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Organic farming research project report submitted to the Organic Farming Research Foundation:

Project Title:

Controlling weeds in organic crops through the use of flame weeders

FINAL PROJECT REPORT

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Introduction

Several recent developments have resulted in the need for a new examination of flaming as a non-chemical method of weed control. First, there has been an increase in the number of soybean producers growing organic soybeans for the edible soybean market. These producers need a method of weed control that does not rely on chemicals. Second, new technologies in burner design and the use of water shields have increased the efficiency and effectiveness of flame weeders in destroying weeds while at the same time decreasing the harmful effects of heat on the crop plant. Finally, there is a growing realization among crop producers that the ecology of chemical weed control systems lead to persistent hard-to-manage weeds which demand more chemicals or a change in crops or crop genetics. Flame weeding would retard the evolutionary trend toward chemically resistant weeds since no plant is immune to temperatures above the boiling point of water.

Flame cultivation is not a new concept. Various attempts have been made to develop equipment for flaming weeds since the first flamer was built in 1852 (Edwards, 1964). With the development of the successful Stoneville propane burner in 1948, flame weeding became economically feasible. Increasing acceptance on the part of corn, soybean, cotton, and vegetable growers in the late 1950s and early 1960s resulted in over 25,000 flame weeders in commercial use by 1965. Unfortunately, improvement in the efficacy of chemical herbicides and increasing propane costs almost ended the use of flaming. In 1995, the use of flaming as a method of weed control was only practiced on less than I 0,000 acres of cotton mainly in the lower Mississippi delta.

Flaming destroys weeds by increasing cell temperature in the cortex region of the stern or in the leaf to the point that proteins are denatured resulting in loss of cell function and rupture of cell walls (Lalor and Buchele, 1968). To accomplish this, the temperature in the vicinity of the weed must exceed 600 to 800 ^{o}C for 0.1 s or more. The efficacy of the flaming process is controlled by three factors: 1) the amount of heat output from the burner, 2) the speed at which the flamer is operated, and 3) the distance from the weed to the mouth of the burner. The amount of heat output by the burner is primarily driven by the amount of propane gas flowing through the burner as controlled by the gas pressure. Therefore, the operator can control heat output by adjusting gas pressure and the speed of the flamer by adjusting tractor speed. Figure 1 shows the effect of heat output and exposure time on the efficacy of the flamer. The other factor that can be controlled is the distance between the burner and the weed. Figure 2 shows the heat pattern commonly found at the mouth of a burner. When properly adjusted for cross-flaming, the burners are pointed toward the row, angled down at a 45' angle, and staggered so that the flame crosses beneath the canopy and contacts small weeds growing in the row (Thomas, 1964).

Studies have shown that flaming can be effective in controlling a wide range of grass and broadleaf weeds (Lien et al., 1967). The best weed control is achieved by performing 2 to 3 passes with the flamer. When performed properly, flaming can be as effective as chemical weed control treatments. The benefits of flaming are that it does not leave chemical residues and is not affected by weather variability. The disadvantages of flaming are that several applications are necessary, it requires timely application, it does not have any residual weed control effects, and weeds that emerge with the crop are difficult to control without injury to the crop. Devices such as air curtains or water shields can assist in protecting small crop plants, but the key to effective weed control is to have a large size difference between the crop and the weed.

In North Carolina, fledgling enterprises have been started to provide edible soybeans to markets in Japan, colored cottons for the textile industry, and vegetables for markets in the Baltimore/Washington D.C./Philadelphia area. Of primary importance to these enterprises are effective weed control measures. The risk of unmanageable weed threatens the financial stability of these enterprises. Unfortunately, weed control techniques that were available prior to the advent of herbicides have not been practiced extensively nor have they been improved through the use of new technologies. A limited number of weed control options exist for farmers using organic fanning practices. Cultivation is the most widely used weed control method for organic growers. However, it has a number of disadvantages. First cultivation cannot control weeds growing within the crop row. Second, cultivation limits the use of no-till farming practices which are important in improving soil tilth. Finally, cultivation close to the crop row results in root pruning which restricts the amount of plant available water. By incorporating new technologies flame weeding can enhance weed management success and greatly reduce the risk of failure in organic cropping systems. Furthermore, this technique can be used effectively in conjunction with other cultural and biological practices such as burning down cover crops prior to planting.

