Wheat Quality: Impact of Soil Fertility and Environmental Factors

Nutrient Management Webinar
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Webinar Overview

• Define Soft Red Winter Wheat (SRWW) quality.

• Identify SRWW quality characteristics.
  – What’s important to the industry and to farmers.

• What influences wheat quality?
  – Genetics
  – Environment (weather)
  – Soil fertility (nutrient availability)

• Nutrient role in wheat production and quality.
Wheat Quality
Different for each link in the chain

Wheat breeder → Seed of new wheat cultivars → Farmers

Farmers → Transportation → Mill

Mill → Baker

Baker → Consumer

Elevator
Six Wheat Classes in U.S. Quality is Different for Each

- Wheat Class = \( f_x(\text{genetics + climate}) \)
What is Wheat Quality?

• Industry definition of wheat quality: 
  **Suitability of flour** for end-use products

• Wheat quality ≠ one single property. 
  $f_x$ (milling + chemical + baking/processing + physical characteristics)

Are all these important to a farmer?
SRWW Milling Quality

- **Flour yield**
  - Genetically controlled - primarily
  - Environment (weather) can influence.
    - Drought
    - Disease
  - SRWW flour yield = 74 - 80%
    - Break flour yield = 30 - 34%
- Soil fertility has no role when there are no nutrient deficiencies.
SRWW Milling Quality

- **Protein**
  - Influenced by genetics, environment, and fertility (nitrogen).
  - SRWW = lower protein content than HRW.
    - 7-11% SRWW
    - 12-16% for HRW
      - High gluten content in HRW
  - No premium for high protein SRWW

DOES FERTILITY MATTER??
SRWW Baking Quality
Many End Use Products

• 3 categories of SRWW products.
• Mills given specs for flour from end-users.
  – Vary depending upon the product.
SRWW Baking Quality
Chemically Leavened Products
Baking Powder

- Rich in sugar and fats
- Product “tenderness” important
- Important characteristics
  - Water absorption of flour (cake size)
  - Cookie spread (packaging criteria)
- Controlled by genetics.
- Environmental influence.
- Fertility has no role.
SRWW Baking Quality
Yeast Leavened Products

• Low in sugar and fats
• Product “tenderness” important
• Important characteristics
  – Consistency in flour protein is important
  – Do not want any starch damage
• Controlled by genetics
• Environmental influence
• Fertility has no role
SRWW Baking Quality
Non-Baked Products

- Batters
  - Low protein; weak gluten; low amylase activity
- Noodles
  - Protein (gluten) properties intermediate to flat breads and cookies.
  - Intermediate H₂O absorption but rapid H₂O uptake (short mixing time)
  - Fine granulation of flour (soft wheat)
- Controlled by genetics
- Environmental influence
- Fertility has no role
### U.S. Standards for Wheat

#### Important Quality Factors for Farmers

<table>
<thead>
<tr>
<th>Grade</th>
<th>Minimum limits of --</th>
<th>Test weight per bushel</th>
<th>Damaged kernels</th>
<th>Total²</th>
<th>Foreign Material</th>
<th>Shrunken and broken kernels</th>
<th>Defects (total)</th>
<th>Contrasting classes</th>
<th>Total³</th>
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</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>(pounds)</td>
<td>(percent)</td>
<td>(percent)</td>
<td>(percent)</td>
<td>(percent)</td>
<td>(percent)</td>
<td>(percent)</td>
<td>(percent)</td>
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<tr>
<td>U.S. No. 1</td>
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<td>58.0</td>
<td>0.2</td>
<td>0.2</td>
<td>0.4</td>
<td>3.0</td>
<td>3.0</td>
<td>1.0</td>
<td>3.0</td>
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<tr>
<td>U.S. No. 2</td>
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<td>57.0</td>
<td>0.2</td>
<td>1.0</td>
<td>0.7</td>
<td>5.0</td>
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<td>2.0</td>
<td>5.0</td>
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<tr>
<td>U.S. No. 3</td>
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<td>55.0</td>
<td>0.5</td>
<td>0.5</td>
<td>0.7</td>
<td>3.0</td>
<td>3.0</td>
<td>2.0</td>
<td>5.0</td>
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<tr>
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<td>53.0</td>
<td>1.0</td>
<td>1.0</td>
<td>0.7</td>
<td>3.0</td>
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<td>0.0</td>
<td>10.0</td>
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<td>51.0</td>
<td>1.0</td>
<td>1.0</td>
<td>0.7</td>
<td>3.0</td>
<td>3.0</td>
<td>0.0</td>
<td>10.0</td>
</tr>
<tr>
<td>U.S. Sample grade</td>
<td></td>
<td>50.0</td>
<td>3.0</td>
<td>3.0</td>
<td>0.0</td>
<td>20.0</td>
<td>20.0</td>
<td>10.0</td>
<td>10.0</td>
</tr>
</tbody>
</table>

