Production & breeding of organic barley for craft malt

Brigid Meints, Post-doc

Oregon State University

Oregon State University

Organic malting and brewing

- U.S. organic beer sales have increase from $9 million in 2003 to $92 million in 2014
- To be certified organic, beer must contain 95% organically produced ingredients
- Can also have a “made with organic” label, which requires 70% of ingredients to be organic
- Cost and availability of organic ingredients is biggest challenge
- Appeals to niche market, although even “big” beer is getting involved

https://www.foodrepublic.com/2016/06/02/what-is-organic-beer/

Organic barley production in the US

- Demand for organic products is growing rapidly
- Second most widely grown organic small grain in US
- 2.05 million acres total grown in US (2018)
- 51,254 acres of certified organic barley harvested worth $16.9 million (2016)

Yield establishment

- Yields are often lower in organic than in conventional production
  - Barley: -24%
- Quality can also be affected:
  - Plump kernels
  - Protein
- Main reasons:
  - Pests
  - Weeds
  - Fertility management

Pest Management

Oregon State University

Rusts:

- Stripe rust (*Puccinia striiformis* f.sp. *hordei*)
  - Spores form in bright orange stripes on leaves
  - In severe infections, spores can be found on stems and awns


- Leaf rust (*Puccinia hordei*)
  - Spores are darker orange brown and don’t form in a specific pattern


Ergot

- Ergot (*Claviceps purpurea*)
  - Infects cereals and wild grasses
  - Can be problematic with wet, cool weather during flowering
  - Fungus grows in place of grain to form hard purple/black sclerotia
  - Sclerotia contain mycotoxins
  - Can be avoided by planting clean seed, practicing good rotations, and deep tillage

Smuts

- Covered smut (*Ustilago hordei*)
  - Spores survive on surface of grain or in soil
  - Harvested with clean grain
  - Can reduce quality
  - Environmental conditions influence severity of infection

- Loose smut (*Ustilago nuda*)
  - Seedborne
  - Yield reduction equivalent to percent smutty heads
  - Quality of harvested grain not affected

http://www.apsnet.org/edcenter/intropp/lessons/fungi/basidiomycetes/pages/stinkingsmut.aspx

Other foliar diseases

- Scald (*Rhynchosporium commune*)
  - Spreads through water droplets
  - Seed and soilborne

- Powdery mildew (*Blumeria graminis*)
  - Heavy dews and dense stands promote growth of the pathogen

Fusarium Head Blight (Scab)

- Caused primarily by *Fusarium graminearum*
- Symptoms: premature bleaching of infected heads
- Fungus produces the mycotoxin deoxynivalenol (DON)
- Crop rotation, burying crop residue, and irrigation timing can help reduce disease load

http://daafmaapextweb.gnb.ca/010-002/Thumbnails.aspx?Culture=en-CA&Id=254

Barley Yellow Dwarf Virus

- Aphids can transmit BYDV
  - Planting date
  - Removing green bridge
  - Significant yield losses possible

