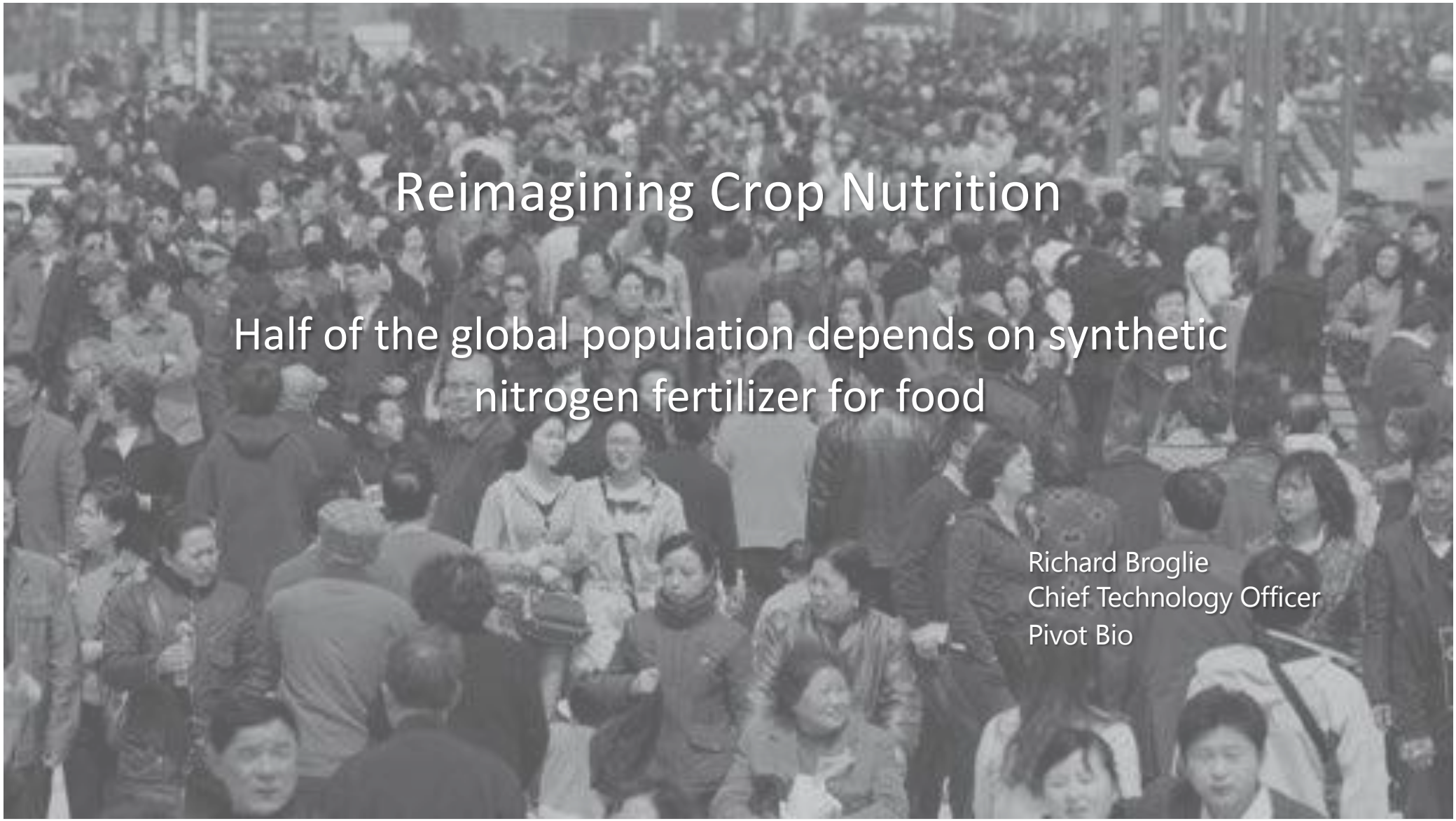
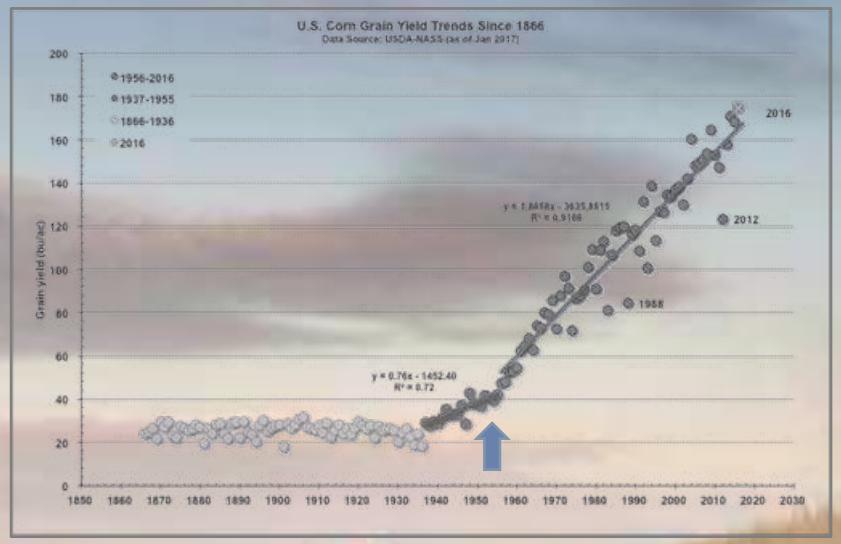


