FINAL REPORT

ON

HORTICULTURAL DEVELOPMENT COUNCIL

PROJECT FV/107

'Field Vegetables: Mechanical and Mulching Weed Control Techniques'

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CONTENTS

1. INTRODUCTION

This final report summarises the technical and financial studies undertaken within HDC Project FV/107 theme 'Field vegetables : mechanical and mulching weed control techniques'. The work was undertaken under the auspices of the Edinburgh School of Agriculture Organic Farming Centre and the SAC/Edinburgh University Sustainable Farming Systems Initiative. The results of three seasons of trials are described, along with a report on a visit to review work in this area at major European centres. For completion, a further report is included by Dr K Davies from a recent meeting of a relevant working group established under the auspices of the European Weed Research Society. This latter report is not directly funded by HDC, and is partly funded through the Sustainable Farming Systems Initiative.

The interest in non-chemical weed control in vegetables is being revived for three principal reasons: increased consumer interest in more sustainable agricultural systems (from reduced input to integrated and organic), increasing grower demand for a reduction in variable costs, and evidence that for registration and commercial reasons the availability of herbicides for minor crops will diminish considerably in the medium term. Mechanical weed control techniques have not attracted much research and development in the UK in the last 40 years. They were originally developed against a background of readily available, and comparatively inexpensive labour. A reversion to such techniques without modification may mean increased costs to the grower, so the scenario is set for a re-examination of non-chemical weed control approaches to improve their efficiency.

The trials reported here describe the comparative technical and financial efficiencies of different types of inter-row weeder, and compares them with the use of a polyethylene mulch. Then, given the importance of in-row weeding and the perceived difficulty in developing machines that will weed automatically in crop rows, the trials concentrated on the spatial arrangement of crop plants and how that effects weeding efficiency and crop tolerance of machinery being used in two directions around the plants. The financial implications of the spatial arrangement of plants are discussed, accepting that the spatial patterns were experimental and not (yet) of field use.

The results of the trials are put into a general advisory context and suggestions for future approaches made based both on these results and the reviews of other work, primarily in Europe.

Report structure:

1. Summary (including future research suggestions)
2. Report on trials 1991
3. Report on trials 1992
4. Report on trials 1993
5. Report on study tour 1992
6. Report on EWRS Working Group on Physical Weed Control 1994
7. Conclusions.

2. SUMMARY

- The results of three seasons of trials comparing established and a novel approach to weed control in vegetable brassica row crops with machinery are presented, together with the use of black polyethylene mulches and, in one season, to herbicide use.

- Three types of machinery for weed control were compared: a rolling cultivator, spring-tines and a 'Brush-Weeder'. There were few differences in the level of weed control obtained between the crop rows, but the 'Brush-Weeder' showed greater energy efficiency, although it was slower to operate.

- It was found that yield loss due to weeds being left within the crop row could account for up to 50% of yield. In-row hand-weeding was required when machines were used between crop rows to avoid this yield loss.

- Trials were initiated to examine the potential for a novel approach to weed control: planting the crop on a rectangular grid to allow the machinery to work in two directions. Spring-tines and 'Brush-Weeder' were compared. This approach greatly improved overall weed control without recourse to hand-weeding, but significantly reduced plant and crop yield. This may be due to factors associated with soil compaction by excessive wheeling, or due to plant disturbance by two-way cultivation. The factors associated with crop tolerance require further research, but the approach looks promising for weed control.

- Drilled crops were thinned to a stand using the weed cultivators to produce the rectangular grid of plants. In practise precision drilling to stand would be required, with considerable precision. The level of weed control, however, was as high as that achieved in the planted grid, but with similar levels of yield reduction.

- Overall, however, the use of black polyethylene mulch gave the highest crop yields in the planted crops. In one drilled calabrese trial the use of herbicide gave the highest yield, but not significantly higher than the use of tines with hand-weeding in the crop row.

- Two reviews are included of other work in Europe on non-chemical weed control. Most of the directly relevant work was on improving between row weed cultivation by getting closer to the crop. This requires improved machine guidance systems, but also machine design. In particular, there is interest in novel brush weeding designs.

There is considerable interest in thermal weed control, but there are major selectivity difficulties and the techniques may only be useful in high specialised situations.

The Dutch, in particular, are looking at alternatives to polyethylene mulches; notably novel materials based on waste paper.

- There is some very novel work in the Netherlands with planting sugar beet modules in a grid and working in two directions. They have reported less damage than we have seen. This emphasises that there is potential for this approach to weed control that requires further development.

- A financial analysis has been carried out on the three years trial data. This is to show how the different weed control treatments compare and to assess how financially feasible each treatment would be in a real farm situation. Enterprise margins were generated from the plot yield data and historical cost information. Any item or process that could be easily allocated to each plot was included in the calculation of the enterprise margins. The results are as follows:

    - The black mulch was effective in controlling weeds but is rather expensive to implement. This reduces the potential enterprise margin.

    - The cost of hand-weeding was more than offset by the increase in marketable yield and corresponding enterprise margin in all of the trials. This is financially practicable in high value crops such as vegetables.

- The mechanical treatments were all effective at reducing weeds and increasing the yield available for sale. However, there was no clear ranking as to which weeder performed best overall. Each crop reacted differently to the weeders and the effect on yield is carried through to the individual enterprise margins as found in the yearly reports.

- The grid treatment was not financially viable due to the severe effect on the marketable yield from each plot. The cost of weeding was not significantly greater than the cost in the conventional row plots but the yield and hence revenue were substantially reduced.

3. REPORT ON TRIALS 1991

cst/plant/RMcK953/1

PART 1: WEEDS

1. Introduction

The objective of the first year of experimentation within this project was to evaluate readily available techniques for non-chemical weed control principally for efficacy and crop responses.

This part of the report examines weed control efficacy and crop responses to treatments, from three trials undertaken in summer 1991. The results of these trials, and proposed examination of techniques being used in other parts of Europe (please see separate study to our report) will assist in the design and evaluation of new approaches and novel techniques.

The 1991 trials focused on brassica crops: calabrese and cabbage, designed to give short and medium/long season comparison, and differing growth habit comparisons. The trials were undertaken at the Edinburgh School of Agriculture Organic Farming Centre at Jamesfield, Fife.

2. Site and Treatment Details

2.1 Site Details

2.1.1 Farm: Jamesfield, Abernethy, Fife OS: NT 205 183

2.1.2 Farmer: A Miller

2.1.3 Soil Series: Carey/Carpow

Soil Type: ZSL

2.1.4 Height above sea level: 15m

Aspect: Open, slight northerly incline towards River Tay.

2.1.5 Meteorological Data for 1991:

Month	Total Rainfall (mm)	Temperature (mean ^{o}C)
March	77	6.3
April	62	7.7
May	15	11.7
June	104	11.6
July	84	15.6
August	14	15.8
September	56	12.9
October	68	8.9

2.1.6 Manuring: 20t/ha FYM in March 1991.

1750 kg/ha meat and bone meal prior to planting.

2.1.7 Other Routine Management: Prior to planting of modules, the ground was given two passes of a Roterra cultivator to control already emerged weeds.

2.2 Treatment Details

2.2.1 Weed Control Machinery (see Part 2)

0 = `Opico' Rolling Cultivator
T = Spring-Tine Cultivator with guard discs.
B = Inter-row `Brush-Weeder'

M = Black polythene mulch - horticultural grade

C = Untreated control

2.2.2 Treatments 0, T and B plots were divided in two. One half was given a hand-weeding treatment within the crop rows. The crop rows in the other half remained unweeded to compare the effect of leaving weeds within the crop rows.

2.3 Trial Details

2.3.1 Crops:

Trial I	:	Savoy-type Cabbage, cultivar Wallasa
Trial II	:	Multi-purpose Cabbage, cultivar Espoir
Trial III	:	Calabrese, cultivar Marathon

2.3.2 Plot Size and Replication: Plot size was 30 - 40m x 1.68m, except for treatment C (untreated) which was restricted to 15 - 20m x 1.68m. Half of the length of the plots with treatments 0, T and B (15 - 20m) was given an in-row hand-weeding on the same date as the inter-row cultivation. Each plot had three crop rows 0.56m apart. Crop plants were planted as modules at 0.3m spacing within the rows. The treatments were fully randomized within 4 replicate blocks per trial.

2.4 Dates

2.4.1 Operations:

Trial	Planting	Mechanical Weed Control*		Harvest
		1	2	
I	05.06.91	05.07.91	26.07.91	30.08/19.09.91
II	26.07.91	13.08.91	03.09.91	30.10.91
III	05.06.91	05.07.91	26.07.91	12-26.08.91

* Includes hand-weeding where appropriate.

2.4.2 Weed and Crop Growth Stages:

	Trial					
	I		**II**		**III**	
	Weed Cover	**Crop Height**	**Weed Cover**	**Crop Height**	**Weed Cover**	**Crop Height**
Timing 1	80%	3-4 leaf	40%	3-4 leaf	45%	3-4 leaf
Timing 2	60%	>15 cm	65%	>15 cm	70%	20 cm

2.5 Assessments

2.5.1 Weed assessments as per tables in Results and Discussion sections.

2.5.2 Yield of marketable heads and head counts were taken from a randomly selected 5m length of the middle of the three crop rows per plot and sub-plot (+/- hand-weeding in rows).

3. Results

The results are presented separately for each of the three trials. Comparison of results are given in the Discussion and Conclusion Sections.

3.1 Trial I: Cabbage cv. Wallasa

3.1.1. Weed Control

Table 1. Trial I: Cabbage: % ground cover weeds 2-3 weeks after weed control cultivation.

Treatments	Hand-weeded	Cultivation 1	
		In crop rows	**Between Crop rows**
Rolling Cultivator	+	32.5	20.8
	-	76.3	27.0
Tine	+	45.3	17.0
	-	86.3	23.8
Brush	+	41.5	31.3
	-	85.0	46.3
Mulch		0.3	0.0
Control		93.3	96.3
	SED	7.12	4.91

Full details of weed control assessments and weed numbers prior to cultivations are available from authors.

Hand-weeding reduced weed control levels in the crop-rows, but also reduced levels inter-row. This may be due to prevention of the spreading of creeping weeds from the crop rows. There was little difference in final weed control levels between the Rolling Cultivator and the Tine treatments; both were better than the Brush-Weeder.

3.1.2 Crop vigour

Table 2. Trial I: Cabbage: Crop vigour 2-3 and 6 weeks after cultivation

Treatment	Hand-weeded	Crop Vigour (0-10 good)	
		Cultivation	
		1	2
Rolling Cultivator	+	8.6	8.0
	-	8.4	8.0
Tine	+	8.1	7.9
	-	7.6	7.8
Brush	+	8.3	8.1
	-	8.2	7.7
Mulch		8.9	9.7
Control		7.7	7.2
	SED	0.23	0.40

Mulching gave the best crop vigour. Hand-weeding improved crop vigour, at least initially, in the mechanical weed plots. Tines may have caused more damage than the other systems, but the difference may be due to initial levels of weed control (Table 1).

3.1.3 Crop Yield

Table 3. Trial I: Cabbage: Harvest Data

Treatments	Hand-weeded	Marketable plant no. thousands/ha	Marketable yield t/ha	Head weight kg	Unmarketable yield t/ha
Rolling Cultivator	+	31.25	29.91	0.94	8.13
	-	19.64	17.77	0.88	14.11
Tine	+	20.32	16.37	0.79	10.08
	-	11.99	9.35	0.68	12.11
Brush	+	21.52	22.20	0.77	11.39
	-	26.28	17.32	0.86	9.97
Mulch		33.04	32.50	1.00	4.38
Control		8.04	5.27	0.66	17.08
	SED	8.464	8.240	0.121	4.169

Use of the polythene mulch gave the best yield response, but it was not significantly better than the use of the Rolling Cultivator with hand-weeding in rows. The crop responded much better to the use of the Rolling Cultivator than the other machines. There were difficulties with the Brush-Weeder in one block, and this may have been reflected in the unexpected yield response comparison between +/- hand-weeding.

3.2 Trial II: Cabbage cv. Espoir

3.2.1 Weed Control

Table 4. Trial II: Cabbage: % ground cover weeds 2-3 weeks after weed control cultivation

Treatments	Hand-weeded	Cultivation			
		1		2	
		In crop rows	Between crop rows	In crop rows	Between crop rows
Rolling Cultivator	+	18.8	3.7	15.3	2.5
	-	60.0	0.8	46.5	0.9
Tine	+	29.5	4.3	18.3	4.8
	-	69.8	20.0	53.3	2.8
Brush	+	27.3	7.1	17.3	7.3
	-	68.3	3.6	63.0	3.6
Mulch		6.1	0.0	0.4	0.0
Control		73.8	82.7	57.0	66.3
	SED	6.09	9.37	6.33	2.24

Full details of weed control assessments and weed numbers prior to cultivations are available from authors

There were no significant differences between the levels of weed control with the three machines in this trial. Hand-weeding clearly improved weed control. Drier conditions during this trial period reduced late weed growth, and possibly the differences between the cultivation treatments.

3.2.2 Crop Vigour

Table 5. Trial II: Cabbage: Crop vigour 2-3 weeks after cultivation

Treatment	Hand-weeded	Crop Vigour (0-10 good) Cultivation	
		1	2
Rolling Cultivator	+	8.0	8.0
	-	6.9	7.5
Tine	+	7.6	7.7
	-	6.7	7.6
Brush	+	7.2	7.8
	-	6.5	7.3
Mulch		8.9	8.5
Control		5.3	6.5
	SED	0.27	0.25

Hand-weeding in crop rows clearly improved crop vigour, but not to the extent of using polythene mulch.

3.2.3 Crop Yield

Table 6. Trial II: Cabbage: Harvest Data

Treatments	Hand-weeded	Marketable plant no. thousands/ha	Marketable yield t/ha	Head weight kg	Unmarketable yield t/ha
Rolling Cultivator	+	20.54	16.70	0.79	11.96
	-	10.71	6.79	0.66	14.39
Tine	+	25.00	19.02	0.76	9.71
	-	9.82	7.05	0.65	11.25
Brush	+	14.29	10.45	0.72	18.03
	-	11.61	8.75	0.74	12.32
Mulch		26.68	23.84	0.83	12.93
Control		0.00	0.00	-	5.96
	SED	8.14	6.78	-	4.142

Use of polythene mulch increased yield at this site by over 4t/ha compared with the best mechanical weed control treatment (spring-tines with hand-weeding in rows). However, because of variation across the site, this difference was not significant. Hand-weeding had a major effect in this trial, and no weed control resulted in no marketable heads. Yield of unmarketable heads was high.

