UNIVERSITY OF ARKANSAS

Improving the Efficiency of Soil and Foliar Nitrogen Fertilization with a Urease Inhibitor

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The Problem

- The cotton crop needs large amounts of nitrogen, about 125 kg N/ha.
  - 2 – 5% of plant dry matter *(Marschner, 1995)*
  - Involved in many metabolic processes, protein and nucleic acids etc
- N deficiencies result in poor growth and lower yields.
  - Decreased leaf area, growth rate, protein, photosynthetic rate, and hydraulic conductivity , and increased fruit shed, root:shoot ratio, and premature cutout *(Radin and Mauney, 1986; Wullschleger and Oosterhuis, 1990)*
- Cotton has low N-use-efficiency, only about 20-30 % of N applied is recovered by the plant *(Karlen et al., 1996; Constable and Rochester, 1988)*
- Nitrogen fertilizer is expensive and constitutes >10% of total production cost.

Recovery Efficiency

- ↑N Uptake = ↑N Availability / ↓N losses

✓Increase availability by N(urea) Fertilization

✓Decreases losses using additives to inhibit loss of N

Urease Inhibitor : *N-(n-butyl) thiophosphoric triamide* (NBPT)

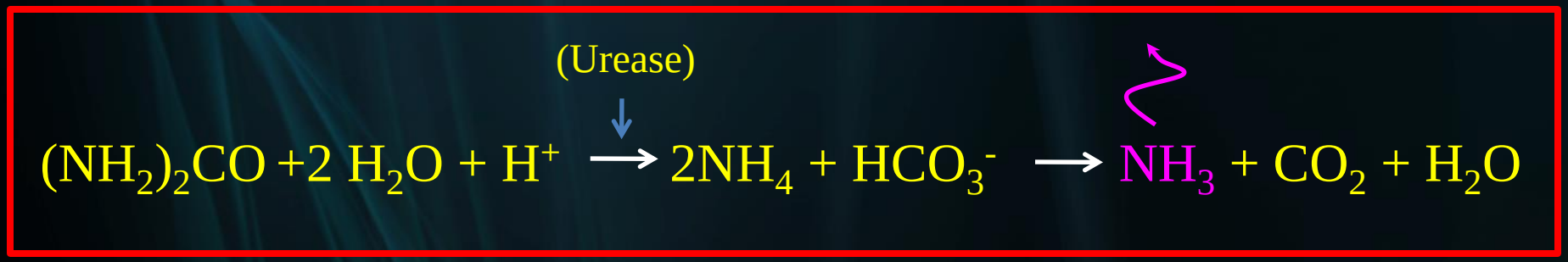
Inhibit urea hydrolysis - ↓ NH_3 volatilization

Nitrification inhibitor - *Dicyandiamide* (DCD)

Inhibit nitrate formation in the soil - ↓ leaching and denitrification

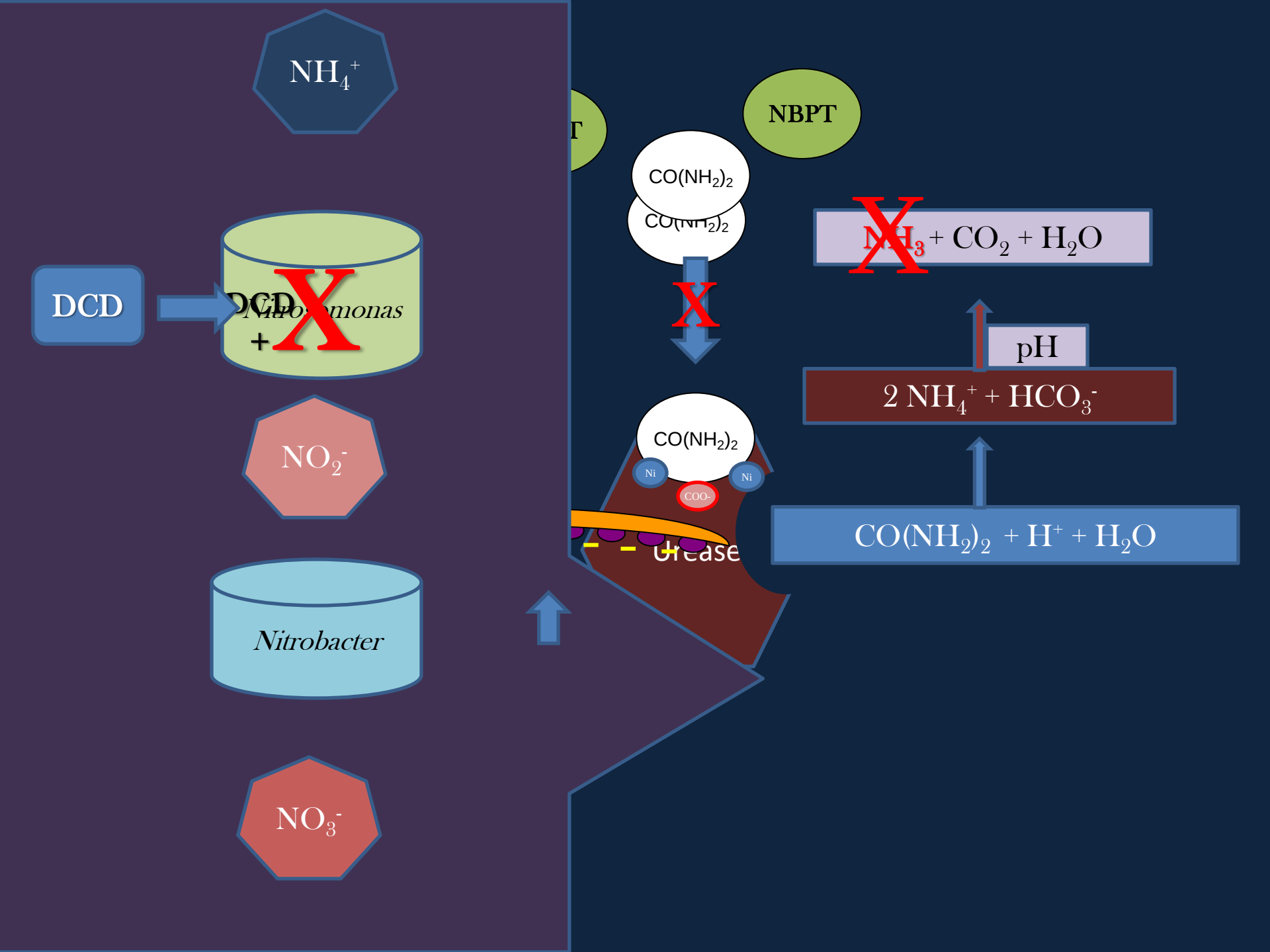
NBPT

- *N-butyl thiophosphoric triamide* - Urease Inhibitor



Benefit of NBPT to soil applied urea is well understood.

