Flame Weeding for Vegetable Crops

Current Topic

By Steve Diver
NCAT Agriculture Specialist
June 2002

Introduction

Photo courtesy of Flame Weeders, Glenville, WV

Flame weeding—a type of *thermal* weed control—was commonly used in row crops like cotton and sorghum from the late 1930s until the mid-1960s, when selective herbicides became widely available. In the 1980s and '90s, flame weeding made a rapid comeback as a non-chemical weed control technique, especially among organic farmers.

Flame weeding, also called flame cultivation, relies on propane gas burners to produce a carefully controlled and directed flame that briefly passes over the weeds. The intense heat *sears* the leaf, causing the cell sap to expand and disrupt cell walls. Foliage that retains a thumb print when pressure is applied between your thumb and finger has been adequately flamed. The flamed weeds soon wilt and die, usually in one to three days.

Weeds are most susceptible to flaming when they are seedlings, 1 or 2 inches tall. Broadleaf weeds are more susceptible to lethal flaming than grasses. Grasses develop a protective sheath by the time they are approximately 1 inch tall and may require a second flaming. Repeated flaming can likewise be used to suppress perennial weeds such as field bindweed.

Flame weeders come in a range of human- and tractor-powered models. Market-farming equipment options include hand-held single-torch flamers, as well as push-wheeled multiple-torch flamers mounted under a flame hood. Tractor-powered kits are available in 2, 4, 6, and 8-row models, with or without a flame hood; other options include a complete toolbar setup with accompanying cultivator attachments for between-row mechanical cultivation.

Farmer feedback on flame weeding has been positive. Joe Fitzgerald, a farmer near Dubuque, Iowa, reported that "a blind person can see the difference in weed control" between flamed and unflamed organic corn, even though both plots had also been rotary-hoed and cultivated (1).

ATTRA is the national sustainable agriculture information service operated by the National Center for Appropriate Technology under a grant from the Rural Business-Cooperative Service, U.S. Department of Agriculture. These organizations do not recommend or endorse products, companies, or individuals. ATTRA is headquartered in Fayetteville, Arkansas (P.O. Box 3657, Fayetteville, AR 72702), with offices in Butte, Montana and Davis, California.

Pre-emergent Flaming

Controlling weeds before the crop emerges is known as pre-emergent weed control. In vegetable crops, there are two distinct ways to use pre-emergent flaming: the stale seedbed technique and the peak emergence technique.

Stale Seedbed Technique

The stale seedbed technique is a form of early-season weed control in direct-seeded crops. Seedbed preparation and soil stirring—for example, hilling the soil into beds—always results in a flush of weeds. With this technique, instead of sowing vegetable seeds into freshly prepared soil, planting is delayed. The aim is to knock down the early-germinating weeds, and perhaps a second flush of weeds, without further soil tillage (which would bring new weed seeds to the surface). The vegetable crop is then seeded into a weed-free bed. Most often, shallow tillage or herbicides are used to knock down the flush of weeds, but flaming is an alternative technique. Growers will sometimes pre-irrigate to induce more weed growth before flaming.

This technique can also be used to prepare a stale seedbed prior to setting out transplants. Essentially, you are helping your vegetable crops get off to a good start by eliminating early-season weed competition. Once the vegetable canopy forms, shade reduces weed germination; weed seedlings that do sprout can be controlled by mechanical cultivation.

Flame off the first flush of weeds for a clean seedbed.

The *critical weed-free period* is the minimum length of time a crop must remain nearly weed-free to prevent reductions in yield or quality. For most vegetables, this is usually the first quarter or third of their growing period—something like four to six weeks after seedling emergence, and slightly less for transplants. Weeds emerging after this period have less impact on vegetable yields than early-season weeds.

Critical Weed-Free Periods for Selected Weeds in Vegetable Crops

Crop	Location of Study	Critical Weed-Free Period*	Major Weeds Present
Snap beans	NJ, MA	Emergence to Full Bloom, 2 to 4 WAE	cocklebur, purslane
Cabbage (transplanted)	Ontario	3 to 4 WAP	lambsquarters, pigweed, crabgrass, green foxtail
Muskmelon	Israel	4 to 6 WAE 0 to 3 WAE	pigweed species, smooth amaranth
Onions	OR	All season	redroot pigweed
Summer squash	CT	4 to 6 WAT	quackgrass, lambsquarters, ragweed
Sweetpotato	Phillipines	2 to 4 WAT	grasses, morningglory
Tomato (bare ground)	Ontario	28 to 35 DAT	lambsquarters, ragweed, pigweed, crabgrass, foxtail, purslane
Watermelon	NC	2 to 4 WAT	large crabgrass

*WAE: weeks after emergence; WAP: weeks after planting; DAT: days after transplanting; and WAT: weeks after transplanting.