Reimagining Crop Nutrition

Half of the global population depends on synthetic nitrogen fertilizer for food

Richard Broglie
Chief Technology Officer
Pivot Bio

Introduction of synthetic nitrogen fertilizer was a key factor in the green revolution

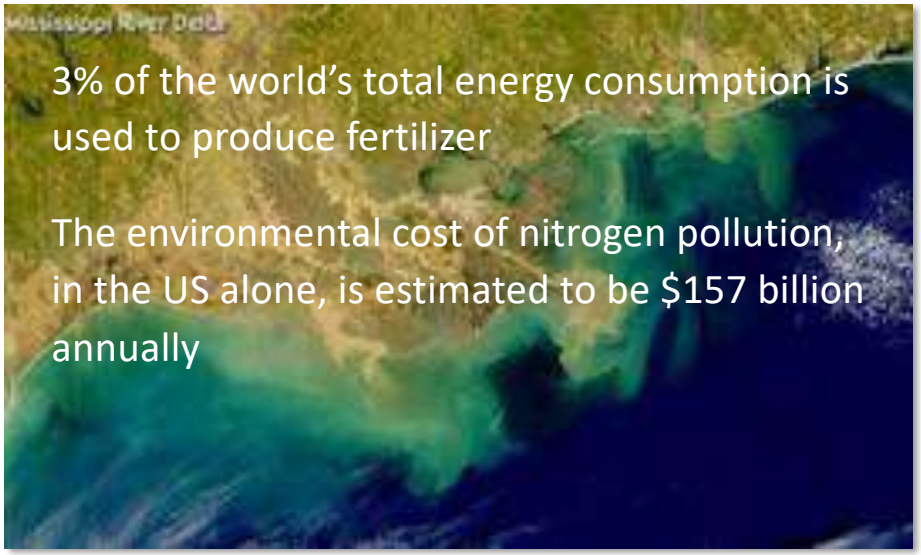


- Over 118 million metric tons of synthetic nitrogen is consumed worldwide
- Half is applied to corn, wheat and rice crops

A century of synthetic fertilizer production has disrupted the earth's nitrogen cycle more dramatically that any event in 2.5 billion years

Threats of nitrogen pollution

- Water quality
- Air quality
- Greenhouse gas balance
- Ecosystems and biodiversity
- Soil quality



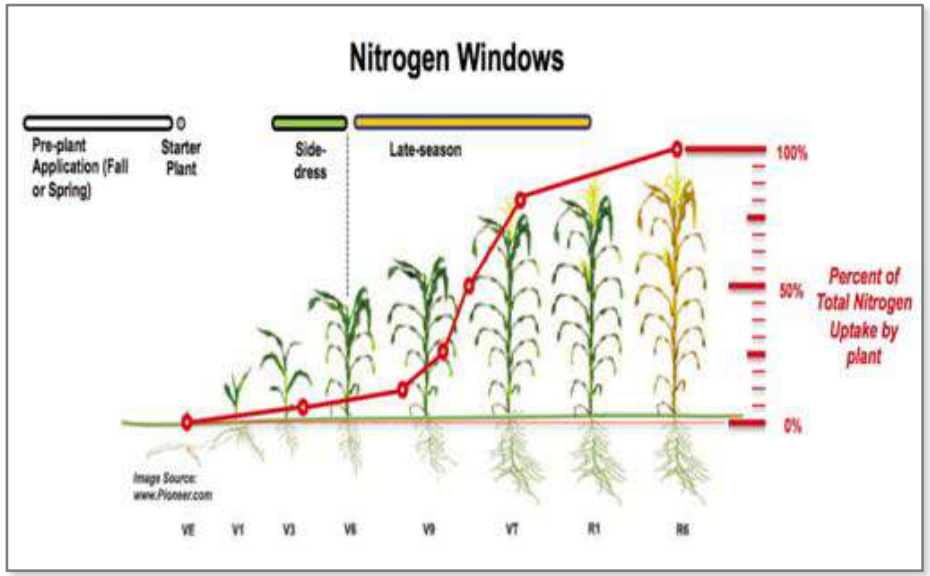
3% of the world's total energy consumption is used to produce fertilizer