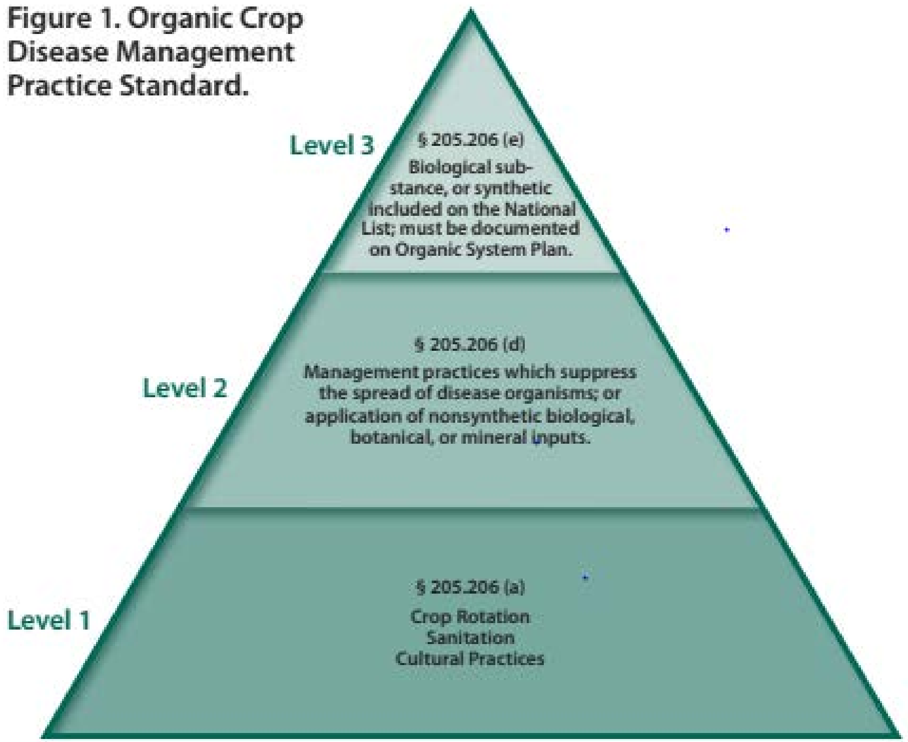
Insects

- Cereal Leaf Beetle
  - Larvae cause damage by eating green tissue between leaf veins
  - Reduces photosynthetic capability of plant
- Wireworms
  - Feed on germinating grains and seedlings
  - Rotations can help prevent issues

https://pnwhandbooks.org/insect/agronomic/small-grain/small-grain-wireworm

IPM

- Cultural practices and scouting
- Biocontrol: predatory insects can be released to control insect and disease pests
  - Ex: predatory moth that feeds on cereal leaf beetle larvae
  - Ex: Bacterium that slows Septoria development on wheat
- Irrigation timing during flowering can help prevent certain diseases (rusts, FHB)

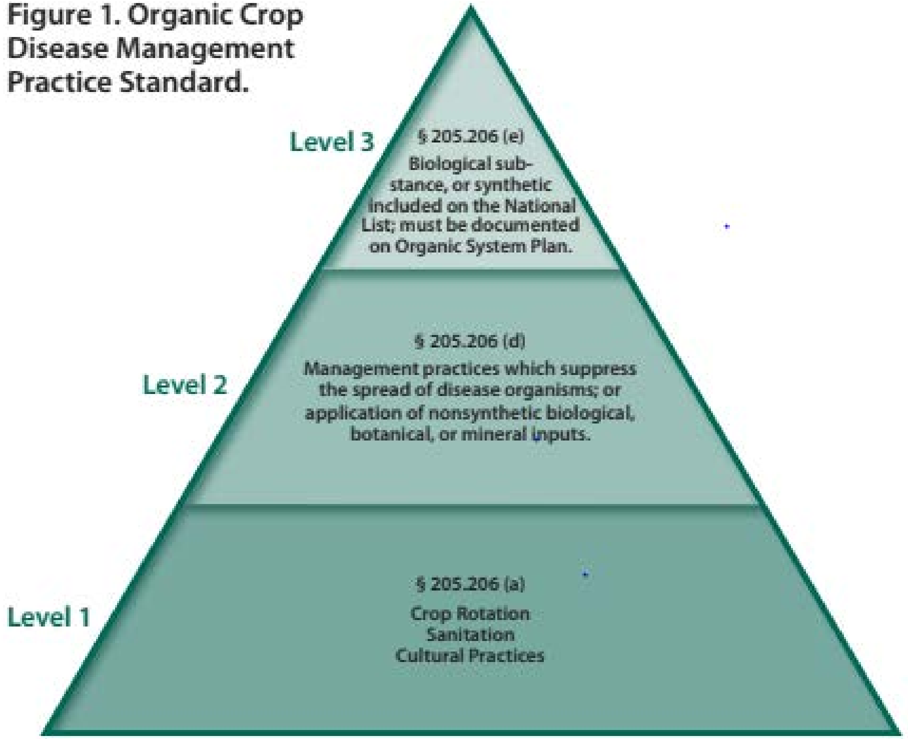


https://www.canr.msu.edu/foodsystems/uploads/files/disease-and-insect-management-in-organic-small-grains.pdf

IPM

- Burying crop residue and destroying volunteers can help reduce spore load
- Rotations that included at least two-years of a non-susceptible host can help break disease cycles
- Steam or hot water treatments can potentially help reduce external spore load

Figure 1. Organic Crop Disease Management Practice Standard.



