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Importance of Quality Grain to Produce Quality Malt

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Why is Quality important?
Let's consider why is malt used in brewing

- Malt provides fermentable extract
- Malt enzymes convert starch to sugars and protein to amino acids.
- Malt provides color
- Malt provides flavor
- Malt protein contribute to foam

Poor quality grain leads to poor quality malt

Poor quality malt can impact all of the above

Part I:
How poor grain grain quality impacts malt and beer

Most Common Grain Quality Problems

- Grain protein
  - Often too high, but yes it can also be too low!
- Low kernel plumpness
- Poor germination
- Contamination with molds and mycotoxins
- Damaged grain (*e.g.* skinned and broken)

Variety

- Brewers can be very specific to varieties used.
- Malting barley is purchased on a varietal basis.
- Many brewers utilize varietal blends.

- There are distinct genetic differences in agronomic performance, disease resistance and quality between varieties.

Why is Grain Protein Important?

- Inverse relationship between protein and starch.
  - Protein is formed first during kernel development.
  - Starch synthesis and kernel fill occur last.
- Thinner, high protein kernels have less extract.

Why is Grain Protein Important?

- Specifications
  - US 6-row <13.5%
  - US 2-row <12.5%
  - European 2-row 9-11.5%
- Craft vs. adjunct brewer specifications
  - Adjunct brewing requires higher protein

Why is Grain Protein Important?

- **Malt Extract**
  - There is an inverse relationship between protein and malt extract
  - Higher grain protein= lower malt extract
    - The brewer needs to use more malt to produce the same amount of beer
  - Economic Impact
    - Becomes more important as the production capacity of brewer increases

Why is Grain Protein Important?

- **Enzymes**
  - Amylase levels increase with grain protein.
    - Amylases are responsible for converting starch to fermentable sugars in mashing.
  - Too high protein (amylase) malt may convert too quickly in the brewhouse.
    - Malt is difficult to handle.
  - Very low protein malt may have inadequate enzyme.
    - Long conversion times in mashing

Why is Grain Protein Important?

- **Soluble (wort) Protein**
- About 4-6% of the total malt (weight) is converted to soluble protein during malting and mashing.
- About 40% of the total grain protein is converted to soluble protein during malting.
  - S/T protein (Kolbach Index)

Why is Grain Protein Important?

- **Soluble (wort) Protein**
  - Soluble protein (protein, peptide and amino acids) is important for yeast growth in fermentation and also in malt/beer color development.
  - Higher protein malts yields higher wort protein
    - Can cause fermentation issues for the brewer
    - Can cause too much color development in malt and beer.
    - Can cause haze in packaged beer
  - Very low protein grain may yield inadequate soluble protein
    - Inadequate color development and poor fermentation

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Why is Kernel Plumpness Important?

- **Concerns with thin grain are similar to high protein**
  - Thin grains are higher in protein (lower in starch)
  - Thin grains have lower malt extract
  - Thin grains have high enzyme levels
  - Thin grains have a higher proportion of husk which can impact beer flavor

Why is Kernel Plumpness Important?

- US 6-row:
  - >70% on 6/64" (0.238 cm) sieve
- US 2-row
  - >85% on 6/64" sieve
- European 2-row
  - >90% on 6/64" sieve

Why is Germination Important?

- **Germination >95%**
  - Malt must germinate in order to produce enzymes and modify.
  - Non-germinated grain will have lower extract.
    - Endosperm does not modify in dead kernels
  - Non-germinated grain can cause filtration problems
    - Beta-glucans are not degraded in dead kernels
  - Dead grains can be prone to mold growth in malting

Why is Germination Important?

- Test to determine if the grain is
  - Viable, dormant or dead: Germinative energy (4 mL) and germinative capacity (H_2O_2)
  - Water sensitive: Germinative energy (4 mL and 8 mL)

Grain Moisture

- Should be 12% or less for storage
  - Improper storage can damage grain quality
    - Increasing temperature and humidity accelerate damage
      - respiration losses (weight loss)
      - reduced germination
      - Growth of storage fungi
  - Grain drying temp. >45°C (113 F) can damage germination

Materials other than barley

- Common materials:
  - other grains
  - weed seeds
  - oilseeds
  - stones, dirt
- Can damage product quality (e.g flavor) or equipment.
- Buyer is purchasing grain and not dockage

Kernel Damage-Skinned and Broken

- Only 1/2 of a broken kernel germinates
- Similar malting and brewing problems to poor germination
- Broken kernels are susceptible to mold growth during malting.
- Husk protects the growing acrospire during germination.

