CONTRACT REPORT

C009003

Field Vegetables
Comparison of Spray Application Methods
(FV72)

Commercial-in-Confidence

Agricultural Development and Advisory Service

Report to: Horticultural Development Council
18 Lavant Street
Petersfield
Hants
GU32 3EW

ADAS Contract Manager: S W Perkins
ADAS Cambridge
Brooklands Avenue
Cambridge
CB2 2BL
Tel: 0223 462762

Period of investigation: May 1991-February 1992

Date of issue of report: May 1992

No. of pages in report: 44

No of copies of report: 10

This is ADAS copy No: 2

PRINCIPAL WORKERS

Dr J Blood-Smyth	ADAS Cambridge
G Talbot	ADAS Cambridge
T Brassington	ADAS Bedford
D Ann	ADAS Winchester
Dr M Saynor	ADAS Reading
K Graham	ADAS Oxford

AUTHENTICATION

I declare that this work was done under my supervision according to the procedures described herein and that this report represents a true and accurate record of the results obtained.

.... Date 27 May 1992 ....

Stephen Perkins - Contract Manager

Report authorised by:

....

Dr M J Griffin
ADAS Cambridge
Brooklands Avenue
Cambridge
CB2 2BL

Tel: 0223 462762

CONTENTS

Summary

The effectiveness of applying pesticides using a Hardi Twin and an Airtec sprayer was compared with a conventional hydraulic sprayer in drilled lettuce, planted brussels sprout and drilled leek crops. A range of spray volumes and two pesticide rates were used for each machine and crop. Pest and disease levels in all three crops were comparatively low in 1991 and this should be borne in mind when assessing the suitability of treatments for general use when attacks could be more severe.

Lettuce

The crop drilled in early July was sprayed and assessed four times. At the second assessment (5-6 leaves), the conventional sprayer using 600, 200 and 100 l/ha) gave better control of aphids than the Airtec or Hardi treatments which were applied at 200 and 100 l/ha. Subsequently, aphid numbers reduced due to high levels of parasitism. However, following a spray of Ambush C, applied to control caterpillar, numbers of lettuce-currant aphids in particular increased. None of the later treatments used gave a significant control of aphids in the hearted lettuce compared with untreated plots; more frequent sprays were probably needed at this crop stage. Reducing the dose rate of Pirimor from 280 g/ha to 90 g/ha product did not significantly affect the degree of control, though there was a trend to higher aphid numbers at the lower rate.

Brussels Sprouts

Trials were conducted on a crop transplanted in mid-May 1991, notable for the late migration of cabbage aphid and numbers in the trial were low. When cabbage aphid was assessed early in August, Airtec and Hardi machines had the edge on the conventional spraying, both with control on the lower leaves and in the plant tops. By the end of August, Airtec and Hardi plots, but not the conventionally sprayed plots, had significantly less aphids than the unsprayed control. The Hardi Machine had marginally better results.

In January 1992, when the buttons were inspected, all 3 machines had significantly reduced aphid numbers compared to unsprayed plots, with a trend to the Hardi being most effective.

Disease levels were low throughout the season with powdery mildew being the most evident. Spraying reduced the amount of leaf and petiole symptoms with the Hardi sprayer giving the best control. There was button spotting at harvest, some of which was attributable to mildew; all sprayers were effective in reducing this.

Half dose rates of both instecticides and fungicides used in the trial did not give significantly poorer control than full-rate. The picture on volumes is less clear-cut, but there is evidence that lower volumes (eg 100 rather than 200 l/ha) early in the crop's life do not lead to a loss of control.

Leeks

A drilled crop was sprayed 5 times with 2 insecticides and 3 fungicides either alone or in combination and the effects on thrips and leek rust were recorded.

Inexplicably, sprays of Decis gave hardly any control of thrips. In contrast sprays of Dursban 4 controlled thrips well even at half rate in high and low columes of water, when applied with the conventional or the Hardi sprayer. Dursban 4 was equally effective when applied with the Airtec sprayer at half rate in the larger volume of water but other treatments using this sprayer were not applied because the sprayer vehicle broke down.

Good control of a modest rust attack was achieved with fungicides applied with a conventional hydraulic sprayer or the Hardi sprayer at both the higher and lower spray volumes even when using only half rate of product. A similar result was achieved with the Airtec sprayer used to apply fungicides at half rate in 200 l/ha. Again it was not possible to complete the other Airtec treatments because of problems with the sprayer carrier.

The extent of leaf necrosis measured just before harvest was not significantly different in any of the sprayed plots receiving the full spray programme irrespective of the type of sprayer, rates of pesticides or water volumes were used.

Overall in most situations air-assisted sprayers showed promise for the control of a range of pests and disease in the crops studied. Reducing the volume did not adversely affect control, with the exception of a single assessment on the lettuce crop. Under the relatively low pest and disease pressures encountered in the commercial crops studied, reducing pesticide rate did not lead to significantly higher levels of pathogens.

OBJECTIVE

To examine the effectiveness of crop sprayers using forms of air-assistance, compared with a conventional hydraulic sprayer for the control of pest and disease in a range of vegetable crops.

INTRODUCTION

In recent years crop sprayers offering some form of air-assistance in their spray delivery systems have become available and their commercial use in arable crops is now becoming more common. Advertised benefits include better penetration of dense crops, less dependency on 'ideal' weather conditions for spraying, reduced pesticides and water volumes necessary for pathogen control and a reduction in wind drift and spraying time. Thus the potential benefit of these machines to the vegetable grower is large. Typically high water volumes (400-600 l/ha or more) are employed, frequent timely applications are needed and current market demand is for produce with minimal pesticide applications consistent with adequate pest and disease control. Moreover the morphology of many vegetable crops renders some surfaces(e.g. undersides of leaves) difficult to reach; delivery systems which give better droplet distribution (1) should *prima facie* offer the prospect of improved control of pathogens.

