Evapotranspiration in Center-Pivot-Irrigated Malting Barley: Critical Timings and Quantity

2019 Southern Rocky Mountain Ag Conference
Monte Vista, CO
February 7, 2019

Dr. Howard Neibling, P.E.
Water Management Engineer
University of Idaho
Fourth National Climate Assessment

• Vol 2 released after Thanksgiving, 2018
  • 13 agencies
  • Over 300 authors
  • Very rigorous public and peer review
Findings for the PNW

• More extreme events (more danger of water storage facility failure, larger flooding etc.)
• “Current water management and planning principles typically do not address risk that changes over time, leaving society exposed to more risk than anticipated.”
• Higher ET
• “Reduced snow-to-rain ratios are leading to significant differences between the timing of water supply and demand”
CALC 15 DAY WATER USE
SFR. GRAIN 4/1 PLANT
Kimberly 1965-1978

CALC CROP ET, In./DAY

MONTH OF YEAR
Twin Falls AGRIMET Peak Alfalfa ET

$y = 0.0014x - 2.3456$

$R^2 = 0.2482$
Growth Stage – Stress Effects

• Vegetative (except tillering)
  • Stress shortens plant
  • Yield reduction: 2% / 10% < ET

• Tillering
  • Stress limits number of heads
  • Total # heads & # seeds/head determined by end of tillering & start of elongation (height about 6 in)

• Flowering
  • Stress limits number of kernals
  • Yield reduction: 6.5% / 10% < ET

• Yield formation
  • Stress: incomplete head fill & limits kernal size
  • Yield reduction: 5.5% / 10% <ET
Barley

Yield loss due to 1” ET deficit in crop stage:

• Vegetative (except tillering): 2% of max yield
• Tillering: stress reduces the number of heads and seeds per head. This yield loss cannot be reclaimed by later proper water management
• Boot-flower: about 11% of max yield
• Flowering: 16% of max yield
Barley Yield Loss Cont.

• Soft dough: about 9% of max yield
• Yield formation: 8% of max yield
• After soft dough: very little or negative if 2 inches usable water in root zone
• Uniform across entire season: 6% of max yield
Unrestricted effective rooting depths of
Selected mature crops (Ashley et al.)
Early Season Management

• Check soil moisture to anticipated maximum rooting depth (24-30 inches)
• Be aware of early-season crop root depth and moisture in root zone
• If water is available and root zone is dry, irrigate to fill profile and avoid stress before tillering (MAD <0.5)
• If water is not available until after tillering but maximum root zone is only partially full, irrigate to fill root zone before boot
• Do not over-irrigate (cools and retards growth)
30-year Average Grain ET, Kimberly

AGRIMET Estimated ET, in/d

- Winter grain: 6.5 gpm/ac
- Spring grain: 0.75 in

4.5 weeks

Neibling, UI Extension
Aberdeen Small Grain

AgriMet Estimated ET, In/d

Date

6/7 6/21 7/5 7/19 8/2 8/16 8/30 9/13 9/27

Gpm/ac

0.25

0.3

0.4

0.45

6.5

0

0.05

0.1

0.15

0.2

0.25

0.3

0.35

0.4

0.45

2006

92-09 avg

Neibling, UI Extension
Late Season
Wheat yield with irrigation cutoff at several crop stages relative to yield with full-season irrigation.

Neibling, UI Extension
Average of 2000, 2001, and 2002 soil water contents at harvest for different water cutoff treatments. Also shown is average soil water content at the beginning of the experiment (about mid-June).