The environmental cost of nitrogen pollution, in the US alone, is estimated to be $157 billion annually

Source: Our Nutrient World (http://nora.nerc.ac.uk/id/eprint/500700/1/N500700BK.pdf)
The Anthropocene is functionally and stratigraphically distinct from the Holocene SCIENCE 8 January 2016 • Vol 351 Issue 6269

The challenge of matching nutrient supply with crop needs

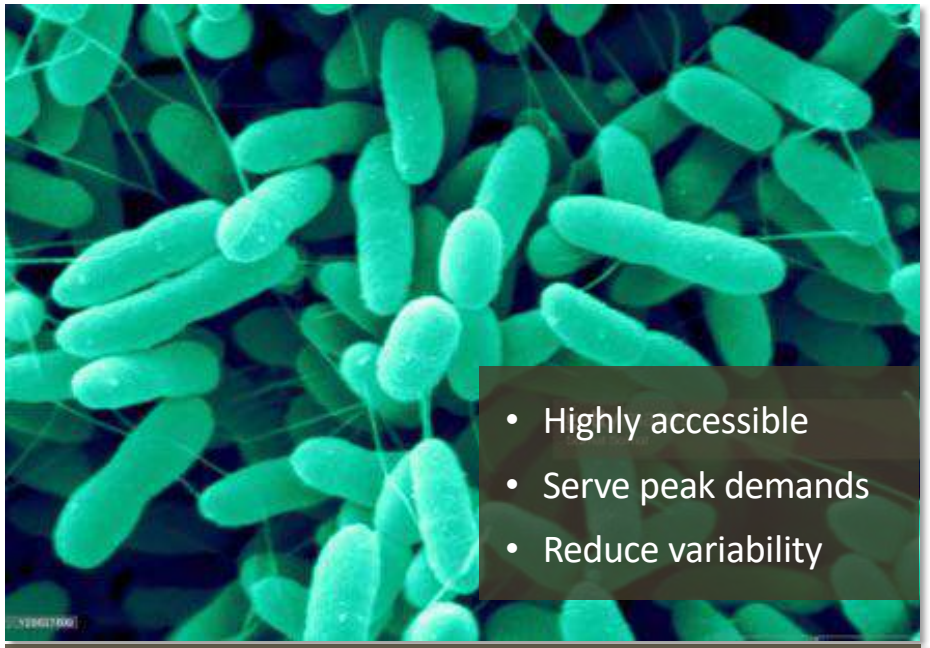
- 10% of total N needed is taken up from VE to V6
- 70% of total N needed between V6 and tassel