Work to test manufacturer's claims has been undertaken or is in progress for a number of arable crops and some results have been published(1). With the exception of brussels sprouts, this has not included field vegetable crops. In the experiments relating to sprouts, the control of leaf and button diseases has been assessed in comparisons between a Degania sleeve-boom sprayer and a conventional hydraulic machine. With the treatments employed, the air-assisted machine gave disease control equivalent to the conventional application. When dose or volume was reduced the air-assisted machine showed a trend to better control than the commercial sprayer. The effects of these application techniques on pests were not recorded. (1,2).

In the 1991 work, three crops were studied, namely drilled lettuce, transplanted brussels sprouts and drilled leeks. The crop sprayers used were the Hardi Twin, a sleeve-boom sprayer with air-assistance propelling the spray droplets into the crop and the Airtec sprayer where air bubbles are incorporated within the spray droplets being applied. The conventional hydraulic sprayer comparison was provided in each case by the Hardi equipment without the air-assistance. All treatments were designed to give spray applications of medium spray quality in accordance with the manufacturer's recommendations with tractor speed being varied as little as possible between treatments. Because of the differing treatments and assessment methods, work on each crop is described successively.

A. LETTUCE

Three variables were examined in the experiment - a) sprayer type b) spray volume and c) pesticide dose rate. The target pests for assessment were leaf aphids. The specific aphicide pirimicarb (as 'Pirimor') was selected for the trial because of its translaminar/contact action. Choice of a systemic insecticide during any stage of the crop could have masked the effect of the other treatments. During the life of the crop, a light attack of caterpillar developed; although a spray of cypermethrin had to be applied, numbers of caterpillars were insufficient to assess satisfactorily for trial purposes. No diseases developed in the course of the trial.

Treatments

1. Unsprayed control

Conventional hydraulic

2. 600 l/ha, 280 g/ha 'Pirimor'
3. 200 l/ha, 280 g/ha 'Pirimor'
4. 200 l/ha, 90 g/ha 'Pirimor'
5. 100 l/ha, 280 g/ha 'Pirimor'
6. 100 l/ha, 90 g/ha 'Pirimor'

Hardi Twin

7. 200 l/ha, 280 g/ha 'Pirimor'
8. 200 l/ha, 90 g/ha 'Pirimor'
9. 100 l/ha, 280 g/ha 'Pirimor'
10. 100 l/ha, 90 g/ha 'Pirimor'

Airtec

11. 200 l/ha, 280 g/ha 'Pirimor'
12. 200 l/ha, 90 g/ha 'Pirimor'
13. 100 l/ha, 280 g/ha 'Pirimor'
14. 100 l/ha, 90 g/ha 'Pirimor'

Sprayer settings - See Appendix 1.

Layout

A randomised block design with 3 replicates was used. Plot size was 25 m long x 6 m (3 beds) wide.

Dates of spray application

23 July
1 August
14 August
5 September*

* Ambush C included for caterpillar control.

Assessment scores and dates

On each assessment date, 12 plants per plot were assessed for aphids and scored according to the following scale:-

Aphid number	Score
Absent	0
1-5	1
6-20	2
21-100	4
>100	8

Scores are totalled for the 12 plants assessed and presented in this form in the results tables. Lettuce plants were scored on 4 dates: 31 July, 9 August, 16 August, 12 September. At the first and last assessment whole plants were scored; at the second and third assessments one old leaf and one new leaf per plant were scored.

Results and Discussion

Table 1. Aphid infestation index 31 July 1991. Mean of dose rates.

Spray Method	Spray Volume (l/ha)	Aphid infestation index
Untreated	-	17.33 bc
Hydraulic	600	18.67 c
Hydraulic	200	16.50 abc
Hydraulic	100	10.67 a
Hardi	200	14.33 abc
Hardi	100	13.33 abc
Airtec	200	16.33 abc
Airtec	100	11.83 ab
SED		2.64

Values followed by the same letter are not statistically different, at the 5% level (Duncan's multiple range test)

At the first assessment, aphid numbers were low across all treatments (av. score per head 1.2) and differences were small. Although the plants were young (two leaves unfolded stage) only one treatment gave significant control compared with the unsprayed and this was a low volume(100 l/ha) treatment. The aphicide 'Pirimor' is normally recommended for use at a standard dilution rate. In this experiment it was used at 2 rates of product per hectare irrespective of volume. The results therefore would suggest that the higher volumes employed led to insufficient active ingredient being deposited on the very small plants at this early spray date. Results between dose rates (Appendix 5) are however rather variable. There were no differences between machines in the level of control achieved.

Table 2 **Aphid infestation index 9 August 1991. Mean of dose rates.**

Spray Method	Spray Volume (l/ha)	Aphid infestation index
Untreated	-	8.67
Hydraulic	600	3.00
Hydraulic	200	4.83
Hydraulic	100	5.33
Hardi	200	6.33
Hardi	100	5.67
Airtec	200	7.83
Airtec	100	7.67
SED		1.66

Table 2a **Aphid infestation index 9 August 1991. Mean of doses and volumes.**

Spray Method	Aphid infestation index
Untreated	8.67 b
Hydraulic	4.67 a
Hardi	6.00 ab
Airtec	7.75 ab
SED	1.48

Values followed by the same letter are not statistically different, at the 5% level.

At the second assessment (plants at 5/6 leaves) numbers of aphids (principally *Myzus persicae*, the peach-potato aphid) were very low and natural parasitism was in evidence. Given this situation only one treatment succeeded in reducing aphid numbers at the second spray application - the hydraulic treatment at 600 l/ha - compared with unsprayed. It seems clear that the volume told on the relatively open target that the plants still presented at this stage. The effect of dose rate (Appendix 6) again showed no obvious trend with numbers of aphids similar at both 280 and 90 g/ha rates.