Our goal is to re-introduce flaming as a method of cultural weed control by working to enhance current systems with improved technology and by demonstrating field techniques and systems which make effective use of this procedure. The success of this project has the potential for introducing new systems of weed control in organic and conventional agricultural with subsequent reductions in the use of pesticides and herbicides.

Materials and Methods

The objectives of this project were to test flaming on organic grown crops common to North Carolina. The selected crops were popcorn, soybeans, and cotton. Two fields were selected on farms with a history of growing organic crops in the tidewater region of the state. Soil testing found high levels of phosphorus and potassium. Chicken litter was applied to both fields in the fall of 1993 at a rate of 4480 kg ha^{-1}. A split-split plot arrangement was used in which the crop (popcorn, soybean, or cotton) was the main plot tillage system (conventional or no-till) was designated as the subplots, and flaming, cultivation, hand weeding, or no weed control was designated as the sub-subplots.

On the subplots using conventional tillage practices, a disk and field cultivator were used to prepare the land prior to planting. On the no-till subplots, a rye cover crop was planted on 4 January, 1994. Prior to planting, the no-till plots scheduled to receive flaming were completely flamed by setting a two-row flamer so that the burners covered the entire area. This pre-plant flaming was used to kill the rye cover crop and any small weed seedlings present in the no-till subplots. The no-till subplots scheduled to receive cultivation were mowed prior to planting to kill the rye cover crop and any emerged weeds.

Each crop was seeded according to the planting recommendations for that crop based on the North Carolina Cooperative Extension Service guidelines. Popcorn was planted in 36 inch rows on 5 May and 12 May at a seeding rate of 22,000 seeds per acre. Soybeans were planted in 36 inch rows on 31 May and 4 June at a seeding rate of 150,000 seeds per acre. Cotton was planted in 36 inch rows on 16 May and 22 May.

Two post-emergence flaming treatments were applied to the sub-subplots designated to receive flaming. The first was applied 8 to 10 days after emergence. The second was applied 16 to 21 days after emergence (just prior to canopy closure). Two postemergence cultivations were also performed on the sub-subplots designated to receive cultivation as the method of weed control. At both locations the cultivation treatments were done at the same time as the flaming treatments. The no weed control (check) sub-subplots did not receive any cultivation or flaming.

We evaluated flame weeder costs for both pre-plant burn down and row crop weeding. This was done by weighing LP gas bottles before and after application on plots and then converting lbs. to gallons of LP gas based on a standard conversion at a temperature of 80 degrees F. In this study, we used plots that were 24 feet wide and 40 feet long. Tractor speed was varied from 2 mph to 6 mph. In the case of the burn down application, 8 burners were used. These were operated at pressures of 15, 18, 21, and 24 lbs. per square inch. In the row crop weeding operation, 4 burners were used and were tested at pressures of 12, 15, 18, and 21 lbs. per square inch.

Several parameters were measured in each sub-subplot. These included crop emergence (percent of planted seed), weed emergence (weeds per square foot), crop height at canopy closure, weed biomass at flowering (silking in popcorn, R3 in soybeans, and first flower in cotton), crop yield, the amount of propane used and the cost of the operation. These were compared using the appropriate statistical analysis (SAS, 1989).

Results and Discussion

Analysis found no statistical differences in crop emergence between either the conventionally tilled or no-till subplots or among the four weed control treatments. There was a significant interaction between crop and tillage practice and crop and weed control for both the amount of weed biomass and crop yield. However, for all three crops the response pattern in both weed biomass and crop yield were similar across tillage practices (Figs. 3, 4, and 5). There were no significant interactions between tillage practice and weed control for either weed biomass or crop yield, nor was there a three way interaction between crop, tillage practice, and weed control.