But addition of Urease Inhibitor to Foliar Urea ?


NH_4^+
NBPT
$CO(NH_2)_2$
$CO(NH_2)_2$
$NH_3 + CO_2 + H_2O$
DCD
DCD
+
Nitrosomonas
pH
$2\ NH_4^+ + HCO_3^-$
NO_2^-
$CO(NH_2)_2$
Ni
Ni
COO-
Urease
$CO(NH_2)_2 + H^+ + H_2O$
Nitrobacter
NO_3^-

Cotton

- Only limited research:
  - ✓ NBPT
    - Increased ^{15}N recovery (*Earnest and Varco, 2006*)
  - ✓ DCD (1980s)
    - Results in yield - adequate rainfall conditions (*Frye et al., 1989; Gordon et al., 1990*)
    - Toxic effect - concentrations >15% (*Reeves et al., 1988; Reeves and Touchton 1986, 1989*)

- Little is known about:
  - ✓ Effect of these inhibitors on the physiology and growth of cotton.
  - ✓ Cotton response to soil and foliar applications of NBPT and DCD
  - ✓ Effects of the inhibitors under stress conditions

OBJECTIVE:

To study the effects of soil- and foliar- applied urea with NBPT and DCD on cotton growth and yield and effect of heat and salinity stress.

Studies Conducted:

1. Physiological and yield responses of field-grown cotton to **soil** application of Urea with NBPT and DCD.

2. Physiology and yield responses of cotton to **foliar** application of Urea with NBPT.

3. Influence of High Temperature and Salinity on Urea fertilization with NBPT and DCD.

Physiological and Yield Responses of Field-Grown Cotton to Soil Application of Urea with NBPT

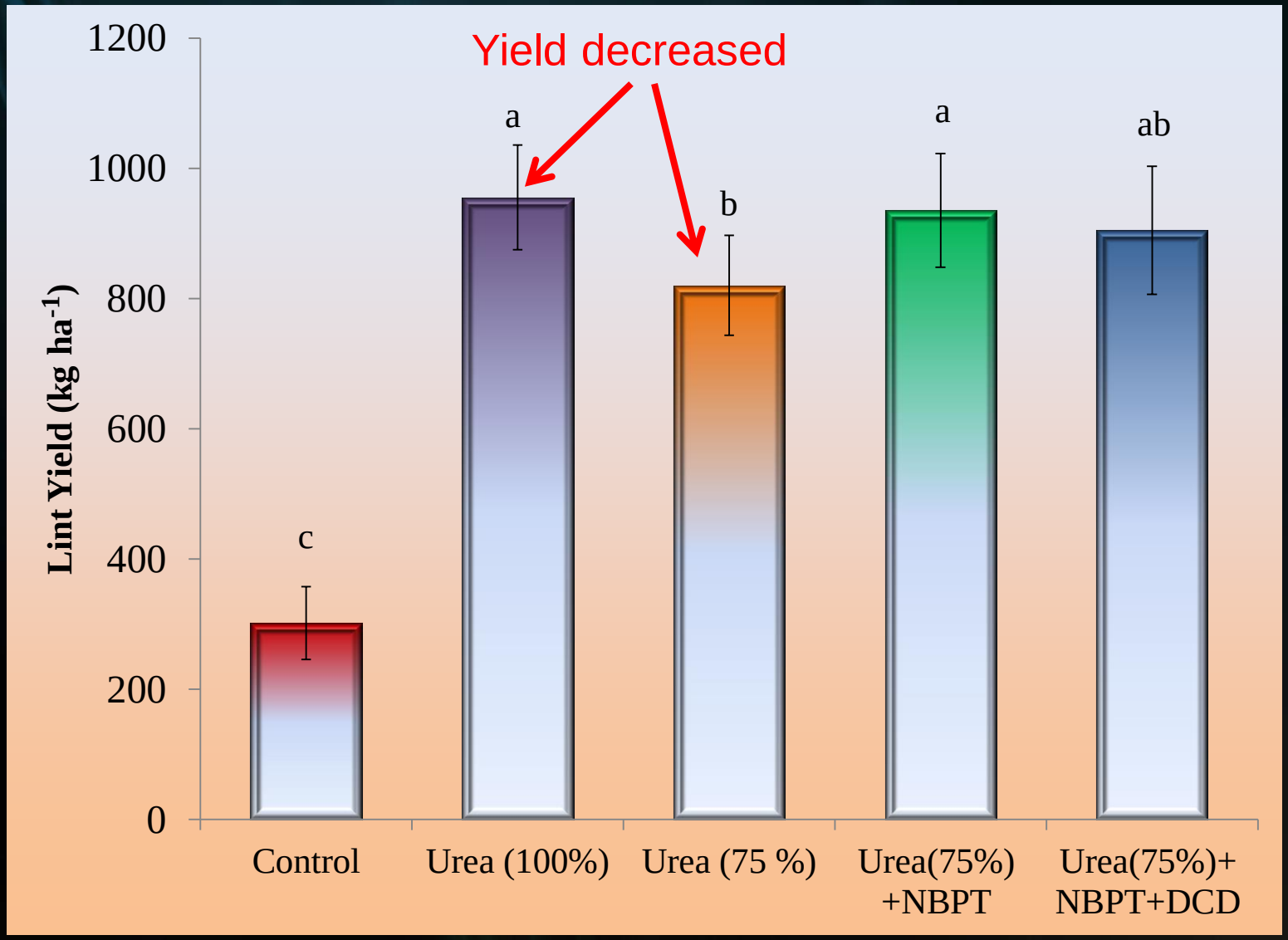
Material and Methods

- Location: Marianna, Arkansas
- Cultivar: ST 4554 B2RF – standard management (except N)
- Design : RCBD with 5 treatments and 5 replications

