Non-Chemical Weed Control in Rice Systems

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Weeds in California Rice

• Can reduce yields by as much as 50%-100%, if uncontrolled
• Particularly problematic in systems where the same crop is planted in a similar fashion, year after year
  • California rice: flooded, without rotation, for 100 years
• Most weed control:
  • Combination of flooding and herbicides
Grasses

- Late watergrass
- Early watergrass
- Barnyardgrass
- Sprangletop
# Sedges & broadleafs

<table>
<thead>
<tr>
<th>Smallflower umbrella sedge</th>
<th>Ricefield bulrush</th>
<th>Redstem</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arrowhead</td>
<td>Water plantain</td>
<td></td>
</tr>
</tbody>
</table>

**Images:**
- Smallflower umbrella sedge
- Ricefield bulrush
- Redstem
- Arrowhead
- Water plantain
Weedy Rice: 7 biotypes

Photos: Timothy Blank, CCIA
Major Principles of Weed Management:

1) Managing weed seedbank (reducing)
2) Preventing more seeds from being deposited in the seedbank
3) Knowing the "critical period of competition" – for each weed (most yield damage)
Ed Zaborski, University of Illinois (adapted from Altieri, 1995).
“Many little hammers.............”

Pesticides
Cultural
Mechanical
Sanitary
Biological
Host Plant Resistance

NOTE:
Some practices may fall into several categories
What is “Cultural Control”?  

Agronomic practices that:

- Optimize growing conditions for the crop
- Create unfavorable conditions for the pest
Cultural Control Examples

• Irrigation:
  • Example: flooding suppresses some weed species (i.e. rice)
  • Example: drip irrigation waters only area around crop roots

• Burning residues:
  • Example: can kill some large weed seeds
  • UNKNOWN how well this works in rice

• Tillage:
  • Shallow tillage can disturb shallow-rooted annuals
What is Mechanical Control?

Uses machinery and/or other tools to control pests:

- Tillage
- Physical barriers (black plastic, mulch)
What is Sanitary Control?

Methods to avoid introducing a pest into a field:

– Cleaning field equipment

– Planting certified seed

– Quarantines
Use of Non-Chemical Controls in Rice

1. Winter Flooding
2. Stale Seedbed
3. Irrigation Management
4. Crop rotation or fallow
5. Sanitation

6. Cover crops?
7. Burning?
Winter flooding

- Seed viability of weedy rice (WD-3) and cultivated rice (Hopum) after wintering on the surface of a paddy field
- November 2008 to April 2009

- Does this work for other weed species?
  - Unknown at this time
  - Likely similar pattern for large-seeded weeds (watergrass)

Baek and Chung, 2012
A) Seed viability on a dry paddy

B) Seed viability on a flooded paddy

Baek and Chung, 2012
Stale (False) Seedbed
Stale Seedbed: Application in Rice

• Field flooded and then water was allowed to subside

• Timing of application based on GDD predictions for late watergrass

• Sprayed glyphosate 12 Days After beginning of watering based on :
  • Predicted 90% emergence for Flood:
    • 154 GDD
Late Watergrass

Weed Emergence (%) vs. Growing Degree Days (GDD in °C d)

- 75% germination corresponds to 12 Days After Watering
- Observed data points
Stale Seedbed

Conventional Flood
Weed Emergence (%)

Growing Degree Days (GDD in °C d)

Smallflower Umbrella Sedge

Observed

67% germination

12 Days After Watering

300
Weed Emergence (%) vs. Days After Watering for Ricefield Bulrush.
Stale Seedbed

• Instead of using a chemical method (glyphosate), tillage could also be used
  • Must be shallow tillage, to ensure that more weed seeds are not brought to the surface

• Alternatively, could be used during a fallow season:
  • Repeated flushing and tilling

• Most effective for watergrass/barnyardgrass species
Irrigation Management

• Alternative irrigation methods:
  • Dry-seeding (using a drill) vs. wet-seeding
  • No permanent flood (flush irrigation)
  • Systems from other parts of the world:
    • Alternate Wetting and Drying (AWD)