Source: Sustainable Practices for Vegetable Production in the South
Dr. Mary Peet, North Carolina State University
http://www.cals.ncsu.edu/sustainable/peet/IPM/weeds/c07weeds.html

Peak Emergence Technique

In the peak-emergence flaming technique, vegetable seeds are promptly sown after seedbed preparation. Just before vegetable seedlings emerge, the bed is flamed to kill seedling weeds (which tend to sprout faster). The aim is to eliminate the first flush of weeds and catch the seedling weeds when they are young and susceptible, while avoiding damage to the vegetable crop (2, 3).

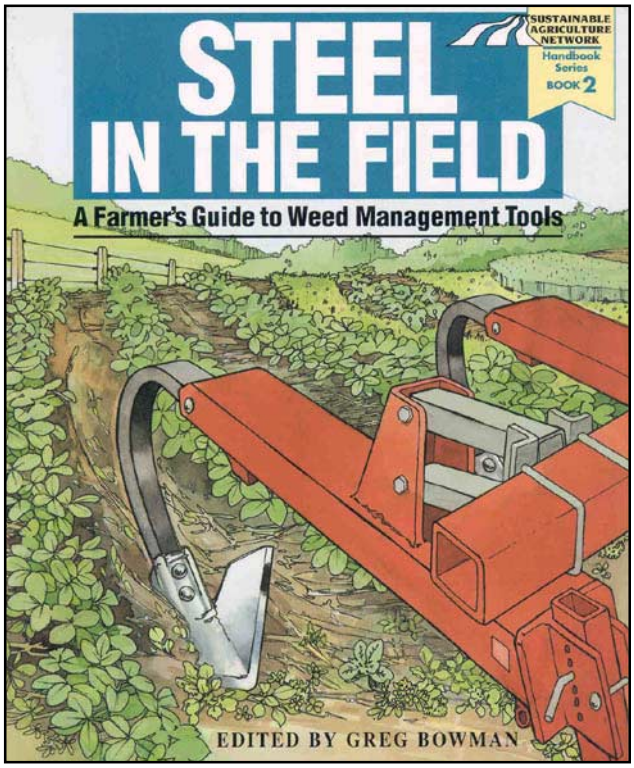
This second method is especially well suited to slow-germinating, direct-seeded crops like carrots and parsnips. At optimum soil temperatures, carrots germinate approximately seven to eight days after planting. In this case, weeds would be flamed off after five or six days. However, carrots are commonly planted in cool soils and germination may take as long as 14 to 21 days. Consequently, it's best to dig into the row to check on the progress of seedlings and time the flaming accordingly. Some growers place a pane of glass or plastic strip over a small section of the bed to speed up carrot seed germination. The field is flamed when the carrots under the glass emerge. The rationale is that the carrots in bare soil will typically emerge a few days later.

In European trials, flaming alone reduced weed populations in carrot beds by 80 percent (3).

As carrots are particularly difficult to weed, this technique is a real boost to organic farmers. Steve Meyer, a market gardener in West Virginia who flames carrots, onions, and beets, said, "The difference in weed control between flamed and unflamed beds is like night and day" (4).

Following flaming, and for the duration of the growing season, a mechanical weed-control system can be used for carrots, employing specialized cultivators (finger weeders, inter-row brush hoes, steerage hoes) or standard cultivators and wheel hoes. Refer to *Steel in the Field: A Farmer's Guide to Weed Management Tools*, a practical handbook from the Sustainable Agriculture Network, for descriptions and illustrations of mechanical cultivation tools (5).

The following table shows the approximate number of days to carrot seedling emergence at various soil temperatures, when seeds are planted ½ inch deep.