Table 3. Aphid infestation index 16 August 1991. Mean of dose rates.

Spray Method	Spray Volume (l/ha)	Aphid infestation index
Untreated	-	3.00
Hydraulic	600	2.00
Hydraulic	200	1.00
Hydraulic	100	2.67
Hardi	200	1.83
Hardi	100	1.00
Airtec	200	1.83
Airtec	100	2.17
SED		1.02

Despite favourable weather conditions for aphid development numbers had declined further by the third assessment with parasitic wasps much in evidence. About half of the aphids noted at the third assessment were parasitised. As numbers were so low, statistical differences could not be detected between treated and untreated plots.

Table 4. Aphid infestation index 12 September 1991. Mean of dose rates.

Spray Method	Spray Volume (l/ha)	Aphid infestation index
Untreated	-	14.67
Hydraulic	600	10.67
Hydraulic	200	10.33
Hydraulic	100	14.00
Hardi	200	11.67
Hardi	100	12.00
Airtec	200	11.17
Airtec	100	11.67
SED		4.35

Following the final spray application on 5 September when cypermethrin was included for caterpillar, it was noticeable that aphid numbers increased, perhaps as a result of the loss of natural enemies. At this stage aphids were almost entirely lettuce currant aphid (*Nasonovia ribisnigri*) which were located towards the centre of the developing heads. Despite the increase in numbers, none of the spray treatments effected a statistically valid reduction in aphids although there was a trend to lower infestation scores with most treatments. This apparent failure to control the aphid population may have been the result of winged aphids migrating into the crop. More frequent spray applications may have obviated this problem.

Table 5 Effect of dose rate and spray volume on infestation index Mean of all application methods.

Assessment date	Pirimar Dose Rate (g/ha)		Spray volume (l/ha)		
	280	90	600	200	100
31 July	14.05	14.39	18.67	15.72	11.94
9 August	5.67	6.44	3.00	6.33	6.22
16 August	1.38	2.22	2.00	1.55	1.95
12 September	10.29	13.39	10.67	11.06	12.56
Mean	7.85	9.11	8.59	8.67	8.17

Detailed results for each assessment date are reproduced at Appendices 5-8. Table 5 summarises the effect of dose rate and spray volume on the control of aphids obtained.

Differences between the two dose rates used were small, with a trend to slightly higher aphid numbers at the reduced dose rate. At the first assessment the lower spray volume of 100 l/ha was marginally more effective, probably because the lower dilution caused more chemical to reach and stay on the target. Thereafter there were no statistical differences between treatments due to spray volume.

B. BRUSSELS SPROUTS

The same parameters of spray application as for lettuce were examined, namely sprayer type, spray volume and pesticide rate. Numbers of cabbage aphid (*Brevicoryne brassicae*) and caterpillars were assessed during the trial as were foliar diseases. Generally the crop was grown to good commercial practice, but no pre-planting granules for aphid control were applied and only non-systemic insecticides were used so as not to mask other treatment effects.

Treatments

1. Unsprayed control

Conventional hydraulic

2. 800 l/ha, full pesticide dose
3. 800 l/ha, half dose
4. 400 l/ha, full dose
5. 400 l/ha, half dose
6. 200 l/ha, full dose
7. 200 l/ha, half dose
8. 100 l/ha, full dose
9. 100 l/ha, half dose

Hardi Twin

10. 200 l/ha, full dose
11. 200 l/ha, half dose
12. 100 l/ha, full dose
13. 100 l/ha, half dose

Airtec

14. 200 l/ha, full dose
15. 200 l/ha, half dose
16. 100 l/ha, full dose
17. 100 l/ha, half dose

Dose Rates

Product	Full dose	Half dose
Ambush C	250 ml/ha	125 ml/ha
Aphox	280 g/ha	140 g/ha
Demeton-S-methyl	650 ml/ha	325 ml/ha
Bayfidan	500 ml/ha	250 ml/ha
Benlate	1.1 Kg/ha	0.55 Kg/ha
Bravo	3.0 l/ha	1.5 l/ha
Folio	2.0 l/ha	1.0 l/ha

Sprayer settings - See appendix 2

Layout

A randomised block design with 3 replicates was used. Plot size was 20 m long x 6 m (8 rows) wide.

30 July	Aphox + Bayfidan
22 August	Aphox + Folio + Benlate
20 September	Aphox + Ambush C + Bravo + Bayfidan
8 October	DSM + Folio + Benlate

'Agral' wetter was added on each occasion.

Assessments: Scoring and Dates

a) Pests

Plants were assessed for cabbage aphid and caterpillar on 8 and 30 August and the sprout buttons were scored for damage from these pests on 8 January. Intermediate assessments between these dates had been planned but the low levels of pests recorded in the untreated plots made full assessments of little value.

Cabbage aphid was assessed on the following scoring system:-

Aphid number	Score
Absent	0
1-5	1
6-25	2
26-50	4
>50	8

12 plants per plot were assessed and the total infestation index is presented in the results tables. At the first two dates, one upper and one lower leaf per plant were assessed. The button assessment was conducted on 50 buttons per plot (c. 6 buttons from 12 plants) and results recorded as % damage from aphid or caterpillar. At the first 2 assessments numbers of caterpillars per 12 plants (2 leaves per plant) were recorded.

b) **Leaf disease**

Plants or sprout buttons were scored for disease on 4 occasions. On 18 October and 21 November very low levels of disease were present and only data from the untreated plots is presented. A full assessment of foliar disease was carried out on 16 December with both leaves and petioles being scored. Close to harvest some fine spotting of the developing buttons was evident, and a further assessment of this and some Botrytis infection was completed on 14 January.