Neibling, UI Extension
Moravian 37 Malting Barley Yield vs. Water Cutoff Time

Burley, ID

Qureshi and Neibling, 2009
Malting Barley, average of 2000, 2001 and 2002 data

Qureshi and Neibling, 2009
Percent Blacktip Infection, 2000 Malting Barley

<table>
<thead>
<tr>
<th>Crop Stage</th>
<th>Milk</th>
<th>Soft dough</th>
<th>Post-soft dough</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percent infected kernels</td>
<td>3</td>
<td>4</td>
<td>9</td>
</tr>
</tbody>
</table>

Barley production contracts allow for product rejection at disease and damage levels > 5%

Neibling, UI Extension
Crop water used (inches) for selected malting barley and hard red spring wheat crop stages and total seasonal use.

<table>
<thead>
<tr>
<th>Crop stage</th>
<th>2-row malting barley</th>
<th>Hard red spring wheat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Emergence to milk</td>
<td>11.6</td>
<td>14.3</td>
</tr>
<tr>
<td>Milk to Soft Dough</td>
<td>3.4</td>
<td>2.1</td>
</tr>
<tr>
<td>Soft Dough to Hard Dough</td>
<td>1.9</td>
<td>0.8</td>
</tr>
<tr>
<td>Hard Dough to harvest</td>
<td>0.8</td>
<td>1.2</td>
</tr>
<tr>
<td>Seasonal Total</td>
<td>17.7</td>
<td>18.4</td>
</tr>
</tbody>
</table>
Scheduling last irrigation on cereals

Neibling, UI Extension
Outline

• Study Overview
• Final Irrigation by Nitrogen
  • Yield
  • Quality
• Final Irrigation by Variety
  • Yield
  • Quality
Study Overview

- Study One
  - Final Irrigation Timing
    - Boot, Soft Dough (SD), Soft Dough + 7d (SD7)
  - Nitrogen Application Rate
    - 0, 50, 100, and 150 lb N/ac
- Study Two
  - Final Irrigation Timing
  - Variety
    - M69, M169, M150, and AC Metcalfe

Rogers and Neibling, UI Extension
Irrigation and water usage 2015

- WSU Irrigation scheduler estimated water in soil profile in study
  - Available at: http://weather.wsu.edu/is/
  - Red line indicates crop stress
    - Boot cutoff is severely stressed for a large portion of growth
    - Soft Dough resulted in sufficient water to finish crop from stored water in the soil profile
    - Soft Dough + 7d resulted in sufficient water without the usage of stored soil water

- Irrigation cutoff at Soft Dough was sufficient to finish the crop on the silt-loam soil in the study

Rogers and Neibling, UI Extension
Yield and Protein Response 2015

- **Relative Grain Yield (%)**
  - Applied N (lb N/ac) + 85 lb Inorganic N

- **Protein (%)**
  - Applied N (lb N/ac) + 85 lb Inorganic N

- Rogers and Neibling, UI Extension
Irrigation and water usage 2016

Water was sufficient to avoid plant stress in all treatments until after irrigation was cutoff.

Water stress was severe at the boot cutoff—however, several timely rains provide some water.

This is likely why plant response was less than 2015.

Soft dough cutoff retained sufficient water to finish the crop for yield and quality goals.

Cutoff at soft dough as compared to soft dough + 7d resulted in nearly a 13% reduction in irrigation water usage during the 2016 growing season while retaining yield and quality goals.

Rogers and Neibling, UI Extension
Yield and Protein Response 2016

Rogers and Neibling, UI Extension
Varietal Response 2016

- Yields were lower within a variety at the boot cutoff
- Yield were numerically reduced at SD7 – see previous on aphid issue
- M169, which was not included in 2015, performed particularly well exhibiting higher yields than other varieties at the boot cutoff, where M150, M69, and Metcalfe did not differ

Rogers and Neibling, UI Extension
Varietal Response 2016

• M169 also outperformed the other varieties at the soft dough stage where the highest yield was measured.
• As before, irrigation past soft dough did not improve yield and thus, data supports the recommendation to cut irrigation at SD when soil water is sufficient.
• Yield reductions at boot were less severe than 2015 likely due to cooler temperatures and more available moisture from timely rains.