https://www.canr.msu.edu/foodsystems/uploads/files/disease-and-insect-management-in-organic-small-grains.pdf

Variety Selection

- Grow varieties with known genetic resistance to diseases that are a problem in your area
- Grow pathogen-free seed if possible to prevent seed-borne disease pressures
- Blending varieties with different resistances can reduce crop failure due to diseases and pest

Organic pesticides

- Check the Organic Materials Review Institute (OMRI) or certifying agency’s approved material list for approved organic fungicides/insecticides
- Elemental sulfur or copper can help reduce impact of some diseases (rusts, mildew), but multiple applications may be necessary

Fertility Management

Oregon State University

Nitrogen

- Nitrogen (N) often the most limiting nutrient in organic small grain production
- Insufficient nitrogen
  - Low yields
  - Low grain protein
- Excess nitrogen
  - Leaching
  - Lodging
  - Grain protein levels above the target

Organic nitrogen sources

- Existing soil nitrogen
- Green manure
- Manure
- Compost
- Blood meal
- Feather meal

Cost of Plant Available Nitrogen

	Poultry litter	Pelletized litter	Feather meal	Feather meal-litter blend (7-2-2)	Hairy vetch	Austrian Winter Pea	Crimson Clover
Cost $/lb of PAN	0.63	3.10	2.60	3.60	0.81	1.01	0.30

Spargo, 2012. Soil Fertility Management in Organic Grain Cropping Systems

Manure

- Nutrient content can be inconsistent
    - Very important to test each batch before applying
- Cost and availability
- Can be difficult to spread evenly
- Synchrony N release/demand
- Can have issues with excessive P

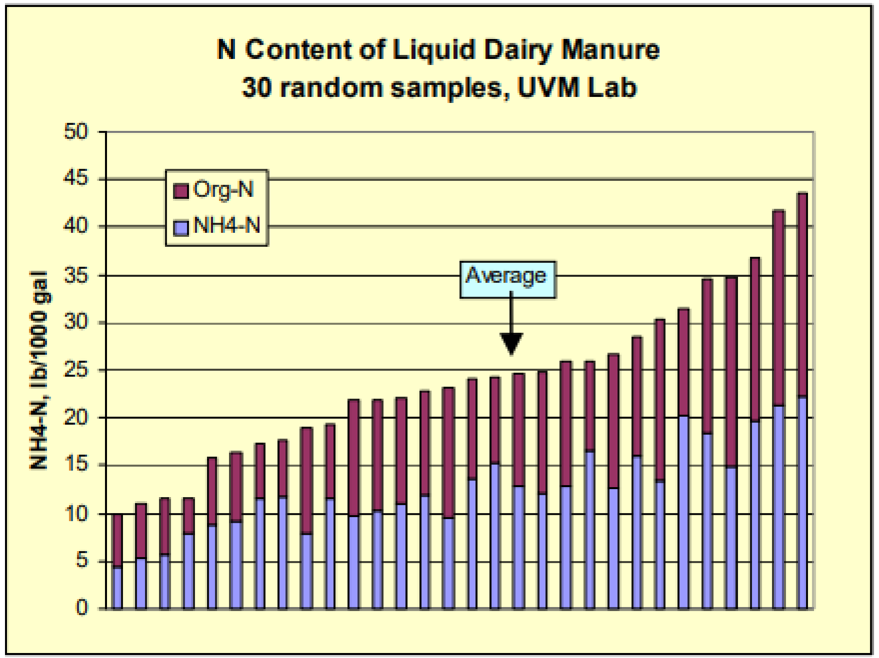


Figure 3. Nitrogen content (NH_4-N and organic N) of 30 random dairy manure samples analyzed by the Agricultural and Environmental Testing Lab, University of Vermont (Jokela and Meisinger, 2004).