Above – Skinned and broken kernels from improper threshing.
Below – Skinned and broken kernels of germinated barley. Note exposed sprouts.

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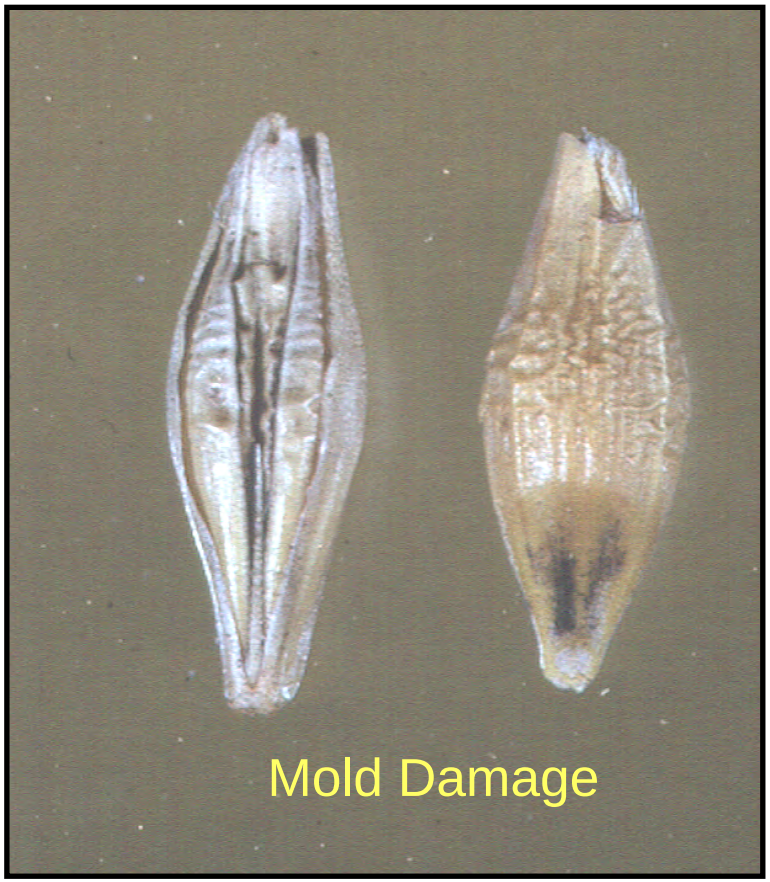
AMBA

Kernel Damage-Skinned and Broken

Skinning and Breakage caused by

- -Improper combine setting
- -Harsh handling in transport
- -Husk adherence is a genetic trait.
  - Some varieties are prone to skinning

Kernel Damage - Other Factors



- Damage results from poor growing environment, and poor harvest or storage conditions.
  - Examples of damage are:
    a. frost damage
    b. heat damage
    c. mold damage
    d. skinned and broken kernels
- Damaged kernels are part of the US Official Barley Grade
- Damage often reduces germination

