# ADAS

**Food, Farming, Land and Leisure**

**HORTICULTURAL DEVELOPMENT COUNCIL**
**PROJECT FV 119**

## FINAL REPORT: YEAR 2, 1993

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| **PROJECT TITLE:** | **INTEGRATED PEST MANAGEMENT OF INSECT PESTS IN BRASSICA CROPS ("SUPERVISED" CONTROL) FV 119** |
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## FOOD, FARMING, LAND AND LEISURE

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# RELEVANCE TO GROWERS AND PRACTICAL APPLICATION

## APPLICATION

**Objective of project:** **To evaluate practical sampling methods and establish robust treatment thresholds for control of cabbage aphid and foliage - feeding caterpillars on Brussels sprouts. To provide a cost-effective pest monitoring system that reduces insecticide spray treatments, while minimising economic crop damage by the pests.**

**Key results:**

The treatment thresholds under test were effective in both years but pest pressure was light from both cabbage aphids and caterpillars. The sampling system was shown to be robust at the pest populations encountered in the two years. A Robustness Analysis indicated that the sample size used (100 plants per plot) was more reliable for larger threshold numbers of pests than for thresholds of 5% plants infested or below. Fewer spray applications were applied to "supervised" plots on the basis of pest thresholds, compared to "routine" treatment. In 1992, a mean of 6.8 routine treatments of demeton-S-methyl (DSM) tank-mixed with deltamethrin formulated as Decis, was reduced to 3.3 applications. In 1993 the reduction was from 6.0 to 3.6 applications of DSM: and to 4.4 for pirimicarb formulated as Aphox. For Decis, the reduction was from 6.0 to 0.6; a saving of 90% in applications for caterpillar control. DSM gave better and more persistent control of aphids than Aphox but its efficacy declined later in the season. Decis gave excellent control of all caterpillar species in both years.

At harvest 1992 there was slightly more pest damage in "supervised" than "routine" plots from both cabbage aphids and caterpillars but the differences were not significant. In 1993 there was very little damage from either pest but at one site (Berkshire) where cabbage aphid infested the buttons, Aphox gave considerably less protection from attack than DSM with proportionately reduced marketability. In both years, slug damage to sprout buttons was worse in "supervised" plots treated with DSM and Decis than in those treated routinely. This result was presumably a response to fewer insecticide applications. There was no obvious increase in cabbage aphid or caterpillar attack near to headlands but in 1992, slug damage was worse near the field edge, decreasing in a gradient further into the crop. In 1993 this effect was not evident with severe damage extending throughout the plots. The "supervised" system was again economically favourable where DSM was used, with an average margin, "routine" treatment over "supervised" control, of £7 per hectare. For treatment with Aphox, the average penalty was £97.

Initial observations on aphid parasitism showed that the cabbage aphid parasitic wasp *Diaeretiella rapae* (McIntosh) was the predominant parasitoid at all sites. From observations after insecticide treatment of apparently unparasitised aphid colonies, it appears that DSM and Aphox do not greatly suppress the subsequent development of parasitised aphids ("mummies").

**Opportunity for application:**

Pest levels were generally low in both years but the monitoring system should be tested by growers to familiarise themselves with the principles involved. It is suggested that part-fields should be treated on the basis of threshold cabbage aphid and caterpillar numbers and the subsequent marketable yield compared with areas receiving conventional applications based on standard farm policy. When testing this system:-

- Inspect not fewer than 100 plants for caterpillars and aphids in at least two separate locations in each crop. Sample plants on a plan similar to that shown in Appendix 1. (Past experience and R&D on aphid flight patterns has shown that it is often appropriate to begin plant assessments on the Western/South-Western headland and/or adjacent to the nearest host crop).

- The threshold for caterpillar control should apply only to young larvae feeding on or near buttons. Do not apply a zero threshold to caterpillars that are due to pupate or are feeding only on outer leaves. For accurate assessment, it is necessary to recognise the most frequently-encountered caterpillar species. It is particularly important to distinguish between larvae of the diamond-back moth and young caterpillars of the larger moth species. ADAS/ CSL identification cards IC40-IC56 provide photographs and a key to recognition of the 10 species that most frequently infest brassica crops.

- Do not routinely treat headlands on the assumption that pest levels are greater at the edges of the crop.

- Watch out for increased slug incidence and use an appropriately-timed molluscicide where "supervised" control is adopted.

- Since Aphox is shown to be less persistent than DSM, it should be used early in the season and alternated with DSM if aphid numbers increase later in the season.

- Since neither aphicide proved fully effective in late autumn, aim to apply the last treatments before mid-September.

## SUMMARY

In this second year of an experiment located at five sites, the systematic sampling system for Brussels sprouts was modified to provide robust treatment thresholds for control of cabbage aphid (*Brevicoryne brassicae*) and a complex of several species of cabbage caterpillar. Two different "supervised" treatments compared the effectiveness of the aphicides demeton-S-methyl (DSM) and pirimicarb (Aphox). Deltamethrin (formulated as Decis) was used for caterpillar control in both treatments. "Routine" plots received fortnightly applications of DSM and Decis. Pest thresholds, based on percentage plants infested (as selected by a systematic sampling plan), were reduced progressively during the life of the crop. These reductions reflected the impact on marketability, of pest damage close to harvest. The sampling system was shown to be robust at the pest populations encountered in the two years. A Robustness Analysis indicated that the sample-size used (100 plants per plot) was more reliable for larger thresholds than for thresholds of 5% or fewer plants infested. Little further improvement resulted from increasing the sample size to 150 plants per plot.

Cabbage aphid infestations developed during the season at all sites and thresholds were frequently exceeded. Fewer spray applications were applied to "supervised" plots on the basis of pest thresholds, compared to "routine" treatment. A mean of 6.0 "routine" treatments were reduced to 3.6 applications of DSM and 4.4 of Aphox. Demeton-S-methyl consistently gave better aphid control than pirimicarb, but at three of the five sites, the effectiveness of DSM declined in September. At one site, aphids infested sprout buttons and Aphox failed to prevent reductions in marketable yield. Caterpillars were few in number at all sites and the overall 6.0 "routine" applications were reduced to 0.7 and 0.6 (a 90% reduction) in the two "supervised" control treatments. At harvest, slight, superficial damage was found on up to 1.1% of buttons at two sites, with none at the remaining three sites.

Overall yield differences between treatments were negligible at harvest but percentage marketability of sprouts was usually lower in the "supervised" treatments, resulting in slightly smaller economic returns compared to the "routine" treatment. At one site, the percentage of marketable sprouts (and margin over cost of aphid and caterpillar control) was greater following the use of "supervised" control than for "routine" treatments. Overall, reducing pesticide usage by 33% incurred a loss in marketability of 2.9%. However, these reductions in marketability were almost entirely due to slug damage in the "supervised" plots. When the effect of slug damage was excluded, the overall loss was reduced to only 0.2%. The "supervised" system at all sites was then economically comparable with or more favourable than the "routine" treatment (ie margins over cost for DSM and Decis averaging £7 per hectare and not exceeding £55 per hectare at any site).

At all five sites, slug damage was worse in "supervised" plots treated with DSM than in those sprayed with pirimicarb or with the routine tank-mix. Reasons for these differences are unclear but are probably linked to the reduced number of insecticide applications made to the "supervised" control treatments. In contrast to 1992, severe slug damage in 1993 was not restricted to the headlands but was well distributed throughout the crop.

Initial observations on aphid parasitism showed that the cabbage aphid parasitic wasp *Diaeretiella rapae* (McIntosh) was the predominant parasitoid at all sites. From observations after insecticide treatment of apparently unparasitised aphid colonies, it appears that DSM and Aphox do not greatly suppress the subsequent development of parasitised aphids ("mummies").

# EXPERIMENTAL SECTION

## INTRODUCTION

Horticultural brassica crops in the United Kingdom occupy 54,000 ha and their marketed value is £213 million (Basic Horticultural Statistics for the UK, 1984-1993). They are sprayed extensively to control insect pests. Recent MAFF Pesticide Usage Surveys indicate that on average, crops are treated with 3 insecticide applications to control foliage pests. Long-season brassicas such as Brussels sprouts, receive more. The principal insect pests are caterpillars and aphids against which 83% of insecticide applications are targeted.

Frequent routine treatments to control aphids and caterpillars in leaf and flowerhead brassicas are expensive and generally unnecessary. Monitoring to assess pest numbers is also expensive in staff time and if done incorrectly, can lead to unacceptable levels of pest damage. Validated treatment thresholds (tolerance levels) based on pest monitoring, are needed for various stages of growth in a range of brassica crops. Pest control decision-making on the basis of pest monitoring and treatment thresholds is termed "supervised" control. The practical value of such a system is best tested by experiments in which insecticide applications are based on arbitrary thresholds assessed by conventional sampling methods and subsequently evaluated on the basis of crop damage and marketable yields.

Various sampling techniques were investigated in the 1980s at HRI Wellesbourne, in Holland and in the USA (Theunessen and Den Ouden 1985), (Theunessen 1988). In the same period, comparative descriptions and identification keys were prepared to aid recognition of caterpillars infesting brassica crops (Emmett 1980, Emmett 1982). Damage thresholds for cabbage aphids and caterpillars were tested in Austria, England, Germany (Federal Republic), Ireland and Switzerland as part of a project co-ordinated by staff at HRI Wellesbourne (Hommes et al 1988). A "supervised control" experiment was based on these parameters at Wellesbourne in 1987. Results indicated that effective control without significant loss of crop quality could be achieved with about half the number of insecticide applications used in conventional control methods.

Integrated management of brassica pests is currently under investigation by HRI and ADAS staff at HRI Stockbridge House and Kirton, and at ADAS Arthur Rickwood (Blood-Smyth et al 1992, Blood-Smyth et al 1993, Paterson et al 1994). The sampling method used in this work is highly accurate to establish and validate robust treatment thresholds. However, it is not intended to be a practical system for farm use.

"Supervised" systems are now at an advanced stage for several vegetable crops in mainland Europe. A 50% reduction in pesticide usage is required in Holland by halving the quantity of active ingredient used, and in Sweden and Denmark by halving the number of applications (Anon. 1988, Pimentel et al 1991). If consumers or legislation make similar demands in the UK, any reduction can only be logically applied by using a set of validated treatment criteria that are acceptable to growers. Without these "tools" we will fall behind our continental competitors in pest management expertise.

It is a requirement under the Food and Environment Protection Act to protect environment and consumer from unnecessary use of insecticides. Similarly, to comply with COSHH, pesticides must be used only when needed. Again, only by using robust treatment thresholds can these decisions be made without risking crop loss to pests.

The National Farmers Union Pesticide Working Group is formulating a programme for implementing the NFU Pesticide Policy, especially wider development and uptake of IPM. This policy is being promoted through a Joint Working Group comprising the NFU, MAFF, Supermarket and Consumer Groups. Such enterprises strengthen the need for rapid evaluation of "supervised" systems in as wide a range of farms, soils and geographical conditions as possible.

This project was therefore devised to take the experience gained at experimental centres in the previous two years, onto a range of commercial brassica holdings for practical evaluation. A two-year experiment was set up with funding from HDC to evaluate a systematic sampling technique and to test treatment thresholds for control of cabbage caterpillars and cabbage aphid on Brussels sprouts, on farms in 5 commercial brassica-producing areas of the UK. In the second year, it was also intended that the value and practicality of attracting/maintaining parasitoids of cabbage aphid might be assessed and preliminary observations were made at all sites.

The results of the second year of this study are reported here, together with relevant information from year 1 and conclusions based on the work in both years.

## MATERIALS AND METHODS

Experiments were carried out at a commercial farm in each of the Vale of York, Lincolnshire, Worcestershire, Bedfordshire and Berkshire. Four of the sites were in the same localities in both years but the Western site in 1992 was located in Warwickshire.

### Treatments:

In contrast to 1992, when there were two treatments only, in 1993 the following three treatments were replicated three times.

1. **"Routine":**

   A tank-mix of demeton-S-methyl applied at 325g ai per hectare (560ml per hectare of Campbell's DSM) and Deltamethrin at 3.75g ai per hectare (150ml per hectare of Decis) to protect the crop against aphids and caterpillars respectively. Treatment to be applied fortnightly in 600 litres of water per hectare.

2. **"Supervised 1":**

   Insecticides as above, but applied either singly or in tank-mix according to monitoring results, ie demeton-S-methyl only, at 325g ai per hectare, if aphid threshold exceeded. Deltamethrin only, at 7.5g ai per hectare (300ml per hectare of Decis) if caterpillar threshold exceeded. Both insecticides applied if both thresholds exceeded.

3. **"Supervised 2":**

   Insecticides applied as above, but substituting pirimicarb applied at 210g ai per hectare (420g per hectare of Aphox together with added wetter) for demeton-S-methyl.

### Design and Layout

Nine plots were established as a randomised block design of three blocks and three treatments. Plots were not less than 2,240m$^2$ area eg 40 x 56m or 22.5 x 100m with not fewer than 5,000 plants per plot.

The trials were laid out in early to mid-June, usually at the eight true leaf stage on crops planted late April or early May and grown either on bed systems or in single rows, at plant spacings of 51 x 51cm. Each plot included a cropped headland area of not less than 22m width, adjacent to the field edge.

## GROWING SEASON PEST ASSESSMENTS

A systematic method was used to assess pest numbers in the crop  The headland area was not assessed or treated separately because this task in 1992 proved too time-consuming both for consultants and growers. Also these harvest assessments had indicated a more even distribution of caterpillar and aphid infestation than was expected, with little obvious merit in headland spraying.

"Supervised" plots were visited at fortnightly intervals to assess pest numbers in the central 13 rows of each plot (see Appendix 1 for field assessment sampling plan). Starting from the first plant of the selected row, every fourth plant was assessed until 25 plants had been checked. The assessor then moved across four rows and checked every fourth plant on the return traverse to the headland. This process was repeated for a third and fourth traverse until 100 plants had been checked in the plot. Where the crop was grown on a bed system and assessments had to be made across the line of the beds (Worcestershire site) a plant in the centre row of each bed was assessed until 25 beds had been traversed.

Numbers of cabbage aphids and caterpillars were compared with pre-determined thresholds and a decision made on the need to apply insecticides. Threshold values were lowered as the plants matured to allow for low (often zero) commercial tolerances for pest damage in harvested buttons.

### Pests Assessed

**1. Aphids**

Each selected plant was examined for presence of live wingless cabbage aphids (*Brevicoryne brassicae*).

**2. Caterpillars**

Each selected plant was examined for presence of cabbage caterpillars. The threshold for these pests was applicable to the following major species:-

| | |
|---|---|
| small white butterfly | - *Pieris rapae* |
| green-veined white butterfly | - *Pieris napi* |
| cabbage moth | - *Mamestra brassicae* |
| diamond-back moth | - *Plutella xylostella* |

Pests were not counted, infestations were recorded as percent infested plants.

## TREATMENT THRESHOLDS AND DECISIONS

In 1993, a nil-tolerance for cabbage aphid and caterpillars (all species) was introduced 16 weeks after planting. Threshold values otherwise remained essentially as in 1992 but with the successive reductions operating at an earlier crop development stage. These thresholds are given at Table 1.

**TABLE 1 Treatment thresholds 1993 - percent plants infested (1992 threshold values)**

| PEST | GROWTH STAGE OF BRUSSELS SPROUT PLANTS | | |
|---|---|---|---|
| | **0-10 weeks** | **11-15 weeks** | **16 weeks onwards** |
| Aphid | 10 (20) | 5 (10) | 0 (5) |
| Caterpillar (all species) | 40 (40) | 5 (40) | 0 (5) |

The 0-10 weeks threshold (10% aphid, 40% caterpillar) applied at most sites up to about mid-July. The 11-15 week threshold (5% both pests) applied up to mid/late August when the zero tolerance of "16 weeks onwards" came into force.

Treatment decisions are given in Table 2.

**TABLE 2 - Growing-season Pest Assessments - treatment decisions 1993**

**Numbers of infested plants out of 100 (field including headland) with action required at three threshold values**

| THRESHOLD | NO SPRAY | SPRAY | NO DECISION |
|---|---|---|---|
| 5% | 2 | 8 | 3 - 7 |
| 10% | 6 | 14 | 7 - 13 |
| 40% | 32 | 46 | 33 - 45 |

Each plot was considered separately, eg plots that achieved threshold numbers were sprayed, those that did not, remained unsprayed on that occasion. In 1992 where headland plants were heavily infested with one or both pests, there was an option to treat only the headlands. This option was not imposed since it was not practical at all sites. Where the entire plot was to be treated, then the threshold was determined on the percentage infestation of the total 100 plants inspected, (see annual report, year 1: 1992). In 1993 to ensure that all sites were comparable, this option was omitted. Instead, the thresholds were applied to headland and field together so that the headland area (ie the first six rows) accounted for about six plants in the 100 plant sample.

The treatment decision criteria were computed by Andrew Mead of the Biometrics Department, HRI Wellesbourne. For each sample size and threshold the probability of spraying when pest numbers are below the treatment threshold, was set at $\leq$0.15 (1:6.7). The probability of **not** spraying when pest numbers exceed the treatment thresholds, was set at 0.05 (1:20). This "fail-safe" system was also subjected to a Robustness Analysis.

**Robustness Analysis**

For each sample size and threshold it is possible to calculate the ranges and numbers of infested plants which should lead to each of the 3 possible decisions (No Spray, No Decision, Spray). These values are calculated by constructing appropriate confidence limits (5%, 15%) for each of the observable proportions of infested plants and including in the "No Decision" range any proportion whose confidence limits include the threshold.

For any true infestation level it is possible to calculate, for any sample size, the probability of observing any particular number of infested plants, assuming that the number of infested plants follows a binomial distribution with parameters equal to the sample size and to the true infestation level. Information is not currently available, regarding the spatial distribution of infested plants. However, they may not always follow the binomial distribution and this aspect of sampling technique is being investigated in current MAFF funded work at HRI and ADAS Arthur Rickwood. From the Robustness Analysis can be calculated (for any sample size/threshold/true infestation level combination), the probability of making each of the 3 possible decisions. This information was used to investgate the robustness of various sample sizes (from 50 to 150 plants) while using this fixed-sized sampling scheme for decison making.

**Parasitoid Assessment**

Preliminary assessments of cabbage aphid parasitism were undertaken in July/August at all sites. Before treatment, up to 10 plants were examined for the presence of parasitoids, based on the presence of "mummies" ie aphids with papery texture and bronzed discoloration which characterises infestation by *Diaeretiella rapae*, or *Aphidius* sp. Aphid colonies were recorded as parasitised or apparently healthy. Three weeks after treatment, these colonies were re-examined and the number of parasitised "mummies" was noted.

## HARVEST SAMPLING AND PEST ASSESSMENT

Plants were harvested for yield and pest damage assessment. Harvest dates ranged from early October at the Worcestershire site to mid-November in Lincolnshire. A total of 40 plants per plot were examined. These plants were chosen by the following method. Starting from the headland, five rows into the crop were selected (rows 8, 16, 24, 32 and 40 along the headland of each plot). Starting at the first plant in row 8, every twelfth plant in each selected row was taken, moving up one plant in each successive row (see Appendix 2 for sampling plan). To assess pest numbers at increases distances into the crop, the results were recorded in eight separate zones. The first zone was near to the headland. Each subsequent zone was 12 plants further in to the crop. Thus the eight zones were defined as 1-5, 12-16, 24-28, 36-40, 48-52, 60-64, 72-76 and 84-88 plants into the plot. A sub-sample of sprouts for pest assessment was taken by removing a top, middle and bottom sprout from each of the 40 plants sampled in each plot (a total of 120 sprouts per plot. Each sprout was examined for -

1. External pest damage or presence (aphid, caterpillar or slug).

2. Pest damage/presence under the wrapper leaves (aphid or caterpillar) removable by trimming.

3. Internal pest damage/presence (aphid, caterpillar, slug or cabbage root fly larvae).

Yield and size grade assessments were made by removing all the sprouts from each of 8 plants per plot (one plant from each of the 8 zones sampled), and recording the number and weight of sprouts in each of the following size grades: <12.5mm, 12.5-20mm, 21-30mm, 31-40mm and >40mm. The sprouts used for pest damage assessment were also included in the grading assessments.

