Title: Safflower Oilseed Production under Deficit Irrigation and Variable N Fertilization

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Graduate Students: none

Technical Support: Partial Funding - Time slip

Duration: 3 years

Background: The production of oilseed crops represents a unique opportunity for PNW producers to provide a biodiesel feedstock for an emerging renewable energy industry. The inclusion of oilseeds in rotation offers producers an alternative strategy to improve farm economies and gain additional benefits that improve soil and water conservation, reduce pest cycles, and diversify cropping systems. In addition to the Nations’ transportation needs a likely market for alternative fuels is within agriculture itself. Low-cost alternative fuels can be used to power farm equipment and small agricultural production and processing facilities within rural communities. A Pacific Northwest biofuel industry has the potential for assisting rural and farm development, aiding our national security through increased reliance on domestic renewable energy, and mitigating environmental concerns such as greenhouse gas emissions. For example, biodiesel is an EPA approved renewable fuel that can be produced either from regionally farmed oilseed crops or from recycled vegetable and animal fats. Development of biodiesel crushing and processing plants within the region could effectively add to state and, in particular, rural and farm economies by utilizing area commodities through the creation of a new job related infrastructure.

Biodiesel has been made from soybeans, sunflower seed, cottonseed, canola and rape seed, crambe, safflower, flaxseed, and mustard seed. Currently, soybeans are the most commonly used fuel feedstock in the U.S., where rapeseed is the primary feedstock in Europe. Safflower (Carthamus tinctorius) belongs to the Compositae family and can be used for food, flower arrangements, medicine or dye. Safflower can tolerate extreme weather conditions. It is considered a low input and drought tolerant crop, but responds well with irrigation and fertilizers. It is planted in early spring and reaches maturity in about 5 months in Washington. Oilseed yield is about 3000 to 3500 lbs with oil concentrations of 42 to 48% dependent on variety.

Objectives: To determine: 1) Varietal responses of safflower to deficit irrigation and N fertilization under center pivot irrigation, 2) oil production and quality under deficit irrigation and N fertilization. Note: Economic analyses will be conducted in the third year if funding allows.

Methods: The second year of the three year study was conducted at the USDA-ARS Integrated Cropping Systems Research Field Station near Paterson, Benton County, WA (45°56’N, 119°29’W; 114 m above sea level) on a Quincy sand (Xeric Torripsamments) containing 4 g kg⁻¹ of organic C and 0.37 g N kg⁻¹. The area is characterized by an annual average precipitation of 178 mm,
mostly occurring as rain/snow mix during winter months, making supplemental irrigation necessary. The surface soil (0-15 cm) has a bulk density of 1.33 kg m$^{-3}$, a sand and silt content of 917 and 56 g kg$^{-1}$, and a pH of 6.7.

Two safflower (*Carthamus tinctorius* L.) varieties, S345 and CW99OL, were planted in April 2008 and 2009 under center pivot irrigation. The experimental design was a strip-split plot with four replications. The main plot consisted of safflower variety; splits were irrigation and fertilization rate. In April 2008 and 2009 the field received a blended dry granular fertilizer containing 64 kg P$_2$O$_5$ ha$^{-1}$, 220 kg K$_2$O ha$^{-1}$, 22 kg S ha$^{-1}$, and 1.3 kg B ha$^{-1}$ applied with a tractor using a Barber™ spreader. Each cultivar was planted at a seeding rate of 56 kg seed ha$^{-1}$ with a Tye grain drill. Fertilizer treatments consisted of four split N application rates (at approximately two week intervals), the low rate treatment received four 28 kg N ha$^{-1}$ (for a total in-season rate of 112 kg N ha$^{-1}$ yr$^{-1}$), the high rate treatment received 28 kg N ha$^{-1}$ on April 28 and three applications of 45 kg N ha$^{-1}$ (for a total in-season rate of 162 kg N ha$^{-1}$ yr$^{-1}$). Irrigation treatments were 90 and 70% of ET with approximate in-season (May-September) applications of 75 and 58 cm of irrigation, respectively. Water use will be analyzed from measurements of soil water status using neutron probe accounting procedures. The 2008 and 2009 irrigation applications and water use are currently being analyzed. Safflower yield of each treatment was determined by harvesting a 1.2 by 9 m area with a Wintersteiger plot combine. Oil analyses were determined by an independent laboratory in 2008. Oil analyses are pending for the 2009 crop year.