Steel in the Field, SAN Publications

Days to Emergence for Carrots at Different Soil Temperatures

Soil temp. (°F)	32	41	50	59	68	77	86
Days to emergence	NG*	51	17	10	7	6	6

*NG=No germination

Source: Lorenz, Oscar A. and Donald N. Maynard. 1980. Knott's Handbook for Vegetable Growers. 2nd ed. Wiley-Interscience, John Wiley & Sons, New York. p. 56

To increase the effectiveness of flame weeding on vegetable beds for carrots and other direct-seeded crops, Thermal Weed Control Systems, Inc. of Neillsville, Wisconsin, offers a flame hood similar to those used in Europe. Ron Jones of Thermal Weed Control Systems calls it a "hover burner." The tractor-drawn models he manufactures have 5 to 7 burners, and cost in the neighborhood of $2,250. Jones explained that lettuce growers are also using the hover burner between sequential crop plantings to control insect and disease problems. Flame Weeders, a small company in West Virginia, manufactures push-flamers for market farmers that are wheel-mounted with flaming hoods; these range in price from $300 to $400.

An Australian report provided the following summary of pre-emergence flaming (6):

"Pre-emergence technique used by organic farmers was tested and adapted to Australian conditions. This technique was used one day before seeding and one day before emergence on carrots and onions. The first manual weeding (hand hoeing) was completely eliminated. A labor cost for hand weeding a plot 1m x 100 m was reduced from $160 to $2.50 LPG [Liquid Propane Gas] cost.

"Only one flame treatment was used for sweet potatoes and lettuce one day before the seedlings were transplanted into the ground. One row of sweet potatoes was 95% weed free for four months (from transplanting to harvesting). The lettuces were without weeds for one month between planting seedlings to harvest.

"We recommend one heat treatment for the crops with good ability to suppress weeds such as beans, pumpkins, sweet potatotes, potatoes, cucumbers, melons, sweet corn and transplanting crops. Two passes are recommended for the crops with poor ability to suppress weeds such as radishes, carrots, greens, onions, tomatoes, lettuce, broccoli and cabbage.

"Cleanup of a seed bank is possible with multiple passes (up to five). In spring and early summer the second treatment will often have to take place from a week to at most 10 days after the first. The third treatment follows after 10 to 12 days, the fourth 2 to 3 weeks later and the fifth 4 to 6 weeks thereafter. The best results are achieved by sticking to the schedule and when the weeds are between 1 and 2 cm in height."

Post-emergent Flaming

Flame weeding can be applied *after* the vegetable crop has emerged by directing the flame away from the crop plants, by shielding the crop, or by flaming at a time when crop stems are resistant to heat. This method is also known as "selective flaming." Directing flames into the crop row is a scary thought, but some plants can withstand the heat, especially after they've put on sufficient vegetative growth. The result is a non-chemical means of *in-row* weed control; for organic farmers, this is a significant tool. For example, see the pictures on flame weeding for corn at *Reducing Herbicide Usage on the Farm*, a joint project of Agricultural Utilization Research Institute (AURI) and Sustainable Farming Association of Minnesota (SFA), at: <http://www.auri.org/proproj/flamewee.html>.

Reports from the literature include the following examples:

- Sweet corn can be flamed when it reaches a height of 4 inches, and thereafter until it reaches canopy.
- Irish potatoes are flamed to control Colorado potato beetle, achieving 70–80% reduction of overwintering adults and 35% reduction of hatching eggs.
- Tomato plants can be flamed with very little stress when transplants are eight weeks old.
- Onions can be flamed for the first time when they are only 2 to 3 inches high.
- Cole crops can be flamed 2–3 weeks after transplanting.

Cross Flaming

Cross flaming is one of several methods that can be used to flame weeds in emerged crops. Burners are placed at an angle on either side of the row, in a staggered pattern so that the combined flames cover the entire drill row area. Setting burners directly opposite each other should be avoided, since this can create turbulence and cause flames to boil up and damage crop leaves.

During treatment, flames blow through the base of the crop, selectively killing weeds within the row without damaging the relatively heat-tolerant crop stems. Flames do not come in direct contact with crop foliage.

The specific flaming angle, flaming pattern, and flame length vary with the manufacturer's recommendations, but range from 30° to 40°, at 8 to 12 inches above the base of the plants, with flame lengths of approximately 12 to 15 inches. It is easiest to adjust the flame at night, when the flame path can be seen most clearly.

Some experimentation will be necessary to determine the appropriate ground speed for each crop and situation. Weed density, the age of the weeds, and weather conditions affect flaming results. Ground speeds can range from 3 to 5 miles per hour.