## RESULTS

### Pest Population Development

At all sites except Berkshire, both aphicides gave good initial control but where Aphox was used the aphid populations recovered quickly and were then poorly controlled for the remainder of the season. Application of DSM suppressed the aphid population more effectively than Aphox at **all** sites. (Figs 1-5). The efficacy of DSM declined later in the season at all sites but aphid control was usually adequate, except at the Berkshire site (Fig 5).

Comparison of the Bedfordshire and Berkshire sites (Figs 4 and 5) illustrates the variability of late-season control with DSM. In Bedfordshire a cabbage aphid population of around 20% plants infested in late August, was reduced by DSM to 1% at harvest in November. In the Aphox-treated plots, the population increased so that by 11 November more than 40% of plants were infested. The aphid colonies were mainly on the leaves and crowns with the buttons remaining almost completely clean.

In Berkshire, aphid numbers were poorly controlled initially and increased from late August in both DSM and Aphox-treated plots. By late October more than 50% of plants were infested in plots treated with Aphox while the DSM treatment averaged 39% infestation. At this site the aphids colonised the buttons as well as the leaves and reduced marketable yield at harvest. In Worcestershire (Fig 3) a severe aphid infestation (72% plants colonised in early July) was moderately suppressed (9% infestation at harvest) by six applications of DSM. In Aphox-treated plots, the treatment threshold was exceeded at every fortnightly visit so that eight applications were needed. In spite of these frequent sprays, 27% of plants remained colonised at harvest. The Berkshire results, those from Yorkshire and to a lesser extent from Lincolnshire, confirmed those of 1992 when there was a tendency to reduced efficacy of DSM towards the end of the season. In 1992 at the one site (Bedfordshire) where Aphox was compared with DSM, cabbage aphids were poorly controlled by Aphox especially in the Autumn when DSM-treated plants had 8% and Aphox-treated plants 45% plants infested.

Caterpillars were generally few in number but the Lincolnshire and Worcestershire sites were infested with threshold numbers of diamond back moth, cabbage moth and small white butterfly. At both sites and in one replicate of the Yorkshire trial, where diamond-back moth was the predominant species, at least 10% of plants were infested in early/mid-July. At the two sites where threshold numbers of caterpillars were exceeded and Decis was applied, (Figs 6 and 7), good control of caterpillars was achieved. At the Lincolnshire site (Fig 6), a Decis treatment on 31 July gave excellent control of a rapidly-developing population of diamond-back moth which was then suppressed for the remainder of the season. Slight increases in percent plants infested during August and September were mainly due to single individuals of silver Y moth (*Plusia gamma*) or small white butterfly.

No whitefly problems were encountered in 1993, in contrast to 1992 when they were abundant at two sites but caused no damage to buttons.

***Parasitoids of cabbage aphid:***

Cabbage aphid parasites were identified from aphid "mummies" at all sites. They were found to be *Diaeretiella rapae* (McIntosh). Although more "mummies" were found in Aphox-treated plots, the percentage difference was usually unexpectedly small, ie in Worcestershire, only 10% more colonies were found with "mummies" in Aphox-treated plots compared to DSM-treated plots. The value for Bedfordshire was 4% and for Berkshire 30% increase in percentage of colonies with "mummies" in Aphox-treated plots. At the Yorkshire site after marking in early August, DSM gave virtually complete control of aphids and no "mummies" were found. Aphox was almost ineffective on that occasion and all the marked colonies developed "mummies" with up to 46% of aphids parasitised. Although colonies with apparently healthy aphids were subsequently found to develop "mummies" after treatment with DSM or Aphox (Fig 8), it remains unclear if the adult wasps were viable within their pupae.

***Harvest assessment of pest damage to buttons* and marketable yield:**

Cabbage aphid and caterpillar damage at harvest were slight at all sites except Berkshire where cabbage aphid damaged 5.4% of sprouts in the Aphox-treated plots (Table 3). This value contrasted with 1.4% attack from the DSM treatment and 0.8% in "routinely" treated plots. At this and the Worcestershire site, aphids were present on up to 1.4% of sprout buttons in Aphox-treated plots but only superficially on wing-leaves. At the Bedfordshire site where no aphid damage was recorded, 1.7% of "routinely"-treated plants had infested wing-leaves while the "supervised" treatments were virtually clean.

As in 1992, aphid and caterpillar infestations developed throughout the sampling area and were not concentrated near to headlands.

Slugs again damaged buttons at all sites especially in Berkshire and Worcestershire. As in 1992, more sprouts were attacked by slugs in "supervised" than in "routine" treatments. At all five sites, slug damage was slightly worse in "supervised 1" than "supervised 2" plots. At the Worcestershire site, a 19.2% button attack (DSM plots), was suppressed in the routine treatment to 5.4%. These differences were significant at $P = 0.05$.

In contrast to the results in 1992 when slug damage was more serious near to headlands, in 1993 the slug attack was well distributed throughout the eight zones and did not decline with distance into the crop (Table 6 and Fig 9A and 9B).

At three sites, more pest damage at harvest was present in both "supervised" treatments than in "routine" plots so that up to 14% more marketable sprouts were recorded from "routinely" treated plots (Table 4 and Fig 11). These differences were almost entirely due to slug damage. When the effect of slugs was removed, mean percent marketable sprouts in "supervised" plots exceeded 99.5% at all sites except Berkshire (Table 5 and Figs 10 and 12). At the Berkshire site, the loss of marketability due to cabbage aphid and caterpillar was 0.3% in DSM-treated plots and 5.2% where Aphox failed to suppress the population. Overall, there was no loss of marketability in "Supervised 1" and only 0.4% penalty in "Supervised 2".

**Treatment Thresholds and Sampling Technique**

The treatment thresholds for cabbage aphid and caterpillars were robust in 1993, as expected following the modifications. Where sub-threshold populations were untreated the pests did not get out of hand. Where threshold numbers were treated, they caused minimal crop damage. Statistical evaluations (Robustness Analyses) were undertaken to establish if the sampling number was optimum ie if fewer plants sampled would lead to similar treatment decisions.

**Robustness Analysis**

The analysis indicated that in general, increasing sample size increases the probability of making the correct decision while decreasing the probability of making a "No Decision". However, due to the discrete nature of the data, the increases/decreases are not smoothly continuous, ie the ranges of numbers of infested plants which lead to each of the possible decisions can only increase or decrease by integer numbers of plants. These patterns are more confused the closer the true infestation level is to the threshold. Larger sample sizes are required for smaller thresholds than for larger thresholds, (greater than 150 plants at the 5% threshold but possibly fewer than 100 plants at the 40% threshold) before there is no further benefit from increasing sample size (Appendices 18-22).

In choosing the sample size for a particular threshold it is necessary to compromise between what is practical and the probability of getting a "No Decision" result when close to the threshold. The related problems of choosing a maximum sample size for a sequential sampling scheme are discussed by Lynn and Mead (1994).

From the table given at Appendix 20, it may be seen that in practice, with a 10% threshold and a true infestation level of 10% there is little advantage to increasing the sample number from 100 to 150 plants because there is almost no decrease in the probability of achieving "No Decision" values. The same considerations apply at the 5% threshold with 5% infestation and the 40% threshold with 40% infestation. In general, this analysis confirms the robustness of the 100 plant sample, especially at sub-threshold infestations where "No Spray" decisions (the correct choice) are achieved progressively less frequently as the sample number is decreased. The graphs at Appendices 23-25 illustrate for the 10% threshold level, the effect on the probabilities of reaching each decision outcome, of changing sample size from 50 to 100 plants. These probabilities are given for a range of infestation levels from 1% to 99% plants infested.

Two patterns are apparent:-

- The range of percentage plants infested over which the No Decision outcome is most probable, decreases as sample size increases.

- As sample size increases, the ranges of percentage plants infested over which **two** of the outcomes are probable, becomes progressively narrower.

Using these graphs, an appropriate sampling size may be chosen, above which there is no significant reduction in these ranges. It appears that at the larger thresholds (10% infestation and above) there is little advantage to increasing the sampling size above 100 plants per plot. At the 5% threshold and below, while there is relatively little advantage in increasing from 100 to 150 plants, there is some continued improvement when increasing the sample size above 150 plants per plot.

### *Numbers of Spray Applications*

Spray applications for aphid control were reduced from a mean of six tank-mixes to 3.6 applications of DSM or 4.4 of Aphox (Table 7 and Fig 10). At the Worcestershire site (Appendices 5 and 15) there was no saving in the Aphox-treated plots which needed eight applications in response to continually exceeded aphid thresholds. Conversely, only three Aphox applications were made in Bedfordshire and Lincolnshire (Appendices 4, 6 9 and 11) though wet weather prevented at least one spray at each site when thresholds were exceeded.

Decis for caterpillar control was not required at three of the five sites and was applied no more than twice at the other two. Sprays of Decis were therefore reduced from 6 to a mean of 0.6 applications, (Table 7).

## ECONOMIC RESULTS

Tables 7 and 8 give average economic data for the five sites combined, ie yield and crop values together with mean costs of insecticide applications and crop monitoring for "routine" and the two "supervised" treatments. It may be seen that supervised control led to an average reduction in insecticide usage of 27% for Aphox, 40% for DSM and 89% for Decis. Fig 10 and Appendices 13-17 also give numbers of insecticide applications and percent marketable sprouts at the five sites.

The exclusion of crop walking (monitoring) costs from the variable costs of "routine" treatment (Tables 7 and 8 and Appendices 3-7 and 8-12) probably imposes an unjustified penalty on the system since most growers walk or engage consultants to do so in spite of "routinely" treating. Without this financial penalty, the "supervised" control system would be economically more attractive.

Our marketability criteria were far more stringent than could be imposed by Supermarkets ie an undamaged sprout with a single aphid found by destructive assessment was recorded as "unmarketable". In addition, more than 90% of the apparent yield penalty (50% in 1992), was due to slug damage.

With the effect of slug excluded (Table 8 and Appendices 8-12), "routine" treatment may be regarded as unjustifiably expensive with "supervised" control the preferable option. Table 7 includes damage by slugs. The average margin "routine" over "supervised 1" was £178, while that of "routine" over "supervised 2" was £151. Table 8 excludes the effect of slug damage so that only the effect of aphid and caterpillar remain. It may be seen that the average margin of "routine" over "supervised 1" was then reduced to £7 with that of "routine" over "supervised 2" somewhat higher at £97. The overall margin for "supervised 2" was influenced by the aphid attack at the Berkshire site. A value of 94.8% marketable sprouts for Berkshire, contrasts with values of not less than 99.6% for the other four sites (Appendices 8-12). However, taking all sites except Berkshire, the average margin of "routine" over "supervised 2" still remains around £80.

Appendices 8-12 give economic data for the five sites in 1993. At the Yorkshire site the margins were clearly in favour of "supervised" control. Spray costs were higher in the "routine" treatment which gave little or no improvement in percent marketable sprouts (Appendix 3). There was little economic change when the effect of slug damage was excluded (Appendix 8) because slugs were relatively unimportant at this site.

The Lincolnshire experiment (Appendices 4 and 9) produced margins in favour of "routine" treatment because only four "routine" sprays were applied in the unfavourable weather conditions prevailing in August/September. Small savings in spray applications were therefore counteracted in the "supervised" treatments by monitoring costs and the price of Aphox.

The Worcestershire site had severe slug damage in the two "supervised" treatments with much less in the "routine" (Table 3). Frequent sprays to control aphids were needed in "supervised" treatments, increasing spray costs especially of Aphox. Large margins (up to £622) were therefore produced in favour of the "routine" treatment (Appendix 5). With the effect of slugs excluded (Appendix 10) the position improved greatly to a £47 margin of "routine" over "supervised control 1". "Supervised control 2" was still £200 in arrears due to the cost of Aphox and the presence of aphids at harvest.

In Bedfordshire a margin of £114 in favour of "routine" treatment (Appendix 6) was reduced to £14 in "supervised 1" when the effect of slug was excluded (Appendix 11). The presence of aphids in 1.7% of buttons harvested from the "routine" treatment (Table 3) influenced this result in favour of "supervised" control.

The Berkshire margins for "supervised 1" improved from £109 to £27 after the effect of slug damage was excluded, because this treatment was heavily infested with slug but less so with aphid (Table 3; Appendices 7 and 12). The margin for "supervised 2" worsened because it had least slug and most aphid.

The overall margins for the use of "supervised" control with demeton-S-methyl (Table 8) are close to parity ie at an average cost of only £7 per hectare for using this procedure, its adoption (assuming pest incidence similar to 1992 and 1993) is virtually cost-free. For "supervised" control with Aphox, the higher price of this product, coupled with potential loss of marketability if it proves less effective than demeton-S-methyl, can lead to a penalty per hectare of almost £100.

## CONCLUSIONS

- "Supervised" control led to production of good quality Brussels sprout buttons with no yield loss and insignificant losses of marketability from aphid or caterpillar damage.

- The sampling method, though time-consuming, led to reliable treatment-decisions in the two years under test. From the Robustness Analysis, there seemed little merit in increasing numbers of sampled plants from 100 to eg 150. Although some improvement in precision could be achieved especially at the 5% threshold, the "diminishing returns" are unlikely to justify the increased effort involved.

- The modified thresholds in 1993 appeared to be robust, as did the original thresholds in 1992. Increased "safety" was introduced in response to grower concerns about virus incidence and supermarket tolerances. In consequence, they may now err on the side of caution, potentially leading to the use of unnecessary sprays.

- The presence of aphids at harvest and any consequent slight loss of marketable yield (Tables 3 and 4) resulted from poor control by the aphicides rather than from any failure of the monitoring system or treatment thresholds.

- Demeton-S-methyl was usually effective, apparently suppressing cabbage aphid populations for several weeks. In the autumn, the effectiveness of this insecticide appeared to decline so that aphid numbers increased close to harvest (eg Figs 1, 2 and 5).

- Pirimicarb was less effective and/or less persistent than demeton-S-methyl for control of cabbage aphid in Brussels sprouts. Where populations were well controlled, they recovered more quickly (or the plants were subsequently re-infested) leading to need for further sprays (Figs 2, 4 and 5).

- Decis gave reliable control of caterpillars. Potentially damaging populations of diamond-back moth were virtually eliminated after treatment. Other species were present in small numbers only and caused no problems (Figs 6 and 7).

- Parasitoids infesting cabbage aphid were always of the cabbage aphid parasitic wasp (*Diaeretiella rapae*). Preliminary assessments at all sites and especially the increasing development of aphid "mummies" during August and September at the Yorkshire site (Fig 8), suggest that DSM may be less damaging to this parasitoid than was expected.

- Slugs were more troublesome in "supervised" treatments than in "routinely"-treated plots, indicating that frequently-applied insecticides may have retarded their feeding activity (Table 3). Slug damage was also consistently worse in "Supervised 1" (DSM) plots than in "Supervised 2" (Aphox). At the Worcestershire site there was significantly more slug damage in both "supervised" treatments than in the "routine", yet similar numbers of aphicide sprays were applied (Table 3 and Appendix 10). This result suggests that Decis may have been an influencing factor, since only two caterpillar sprays were applied in the "supervised" treatments compared to eight in the "routine" plots. If this conclusion is valid, then the use of "supervised" systems might require a more prophylatic approach to slug control.

- Aphid and caterpillar attacks in both years were distributed across all zones and were not more concentrated near to headlands. It is evidently not feasible to assess whole-crop infestations by reference only to field edges (Table 6 and Table 1, Annual Report, Year 1:. 1992).

- Slugs were more numerous near to headlands in 1992 than in 1993 so their distribution cannot be reliably assessed by reference only to field edges. However, unlike aphid and caterpillar populations, it is probable that absence of slugs near to headlands indicates low incidence throughout the crop (Table 6 and Table 1, Annual Report, Year 1: 1992).

- The economic evaluations indicated that, using DSM as the aphicide, "supervised" control cost virtually nothing (Table 8). The penalty for use of Aphox averaged around £100 per hectare. Where large numbers of sprays were saved by the system and there was no loss of marketability, as at the Yorkshire site, then "supervised" control was up to £108 per hectare more profitable than "routine" treatment (Appendices 3 and 8).

Although pest numbers were small in both years of this project, the "supervised" control system was shown to be robust under the prevailing conditions. It was also economically acceptable, especially where DSM was used. It is concluded that this pest monitoring system should be tested by growers to familiarise themselves with the principles involved. Active participation will help to validate and refine the system and to further test the practicality of the procedures for on-farm use (see Opportunity for Application above for suggested procedures).

In 1994, a LINK Project, co-funded by MAFF, HDC and Microbio Limited (a subsidiary of the Agricultural Genetics Company), began to investigate adaptive sampling and control of caterpillars on horticultural brassicas. Objectives of this study include the forecasting of caterpillar attacks to accurately target pest monitoring. Also to determine the spatial distribution of caterpillars within Brussels sprout crops. A similar project, funded by MAFF Horticulture and Potatoes Directorate (HPD) is investigating the distribution of cabbage aphid. The work on both these projects is being undertaken by HRI with ADAS participation in East Anglia and Yorkshire. As results and information become available from this work, so treatment thresholds and sampling procedures may change. But the more experience consultants and growers acquire, on pest monitoring and threshold application, the better able they will be to utilise new guidelines and maintain expertise in the rapidly-advancing field of integrated pest management.

## FURTHER WORK

Further work is needed to test "supervised" control in seasons with high incidence of aphid and caterpillar attack. This information may develop from the current MAFF LINK and MAFF HPD-funded projects.

The effect of insecticides on slugs should be investigated, including the potential disruption of normal feeding behaviour by pyrethroid insecticides or by combinations of the three actives used in this project.

The susceptibility of *Diaeretiella rapae* to aphicides requires detailed study. In particular, the viability of immature parasitoids within their aphid "mummies" should be assessed following treatments with DSM.

The requirements for high quality crops and minimal pesticide usage, demand an improved understanding of the statistical properties of sampling schemes for integrated pest management. Some expertise has been developed in the Biometrics Department of HRI Wellesbourne but funding is now needed for further investigation of these problems. Such studies should also include the establishment of optimum sample sizes (numbers of assessed plants per 'plot') for a range of crop areas/sizes.

