Measuring roots, *in situ*, of *Centaurea solstitialis* and two late summer perennial plant species, *Grindelia camporum* and *Elymus glaucus*

Steve Young, Vic Claassen and Joe DiTomaso - LAWR and Plant Sciences Departments - University of California, Davis
California Grasslands – history and dynamics

Past to Present:

• Decline in native species - aggressive non-natives
• Large-scale replacement of natives by exotic species
  – Introduction of non-native seed
  – Overgrazing
  – Periods of drought
  – Fire suppression
• Total grasslands in California = 9.2 million ha and native grasslands < 800,000 ha (~9%)
Root morphology

Occupation of Soil Space
- Root density
- Surface area
- Rooting depth

Overlap of Neighboring Root Systems

Mycorrhizae

Spatial and Temporal Partitioning
- Taproot
- Fibrous root

Physiological Attributes
Underground dynamics of plants in CA – Spring

- Centaurea
- Grindelia
- Elymus

CO₂ flux

CO₂ concentration
Underground dynamics of plants in CA – Summer

- *Centaurea*
- *Grindelia*
- *Elymus*

**CO₂ flux**

**CO₂ concentration**

**H₂O**
Underground dynamics of plants in CA – Fall

Centaurea

Grindelia

Elymus

H2O

CO2 flux

CO2 concentration

Underground dynamics of plants in CA – Fall

Centaurea

Grindelia

Elymus

H2O

CO2 flux

CO2 concentration
Underground dynamics of plants in CA – Winter

- Centaurea
- Grindelia
- Elymus

CO$_2$ flux

CO$_2$ concentration

H$_2$O
Field studies were conducted with above- and belowground measurements to better understand resource allocation and timing of late season plant species.
Plot scale

Soil atmosphere probe ([CO₂])

Roots
Soil °C
Soil [CO₂]
Soil [CO₂]
Soil water
Root growth - methods

Root chamber

– viewing window below the soil surface
– vertical area covers approximately 2 m²
Root growth - methods

• Weekly root counts
  – First root appearance (February 21, 2006)
  – Final root senescence (November 1, 2006)
Centaurea root distribution at 30 cm

roots/cm²

Spring rain: 4/16

Fall rain: 11/1

2/7/06 4/27 6/1 11/1/06

- Rosette (2/7)
- Bolt (5/24)
- Bud (6/7)
- Flower (7/5)
- Seed (8/23)
Centaurea root distribution at 180 cm

roots/cm²

2/7/06 4/27 5/25 6/1 6/15 7/5 8/23 11/1/06

Rosette (2/7) Bolt (5/24) Bud (6/7) Flower (7/5) Seed (8/23)
Grindelia root distribution at 30 cm

- Bud (5/24)
- Flower (6/14)
- New shoots (10/17)
- Seed (11/1)

Fall rain: 11/1
Grindelia root distribution at 180 cm

- **Bud (5/24)**
- **New shoots (10/17)**
- **Flower (6/14)**
- **Seed (11/1)**

Y-axis: roots/cm²

X-axis: Dates from 2/7/06 to 11/1/06
Elymus root distribution at 30 cm

Fall rain: 11/1

New shoots

Seed
Elymus root distribution at 180 cm

roots/cm²

New shoots

Elymus root distribution at 180 cm

roots/cm²

New shoots

Elymus root distribution at 180 cm

roots/cm²

New shoots

Elymus root distribution at 180 cm

roots/cm²

New shoots

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Elymus root distribution at 180 cm

roots/cm²

New shoots

Elymus root distribution at 180 cm

roots/cm²
### Centaurea peak roots at 4 depths

<table>
<thead>
<tr>
<th>Data</th>
<th>30 cm</th>
<th>60 cm</th>
<th>120 cm</th>
<th>180 cm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rosette</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(4/27)</td>
<td>0.75</td>
<td>0.72</td>
<td>0.66</td>
<td>0.54</td>
</tr>
<tr>
<td>Bolting</td>
<td></td>
<td></td>
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<tr>
<td>(5/24)</td>
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<td></td>
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<tr>
<td>(5/24)</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Spiney</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>(6/14)</td>
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</tr>
</tbody>
</table>

- **Roots** (#/cm²)
- **Water** (%)
- **CO₂** (µg C)
## Grindelia peak roots at 4 depths

<table>
<thead>
<tr>
<th>Data</th>
<th>30 cm</th>
<th>60 cm</th>
<th>120 cm</th>
<th>180 cm</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Flowering</strong></td>
<td>(6/14*)</td>
<td>(6/14*)</td>
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<td>(6/14*)</td>
</tr>
<tr>
<td>Roots (#/cm²)</td>
<td>0.41</td>
<td>0.47</td>
<td>0.87</td>
<td>0.25</td>
</tr>
<tr>
<td>Water (%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CO₂ (µg C)</td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

