Crop Coefficients for Estimating Small Grain Water Use, 2004

M. J. Ottman

Summary

Crop coefficients are used to estimate water use from reference evapotranspiration values provided by weather stations. Four varieties of barley and durum were planted at the Maricopa Agricultural Center early December and early January and one durum variety was planted at the Yuma Valley Agricultural Center in late December and mid-February. Water use was estimated from neutron probe readings and crop coefficients were calculated by dividing water use by reference evapotranspiration. The crop coefficients calculated in this study peaked from 1.0 to 1.3, and the peak averaged about 1.16. Some differences were detected among planting dates and varieties, but it has yet to be determined if these differences are of practical significance.

Introduction

Crop coefficients are used to calculate water use from weather data. The crop coefficient increases as the crop develops, reaches a peak, and then decreases as the crop senesces. Crop coefficients are most accurate if locally developed using current cropping practices. Crop coefficients have not been developed for Arizona, and we currently rely on values from California or values estimated indirectly from water use work done on outdated varieties by the Water Conservation Research Laboratory in Phoenix in the 1950’s and 1960’s. We intend to use the crop coefficients developed in Arizona to provide water use estimates for the Small Grain Advisory and for AZSCHED, irrigation scheduling software for Arizona. The purpose of this study is to develop crop coefficients for wheat and barley in Arizona.

Procedures

Four durum varieties (Duraking, Kronos Orita, and WPB 881) and four barley varieties (Barcott, Baretta, Max, and Mucho) were planted at two dates (Dec 3, 2003 and Jan 7, 2004) at the Maricopa Agricultural Center. The plots were 42 ft by 40 ft in size and replicated twice in a randomized complete block design. Two neutron access tubes were installed per plot. Cultural practices are presented in Table 1. Water use was estimated in 1 ft depth increments to 5 ft from neutron probe readings before and after each irrigation. Crop coefficients were calculated by dividing water use by reference evapotranspiration (ETo, original AZMET calculation method) from AZMET.

Kofa durum was planted at two dates (Dec 29, 2003 and Feb 13, 2004) at the Yuma Valley Agricultural Center in 5 acre fields. Six neutron access tubes were installed in the center portion of each field. Cultural practices for this site can be found in Table 1. Water use and crop coefficients were calculated similarly to the Maricopa location.
Results and Discussion

This was a poor growing season for small grains and yields were lower than usual in these tests compared to past years. Total precipitation was near the average for the growing season (Table 2). Growing season temperature was near or above average. However, the defining characteristic of this growing season was the hottest March on record at all locations. This, combined with one of the coldest February on record, resulted in hot temperatures occurring earlier than usual and may have been responsible for the lower yields measured this year.

Small grain crop coefficients according to the FAO Irrigation and Drainage Paper 56 are 1.15 at midseason and 0.25 at the end of the season (Allen et al., 1998). Initial values are not provided. At Maricopa, the midseason values for the December planting were 1.15 (barley) and 1.07 (durum) for the December planting and were 1.21 (barley) and 1.20 (durum) for the January planting (Table 6). At Yuma, the midseason values for durum were 1.18 for the January planting and 1.13 for the February planting (Table 7). The end of the season values varied from 0.04 to 0.62 depending on exactly when the last measurements were recorded and when the last irrigation was applied. The Kc values were higher at the second planting at Maricopa, but not at Yuma, in contrast to previous years. Varietal differences in Kc values exist, but whether or not these differences are of practical significance is yet to be determined.

References


Acknowledgements

The technical assistance of Tony Gomez and Mary Comeau is greatly appreciated.

Table 1. Cultural practices for the small grains planted at Maricopa and Yuma.