3.3 <u>Trial III: Calabrese cv. Marathon</u>

3.3.1 Weed Control

Table 7. Trial III: Calabrese: final weed assessment; % ground cover on 12.08.91

Treatments	Hand-weeded	Cultivation	
		In crop rows	Between crop rows
Rolling Cultivator	+	49.5	32.5
	-	93.8	38.8
Tine	+	73.8	35.0
	-	100.0	77.0
Brush	+	73.8	47.0
	-	97.5	80.3
Mulch		1.9	0.0
Control		100.0	100.0
	SED	8.20	10.79

Full details of weed control assessments and weed numbers prior to cultivation are available from authors.

Hand-weeding clearly reduced weeds in the crop rows, but there was some regrowth by harvest. The Rolling Cultivator and spring-tines gave better weed control in between crop rows than the Brush-Weeder. Weed growth between crop rows was greater where no hand-weeding within crop rows had been undertaken; indicating that weeds were spreading out from the crop rows.

3.3.1 Crop Vigour

Table 8. Trial III: Calabrese: crop vigour 2-3 weeks after cultivation

Treatments	Hand-weeded	Crop Vigour (0-10 good)	
		Cultivation	
		1	2
Rolling Cultivator	+	8.0	7.9
	-	8.2	7.9
Tine	+	7.9	7.8
	-	7.9	7.7
Brush	+	8.4	8.1
	-	8.3	7.9
Mulch		8.8	8.9
Control		7.2	6.5
	SED	0.16	0.36

Use of polythene mulch clearly improved crop vigour over cultivation. The Brush-Weeder may have had less effect on the crop than the other cultivators. Weed control overall gave a large improvement in crop vigour.

3.1.3 Crop Yield

Table 9. Trial III: Calabrese: harvest data (accumulated from three harvest dates)

Treatments	Hand-weeded	Marketable Head no. thousands/ha	Marketable yield t/ha	Marketable Head weight kg
Rolling Cultivator	+	70.54	9.55	0.14
	-	70.54	8.48	0.12
Tine	+	83.93	11.43	0.14
	-	74.11	9.55	0.13
Brush	+	72.32	9.60	0.13
	-	75.89	10.45	0.14
Mulch		89.29	15.09	0.17
Control		75.00	6.07	0.08
	SED	10.017	1.761	0.020

There is a clear advantage in the use of polythene mulch over other treatments in terms of marketable head numbers and yield, and head size. The yield advantage over other means of weed control amounted to over 3.5t/ha.

The spring-tines, with in-row hand-weeding, gave the best yield response of the cultivator treatments. The spring-tines treatment was the only treatment showing a clear difference between +/- hand-weeding. In general, hand-weeding had far less effect than in the cabbage trials.

4. Discussion

4.1 Use of black polythene mulch gave the best weed control. Crop vigour was also improved over other treatments. This may in part be due to better weed control, but influences on ground temperature and moisture levels, and on nutritional availability, may have played a part. Similarly, the consistent improvement in crop yield would be due to better weed control and growing conditions. The yield differences over the best cultivation treatment were about 3.5t/ha more marketable calabrese, 2.5t/ha more marketable cabbage cv. Wallasa, and 4.8t/ha more marketable cabbage cv. Espoir.

4.2 The table (10) below gives the mean weed control achieved in between the crop rows at about 2-3 weeks after treatment with the cultivators.

Table 10. Mean % weed control achieved with the cultivators, c 2-3 weeks after treatment, in the three trials

Treatments	Hand-weeded	% weed control (cf Untreated)
Rolling Cultivator	+	84.4
	-	82.7
Tine	+	83.8
	-	70.0
Brush	+	75.2
	-	65.5

The Rolling Cultivator and the spring tines are clearly more effective than the Brush-Weeder. Of interest, however, is the increase in weed cover (reduction in % weed control) where there was no hand-weeding in the crop rows, and this was particularly marked with the spring-tines and Brush-Weeder. This indicates that a feature of the Rolling Cultivator method reduced the ability of weeds within the crop rows to regrow into the area between the crop rows.

4.3 The Rolling Cultivator with in-row hand-weeding gave the best yield response from a cultivator at Trial I cabbage site, but the spring tines with hand-weeding gave the best response at the other sites. In general the Brush-Weeder gave the poorest yield response, but the Rolling Cultivator gave an equally poor response in the calabrese trial (Trial III).

4.4 Hand-weeding within crop rows in plots treated with cultivators had a major impact on crop yield of cabbage, but not of calabrese (Table 11):

Table 11. Average marketable yield from mechanical weed control treatment with and without in-row hand weeding in the three trials.

Treatment	Crop		
	Calabrese (Marathon)	**Cabbage (Wallasa)**	**Cabbage (Espoir)**
	t/ha	t/ha	t/ha
With hand-weeding	10.19	22.83	15.39
No hand-weeding	9.49	14.81	7.53
Control	6.07	5.27	0.00
SED	1.761	8.240	6.780

The difference between cabbage and calabrese may reflect differences in length of growing season, but also differences in growth habit. The more prostrate habit of the cabbage plant may encourage competition. However, other factors such as relative ability to compete for moisture and nutrition may have played a part. Equally calabrese may be more sensitive to disturbance due to hand-weeding, so did not react positively to the extra weeding. Head number and weight reacted similarly to total marketable yield.

5. Conclusions

It is evident from these trials that the use of black polythene mulch has major benefit in marketable yield, product number and size over the use of machinery for weed control.

The Rolling Cultivator and spring-tines are probably to be preferred to the Brush-Weeder, in terms of weed control and yield.

Where cultivators are used, it is necessary to weed in the crop rows as well. However, there is evidence that some crops may not be as sensitive; calabrese may be much more tolerant of weeds in rows than cabbage. Nevertheless, the difficulties of in-crop row weeding with available machinery must be addressed as hand-weeding is unlikely to find much favour in the commercial situation, except on some organic holdings. The design of machinery and planting designs will be critical in allowing maximum response to weed control in non-herbicide/non-mulching situations.

PART 2: MACHINES

1. Description of Equipment

Three types of implement designed to control weeds mechanically in row crops and beds were used.

Brush-Weeder (Baertschi) - This unit consists of a number of bush sections mounted on a pto-driven shaft. Each brush unit comprises of polypropylene bristles radiating from a central bush. The distance between adjacent brush rolls can be adjusted to accommodate different sizes and row numbers of growing plants. Plants are protected from damage by the brushes by means of vertical plates.

During operation, the brush units brush weeds from the soil against a vertical curtain where soil is knocked from the roots. The weed's roots are exposed and desiccation occurs. Forward speed, rotational speed of the brushes and brush depth can be varied to suit the prevailing soil/weed conditions. Transverse movement of the brushes is achieved manually by an operator sitting on the machine.

Spring-tine Weeder (Kongskilde) - Each weeding row unit consists of four 'A' blades attached to spring-tines. The spring-tines are mounted on a carrier which is in turn attached to the main beam via a parallel linkage. A pair of serrated discs protect each crop row from damage during the weeding operation. When operating in semi-mature crops, the discs can be held out of work. Tines can be adjusted to accommodate various row widths.

The implement is designed to undercut weeds and leave them exposed on the surface. The vibrating nature of the tines is designed to avoid build-up of weeds around the tine.

Rolling Cultivator (Opico) - Each weeding unit consists of a number of ground-wheel driven spider wheels. The design of the wheels is such that the wheels cut through the soil on initial contact and throw the soil and weeds backwards. By angling the direction of the weeding unit, soil can be thrown away from, or towards, the crop. The action on the weeds is to leave them exposed on the soil surface.

The power unit used for all weed control treatments was a MF-575 tractor fitted with row crop wheels. The fuel system of the tractor was modified to allow actual fuel use data to be recorded.

2. Fuel Use, Rates of Work

For each replicate, the time and the fuel used to travel 30 m was recorded.

Two readings each were made for both uphill (U) and downhill (D) travel.

Trial II Cabbage, 13.08.91, 20 m length, 1.68 m beds.

Trial III Calabrese, 26.07.91, 30 m length, 1.68 m beds.

Brush-Weeder

Gear: 3rd Low, High multi-power, 900 rpm.

	Trial II		Trial III	
	Time (s)	**Fuel (ml)**	**Time (s)**	**Fuel (ml)**
U	22	14	36	20
D	21	13	35	17
U	22	13	36	20
D	23	12	36	19
mean	22	13	35.75	19.00

Mean spot rate of work:

0.55 ha/h 0.51 ha/h

Mean specific energy consumption:

145 MJ/ha 140.7 MJ/ha

Spring-tine Weeder

Gear: 1st High, High multi-power, 1500 rpm.

	Trial II		Trial III	
	Time (s)	**Fuel (ml)**	**Time (s)**	**Fuel (ml)**
U	9	13	15	27
D	9	12	14	24
U	9	15	14	23
D	9	13	14	24
mean	9	13.2	14.25	24.5

Mean spot rate of work:

1.34 ha/h 1.27 ha/h

Mean specific energy consumption:

148.3 MJ/ha 182.8 MJ/ha

Rolling Cultivator

Gear; 1st High, High multi-power, 1500 rpm.

	Trial II		Trial III	
	Time (s)	Fuel (ml)	Time (s)	Fuel (ml)
U	9	12	14	25
D	9	13	14	20
U	9	13	14	24
D	9	11	13	21
mean	9	12.25	13.75	22.5

Mean spot rate of work:

1.34 ha/h　　　1.32 ha/h

Mean specific energy consumption:

137.1 MJ/ha　　　167.48 MJ/ha

3. **Observations regarding weeding operations**

(i) Machines were set up to disturb as much of the ground as possible without causing plant damage. A lack of guard or discard rows where `test' runs could be made rendered this exercise difficult.

(ii) Due to poor weather conditions between weeding treatments at sites I and III, both the crop and the weeds were well grown when the second weed control pass was possible. The following points were observed during the second weeding pass:

(a) It was not possible, especially with the Tine and Rolling Cultivator, to prevent some damage to the crop. It is doubtful if a farmer would have attempted to control the weeds at this stage.

(b) The Brush-Weeder was incapable of dislodging the weeds and tended to roll over and damage the stems and leaves.

(c) The leg of the Tine Weeder tended to block with weeds which resulted in bulldozing and crop damage.

(d) Due to the relatively deep roots of the weeds, the Rolling Cultivator ran over the weeds rather than dislodging them.

4. Conclusions

All three mechanical treatments achieved acceptable results when working with small weeds.

The Brush-Weeder appeared to perform better than the other implements, possibly due to its slower output and the ability manually to control the lateral movement of the brushes.

Both rates of work and energy use were similar for the Rolling Cultivator and the Spring-tine implements and were higher than for the Brush-Weeder. The fuel use of the tractor was recorded when operating at the weeding forward speeds and gears. This work was carried out on a different date from those above and is therefore not strictly comparable. However, the results indicate that the majority (80-90%) of the fuel is utilised in propelling the tractor when the Brush-Weeder is being used.

PART 3: FINANCIAL IMPLICATIONS

Full enterprise margins were calculated for each treatment. The enterprise margins include costs of: cultivation, plants, fertiliser, all labour and materials and marketing. The gross revenue includes only the marketable yield for each of the treatments.

% MARKETABLE YIELD WITH, AND WITHOUT, IN-ROW HAND-WEEDING

Treatment		Crop	
	Cabbage (Wallasa)	Cabbage (Espoir)	Calabrese (Marathon)
With hand-weeding	69%	54%	99%
No hand-weeding	54%	38%	99%
Mulch	88%	65%	99%
Control	24%	0%	99%

Enterprise Margins:

MEAN ENTERPRISE MARGIN FOR EACH TREATMENT (£/HA)

Treatment		Crop	
	Cabbage (Wallasa)	Cabbage (Espoir)	Calabrese (Marathon)
With hand-weeding	3011	1381	5366
No hand-weeding	1618	26	5229
Mulch	4125	2226	7897
Control	-445	-1601	2782

MEAN ENTERPRISE MARGIN FOR EACH TREATMENT (£/HA)

Treatment		Crop	
	Cabbage (Wallasa)	Cabbage (Espoir)	Calabrese (Marathon)
Opico Rolling Cultivator	3419	773	4708
Spring-Tine Weeder	1018	1056	5773
Brush-Weeder	2508	280	5412

Conclusions

1. The mulching treatment gave the highest marketable yield and enterprise margin in all trials.

2. Hand-weeding within crop rows gave significant benefits over non-weeding within rows but was lower than the mulch treatments.

3. There can be no clear ranking of the mechanical weed control methods.

4. The additional costs associated with the black polythene mulch are clearly financially worthwhile.

4. REPORT ON TRIALS 1992

PART 1: WEEDS AND MACHINES

1. Introduction

The 1991 trial series showed the importance of weeding to crop growth and yield in vegetable brassica crops. Using a black polyethylene mulch had the greatest effect on weed control and crop yield, but given the cost of the product, it was still desirable to examine mechanical methods of weed control. The three machines examined in 1991 were a Rolling Cultivator, Spring Tines and a Brush-Weeder. Although the latter was marginally less effective in terms of weed control, it had running cost advantages. The major impact on crop yield, however, was where hand-weeding within crop rows had been undertaken along with machine between-row weeding. This was particularly evident in cabbage when compared with calabrese.

It was considered that weed control with machinery in large scale field vegetable crops would not be satisfactory without addressing the problem of weed control within crop rows. Manual weeding was considered as a long-term option.

Trials in 1992 examined the potential for cross-weeding by machine by planting cabbage in rectangular rather than row pattern. As purpose-built planters are not available to undertake such an operation, it was done by hand. It was assumed that future design of machinery and planting designs would be able to cope with this novel approach. Comparison was made with weed control in crops planted in the row using machinery (Brush-Weeder and Spring Tines), mulching (black polyethylene) and herbicides.

The 1992 trials initially focused on cabbage as a model crop. However, the plants which were not treated with pesticides as the trials simulated organic production systems were severely affected by cabbage root-fly damage as well as droughting. This damaged the trial design so that there were limitations on the statistical analyses possible, and in the direct comparison between cross-planted and row-crops.

