortification of food** - balanced nutrient fertilization enriches crops with **Zn**, Fe, Cu, Ca, Mg, S, in addition to N, P(???) and K

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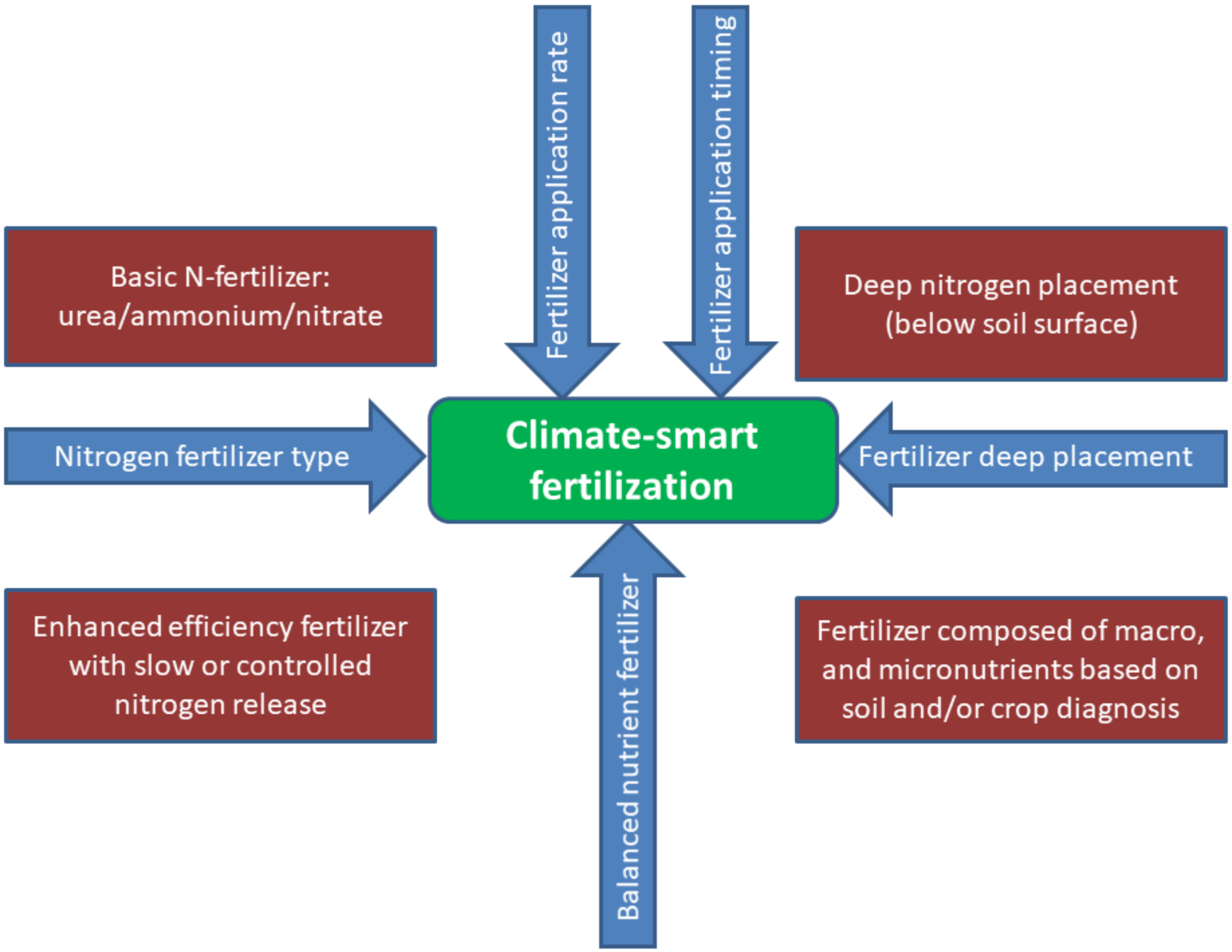
Strategies for climate-sensitive fertilization

4-R Nutrient Stewardship

- Right rate
- Right timing
- Right placement
- Right product



Focus of Presentation

"Right product":

- Balanced nutrient fertilizers

Climatic events affect crop production but are mitigable by balanced nutrient fertilization

- ❑ Climate change (CC) results in environmental events that impede agricultural production
- ❑ For Myanmar’s rice systems, these events include disease, drought, salinity, and flooding
- ❑ Balanced fertilization (BF) can mitigate both fertilizer-induced GHG production & CC events
- ❑ Little evidence, if any, of **strategic** balanced fertilization in rice production in Myanmar
- ❑ Is Myanmar missing out on the range of benefits obtainable from strategic BF regimes?