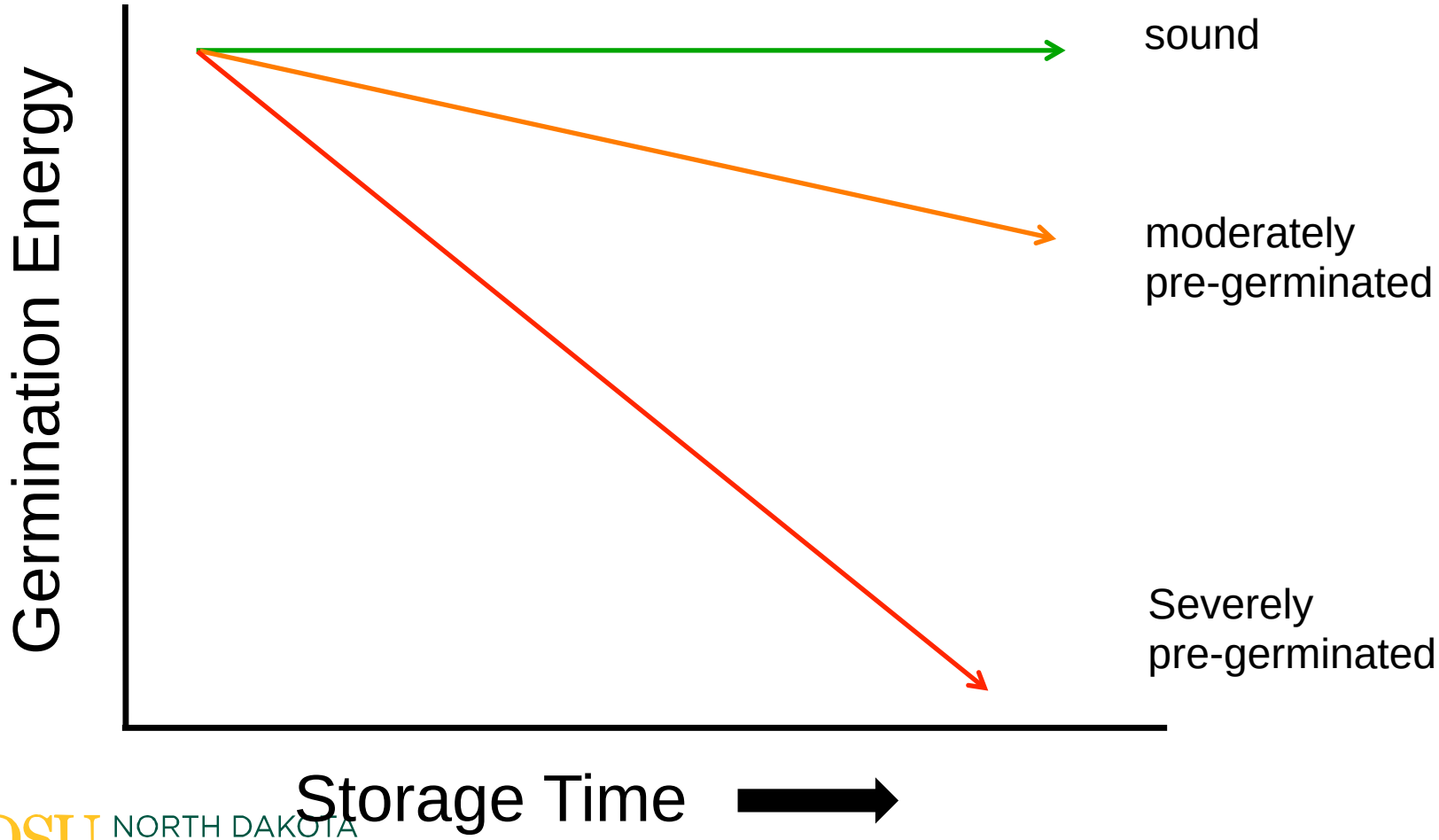
Pre-Harvest Sprouting (PHS)

- Occurs during moist harvest conditions
- Sprouted grain may not re-germinate
  - Germination of sprouted grain may decrease under poor storage conditions
  - Often reduced malt quality
- Visual signs of PHS are often not present

http://www.ontariograinfarmer.ca

Germination Loss and PHS

(from: A. MacLeod, Hartwick College)



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Molds and Mycotoxins

Ergot

- Caused by *Claviceps purpurea*
- Ergot contains toxic alkaloids
- Especially problematic in rye
- Very low tolerance levels in grain
  - <0.10% in barley

Molds and Mycotoxins

- Deoxynivalenol (DON, vomitoxin) is the rincipal mycotoxin of concern with small grains.
- DON is a secondary metabolite produced by several species of *Fusarium.*
- *Fusarium graminiearum* causes a disease on wheat, barley and rye; Scab or Fusarium Head Blight.

Molds and Mycotoxins

- FHB is of concern because:
  - FHB lowers grain yield and malt quality
    - FAN and soluble protein
  - DON on malt is transferred to beer
  - DON is a public health concern
  - DON is a public perception concern
  - *Fusarium* produces other metabolites that cause beer gushing

Part II. Factors Impacting Grain Quality

What Impacts Grain Quality?