One very poor block of cabbage was ploughed out, and replaced with a drilled Swede trial with similar treatments to the planted crop, to give an idea of the potential of such treatments in sown rather than transplanted crops. However, different establishment dates limited the viability of such a comparison.

This report, therefore, presents all the information available from the 1992 trial series, with the proviso that the pest damage makes some comparisons weak. It has been decided that future trialling in this series should avoid the organic situation to reduce the impact of such external factors.

2. Site and Treatment Details

2.1 Site Details

2.1.1	Farm:	Bush Estate Midlothian OS NT: 244 638
2.1.2	Farmer:	Scottish Centre for Agricultural Engineering
2.1.3	Soil Series:	Darvel
	Soil Type:	Freely drained brown calcareous and brown forest soil
2.1.4	Height above sea level:	190 m

2.1.5 Meteorological Data for 1992:

Month	Temperature mean °C	Total rainfall (mm)
April	6.9	66.5
May	11.1	34.3
June	13.5	36.3
July	14.1	51.3
August	13.1	128.4
September	10.9	129.3
October	5.6	58.3
November	5.0	109.0
December	2.5	49.6

2.1.6 Manuring:

N: 225 kg/ha (split 120/105 kg/ha)
P: 75 kg/ha
K: 175 kg/ha

2.1.7 Other Routine Management: Prior to planting of modules/sowing, the ground had been ploughed, and given one pass of a Roterra cultivator to control weeds and prepare a seedbed.

2.2 Treatment Details

2.2.1 Treatment Materials:

T = Spring Tine Cultivator with guard discs

B = Inter-row 'Brush-Weeder'

M = Black polyethylene mulch - 50* horticulture grade

C = Untreated

H = Herbicide (Cabbage Trial): Dacthal W75 + Ramrod
at 9 1+9 kg/ha, applied pre-emergence of weeds on 22/5/92. Crop at 2-3 leaf stage.

Treatments T and B were divided into two in the Cabbage Trial. One half was given a hand-weeding within the crop rows.

The cross-planted areas were weeded with the 'Brush-Weeder' in two directions through the rectangular grid of plants.

2.3 Trial Details

2.3.1 Crops: Trial I: Cabbage, cultivar Pedrillo
Trial II: Swede, cultivar Marian

2.3.2 Plot Size and Replication; Cabbage Planting Trial:

Plot size was 28 m of row x 1.68 m wide. Half the length of some plots with treatments T and B (15 m) was given an in-row hand-weeding just following the inter-row cultivation. Each plot had three crop rows 0.56 m apart. Crop plants were planted as modules at 0.3 m (12") spacing within the rows, and at 0.36 m (15") spacing within the grid area of 28 x 25 m. Initially the design was for 3 replicates of the treatment series, but cabbage root fly-droughting damage led to plot selection within two blocked areas, and for purposes of analysis, it has been assumed that the design is a full randomisation of unequal plot numbers for each treatment. The analysis has therefore been limited to standard error within each treatment; rather than a full analysis of variance.

2.3.3 Plot Size and Replication; Swede Sown Trial:

Plot size was 28 m of row x 0.56 m wide. Each plot had 3 crop rows 0.56 m apart. The seed was sown at 75 mm spacing in the rows. The grid area was sown at the same spacing, and the weeding machine (Brush-Weeder) was used to thin out the sown plants as it weeded, to a grid pattern. The limited design possibilities for this additional trial has again required analysis to be restricted to the assumption of a full randomisation of unequal plot numbers for each treatment. The analysis has therefore been limited to standard error within each treatment, rather than a full analysis of variance.

2.4 Dates

2.4.1 Operations

Trial	Plant/Sowing	Mechanical Weed Control* 1	2	Harvest
I Cabbage	15.5.92	15.6.92	10.7.92	5.11.92
II Swede	2.7.92	10.7.92	21.7.92	11.2.93

* Includes hand-weeding within 2 days.

2.5 Assessments

2.5.1 Weed assessments as per tables in Results and Discussion Sections.

2.5.2 The cabbages were randomly selected from each treatment plot from the middle of the three crop rows. Overall crop yields are not possible to calculate because of missing plants so yield analysis has been based on individual cabbage head weight. Similarly, swede yield has been determined as mean individual swede weight within 5 m row length of treatment plots.

3. Results

The results are presented separately for each of the two trials. Comparison of results are given in the Discussion Section.

3.1 Trial I: Cabbage

3.1.1 Weed Control

Table 1. Effect of treatment on weed numbers/m^2 in cabbage trial.

	3w after planting* (1 w before hoeing)
Brush-Weeder in row	147.8
Spring Tines in row	133.3
Brush-Weeder grid+	126.4
Black polyethylene	0
Herbicide	9.0
Untreated	116.3

* 2 w after herbicide; + two passes, at right-angles.

The herbicide treatment, as well as the polyethylene mulch, had given good control of weeds despite very dry conditions. The main weeds on the site were annual meadow-grass, common chickweed, fat-hen, black bind-weed, redshank and knotgrass. There were patches of couch, and annual nettle, mayweed, shepherd's purse, common hemp-nettle, sow thistle and groundsel also present. Full details of individual species are available from the authors.

Table 2. Effect of treatment on weed numbers and ground cover two weeks after cultivation (6½ weeks after planting) in cabbage trial.

	Weeds Numbers/m^2	Weed ground cover %
Brush-Weeder in row	49.4	33.2
Spring Tines in row	26.1	20.8
Brush-Weeder grid+	86.2	41.2
Black polyethylene	0	0
Herbicide	20.8	13.2
Untreated	104.0	48.5

+ two passes, at right-angles.

New weed growth was rapid following the first cultivation, with the advent of rainfall. In particular, fat-hen and red dead-nettle emergence increased, and those surviving cultivations grew rapidly. Brush-weeding in the grid was not as successful as in the rows, but rather more plants have been affected by cabbage root-fly and drought allowing larger spaces for weed development than in the rows.

Table 3. Effect of cultivation on weed control in cabbages after 11 weeks

	Weed % ground cover	
Hand-weeding in row	-	+
Brush-Weeder in row	77.5	56.5
Spring Tines in row	81.3	58.3
Brush-Weeder grid+	72.0	-
Black polyethylene	0	-
Herbicide	40.5	-
Untreated	97.5	-

+ two passes, at right-angles.

Weed growth was very rapid following wet July and August conditions when further cultivation was difficult. In the cultivated plots there were fewer weeds (numbers not assessable at this date), but those present were larger. Hand-weeding reduced the overall effect on plot ground-cover by about 20%. Herbicide treated plots were also weedy by this time.

3.1.2 Crop Yield

The damage due to cabbage root-fly on the grid plots was considered too severe for valid yield assessment in a statistically meaningful way. Despite the loss of one block, we have analysed the remaining plots as a fully randomised block. However, we have limited analysis to mean yield per plant, and to standard error (SE) determination for each treatment (Table 4).

Table 4. Effect of weed control cultivation on cabbage plant yield

Cultivation	Hand-weeded in row	Yield per Plant kg	SE +/-
Brush-Weed	+	1.813	0.094
Brush-weed	-	1.343	0.094
Spring Tines	+	2.088	0.181
Spring Tines	-	1.608	0.181
Black polyethylene		1.981	0.175
Herbicide		1.947	0.175
Untreated		0.431	0.175

The impact of hand-weeding in the crop row on plant weight was clear and statistically significant. There was probably no statistically significant difference between the use of herbicide, black polyethylene or the mechanical weed control method (so long as there was weed control in the crop row).

3.2 Trial II: Swedes

3.2.1 Weed Control

Table 5. Effect of treatment on weed control in swede trial, 5 weeks after second cultivation

	% ground cover (overall plot)
Brush-Weeder in row	29.4
Spring Tines in row	30.0
Brush-Weeder in grid	11.9
Untreated	57.5

The use of the Brush-Weeder in the grid gave the best long-term weed control.

3.2.2 Crop Vigour

In order to assess the impact of cross-weeding on the grid arrangement on crop thinning when grown from seed, a measure of crop ground cover was taken 5 weeks after final cultivation (Table 6).

Table 6. Impact of cultivation on crop growth in Swede trial

	% ground cover of crop
Brush-Weeder in row	72.0
Spring Tines in row	70.0
Brush-Weeder in grid	76.8
Untreated	47.5

There was no difference between the weed cultivation approaches, and all gave considerable improvement over no weed control.

3.2.3 Crop Yield

The limitation of replication within this trial precluded detailed analysis. However, standard errors of individual root weights have been determined (Table 7).

Table 7. Effect of weed control cultivation on Swede plant yield

Cultivation	**Yield per Plant kg**	**SE +/-**
Brush-Weeder in row	0.541	0.302
Spring Tines in row	0.722	0.390
Brush-Weeder in grid	0.316	0.022
Untreated	0.619	0.477

Variation in weight precludes a clear analysis of these results. There was less variation in weight in the grid; however, there is a suggestion that root weight was lower in the grid than in rows. Weed growth was not as severe in this later trial, and the swede crop was not greatly affected by the weed population present. Root weight was probably lighter in the grid pattern because of increased plant disturbance.

4. Discussion

The damage to the cabbage crop and the difficult weather conditions, leading to unusually delayed weed growth, precluded detailed analysis of this trial. There was an indication that weed control in the grid planting arrangement was not as good as in the rows in the cabbage trial, but in the Swede trial it was generally better. This may be more to do with the variation in pattern of weed emergence than differences between crops. Unfortunately the cabbages in the grid could not produce enough samples to give a yield analysis. It is of interest, however, that, in the row crops, the need to weed in crop rows is very evident, and reflects our 1991 results. Unlike 1991, however, there was no clear advantage from using black polyethylene. It is not clear why this happened. Certainly the similarity in yield between treatments despite high weed levels towards the end of the trial reflects the sufficiency of the early weed control despite the difficult conditions. The importance of early weed control in brassica crops has been stressed by many workers.

Of more concern, is the lower yield of Swedes found on the grid than in the rows. It is not clear whether this is a function of the novel manner of growing this crop and crop crowding, or because of the limitations in the trial design in this late addition to the series. Nevertheless, this requires re-examination in further trials.

The trial series in 1992 has therefore had some unforeseen limitations to its success. However, there is no physical constraint to use a cross-weeding technique on a grid pattern and the importance of weeding in crop rows is emphasised.

PART 2: FINANCIAL IMPLICATIONS

Full enterprise margins were calculated for each treatment. The enterprise margins include costs of:

> cultivation, based on contractors charges; all materials such as plants, seed, fertiliser, sprays; all labour calculated as if on a casual basis; transport and marketing. The gross revenue includes only the marketable yield of the crop.

	Cabbage Marketable Yield (t/ha)	Swede Marketable Yield (t/ha)
Untreated	10.10	41.35
Brush	31.47	36.14
Tines	37.68	48.23
Brush and Hand-weed	42.49	Grid 21.11
Tine and Hand-weed	48.93	-
Herbicide	45.63	-
Black polythene mulch	46.42	-

Assumptions

Germination of seed/Survival of modules = 80%
Marketable yield = 50% total crop yield

ENTERPRISE MARGINS £/HA

Treatment	Cabbage
Tine and Hand-weed	4335
Herbicide only	4142
Brush and Hand-weed	3524
Tine	3300
Black Mulch	2911
Brush	2518
Untreated	-152

ENTERPRISE MARGINS £/HA

Treatment	Swede
Tine	3262
Untreated	2781
Brush	2359
Brush Grid	1215

Conclusions

There were several problems encountered in the assessment of the financial implications of the different weed control techniques. The cabbage root fly and the effects of the droughtiness made an overall plot yield impossible to calculate. The total yield per hectare was extrapolated from the yield per plant and plant density. This made the total yield unrealistically large. To counteract this it was assumed that the germination rate was 80 per cent and of the plants surviving only 50 per cent of the crop yield would be marketable.

Cabbage Trial

The mechanical treatments which gave the highest margins were the combinations of the tine and hand-weed and brush and hand-weed. The extra cost of the hand-weeding was more than compensated by the associated increase in yields.

The herbicide treatment also gave a good overall yield at relatively low cost and hence the second highest margin. This can be compared to the mulch treatment which gave a comparable yield but had high input costs. This results in a lower margin.

Swede Trial

The tine treatment gave the highest margin over costs. This was due to an increase in yield of over 30 per cent on the brush treatment and 17 per cent on the untreated plot. The grid treatment had the lowest margin due to the overall small yield.

5. REPORT ON TRIALS 1993

PART 1: WEEDS AND MACHINES

1. Introduction

The 1991 trial series showed the importance of weeding to crop growth and yield in vegetable brassica crops. Three types of cultivator were tried, a rolling cultivator, spring tines and a "Brush-Weeder". There were some differences in the levels of weed control achieved between crop rows, but the biggest impact on crop yield was where hand-weeding had also been undertaken within the crop rows. The identification of a need for improved in-row crop weeding rather than for any major improvement on between-row weeding before such approaches could be acceptable prompted the initiation of trials in 1992 to examine the potential for cross-weeding by planting or sowing the crops in a rectangular ('grid') pattern rather than in a row distribution. Planting was undertaken by hand in the absence of suitable commercial machinery to plant on a grid pattern. The spring tine and 'Brush-Weeder' cultivators were used in this series, which again emphasised the importance of in-row weeding. The weed control was not quite as good on the grid pattern as in between crop rows, but the trials were confounded by severe droughting and cabbage rootfly damage in the organic approach. In a sown swede trial, weed control was best in the grid pattern, but crop yield was reduced. However, the trials indicated that there was no physical constraint to use of a cross-weed technique on an agreed pattern, and that this should be re-examined under better growing conditions.

The 1993 approach has, therefore, looked at ways in which working and weeding to a grid can be done easily on a farm, and the consequences of such planting/sowing arrangements on weed control and yield. This is again compared with row crops, and, as throughout this trial series, compared with the use of black polyethylene weed mulch in row crops. A herbicide-based treatment was included, but heavy rain following treatment reduced vigour, and that treatment has been excluded from the comparison in case it proved inaccurate.

