



The Forever Green Agriculture Initiative

Developing High-Efficiency Agriculture and Food Systems

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Forever Green Initiative

- Develop **winter-annual and perennial crops** for inclusion in existing cropping systems
- Provide “**continuous living cover**” on the soil
- **Protect soil and water** resources
- Create **new economic opportunities** for farmers and rural communities



New Food/Feed/Fuel
Ingredients

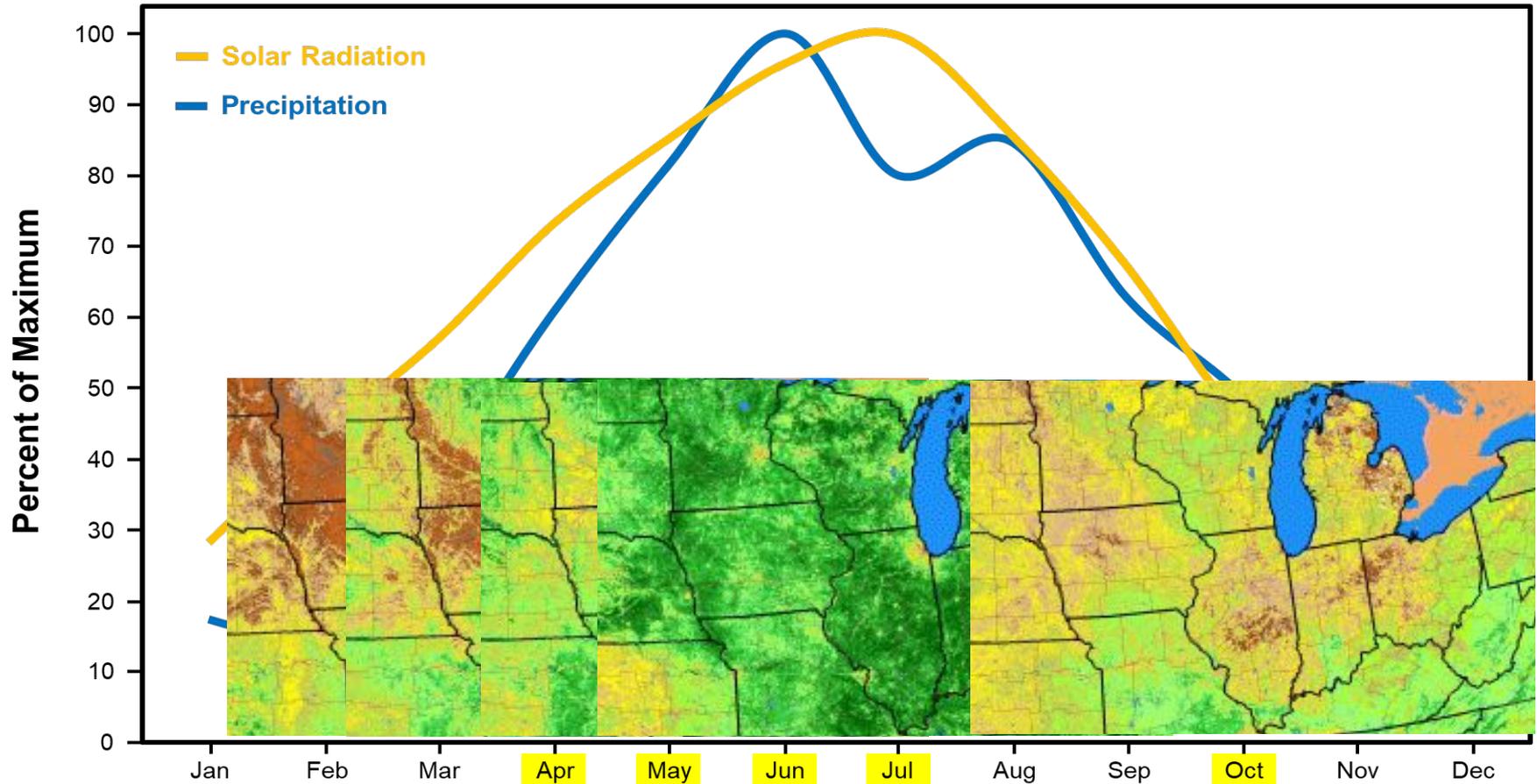


New Economic
Opportunities

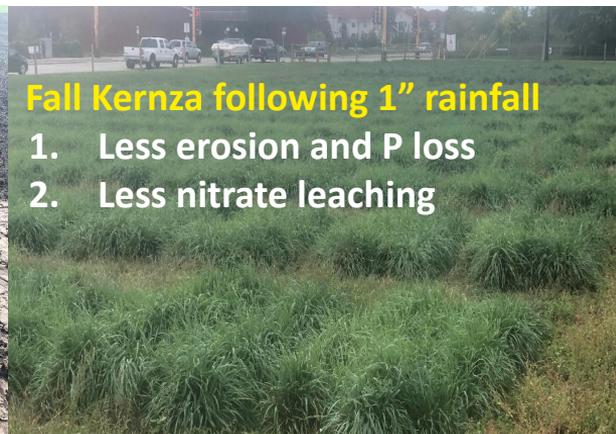


Ecosystem
Services

Current Seasonal Midwest Landscape Cover



“Continuous Living Cover” Cropping Systems



Forever Green Crops Provide: New, Unique Food, Feed and Energy Products for Commercialization



Oils



Fiber



Protein



Phytonutrients

Forever Green Crops Provide: New Economic Opportunities



High Value Food, Feed and Energy
Ingredients



Green Marketing: Ecosystem Services,
Greenhouse Gas Reduction



Innovative Healthy Food Products



New Economic Opportunities for
Farmers and Rural Communities

Forever Green Crops Provide: Environmental Services

- Rural well water protection
- Clean lakes and streams
- Nutrient management
- Pollinator habitat
- Wildlife habitat
- Carbon sequestration
- Soil protection
- Soil health
- Weed suppression



How do we get these plants on the landscape?

Collaboration across disciplines in both public and private sectors



Plant Breeding and Genomics



Agronomics
Soil & Water Science



Food Science & Bioproducts



Commercialization



Supply Chain Development



Perennial Crops

- **Kernza® intermediate wheatgrass** – grain, forage, biomass
- **Perennial sunflower** – edible seeds, oil & protein
- **Native polyculture grassland mixtures** – biomass, forage natural products
- **Perennial flax** – edible oil and protein
- **Kura clover** – N-fixing cover crop
- **Silphium** – edible oil and protein
- **Alfalfa** – food grade protein and feed
- **Perennial cereal rye** – food and feed grain

