Managing Agricultural Landscapes for Ecosystem Services, Productivity & Profit

A Forever Green Agriculture Initiative

Donald Wyse, U of MN

How did agricultural landscapes lose their diversity?

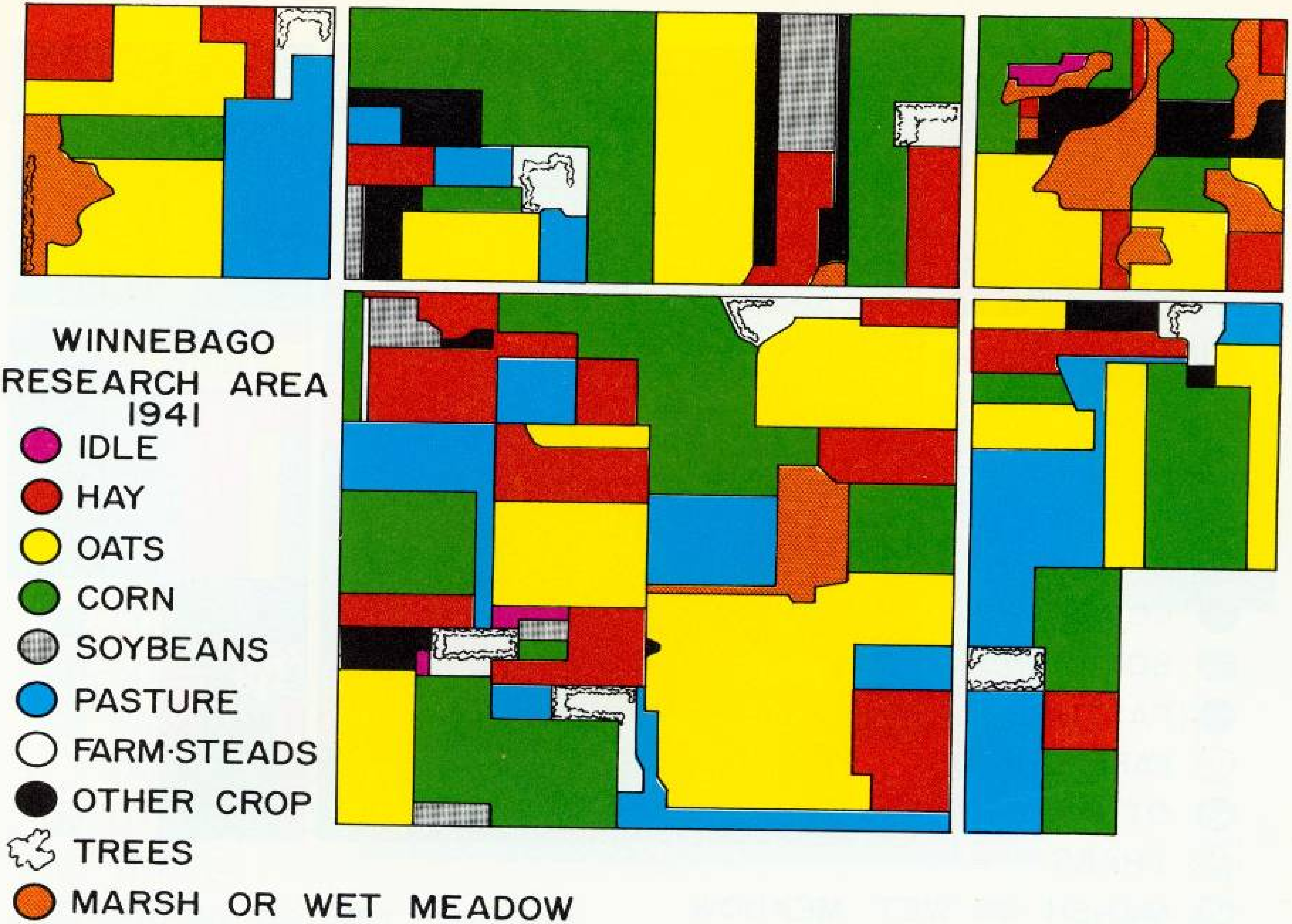


Figure 19. Cover map of the Winnebago pheasant study area, 1941.

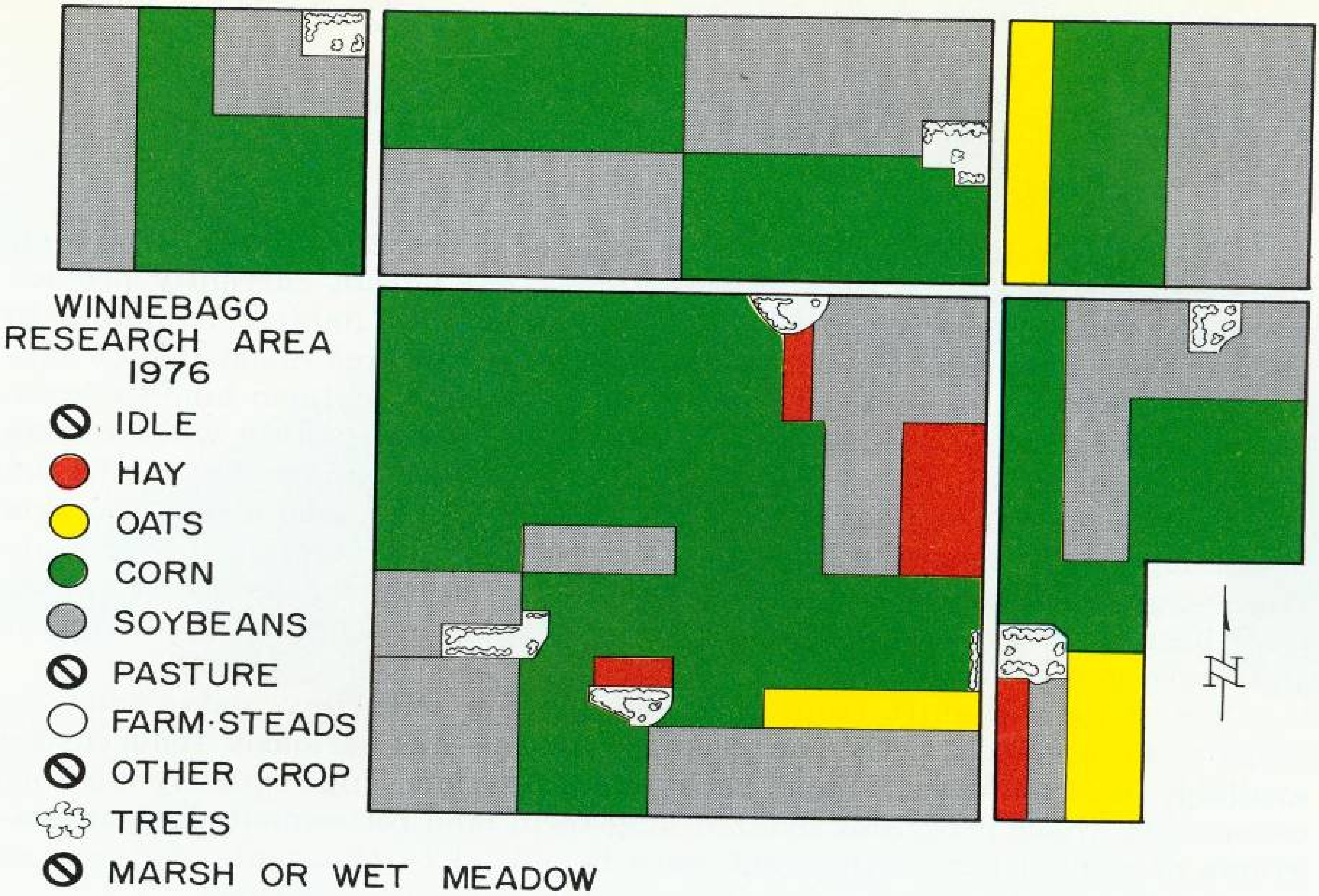


Figure 23. Cover map of the Winnebago pheasant study area, 1976.

Protein efficiency 6 %
1lb beef 5,214 gal water
1lb potatoes 24 gal water

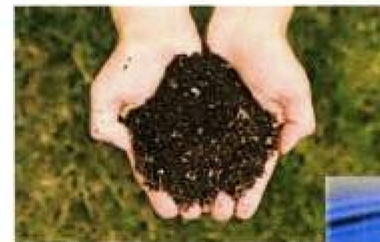

Protein efficiency 14%
1lb Pork 1,630 gal water
1lb Potatoes 24 gal water

What are some of the **consequences** resulting from the loss of landscape diversity and continuous living soil covers?

Ecosystem Services

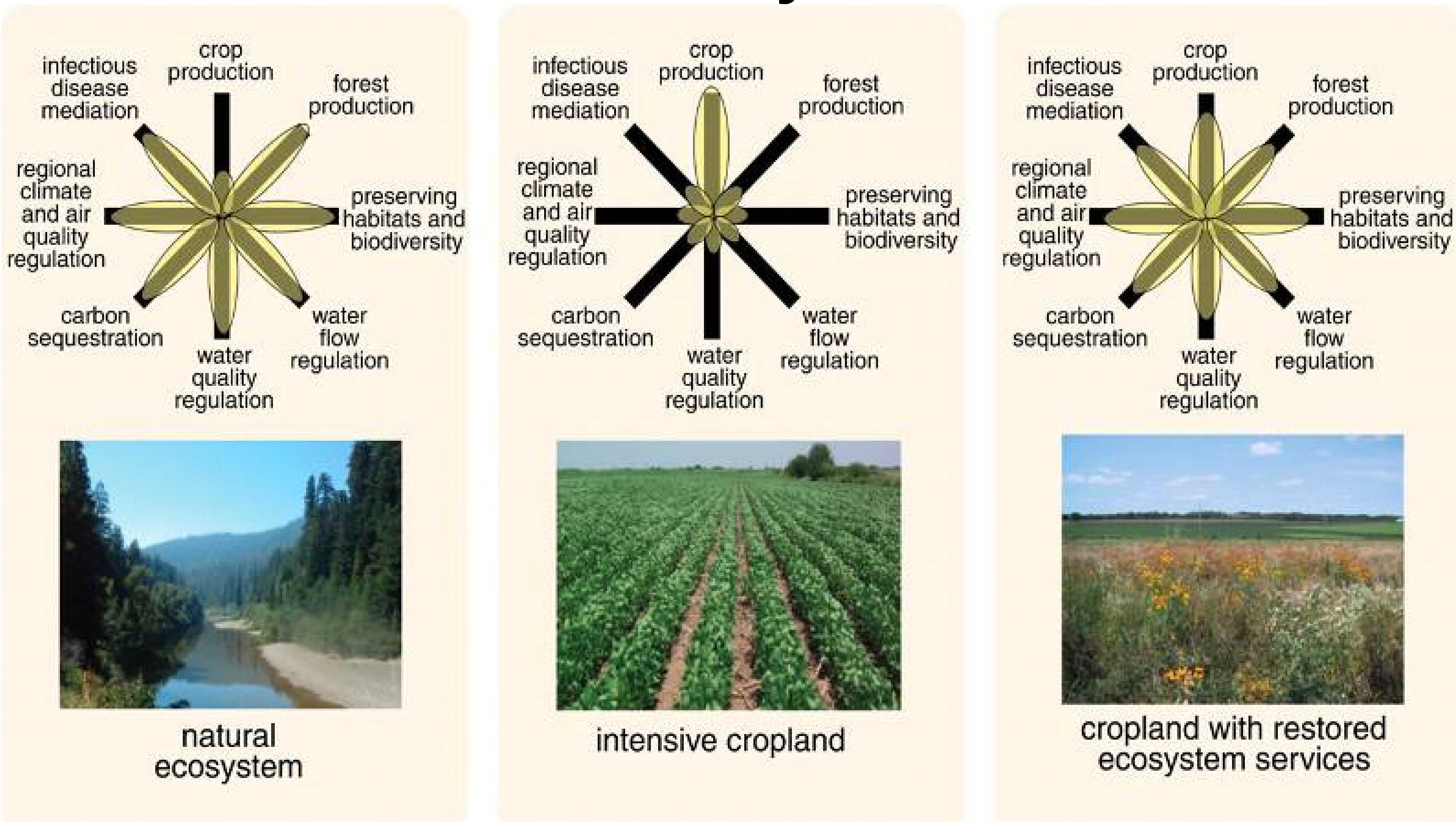
The benefits people obtain from ecosystems

- Supporting
  - Nutrient cycling, soil formation…
- Provisioning
  - Food, fuel…
- Regulating
  - Pollination, pest suppression...
- Cultural
  - Recreation, aesthetic…



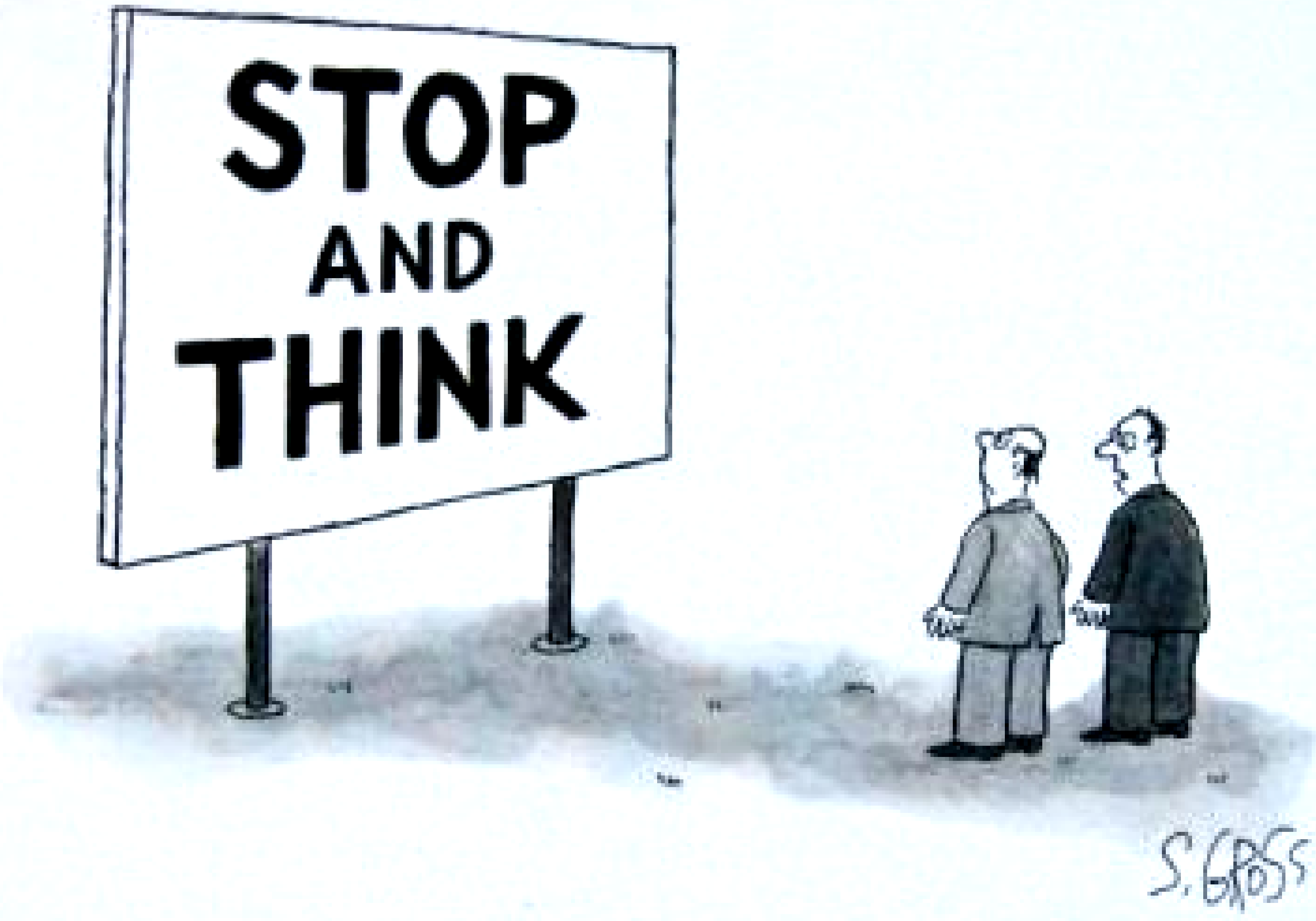

Costanza *et al.* Nature 1997
Millennium Ecosystem Assessment 2005
Swinton *et al.* Am. J of Agric. Econ. 2006

Conceptual framework for comparing land use and trade-offs of ecosystem services



J. A. Foley et al., Science 309, 570 -574 (2005)

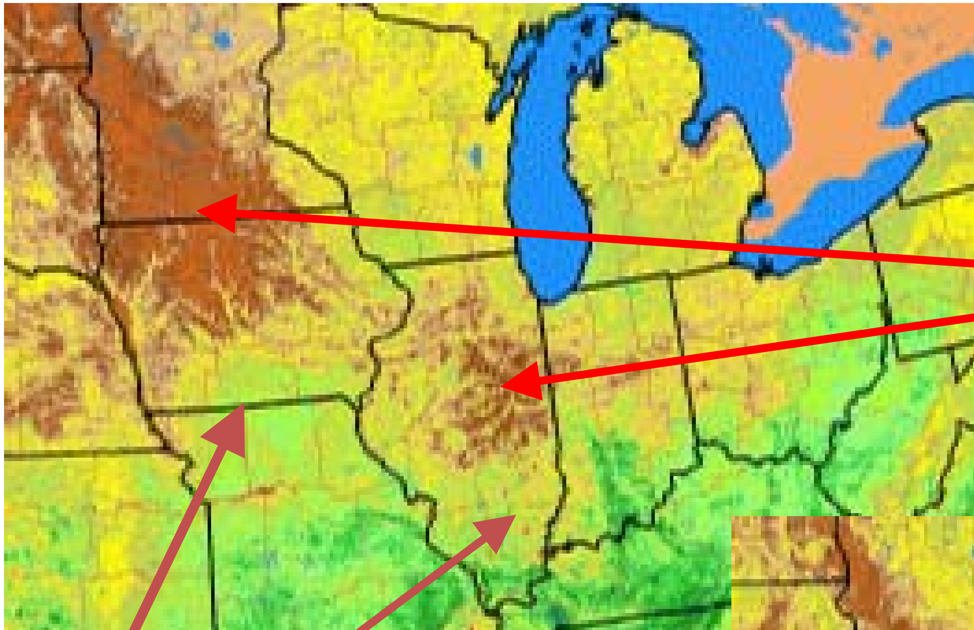
Published by AAAS



"It sort of makes you stop and think, doesn't it."

Minnesota’s Brown Period

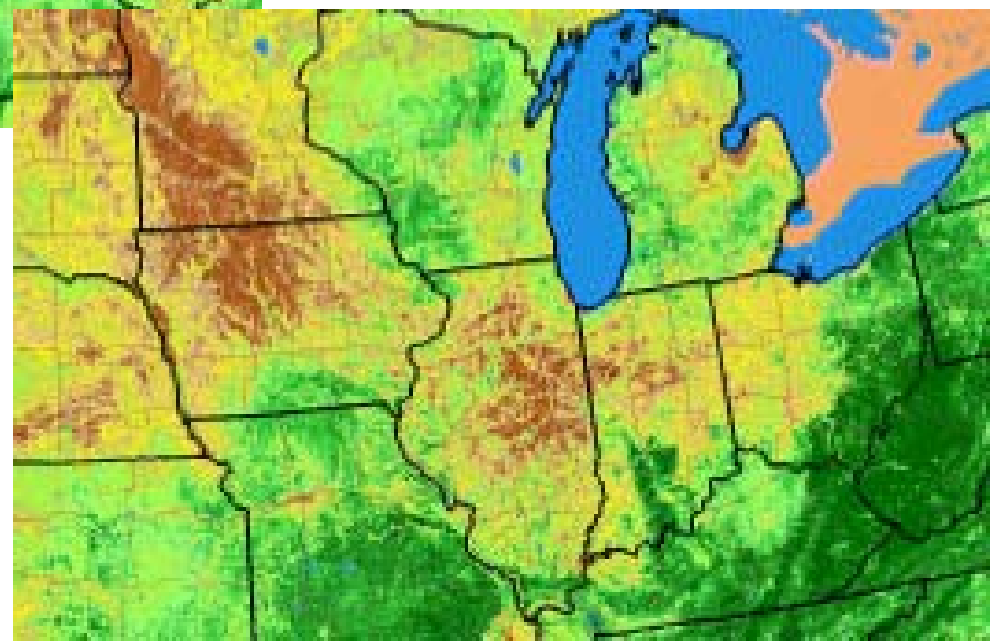
Satellite images of vegetative activity.



April 20 – May 3

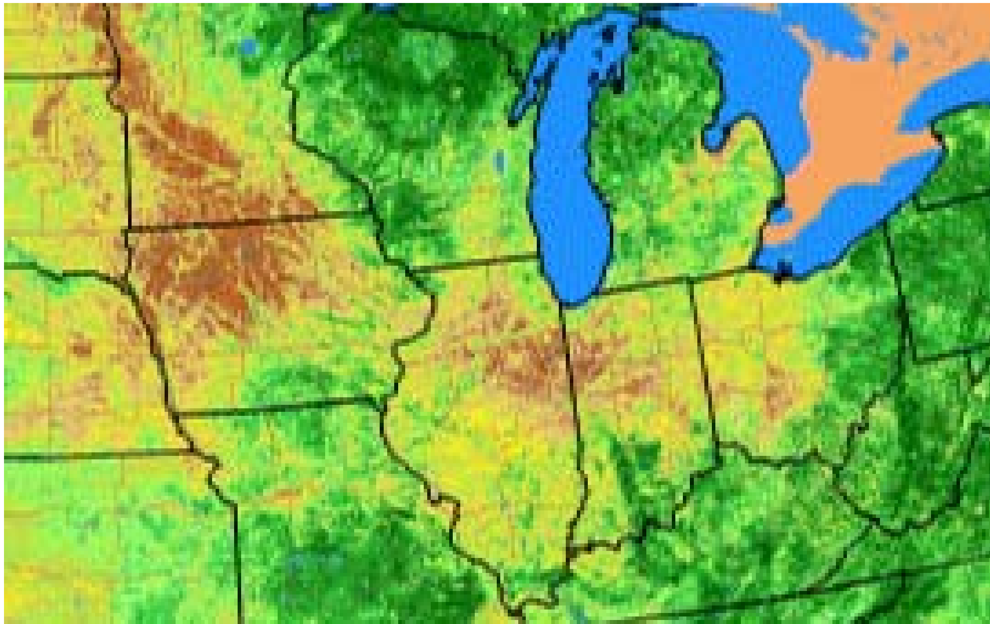
Areas of annual row cropping

Areas of perennial vegetation

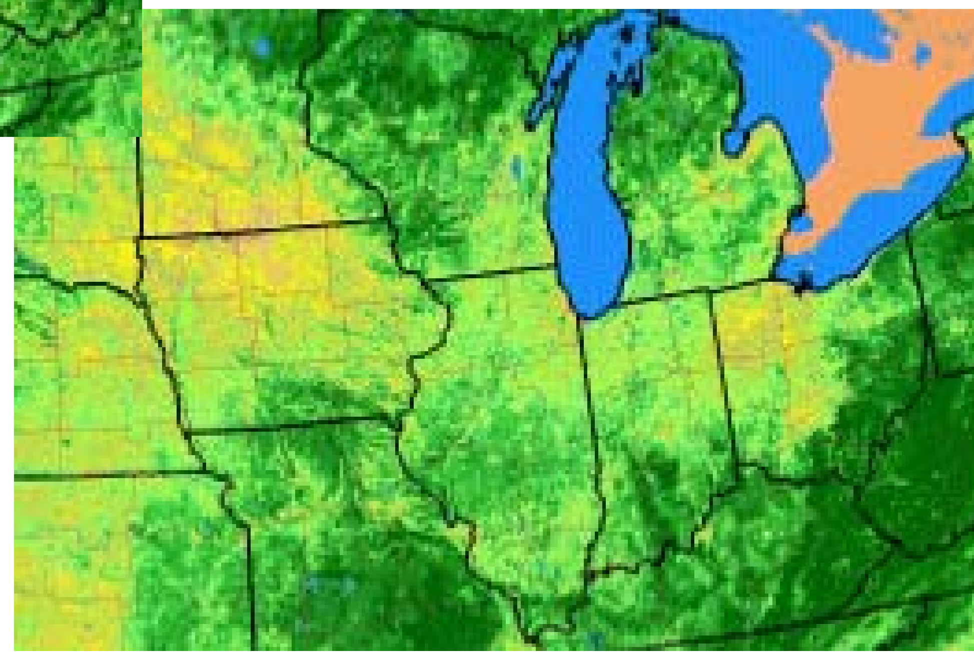


May 4 – 17

Satellite images of vegetative activity.



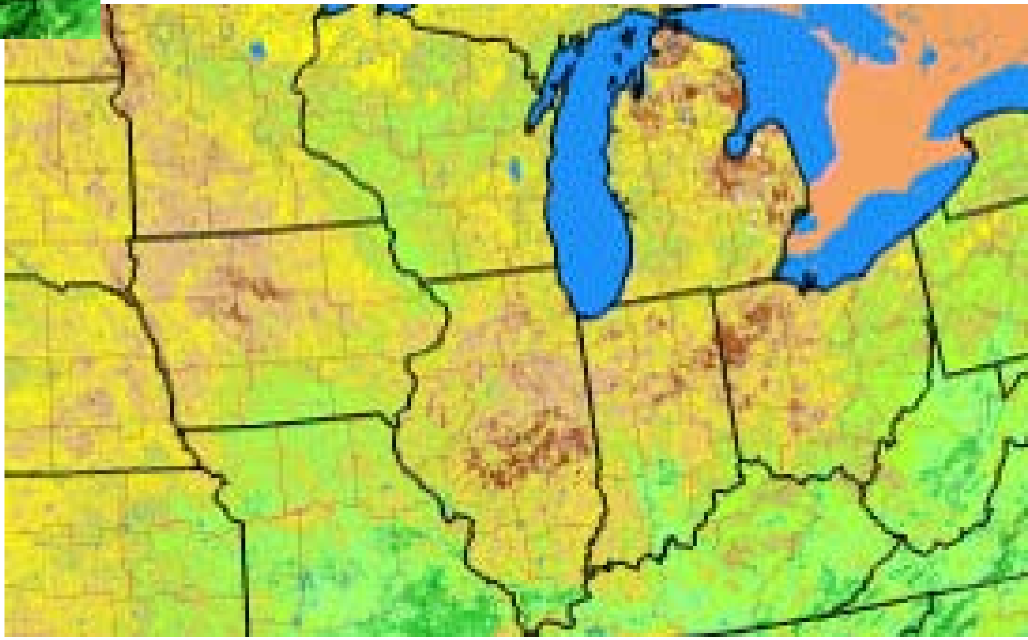
May 18 - 31



June 15 - 28

Satellite images of vegetative activity.