*transplanted on 2/20/06
### Elymus peak roots at 4 depths

<table>
<thead>
<tr>
<th>Data</th>
<th>30 cm</th>
<th>60 cm</th>
<th>120 cm</th>
<th>180 cm</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Vegetative</strong> (4/19)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Vegetative</strong> (5/3)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Seeding</strong> (5/24)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Seeding</strong> (8/30)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Roots (#/cm²)</td>
<td>0.89</td>
<td>0.64</td>
<td>0.38</td>
<td>0.40</td>
</tr>
<tr>
<td>Water (%)</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>CO₂ (μg C)</td>
<td></td>
<td></td>
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</tbody>
</table>
Root activity - methods

• Soil moisture
  – Frequency: weekly
  – Method: Neutron probe at 30, 60, 120, 180 cm

• Soil [CO₂]
  – Frequency: weekly
  – Method: Soil atmosphere probes at 30, 60, 120 cm*

• Soil temperature
  – Frequency: bi-hourly
  – Method: HOBO™ data loggers at 30, 60, 120 cm

Soil water in 2006

- 30 cm
  - GRI 30cm
  - ELY 30cm
  - YST 30cm
  - CON 30cm

- 60 cm
  - GRI 60cm
  - ELY 60cm
  - YST 60cm
  - CON 60cm

- 120 cm
  - GRI 120cm
  - ELY 120cm
  - YST 120cm
  - CON 120cm

- 180 cm
  - GRI 180cm
  - ELY 180cm
  - YST 180cm
  - CON 180cm

Graphs show the percentage of water (% H2O) over time from March 29 to October 25 for depths of 30 cm, 60 cm, 120 cm, and 180 cm.
<table>
<thead>
<tr>
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<td><strong>Roots</strong></td>
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<tr>
<td>(#/cm²)</td>
<td>33</td>
<td>16</td>
<td>18</td>
<td>14</td>
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<tr>
<td><strong>Water</strong></td>
<td></td>
<td></td>
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<tr>
<td>(%)</td>
<td>33</td>
<td>25</td>
<td>24</td>
<td>25</td>
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<tr>
<td><strong>CO₂</strong></td>
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<td>12</td>
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<td>CO₂ (μg C)</td>
<td>28</td>
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### Elymus peak roots at 4 depths

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<td>CO₂ (μg C)</td>
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Soil $[\text{CO}_2]$ in 2006

![Graphs showing soil CO$_2$ levels at 30 cm, 60 cm, and 120 cm depths over time from 3/29 to 11/1.](image)
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<td></td>
</tr>
<tr>
<td>CO$_2$ (μg C)</td>
<td>36</td>
<td>22</td>
<td>24</td>
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<tr>
<td>Roots (#/cm$^2$)</td>
<td>16</td>
<td>20</td>
<td>11</td>
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### Elymus peak roots at 4 depths

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</tr>
<tr>
<td>CO₂ (μg C)</td>
<td>Seeding (5/24)</td>
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<td>22</td>
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<td></td>
<td>Seeding (8/30)</td>
<td>16</td>
<td>15</td>
<td>11</td>
</tr>
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</table>
Summary - root growth

• **Centaurea**
  – Peak coincided with earlier phenological development.
  – Decline from flowering to seeding.

• **Grindelia**
  – Peak at all depths occurred early summer.
  – Growth continued at deep depths.

• **Elymus**
  – Peak occurred later at deeper depths with decline only at shallow depths.
Summary - root activity

- Peak soil moisture depletion
  - **Centaurea**
    - shallow: rosette to bolt (31% loss)
    - deep: bolt to bud (24-27% loss)
  - **Grindelia**
    - Similar to Centaurea
  - **Elymus**
    - Shallow similar to Centaurea
    - Deep > 10% (SWC) late in season

- Peak soil $[\text{CO}_2]$  
  - **Centaurea, Grindelia, and Elymus**
    - Occurred early in season
## Root conclusions

### Belowground life cycle

<table>
<thead>
<tr>
<th>Phases</th>
<th>CEN</th>
<th>GRI*</th>
<th>ELY</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>deep</td>
<td>shallow</td>
<td>deep</td>
</tr>
<tr>
<td>Construction</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(peak [CO₂])</td>
<td>Ros</td>
<td>Ros</td>
<td>Veg</td>
</tr>
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<td></td>
<td></td>
<td></td>
<td>Veg</td>
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<td></td>
<td></td>
<td></td>
<td>Veg</td>
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<tr>
<td>Resource acquisition</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>(↓% SWC)</td>
<td>Bol</td>
<td>Bud</td>
<td>Veg</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Veg</td>
</tr>
<tr>
<td>Termination</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>(↑% dead roots)</td>
<td>Bud</td>
<td>Flower</td>
<td>?</td>
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<td>?</td>
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</tbody>
</table>

*2007 data*
Root implications

• *Centaurea* control
  – Control early (before loss in SWC)
    • Reduce impact on desirable species

• *Grindelia* and *Elymus* establishment
  – Adequate soil water content
    • Location (slope, aspect, root depth)
    • Soil conditions (texture, structure, nutrients)
  – Precipitation patterns (‘dry’ vs ‘wet’ years)
    • Planting date
    • Weed control (see above)
Questions?