<table>
<thead>
<tr>
<th>Cultural practice</th>
<th>Maricopa</th>
<th>Yuma Valley</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Dec 3 planting</td>
<td>Jan 7 planting</td>
</tr>
<tr>
<td>Field</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>Border</td>
<td>8-9</td>
<td>10-11</td>
</tr>
<tr>
<td>Soil type</td>
<td>Sandy clay loam</td>
<td>Sandy clay loam</td>
</tr>
<tr>
<td>Preplant soil NO₃-N</td>
<td>7.7 ppm</td>
<td>7.7 ppm</td>
</tr>
<tr>
<td>Preplant soil P</td>
<td>6.5 ppm</td>
<td>6.5 ppm</td>
</tr>
<tr>
<td>Row spacing</td>
<td>7 inches</td>
<td>7 inches</td>
</tr>
<tr>
<td>Barley seeding rate</td>
<td>80 lbs/acre</td>
<td>80 lbs/acre</td>
</tr>
<tr>
<td>Durum seeding rate</td>
<td>100 lbs/acre</td>
<td>100 lbs/acre</td>
</tr>
<tr>
<td>Irrigation and fertilization</td>
<td>12/03 + 48 lbs N/a and 60 lbs P₂O₅/a</td>
<td>---</td>
</tr>
<tr>
<td></td>
<td>01/07 + 48 lbs N/a and 60 lbs P₂O₅/a</td>
<td>2/06 + 50 lbs N/a</td>
</tr>
<tr>
<td></td>
<td>03/01 + 55 lbs N/a</td>
<td>2/26 + 50 lbs N/a</td>
</tr>
<tr>
<td></td>
<td>03/18 + 46 lbs N/a</td>
<td>3/12 + 50 lbs N/a</td>
</tr>
<tr>
<td></td>
<td>04/01 + 46 lbs N/a</td>
<td>3/26</td>
</tr>
<tr>
<td></td>
<td>04/16</td>
<td>4/08</td>
</tr>
<tr>
<td></td>
<td>04/30</td>
<td>4/22</td>
</tr>
<tr>
<td></td>
<td>5/06</td>
<td>5/06</td>
</tr>
<tr>
<td>Total N applied</td>
<td>218 lbs N/a</td>
<td>172 lbs N/a</td>
</tr>
</tbody>
</table>
Table 2. Climatic data from AZMET for Maricopa and Yuma Valley during the 2004 growing season ranked and compared to the long-term average. The rankings of the months are from low to high.

<table>
<thead>
<tr>
<th>Climate variable</th>
<th>Unit</th>
<th>Year(s)</th>
<th>Dec</th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Dec-May</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>2004</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Max Temp.</td>
<td>°F</td>
<td>2004</td>
<td>14</td>
<td>13</td>
<td>3</td>
<td>18</td>
<td>9</td>
<td>14</td>
<td>14</td>
</tr>
<tr>
<td>Min Temp.</td>
<td>°F</td>
<td>1987-2004</td>
<td>67</td>
<td>67</td>
<td>66</td>
<td>84</td>
<td>84</td>
<td>97</td>
<td>78</td>
</tr>
<tr>
<td>Ppt.</td>
<td>inches</td>
<td>2004</td>
<td>0.16</td>
<td>0.71</td>
<td>0.91</td>
<td>0.28</td>
<td>0.98</td>
<td>0.00</td>
<td>3.03</td>
</tr>
<tr>
<td></td>
<td>inches</td>
<td>1987-2004</td>
<td>0.64</td>
<td>0.66</td>
<td>0.81</td>
<td>0.75</td>
<td>0.31</td>
<td>0.14</td>
<td>3.27</td>
</tr>
</tbody>
</table>

Maricopa

| Max Temp.        | °F   | 2004    | 10  | 15  | 3   | 18  | 13  | 11  | 14      |
| Min Temp.        | °F   | 1987-2004 | 34  | 39  | 36  | 51  | 52  | 60  | 45      |
| Ppt.             | inches | 2004     | 0.16 | 0.71 | 0.91 | 0.28 | 0.98 | 0.00 | 3.03    |
|                  | inches | 1987-2004 | 0.64 | 0.66 | 0.81 | 0.75 | 0.31 | 0.14 | 3.27    |

Yuma

| Max Temp.        | °F   | 2004    | 10  | 9   | 3   | 18  | 9   | 11  | 11      |
| Min Temp.        | °F   | 1987-2004 | 68  | 68  | 69  | 86  | 85  | 94  | 78      |
| Ppt.             | inches | 2004     | 0.00 | 0.06 | 0.20 | 0.10 | 0.69 | 0.00 | 1.05    |
|                  | inches | 1987-2004 | 0.37 | 0.31 | 0.34 | 0.35 | 0.16 | 0.04 | 1.55    |

Table 3. Heading, flowering and physiological maturity for the varieties planted at two dates at Maricopa.