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## GLOSSARY

| | |
|---|---|
| ♦ COSHH: | Control of Substances Hazardous to Health Regulations 1988. |
| ♦ FEPA: | Food and Environment Protection Act 1985. |
| ♦ IPM | Integrated Pest Management |
| ♦ Mummies: | Shrivelled skins of aphids infested with parasitoid. |
| ♦ Parasitoid: | An insect which completes its immature stages on or in another insect: feeds on and kills its host. |
| ♦ Sequential Sampling: | Sampling of plants selected on the basis of assessment results from previously-selected plants. |
| ♦ Systematic Sampling: | Sampling of plants selected on a geometric pattern. |
| ♦ Supervised Control | Treatment decisions on the basis of assessment and identification of threshold numbers of pests. |
| ♦ Zoning: | Division of sampling units into discrete areas of crop taken progressively further into the field. |

**TABLE 3**

**Mean percent sprout buttons at harvest with pest damage/presence for each site, in supervised and routine plots.**

| SITE | TREATMENT | PEST DAMAGE TOTAL | | PEST DAMAGE APHID | PEST DAMAGE CATERPILLAR | PEST DAMAGE SLUG | | PEST PRESENCE TOTAL | PEST PRESENCE APHID | PEST PRESENCE CATERPILLAR |
|---|---|---|---|---|---|---|---|---|---|---|
| OVERALL | ROUTINE | 4.3 | (11.9) | 0.0 | 0.0 | 4.0 | (11.6) | 0.4 | 0.4 | 0.0 |
| | SUPERVISED 1 | 8.5 | (16.9) | 0.3 | 0.2 | 8.0 | (16.4) | 0.1 | 0.1 | 0.0 |
| | SUPERVISED 2 | 5.5 | (13.6) | 0.8 | 0.1 | 5.0 | (12.9) | 0.5 | 0.5 | 0.0 |
| SED (treatment means - 17 df) | | - | (1.8) | - | - | - | (1.8) | - | - | - |
| WORCS | ROUTINE | 5.4 | (13.4) | 0.0 | 0.0 | 5.4 | (13.4) | 0.0 | 0.0 | 0.0 |
| | SUPERVISED 1 | 19.2 | (26.0)* | 0.0 | 0.0 | 19.2 | (26.0)* | 0.3 | 0.3 | 0.0 |
| | SUPERVISED 2 | 15.0 | (22.8)* | 0.0 | 0.0 | 15.0 | (22.8)* | 1.4 | 1.4 | 0.0 |
| BEDS | ROUTINE | 5.2 | (13.2) | 0.0 | 0.0 | 5.2 | (13.2) | 1.7 | 1.7 | 0.0 |
| | SUPERVISED 1 | 8.8 | (17.3) | 0.0 | 0.0 | 8.8 | (17.3) | 0.0 | 0.0 | 0.0 |
| | SUPERVISED 2 | 5.1 | (13.1) | 0.0 | 0.0 | 5.1 | (13.1) | 0.3 | 0.3 | 0.0 |
| LINCS | ROUTINE | 0.1 | (1.3) | 0.0 | 0.0 | 0.1 | (1.3) | 0.0 | 0.0 | 0.0 |
| | SUPERVISED 1 | 0.9 | (5.5) | 0.0 | 0.0 | 0.9 | (5.5) | 0.0 | 0.0 | 0.0 |
| | SUPERVISED 2 | 0.2 | (2.5) | 0.0 | 0.0 | 0.2 | (2.5) | 0.0 | 0.0 | 0.0 |
| YORKS | ROUTINE | 1.0 | (5.6) | 0.0 | 0.3 | 0.8 | (5.0) | 0.0 | 0.0 | 0.0 |
| | SUPERVISED 1 | 2.0 | (8.1) | 0.0 | 1.1 | 1.4 | (6.7) | 0.0 | 0.0 | 0.0 |
| | SUPERVISED 2 | 0.4 | (3.4) | 0.0 | 0.0 | 0.4 | (3.4) | 0.0 | 0.0 | 0.0 |
| BERKS | ROUTINE | 19.1 | (25.9) | 0.8 | 0.0 | 17.6 | (24.8) | 0.0 | 0.0 | 0.0 |
| | SUPERVISED 1 | 21.5 | (27.6) | 1.4 | 0.0 | 19.9 | (26.5) | 0.3 | 0.3 | 0.0 |
| | SUPERVISED 2 | 19.4 | (26.1) | 5.4 | 0.8 | 14.9 | (22.7) | 1.3 | 1.3 | 0.0 |
| SED (same site - 17 df) | | - | (3.9) | - | - | - | (4.0) | - | - | - |
| SED (same treatment - 17 df) | | - | (5.0) | - | - | - | (5.1) | - | - | - |

* = Significantly different from Routine Treatment. P = 0.05

**TABLE 4**

**Mean percent marketable sprout buttons at harvest. Percentages angle transformed before analysis and back-transformed. (Angle transformed means shown in parentheses)**

| SITE | TREATMENT | PERCENTAGE MARKETABLE | |
|---|---|---|---|
| OVERALL | ROUTINE | 95.6 | (77.8) |
| | SUPERVISED 1 | 91.5 | (73.1) |
| | SUPERVISED 2 | 93.9 | (75.7) |
| SED (treatment means - 17 df) | | - | (1.7) |
| WORCS | ROUTINE | 94.6 | (76.6) |
| | SUPERVISED 1 | 80.6 | (63.9)* |
| | SUPERVISED 2 | 82.7 | (65.5)* |
| BEDS | ROUTINE | 93.3 | (75.0) |
| | SUPERVISED 1 | 91.2 | (72.7) |
| | SUPERVISED 2 | 94.7 | (76.6) |
| LINCS | ROUTINE | 100 | (88.8) |
| | SUPERVISED 1 | 99.1 | (84.5) |
| | SUPERVISED 2 | 99.8 | (87.5) |
| YORKS | ROUTINE | 99.0 | (84.4) |
| | SUPERVISED 1 | 98.0 | (81.9) |
| | SUPERVISED 2 | 99.7 | (86.6) |
| BERKS | ROUTINE | 81.4 | (64.5) |
| | SUPERVISED 1 | 78.4 | (62.3) |
| | SUPERVISED 2 | 78.4 | (62.3) |
| SED (same site - 17 df) | | - | (3.8) |
| SED (same treatment - 17 df) | | - | (4.7) |

* = Significantly different from Routine treatment. P = 0.05

**TABLE 5**

**Mean percent marketable sprout buttons at harvest, excluding those damaged by slugs. Percentages angle transformed before analysis and back-transformed. (Angle transformed means shown in parentheses)**

| SITE | TREATMENT | PERCENTAGE MARKETABLE | |
|---|---|---|---|
| OVERALL | ROUTINE | 100 | (89.5) |
| | SUPERVISED 1 | 100 | (88.8) |
| | SUPERVISED 2 | 99.6 | (86.5) |
| SED (treatment means - 17 df) | | - | (0.5) |
| WORCS | ROUTINE | 100 | (90.0) |
| | SUPERVISED 1 | 100 | (89.1) |
| | SUPERVISED 2 | 99.6 | (86.4) |
| BEDS | ROUTINE | 99.8 | (87.4) |
| | SUPERVISED 1 | 100 | (90.0) |
| | SUPERVISED 2 | 100 | (89.4) |
| LINCS | ROUTINE | 100 | (90.0) |
| | SUPERVISED 1 | 100 | (90.0) |
| | SUPERVISED 2 | 100 | (90.0) |
| YORKS | ROUTINE | 100 | (89.4) |
| | SUPERVISED 1 | 99.0 | (88.2) |
| | SUPERVISED 2 | 100 | (90.0) |
| BERKS | ROUTINE | 100 | (90.0) |
| | SUPERVISED 1 | 99.7 | (86.6)* |
| | SUPERVISED 2 | 94.8 | (76.8)* |
| SED (same site - 17 df) | | - | (1.0) |
| SED (same treatment - 17 df) | | - | (1.4) |

* = Significantly different from Routine treatment. P = 0.05

TABLE 6

**Mean percent sprout buttons at harvest with pest damage/presence for all sites, in "zones" ie A = Nearest Headland; H = Furthest into Crop**

**"ROUTINE TREATMENT"**

| ZONE | PEST DAMAGE | | | | PEST PRESENCE | | |
|---|---|---|---|---|---|---|---|
| | TOTAL | APHID | CATERPILLAR | SLUG | TOTAL | APHID | CATERPILLAR |
| A | 8.2 | 0.0 | 0.0 | 8.2 | 2.1 | 2.1 | 0.0 |
| B | 6.7 | 0.0 | 0.0 | 6.7 | 0.0 | 0.0 | 0.0 |
| C | 8.7 | 0.0 | 0.0 | 8.7 | 0.0 | 0.0 | 0.0 |
| D | 3.6 | 0.0 | 0.5 | 3.1 | 0.0 | 0.0 | 0.0 |
| E | 4.1 | 0.0 | 0.0 | 4.1 | 0.0 | 0.0 | 0.0 |
| F | 6.2 | 0.5 | 0.0 | 5.6 | 0.0 | 0.0 | 0.0 |
| G | 3.6 | 0.0 | 0.0 | 3.6 | 0.0 | 0.0 | 0.0 |
| H | 4.6 | 0.0 | 0.0 | 4.6 | 1.0 | 1.0 | 0.0 |

**"SUPERVISED TREATMENT 1"**

| ZONE | PEST DAMAGE | | | | PEST PRESENCE | | |
|---|---|---|---|---|---|---|---|
| | TOTAL | APHID | CATERPILLAR | SLUG | TOTAL | APHID | CATERPILLAR |
| A | 16.9 | 0.0 | 0.9 | 16.0 | 0.4 | 0.4 | 0.0 |
| B | 9.3 | 0.0 | 0.0 | 9.3 | 0.0 | 0.0 | 0.0 |
| C | 16.0 | 0.4 | 0.0 | 15.6 | 0.4 | 0.4 | 0.0 |
| D | 10.7 | 0.9 | 0.0 | 9.8 | 0.0 | 0.0 | 0.0 |
| E | 10.0 | 0.4 | 0.0 | 12.9 | 0.0 | 0.0 | 0.0 |
| F | 11.6 | 0.0 | 0.0 | 11.6 | 0.0 | 0.0 | 0.0 |
| G | 12.4 | 0.0 | 0.0 | 12.4 | 0.0 | 0.0 | 0.0 |
| H | 10.2 | 0.4 | 0.9 | 8.9 | 0.0 | 0.0 | 0.0 |

**"SUPERVISED TREATMENT 2"**

| ZONE | PEST DAMAGE | | | | PEST PRESENCE | | |
|---|---|---|---|---|---|---|---|
| | TOTAL | APHID | CATERPILLAR | SLUG | TOTAL | APHID | CATERPILLAR |
| A | 12.9 | 0.0 | 0.0 | 12.9 | 0.0 | 0.0 | 0.0 |
| B | 9.5 | 0.5 | 0.0 | 9.5 | 0.5 | 0.5 | 0.0 |
| C | 8.1 | 0.5 | 0.0 | 7.5 | 1.0 | 1.0 | 0.0 |
| D | 12.4 | 2.4 | 1.0 | 10.0 | 1.4 | 1.4 | 0.0 |
| E | 8.1 | 0.5 | 0.0 | 7.6 | 0.5 | 0.5 | 0.0 |
| F | 9.1 | 1.0 | 0.0 | 8.1 | 0.0 | 0.0 | 0.0 |
| G | 11.4 | 0.5 | 0.0 | 11.0 | 1.0 | 1.0 | 0.0 |
| H | 10.5 | 1.0 | 0.0 | 10.0 | 0.0 | 0.0 | 0.0 |

TABLE 7

## ECONOMIC EVALUATION (INCLUDING SLUG DAMAGE) 1993

**SITE: OVERALL**

| | | | |
|---|---|---|---|
| PERCENT MARKETABLE SPROUTS: | ROUTINE | = | 95.6 |
| | SUPERVISED 1 (DSM) | = | 91.5 |
| (FROM PEST ASSESSMENTS) | SUPERVISED 2 (APHOX) | = | 93.9 |
| PERCENT DIFFERENCE DUE TO PESTS: | ROUTINE - SUPERVISED 1 | = | 4.1 |
| | ROUTINE - SUPERVISED 2 | = | 1.7 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| FARM CROP YIELD (ROUTINE): | = | 13.1t/ha | | | ROUTINE CROP VALUE: | = | £3995 |
| CROP PRICE: | = | £319/t | = | 4179 | SUPERVISED 1 CROP VALUE | = | £3824 |
| | | | | | SUPERVISED 2 CROP VALUE | = | £3924 |

<u>Treatment and Monitoring Costs, Crop Value and Margin Over Costs</u>

| | DSM | | APHOX | | DECIS | | APPLICATIONS | | MONITORING VISITS | | TOTAL COST | CROP VALUE | MARGIN OVER COST |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | NOS. OF SPRAYS | COST £ | NOS. OF SPRAYS | COST £ | NOS. OF SPRAYS | COST £ | NOS. | COST £ | NOS. | COST £ | £ | £ | £ |
| ROUTINE | 6 | 32.6 | - | - | 6 | 31.8 | 6 | 120 | 0 | 0 | 184.4 | 3995 | 3811 |
| SUPERVISED 1 | 3.6 | 19.5 | - | - | 0.7 | 3.7 | 4.2 | 84 | 8.4 | 84 | 191.2 | 3824 | 3633 |
| SUPERVISED 2 | - | - | 4.4 | 82.5 | 0.6 | 3.2 | 4.6 | 92 | 8.6 | 86 | 263.7 | 3924 | 3660 |

AVERAGE MARGIN ROUTINE OVER SUPERVISED 1 = 178
AVERAGE MARGIN ROUTINE OVER SUPERVISED 2 = 151

Farm practice: Crop walking every 1-2 weeks, tank-mix sprays routinely at 2-3 week intervals

ADAS

**TABLE 8**

## ECONOMIC EVALUATION (EXCLUDING SLUG DAMAGE) 1993

**SITE: OVERALL**

| | | | |
|---|---|---|---|
| **PERCENT MARKETABLE SPROUTS:** | **ROUTINE** | = | **100** |
| | **SUPERVISED 1 (DSM)** | = | **100** |
| **(FROM PEST ASSESSMENTS)** | **SUPERVISED 2 (APHOX)** | = | **99.6** |
| **PERCENT DIFFERENCE DUE TO PESTS:** | **ROUTINE - SUPERVISED 1** | = | **0** |
| | **ROUTINE - SUPERVISED 2** | = | **0.4** |

**FARM CROP YIELD (ROUTINE): = 13.1t/ha**

**CROP PRICE: = £319/t = 4179**

**ROUTINE CROP VALUE: = £4179**

**SUPERVISED 1 CROP VALUE = £4179**

**SUPERVISED 2 CROP VALUE = £4162**

**Treatment and Monitoring Costs, Crop Value and Margin Over Costs**

| | DSM | | APHOX | | DECIS | | APPLICATIONS | | MONITORING VISITS | | TOTAL COST | CROP VALUE | MARGIN OVER COST |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | NOS. OF SPRAYS | COST £ | NOS. OF SPRAYS | COST £ | NOS. OF SPRAYS | COST £ | NOS. | COST £ | NOS. | COST £ | £ | £ | £ |
| ROUTINE | 6 | 32.6 | - | - | 6 | 31.8 | 6 | 120 | 0 | 0 | 184.4 | 4179 | 3995 |
| SUPERVISED 1 | 3.6 | 19.5 | - | - | 0.7 | 3.7 | 4.2 | 84 | 8.4 | 84 | 191.2 | 4179 | 3988 |
| SUPERVISED 2 | - | - | 4.4 | 82.5 | 0.6 | 3.2 | 4.6 | 92 | 8.6 | 86 | 263.7 | 4162 | 3898 |

AVERAGE MARGIN ROUTINE OVER SUPERVISED 1 = 7
AVERAGE MARGIN ROUTINE OVER SUPERVISED 2 = 97

Farm practice: Crop walking every 1-2 weeks, tank-mix sprays routinely at 2-3 week intervals

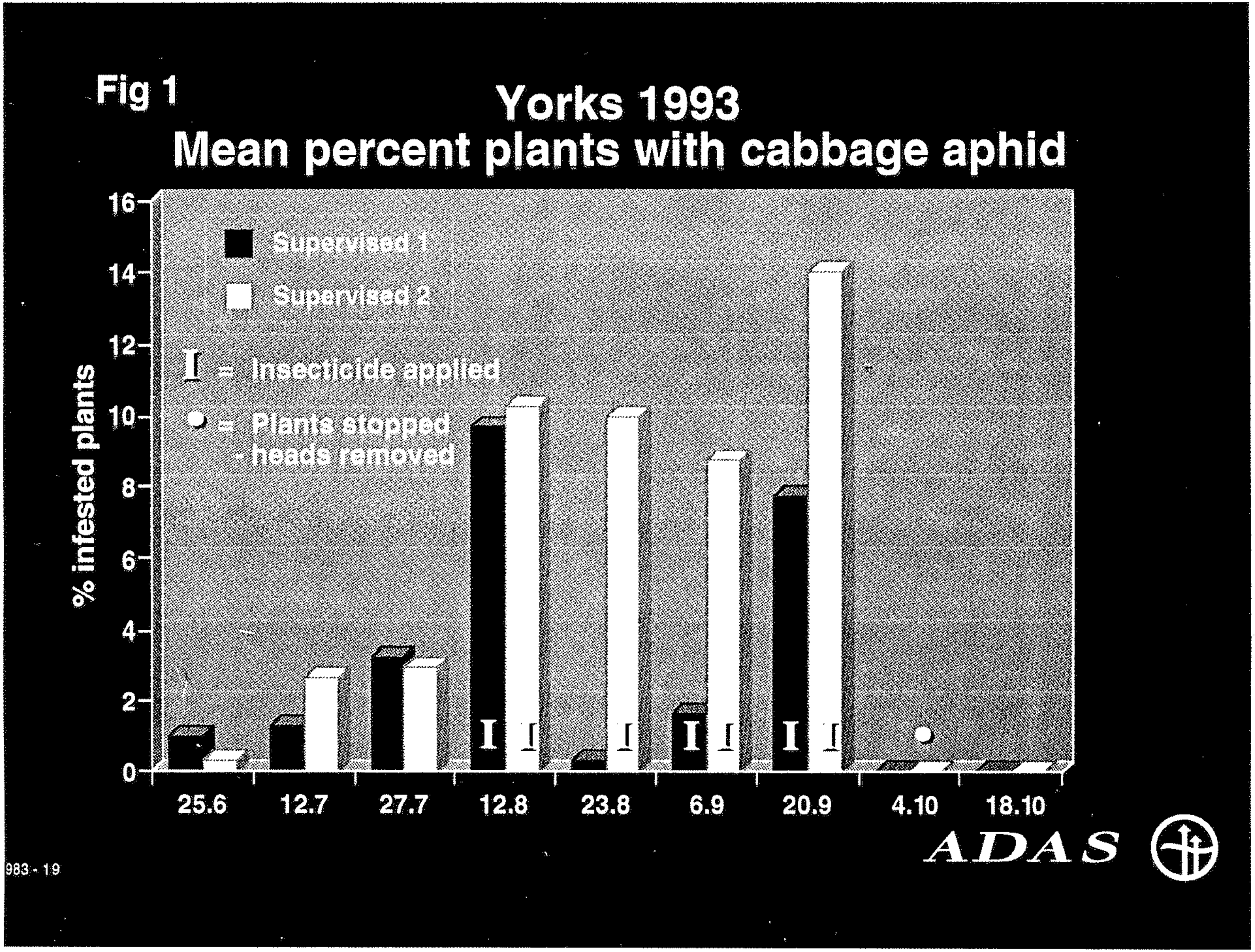
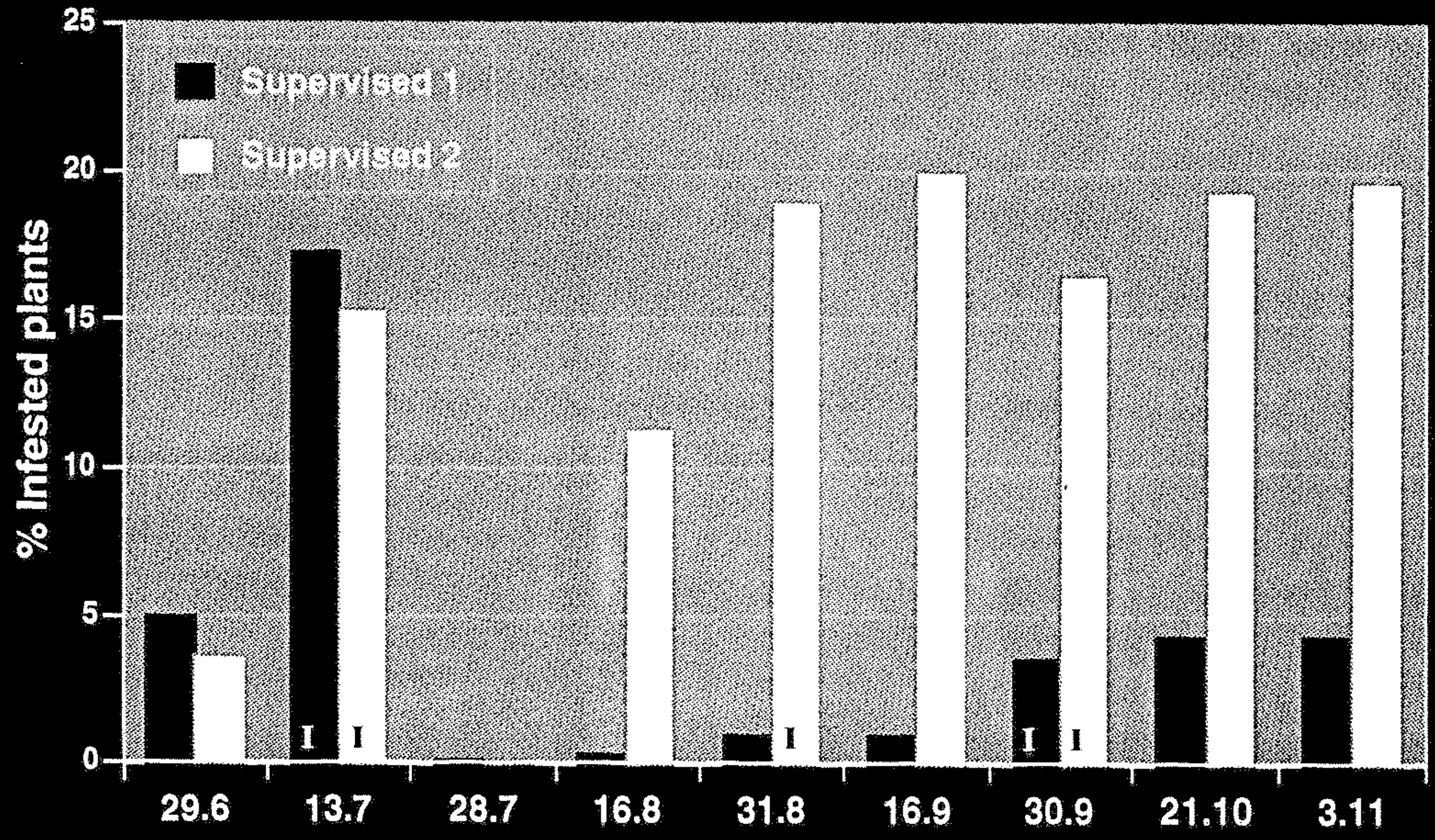