For all three crops, there was a significant difference in the amount of weed biomass between the conventional tillage and no-till treatments (Figs. 3, 4, and 5). In all cases, the amount of weed biomass was greater in the conventional tilled plots. This was due to the effect of the cover crop in suppressing weed germination (data not shown).

The number of germinating weed seedlings were consistently lower in the no-till plots where the rye cover crop was planted. Flaming did not reduce the number of germinating weed seedlings when compared to the non-flamed plots.

In all three crops, there was a significant difference in weed biomass among the four weed control treatments (Figs. 3, 4, and 5). Hand weeding had the lowest weed biomass followed by flaming which had significantly less weed biomass than the cultivated plots. The no weed control plots always had the highest amount of weed biomass in these fields.

There were no significant differences in grain or lint yield between the conventional or no-till treatments regardless of the crop planted (Figs. 3, 4, and 5). However, crop yields tended to be higher in the no-till plots. In all three crops, there were significant differences among the four weed control treatments for grain or lint yield. In all cases, the no weed control treatment had the lowest grain or lint yields. While grain yields for both the popcorn and soybean did not significantly differ between the flaming and cultivation treatments, yields were always higher in the flame weeded plots. There was a significant difference in lint yields between the flame and cultivation treatments. The flame weeded plots had higher lint yields than the plots that were cultivated. In all cases, the hand weeded plots had significantly higher grain or lint yields.

Our trials showed that for burn down application you need to use maximum gas pressure at speeds of less than 2 mph to be effective. This Estates to a cost of $14.11 or more (Tables 1 and 2). For row crop weeding, pressures of 18 to 20 lbs. per sq. in. at speeds of 4 to 6 mph gave the best results. This means that costs ranged from $4.00 down to $2.08 depending on the pressure-speed combination selected.

Table 1. Gallons of LP gas used based on pressure and tractor speed.

	Gals LP Gas Used Per Acre					
Pressure	Burn Down			Row Crop Weeding		
(lbs per sq in)	2 mph	4 mph	6 mph	2 mph	4 mph	6 mph
12	N/A	N/A	N/A	7.2	4.4	2.4
15	17.0	10.3	5.7	8.1	4.9	2.7
18	18.1	11.3	6.5	9.0	5.6	3.2
21	19.6	12.5	7.6	10.1	6.4	3.9
24	21.7	14.0	8.8	N/A	N/A	N/A

Table 2. Cost of flaming based on gas pressure, tractor speed and the price of LP gas calculated at $0.65 a gallon (current agricultural application price).

	Cost of LP Gas Per Acre					
Pressure	Burn Down			Row Crop Weeding		
(lbs per sq in)	2 mph	4 mph	6 mph	2 mph	4 mph	6 mph
12	N/A	N/A	N/A	4.68	2.86	1.56
15	11.05	6.70	3.71	5.27	3.19	1.76
18	11.77	7.35	4.23	5.85	3.64	2.08
21	12.74	8.13	4.94	6.57	4.16	2.54
24	14.11	9.10	5.72	N/A	N/A	N/A

Conclusions

This study shows that weed control in organic crops can be improved by the use of a cover crop in conjunction with no-till systems and by flaming. Weed biomass was consistently lower in the no-till system because the cover crop reduced the number of weed seedling which germinated. The use of flame weeding also consistently reduced weed biomass when compared to conventional cultivation. The combination of the cover crop/no-till system and flaming came the closest to the hand weeded plots in terms of weed control.

The same combination of cover crop/no-till and flaming also had the highest grain or lint yields of any treatment other than the hand weeding. Although grain or lint yields were not significantly higher in the cover crop/no-till system, this system did show some yield improvement over conventional tillage. The lack of a clear yield difference is probably due to the effect of the cover crop on plant available moisture at planting. Flaming consistently produced better weed control and higher crop yields even though the popcorn and soybean yields were not significantly greater when compared to the cultivation treatment.