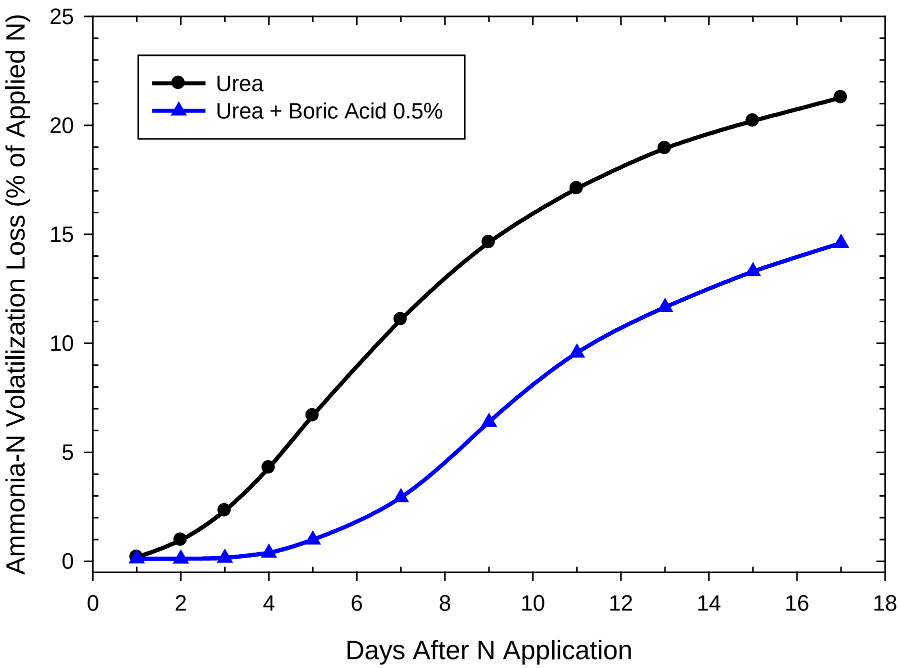
Event	Mitigating nutrients	Potential mechanism
Drought	zinc, copper, boron	Involvement in enzymatic and non-enzymatic activities related to abiotic stress and water relations; hormonal regulation of leaf stomata (Zn)
Disease	copper, zinc, boron, nickel, manganese, iron, calcium, chloride, magnesium, sulfur	Cellular activities related to induction of systemic resistance, cell wall structural integrity, stimulation of antipathogenic metabolites; direct pathogen inhibition
Salinity	potassium, zinc, iron	Reduction of sodium accumulation, enhanced anti-oxidative activities

Role of balanced nutrition in mitigating N loss

Trt	N_2O flux (mg N_2O-N m^{-2}) Soils 1	2	Trt mean
Urea	0.65	0.82	0.74 a
U-Cu	0.56	0.65	0.61 b
U-Zn	0.56	0.60	0.58 b
U-CuZn	0.44	0.60	0.52 bc
U-DMPP	0.47	0.51	0.49 c
U-DMPPCuZn	0.35	0.41	0.38 d
OneBaja	0.37	0.68	0.52 bc
U-S	0.51	0.74	0.63 b
U-Dol	0.64	0.85	0.74 a

Dol; dolomite = Mg and Ca

Khariri et al. 2016



Singh et al.

- Formulating urea with other nutrients reduces N loss
- Some nutrient elements are urease or nitrification inhibitors

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Effect of balanced nutrition at different N intensities