1. Weed control and crop response

1.1 Site Details

Farm:	Bush Estate Midlothian OS NT: 244 638
Farmer:	SAC
Soil Type:	Freely drained brown calcareous and brown forest soils of the Darvel Series
Height above sea level:	180 m and slightly SE

Meteorological Data for 1993:

Month	**Temperature mean °C**	**Total rainfall (mm)**
April	6.9	86.3
May	9.1	137.1
June	12.7	71.6
July	13.1	47.8
August	12.2	42.5
September	10.7	105.6
October	6.3	179.3

Manuring:	N: 225 kg/ha (split 120/105 kg/ha) P: 75 kg/ha K: 175 kg/ha
Other Routine Management:	Prior to planting/sowing, the ground had been ploughed, and given one pass of a Roterra cultivator to control weeds and prepare a seedbed. All plants were dipped in insecticide prior to planting to control cabbage rootfly and also had granular pesticides in the seedbed.

1.2 Treatment Details

Treatment Materials:

T = Spring Tine Cultivator with guard discs

B = Inter-row 'Brush-Weeder'

M = Black polyethylene mulch - 50* horticulture grade

The crops planted or sown in rows were divided into with and without hand-weeding in the row. There was also a hand-weeded control, weeded for the first 6 weeks after establishment. The cross planted area was weeded with the implements in two directions, at right angles to each other through the rectangular grid of plants. The sown crop was drilled in rows and the weeding machinery was used to thin the plants to a square grid. Thereafter the weed cultivations were undertaken in two directions as for the planted crop. See Figures 1 and 2.

Each of the trials was mechanically weeded twice. The crops in the grids were weeded twice in both directions. In crop row and other hand-weeding were also undertaken twice at approximately the same time (within 48h). This occurred about 2 weeks and 4 weeks after planting and 3 weeks and 5 weeks after sowing.

Crops:

I	Calabrese, cv Marathon	planted on 11-12.5.93
II	Calabrese, cv Marathon	sown on 26.5.93

Plot size and replication:

Crop beds were 1.68 m wide, with four crop rows. The row crop plots were 10 m long. The grid pattern is described in Figure 2. The grid plots consisted of 9 grids of 1.68 m x 1.68 m. The plants were planted at 37 cm spacing along the rows, in the row plots and the grid plots, with 37 cm spacing between the rows. The sown crop was sown at the same row width and the cultivators were used to thin the crop to the same grid pattern as for the panted crop. The number of plants in the different plots are given in Table 4. Row plots were split into a higher and lower seed rate: 6 kg/ha and 9 kg/ha. All treatments were replicated in three blocks as shown in Figure 1. Randomisation was not complete for technical/management reasons, but variability was greatest between replicates, rather than within replicates.

Figure 1. 1993 Trials Lay-out

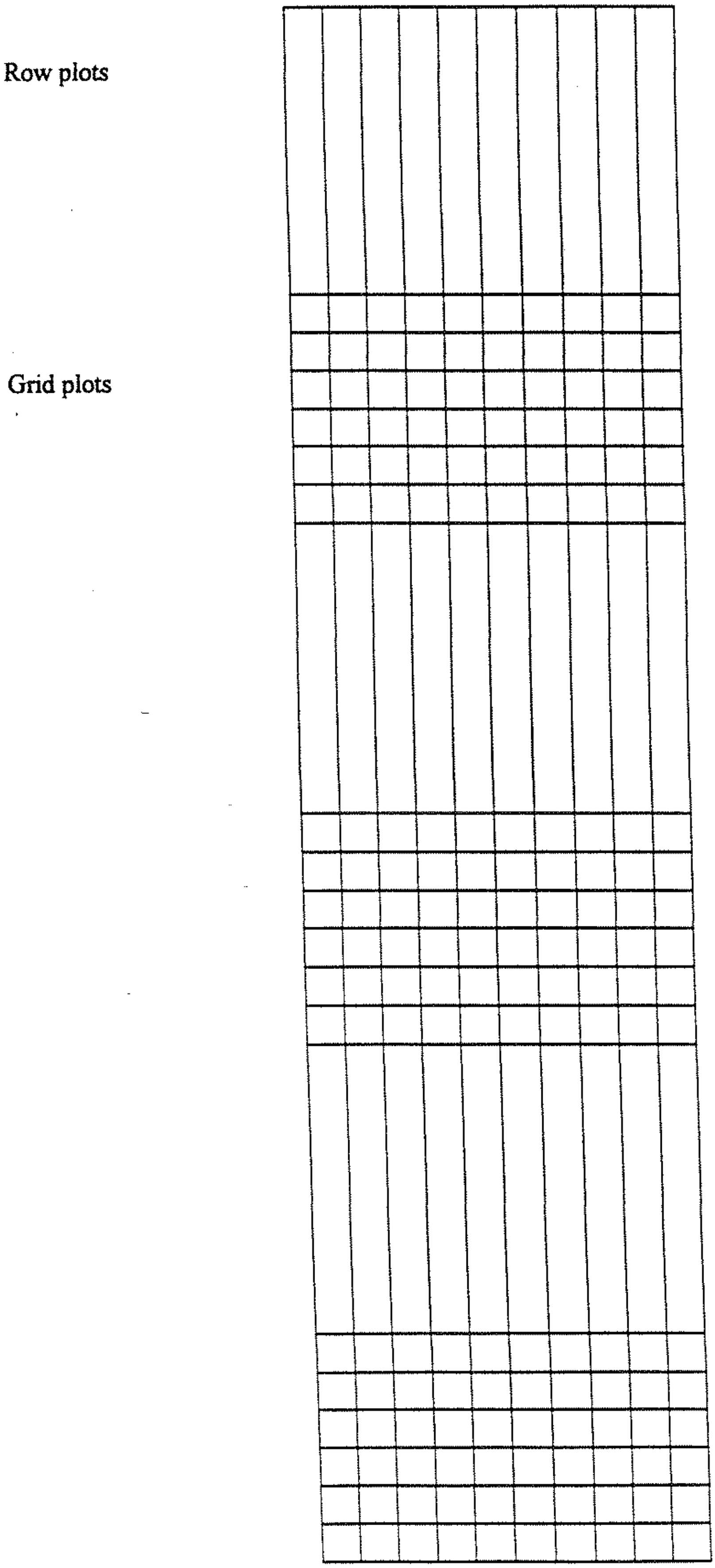
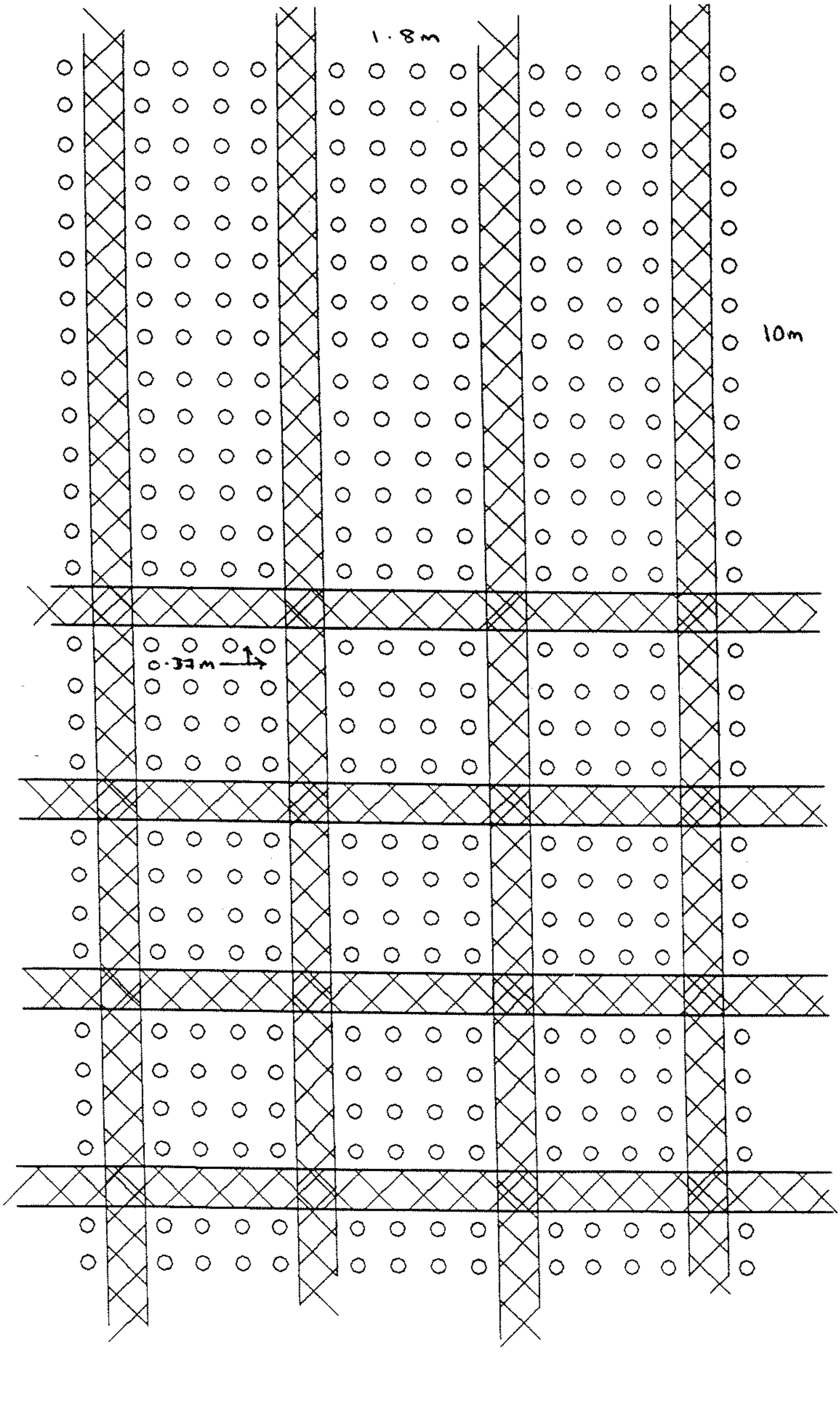


Figure 2. 1993 Trials ; pattern of wheelings and grid and row plots

Row plots

Grid plots



1.3 Assessments

Assessments were undertaken of % weed ground cover 6 weeks after treatment. The calabrese were harvested from an area of 5m length in the middle of each treatment plot of 4 rows (1.68 m), and from all plants in the grid plots. All heads were cut, counted and weighed within two size categories, less and more than 75 mm (marketable), and measurements totalled over the cutting season as recorded in the results tables.

1.4 Results

1.4.1 Weed Control

Tables 1 and 2 give the levels of weed control six weeks after the treatment in planted and drilled calabrese, as a percentage ground cover of remaining weeds.

The herbicide failed to control grass weeds in the planted crop, and the mechanical weed control methods performed significantly better, except within crop rows where an extra hand-weeding was required. There was otherwise no significant differences between treatments. The pattern of response was generally similar in the drilled crop, except that the herbicide worked as well on grass weeds as the cultivations. There was a trend to less effective weed control within the grid plots than between the rows in the row plots, but this was not a significant difference. The best overall weed control was, however, clearly that from use of a black polyethylene mulch in the planted crop.

1.4.2 Crop Response

The yield from each treatment in the planted crop is given in Table 3. It is clear that the best yield response comes from use of the polyethylene mulch, giving a benefit of over 1 t/ha over the best mechanical treatments. The best of these were the use of machinery between the rows with hand-weeding within the rows. There was no difference between the use of tines or 'Brush-Weeder'. The hand-weeding within crop rows added about 2.5 t/ha to the row crop yields. However, crop yield within the grid plots were very low; only just significantly better than in the untreated plots.

This corresponds to a reduction in the number of heads/plant, and, in particular, in their weight, compared with the other treatments (Table 3). This is compounded by a reduction in final plant numbers per unit area within the grid plots compared with the row plots (Table 4).

In the drilled crop, the machinery was also used to thin the seedlings and structure the grid plots. This reduced plant numbers to a figure similar to that of the planted crop (Table 4). Extra plant thinning was included as a treatment in some of the row plots with hand-weeding. Otherwise plant numbers were rather higher in the drilled than the planted crop.

Table 5 gives the yield response to treatment in the drilled crop. In this trial, the herbicide treatment gave the best yield response. The use of a tine + hand-weeding gave a similar yield response, otherwise other treatments gave a significantly lower yield, including 'Brush-Weeder + hand-weeding'. However, the grid plots again had a much reduced yield. This corresponds to the reduction in plant numbers, but also to a tendency towards lower yield/plant compared with the best row treatments, and, in the case of the 'Brush-Weeder' treatments, a reduction in heads/plant.

Table 1. Effects of treatment on ground cover of weeds 6 weeks after treatment; planted crop

	% ground cover			
	Between rows		In-Rows	
	BLW	**Grass**	**BLW**	**Grass**
Untreated	62	23	73	26
Brush	4	4	58	33
Tines	2	6	33	44
Brush + hand-weed	1	2	1	5
Tine + hand-weed	1	6	3	6
Hand-weed only	4	9	4	12
Herbicide	3	39	2	25
Black mulch	0	0	0	0
Brush Grid			4	9
Tine Grid			2	9

BLW = Broad-leaved weeds

Table 2. Effects of treatment on ground cover of weeds 6 weeks after treatment; drilled crop

	% ground cover			
	Between rows		In-Rows	
	BLW	**Grass**	**BLW**	**Grass**
Untreated	43	20	48	13
Brush	5	7	50	23
Tines	4	3	58	15
Brush + hand-weed	4	4	1	2
Tine + hand-weed	3	3	2	3
Hand-weed only	6	7	4	1
Herbicide	1	7	1	5
Brush Grid			10	8
Tine Grid			14	6

BLW = Broad-leaved weeds

Table 3. Effects of treatment on crop yield; planted calabrese

	Number of heads/plant No	Yield/ head g	Total yield of crop t/ha
Untreated	0.6	50	0.79
Brush	1.2	147	2.41
Tines	2.7	222	3.67
Brush + hand-weed	3.6	372	6.11
Tine + hand-weed	3.1	369	5.88
Hand-weed only	3.1	295	4.54
Black mulch	4.0	420	7.41
Brush Grid	1.5	126	1.37
Tine Grid	1.1	127	1.34
SED+/-	0.39	14.2	0.573

Table 4. Final number of plants following each treatment in planted and drilled crops

	Planted	Drilled
Untreated	4.7	14.6
Brush	4.9	13.9
Tines	4.8	13.5
Tines	-	7.9 (thinned)
Brush + hand-weed	4.9	7.9 (thinned)
Tine + hand-weed	4.8	4.9 (thinned)
Hand-weed only		
Herbicide	-	14.7
Black mulch	5.3	-
Brush Grid	3.2	4.8
Tine Grid	3.2	4.6

Table 5. Effects of treatment on crop yield; drilled calabrese

	Number of heads/plant No	Yield/ plant g	Total yield of crop t/ha
Untreated	0.7	43	6.20
Brush	0.8	48	6.73
Tines	1.1	52	7.04
Tines (thinned)	1.1	97	6.88
Brush + hand-weed (thinned)	0.9	88	6.94
Tine + hand-weed (thinned)	1.0	93	8.22
Hand-weed only	0.9	111	6.72
Herbicide	1.0	60	8.84
Brush Grid	0.8	43	2.06
Tine Grid	1.2	68	3.09
SED+/-	0.12	11.9	1.085

2. Equipment Factors

2.1 Equipment used

Two implements designed to mechanically control weeds in row crops and beds were used.