Results and Discussion - Pests

Table 6. Aphid infestation index: first assessment 8 August 1991 Mean of dose rates.

Spray Method	Spray Vol (l/ha)	Aphid Index
Untreated	-	1.00
Hydraulic	800	0.50
	400	0.50
	200	1.17
	100	0.50
Hardi	200	0.83
	100	1.67
Airtec	200	1.50
	100	0.67
SED		0.95

Table 7. Caterpillar infestation; first assessment 8 August 1991 Mean of dose rates.

Spray Method	Spray Vol (l/ha)	Caterpillar numbers (12 plants)
Untreated	-	0.67
Hydraulic	800	1.00
	400	1.67
	200	2.33
	100	0.50
Hardi	200	0.83
	100	1.67
Airtec	200	1.17
	100	1.50
SED		1.05

At the first assessment date 9 days after the first spray application cabbage aphid and caterpillar levels in all plots, including untreated, were very low and there were no significant differences between any of the treatments.

Table 8. Aphid infestation index: Second assessment 30 August 1991 Mean of dose rates.

Spray Method	Spray Vol (l/ha)	Aphid Index
Untreated	-	6.67
Hydraulic	800	2.00
	400	2.67
	200	3.67
	100	3.50
Hardi	200	1.67
	100	0.83
Airtec	200	1.50
	100	1.33
SED		1.77

Table 8a. Aphid infestation index; 30 August 1991 Mean of dose rates.

Spray Method	Aphid index	Angular Transformation
Untreated	6.67	2.54[b]
Hydraulic	2.96	1.81[ab]
Hardi	1.25	1.43[a]
Airtec	1.42	1.49[a]
SED		1.54

Values followed by the same letter are not significantly different, at the 5% level.

Table 9. Caterpillar infestation index: second assessment 30 August 1991 Mean of dose rates.

Spray Method	Spray Vol (l/ha)	Caterpillar Numbers (12 Plants)
Untreated	-	0.67
Hydraulic	800	0.33
	400	0.17
	200	0.17
	100	0.50
Hardi	200	0.17
	100	0.17
Airtec	200	0.50
	100	0.67
SED		0.50

By the end of August at the second assessment, aphid numbers had increased with highest numbers in the untreated plots (Appendix 9) Comparison of the machines used shows that both the Hardi Twin and Airtec sprayers gave significantly better control of cabbage aphid than the conventional hydraulic or untreated plots, meaned across volumes and dose rates. There was a trend to higher aphid numbers at the lower volumes with the conventional treatment, highlighting the superiority of the air-assisted machines on a like for like volume basis. This is principally attributable to the poorer performance of the half-dose treatment when applied with the conventional hydraulic sprayer. At full dose rates performance was comparable between the machines.

Caterpillar numbers remained low (Appendix 10). At this second assessment date fewer caterpillars were found in the treated plots compared with untreated with lowest numbers in the Hardi treated plots, though differences were not significant.

1991 was characterised by a particularly late migration of cabbage aphid into brassica crops and this was reflected at the final assessment of sprout buttons close to the harvest date. (Full details Appendix 11)

Table 10. % buttons infected with aphids 8 January 1992 Mean of dose rates.

Spray Method	Spray Volume (l/ha)	% Buttons Infested	Angular Transformation
Untreated	-	56.0	48.5
Hydraulic	800	9.3	15.4
	400	8.7	16.8
	200	12.3	19.5
	100	15.7	23.1
Hardi	200	7.7	15.1
	100	11.3	19.2
Airtec	200	10.7	17.4
	100	22.7	27.9
SED			5.13

Table 10a. % buttons infested with aphids 8 January 1992
Mean of dose rate and volumes

Spray Method	% buttons Infested	Angular Transformation
Untreated	56.0	48.5 [b]
Hydraulic	11.5	18.7 [a]
Hardi	9.5	17.1 [a]
Airtec	16.7	22.7 [a]
SED		4.44

Values followed by the same letter are not significantly different, at the 5% level.

All spray treatments significantly reduced aphid numbers. Looking at individual treatments (Appendix 11) there was a trend to higher numbers of aphids at lower volumes; however both Hardi and Airtec at 200 l/ha produced results equivalent to the conventional hydraulic machine at 400 and 800 l/ha. Reducing the aphicide dose to half rate led to increased aphid numbers with the conventional application except at 800 l/ha, but had no apparent effect with the air-assisted sprayers.

Table 11. % buttons damaged by caterpillar 8 January 1992
Mean of dose rates.

Spray Method	Spray Volume (l/ha)	% Buttons Damaged	Angular Transformation
Untreated	-	18.67	25.2
Hydraulic	800	5.00	12.4
	400	5.00	11.5
	200	6.67	14.0
	100	7.00	12.1
Hardi	200	7.0	13.9
	100	10.00	15.9
Airtec	200	5.67	13.7
	100	3.67	10.8
SED			5.16

Table 11a. % buttons damaged by caterpillar 8 January 1992
Mean of dose rate and volumes

Spray Method	% buttons Damaged	Angular Transformation
Untreated	18.67	25.3[b]
Hydraulic	5.92	12.5[a]
Hardi	8.50	14.9[a]
Airtec	4.67	12.3[a]
SED		3.61

Values followed by the same letter are not significantly different, at the 5% level.

A similar picture is shown with the assessment of caterpillar damage with all sprayers showing a significant level of control compared with untreated. There is no clear trend with volume of application. Again the amount of damage recorded with the conventional application treatments increased when the pesticide rate was halved; this picture was less apparent with the other application methods. (See also Appendix 12).

Results and Discussion - Foliar Disease

Early assessments of the trial showed very low levels of leaf disease which was not favoured by the dry weather conditions.

Table 12. Leaf disease assessment - untreated plots 18 October and 21 November 1991. % leaf area affected.

