Flaming: Potential tool for weed management
“UNL - Flame Weeding Team ~ 30 people”

- **Agronomy Department & Haskell Agricultural Lab:**
  - Professor Dr. Stevan Knezevic & Dr. Jon Scott (Weed Technologist)
  - S. Ulloa (PhD student) & Dr. Avishek Datta (Post Doc)
  - Heverton T., Andray D., Claudio C., Jaymo N., Sidnei (Brazil), Marco M. (Italy),
  - Pierre M. (France), Robert Leskovsek (Slovenia), Dr. Tursun N. (Turkey)
  - Dr. Malidza, Igor Elezovic, Strahinja S., Dejan Nedeljkovic, Ana Obradovic. (Serbia)

- **Department of Mechanical Engineering:**
  - Professor Dr. George Gogos, Chris Bruening (MS/PhD student), Brian Neilson, (MS) Jared Miller and Dustin Simpson

- **Organic producers:** Liz Sarno, Mike Ostry, Larry Stanislav, Randy Fendrich, Gerald Humlicek, Paul and Dan Huenefeld, Mark Ramaeker

- **Resulted in:** 20+ publications, >100 abstracts, 2 patents, ~$2 mil in grants
  - Flame Weeding Manual (36 pages, text & pics, PERC website)
Propane-Fueled Flame Weeding in Corn, Soybean, and Sunflower

Executive Summary

Propane-fueled flame weeding provides multiple advantages over chemical and mechanical weed management methods and is effective in both conventional and organic crop production systems. The systems use a propane-fueled burner to expose weed plant tissues to high levels of heat that rapidly change the internal temperature of plant cells and cause plant cells to rupture. The resulting loss of water and denaturing of proteins drastically reduces the weed’s ability to survive and kills the plant. Because propane is nontoxic and does not contaminate ground water, it is an acceptable non-chemical weed control option in organic production and can be used in other locations where herbicide use is undesirable, such as in cities, parks, and other urban settings.

To provide a comprehensive overview of propane-fueled flame weeding, this guide consists of the following chapters:

1. Background: The Need for Alternative Weed Control Methods
2. Introduction to Propane-Fueled Flame Weeding
3. How Propane-Fueled Flame Weeding Works
4. Flame Weeding Equipment Components and Configurations
5. Recommended Propane Dosage at Different Weed Growth Stages
6. Crop Tolerance To Post-Emergent Flame Weeding
How flaming works?

- Thermal energy transfer from the flames to the leaf
  - $\sim 50^\circ C$ (130F) coagulates proteins (enzymes)
  - $\sim 100^\circ C$ (220F) for only 0.1 second = water boiling
  - $\sim 500^\circ C$ for only 0.1 second = cell membrane bursts
  - Coagulation of proteins in the cell and cell wall
  - Cell water evaporates, tissue injury or plant dead
  - Temperature of the flame ranges from 500-1200 C (1000-2500F)
Thumb-print (The evidence)
Evolution of our Flame Weeding Equipment ……
Our research flamers
Open flames = “wasted heat”
Initial Prototype Hood/torch Design

- Increased exposure time at higher temperatures
  - containment of combustion gases
  - optimized air entrainment
4-Row Band/Full Flamer

• Versatile: banded or full flaming, 30” – 38” row widths
  • Electronic Ignition with flame detection
  • Treatment Recipes
FULL FLAMING

Flaming: covers all 30 inches
Propane Dose: 9 GPA (45 kg/ha)
8-row flamer
Electronic Ignition System

- Ignite and extinguish torches remotely
- No more manual ignition and pilot flames
- Safer end-row turns
- Flame detection provides valuable feedback
Banded/Full Flame Weeders

- Versatile: banded or full flaming, 30” – 38” row widths
- Electronic Ignition with flame detection
- LPG tank rated for mobile use
- Treatment Recipes
Hoods - Full Season Adjustability

Closed – Early Season

Open – Late Season
4 Possible Torch/Hood Combinations

2 torch configurations x 2 hood configurations

1. Banded flaming + Fully closed hoods
2. Banded flaming + Partially open hoods
3. Full flaming + Fully closed hoods
4. Full flaming + Partially open hoods
Torch Orientation