The 'Brush-Weeder' (Baertschi and Co) - this unit consists of a number of brush sections mounted on a pto-driven shaft. Each brush unit comprises of polypropylene bristles radiating from a central brush. The distance between the radiating brush rolls can be adjusted to accommodate different sizes and row numbers of growing plants. Plants are protected from damage by the brushes by means of vertical plates.

During operation, the brush units brush weeds from the soil against a vertical curtain where the soil is knocked from the roots. The weeds' roots are exposed and desiccation occurs. Forward speed and rotational speed of the brushes can be varied to suit the prevailing weed conditions. Transverse movement of the brushes is achieved manually by an operator sitting on the machine.

The spring-tine weeder (Kongskilde) - each weeding row unit consists of 4'A' blades attached to a spring. The spring-tines are mounted on a carrier which is in turn attached to the main beam via a parallel linkage. A pair of serrated discs protects each crop row from damage during the weeding operation. When operating in semi-mature crops, the discs can be held out of work. Tines can be adjusted to accommodate various row widths.

The implement is designed to undercut weeds and leave them exposed on the surface. The vibrating nature of the tines keeps them free of clinging weeds.

The power unit used for all weed control treatments was a MF-575 tractor fitted with row crop wheels.

2.2 Rates of Work

The rates of work and fuel consumption were measured for each machine (Table 6).

Table 6. Work rate and energy consumption for the spring-tine and 'Brush-Weeder' cultivators

	Mean spot rate of work ha/h	**Mean specific energy consumption MJ/ha**
'Brush-Weeder'	0.53	145
Spring-tines	1.30	160

The spring-tines worked faster than the 'Brush-Weeder' but at greater energy consumption.

3. Discussion

There were no major differences in the level of weed control between the machines used and between use in between the crop rows in the row plots and in the grid plots. The poor performance of the crops in the grid plots is, therefore, due to other factors probably related to the use of the machinery. The plants on the edge of each grid plot may have been subject to greater soil compaction from the tractor wheelings within the rooting area than plants in the row crop. Equally, the two directions of disturbance from weeding cultivations may have proved excessive in the grid plots; although we have no measured evidence for this. These factors may have led to a form of root pruning of the crop plants.

This system of planting on a rectangle and cross-weeding therefore has potential in terms of weed control, but requires further development in terms of reducing the effects on the crop.

The importance of weeding within the crop rows is again clearly seen in this trial series, with perhaps 40-50% of calabrese yield loss being due to weeds in the crop row.

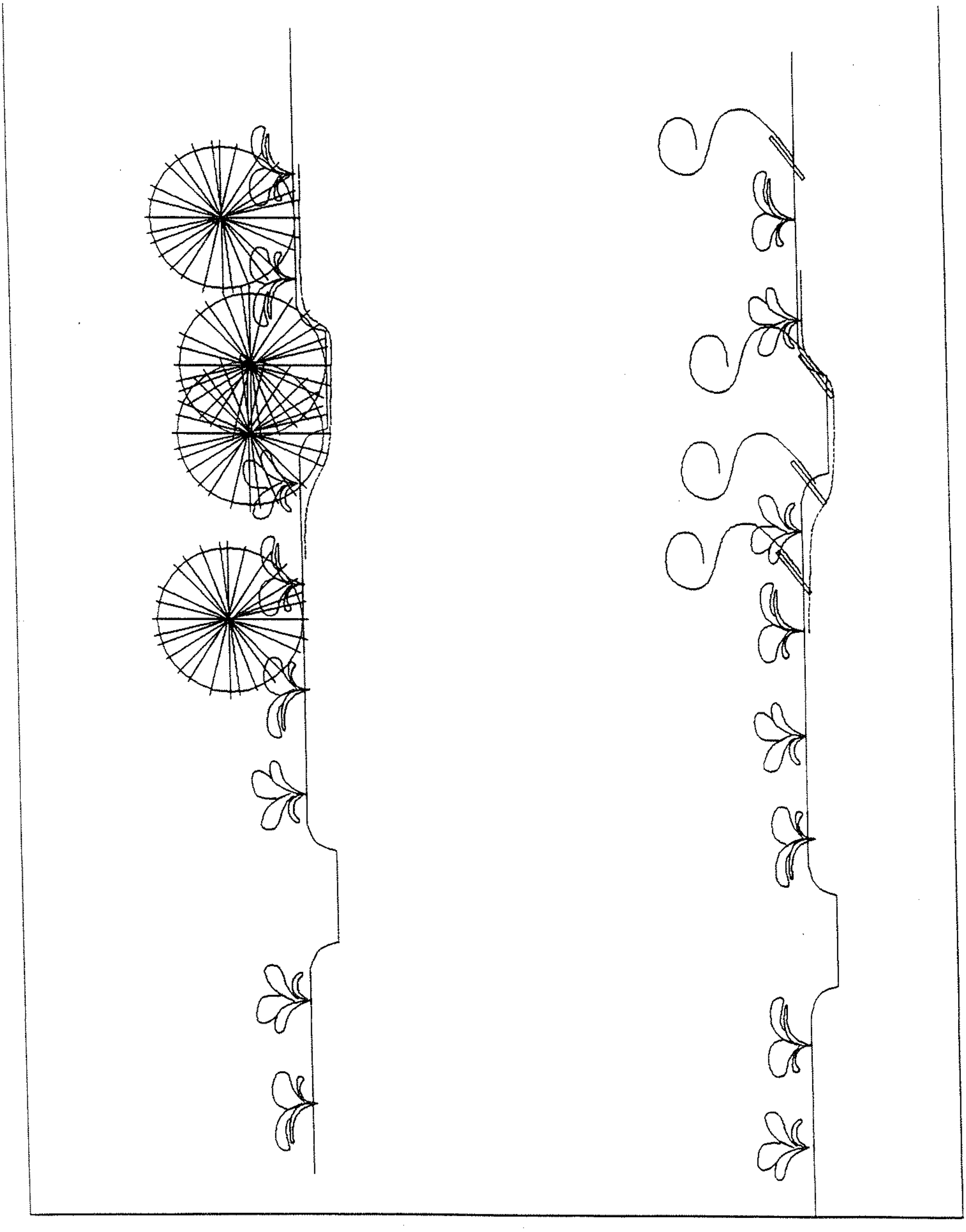
The benefit of using a polyethylene mulch in the planted crop is again clear. This treatment probably improved yield by 15-20% over the use of machinery with hand-weeding within the crop rows.

The use of a herbicide showed yield benefits in the drilled calabrese crop, but only marginally over tine cultivation with hand-weeding. There was little advantage in terms of weed control. There was severe crop damage from the herbicide in the planted crop, probably due to heavy rainfall after treatment and these yield data were omitted. The herbicide at this timing also failed to give grass weed control, which was much better from the mechanical treatments.

The 'Brush-Weeder' was more efficient in energy terms than the spring-tines, but did not work as quickly. This could increase labour costs. In general, the levels of weed control obtained were similar, and there was seldom a difference in the effect on the crop. There was some indication of less tolerance in the drilled crop to the 'Brush-Weeder'. The tractor used in these trials could in practice be replaced by a smaller lighter tractor which would have provided sufficient power and maintained the same work-rate. This may have reduced soil compaction around the plants in the grid plots in particular, possibly reducing some of the crop safety problems seen in this trial series. This warrants further investigation.

The kind of equipment used for cultivation within the grid also requires further investigation for crop safety purposes. It is possible that the equipment used is creating too much root disturbance and machinery with a different mode of action may be required.

Figure 3. Depth control and soil disturbance with the 'Brush-Weeder' and spring-tines



PART 2: FINANCIAL IMPLICATIONS

Full enterprise margins were calculated for each treatment. The enterprise margins include costs of:

> cultivation, based on contractors charges; all materials such as plants, seed, fertiliser, sprays; all labour calculated as if on a casual basis; transport and marketing. The gross revenue includes only the marketable yield of the crop.

	Planted Marketable Yield (t/ha)	Drilled Marketable Yield (t/ha)
Untreated	0.79	6.20
Brush	2.41	6.73
Tines	3.67	7.04
Brush and Hand-weed	6.11	6.94
Tine and Hand-weed	5.88	8.22
Hand-weed only	4.54	6.72
Black polythene mulch	7.41	H 8.84
Brush Grid	1.37	2.06
Tine Grid	1.34	3.09
Tine Thinned	-	6.88

H = Herbicide treatment

ENTERPRISE MARGINS £/HA

Treatment	Planted
Brush and Hand-weed	2374
Black Mulch	2232
Tine & Hand-weed	2209
Tine	1033
Hand-weed only	857
Brush	128
Brush Grid	- 641
Tine Grid	- 662
Untreated	- 1014

ENTERPRISE MARGINS £/HA

Treatment	Sown
Tine & Hand-weed	4532
Tine	4096
Tine Thinned	3970
Brush	3884
Brush & Hand-weed	3613
Untreated	3526
Hand-weed only	3065
Tine Grid	1237
Brush Grid	497

Conclusions

The 1993 trials were a comparison of weeding techniques in planted and drilled calabrese plots. The margins calculated for the planted calabrese were significantly lower than the margins calculated for the drilled calabrese. This was accountable to the higher input costs of planting and lower total yield in the plots.

The herbicide treatment in the drilled plot was not financially analysed due to production problems after application.

Planted Calabrese

The mechanical brush and hand-weed treatment produced the greatest overall margin. The black mulch treatment has the second highest margin. Despite having the highest yield in the trial, the cost of applying the mulch substantially reduced the margin.

The yields in the grid trials were very low. This resulted in a negative margin/loss with the costs exceeding the overall revenue from the sale of the crop.

Drilled Calabrese

The yield ranged from 3.06 to 8.84 t/ha in the drilled trials. This was significantly better than the planted trial. The top three margins were all from the tine treatments. The combination of the tine weeder and hand-weeding gave the highest margin. This is attributed to the high yields obtained in each of the tine plots. The grid system greatly lowered the total yield of both the brush and tine treatments.

6. Report on Study Tour 1992

Report of a visit to The Netherlands and Denmark

April 1992

Monitoring Approaches Towards Non-chemical Weed Control

HORTICULTURAL DEVELOPMENT COUNCIL

PROJECT FV/107

'Field Vegetables: mechanical and mulching weed control techniques'

Project Team:

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Location: SAC Edinburgh

Start Date: 1.5.91

1. The Netherlands

There is a major effort, backed by the government, towards the reduction of pesticide inputs (see Appendix). We visited two centres which are developing reduced herbicide approaches to weed control.

1.1 Lelystad

J. Jonkers and colleagues are working on the following:

1.1.1 Inter-row mechanical hoeing combined with on-row herbicide treatments. They are using celery as their model crop. There is a problem with such combined equipment in that the hoeing produces dust which can cover the foliage of the weeds in the row, and, as a consequence, reduce the efficacy of contact herbicides. However, the equipment can be used very successfully. While it can reduce chemical costs, it does not avoid the problem of lack of available chemicals.

1.1.2. The use of ridging to reduce weed growth. In the case of celery, they prepare the ridge two weeks before sowing. There are less weeds on the ridge because of drier conditions. A contact spray may be used before sowing. They drill two rows on the ridge, then use further ridging-up to control weeds. The use of ridges to reduce herbicide use on the crop warrants further investigation.

1.1.3 Ridge-hoers. Using specially designed angled blades, they claim to be achieving 80% weed control on ridges.

1.1.4 Soil types. Growing vegetables in lighter soils greatly facilitates mechanical weed control, and ridging for weed control.

1.1.5 Use of brush-weeders in a range of row crops.

1.1.6 Infra-red burners. Work on infra-red burners for weed control indicates that they are not as effective as direct burners, both only burning off surface weed growth. They do not control perennials.

1.1.7 Use of laser-guidance of machinery across fields.

1.1.8 Carrots. They have found it impossible to use machines in carrots sown in 10-12cm rows. They are working instead on split-applications of herbicides. Where carrots are grown in 50-75cm rows, then cultivators are used. Carrots are also grown on ridges (50cm with 1 row; 75cm with 2 rows).

1.1.9 Use of mechanical weed control in peas. The peas are grown in 25-50cm rows; they have found no yield differences with narrower rows. They are cross-harrowing one week before, and just at, emergence, using fixed tines.

1.1.10 Mulches. They are particularly interested in paper mulches. The darker the colour of the mulch paper the better. It is being used in leek and iceberg lettuce crops. They are looking at the use of machines for weed control on paths between the rows of paper covered beds; and the use of cooking oil along the edges of the paper sheets which assists in preserving the paper.

1.2 IMAG-CABO, Wageningen

1.2.1 van Zuydam is working on mechanical weed control, particularly on the development of gantries for cultivations, band-sprays, hoeing, etc, guided by lasers from fixed points. Sugar-beet is used for the work, but the principles involved apply to many row crops. It is also used for more precise fertiliser placement. Hoeing is undertaken in the first instance with vibrating firm tines with chisel points. Guard discs protect the crop. The worked area reduces as the crop grows.

1.2.2 They have examined cultivating in the dark to reduce weed growth, as indicated by Hartmann et al in Germany, but have found this technique to be of little or no practical use.

1.2.3 They are working with the University of Berlin and the University of Turin on precise placement of herbicides to reduce use. The importance of back-up of available herbicides was stressed with mechanical weed control.

1.2.4 The systems used for gantry-positioning may be accurate enough for precise cross-planting and cross-hoeing, but the present set-up could also allow precise row-planting and use of reciprocating hoes.

1.2.5 Lotz is examining how often agroclimatic conditions are suitable for mechanical weed control, using weather data; and the costs of potential delays in weed control owing to a wait for better weather conditions.

