Breeding Multi-Use Naked Barley for Organic Systems

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Barley (*Hordeum vulgare*)

- Fourth most widely grown cereal in the world
- Second most widely grown organic small grain in US
- 2.05 million acres grown in US (2018)
Barley end-uses

- Feed/Forage
- Malt
- Food

Covered vs. Naked
The *Nud* Gene

- Controls the naked vs. covered phenotype
- Arose by spontaneous mutation ~6500 BCE
- Single locus on chromosome 7HL
- *Nud* allele present: lemma and palea adhere to the kernel
- *nud* allele present: lemma and palea thresh freely

Traits of Interest related to *nud*

- Threshability
- Resistance to embryo damage/germination
- Seedling vigor
- Emergence/establishment
- Yield
- Disease resistance
- β-glucan content
Threshability

- Ease of hull removal
- Canadian standards
  - Food grade: 5% grain with undetached hulls
  - Feed grade: 15% grain with undetached hulls
- Controlled by two genes
- Good threshability associated with rounder grains and thin hulls
- Scored visually

Resistance to Embryo Damage

- Poor or uneven germination
- Size and shape of grain
- Cultural practices during harvesting and cleaning
- Adjust combine settings
- Visual scoring and germination testing
Yield

- Naked barley is reported to yield less than covered barley
- Poor emergence, germination, or reduced seedling vigor can have an effect on yield
- Expect 10-13% lower yields due to lack of hull
- Higher seeding rate recommended
- Less breeding devoted to naked barley
- Several studies show that naked barley breeding lines can compete with covered lines

Choo et al. 2001; Thomason et al. 2009; Meints et al. 2015

Grain β-glucan and waxy starch

- There are qualitative and quantitative genetic components to grain β-glucan
- Waxy trait controlled by a recessive mutation in the granule-bound starch synthase 1 (GBSS1) gene (wx allele)
- Normal starch contains ~25% amylose and waxy starch has 0-10% amylose
- Breeders can select for higher grain β-glucan by targeting the recessive allele

Patron et al., 2002
Seed coat color

• Blue and purple contain anthocyanins, black contain melanin
• Purple and black located in pericarp, blue in aleurone layer (exhibits xenia)
• Black, purple, and blue seed coats are found predominately in landraces from areas of the world where barley remains a staple crop

Buckley, 1930; Bellido et al., 2009; Faris, 1955; Myler and Stanford, 1942; Woodward, 1941; Woodward and Thieret, 1953

Breeding for Organic Systems

• Most barley varieties bred for conventional systems
• Selections made under organic conditions are often better suited for organic production systems
• Target:
  • Disease resistance
  • Weed competition
  • Input-use efficiency
Diseases

- Stripe rust
- Leaf rust
- Stem rust
- Scald
- Covered smut
- Loose smut
- Ergot
- Barley Yellow Dwarf Virus
- Powdery mildew

Weeds

- Stand counts
- Early vigor ratings
- Early plant height
- Weed counts in plots
- Growth habit
- Canopy coverage
Winterhardiness:

- Growth habit: Winter, spring, facultative
- Score for winter survival
- Frost damage
- Collaborative nurseries

Feed Barley

- 75% of world barley acres for animal feed
- Breeding naked feed barley began in ~1970s in Canada for monogastric feed
- Hull has no benefit for non-ruminants
- By early 2000s, 24 naked barleys released and ~750,000 acres of naked barley being grown in western Canada
Feed Barley

• Digestible energy (DE) and/or Metabolizable energy (ME)
• Breeders target high levels of DE, high starch, low non-starch polysaccharides
• High levels protein
• β-glucans are problematic

Feed Barley

• Naked barley is a superior feed for swine
• Can also be a good feed for poultry
  • β-glucan is an issue, especially for young chicks
  • Older hens and roosters handle it better
• Naked barley can also be a good energy source for cattle

• Our study:
  • Layer hens
  • Broilers
Malt Barley

- Barley is the optimum substrate for malting and brewing/distilling
- Nearly all malt barley bred with a hull
  - Protects acrospires
  - Helps with filtration during lautering
- Advances in brewing technology, including mash filters can mitigate this
- Naked barley has the potential to have significantly higher levels of malt extract and improved beer quality

Malt Barley

- Concerns with malting naked barley:
  - Higher screening losses
  - High temps during kilning can result in low friabilities due to case-hardening
  - High β-glucan
- Breeders can select for:
  - Softer kernels
  - Large kernels
  - Round, short grains
  - Low/moderate β-glucan
Malt Barley

- Modification and protein levels can be problematic
- May be necessary to adjust steep and germination schedules to successfully malt naked barley
- Multi-step steep and longer germination resulted in:
  - Higher steep-out moistures
  - Higher friability
  - Lower β-glucan levels
  - Higher Kolbach Indices

- Our study:
  - Pilot malts
  - Looking at colored barley for malting
  - Using CLP to determine appropriate steep and germination regime

Edney and Rossnagel 2000; Stewart et al. 2004; Swanston and Middlefell-Williams 2012; Krstanovic et al. 2015