Winter Annual Crops

- **Pennycress** – edible oil & protein, biofuel
- **Camelina** – edible oil & protein, biofuel
- **Winter barley** – food, malting barley
- **Hairy vetch** – N-fixing cover crop
- **Winter and spring field pea** – food grade protein
- **Winter hybrid rye**—food and feed grain

Native Woody Crops

- **Hazelnuts** – edible nut with oil/protein
- **Shrub willow** – biomass
- **Elderberry** – antioxidant-rich fruit
- **Agroforestry** – woody, herbaceous crop mixtures for feed, food, and fuel



Forever Green Crops: From Research To Field To Table & Beyond



Photos: Mette Nielsen



Brief summary of outcomes supported in part by previous State of Minnesota Funds

- State funds leveraged 5-fold
- 16 coordinated Forever Green crop development platforms
- MN-Clearwater Kernza® variety
- Winter barley variety
- Winter-hardy hairy vetch variety
- 6 hazelnut lines for on-farm evaluation
- Short-season winter camelina line
- Domesticated pennycress, a winter-hardy oilseed crop
- Coordination of FGI with MN communities, seed companies, farmers, grain processors, and commercialization and supply chain network



Intermediate Wheatgrass or Kernza®

Thinopyrum intermedium

Perennial grass with high biomass and large grain size

Enterprises:

- Beer/Whiskey
- Food
- Biomass
- Grazing





Annual wheat (on left in each panel) and Perennial wheatgrass

Intermediate Wheatgrass: Attributes



Large seeds

- 10-15g/1000 seeds



Large biomass

- Comparable to big bluestem and switchgrass



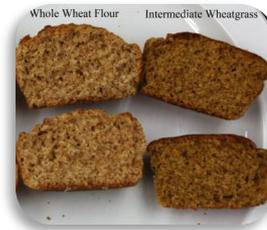
Disease resistance

- Lr38, Sr43, Sr44, Pm40, Pm43...



Grazing potential

- Fall and spring grazing
- High forage quality
- Grazing helps maintain grain yield



Favorable end-use food

- Wheat-wheatgrass blends
- High protein
- Unique flavor

Intermediate Wheatgrass: Breeding Goals

- Grain Yield
- Yield Longevity
- Seed Size
- Shatter Resistance
- Free Threshing
- Spike traits (length, weight)
- Height
- Lodging Resistance
- Diseases (FHB, Ergot)
- End-use Quality & Food Products



