ORGANIC FARMING RESEARCH FOUNDATION

Project report submitted to the Organic Farming Research Foundation:

Project Title:

Evaluation of In-Row Weed Cultivators in Organic Soybeans and Corn

FINAL PROJECT REPORT

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Project summary

Weed control is a major concern for organic farmers. While there are various implements that offer excellent weed control between rows they provide limited in-row weed control. This project evaluated the following types of in-row weeders during the 2002 field season: 1) Williams Tool System (tine weeder), 2) wiggle hoe, 3) rolling cultivator, 4) finger weeder, and 5) Bezzerides Cultivator System with spyder set and spring hoe. It was expected that some cultivators may offer better in-row weed control than others. Replicated trials were conducted in soybean and corn fields on a certified organic grain farm in Wayne County, Ohio and in soybeans on certified organic research land at Ohio State University's Ohio Agriculture Research and Development Center in Wooster, Ohio. There was an extreme drought during the 2002 field season and adverse field conditions greatly influenced the trials. Results under drought conditions indicated that the in-row cultivators generally reduced the weed counts although in the majority of the cases the reduction was not statistically significant at the 5% level. Yields were reduced in relation to previous years, and from an economic point of view the use of the in-row cultivators was not justified. Multiple years of data under better field conditions are needed before the implements can be ranked according to their effectiveness and costs/benefits.

Introduction

National and state surveys show that weed management is one of the major concerns of organic farmers. Weed control after crop plants have emerged can become a significant and costly problem. Weeds appear between rows (inter-row) and within rows (intra-row). It is important to control both for maximum productivity. Given current weed management practices by organic grain farmers in Ohio, intra-weed control remains a limiting challenge for many. A number of these farmers have requested that Ohio State University evaluate the use of specialized in-row mechanical weed control implements. Scientific information on mechanical intra-row weed control is limited, especially for research conducted under organic conditions. In collaboration with an experienced organic grain farmer, replicated trials were conducted in soybean, corn and sunflower fields on a certified organic grain farm in Wayne County, Ohio and in soybeans on research land that was organically certified in spring 2002 at Ohio State University's Ohio Agriculture Research and Development Center in Wooster, Ohio. The sunflower field was added to the corn and soybean fields to enhance the testing of the implements. Initially, it was proposed to evaluate six different types of in-row weeders during the 2002 field season: 1) Williams Tool System, 2) wiggle hoe, 3) rolling cultivator, 4) finger weeder, 5) Bezzerides Cultivator System with spyder set and spring hoe, and 6) Bezzerides Cultivator System with spyder set and torsion weeders. After preliminary trials it was decided that the sixth configuration was very similar with the fifth, and with the agreement of the farmer it was decided to withdraw it from the trials.

Objectives

1. To investigate the abilities of six in–row weeding implements to control in-row weeds in organic soybeans and corn. The initial selected six implements were reduced to five after preliminary trials showed that the Bezzerides Cultivator System with spyder set and spring hoe, was similar with the Bezzerides Cultivator System with spyder set and torsion weeders. This change was made with the agreement of the farmer. Also it was decided to use the Williams tool system as the tine weeder without the optional side knives offered.

2. To evaluate the economic costs and benefits, including labor, of six in-row weeding implements in organic soybeans and corn.

Materials and methods

A randomized block design with five replications was used to evaluate five implements and a control in all experiments. The treatments are:

1) ***Tine weeder (Figure 1)***
2) ***Wiggle Hoe (Figure 2)***
3) ***Rolling Cultivator (Figure 3)***
4) ***Finger Weeder (Figure 4)***
5) ***Bezzerides Cultivator System with Spyder Set and Spring Hoes (Figure 5)***
6) ***Control – standard row cultivation only***

Figure 1. Tine weeder.

The tine weeder (Fig. 1) cultivates blind before and after emergence in the row and between the rows. They can root out small weeds while they are not effective for larger weeds. Tines can be adjusted to offer aggressive action. For after-emergence weeding operations, a trial should be conducted to adjust the penetration angle of the spring tines. If wrongly adjusted, it could either have minimum effect on the weeds or our crop plants will be eliminated together with small weeds.

Figure 2. Wiggle hoe.

The wiggle hoe (Fig. 2) is a toolbar mounted on an in-row cultivator. It uses hand steered side knives that are controlled by an operator and can be moved in and out. Knives can reach very close to the row and eliminate the weeds. At the same time if the operator loses control of the implement, it can damage the crop plants.

Figure 3. Rolling cultivator.

Rolling cultivator (Fig. 3) uses units of twisted blades that provide a slicing action and can move soil laterally as well as uprooting small weeds and mulching. The angle of the gangs can be adjusted. For the purposes of this experiment they were placed 8 inches apart.

Figure 4. Finger weeder.

Finger weeder (Fig. 4) consists of steel cone wheels that are ground driven (spike tines on the bottom) and they have rubber fingers on their perimeter. The rubber fingers engage with the soil just below the surface uprooting small weeds located very close to the crop plants.

Figure 5. Bezzerides Cultivator System with Spyder Set and Spring Hoes

Bezzerides Cultivator System consists of a pair of steel wheels located in the front of the cultivator which crumbles soil and dislodges weeds very close to the row. The spring hoes follow the wheels and slightly move soil between crop plants in the row.

Experimental design

Three experiments were established on Canaan Creek Organic Farm on soybean, corn and sunflower fields. A fourth experiment in soybeans was established on OARDC land that was organically certified in 2002. The distance between the two fields was around 20 miles. Each sample plot was four rows wide (10 ft) by at least 200 feet long. This length is long enough to give each implement a fair evaluation at its recommended velocity. Farm management was the same for all plots up until time to begin row cultivating. All plots were row cultivated as usual for organic soybean, corn and sunflower management. The implements were used as separate passes in this evaluation. Timing and frequency of implement use was based on a consensus of farmer input, manufacturer recommendation and researcher judgment. Figure 6 shows the experimental layout on the OARDC land. The layouts on the Creek Organic Farm were similar.

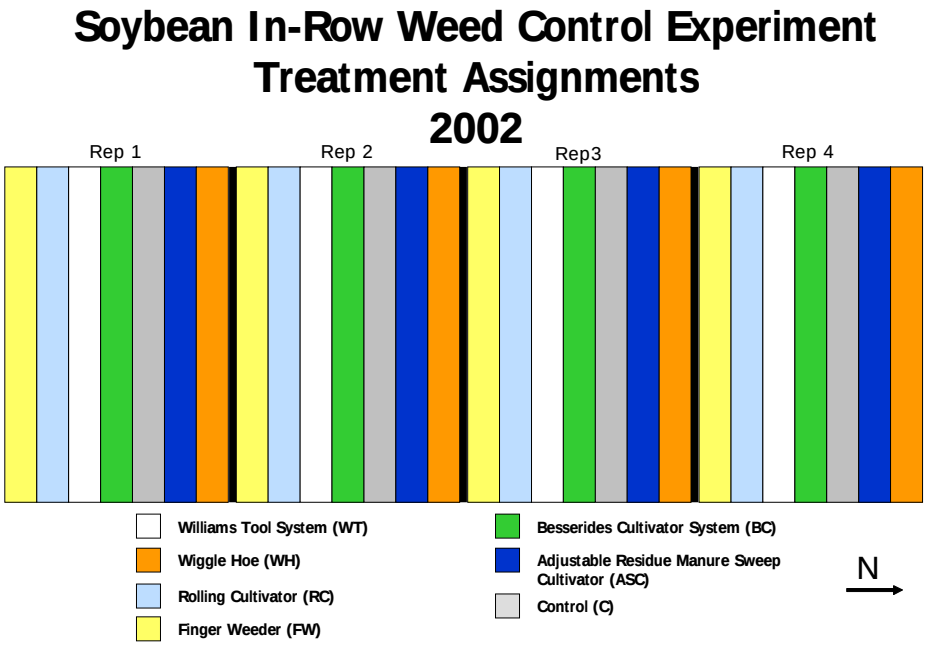

Figure 6. Treatment assignments for the West Badger Farm.