Rogers and Neibling, UI Extension
Varietal Response 2016

- Protein was within acceptable ranges for malting for all treatment combinations.
- However, the proteins from the boot cutoff were significantly greater for each variety where the SD and SD7 cutoff timings did not differ.
Main Points from results

• Approximately 135 lb N (applied + soil N) resulted in maximum yield and good protein
• Protein generally increases as N rates go up, but as many saw in 2016 yields went up and proteins remained stable
• Likely related to weather and growing patterns during the year

Rogers and Neibling, UI Extension
Main Points from results

- Early cutoffs will decrease grain yield and elevate proteins
- 2015 saw much greater protein elevation than in 2016
- Early cutoff also decreases plumps
- Yield from SD7 was slightly less than SD in 2016
Irrigation and Nitrogen

- Kimberly R&E Center - (Moravian 69)
  - Irrigation cutoffs at “Boot, Soft Dough, and Soft Dough + 7d”
  - Preplant applied N at “0, 50, 100, and 150 lb N/ac” as urea

- Results
  - Boot cutoff severely decreased yields at all N rates compared to other treatments
  - Soft Dough and Soft Dough + 7d did not differ
    - Largest yield was achieved at 50 lb applied N or 135 lb applied plus inorganic N
    - Maximum yield was achieved at ~1.1 to 1.2 N/bu yield
Irrigation and Nitrogen

- Results
  - Nearly 20% water reduction when irrigation was completed at Soft Dough as compared to Soft Dough + 7d
  - Proteins at Boot cutoff averaged 16.1% where only the 0 lb N/ac rate was less than 14%
  - Proteins for Soft Dough and Soft Dough + 7d averaged 12.8%
  - Plumps averaged 83% at Soft Dough and Soft Dough + 7d cutoff
  - At least 2.5 inches of available soil water are needed to finish the crop from soft dough to harvest

Dr. Chris Rodgers, UI, Aberdeen
Water usable by crop without water stress (inches) when initially at field capacity (e.g. MAD=0.5).

<table>
<thead>
<tr>
<th>Root zone depth, inches</th>
<th>Sandy loam</th>
<th>Light-textured silt loam</th>
<th>Heavier-textured silt loam</th>
</tr>
</thead>
<tbody>
<tr>
<td>12</td>
<td>0.8</td>
<td>1.0</td>
<td>1.2</td>
</tr>
<tr>
<td>24</td>
<td>1.6</td>
<td>2.0</td>
<td>2.4</td>
</tr>
<tr>
<td>36</td>
<td>2.4</td>
<td>3.0</td>
<td>3.6</td>
</tr>
</tbody>
</table>

Irrigation (inches) needed past Soft Dough for no yield or quality reduction.

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<td>0</td>
<td>0</td>
</tr>
<tr>
<td>36</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
Updated Extension Publication

- University of Idaho Bulletin 912
- Agronomic information
- Soil water information
- Nitrogen usage
- Crop staging
- Economic analysis
Scheduling the Final Irrigation for Wheat and Barley

H. Neibling, C. W. Rogers and Z. Qureshi

Introduction

CROP PRODUCTION IN IRRIGATED AREAS is becoming more water constrained. In many areas, municipal water use is increasing with urban expansion where periodic drought episodes occur. Water rights adjustments will potentially reduce the amount of available irrigation water, particularly

...bullets is to help growers determine the optimum timing and amount of the final irrigation application needed to sustain agronomic and economic returns for wheat and barley production.

In addition to yield, grain quality (e.g., protein, plumpness, test weight) of wheat and barley is a crucial consideration for end-use quality. For example, water management during grain formation stages affects...
Late-Season Recommendations

• For optimum yield, water use and grain quality have >2” avail water at soft dough:
  • stop irrig with full profile at soft dough on deep, non-sandy soils
  • give one irrigation after soft dough on shallow or sandy soils
  • cut off water at or before soft dough if high pumping costs or other water need
Late-Season Recommendations Cont.

