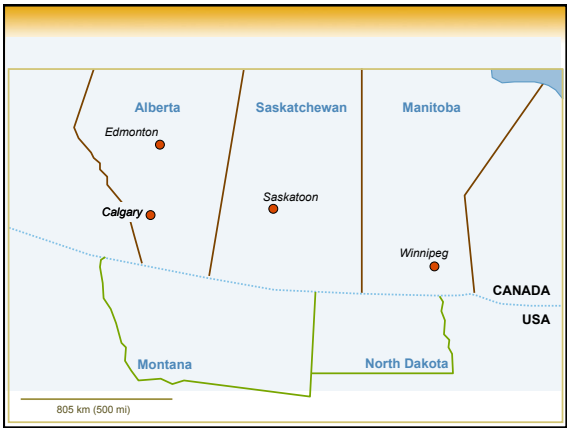
Organic wheat breeding and agronomy research at the University of Alberta



Introduction

- Spring wheat is Alberta's most widely grown crop with 5.85 million acres planted in 2001. It's kinda big in Canada too.
- The U of A wheat breeding program is a very very small adjunct to the main programs at AAFC (Swift Current, Winnipeg, Brandon and Lethbridge) and the U of Saskatchewan.

Students who actually did this work

- *Dr.* Alireza Navabi, *Dr.* Heather Mason, *Dr.* Rory Degenhardt, Amy Kaut, *Dr.* Todd Reid, Lisa Shippelt, *Dr.* Alison Nelson
- Hiroshi Kubota, Klaus Strenzke, Mohammud Asif

Organic wheat research and breeding at the U of Alberta

- 11 acres on University lands managed organically since 1999.
- Three year rotation with winter triticale and a perennial legume or cereal / pea plow down.
- Certified organic farmer cooperators (Snider / Gaborski) 100 km away.

Organic

Conventional

Objectives or Hypotheses

1. Develop a crop ideotype (An 'ideal body type') for spring bread wheat grown under organic management.
2. Understand the genetic mechanisms of competitive ability, and use that understanding to develop bread wheat cultivars for production under organic farming systems.
3. Develop long-term agronomic strategies for the organic production of wheat, in mixtures with annual grain or pulse crops.

Research in organic breeding:

- Older varieties may be better suited to low input, high stress environments
- IE they may be more competitive and better able to withstand low nutrient levels
- Selected prior to chemical fertilizers and pesticides

But

- Where should you breed for organic?

Dissecting Yield Trials

Alireza Navabi

Grain yield data from the regional hard red spring wheat variety trials from 1981 to 2002 (472 location years assessing 64 wheat genotypes) in Alberta Canada.

Location was always the main contributor to yield variation across years, accounting for 67 % to 98 % of the [G + L + GL] variance. In addition, the Genotype x Location component was greater than the Genotype component in all years.

Genotype accounted for 9 to 21% of the [G + L + GL] variance in any year.

Varieties Neepawa and Katepwa in early 1980's, Laura in late 1980's, CDC-Teal and AC-Barrie in 1990's and Superb in early 2000's were grown on vast areas.

WHY?

Organic Farmer Survey Results 2003

- **Major Crop Production Concerns**

1) Weeds (72%) 2)Fertility (28%); followed by cultivar choice, Insect and Disease problems

- **Perceptions of Research Focus**

1) Fertility managements (29%); 2) Rotations; followed by production techniques, weed control and cultivar development

- ***Plant breeding and cultivar choice was not actually considered very important by farmers' surveyed***

What we've done since learning that nobody really cares what we do

1) Historical wheat varieties
2) Wheat with and without weed competition, at normal and double seeding rates,
3) Wheat variety mixtures
4) Miixtures of crops (wheat, oats, barley, triticale, pea and canola) with and without weed competition
5) Mapping populations (ITMI; Attila x Barrie; CDC Go x Teal)
6) Low P study of 50 odd genotypes from Canada and CIMMYT
7) Soil biota studies of interactions with wheat varieties and /or weeds

What we'll talk about a bit today

1) Study of 32 historical wheat varieties on organic and inorganic land
2) Study of 11 wheat varieties (and 2 barley) with and without weed competition, at normal and double seeding rates, on organic and inorganic land
3) Sensory and chemical evaluation of the historical wheat varieties grown on organic and inorganic land
4) Population of Attila x Barrie (about 90 random inbred line population) grown on 5 or 6 sites of both organic and inorganic land + breeding selection study
5) Wheat variety studies for soil biota data; grain macro and micro nutrient analyses

Heather Study 1

The Weed Competitive Ability of Canada Western Red Spring Wheat Cultivars Grown under Organic Management

Heather Study 1 - Conclusions

- Canadian spring bread wheat cultivars perform differently in conventional and organic management systems
- Height, early season vigor, early heading and maturity, and spikes m^{-2} are associated with grain yield and lower weed biomass in organic systems
- Organic spring wheat ideotype:
  - Taller cultivar with fast early season growth, early maturity and a greater number of fertile tillers

Study 3

Cultivar and seeding rate effects on the competitive ability of organic spring cereals in the northern Canadian Prairies

Study 3 - Results

Seeding Rate Effects on Wheat and Barley

	Grain yield (t ha^{-1})	Kernel weight (g)	Days to Maturity	Natural weed biomass (g m^{-2})
Seeding Rate (SR)				
single	**2.6**	**32**	**99**	**98**
double	**2.9**	**31**	**97**	**71**
F test seeding rate	***	*	**	***
SE_{diff}	**0.06**	**0.3**	**0.9**	**3.6**
V*SR	***ns***	**	***ns***	***ns***

F values significant at *** 0.01, ** 0.05, * 0.1, ns denotes non-significance

Study 3 - Conclusions

- Height, strong early season vigour and early maturity are related to competitive ability on organic land
- Doubling the seeding rate may be an effective tool for suppressing weeds and increasing grain yield under organic growing conditions
- Overall benefits of increasing the seeding rate of wheat are not cultivar specific

Study 4 - Conclusions

- Tallness and early heading and maturity are most strongly associated with grain yield and/or weed suppression in highly weedy environments
- Wheat cultivars differ in their yield and weed stability
  - Older cultivars were more yield stable
  - Semi-dwarf cultivars were less weed stable

Lisa and Heather

Does growing Canadian hard red spring wheat under organic management alter its breadmaking quality?