7 CFR §205.205 Crop rotation practice standard

The producer must implement a crop rotation including but not limited to sod, cover crops, green manure crops, and catch crops that provide the following functions that are applicable to the operation:

- Maintain or improve soil organic matter content
- Provide for pest management in annual and perennial crops
- Manage deficient or excess plant nutrients
- Provide erosion control

Cover crops

Benefits

- Reduced soil erosion
- Increases soil organic matter
- Enhanced biodiversity
- Reduced weed pressure
- Reduced pest pressure

Choosing crops for a crop rotation

Factors to consider

- Environment
- Resources
- Costs
- Market
- Farm type
- Goals of the farmer

- General guideline: Do not plant small grains following small grains (to reduce disease pressure)

Crops preceding small grains

	Winter Grains	Spring Grains
Good preceding crops	Legumes (e.g. clover alfalfa, soybeans, field peas) Vegetable crops	Legumes (e.g. clover, alfalfa) Potatoes
Bad preceding crops	Wheat Barley Rye	Wheat Barley Rye

Adapted from Benscher et al. (2013). Management for High Quality Wheat and Ancient Grain Production in the Northeast.

Cover Crops

For nitrogen

- Legumes (e.g. winter pea, red clover, hairy vetch, soybeans)
  - Able to fix N
  - Supply N to the following crop (25-75 lbs N/acre)
  - Often planted as green manure
  - Timing of termination can be critical

To reduce soil compaction

- Brassicas (e.g. turnips, radish)

Cover Crops

	Legume	Grass	Crucifer	Mix
N fixation potential	High	Limited	None	High
N recovery	Low-Moderate	High	Very high	Moderate-high
Residue C:N ratio	Low	High	Low	Moderate
Available N release	Rapid	N-immobilization	Rapid	Slow
N leaching	High	Low	High	Low-Moderate

N dynamics of cover crops.
Adapted from Schonbeck (2018). Nutrient Management for Crops, Soil, and the Environment.

Weed Management

Oregon State University

Weeds in organic systems

- Because of larger seed size, barley can be quite competitive against weeds
- The narrow rows of the grain drill allow for greater competition
- Quick canopy growth also gives barley an advantage over weeds

Weeds in organic systems

- However, weeds can still be a huge issue
  - Reduce yield
  - Reduce quality
  - Can harbor pest and diseases
  - Compete for essential nutrients
  - Green weed material and seed during harvest

- Problematic because grain production has become very input intensive and conventional agronomic practices will not work in organic systems

Rotations

- Good legume rotations can help prevent or reduce weed pressure
- Rotations can help break weed life cycles
- Continuous small grain production can lead to weed problems with similar ecological niches
  - E.g. winter annual grass weeds

Planting Design

- Winter grains are often better at competing against annual weeds
- Spring grains may require additional weeding methods, planting early in spring can help control weeds
- Recommended to increase seeding rate ~25% for organic production to increase competitiveness with weeds

Planting Design

- Narrower row spacing on drill or cross-drilling may improve crop competiveness with weeds
- Delay planting to allow at least one flush of weeds that can be tilled
- While planting, check seed depth and spacing on drill

Intercropping

- Can broadcast seed legumes into winter grain crop in the spring
- Establishes green manure/sod crop while also suppressing weeds
- Be careful when selecting legume- some grow to tall and can interfere with grain harvest

https://agcrops.osu.edu/newsletter/corn-newsletter/modified-relay-intercropping-wide-row-wheat

Variety Selection

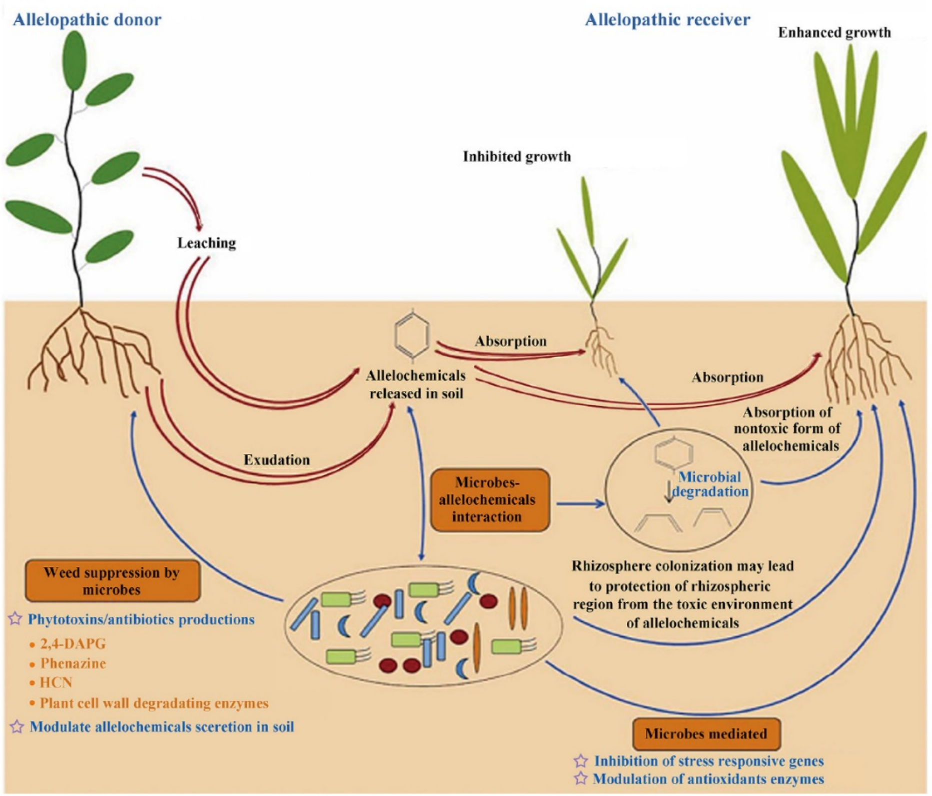
- Certain varieties will compete better against weeds
- Morphological traits of importance
  - Prostrate vs. erect growth habit
  - Early vigor and early plant height
  - Leaf inclination
  - Tillering capacity
  - Seed size
  - Initial shoot and root growth rates