- Rapid period of growth from V6 to VT
- Yield is impacted by low N at V6 to V10

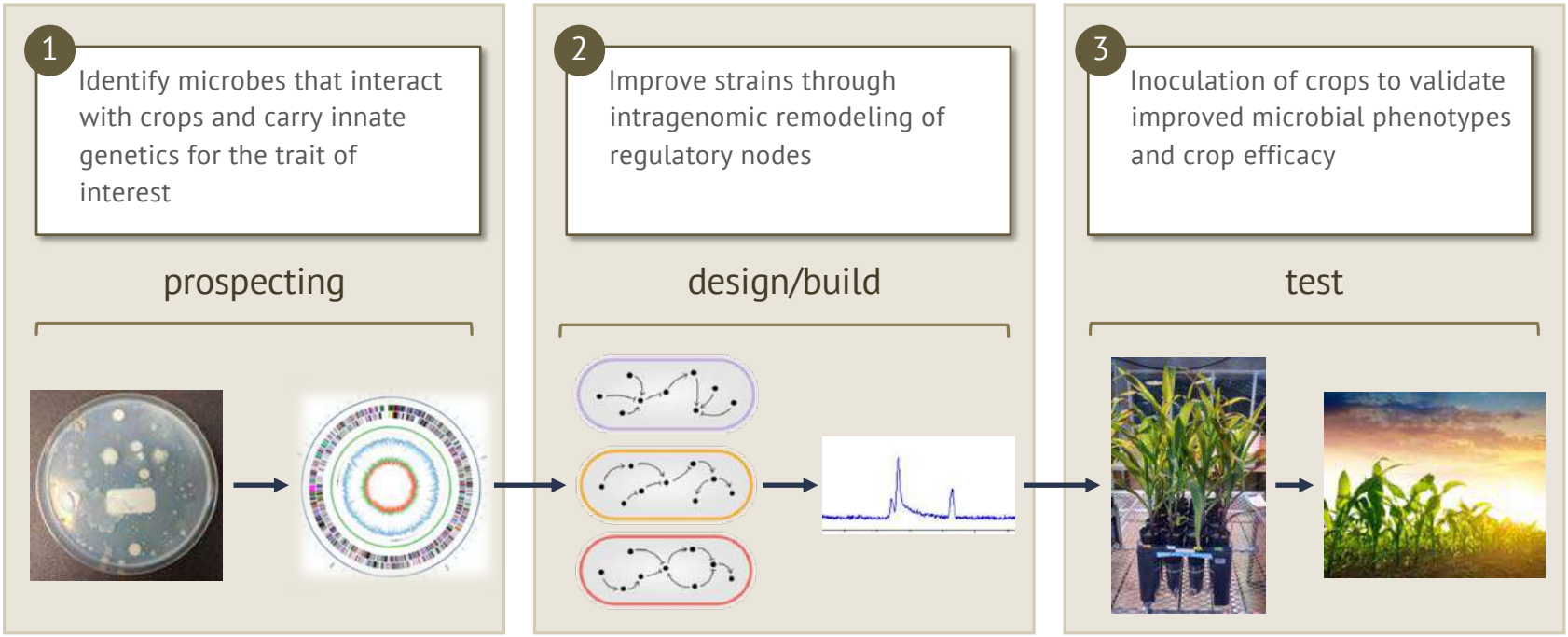
Pivot Bio develops microbes that fertilize crops

CHEMICALS ARE STATIC AND DEGRADE



MICROBES INTERACT AND GROW

Pivot Bio's approach to strain optimization



Long-term nitrogen use causes evolution of less-cooperative mutualists

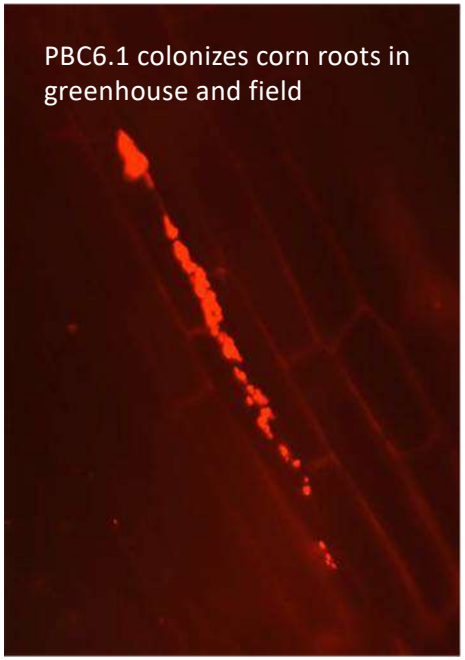
Supplementing nitrogen has selected against BNF

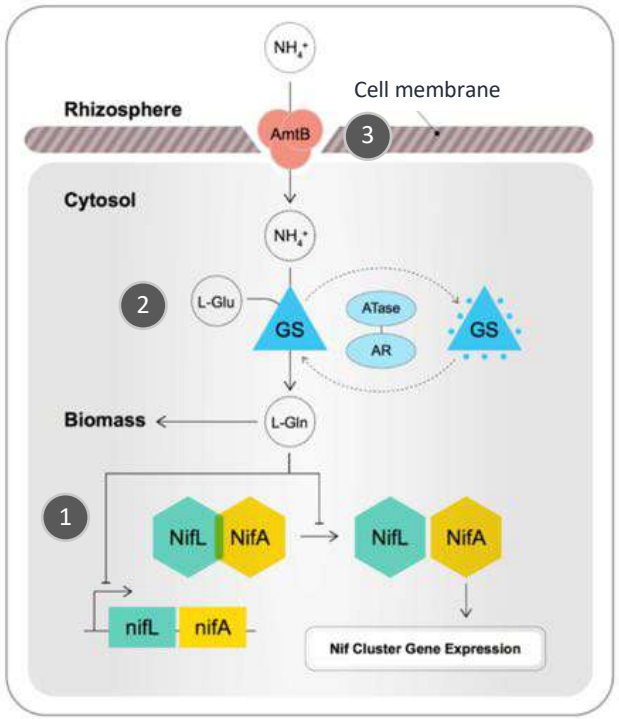
- 22 year N-addition ecological study
- Compared soil communities or single microbes from N-fertilized and non-fertilized plots
- Rhizobium strains from N-fertilized treatments provide fewer growth benefits to their hosts

