Innovating for the Future
Improving NUE in Corn Hybrids

Jeff Coultas
Technology Product Manager
Monsanto Company

What is Nitrogen Use Efficiency (NUE) and How will It Be Improved?

- Current status of corn NUE
- Current trait impact
- Biotechnology trait development

Nitrogen Use Efficiency (NUE)

NUE is defined as the ratio of grain yield to nitrogen supplied from soil & applied fertilizer

- Grain yield or grain N yield/lb total plant N uptake

N uptake efficiency

- **Ability of plant to mine & assimilate soil N**
- **Percent fertilizer N in plant at maturity**

N utilization efficiency

- **Ratio of grain yield to plant N**
- **N transport within plant to reproductive tissues**

Why is Nitrogen Use Efficiency NUE Improvement Important?

- **Worldwide cereal grain NUE is between 30-35% (Raun & Johnson)**
  - estimates as high as 50%
- **Balance is lost or not utilized by the plant**
  - Lost production potential
  - Water quality concerns
- **Cost & availability of N fertilizer**
- **Genetic diversity within corn germplasm**
- **Breeding advancements & functional genomics offer means to discover new transgenes**

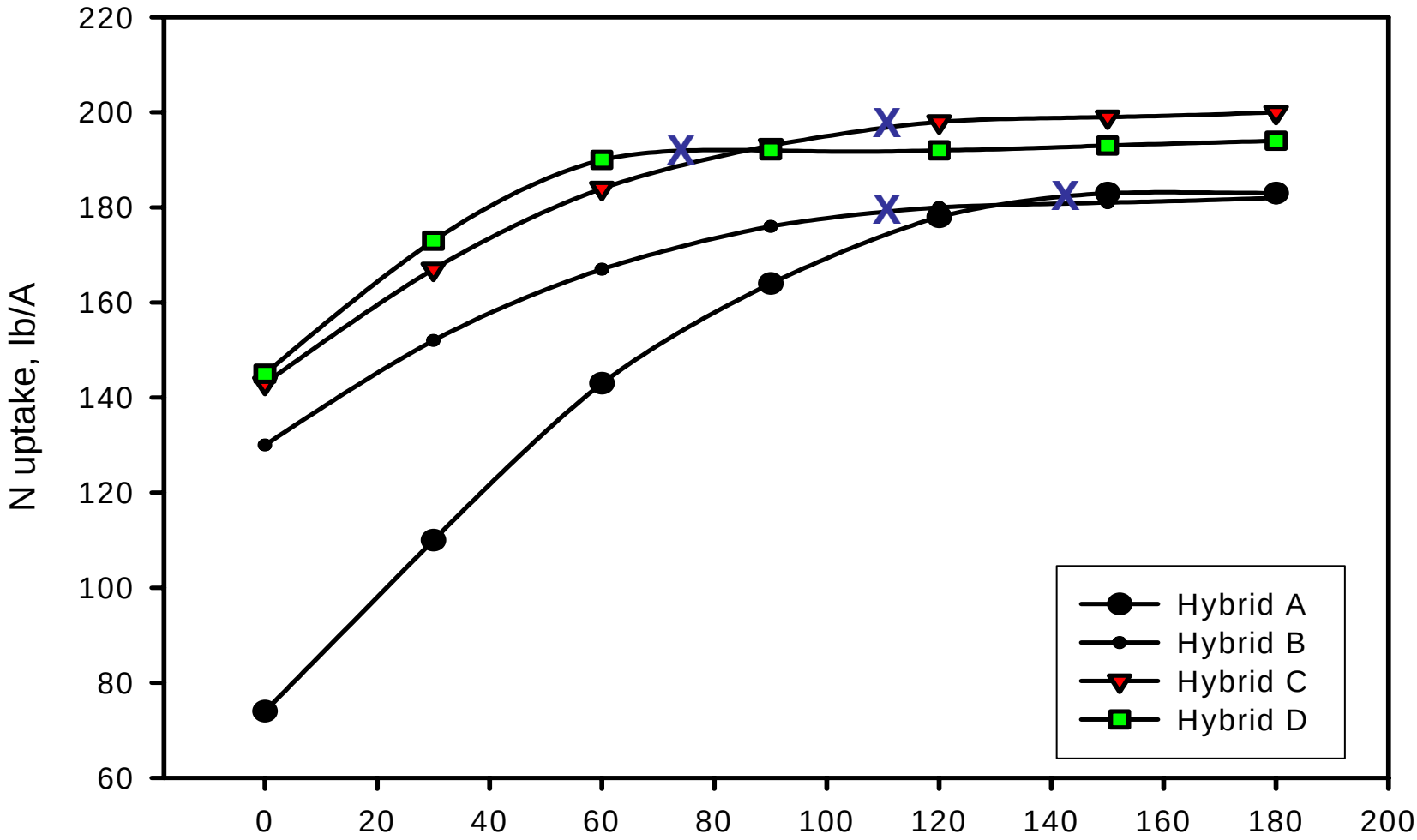
Genetic Diversity for NUE in Corn

Genotype	Yield Change	NUE	NuptakeE	NutilizationE
6 commercial hybrids	4.4	25	56	40
B73xCML52	9.7	48	94	51
B73xCML247	9.0	44	48	92
B73xMo18W	8.7	43	40	108
B73xKi11	6.5	32	61	53
B73xTzi8	5.6	28	22	125
B73xKi3	5.0	25	26	97
B73xNC350	4.6	23	92	25
B73xTx303	4.2	21	36	59
B73xCML277	4.2	21	31	67
B73xMo17	3.9	19	27	70
B73xCML333	3.9	19	26	74
B73xOh43	3.4	17	25	66
B73xMS71	2.5	12	26	47