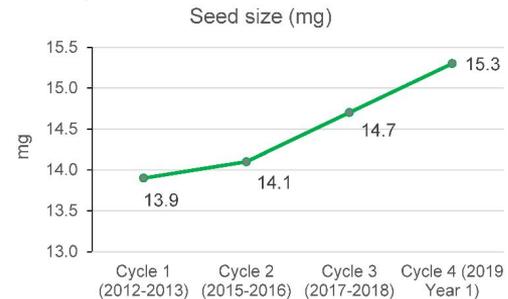
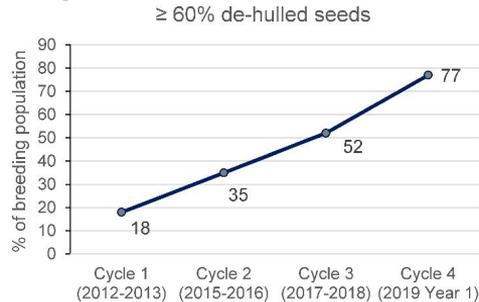
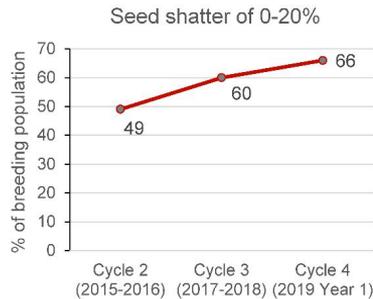
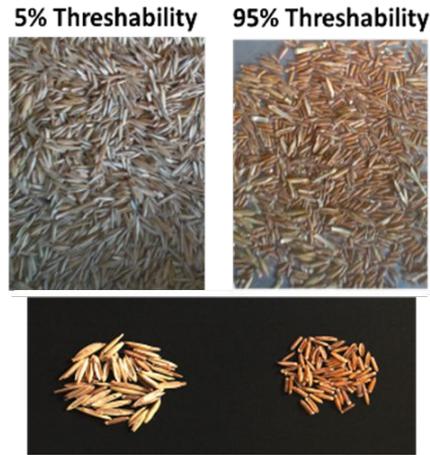
Dr. Pam Ismail



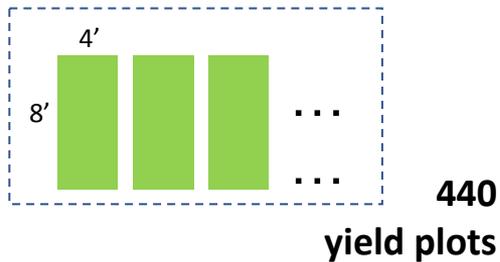
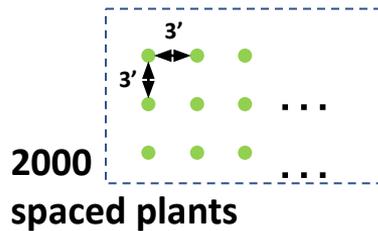
Dr. George Annor

Intermediate Wheatgrass: Genomic Selection

Trait Improvement after 4 Breeding Cycles



Breeding Nurseries

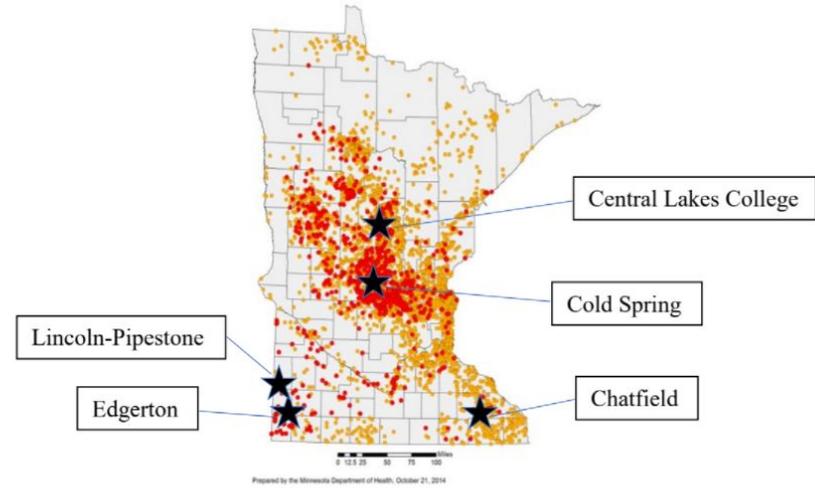
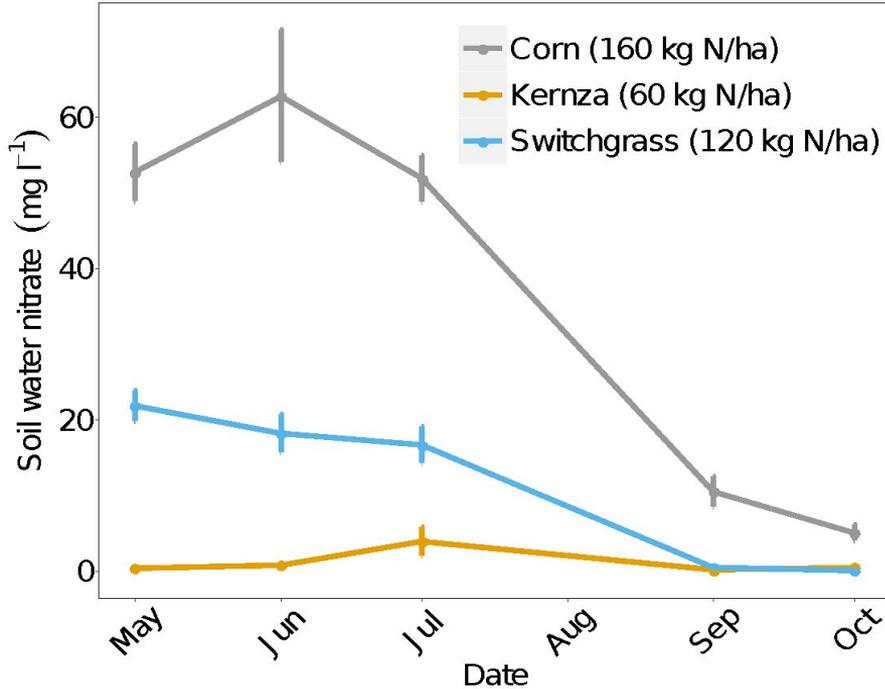