- Variety choice and seed quality.
- Grower practice
  - Seeding, fertilization, disease control, pest control, weed control, harvest
- Biotic and abiotic stress during the growing season.
- Grain storage.

Malt Quality Starts in the Field: Abiotic and Biotic Stress Grower Practices

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Growth Stages of Barley

- It is important to understand the growth stages of barley, and how stress impacts:
  - Yield
  - Quality
- Monitoring crop quality throughout the season, may lead to less surprises after harvest


Growth and development guide for spring barley

by P.M. Anderson, E.A. Oelke, and S.R. Simmons

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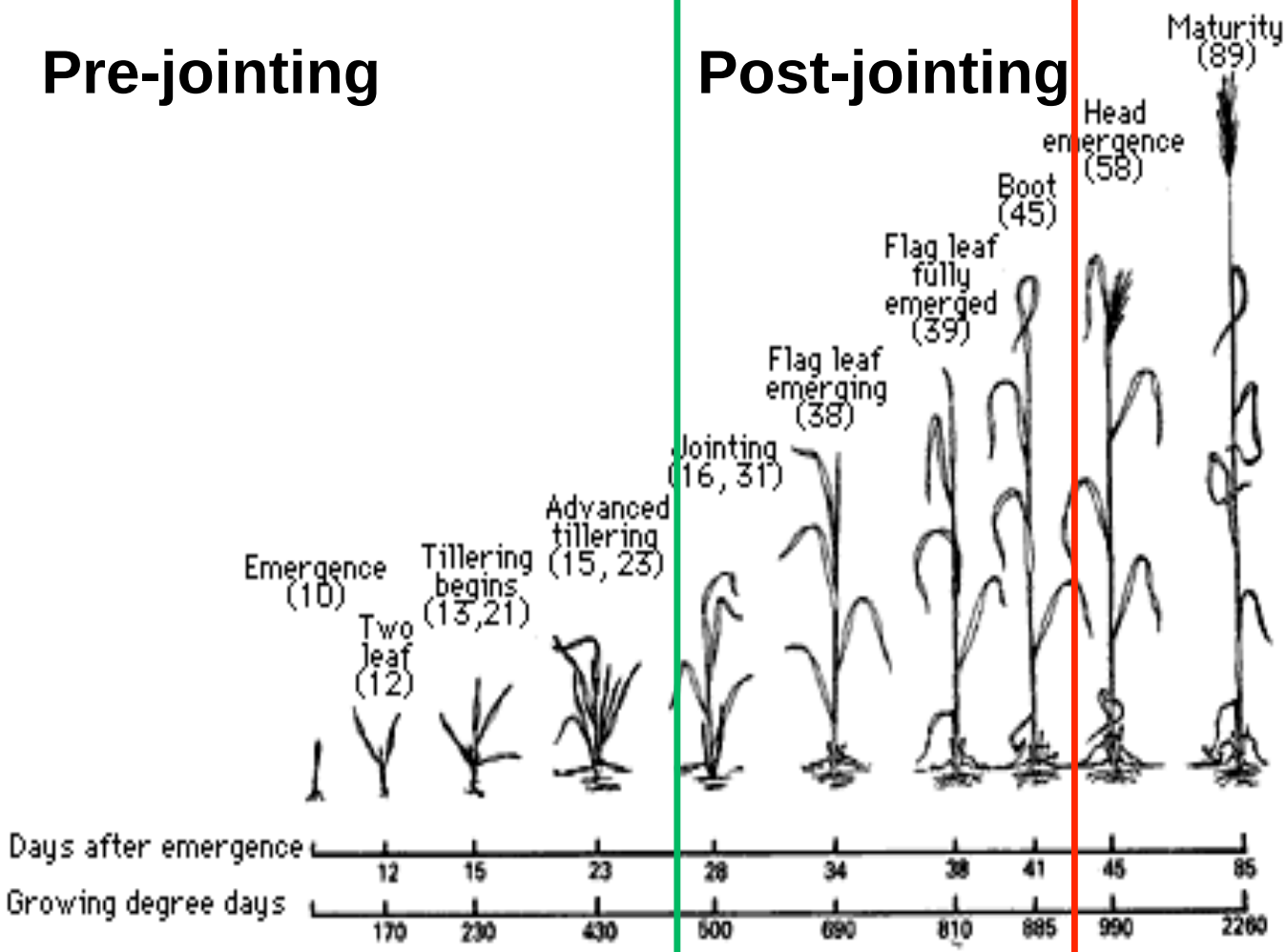
Growth Stages of Barley