• Why? Different weeds germinate under different irrigation systems
A

DRILL-SEEDED ALTERNATE WET DRY

Drill-Seed, Flush
Flowering

Tiller initiation
Tillering
Panicle initiation

B

WATER-SEEDED ALTERNATE WET DRY

Flood, Seed
Flowering

Tiller initiation
Tillering
Panicle initiation

C

WATER-SEEDED CONTROL

Flood, Seed
Flowering

Tiller initiation
Tillering
Panicle initiation
Experimental Setup

0.22 ha

Weedy Sections

DS-AWD = Drill-Seeded Alternate Wet Dry
WS-AWD = Water-Seeded Alternate Wet Dry
WS-Control = Water-Seeded Control
DRILL-SEEDED ALTERNATE WET DRY

Drill-Seed, Flush
Flowering
Tiller initiation
Tillering
Panicle initiation

WATER-SEEDED ALTERNATE WET DRY

Flood, Seed
Flowering
Tiller initiation
Tillering
Panicle initiation

WATER-SEEDED CONTROL

Flood, Seed
Flowering
Tiller initiation
Tillering
Panicle initiation
Within-Season Differences: Smallflower and Watergrass

% Cover at Tillering

Note: Different letters indicate significant differences at $P < 0.05$
Frequency: Smallflower Umbrella Sedge

* P < 0.05

Brim-DeForest et al. 2017
Yields – Weedy vs Weed-Free

Note: Different letters indicate significant differences at P < 0.05

Brim-DeForest et al. 2017
Conclusions

• Water-seeded systems dominated by grasses, sedges and broadleaves
• Dry-seeded system dominated by grasses
• Due to 100% yield losses, DS-AWD is only a viable option with excellent weed control
• WS-AWD may be a viable means to reduce water usage while maintaining yields and weed control
  • Increase in smallflower umbrella sedge in WS-AWD system compared to WS-Control
Timing of Emergence
Species-Specific Emergence Data Under Variable Irrigation Systems
Watergrass Complex (mimic)

• Rapid emergence (most plants emerge around the same time)
• Emerges under all irrigation systems
Watergrass (Flooded)

Weed Emergence (%) vs. Growing Degree Days (GDD in °C d)

- 2013 Observed
- 2014 Observed
Weed Emergence (%)

Growing Degree Days (GDD in °C d)

2013 Observed
2014 Observed
Watergrass Complex (mimic)

The graph shows the change in density (Plants 0.25 m$^{-2}$) over days after seeding under flooded and dry conditions. The graph compares WS-Control and DS-AWD conditions.

- **Flooded conditions**
- **Dry conditions**
Sprangletop

- Emerges under both dry and wet-seeded conditions
- Later emergence initiation in wet-seeded
Sprangletop

Density (Plants 0.25 m$^{-2}$) vs. Days After Seeding

- **WS-Control**
- **DS-AWD**

Dry conditions

Flooded conditions
Ricefield Bulrush

• Prolonged emergence period
• Emerges only under flooded conditions
Weed Emergence (%)

Days After Watering

Ricefield Bulrush

90% emergence

Observed
Ricefield Bulrush

Density (Plants 0.25 m\(^{-2}\))

Days After Seeding

- **WS-Control**
- **DS-AWD**

Flooded conditions

Dry conditions
Smallflower Umbrella Sedge

- Evidence of biphasic emergence
  - “Second flush”
- Greater numbers of plants emerge under flooded conditions than dry-seeded
Weed Emergence (%)

Growing Degree Days (GDD in °C d)

Smallflower Umbrella Sedge (Flooded)

- 2013 Observed
- 2014 Observed
Biphasic Emergence

• Indicative of two biotypes in the field:
  • One germinates quickly
    • Low dormancy
  • One germinates more slowly
Smallflower Umbrella Sedge

Days After Seeding

Density (Plants 0.25 m\(^{-2}\))

- WS-Control
- DS-AWD

Flooded conditions

Dry conditions
Ducksalad

- No plants by end of season (lifecycle ends)
Redstem

- Emergence begins around canopy closure

![Graph showing Redstem emergence under different conditions. The graph plots Days After Seeding on the x-axis and Density (Plants 0.25 m$^{-2}$) on the y-axis. There are two curves: one for WS-Control (dotted line) and one for DS-AWD (dashed line). The graph indicates that emergence is higher under flooded conditions compared to dry conditions.](image-url)
Irrigation: Dry-Down

- For ricefield bulrush control
- Starts with deep flooding (up to 10 inches approx.)
  - Should reduce grass emergence
- Followed by drain
  - Recommendation from Fischer et al. 2010:
    - 34 DAS
- Unsure of average flood duration under field conditions (grower practices)
- Drain period

\[ \text{Relative yield} \]

\[ \text{Proportion of rice to } S. \text{ mucronatus plants} \]

\[ \text{rice (●) bulrush (○)} \]

Fischer et al. 2010
Crop Rotation?