Release of 'MN-Clearwater'



Kernza & Water Quality

Drastic reductions in nitrate leaching potential



Private wells at risk of nitrate contamination in Minnesota.
Credit: Minnesota Department of Health.

Commercial Forever Green Food Products

PANCAKES WITH A PURPOSE

The latest delicious dish made with **KERNZA®** sustainable grain.



Birchwood CAFE

KERNZA® • Regenerates Topsoil • Draws Down Carbon



THE PERENNIAL



4 OZ FLOUR FREE

SPROUTED Whole Grain KERNZA

patagonia PROVISIONS

ORGANIC KERNZA® FUSILLI
perennial grain pasta
NET WT. 14 OZ (397g)

LIMITED EDITION

MADE WITH

CASCADEAN FARM ORGANIC

CLIMATE SMART KERNZA GRAINS

MADE WITH

SOIL HEALTH WATER HEALTH

WHOLE GRAIN AND CEREAL WHEAT THINS WITH MORE THE CLASSIC CEREAL



REUSABLE ZIP

THE WORLD'S FIRST "DIRTY" GRAIN

Perennial PANTRY™

slow flavor perfected time is on the page

Kernza® WHOLE GRAIN

HELP SAVE THE PLANET

NET WT 14 OZ (397g)

DUMPLIN & DINE

EXCEPTIONALLY CURIOUS NOODLES



THE SPROUTED GRAIN

KERNZA KRUNCH

PERENNIAL PROTEIN CEREAL

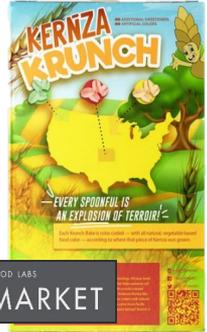
THE ALPHA FOOD LABS

FUTURE MARKET



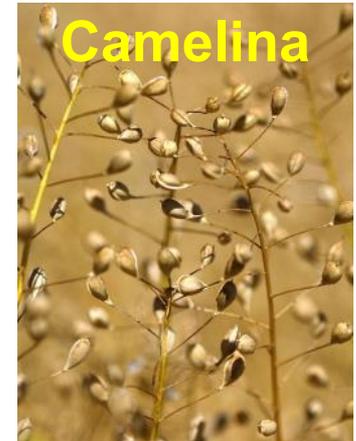
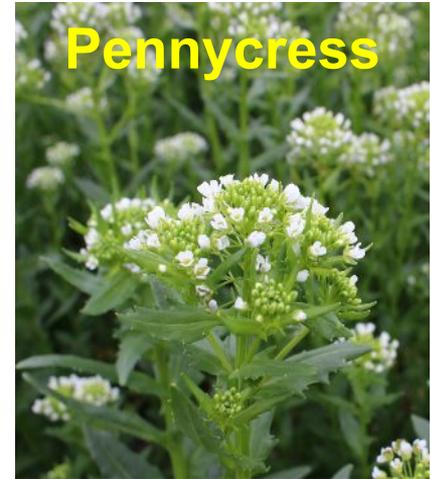
KERNZA KRUNCH

EVERY SPOONFUL IS AN EXPLOSION OF TERRA!