Parallel with crop row

Angled down at 30° - 45°

Torch Angle
Torch Configuration

Full Flaming

30 in
Hood Configuration

Fully closed – Early season flaming

Partially open – Late season flaming
Torch Configuration

Banded Flaming

12 in
Banded Flaming
Hoods - Full Season Adjustability

Closed – Early Season

Open – Late Season
Recommended Equipment Setups for given Crop Recipes

**Corn & Sorghum**

**Early Treatment (VE – V4)** – *Banded* flaming with *closed* hoods

**Late Treatment (V5 – V10)** – *Banded* flaming with *open* hoods

**Alternative** – above treatments with Full Flaming when:
- Fields are too wet to cultivate
- Minimize tillage and/or cultivation can injure crop

**Soybeans & Sunflower**

**Early Treatment (VE – VC)** – *Banded* flaming with *closed* hoods

**Late Treatment (Soybean: V4-V5, Sunflower: V8-V10, >18”)**
- *Banded* flaming with *open* hoods

**Alternative** – above treatments with Full Flaming when:
- Fields are too wet to cultivate
- Minimize tillage and/or cultivation can injure crop
# Propane rates in Gallons per acre

<table>
<thead>
<tr>
<th>Pressure (PSI)</th>
<th>Speed (mph)</th>
<th>1</th>
<th>2</th>
<th>4</th>
<th>6</th>
<th>8</th>
<th>10</th>
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</thead>
<tbody>
<tr>
<td>10</td>
<td></td>
<td>10.24</td>
<td>5.12</td>
<td>2.56</td>
<td>1.71</td>
<td>1.28</td>
<td>1.02</td>
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<tr>
<td>20</td>
<td></td>
<td>18.16</td>
<td>9.08</td>
<td>4.54</td>
<td>3.03</td>
<td>2.27</td>
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<tr>
<td>40</td>
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<td>34.00</td>
<td>17.00</td>
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<tr>
<td>50</td>
<td></td>
<td>41.92</td>
<td>20.96</td>
<td>10.48</td>
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<td>60</td>
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<td>49.84</td>
<td>24.92</td>
<td>12.46</td>
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<td>70</td>
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<td>57.76</td>
<td>28.88</td>
<td>14.44</td>
<td>9.63</td>
<td>7.22</td>
<td>5.78</td>
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<td>80</td>
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<td>65.68</td>
<td>32.84</td>
<td>16.42</td>
<td>10.95</td>
<td>8.21</td>
<td>6.57</td>
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<tr>
<td>90</td>
<td></td>
<td>73.60</td>
<td>36.80</td>
<td>18.40</td>
<td>12.27</td>
<td>9.20</td>
<td>7.36</td>
</tr>
</tbody>
</table>
250 gallon LPG tank @ 5 GPA (banded flaming) ≈ 40 acres per fill

Row Width: 30 in

<table>
<thead>
<tr>
<th>Operating Speed - Pressure</th>
<th>Time to Cover 40 Acres (hr) vs. Equipment Size (rows)</th>
</tr>
</thead>
<tbody>
<tr>
<td>mph</td>
<td>psig</td>
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<td>2.0</td>
<td>15</td>
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<td>2.5</td>
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<td>4.0</td>
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<td>4.5</td>
<td>40</td>
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<tr>
<td>5.0</td>
<td>45</td>
</tr>
</tbody>
</table>
CULTIVATION
Four-row Nobel cultivator
Cultivation: 20 inches between row

CULTIVATION + FLAMING
• Propane Dose: 4 GPA (20 kg/ha)

FLAMING HOODS AND TORCHES
• Cultivation: 20 inches between row
• Flaming: 12 inches within row
4-Row Flamer/cultivator

- Band-flaming and cultivation in one trip
- Requires proper field conditions for cultivation
16-row flamer+cultivator
Propane tank = 500 gall
Cat track tractor = 300HP
Location: Jefferson, Iowa
Weed Response to Propane Flaming
Objectives

1. To describe PROPANE DOSE-RESPONSE CURVES for ~20 weed species as influenced by application time (plant size)

2. To select PROPANE dose from the curve to:
   - control the weeds
   - offset its competitive ability against crop
Plot layout

Flaming
(Doses of propane)

12 kg/ha
30 kg/ha
44 kg/ha
68 kg/ha
Weeds before flaming
Weeds 5 days after flaming