Brewing

- Limited data on brewing trials
- Theoretical advantages:
  - Economic benefits associated with storage costs
  - Higher extract levels
  - Potential quality advantages
  - Improved physical stability in finished beer
- Studies have used 50-100% naked barley successfully

- Our study:
  - Two naked lines + covered check
  - Compared using lauter tun and mash filter by OSU Fermentation Science
**Distilling**

- The distilling community is interested in naked barley for whiskey due to increased alcohol yields.
- Research has shown that malt modification may be more important for rapid filtration than the hull.
- Using a modified malt schedule, researchers found that naked malt had good levels of amylolytic enzymes.
- Naked malts produced wort with shorter filter times and higher predicted spirit yield than the covered check.

Agu et al. 2009; Swanston and Middlefell-Williams 2012

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**Food Barley**

- Rich traditional and culinary significance in many cultures around the world.
- In US, barley has almost disappeared as a food.
- On the rebound due to increased knowledge of the benefits of fiber and whole grain nutrition.
- Clinical studies show the positive effects of β-glucan on human health:
  - Lowering post-prandial blood glucose levels
  - Lowering plasma LDL cholesterol concentrations
  - Protection against mutagenic agents
Health claims for barley

• In 2006, the FDA approved a health claim for barley. It allows:
  “foods containing barley to claim that they reduce the risk of coronary heart disease. Specifically, whole grain barley and dry milled barley products such as flakes, grits, flour, and pearled barley, which provide at least 0.75 grams of soluble fiber per serving” (21 CFR 101.81)

• European health claim in 2011 and Canadian health claim in 2012

Food Barley

• Can be used in multiple applications
  • Flour
  • Grits
  • Flakes
  • Steamed
  • Toasted
  • Extruded

• Has potential in numerous food products
  • Risen and flat breads
  • Pastries
  • Pancakes
  • Cookies
  • Noodles
  • Tortillas
  • Tea
Food Barley

- Targets for Breeders:
  - β-glucan content
  - Protein
  - Kernel hardness
  - Whole grain nutrition
  - Functionality
  - Minerals
  - Antioxidant capacity

Effects of β-glucans

- β-glucans are the most important factor influencing flour yield
  - Genotypes with high levels of β-glucan resist breakdown and produce a greater proportion of larger sized particles during roller milling
  - Low β-glucan varieties contain less β-glucan and have thinner cell walls, making them easier to mill

- Alteration of dough properties
  - Dramatic increase in water absorption
  - Increased dough strength
  - Reduced dough resistance to extension
  - Impacts on starch pasting properties, lowered gel viscosity, increasing gelatinization temperature

Bhatia 1997; Wood 2007; Izydorczyk and Dexter 2008
Sensory Exploration

- Hedonic, preference, and descriptive tastings
- Steamed grain, bread, crackers, digestives, biscuits, roasted tea, hot steep
- Flavor, texture, aroma, color, overall

‘Developing Multi-use Naked Barley for Organic Farming Systems’

- Funded by USDA-NIFA-OREI in 2017 for three years
- Participating states: Oregon, Washington, Minnesota, Wisconsin, and New York
- Research, extension, education components
- Evaluate agronomic, food, feed, and malting and brewing performance under organic conditions
- Measure the economic, environmental, and health benefits of organic naked barley production and products
Key Resources

- **Oregon Naked Barley Blend (ONBB):**
  - A fun and educational blend of 753 pure lines

- **The diversity panel:**
  - 384 genetically diverse lines for improving barley in organic systems

- **Multi-region agronomic and yield trials:**
  - 20 advanced naked lines

- **On-farm production:**
  - For large-scale evaluations of farm to finished product performance

Field Trials

- Regional fall and spring yield trials
- Fall and spring diversity panel
- Assess for agronomic traits, weed competitiveness, resistance to biotic and abiotic stresses
- Assess for quality traits
- GWAS on diversity panel
Outreach

• Workshops on best management practices, benefits, and processing procedures
• For students, gardeners, growers, researchers, processors, and consumers

Outreach Opportunities

• Barley Day
• CBN Variety Showcase
• Organic Seed Growers Conference
• Organicology
• The Grain Gathering
• Cascadia Grains Conference
• Workshops and classes
• Greenmarket Grains
Education

- Each state has a lead teacher
- Collaborate on lesson plans
- Fieldtrips
- Classroom visits
- Math, science, agriculture, nutrition

Conclusions

- Breeding multi-use naked barley can give organic farmers a second or third option for sales
- Should have moderate levels of β-glucan and normal starch
- Farmers, processors, producers, and consumers can benefit from naked barley, education is necessary for acceptance
Acknowledgements and Further Resources

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• Developing Multi-use Naked Barley for Organic Farming Systems: USDA-NIFA-OREI Grant 2017-51300-26809
• Web: eorganic.info/barley and barleyworld.org/orei-project
• Instagram and Facebook: @multibarley
• Ideas for future naked barley webinars? Email: brigid.meints@oregonstate.edu