<table>
<thead>
<tr>
<th>Planting date</th>
<th>Stage</th>
<th>Barcott</th>
<th>Baretta</th>
<th>Max</th>
<th>Mucho</th>
<th>Duraking</th>
<th>Kronos</th>
<th>Orita</th>
<th>WPB 881</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Maturity</td>
<td>4/27</td>
<td>5/06</td>
<td>5/09</td>
<td>4/30</td>
<td>5/06</td>
<td>5/07</td>
<td>5/08</td>
<td>5/05</td>
</tr>
</tbody>
</table>
Table 4. Crop growth stages when neutron probe readings were recorded for the two planting dates at Yuma.

<table>
<thead>
<tr>
<th>Planting date</th>
<th>Date</th>
<th>December 29</th>
<th>February 13</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>1-2 nodes</td>
<td>---</td>
</tr>
<tr>
<td></td>
<td>2/18</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>3/04</td>
<td>2-3 nodes</td>
<td>2.75 leaf</td>
</tr>
<tr>
<td></td>
<td>3/09</td>
<td>Last leaf visible</td>
<td>4.4 leaf</td>
</tr>
<tr>
<td></td>
<td>3/18</td>
<td>Boot</td>
<td>5.5 leaf</td>
</tr>
<tr>
<td></td>
<td>3/24</td>
<td>Heading</td>
<td>---</td>
</tr>
<tr>
<td></td>
<td>3/31</td>
<td>Flowering + 2 days</td>
<td>2 nodes</td>
</tr>
<tr>
<td></td>
<td>4/07</td>
<td>Kernel watery</td>
<td>Boot</td>
</tr>
<tr>
<td></td>
<td>4/13</td>
<td>Milk</td>
<td>Heading</td>
</tr>
<tr>
<td></td>
<td>4/21</td>
<td>Soft dough</td>
<td>Flowering</td>
</tr>
<tr>
<td></td>
<td>4/26</td>
<td>Late soft dough</td>
<td>Early kernel watery</td>
</tr>
<tr>
<td></td>
<td>5/05</td>
<td>Physiological maturity</td>
<td>---</td>
</tr>
<tr>
<td></td>
<td>5/11</td>
<td>Straw dead except lodged</td>
<td>Soft dough</td>
</tr>
<tr>
<td></td>
<td>5/27</td>
<td>Harvest ripe</td>
<td>Physiological maturity – 3 days</td>
</tr>
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</table>

Table 5. Grain yields for the varieties planted at two dates at Maricopa.

<table>
<thead>
<tr>
<th>Planting date</th>
<th>Barcott</th>
<th>Baretta</th>
<th>Max</th>
<th>Mucho</th>
<th>Duraking</th>
<th>Kronos</th>
<th>Orita</th>
<th>WPB 881</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>lbs/acre</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dec 3</td>
<td>4473</td>
<td>6153</td>
<td>7261</td>
<td>5160</td>
<td>6506</td>
<td>6078</td>
<td>6264</td>
<td>6244</td>
</tr>
<tr>
<td>Jan 7</td>
<td>3131</td>
<td>3990</td>
<td>3741</td>
<td>3330</td>
<td>3886</td>
<td>3115</td>
<td>3538</td>
<td>4087</td>
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</table>
Table 6. Crop coefficients calculated for various growth periods for the two plantings at Maricopa.