10 GPA
Weeds before flaming

Weeds after flaming
Field bindweed (*Convolvulus arvensis*) control

<table>
<thead>
<tr>
<th>Growth stages</th>
<th>ED90 (kg/ha) @ 14 DAT</th>
<th>ED90 (GPA) @ 14 DAT</th>
</tr>
</thead>
<tbody>
<tr>
<td>8-L</td>
<td>40 (6)</td>
<td>8</td>
</tr>
<tr>
<td>10-L</td>
<td>31 (5)</td>
<td>7</td>
</tr>
<tr>
<td>40-L</td>
<td>57 (10)</td>
<td>12</td>
</tr>
</tbody>
</table>
### Dose of propane needed to control these weeds:

<table>
<thead>
<tr>
<th>Weed species</th>
<th>Weed height</th>
<th>Growth stage</th>
<th>Propane dose (GPA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bindweed</td>
<td>3”</td>
<td>8 L</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>20”</td>
<td>40 L</td>
<td>12</td>
</tr>
<tr>
<td>Kochia</td>
<td>6”</td>
<td>10 L</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>20”</td>
<td>flowering</td>
<td>16</td>
</tr>
<tr>
<td>Morningglory</td>
<td>8”</td>
<td>10 L</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>24”</td>
<td>flowering</td>
<td>14</td>
</tr>
<tr>
<td>Redroot pigweed</td>
<td>3”</td>
<td>5 L</td>
<td>14</td>
</tr>
<tr>
<td></td>
<td>30”</td>
<td>flowering</td>
<td>18</td>
</tr>
<tr>
<td>Velvetleaf</td>
<td>5”</td>
<td>7 L</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>20”</td>
<td>16 L</td>
<td>20</td>
</tr>
<tr>
<td>Weed species</td>
<td>Weed height</td>
<td>Growth stage</td>
<td>Propane dose (GPA)</td>
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<tr>
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</tr>
<tr>
<td>Venice mallow</td>
<td>4”</td>
<td>5 L</td>
<td></td>
</tr>
<tr>
<td></td>
<td>18”</td>
<td>flowering</td>
<td>11</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>15</td>
</tr>
<tr>
<td>Waterhemp</td>
<td>2”</td>
<td>3 L</td>
<td></td>
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<tr>
<td></td>
<td>9”</td>
<td>9 L</td>
<td>8</td>
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<td></td>
<td></td>
<td></td>
<td>10</td>
</tr>
<tr>
<td>Foxtail green</td>
<td>4”</td>
<td>7 L</td>
<td></td>
</tr>
<tr>
<td></td>
<td>12”</td>
<td>flowering</td>
<td>18</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>25</td>
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<tr>
<td>Foxtail yellow</td>
<td>3”</td>
<td>4 L</td>
<td></td>
</tr>
<tr>
<td></td>
<td>12”</td>
<td>flowering</td>
<td>18</td>
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<td></td>
<td></td>
<td></td>
<td>25</td>
</tr>
<tr>
<td>Barnyardgrass</td>
<td>6”</td>
<td>7 L</td>
<td></td>
</tr>
<tr>
<td></td>
<td>12”</td>
<td>flowering</td>
<td>16</td>
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<td></td>
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<td>25</td>
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<tr>
<td>Study in 2012</td>
<td>90% weed control</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Rate</td>
<td>Common lambsquarter</td>
<td>Tansy mustard</td>
<td>Henbit</td>
</tr>
<tr>
<td>Growth stage</td>
<td>48 kg/ha (10 GPA)</td>
<td>55 kg/ha (12 GPA)</td>
<td>48 kg/ha (10 GPA)</td>
</tr>
<tr>
<td>1 DAT</td>
<td>5-L (4 cm)</td>
<td>9-L (10 cm)</td>
<td>fl (32 cm)</td>
</tr>
<tr>
<td>14 DAT</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Study in 2012 includes evaluations of weed control efficacy at 1 and 14 days after treatment (DAT) for Common lambsquarter, Tansy mustard, and Henbit. Rates are specified in kg/ha with GPA (Growing Point Adjusted) rates in parentheses. Growth stage images are provided at 1 DAT for each species, with Common lambsquarter at 5-L (4 cm), Tansy mustard at 9-L (10 cm), and Henbit at fl (32 cm).
Henbit – good control