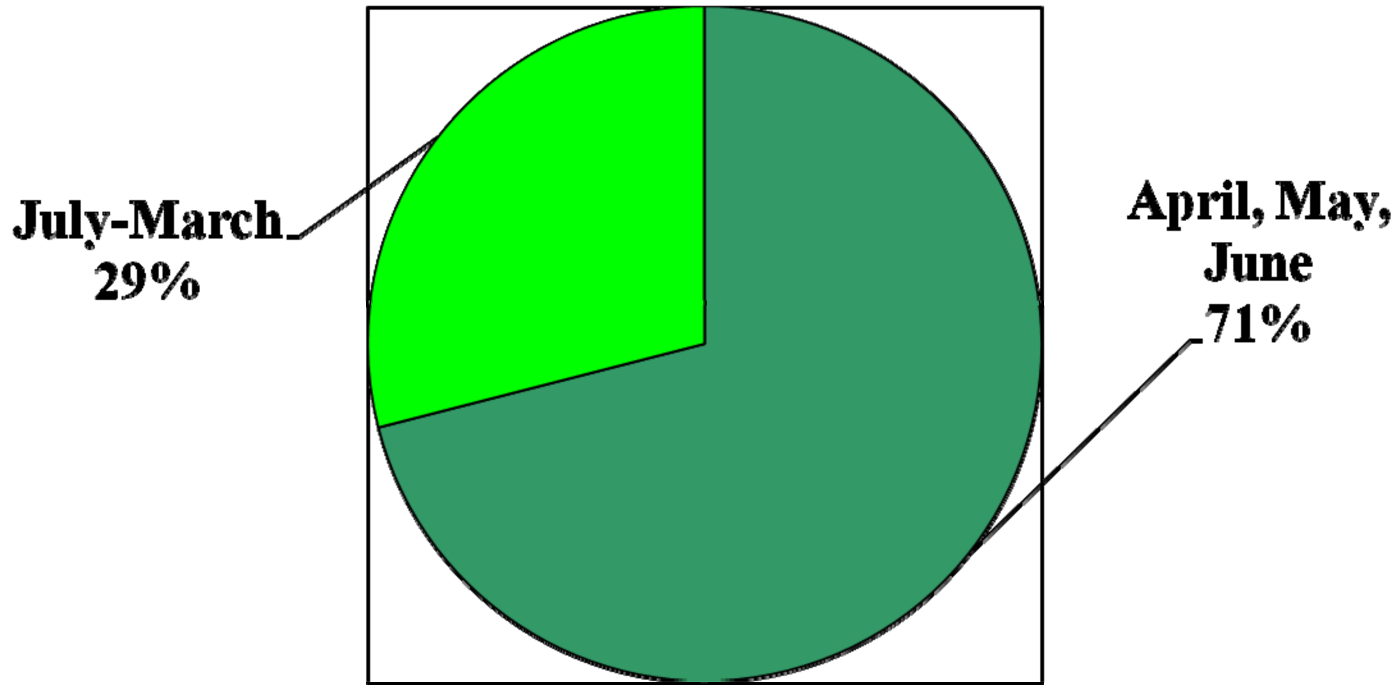
July 13 - 26

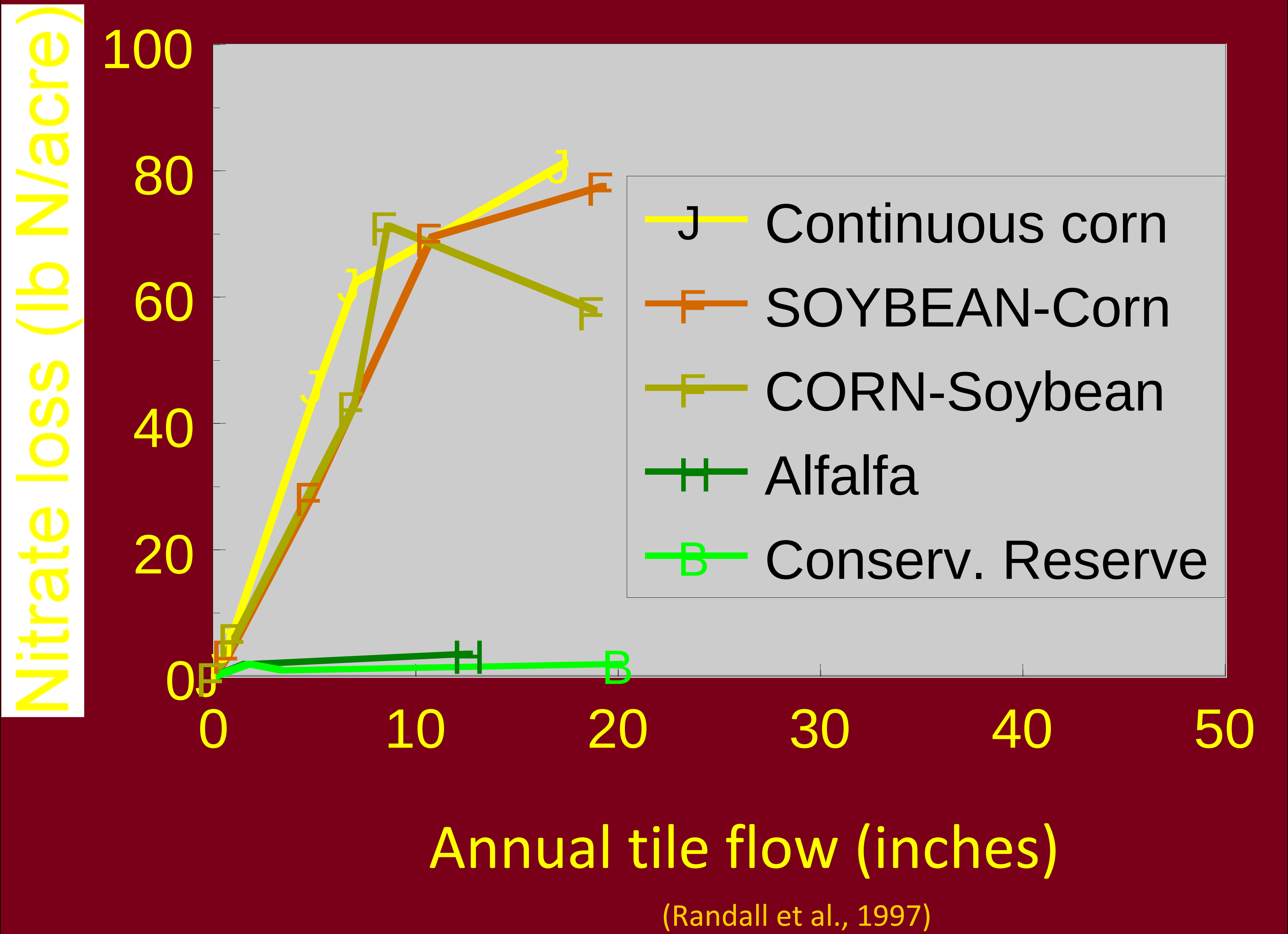


October 5 - 18

Annual Tile Drainage Loss in Corn-Soybean Rotation

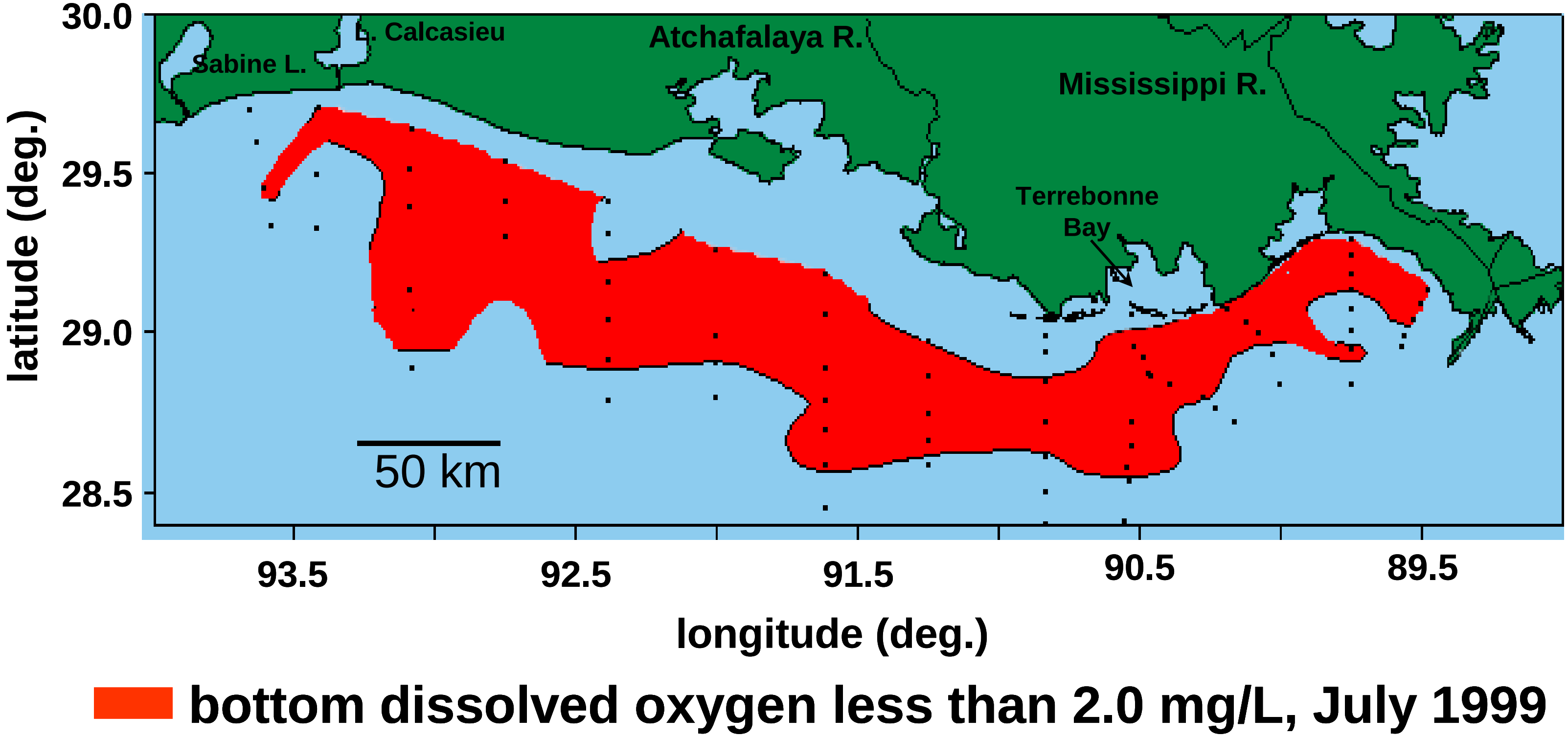
Waseca, 1987-2001



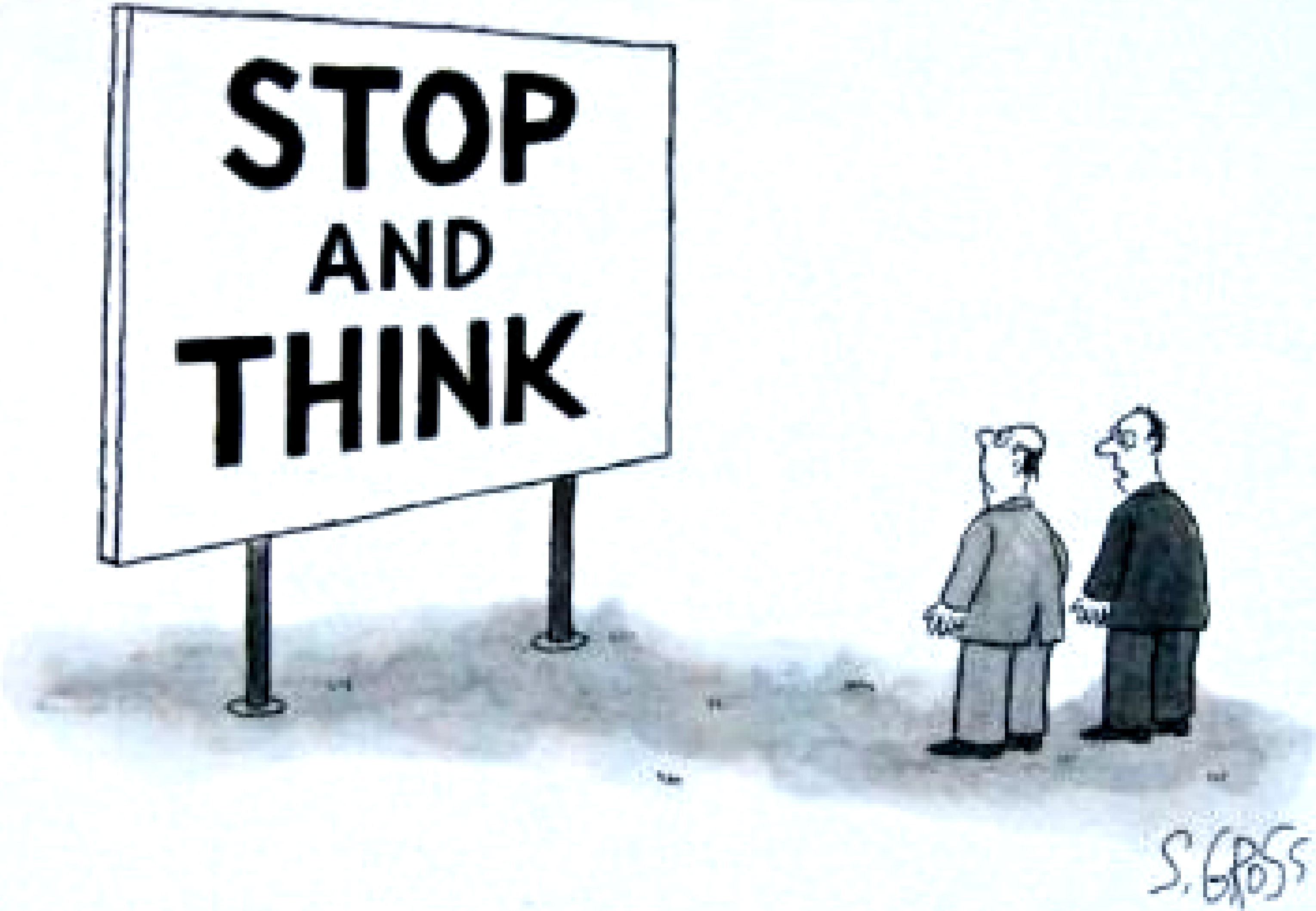


Nitrate loss (lb N/acre)
100
80
60
40
20
0
0
10
20
30
40
50
Continuous corn
SOYBEAN-Corn
CORN-Soybean
Alfalfa
Conserv. Reserve
Annual tile flow (inches)
(Randall et al., 1997)

Hypoxia in the Gulf of Mexico



Rabalais et al. 2000



"It sort of makes you stop and think, doesn't it."

Covering the Brown: Continuous Living Cover

Our Agriculture could achieve more production, efficiency & conservation

How: Add winter-annual crops & perennials to summer-annual cropping systems like corn and soybean

Why:

New economic opportunities for farmers & rural communities

Many other benefits for Minnesota

Visualization of perennial & annual crops in Central Iowa

Adding perennials & winter annuals does four very important things

- Creates value from underused and new resources
- Enhances soil, water, wildlife & biodiversity
- Insures against climate variability
- New economic opportunity

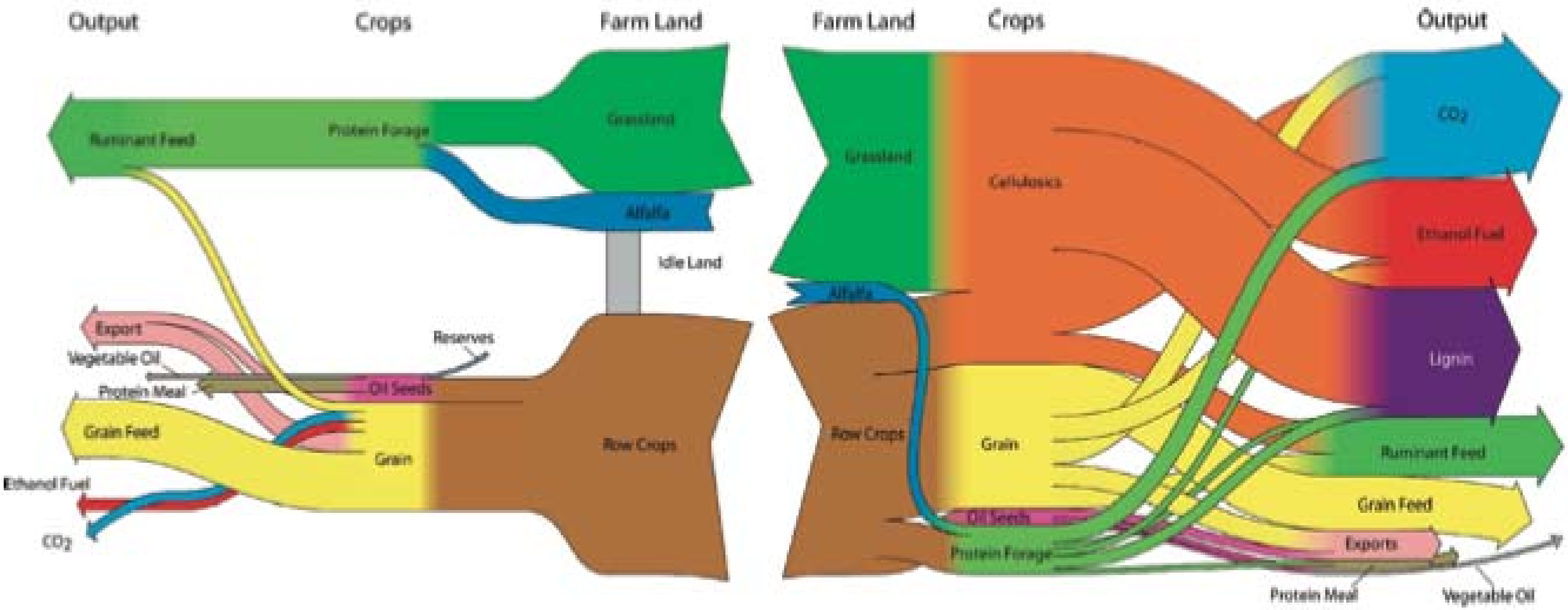
Applying this vision to Midwest Agriculture

Current Ag Outputs

- Food
- Feed
- Biofuel (just a little…)

More Perennials and Winter annuals

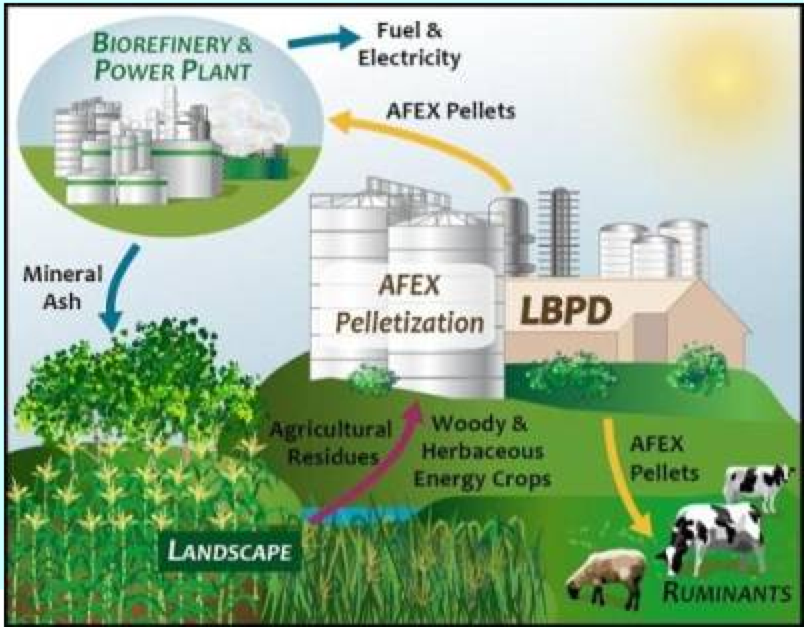
- **More** food & feed
- **Much** more biofuel & natural prod.
- **More** soil, water, wildlife



Getting There from Here: Forever Green

Getting perennials & winter annuals on the landscape by germplasm development, new agronomic practices, commercialization & supply-chain development

- **New genetic technologies allow rapid germplasm development**
- **Develop new agronomic practices (e.g. seeding tech.**
- **Commercialization: new market opportunities**
- **Supply chains: from production to end use**



Forever Green Plant Based Enterprise Development Projects:

1. Field Pennycress
2. Intermediate Wheatgrass
3. Camelina
4. Winter Barley
5. Hairy Vetch
6. Winter Rye
7. Kura Clover
8. Perennial Sunflower
9. Hazelnut
10. Native Plant Poly-cultures
11. Native Plant Natural Products
12. Perennial Flax
13. Agroforestry

1. Field Pennycress

Enterprises:

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

PI D. Wyse

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 oil for biofuel

-High seed yields – up to 1600 lbs +/acre in MN

- Seeds high in oil
  - 20-36%/wt = 404 L/acre oil = 87 gal/acre biodiesel
- Ideal composition for biodiesel production
  - 32% erucic (22:1)
  - 22% linoleic (18:2)
  - 11% linolenic (18:3)

- Technology for conversion to biodiesel in place

Corn/PC/Soybean Rotation

Pennycress seeded into corn

Pennycress late fall

Pennycress mid-May

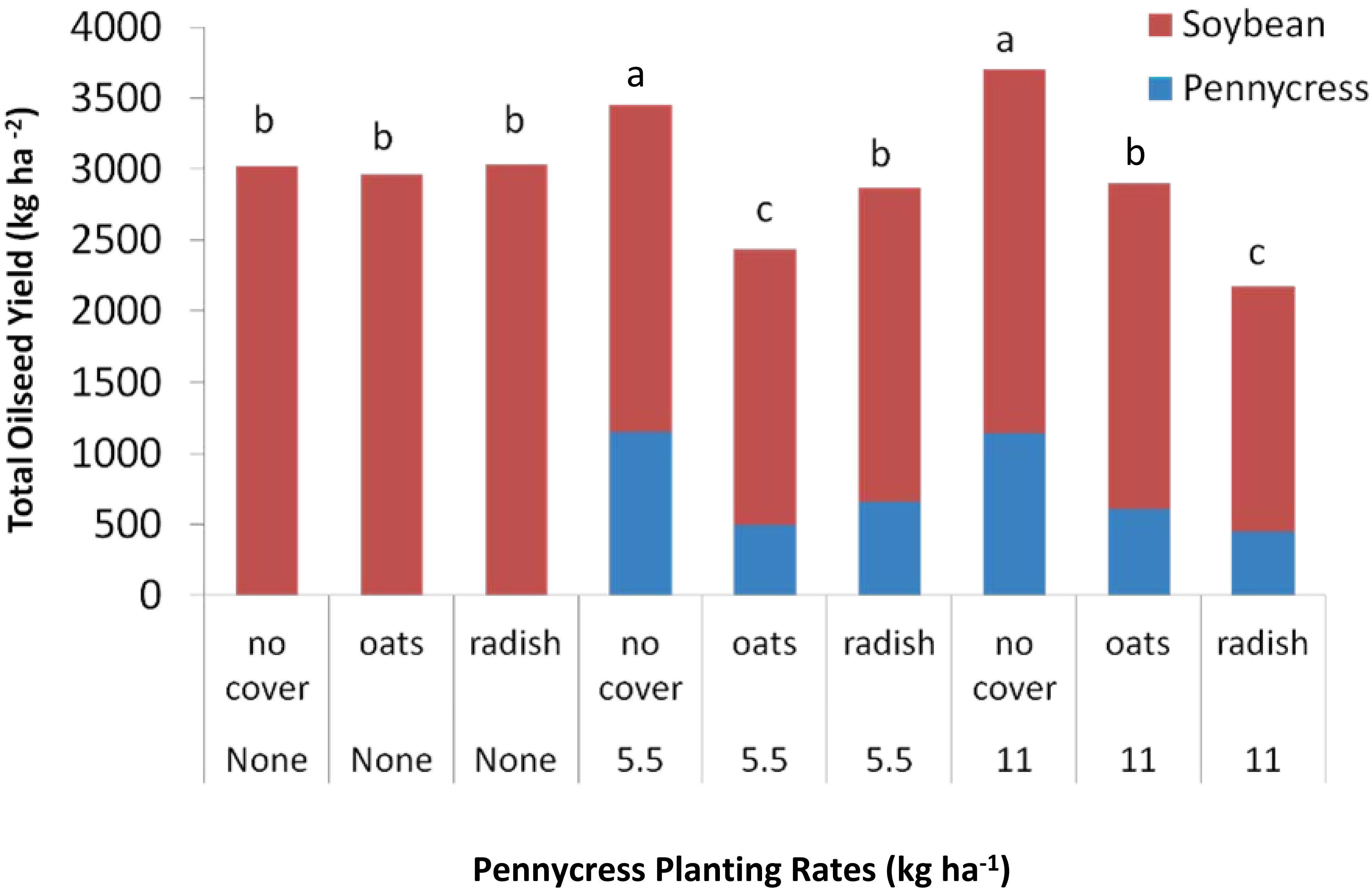
Soybean planted no till into pennycress stubble 1st week of June

Fall soybean with pennycress regrowth


Pennycress with no cover
Late Fall

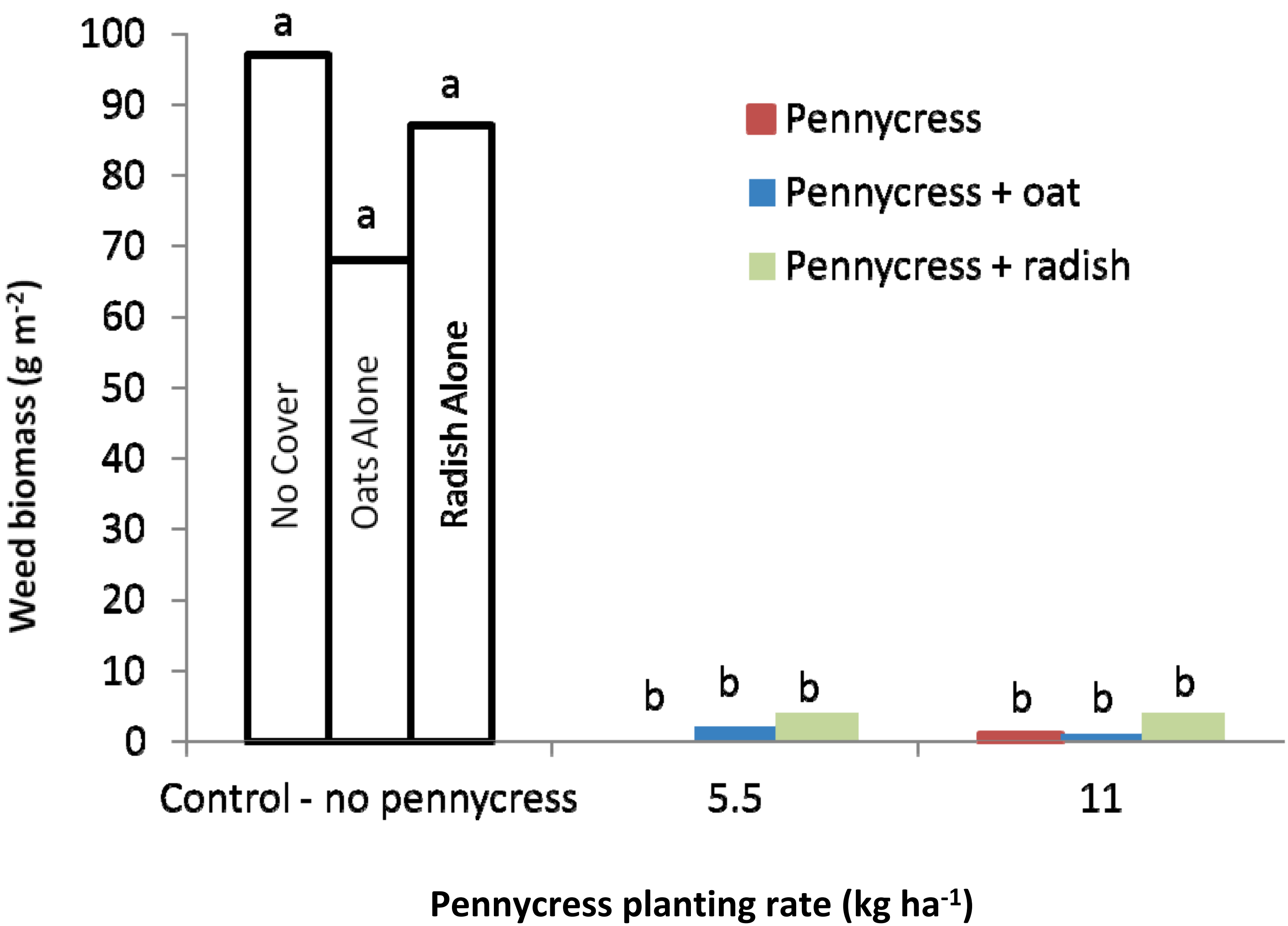

Oat fall cover


Groundhog radish for fall
cover
Late Fall



Total oilseed yields at Rosemount, MN in 2012 as affected by planting rate of pennycress and fall cover. Columns with the same letters are not significantly different (LSD =670). Planting rate for oat was 66 kg ha^{-1} and 11 kg ha^{-1} for radish.

Weeds/no pennycress vs Weeds/pennycress



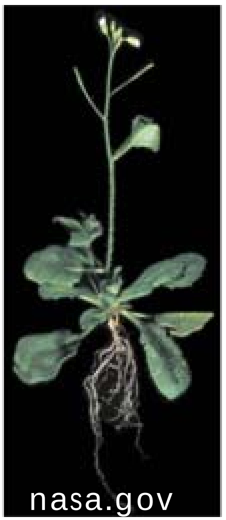
Weed biomass at Rosemount, MN in 2012 as affected by planting rate of pennycress. Columns with the same letters are not significantly different (α =.05).

Pennycress interseeded in corn

Pennycress interseeded in soybean

Pennycress in fall (Oct 24th)

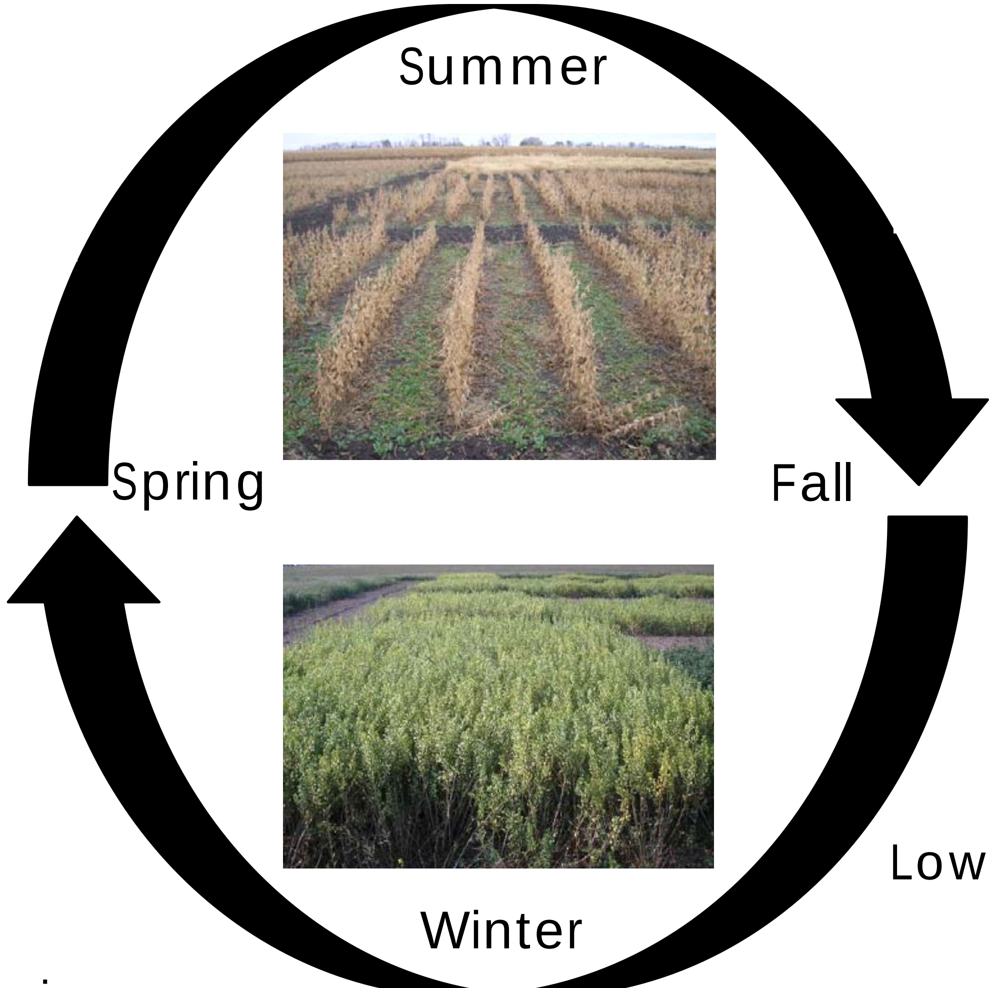
Using *Arabidopsis* and new genomic technologies to improve pennycress



-**Identify pennycress genes for important agronomic traits through DNA sequencing**

-**Develop genomic resources for genomic-assisted breeding**

Translation of *Arabidopsis*-based knowledge to pennycress



GTR1/GRT2
Oil content

Improved seed characteristics

Flowering time pathway

Faster flowering

DOG1
GA / ABA Pathways

Low seed dormancy

Breeding

- Germplasm collected from Europe, South America, and North America
- Total of 72 accessions
- 82 successful crosses made--2013
- High yielding MN lines treated with EMS, Fast Neutron, and Gamma irradiation
- Observation fields planted to observe spring or winter habit, yield, height, oil content, etc.