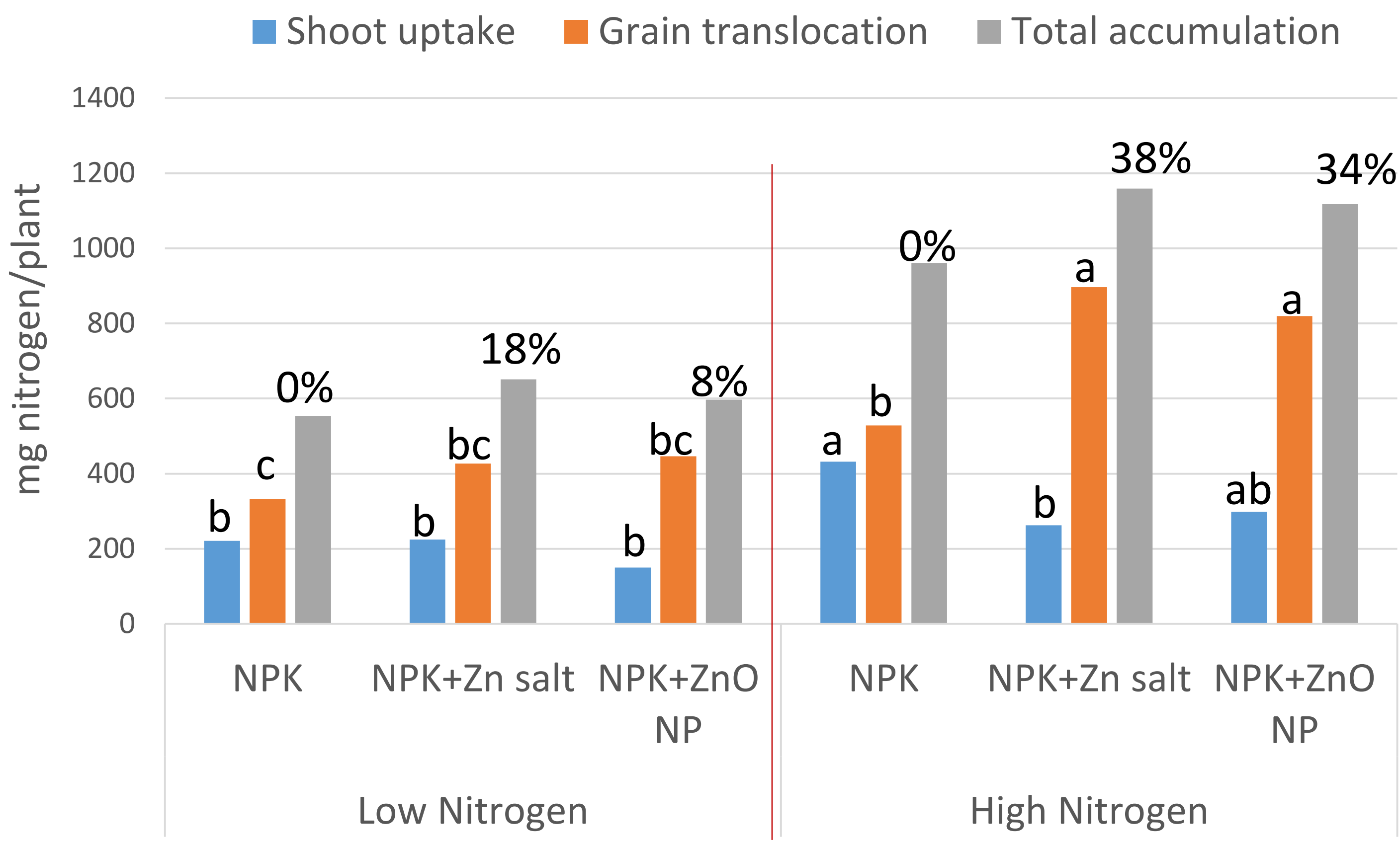
+Zn

Zn salt = $Zn\text{-}SO_4$
ZnO NP = nanopowder zinc oxide

(6 mg Zn /kg)

Low N (100 mg/kg)

High N (200 mg/kg)



- ✓ Zn enriches grains with nitrogen
- ✓ Zn increases nitrogen accumulation by plant
- ✓ Both outcomes regardless of N application rate and Zn type

Dimkpa et al. 2017a

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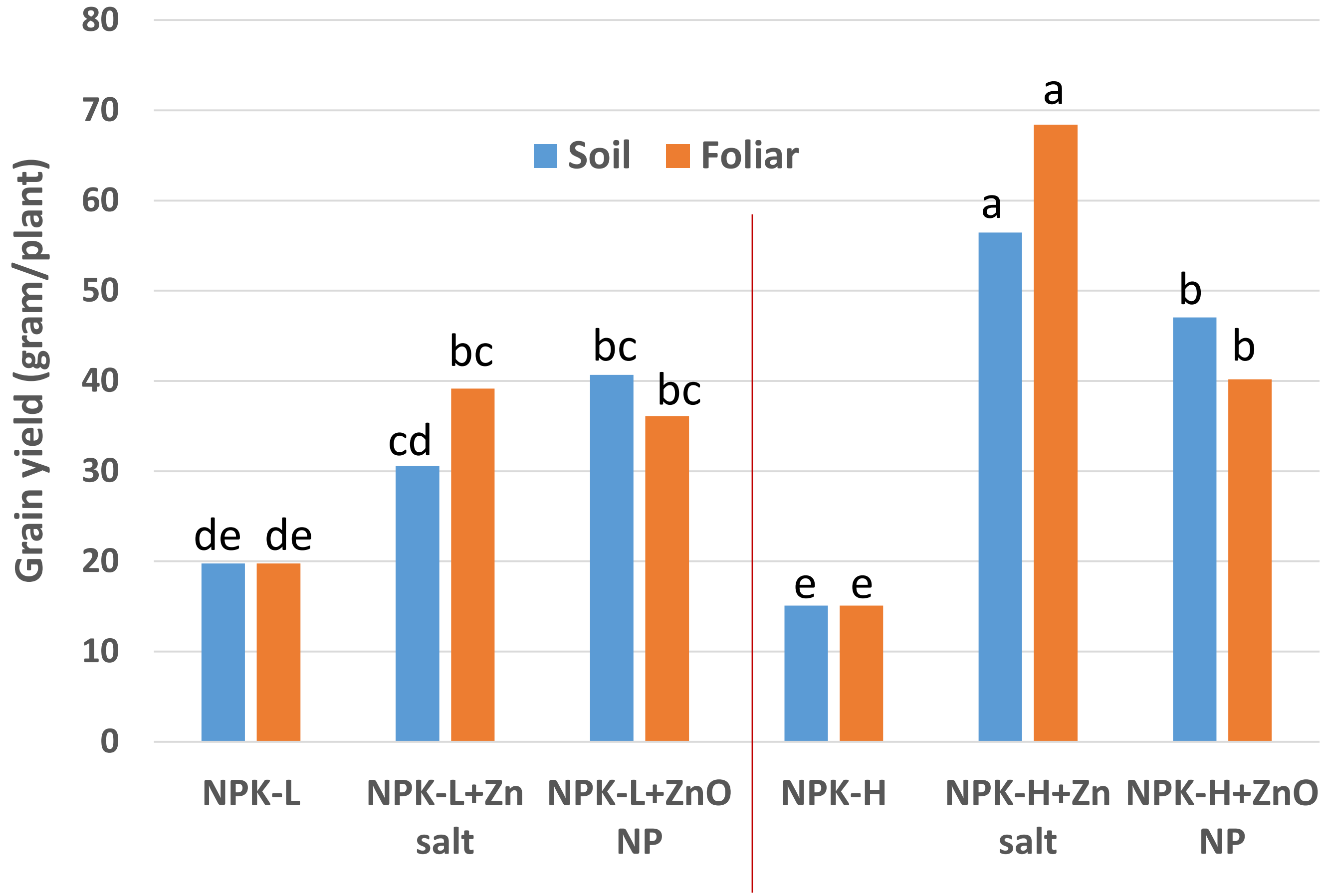
Effect of balanced nutrition on crop yield