Weese et al. EVOLUTION 69-3: 631-642 doi:10.1111/evo.12594

Remodeling a corn root-associated diazotroph

nif gene cluster
encoding nitrogenase
biosynthesis genes

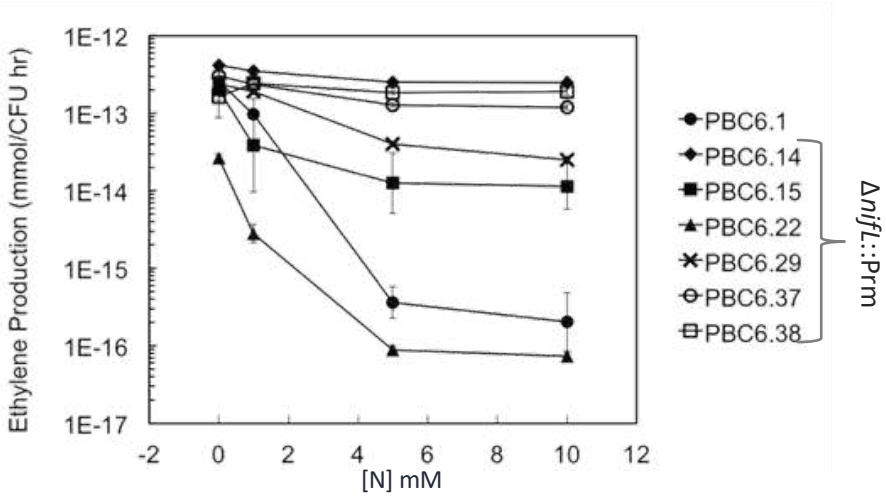




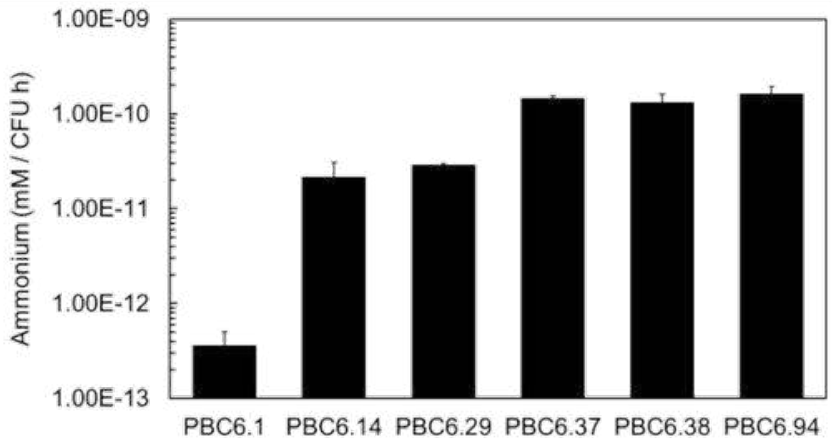
1. Decouple nitrogenase biosynthesis from nitrogen sensing
2. Limit assimilation of newly fixed nitrogen
3. Abolish reuptake of secreted ammonium

