Developing High-Efficiency Agricultural and Food Systems: A Forever Green Agriculture Initiative

Donald Wyse
University of Minnesota
Figure 19. Cover map of the Winnebago pheasant study area, 1941.
Figure 23. Cover map of the Winnebago pheasant study area, 1976.
May 4 – 17

Areas of annual row cropping

April 20 - May 3

Areas of perennial vegetation

Satellite images of vegetative activity.
Satellite images of vegetative activity.

May 18 - 31

June 15 - 28
Satellite images of vegetative activity.

July 13 - 26

October 5 - 18
Monthly Precipitation in the Cottonwood River Watershed

Annual precipitation = 26.8 in
Oct. through April precipitation = 9.4 in (35.2% of annual)

Source: MN St. Clim. Office
Annual Tile Drainage Loss in Corn-Soybean Rotation
Waseca, 1987-2001

- April, May, June: 71%
- July-March: 29%
Developing New Perennial and Winter Annual Crops to Enhance Minnesota’s Soil and Water Resources

PERENNIAL CROPS
- Intermediate wheatgrass “Kernza” – wheat-like grain, forage, biomass
- Perennial sunflower – edible seeds, oil
- Native polyculture grassland mixtures – biomass, forage, natural products
- Perennial flax – edible oil
- Kura clover – N-fixing cover crop
- Silphium – edible oil

WINTER ANNUAL CROPS
- Pennycress – oil, biofuel, cover crop
- Camelina – edible oil, biofuel, cover crop
- Winter barley – food, malting barley
- Hairy vetch – cover crop, N-fixation

NATIVE WOODY CROPS
- Hazelnuts – nuts, edible oil
- Shrub willow – biomass
- Elderberry – antioxidant-rich fruit
- Agroforestry – woody and herbaceous crop mixtures for feed, food and fuel
Intermediate Wheatgrass
Kernza™
*Thinopyrum intermedium*
Enterprises:
Beer/Whiskey
Food
Biomass
Grazing
Funding: IREE, MDA, Forever Green
Initiative, The Land Institute
Intermediate wheatgrass

---- Environment services

- Reduce erosion and soil nitrate leaching
- Reduce inputs of energy and pesticide
- Increase carbon sequestration
Intermediate wheatgrass in Minnesota
Intermediate wheatgrass

---- Agronomic traits

**Large seeds**

---- 10-15g/1000 seeds

**Large biomass**

---- comparably to big bluestem and switchgrass

**Disease resistance**

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

**Favorable end-use food**

wheat, wheatgrass
Intermediate wheatgrass

Our goal

— Obtain a commercially viable perennial grain/biomass crop

Wild Perennial

Domestication

Perennial Grain

Increase grain yield and biomass

Enhance grain quality for food
Sequencing the Kernza Genome

Project started in 2016

Chromosome-scale assembly completed 3/31/17

Intermediate Wheatgrass Project

Intermediate Wheatgrass (IWG) is a highly productive perennial grass species that is being developed as a new biomass and grain crop. As a perennial crop, IWG can provide essential ecosystem services to current agricultural practices such as stabilizing soil with its deep root structure, reducing nutrient runoff, and limiting weed growth. IWG produces biomass quantities similar or greater than switchgrass, with the added potential of 4,000 kg/ha of grain that can be substituted for wheat in food products with minor changes to recipes. There have been significant efforts to improve IWG through traditional breeding. There remains an immediate need for new crops that provide both economic value and ecosystem services, and the rapid development of such species will enable society to immediately reap the potential benefits. These crops epitomize a potential solution for the call of sustainable intensification and meeting feedstock production needed for biofuels and hold great promise to increase the resilience of agricultural systems in light of serious environmental issues facing agriculture.