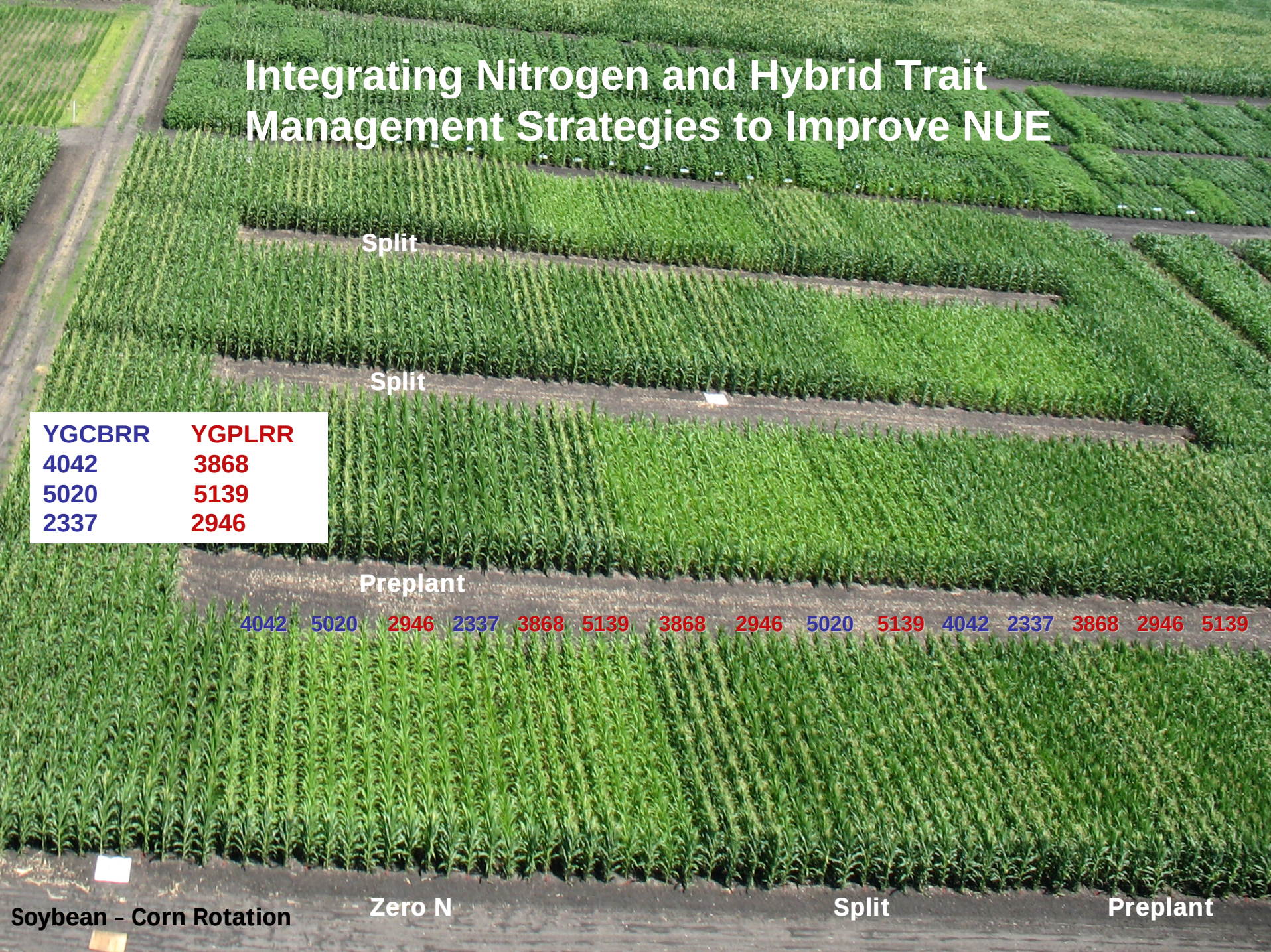
Source: Moose, Below, Buckler – Gene discovery for maize responses to nitrogen project proposal