• Water past soft dough on most soils:
  • does not improve yield
  • may reduce test weight & protein
  • may increase blacktip infestation
  • wastes water and energy (adds cost for no benefit)
  • can leach crop nutrients
How much water to add?

• Calculate based on soil texture and root zone depth
• Monitor soil moisture and see if wetting front moves below root zone after irrigation
• In some soils may be limited by runoff
Sprinkler System Considerations
Why should pivots be designed to meet peak mid-season ET?

• ET is increasing (about 0.05in/d higher now than in 1992 at Kimberly)
• Allows pivot to be run less during critical disease periods to help prevent or minimize disease
• Allows deficit irrigation in certain periods because the system can catch up later to minimize stress in critical crop stages
• However, this requires better irrigation scheduling to assure that over-watering does not occur

Neibling, UI Extension
What do you do when capacity < ET?

- Fill profile early!
- Assure no runoff, but
- Slow pivot down until runoff almost occurs (moves water deeper)
- Shut off end gun and irrigate the rest
- Pray for rain

Neibling, UI Extension
Day vs. Night Evaporation from Sprinklers

• Evaporation difference can be up to 9%
• Run pivots at other than even multiple of 24 hours to avoid irrigating the same areas always at night or always in mid-day.
50% of applied water lost on a hot windy day
With MESA relative to LESA
Drop spacing typically 60, 40 or 30 inches, depending on crop, soils,...
Range of water-saving options: really a cost-benefit analysis for each site

- Most savings: Dragon-line: **AE=98%**, 20K upgrade
- Next: LESA with heads 12-18” above ground, 3-4 ft spacing, **AE=95%**, upgrade, 12K
- Next: LESA with heads 36-42” above ground, 5 ft spacing, **AE= 90%**, upgrade, 8K
- Next: MESA with current spacing, **AE=70-85%**, no upgrade required
Summary - Pivots and Linears

• Avoid excessive early and late-season irrigation
• Irrigation interval will be shorter than set-move because of less water added per irrigation
• Manage system to enter peak use period with a full root zone because systems are usually not sized to meet peak demand
• Use faster rotation speeds, dammer diking, soil conditioners(?) or ozone(?) to reduce runoff
• Watch for accumulating Na and other salt buildup

Neibling, UI Extension
Irrigation system water application rate
(inches per day)

- Center Pivot or Linear-move:
  
gross application = gpm/ac * 0.05303
  net application = gross application * AE (in %)/100

Example: what is the gross and net water application rate for a 125-ac pivot with 875gpm water supply? Application efficiency (AE) = 85%

gpm/ac = 875/125 = 7
gross application = 7*0.05303 = 0.37 in/d
net application = 0.37 in/d *(85/100) = 0.32 in/d

Neibling, UI Extension
Idaho, Oregon, Washington
Irrigation website:

http://irrigation.wsu.edu
### Depth Penetrated by a 1-inch Net Water Application (assuming uniform soil properties and uniform initial soil moisture with depth)

<table>
<thead>
<tr>
<th>Avg. Water Holding Capacity (in/ft)</th>
<th>Sand</th>
<th>Loam</th>
<th>Silt Loam</th>
<th>Clay</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0</td>
<td>1.0</td>
<td>1.7</td>
<td>2.1-2.4</td>
<td>2.2</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Soil Depth (% depleted)</th>
<th>Sand</th>
<th>Loam</th>
<th>Silt Loam</th>
<th>Clay</th>
</tr>
</thead>
<tbody>
<tr>
<td>25</td>
<td>48</td>
<td>28</td>
<td>20</td>
<td>22</td>
</tr>
<tr>
<td>35</td>
<td>34</td>
<td>20</td>
<td>14</td>
<td>16</td>
</tr>
<tr>
<td>50</td>
<td>24</td>
<td>14</td>
<td>10</td>
<td>11</td>
</tr>
<tr>
<td>75</td>
<td>16</td>
<td>9</td>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td>100</td>
<td>12</td>
<td>7</td>
<td>5</td>
<td>5</td>
</tr>
</tbody>
</table>