2. Intermediate Wheatgrass Enterprises:

Beer/Whiskey

Food

Feed

Biomass

Grazing

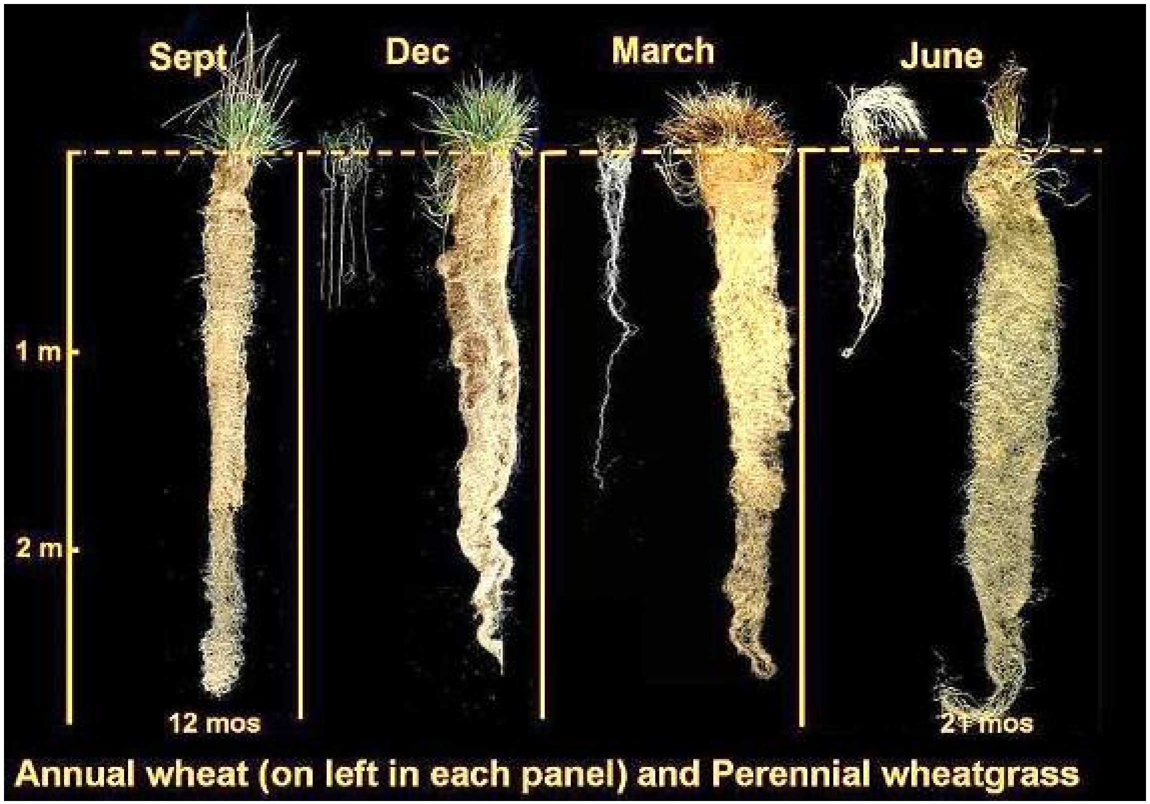
PI D. Wyse

Intermediate wheatgrass in Minnesota

St. Paul Campus

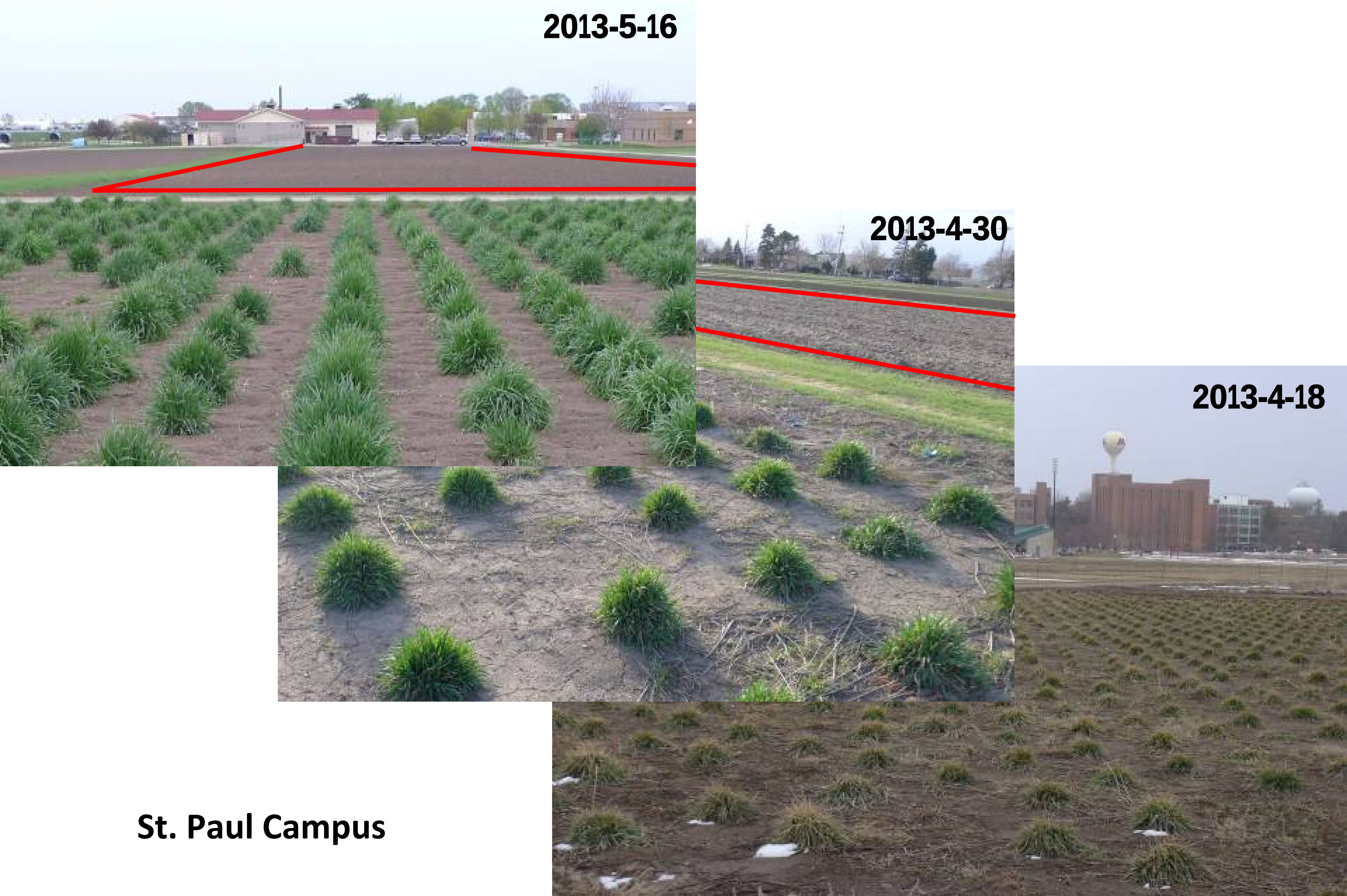
Intermediate wheatgrass

---- Environment services



- **Reduce erosion and soil nitrate leaching**
- **Reduce inputs of energy and pesticide**
- **Increase carbon sequestration**

Intermediate wheatgrass in Spring



St. Paul Campus

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

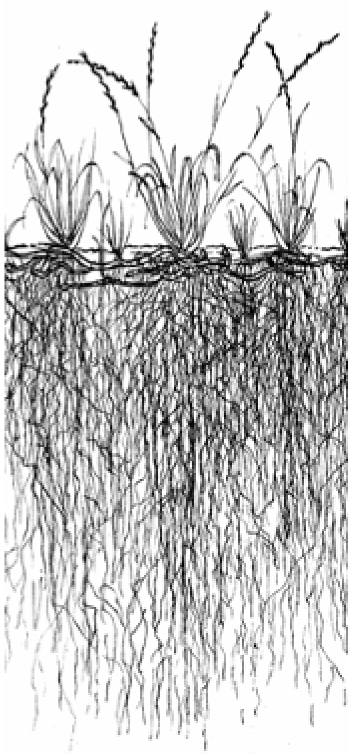
---- wheat-wheatgrass blends

Intermediate wheatgrass

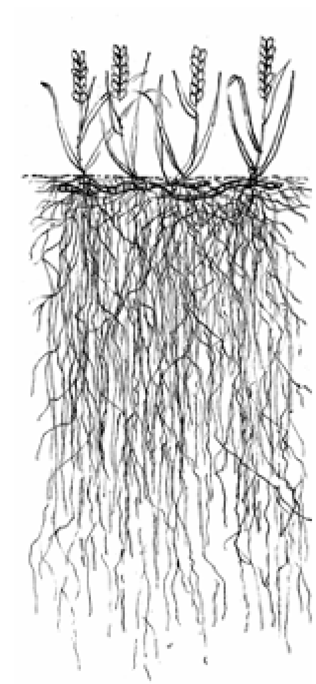
Our goal

—— **Obtain a commercially viable perennial grain/biomass crop**

Wild Perennial



Domestication

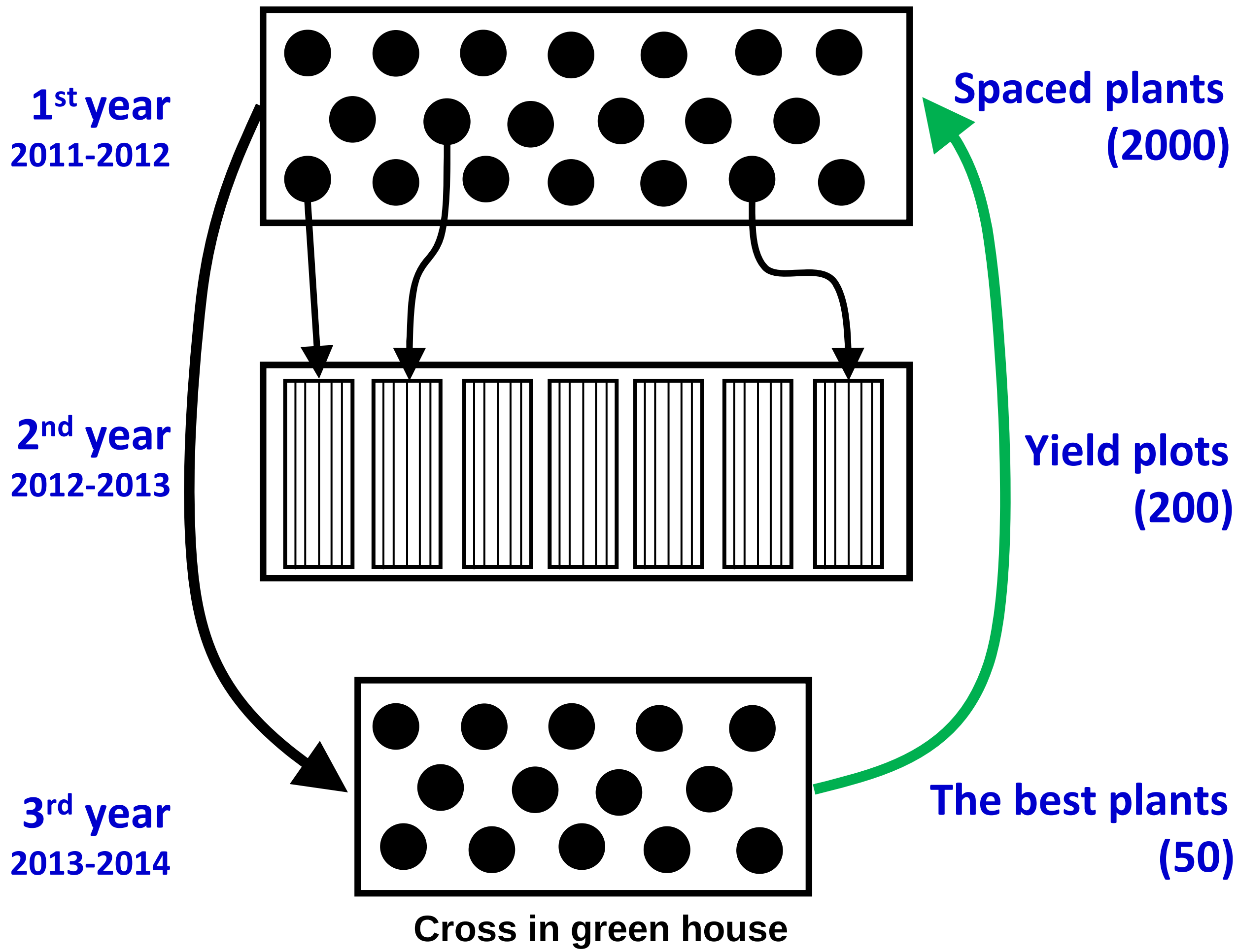


Perennial Grain

Increase grain yield and biomass

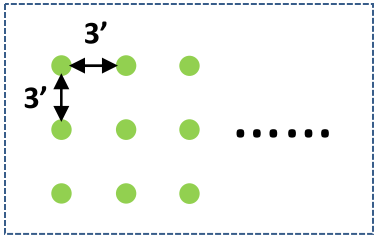
Enhance grain quality for food

Intermediate wheatgrass Breeding

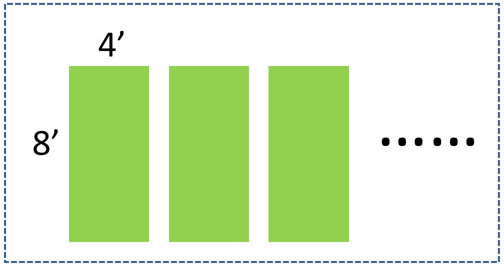


Select plants with big seeds, large grain yield and biomass.

Breeding nurseries in St. Paul

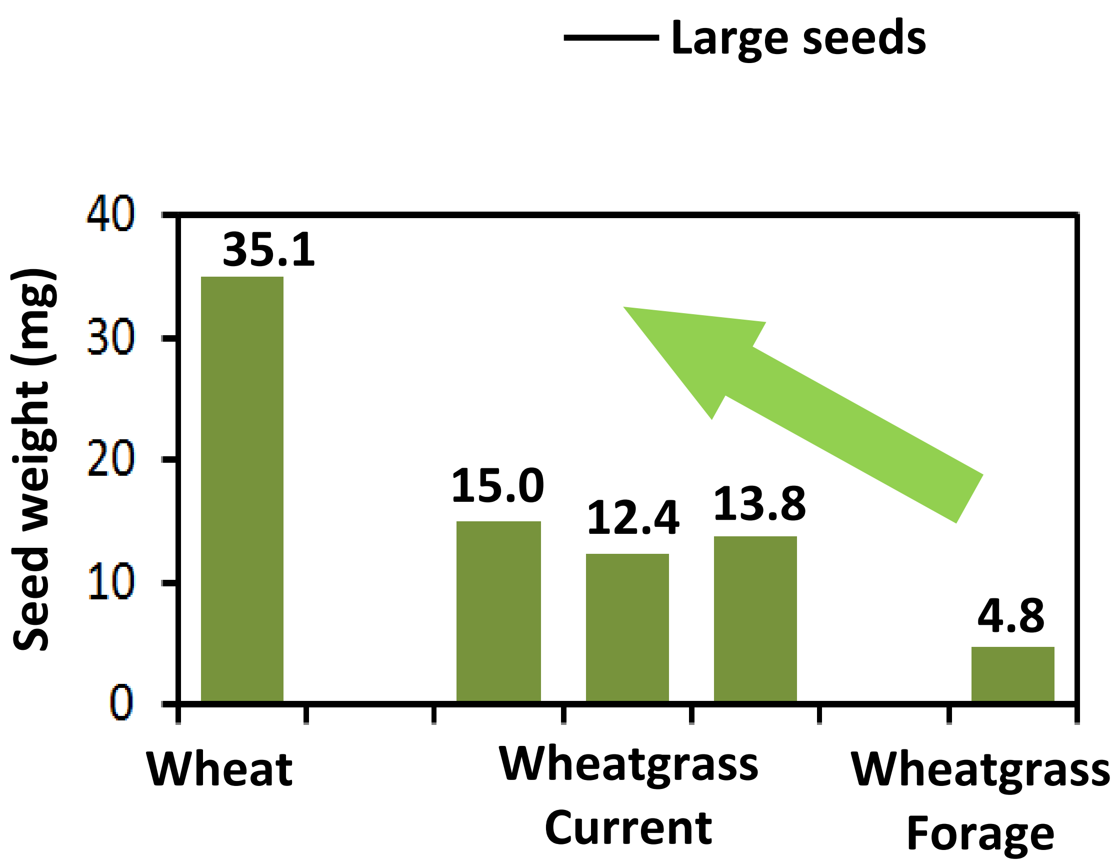


2000 spaced plants



440 yield plots

Intermediate Wheatgrass improvement



Intermediate Wheatgrass improvement

—— **Non-shattering**

Shattering **Selected**

Intermediate wheatgrass improvement

Second Year Yield of Clone Plots

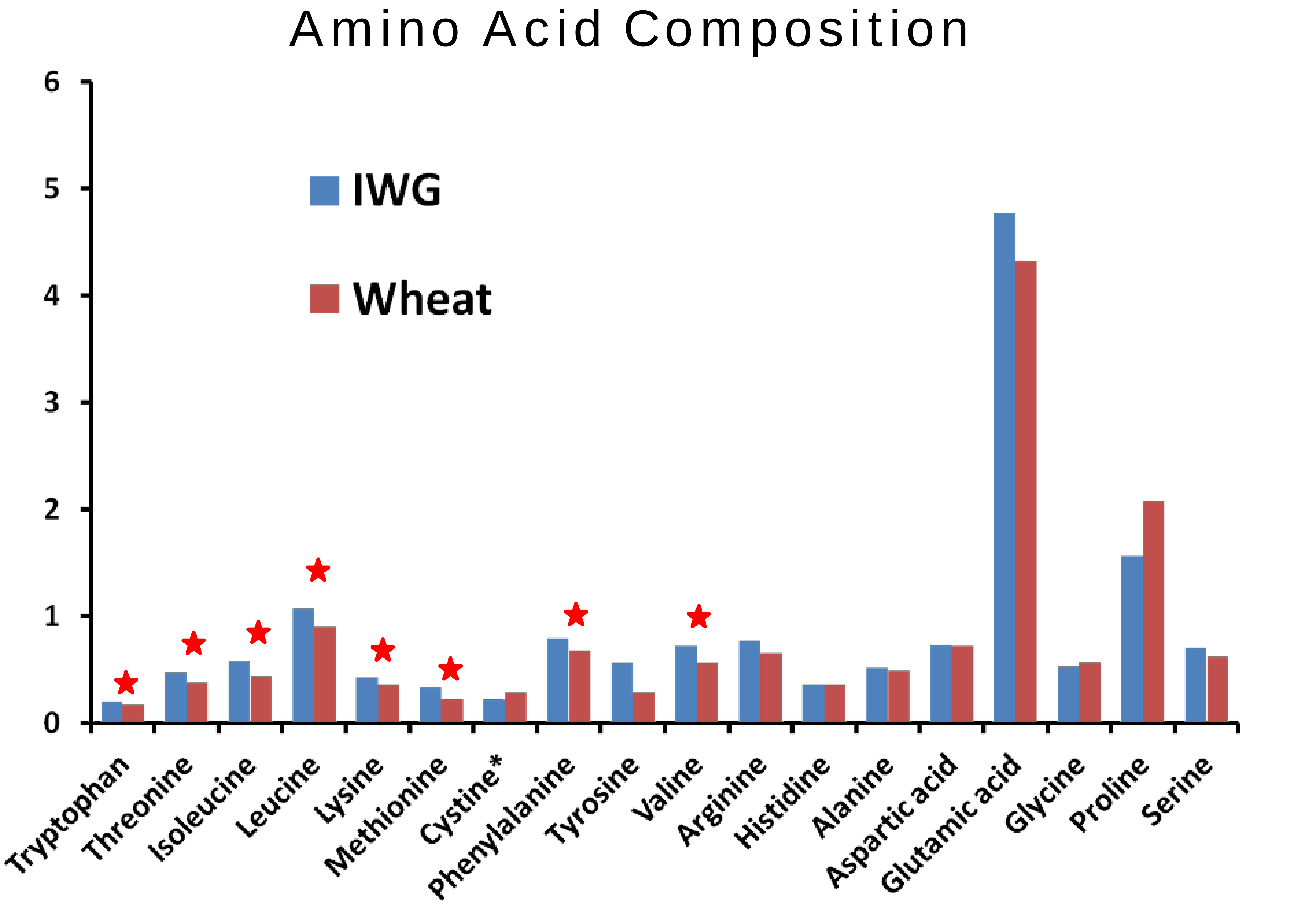
	Biomass				Seed Yield				Seed Weight			
Population	Minnesota		Kansas		Minnesota		Kansas		Minnesota		Kansas	
	$g\ m^{-2}$								$mg\ seed^{-1}$			
Cycle 0	1690	±160	1650	±160	84	±14	68	±14	5.73	±0.39	4.10	±0.39
Clarke	2000	±160	2170	±160	117	±14	49	±14	5.10	±0.39	3.73	±0.39
High Seed Mass line	2380	±220	1660	±110	212	±19	88	±10	9.26	±0.87	7.57	±0.66
High Seed Yield Line	1830	±140	1810	±100	192	±12	100	±9	7.60	±0.68	6.07	±0.62

Best intermediate wheatgrass seed yield in MN 1,882 lb/A

Average spring wheat seed yield in MN 2,820 lb/A

Evaluation of intermediate wheatgrass grain for food use

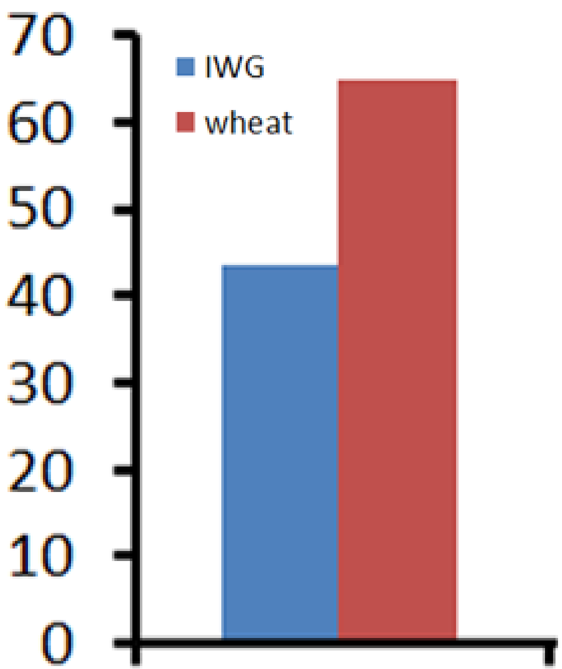
Testing

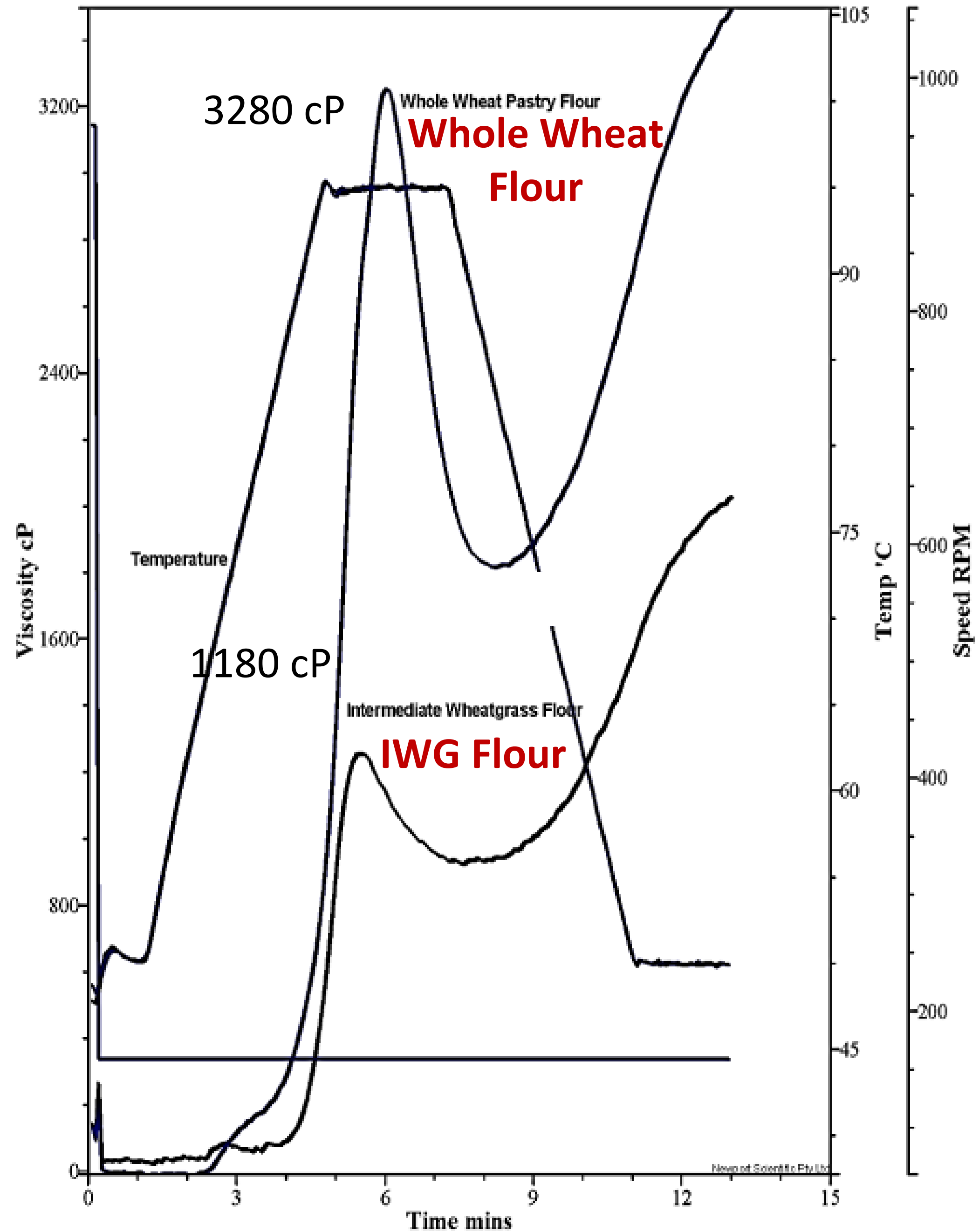


Amino Acid Composition
6
5
4
3
2
1
0
IWG
Wheat
Tryptophan
Threonine
Isoleucine
Leucine
Lysine
Methionine
Cystine*
Phenylalanine
Tyrosine
Valine
Arginine
Histidine
Alanine
Aspartic acid
Glutamic acid
Glycine
Proline
Serine

Starch functionality

Less starch – less viscosity





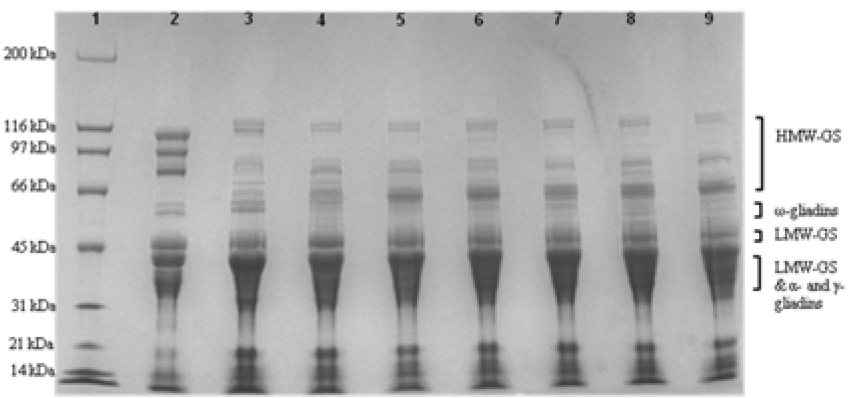
Protein

- Wheat gluten:
  - Holds gas
  - Viscoelastic properties

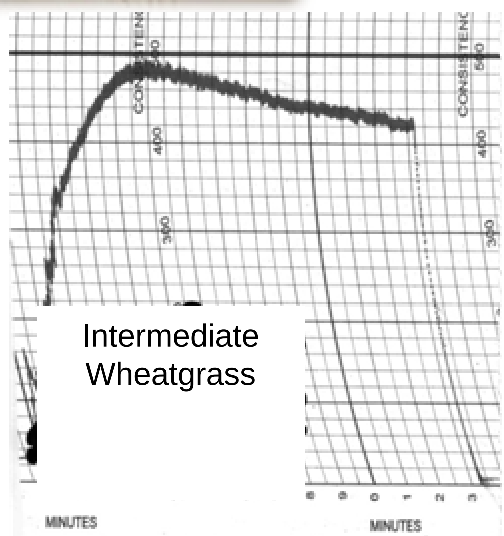
Developed wheat flour dough

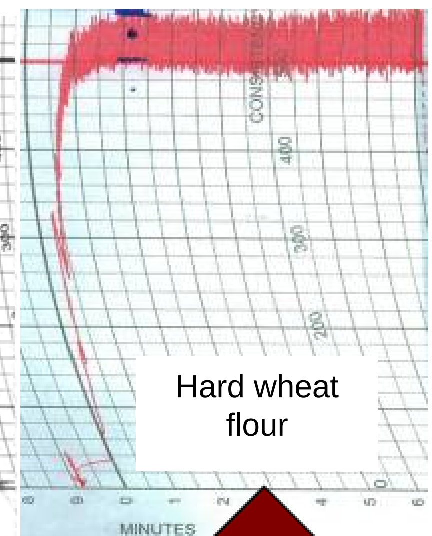
- IWG hydrates in the Farinograph and does not develop well
- 35.8% water absorption (14% M equivalent, constant dough wt)

- Intermediate wheat grass has virtually no gluten forming ability



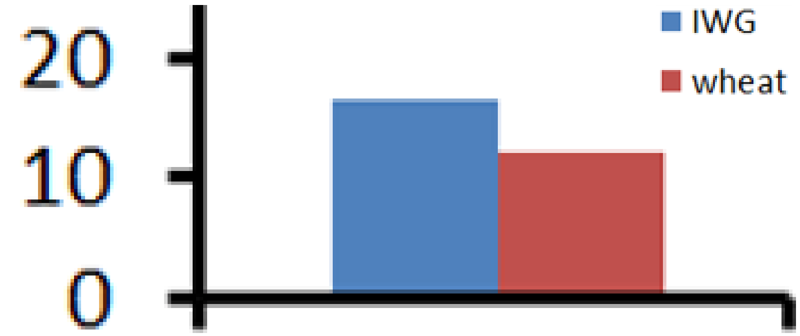
Protein patterns of wheat glutens by SDS-PAGE. Lane 1: protein marker; 2: whole wheat flour gluten; 3: Bulk intermediate; 4: IWG LI-1; 5: IWG LI-2; 6: IWG LI-3; 7: IWG LI-4; 8: IWG LI-5A; 9: IWG LI-5B





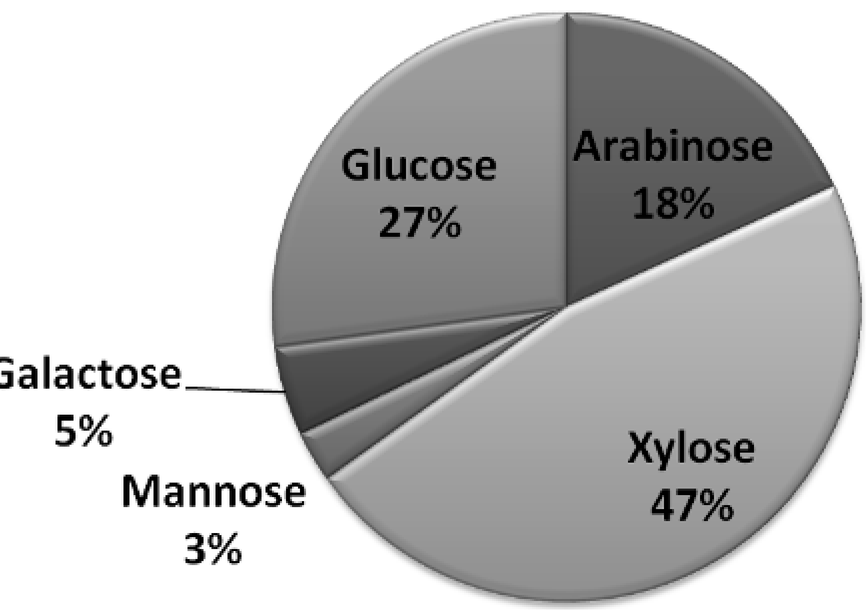
White bread wheat: Over 60% at 15% protein