Pre-jointing | **Post-jointing**



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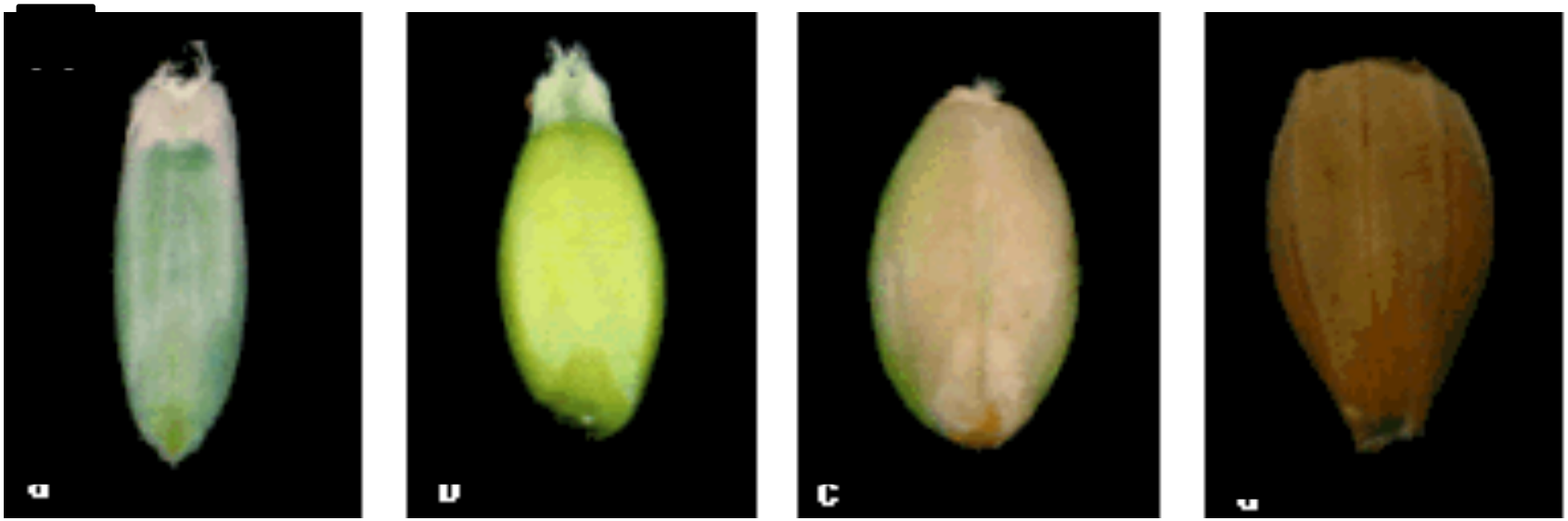
http://www.extension.umn.edu/distribution/cropsystems/DC2548.html#fig7

Kernel Development Stages: Grain Fill



Watery ripe **Late milk** **Hard dough** **Ripe**

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http://www.extension.umn.edu/distribution/cropsystems/DC2548.html#fig7

Pre-jointing Stages

- Main impacts of stress will be on grain yield
  - Reduced number of plants or tillers
- Common Factors:
  - Excessive temperatures
  - Freezing temperatures
  - Insufficient moisture
  - Plant nutrition
  - Diseases
  - Weed competition

Post-jointing to Pollination

- Impacts are largely on grain yield
- Factors:
  - Excessive temperatures at jointing
  - Excessive temperatures at pollination
    - Reduced kernel number
  - Freezing temperatures at pollination
    - Reduced kernel number
  - Plant nutrition

Post-spike Emergence

- Stress following spike emergence can reduce grain fill
  - Yield
    - Smaller lighter grain (lower test weight)
  - Quality
    - Thinner and higher protein grain
- Factors
  - Excessive temperatures
  - Insufficient moisture
  - Plant nutrition
  - Weed competition
  - Diseases
  - Insects

Summary: Biotic and Abiotic Stress

- Biotic and abiotic stresses throughout the growing season can impact yield and malting quality.
- Stresses occurring early in the growing season can <u>reduce yield</u> due to fewer plants, tillers, and kernels per spike.
- Stresses following pollination can result in reduced quality (and yield).
  - Lower kernel weight/ plumpness and high protein.