Photo courtesy of Dr. Wayne A. LePori, Department of Agricultural Engineering, Texas A&M

Parallel Flaming

Parallel flaming is a technique used to control weeds close to the rows for crops that are small or cannot tolerate cross-flaming. In this method, burners are set parallel to the direction of the crop row. A crop shield is sometimes employed to protect the crop.

Cross-flaming and parallel-flaming rigs are often combined with mechanical cultivators to control weeds between the rows. Mechanical implements may include tines, sweeps, or rolling cultivators.

Middle Flaming

A third method of post-emergent flaming is middle flaming. Two burners are installed under a lightweight hood that covers the row middles. The hood directs the flames to the weeds in the row middles while protecting the adjacent crop foliage.

Water-shielded Flaming

Water-shielded flaming is a technique that was developed for use on cotton farms in the Mississippi Delta. Water nozzles are placed on the flame rig to direct fans of water onto the crop plant for extra protection.

Infra-red Weed Control

Infra-red weeders—first developed in Europe—are heated by a propane torch, but the flame is directed toward a ceramic element or steel plate that radiates at temperatures of 1800 to 2000 °F. The danger associated with an open flame is thereby minimized. The mechanism of weed control is the same as in flame weeding; cell contents—plasma and proteins—are disrupted and the plant wilts down and dies. Infra-red heaters are available in hand-held, push-wheeled, and tractor-mounted models. In addition to weeding, the tractor-mounted infra-red thermal units are used to control Colorado potato beetle and potato vine desiccation. Some of the tractor models feature the injection of forced air to increase the effect.

In North America, a line of Swiss-made infra-red weeders are available through two companies: Forevergreen and Rittenhouse (see **Further Resources** below).

These range from hand-held to push-wheeled models suited to gardening, landscaping, nurseries, municipalities, and market farming. The hand-held and push-wheeled infra-red weeders appropriate for market farming are available in the $900 to $1,200 range. While infrared weeders appear to be a promising new thermal weed control tool, the equipment expense remains prohibitive for many smaller-scale market farmers. By comparison, a push-wheeled flame weeder is $300–$400.

Photo courtesy of Forevergreen

Steam + Hot Water Weed Control

Steam weed control and hot-water weed control have attracted attention in trade magazines, especially the fruit and vine grower magazines. High-temperature water provides a form of thermal weed control, yet eliminates the danger of flame application in arid regions where open fires are a hazard.

The January–March 2002 issue of *Weed Technology* featured a research article on steam application for cropland weeds (7). A custom-built, prototype steam generator-applicator machine with combined tillage implements was used in field trials. Weed control was comparable to glyphosate herbicide in some trials, and less spectacular in others. Factors affecting its use were: age of weeds, slow application speed, amount of steam applied, and cost of propane fuel. The authors concluded that improvements to steam equipment may make conservation tillage an option for organic farmers, by enabling no-till weed control without herbicides.

Altogether, the limiting factor to hot-water weed control is affordable small-scale equipment. There are three brands in North America: Waipuna, Aqua Heat, and Aquacide (See **Further Resources** below). However, they range in price from $9,000 to $35,000 and are primarily geared to municipal and institutional use for vegetation control around parks, lakes, and athletic fields, as well as non-cropland weed control around sidewalks, streets, and parking lots.

Practically speaking, innovative small-scale vegetable farmers are faced with scrapping together their own steam devices. Another option, perhaps, is collective ownership of equipment on a district-wide basis. Nevertheless, the technology exists and therefore it is mentioned here, along with equipment suppliers and web resources, for those growers who wish to investigate it further.

References

1) Anon. 1999. Flame weeding for weed management. The Practical Farmer [Practical Farmers of Iowa]. Winter. p. 17.

2) Desvaux, R. and P. Ott. 1988. Introduction of thermic weed control in southeastern France. p. 479–482. In: Patricia Allen and Debra Van Dusen (eds.) Global Perspectives on Agroecology and Sustainable Agricultural Systems. Proceedings of the Sixth International Scientific Conference of IFOAM, UC-Santa Cruz, CA, Aug. 18–20, 1986.

3) Daar, Sheila. 1987. Update: flame weeding on European farms. The IPM Practitioner. March. p. 1–4.

4) Steve Meyer. March 2000. Personal communication.

5) Bowman, Greg (ed.) 1997. Steel in the Field: A Farmer's Guide to Weed Management Tools. Sustainable Agriculture Network, Handbook Series No. 2. Sustainable Agriculture Publications, University of Vermont. 128 p.