The extra cost of the LP gas and a flamer represents the cost difference between flaming and cultivation. A flame kit runs around $2,800.00 for an 8 row kit, a 300 gallon propane tank can cost $500.00, and water shield could be assembled for less than $500.00. Therefore, the investment costs for getting setup needs to be considered based on the number of acres over which the unit will run. Labor costs for running the unit should be similar to those for using a sprayer or cultivator. Using present technologies a burn-down flaming will cost over $14.00 per acre. Based on the yield response found in this study, this cost would be returned in this situation. More work on the consistency of yield increases needs to be done to determine if this will be the case in all situations. In this study, post-emergence flaming costs were $5.92 per acre. This cost was easily returned in the increase in grain or lint yield found in these fields.

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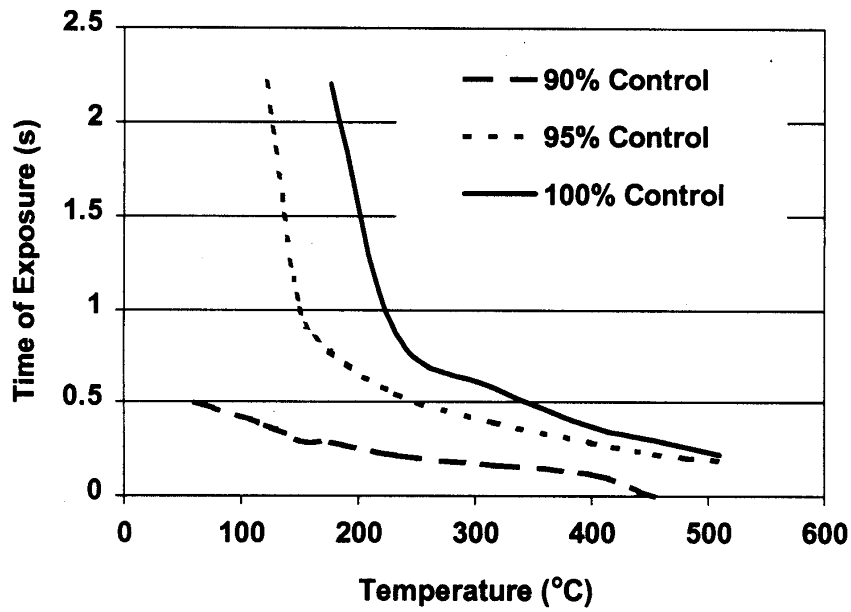

Fig. 1. Effect of temperature and time of exposure on the efficacy of flaming for killing plant tissue. Source Lalor and Buchele, 1968.

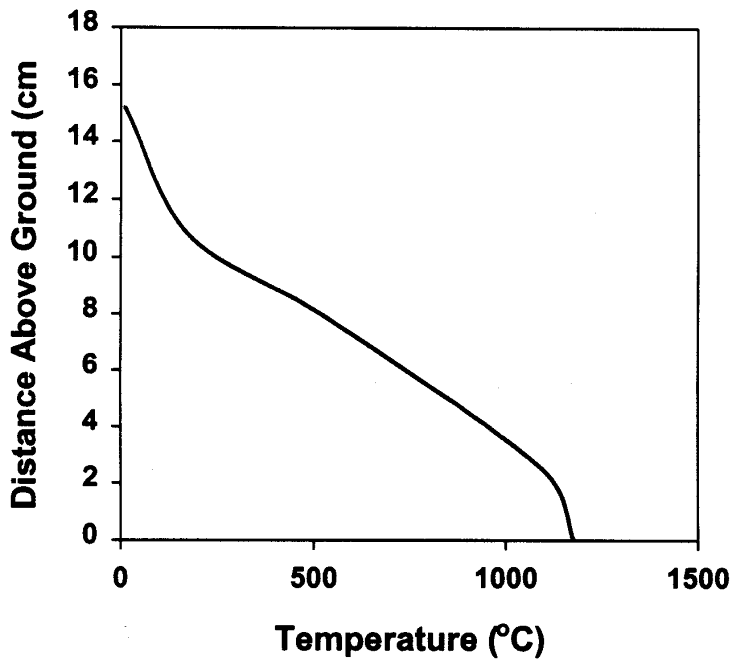

Fig. 2. Effect of distance from burner on the temperature experienced by the plant. Source Thomas, 1964

Fig. 3. Effect of tillage practice and weed control treatment on weed biomass at silking and grain yield of popcorn.