The following variables were monitored to assess the performance of the weeding implements*:*

1) Number of in-row weeds. The number of weeds was counted in the first two inches on each side of the row and the second two inches on each side of the row (Fig. 7). It was attempted to evaluate the impact of the implements very close to the row and not so close to the row.

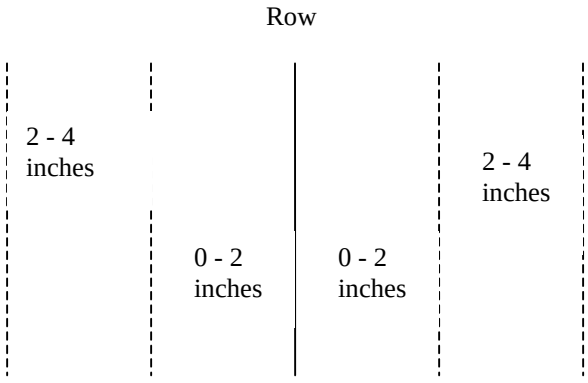

Figure 7. Areas of sampling.

2) Number of crop plants. Number of remaining crop plants after the in-row cultivation. Since the in-row cultivators operate very close to the row this measurement intended to investigate the damage if any on the crop plants due to the cultivating operation.
3) Biomass of in-row weeds. Biomass of in-row weeds was not counted due to the small biomass of the weeds.
4) Crop yield. It was influenced significantly from the adverse weather conditions (drought) and ranged from low to very low.

Three random subplots per plot were established for all evaluations. The number of weeds and corn/soybean plants remaining (within rows) were manually counted 2-3 weeks after the treatments, allowing plants that were only partly damaged to recover. Analysis of variance and LSD's was used to analyze treatment effects and statistical differences among implements and the no-implement control. The velocity and the depth of the cultivating operations per implement are shown in Table 1. It should be noted that the relatively low velocities are due to the proximity of the tools to the row. Low velocities limits the damage to the crop plants.

Table 1. Implements, operating velocities and depths (numbers are approximate).

	Operating speed (miles/hour)	**Depth of cultivation (in)**
Tine weeder	4 miles/hour	2 inches
Wiggle Hoe	2 miles/hour	2-3 inches
Rolling Cultivator	4 miles/hour	2 inches
Finger Weeder	2 miles/hour	1-2 inches
Bezzerides Cultivator System with Spyder Set and Spring Hoes	2 miles/hour	2 inches

Meteorological data

Weather conditions played an important role in those trials. During May - September 2002, precipitation was lower than the average. The data presented in figures 7 and 8 are taken from the Wooster, Ohio weather station (latitude: 40° 47' N, longitude: 81° 55' W, elevation: 1020 ft).

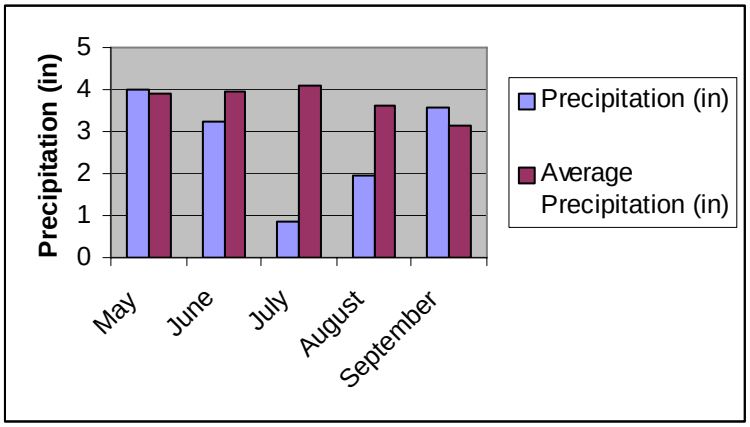

Figure 7. Precipitation data in Wooster weather station for May – September 2002.

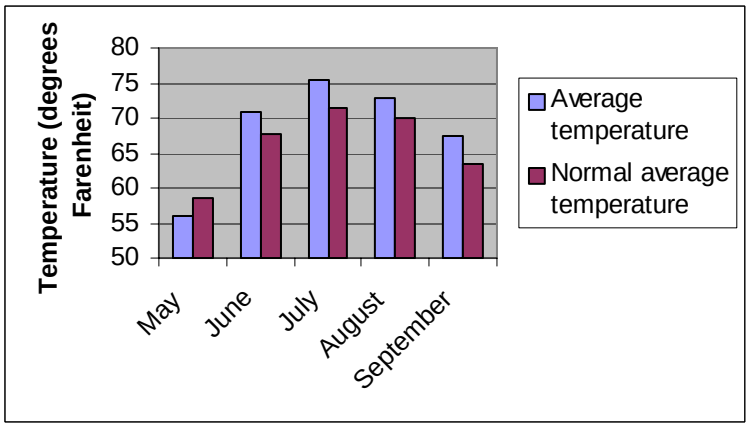

Figure 8. Temperature data for Wooster weather station for May – September 2002.

These adverse weather conditions (extreme drought and higher than average temperatures) did not facilitate a fair evaluation of the implements. The need to keep the moisture in the soil became a very important factor in determining the number of passages with the implements. Stirring of the soil will have resulted in further reducing the soil moisture, which was rejected by the farmer.

Canaan Creek Organic Farm

Soybeans experiment

July 2002

The soybeans in the Canaan Creek Organic Farm were planted on June 6, 2002. The first between the rows cultivation took place in the week of June 17, 2002. The first in-row cultivation took place in June 27-28, 2002. The weed counts for the first in-row cultivation were taken in July 10-11, 2002. Figure 9 shows the soybean and weed development on June 27, 2002. The predominant weeds were giant ragweed (*Ambrosia trifida*) and foxtail (predominantly giant) (*Setaria faberi*).

Figure 9. Weeds and soybeans on June 27, 2002.

Figure 10 shows the number of weeds at 0 - 2 inches distance on each side of the row. The number of weeds was reduced compared with the control, but the reduction was not statistically significant at the 5% level.