2. DENMARK (FLAKKEBJERG)

There are 22 weed scientists at Flakkebjerg, funded mostly from a tax on the sale of pesticides. It is, as a consequence, now one of the leading weed research centres in the World. As in The Netherlands, there is now a general requirement to reduce herbicide use. The Danes are generally approaching the problem by research into more precise use of herbicides, by developing complex databases to help on a field-by-field basis, and by the use of machinery for weed control.

2.1 Rasmusson is leading the work on the use of tined harrows for weed control. Chain harrows are also used: before crop emergence, and, in the case of cereals, also just post-emergence. Both furrows and the crop itself can be used to guide tines with remarkably little crop damage.

2.2 The factor that has most influence in controlling weeds with tined implements is the covering of the weeds with soil, rather than uprooting. It is equally important not to cover the crop with too much soil, or yield can be reduced. Rasmusson is attempting to determine how much soil cover is enough, and will try to relate soil quantity needed to harrow-type, soil type and working speeds.

2.3 Rasmusson indicated that the effectiveness of tined harrows decreases when the soil clay content increases above 20%. This result confirms the views of the Dutch (1.1.4) that mechanical weed control is facilitated by growing crops in lighter soils.

2.4 They have found that control of certain weeds is particularly difficult with machines; notably, fast growing species with 'woody' stems e.g. fat-hen, charlock.

2.5 There is work on the use of brush-weeders of varying design and on the use of flamers. The latter are considered very expensive in energy terms. Self-steering hoes using land-wheels in furrows are of particular interest.

2.6 Work at Copenhagen University is examining the development of automatic sensors to 'feel' crop rows, the idea being to fit these sensors to hoeing equipment. This study is at an early stage, but could have some potential.

2.7 A novel idea was the growing of spring barley in 50cm beds the year before a following row crop, using harrowings in the spaces between the beds to encourage weed growth. These beds are then destroyed. The row crops are then planted in what are virtually fallowed rows at 50cm spacing, into a somewhat diminished weed seedbank.

2.8 Cristiansen is looking at the use of remote sensing; notably, the reflection of light from the crop canopy in terms of red/far-red wavelengths to assist in steering equipment away from the crop plants.

2.9 There was survey evidence that Danish organic farmers required 300 hours per growing season to weed one hectare of row crops.

The use of shielded flame weeders reduced the need for hand-weeding by half. In the case of onions, two flamings considerably reduced the need for hand-weeding, and onions can withstand flaming just after emergence. This technique could also probably work well in leeks.

2.10 Kudsk is examining the effects of night cultivation on weed growth. He is coming to the same conclusion as the Dutch, in that there is little of practical value. There is a strong feeling at the institute that whatever techniques they develop for weed control, there is a need to maintain low weed seedbanks.

3. GENERAL POINTS

3.1 There seemed to be relatively little work going on at these leading centres on crop row-spacing and spatial arrangements to improve mechanical weed control. The need for improvement in weed control, especially within the crop row, was universally recognised.

3.2 The use of herbicides just on the crop row, and cultivating between rows, was a common approach; but this technique relies on suitable herbicides being available which may not be the case in the future. It may be however, a useful approach to reducing costs in some crops.

3.3 The use of high ridges to grow bedded crops may prove useful in reducing weed growth, and alongwith appropriate cultivation equipment, may warrant further investigation.

3.4 Mechanical weed control tends to be more successful on lighter soils. This could have major implications on where such crops are grown in the future.

3.5 Harrows and tines could be used in a wider range of cropping situations. Brush-weeders are commonly used with flamers invoking varying opinions. The use of crop sensors and precise planting could, however, make a very useful contribution to weed control.

3.6 The Dutch seemed particularly keen on the use of paper mulches for high value crops, and they felt that the price may come down with use.

Appendix

essentials

Multi-Year Crop Protection Plan

Policy objective

The Multi-Year Crop Protection Plan of the Netherlands aims to have agricultural business management (production and trade) and open space management satisfy the requirements of optimum crop protection in 2000. By then the use of pesticides is to be halved. The potential of crop protection methods beneficial to man and the environment and suitable for sustainable and cost-effective farming systems is to be fully realized, and the susceptibility to diseases and pests as well as the structural dependence on chemical substances is to be reduced. The Multi-Year Crop Protection Plan fits in with the Agricultural Structure Memorandum and the Nature Policy Plan, and is also in keeping with the wider context of the National Environmental Policy Plan and the Third National Policy Document on Water Management.

Targets

The targets of the Multi-Year Crop Protection Plan concern the periods of 1990-1995 and 1995-2000. In comparison with the current use the total pesticide use is to be reduced by more than 35 per cent in 1995 and by at least 50 per cent in 2000.
All agricultural production sectors will contribute to the reduction. These contributions are specified in separate essentials per sector. Insofar as agriculture will continue to rely on chemicals, emissions to the environment are to be severely curtailed. Additional measures will be required to reduce pesticide emissions by at least the following percentages:

Reduction of emissions to:	1995	2000
Air	38 %	50 %
Soil/ground water	48 %	75 %
Surface water	70 %	90 %

Procedure

The development of the plan was supervised by an interministerial steering committee of the Ministry of Agriculture, Nature Management and Fisheries, the Ministry of Social Affairs and Employment, the Ministry of Housing, Planning and the Environment, and the Ministry of Welfare, Health and Cultural Affairs; apart from these ministries, the Ministry of Transport and Public Works also made a major contribution.
The policy intentions of the plan have been submitted for consideration to various social groups. When they have had their say the plan will be sent to the Second Chamber of Parliament to be debated.

Crop protection

In the Netherlands some 600 different crops are grown and 5000 to 6000 diseases and pests have been identified, including fungi, bacteria, viruses, insects, nematodes, and weeds.
Dutch agriculture is vulnerable to diseases and pests, and is as yet heavily dependent on pesticides because of highly specialized farming systems, which result in limited crop rotations, and because of climatic conditions. The fact that the Netherlands as a big exporter has to consider internationally applying high-quality requirements, for example for the appearance of products, also plays a part.

International aspects

Plant diseases and pests are transboundary; they spread both actively and passively. Passive spread has strongly increased as a result of international trade in agricultural products. The Netherlands sets great store by European harmonization of pesticide approval regulations. At the same time, however, the disparities among the member states in climate, production conditions and environmental requirements are to be taken into account. These disparities may lead to differences in pesticide approval and use.

Current pesticide use

The use of pesticides in the Netherlands is considerable compared to some of its neighbouring countries. At present it averages about 10 kg of active ingredients per ha of cultivated land. The considerable use is partly connected with the intensive character of Dutch agriculture, which aims at a high production per hectare.
The annual use of the various types of pesticides is as follows: soil disinfectants 8 578 000 kg of active ingredients; insecticides/acaricides 575 000 kg of active ingredients; fungicides 4 147 000 kg of active ingredients; herbicides 3 639 000 kg of active ingredients; other substances 1 233 000 kg of active ingredients (source: Nefyto, 1988).

Estimated use per sector (x 1 000 kg)

Arable farming	14 200
Bulb culture	2 100
Field vegetable growing	1 300
Livestock farming	880
Floriculture	630
Arboriculture	500
Protected vegetable growing	470
Fruit culture	470
Parks, countryside and embankments	140
Mushroom culture	10

Need for pesticide use reduction

The large-scale use of pesticides causes public anxiety. First, there is fear that the quality of our environment, our nature, food, and drinking water are affected. Increasing knowledge, moreover, leads to concern about the health of consumers and of those who apply pesticides.
Secondly, from an agricultural viewpoint there is also ample reason for reducing the use of pesticides, because substances appear to be losing their efficacy. Resistance problems are increasing and the degradation of pesticides by micro-organisms is accelerating. As a result, the costs for farmers may rise and problems may occur in the export of Dutch products.
Thirdly, import requirements made by other countries force the Dutch towards producing agricultural products with a maximum phytosanitary quality on the one hand and minimum pesticide residue levels on the other.

The Multi-Year Crop Protection Plan initiates a restructuring towards systems of production, processing and marketing which will manage on considerably smaller amounts of pesticides. These systems not only involve safe production conditions and reliable food quality but, consequently, agricultural sustainability as well. Obviously, such a restructuring cannot be realized in current agricultural production in the short run. That is why a certain dependence on pesticides during the planning period is inevitable.

Crop protection policy

The crop protection policy conducted by the Dutch government is an integrated framework and includes the specific policy on pesticides aimed at, for example, the environment, public health, occupational safety, surface water quality and economic exigency. The policy on pesticides is reflected particularly in the clearance of pesticides.

Three strategies

The Multi-Year Crop Protection Plan lays down three strategies, each worked out per agricultural production sector. The three strategies are:
- reduction of the **dependence** on chemical pesticides;
- reduction of the **use** of chemical pesticides;
- reduction of the **emissions** of chemical pesticides to the environment, particularly ground water, surface water and air.

In addition, pesticide use will be tackled per substance through the clearance policy on pesticides. Especially the stricter requirements for pesticides made from the point of view of environmental protection have resulted in proposals for the restructuring of the currently approved package of pesticides. Concern about the quality of ground water and surface water has played a major part in this. Restructuring will be phased in order to enable farmers to change over to alternative substances and methods.

First strategy

Reduction of the dependence on pesticides
Integrated farming systems and organic agriculture will be vigorously encouraged. In integrated farming systems the input of artificial fertilizers and pesticides is

considerably lower than in conventional, intensive production systems. Organic farming does not use any synthetic or chemical substances.
Farmers will be encouraged to make wider use of healthy starting material, to handle imported planting material most carefully, to rotate crops more frequently if possible; to grow less susceptible varieties, to apply (artificial) fertilizers more sparingly, and to take hygienic measures.

Second strategy

Reduction of the use of pesticides
For various agricultural sectors soil disinfectants will be obtainable by prescription only; moreover, these substances are not to be applied more often than a maximum number of times.
The use of herbicides will decrease down by a combination of chemical and non-chemical weed control methods. The same goes for chemical haulm killers. By using supervised control, biological control and improved application equipment the use of fungicides and insecticides in particular will fall.

Third strategy

Reduction of the emissions of pesticides
Reductions in pesticide use will result in corresponding reductions in pesticide emissions to the environment. Nevertheless, particularly in closed cultivation systems additional measures will be required in certain cases to achieve the emission reductions desired. This concerns especially effluents from glasshouse cultures and champignon farms. Application equipment is to be improved in such a way that as much substance as possible will reach the aim without spilling into the environment.

Approval policy

In a crop protection policy that is well-considered with regard to environmental management, occupational safety and public health, the approval of pesticides plays an important part. This should be taken into account in the execution of the Multi-Year Crop Protection Plan. It does not imply that an approved pesticide which is no longer considered admissible because of new insights and/or new information cannot be withdrawn. However, in the restructuring of the approved pesticides the policy intentions of the Multi-Year Crop Protection Plan will be taken into account in order not to hinder the sustainable change-over to well-considered crop protection.

Policy instruments

Legislation
Under the Pesticides Act the following measures will be taken in addition to the above-mentioned stricter clearance requirements:
- the introduction of a recognized certificate of competence for the application of pesticides;
- the introduction of quality requirements for and an obligatory overhaul of application equipment;
- the distribution of soil disinfectants by prescription only and on conditions;
- the introduction of stricter use requirements;
- the introduction of a destination levy on pesticides;
- the introduction of a tariff increase for assessing the admissibility of pesticides;
- the introduction of a supply and use registration.

In addition, under the Plant Diseases Act and the Seeds and Planting Materials Act severe requirements will be made for the condition of planting material where necessary. In certain cases measures will be taken under the Pollution of Surface Waters Act, the Control of Pollution Act and the Soil Protection Act which will affect the use of pesticides by farmers.

Extension
The instrument of extension is very much suited to bring about changes in behaviour and to provide for a rapid circulation of information. The Information and Knowledge Centre (IKC) and the Agricultural Extension Service (DLV) play a very important part in this. In addition to the 25 staffing posts established at present, another 15 posts will be made available to Multi-Year Crop Protection Plan officials. Furthermore, £ 300 000 extra will be put up for extension materials.

Education
A special crop protection training programme has been developed for agricultural day-schools and courses. In the future everybody applying pesticides or having them applied, buying or selling them and/or advising on them will have to satisfy certain competence requirements. The training programme provides the necessary knowledge and insights. Extra requirements will be laid down for pesticide trade and distribution.

Research
The realization of the objectives of the Multi-Year Crop Protection Plan largely depends on current research and future research. In several areas, such as the detection and sampling of soil diseases, the harmful effects of pesticides on the environment (ecotoxicology), application techniques that restrict emissions, and

biological control of diseases, pests and weeds, research will have to be stepped up.

Incentives
Under the Structural Improvement and the National Complementary regulations of the Development and Reconstruction Fund for Agriculture, contributions may be given to the costs of certain investments made to protect and improve the environment, including investments aimed at reducing the use of pesticides, in order to encourage the willingness to invest.
Organic farming will be encouraged by:

- support for the change-over from conventional to biodynamic or ecological farming;
- subsidization of enlargement of the product range bearing the SKAL alternative production mark;
- subsidization of information on organic farming;
- the Ministry of Agriculture, Nature Management and Fisheries will put forward a proposal for a regulation in the context of EC extensification (change-over to organic or ecological farming).

Progress control and evaluation

Progress and evaluation of the measures taken will be controlled by an interministerial co-ordinating committee. Every two years a progress report will be drawn up for the Second Chamber of Parliament, in which the effects of the measures will be described. The years 1995 and 2000 will be the gauges to determine whether additional measures are required. To evaluate the effects of the measures a use registration system will be developed by the Dutch Central Bureau of Statistics and the Ministry of Agriculture, Nature Management and Fisheries. Through monitoring, surveys and checks it will be verified to what extent the targeted emission reductions are achieved.

Consequences for agribusiness

The execution of the Multi-Year Crop Protection Plan makes considerable demands of agribusiness. The extra investments are estimated to approximate to £ 700 million from now to 2000; the extra costs are estimated to rise to more than £ 240 million per year in 2000.
For many years farmers have been winding up their businesses. The measures of the Multi-Year Crop Protection Plan are expected to accelerate this development. The majority of farms will be able to cope with the consequences of the Multi-Year Crop Protection Plan and will remain viable in the longer run. These farms are already making considerable efforts to meet the requirements of the plan or have sufficient structural and financial resources to realize the necessary adjustments. This group of farms is large enough in number and production value to safeguard the future of the various sectors. Together they are the basis of a competitive, safe and sustainable plant sector.