Uptake Response for Four Hybrids

Conventional breeding improvement

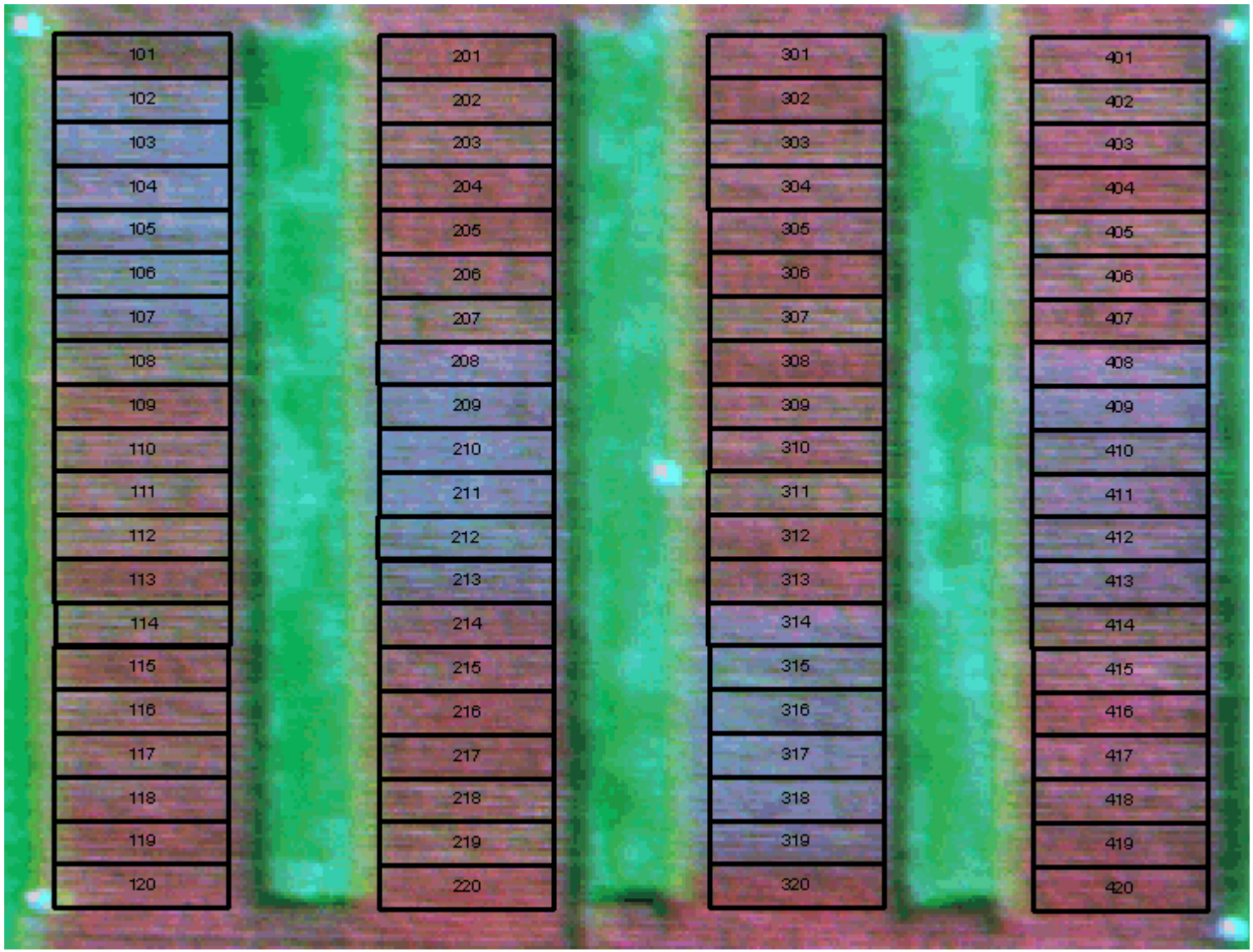


X = EONR— Economic optimum N rate; the point where the last increment of N returns a grain yield increase large enough to pay for that N.


Integrating Nitrogen and Hybrid Trait Management Strategies to Improve NUE
Split
Split
YGCBRR YGPLRR
4042 3868
5020 5139
2337 2946
Preplant
4042 5020 2946 2337 3868 5139 3868 2946 5020 5139 4042 2337 3868 2946 5139
Soybean – Corn Rotation
Zero N
Split
Preplant