Fig 1
Yorks 1993
Mean percent plants with cabbage aphid
% infested plants
16
14
12
10
8
6
4
2
0
Supervised 1
Supervised 2
I = Insecticide applied
= Plants stopped
- heads removed
25.6
12.7
27.7
12.8
23.8
6.9
20.9
4.10
18.10
ADAS
983 - 19

Fig 2

# Lincolnshire 1993

## Mean percent plants with cabbage aphid




I = Insecticides applied in response to threshold values

ADAS

1304 - 1

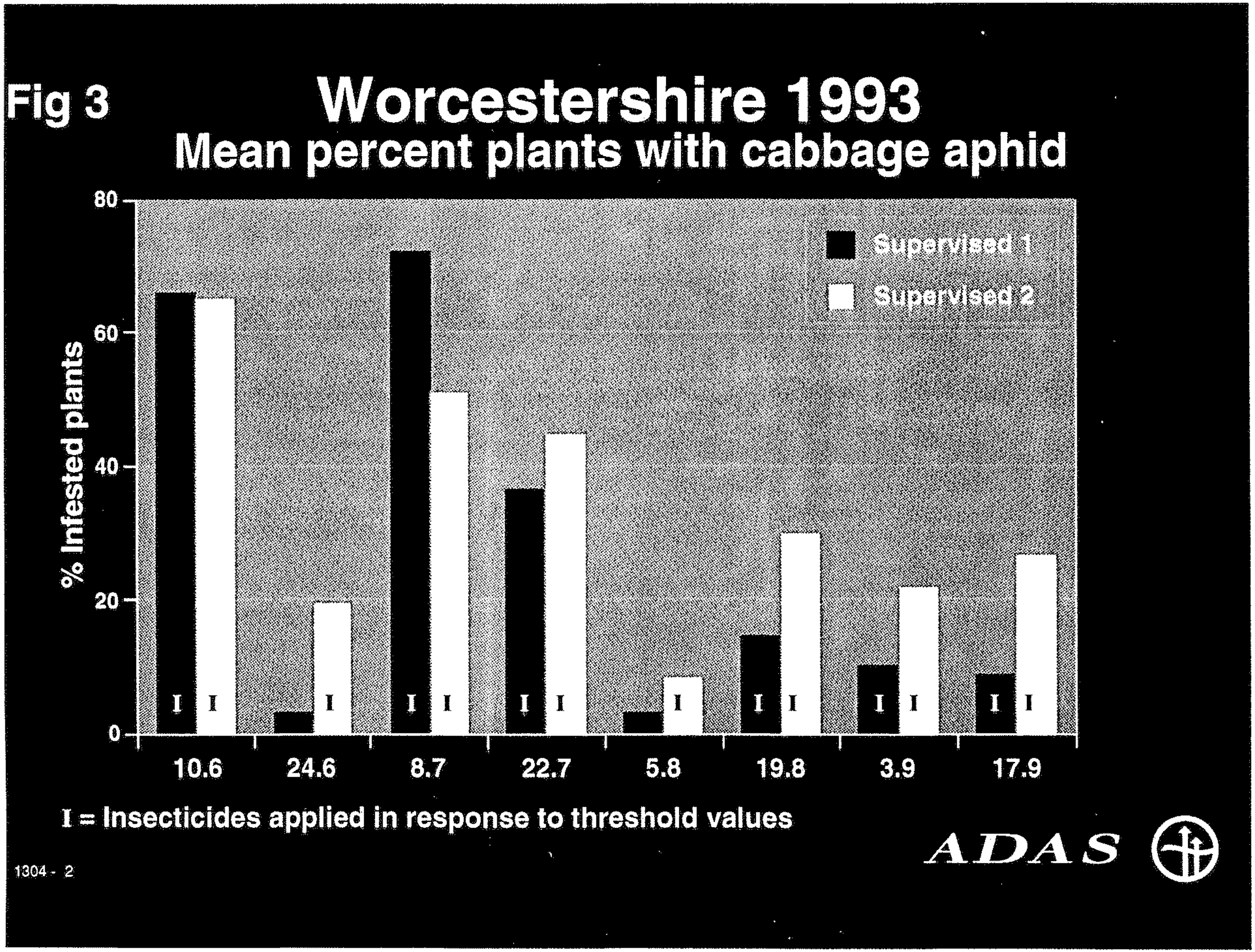
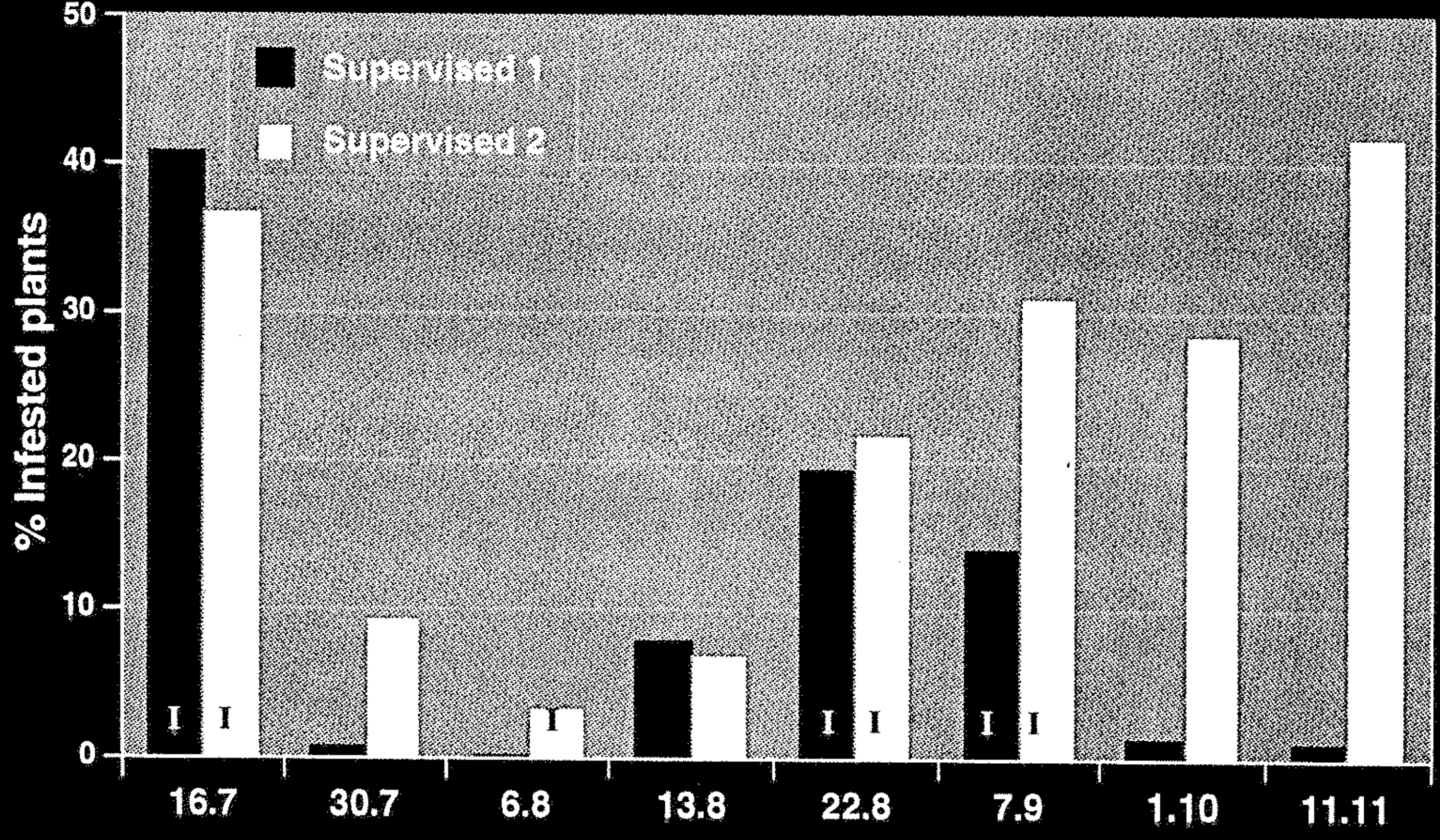


Fig 3
Worcestershire 1993
Mean percent plants with cabbage aphid
% Infested plants
80
60
40
20
0
Supervised 1
Supervised 2
I
10.6
24.6
8.7
22.7
5.8
19.8
3.9
17.9
I = Insecticides applied in response to threshold values
ADAS
1304 - 2

## Fig 4 Bedfordshire 1993
## Mean percent plants with cabbage aphid




I = Insecticides applied in response to threshold values

ADAS

1304 - 3

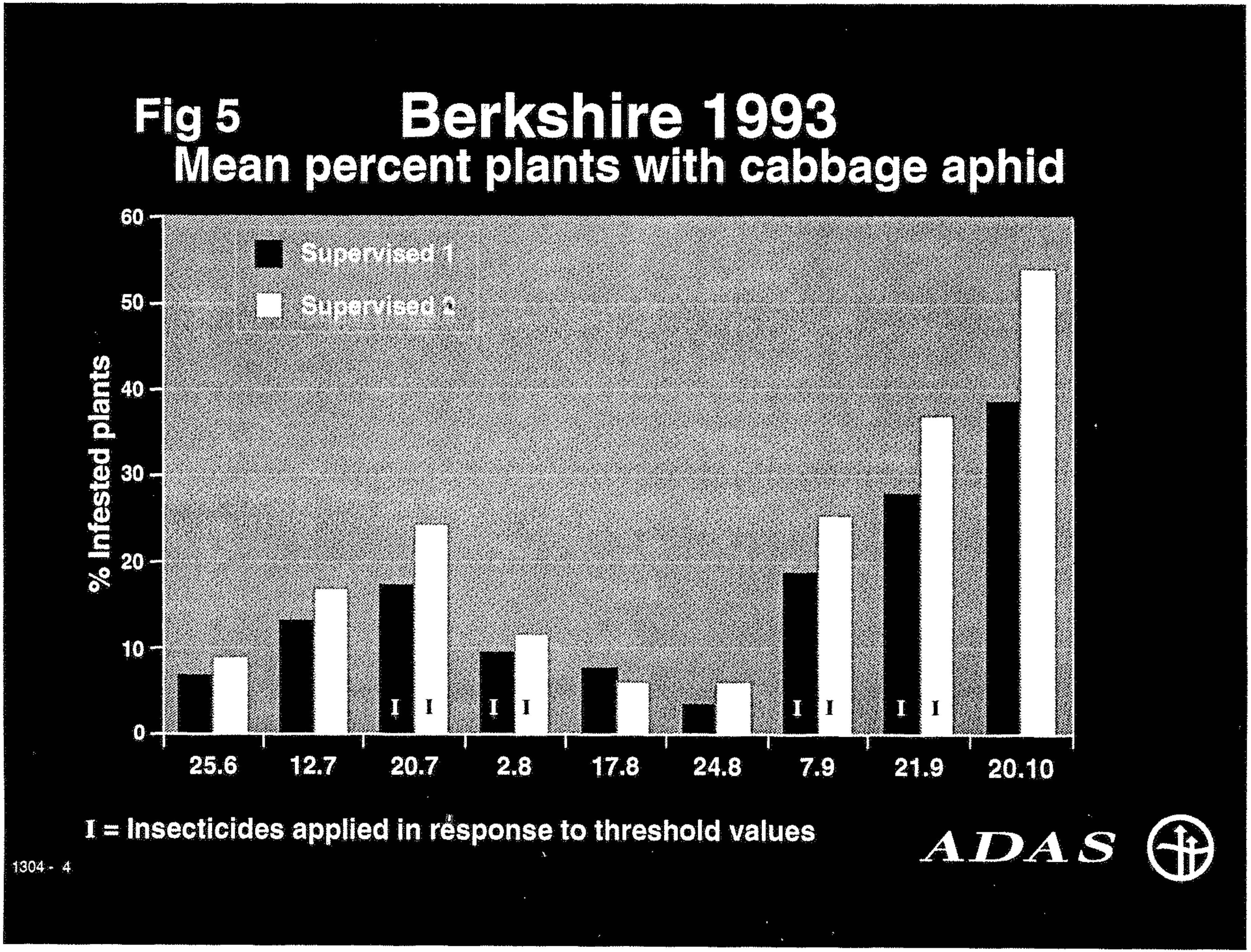


Fig 5 Berkshire 1993
Mean percent plants with cabbage aphid
% Infested plants
60
50
40
30
20
10
0
Supervised 1
Supervised 2
I I
I I
I I
I I
25.6
12.7
20.7
2.8
17.8
24.8
7.9
21.9
20.10
I = Insecticides applied in response to threshold values
ADAS
1304 - 4

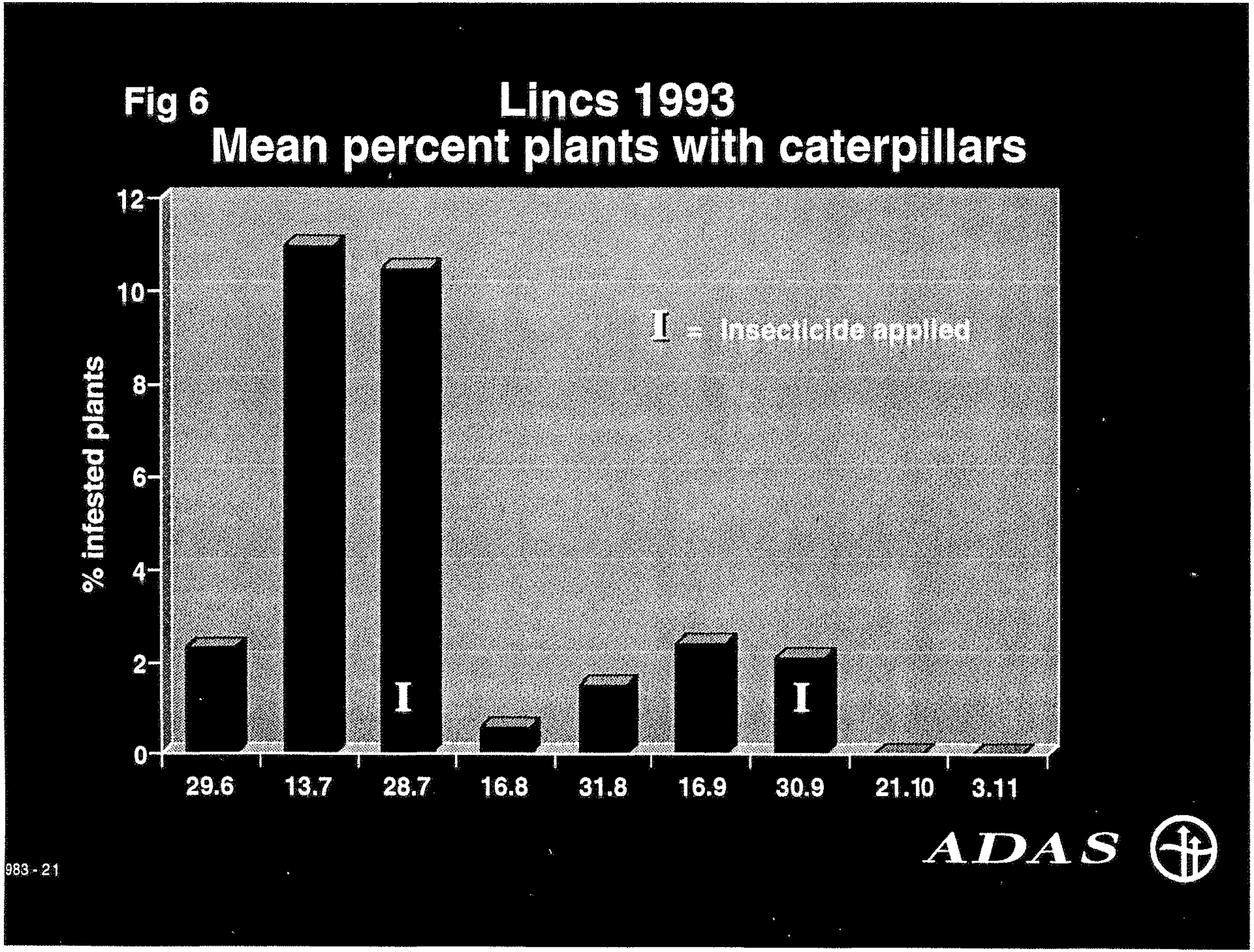
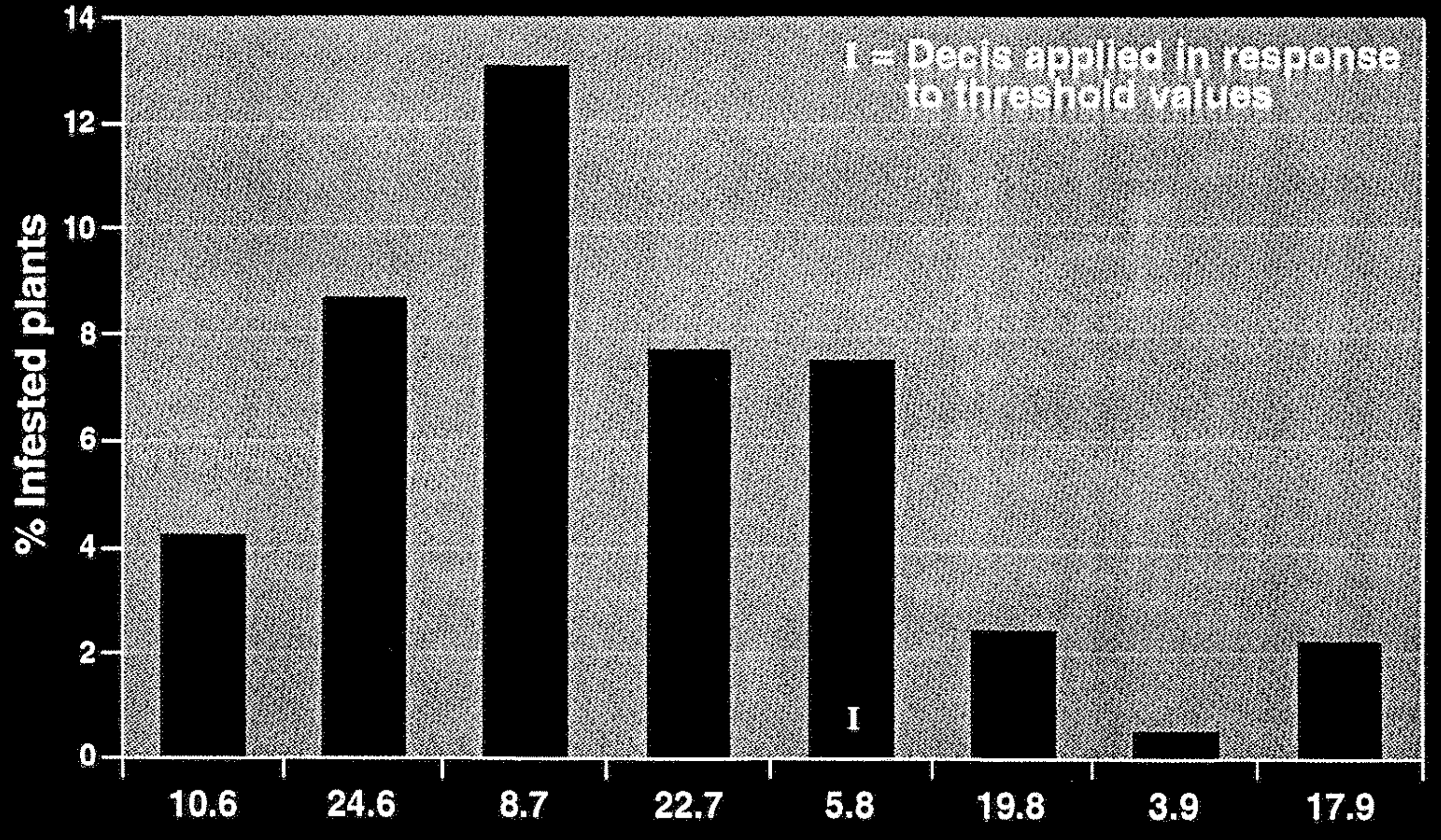