Biocontrol

- Known insects that target weeds
- Especially helpful for perennial weeds
- Ex: mites and moths for field bindweed, which is especially hard to get rid of in organic systems


Allelopathy

- Allelopathy refers to the chemical inhibition of one species by another
- The "inhibitory" chemical is released into the environment where it affects the development and growth of neighboring plants.
- Some small grains (rye, barley, wheat) have known allelopathic properties that may help with weed control



Cheng, F. and Cheng, Z., 2015. Research progress on the use of plant allelopathy in agriculture and the physiological and ecological mechanisms of allelopathy. *Frontiers in plant science*, *6*, p.1020.

Mechanical weed management

- Drilled grains are less conducive to mechanical control than row crops
- Blind vs. inter-row cultivation

Tine weeders

- Tine harrow weeders can help control small annual weeds
- Flexible metal tines uproot weeds and bring them to the surface to dry out
- Timing is critical- only effective when weeds are in the “white thread” stage
- Can be extremely effective- killing up to 90% of the weeds in the field if timing and conditions are ideal
- May be necessary to overseed grain to account for some loss (up to 10%) during tine weeding

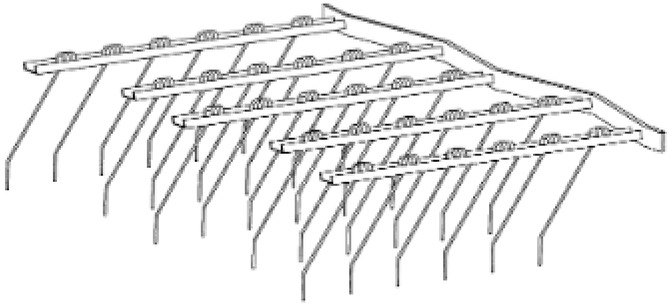


Fig. 2. The principle of the spring tine harrow.

Lötjönen T., and H. J. Mikkola. 2000

Rotary hoes

- Covers weeds with soil and uproots them
- Treats entire field
- Has been used for row crops for a long time in the U.S.
- Early weeding is most effective