Integrating Nitrogen and Hybrid Trait Management Strategies to Improve NUE

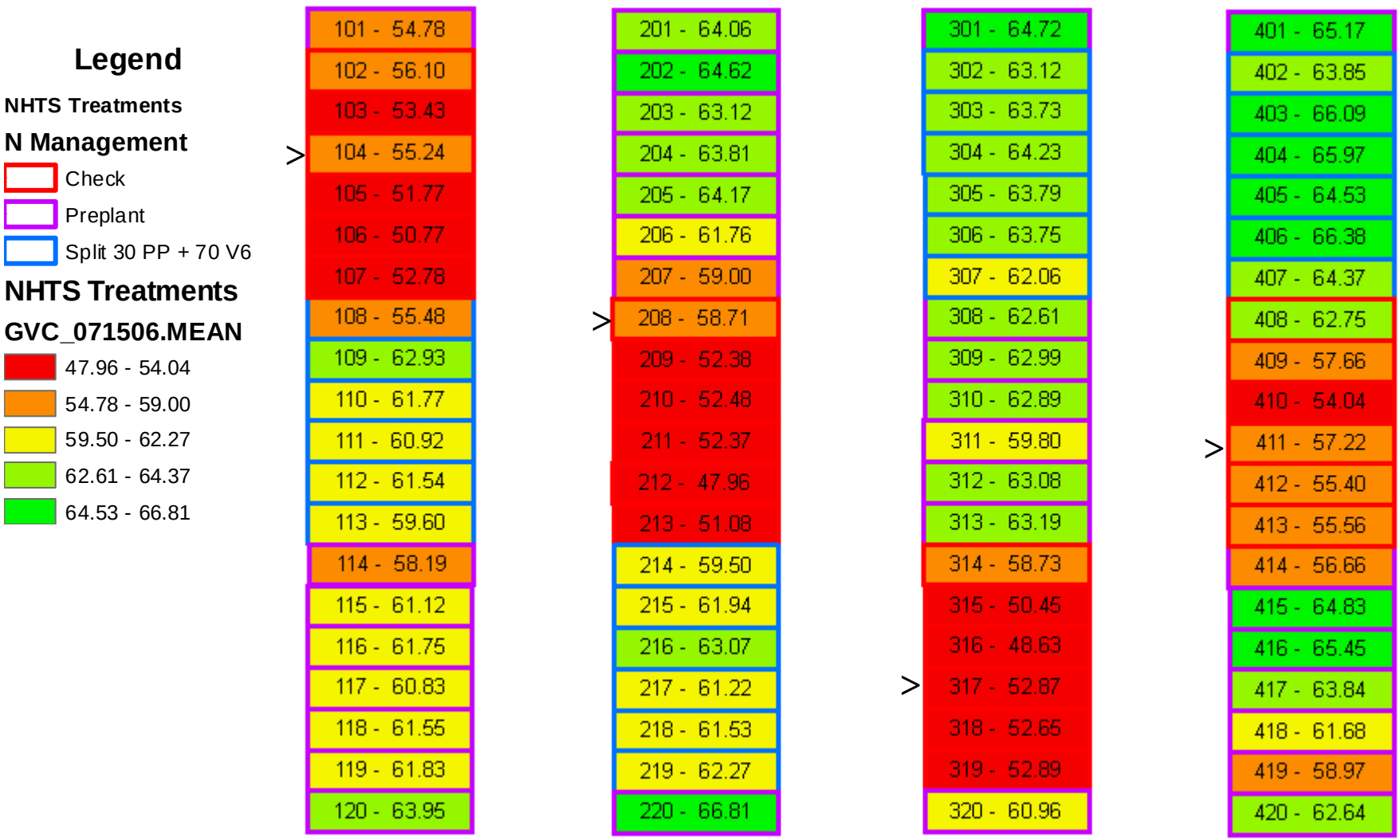
Color Infrared Image - July 15, 2006



2006 Soybean x Corn Rotation

Integrating Nitrogen and Hybrid Trait Management Strategies to Improve NUE

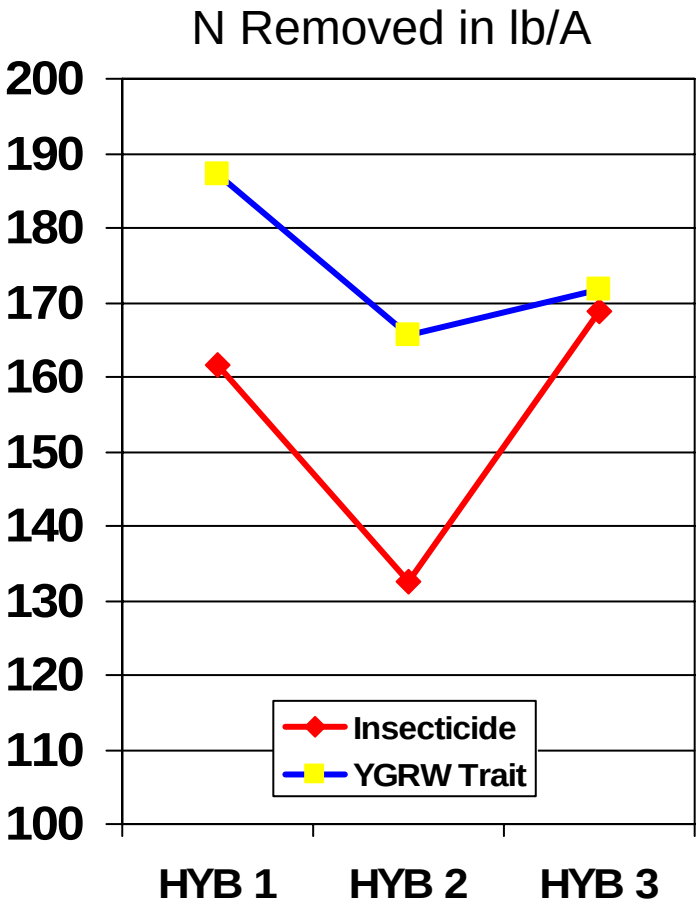
Green Vegetative Index (GVI) - July 15, 2006