Fig 6
Lincs 1993
Mean percent plants with caterpillars
% infested plants
0
2
4
6
8
10
12
29.6
13.7
28.7
16.8
31.8
16.9
30.9
21.10
3.11
I = Insecticide applied
I
I
ADAS
983 - 21

## Fig 7 Worcestershire 1993
### Mean percent plants with caterpillars




**Supervised 1 and 2 combined (both Decis treated)**

ADAS

1304 - 5

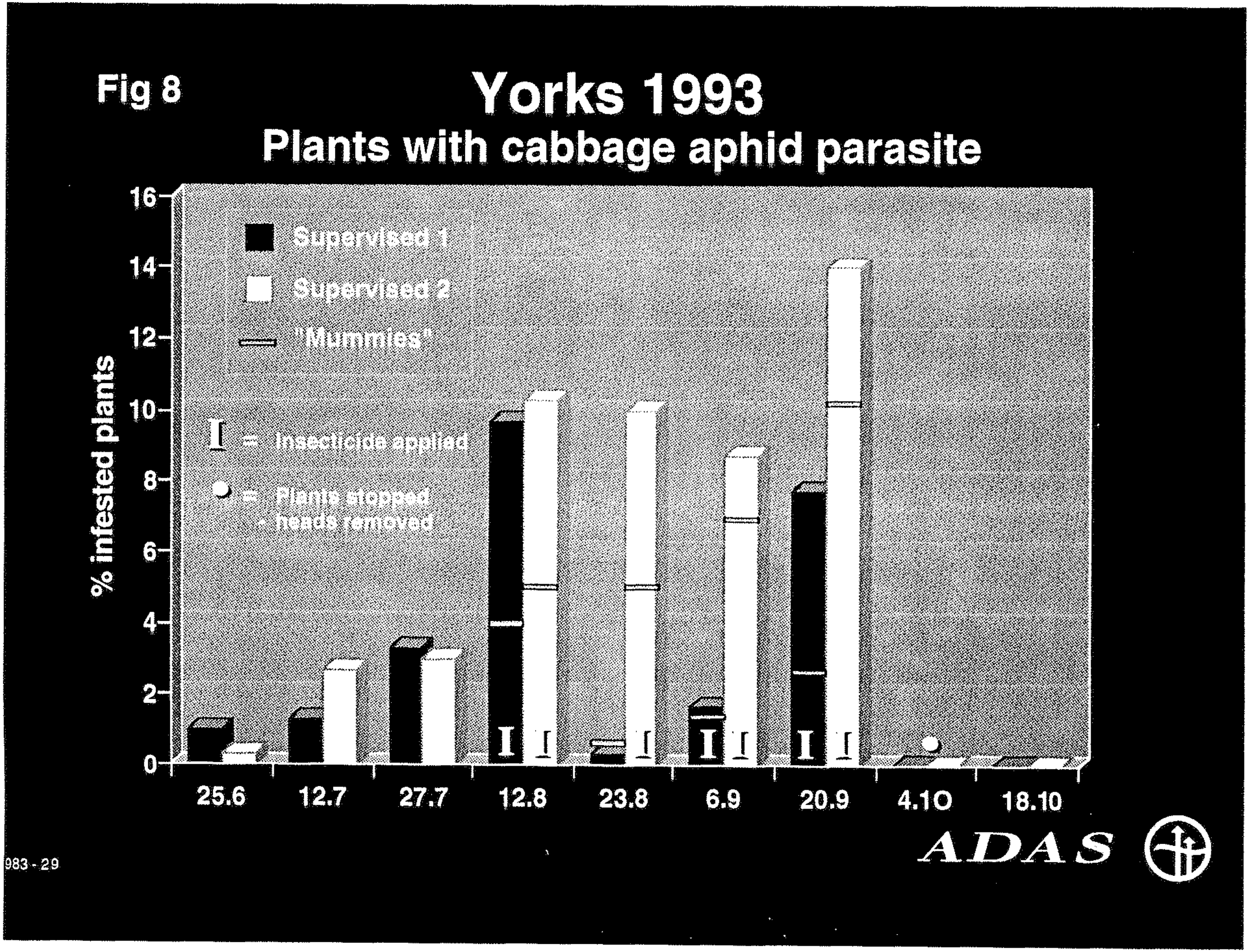


Fig 8
Yorks 1993
Plants with cabbage aphid parasite
% infested plants
16
14
12
10
8
6
4
2
0
Supervised 1
Supervised 2
"Mummies"
I = Insecticide applied
= Plants stopped
- heads removed
25.6
12.7
27.7
12.8
23.8
6.9
20.9
4.1O
18.10
ADAS
983 - 29

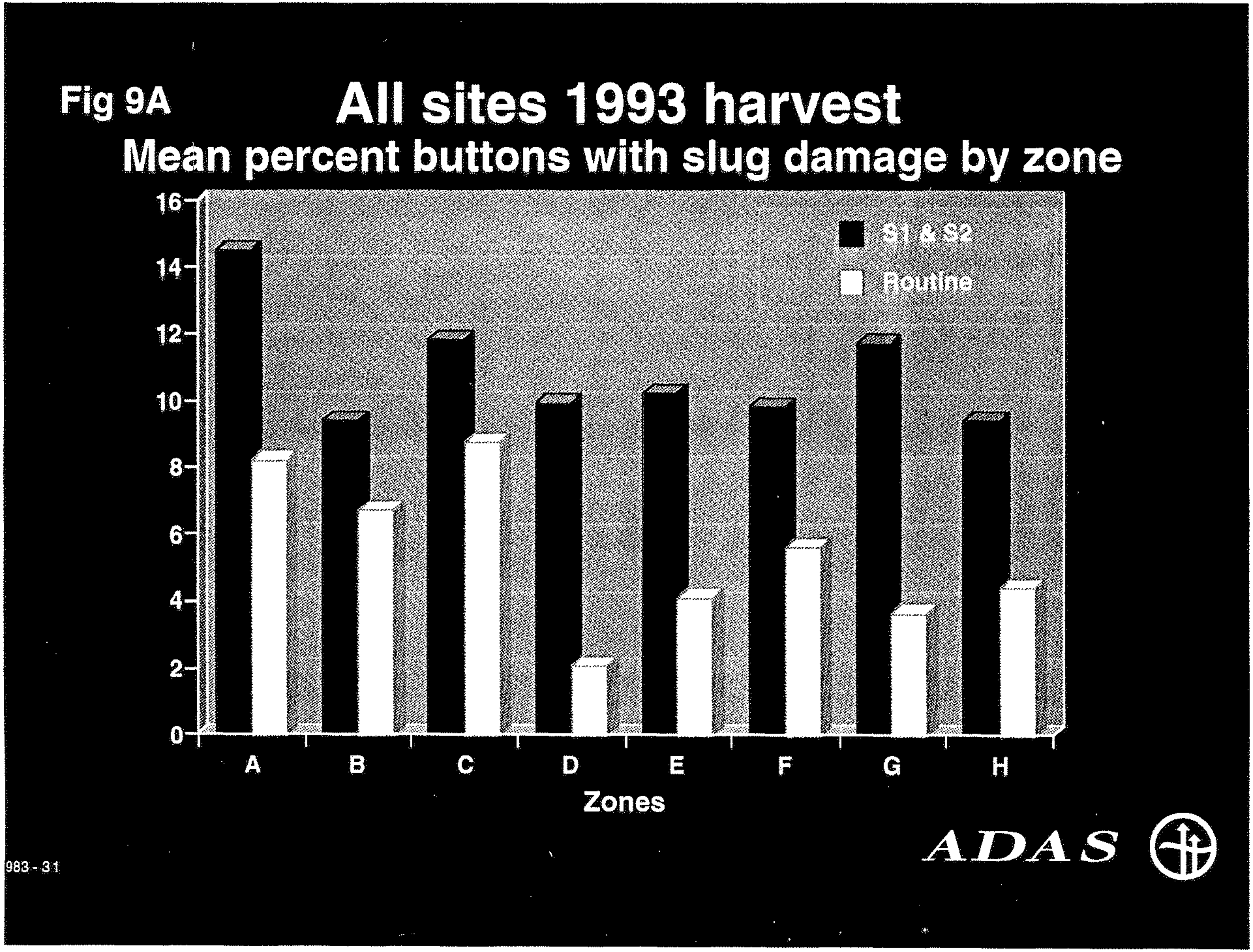
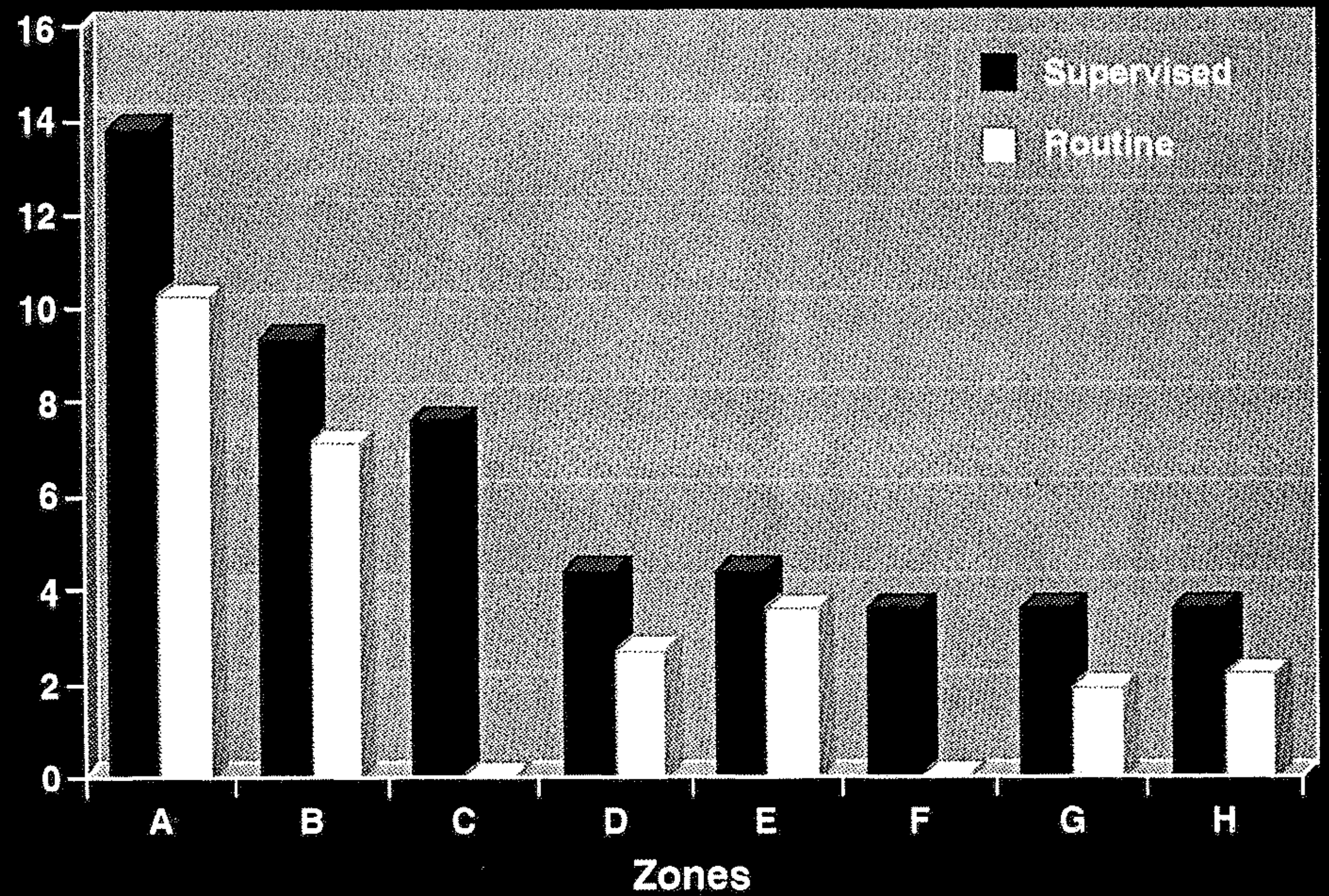


Fig 9A
All sites 1993 harvest
Mean percent buttons with slug damage by zone
16
14
12
10
8
6
4
2
0
S1 & S2
Routine
A
B
C
D
E
F
G
H
Zones
ADAS
983 - 31