+Zn

Zn salt (6 mg/kg)
Nano ZnO (NP)
(6 mg/kg)
Soil applied
Foliar applied

L = low N (100 mg/kg)
H = high N (200 mg/kg)



- ✓ Zn increase sorghum grain yield regardless of N application rate, Zn type, and Zn delivery route

Dimkpa et al. 2017a

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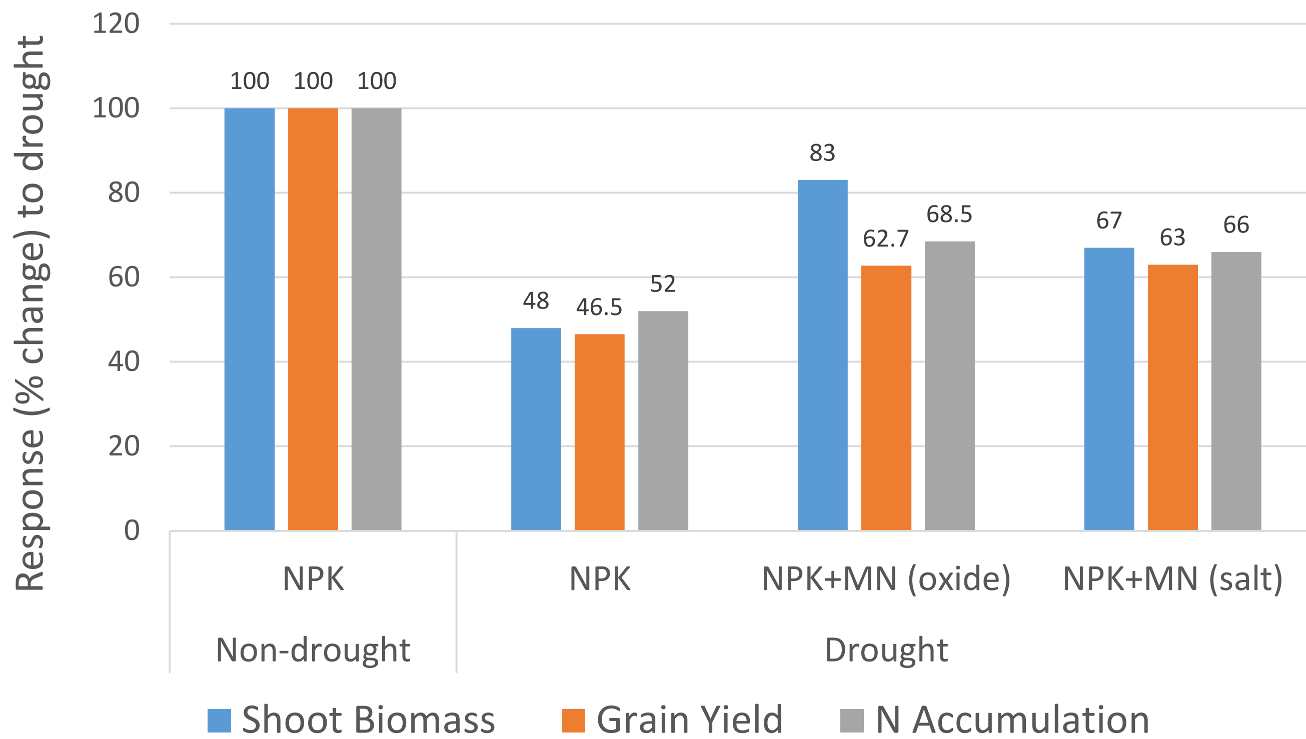
Effect of balanced nutrition on nitrogen use under drought stress

50% FMC
N (20 mg/kg)
MN = micronutrients
As oxides or salts:
Zn (2.8 mg/kg)
Cu (1.3 mg/kg)
B (0.6 mg/kg)



