

"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)

<u>Department of Mechanical Engineering:</u>

- Professor Dr. George Gogos, Chris Bruening (MS/PhD student), Brian Neilson, (MS) Jared Miller and Dustin Simpson
- <u>Organic producers</u>: Liz Sarno, Mike Ostry, Larry Stanislav, Randy Fendrich, Gerald Humlicek, Paul and Dan Huenefeld, Mark Ramaeker
- <u>Resulted in:</u> 20+ publications, >100 abstracts, 2 patents, ~\$2 mil in grants
 Flame Weeding Manual (36 pages, text & pics, PERC website)

Flame Weeding Manual



Propane-Fueled Flame Weeding in Corn, Soybean, and Sunflower





CONTRIBUTORS:

AUTHORS: Stevan Z. Knezevic, Avishek Datta, Chris Bruening, and George Gogos



Strahinja Stepanovic, Brian Neilson, Ana Obradovic, Jon Scott, and Dejan Nedeljkovic

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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



- 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

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Open flames = "wasted heat"

Initial Prototype Hood/torch Design



- Increased exposure time at higher temperatures
 - containment of combustion gases
 - optimized air entrainment

Flaming Equipment

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)







<u>8-row flamer</u>





Electronic Ignition System

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



Flaming Equipment

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



Equipment Configuration

4 Possible Torch/Hood Combinations

2 torch configurations x 2 hood configurations

Banded flaming + Fully closed hoods
 Banded flaming + Partially open hoods

3. Full flaming + Fully closed hoods4. Full flaming + Partially open hoods



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Parallel with crop row

Angled down at 30° -45°



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· ·<u>Torch Configuration</u>

Full Flaming



Full flaming

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Hood Configuration

Fully closed – Early season flaming Partially open – Late season flaming



• <u>Torch Configuration</u>

Banded Flaming



Banded Flaming



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. Hoods - Full Season Adjustability

Closed – Early Season

Open – Late Season





: <u>Recommended Equipment Setups</u> <u>for given Crop Recipes</u>

<u>Corn & Sorghum</u>

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

Pressure	Speed (mph)							
(PSI)	1	2	4	6	8	10		
10	10.24	5.12	2.56	1.71	1.28	1.02		
20	18.16	9.08	4.54	3.03	2.27	1.82		
30	26.08	13.04	6.52	4.35	3.26	2.61		
40	34.00	17.00	8.50	5.67	4.25	3.40		
50	41.92	20.96	10.48	6.99	5.24	4.19		
60	49.84	24.92	12.46	8.31	6.23	4.98		
70	57.76	28.88	14.44	9.63	7.22	5.78		
80	65.68	32.84	16.42	10.95	8.21	6.57		
90	73.60	36.80	18.40	12.27	9.20	7.36		

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<u>Time – Effect of Equipment and Tank Size</u>

250 gallon LPG tank @ 5 GPA (banded flaming) ≈ 40 acres per fill

Row Width: **30** in

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Operating Speed - Pressure		Time to Cover 40 Acres (hr) vs. Equipment Size (rows)						
mph	psig	4	6	8	10	12		
2.0	15	16.5	11.0	8.3	6.6	5.5		
2.5	20	13.2	8.8	6.6	5.3	4.4		
3.0	25	11.0	7.3	5.5	4.4	3.7		
3.5	30	9.4	6.3	4.7	3.8	3.1		
4.0	35	8.3	5.5	4.1	3.3	2.8		
4.5	40	7.3	4.9	3.7	2.9	2.4		
5.0	45	6.6	4.4	3.3	2.6	2.2		
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CULTIVATION Four-row Nobel cultivator **Cultivation:** 20 inches between row



FLAMING HOODS AND TORCHES



CULTIVATION + FLAMINGPropane Dose: 4 GPA (20 kg/ha)



Cultivation: 20 inches between row
Flaming: 12 inches within row

Flaming Equipment

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

 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





Weeds before flaming



Weeds 5 days after flaming 10 GPA



Weeds before flaming



Weeds after flaming






Growth stagesED90 (kg/ha) @ 14 DATED90 (GPA) @ 14 DAT8-L40 (6)810-L31 (5)740-L57 (10)12



Field bindweed (Convolvulus arvensis) control

Dose of propane needed to control these weeds:

Weed species	Weed height	Growth stage	Propane dose (GPA)
Bindweed	3"	8 L	8
	20"	40 L	12
Kochia	6"	10 L	8
	20"	flowering	16
Morningglory	8"	10 L	12
	24"	flowering	14
Redroot pigweed	d 3"	5 L	14
	30"	flowering	18
Velvetleaf	5"	7 L	12
	20"	16 L	20

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Dose of propane needed to control these weeds:

Weed species	Weed height	Growth stage	Propane dose (GPA)
Venice mallow	4"	5 L	11
	18"	flowering	15
Waterhemp	2"	3 L	8
	9"	9 L	10
Foxtail green	4"	7 L	18
	12"	flowering	25
Foxtail yellow	3"	4 L	18
	12"	flowering	25
Barnyardgrass	6"	7 L	16
	12"	flowering	25

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Study in 2012 Rate

Growth stage

1 DAT

14 DAT

90% weed control

Common lambsquarter

48 kg/ha (10 GPA)







Tansy mustard

55 kg/ha (12 GPA)







Henbit

48 kg/ha (10 GPA)







Henbit – good control

Flamed @ Flowering 12" or 32 cm tall

14 DAT

1 DAT





Partial control of these species

CDECIEC	Field pe	ennycress	Dandelion	Cutleaf ever	ing primrose	Gian	it ragwe	ed
SPECIES	(Thlaspi arvense)		(Taraxacum officinale)	(Oenothera lacinata)		(Ambi	(Ambrosia trifida)	
	GS-I	GS-II	GS-I	GS-I	GS-II	GS-I	GS-II	GS-III
Growth	8-L	14-L	flowering	7 cm RD	18 cm RD	3-L	5-L	7-L
Stage	3 cm high	15 cm high	10 cm RD		Flowering	3 cm	9 cm	17 cm
1 DAT	33	50	63	62	38	57	47	83
7 DAT	27	47	58	43	27	37	40	73
14 DAT	22	41	33	30	18	23	13	47
21 DAT	15	32	18	28	15	10	7	32

• 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





14 DAT

GS-II: 14-L



1 DAT



7 DAT



14 DAT



Dandelion – suppression of growth

Not flamed





14 DAT

Flamed with 10 GPA



No flowering !

Cutleaf evening primrose







14 DAT



Giant Ragweed: Much Regrowth

5-Leaf

Before flaming



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?



to single and multiple flaming

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Crop tolerance to single and multiple flaming (2010 – 2011)

 To test corn and soybean tolerance to single and multiple flaming <u>with torches positioned parallel with crop row</u> (a) <u>6 "on both sides of crop row.</u>

Corn tolerance to single and multiple flaming - 2010

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- <u>Treatment list:</u>
- 1. Weed-free control
- 2. Weedy season-long
- 3. Flaming once (V2)
- 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)

- Tractor Speed: 3MH
- Propane rate:10 GPA
- Row spacing: 30"



Treatments

•Corn tolerance to single and multiple flaming - 2010

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•	<u>Treatments</u>	<u>Yield (t/ha)</u>	<u>Yield (bu/acre)</u>
•	1. Weed-free control	12.20	194.35
•	2. Weedy season-long	8.57	136.52
•	3. Flaming once (V2)	12.16	193.71
•	4. Flaming twice (V2, V4)	12.30	195.94
•	5. Flaming thrice (V2, V4, V6)	10.97	174.75
•	6. Flaming twice (V2, V6)	12.28	195.62
•	7. Flaming once (V4)	12.29	195.78
•	8. Flaming twice (V4,V6)	11.70	186.38
•	9. Flaming once (V6)	12.00	191.16

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Soybean tolerance to single and multiple flaming - 2010

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- <u>Treatment list:</u>
- 1. Weed-free control
- 2. Weedy season-long
- 3. Flaming once (VC)
- 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)

- Tractor Speed: 3MH
- Propane rate:10 GPA
- Row spacing: 30"



Soybean Injury by Multiple Flamin

Soybean tolerance to single and multiple flaming - 2010

•	Treatment	Yield (t/ha)	<u>Yield (bu/acre)</u>
•	1. Weed-free control	3.63	53.98
•	2. Weedy season-long	1.33	19.78
•	3. Flaming once (VC)	3.54	<u>52.64</u>
•	4. Flaming twice (VC, V2)	2.28	33.90
•	5. Flaming twice (VC,V5)	3.43	<u>51.01</u>
•	6. Flaming thrice (VC, V2, V	75) 0.49	7.29
•	7. Flaming once (V2)	1.24	18.44
•	8. Flaming twice (V2, V5)	1.04	15.47
•	9. Flaming once (V5)	3.52	<u>52.34</u>
		• • •	• • • •