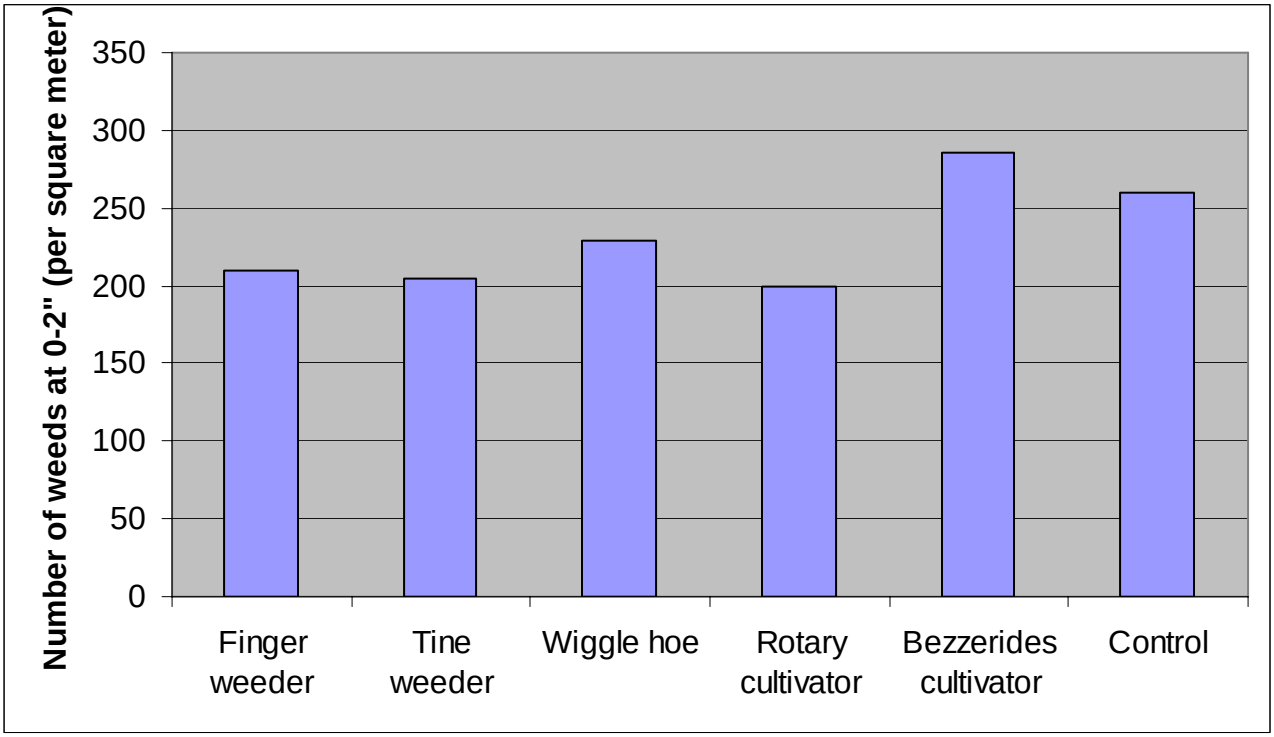

Figure 10. Weed counts (0 – 2 inches on each side of the row) on the soybean field, July 10-11 (lsd = 152.48, 0.05).

Figure 11 shows the number of weeds at a distance 2 – 4 inches on each side of the row. The difference between the control plots and the rest of the implements is not statistically significant at the 5% level.

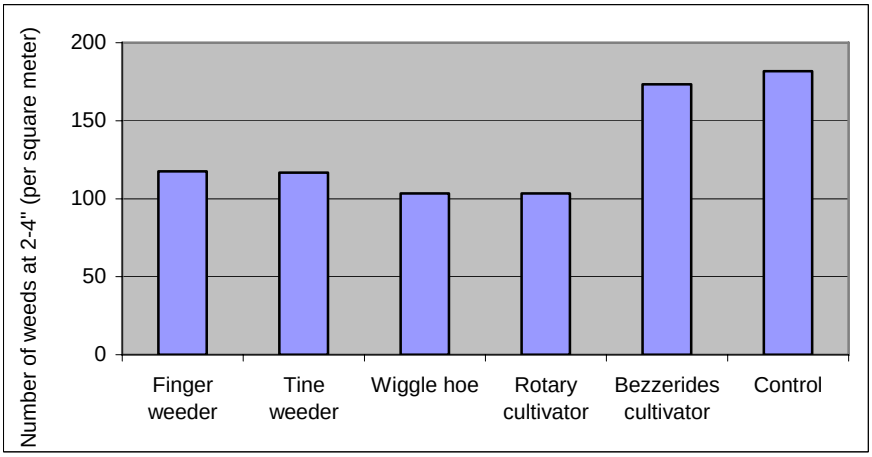

Figure 11. Weeds at 2 - 4 inches on each side of the row, July 10-11 (lsd = 123.74, 0.05).

Figure 12 shows the total number of weeds at 8 inches (0 - 4 inches on each side of the row). The difference between the control plot and the implements is not statistically significant at the 5% level.

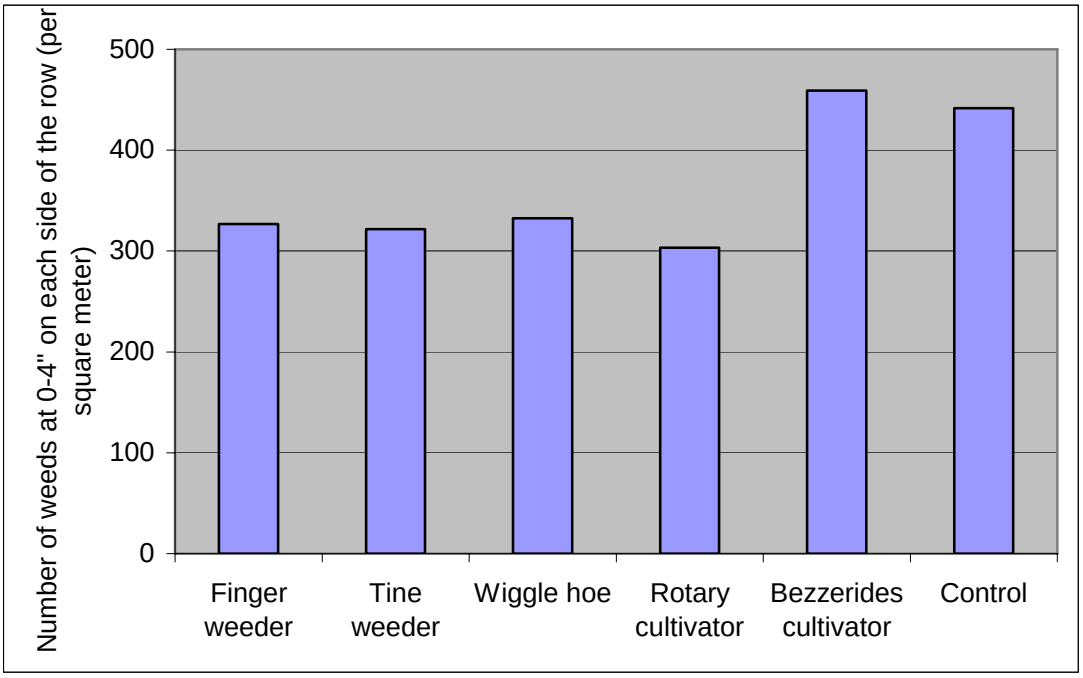

Figure 12. Weeds at 8 inches (0 - 4 inches on each side of the row), counted July 10-11 (lsd = 253.26, 0.05).

The number of soybean plants is shown in Figure 13. The difference in plant numbers between control and implements is not statistically significant at the 5% level.