• Not a lot of data on this in California rice
• Mostly anecdotal
• Growers are practicing crop rotation, but how much is unknown
• Effects on weeds, diseases, etc. not quantified

• Initial data collection (small survey) this year (2019)
Methods

• Survey mailed to about 1200 people
  • Used Agricultural Commissioner’s lists

• Emailed to about 800
  • California Rice Commission email lists

• Response rate
  • Roughly 8%

• Trying to obtain information related to management practices and
## Survey Respondents

<table>
<thead>
<tr>
<th>County</th>
<th>Number of farms managed</th>
<th>Average acreage managed</th>
<th>Std Deviation</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Butte</td>
<td>39</td>
<td>754</td>
<td>828</td>
<td>5</td>
<td>300</td>
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<tr>
<td>Sutter</td>
<td>38</td>
<td>1087</td>
<td>1527</td>
<td>28</td>
<td>8500</td>
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<tr>
<td>Yuba</td>
<td>21</td>
<td>597</td>
<td>422</td>
<td>10</td>
<td>1500</td>
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<tr>
<td>Glenn</td>
<td>47</td>
<td>600</td>
<td>1043</td>
<td>24</td>
<td>7000</td>
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<tr>
<td>Colusa</td>
<td>30</td>
<td>991</td>
<td>1923</td>
<td>65</td>
<td>10000</td>
</tr>
<tr>
<td>Placer</td>
<td>10</td>
<td>415</td>
<td>224</td>
<td>95</td>
<td>900</td>
</tr>
<tr>
<td>Sacramento</td>
<td>9</td>
<td>295</td>
<td>253</td>
<td>40</td>
<td>925</td>
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<tr>
<td>Yolo</td>
<td>16</td>
<td>1837</td>
<td>2530</td>
<td>10</td>
<td>10000</td>
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<tr>
<td>San Joaquin</td>
<td>2</td>
<td>1100</td>
<td>0</td>
<td>1100</td>
<td>1100</td>
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</table>
Survey Respondents

<table>
<thead>
<tr>
<th>Grower Demographic</th>
<th>n</th>
<th>%</th>
<th>Acreage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rice Grower</td>
<td>145</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pest Control Advisor (PCA)</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Both Rice grower and PCA</td>
<td>6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>3</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>n</th>
<th>%</th>
<th>Acreage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grew organic rice</td>
<td>11</td>
<td>7.6%</td>
<td>2514</td>
</tr>
<tr>
<td>Do not grow organic rice</td>
<td>134</td>
<td>92.4%</td>
<td>1050</td>
</tr>
</tbody>
</table>

Average Age 58
Std deviation 13
Min 25
Max 92
## Crop Rotation

<table>
<thead>
<tr>
<th>Crop rotation</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td># of responses</td>
<td>139</td>
</tr>
<tr>
<td>% did in 2018</td>
<td>12.2%</td>
</tr>
<tr>
<td>Average acreage</td>
<td>965</td>
</tr>
<tr>
<td>Std deviation</td>
<td>989</td>
</tr>
</tbody>
</table>

Most common crops rotated:
- Sunflowers (10)
- Tomatoes (8)
- Wheat (5)
- Safflower (4)
- Vetch
- Corn
- Bell beans
- Forage hay
- Oatseed
- Pea seed
- Vineseed
- Melons
- Grain
- Dry beans
- Barley
- Wild rice
- Fallow
Crop Rotation

Participants who did not rotate crops (87.8%):

• Soil type (79)
• Field layout (48)
• Marketability of rotation crops (46)
• Lack of equipment/resources (32)
• Landlord/lease agreements
• Small acreage
• Water shortages or flooding
• Alternative winter land use (e.g. duck hunting)
Why Crop Rotation in rice?