Leaf Position	Powdery mildew		Downy mildew		Alternaria leaf spot		White Blister	
	Oct	Nov	Oct	Nov	Oct	Nov	Oct	Nov
Top	0.2	0.4	0.0	0.0	0.00	0.0	0.00	0.0
Middle	0.4	1.4	0.0	0.0	0.00	0.0	0.01	0.0
Bottom	0.6	2.2	0.1	0.2	0.02	0.1	0.01	0.0

Subsequently there was some further development of powdery mildew, but other diseases failed to increase as a result of the climatic conditions and/or the spray programme applied. A full disease assessment was performed on 16 December. (Appendix 13).

Table 13. % Powdery mildew development 16 December 1991
Mean of spray volumes and dose rates.

	POWDERY MILDEW			
Spray Method	% Leaf area	Angular Transformation	% Petiole area	Angular Transformation
Untreated	1.23	6.36	5.33	13.16[b]
Hydraulic	0.79	4.78	2.30	8.28[a]
Hardi	0.47	3.70	1.68	6.92[a]
Airtec	0.78	4.87	2.83	9.46[a]
SED	0.231	0.915	0.816	1.537

Despite mildew levels being low there was a significant reduction from applying fungicides, with a trend to the Hardi machine giving the largest reduction in infection on both leaves and petioles.

Close to harvest some fine black spotting was evident on the sprout buttons. Some of these lesions were found to be associated with powdery mildew. Some authorities in the past have attributed black speckling of sprout buttons to a hypersensitive reaction to powdery mildew spores. Low levels of Botrytis were also present on some buttons. As there appeared to be variable levels of these symptoms across the trial, a further assessment of the buttons was performed.

Table 14. Effects of sprayer type on button spotting and Botrytis levels. 14 January 1992.

Spray Method	% Button spotting area	Transformation	% Botrytis number	Transformation
Untreated	6.33	14.51[b]	3.67	10.96
Hydraulic	2.58	9.06[a]	1.17	4.19
Hardi	2.25	8.48[a]	1.17	4.00
Airtec	2.83	9.47[a]	2.17	7.16
SED	0.640	1.114	0.985	3.056

All spraying methods significantly reduced the amount of button spotting recorded; there was a trend to lower levels of botrytis, particularly with the conventional and Hardi treatments, but this did not reach statistical significance.

C. LEEKS

Sprayer type, spray volume and pesticide dose were again examined for the leek crop. Target pathogens for assessment were leek rust (*Puccinia allii*) and onion thrip (*Thrips tabaci*). An April drilled crop was used with sprays being applied between July and October.

Treatments

1. Unsprayed control

Conventional hydraulic

2. 600 l/ha, full pesticide dose
3. 600 l/ha, half dose
4. 200 l/ha, full dose
5. 200 l/ha, half dose

Hardi Twin

6. 200 l/ha, full dose
7. 200 l/ha, half dose
8. 75 l/ha, full dose
9. 75 l/ha, half dose

Airtec

10. 200 l/ha, full dose
11. 200 l/ha, half dose
12. 75 l/ha, full dose
13. 75 l/ha, half dose

Dose Rates

	Rate of product per ha	
	Full dose	Half dose
Insecticides:		
chlorpyrifos 40.8% ec (Dursban 4)	2 l	1 l
deltamethrin 2.5% ec (Decis)	300 ml	150 ml
Fungicides:		
fenpropimorph 75% ec (Corbel)	1 l	500 ml
ferbam + maneb + zineb 85% wp (Trimanzone)	3 kg	1.5 kg
triadimefon 25% wp (Bayleton)*	1 kg	500 g

* Agral added at 300 ml per 1000 l water

Sprayer settings - See appendix 3

Layout

A 3 x 2 x 2 factorial design with 3 replicates (+ untreated control) was used. Plot size was 25 m long x 9 (5 beds wide).

Dates of pesticide application and weather conditions:

26 July	Decis + Trimanzone	(one Airtec half rate 75 l/ha and all Airtec full rate 75 l/ha plots not sprayed due to sprayer vehicle failure)	sunny, warm with light breeze.
15 August	Decis + Trimanzone		warm and sunny
29 August	Corbel		warm and sunny
12 September	Decis + Bayleton		
24 October	Dursban + Corbel	(two Airtec full rate 75 l/ha and all Airtec half rate 751/ha and full rate 200 l/ha plots not sprayed due to sprayer failure).	cloudy light breeze

Pest disease and leaf necrosis assessment methods

Thrips	- 10 plants per plot selected at random from the centre 20 m of middle three beds. Numbers of adult and nymph thrips per plant counted.
Rust and leaf necrosis	- 10 plants per plot selected at random from the centre 20 m of middle three beds. Percentage area affected estimated on unfurled leaves of each plant.

Some mechanical problems were encountered in applying treatments to the 'Airtec' plots, principally due to failure of the sprayer carrier so a complete set of results for this machine is not available.

Results and Discussion

Table 15. Mean No thrips per plant on 5 August, 10 days after spraying with Decis.

Sprayer	Pesticide rate	Water Volume	Live thrips per plant
Conventional	full rate	600 l/ha water	2.6
	half rate	600 l/ha water	3.7
	full rate	200 l/ha water	1.5
	half rate	200 l/ha water	1.6
Hardi	full rate	200 l/ha water	1.7
	half rate	200 l/ha water	1.7
	full rate	75 l/ha water	1.8
	half rate	75 l/ha water	1.7
Airtec	full rate	200 l/ha water	3.0
	half rate	200 l/ha water	1.8
	full rate	75 l/ha water	*
	half rate	75 l/ha water	1.7 (2 plots only)
Untreated		75 l/ha water	3.3
		S.E.D.	1.08

* Not sprayed with Decis due to sprayer vehicle failure

Table 16. Mean No thrips per plant on 4 November, 11 days after spraying with Dursban 4.