**Results:**

- Safflower oilseed yields averaged 3220 kg ha$^{-1}$ in 2008 and 2286 kg ha$^{-1}$ in 2009 for all treatments under center pivot irrigation on the Quincy sand soil type.
- Safflower oilseed yields were significantly lower in 2009 than 2008 (-1000 kg ha$^{-1}$) due to a high density of hairy nightshade within the fields – poor weed control.
- Safflower oilseed yields were significantly higher (+224 kg yield ha$^{-1}$) under the 112 than 162 kg N ha$^{-1}$ fertilizer rate in 2008, indicating low N rates (<112 kg ha$^{-1}$) are viable.
- Safflower oilseed yields were not significantly different between the 90 and 70% ET treatments, indicating a potential 17 cm water savings using a deficit irrigation strategy. Water use efficiencies among varieties are currently being determined.
- Varieties showed significant differences to deficit irrigation and N fertilization.
  - Both varieties had higher yields (~200 - 600 kg ha$^{-1}$) under the 70% of ET irrigation and 112 kg N ha$^{-1}$ fertilizer regimes.
  - The S345 variety had significantly greater oilseed yields (~300 kg ha$^{-1}$) at the 70% of ET irrigation and 112 kg N ha$^{-1}$ regimes than the CW99OL variety in 2008 but were not different in 2009 (Table 1).
- Oil yield of each variety for the 2008 CY by treatment showed that at 70% ET and 112 kg ha$^{-1}$ rate oil contents were 4-5% greater than the high irrigation and fertilizer rates. Quality analyses of the oil are currently being evaluated.
Table 1. Safflower oilseed yields for S345 and CW99OL varieties under variable fertilizer and irrigation rates.

<table>
<thead>
<tr>
<th>Variety</th>
<th>Fertilizer Rate</th>
<th>Irrigation Rate</th>
<th>CY2008 Yield</th>
<th>CY2009 Yield</th>
<th>Oil Yield</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>kg N ha(^{-1})</td>
<td>% of ET</td>
<td>kg ha(^{-1})</td>
<td>%</td>
<td>kg ha(^{-1})</td>
</tr>
<tr>
<td>CW99OL</td>
<td>162</td>
<td>90</td>
<td>3084 a</td>
<td>35</td>
<td>2160 a</td>
</tr>
<tr>
<td></td>
<td>162</td>
<td>70</td>
<td>3026 a</td>
<td>38</td>
<td>1975 a</td>
</tr>
<tr>
<td></td>
<td>112</td>
<td>90</td>
<td>3103 a</td>
<td>38</td>
<td>2274 a</td>
</tr>
<tr>
<td></td>
<td>112</td>
<td>70</td>
<td>3250 ab</td>
<td>40</td>
<td>2517 ab</td>
</tr>
<tr>
<td>S345</td>
<td>162</td>
<td>90</td>
<td>3017 a</td>
<td>36</td>
<td>2663 b</td>
</tr>
<tr>
<td></td>
<td>162</td>
<td>70</td>
<td>3326 ab</td>
<td>38</td>
<td>2128 a</td>
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<td></td>
<td>112</td>
<td>90</td>
<td>3370 ab</td>
<td>38</td>
<td>2077 a</td>
</tr>
<tr>
<td></td>
<td>112</td>
<td>70</td>
<td>3557 b</td>
<td>40</td>
<td>2494 ab</td>
</tr>
</tbody>
</table>

ET - evaporation/transpiration. Means followed by the same letter are not significantly different at p<0.5.

**Impact/Potential Outcome:** The results of this research will provide production information under deficit irrigation and N fertilization under center pivot irrigation. This research will result in information delivered to growers on the agronomic practices needed to successfully produce safflower as well as the chemical composition of the oil as a biodiesel feedstock and identification of components of the oil that may have greater value for other uses, such as nutraceuticals. In addition energy producers will use this information to adjust energy production goals. This data will also be useful in the development of secondary markets such as C-credit trading following a Life Cycle Analysis.

**Outreach:** Dr. An Hang gave a presentation describing the study at the USDA-ARS Paterson Integrated Cropping Systems Field Day on July 9, 2008.

**Publications:** Abstract- Dr. An Hang presented results at the 2008 ASA meetings in Houston, TX, October 2008.

**Future plans:** The study will be completed following the 2010 growing season. Economic analyses will be conducted in the third year if sufficient funding is available. In that event we would use Enterprise Budgets developed by Washington State University and information provided by cooperating growers to determine the economic viability of safflower production for the developing biodiesel industry. The economics of a safflower bioenergy crop using deficit irrigation and N fertilizer would be analyzed using standard accounting procedures for farm management cost and return estimates. Potential safflower growers will be able to use a spreadsheet format based from this information for easier decision-making (see [http://www.farm-mgmt.wsu.edu/Excel-docs/eb2009E.xls](http://www.farm-mgmt.wsu.edu/Excel-docs/eb2009E.xls)).