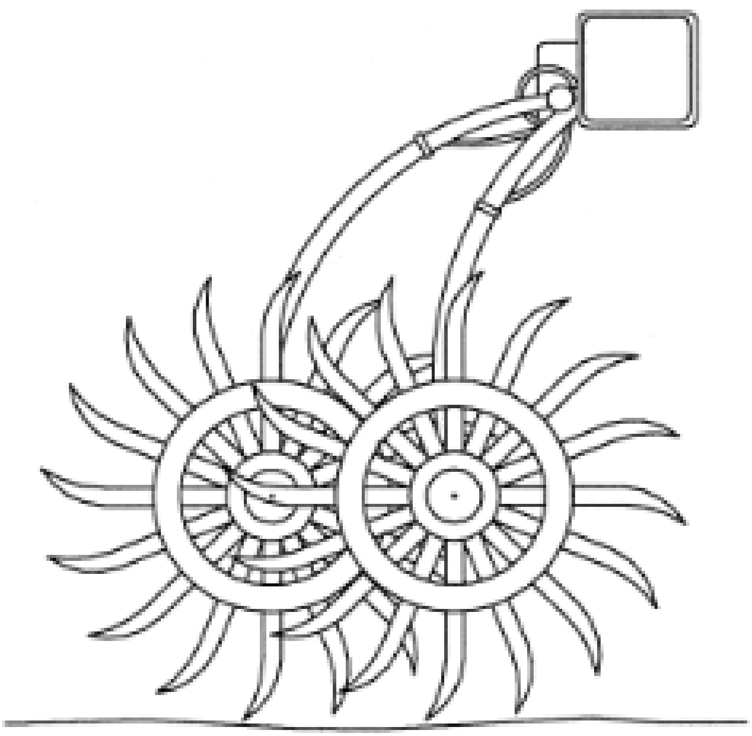


Fig. 3. The principle of the rotary hoe.

Lötjönen T., and H. J. Mikkola. 2000

Inter-row hoes

- Using wider spacing and an inter-row hoe can achieve more targeted control
- Similar to corn and soy cultivators
- Weeds are undercut or buried, so timing and conditions are less critical
- Can be performed multiple times through the season
- Less crop damage
- Can control creeping perennials more effectively

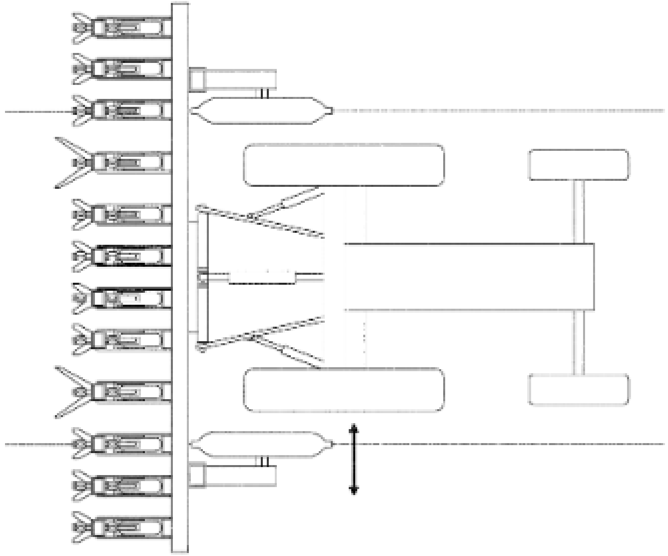


Fig. 1. The type of inter-row hoe and the steering method used in the study. Steering is marked by an arrow.

Lötjönen T., and H. J. Mikkola. 2000

Grain storage

Oregon State University

Post-harvest

Seed cleaning

- To improve seed quality by removing impurities (e.g. plant residues, weeds, off-type seeds, low quality seeds)
- Examples
  - Air screen cleaner
  - Gravity separator
  - Color sorter

Harvest Issues

Pre-harvest sprouting

- Germination of the grain in the spike prior to harvest
- Caused by prolonged rainfall and/or high humidity before harvest.
- Reduces grain quality

http://flywaybrewing.blogspot.com/2014/04/seed-to-tap-arkansas-native-beer-project.html

Management

- Variety selection
- Harvest time

Storage

Storage insects in small grains

- Granary weevil
- Lesser grain borers
- Angoumois grain moth

From left to right: Granary weevil, Lesser grain borer, Angoumois grain moth. Source: USDA (2015). Stored-Grain Insect Reference.

Storage

- Only store dry and clean seed
- Insect control during storage
  - Grain moisture (should be below 12%)
  - Temperature
  - Beneficial Insects
  - Sanitation
  - Diatomaceous earth

Table 1. Insect Activity at Various Temperature Ranges.

Temperature	Insect Activity
86°F (30°C)	Optimal temperature for insect activity
77°F (25°C)	Reproductive rate is cut in half
68°F (20°C)	Insects stop developing
50 – 59°F (10 – 15°C)	Activity stops

Flinn, P.W. 1998. Temperature Efects on Efcacy of Choetospila elegans (Hymenoptera: Pteromalidae) to Suppress Rhyzopertha dominica(Coleoptera: Bostrichidae) in Stored Wheat.