6) Janvanociski, Zlatko. 1999. Thermal infrared weed control. WA Bank Landcare Conference, "Where Community Counts," Esperance, Australia. Accessed at: <http://www.wn.com.au/landcareconf/Javanociski.doc>.

7) Kolberg, Robert L., and Lori J. Wiles. 2002. Effect of steam application on cropland weeds. Weed Technology. Vol. 16, No. 1. p. 43–49. Accessed at: <http://www.bioone.org/bioone/?request=get-abstract&issn=0890-037X&volume=016&issue=01&page=0043>.

Further Resources

Equipment and Supplies

Flame Engineering, Inc.
P.O. Box 577
LaCrosse, KS 67548
888-388-6724
Fax: 785-222-3619
E-mail: flame@awav.net
http://www.flameengineering.com

Manufacturer of the famous Red Dragon hand-held flamer as well as alfalfa flamers, row-crop flamers (2 to 8-row kits), and a grape vine berm flamer that can also be used in orchards. A major supplier of liquid propane accessories to the flame weeding industry. See their online book, *Agricultural Flaming Guide*.

Thermal Weed Control Systems, Inc.
N1940 State Hwy 95
Neillsville, WI 54456
715-743-4163
Fax: 715-743-2921
Contact: Ron Jones
E-mail: jonesconsulting@juno.com

Manufacturer of row crop flamers (flame kits and complete units) that combine flamers for in-row weed control and rolling cultivators for between-row cultivation. Row-crop flaming kits are available for 4, 6, and 8 rows. A flame hood setup is also available.

LP Weed Burner
56360 200th Street
Wells, MN 56097
507-553-5633
Contact: Dennis Lutteke

Manufacturer of row crop flamers (flame kits and complete units) adaptable to cultivators or toolbars.

Peaceful Valley Farm Supply
P.O. Box 2209
Grass Valley, CA 95945
888-784-1722 Toll-Free
530-272-4769 Local
Fax: 530-272-4794
E-mail: contact@groworganic.com
http://www.groworganic.com

Organic farm equipment and supply dealer, carries: hand-held flamers, backpack frames for propane tanks, row crop flame kit suitable for mounting on a toolbar and flaming 4 rows.

Flame Weeders
1711 Mud Lick Rd.
Glenville, WV 26351
304-462-7606
Contact: Steve Myer
E-mail: info@flame-weeders.com
http://www.flame-weeders.com

Farm-based equipment manufacturer specializing in flame weeders for market farmers. The flamers are mounted on wheels, combined with a flaming hood; the propane tank is carried on a back-pack frame. Models range in size from four torches at 24 inches in width to five torches at 30 inches in width, ranging in price from $300 to $400.

Forevergreen
19974 12 Avenue
Langley, BC
Canada V2Z 1W3
604-534-9326
Fax: 604-530-7129
E-mail: info@chemfree-weedcontrol.com
http://www.chemfree-weedcontrol.com

North American distributor of the Swiss-made Eco-Weeder, an infra-red thermal weeder heated by a propane flame passing over a ceramic casing. Models include hand-held and push-wheeled weeders for use around the home and in gardens, parks, market gardens, small farms, and orchards. Models: Punto Lady | Junior 3 Agri I / II | Agri Ronco | Agri IV 2 & 3 | Agri IV.

Rittenhouse & Sons
RR#3, 1402 Fourth Ave
St. Catharines ON, Canada
L2R 6P9
800-461-1041 Professional Sales
905-684-8122 Local
Fax: 905-684-1382
E-mail: prosales@rittenhouse.ca
http://www.rittenhouse.ca

See the section Alternatives for Weed & Pest Control. Rittenhouse sells the Infra-Weeder series in a price range of $210 for the hand held Infra-Weeder Eliminator (8.5 cm x 17cm plate), to $880 for the hand-held Infra-Weeder 100 (6" x 11" plate), to $1,200 for the push-wheeled Infra-Weeder 300 (8" x 12" plate).

Waipuna USA
1050 W. Lilycache
Bowlingbrook, IL 60440
630-514-0364
Fax: 630-759-8155
E-mail: jeffw@waipuna.com
Contact: Jeff Wingren
http://www.waipuna.com

Waipuna, from New Zealand, specializes in a hot foam system; the foam is derived from coconut sugar and corn sugar and is approved for organic production. A single-burner generator covers a width of 8 to 10 inches in the $22,000 price range. A double-burner generator covers a width of 24 to 32 inches in the $35,000 price range. Currently these are geared to municipalities, park departments, airports, and institutional settings. An agricultural unit is under development, with an aim toward orchards, vineyards, and similar agricultural applications.