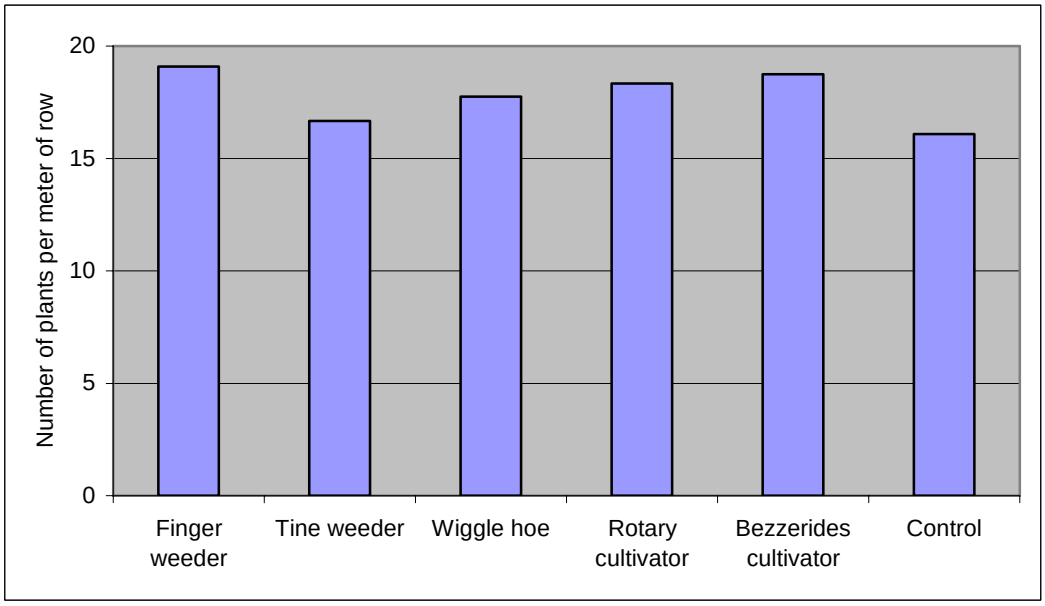

Figure 13. Number of soybean plants per meter of row (lsd = 3.80, 0.05).

In general all implements reduced the number of in-row weeds. The reduction was greater at 2 - 4 inches. The implements did not cause any significant damage to the soybeans.

October 2002

The measurements were repeated on October 14, 2002, just before the harvest.

Figure 14 shows the number of weeds per square meter on 8 inches (0 - 4 inches on each side of the row). The difference between the control and implements is not statistically significant at the 5% level.

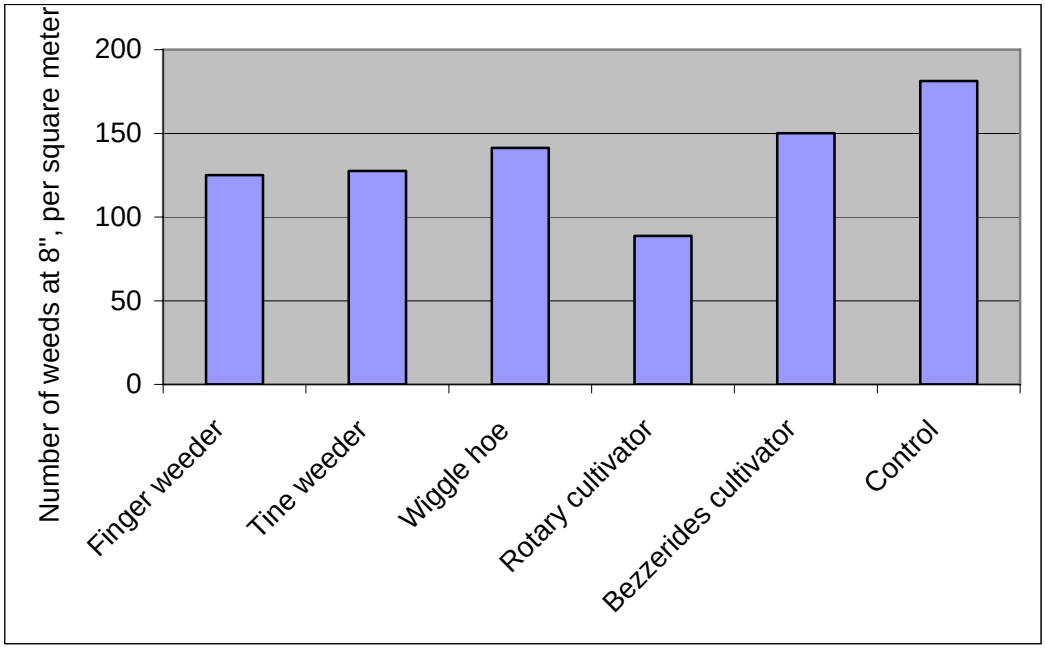

Figure 14. Weeds at 8 inches (0 - 4 inches on each side of the row), Oct. 14 (lsd = 98.00, 0.05).

Soybean field, West Badger Farm

July 2002

The soybeans in the West Badger farm were planted on June 6, 2002. The first in-row cultivation took place on July 1, 2002. The weed counts were taken on July 12-15, 2002. Figure 15 shows the soybeans and weeds developed on July 1, 2002. Due to a lack of space there was no control plot for 3 repetitions. For this reason the control was not used for statistical purposes. Predominant weeds were giant ragweed (*Ambrosia trifida*), foxtail (*Setaria faberi*), redroot pigweed *(*A*maranthus retroflexus*) and lambsquarters (*Chenopodium album*).

Figure 15. Weeds and soybeans on July 1, 2002.

Figure 16 shows the number of weeds at 0 - 2 inches on each side of the row. The difference between implements is not statistically significant at the 5% level.

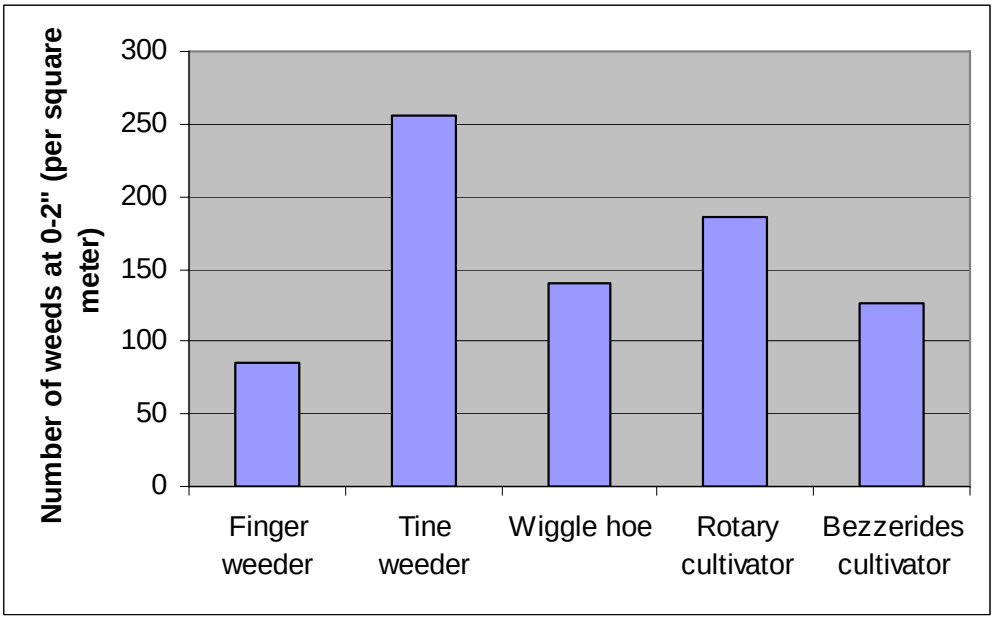

Figure 16. Weed counts on the West Badger Farm at 0 – 2 inches on each side of the row, July 12-15 (lsd = 150.92, 0.05).

Figure 17 shows the number of weeds at a distance 2 - 4 inches on each side of the row. The difference between wiggle hoe and tine weeder is statistically significant at the 5% level.