#### Influences

- Non-Fertility Production Practices
- Weather

**What Influences T.W.?**

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**SRWW**

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**SRWW Physical Quality**

**U.S. Federal Grain Inspection Service**
## 2013 Maryland Variety Trials

Costa et al., 2013 Agronomy Facts #19

<table>
<thead>
<tr>
<th>Variety</th>
<th>Yield (Bu/a)</th>
<th>Test Weight (lb/bu)</th>
</tr>
</thead>
<tbody>
<tr>
<td>USG 3404</td>
<td>83.5</td>
<td>56.6</td>
</tr>
<tr>
<td>USG 3315</td>
<td>78.5</td>
<td>58.4</td>
</tr>
<tr>
<td>MAS #4</td>
<td>76.4</td>
<td>59.6</td>
</tr>
<tr>
<td>MAS #23</td>
<td>75.6</td>
<td>55.7</td>
</tr>
<tr>
<td>Jamestown</td>
<td>66.9</td>
<td>59.2</td>
</tr>
</tbody>
</table>

Genetics has large role. Choose varieties that yield well and have high T.W.
Influence of Weather on Test Weight
2006 Maryland Variety Trials

Environment can have a huge influence
June 24 – July 8, 2006
Rainfall = 6 - 9 inches

<table>
<thead>
<tr>
<th>Variety</th>
<th>TW (lb/bu) 2006 Allen</th>
<th>TW (lb/bu) 2006 Clarksville</th>
</tr>
</thead>
<tbody>
<tr>
<td>McCormick</td>
<td>63.0</td>
<td>59.5 (-4.1)</td>
</tr>
<tr>
<td>Tribute</td>
<td>61.7</td>
<td>58.8 (-2.9)</td>
</tr>
<tr>
<td>SS 520</td>
<td>58.9</td>
<td>53.1 (-5.8)</td>
</tr>
<tr>
<td>Pioneer 26R15</td>
<td>58.4</td>
<td>54.5 (-3.9)</td>
</tr>
<tr>
<td>SS 560</td>
<td>57.8</td>
<td>55.5 (-2.3)</td>
</tr>
</tbody>
</table>

Fertility did not have any influence

Costa et al., 2006  Agronomy Facts #19
Test Weight and SRWW

- TW = lb/bu (32 quarts)
  \[ f_x (\text{kernel density} + \text{packing efficiency}) \]

What causes packing efficiency to change?

Reduction in packing efficiency causes lower TW.
How do rain events change test weight?

- Kernels swell
  - Imbibe water
- Packing efficiency
  - Less kernels in TW container and TW drops.
- Greater concern
  - Was germination initiated?

Germinated Wheat Results in Falling Number Change

Low test weight indicates a problem may exist.

What does “falling number” mean?
What happens when wheat sprouts?