Proposer’s Name: Jesse Poland, Kansas State University

CSP Plans – FY 2016

One of the selected CSP projects involves sequencing intermediate wheatgrass (Elymus trachycaulus), depicted on the left. The hairy glumes and lemmas are characteristic of Agropyron medium intermediate but have been tipped glabrous lemmas. [MatLaya, CC BY-SA 2.0 (public domain)]
Intermediate Wheatgrass improvement

Seed weight

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Large seeds

1 cm
Breeding nurseries in St. Paul

2000 spaced plants

440 yield plots
Irrigation boosts potatoes, but Park Rapids pays more for water

Dan Gunderson • Park Rapids, Minn. • Feb 13, 2014

Tainted drinking water is costing Minnesota taxpayers millions

Randall's water emergency is the latest sign of an environmental problem in Minnesota. Nitrogen fertilizer is leaching into groundwater from farm fields, contaminating wells and costing taxpayers millions of dollars a year.

By Tony Kennedy Star Tribune • APRIL 29, 2015 — 12:24PM
Soil moisture beneath annual and perennial crops

Soil moisture content 100 cm below soil surface in corn, Kernza, and switchgrass at Waseca in 2015.

Junge et al., unpublished
Soil water nitrate concentration beneath annual and perennial crops

Nitrate content in soil water 50 cm below soil surface in corn, Kernza, and switchgrass when fertilized with 160 kg N per ha (state average for corn) in 2013, one year after seeding.

Junge et al., unpublished
Soil water nitrate concentration beneath annual and perennial crops

Nitrate content in soil water 50 cm below soil surface in corn, Kernza, and switchgrass when fertilized with N rates optimize for grain production in 2014.

Junge rs et al., unpublished
Kernza Agronomics

- Nitrogen rates
- Row spacing
- Harvest timing
- Grazing - dual use
- Legume intercropping
- Yield persistence
Evaluation of intermediate wheatgrass grain for food use
Kernza Food Science

- Gluten composition
- Protein analysis
- Storability
- Flavor profiling
General Mills boosts eco-friendly grain Kernza
Kernza Commercialization
Kernza Commercialization

The Draft Horse

Birchwood Cafe

Dumpling & Strand

Common Roots Cafe

Baker's Field

Bang Brewing
Field Pennycress
*Thlaspi arvense*

Enterprises:
Oil—biodiesel/food
Protein—food and feed
Double or relay crop with soybean

Funding source: DOE/USDA, U of MN, MDA, Forever Green Initiative
Thlaspi arvense
Pennycress

Brassicaceae
(mustard family)

Extremely cold tolerant winter annual

Rapid seed maturity

High oil content

Double or relay cropping potential with soybean

Diploid/good breeding potential
Pennycress breeding targets

**Domestication traits**
- Uniform germination ✓
- Reduced seed shatter ★
- Earlier flowering and maturity ★

**Agronomic Traits**
- Lodging resistant
- Seed yield ✓

**End-use quality traits**
- Oil content and quality
  - Edible (low erucic) ★
  - Industrial (high erucic)
- Low glucosinolates

✓ = Improved pennycress line identified, field testing in process
★ = Major gene(s) identified as of 1/31/2018

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April 15, 2016. Wild type pennycress compared to early flowering pennycress line.

Fatty acid profile of new low erucic pennycress compared to wild type pennycress and canola.

- Percent Fatty Acid in Oil
- New low erucic pennycress
- Wild type pennycress
- Canola
Pennycress breeding at UMN: Solutions

Three images of plant samples labeled as wild type, A7 129, and A7 236. Below these images is a line labeled "Thlaspi arvense putative SPATULA ortholog" with a mutation from C to T indicated. An arrow points to the right labeled "New reduced shatter lines."
Missed opportunities for biomass production

Biomass production

nitrogen loss

Annual grain crop

Summer
Autumn
Winter

Large opportunities for nitrogen leaching
1. Plant cover crop in corn
2. Harvest corn over cover crop
3. Cover crop lies dormant
4. Plant soybean into cover crop
5. Harvest cover over soybean
6. Summer crop grows
Pennycress seeded into corn

Soybean planted no till into pennycress stubble 1st week of June

Pennycress mid-May

Pennycress late fall

Corn/PC/Soybean Rotation

Fall soybean with pennycress regrowth
Relay planting soybean into oilseed cover crops
2014 Soybean and Oilseed yield St. Paul

Yield (Bu per acre)

- Control plot- Full season
- Control plot- Sequential
- Pennycress- Sequential
- Pennycress- Early harvest
- Pennycress- Late harvest
- Camelina- Sequential
- Camelina- Early harvest
- Camelina- Late harvest

- Oilseed yield potential
- Soy yield
Weeds/no pennycress vs Weeds/pennycress
No limit to end use potential!