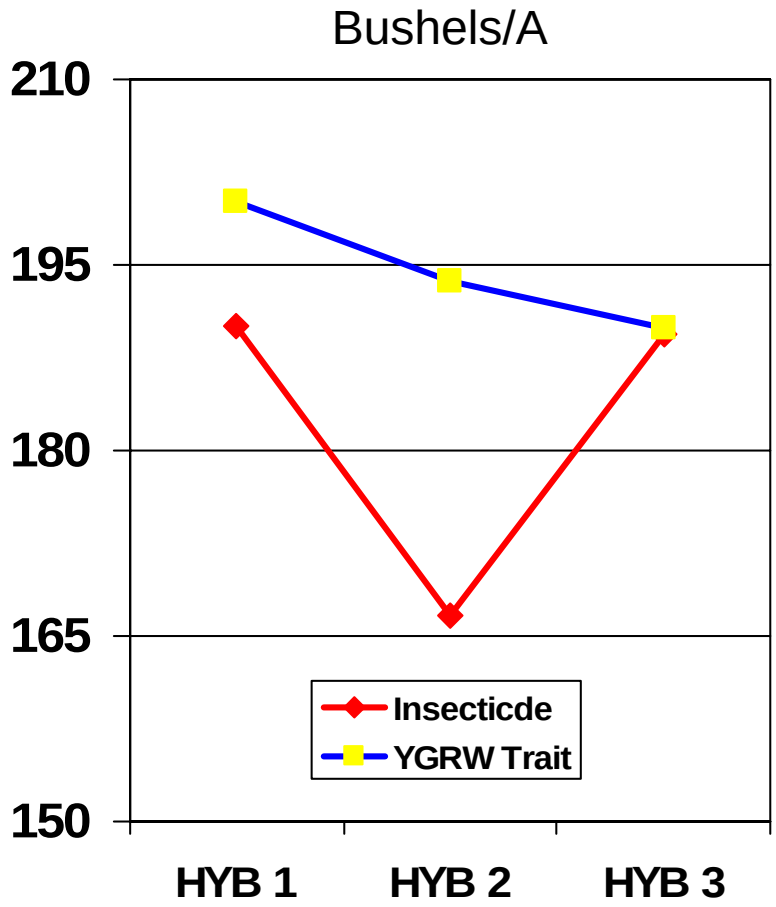


2006 Corn x Soybean Rotation

Integrating Nitrogen and Hybrid Trait Management Strategies to Improve NUE

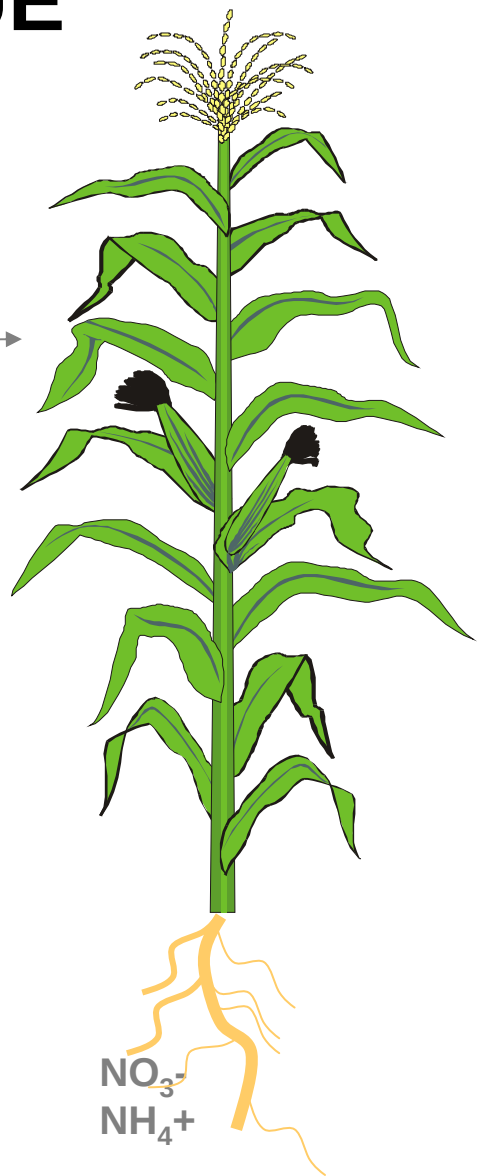
Genetic & Trait Effects on N & Yield





2006 Continuous corn rotation

Processes that Impact NUE



Parameters to measure:

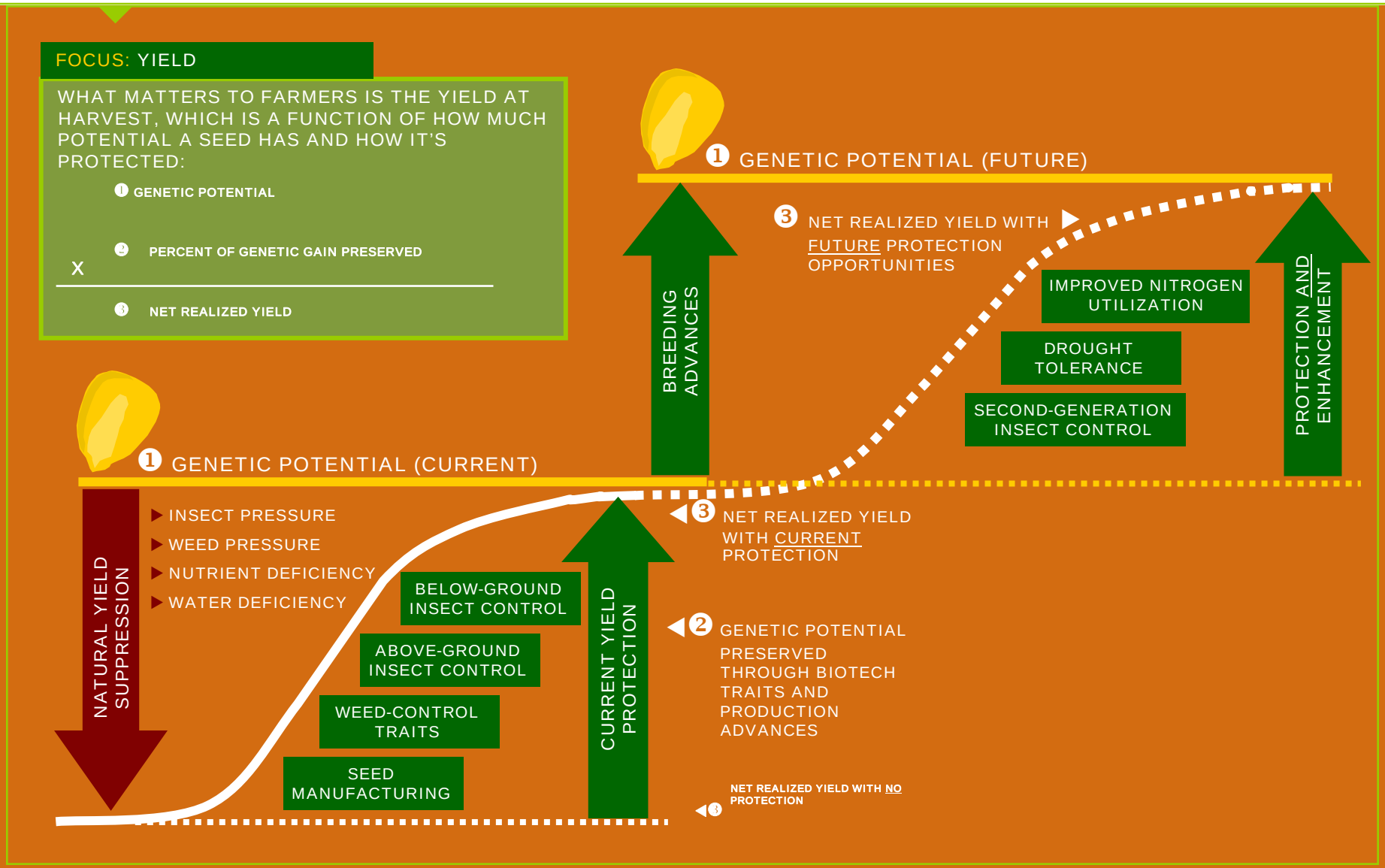
- Yield
- Growth
- Chlorophyll
- Amino acids, sugars
- N content

Screen genes under limiting N conditions to magnify effects

NUE Goals

- **Extract more applied and soil nitrogen to improve yield and lessen environmental loss**
  - Mine and assimilate more soil N
- **Use known genetic variation in corn germplasm to improve N utilization for corn yield**
  - Marker assisted selection and breeding technology
  - Gene discovery & transfer to corn
- **Employ functional genomics to identify N-responsive genes and impact on the efficiency of N use in corn**