Aqua Heat Technology, Inc.
5155 E. River Road, Suite 405
Minneapolis, MN 55421
763-785-2661
Contact: Harry Rajamannan

Aqua Heat is the company in Minnesota that developed hot-water weed-control equipment for orchards, vineyards, and park departments.

OESCO, Inc.
P.O. Box 540, Route 116
Conway, MA 01341
800-634-5557 Toll-Free
413-369-4335 Local
Fax: 413-369-4431
Email: info@oescoinc.com
http://www.oescoinc.com

Supplier of the Aquacide hot water weed control equipment system, in the price range of $9,000, geared to nursery production, landscapes, and park departments.

Videos

Vegetable Farmers and Their Weed-Control Machines is a 75-minute educational video on mechanical cultivation and flame weeding equipment produced in 1996 by Vern Grubinger (University of Vermont) and Mary Jane Else (University of Massachusetts), with funding from USDA-SARE. Cost is $12.00 from:

NRAES — Natural Resource, Agriculture, and Engineering Service
Cooperative Extension
152 Riley-Robb Hall
Ithaca, New York 14853-5701
607-255-7654
Fax: 607-254-8770
E-mail: nraes@cornell.edu
http://www.nraes.org/publications/sarev1.html

Web Resources

Thermal Weed Control: Flame Weeding

Flame Cultivation in Cotton
Mississippi State University Extension Service, IS 1500
http://msucares.com/pubs/is1500.htm

Flame weeding has a long history of use in the Mississippi Delta states. This fact sheet from Mississippi State University provides a brief introduction and summary on flame cultivation for cotton.

Flame Engineering, Inc. On-Line Agricultural Flaming Guide
http://www.flameeng.com/flamingg.htm

The Agricultural Flaming Guide provides a history of flame cultivation, with a summary of methods and flaming techniques for corn, soybeans, grain sorghum, cotton, potatoes, tomatoes, cole crops, alfalfa, and grape vineyards.

Other Practices to Control Weeds: Flame Weeding
Sustainable Practices for Vegetable Production in the South
Dr. Mary Peet, NCSU
http://www.cals.ncsu.edu/sustainable/peet/IPM/weeds/otherpra.html

Dr. Mary Peet published one of the very first books on sustainable vegetable production. This section touches on flame weeding, with a couple of farmer profiles.

Hot Tips For Flame Weeding
From: *Steel in the Field*, SAN Publications
http://wsare.usu.edu/docs/steel/p27-28.html

A section on flaming from *Steel in the Field*, a publication from SAN (Sustainable Agriculture Network). *Steel in the Field* is a practical handbook on non-chemical weed control, with very helpful diagrams and descriptions of 37 specialized cultivators used in mechanical weed control; highly recommended for the organic farmer's bookshelf.

Flame Weeding
Reducing Herbicide Usage on the Farm project | Agricultural Utilization Research Institute (AURI) and Sustainable Farming Association of Minnesota (SFA)
http://www.auri.org/proproj/flamewee.html

A report on flame weeding techniques and field trials on vegetable farms in Minnesota.

Flame Weeding for Weed Control and Renovation with Strawberries
Greenbook 2000, Energy and Sustainable Agriculture Program, Minnesota Department of Agriculture
http://www.mda.state.mn.us/ESAP/greenbook2000/FruitsWildung.pdf

Flame Weeding for Weed Control and Renovation with Strawberries
Greenbook 2001, Energy and Sustainable Agriculture Program, Minnesota Department of Agriculture
http://www.mda.state.mn.us/ESAP/greenbook2001/2001gb37.pdf

These two research reports summarize field trials on flame weeding for strawberries in Minnesota, with relevant details on weed control techniques and tips for flame weeding.

A Review of Non-Chemical Weed Control Techniques
S. Parish, Biological Agriculture and Horticulture, Vol. 7
http://www.eap.mcgill.ca/MagRack/BAH/BAH%205.htm

A reprint of a classic article in the journal *Biological Agriculture and Horticulture*, from one of the European researchers.