✓ Drought inhibits plant (soybean) growth, yield, and N accumulation
✓ Inclusion of Zn, B, and Cu mitigates drought effects

Dimkpa et al. 2017b

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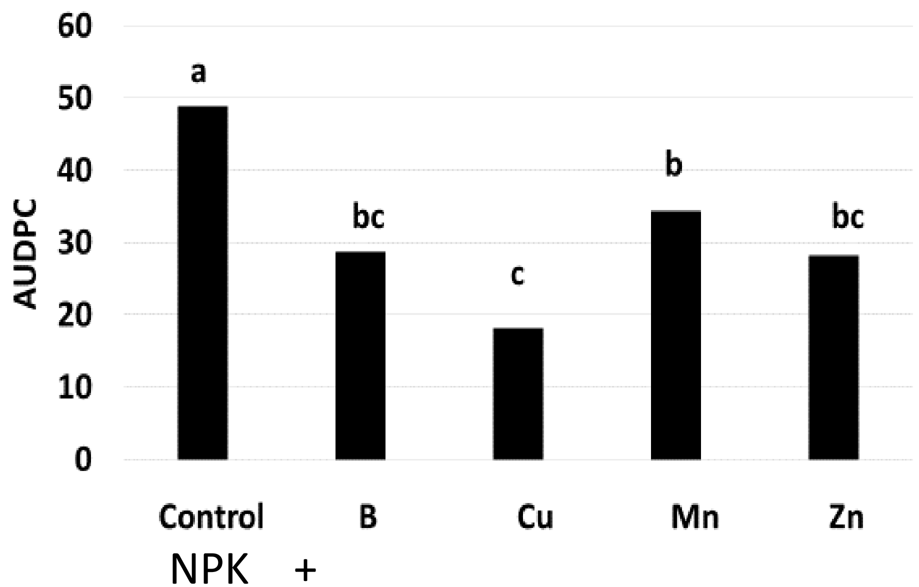
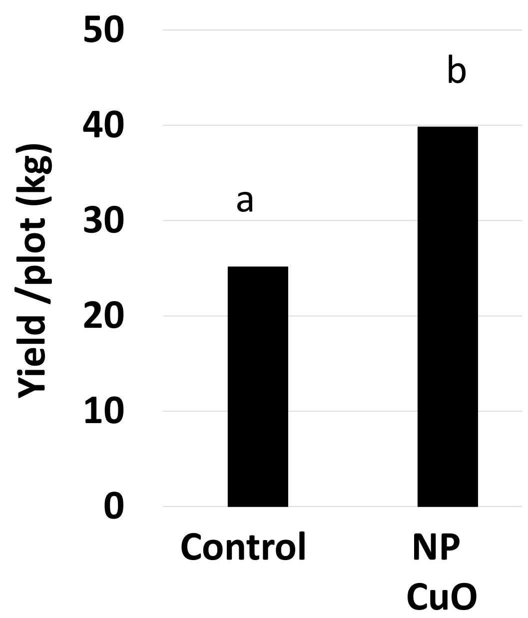
Effect of balanced nutrition under disease incidence

- Watermelon + *Fusarium* (ubiquitous soil pathogenic fungi)
- 2 ml of 1 mg/ml solution/plant (foliar spray) of each nutrient





✓ Micronutrients lower disease progression, thereby increasing yield

AUDPC = area under disease progress curve
Higher AUDPC = higher disease severance

Elmer, Dimkpa et al. (in revision)

Effect of balanced nutrition under salinity incidence

Conductivity (EC; dS M^{-1})	Parameter measured	Zinc (mg/kg) 0	10	% Change
1.1	Grain yield (g/plant)	3.57	6.35	78
6.5		3.10	3.52	14
12.3		2.24	2.49	11
1.1	Nutrient uptake	22.4	75.4	237
6.5	Zn (mg/kg)	18.6	39.7	113
12.3		15.4	30.5	98
1.1	K (mg/kg)	13.6	16.0	18
6.5		9.3	11.8	27
12.3		4.9	8.1	65
1.1	Na (mg/kg)	2.2	1.8	-18
6.5		2.8	2.3	-18
12.3		4.5	2.7	-40

Under salinity stress, Zn:

- ✓ Stimulates grain yield
- ✓ Promotes Zn uptake
- ✓ Enhances K uptake
- ✓ Inhibits Na uptake

Adapted from Keshavarz and Sadat, 2016

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Summary

Inclusion of secondary and **micronutrients** in fertilizer recommendations can achieve strategic goals related to mitigating (i) fertilizer's contribution to climate change (CC) and (ii) effect of CC on crop production:

- ❑ Increases N uptake
- ❑ Lowers N loss [volatilization (NH_3) and emission (N_2O)]
- ❑ Mitigates CC-induced yield decline
- ❑ Increases disease tolerance
- ❑ Could reduce the rate of N application
- ❑ Improves nutrient content of crops under a changing climate
- ❑ Collectively engenders a climate-resilient production system

Coating: an efficient and effective strategy to include micronutrients with nitrogen