Fig 9B

# All sites 1992 harvest

## Mean percent buttons with slug damage, by zone




ADAS

983 - 11

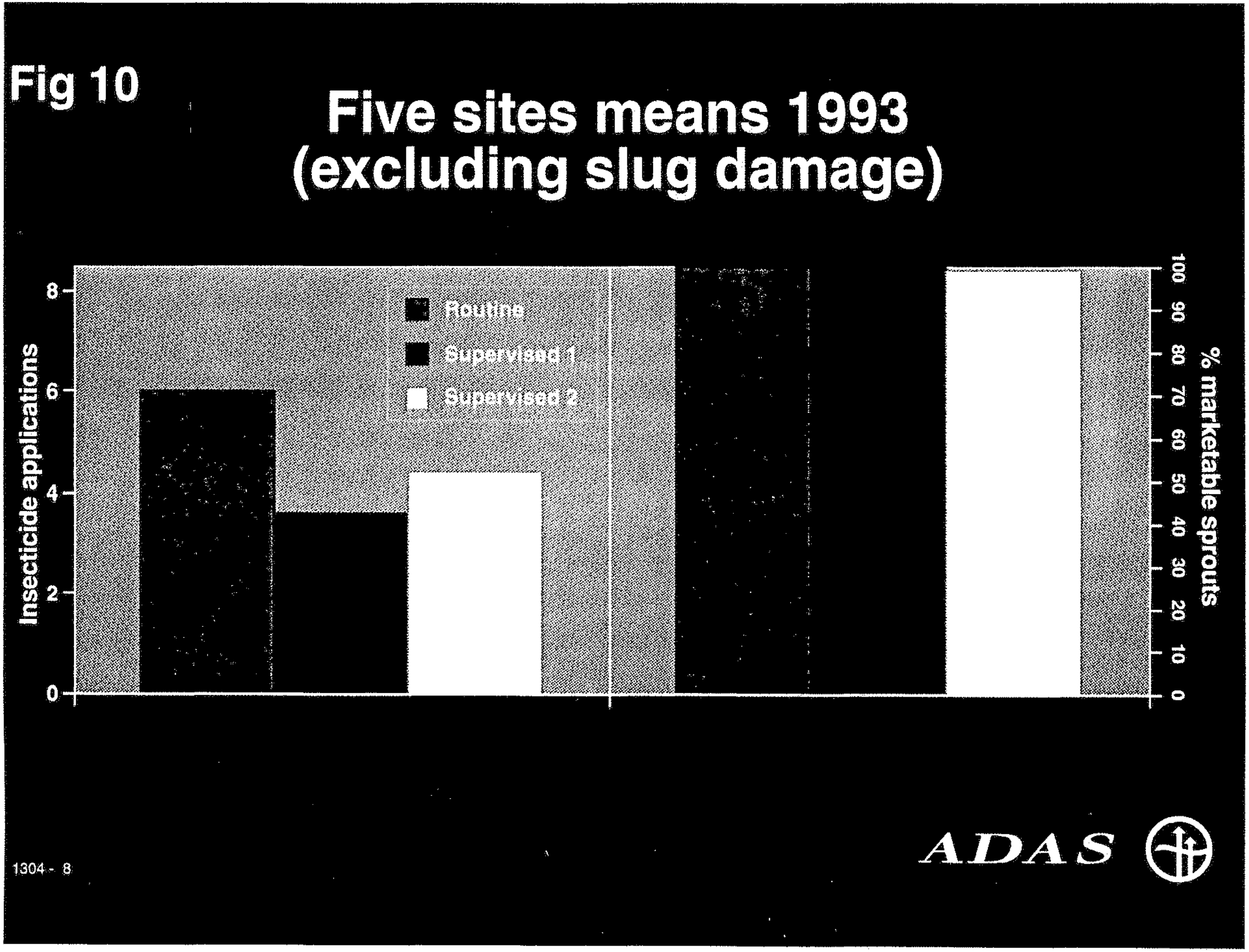
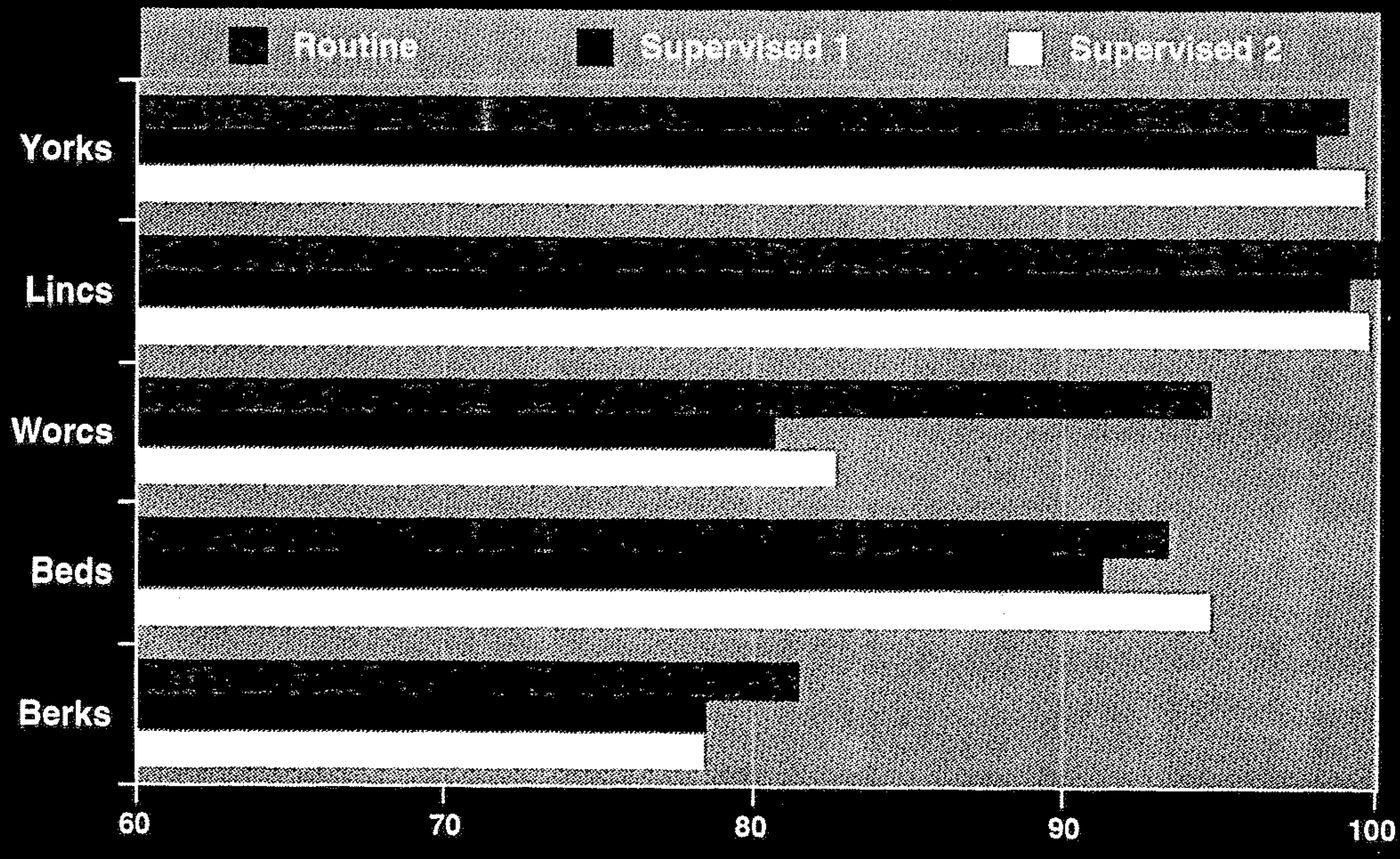


Fig 10
Five sites means 1993
(excluding slug damage)
Insecticide applications
0
2
4
6
8
Routine
Supervised 1
Supervised 2
% marketable sprouts
0
10
20
30
40
50
60
70
80
90
100
ADAS
1304 - 8

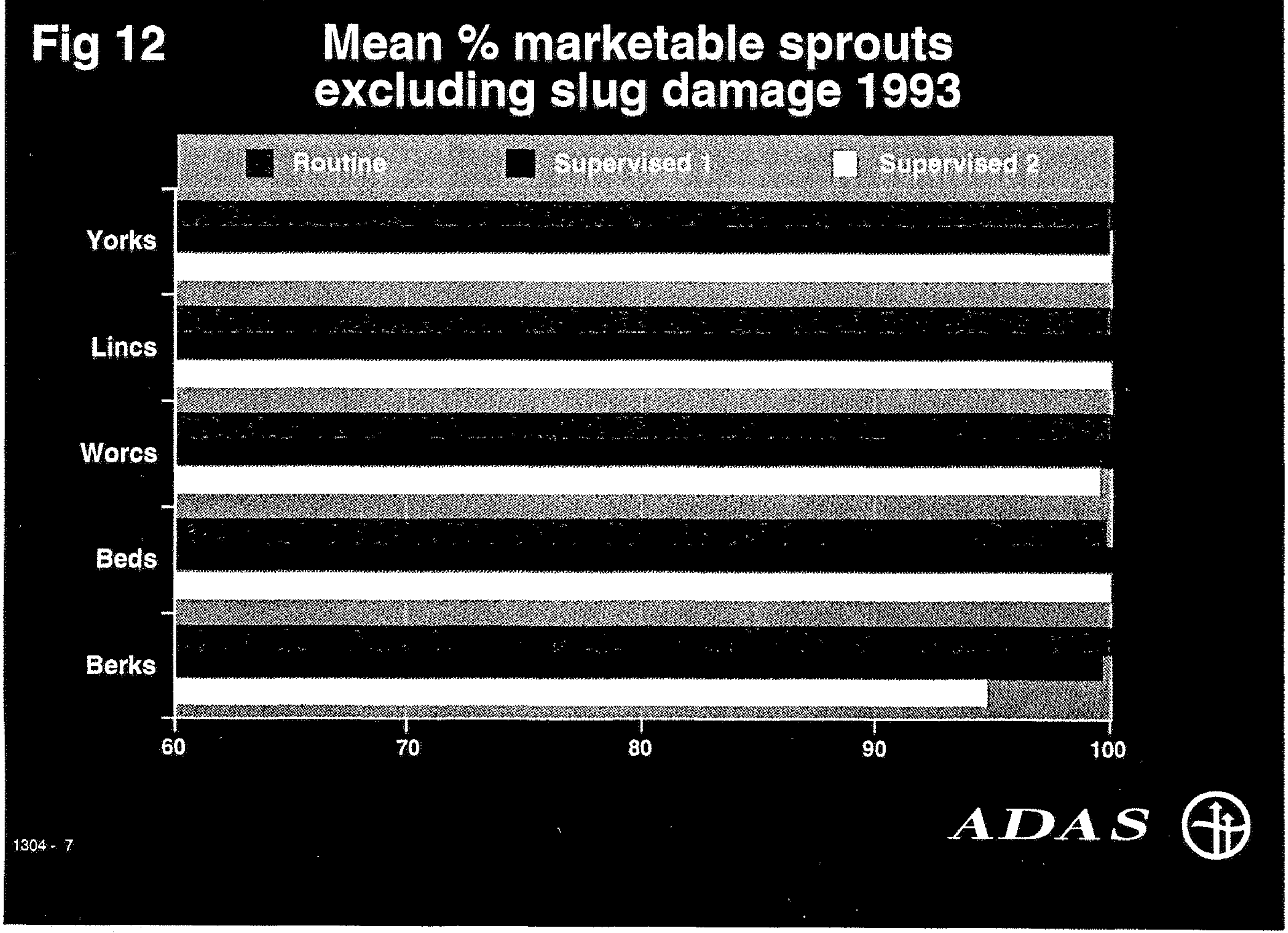
Fig 11
## Mean % marketable sprouts at harvest 1993




ADAS

1304 - 6

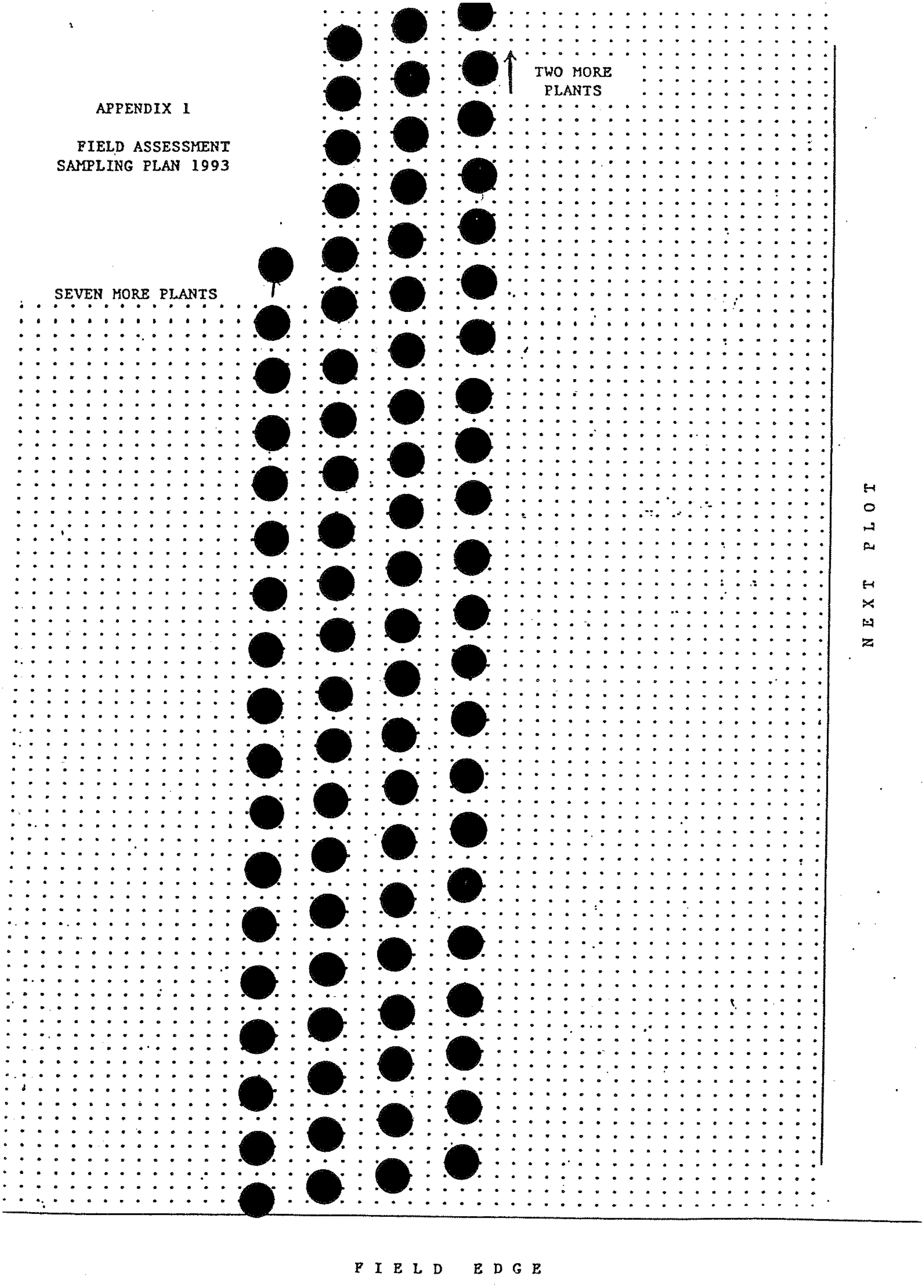
Fig 12



Mean % marketable sprouts excluding slug damage 1993
Routine
Supervised 1
Supervised 2
Yorks
Lincs
Worcs
Beds
Berks
60
70
80
90
100
ADAS
1304 - 7

APPENDIX 1

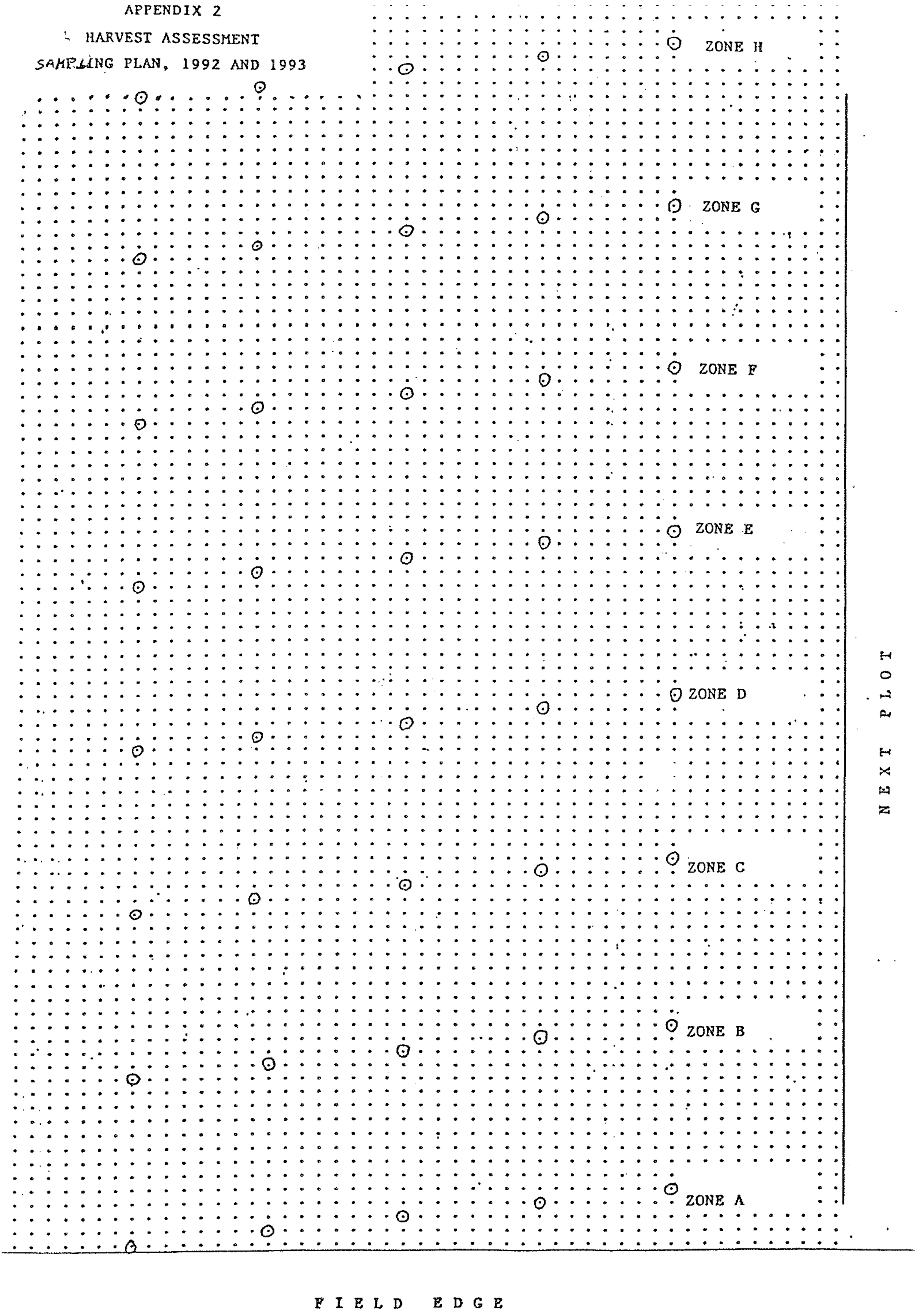
FIELD ASSESSMENT SAMPLING PLAN 1993



APPENDIX 2

HARVEST ASSESSMENT

SAMPLING PLAN, 1992 AND 1993



APPENDIX 3

## ECONOMIC EVALUATION (INCLUDING SLUG DAMAGE) 1993

| | | | |
|---|---|---|---|
| SITE: YORKSHIRE | | | |
| PERCENT MARKETABLE SPROUTS: | ROUTINE | = | 99.0 |
| | SUPERVISED 1 (DSM) | = | 98.0 |
| (FROM PEST ASSESSMENTS) | SUPERVISED 2 (APHOX) | = | 99.7 |
| PERCENT DIFFERENCE DUE TO PESTS: | ROUTINE - SUPERVISED 1 | = | 1.0 |
| | ROUTINE - SUPERVISED 2 | = | +0.7 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| FARM CROP YIELD (ROUTINE): | = | 15.4t/ha | | | ROUTINE CROP VALUE: | = | £3430 |
| CROP PRICE: | = | £225/t | = | 3465 | SUPERVISED 1 CROP VALUE | = | £3396 |
| | | | | | SUPERVISED 2 CROP VALUE | = | £3455 |

<u>Treatment and Monitoring Costs, Crop Value and Margin Over Costs</u>

| | DSM | | APHOX | | DECIS | | APPLICATIONS | | MONITORING VISITS | | TOTAL COST | CROP VALUE | MARGIN OVER COST |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | NOS. OF SPRAYS | COST £ | NOS. OF SPRAYS | COST £ | NOS. OF SPRAYS | COST £ | NOS. | COST £ | NOS. | COST £ | £ | £ | £ |
| ROUTINE | 9 | 48.8 | - | - | 9 | 47.7 | 9 | 180 | 0 | 0 | 276.5 | 3430 | 3153 |
| SUPERVISED 1 | 3 | 16.3 | - | - | 0 | 0 | 3 | 60 | 9 | 90 | 166.3 | 3396 | 3230 |
| SUPERVISED 2 | - | - | 4 | 75.0 | 0 | 0 | 4 | 80 | 10 | 100 | 255.0 | 3455 | 3200 |

AVERAGE MARGIN ROUTINE OVER SUPERVISED 1 = 77
AVERAGE MARGIN ROUTINE OVER SUPERVISED 2 = 47

Farm practice: Crop walking every 1-2 weeks, tank-mix sprays routinely at 2-3 week intervals

**APPENDIX 4**

## ECONOMIC EVALUATION (INCLUDING SLUG DAMAGE) 1993

**SITE:** LINCOLNSHIRE

| | | | |
|---|---|---|---|
| **PERCENT MARKETABLE SPROUTS:** | ROUTINE | = | 100 |
| | SUPERVISED 1 (DSM) | = | 99.1 |
| **(FROM PEST ASSESSMENTS)** | SUPERVISED 2 (APHOX) | = | 99.8 |
| **PERCENT DIFFERENCE DUE TO PESTS:** | ROUTINE - SUPERVISED 1 | = | 0.9 |
| | ROUTINE - SUPERVISED 2 | = | 0.2 |

| | | | | | | |
|---|---|---|---|---|---|---|
| **FARM CROP YIELD (ROUTINE):** | = 12t/ha | | | ROUTINE CROP VALUE: | = | £6000 |
| **CROP PRICE:** | = £500/t | = | 6000 | SUPERVISED 1 CROP VALUE | = | £5946 |
| | | | | SUPERVISED 2 CROP VALUE | = | £5988 |