<table>
<thead>
<tr>
<th>Growth period</th>
<th>Barley</th>
<th>Durum</th>
<th>Barley</th>
<th>Wheat</th>
<th>All</th>
<th>LSD .05</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Barcott</td>
<td>Baretta</td>
<td>Max</td>
<td>Mucho</td>
<td>Dural King</td>
<td>Kronos</td>
</tr>
<tr>
<td>Dec 3 planting</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12/22-1/28</td>
<td>0.459</td>
<td>0.394</td>
<td>0.454</td>
<td>0.456</td>
<td>0.404</td>
<td>0.394</td>
</tr>
<tr>
<td>2/2-2/20</td>
<td>1.052</td>
<td>1.022</td>
<td>0.975</td>
<td>0.897</td>
<td>1.018</td>
<td>0.996</td>
</tr>
<tr>
<td>3/4-3/17</td>
<td>1.252</td>
<td>0.967</td>
<td>1.112</td>
<td>1.107</td>
<td>1.057</td>
<td>1.052</td>
</tr>
<tr>
<td>3/22-3/31</td>
<td>1.107</td>
<td>1.145</td>
<td>1.229</td>
<td>1.157</td>
<td>1.099</td>
<td>1.028</td>
</tr>
<tr>
<td>4/6-4/15</td>
<td>1.030</td>
<td>1.116</td>
<td>1.217</td>
<td>1.053</td>
<td>1.114</td>
<td>1.053</td>
</tr>
<tr>
<td>4/22-4/29</td>
<td>0.711</td>
<td>0.849</td>
<td>1.080</td>
<td>0.792</td>
<td>1.063</td>
<td>1.100</td>
</tr>
<tr>
<td>5/6-5/20</td>
<td>0.410</td>
<td>0.449</td>
<td>0.572</td>
<td>0.373</td>
<td>0.118</td>
<td>0.110</td>
</tr>
<tr>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Jan 7 planting</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2/2-2/20</td>
<td>0.393</td>
<td>0.374</td>
<td>0.454</td>
<td>0.360</td>
<td>0.392</td>
<td>0.353</td>
</tr>
<tr>
<td>3/4-3/17</td>
<td>1.063</td>
<td>0.957</td>
<td>1.090</td>
<td>0.921</td>
<td>1.175</td>
<td>1.154</td>
</tr>
<tr>
<td>3/22-3/31</td>
<td>1.168</td>
<td>1.203</td>
<td>1.284</td>
<td>1.142</td>
<td>1.239</td>
<td>1.229</td>
</tr>
<tr>
<td>4/6-4/15</td>
<td>1.186</td>
<td>1.213</td>
<td>1.285</td>
<td>1.147</td>
<td>1.263</td>
<td>1.216</td>
</tr>
<tr>
<td>4/22-4/29</td>
<td>1.180</td>
<td>1.132</td>
<td>1.336</td>
<td>0.866</td>
<td>1.096</td>
<td>1.084</td>
</tr>
<tr>
<td>5/6-5/13</td>
<td>0.656</td>
<td>0.707</td>
<td>0.775</td>
<td>0.546</td>
<td>0.594</td>
<td>0.476</td>
</tr>
<tr>
<td>5/13-5/26</td>
<td>0.181</td>
<td>0.037</td>
<td>0.074</td>
<td>0.104</td>
<td>0.019</td>
<td>0.190</td>
</tr>
</tbody>
</table>

Table 7. Crop coefficients calculated for various growth periods for the two plantings at Yuma.

<table>
<thead>
<tr>
<th>Time period</th>
<th>Dec 29 planting</th>
<th>Feb 13 planting</th>
</tr>
</thead>
<tbody>
<tr>
<td>3/4 - 3/9</td>
<td>0.885</td>
<td>0.560</td>
</tr>
<tr>
<td>3/18 - 3/24</td>
<td>1.039</td>
<td>0.819</td>
</tr>
<tr>
<td>3/31 - 4/7</td>
<td>1.185</td>
<td>1.127</td>
</tr>
<tr>
<td>4/13 - 4/21</td>
<td>1.039</td>
<td>0.818</td>
</tr>
<tr>
<td>4/26 - 5/5</td>
<td>0.616</td>
<td>---</td>
</tr>
<tr>
<td>5/11 - 5/27</td>
<td>0.193</td>
<td>0.618</td>
</tr>
</tbody>
</table>