- Imbibition of water triggers release of enzyme (alpha-amylase).
- Alpha-amylase cleaves starch into sugar molecules.
- Flour baking properties affected.
- Does soil fertility influence falling number?
### 2006 Wheat Falling Number Values

**June 24 – July 8, 2006**  
**Rainfall = 6 - 9 inches**

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>Poplar Hill</th>
<th>Keedysville</th>
<th>Wye</th>
</tr>
</thead>
<tbody>
<tr>
<td>McCormick</td>
<td>436</td>
<td>369</td>
<td>401</td>
</tr>
<tr>
<td>Pioneer 26R15</td>
<td>401</td>
<td>247</td>
<td>165</td>
</tr>
<tr>
<td>Chesapeake</td>
<td>295</td>
<td>293</td>
<td>164</td>
</tr>
<tr>
<td>USG 3342</td>
<td>450</td>
<td>232</td>
<td>77</td>
</tr>
</tbody>
</table>

Costa, Cooper, and Kratochvil (2006)

Genetics plays a large role  
Environment (weather) initiates the process  
Fertility has no influence
Scab Impact on Quality aka Fusarium Head Blight

- Bleached spikes or spikelets
- Pink/salmon colored spore masses on glumes

Vomitoxin or **DON** levels become a problem

1 ppm DON in flour is all that is acceptable

**Tombstone seed**
What Influences Scab (DON) Severity?

• **Host - multiple**
  – Wheat, corn, barley, oats, grasses
  – All varieties have some level of susceptibility (genetic)

• **Pathogen**
  – Overwinters on host plant residue.

• **Environment**
  – Infections occur during rainy, humid periods before, during, and after flowering

• **Soil fertility**
  – Has no influence on amount of disease
Best practice for minimizing scab and falling number problems?

Favorable weather during wheat flowering. Favorable weather during wheat harvest.
Role of Soil Fertility
Wheat Production and Quality
• Nutrition (fertility) allows plant:
  – TO BE ALL IT CAN BE.
Nutrient Deficiencies and Toxicities

- **Deficiency**
  - Insufficient quantity for needs of the growing plant.

- **Liebig’s Law of the Minimum**

- **Toxicity**
  - In excess of needs - decreases plant growth or quality.
# Macronutrients (6)

<table>
<thead>
<tr>
<th>Macronutrient (6)</th>
<th>Plant function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrogen (N)</td>
<td>Amino acids-proteins</td>
</tr>
<tr>
<td>Phosphorus (P)</td>
<td>Nucleic acids, ATP</td>
</tr>
<tr>
<td>Potassium (K)</td>
<td>Catalyst, ion transport</td>
</tr>
<tr>
<td>Calcium (Ca)</td>
<td>Cell wall component</td>
</tr>
<tr>
<td>Magnesium (Mg)</td>
<td>Chlorophyll</td>
</tr>
<tr>
<td>Sulfur (S)</td>
<td>Amino acids</td>
</tr>
</tbody>
</table>
## Micronutrients (6)

<table>
<thead>
<tr>
<th>Micronutrient</th>
<th>Plant function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boron (B)</td>
<td>Cell walls; reproduction</td>
</tr>
<tr>
<td>Chlorine (Cl)</td>
<td>Photosynthesis</td>
</tr>
<tr>
<td>Copper (Cu)</td>
<td>Component of enzymes</td>
</tr>
<tr>
<td>Iron (Fe)</td>
<td>Chlorophyll synthesis</td>
</tr>
<tr>
<td>Manganese (Mn)</td>
<td>Activates enzymes</td>
</tr>
<tr>
<td>Zinc (Zn)</td>
<td>Activates enzymes</td>
</tr>
</tbody>
</table>
Identifying Nutrient Disorders

• Compare normal plants with those that show problem

• Examine new and older leaves
  – Old leaf deficiencies = mobile nutrients
    • move from one place to another
  – New leaf deficiencies = immobile nutrients
    • do not readily move
Mobile Nutrients

“Old Leaves”

- Nitrogen
- Phosphorus
- Potassium
- Magnesium
- Chloride
Immobile Nutrients
“New Leaves and Terminal Buds”

- Sulfur
- Calcium
- Iron
- Zinc
- Copper
- Boron
- Manganese
Importance of pH
Nitrogen
Mobile