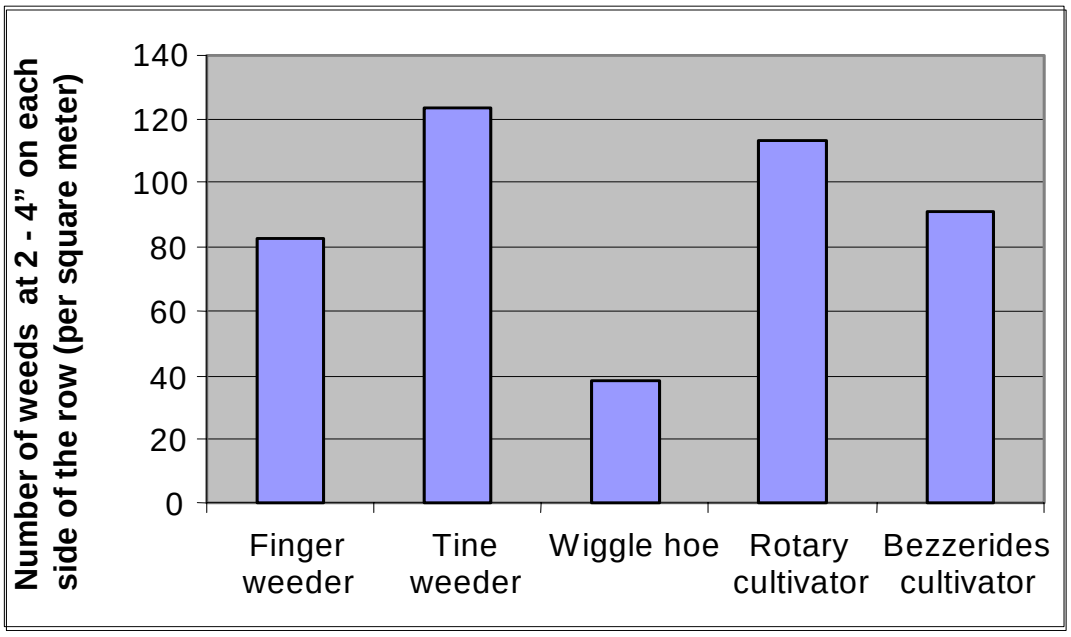

Figure 17. Weed counts on the West Badger Farm at Weeds at 2 - 4 inches on each side of the row, July 12-15 (lsd = 80.78, 0.05).

Figure 18 shows the number of weeds at a distance 0 - 4 inches on each side of the row. While the difference between the implements is not statistically significant at the 5% level, the finger weeder and wiggle hoe reduced the most the number of weeds at 0-4 inches on each side of the row.

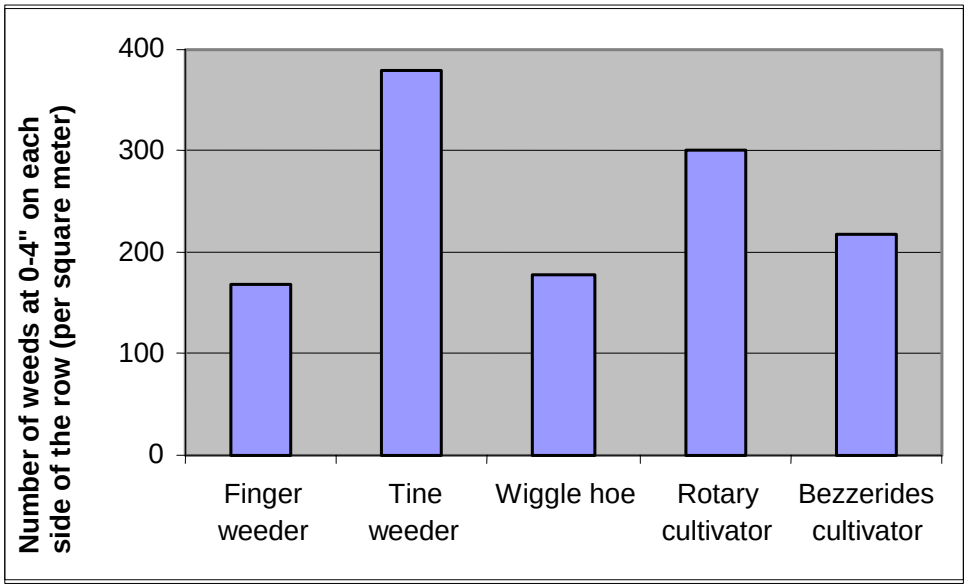

Figure 18. The number of weeds at 0 - 4 inches on each side of the row, July 12-15 (lsd = 215.62, 0.05).

Figure 19 shows the number of the soybean plants in the field. The difference is not statistically significant at the 5% level.

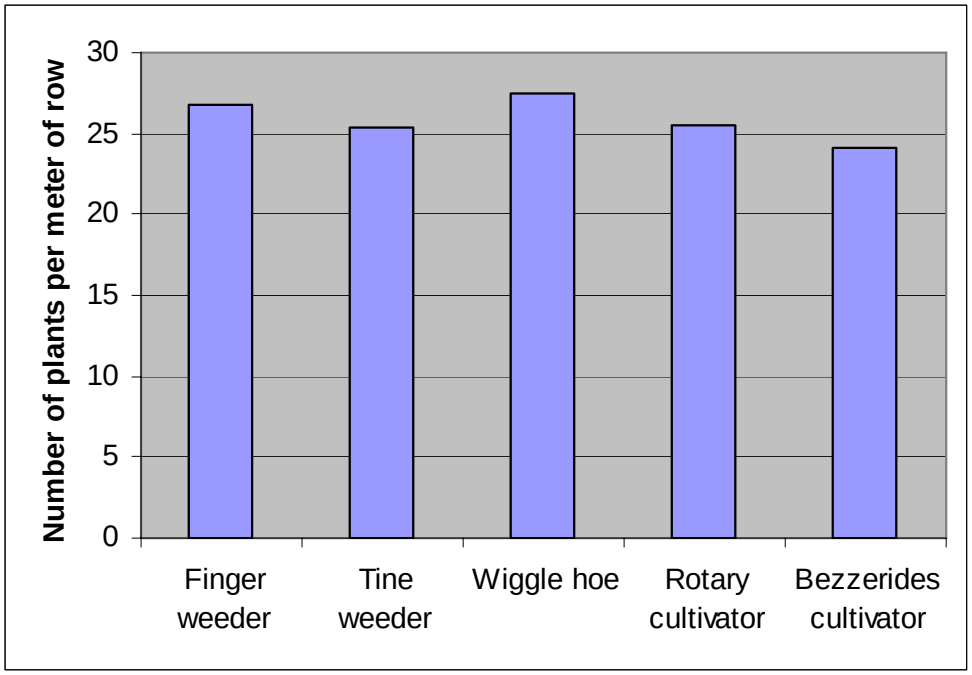

Figure 19. Number of soybean plants per meter of row, July 12-15 (lsd = 3.81, 0.05).

August 2002

The next in-row cultivation took place on July 24. The weed count took place on August 30. Weeds were counted at 0 - 4 inches on each side of the row (Fig 20). The difference between implements is not statistically significant at the 5% level.

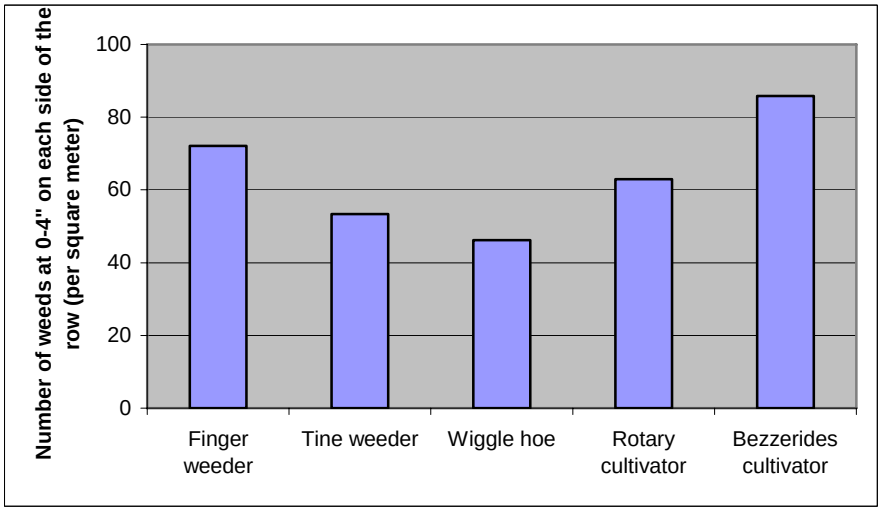

Figure 20. Weeds at 0 - 4 inches on each side of the row, Aug. 30 (lsd = 41.49, 0.05).