Sprayer	Pesticide rate	Water Volume	Live thrips per plant
Conventional	full rate	600 l/ha water	0.9
	half rate	600 l/ha water	1.3
	full rate	200 l/ha water	1.3
	half rate	200 l/ha water	1.1
Hardi	full rate	200 l/ha water	0.9
	half rate	200 l/ha water	1.7
	full rate	75 l/ha water	1.1
	half rate	75 l/ha water	0.5
Airtec	full rate	200 l/ha water	*
	half rate	200 l/ha water	0.8
	full rate	75 l/ha water	*
	half rate	75 l/ha water	*
Untreated		75 l/ha water	12.1
		S.E.D.	2.08

* Not sprayed with Decis due to sprayer vehicle failure

Table 17. Mean % leaf area per plant with rust on 4 November

Sprayer	Pesticide rate	Water Volume	% leaf area with rust
Conventional	full rate	600 l/ha water	0.01
	half rate	600 l/ha water	0.02
	full rate	200 l/ha water	0.03
	half rate	200 l/ha water	0.05
Hardi	full rate	200 l/ha water	0.03
	half rate	200 l/ha water	0.12
	full rate	75 l/ha water	0.06
	half rate	75 l/ha water	0.04
Airtec	full rate	200 l/ha water	+
	half rate	200 l/ha water	0.01
	full rate	75 l/ha water	*
	half rate	75 l/ha water	*
Untreated		75 l/ha water	0.53
		S.E.D.	0.057

* Not sprayed with with fungicide on 26 July or 24 October due to sprayer vehicle and sprayer failure.

\+ Not sprayed with fungicide on 24 October due to sprayer failure.

Spraying with Decis inexplicably gave no control of onion thrips (Table 15). However when Dursban 4 was used, effective control was achieved whichever sprayer was used and with the lower dose of the chemical and the lower volumes of spray liquid (Table 16). The level of control achieved with the different sprayers, different doses of the chemical and different spray volumes was similar.

Table 18. Mean % leaf area per plant with necrosis on 4 November

Sprayer	Pesticide rate	Water Volume	% leaf area with necrosis
Conventional	full rate	600 l/ha water	39.5
	half rate	600 l/ha water	42.3
	full rate	200 l/ha water	40.5
	half rate	200 l/ha water	44.3
Hardi	full rate	200 l/ha water	42.1
	half rate	200 l/ha water	39.0
	full rate	75 l/ha water	42.4
	half rate	75 l/ha water	43.7
Airtec	full rate	200 l/ha water	not assessed
	half rate	200 l/ha water	34.9
	full rate	75 l/ha water	not assessed
	half rate	75 l/ha water	not assessed
Untreated		75 l/ha water	48.2

* principally caused by a combination of Cladosporium leaf blotch (*Cladosporium allii-cepae*) and natural senescence.

A similar level of performance was achieved with fungicides for control of rust (first seen on 29 August) (Table 17) but the extent of the disease on the unsprayed control was modest when recorded in November. The disease was affecting very few plants indeed, even in unsprayed controls when the plots were re-examined in March shortly before harvest. The extent of leaf necrosis [principally caused by a combination of Cladosporium leaf blotch (*C. allii-cepae*) and natural senescence] measured at this time was not significantly different in any of the sprayed plots receiving a full spray programme, irrespective of the type of sprayer, rates of pesticide or water volumes used.

Future lines of work

There was no obvious reason why Decis gave such poor control of thrips although previously it has been similarly ineffective when applied commercially on this farm. Elsewhere it has usually been effective and the reason for this merits investigation.

In contrast, Dursban 4 and regime of fungicides controlled thrips and rust well even at half rate however they were applied.

Including an even lower rate of pesticide in future trials would increase the likelihood of demonstrating differences in pest and disease control attributable to differences in performance of the sprayers.

Selected Bibliography

1. B.K. Cooke, E.C. Hislop, P.J. Harrington, N.M. Western and F. Humperson-Jones, "Air-assisted spraying of arable crops in relation to deposition, drift and pesticide performance". Crop Protection 1990 vol. 9, p. 303-311.

2. D. Ann. "Fungicide application methods for control of Brussels Sprout diseases". ADAS Plant Pathologists Technical Conference 1988 (unpublished data).

3. Anon. "Air-assisted spraying: useful technology but more research is needed". BCPC Annual Review 1991, p. 12.

Acknowledgements

A considerable number of people were of great assistance in the execution of this work and recording of the trials. Thanks in particular are due to Mr John Shropshire of G Shropshire and Sons, Mr Jim Clayton of E.W. Pepper Ltd and Mr Phillip Emmett of W.C. Emmett and Sons Ltd who kindly provided sites, facilities and staff; Mr Bill Taylor of Hardi Ltd and Messrs Clive Christian and Alistair Hett of Cleanacres Machinery Ltd who provided technical advice and assistance with their machines; Dr Paul Miller of Silsoe Research Institute and Mr Simon Cooper of Harper Adams Agriculture College who kindly made machines available for use in the trial work.

Lastly, we are grateful to the spray operators for their skill and enthusiasm which helped the conduct of the trials considerably.

APPENDIX 1

SPRAYER SETTINGS - LETTUCE TRIAL

Vehicle	Sprayer	Application rate (l/ha)	Nozzle	Pressure		Air assist settings	Gear, engine revs and speed of travel
				Liquid	Air		
Ford 6600 tractor	Hardi Twin* 12 metre sprayer	600	410/30	9 bar	-	-	6th gear, Hi dual power, 2050 rpm. 10 km/hr
		200	410/20	2.25 bar			6th gear, Hi dual power, 2050 rpm, 10 km/hr
		75	410/14	1.5 bar			6th gear, Hi dual power, 2050 rpm 10 km/hr
	Airtec+ Twin Fluid sprayer	200	50 thou restrictor	60 psi	25 psi		6th gear Hi dual power. 2050 rpm 10 km/hr
		75	35 thou restrictor	40 psi	20 psi		6th gear, Hi dual power, 2050 rpm 10 km/hr

* Boom height 0.5 m above crop; when air-assistance used, deflector angled fully forward.
\+ Boom height 0.6 m above crop.