Flamed @ Flowering 12” or 32 cm tall

1 DAT

14 DAT
Partial control of these species

<table>
<thead>
<tr>
<th>SPECIES</th>
<th>Field pennycress (Thlaspi arvense)</th>
<th>Dandelion (Taraxacum officinale)</th>
<th>Cutleaf evening primrose (Oenothera lacinata)</th>
<th>Giant ragweed (Ambrosia trifida)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Growth stage</td>
<td>GS-I 8-L 3 cm high</td>
<td>GS-I flowering 7 cm RD</td>
<td>GS-I 7 cm RD flowering</td>
<td>GS-I 3-L 3 cm high</td>
</tr>
<tr>
<td></td>
<td>GS-II 14-L 15 cm high</td>
<td></td>
<td>GS-II 18 cm RD Flowering</td>
<td>GS-II 5-L 9 cm</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>GS-III</td>
<td>GS-III 7-L 17 cm</td>
</tr>
<tr>
<td>1 DAT</td>
<td>33</td>
<td>63</td>
<td>62</td>
<td>57</td>
</tr>
<tr>
<td>7 DAT</td>
<td>27</td>
<td>58</td>
<td>43</td>
<td>37</td>
</tr>
<tr>
<td>14 DAT</td>
<td>22</td>
<td>33</td>
<td>30</td>
<td>23</td>
</tr>
<tr>
<td>21 DAT</td>
<td>15</td>
<td>18</td>
<td>28</td>
<td>10</td>
</tr>
</tbody>
</table>

- Growth stage (GS) defined by:
  - number of true leaves (-L)
  - rosette diameter (-cm RD)
  - plant height (-cm high)

- DAT – days after treatment
Field pennycress – temporary stunting

GS-I: 8-L

1 DAT

7 DAT

14 DAT

GS-II: 14-L

1 DAT

7 DAT

14 DAT
Dandelion – suppression of growth

Not flamed

Flamed with 10 GPA

14 DAT

No flowering!
Cutleaf evening primrose

GS-II: Flowering
8” or 18 cm tall

1 DAT
7 DAT
14 DAT
Giant Ragweed: Much Regrowth

-before flaming

5-Leaf

14 DAT - Amazing Recovery!
Conclusion

• Most broadleaf weeds were controlled with 40-70 kg/ha (8-12 GPA) and provided a 90% control.

• Grasses were harder to control than broadleaf species
  – Likely due to growing point position at the time of flaming
  – Most grassy species recovered few weeks after flaming

• Some winter annuals regrew (field pennycress, primrose) due to thicker leaves with much moisture

• Perennials regrew from taproot (dandelion)

• Giant ragweed regrew (even after 3 flamings)
  – Cellulose has heat retarding ability?
  – Secondary buds triggered by heat or by the damage to the plant?
Crop tolerance to single and multiple flaming
Crop tolerance to single and multiple flaming (2010 – 2011)

- To test corn and soybean tolerance to single and multiple flaming *with torches positioned parallel with crop row @ 6” on both sides of crop row.*
Corn tolerance to single and multiple flaming - 2010

Treatment list:

1. Weed-free control - Tractor Speed: 3MH
2. Weedy season-long - Propane rate: 10 GPA
3. Flaming once (V2) - Row spacing: 30”
4. Flaming twice (V2, V4)
5. Flaming thrice (V2, V4, V6)
6. Flaming twice (V2, V6)
7. Flaming once (V4)
8. Flaming twice (V4, V6)
9. Flaming once (V6)
Corn Injury by Multiple Flaming-20

Injury (%)