Grower Practices and Grain Quality

- Crop rotation
- Seedbed preparation
- Seeding rate
- Plant nutrition
- Weed control
- Disease control
- Pest control
- Harvest practice
- Grain drying and storage

Plant Nutrition for Malting Barley

- Barley responds well to nutrients limiting in the soil, especially nitrogen (N).
- However, too much N can increase protein.
- The amount of fertilizer to apply is dependent on:
  - Intended end use of the barley (malt vs feed)
  - Residual soil N in the soil
  - Expected yield

Impacts of Excessive Nitrogen

- Excessive grain protein
  - Especially problematic under drought-like conditions.
- Lush plant growth
  - Susceptible to lodging and plant diseases.
  - Lodged plants often have thinner, low-weight kernels high in protein.

Determining Soil N Needed

- Growers should be encouraged to sample and test their soil for residual soil fertility (N, P, K).
- Testing can be done using soil core probes that sample to a depth of 2 feet.
- Malting barley has lower N requirements than wheat or feed barley.
- It is better to underestimate the amount of N to apply to malting barley.

Work with your Extension Service

Fertilizing Malting and Feed Barley

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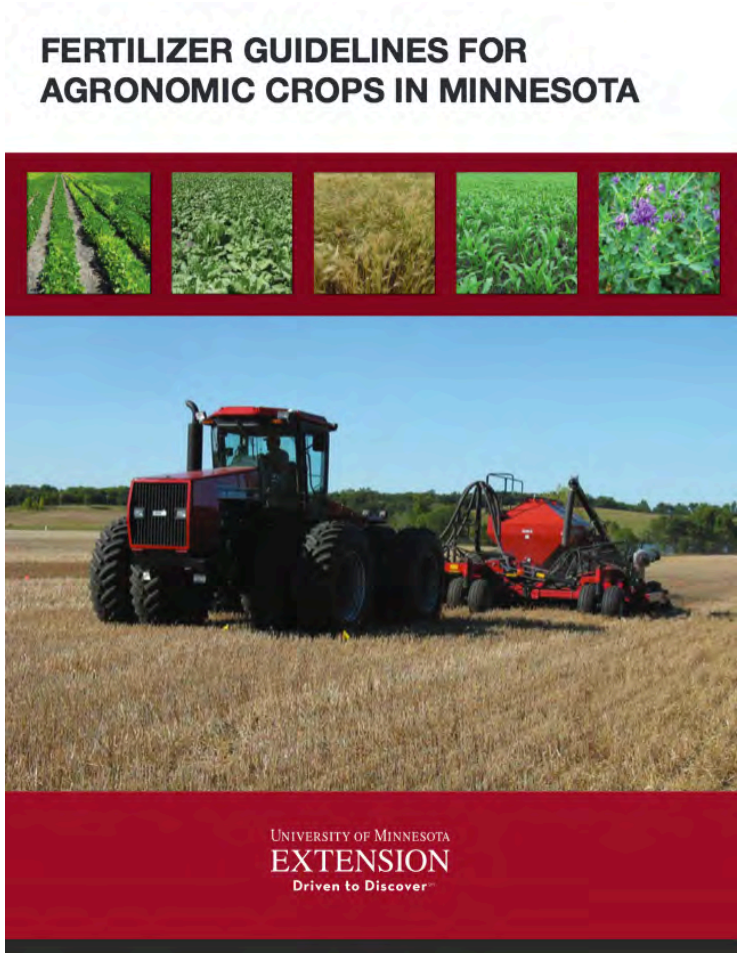

Nutrient recommendations for malt and feed barley in the Midwest United States

Yield goal Bu/Ac	Soil N plus fertilizer N required for malt barley lb/ac (2 ft depth)	Soil N plus fertilizer N required for feed barley lb/ac (2 ft depth)
40	73	90
60	112	124
80	152	168
100	191	213

Reproduced with minor modifications from Peel, M.D. (2000) *Barley Production Guide*. Fargo, ND: North Dakota State University Extension Service, with permission.