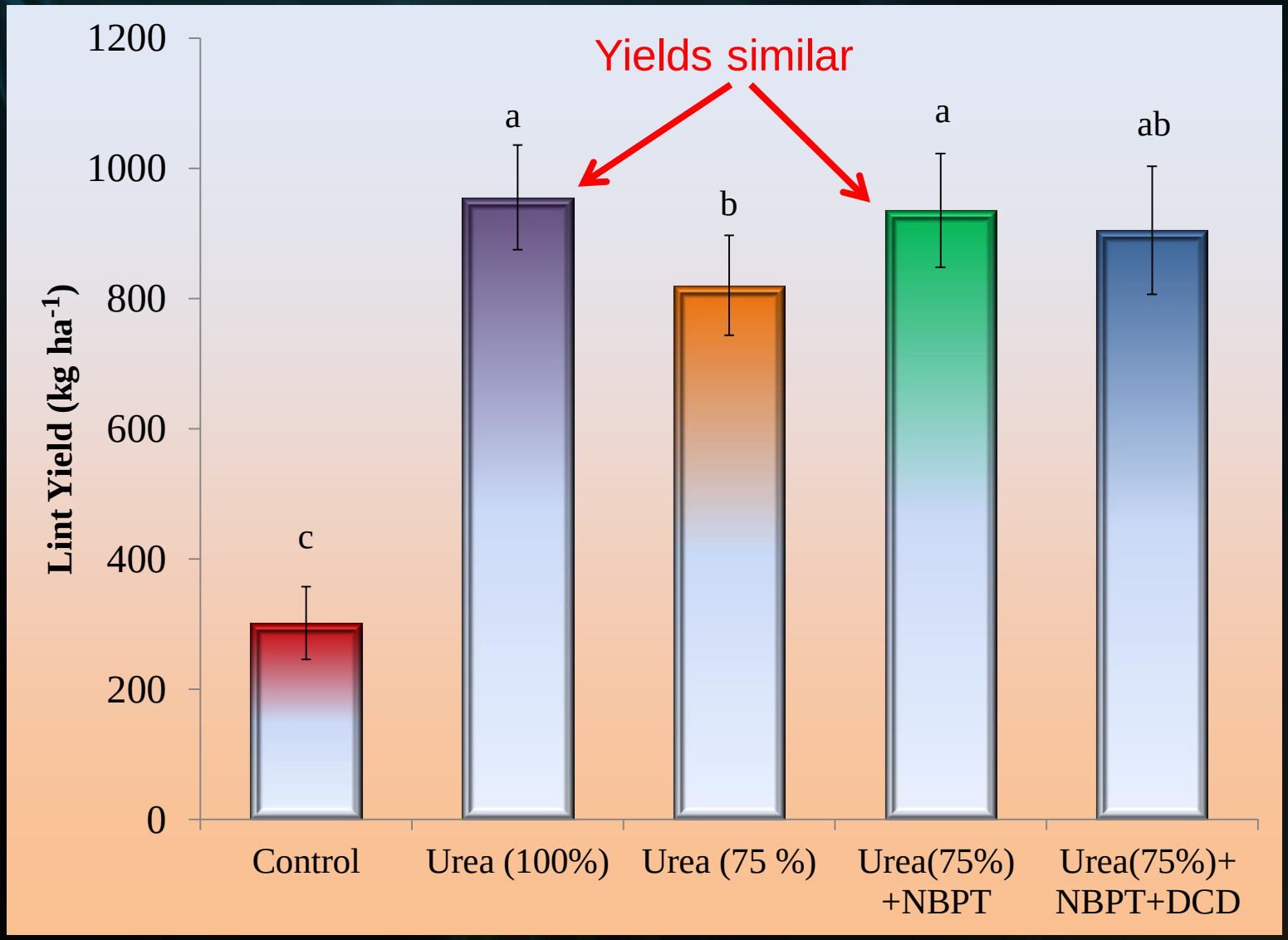
Treatments	N Rate (kg/ha)	N Source	Split Applied
Treatment 1	0	-	
Treatment 2	125 (100%)	Urea	At 10 days After Germination
Treatment 3	94 (75%)	Urea	
Treatment 4	94 (75%)	Urea + NBPT (Agrotain)	At PHS Stage
Treatment 5	94 (75%)	Urea+NBPT+DCD (Super U)	

Measurements: N uptake, partitioning, N use efficiency, chlorophyll, cotton yield