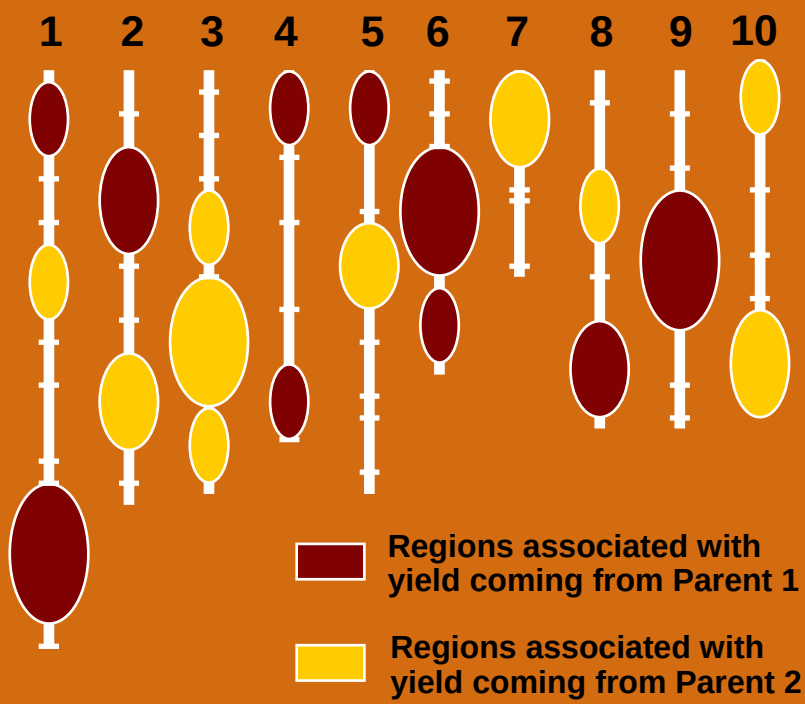
Breeding and Biotechnology Improvements in Concert Will Deliver Greater Yield Potential



Markers Allow Breeders to Get Best Combinations of Germplasm Faster With Greater Predictability

TRACKING CHARACTERISTICS FOR YIELD

YIELD-RELATED AREAS ON CORN CHROMOSOMES



MARKERS

OVERVIEW:

A corn plant has 40,000 genes spanning 10 chromosomes. Characteristics – or traits – are built from different pieces on different chromosomes. Markers are DNA 'flags' that indicate where particular genes are located

APPLICATION:

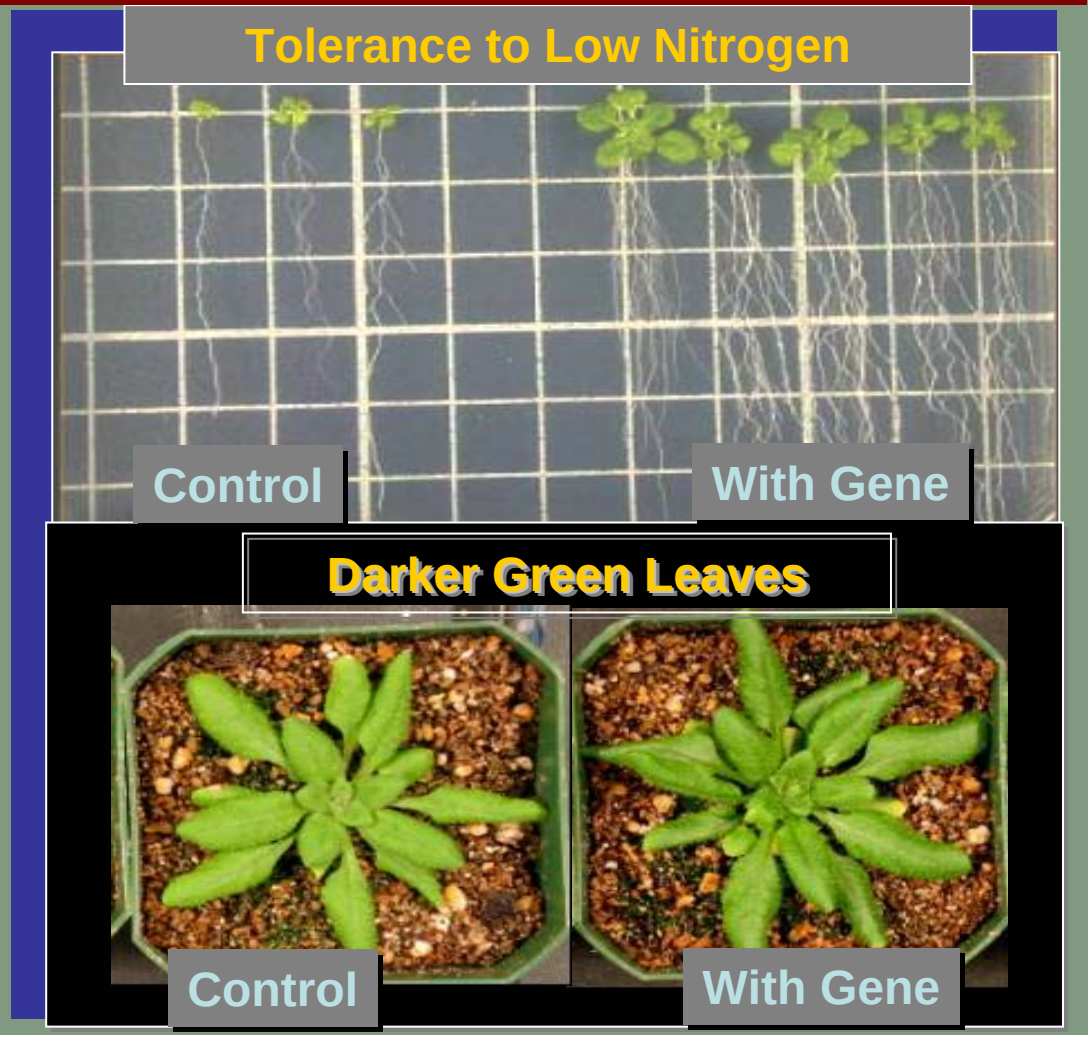
Using markers to make better selections, breeders can improve the probability of success:

Probability of finding 1 trait that is controlled by 20 genes	
"Random" crosses:	1 per trillion
After application of markers and breeding technology	
1 in 5	

Using Nitrogen Efficiently

Nitrogen Tolerant Genes

- Increase efficient nitrogen utilization
- Improve crop performance
- Enhance nitrogen uptake
- Manage yield variability
- Produce greater output per unit input

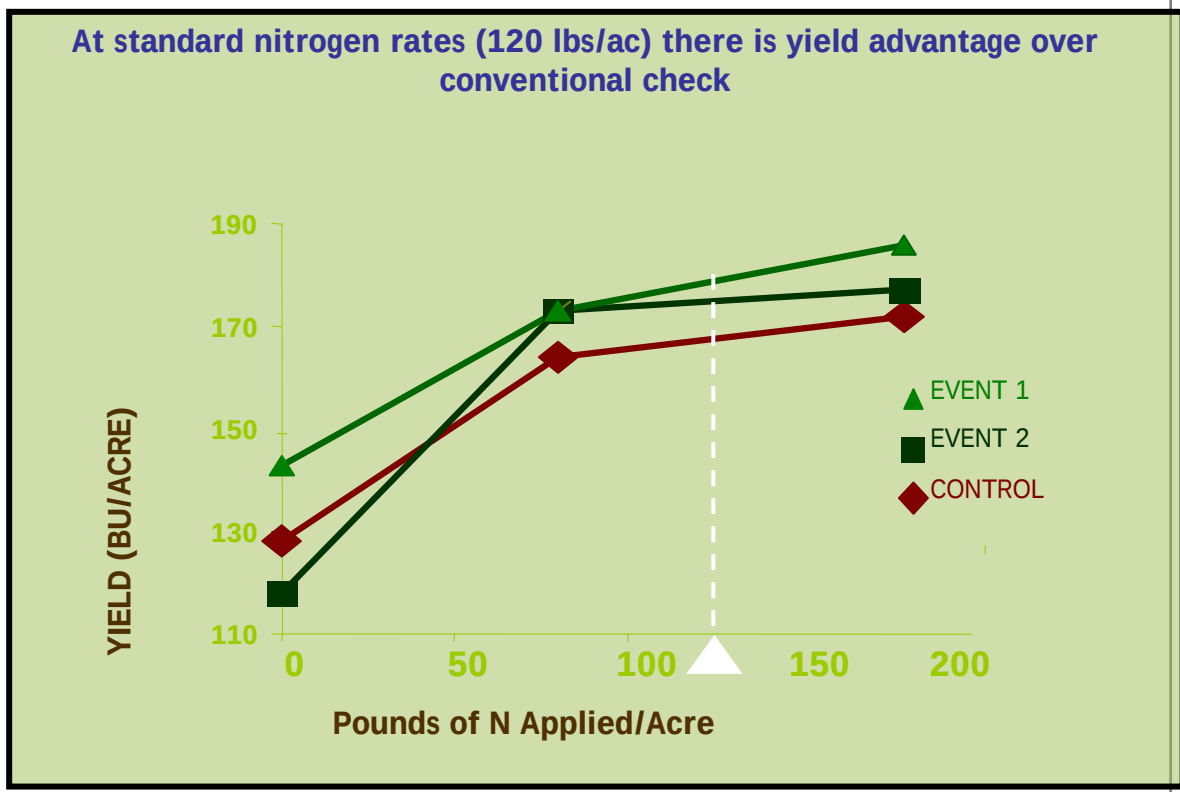


Discovery	Phase 1 Proof of Concept	Phase 2 Early Development	Phase 3 Adv. Development	Phase 4 Pre-Launch	Launch

Building Yield Enhancement By Using Nitrogen Efficiently

Nitrogen Utilization Corn Update

- Industrial scale genomics efforts is generating leads
- Lead events show roughly 10% yield increase in multi-locations field trials
- Up Next: Optimization to improve trait performance and continued screening



Discovery	Phase 1 Proof of Concept	Phase 2 Early Development	Phase 3 Adv. Development	Phase 4 Pre-Launch	Launch

Summary

- Improving NUE will contribute to greater yield performance & efficient N use
- Corn hybrids will use nitrogen more efficiently
  - Conventional breeding has improved uptake
  - Genetic diversity exists within corn germplasm
  - Advanced breeding techniques will raise yield potential
  - Biotechnology & genomics will improve utilization
- Input traits like YieldGard® RW enable better N use and preserve yield potential
- Biotechnology traits for efficient N use are in early field evaluation