Dietary Fiber



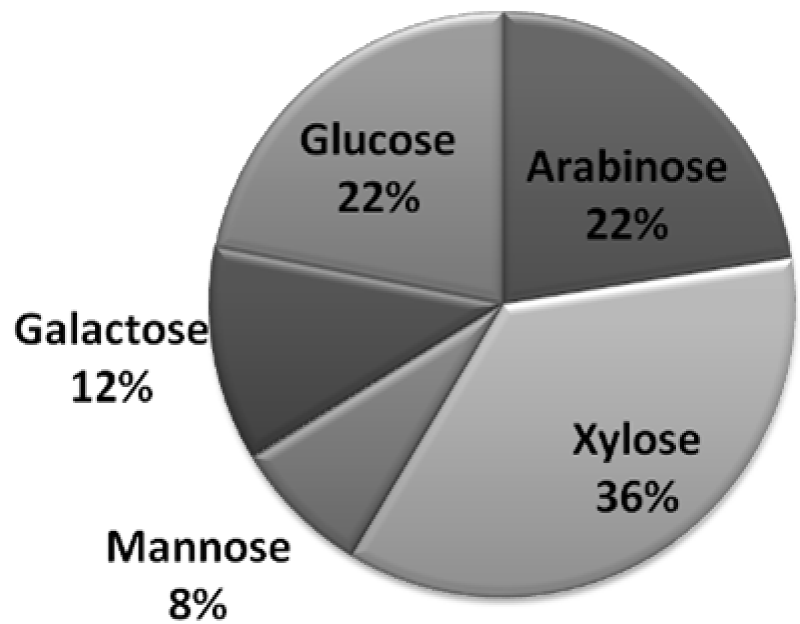
Insoluble Fiber: 13.4%

Neutral Monosaccharide composition

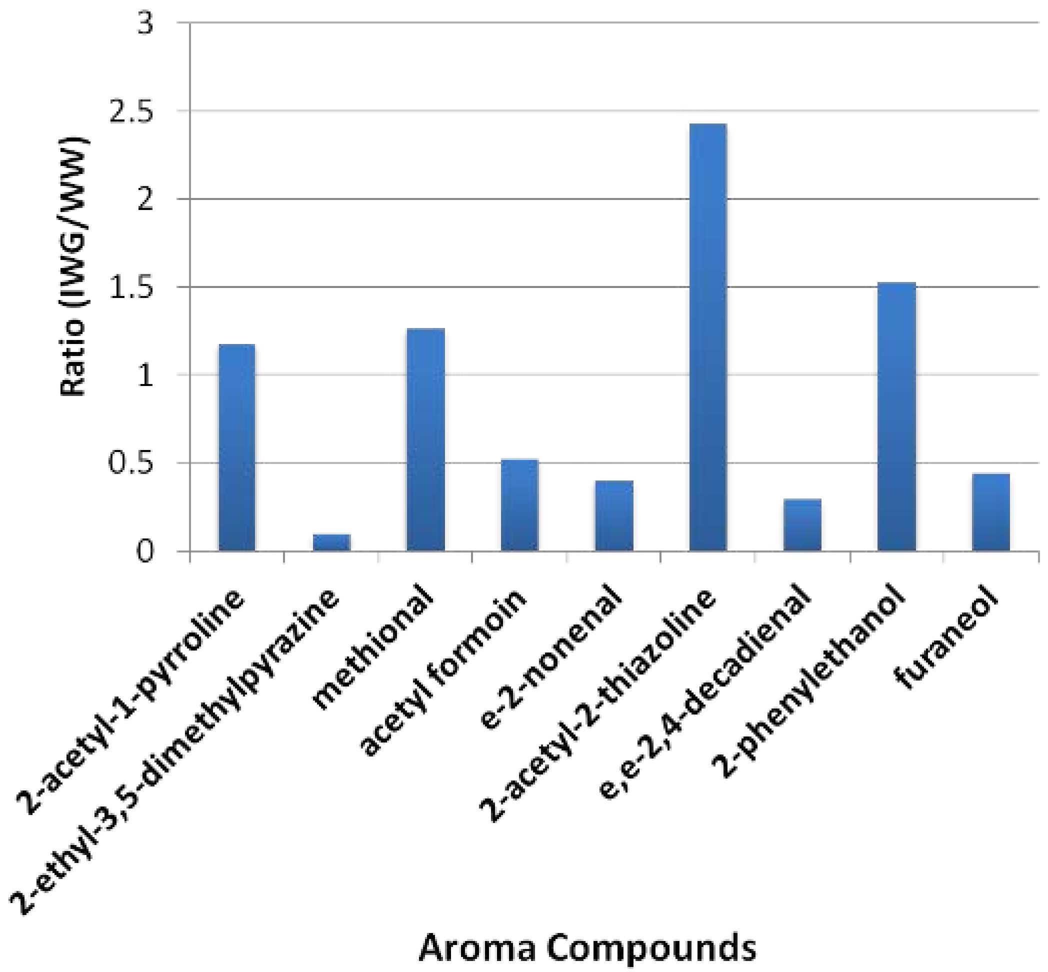


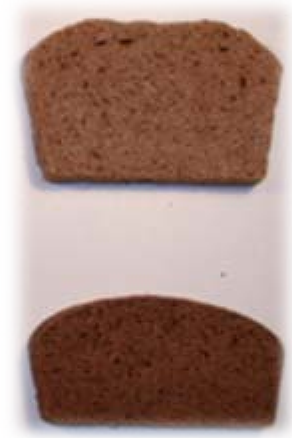
Soluble Fiber: 3.0%

Neutral Monosaccharide composition



Flavor Development in IWG

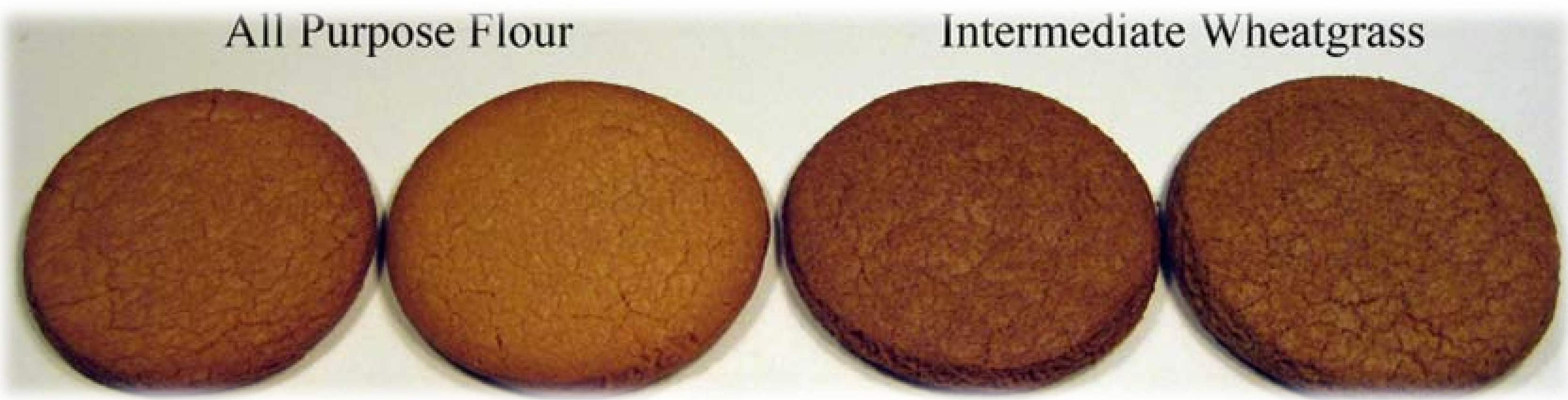




Aroma Compound	IWG Concentration (ug/kg)
2-acetyl-1-pyrroline	5.4
2-ethyl-3,5-dimethylpyrazine	0.17
methional	547
acetyl formoin	1241
e-2-nonenal	0.82
2-acetyl-2-thiazoline	37
e,e-2,4-decadienal	0.69
2-phenylethanol	32.
furaneol	2296

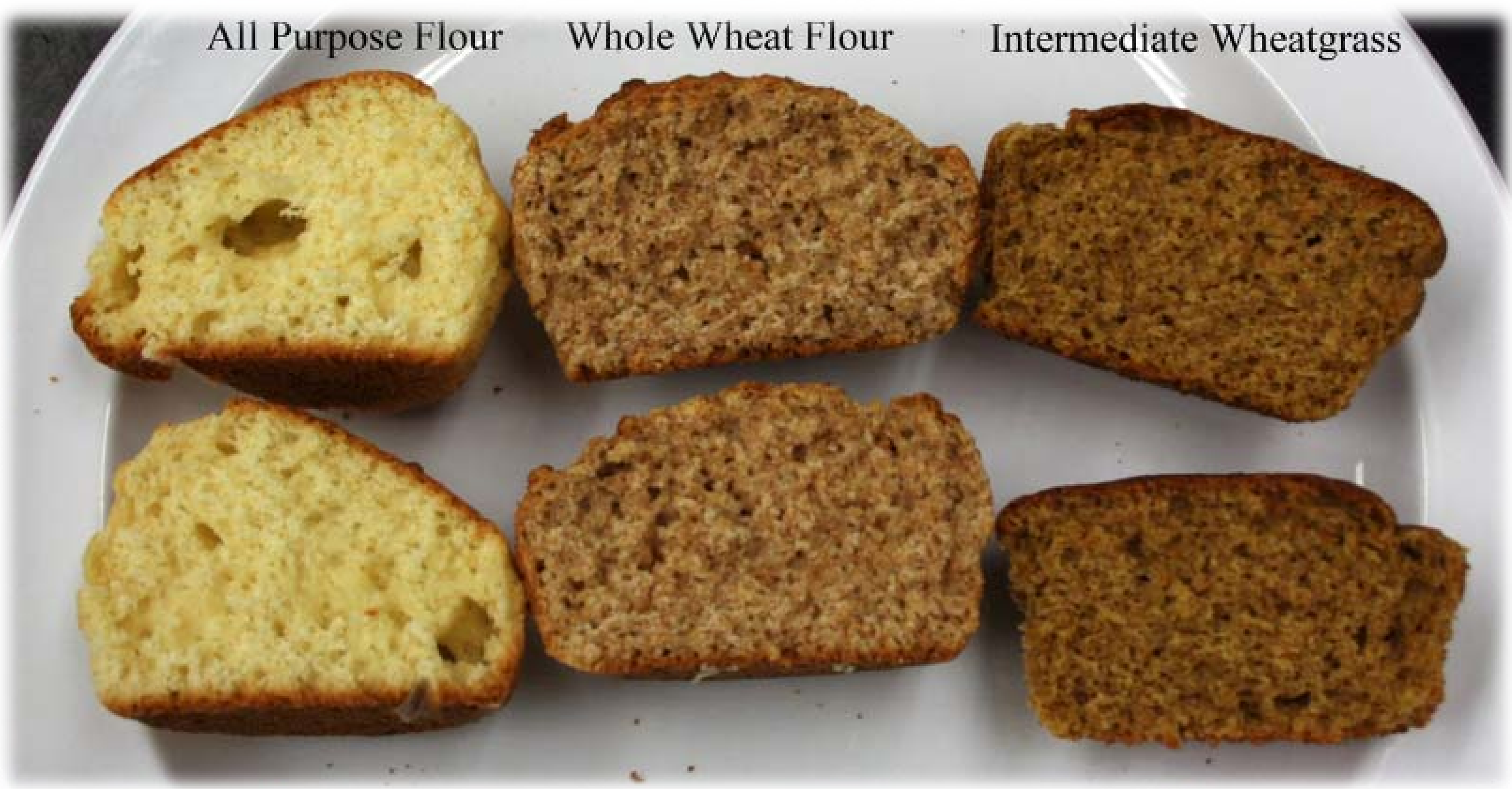
Food products

Cookies are good



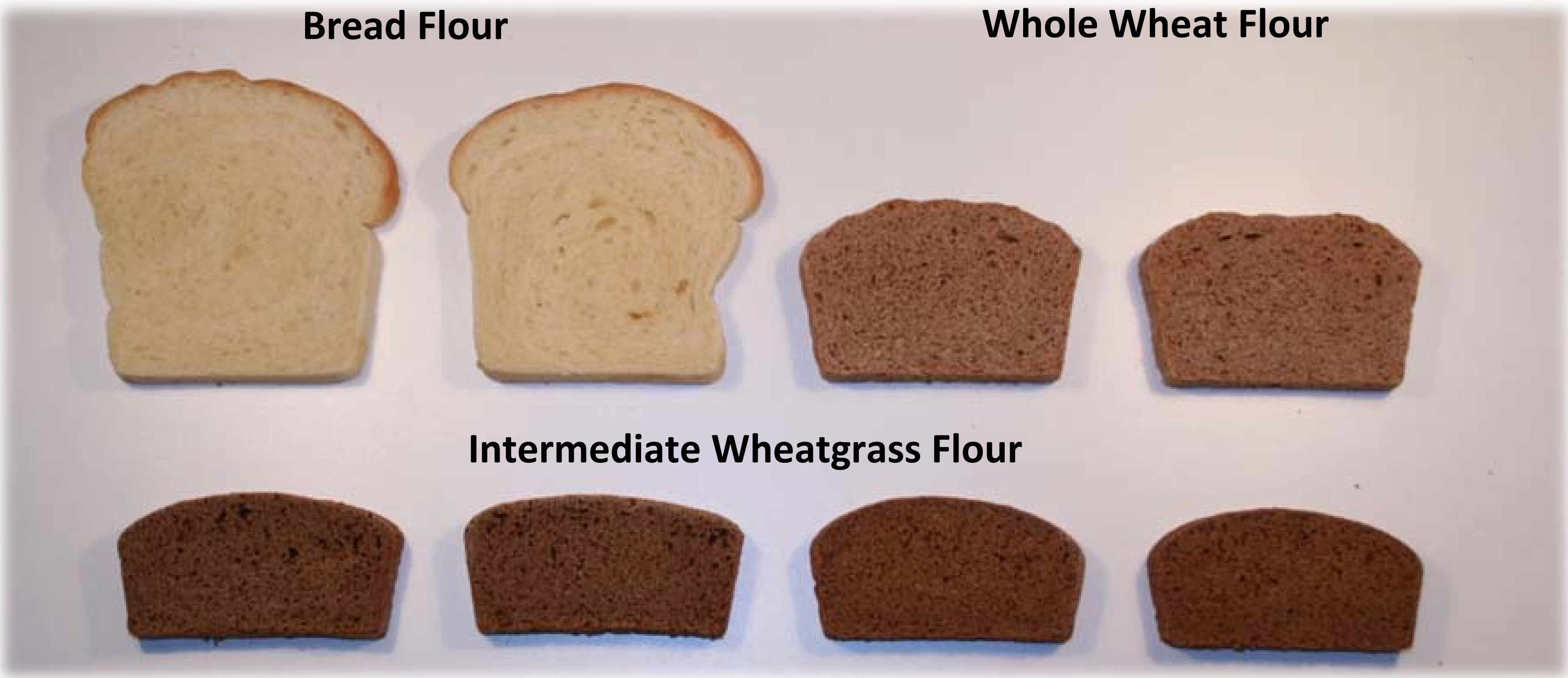
Food products

Muffins are OK



Food products

Yeast bread is not good alone



However,

20 to 50% IWG produces a good bread product

Intermediate Wheatgrass Program

- **Analyze the Genetic mechanisms of agronomic traits**

- **Evaluate improved germplasm**
  - Evaluate functionality of grain starch and protein
  - Determine seed composition
  - Consumer test grain based products
  - Characterize the flavor

- **Develop commercial cultivars**

3. Camelina

PI R. Gesch

Camelina

- *Camelina sativa* L. – Brassicaceae (mustard family)
  - AKA false flax
  - High seed oil content ~35-42%
  - ≥ 35% 18:3 α-linolenic
    - Also high in tocopherols
    - **Food and industrial uses**
  - Short life cycle
  - Winter and spring types
  - Double and relay cropping potential

Camelina as a Biofuel Crop

- Advanced biofuel feedstock – aviation fuel

- Diversify cropping systems
  - Disrupt pest and pathogen cycles
  - Suppress weeds
    - Glucosinolates may act to biofumigate soil (*Kirkegaard & Sarwar, 1998 P&S*)
- Ecosystem services
  - Provide habitat for bees and other beneficial insects

- Requires low agricultural inputs

Excellent Winter Survival

98 ± 13% winter survival – planted mid-September

- Seed yields
  - Winter types generally 1200 – 1500 lbs/acre in MN
  - Spring types as high as 2400 lbs/acre
- Breeding needed to improve yields of winter types

Winter camelina suppresses weeds

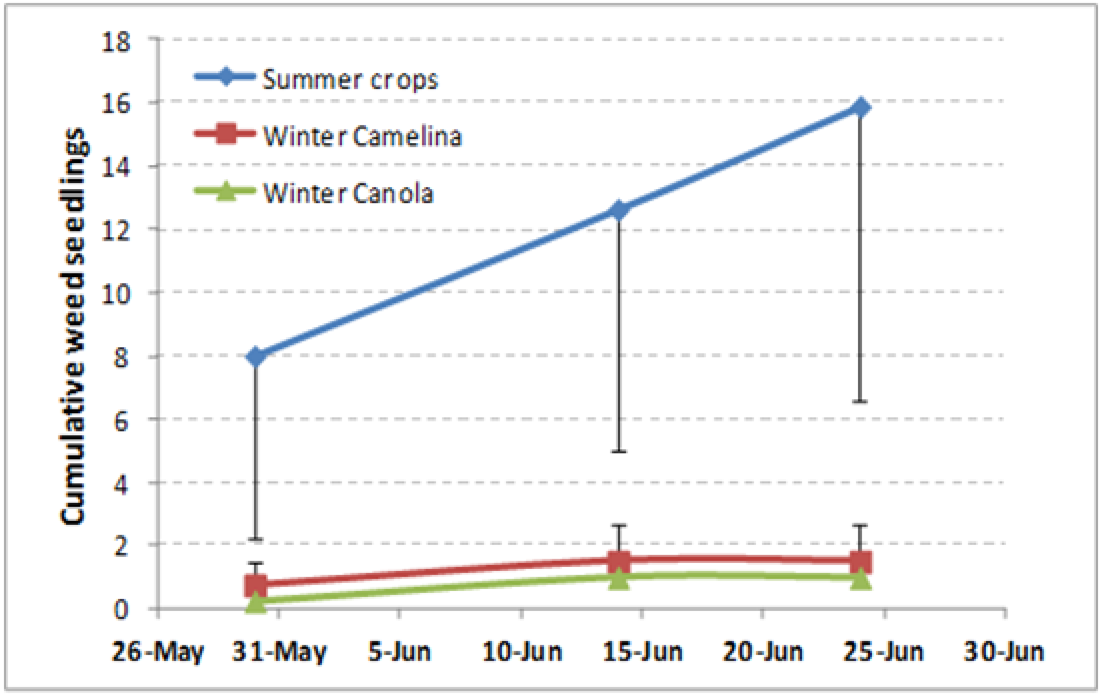
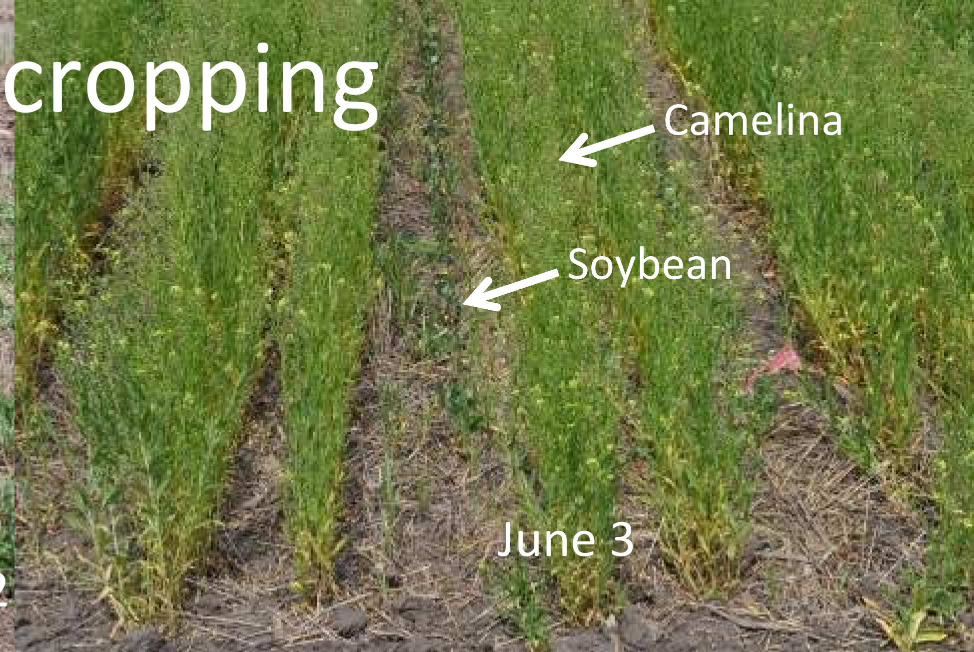


Figure 3. Emergence of summer annual weeds, primarily nightshades and pigweeds, was suppressed appreciably by both winter camelina and winter canola compared to that in adjacent summer crops (corn and soybean) in western Minnesota. (USDA-ARS Swan Lake Research Farm, 2013.)

Double-Cropping Advantages

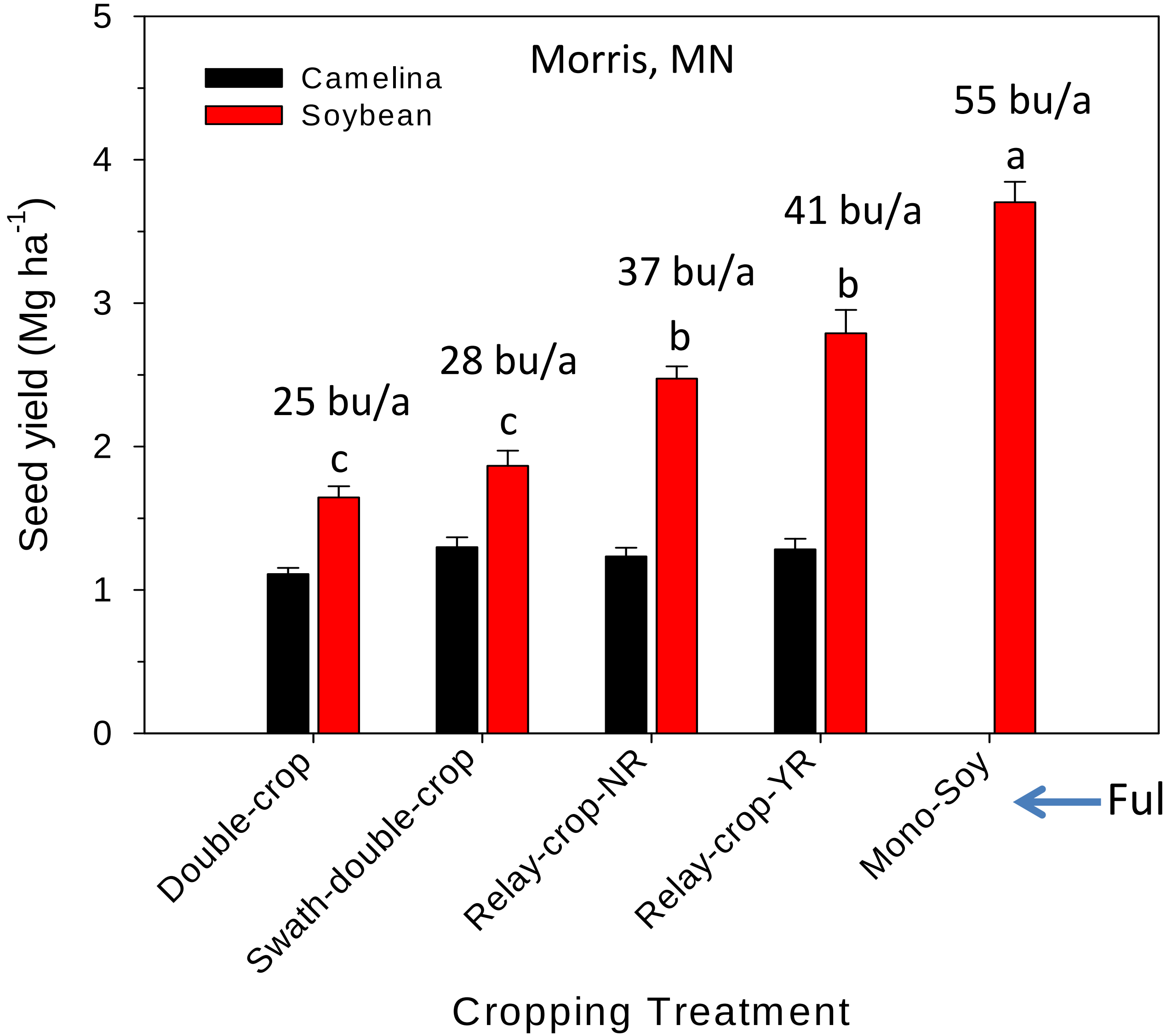
- Provide a winter “cash” cover crop
  - Prevent erosion & take up excess N & P
- Reduce food vs. fuel debate
  - Reduce land-use competition
  - Produce a food and fuel crop in one season
- Added income & potentially more energy

Relay-cropping



	Ht (cm)
W. Cam.	78 ± 4
Relay-Soy	27 ± 2
Mono-Soy	36 ± 4

Winter camelina – soybean double crop study (2-yr Avgs.)



Full season soybean

Camelina consistently yielded ~1200 lbs/a in all treatments.

Camelina – soybean double crop

	Oil Yield (L ha^{-1})			
Treatment	Camelina	Soybean	Combined	Gal/a
Double-crop	495	396 c	906 b	97
Relay-crop-NR	588	513 bc	1101 ab	118
Relay-crop-YR	615	618 b	1233 a	132
Swath-DC	564	434 bc	999 b	107
Mono-Soy	-	915 a	915 b	98

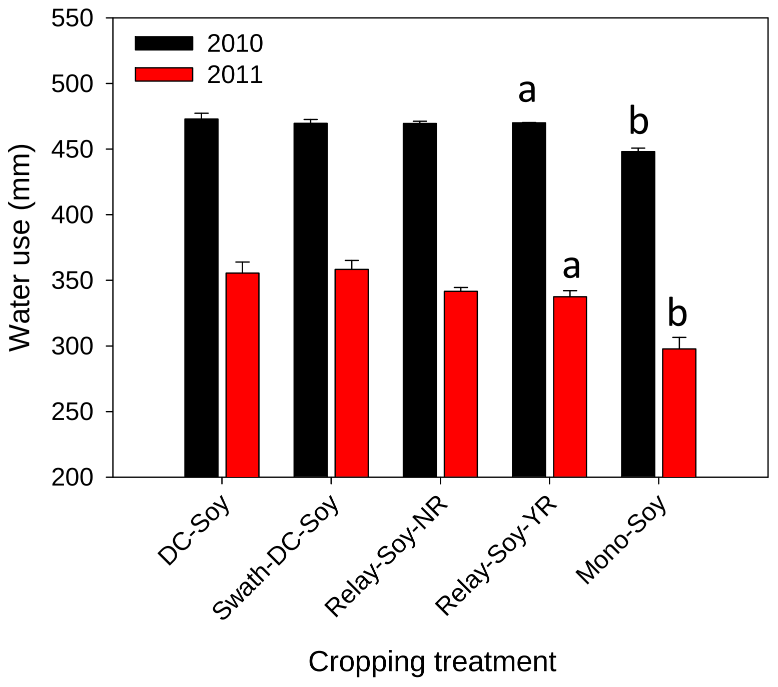
YR = treated with glyphosate; NR = no glyphosate
Swath-DC = swathing camelina before planting soybean

Early fall with winter camelina inter-seeded in soybean (camelina will over winter and flower in spring)

Camelina – Soybean DC System

- Low inputs
  - Can be no-till seeded
  - Low N requirement (40 – 70 lbs/acre)
- Relatively low seasonal water use

Between April and September



Breeding Needs

- **Earlier flowering and seed set**
- **Larger seed size**
- **Higher oil content and modify fatty acid profile for biofuels and <u>bioproducts</u>**
- **Improved seed yield of winter types**

3. Winter Barley

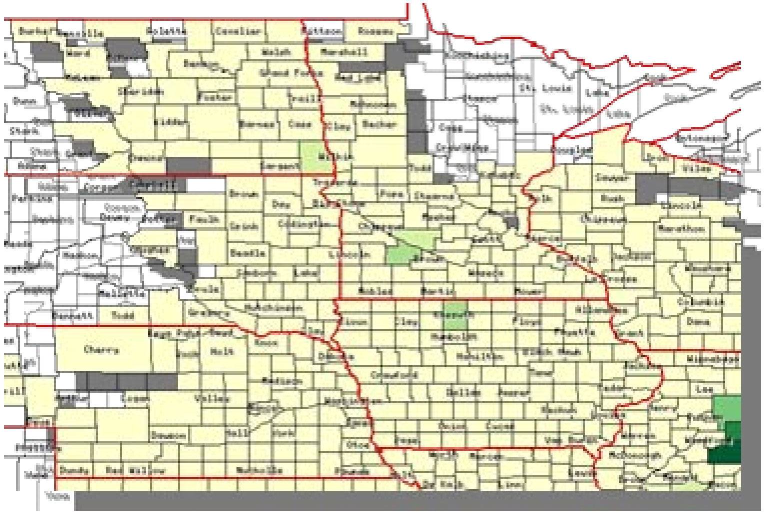
Enterprises:
Barley malt
Livestock feed
Double crop with soybean