Effect of NBPT and DCD with Urea on Yield



Effect of NBPT and DCD with Urea on Yield



Control

Urea-100

Urea-75

Growth reduced

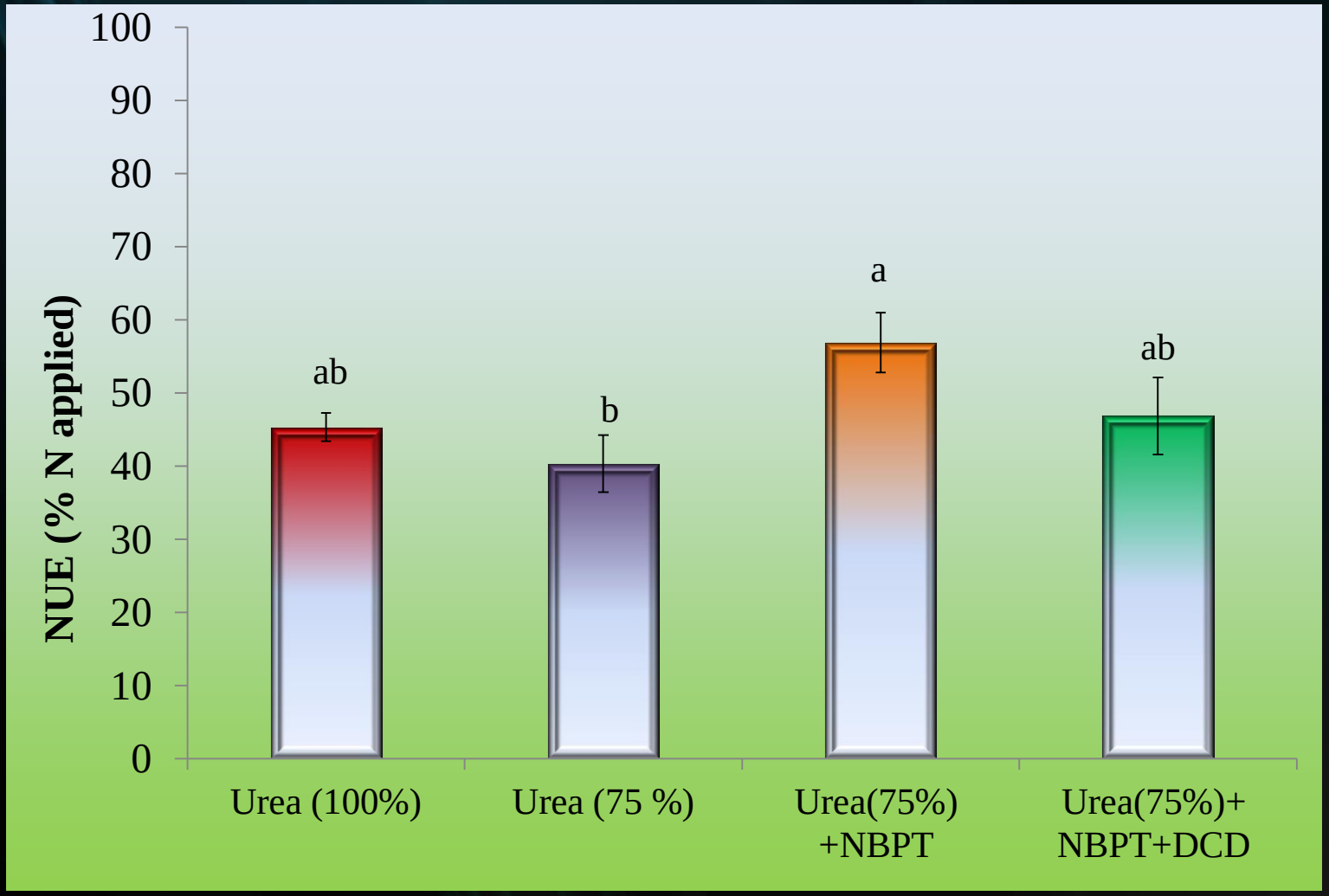
Growth similar

Urea-75+NBPT

Cotton growth in the five treatments

Urea-75+NBPT+DCD

Effect of NBPT and DCD with Urea on Nitrogen Use Efficiency



Nitrogen Use Efficiency = [N content of treatment – unfertilized control / Applied N] x 100%

Summary

(Field Experiments : Soil Applications)

- Application of urea with NBPT increased N fertilizer use efficiency of cotton.
- Sub-rates of nitrogen with NBPT maintained cotton growth and yield equal to the levels of the full recommended urea application.
- Addition of DCD to urea had no beneficial effect on yield or nitrogen use efficiency

To Study the Effects of Foliar Urea Application with NBPT on Cotton Plants

FOLIAR UREA

Foliar Nutrient Application

- Main Purpose: Supplement Soil Nutrients
  - (+) low cost, rapid response , avoid root problems
  - (-) foliar burn, chemical incompatibility, limited amount

Urea – main N source for foliar N application

- Rapid absorption, low salt index and low phytotoxicity

Results of foliar urea in cotton yields

- Variable*:* related to soil conditions, N availability, fruit load and environmental conditions. *(Maples and Barker, 1993; Oosterhuis and Bondada, 2001; Roberts et al., 2006; Wilborn et al., 2006)*

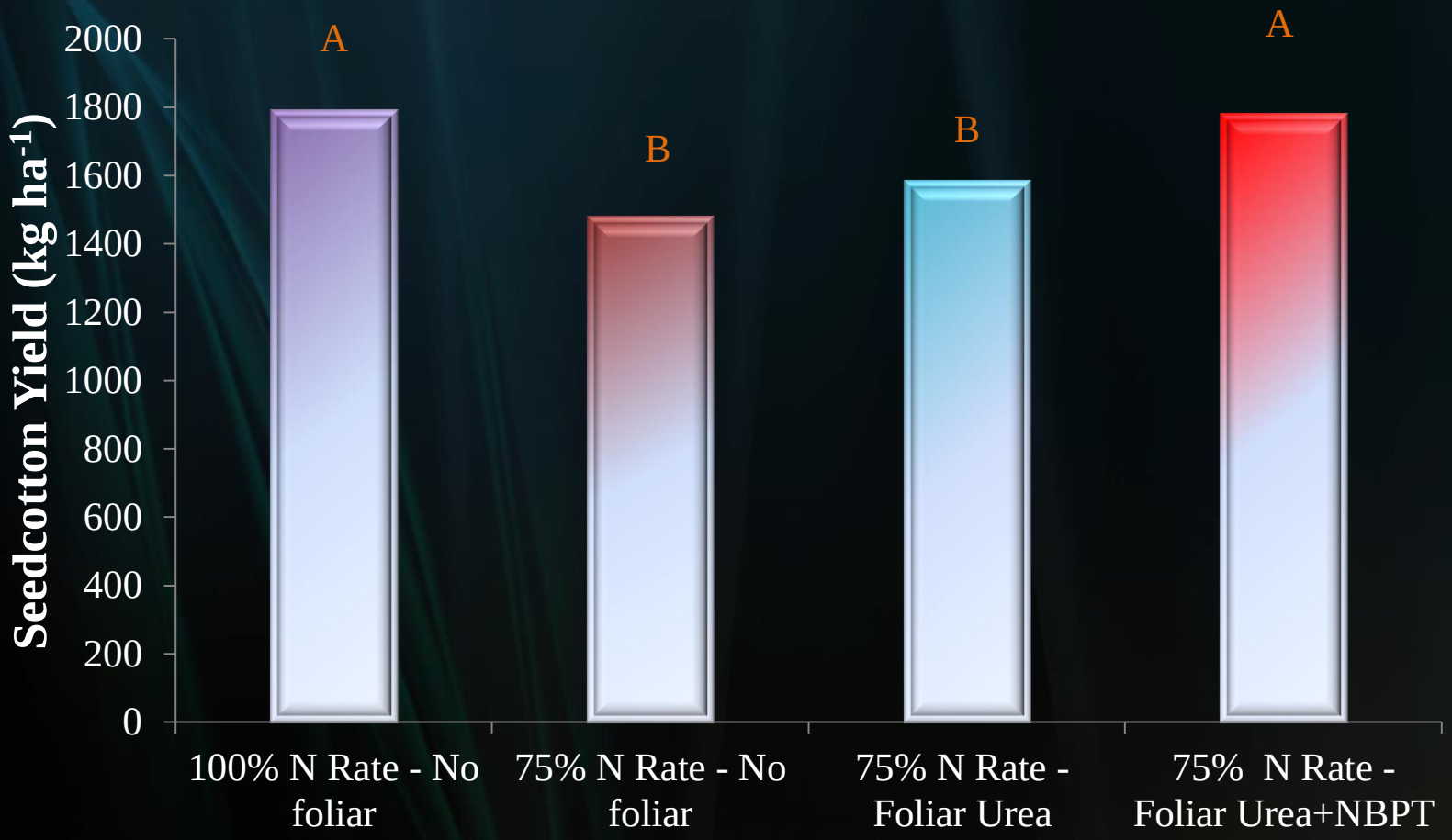
Field Study: Foliar Application

- Location: Lon Mann Cotton Research Station, Marianna, AR
- Cultivar: ST 4554 B2RF – Standard Management (Except N)
- Design : RCBD with 4 treatments and 5 replications