Urea
Blank-dye-coated urea
Zn-coated urea in dye
Cu-coated urea in dye
B-coated urea in dye

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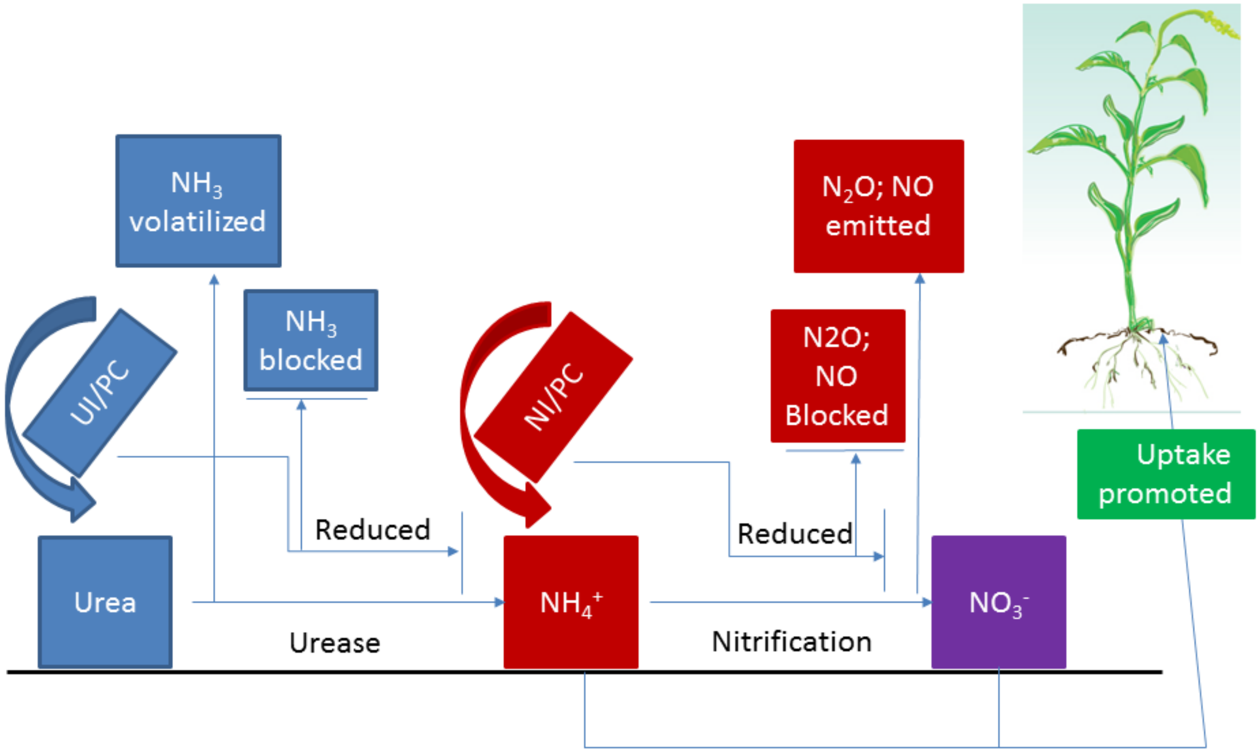
Thanks

Additional Resources

Nitrogen transformation and losses

N transformation is central to fertilizer's role in climate change



Pathways for N transformation and losses: introduction of urease inhibitor (UI), polymer coatings (PC) or nitrification inhibitors (NI) reduces N transformation rates and losses. Reduction in N loss implies increased N uptake by plants and less atmospheric and terrestrial N pollution

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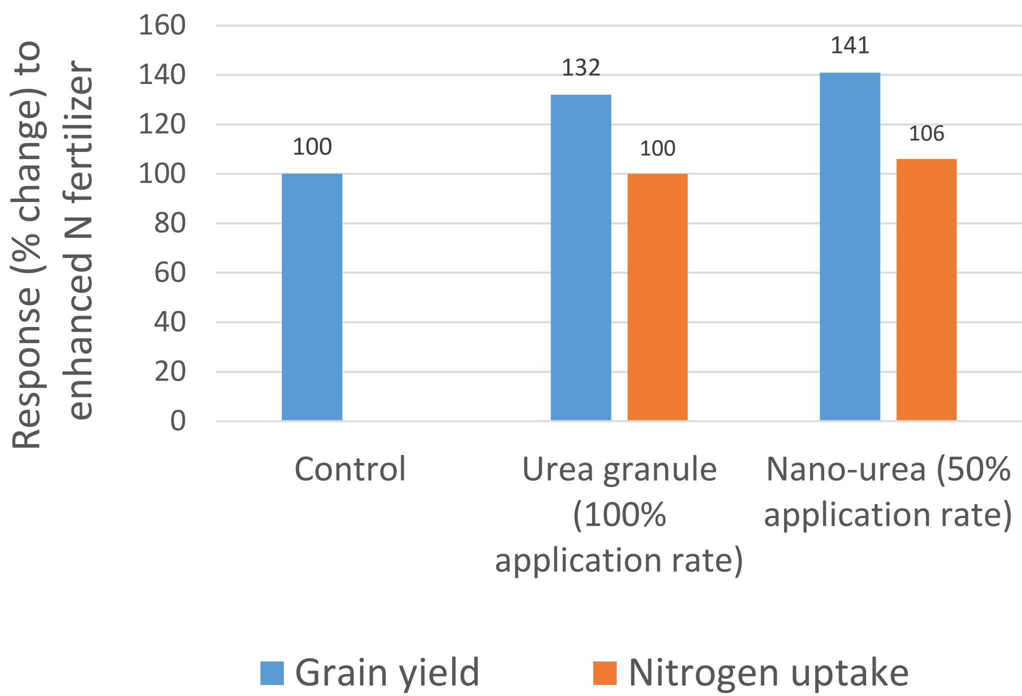
EEF (nU-HAP) for improving rice N use efficiency