Remodeled strains fix nitrogen and excrete ammonium

Decoupling nitrogenase expression from exogeneous nitrogen repression

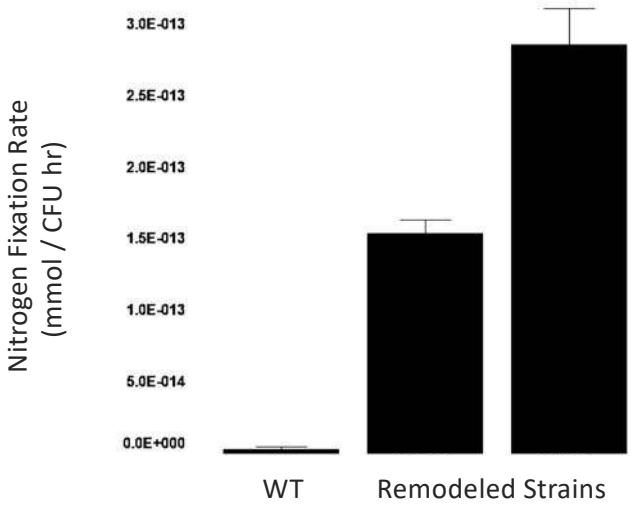


Modulating N assimilation to release ammonium

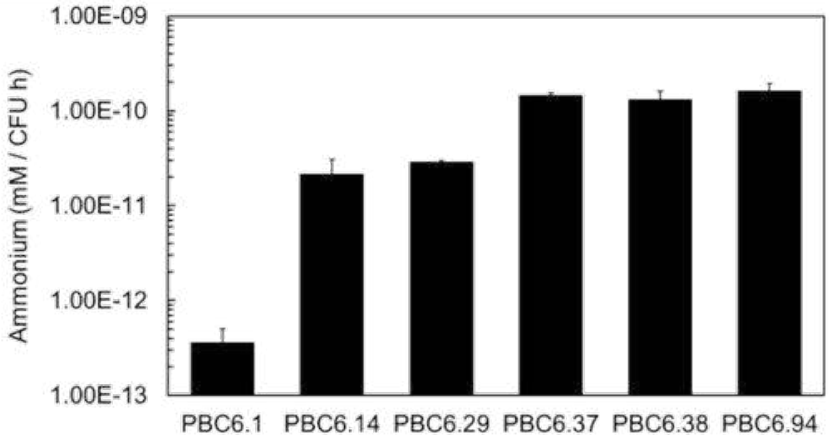


Remodeled strains fix nitrogen and excrete ammonium

Decoupling nitrogenase expression from nitrogen status increases fixation



Modulating N assimilation to release ammonium

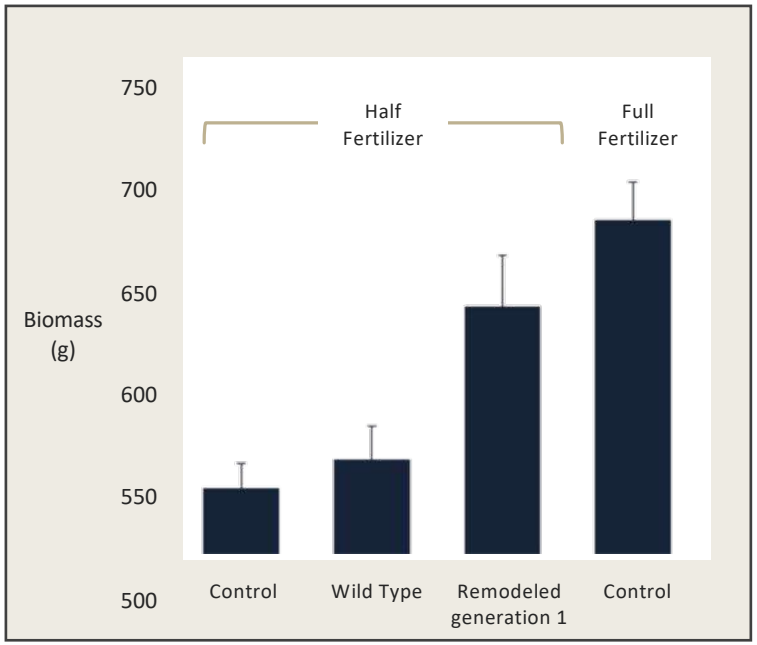