Effects on Quality
Lower protein
Less yield

Older leaves

Chlorotic appearance

V-shaped yellowing

Function
Amino acids and proteins

Lower protein
Less yield

R Taylor
Conditions favoring N deficiency

- Sandy soils
- Cold soils
- Leaching after heavy rains
- Flooded or ponded soils
- Dry soils - particularly during rapid growth
- Inadequate fertilization
Excess Nitrogen

Dark Green Foliage
Lodging

Effects on Quality
Lower test weight with lodging
Better disease environment
Phosphorus
Mobile

Leaf purpling

Stunted growth

Function
Nucleic acids, ATP
Conditions favoring P deficiency

- Cold soils that are too wet or too dry
- P applied where roots cannot absorb it
- Compacted soils – restricted root growth
- Injured roots
Chlorotic or necrotic leaf margins

Symptoms on lower leaves first

Potassium Mobile

Excess K may cause deficiencies in Ca and Mg

Ion transport, catalyst
Conditions favoring K deficiency

- Sandy soils
- Weathered soils
- Excessively dry/wet soils
- Compacted soils
- High organic matter soils
- Limited early root growth
- Root pruning
- Heavy removal by preceding crop
Uniform chlorosis of (younger) leaves

Excess S may cause premature leaf drop.

**Favorable Conditions**
- Low pH, sandy soils
- Soils with low O.M.
- Cold, dry soils in spring
  - Delayed release from O.M.
Stunted growth

Calcium Immobile

Functions
Cell wall & cell membrane structure and strength

No root elongation; remain stubby

Favorable Conditions
- Low pH soils < 5.0
- Excessive Al and Mn likely to occur first.

Excess Ca may cause K or Mg deficiency
Magnesium Mobile

Interveinal chlorosis – older leaves

Beaded streaking

Favorable Conditions
• Low pH soils
• Sandy soils after heavy rain events
• High soil K levels

High plant conc. tolerated; May cause Ca & K imbalance resulting in stunted growth.
Sterile heads/male sterility.
Brittle leaves with small dead spots.

Excess B causes chlorotic leaf tips followed by necrosis and defoliation.

Boron Immobile

Functions
Wheat anther development
Cell wall structure

Favorable Conditions
• Sandy soils low in O.M.
• Drought – no release from OM.
• High pH
Zinc Immobile

Function
Enzyme activation

Interveinal chlorosis or white band from base to leaf tip

Young leaves look stunted

Favorable Conditions
- High soil pH
- Low O.M. soils
- Cool, wet soils
- High P soils

Excess Zn may cause Fe deficiency
**Manganese Immobile**

**Function**
Enzyme activator for photosynthesis

**Favorable Conditions**
- High pH soils
- Sandy soils & high O.M. content
- Sludged soils
- Peat or muck soils

**Leaves mostly yellow; Dark green next to veins**

**Excess Mn:** older leaves with brown spots surrounded by chlorotic zone.
Iron Immobile

Excess Fe may cause bronzing of leaves with tiny brown spots

Interveinal chlorosis on young leaves

Leaf veins remain green

Function Chlorophyll synthesis

Deficient

Favorable Conditions
- High pH soils
- Cold, wet, poorly drained soils
Copper
Immobile

Copper toxicity appears at low pH; effects seed germination, shoot vigor and iron availability.

Function
Component of some enzymes

Looks similar to Fe deficiency

Youngest leaves yellow and stunted

Leaf tips may die

Favorable Conditions
- High O.M. soils
- High soil pH >7.5
- Heavily sludged soils
Excess chlorine often appears as wilted plants; associated with excess salt uptake.

Function
Photosynthesis

Yellow blotches

Rarely a problem if potash (KCl) is used.
Summary

• Wheat quality primarily affected by genetics.
• Environment (weather) can have an influence (positive or negative).
• Soil fertility has little to no effect on quality.
• Deficient pH and/or nutrients will affect grain yield much more than grain quality.
Wheat Quality Recommendations

1. Choose good yielding varieties with high test weight.

Favorable Weather at Flowering
Favorable Weather at Harvest
Thank You!!