1 DAT
7 DAT
14 DAT
28 DAT

Treatments

0 20 40 60 80

Injury (

3 4 5 6 7 8 9

Dat
## Corn tolerance to single and multiple flaming - 2010

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Yield (t/ha)</th>
<th>Yield (bu/acre)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Weed-free control</td>
<td>12.20</td>
<td>194.35</td>
</tr>
<tr>
<td>2. Weedy season-long</td>
<td>8.57</td>
<td>136.52</td>
</tr>
<tr>
<td>3. Flaming once (V2)</td>
<td>12.16</td>
<td>193.71</td>
</tr>
<tr>
<td>4. Flaming twice (V2, V4)</td>
<td>12.30</td>
<td>195.94</td>
</tr>
<tr>
<td>5. Flaming thrice (V2, V4, V6)</td>
<td>10.97</td>
<td>174.75</td>
</tr>
<tr>
<td>6. Flaming twice (V2, V6)</td>
<td>12.28</td>
<td>195.62</td>
</tr>
<tr>
<td>7. Flaming once (V4)</td>
<td>12.29</td>
<td>195.78</td>
</tr>
<tr>
<td>8. Flaming twice (V4, V6)</td>
<td>11.70</td>
<td>186.38</td>
</tr>
<tr>
<td>9. Flaming once (V6)</td>
<td>12.00</td>
<td>191.16</td>
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</tbody>
</table>
Soybean tolerance to single and multiple flaming - 2010

- Treatment list:
  1. Weed-free control - Tractor Speed: 3MH
  2. Weedy season-long - Propane rate: 10 GPA
  3. Flaming once (VC) - Row spacing: 30”
  4. Flaming twice (VC, V2)
  5. Flaming twice (VC, V5)
  6. Flaming thrice (VC, V2, V5)
  7. Flaming once (V2)
  8. Flaming twice (V2, V5)
  9. Flaming once (V5)
Soybean Injury by Multiple Flaming

Injury (%)

0 20 40 60 80 100

1 DAT 7 DAT 14 DAT 28 DAT

Treatments

1 2 3 4 5 6 7 8 9
### Soybean tolerance to single and multiple flaming - 2010

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Yield (t/ha)</th>
<th>Yield (bu/acre)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Weed-free control</td>
<td>3.63</td>
<td>53.98</td>
</tr>
<tr>
<td>2. Weedy season-long</td>
<td>1.33</td>
<td>19.78</td>
</tr>
<tr>
<td>3. Flaming once (VC)</td>
<td>3.54</td>
<td>52.64</td>
</tr>
<tr>
<td>4. Flaming twice (VC, V2)</td>
<td>2.28</td>
<td>33.90</td>
</tr>
<tr>
<td>5. Flaming twice (VC, V5)</td>
<td>3.43</td>
<td>51.01</td>
</tr>
<tr>
<td>6. Flaming thrice (VC, V2, V5)</td>
<td>0.49</td>
<td>7.29</td>
</tr>
<tr>
<td>7. Flaming once (V2)</td>
<td>1.24</td>
<td>18.44</td>
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<tr>
<td>8. Flaming twice (V2, V5)</td>
<td>1.04</td>
<td>15.47</td>
</tr>
<tr>
<td>9. Flaming once (V5)</td>
<td>3.52</td>
<td>52.34</td>
</tr>
</tbody>
</table>
Conclusion:

- Corn was tolerant at each V2, V4 and V6
- Soybean was tolerant at VC and V5 stages
- Corn and soybean could tolerate 2 flaming operations per season
# Take home message

## Crop Growth Stages Tolerant to Flame Weeding

<table>
<thead>
<tr>
<th>Crop</th>
<th>Broadcast flaming</th>
<th>Next to crop row (flames below crop canopy)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Field corn</td>
<td>VE-V1</td>
<td>V1 - V10</td>
</tr>
<tr>
<td>Pop corn</td>
<td>VE-V1</td>
<td>V1 - V10</td>
</tr>
<tr>
<td>Sweet corn</td>
<td>VE-V1</td>
<td>V1 - V10</td>
</tr>
<tr>
<td>Sorghum</td>
<td>VE-V1</td>
<td>V1 - V10</td>
</tr>
<tr>
<td>Soybean</td>
<td>VE-VC</td>
<td>V4 - V5</td>
</tr>
<tr>
<td>Sunflower</td>
<td>VC</td>
<td>V8 - V14</td>
</tr>
<tr>
<td>Winter wheat</td>
<td></td>
<td>do not recommend flaming post emergent</td>
</tr>
</tbody>
</table>

- Note: maximum of two flaming operations
# Crop Growth Stages Tolerant to Flame Weeding