Multi-Year Crop Protection Plan per sector

The strategies of the Multi-Year Crop Protection Plan have been worked out in separate essentials for the following sectors: arable farming, field vegetable growing, bulb (and bulb flower) culture, arboriculture, fruit culture, livestock farming, protected vegetable growing, floriculture, mushroom culture, and parks, countryside and embankments.

More information

For further information please contact the Ministry of Agriculture, Nature Management and Fisheries, PO Box 20401, 2500 EK The Hague, The Netherlands.
Telephone 70 - 379 20 62

The Hague, August 1990
Ministry of Agriculture, Nature Management and Fisheries
Information and External Relations Department

Field vegetable growing

Current situation

The area under field vegetables is more than 45 000 ha, a third of which is under cabbage.
The use of pesticides greatly varies for each crop and ranges between 1 kg (broad bean) to 200 kg of active ingredients per ha (strawberry). The total use is about 1 275 tonnes of active ingredients per year, an average of 28 kg per ha.
Like in arable farming, soil disinfectants and pesticides for soil treatment contribute significantly to the total use of pesticides (more than 70%) as a result of the intensive production methods of the sector.

Target reductions

As to field vegetable growing, the Multi-Year Crop Protection Plan lays down an average pesticide reduction of 30% of the current use in 1995 and more than 40% in 2000. Generally speaking, emissions to the environment will fall by at least the same percentages.

Measures

The change-over to integrated and organic farming methods will be encouraged by public information and education campaigns.

Reductions in the use of soil disinfectants will be realized by strictly regulating their use through making them available by prescription only and through reducing the frequency of soil disinfection.

The use of herbicides will be reduced by encouraging the integrated application of chemical and non-chemical weed control (including band spraying, mechanical and hand weeding, selective herbicide application, and protective covering of the soil).
The use of insecticides/acaricides and fungicides will be reduced by encouraging the use of healthy starting material, the application of biological and integrated control, and the use of insect screens.

A major point is the improvement of the efficacy of pesticide application by formulating requirements for the operator's competence, for application equipment, and by obliging operators to have it overhauled.

The additional measures to reduce emissions particularly aim to avoid drift and evaporation during pesticide application and to prevent pesticides from spreading to the surface water via spray residues and rinsings.

Consequences

The measures will necessitate farm adjustments and lead to extra investments and costs. Further details are to be found in the Multi-Year Crop Protection Plan. Specialized strawberry breeders will be affected most.

The Significance of the Multi-Year Crop Protection Plan

Arable farming

Current situation

About 750 000 ha of the Netherlands is devoted to arable farming: about half is covered by cereals and maize together. Potatoes and sugar beet are grown on 20% and 15% respectively. The total use of pesticides in arable farming is some 14 000 tonnes of active ingredients a year, which amounts to an average of about 19 kg per ha.
Soil disinfectants and pesticides for soil treatment, which are applied in particular in intensive potato and sugar beet production, account for about 70% of the total use.

Target reductions

As to arable farming, the Multi-Year Crop Protection Plan lays down a pesticide reduction of almost 40% of the current use in 1995 and almost 60% in 2000. Generally speaking, emissions to the environment will fall by at least the same percentages.

Measures

The change-over to integrated and organic farming methods will be encouraged by public information and education campaigns.

Reductions in the use of soil disinfectants will be realized by strictly regulating their use through making them available by prescription only and through reducing the frequency of soil disinfection.
The use of herbicides will be reduced by encouraging the integrated application of chemical and non-chemical weed control (including band spraying, mechanical and hand weeding, and low-dose systems).
Chemical haulm destruction will be drastically reduced by the application of renewed haulm pulling and haulm stripping systems.
The use of insecticides/acaricides and fungicides will be reduced by encouraging the use of healthy starting material, the application of biological and integrated control, and the improvement of application techniques.

A major point is the improvement of the efficacy of pesticide application by formulating requirements for the operator's competence, for application equipment, and by obliging operators to have it overhauled.

The additional measures to reduce emissions particularly aim to avoid drift and evaporation during pesticide application and to prevent pesticides from spreading to the surface water via spray residues and rinsings.

Consequences

Especially in the peaty "Veenkoloniën" area in the north-east of the Netherlands the measures will necessitate farm adjustments and lead to extra investments and costs. In this area the adjustments will mainly concern lower potato frequencies. The current policy on potato-sick land will be adjusted in order to fit in well with the soil disinfection reductions. Further details are to be found in the Multi-Year Crop Protection Plan.

The Significance of the Multi-Year Crop Protection Plan

Floriculture

Current situation

In 1988 the area under protected floricultural products was more than 4 700 ha (more than 3 600 ha of cut flowers and 1 100 ha of pot plants) and that under field floricultural products almost 1 900 ha (especially flower culture).
The total use of pesticides in the sector amounts to about 630 000 kg of active ingredients a year, which is an average use of 96 kg per ha.
The share of soil disinfectants and pesticides for soil treatment is about 65%. The crop chrysanthemum (625 ha) uses 140 000 kg of active ingredients: a use of more than 220 kg per ha. The current way of growing roses also requires almost 150 kg of active ingredients per ha.

Target reductions

As to floriculture, the Multi-Year Crop Protection Plan lays down a pesticide reduction of more than 50% of the current use in 1995 and about 65% in 2000. Generally speaking, emissions to the environment will fall by at least the same percentages. In addition, in 2000 closed systems will enable a 99% reduction of emissions to the surface water.

Measures

The development and the use of soilless culture systems will be encouraged as much as possible, also with regard to minor crops.

Soil steaming (by underpressure) will be encouraged on those farms which will continue to use the soil for whatever reason.

As of 1995 soil disinfectants and pesticides for soil treatment will be obtainable by prescription only and on conditions.

The use of insecticides/acaricides and fungicides will be reduced by encouraging the use of healthy starting material, the application of biological and integrated control, and the improvement of application techniques.

A major point is the improvement of the efficacy of pesticide application by formulating requirements for the operator's competence, for application equipment, and by obliging operators to have it overhauled.

Other measures concern the intensification of import inspections and, consequently, the encouragement of resistant and tolerant varieties, as well as encouragement of the appropriate production and hygienic measures. Research into restricted uses of growth regulators, glasshouse disinfectants and cleansers will be encouraged. This also goes for a replacement for silver thiosulphate, with which flowers are pretreated. The keeping life of flowers not pretreated with chemicals will become a major criterion in selecting new cut flower varieties and/or cultivars.

Consequences

The measures will necessitate farm adjustments and lead to extra investments and costs. Further details are to be found in the Multi-Year Crop Protection Plan.

The Significance of the Multi-Year Crop Protection Plan

Arboriculture

Current situation

In 1989 Dutch arboriculture covered more than 6 500 ha: major arboricultural crops are forest trees and hedging plants (well over 1 700 ha), park and avenue trees (more than 1 300 ha) and ornamental conifers (1 050 ha). Arboriculture is centred in nurseries at Boskoop, Opheusden and Zundert.
The use of pesticides in arboriculture totals more than 500 000 kg of active ingredients a year; the average use is 77 kg per ha.
In this sector, too, soil disinfectants and pesticides for soil treatment contribute significantly (75%) to the figures. In arboriculture chemicals are in particular applied to rose rootstocks, and Callunas and Ericas.

Target reductions

As to arboriculture, the Multi-Year Crop Protection Plan lays down a pesticide reduction of 25% of the current use in 1995 and 32% in 2000. Generally speaking, emissions to the environment will fall by at least the same percentages.

Measures

Reductions in the use of soil disinfectants will be realized by strictly regulating their use through making them available by prescription only and through reducing the frequency of soil disinfection as well as by changing over to container culture and encouraging rotations.

The use of herbicides will be reduced by encouraging the integrated application of chemical and non-chemical weed control (including band spraying, mechanical and hand weeding, and change-over to container culture).
Reductions in the use of soil disinfectants will be realized by strictly regulating their use through making them available by prescription only and througn reducing the frequency of soil disinfection. Besides, the knowledge of diseases, pests and pesticides should be increased.

Research into the application of knowledge of susceptibility and resistance to diseases is to be promoted.

A major point is the improvement of the efficacy of pesticide application by formulating requirements for the operator's competence, for application equipment, and by obliging operators to have it overhauled.

Consequences

The measures will necessitate farm adjustments and lead to extra investments and costs. Further details are to be found in the Multi-Year Crop Protection Plan. The measures will particularly affect nurseries growing forest trees and hedging plants, Ericas and Callunas.

The Significance of the Multi-Year Crop Protection Plan

Bulb (and bulb flower) culture

Current situation

Bulb culture in the Netherlands covers almost 18 000 ha: about 40% of the area is devoted to tulip, the largest crop. In bulb culture the average pesticide use is 120 kg of active ingredients per ha. The total use of pesticides in the sector amounts to 2 100 tonnes of active ingredients a year.
The sector has to deal with a considerable number of soil-borne diseases. Different bulb crops are often affected by the same pathogens. The share of soil disinfectants and pesticides for soil treatment in the total use of pesticides is large, that is, 63% and 89% in bulb culture and bulb flower culture respectively.

Target reductions

As to bulb culture, the Multi-Year Crop Protection Plan lays down a pesticide reduction of about 45% of the current use in 1995 and more than 60% in 2000. Generally speaking, emissions to the environment will fall by at least the same percentages.

Measures

Reductions in the use of soil disinfectants will be realized by strictly regulating their use through making them available by prescription only and through reducing the frequency of soil disinfection.
As a result, the current specialized bulb culture areas will have to practise wider rotations. That is why about 300 ha of tulip culture will be moved to other parts of the Netherlands. In bulb flower culture reductions will be achieved in particular by developing and changing over from field forcing to box growing and/or hydroponics, and steaming the soil or substrate.

The use of herbicides will be reduced by encouraging the integrated application of chemical and non-chemical weed control (including band spraying, mechanical and hand weeding, low-dose systems, and mulching).
The use of insecticides/acaricides and fungicides will be reduced by encouraging the use of healthy starting material, the application of biological and integrated control, and the improvement of application techniques.
For this purpose combined research and extension programmes will be drawn up in order to reach a reduction in the use of chemicals to combat the Botrytis fungus, viral infections, and thrips damage.

A major point is the improvement of the efficacy of pesticide application by formulating requirements for the operator's competence, for application equipment, and by obliging operators to have it overhauled.

Consequences

The measures will necessitate farm adjustments and lead to extra investments and costs. Further details are to be found in the Multi-Year Crop Protection Plan. Farms on sandy soil will require more adjustments to cope with the consequences of the Multi-Year Crop Protection Plan than farms on stronger soils.

The Significance of the Multi-Year Crop Protection Plan

Fruit culture

Current situation

Fruit culture in the Netherlands is carried out on more than 23 000 ha, the most important crops being apple (15 300 ha), pear (5 200 ha), cherry and plum (1 250 ha), and ligneous minor fruit (about 550 ha). Besides, the Netherlands has more than 1 100 ha of fruit tree nurseries.
The total use of pesticides in fruit culture amounts to more than 470 000 kg of active ingredients a year: the average use per ha is 20 kg.
These figures are mainly the result of the use of soil disinfectants in fruit tree nurseries and the application of fungicides to particularly scab and mildew in apple and pear.

Target reductions

As to fruit culture, the Multi-Year Crop Protection Plan establishes a pesticide reduction of about 23% of the current use in 1995 and almost 45% in 2000. Generally speaking, emissions to the environment will fall by at least the same percentages. In addition, the introduction of advanced application equipment will realize additional emission reductions.

Measures

Reductions in the use of soil disinfectants will be realized by strictly regulating their use through making them available by prescription only and through reducing the frequency of soil disinfection. This applies almost exclusively to fruit tree nurseries.
The use of herbicides will be reduced by encouraging the integrated application of chemical and non-chemical weed control (including local spraying, mechanical and hand weeding, tree strip covering, filling up).
The use of insecticides/acaricides and fungicides will be reduced by encouraging the use of healthy starting material, the application of biological and integrated control, and the improvement of application techniques. Particularly in fruit culture these techniques are significant to reduce the emissions of pesticides to the environment.

A major point is the improvement of the efficacy of pesticide application by formulating requirements for the operator's competence, for application equipment, and by obliging operators to have it overhauled.

The above-mentioned measures will be combined in integrated and organic farming systems, whose development and application will be encouraged through research and extension.

Consequences

The measures will necessitate far-reaching farm adjustments and in many cases lead to extra investments and costs (labour, capital expenditure, yields). Further details are to be found in the Multi-Year Crop Protection Plan.

The Significance of the Multi-Year Crop Protection Plan

Protected vegetable growing

Current situation

The area of vegetable growing under glass is more than 4 400 ha: in 1988 the Netherlands had 6 300 protected vegetable holdings with an average size of 7 000 m^2.
The total use of pesticides in the sector approximates to 470 000 kg of active ingredients a year, which is an average use of about 106 kg of active ingredients per ha. The share of soil disinfectants and pesticides for soil treatment in the total use is about 85%.
Since in fruit vegetable production, such as tomato, sweet pepper and cucumber, biological control is applied on 90% of the area under glass, only small quantities of insecticides are used.

Target reductions

As to protected vegetable growing, the Multi-Year Crop Protection Plan lays down a pesticide reduction of 50% of the current use in 1995 and 65% in 2000. Generally speaking, emissions to the environment will fall by at least the same percentages. In addition, in 2000 closed systems will enable a 99% reduction of emissions to the surface water.

Measures

The development and the use of soilless culture systems will be encouraged as much as possible, also with regard to minor crops.

Soil steaming (by underpressure) will be encouraged on those farms which will continue to use the soil for whatever reason.

As of 1995 soil disinfectants and pesticides for soil treatment will be obtainable by prescription only and on conditions.
The use of insecticides/acaricides and fungicides will be reduced by encouraging the use of healthy starting material, the application of biological and integrated control, and the improvement of application techniques.

A major point is the improvement of the efficacy of pesticide application by formulating requirements for the operator's competence, for application equipment, and by obliging operators to have it overhauled.

Other measures concern the production and use of resistant and tolerant varieties, appropriate production and hygienic measures, and research into alternatives to glasshouse disinfectants and cleansers.