50% less urea:

- ❖ Produced ca. 7% more yield
- ❖ Caused 6% more N uptake

Benefits:

- o Less fertilizer requirement
- o More grain yield
- o More nutrient use (uptake)
- o Less nutrient loss

Kottegoda et al. 2017

EEF = enhanced efficiency fertilizer

nU-HAP nano urea-hydroxyapatite (''nano-urea'')

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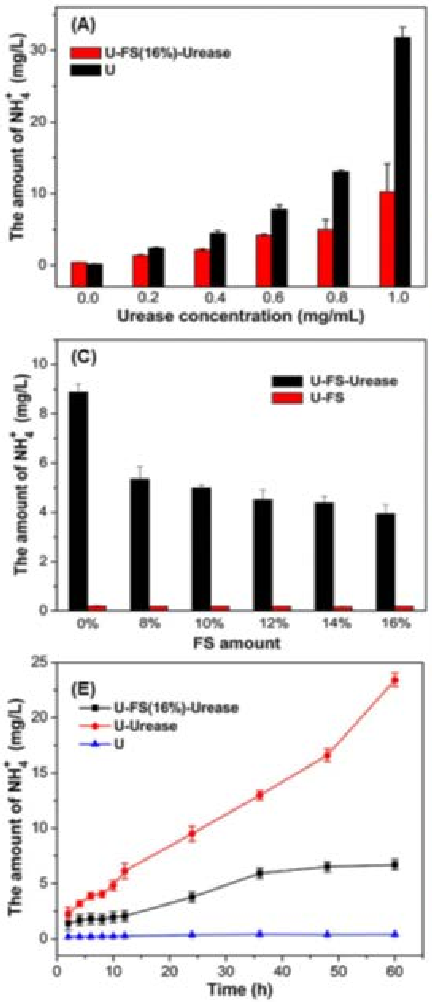
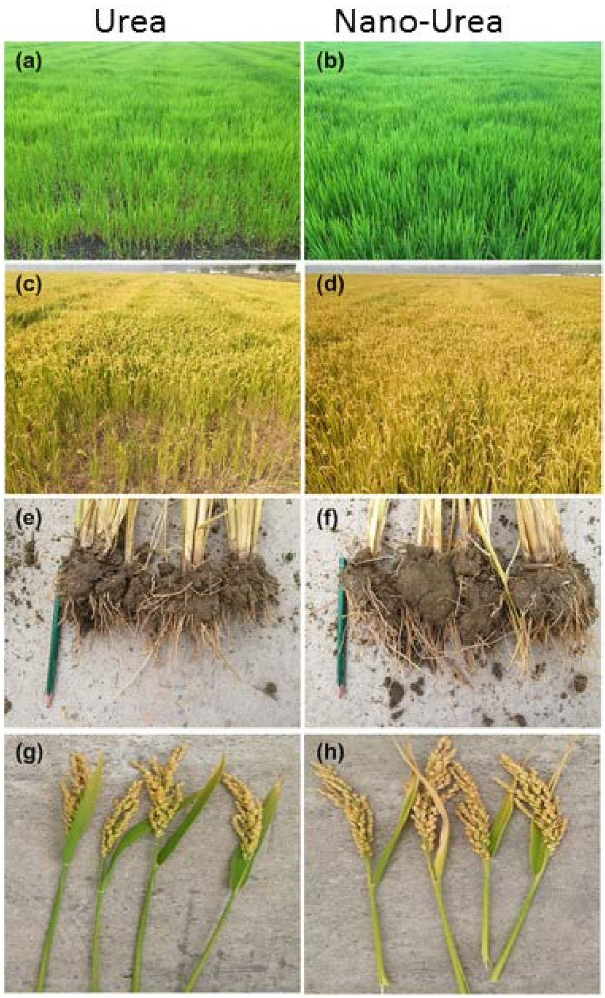
Urea hydrolysis inhibition by EEF increases rice yield

- Reduction in rate of urea hydrolysis by nUI under increasing urease concentration
- Increasing the amount of nUI decreases NH_4^+ production
- Less urea hydrolysis over time due to nUI