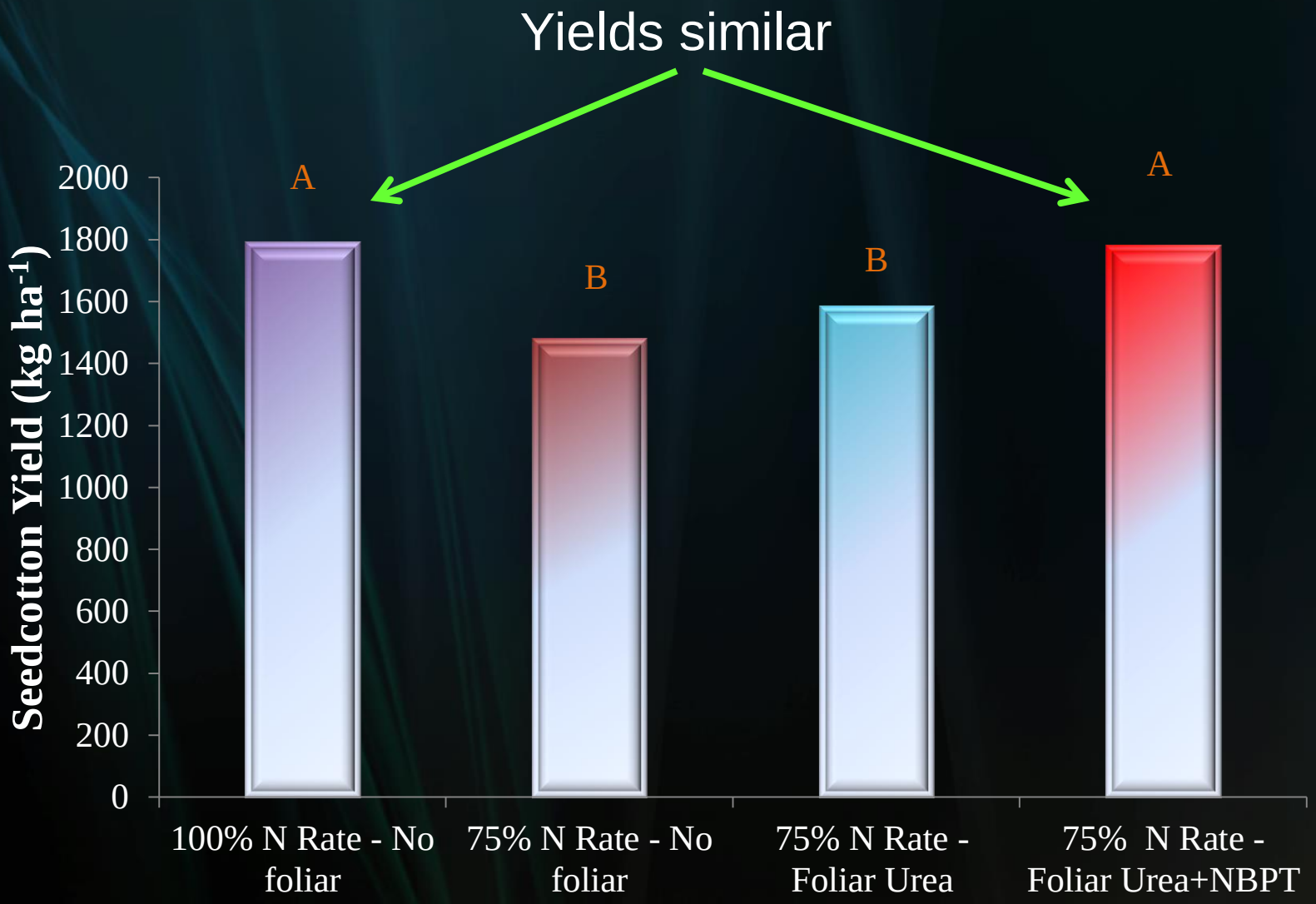
Treatment	Nitrogen	
	Soil N Application (kg/ha)	**Foliar Nitrogen Application (12 kg N/ha)**
1. 100% Soil N Rate – No Foliar	112 (100%)	No
2. 75% Soil N Rate – No Foliar	84 (75%)	No
3. 75% Soil N Rate - Foliar Urea	84 (75%)	Urea *at FF and FF+2weeks*
4. 75% Soil N Rate - Foliar Urea + NBPT	84 (75%)	Urea + NBPT (0.84%) *at FF and FF+2weeks*