• Allows for dry conditions
  • Different weed species emerge
• Can utilize tillage in some crops (not possible during the season in rice)
• Should reduce weed seed bank over time
• Unknown number of years or crops that will maximize weed seed reduction
<table>
<thead>
<tr>
<th>WEED OUTCOME</th>
<th>YEAR 1</th>
<th>YEAR 2</th>
<th>YEAR 3</th>
<th>YEAR 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Poor</td>
<td><img src="corn1.png" alt="Corn" /></td>
<td><img src="corn2.png" alt="Corn" /></td>
<td><img src="corn3.png" alt="Corn" /></td>
<td><img src="corn4.png" alt="Corn" /></td>
</tr>
<tr>
<td>Fair</td>
<td><img src="corn1.png" alt="Corn" /></td>
<td><img src="soybean1.png" alt="Soybean" /></td>
<td><img src="corn3.png" alt="Corn" /></td>
<td><img src="soybean4.png" alt="Soybean" /></td>
</tr>
<tr>
<td>Better</td>
<td><img src="corn1.png" alt="Corn" /></td>
<td><img src="wheat1.png" alt="Wheat" /></td>
<td><img src="soybean3.png" alt="Soybean" /></td>
<td><img src="soybean4.png" alt="Soybean" /></td>
</tr>
<tr>
<td>Best</td>
<td><img src="corn1.png" alt="Corn" /></td>
<td><img src="wheat1.png" alt="Wheat" /></td>
<td><img src="soybean3.png" alt="Soybean" /></td>
<td><img src="alfalfa.png" alt="Alfalfa" /></td>
</tr>
</tbody>
</table>
Cover Cropping

• Currently used in rice for adding nitrogen (and biomass/carbon) to the soil

• Planted in the fall, tilled under in the spring

• Can it be used for weed control?
Typical rice cover crop

Rice season weed emergence

At the end of January, fields drained and allowed to dry.

Preparing fields for planting in March by plowing to "open" the ground to facilitate faster drainage.

Seed bed preparation begins in late March/early April using discs to break clods.

The final steps of seedbed preparation take place in late April/early May: fields leveled, rolled, and fertilizer applied.

Once the seedbed is ready, fields are flooded and aerial seeded with presoaked rice seed.

The first 30-40 days focus on good crop establishment and weed control.

Rice cover crops can help reduce weed emergence.

Rice straw is generally incorporated into the field after harvest. If there are disease problems, rice straw may be burned.

The crop is harvested in September and October.

Fields drained mid to late August.

Early August rice in many fields is flowering (or heading) with the panicle visible.
When to use

• Cover crop season before not overwinter
• Can use cover crop for weed suppression if planted April-May
• Similar effects to crop rotation
Current use of non-chemical methods in rice

• Not a lot is known....
• Some preliminary data from our survey
• DID NOT include cover cropping
• Unfortunately, hard to correlate the data with county, since many growers farmed over multiple counties
• Respondents = approximately 6% of rice growers
• Planning to redo this survey every 5 to 10 years, should give a better picture of farming practices
# Growers: Practice

<table>
<thead>
<tr>
<th></th>
<th>Drill /dry seeding</th>
<th>Winter flooding</th>
<th>Burning</th>
<th>Stale seedbed</th>
<th>Crop rotation</th>
</tr>
</thead>
<tbody>
<tr>
<td># of responses</td>
<td>152</td>
<td>151</td>
<td>150</td>
<td>143</td>
<td>139</td>
</tr>
<tr>
<td>% did in 2018</td>
<td>9.2%</td>
<td>82.8%</td>
<td>25.3%</td>
<td>7.0%</td>
<td>12.2%</td>
</tr>
<tr>
<td>Average acreage</td>
<td>756</td>
<td>835</td>
<td>108</td>
<td>272</td>
<td>965</td>
</tr>
<tr>
<td>Std deviation</td>
<td>750</td>
<td>1108</td>
<td>115</td>
<td>321</td>
<td>989</td>
</tr>
</tbody>
</table>

**Duration:** (122 responses)

<table>
<thead>
<tr>
<th>Duration</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;1 Month</td>
<td>3.3%</td>
</tr>
<tr>
<td>1 Month</td>
<td>2.5%</td>
</tr>
<tr>
<td>2 Months</td>
<td>13.1%</td>
</tr>
<tr>
<td>3 Months</td>
<td>56.6%</td>
</tr>
<tr>
<td>4 Months or more</td>
<td>24.6%</td>
</tr>
</tbody>
</table>
Questions?