**Treatment and Monitoring Costs, Crop Value and Margin Over Costs**

| | DSM | | APHOX | | DECIS | | APPLICATIONS | | MONITORING VISITS | | TOTAL COST | CROP VALUE | MARGIN OVER COST |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | NOS. OF SPRAYS | COST £ | NOS. OF SPRAYS | COST £ | NOS. OF SPRAYS | COST £ | NOS. | COST £ | NOS. | COST £ | £ | £ | £ |
| ROUTINE | 4 | 21.7 | - | - | 4 | 21.2 | 4 | 80 | 0 | 0 | 122.9 | 6000 | 5877 |
| SUPERVISED 1 | 2 | 10.9 | - | - | 1.3 | 6.9 | 3 | 60 | 10 | 100 | 177.8 | 5946 | 5768 |
| SUPERVISED 2 | - | - | 3 | 56.2 | 1 | 5.3 | 3 | 60 | 10 | 100 | 221.5 | 5988 | 5766 |

AVERAGE MARGIN ROUTINE OVER SUPERVISED 1 = 109
AVERAGE MARGIN ROUTINE OVER SUPERVISED 2 = 111

Farm practice: Crop walking every 1-2 weeks, tank-mix sprays routinely at 2-3 week intervals

**APPENDIX 5**

## ECONOMIC EVALUATION (INCLUDING SLUG DAMAGE) 1993

**SITE: WORCESTERSHIRE**

| | | | |
|---|---|---|---|
| **PERCENT MARKETABLE SPROUTS:** | **ROUTINE** | = | **94.6** |
| | **SUPERVISED 1 (DSM)** | = | **80.6** |
| **(FROM PEST ASSESSMENTS)** | **SUPERVISED 2 (APHOX)** | = | **82.7** |
| **PERCENT DIFFERENCE DUE TO PESTS:** | **ROUTINE - SUPERVISED 1** | = | **14.0** |
| | **ROUTINE - SUPERVISED 2** | = | **11.9** |

**FARM CROP YIELD (ROUTINE): = 11.6t/ha**

**CROP PRICE: = £314/t = 3642**

**ROUTINE CROP VALUE: = £3449**

**SUPERVISED 1 CROP VALUE = £2935**

**SUPERVISED 2 CROP VALUE = £3012**

**Treatment and Monitoring Costs, Crop Value and Margin Over Costs**

| | DSM | | APHOX | | DECIS | | APPLICATIONS | | MONITORING VISITS | | TOTAL COST | CROP VALUE | MARGIN OVER COST |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | NOS. OF SPRAYS | COST £ | NOS. OF SPRAYS | COST £ | NOS. OF SPRAYS | COST £ | NOS. | COST £ | NOS. | COST £ | £ | £ | £ |
| ROUTINE | 8 | 43.4 | - | - | 8 | 42.4 | 8 | 160 | 0 | 0 | 245.8 | 3449 | 3203 |
| SUPERVISED 1 | 6 | 32.6 | - | - | 2 | 10.6 | 8 | 160 | 9 | 90 | 293.2 | 2935 | 2642 |
| SUPERVISED 2 | - | - | 8 | 150 | 2 | 10.6 | 9 | 180 | 9 | 90 | 430.6 | 3012 | 2581 |

AVERAGE MARGIN ROUTINE OVER SUPERVISED 1 = 561

AVERAGE MARGIN ROUTINE OVER SUPERVISED 2 = 622

Farm practice: Crop walking every 1-2 weeks, tank-mix sprays routinely at 2-3 week intervals

APPENDIX 6

## ECONOMIC EVALUATION (INCLUDING SLUG DAMAGE) 1993

**SITE:** BEDFORDSHIRE

| | | | |
|---|---|---|---|
| **PERCENT MARKETABLE SPROUTS:** | **ROUTINE** | = | **93.3** |
| | **SUPERVISED 1 (DSM)** | = | **91.2** |
| **(FROM PEST ASSESSMENTS)** | **SUPERVISED 2 (APHOX)** | = | **94.7** |
| **PERCENT DIFFERENCE DUE TO PESTS:** | **ROUTINE - SUPERVISED 1** | = | **2.1** |
| | **ROUTINE - SUPERVISED 2** | = | **+1.4** |

**FARM CROP YIELD (ROUTINE):** = **14.4t/ha**

**CROP PRICE:** = **£300/t** = **4320**

**ROUTINE CROP VALUE:** = **£4031**

**SUPERVISED 1 CROP VALUE** = **£3940**

**SUPERVISED 2 CROP VALUE** = **£4091**

**Treatment and Monitoring Costs, Crop Value and Margin Over Costs**

| | DSM | | APHOX | | DECIS | | APPLICATIONS | | MONITORING VISITS | | TOTAL COST | CROP VALUE | MARGIN OVER COST |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | NOS. OF SPRAYS | COST £ | NOS. OF SPRAYS | COST £ | NOS. OF SPRAYS | COST £ | NOS. | COST £ | NOS. | COST £ | £ | £ | £ |
| ROUTINE | 4 | 21.7 | - | - | 4 | 21.2 | 4 | 80 | 0 | 0 | 122.9 | 4031 | 3908 |
| SUPERVISED 1 | 3 | 16.3 | - | - | 0 | 0 | 3 | 60 | 7 | 70 | 146.3 | 3940 | 3794 |
| SUPERVISED 2 | - | - | 3 | 56.2 | 0 | 0 | 3 | 60 | 7 | 70 | 186.2 | 4091 | 3905 |

AVERAGE MARGIN ROUTINE OVER SUPERVISED 1 = 114
AVERAGE MARGIN ROUTINE OVER SUPERVISED 2 = 3

Farm practice: Crop walking every 1-2 weeks, tank-mix sprays routinely at 2-3 week intervals

ADAS

APPENDIX 7

# ECONOMIC EVALUATION (INCLUDING SLUG DAMAGE) 1993

**SITE:** BERKSHIRE

| | | | |
|---|---|---|---|
| PERCENT MARKETABLE SPROUTS: | ROUTINE | = | 81.4 |
| | SUPERVISED 1 (DSM) | = | 78.4 |
| (FROM PEST ASSESSMENTS) | SUPERVISED 2 (APHOX) | = | 78.4 |
| PERCENT DIFFERENCE DUE TO PESTS: | ROUTINE - SUPERVISED 1 | = | 3.0 |
| | ROUTINE - SUPERVISED 2 | = | 3.0 |

FARM CROP YIELD (ROUTINE): = 11.9t/ha

CROP PRICE: = £225/t = 3034

ROUTINE CROP VALUE: = £2470

SUPERVISED 1 CROP VALUE = £2379

SUPERVISED 2 CROP VALUE = £2379

**Treatment and Monitoring Costs, Crop Value and Margin Over Costs**

| | DSM | | APHOX | | DECIS | | APPLICATIONS | | MONITORING VISITS | | TOTAL COST | CROP VALUE | MARGIN OVER COST |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | NOS. OF SPRAYS | COST £ | NOS. OF SPRAYS | COST £ | NOS. OF SPRAYS | COST £ | NOS. | COST £ | NOS. | COST £ | £ | £ | £ |
| ROUTINE | 5 | 27.2 | - | - | 5 | 26.5 | 5 | 100 | 0 | 0 | 153.7 | 2470 | 2316 |
| SUPERVISED 1 | 4 | 21.7 | - | - | 0 | 0 | 4 | 80 | 7 | 70 | 171.7 | 2379 | 2207 |
| SUPERVISED 2 | - | - | 4 | 75 | 0 | 0 | 4 | 80 | 7 | 70 | 225.0 | 2379 | 2154 |

AVERAGE MARGIN ROUTINE OVER SUPERVISED 1 = 109
AVERAGE MARGIN ROUTINE OVER SUPERVISED 2 = 162

Farm practice: Crop walking every 1-2 weeks, tank-mix sprays routinely at 2-3 week intervals

APPENDIX 8

## ECONOMIC EVALUATION (EXCLUDING SLUG DAMAGE) 1993

SITE: YORKSHIRE

| | | | |
|---|---|---|---|
| PERCENT MARKETABLE SPROUTS: | ROUTINE | = | 100 |
| | SUPERVISED 1 (DSM) | = | 99.9 |
| (FROM PEST ASSESSMENTS) | SUPERVISED 2 (APHOX) | = | 100 |
| PERCENT DIFFERENCE DUE TO PESTS: | ROUTINE - SUPERVISED 1 | = | 0.3 |
| | ROUTINE - SUPERVISED 2 | = | 0 |

FARM CROP YIELD (ROUTINE): = 15.4t/ha

CROP PRICE: = £225/t = 3465

ROUTINE CROP VALUE: = £3465

SUPERVISED 1 CROP VALUE = £3462

SUPERVISED 2 CROP VALUE = £3465

Treatment and Monitoring Costs, Crop Value and Margin Over Costs

| | DSM | | APHOX | | DECIS | | APPLICATIONS | | MONITORING VISITS | | TOTAL COST | CROP VALUE | MARGIN OVER COST |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | NOS. OF SPRAYS | COST £ | NOS. OF SPRAYS | COST £ | NOS. OF SPRAYS | COST £ | NOS. | COST £ | NOS. | COST £ | £ | £ | £ |
| ROUTINE | 9 | 48.8 | - | - | 9 | 47.7 | 9 | 180 | 0 | 0 | 276.5 | 3465 | 3188 |
| SUPERVISED 1 | 3 | 16.3 | - | - | - | - | 3 | 60 | 9 | 90 | 166.3 | 3462 | 3296 |
| SUPERVISED 2 | - | - | 4 | 75.0 | 0 | 0 | 4 | 80 | 10 | 100 | 255 | 3465 | 3210 |

AVERAGE MARGIN ROUTINE OVER SUPERVISED 1 = 108
AVERAGE MARGIN ROUTINE OVER SUPERVISED 2 = 22

Farm practice: Crop walking every 1-2 weeks, tank-mix sprays routinely at 2-3 week intervals

ADAS

APPENDIX 9

## ECONOMIC EVALUATION (EXCLUDING SLUG DAMAGE) 1993

SITE: LINCOLNSHIRE

| | | | |
|---|---|---|---|
| PERCENT MARKETABLE SPROUTS: | ROUTINE | = | 100 |
| | SUPERVISED 1 (DSM) | = | 100 |
| (FROM PEST ASSESSMENTS) | SUPERVISED 2 (APHOX) | = | 100 |
| PERCENT DIFFERENCE DUE TO PESTS: | ROUTINE - SUPERVISED 1 | = | 0 |
| | ROUTINE - SUPERVISED 2 | = | 0 |

FARM CROP YIELD (ROUTINE): = 12t/ha

CROP PRICE: = £500/t = 6000

ROUTINE CROP VALUE: = £6000

SUPERVISED 1 CROP VALUE = £6000

SUPERVISED 2 CROP VALUE = £6000

**Treatment and Monitoring Costs, Crop Value and Margin Over Costs**

| | DSM | | APHOX | | DECIS | | APPLICATIONS | | MONITORING VISITS | | TOTAL COST | CROP VALUE | MARGIN OVER COST |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | NOS. OF SPRAYS | COST £ | NOS. OF SPRAYS | COST £ | NOS. OF SPRAYS | COST £ | NOS. | COST £ | NOS. | COST £ | £ | £ | £ |
| ROUTINE | 4 | 21.7 | - | - | 4 | 21.2 | 4 | 80 | 0 | 0 | 122.9 | 6000 | 5877 |
| SUPERVISED 1 | 2 | 10.9 | - | - | 1.3 | 6.9 | 3 | 60 | 10 | 100 | 177.8 | 6000 | 5822 |
| SUPERVISED 2 | - | - | 3 | 56.2 | 1 | 5.3 | 3 | 60 | 10 | 100 | 221.5 | 6000 | 5778 |

AVERAGE MARGIN ROUTINE OVER SUPERVISED 1 = 55
AVERAGE MARGIN ROUTINE OVER SUPERVISED 2 = 99

Farm practice: Crop walking every 1-2 weeks, tank-mix sprays routinely at 2-3 week intervals

ADAS

APPENDIX 10

## ECONOMIC EVALUATION (EXCLUDING SLUG DAMAGE) 1993

SITE: WORCESTERSHIRE

| | | | |
|---|---|---|---|
| PERCENT MARKETABLE SPROUTS: | ROUTINE | = | 100 |
| | SUPERVISED 1 (DSM) | = | 100 |
| (FROM PEST ASSESSMENTS) | SUPERVISED 2 (APHOX) | = | 99.6 |
| PERCENT DIFFERENCE DUE TO PESTS: | ROUTINE - SUPERVISED 1 | = | 0 |
| | ROUTINE - SUPERVISED 2 | = | 0.4 |

FARM CROP YIELD (ROUTINE): = 11.6t/ha

CROP PRICE: = £314/t = 3642

ROUTINE CROP VALUE: = £3642

SUPERVISED 1 CROP VALUE = £3642

SUPERVISED 2 CROP VALUE = £3627

**Treatment and Monitoring Costs, Crop Value and Margin Over Costs**

| | DSM | | APHOX | | DECIS | | APPLICATIONS | | MONITORING VISITS | | TOTAL COST | CROP VALUE | MARGIN OVER COST |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | NOS. OF SPRAYS | COST £ | NOS. OF SPRAYS | COST £ | NOS. OF SPRAYS | COST £ | NOS. | COST £ | NOS. | COST £ | £ | £ | £ |
| ROUTINE | 8 | 43.4 | - | - | 8 | 42.4 | 8 | 160 | 0 | 0 | 245.8 | 3642 | 3396 |
| SUPERVISED 1 | 6 | 32.6 | - | - | 2 | 10.6 | 8 | 160 | 9 | 90 | 293.2 | 2935 | 3349 |
| SUPERVISED 2 | - | - | 8 | 150 | 2 | 10.6 | 9 | 180 | 9 | 90 | 430.6 | 3012 | 3196 |

AVERAGE MARGIN ROUTINE OVER SUPERVISED 1 = 47
AVERAGE MARGIN ROUTINE OVER SUPERVISED 2 = 200

Farm practice: Crop walking every 1-2 weeks, tank-mix sprays routinely at 2-3 week intervals

APPENDIX 11

## ECONOMIC EVALUATION (EXCLUDING SLUG DAMAGE) 1993

| | | | |
|---|---|---|---|
| SITE: BEDFORDSHIRE | | | |
| PERCENT MARKETABLE SPROUTS: | ROUTINE | = | 99.8 |
| | SUPERVISED 1 (DSM) | = | 100 |
| (FROM PEST ASSESSMENTS) | SUPERVISED 2 (APHOX) | = | 100 |
| PERCENT DIFFERENCE DUE TO PESTS: | ROUTINE - SUPERVISED 1 | = | +0.2 |
| | ROUTINE - SUPERVISED 2 | = | +0.2 |

FARM CROP YIELD (ROUTINE): = 14.4t/ha

CROP PRICE: = £300/t = 4320

ROUTINE CROP VALUE: = £4311

SUPERVISED 1 CROP VALUE = £4320

SUPERVISED 2 CROP VALUE = £4320

**Treatment and Monitoring Costs, Crop Value and Margin Over Costs**

| | DSM | | APHOX | | DECIS | | APPLICATIONS | | MONITORING VISITS | | TOTAL COST | CROP VALUE | MARGIN OVER COST |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | NOS. OF SPRAYS | COST £ | NOS. OF SPRAYS | COST £ | NOS. OF SPRAYS | COST £ | NOS. | COST £ | NOS. | COST £ | £ | £ | £ |
| ROUTINE | 4 | 21.7 | - | - | 4 | 21.2 | 4 | 80 | 0 | 0 | 122.9 | 4311 | 4188 |
| SUPERVISED 1 | 3 | 16.3 | - | - | 0 | 0 | 3 | 60 | 7 | 70 | 146.3 | 4320 | 4174 |
| SUPERVISED 2 | - | - | 3 | 56.2 | 0 | 0 | 3 | 60 | 7 | 70 | 186.2 | 4320 | 4134 |

AVERAGE MARGIN ROUTINE OVER SUPERVISED 1 = 14

AVERAGE MARGIN ROUTINE OVER SUPERVISED 2 = 54

Farm practice: Crop walking every 1-2 weeks, tank-mix sprays routinely at 2-3 week intervals

ADAS

APPENDIX 12

## ECONOMIC EVALUATION (EXCLUDING SLUG DAMAGE) 1993

**SITE:** BERKSHIRE

| | | | |
|---|---|---|---|
| PERCENT MARKETABLE SPROUTS: | ROUTINE | = | 100 |
| | SUPERVISED 1 (DSM) | = | 99.7 |
| (FROM PEST ASSESSMENTS) | SUPERVISED 2 (APHOX) | = | 94.8 |
| PERCENT DIFFERENCE DUE TO PESTS: | ROUTINE - SUPERVISED 1 | = | 0.3 |
| | ROUTINE - SUPERVISED 2 | = | 5.2 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| FARM CROP YIELD (ROUTINE): | = | 11.9t/ha | | | ROUTINE CROP VALUE: | = | £3034 |
| CROP PRICE: | = | £225/t | = | 3034 | SUPERVISED 1 CROP VALUE | = | £3025 |
| | | | | | SUPERVISED 2 CROP VALUE | = | £2876 |

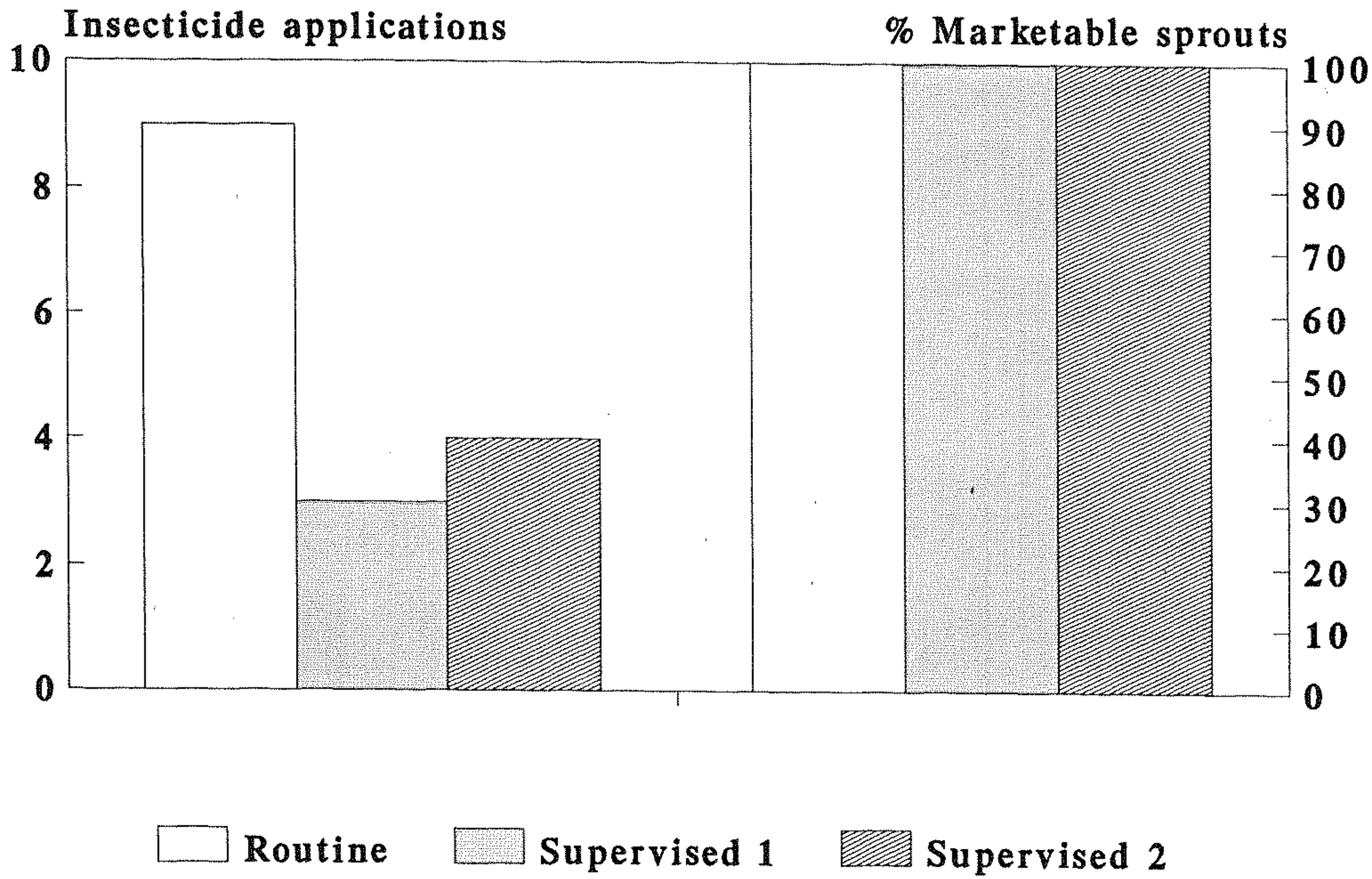
<u>Treatment and Monitoring Costs, Crop Value and Margin Over Costs</u>

| | DSM | | APHOX | | DECIS | | APPLICATIONS | | MONITORING VISITS | | TOTAL COST | CROP VALUE | MARGIN OVER COST |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | NOS. OF SPRAYS | COST £ | NOS. OF SPRAYS | COST £ | NOS. OF SPRAYS | COST £ | NOS. | COST £ | NOS. | COST £ | £ | £ | £ |
| ROUTINE | 5 | 27.2 | - | - | 5 | 26.5 | 5 | 100 | 0 | 0 | 153.7 | 3034 | 2880 |
| SUPERVISED 1 | 4 | 21.7 | - | - | 0 | 0 | 4 | 80 | 7 | 70 | 171.7 | 3025 | 2853 |
| SUPERVISED 2 | - | - | 4 | 75 | 0 | 0 | 4 | 70 | 7 | 70 | 225.0 | 2876 | 2651 |