- Measurement:
  - Urea uptake, urease, membrane leakage and seedcotton yield

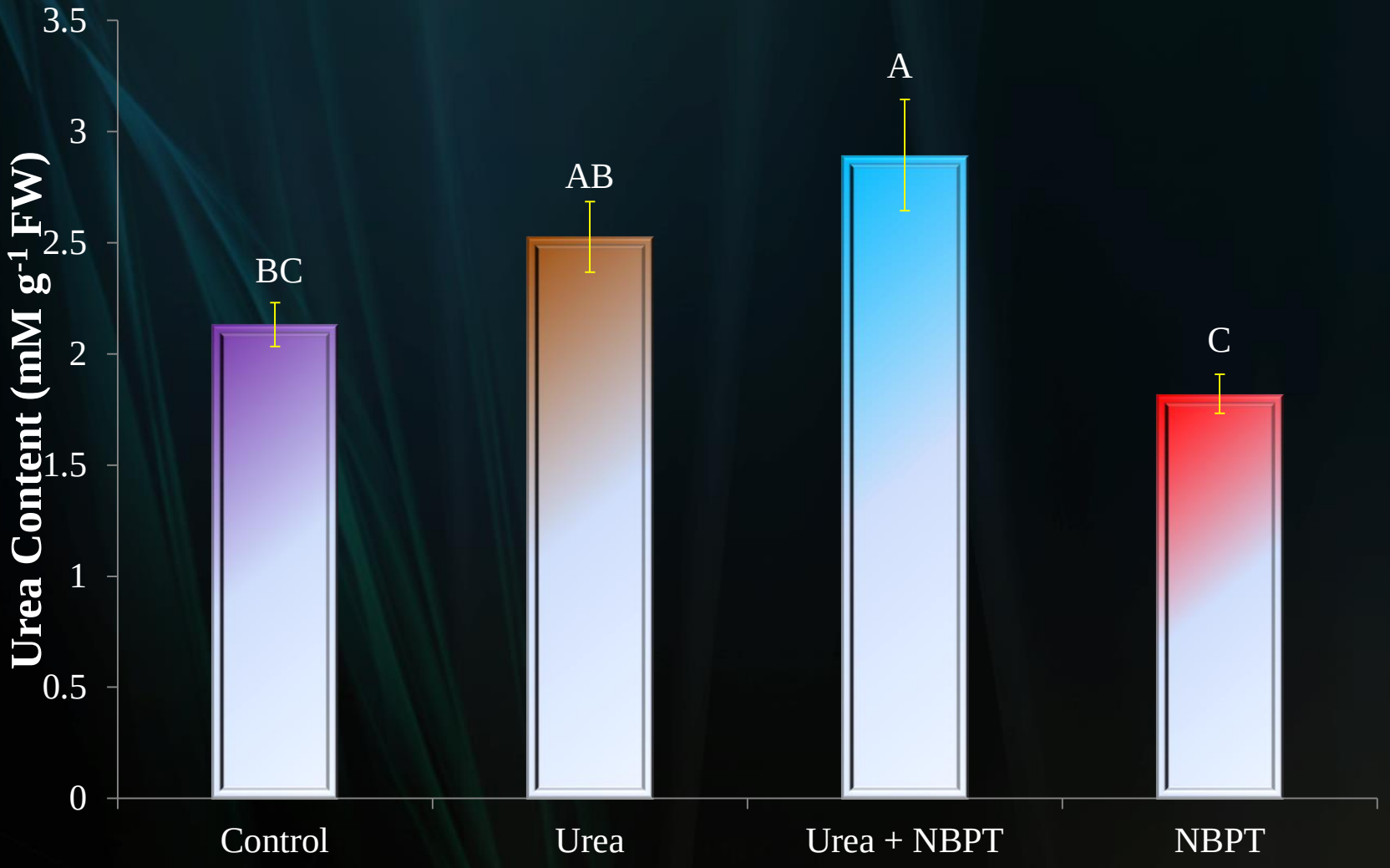
Effect of Foliar Applications on Yield



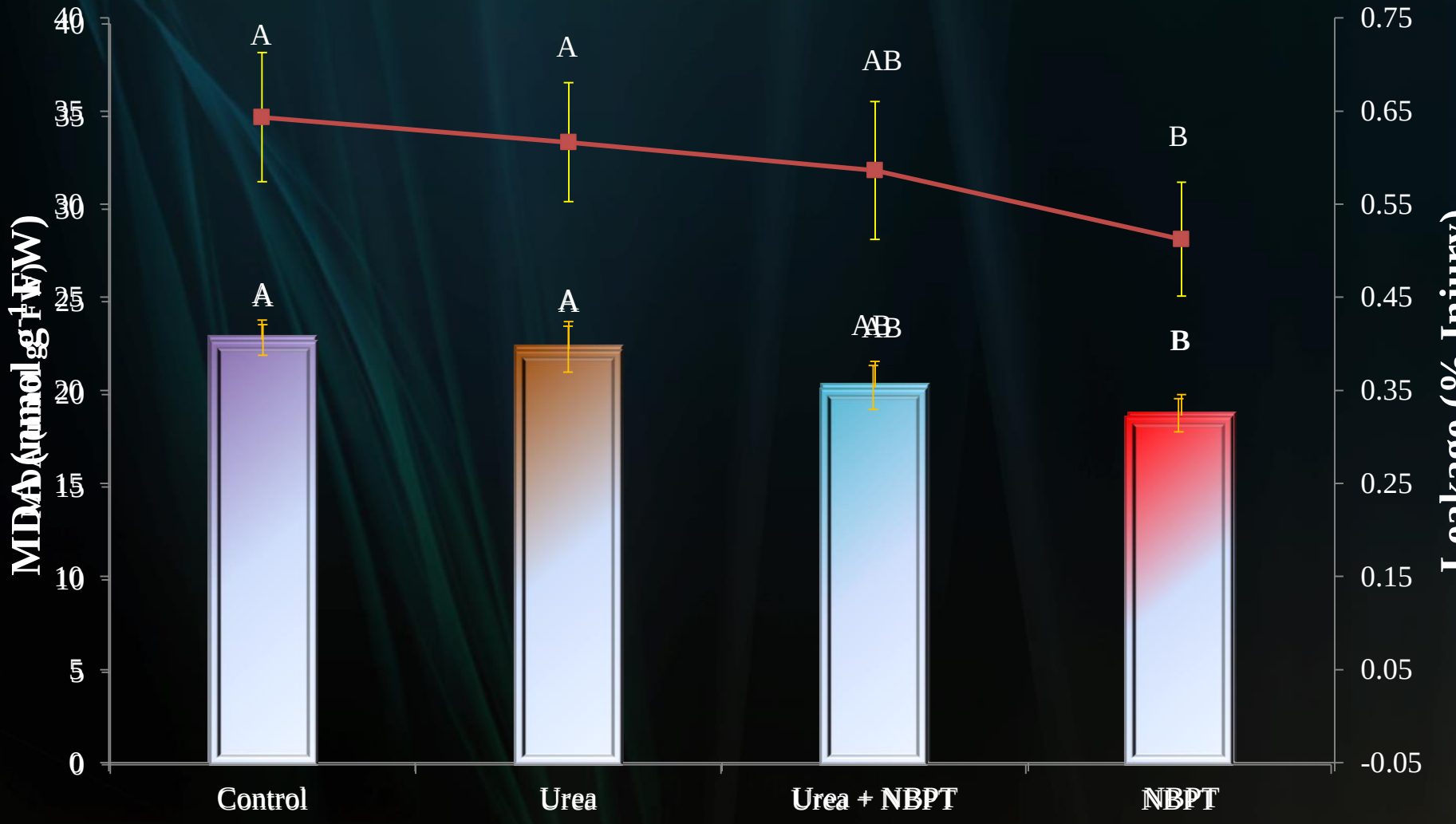
Effect of Foliar Applications on Yield



Effects of Foliar Applications on Leaf Urea Concentration



Effects of Foliar Applications on Membrane Degradation and Leakage



Summary

(Field Experiments : Foliar Applications)

- **Addition of NBPT to foliar applied urea inhibits leaf urease activity and has the potential of increasing cotton yield.**

- **Significant yield response in 1 of 3 years. May be related to plant growth activity and environmental conditions at the time of application.**

Influence of High Temperature and Urea Fertilization with NBPT and DCD on Cotton Growth

Temperature Problem

- Cotton originates from warm climates but does not grow and yield best under high temperatures.