Impact of fixed nitrogen on corn biomass

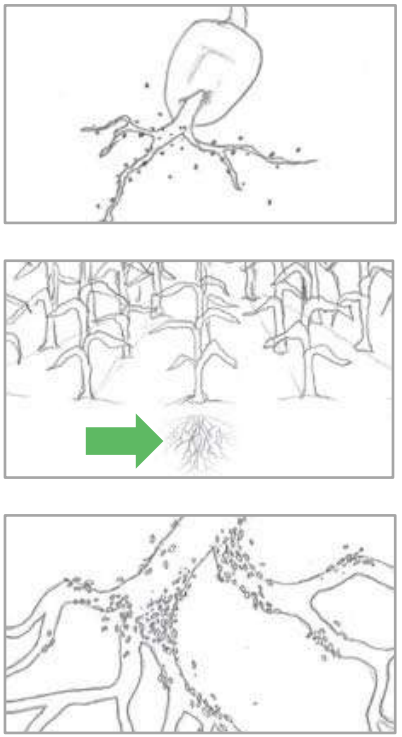
Half Fertilizer

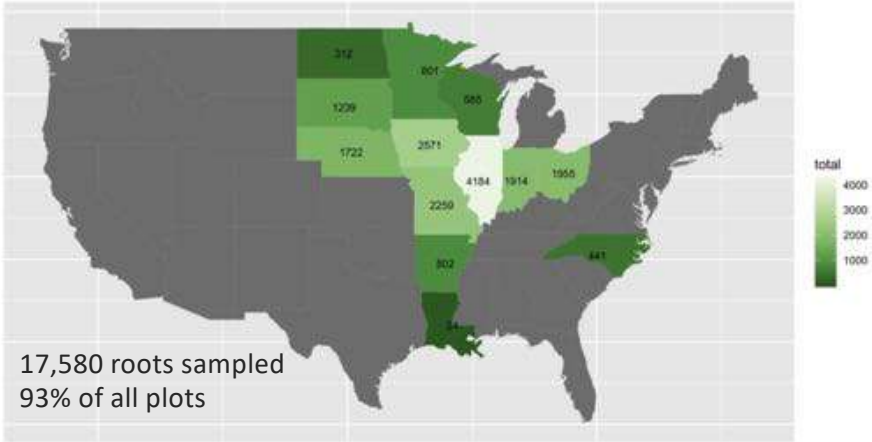
Full Fertilizer

CONTROL	WILD TYPE	REMODELED	CONTROL
N = 20 plants	N = 17 plants	N = 17 plants	N = 20 plants

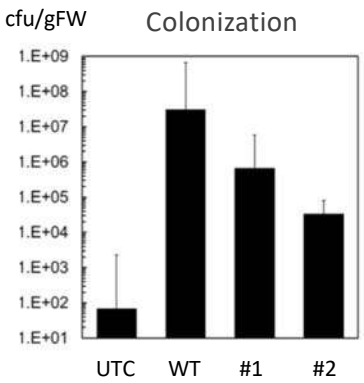


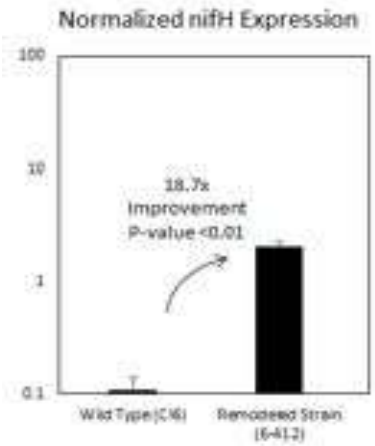
Shovel-omics confirms gene expression and root colonization





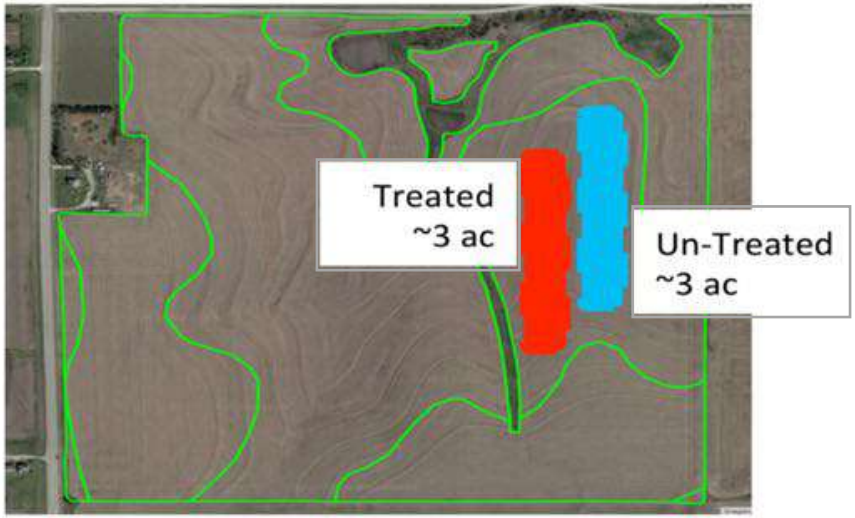
A mobile lab for microbiome DNA/RNA quantification