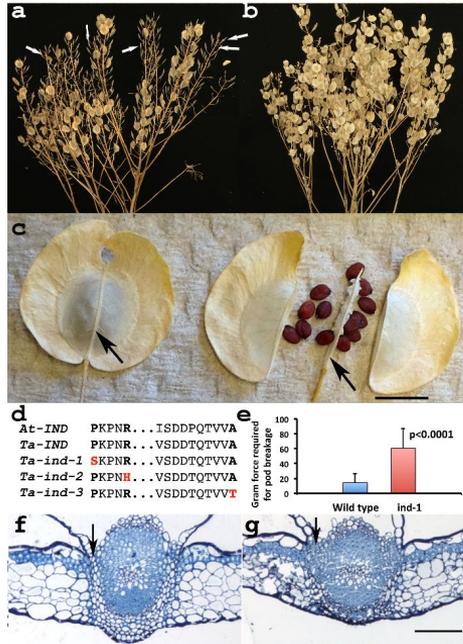
Pennycress and Camelina

- Mustard family
 - Produces an oilseed
 - Wild pennycress has a garlic smell and camelina a mustard-like smell
- Extremely hardy winter annuals
- High yielding, high oil content
- Food and Industrial uses
 - Pennycress:
 - **industrial oil**
 - **edible** with reduced erucic acid and glucosinolates
 - Camelina:
 - **industrial oil**
 - **edible** - heart healthy oil
 - High protein meal for feed and human food use

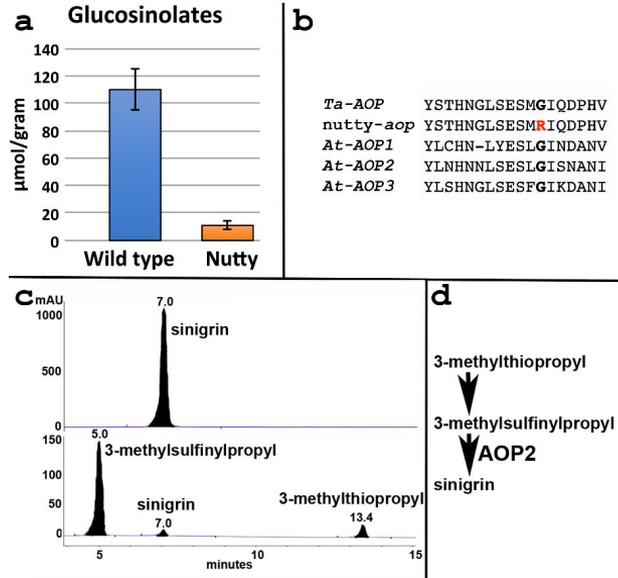


Domestication of pennycress as an oilseed crop

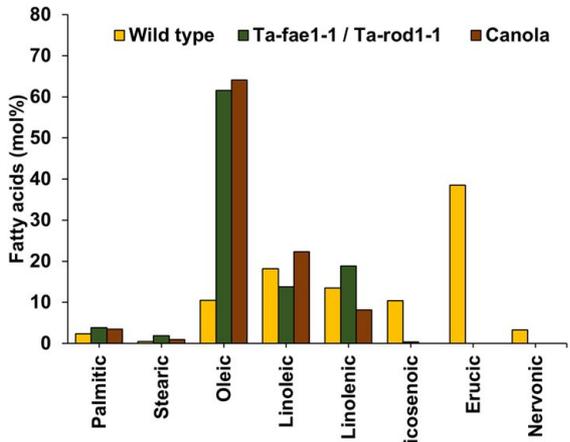
Reduced Seedpod Shatter: Increased Yield



Reduced Anti-nutritional Glucosinolates: Better for Animal Feed



Reduced Erucic and PUFAs: Now Similar to Canola



ARTICLES
<https://doi.org/10.1038/s43016-019-0007-z>
 nature food

news & views

AGRICULTURAL GENETICS

From stinkweed to oilseed

Up to now, creativity, ingenuity, time and more than a little luck have been essential for transforming a wild plant into a new food crop. Building on the understanding of gene function in *Arabidopsis*, the process of domestication can be rapidly accelerated.