<table>
<thead>
<tr>
<th>Crop</th>
<th>Growth Stage</th>
<th>Next to crop row</th>
</tr>
</thead>
<tbody>
<tr>
<td>Field corn</td>
<td>VE-V1</td>
<td>V1 - V10</td>
</tr>
<tr>
<td>Pop corn</td>
<td>VE-V1</td>
<td>V1 - V10</td>
</tr>
<tr>
<td>Sweet corn</td>
<td>VE-V1</td>
<td>V1 - V10</td>
</tr>
</tbody>
</table>

- **Crop** flaming (flames below crop canopy)
Crop Growth Stages Tolerant to Flame Weeding

- **Crop flaming**
  - Soybean: VE-VC
  - **DO NOT FLAME @ VU, V1, V2 & V3**

<table>
<thead>
<tr>
<th>Crop</th>
<th>Broadcast flaming</th>
<th>Next to crop row (flames below crop canopy)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soybean</td>
<td>VE-VC</td>
<td>V4 - V5</td>
</tr>
</tbody>
</table>
## Crop Growth Stages Tolerant to Flame Weeding

<table>
<thead>
<tr>
<th>Crop</th>
<th>flaming</th>
<th>Next to crop row</th>
</tr>
</thead>
<tbody>
<tr>
<td>Broadcast</td>
<td></td>
<td>(flames below crop canopy)</td>
</tr>
<tr>
<td>Sunflower</td>
<td>VC</td>
<td>V8 - V14</td>
</tr>
<tr>
<td>V4</td>
<td></td>
<td>V8-V10</td>
</tr>
<tr>
<td>DO NOT FLAME FROM V2 – V6</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Crop Growth Stages**
- **Sunflower**: VC (V8 - V14), V8-V10
- **DO NOT FLAME FROM V2 – V6**
Propane Flaming and Cultivation in Corn and Soybean
Objectives:

- To test newly designed selective flaming equipment
- To determine the effectiveness of flaming and cultivation for weed management in corn and soybean
Treatments 2011

EARLY TREATMENT
- Corn V3
- Soybean VC

Cultivation → Followed by

Cultivation + flaming → Followed by

Full flaming → Followed by

LATE TREATMENT
- Corn V6
- Soybean V4

Cultivation

Cultivation + flaming

Full flaming
14 Treatments with 4 replications

1. Weed-free control (hand weeding/ hoeing)
2. Weedy season-long
3. Cultivation once (V3)
4. Cultivation twice (V3 & V6)
5. Cultivation once (V3) followed by cultivation + flaming (V6)
6. Cultivation once (V3) followed by full flaming (V6)
7. Cultivation + flaming once (V3)
8. Cultivation + flaming twice (V3 & V6)
9. Cultivation + flaming once (V3) followed by cultivation (V6)
10. Cultivation + flaming once (V3) followed by full flaming (V6)
11. Full flaming once (V3)
12. Full flaming twice (V3 & V6)
13. Full flaming once (V3) followed by cultivation (V6)
14. Full flaming once (V3) followed by cultivation + flaming (V6)
**CULTIVATION**
Four-row Nobel cultivator

*Cultivation:* 20 inches between row

**CULTIVATION + FLAMING**

- **Propane Dose:** 4 GPA (20 kg/ha)

**FLAMING HOODS AND TORCHES**

- **Cultivation:** 20 inches between row
- **Flaming:** 12 inches within row
FULL FLAMING

Flaming: covers all 30 inches
Propane Dose: 9 GPA (45 kg/ha)
Early treatment (hoods closed)

4 in

Late treatment (hoods open)

24 in

Corn V3 and V6

Soybean VC and V4-V5

1 in

18 in
DATA COLLECTION:

– Weed control levels: 1, 7, 14, 28 days after treatment
– Crop injury levels: 1, 7, 14, 28 days after treatment
– Weed Dry matter 60 days after treatment
– Final yield
Weed Control in Corn

3. Cultivation once
4. Cultivation twice
5. Cultivation + flaming once
6. Cultivation + flaming twice
7. Full flaming once
8. Full flaming twice

Weed Control in Soybean

• Cultivation + flaming twice
  • Highest level of weed control
  • Both corn and soybean
Results - Weed Control in Corn

Flaming + cultivation twice (V3 & V6)  
Weed free control
- Weedy season long
- Weed free