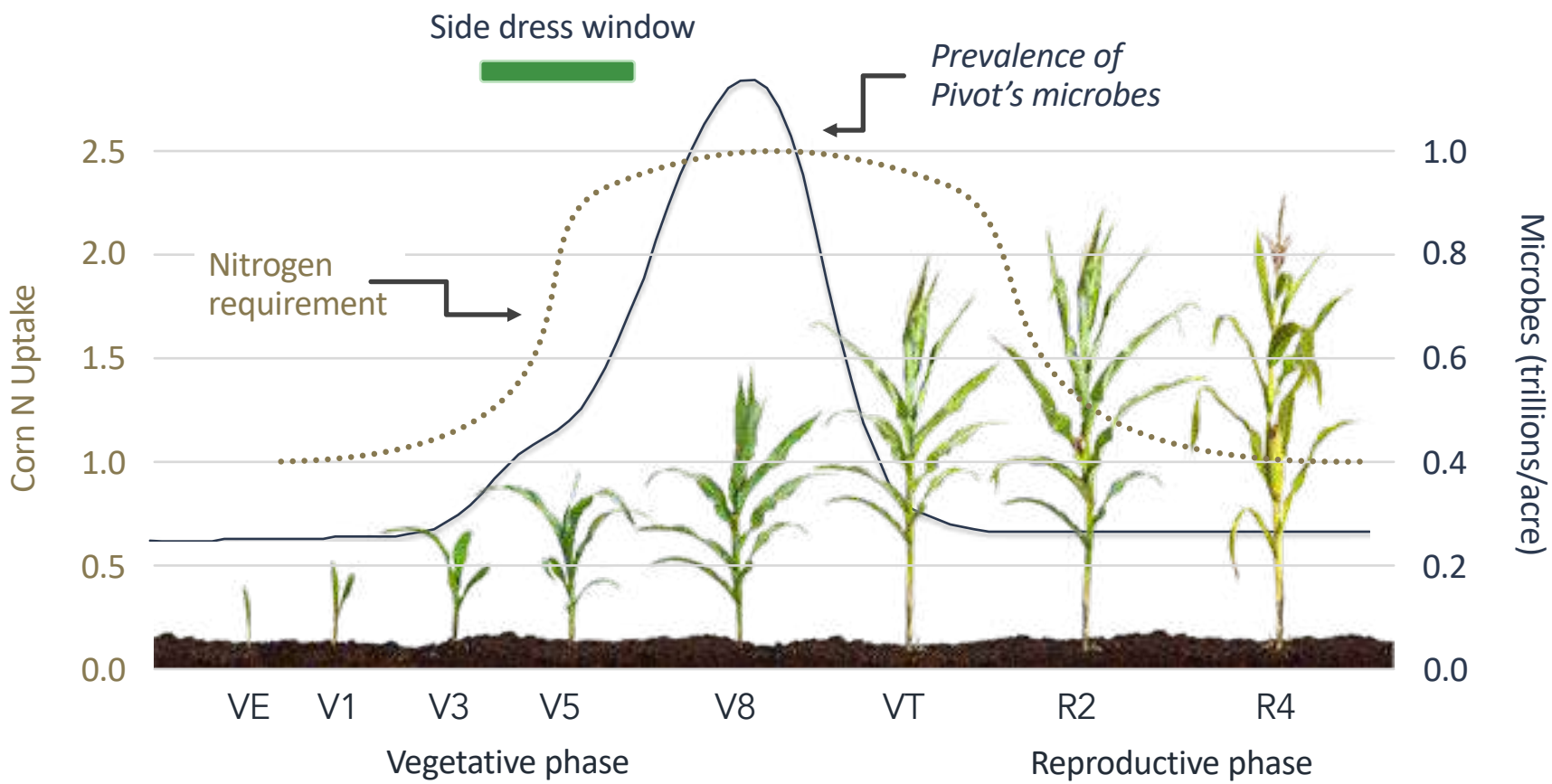


U.S. corn growers are beta-testing our first product

- More than 25 leading U.S. corn growers known to be early adopters and influencers
- Integration into commercial fertility practice as a microbial 'side dress'
- Predicted to deliver the equivalent of 25lbs synthetic N per acre



The crop microbiome can optimize nutrient availability



Convergence of disciplines needed to drive innovation and product deployment

Strain optimization

- Microbiome discovery
- Synthetic biology
- Genomics and machine learning

Validation

- High throughput plant bioassays
- Data science
- Microbial ecology

Formulation

- Material science
- Formulation technologies
- Packaging technologies

Product performance

- Molecular biology
- Biogeochemistry
- Environmental sensing
- Data science

Production

- Chemical engineering
- Downstream processing

In 10 years the fertilizer industry could be very different

TODAY

3%

Global energy used in fertilizer production

>$200B

Fertilizer market size; chemical commodity.

10 YEARS

Biological Breakthrough

Seed is coated with fertilizer. Pricing is value-based.

Nature Plants **3**, Article number: 17012, March 1, 2017

PIVOT BIO

Pivot Bio is on a mission to replace synthetic nitrogen fertilizer with microbes that adhere to the plant's root system and feed the crop each day

www.pivotbio.com @pivotbio