Thermal Weed Control by Flaming: Biological and Technical Aspects
J. Ascard. Department of Crop Production Science, Swedish University of Agricultural Sciences, Uppsala, Sweden
http://zeus.bibul.slu.se/documents/slu/rapport_lantbruksteknik/RLT200/RLT200.HTM

A detailed and informative summary of flame weeding research, apparently an abbreviated version of J. Ascard's thesis through Swedish University of Agricultural Sciences (a 43-page printout).

Comparison of Three Weed Control Methods: Chemical, Flame and Hot Water
University of Queensland (Australia)
http://life.csu.edu.au/agronomy/papers/315/315.html

Hot water was as effective as glyphosate herbicide. Flaming was less effective, but acceptable weed kill was obtained on juvenile weeds.

Great Balls of Fire!
Ecological Farmers Association of Ontario
http://eap.mcgill.ca/MagRack/EFA/EF_95_P_05.htm

A brief report on field trials regarding flame weeding in potato production.

Flame Weeding in the Garden
By Sheila Daar
http://www.gameco.com.au/Flame%20Weeding.htm

An online reprint of The IPM Practitioner article by Sheila Daar, located on the Gameco gas equipment company site in Australia.

Controlling Weeds in Organic Crops Through the Use of Flame Weeders
Ronnie W. Heiniger. Organic Farming Research Foundation. No. 6. Summer. p. 17–19.
http://www.ofrf.org/publications/news/ib6.PDF

A research report from the Organic Farming Research Foundation. The project took place in North Carolina and investigated the use of flame equipment in organic popcorn, soybeans, and cotton. The complete 11-page report is available from OFRF and includes tables with economic cost, gas usage figures based on pressure and tractor speed, and weed biomass and yield figures for popcorn.

Flame Weeding Research at Texas A&M
Dr. Wayne A. LePori, Department of Agricultural Engineering,Texas A&M University
http://baen.tamu.edu/users/lepori/Research/Flame/flame_weeding.htm

Dr. Wayne LePori's flame weeding research program at Texas A&M, in collaboration with Mississippi State University and University of Florida, is aimed at developing new burner designs and equipment modifications for improved flame weeding in cotton, sugar cane, vegetables, and other crops. This site features quarterly research reports and slide presentations, available as downloads, with color photos of equipment, field trials, and research results.

Flame Weeding Research at Nova Scotia Agricultural College | Nabil Rafai
http://www.nsac.ns.ca/eng/staff/nri/

Dr. Nabil Rafai's research site provides results and photos of flame weeding and steam weeding.

Thermal Weed Control:
Infra-Red, Steam, Hot Water, International Companies & Technology

Controlling Weeds Using Propane Generated Flame or Steam Treatments in Crop and Non-Croplands
Dr. Thaddeus Gourd, Adams County, Colorado State University Cooperative Extension
http://www.colostate.edu/Depts/CoopExt/Adams/ag/swcg2002.htm

Colorado State University will compare flame and steam weed control methods and equipment, including the Atarus Stinger.

The Use of Steam as an Alternative Herbicide
Sandra Robinson, Virginia Tech
http://fbox.vt.edu:10021/S/sarobins/robinson.htm
http://fbox.vt.edu:10021/S/sarobins/robinsn2.htm

Reviews the use of the Aqua Heat hot-water weed control system, with a summary of the advantages and disadvantages.

Hot Water Weed Control in Carrboro, NC
http://ftp.oit.unc.edu/arc/waipuna.htm

The Waipuna hot-water weed control system is being used by the Town of Carrboro, North Carolina, as part of its Least Toxic Integrated Pest Management (IPM) policy and pesticide reduction program that seeks least-toxic alternatives.

Hot Water: A "Cool" New Weed Control Method
Journal of Pesticide Reform. Vol. 15, No. 1.
http://www.eap.mcgill.ca/MagRack/JPR/JPR_27.htm

Reprint of a brief article introducing the hot-water weed control method, featuring the Waipuna system from New Zealand.

Effect of Steam Application on Cropland Weeds
Kolbert, Robert L. and Lori J. Wiles. 2002. | Weed Technology. Vol. 16, No. 1. pp. 43–49.
http://www.bioone.org/bioone/?request=get-abstract&issn=0890-037X&volume=016&issue=01&page=0043

Journal article in *Weed Technology*, summarizing research on a custom-built, prototype steam generator-applicator machine with combined tillage implements for use in row crop weed control and no-till agriculture.