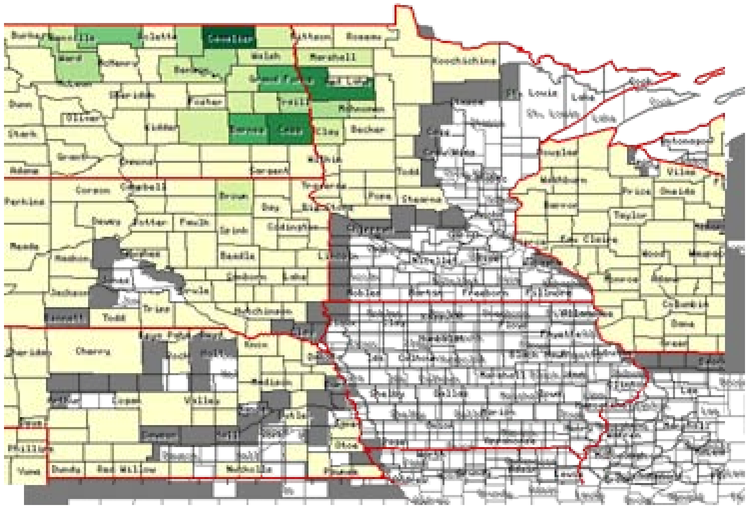
PI K. Smith

Developing Winter Barley for Minnesota

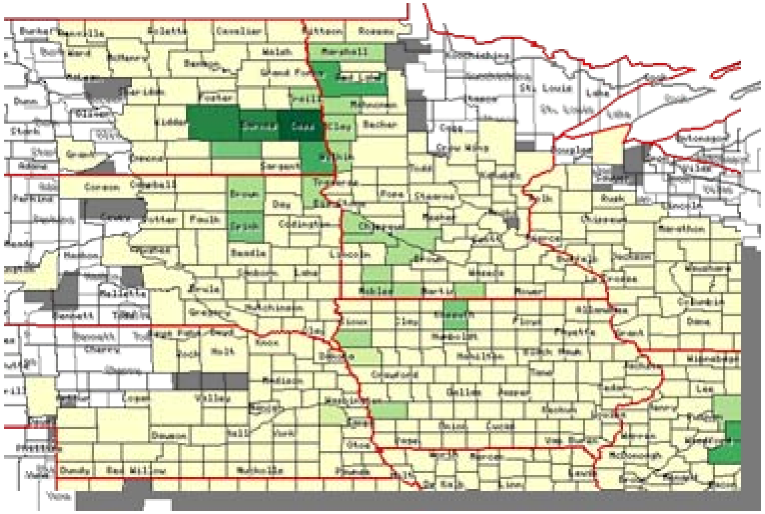
Soybean

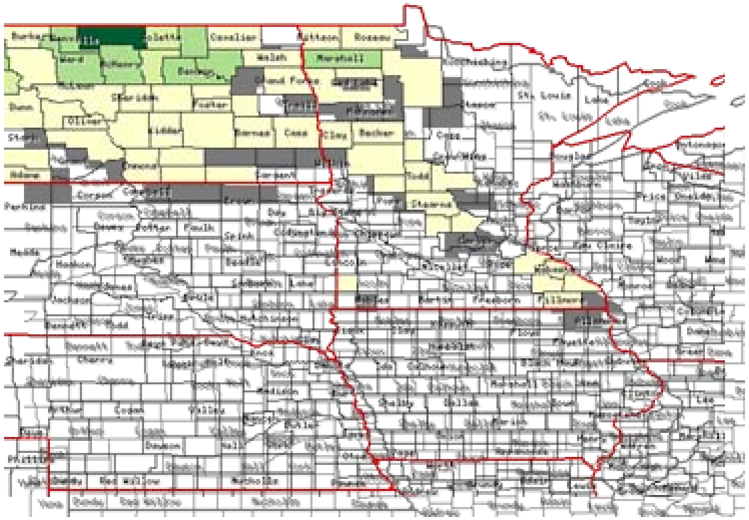
Barley





1990

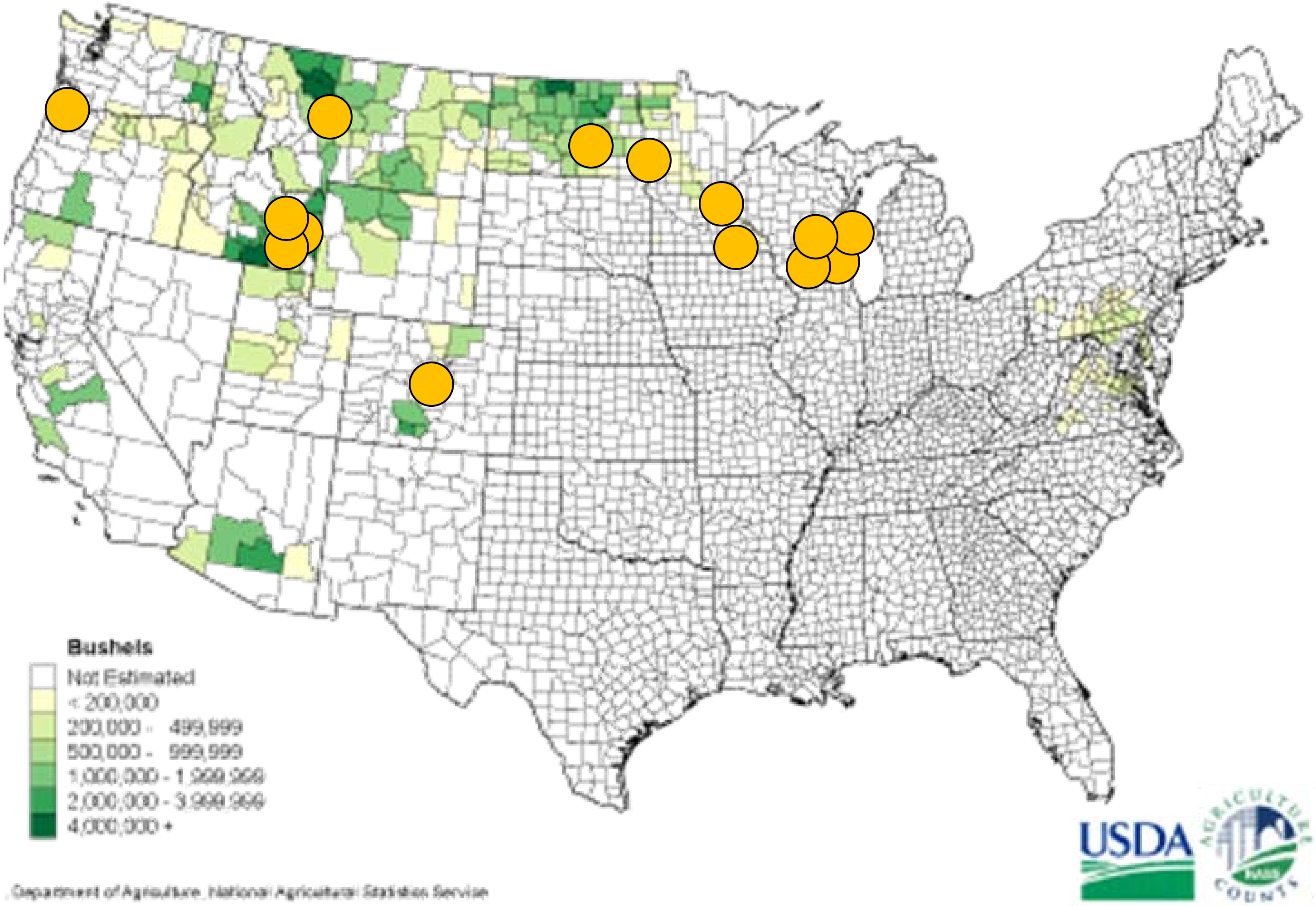




2010

Challenges

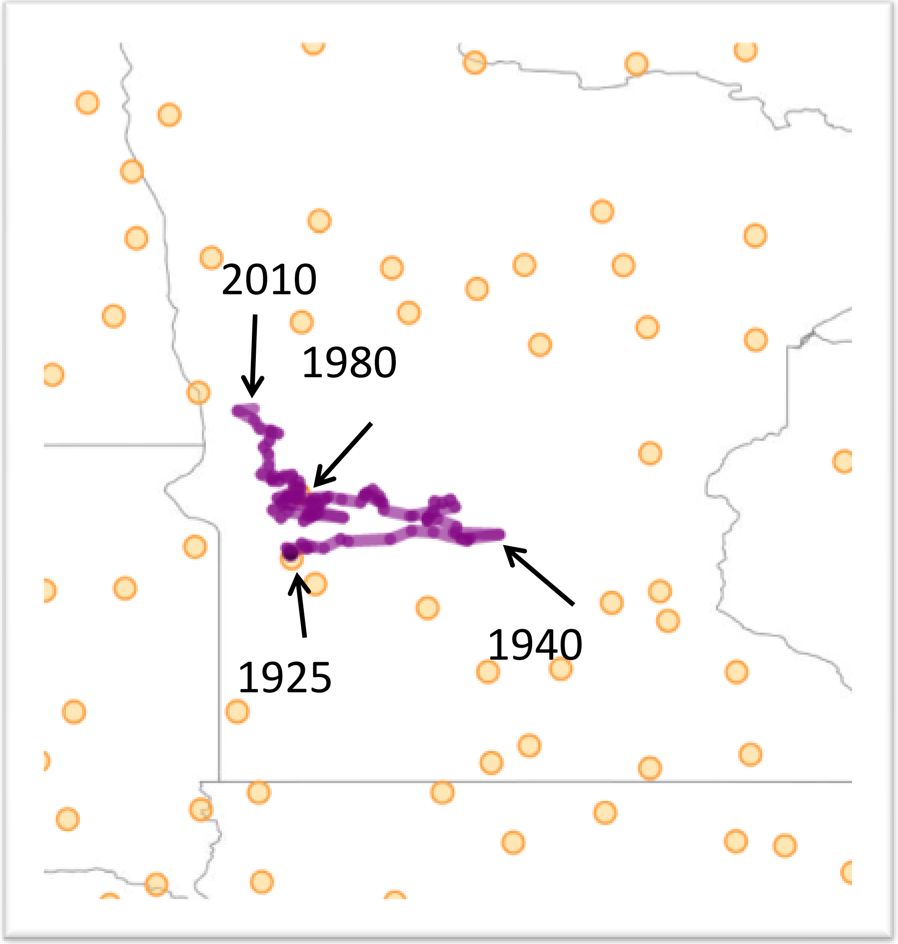
US Malting Infrastructure



Challenges

Climate Change

Climate moves over time
- **Westward movement in dust bowl years**
- **Northward movement in recent years**
- **1980 – 2010 rate is 5 miles/year North**

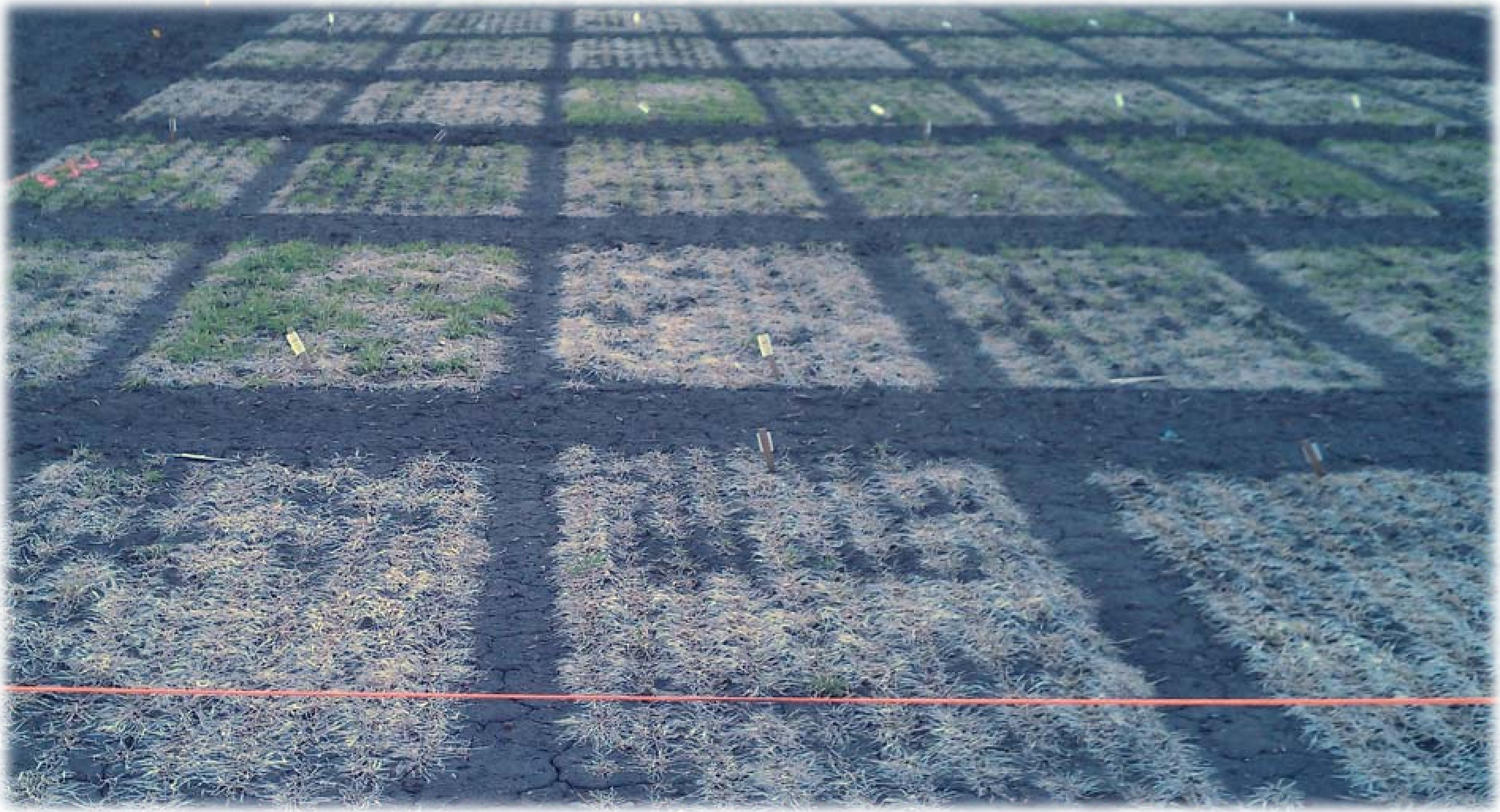


Climate Tracker Website

http://www.cbs.umn.edu/climatetracker/

Challenges

Winterhardiness



Challenges

Agronomic Benefits

Increased Yield, Disease Avoidance, Weed Suppression, Water Use Efficiency

Fall Planted

Spring Planted

Opportunities

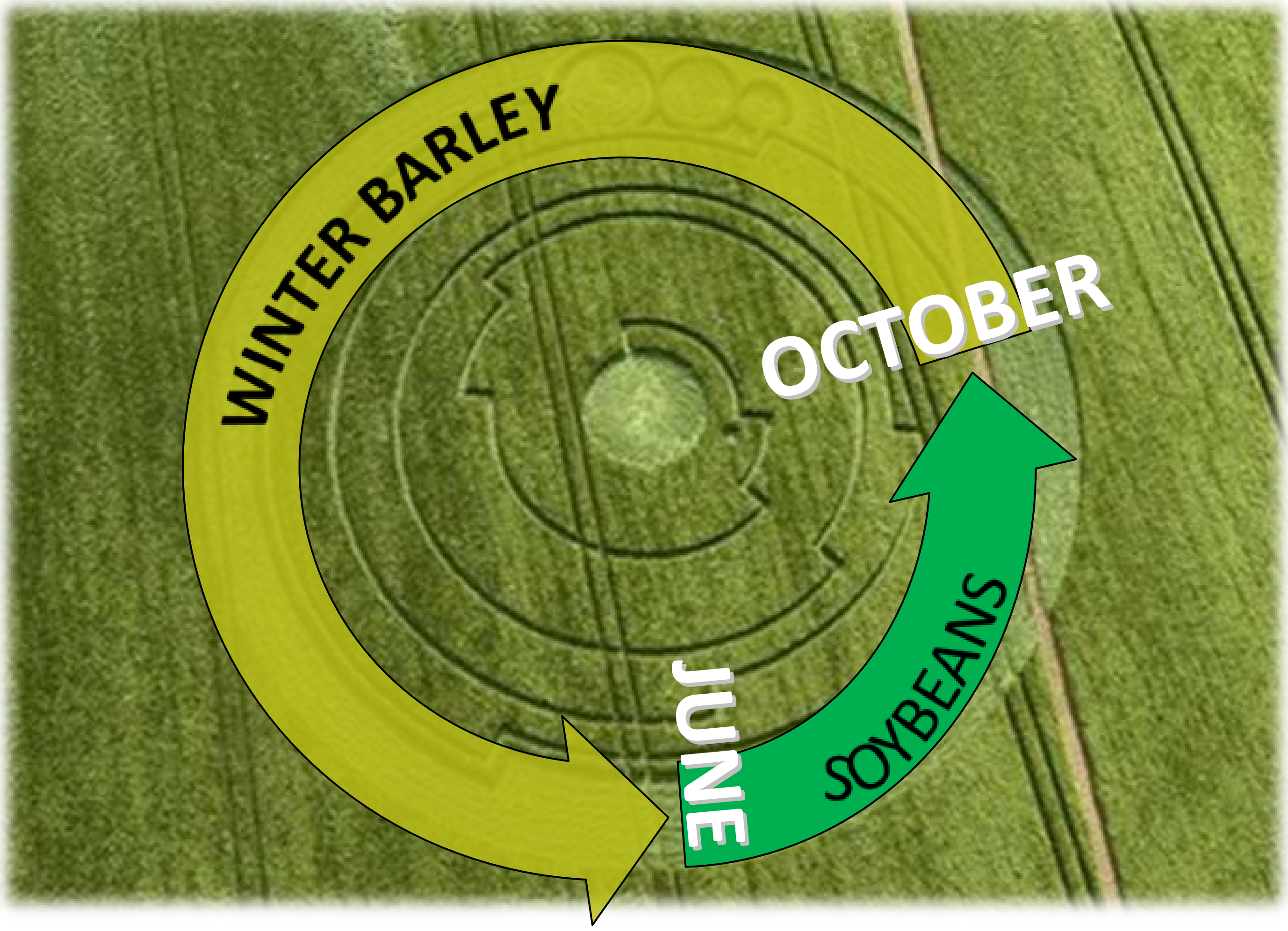
Ecosystem Services

Carbon Sequestration, Nutrient Cycling, Reduced Erosion, Wildlife Habitat

Opportunities

Producer/Industry Benefits

Crop Diversity, Spread Out Field Activities, **Double Cropping**, Earlier Harvest



Opportunities

RESEARCH ACTIVITIES

- Screening wide collection (over 1400 accessions) for winter hardiness
- Generating genomic prediction models to estimate trait phenotypes with genetic markers
- Implementing rapid cycle breeding to accelerate development of winter varieties
- Coordinating national winter barley trial at 14 locations in U.S.

4. Hairy Vetch

Enterprises:
Nitrogen fixation

PI C. Sheaffer

Winter Hardy Hairy Vetch as Cover Crop in Minnesota

Hairy Vetch, *Vicia villosa*

Advantages of hairy vetch as a winter annual cover crop

- Covers exposed soil in winter and early spring
- Conducts biological dinitrogen fixation (100 lb/acre)
- Produces nitrogen rich biomass for green manuring or harvest in spring

Biological Nitrogen Fixation

Symbiotic relationship with N2 fixing bacteria, *Rhyzobium*

Crop Rotation with Cover Crop

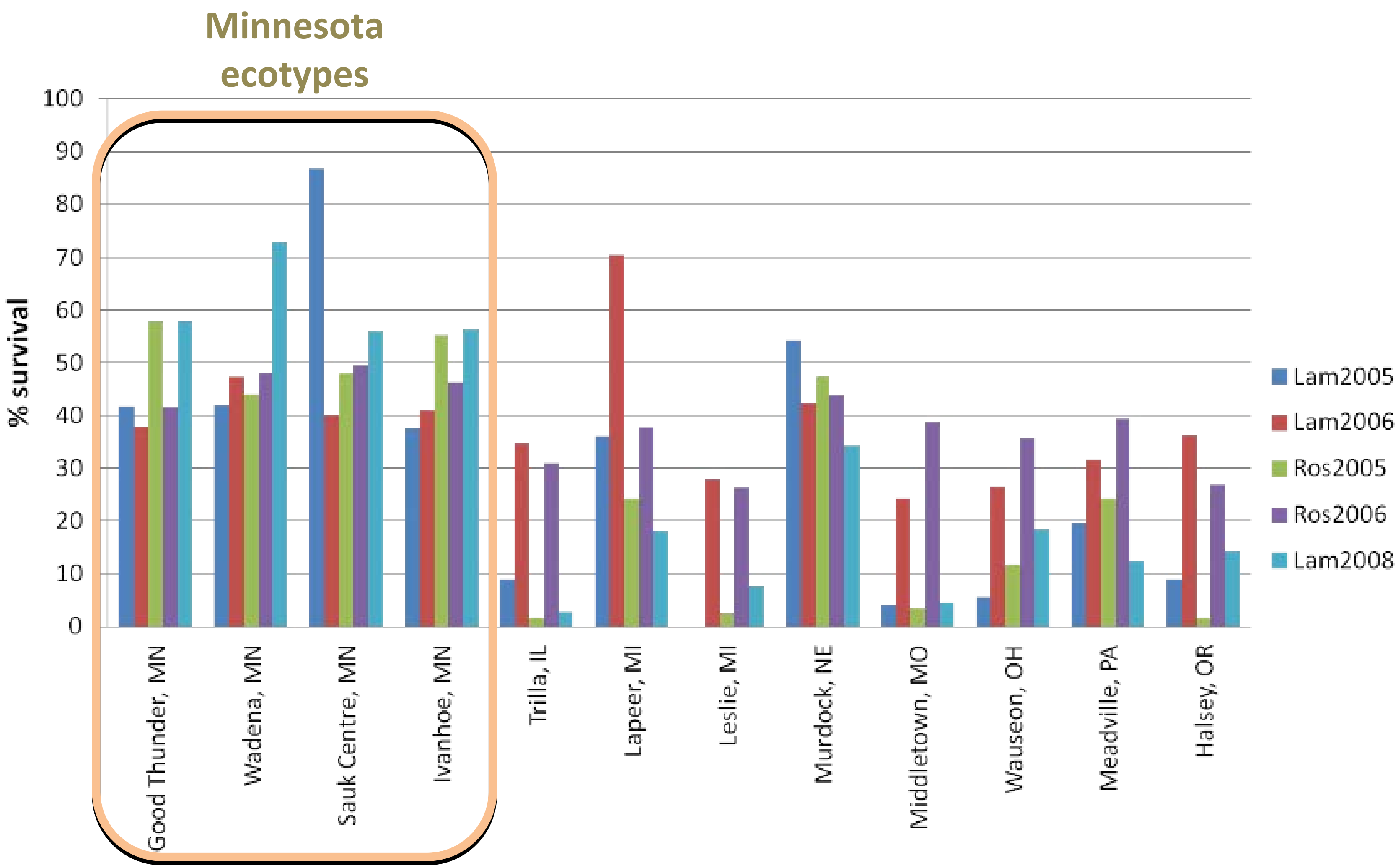
Goals of the breeding project

- **Predictable winter survival**
- **Earlier maturity in spring**
- **Increased biological dinitrogen fixation**
- **Reduce dormancy—reduce weedy characteristics**

Preliminary research with hairy vetch

- **We evaluated 12 ecotypes of hairy vetch from multiple states for winter survival and spring yield.**
- **We found that winter survival and biomass yield was often greatest for ecotypes obtained in Minnesota.**
- **We found that the relative risk (based on variability of results) of growing these ecotypes was least for several Minnesota ecotypes.**

Percent survival of ecotypes by year and site



Our Hairy Vetch Ecotype Evaluation and Variety Development

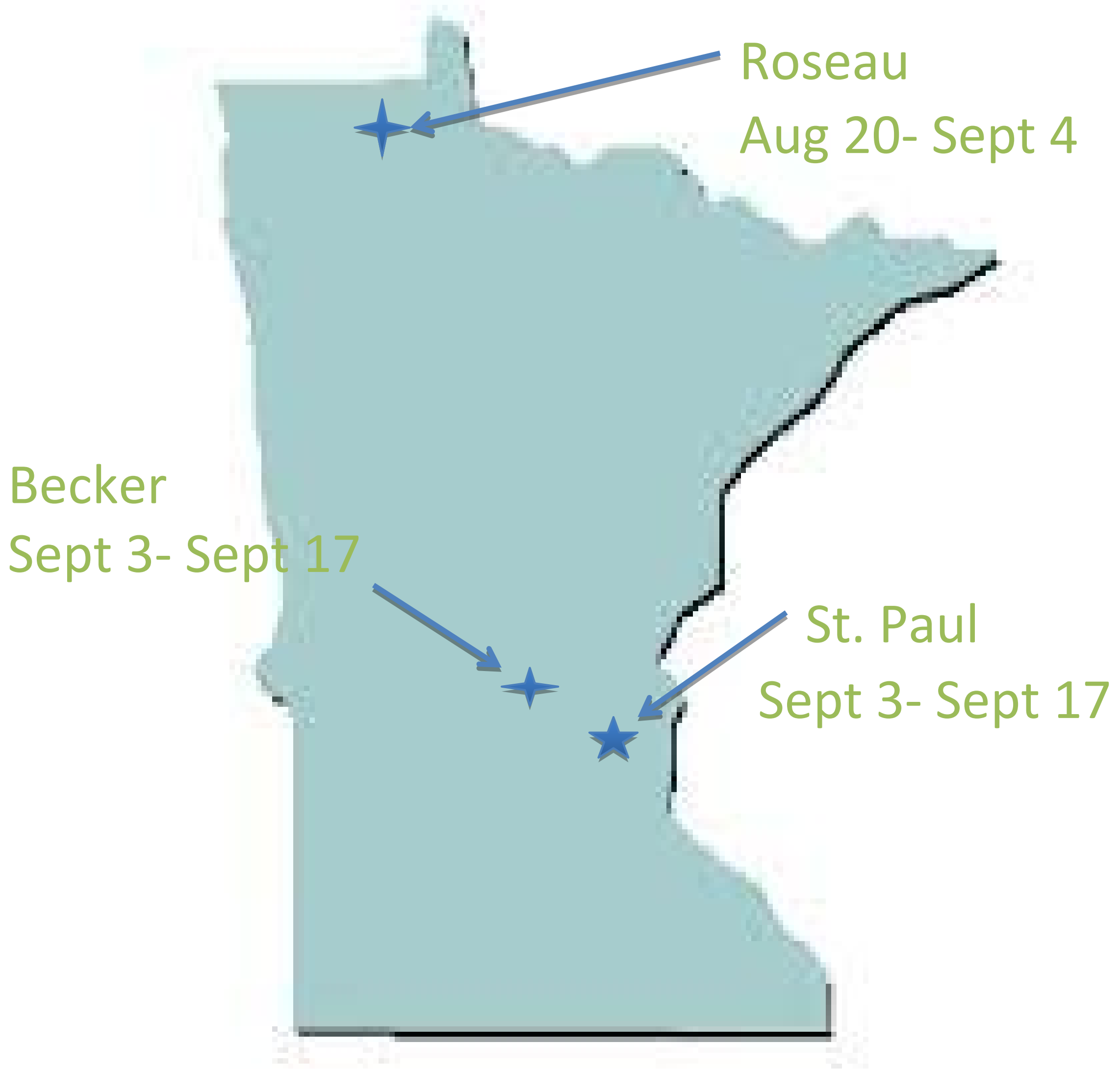
Step 1: Selection among 30 ecotypes

- Winter Hardiness
- Early Maturity/ Early Flowering

Step 2: Variety Development

- Breeding program for selected ecotypes

Research Locations & Planting Dates



Ecotypes Evaluated on Different Planting Date

2 weeks after 2nd planting date

5. Winter Rye

Enterprises:
Nitrogen capture
Grazing

PI P. Porter

St. Paul, April 8, 2002

St. Paul, April 27, 2002

St. Paul, May 24, 2002

St. Paul, May 31, 2002

Morris, May 15, 2002
877 lbs/ac

Waseca, May 15, 2002
1,063 lbs/ac

Lamberton, May 15, 2002
1,724 lbs/ac

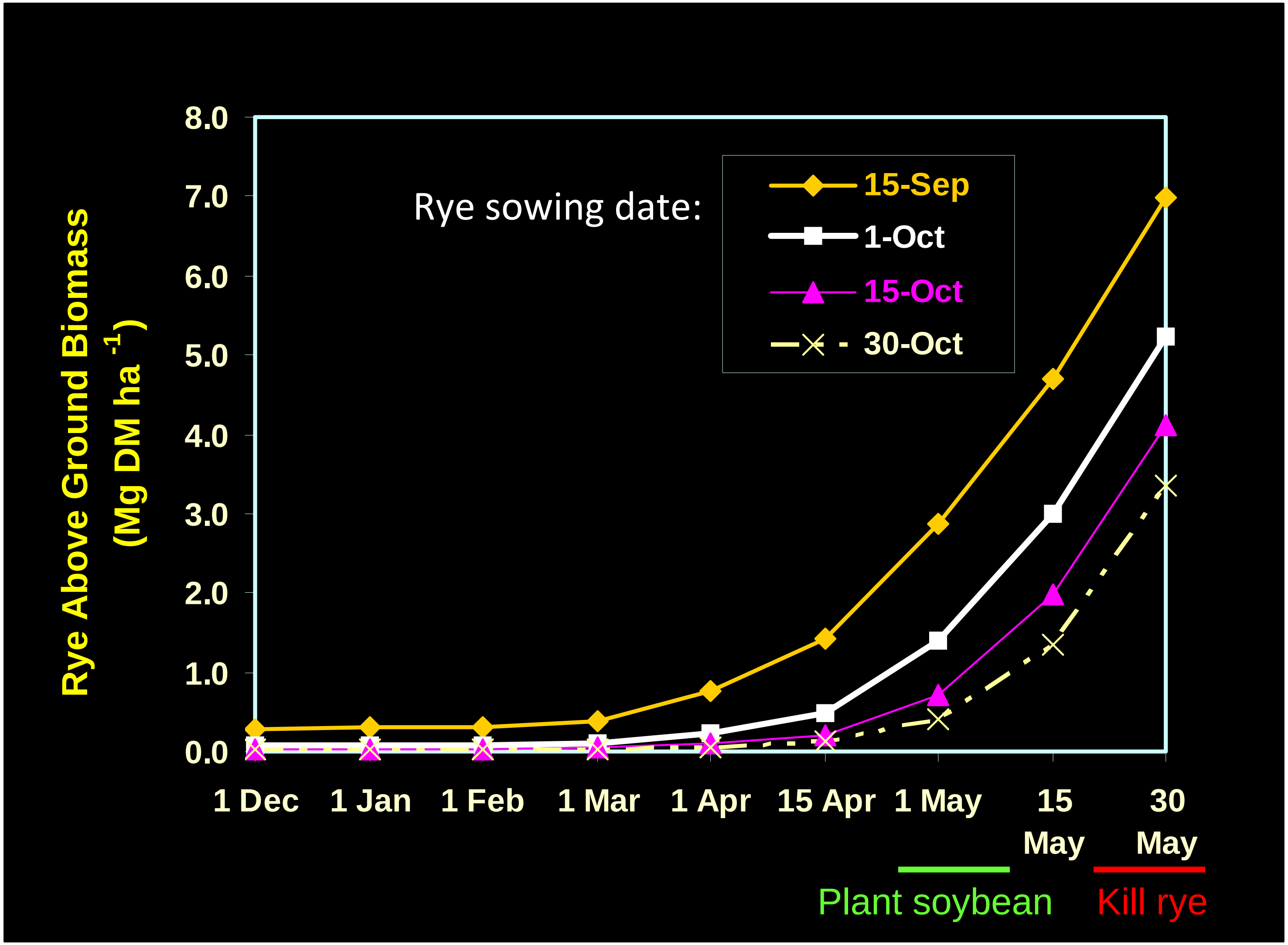
St. Paul, May 10, 2002
3,102 lbs/ac

Winter Rye Issues

- Develop seeding technology to establishment winter rye in standing crop to reduce risk of establishment failure and maximize fall growth

- Breed winter rye with early maturity, dwarf structure and high tillering

Rye biomass as predicted by 'RyeGro'



Lamberton

Feyereisen,'05

Limited Variability in Winter rye for flowering date

- High heritability for flowering time
- Large environmental effect
- 6 day difference between earliest lines and check cultivar ‘Rymin’
- Low genetic diversity for flowering date
- Must flower earlier to increase management options