A **B**

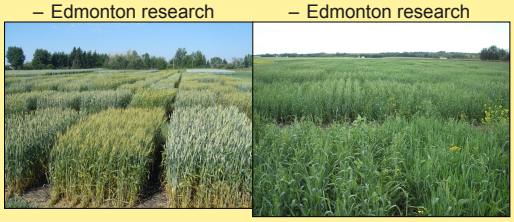
Photographs of 60% whole wheat organic (A) and conventional (B) bread slices (1.4cm thickness)

Conclusions

- Conventional flour produced stronger bread dough than organic flour.
- There were no differences in flavor, aroma, or color attributes, but the panel did perceived organic bread to be more "dense".
- Cultivars perform differently under organic and conventional management
- Older CWRS cultivars are not necessarily better suited to organic bread wheat production
- People can't really tell the difference between but they will pay more for organic if they think it's better for the environment

Realized gains from selection for spring wheat grain yield are different in conventional and organically managed systems

- Organic sites
  - Edmonton research
- Conventional Sites
  - Edmonton research



Should spring wheat breeding for organically managed systems be conducted on organically managed land?

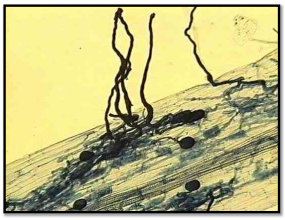
Yes
Sort of..

Conclusions

- Selection differences occur across multi-location tests, and selection for grain yield in organic systems should be conducted within organic systems.
- Data garnered from conventional yield trials does have some relevance towards breeding for organic environments.
- Though these data have relevance for breeding for yield, there are quality and disease resistance issues that need be examined.

Arbuscular mycorrhizal fungi (AMF)

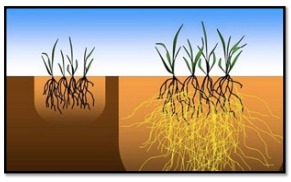
- Fungi that colonize plant roots and form a symbiotic relationship with plants



http://www.biology.ed.ac.uk/research/groups/jdeacon/microbes/arbuimag.htm

Arbuscular mycorrhizal fungi

- Form mutualistic associations with roots of 80% of plant species (Habte 2006)
- Increase surface area and soil area explored by plants for absorption of nutrients in soil



http://www.agro-genesis.com/product_cropscience_microbes.html

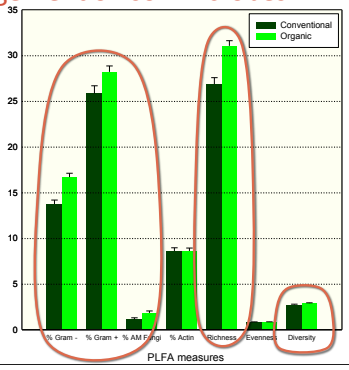
Organic systems & microbes

- Organic systems:
  - Greater levels of organic matter (Bossio et al. 1998; Drinkwater et al. 1995; Shepherd et al. 2002)
  - More weeds
  - Lower nutrient levels
  - More microbial biomass, different structure
  - Higher mycorrhizal colonization and potential

Objectives

- How does management system and wheat cultivar choice affect soil microbial community, crop productivity, and bread making quality?

Management on soil microbes

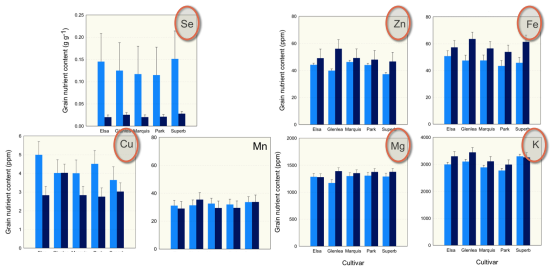


Management on soil microbes

PLFA	Origin	Mean	Indicator value		Monte Carlo
			Conv.	Organic	p<0.05
i14:0	Gram +	35.4 (3.77)	6	74	0.0002
16:1 w5c	Fungi	50.8 (0.94)	45	55	0.0002
i17:0	Gram +	50.4 (0.78)	47	53	0.0002
a17:0	Gram +	50.3 (0.74)	48	52	0.0002
cyc17:0	Bacteria	50.4 (0.77)	53	47	0.0002
i18:0	Gram +	19.8 (3.82)	0	57	0.0002
18:1 w9c	Fungi	50.4 (0.77)	47	53	0.0002
i19:0	Gram +	27.0 (4.06)	6	48	0.0006
20:1 w9c	Fungi	44.8 (3.35)	0	45	0.0002

Three fungal PLFAs were indicators species for the organic system

Grain micronutrient content



Conclusions

- Organic grain had higher Zn, Fe, Mg, K; lower Se, Cu
- Two systems had different microbial structures
- Mycorrhizal fungi levels higher in organic system
- Breeding in conventional systems may have cultivated mycorrhizal dependence in that environment
- Breeding efforts for elevated or stable grain yield have not been at the expense of grain nutrient content in Canadian bread wheat

Thanks