  However, temperatures during the season in the US Cotton Belt are normally above 95F (a threshold for decreases in growth).

- High temperatures effect all aspects of growth including germination, emergence, root growth, vegetative growth and yield development.

  Explicit among these detrimental effects on growth is the absorption, translocation and assimilation of nutrients such as nitrogen.

OBJECTIVE:

To evaluate the effect NBPT and DCD on the physiology and growth of cotton under normal and high temperature conditions.

Material and Methods

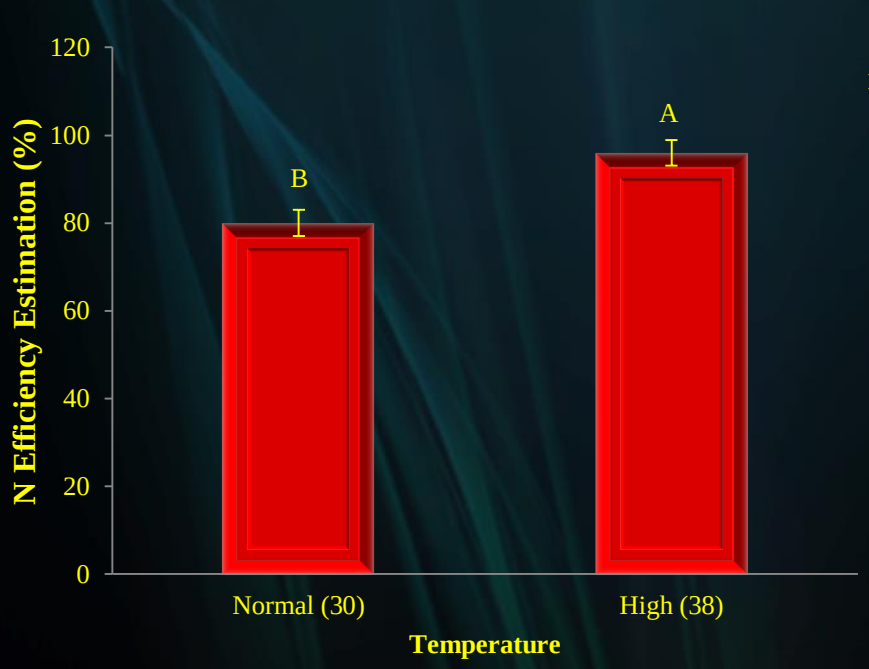
Controlled Environment Chamber

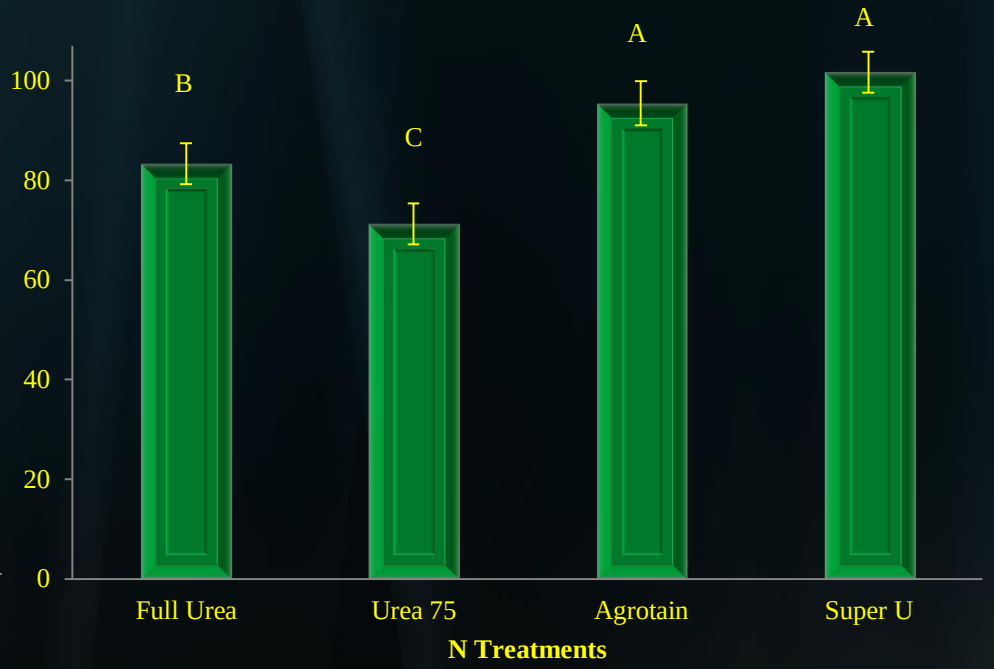
- Location: Altheimer Laboratory, Fayetteville, AR
- Cultivar: *(Gossypium hirsutum)* ST 4554 B2RF
- Soil: Memphis Silt Loam, 2 liter pots
- Treatments:
  - Nitrogen: 5 treatments applied pre-plant and at pinhead square stage.
  - Temperature: Day temperature: Normal 30°C and Heat stress 38°C.

Treatments	N Rate (kg/ha)	N Source	Day Temperatures
Treatment 1	0	-	
Treatment 2	125 (100%)	Urea	
Treatment 3	94 (75%)	Urea	30°C and 38°C
Treatment 4	94 (75%)	Urea+NBPT (Agrotain)	
Treatment 5	94 (75%)	Urea+NBPT+DCD (Super U)	

Complete Randomized Design with 2 factors and 5 replications

Fertilizer N Efficiency





Effect Tests

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
Temp	1	1	1958.7905	14.5123	0.0009*
Treat	3	3	4150.3019	10.2496	0.0002*
Temp*Treat	3	3	1140.6601	2.8170	0.0616

Summary

(Temperature Exp.)

- NBPT performance was not influenced by temperature
- Temperature increased N uptake and therefore protein, chlorophyll, N fertilizer efficiency, and nitrate reductase.
- Addition of DCD had no effect on N Fertilization

Nitrogen Assimilation and Growth of Cotton Seedlings in Response to NaCl Salinity and Urea Application with NBPT and DCD

Salinity Problem

- Salinity: Irrigated areas with arid or semiarid climates *(Letey, 1984)*
- Arkansas: increasing cases - poor irrigation water quality *(Tacker, 2003)*
- Cotton: medium salt-tolerant - threshold (7.7 dS m^{-1}) *(Mass and Hoffman, 1977)*
  - ✓ High Salinity: decrease growth and lint yield *(Ashraf, 2002)* , reduced N uptake*(Reeves and Touchton, 1989)*, toxicity of DCD increased *(Pessarakli and Tucker, 1985)*

OBJECTIVE:

To evaluate the effect of salinity on the growth, stress physiology, and N assimilation of cotton fertilized with urea and NBPT and DCD.