Mutation breeding in winter rye for early flowering

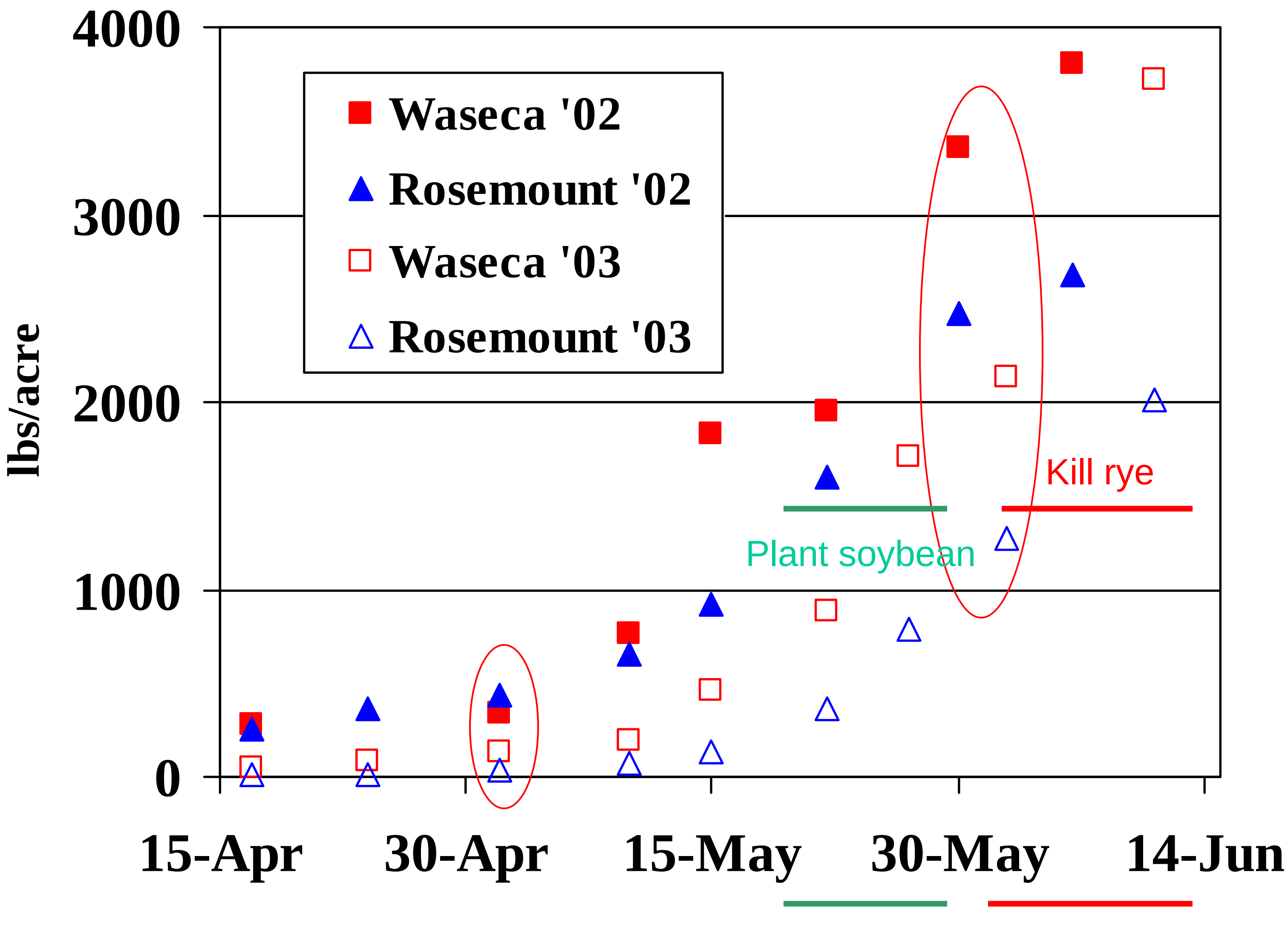
- Selected Half-sib families were exposed to sodium Azide at 2 concentrations
- Point mutations will be induced
- Identify plants that flower earlier

Initiated Fall 2013

S ↑↓ N

MR423
10mM Azide
Control
5mM Azide
10mM Azide
5mM Azide
Control

Winter Rye Aboveground Biomass



De Bruin,'04

6. Kura Clover

Enterprises:
Nitrogen fixation

PI J. Baker

Kura clover Continuous Living Cover

- Honey Production
- Soil conservation
- Pasture; hay
- Living mulch


Kura Clover can fix
150 lb N/acre


MAY 1 2006

Corn in living mulch Rosemount, MN 2011

Silage production equivalent to conventional corn, with substantially less N fertilizer

Cautions & Challenges

- Difficulty of establishment (Low seedling vigor)
- Shortage of seed (Low seed yield)
- High water use
- Need for better technology (agronomic knowledge, better tillage tools, improved varieties, etc.)

Breeding for Improved Seed Yield and Seedling Vigor

- **Poor seedling vigor resulting in stand establishment problems limits the use of kura clover**
- **Selection for lower root:shoot ratios may increase dry matter partitioning to the shoot and improve establishment.**
- **Need to breed lines for high seed yield and seed harvest efficiency**


Vegetative Propagation

8. Perennial Sunflower

Enterprises:
Food grade oil
Biodiesel

PI R. Stupar

Perennial Sunflower

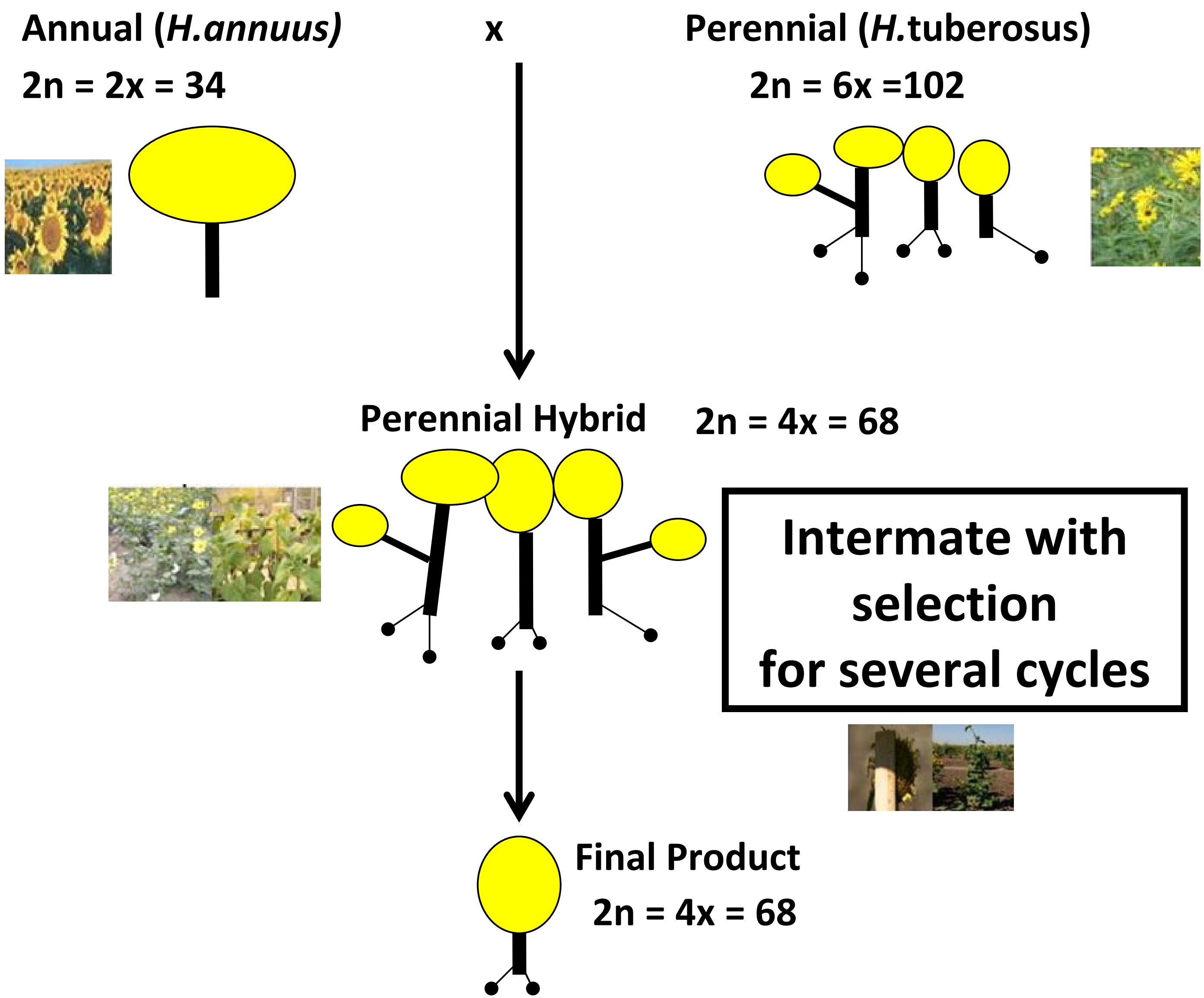
- **Work began in 2001 with collection of wild perennial sunflowers**


Objectives

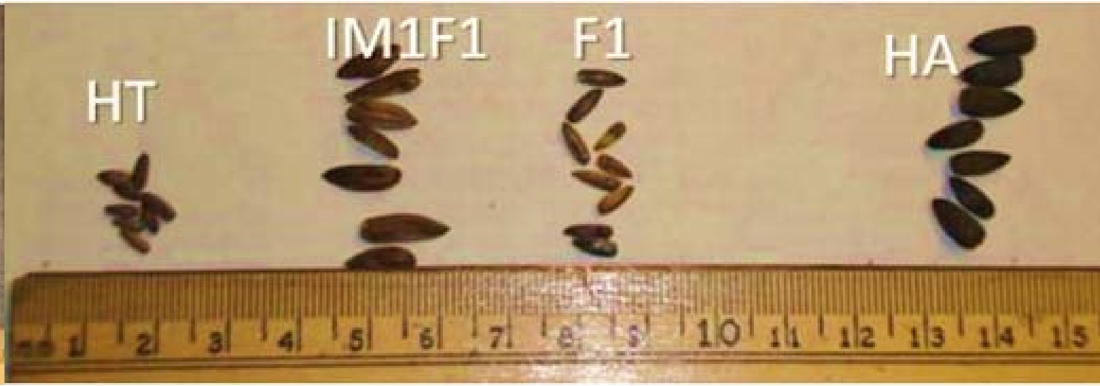
- **Further the development of perennial sunflower populations that have multiple uses on the landscape**

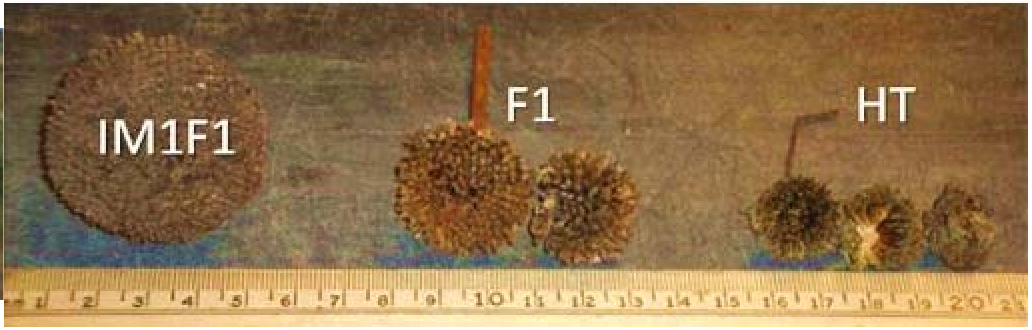
- **Identify the genetic factors that control tuber formation, winter hardiness, and branching**

Our Strategy



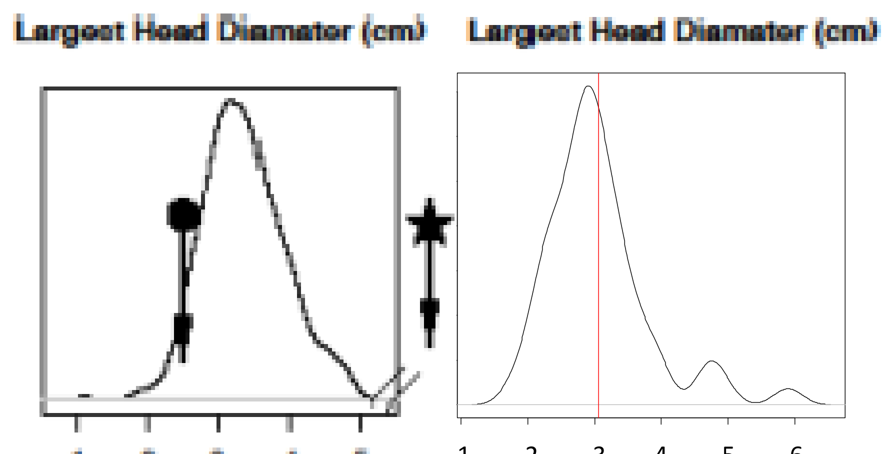
Perennial sunflower Breeding Program





Assessment of IM_1F_1 populations

- **The largest head was 20% larger than the F_1**
- **Some plants ranked in the top 10% for all yield traits!**
- **Selection of most extreme individuals to improve breeding populations**



Perennial Sunflower Selections

9. Hazelnut

Enterprises:
Nuts
Oil
Biodiesel

PI D. Wyse


Native and Native-
European Hybrid Hazelnut:
a new crop for the Upper
Midwest

North American Hazelnuts

- **Two hazel species native to Minnesota**
  - ***Corylus americana,* American hazel**
  - ***Corylus cornuta*, beaked hazel**
- **Traditional staple food of indigenous people**
- **Common in central Minnesota**

Corylus americana, American hazel

Corylus cornuta, beaked hazel

The European Hazelnut
(*Corylus avellana*)

- **Domesticated independently in Iran, Turkey, and Italy (Boccacci and Botta, 2009)**
- **Used by humans for thousands of years**
- **Commercial Production in Turkey, Mediterranean, and Oregon**

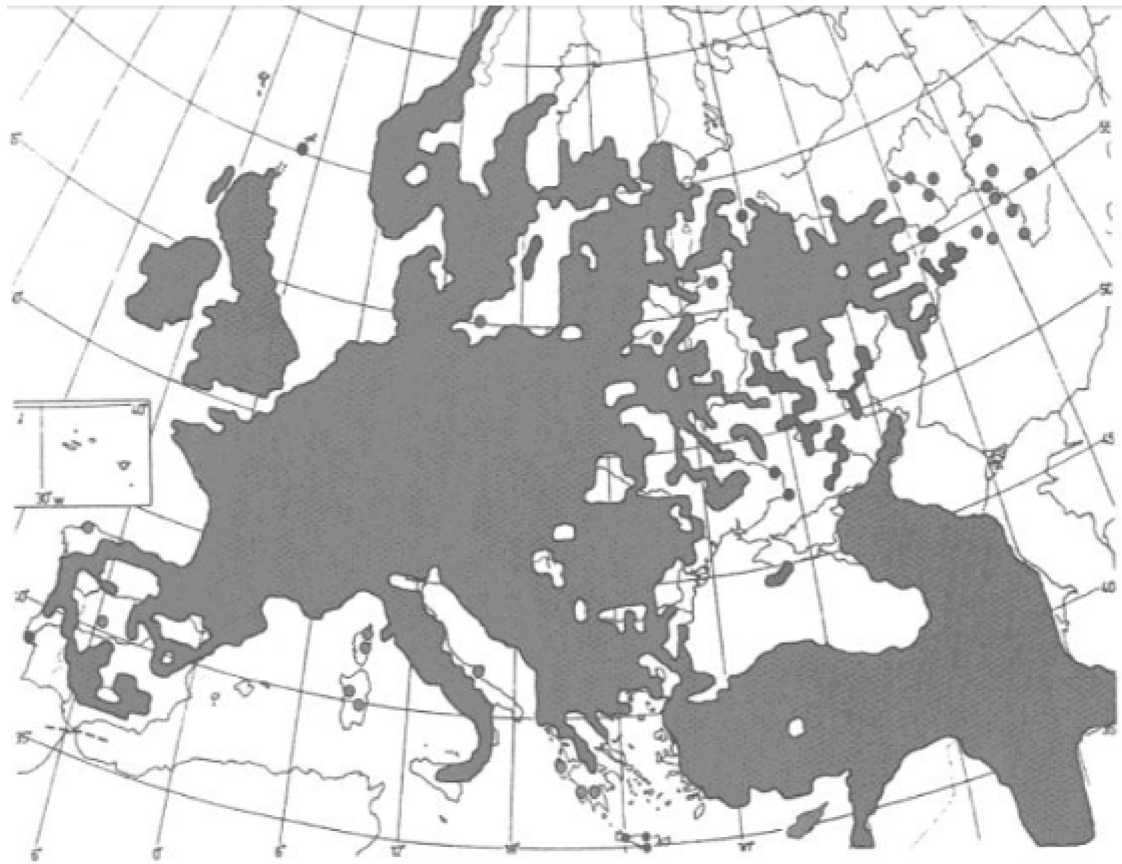


FIGURE 3. Natural distribution of *Corylus avellana* L.

(Mehlenbacher 2003)

Hybrid Hazelnuts

European Hazel *(Corylus avellana)*

- Large nut size
- Thin shells
- Not cold-hardy
- Susceptible to Eastern Filbert Blight (EFB)

American Hazel *(Corylus americana)*

- Smaller nut size
- Thick shells
- Cold-hardy
- EFB tolerant

Hybrid Hazel

Delicious, Nutritious Hazelnuts

- Excellent source of nutrition
  - Protein
  - Monounsaturated fats
  - Dietary fiber
  - Vitamins E and B_6
- Raw or toasted
- Confections
- Chocolate-hazelnut spread

Hazelnut Oil

- 50-75% of dry weight
- 81% oleic acid
- Many uses:
  - Salad oil
  - Cooking oil
  - Cosmetic products
  - Biofuel

New Economic Opportunities

- Local Food Movement
- "Olive oil of the Midwest"
- Unique opportunities for smaller American and hybrid hazels

www.midwesthazelnuts.org

Hazelnuts as Part of the Forever Green Initiative

- Do not require annual tillage
- Strips between rows can be planted with grass or clover
  - Pollinator habitat
  - Continuous living cover
- Riparian buffers
- Windbreaks
- Living snow fences

Hazelnut Germplasm Improvement

Identification of superior hybrid hazels

- **Identify hybrids from on-farm plantings with best kernel quality, yield, EFB tolerance, and cold-hardiness.**
- **Evaluation in replicated performance trials.**

Domestication of American hazel

- **Screen wild populations for superior plants.**
- **Evaluation in replicated performance trials.**

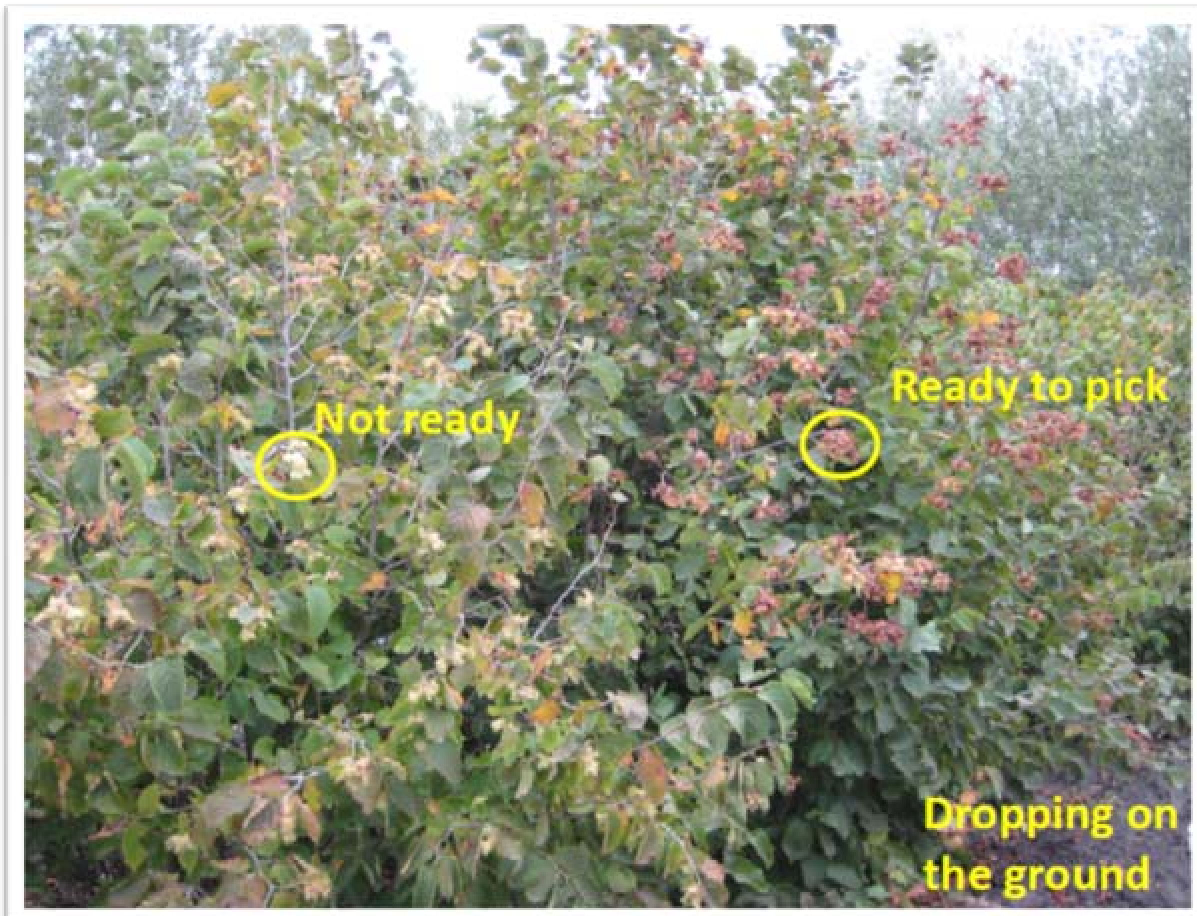
Best from on-farm evaluations

The best of the best will be released to growers as a new cultivar.

A Challenge

Too much variability between seed-propagated hazel plants is agronomically unmanageable.

Example: Nut maturation dates



Solution: Vegetative Propagation to produce genetically identical plants

Micropropagation

Determining Best Management Practices

1. Best Pre-Plant Soil Preparation and Best Weed Control Methods During Establishment

Within-row tillage?

Woodchips within rows?

Planting into killed sod + woodchips?

Landscape fabric?

Comparison Trial to Determine Best Economic Return

(Herbicides and treatment intensity are also being evaluated)

Determining Best Management Practices

2. Nitrogen Fertilization for Sustained Nut Bearing

Previous research found that young hybrid hazelnuts need only very low levels of N fertilization, but N requirements are likely to increase when they become productive.

Determining Best Management Practices

3. Pruning vs Coppicing for Rejuvenation of Mature Bushes.

Pruning

Coppicing

10. Native Plant Polycultures

Enterprises:
Biomass
Natural products

PI C.Sheaffer/D. Wyse

Polyculture grasslands for bioenergy

A Forevergreen initiative

Research Questions

- **What are the bioenergy yields of various polyculture mixtures (with and without N fertilizer)?**

- **Can we identify mixtures that are more "stable" than others? Are some less sensitive to drought years?**

- **What mixtures perform best across various growing conditions?**

Research Design

- **Species composition: Testing 12 species mixtures**
  1. Switchgrass monoculture: 1 species
  2. Big bluestem monoculture: 1 species
  3. Indiangrass monoculture: 1 species
  4. Canada wild rye monoculture: 1 species
  5. Grass polyculture: 4 species
  6. Forb polyculture: 4 species
  7. Legume polyculture: 4 species
  8. Grass and forb polyculture: 8 species
  9. Grass and legume polyculture: 8 species
  10. Forb and legume polyculture: 8 species
  11. Grass, forb, and legume polyculture: 12 species
  12. High diversity: 24 species

Research Design

Native Grasses

Primary

Switchgrass
Big bluestem
Indiangrass
Virginia wild rye

Secondary

Sideoats grama
Little bluestem
Slender wheatgrass
Canada wild rye

Native Legumes

Primary

Showy tick trefoil
Purple prairie clover
Lead plant
Canada milkvetch

Secondary

American licorice
Pale pea
White prairie clover
American vetch

Native Non-legume Forbs

Primary

Maximilian sunflower
Yellow coneflower
Stiff goldenrod
Purple coneflower

Secondary

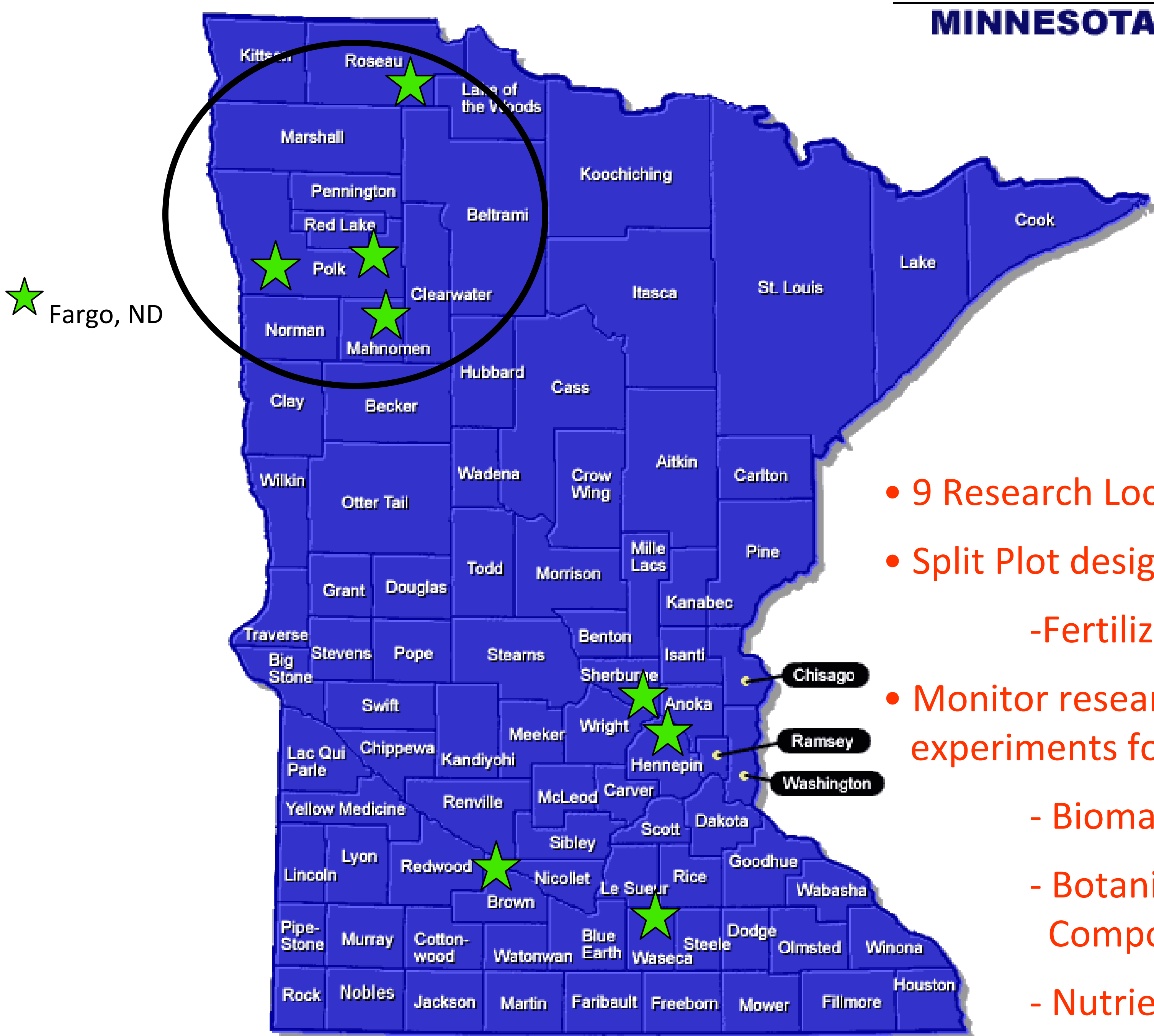
Northern bedstraw
Wild bergamot
Black-eyed Susan
Golden Alexander

Legumes in polycultures

Grass Polycultures

Research Design

- Split plot design: Two fertilizer treatments as main plots
  - 60 lbs. per acres N fertilizer
  - 0 N; control
- 12 species mixtures
- Three replicates per location
- 9 locations



- 9 Research Locations
- Split Plot design
  - -Fertilization
- Monitor research experiments for 10 yrs.
  - Biomass Yield
  - Botanical Composition
  - Nutrient Export

Picture: www.appraisers.com/ images/map_minnesota.gif

Preliminary Results

Variation in biomass yields by species, nitrogen and location treatment

Preliminary Results

Highest yielding species treatments averaged across all years at each location. No N fertilizer.

Location	Maximum yielding treatment	Yield T/A SD
St. Paul	Grass polyculture	2.4 (1.2)
Waseca	Switchgrass monoculture	2.8 (0.7)
Lamberton	Grass polyculture	3.9 (0.6)
Becker	Switchgrass monoculture	1.5 (0.4)
Roseau	High diversity polyculture	2.8 (1.2)
Red Lake Falls	Grass + Legume polyculture	2.9 (1.2)
Mahnomen	Grass + Legume + Forb Polyculture	2.1 (0.7)
Crookston	Grass + Legume polyculture	2.7 (1.0)
Fargo	Grass + Legume polyculture	1.7 (0.8)

Preliminary Results

Highest yielding species treatments averaged across all years at each location. 60 lb N applied per acre

Location	Maximum yielding treatment	Yield T/A SD
St. Paul	Grass + Forb polyculture	2.9 (1.1)
Waseca	Switchgrass monoculture	3.9 (1.0)
Lamberton	**Grass polyculture**	**4.7 (1.0)**
Becker	Grass + Legume polyculture	2.1 (1.0)
Roseau	Canada Wild Rye monoculture	2.8 (1.1)
Red Lake Falls	Grass + Legume polyculture	3.3 (1.2)
Mahnomen	Legume + Forb polyculture	2.7 (0.4)
Crookston	Grass polyculture	3.8 (1.3)
Fargo	Big Bluestem monoculture	2.3 (0.4)

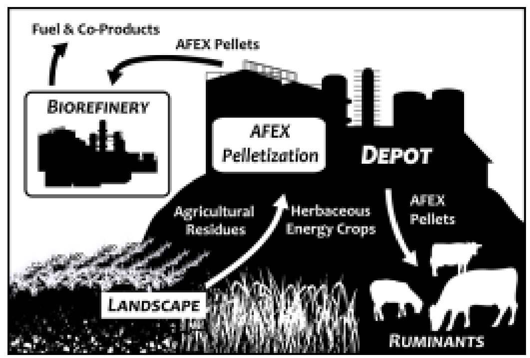
AFEX™ Pellets: A Versatile Biomass Commodity

Supply Chain Scenario

Biorefinery

- 18 million gallons/yr Isobutanol
- 900 Tons/day biomass commodity
- Target cellulosic sugars (~$0.15/lb

Depot



Landscape

- Assumption: average annual yield of 3 tons/acre, $80/ton
- Average hauling distance to depot 10 miles
- Biomass feedstock ~10% of land base

Cattle Feed

- Corn @ $6/bu: $236/ton

Figures audited by DOE 2013

11. Native Plant Natural Products

Enterprises:

Antioxidants
Antimicrobials
Aromatics

PI A. Hegeman/D. Wyse

Developing Economically Valuable Natural Products from Native Minnesota Plants

University of Minnesota and Aveda Collaboration

Alison D. Pawlus, Amanda C. Martin,
Tim Kapsner, Tiffany Thompson, Annette Popp,
Donald L. Wyse, Cindy K. Angerhofer, Adrian D. Hegeman

University of Minnesota, Twin Cities
Departments of Horticultural Science, Plant Biology, Agronomy and Plant Genetics, and the Microbial and Plant Genomics Institute
Botanicals Research Team in Estée Lauder R&D

AVEDA

UNIVERSITY OF MINNESOTA

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Onwonga

UMN Faculty & Staff
Plant Collections/
Consultants

Annette Popp
Microbiology

Project Vision

Activities

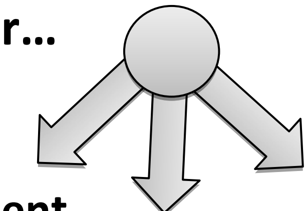
1. Identify Natural Preservatives
2. Construct Botanical Library
   - Resource for Future Screening:
     - Anti-inflammatory, 5-LOX, NF-κB, etc.
     - Antioxidant
     - Anti-aging, MMP Inhibition, etc.
     - Hair loss & Graying

Outcomes

1. Natural Based Preservatives
2. Screenable Natural Resource for High Interest Biological Activities
3. Positive ecosystem services

Project Vision

Native MN perennial plants → **Preservatives for products** = **Good for…**



Our environment

Our local economy

Our health

Project Workflow

Set up partnership and target specific plants in Minnesota

↓

Test plant organs for antioxidant and antimicrobial activity

↓

Optimize collection and compound identification process

↓

Increase throughput, landscape diversity, and expand markets

Why natural preservatives for the cosmetic and personal care market?