This Field is Grown for: Biofuels

This Field is Grown for: Bioplastics

This Field is Grown for: Cooking oil

This Field is Grown for: Plant Protein
Advancing Commercialization of Continuous Living Cover Crops

Nick Jordan
Agronomy & Plant Genetics Department
University of Minnesota
Continuous living cover (CLC) crops: growing markets

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Long Term Nitrogen Reductions in Water

Why we need more continuous productive vegetative cover:

- 0% reduction
- 10% reduction
- 20% reduction
- 30% reduction
- 40% reduction

- 2020
- 2025
- 2035
- ?

Veg. cover
Tile mgmt.
Fertilizer efficiency
Fertilizer efficiency
Veg. cover
Tile mgmt.
Fertilizer efficiency
Fertilizer efficiency
Veg. cover
Tile mgmt.
Fertilizer efficiency
Fertilizer efficiency
CLC Crop Pipeline

Multiple crops in early-stage commercialization

Emerging markets & supply chains

Need to expand scale to drive further commercialization
Commercialization of CLC Crops

The key requirements:

• *New crops that produce commodities & help clean water*

• *Farms & supply chains that deliver CLC crops to market*

• *Profitable end-use markets*
Commercialization of CLC Crops

R&D is needed to advance:
• breeding
• agronomics
• ecosystem services
• supply-chain logistics
• end uses

All are necessary, costly, risky

Keys: Coordinate, share & manage risk
Coordination & Measured Steps

• Expand markets, supply chains, business models
• Create & learn from pilot supply/value chains
• Identify, coordinate & support critical R&D
• Keep sustainability in sight!

Needs coordination through a network
General Mills, Cascadian Farm back development of Kernza wheatgrass

“Realistically, you’ve got to believe that to develop this even from a small niche crop to a small commodity crop is going to take the better part of a decade,” Lynch said.

Proposed Agricultural Diversification Network addresses this challenge
Increasing Continuous Productive Vegetative Cover in Agriculture

Policy statement

Take coordinated action to help achieve clean water by market-driven strategies that increase continuous productive vegetative cover across Minnesota’s agricultural regions.
Achieving Clean Water by Increasing Continuous Productive Vegetative Cover

Develop an Agricultural Diversification Network

To accelerate development of new agricultural systems, featuring high levels of continuous productive vegetative cover

By market-driven strategies that will advance the agricultural & water-based economies
Agricultural Diversification Network for commercialization of CLC Crops
Achieving Clean Water by Increasing Continuous Productive Vegetative Cover

Network organizes and sustains critically needed collaborations:

Among public, private and non-profit sectors

Co-develop CLC crops & cropping systems, supply chains that deliver crops to market, & profitable end-use markets

By research, pilot policies, programs, implementation projects
Achieving Clean Water by Increasing Continuous Productive Vegetative Cover

Create and facilitate a Steering Council

Establish & direct the Agricultural Diversification Network through a robust public-private partnership

Secure resources & share risks for new agricultural systems that enhance water resources & advance Minnesota’s agricultural & water-based economies
Achieving Clean Water by Increasing Continuous Productive Vegetative Cover

New Leverage on Drinking Water Source Protection
Nitrate Leaching and Groundwater

Nitrogen Fertilizer

Unsaturated Zone

Nitrogen Leaching

Groundwater
Kernza and water quality

LCCMR project to support field-scale monitoring of Kernza fields in wellhead protection areas
Achieving Clean Water by Increasing Continuous Productive Vegetative Cover in Minnesota Agriculture

New Leverage on Drinking Water Source Protection

• 350,000 relevant acres in Minnesota
• Goal: enhance vegetative cover by growing CLC crops on sensitive areas
• Diversification Network can coordinate:
  • Priority sites & implementation planning
  • Support for growers: technical & financial
  • Market & supply chain development
  • Monitoring & assessment
  • R&D support