SPRAYER SETTINGS - BRUSSELS SPROUT TRIALS

Vehicle	Sprayer	Application rate (l/ha)	Nozzle	Pressure (dial) Liquid	Pressure (dial) Air	Gear, engine revs & speed of travel
Ford 6600 High clearance	Hardi Twin* 12m sprayer	800	410/36	6.5 bar	-	6th gear Hi Dual Power 2050 rpm 8 km/hr
		400	410/30	4.6 bar	-	6th gear, Hi Dual Power 2050 rpm 10 km/hr
		200	410/20	3.5 bar	-	6th gear, Hi Dual Power 2050 rpm 10 km/hr
		100	410/16	1.7 bar	-	6th gear, Hi Dual Power 2050 rpm 10 km/hr
Zetor	Airtec+	200	50 thou restrictor	60 psi	25 psi	3rd gear, 2050 rpm 10 km/hr, 540 rpm PTO
		100	50 thou restrictor	29 psi	20 psi	3rd gear, 2300 rpm 10 km/hr

* Boom height 0.5 m above crop: with air assistance used, deflector angled fully forward.

\+ Boom height 0.6 m above crop.

APPENDIX 3

SPRAYER SETTINGS - LEEK TRIAL

Vehicle	Sprayer	Application rate (l/ha)	Nozzle	Pressure Liquid	Pressure Air	Air assist settings	Gear, engine revs and speed of travel
		600	Yellow (30)	5.3 bar (on dial)	-	-	1st gear, 1800 rpm and 8 km/hr
				5.4 bar (max setting) (24/10 application only)			1700 rpm, 7.6 km/hr (24/10 application only
Massey Ferguson 550	Hardi air-assist 12 metre sprayer	200	Blue (20)	2-8 bar (on dial) 3-4 bar (24/10 application only)	-	3	1st gear, 2100 rpm and 10 km/hr
		75	Red (14)	1.1 bar (above normal gauge settings	-	3	1st gear, 2100 rpm and 10 km/hr
			Red + Green taped (24/10 application only)	1.4-1.5 bar (24/10 application only)			
Frazier Agribuggy (26/7 application only)	Cleanacres Airtec (twin fluid system)	200	Black marked nozzles (50 thou)	3.4 bar	1.7 bar	-	Med 1, 540 rpm and 8 km/hr
Fendt Tool-carrier		75	Unmarked nozzles (35 thou)	2.3 bar	1.6 bar	-	Med 2, 540 rpm and 10 km/hr

CROP DETAILS

	Variety	Drilling date	Row spacing
Lettuce	Saladin	8 July	38cm av, 2m beds
B. Sprouts	Stephen	13 May *	76cm
Leeks	Winter Derrick	13 April	28cm, 1.8m beds

* Planting date

<u>Lettuce</u> APPENDIX 5

Aphid infestation index first assessment 31 July 1991

Treatment	Spray method	Spray volume l/ha	Pirimor dose rate g/ha	Mean Aphid infestation Index for 12 plants
Untreated				17.33
Treated	Hydraulic	600	280	18.67
		200	280	17.67
		200	90	15.33
		100	280	13.00
		100	90	8.33
	Hardi	200	280	12.00
		200	90	11.67
		100	280	15.00
		100	90	11.67
	Airtec	200	280	13.00
		200	90	19.67
		100	280	9.00
		100	90	14.67

SED 3.04

<u>Lettuce</u>
Aphid infestation index first assessment 31 July
Mean of doses and volumes

Treatment	Spray method	Aphid infestation index
Untreated		17.33
Treated	Hydraulic	14.60+
	Hardi	13.83
	Airtec	14.08

SED 2.36

\+ includes 600/l treatment, 13.58 if excluded

<u>Lettuce</u> APPENDIX 6

Aphid infestation index. Second assessment 9 August 91

Treatment	Spray method	Spray volume l/ha	Pirimor dose rate g/ha	Aphid infestation Index
Untreated				8.67
Treated	Hydraulic	600	280	3.00
		200	280	6.33
		200	90	3.33
		100	280	5.33
		100	90	5.33
	Hardi	200	280	6.67
		200	90	6.00
		100	280	4.33
		100	90	7.00
	Airtec	200	280	6.33
		200	90	9.33
		100	280	7.67
		100	90	7.67
	SED			1.92

Lettuce APPENDIX 7

Aphid infestation index. Third assessment 16 August 1991

Treatment	Spray method	Spray volume l/ha	Pirimor dose rate g/ha	Aphid infestation Index
Untreated				3.00
Treated	Hydraulic	600	280	2.00
		200	280	1.00
		200	90	1.00
		100	280	3.00
		100	90	2.33
	Hardi	200	280	0.33
		200	90	3.33
		100	280	1.00
		100	90	1.00
	Airtec	200	280	0.67
		200	90	3.00
		100	280	1.67
		100	90	2.67
	SED			1.18

Lettuce
Aphid infestation index third assessment 16 August 1991
Mean of doses and volumes

Treatment	Spray method	Aphid infestation index
Untreated		3.00
Treated	Hydraulic	1.87
	Hardi	1.42
	Airtec	2.00
	SED	0.91