- **Environmental concerns**
- **Health concerns**
- **Public opinion**
- **List of acceptable ingredients dwindling**
- **Organic and natural personal care products 8.8% growth in 2010**
- **Aveda Leader in Innovation**
  - **Goal of 100% Petroleum Free Products**
  - **"Care for the World We Live In"**

Plant Material

- Native MN plant
  - "[a plant] that is part of the balance of nature that has developed over hundreds or thousands of years in a particular region or ecosystem"

    - USDA Natural Resources Conservation Service

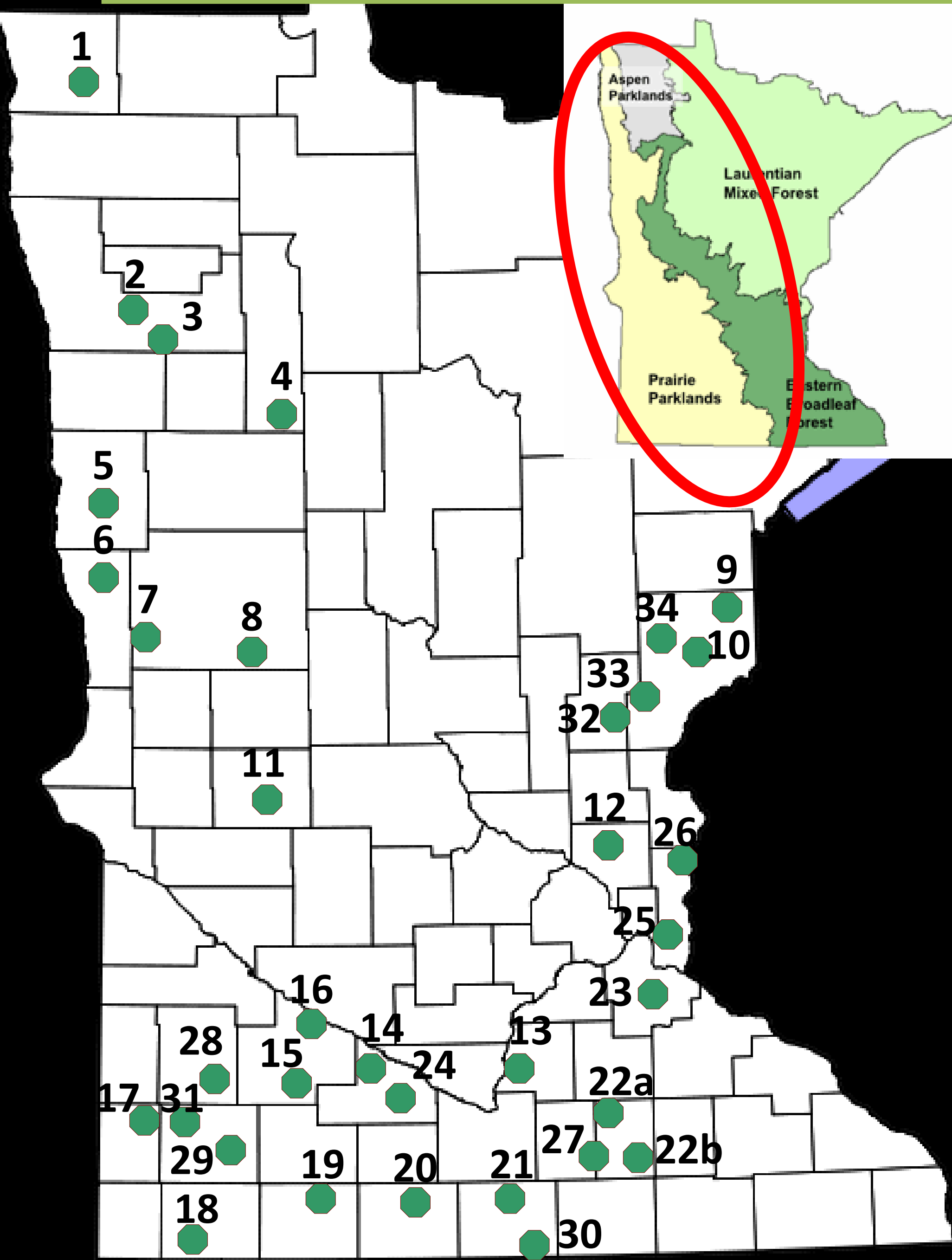
- Plant material and seed collected from
  - Scientific and Natural Areas (SNAs)
  - The Nature Conservancy natural areas (TNCs)
  - MN State Parks
  - UMN experiment station ecological areas
  - Railway roadside ditches

Plant Material

- >200 different MN plants collected as part of botanical library construction

- Key species placed into a field trial to evaluate performance in a controlled setting

MN Native Plant Collection Locations



Location	#	Location	#
Bronson Lake state Park	1	Compass Prairie SNA	18
Pembina Trail Reserve SNA	2	Des Moines River prairie SNA	19
Agassiz Dunes SNA	3	Martin County Roadside	20
Itasca state Park	4	Faribault County Roadside	21
Bluestem Prairie SNA and Buffalo River State Park	5	SROC (Waseca)	22
Western Prarie SNA	6	UMORE (Rosemount)	23
Ottertail Prairie SNA	7	Brown County Roadside	24
Inspirational Peak State Park	8	Afton state park	25
Kerrick Roadside	9	William O'Brian state	26
Nickerson Roadside	10	Janesville roadside	27
Glacial Lake State Park	11	Glynn Prairie SNA	28
Cedar Creek Ecosystem Science Reservce	12	Lundblad Prairie SNA	29
Kasota prairie SNA	13	Osmundson Prairie SNA	30
Cottonwood Prairie SNA	14	Lyon county roadside	31
SWROC (Lamberton)	15	Kanabec County roadside	32
Redwood County Roadside	16	Pine County roadside	33
Prairie Coteau SNA	17	Pine county 123	34

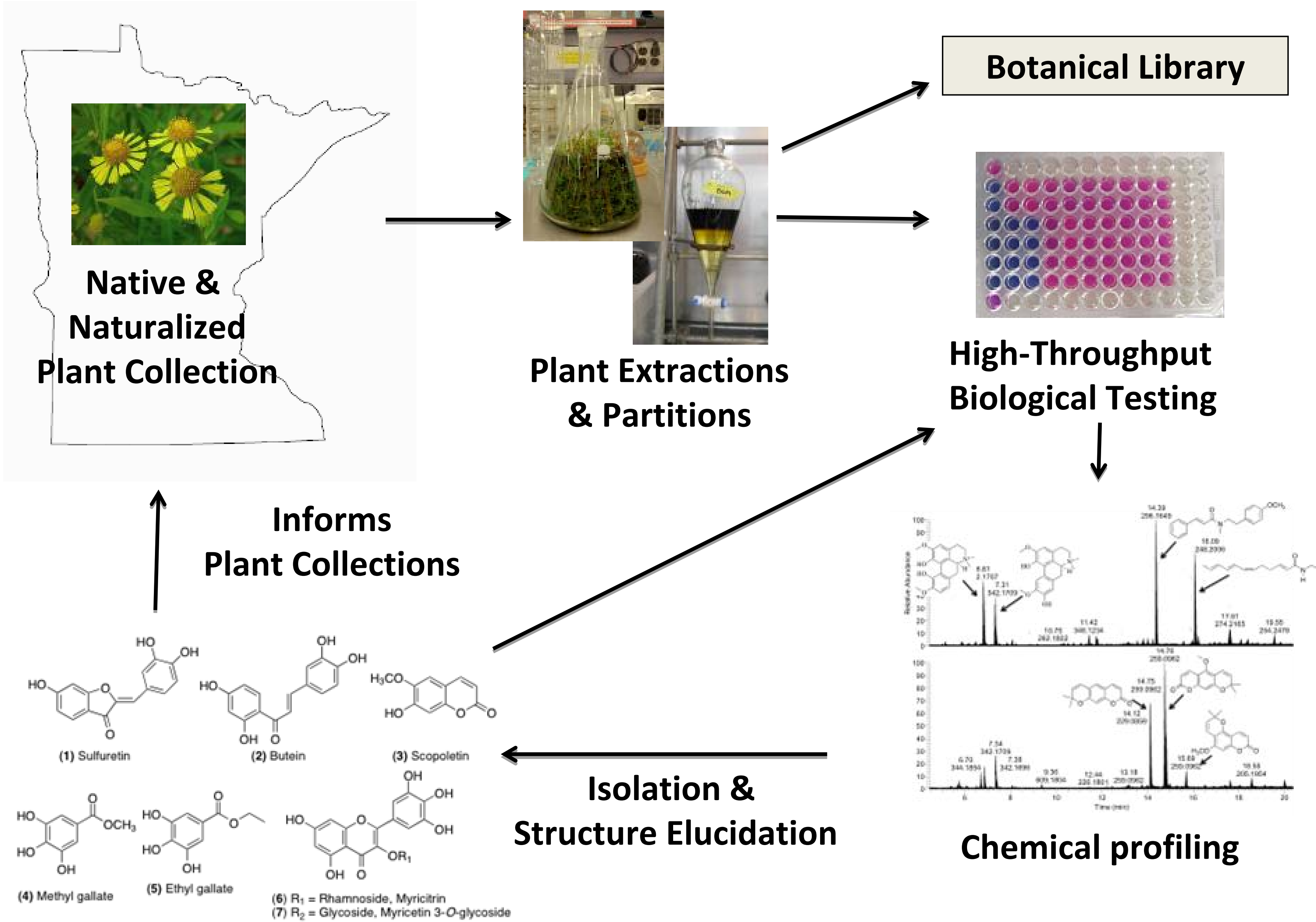
Native Plant Common Garden Establishment Summer 2011

Native Plant Common Garden Summer 2012 & 2013









Native &
Naturalized
Plant Collection
Plant Extractions
& Partitions
Botanical Library
High-Throughput
Biological Testing
Chemical profiling
Isolation &
Structure Elucidation
Informs
Plant Collections
(1) Sulfuretin
(2) Butein
(3) Scopoletin
(4) Methyl gallate
(5) Ethyl gallate
(6) R1 = Rhamnoside, Myricitrin
(7) R2 = Glycoside, Myricetin 3-O-glycoside

Bioassay-guided Fractionation

Active Extract Partition

Silica Gel Flash Chromatography

Fraction 1-3 | **Fraction 4** | Fraction 6-10

Sephadex LH-20

Semipreparative HPLC

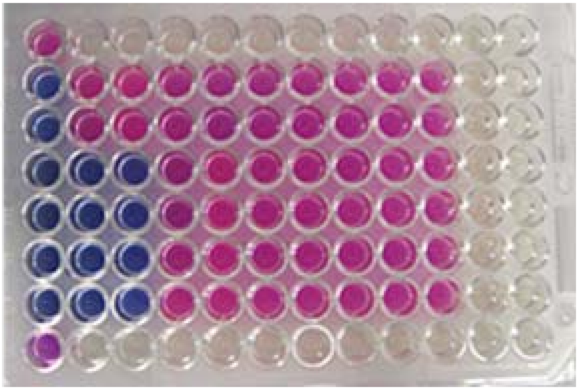
Pure Compound

Identified using high resolution mass spectrometry (HRMS), nuclear magnetic resonance (NMR), optical rotation, UV, IR, etc.

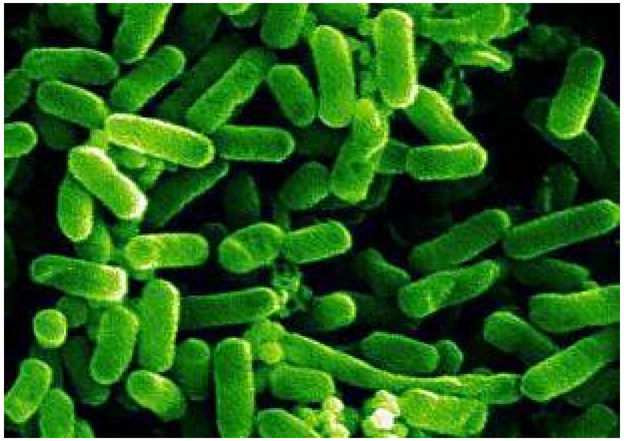
Biological Testing

Current Antimicrobial Testing

- ***Candida albicans***
  - **Fungus**
- ***Staphylococcus aureus***
  - **Gram(+) bacteria**
- ***Pseudomonas aeruginosa***
  - **Gram(-) bacteria**
  - **Aerobic**
- ***Escherichia coli***
  - **Gram (-) bacteria**
  - **Facultative anaerobic**
- ***Aspergillus niger***
  - **Filamentous fungus (mold)**



96-well plate for high throughput testing



E. coli bacteria
source: www.inhabit.com

Antimicrobial Screening Results

1. **Previous Work:**
   - > 1000 MN native and naturalized plants pre-screened
   - Disk-diffusion antimicrobial assay
2. **120 Most active from previous work, recollected & screened**
   - Using partitions and MIC assay to identify water soluble actives)
3. **Evaluated actives: Focused recollection**
4. **To date: 220 plants screened**

- **Representing 76 plant families**
- **99 Species are active against at least 1 microbe**
- **15: Deemed highly promising leads**
  - o **Good biological activity (> 1 microbe)**
  - o **Water soluble active components**
  - o **Promising phytochemistry:**
    - ▪ **Non-toxic/-allergenic/-irritant**
    - ▪ **Additional relevant biological activities**

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Benefits to UMN

- **Proprietary Technology**
- **Unique Library of Plant Extracts for Future Screening**
- **Publications**
- **Leveraging Technical Expertise from MN based Industries**
- **High Value Collaborations**
- **Training Opportunity**
    - **Post-doctoral Fellows**
    - **Graduate Students**
    - **Undergraduate Research Assistants**
    - **UROP projects**

Project Publications

Journal of Medicinal Plants Research

Antimicrobial activity of native and naturalized plants of Minnesota and Wisconsin 2008

Joy R. Borchardt[1], Donald L. Wyse[1], Craig C. Sheaffer[1], Kendra L. Kauppi[2],R. Gary Fulcher[3]
Nancy J. Ehlke[1], David D. Biesboer[4] and Russell F. Bey[2]

Antioxidant and antimicrobial activity of seed from plants of the Mississippi river basin 2008

*** Same authors as above**

Optimization of screening of native and naturalized plants from Minnesota for antimicrobial activity 2012

Peter Gillitzer[1], Amanda Cecilia Martin[2], Michael Kantar[1], Kendra Kauppi[3], Steve Dahlberg[4],
Dmitry Lis[1], Jim Kurle[5], Craig Sheaffer[1] and Donald Wyse[1]*

Phytochemical Analysis, 2013 (*in review*)

Optimized plant extractions for phytochemical library construction: Evaluating solvent systems using metabolomics approaches

Amanda C. Martin[1], Alison D. Pawlus[1], Erin M. Jewett[1], Donald L. Wyse[2], Cindy K. Angerhofer[3], Adrian D. Hegeman[1]

12. Perennial Flax

Enterprises:
Food grade oil
Biodiesel

PI D. Wyse

Perennial Flax

- Began in 2001 with observation blocks of wild perennial flax from the USDA-GRIN system and Black Hills State University (South Dakota)
- Germplasm included two genomic groups, x=9 (self-incompatible) and x=15 (largely self-pollinated)
- Hybridization began in 2004 within and between these groups

Perennial Flax

- Goals of perennial flax improvement
  - Increase seed size
  - Improve wintering ability
  - Select for ability to produce 2 crops per year

Regrowth of nursery plant
1 month after harvest

13. Agroforestry

Enterprises:

Food products
Fuel products

PI C. Sheaffer/D. Current/D. Wyse

Introduction

Agroforestry has been proposed for sustainable biomass cropping

•Potential to utilize "marginal", depositional, or lowland sites

- Strategic niches to minimize competition with food crops

•Potential for increased ecosystem services

- Wildlife / pollinator habitat
- Carbon sequestration
- NPS pollution reduction / water quality

- Landscape and feedstock diversity

Introduction

- Limited information on biomass crop potential in agroforestry systems in U.S. Midwest
- Successful crop establishment is critical to stand longevity and maximizing productive potential
- We need to develop systems before farmers can adopt!

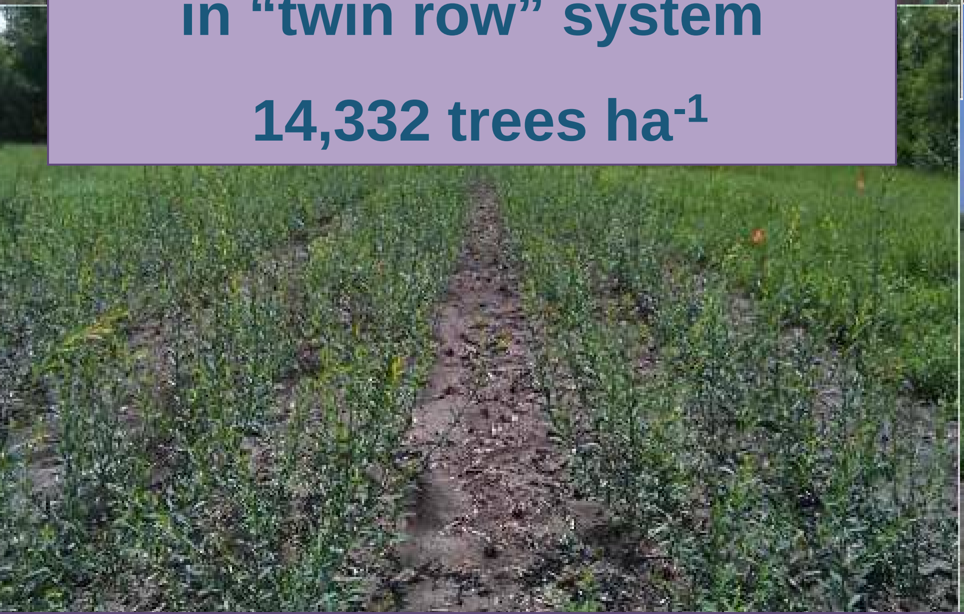
Methods: objectives

Therefore, our short-term objectives we
to:

- To evaluate establishment and yields
  biomass crops in an alley cropping
  system

- To evaluate the effects of tree- crop
  interactions on productivity and
  establishment

Methods: crops



‘Fish Creek’ willow planted in “twin row” system

14,332 trees ha^{-1}

(*Salix purpurea x S. purpurea*)

‘NM6’ poplar planted at 1.2 m grid spacing

6,670 trees ha^{-1}

(*Populus nigra x P. maximowiczii*)

Methods: crops

- **Switchgrass**

(*Panicum virgatum* L.)

  - Local ecotype broadcast at 18.2 kg ha^{-1} (193 seeds m^{-2})

- **Prairie Cordgrass**

(*Spartina pectina* Bosc ex Link)

  - Local ecotype propagated at 107,593 plants ha^{-1} (10.8 plants m^{-2})

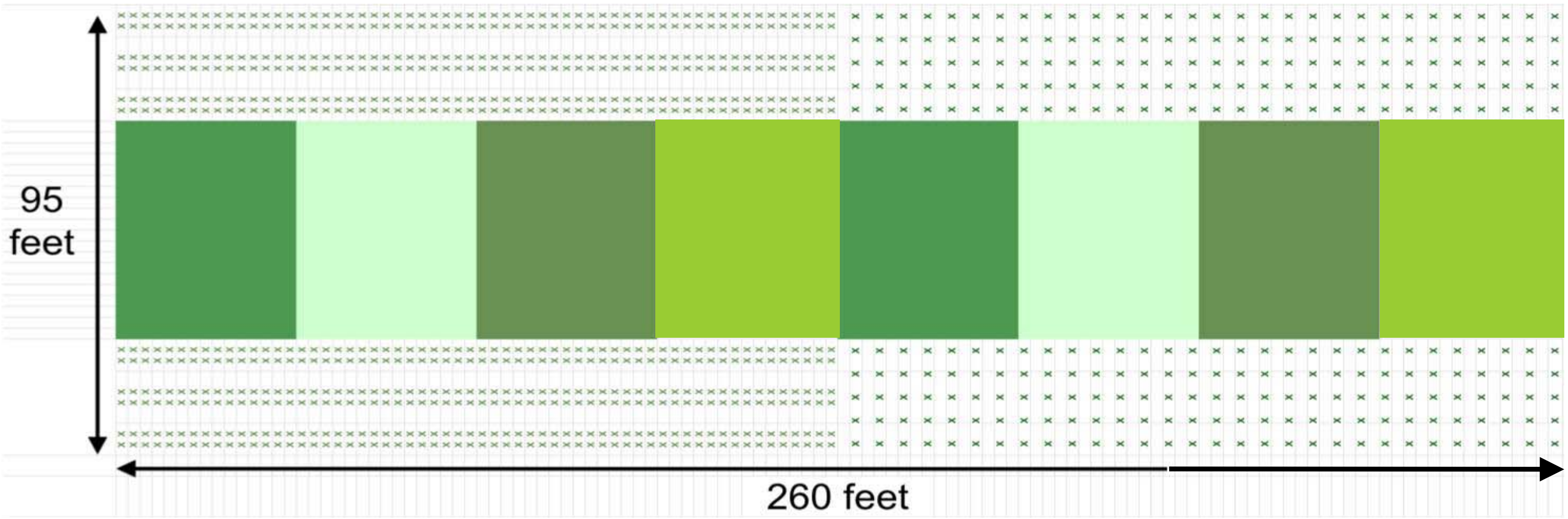
Methods: crops

- **Native tallgrass polyculture**
  - 4 forbs, 4 legumes, 3 grasses broadcast at 17.1 kg ha^{-1} (384 seeds m^{-2})

- **Alfalfa - intermediate wheatgrass mixture**
  - Alfalfafa (*Medicago sativa* L.) Pioneer ’54V48’ at 5.7 kg ha^{-1}
  - ‘Rush’ intermediate wheatgrass (*Thinopyrum intermedium* [Host] Barkworth and Dewey) at 9.1 kg ha^{-1}

Methods: design

- RCBD in split plot arrangement
- 3 on-farm sites: Fairmont, Empire, and Granada, MN
  - 2 floodplain, 1 stream terrace
- 3 years (2010 - 2012)
- 2 woody crops, 4 herbaceous crops
- 15.2 m alley



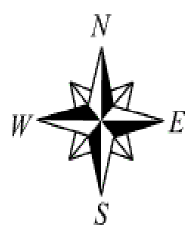
Methods: design

Alley orientation

Empire

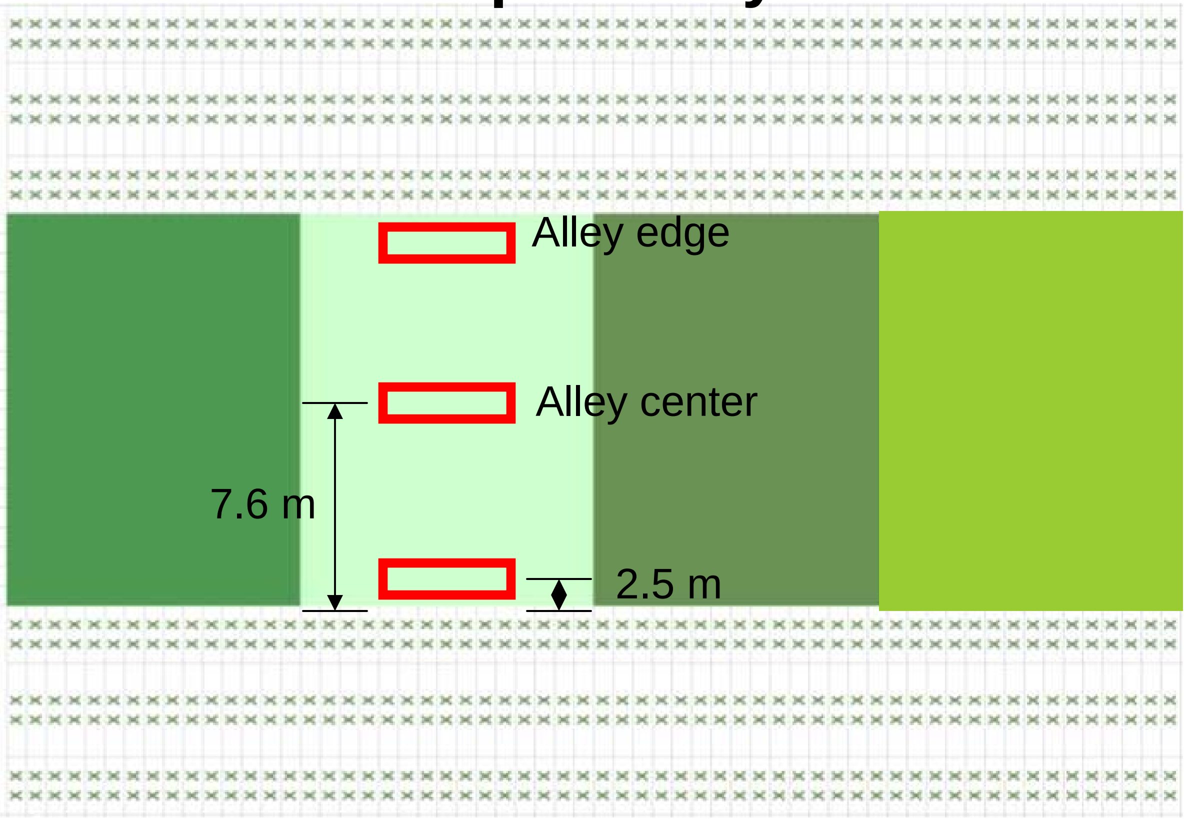
Fairmont

Granada



Methods: sampling

Herbaceous crop sampling – evaluating effects of proximity to trees



Methods: sampling

Tree sampling – evaluating effects of proximity to edge

$n_{poplar} = 8$ $n_{willow} = 6$

Results & discussion

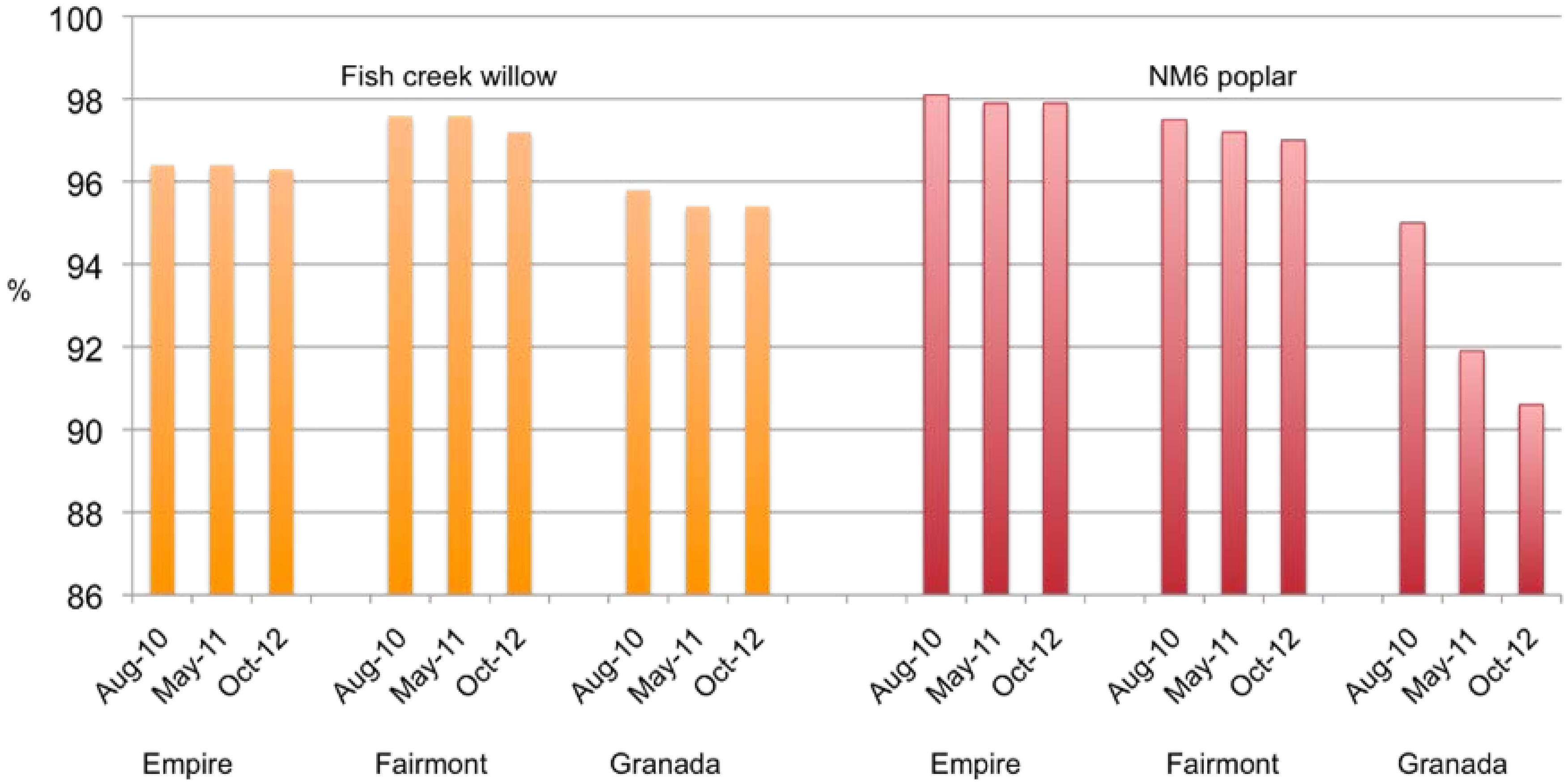


Figure 2: Short rotation willow and poplar survival 3, 12, and 30 months after establishment in alley cropping systems at three Minnesota sites

Results & discussion

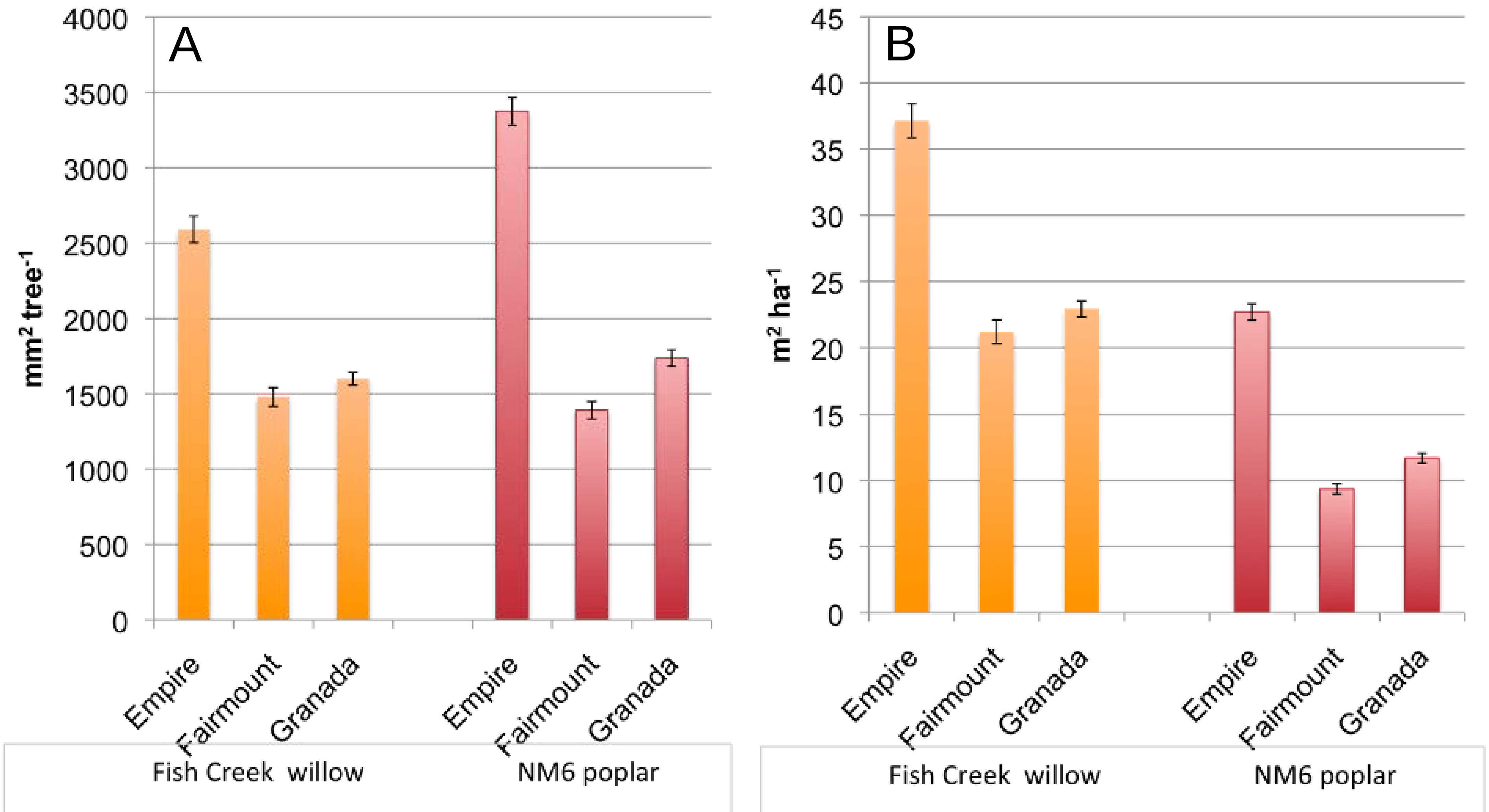


Figure 2: **A)** Basal area per tree and **B)** Stand basal area **(**per hectare) for alley cropped short rotation woody crops following the third growing season in 2012. Means +/- standard errors are presented.