Anne B. Britt

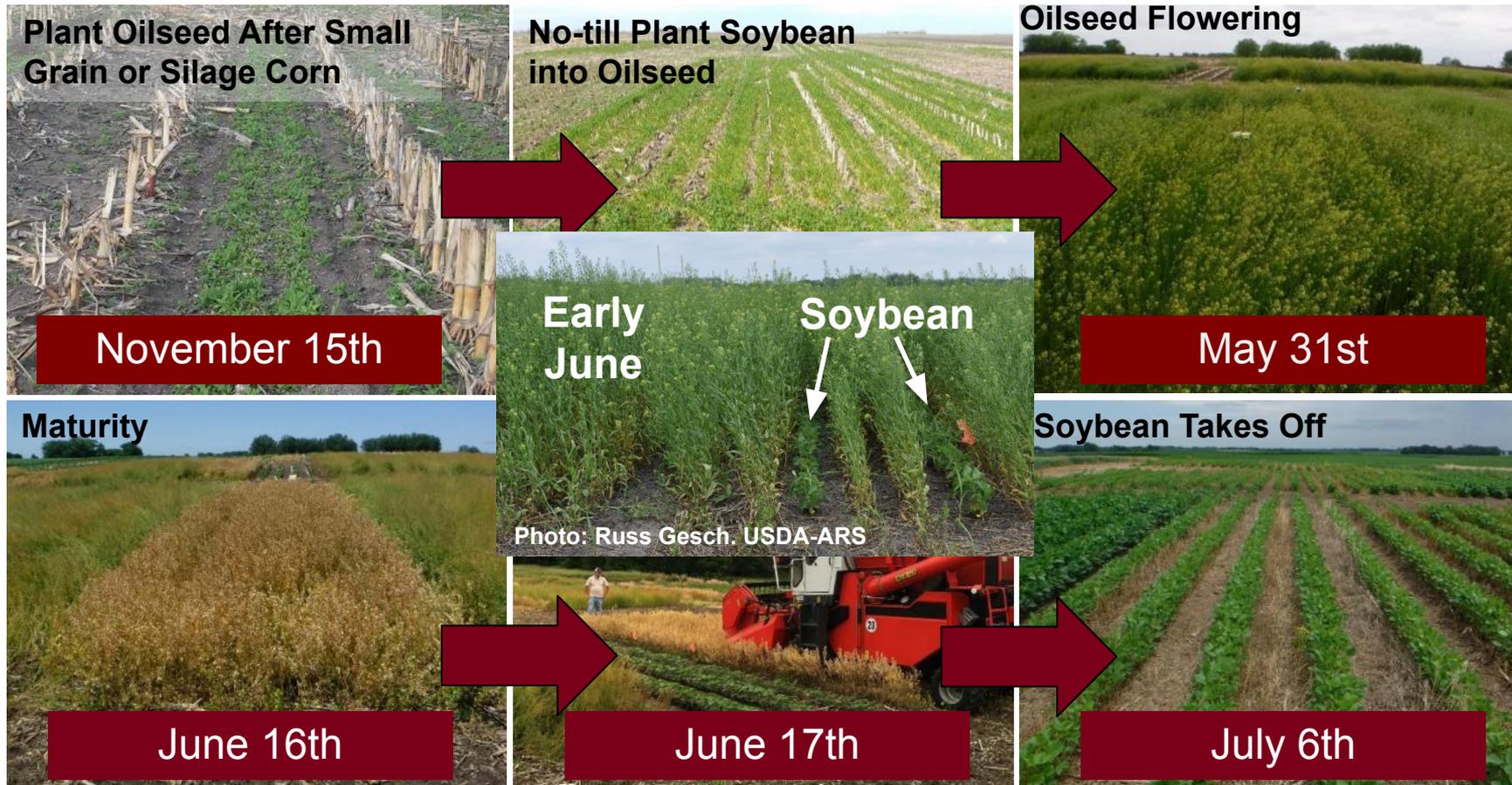
Identification and stacking of crucial traits required for the domestication of pennycress

Ratan Chopra¹, Evan B. Johnson^{1,6}, Ryan Emenecker^{1,9}, Edgar B. Cahoon², Joe Lyons⁵, Daniel J. Kliebenstein⁴, Erin Daniels^{1,10}, Kevin M. Dorn^{1,11}, Maliheh Esfahanian², Nicole Folstad¹, Katherine Frels⁵, Michaela McGinn¹⁰, Matthew Ott⁶, Cynthia Gallaher⁷, Kayla Altendorf⁸, Alexandra Berroyer⁵, Baraem Ismail⁷, James A. Anderson⁸, Donald L. Wyse⁸, Tim Ulmasov⁵, John C. Sedbrook⁵ and M. David Marks^{1*}