**Flaming + cultivation twice (VC+V4)**
Results - Crop Injury (7 and 28 DAT)

<table>
<thead>
<tr>
<th>Treatment</th>
<th>7 DAT</th>
<th>28 DAT</th>
</tr>
</thead>
<tbody>
<tr>
<td>4. Cultivation + flaming once</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Cultivation + flaming twice</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. Full flaming once</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7. Full flaming twice</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Recovered over time regardless of the treatment !!!
Results - Crop Injury

Immediately after flaming

1 DAT
Corn recovery over time

V3

1 DAT

7 DAT

14 DAT

V6

1 DAT

7 DAT
Soybean recovery over time

VC

1 DAT

7 DAT

14 DAT

V4

1 DAT

14 DAT
## Results - Yield

### Corn Treatments

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Yield (t/ha)</th>
<th>Yield (bu/ac)</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Weed-free control</td>
<td>11.3</td>
<td>179</td>
<td>A</td>
</tr>
<tr>
<td>2. Weedy season-long</td>
<td>7.1</td>
<td>113</td>
<td>D</td>
</tr>
<tr>
<td>3. Cultivation once (V3)</td>
<td>8.2</td>
<td>130</td>
<td>CD</td>
</tr>
<tr>
<td>4. Cultivation twice (V3 &amp; V6)</td>
<td>8.4</td>
<td>133</td>
<td>C</td>
</tr>
<tr>
<td>5. Cultivation + flaming once (V3)</td>
<td>8.7</td>
<td>138</td>
<td>C</td>
</tr>
<tr>
<td><strong>6. Cultivation + flaming twice (V3 &amp; V6)</strong></td>
<td><strong>10.9</strong></td>
<td><strong>172</strong></td>
<td><strong>A</strong></td>
</tr>
<tr>
<td>7. Full flaming once (V3)</td>
<td>9</td>
<td>142</td>
<td>BC</td>
</tr>
<tr>
<td><strong>8. Full flaming twice (V3 &amp; V6)</strong></td>
<td><strong>10.1</strong></td>
<td><strong>160</strong></td>
<td><strong>AB</strong></td>
</tr>
</tbody>
</table>

**LSD 0.05**: 0.6 19.2

### Soybean Treatments

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Yield (t/ha)</th>
<th>Yield (bu/ac)</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Weed-free control</td>
<td>3.06</td>
<td>45.3</td>
<td>A</td>
</tr>
<tr>
<td>2. Weedy season-long</td>
<td>1.36</td>
<td>20.3</td>
<td>F</td>
</tr>
<tr>
<td>3. Cultivation once (VC)</td>
<td>1.51</td>
<td>22.5</td>
<td>F</td>
</tr>
<tr>
<td>4. Cultivation twice (VC &amp; V4)</td>
<td>2.27</td>
<td>33.6</td>
<td>D</td>
</tr>
<tr>
<td>5. Cultivation + flaming once (VC)</td>
<td>1.96</td>
<td>29.3</td>
<td>E</td>
</tr>
<tr>
<td><strong>6. Cultivation + flaming twice (VC &amp; V4)</strong></td>
<td><strong>2.78</strong></td>
<td><strong>41.4</strong></td>
<td><strong>B</strong></td>
</tr>
<tr>
<td>7. Full flaming once (VC)</td>
<td>1.50</td>
<td>22.1</td>
<td>F</td>
</tr>
<tr>
<td><strong>8. Full flaming twice (VC and V4)</strong></td>
<td><strong>2.56</strong></td>
<td><strong>38.1</strong></td>
<td><strong>C</strong></td>
</tr>
</tbody>
</table>

**LSD 0.05**: 0.28 3.2
Conclusions

• Best treatment:
  – Flaming + cultivation twice:
    • *Corn*: 90% weed control, 172 bu/ac (10.9 t/ha) yield
    • *Soybean*: 85% weed control, 41.4 bu/ac (2.78 t/ha) yield

• Worst treatment:
  - *Corn*: Cultivation once
    • 30% weed control, 8.2 t/ha yield (130 bu/ac)
  - *Soybean*: Full flaming once
    • 17% weed control, 1.50 t/ha yield (22.1 bu/ac)

• Visual crop injury doesn’t necessarily imply yield loss
• Flaming twice can be an alternative to flaming + cultivation in wet conditions
BANDED FLAMING + “BUFFALO” CULTIVATOR

Followed by