Hot Water Technology
EPA Methyl Bromide Alternatives
http://www.epa.gov/Ozone/mbr/casestudies/volume1/aquaheat.html

A case study on field trials with the Aqua Heat system in Florida, aiming to control nematodes and soil-borne pathogens. Custom applicator costs are estimated at $1,000 to $1,500 per acre for hot water, which is comparable to $1,200 to $1,500 per acre for methyl bromide.

Nursery Soil Fumigation
Dick Karsky, National Proceedings: Forest and Conservation Nursery Associations, 1997
http://www.na.fs.fed.us/spfo/rngr/pubs/np97/fumig.htm

A paper on steam for soil fumigation in field-grown nursery production. This item is included for the notes, photos, and comments on steam technology and equipment in general.

Eco-Weeder (Puzzy Boy)
The Nature Conservancy newsletter
http://tncweeds.ucdavis.edu/tools/puzzy.html

A newsletter about the Swiss-made infra-red eco-weeder from Forevergreen, also known in Europe as the Puzzy Boy.

Bare Ground Control Alternative: Flamers and Steamers
Model Pesticide Reduction Plan, Air Force Center for Environmental Excellence
http://www.denix.osd.mil/denix/Public/Library/AF_P2/Pest/app_b.html

A report on IPM weed control from the Air Force. It reviews the use of flamers and steamers for weed control, with cost estimates and pros and cons.

Thermal Treatment in Agriculture
Primagaz Ltd. (Hungary)
http://www.primagaz.hu/pages/mezogazdasagi/mezogazdasagi.en.html

Manual Thermal Weed Control
http://www.primagaz.hu/pages/mezogazdasagi/kezigyomirtok.en.html

The Heat Sensitivity of Weed Types
http://www.primagaz.hu/pages/mezogazdasagi/gyomokhoerzekenysege.en.html

Weeds are categorized into three levels of heat sensitivity: Highly, Moderately, and Slightly Sensitive to flame weeding.

Atarus Thermal Weed Control (Australia)
http://www.atarus.com.au/thermal.htm

The Atarus Stinger features a technology known as water-quenched combustion—a generator that con verts combusting fuel and water into a high-velocity, high-temperature, moist air flow. It is geared to orchards, vineyards, and row crops. The Atarus Ranger is a hand-held flame torch for use on farms, parks, and other landscapes.

Weed Control | HOAF Group | InfraRed Technology (The Netherlands)
http://www.hoaf.nl/Engels/html/en-onkruid.htm

Greenburner: Potato desiccation | HOAF Group | InfraRed Technology
http://www.hoaf.nl/Engels/html/en-lb_30.htm

Test Results with Greenburner| HOAF Group | InfraRed Technology
http://www.hoaf.nl/Engels/html/en-lb%20bv-expl.htm

The Drackedon Greenburner (UK)
http://www.drackedon.co.uk/prod_en.htm

Potato Haulm Destruction: The Alternative Methods and their Environmental Impacts
Mike Denbigh, student paper, Wye College, July 1997
http://www.drackedon.co.uk/docs_md1_en.htm

Thermal Infrared Weed Control
Zlatko Janvanociski. 1999. WA Bank Landcare Conference, "Where Community Counts," Esperance, Australia
http://www.wn.com.au/landcareconf/Javanociski.doc
A 4-page report from Australia.

ISHS Acta Horticulturae 372: Symposium on Engineering as a Tool to Reduce Pesticide Consumption and Operator Hazards in Horticulture
http://www.actahort.org/books/372/
Symposium abstracts, including a number of papers on thermal weed control.

Puzzy Boy Unkrautvernichter
http://bruehwiler.com/puzzyboy.htm
Web page for a German company selling the Puzzy Boy line of infra-red weeders. The pictures are a fast way to grasp what the different models look like.

UV Weed Control
Kaj Jensen and Electro Light ApS
http://www.kaj.dk/weed-by-uv.htm
Weed Control by ultraviolet (UV) light using high-powered electronic ballasts.

By Steve Diver
NCAT Agriculture Specialist

Edited by Richard Earles
Formatted by Ashley Hill

June 2002

CT165

The electronic version of **Flame Weeding for Vegetable Crops** is located at:
HTML
www.attra.ncat.org/attra-pub/flameweedveg.html
PDF
www.attra.ncat.org/attra-pub/PDF/flameweedveg.pdf