Breeding

Oregon State University

Breeding for Organic Systems

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

Developing Multi-use Naked Barley for Organic Farming Systems

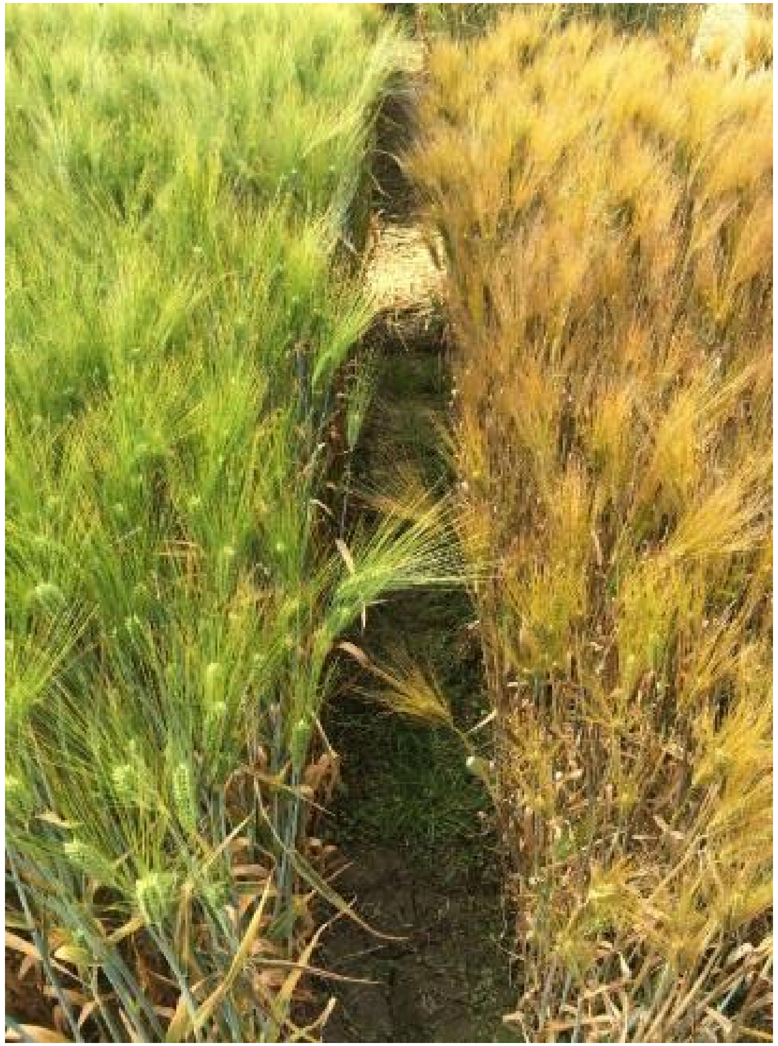
- Funded by USDA-NIFA-OREI in 2017 for three years
- Participating states: Oregon, Washington, Minnesota, Wisconsin, and New York
- Evaluate agronomic, food, feed, and malting and brewing performance under organic conditions
- Measure the economic, environmental, and health benefits of organic naked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

Weeds

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

Selecting for disease resistance

- Severity ratings
- Screening nurseries
- Inoculation
- Pyramiding resistance genes



Winterhardiness

- Score for winter survival
- Frost damage
- Collaborative nurseries

Sourcing certified seed

- Organic certification rules set by NOP require that you try to source seed produced under organic conditions before using conventionally grown seed

- Seed must be untreated and non-gmo for organic production

- Many farmers prefer to save seed and plant it the following year- make sure this is allowed for the variety being grown

- In order to preserve identity and remain free of weed and diseased seed, best to try and source “certified seed”

- Difficulty in sourcing double-certified seed (certified organic “certified” seed)

Key components of an organic production system

Component	
Crop sequence	Crop rotation Cover Crops
Crop management	Variety selection Seed source Planting depth and density Planting date Harvest and storage
Soil management	Tillage
Nutrient management	Fertility
Pest management	Weed management Insect management Disease management

Heiniger and Hamilton (n.d.) Organic Crop Production Systems. In Hamilton (ed). North Carolina Grain Production Guide. North Carolina State University.

THANK YOU

Oregon State University