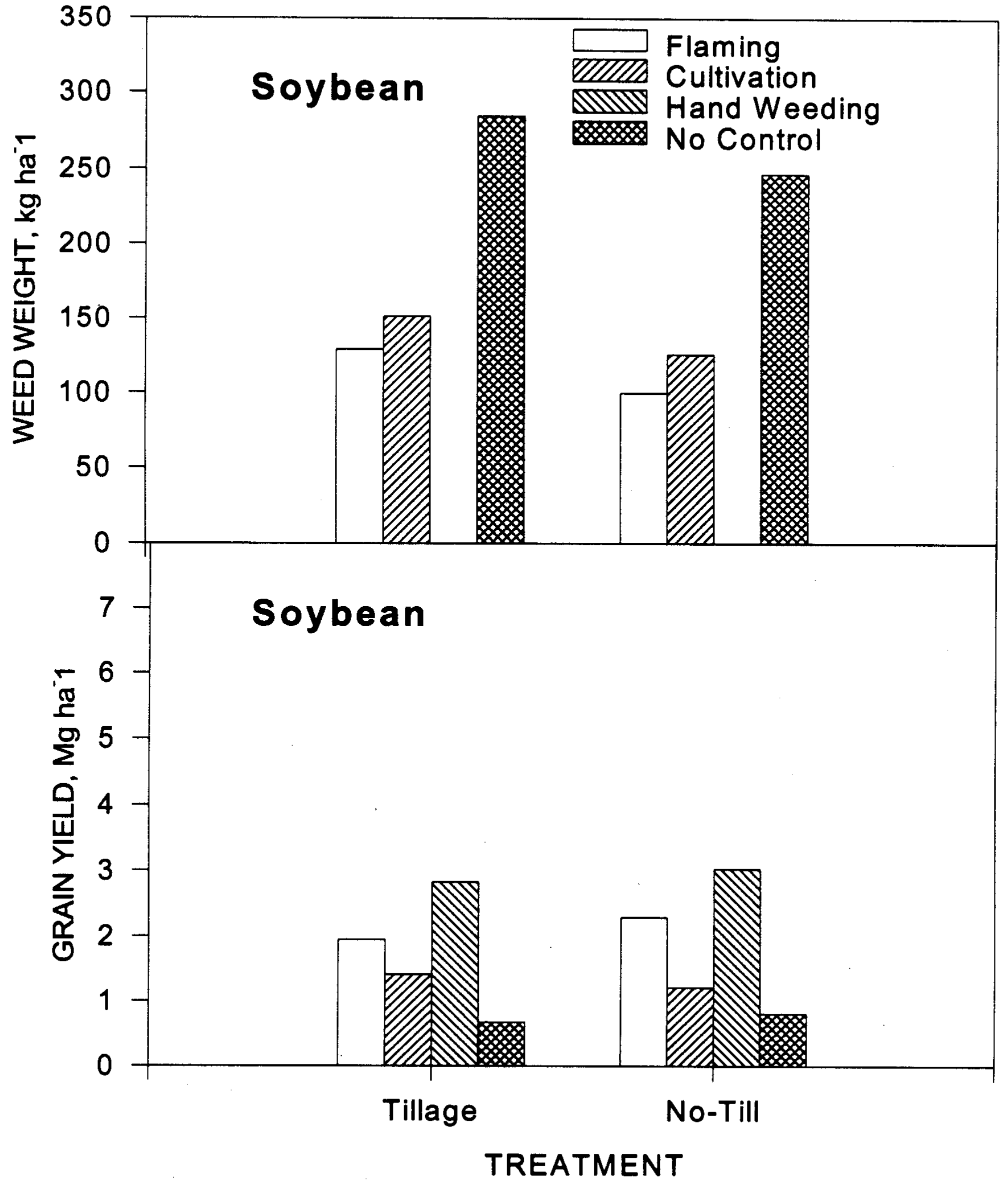

Fig. 4. Effect of tillage practice and weed control treatment on weed biomass at R3 and grain yield of soybean.