Effect of Nano-urea on rice performance		
Site	% yield increase over urea	% less urea used
Huanyuan County, Anhui, China	10.5	20

nUI = nano urease inhibitor

Zhou et al. 2017

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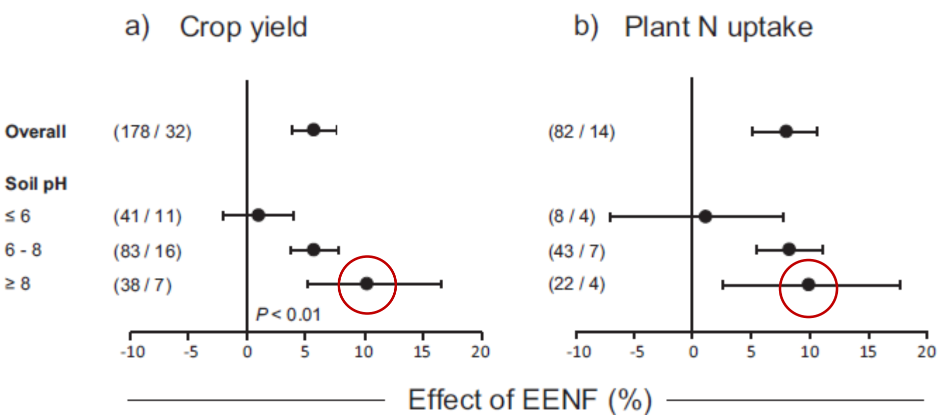
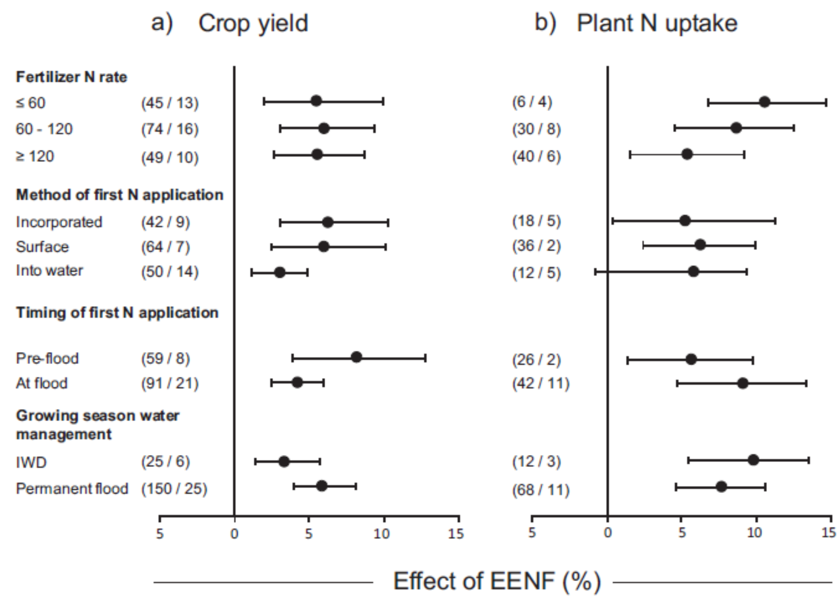
Effect of EEFs on nitrogen use by rice: meta analysis

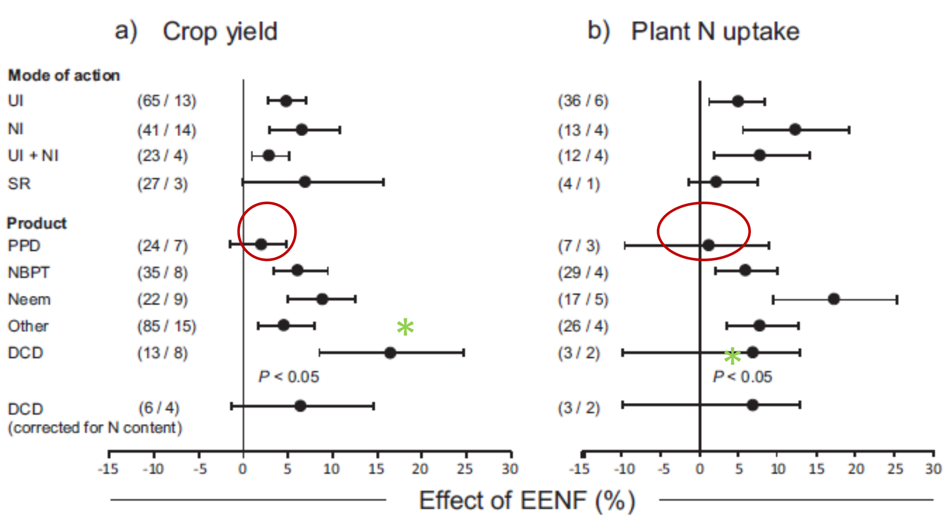
Effect based on soil pH



Effect based on fertilizer management



Effect based on mode of action



- High variability of EEF effects
- Greater effect in alkaline soil
- N- management (rate, method, timing) all critical
- All EEFs are not created equal*

Linquist et al. 2013

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