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Variety Selection

- Growers should be encouraged to grow cultivars desired by maltsters and brewers.
- Cultivars need to be adapted to the region where they are produced.

Plant Diseases

- Diseases can affect three parts of the plants
  - Roots
  - Foliar components (stems and leaves)
  - Spike and kernels
- Disease can reduce both yield and grain quality
  - Reduction in kernel size is a common result
- Both cultural and chemical (fungicides) methods are available for controlling diseases.
  - Crop rotation is very important

Foliar Diseases

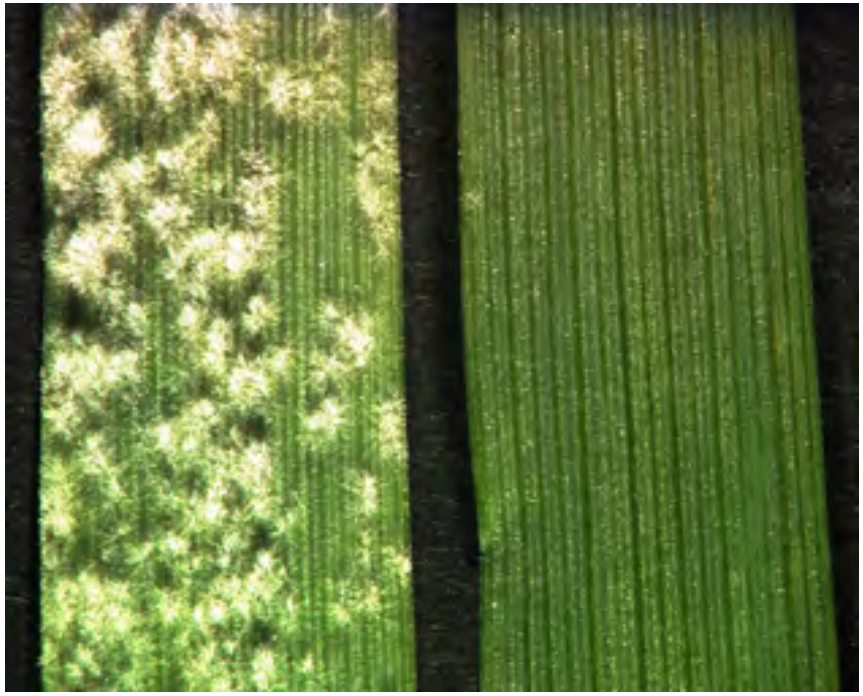
- Predominantly cause damage by reducing kernel weight and plumpness.
  - Yield and quality losses.
- The most important leaves to protect with fungicides are the top two leaves of each tiller.

Symptoms of Foliar Diseases

Spot form of net blotch

Photo courtesy of Dr. Robert Brueggeman, Dept. of Plant Pathology, NDSU.

Powdery mildew



http://www.mpiz-koeln.mpg.de/bildobjekte/research/schulzeLefert/panstruga1/Web_Zoom.jpg

Spike and Kernel Diseases

- These diseases often result in yield and quality losses due to reduced kernel weight.
- Some fungi causing spike diseases can produce mycotoxins.
- Can cause quality problems in malting and brewing (flavor, mycotoxins, gushing)

Symptoms of Spike and Kernel Diseases

Fusarium Head Blight on Barley

Picture courtesy of Brian Steffenson, Univ. of Minn.

Black Point on Barley

http://www.agwine.adelaide.edu.au/images/plant/research/black_point.jpg

Harvesting Malting Barley

- Pre-harvest desiccants (glyphosate) should not be used on malting barley because they can reduce germination.
- Barley harvested at moisture > 13.5% needs to be aerated and dried.
- Barley stored at moisture >13.5% can have mold growth and a rapid loss of germination during storage.

Harvesting, Drying, and Storing Malting Barley

To Get Market Premiums

Maltsters will pay premiums for malting barley that has been harvested in good condition and stored properly. Bright barley with good germination, sound kernels and intact husks are required for malting and brewing.