Neibling, UI Extension
Maximum Storable Water

- Sandy Loam (1.7 in/ft * 0.5 = 0.85 in/ft)
  - 1 ft: 0.8 in
  - 2 ft: 1.7 in
  - 3 ft: 2.6 in

- Silt loam (2.4 in/ft * 0.5 = 1.2 in/ft)
  - 1 ft: 1.2 in
  - 2 ft: 2.4 in
  - 3 ft: 3.6 in
Maintain best soil moisture conditions by irrigation scheduling

• Checkbook, also web and phone app
• Feel and appearance
• Soil moisture sensors
  • With data logger
  • With data logger and transmit to website
AgSense data logger / watermark sensors
Deep Water Loss Chart

Source: WSU AgWeatherNet (weather.wsu.edu)
30-year Average Grain ET, Kimberly

AGRIMET Estimated ET, in/d

Winter grain
Spring grain

6.5 gpm/ac
0.75 in

4.5 weeks

Neibling, UI Extension
Crop Growth vs Soil Water Stress
MAD = 50% for Alfalfa, Grain and Corn

Neibling, UI Extension
<table>
<thead>
<tr>
<th>Crop</th>
<th>Stage of Development</th>
<th>Percent of Available Water Usable Without Yield or Quality Loss</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alfalfa</td>
<td>All stages</td>
<td>55</td>
</tr>
<tr>
<td>Corn, field</td>
<td>All stages</td>
<td>50</td>
</tr>
<tr>
<td>Corn, sweet</td>
<td>All stages</td>
<td>50</td>
</tr>
<tr>
<td>Cereal grains</td>
<td>All stages except boot through flowering and ripening of wheat</td>
<td>55</td>
</tr>
<tr>
<td>Boot through flowering</td>
<td></td>
<td>45</td>
</tr>
<tr>
<td>Ripening (wheat)</td>
<td></td>
<td>90</td>
</tr>
<tr>
<td>Dry beans</td>
<td>All stages</td>
<td>40</td>
</tr>
<tr>
<td>Mint</td>
<td>All stages</td>
<td>40</td>
</tr>
<tr>
<td>Onion</td>
<td>First irrigation</td>
<td>40</td>
</tr>
<tr>
<td>All other irrigations</td>
<td></td>
<td>30</td>
</tr>
<tr>
<td>Pasture</td>
<td>All stages</td>
<td>50</td>
</tr>
<tr>
<td>Potato</td>
<td>All stages except vine kill</td>
<td>35</td>
</tr>
<tr>
<td>Vine kill</td>
<td></td>
<td>50</td>
</tr>
<tr>
<td>Sugar beets</td>
<td>All stages</td>
<td>50</td>
</tr>
</tbody>
</table>

Neibling, 1998
The End -- Questions ??
Irrigation and Nitrogen

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Dr. Chris Rodgers, UI, Aberdeen
What in the World is Soft Dough??

• Squeeze kernel & inside is somewhere between milk and hard dough
• Indentation made by thumbnail disappears almost immediately after pressure is released
• ....
Cumulative Growing Degree Days (base 32 F), Kimberly, ID

Neibling, UI Extension
## Soft Dough Relative to Boot

<table>
<thead>
<tr>
<th></th>
<th>Days</th>
<th>GDD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average</td>
<td>5/31 – 6/24</td>
<td>24</td>
</tr>
<tr>
<td>1992</td>
<td>5/17 – 6/9</td>
<td>23</td>
</tr>
<tr>
<td>1993</td>
<td>5/31 – 6/28</td>
<td>28</td>
</tr>
<tr>
<td>1994</td>
<td>5/24 – 6/19</td>
<td>26</td>
</tr>
</tbody>
</table>

Neibling, UI Extension