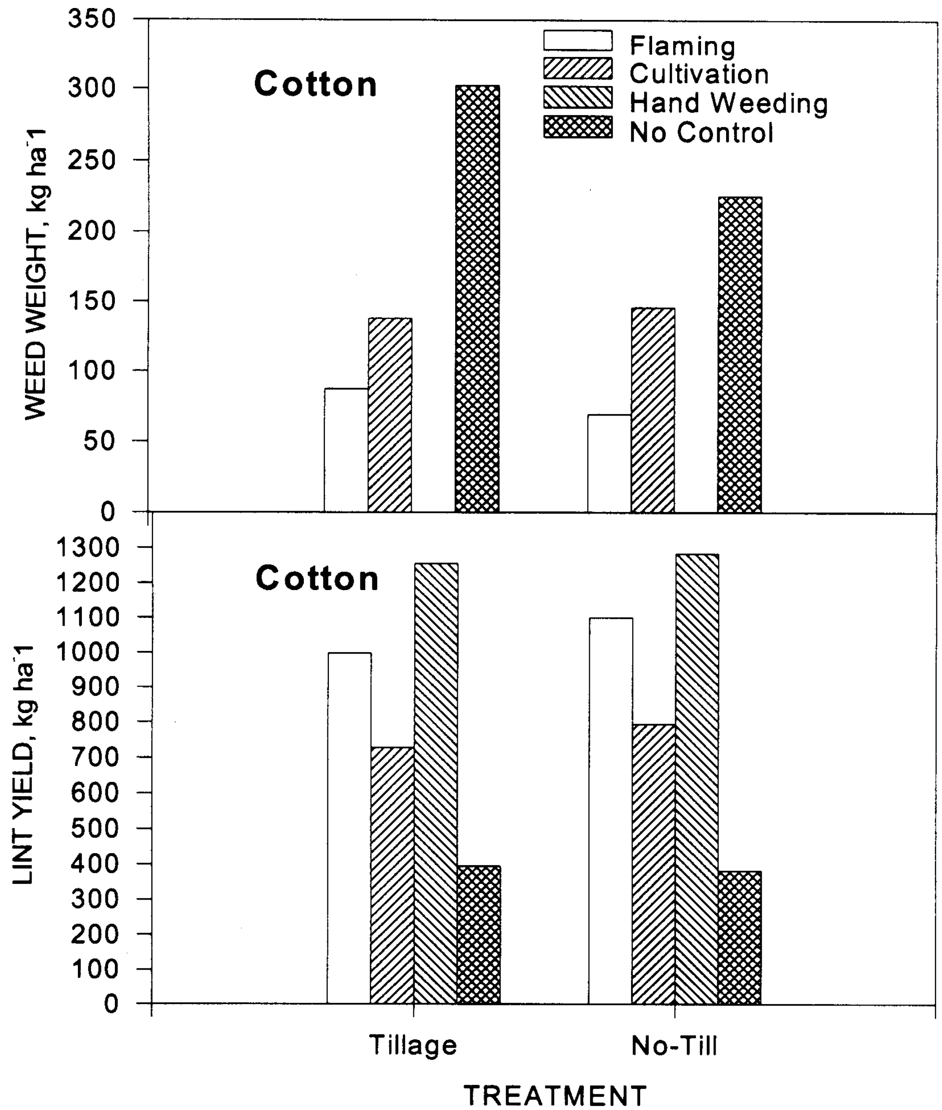

Fig. 5. Effect of tillage practice and weed control treatment on weed biomass at first flower and lint yield of cotton.