Material and Methods

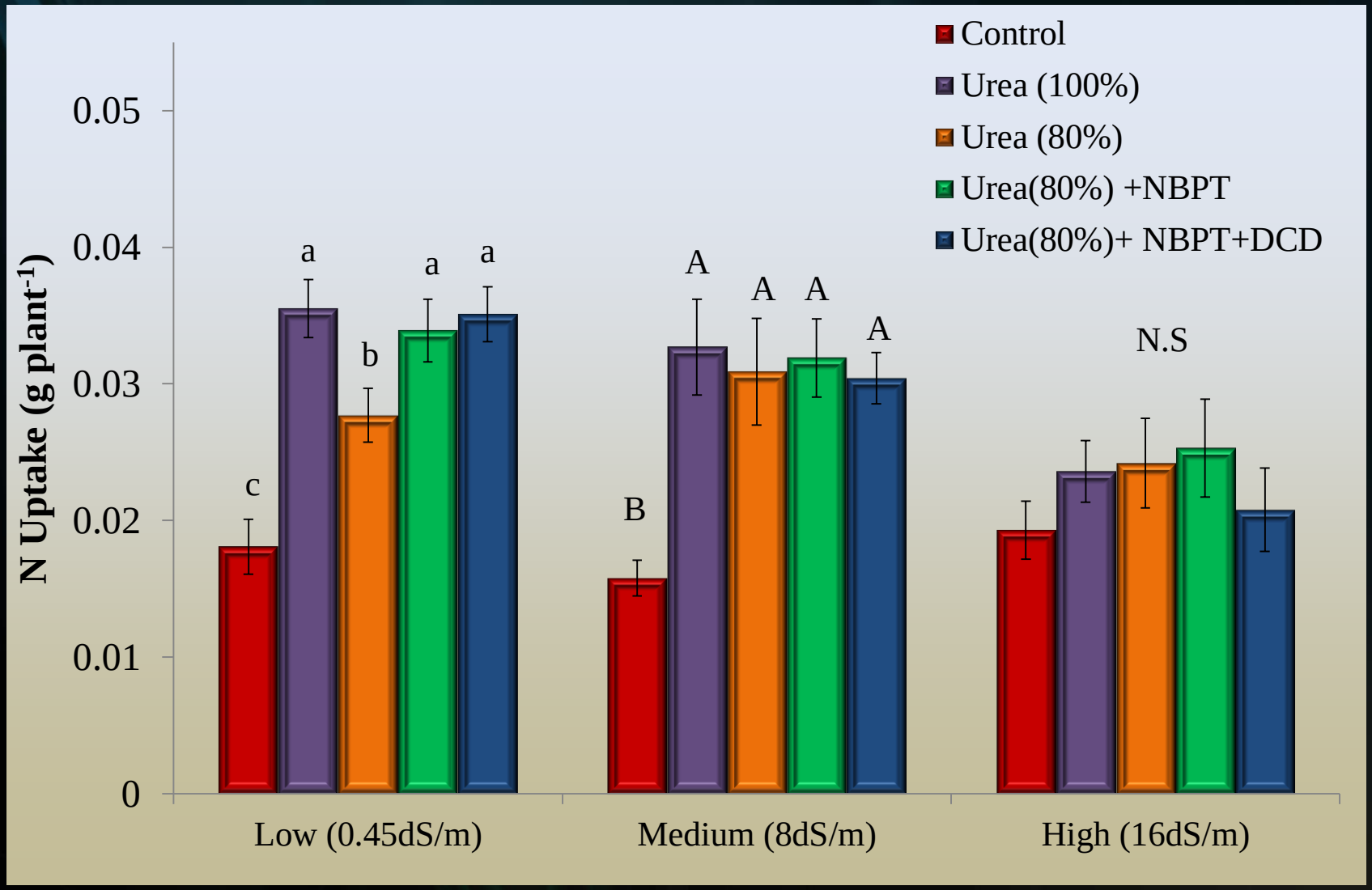
- Location: Altheimer Laboratory, Fayetteville, AR (2010-11)
- Cultivar: ST 4554 B2RF – grow up to pin-head square stage
- Ambient: 30/20°C day/night temperature, 14 h photoperiod

1.5 liter pots –Memphis Silt Loam Soil (Marianna, AR)

Treatments	N Rate (kg/ha)	N Source[1]	Salinity Level[2]
Treatment 1	0	-	
Treatment 2	62.5 (100%)	Urea	Low (0.45 dS/m)
Treatment 3	50 (80%)	Urea	Medium (8 dS/m)
Treatment 4	94 (80%)	Urea+NBPT (Agrotain)	High (16dS/m)
Treatment 5	94 (80%)	Urea+NBPT+DCD (Super U)	

[1] Side-dress applied 3 days after germination. [2]. Salinity stress imposed after germination

N Uptake


Control
Urea (100%)
Urea (80%)
Urea(80%) +NBPT
Urea(80%)+ NBPT+DCD
N Uptake (g plant-1)
0.05
0.04
0.03
0.02
0.01
0
a
b
a
a
c
A
A
A
A
B
N.S
Low (0.45dS/m)
Medium (8dS/m)
High (16dS/m)

Summary

(Salinity Experiment)

- Increasing salinity decreased chlorophyll, protein, nitrate reductase activity, and increased glutathione reductase.
- The addition of NBPT was beneficial for N uptake, but this effect was not observed with increasing levels of salinity above the threshold value
- Addition of DCD did not show any effect

Overall Conclusions

- Application of urea with NBPT will increase N fertilizer use efficiency of cotton.
- Sub-rates (75%) of nitrogen with NBPT will maintain cotton growth and yield equal to the levels of the full recommended urea application.
- **Addition of NBPT to foliar applied urea inhibits leaf urease activity and has the *potential* of increasing cotton yield**
- High temperature did not affect the performance of NBPT and DCD in all measurements.

Acknowledgements

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Agrotain/Koch


THANK
YOU!

Practical Economic Aspect

- Urea = $460 ton
- Additional Cost
- NBPT = $ 0.122 kg of N
- **94 kg ha^{-1} = $12 per ha**
- NBPT+
  DCD = $ 0.239 kg of N
- 94 kg ha^{-1} = $23 per ha