The number of soybean plants per meter is shown in Figure 21. The difference between treatments is not statistically different at the 5% level.

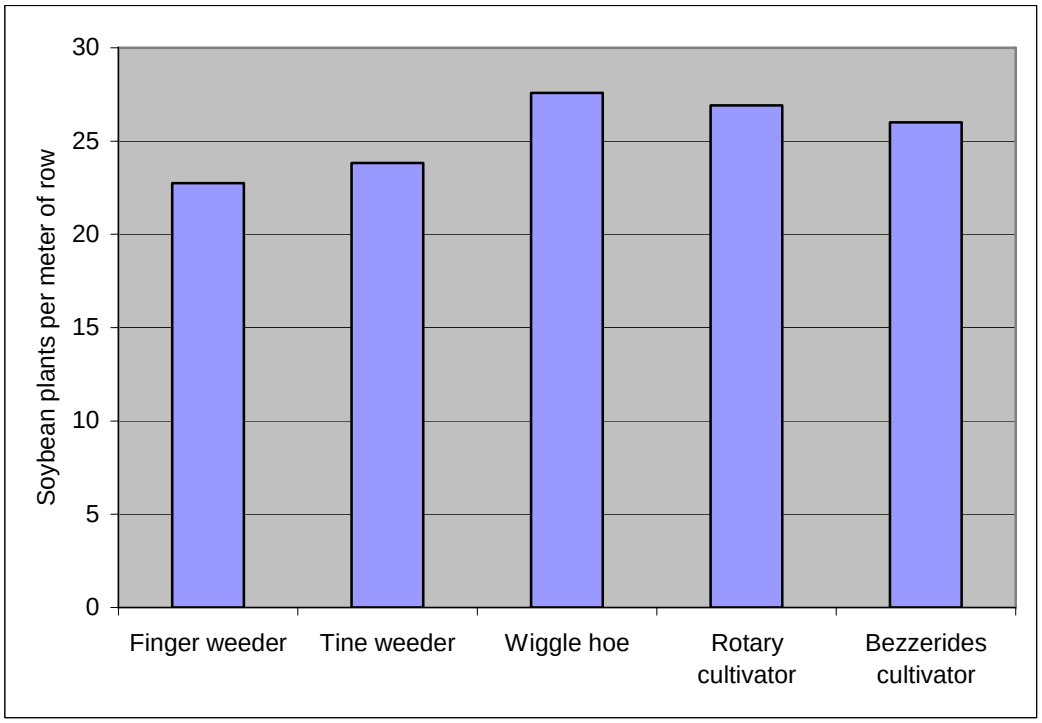

Figure 21. Number of soybean plants per meter of row, Aug. 30 (lsd = 5.16, 0.05).

September 2002

A final count of weeds at 0 – 4 inches on each side of the row was taken on September 28, 2002. Figure 22 shows the number of weeds.

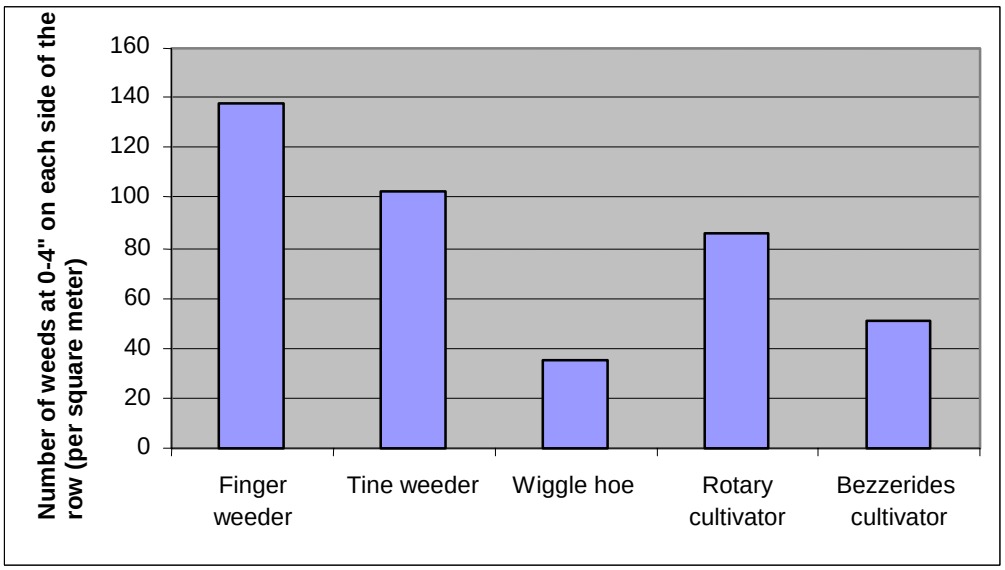

Figure 22. Weeds at 0 - 4 inches on each side of the row, Sept. 28 (lsd = 122.55, 0.05).

The wiggle hoe performed satisfactorily in the West Badger farm.

Canaan Creek Organic Farm
Corn experiment
July 2002

Corn in the Canaan Creek Organic Farm was planted on May 23, 2002. The first between-the-rows cultivation took place in the week of June 21-24, 2002. The in-row cultivation took place on June 26, 2002. The weed counts were taken on July 24, 2002.

Figure 23 shows the corn plants and weeds that had developed by July 24, 2002.

Figure 23. Weeds and corn plants on July 24, 2002.

Figure 24 shows the number of weeds at 0 - 2 inches on each side of the row. The number of weeds was reduced but the reduction was not statistically significant at the 5% level.

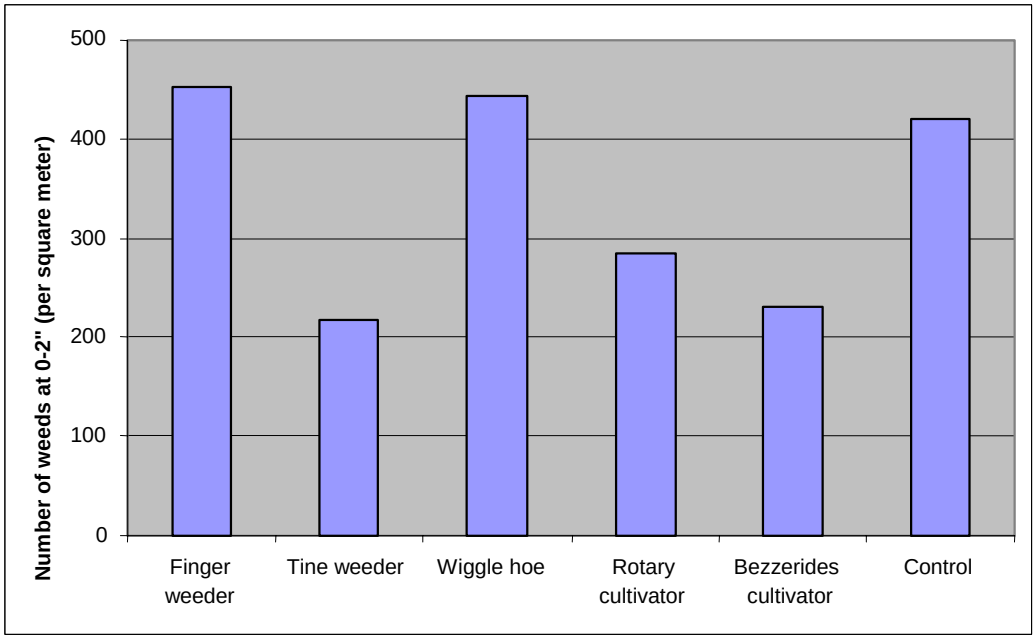

Figure 24. Weed count at 0-2 inches in the corn field, July 24 (lsd = 237.8, 0.05).