Oilseed-Soybean Cropping System: Overview

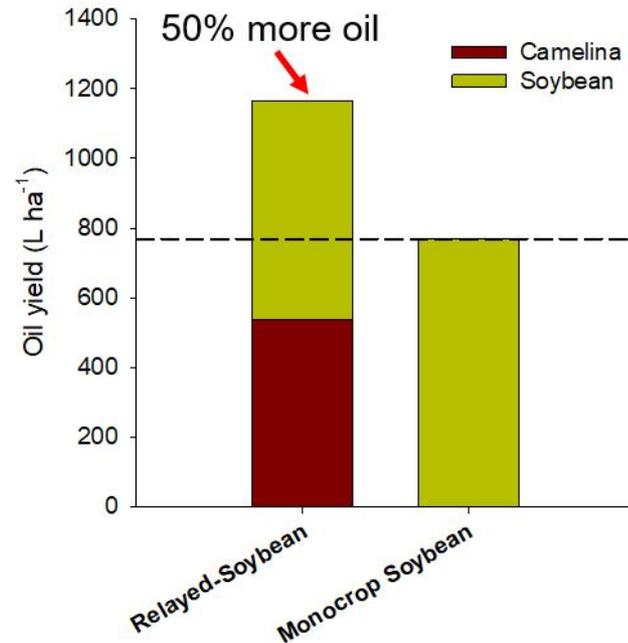
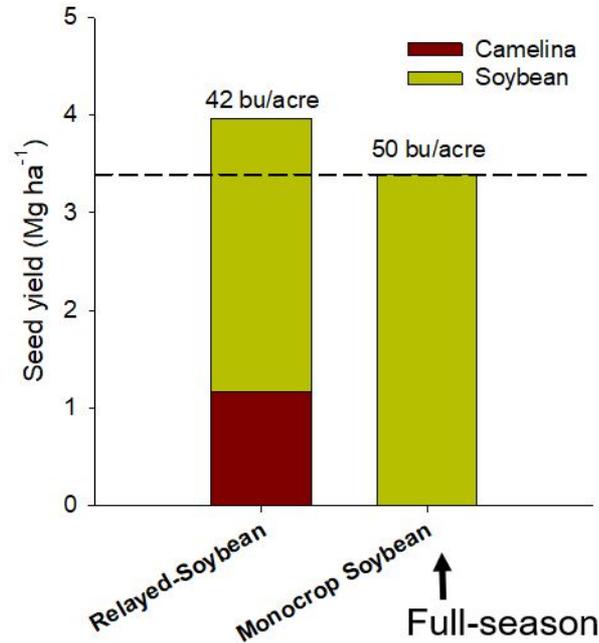


Oilseed-Soybean Cropping System: Overview



Oilseed-Soybean Cropping System: Productivity

Higher total grain and oil production when winter camelina is relayed with soybean



Research Objectives in Corn-Soybean System

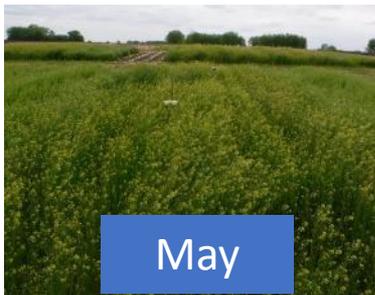
- Develop BMPs for establishing pennycress and camelina in grain corn systems
- Evaluate ecosystem benefits from integrating pennycress and camelina into corn-soybean systems