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

		Broadcast	Next to crop row
•	Crop	flaming	(flames below crop canopy)
•			
•	Field corn	VE-V1	V1 - V10
•	Pop corn	VE-V1	V1 - V10
•	Sweet corn	VE-V1	V1 - V10
•	Sorghum	VE-V1	V1 - V10
•	Soybean	VE-VC	V4 - V5
•	Sunflower	VC	V8 - V14
•	Winter wheat	do not	recommend flaming post emergent

• Note: maximum of two flaming operations

Crop Growth Stages Tolerant to Flame Weeding

	Broadcast	Next to crop row
• Crop	flaming	(flames below crop canopy)
•		
• Field corn	VE-V1	V1 - V10
• Pop corn	VE-V1	V1 - V10
• Sweet corn	VE-V1	V1 - V10



Crop Growth Stages Tolerant to Flame Weeding

	Broadcast	Next to crop row
Crop	flaming	(flames below crop canopy)

• Soybean VE-VC





• DO NOT FLAME @ VU, V1, V2 & V3





Crop Growth Stages Tolerant to Flame Weeding

	Broadcast	Next to crop row
• Crop	flaming	(flames below crop canopy)

- •
- Sunflower



• DO NOT FLAME FROM V2 – V6



V8 - V14



Propane Flaming and Cultivation in Corn and Soybean







- To test newly designed <u>selective</u> 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

LATE TREATMENT

• Soybean V4

Cultivation Followed by

Cultivation Cultivation + flaming Full flaming

Cultivation + flaming <u>Followed by</u>

Cultivation Cultivation + flaming Full flaming

Full flaming

Followed by

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→ Cultivation→ Cultivation + flamingFull 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



FLAMING HOODS AND TORCHES



CULTIVATION + FLAMINGPropane Dose: 4 GPA (20 kg/ha)



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)









Soybean VC and V4-V5





• DATA COLECTION:

- 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

Rating Scale

0% - No Damage 100% - Plant Death

Weed Control in **Corn**

Weed Control in Corn Conventio 100 7 DAT 28 DAT 土土 8 \pm 00 40 20 6 7 5 8 3 4 Treatments

3. Cultivation once

Weed Conltrol (%)

- 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





Weed free



Flaming + cultivation twice (VC+V4)



Results - Crop Injury (7 and 28 DAT)

Corn



- 4. Cultivation + flaming once
- 5. Cultivation + flaming twice
- 6. Full flaming once
- 7. Full flaming twice

Soybean



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

Immediately after flaming

1 DAT





Corn recovery over time



V6









Soybean recovery over time









. Results - Yield

Corn Treatments	Yield (t/ha)	yield (bu/ac)	difference
1. Weed-free control	11.3	179	А
2. Weedy season-long	7.1	113	D
3. Cultivation once (V3)	8.2	130	CD
4. Cultivation twice (V3 & V6)	8.4	133	С
5. Cultivation + flaming once (V3)	8.7	138	С
6. Cultivation + flaming twice (V3 & V6)	10.9	172	Α
7. Full flaming once (V3)	9	142	BC
8. Full flaming twice (V3 & V6)	10.1	160	AB
LSD 0.05	0.6	19.2	

Soybean Treatments	Yield (t/ha)	Yield (bu/ac)	difference
1. Weed-free control	3.06	45.3	А
2. Weedy season-long	1.36	20.3	F
3. Cultivation once (VC)	1.51	22.5	F
4. Cultivation twice (VC & V4)	2.27	33.6	D
5. Cultivation + flaming once (VC)	1.96	29.3	E
6. Cultivation + flaming twice (VC & V4)	2.78	41.4	В
7. Full flaming once (VC)	1.50	22.1	F
8. Full flaming twice (VC and V4)	2.56	38.1	С
LSD 0.05	0.28	3.2	
	0.20	5.2	

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- : Conclusions
- Best treatment:
 - Flaming + cultivation twice:
 - <u>Corn</u>: 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:
 - <u>Corn</u>: Cultivation once
 - 30% weed control, 8.2 t/ha yield (130 bu/ac)
 - Soybean: Full flaming once
 - 17% weed control, 1.50t/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