Figure 25 shows the number of weeds at 2 - 4 inches on each side of the row. The difference between the control and the rest of the implements is not statistically significant at the 5% level.

Figure 25. Weeds at 2 - 4 inches on each side of the row, July 24 (lsd = 319.46, 0.05).

Figure 26 shows the weeds at 0 - 4 inches. The difference between the control and the rest of the treatments is statistically significant at the 5% level for the Bezzerides cultivator and finger weeder.

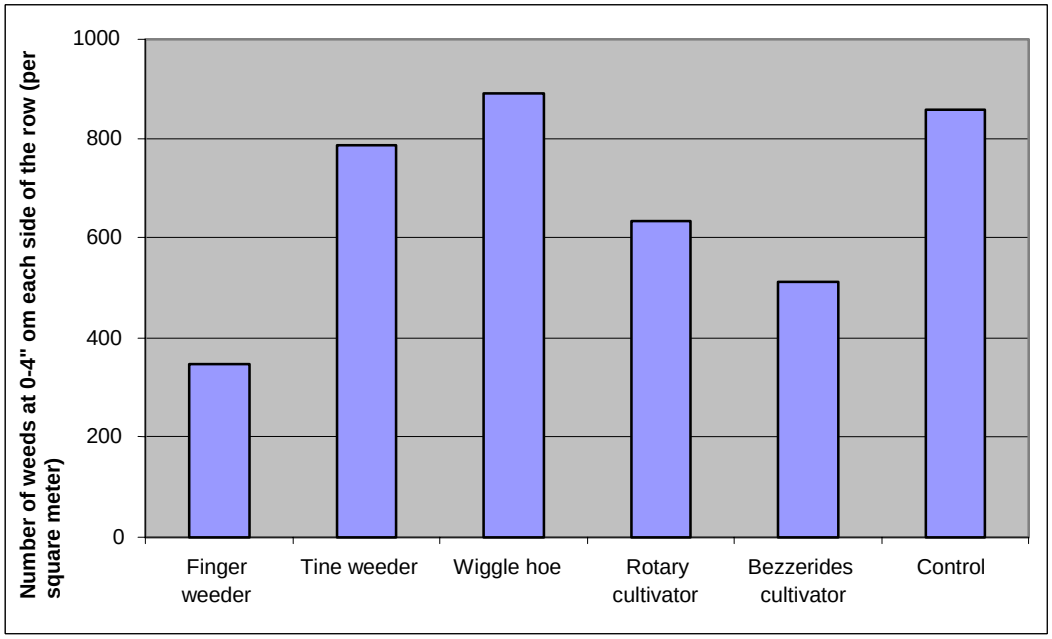

Figure 26. Weeds at 0 - 4 inches on each side of the row, July 24 (lsd = 364.59, 0.05).

Figure 27 shows the number of corn plants per meter of row. The number is significantly lower in the case of the Bezzerides cultivator system at the 5% level.

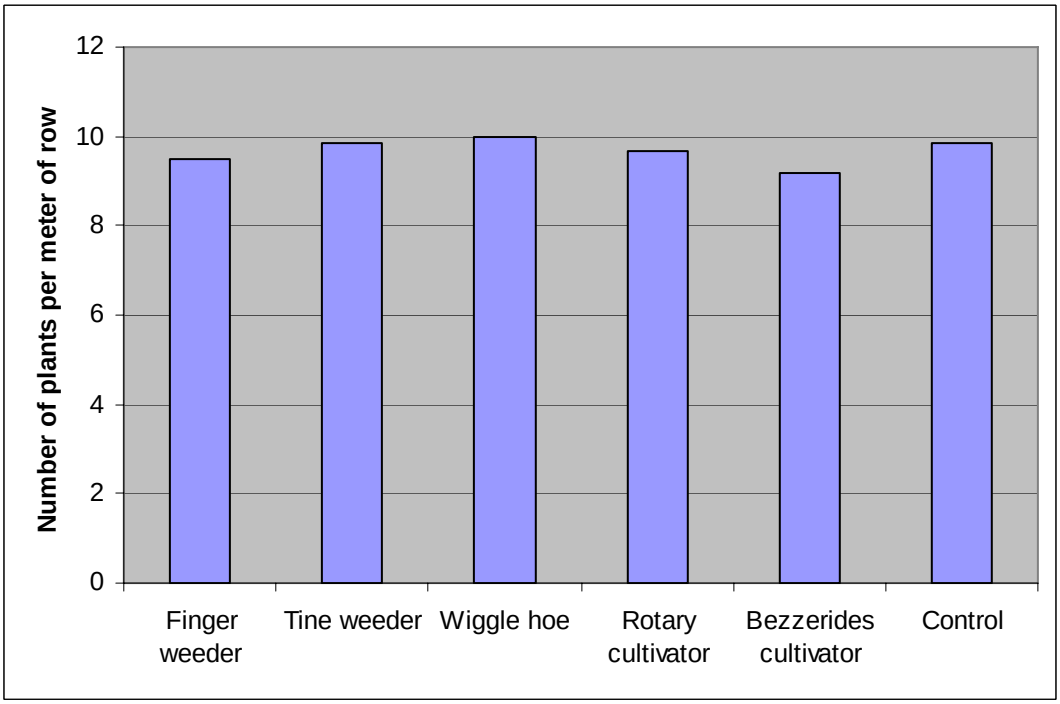

Figure 27. Number of corn plants per meter of row, July 24.

The finger weeder performed well in the 2 - 4 inches operation, although it did not perform well at 0 - 2 inches. The Bezzerides cultivator reduced the number of corn plants.

Canaan Creek Organic Farm
Sunflower experiment
July 2002

The sunflowers in the Canaan Creek Organic Farm were planted on June 6, 2002. The first in-row cultivation took place on July 9-10, 2002. The weed counts were taken in September. Figure 28 shows the sunflowers and weed development on July 10, 2002.

Figure 28. Weeds and sunflower plants on July 10, 2002.

Figure 29 shows the number of weeds in the sunflower field on Sept. 12. The difference between the treatments is not statistically significant at the 5% level.