Results & discussion

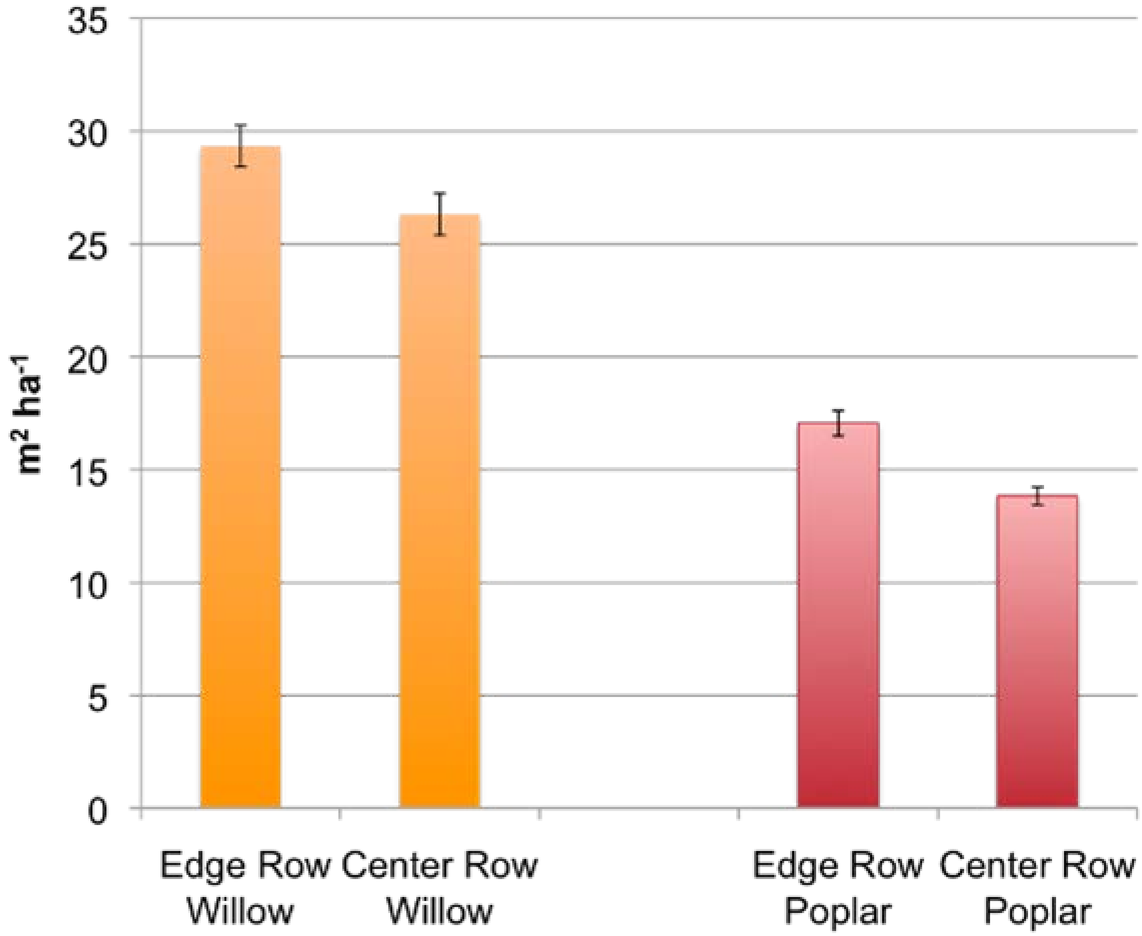


Figure 3: 2012 average basal area per hectare by clone and row position for alley cropped short rotation woody

Results & discussion

Table 2: Establishment index and weed density for four herbaceous alley crops at two Minnesota sites 45 days after seeding.

Treatment	Planting rate (PLSm^{-2})	Establishment index §		Weed density (seedlings m^{-2})	
		Empire	Granada	Empire	Granada
Switchgrass	1,481	0.21 br†	0.33 br	90.4 ar	38.8 as
Alfalfa – wheatgrass	439	0.82 ar	0.90 ar	69.9 ar	30.1 ar
Native polyculture	770	0.18 cr	0.21 br	73.2 ar	72.1 ar
Prairie cordgrass	10.8‡	0.93 r	0.82 s	NA	NA

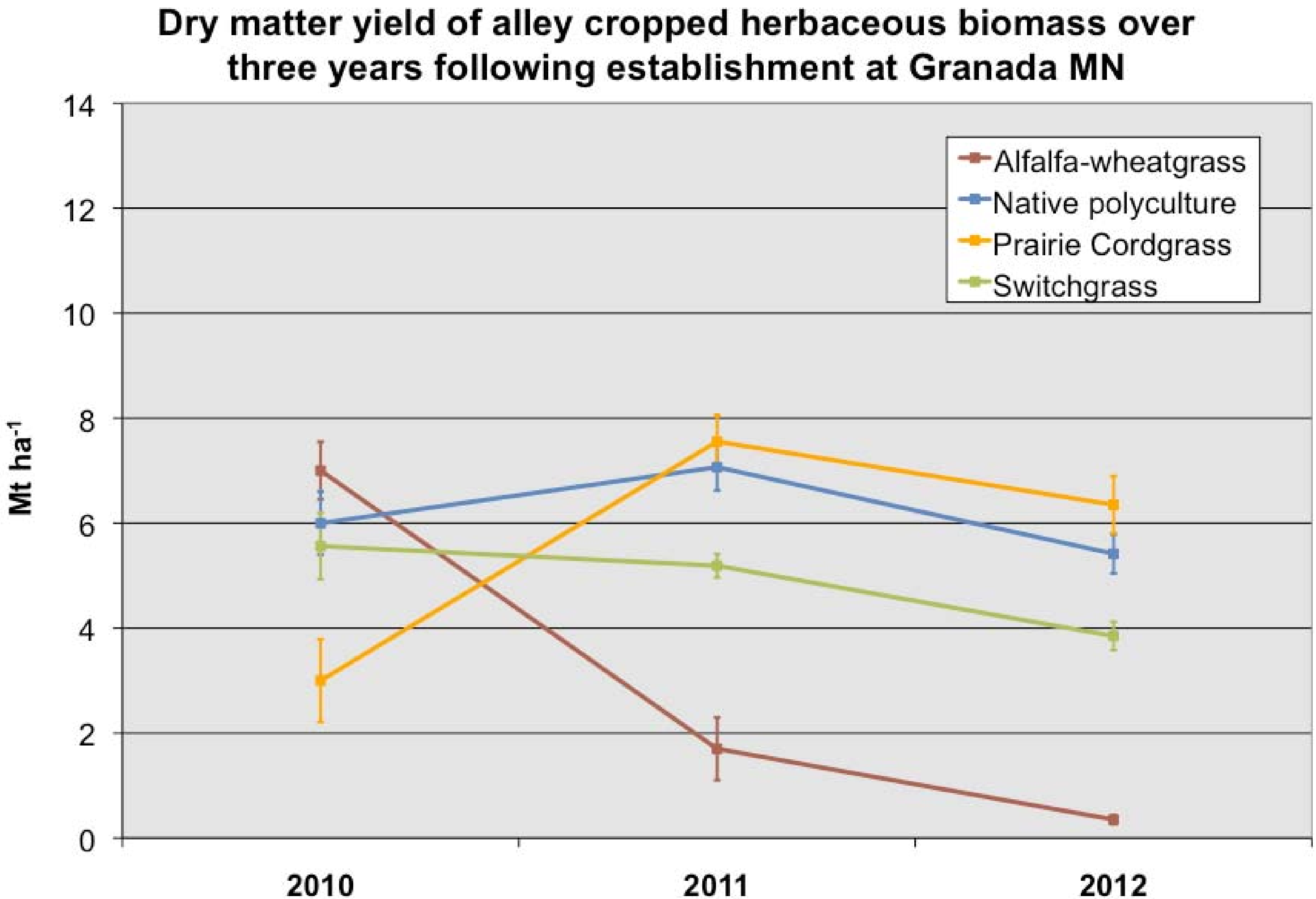
†Within each column and row, means with the same letter are not significantly different based on Tukey's HSD (0.05). Letters a – c are used to denote differences among treatments, while letters r – s are used to denote differences between sites.

‡Live rhizomes were planted rather than seed, thus comparisons to seeded treatments were not made

§Emergence index is calculated as average seedling density / planting rate

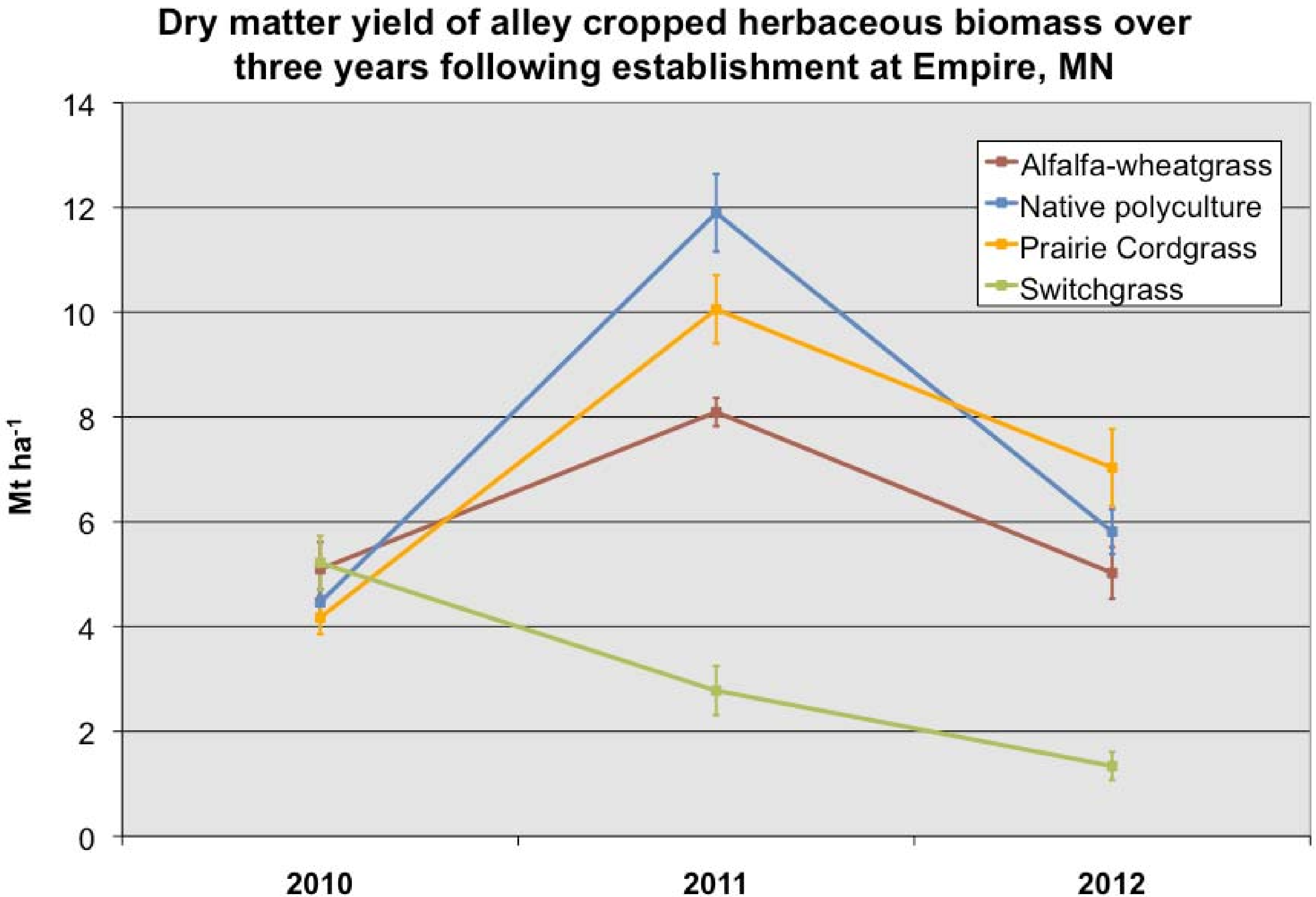
NA: Not applicable; this data was not collected

Results & discussion



Means +/- standard errors

Results & discussion



Means +/- standard errors

Summary

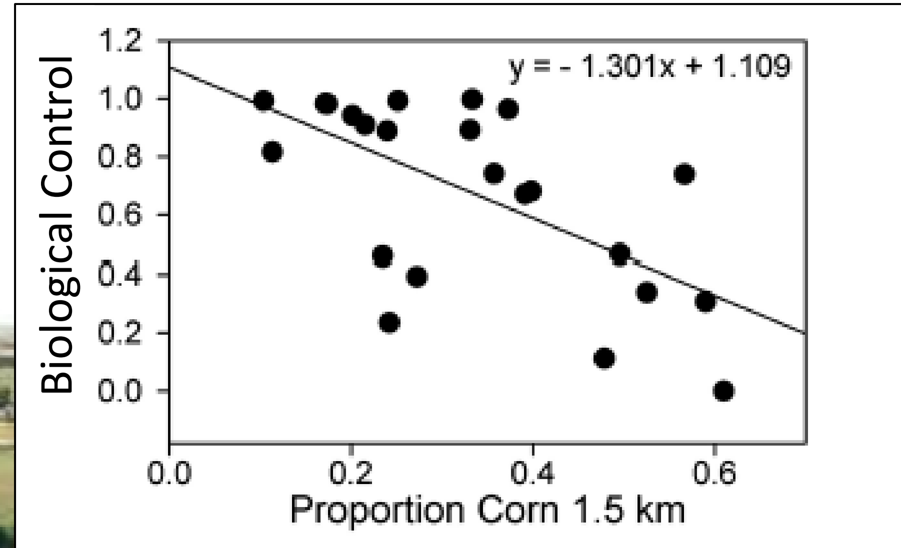
- Herbaceous productivity
  - Good herbaceous crop establishment (high indices)
  - Native polyculture & prairie cordgrass were most productive herbaceous crops so far
  - No difference in edge vs. center alley, but yields are declining overall, possible effect of alley orientation
- Woody productivity
  - Excellent tree survival
  - Edge effects due to alley proximity
  - Differences between clones due to:
    - Tree spacing, individual tree size, coppice / no coppice management, site adaptability

Next steps

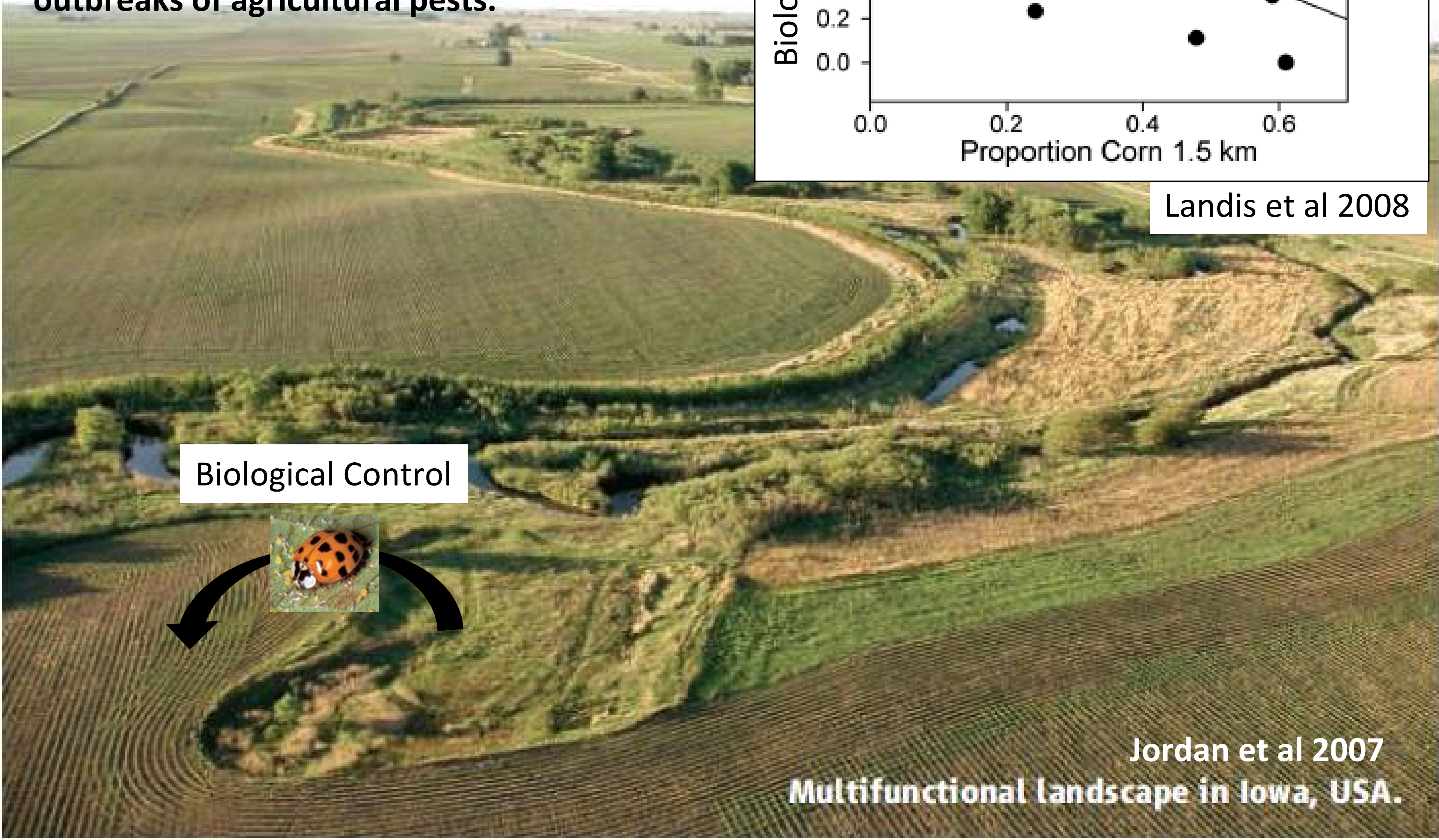
- Effects of interspecies interactions on resource availability and productivity in the alley cropping system
  - What is causing herbaceous yield decline? (light, water, N availability?)
  - Why no edge effects in herbaceous crops?
- Woody biomass harvest and allometrics
- Root biomass distribution and C accumulation since conversion from annual crops

Alley Cropping Systems: Biological Control Index

Agricultural landscapes are dominated by a few annual crops. More land in corn means less grassland and forest habitat for beneficial insect predators and there are more outbreaks of agricultural pests.



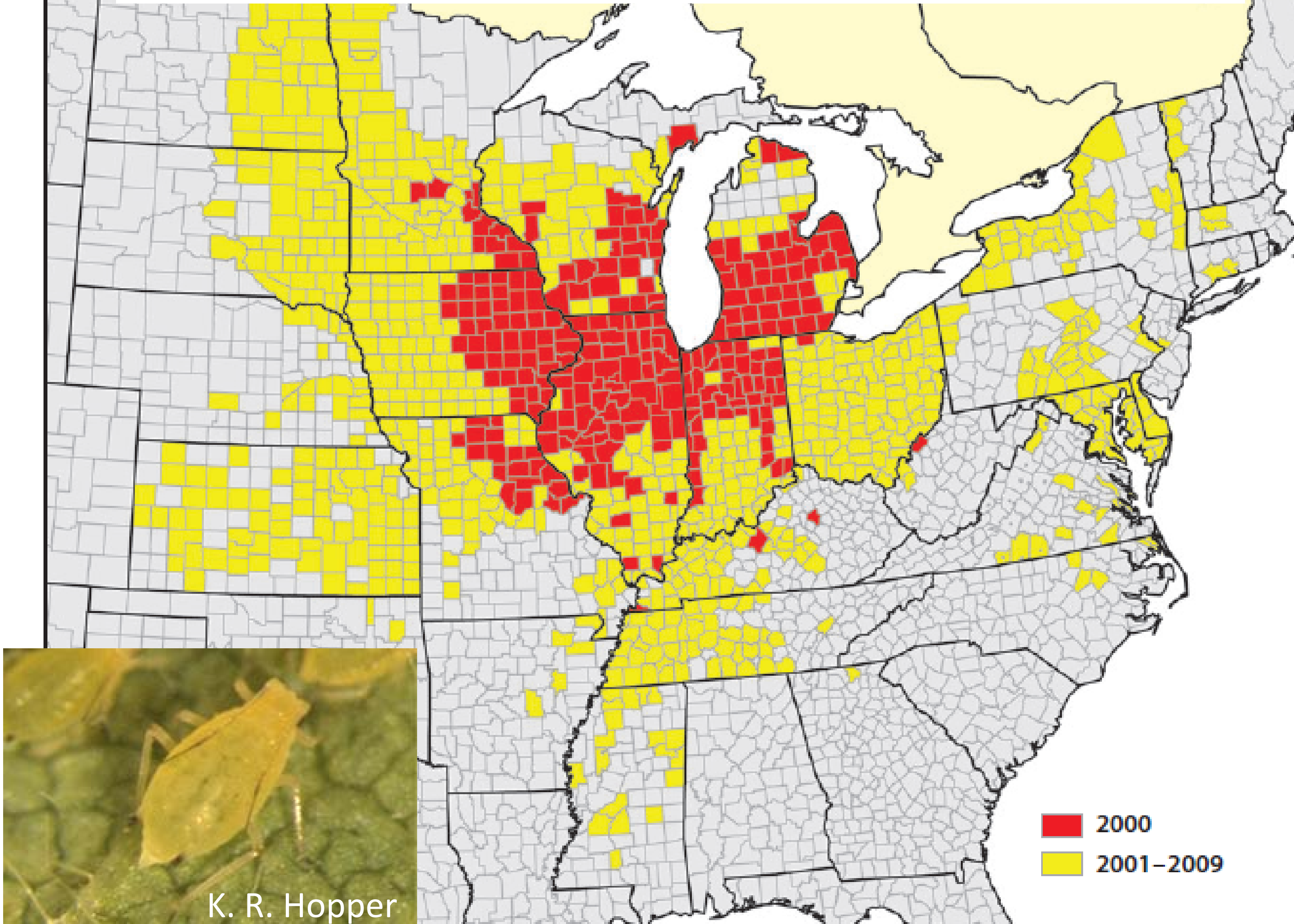
Landis et al 2008



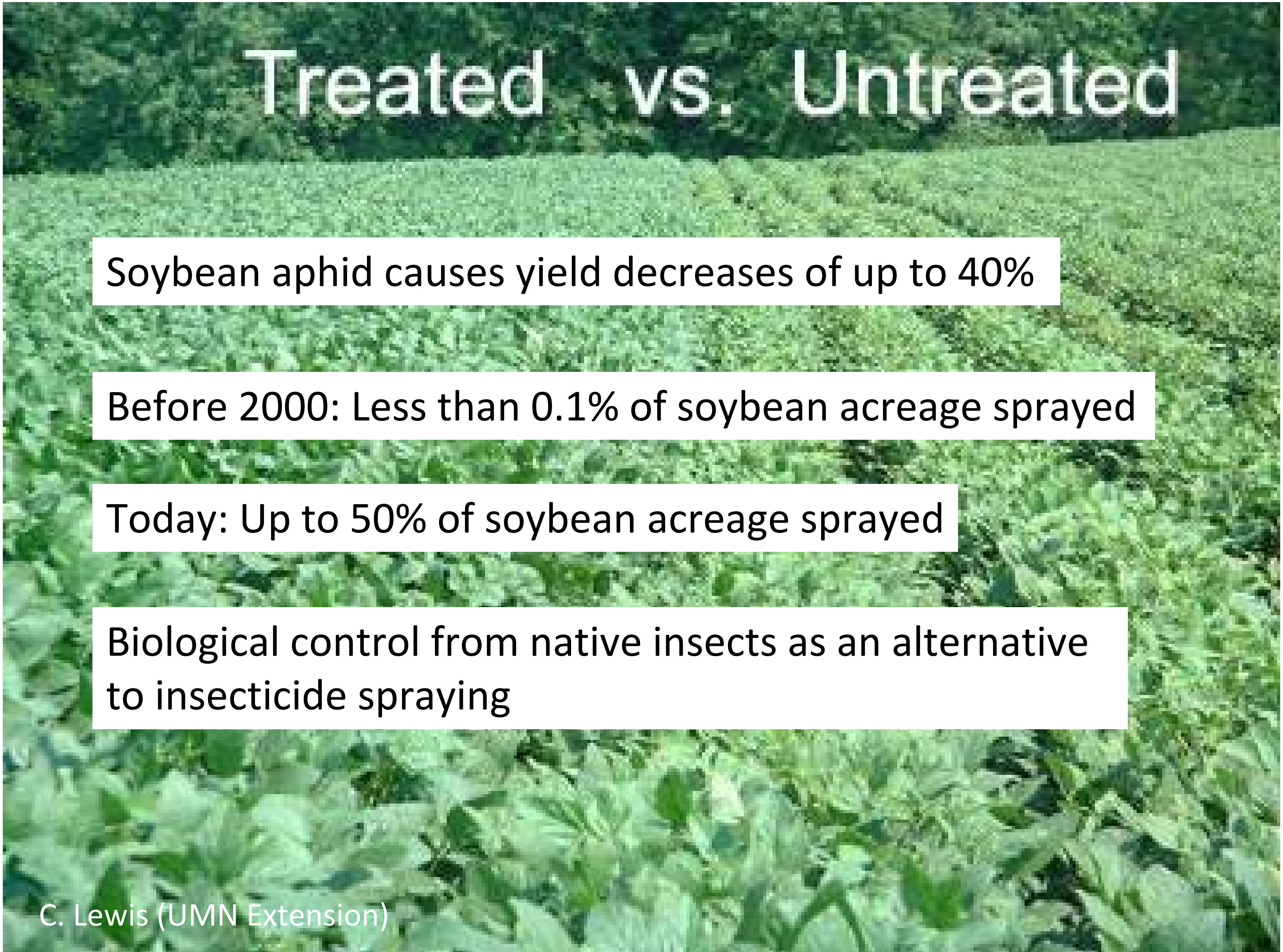
Jordan et al 2007

Multifunctional landscape in Iowa, USA.

Soybean aphid is a major pest in the upper Midwest



Ragsdale et al 2011



Soybean aphid causes yield decreases of up to 40%

Before 2000: Less than 0.1% of soybean acreage sprayed

Today: Up to 50% of soybean acreage sprayed

Biological control from native insects as an alternative to insecticide spraying

C. Lewis (UMN Extension)

Insect Predators of Soybean Aphids in the Upper

Photo Credit: P. Bryant, M. Rice, T. Murray, J. Eckberg

Integrate perennial crops into soybeans to attract predators of the soybean aphid

Tilman et al 2006, Peng et al 1993

Integrated perennial cropping systems support biological control of the soybean aphid and produce perennial bioenergy

Photo Credit: University of Wisconsin