Oilseed Cropping System: Ecosystem Services



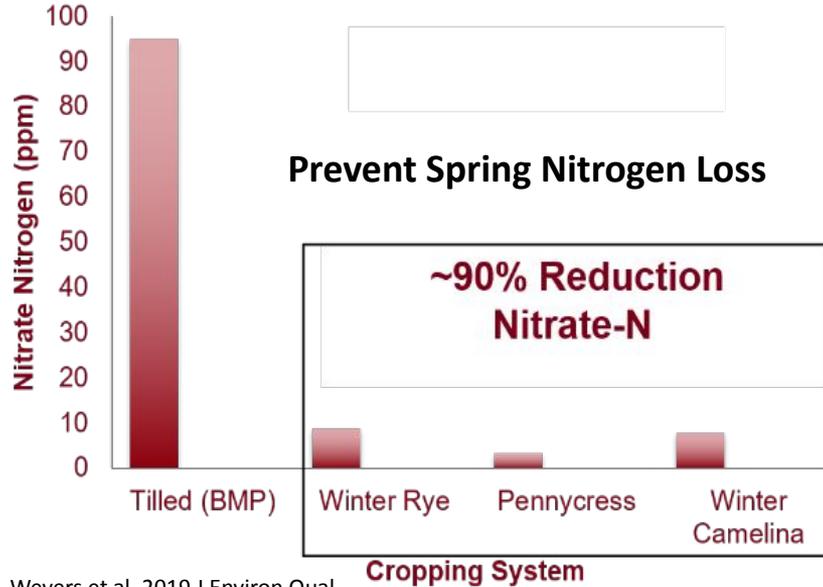
April



May



June



Weyers et al. 2019 J Environ Qual



Reduce Soil Erosion:
Lighter Color = Less Sediment

Weyers et al. 2020 J Environ Qual



Suppress Weeds

Weedy check

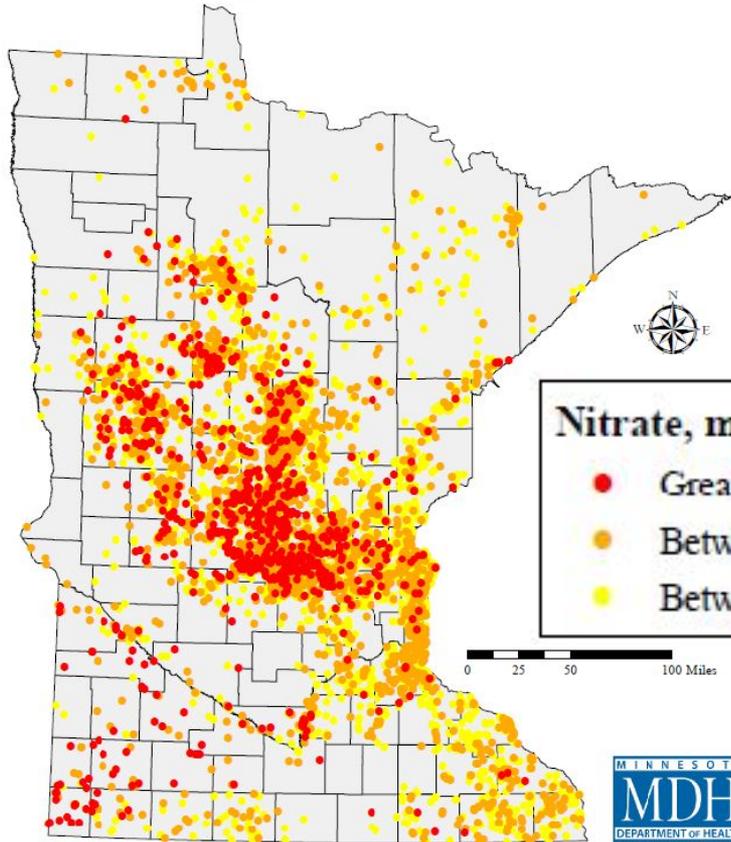
Camelina - no herbicide

Weedy check

Hoerning et al. 2020 Agron J

Nitrate in Private Wells 1990-2015

Map prepared by Minnesota Department of Health, May 2015



High nitrate levels are threatening water quality across the state of Minnesota

← Unsafe levels

← Borderline levels

This map shows 7,814 domestic wells where the nitrate concentration was at least 3.0 mg/L. The source of these data is the MDH WELLS database, which includes results of 222,341 water samples collected at the time of well construction for wells drilled since 1990. Each well is represented by a single sample result. In the few instances where there were multiple sample results for a well, the maximum nitrate value was used.

Oilseed Markets for Camelina and Pennycress:

**Oil for Low-Carbon
Jet Fuel and
Renewable Diesel**

**Vegetable Oil for
Cooking**

**Meal for High-Protein
Food and Feed**



Support Needed to Make the Forever Green Initiative Successful

- Support **research and development** of FGI crops and associated end-use products
- Support development of **markets and supply chains** for FGI crops and associated end-use products
- Support **supply chain actors (companies)** that are working to scale up each FGI crop



S.F. 1314:

Critical Funding for the Forever Green Initiative

Mitch Hunter, PhD

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Adjunct Assistant Professor,
Department of Agronomy and Plant Genetics
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Bill Overview

- Targeted support
- \$2 million per year of base research funding
- One-time \$10 million investment in equipment and infrastructure



Base Research Funding

- \$2 million per year
- Establish long-term stability
- Top priorities:
 - Stabilize soft-funded breeders
 - Maintain expertise in trait discovery
 - Support management of the initiative
- Also support graduate students, post-docs, technicians and other research expenses



Equipment and Infrastructure Funding

- One-time, \$10 million investment
 - The need exceeds \$20 million
- Address critical gaps for our key disciplines
- Identify highest priorities through competitive grant process
- Long-term enhancement of research capacity within FGI and CFANS



Equipment and Infrastructure Funding

- Outcomes:
 - Faster progress toward our goals
 - More efficient use of other public research dollars
 - More opportunities to leverage federal and private funds



Examples: Equipment and Infrastructure Needs

Field Equipment



Lab Equipment



Food Science Equipment