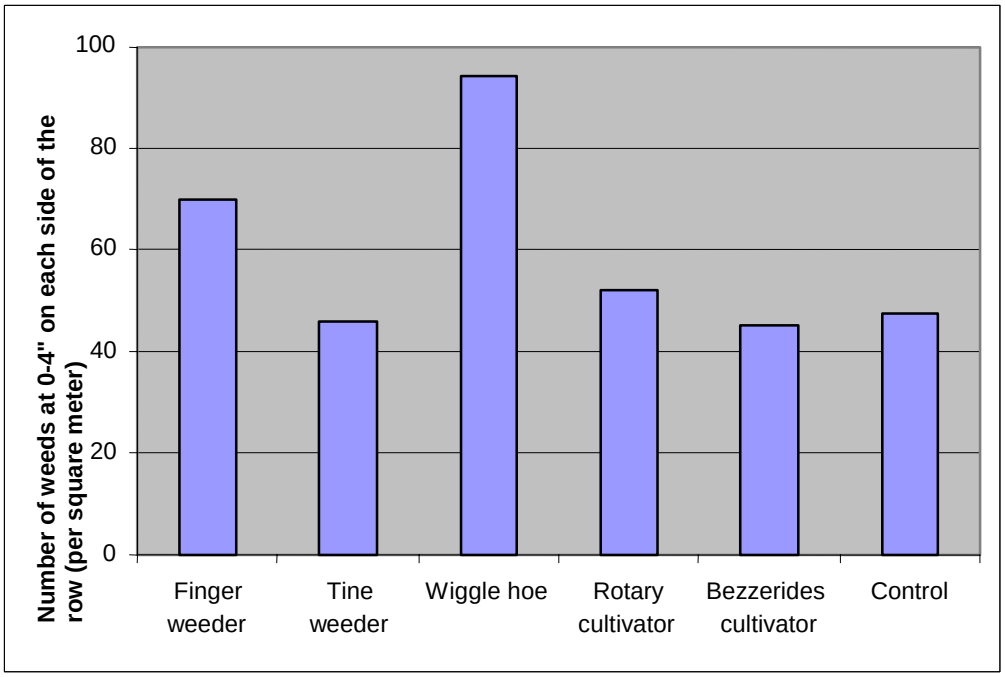

Figure 29. Weeds at 0 - 4 inches on each side of the row, Sept. 12 (lsd = 58.38, 0.05).

Figure 30 shows the number of the sunflower plants in the field. Differences are not statistically significant at the 5% level.

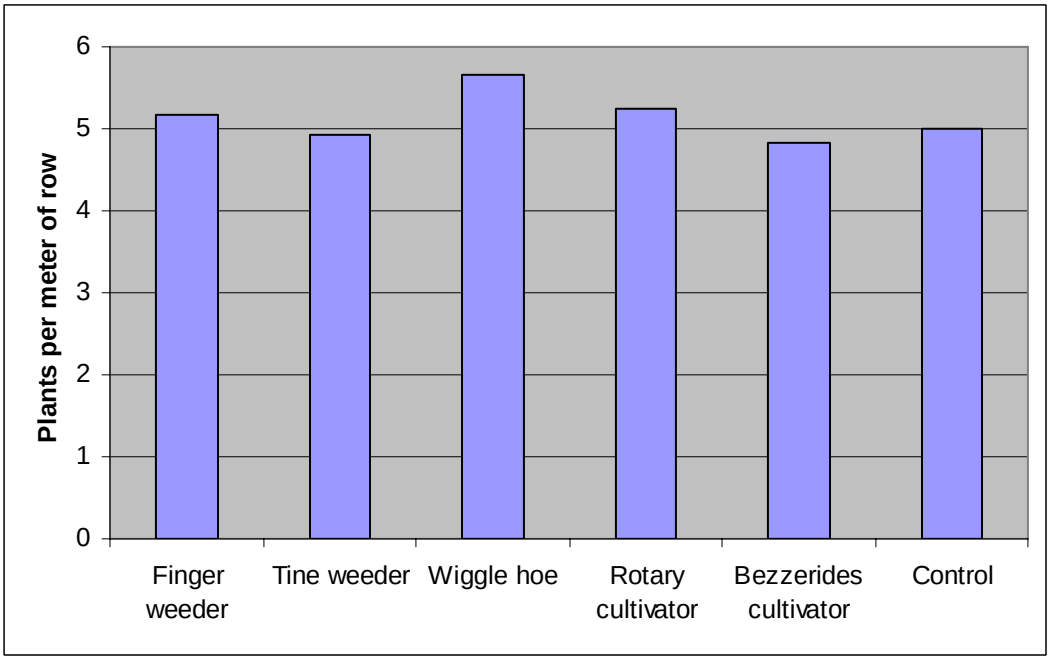

Figure 30. Number of sunflower plants per meter of row Sept. 12 (lsd = 12.97, 0.05).

Yield

Due to the adverse weather conditions the yield was reduced significantly. West Caanan and West Badger farms got the following yields:

	Date harvested	**Yield (bushels/acre)**
Soybeans	October 20	25
Corn	November 3	75
Sunflowers	October 2	55
Soybeans (West Badger)	October 25	15

Economic analysis

An economic analysis of fuel, labor and maintenance costs was carried out using standard D497.4 of the American Society of Agricultural Engineers. It was assumed that the implements will operate 300 hours per year, all are treated as row cultivators, and labor costs were set at $10.00 per hour. Net cost/benefit assessment was not carried out since there was a substantial decrease in yield due to adverse weather conditions.

	Ownership cost (Dec 2003)	**Fuel consumption, lubrication and labor per hour***	**Maintenance cost per year**
Tine weeder	1920.00	11.42 (Fuel consumption 0.45 gallons of diesel per acre)	23.09
Rolling cultivator (2 rows)	2000.00 Used	11.42 (Fuel consumption 0.45 gallons of diesel per acre)	24.05
Finger weeder	1500.00	10.24 (Fuel consumption 0.30 gallons of diesel per acre)	18.04
Bezzerides cultivator	500.00	10.24 (Fuel consumption 0.30 gallons of diesel per acre)	6.01
Wiggle hoe	800.00	20.31 (Fuel consumption 0.40 gallons of diesel per acre)	9.62

* Diesel fuel costs $1.48 per gallon (December 22, 2003).

Conclusions

It should be stressed that the adverse weather conditions (drought) greatly influenced the trials. Yields were reduced in relation to previous years, and from an economic point of view the use of the in-row cultivators was not justified. In-row cultivators were used once with the exception of the West Badger Farm experiment where they were used twice.

Generally, results indicate that there is a reduction in the number of weeds in the rows due to the in-row cultivators, although in the majority of the cases the reduction was not statistically significant at 5% level. The reduction of the weed counts is greater at a

distance 2 – 4 inches on each side of the row in comparison to the area 0 – 2 inches on each side of the row. None of the implements greatly damaged the crop plants.

It should be noted that the experiment was carried out only in 2002. One year of data do not allow us to confidently rank the implements in relation to their effectiveness. At least three years of data are required for this purpose. However, the following observations on specific implements can be made:

The finger weeder reduced the number of the weeds in the majority of the cases.

The tine weeder also performed satisfactorily in the majority of the cases.

The wiggle hoe's performance is subjective to the experience of the operator. In these trials it gave mixed results. It is the most expensive to operate since it needs a skilled operator.

The rotary cultivator and Bezzerides cultivator also gave mixed results.

A major disadvantage of the in-row cultivators is the low velocity at which they operate. They cultivate very close to the row (4 – 6 inches on each side of the row), and high velocities may result in damaging the crop plants. Low velocities (2 – 4 miles/hour) decrease implement productivity and require an abundance of time in which the fieldwork can be completed for satisfactory field conditions. This may make these in-row cultivators impractical for large grain farms, with limited available labor. If placed as an add-on accessory to a row cultivator the situation may be improved (two operations in one pass), but the field operator's productivity is going to be reduced since row cultivators used alone normally operate between 5 – 8 miles/hour (depending on the implement type). However, this is an area of possible future research.

Outreach

Results of this project were presented at the Annual Meeting of the American Society of Agricultural Engineers (July 28-31), Chicago, IL. The OARDC West Badger Farm field experiment and implements were demonstrated to Ohio organic farmers during the annual organic field day, which took place at the Ohio Agriculture Research and Development Center in August 27, 2002.