<u>Lettuce</u>

Aphid infestation index. Fourth assessment 12 September 1991

Treatment	Spray method	Spray volume l/ha	Pirimor dose rate g/ha	Aphid infestation Index
Untreated				14.67
Treated	Hydraulic	600	280	10.67
		200	280	8.33
		200	90	12.33
		100	280	15.00
		100	90	13.00
	Hardi	200	280	7.67
		200	90	15.67
		100	280	9.00
		100	90	15.00
	Airtec	200	280	8.33
		200	90	14.00
		100	280	13.00
		100	90	10.33
	SED			5.02

<u>Lettuce</u>

Aphid infestation index fourth assessment 12 September 1991
Mean of doses and volumes

Treatment	Spray method	Aphid infestation index
Untreated		14.67
Treated	Hydraulic	11.87
	Hardi	11.83
	Airtec	11.42
SED		3.89

Brussels sprouts APPENDIX 9

Aphid infestation index. Second assessment 30 August

Treatment	Spray method	Spray Volume 1/ha	Pesticide dose rate	Aphid infestation Index	Angular trans-formation
Untreated				6.67	(2.54)
Treated	Hydraulic	800	full	0.33	(1.14)
			half	3.67	(2.1)
		400	full	3.67	(1.97)
			half	1.67	(1.48)
		200	full	1.00	(1.38)
			half	6.33	(2.61)
		100	full	1.33	(1.41)
			half	5.67	(2.35)
	Hardi	200	full	1.00	(1.38)
			half	2.33	(1.75)
		100	full	1.33	(1.47)
			half	0.33	(1.14)
	Airtec	200	full	1.00	(1.38)
			half	2.00	(1.66)
		100	full	0.67	(1.24)
			half	2.00	(1.66)
SED					(0.49)

Brussels Sprouts

Caterpillar numbers by treatment. Second assessment 30 August

Treatment	Spray method	Spray Volume l/ha	Pesticide dose rate	Caterpillar per 12 plants	Angular trans-formation
Untreated				0.67	(1.28)
Treated	Hydraulic	800	full	0.33	(1.14)
			half	0.33	(1.14)
		400	full	0.33	(1.14)
			half	0.00	(1.00)
		200	full	0.33	(1.14)
			half	0.00	(1.00)
		100	full	0.33	(1.14)
			half	0.67	(1.28)
	Hardi	200	full	0.00	(1.00)
			half	0.33	(1.14)
		100	full	0.00	(1.00)
			half	0.33	(1.14)
	Airtec	200	full	0.67	(1.28)
			half	0.33	(1.14)
		100	full	0.00	(1.00)
			half	1.33	(1.41)
SED					(0.20)

Brussels Sprouts

Percantage of buttons infested with aphids at harvest 8 January 1992

Treatment	Spray method	Spray Volume l/ha	Pesticide dose rate	Caterpillar per 12 plants	Angular trans-formation
Untreated				56.0	(48.5)
Treated	Hydraulic	800	full	9.3	(14.5)
			half	9.3	(16.3)
		400	full	6.7	(14.7)
			half	10.7	(18.9)
		200	full	7.3	(14.4)
			half	17.3	(24.6)
		100	full	13.3	(21.3)
			half	18.0	(24.8)
	Hardi	200	full	7.3	(14.8)
			half	8.0	(15.5)
		100	full	12.7	(20.0)
			half	10.0	(18.3)
	Airtec	200	full	12.0	(20.3)
			half	9.3	(14.6)
		100	full	24.7	(29.1)
			half	20.7	(26.7)
SED					(5.92)

Brussels Sprouts

Percentage buttons showing caterpillar damage 8 January 1992

Treatment	Spray method	Spray Volume l/ha	Pesticide dose rate	% Buttons infested with caterpillar	Angular trans-formation
Untreated				18.67	(25.3)
Treated	Hydraulic	800	full	3.33	(10.4)
			half	6.67	(14.4)
		400	full	4.00	(9.3)
			half	6.00	(13.7)
		200	full	4.00	(11.3)
			half	9.33	(16.7)
		100	full	4.67	(10.2)
			half	9.33	(14.1)
	Hardi	200	full	4.00	(9.3)
			half	10.00	(18.4)
		100	full	12.67	(17.1)
			half	7.33	(14.8)
	Airtec	200	full	5.33	(13.2)
			half	6.00	(14.2)
		100	full	3.33	(10.4)
			half	4.00	(11.3)
	SED				(5.96)

APPENDIX 13

Brussels Sprouts

Assessment of powdery mildew at 16 December 1991 by treatment.

Treatment	Spray method	Spray Volume l/ha	Pesticide dose rate	% area P.mildew	
				Leaves	Petioles
Untreated				1.2	5.3
Treated	Hydraulic	800	full	0.8	1.8
			half	0.5	1.9
		400	full	0.9	2.3
			half	0.6	1.8
		200	full	0.8	1.8
			half	0.7	2.0
		100	full	1.1	3.3
			half	0.9	3.3
	Hardi	200	full	0.3	0.5
			half	0.4	2.0
		100	full	0.6	2.3
			half	0.7	1.8
	Airtec	200	full	0.9	3.3
			half	0.3	1.0
		100	full	1.0	3.3
			half	0.9	3.3

Brussels Sprouts

Assessment of powdery mildew at 16 December 1991 by treatment.

Treatment	Spray method	Spray Volume l/ha	Pesticide dose rate	% area P.mildew	
				Leaves	Petioles
Untreated				1.2	5.3
Treated	Hydraulic	800	full	0.8	1.8
			half	0.5	1.9
		400	full	0.9	2.3
			half	0.6	1.8
		200	full	0.8	1.8
			half	0.7	2.0
		100	full	1.1	3.3
			half	0.9	3.3
	Hardi	200	full	0.3	0.5
			half	0.4	2.0
		100	full	0.6	2.3
			half	0.7	1.8
	Airtec	200	full	0.9	3.3
			half	0.3	1.0
		100	full	1.0	3.3
			half	0.9	3.3