PROPERLY THRESHED & STORED MALTING BARLEY

Six-Row Barley

Two-Row Barley

Skinned and Broken Kernels

Skinned kernels are kernels with the husk loosened or removed over the germ or with one third or more of the husk skinned off. Broken kernels are kernels which are cracked or broken. Malting barley which is threshed properly and contains a low percent of skinned and broken kernels generally has short pieces of awns still attached to the kernels. Buyers of malting barley do not object to these short pieces of awns even though they may result in lower test weight. The percentage of plump kernels remaining on barley sieves gives a much more accurate measure of kernel plumpness than does test weight.

Prepared and Distributed by:

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Grain Drying

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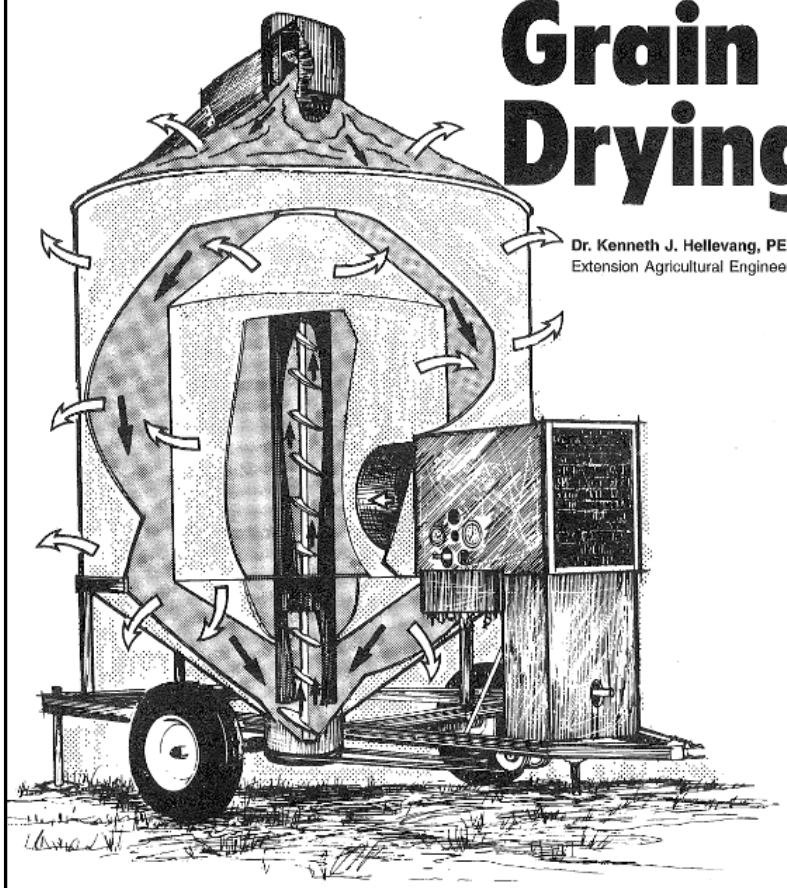
Extension Agricultural Engineer



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Threshing Malting Barley

- Threshing equipment needs to be set correctly to prevent breaking and skinning of barley.
- Skinned and broken kernels reduce germination.
- The husk on barley provides a protective covering to the developing sprout of the kernel during germination.

Kernels Damaged During Threshing

http://www.ambainc.org/pub/Production/Harvesting.pdf

Managing Stored Barley

- Stored grain should be kept cool, dry, and clean to maintain quality.
- Grain containing foreign material and skinned or broken kernels is susceptible to mold and insect damage.
- Grain moisture should be kept below 12% during summer months.
- The allowable storage time for barley is doubled for each 20 ^{o}F that the grain is cooled.

Summarized from information provided by the American Malting Barley Association

Importance of Education for Reducing Barley Quality Losses

- Providing outreach/education to growers, grain handlers, and maltsters is important in preventing or reducing quality losses.
- Region specific recommendations (e.g. plant nutrition) are important.
- Educate the educators.

Responsibilities of the Barley Procurer

- Educate growers on quality requirements of malting barley.
- Track potential problems that may impact barley quality throughout the growing season.
- Be prepared to find alternative markets for barley that is not purchased for malting.
- Be aware that “catastrophic” crop failures can occur and have a plan for grain supply.