Consequences

The measures will necessitate farm adjustments and lead to extra investments and costs. Further details are to be found in the Multi-Year Crop Protection Plan.

The Significance of the Multi-Year Crop Protection Plan

Parks, countryside and embankments

Current situation

The sector of parks, countryside and embankments is very heterogeneous and includes the following partial sectors: public parks, rural areas (wet and dry), roads, railways, and embankments, which in total cover 700 000 ha.
The total use of pesticides in the sector amounts to 140 000 kg of active ingredients a year, almost half of which is used in parks. The sector uses almost exclusively herbicides. The average use is 0.2 kg of active ingredients per ha. Since 1983 the use of chemical pesticides in the sector has fallen by an average of 20%.

Target reductions

As to parks, countryside and embankments, the Multi-Year Crop Protection Plan lays down a pesticide reduction of more than 25% of the current use in 1995 and about 40% in 2000.

Measures

With regard to the application of pesticides in parks, countryside and embankments a package of requirements will be formulated which is technically and legally adequate and fits in well with reality.

Extension on the possibilities of non-chemical weed control and plantations that require less (chemical) maintenance will be encouraged.

Through extension and advices the use of herbicides in afforestation of both plantations and nature reserves will be reduced.

Established control regulations concerning thistle and fire blight will be evaluated and revised in the light of the objectives of nature and landscape management.

Through the Pesticides Act the application of herbicides in water-conducting and temporarily dry water courses will no longer be permitted. In addition, the application of herbicides to banksides will be restricted.

Consequences

The measures will necessitate only limited changes in the management of parks, countryside and embankments and will not lead to very high investments and costs (labour, capital expenditure). Further details are to be found in the Multi-Year Crop Protection Plan.

Livestock farming

Current situation

The use of pesticides in livestock farming especially concerns the control of diseases and pests in grasslands, and ectoparasites and vermin on cattle. In addition, livestock housing and means of transport are disinfected.
The total use of pesticides in livestock farming amounts to more than 700 000 kg (excluding disinfectants), that is, less than 1 kg of active ingredients per ha of grassland. Broadleaf herbicides in established grassland and on behalf of grassland renovation account for about 60% of the use.

Target reductions

As to livestock farming, the Multi-Year Crop Protection Plan lays down a pesticide reduction of more than 20% of the current use in 1995 and 25% in 2000. The reduction will be mainly realized in grassland management.
Generally speaking, emissions to the environment will fall by at least the same percentages.

Measures

The use of herbicides will be reduced by encouraging the integrated application of chemical and non-chemical weed control. Continuation and if necessary intensification of the current extension to encourage good grassland management are very important.

Through the Pesticides Act the application of herbicides in water-conducting and temporarily dry water courses will no longer be permitted. In addition, the application of herbicides to banksides will be restricted.

The development of systems for monitoring damage by leatherjackets and March fly larvae in grasslands will be encouraged.

Measures to reduce the use of pesticides to kill vermin and ectoparasites on cattle will be encouraged (for example in housing, manure storage, farm management and hygiene).

A major point is the improvement of the efficacy of pesticide application by formulating requirements for the operator's competence, for application equipment, and by obliging operators to have it overhauled.

Consequences

The measures will necessitate limited farm adjustments and lead to limited extra investments and costs. Further details are to be found in the Multi-Year Crop Protection Plan.

The Significance of the Multi-Year Crop Protection Plan

Mushroom culture

Current situation

Mushroom culture (mainly champignon) uses about 10 000 kg of active ingredients a year on an area of about 90 ha. The use of pesticides in this sector amounts to some 113 kg per ha.

Target reductions

As to mushroom culture, the Multi-Year Crop Protection Plan lays down a pesticide reduction of almost 15% of the current use in 1995 and about 20% in 2000. Generally speaking, emissions to the environment will fall by at least the same percentages. In addition, in 2000 closed systems will enable a 99% reduction of emissions to the surface water.

Measures

Further development and introduction of indoor composting will be encouraged as much as possible.

Hygiene will be further improved through technical adjustments and the introduction of certain measures. As a result, the use of the disinfectant formaldehyde will be optimized.

Production and use of resistant and tolerant mushroom varieties are encouraged wherever possible.

The possibilities of supervised control and biological control will be examined and applied wherever possible.

The application of pesticides in growing cells will be optimized.

Consequences

The measures will necessitate farm adjustments and lead to extra investments and costs. Further details are to be found in the Multi-Year Crop Protection Plan.

7. REPORT ON EWRS WORKING GROUP ON PHYSICAL WEED CONTROL 1994

European Weed Research Society (EWRS)
Main Subject Area(MSA) - Physical Weed Control

Meeting at Kongskilde Friluftsgård, Sjaellands, Denmark, 2-3 March 1994, attended by Dr. D.H.K. Davies, Crop Systems, Bush, Penicuik.

1 Introduction

This is a new group co-ordinated by the EWRS as a MSA on Physical Weed Control. The aim of the group is to encourage the flow of information within this general area, and to allow the setting up of contacts which could lead to co-ordinated research activities with the possibility of co-ordinated proposals to the EC and other funding bodies. There is a general feeling in the group that this importance of this area is just starting, and may be and may be significant for minor crops in the not too distant future.

About 40 persons attended from 12 European countries, plus Canada. Notable exceptions were French and Italian workers. This was about half of the number of persons interested in joining the group.

Although there were one or two small lapses in group management, the meeting was very successful in establishing links, and it was felt that most presenters were being very open in divulging their work. Discussions were comprehensive and friendly, and entirely in English, which has been agreed to be the language of co-ordination for the group.

The group elected D. Baumann, Swiss Federal Research Station, Department of Weed Control, Wädenswil, as the Chairman, and J. Rasmussen, Department of Weed Control and Pesticide Ecology, Flakkebjerg, Denmark, to put together details of the group members' interests in a publication, as well as the presentations from this meeting (see Conclusions).

2. Presentations

The meeting started with K. Thonke, Head of the Department of Weed Control and Pesticide Ecology, Flakkebjerg, outlining the structure of weed science research in Denmark. There are 3 graduate workers at Flakkebjerg working on mechanical weed control, led by Jesper Rasmussen.

Each member present outlined their overall areas of interest and where relevant, these of associated colleagues. J. Rasmussen should outline these in his report. I outlined the work at SAC on mechanical weed control in vegetables and cereals, use of mulches, and remote sensing (SCAE), plus gave a general view of weed research in Scotland.

The following notes outline some points I found of sufficient interest to make comment, from the 23 presenters, and following discussions.

2.1 Soil Solarization and Mulching (Chair: Ken Davies, UK)

I presented a paper on the pre-planting mulch technique developed by SAC. This evoked considerable questioning and discussion as to why weed growth was reduced by the technique. Annette Binder, Denmark, had tried it with less success - the main difference was the very dry soil conditions when she tried it. We decided that this may indicate that moisture is required, perhaps to encourage germination of weed seeds, and it is thereafter that they are killed, rather than secondary dormancy being a major factor of control. Other workers indicated that they may try the technique.

D. de Barreda (Spain) presented a paper on Solarization techniques where the soil is heated by clear covers to over 40°C in order to kill weed seeds. We felt that this technique is only suited to warmer climates. Conversely he had looked at black polythene for solarization, but had not observed great control of weeds. We felt that this again could be linked to dry soil conditions, and that irrigation prior to cover may be worth examining. We would maintain contact in this area. Portuguese contributors failed to appear at the meeting.

2.2 **Thermal Weed Control** (Chair: Johan Ascard, Sweden)

This largely covered flame weeding, but the Chairman outlined work on hot water+soya oil treatment (Univ. of Minneapolis, USA) electrical weed control (Univ. of Berne, Switzerland), microwaves, and use of Co_2 snow (freezing).

Energy requirements:

Hand-weeding	80 MJ/ha
Mechanical	200 MJ/ha
Electrical	200-800 MJ/ha
Herbicides	400-800 MJ/ha
Flame-weeders	2000-3000 MJ/ha
Plastic mulch	10,000 MJ/ha (used only once)

J. Meyer, (Germany) suggested that less than 20% of the heat from an uncovered flame reaches the weeds, and 30% from a shielded flame. This could be increased to 60%. As the effectiveness of kill depends on tissue type and diameter, then one can get selectivity by fine-tuning temperature, which could also allow in-row weeding.

R. Holmøy, Norway, gave an example of a flamer within a low long trolley, which reduced heat losses and speed efficiency.

J. Andersen, Norway, described the use of hydrogen burners rather than the usual propane-based systems. There was less upward heat loss, which allowed better working under crop plants, in rows.

J. Ascard, Sweden, described dose-response curves showing intensity of flaming required varied between weeds. *Senecio vulgaris* for example, needs much higher heat than other tall weeds with exposed growing points. Prostrate broad-leaved weeds and grass species need higher heat because growing points are often shielded.

2.3 **Soil Tillage** (Chair: Roland Gerhards, Germany)

B. Pallutt (Germany) showed from long-term rotational trials that ploughing encouraged spread of thistles in cereal dominated rotations. Shallow ploughing and disc-harrowing controlled the increase. However, this reduced the control of autumn annuals.

E. Teslo (Norway) described testing 10 implements for effect on weed growth in following crops. Stand density, vigour and yields tended to be higher in plough-based treatments than harrowed treatments, partly due to better grass control.

R. Gerhards (Germany) described his work on photo-control of weeds by tilling at night, in complete dark. This is not completely successful because some weeds do not need light to germinate, and light does penetrate soils over the next light period. There is evidence that the effect is much reduced in autumn tillage. Perhaps those species are less dependent on the phytochrome reaction. More work is needed on influence of soil type, temperatures, moisture and seasonal influences.

J. Ascard (Sweden) had followed up Gerhards' work, and looked at the possibility of light-proof tillage covers so that the work could be done in the day. He achieved a 40% reduction in weed growth. Again the technique was not as effective in the autumn.

2.4 **Mechanical Weed Control** (Chair: Rommie v.d. Weide, Netherlands; Joachim Meyer, Germany; Daniel Baumann, Switzerland)

R.v.d. Weide (Netherlands), is examining interactions between herbicide treatment and cultivations, in light of the Netherlands' requirement for large reductions in pesticide usage. In potatoes, for example, she found that 1 ridging+1 herbicide spray = 2 harrowing+2 ridgings. In cereals 2 sprays = 2.5 harrowings+0.5 spray. Overall she found she could reduce herbicide use by 37-54%?

M. Estler (Germany), wondered whether we need to completely control weeds, and topping only may assist in maintaining soil structure and moisture.

J. Meyer (Germany) pointed out that increasing working speed with machines, particularly the brush-harrow, could cause soil structural problems - with too many fine and very large particles. This could lead to crop problems. He is working with ultrasonic devices to control working depth, but this needs to be automated for both up and down and sideways movement. There are, he mentioned, American electronic guidance systems available.

M. Bent (Wye College, UK) looked at how use of machinery should be evaluated within a farm business (I hold the report).

H. Lee (Wye college, UK) described proposals for work in this area at Wye College, and work that has started with post-graduates.

R. Holmøy (Norway) presented a video on mechanical harrows indicating the best timing on cereals was when the cereal shoots were no more than 30mm, and weeds at cotyledon stage.

Another Dutch video showed the use of Swedish small horizontally rotating brushes (*) which could be used right up to the crop, and, in pairs, to either side of the crop simultaneously. It had excellent effects in tree nurseries as well as vegetable crops, including carrots. This brush system seems to have a number of advantages over the vertically rotating brushes. However, there is still a problem with guidance of the machinery.

D. Baumann (Switzerland) showed that ridging crops with roller cultivations increased weeds intra-row. There were no differences in inter-row weed control. Work on onions showed that use of machines at the loop-crook stage was best to allow recovery from tined harrows. This may also be true for leeks.

B. Melander (Denmark) described the new work starting at Flakkebjerg to look at intra-row weeding, including inter-row cultivation close to the row, and in-row brush-weeding with Swedish machines((*) (THERMEC-B)).

8. CONCLUSIONS

Weed Control

The three trial years have shown that there is little difference in the level of weed control obtained with the different machines tested, and the levels of control obtained were as good as may be expected from a herbicide. However, in the row crop, the lack of weed control in the row by the machines may have led to yield losses of up to 50%. That in part explains the benefits seen in using a black polyethylene mulch for weed suppression. Nevertheless, it was considered that weed control with machinery in large-scale vegetable row crops could not be satisfactory without addressing the problem of weed control within the crow row, without recourse to the inevitable expense of hand-labour.

This problem has been recognised by other workers in Europe, and there has been some attempt to redesign equipment to get closer to crops in the row in order to catch more weeds from within the row. Possibly the most interesting very recent development has been in brush-type weeders, where Swedish designs for small horizontally rotating brushes approaching the crop from an angle allow closer weeding, and could be worth further consideration.

However, in this study we addressed the possibility of cross-weeding by row working machines by planting the crop on a rectangular rather than on a row pattern. Purpose built planters and drills are not yet available to perform such a task, but it was assumed that machines could be designed to cope with this novel approach.

The trials showed that the level of weed control obtained using this approach could be acceptable and using the novel brush designs may be better than the high levels of control we have achieved. -

Crop Effects

The different machines tested showed little difference overall in their effects on the crops grown in the row. Where a herbicide was used satisfactorily in one trial with a drilled crop there was little difference in yield compared with the best mechanical weed control with hand-weeding in the row. However, yield was clearly and consistently better where black polyethylene mulch was used for weed control. This may be due to other factors associated with soil conditions and temperature rather than weed control.

However, there was a major effect on total and individual plant yield from cross-weeding in a crop grid rather than row. We have assumed that this may be due to excessive compaction around the edge of the grids from the tractor wheels, as well as disturbance of the plants by cross-weeding. This latter feature may be overcome by use of some of the recently developed brush designs, or by using a different more shallow working form of cultivator (notably those throwing soil over the weeds rather than pulling them out). Compaction may be partially overcome by use of wider machinery and grids, and lighter equipment. These aspects require further investigation.

Machinery Efficiency

The 'Brush-Weeder' was the most efficient machine in terms of energy consumption, but was slower in action, which could increase labour costs.

Swedish workers have suggested that, as a whole, including costs of production, the use of polyethylene mulches may be much more costly overall in energy terms, and the use of herbicides, more efficient than the use of cultivators. The Dutch are examining natural mulches based on paper which are less energy consuming in production than other forms, and biodegrade readily by the end of the season.