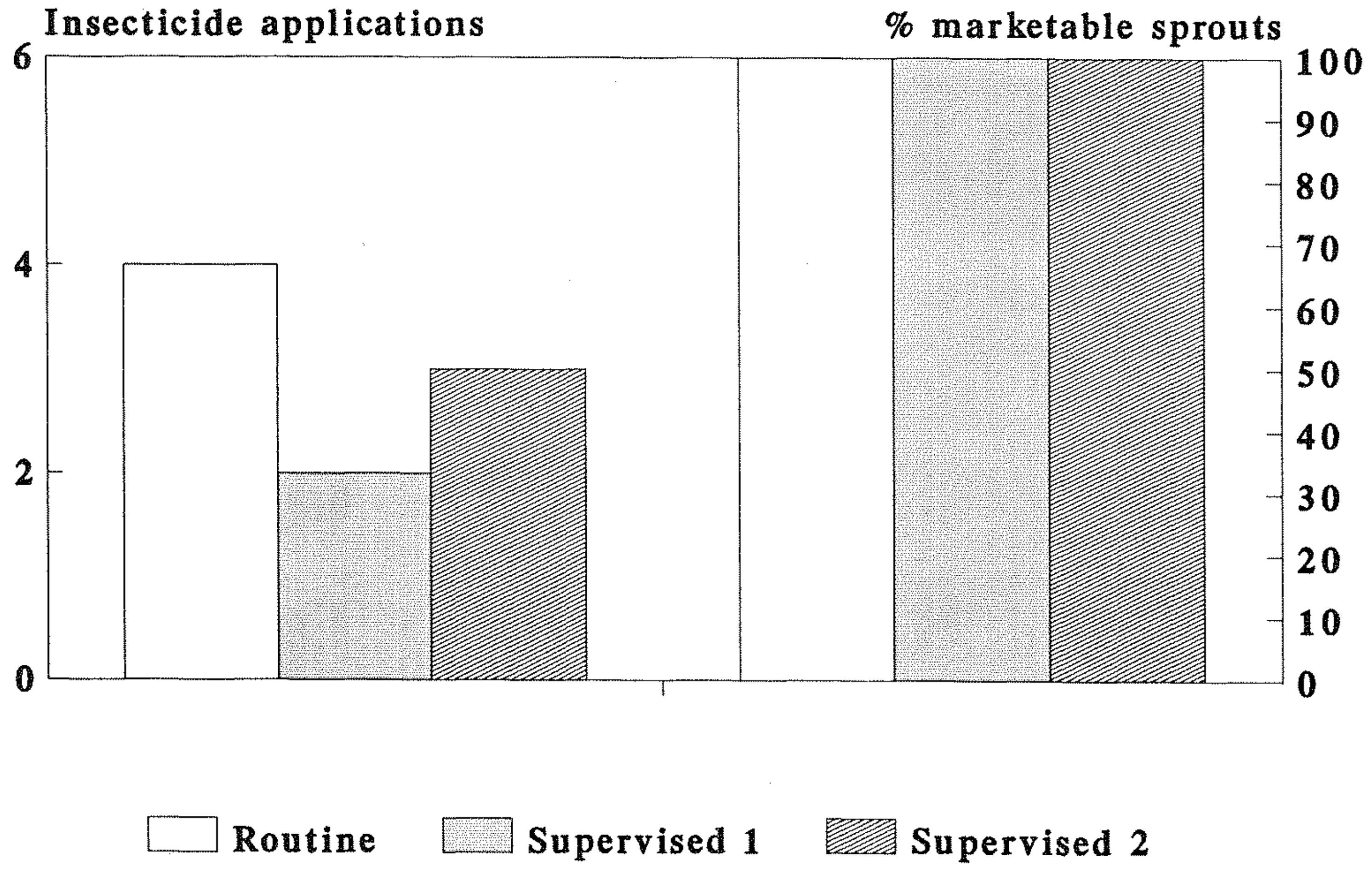
AVERAGE MARGIN ROUTINE OVER SUPERVISED 1 = 27
AVERAGE MARGIN ROUTINE OVER SUPERVISED 2 = 229

Farm practice: Crop walking every 1-2 weeks, tank-mix sprays routinely at 2-3 week intervals

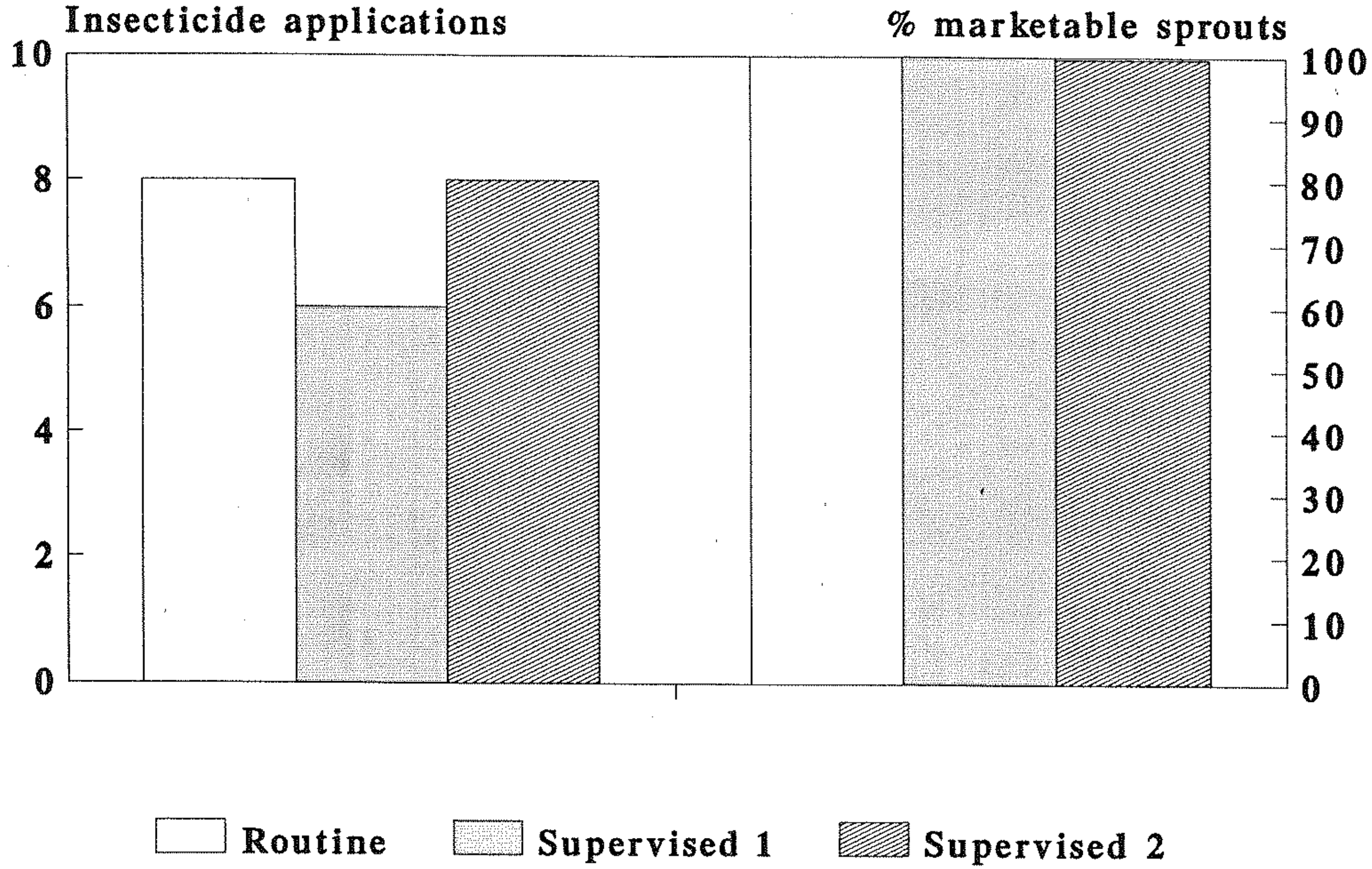
# Appendix 13 Yorkshire 1993 (excluding slug damage)



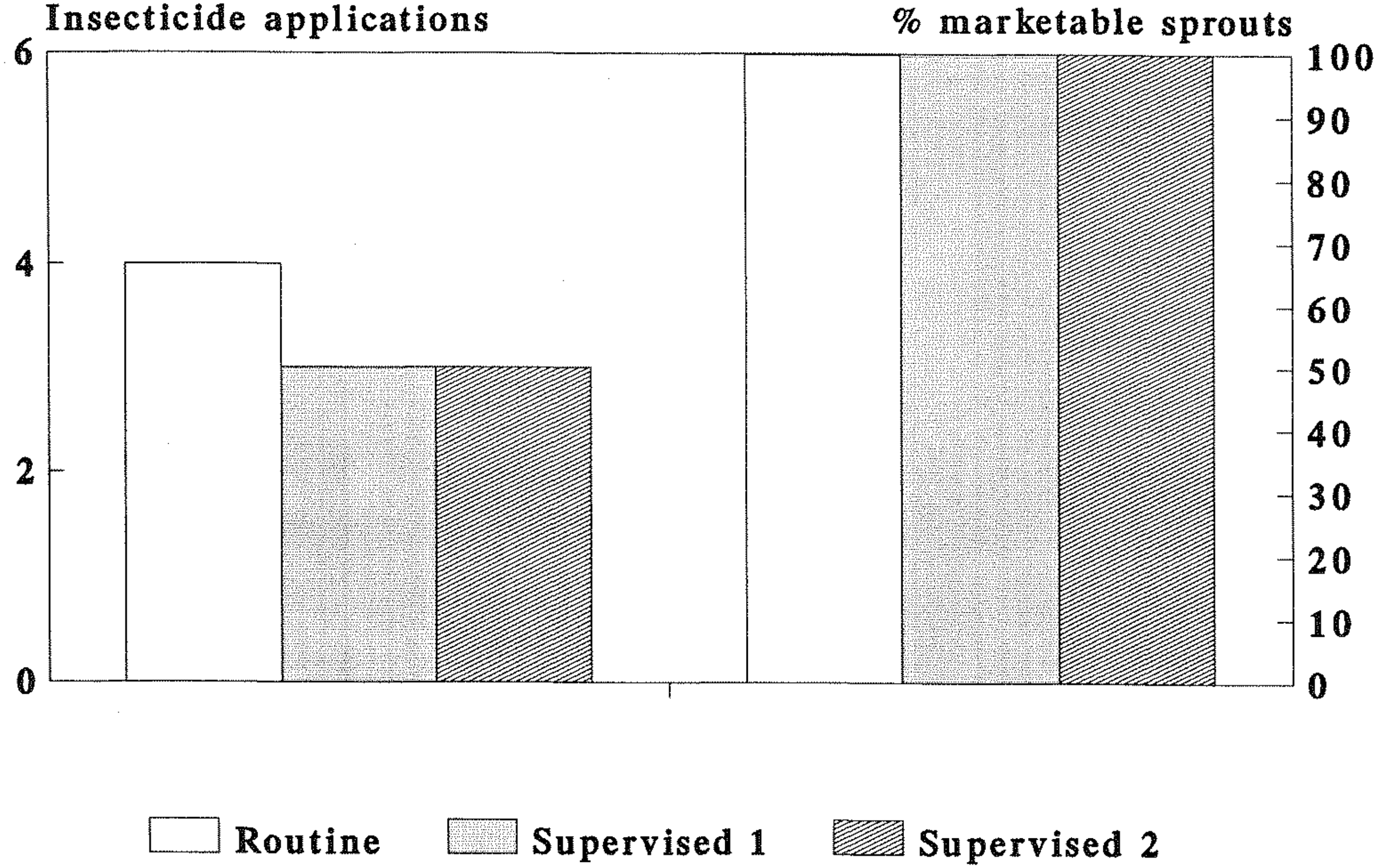
# Appendix 14 Lincolnshire 1993 (excluding slug damage)



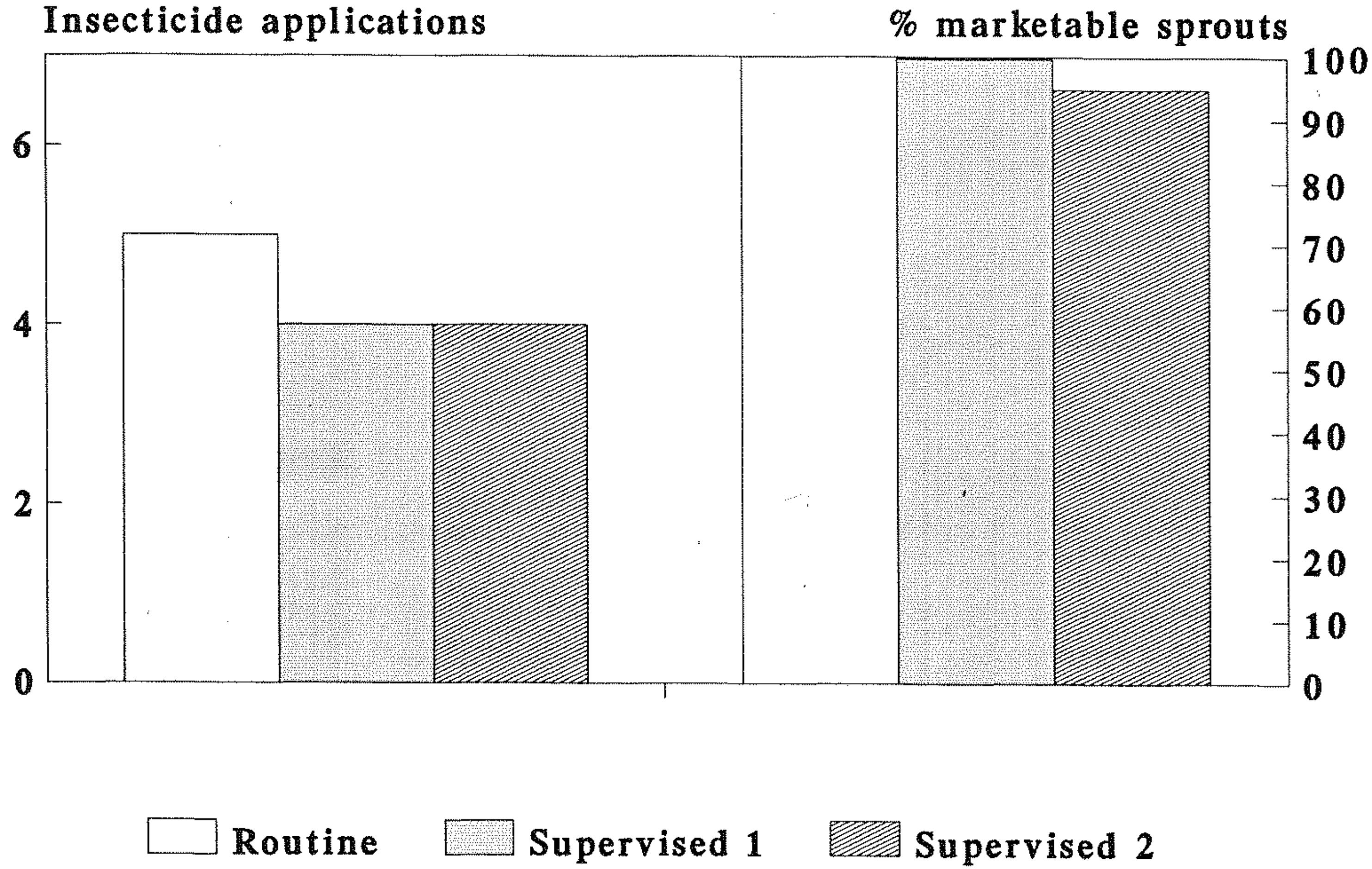
# Appendix 15 Worcestershire 1993 (excluding slug damage)



# Appendix 16 Bedfordshire 1993 (excluding slug damage)



# Appendix 17 Berkshire 1993 (excluding slug damage)



## PROBABILITY OF MAKING EACH OF THREE DECISIONS (NO SPRAY, NO DECISION, SPRAY) FOR SAMPLE SIZES OF 50-150 PLANTS

**Tolerance (Threshold) = 10%**

**a) At a true infestation level of 4%**

| SAMPLE SIZE | PR (NO SPRAY) | PR (NO DECISION) | PR (SPRAY) |
|---|---|---|---|
| 50 | 0.677 | 0.322 | 0.001 |
| 60 | 0.781 | 0.218 | 0.001 |
| 70 | 0.693 | 0.307 | 0.000 |
| 80 | 0.784 | 0.216 | 0.000 |
| 90 | 0.848 | 0.152 | 0.000 |
| 100 | 0.894 | 0.106 | 0.000 |
| 110 | 0.848 | 0.152 | 0.000 |
| 120 | 0.891 | 0.109 | 0.000 |
| 130 | 0.922 | 0.078 | 0.000 |
| 140 | 0.945 | 0.055 | 0.000 |
| 150 | 0.920 | 0.080 | 0.000 |

## PROBABILITY OF MAKING EACH OF THREE DECISIONS (NO SPRAY, NO DECISION, SPRAY) FOR SAMPLE SIZES OF 50-150 PLANTS

**b) At a true infestation level of 8%**

| SAMPLE SIZE | PR (NO SPRAY) | PR (NO DECISION) | PR (SPRAY) |
|---|---|---|---|
| 50 | 0.226 | 0.730 | 0.044 |
| 60 | 0.283 | 0.669 | 0.048 |
| 70 | 0.179 | 0.798 | 0.023 |
| 80 | 0.224 | 0.751 | 0.025 |
| 90 | 0.265 | 0.708 | 0.027 |
| 100 | 0.303 | 0.669 | 0.028 |
| 110 | 0.214 | 0.756 | 0.030 |
| 120 | 0.248 | 0.722 | 0.030 |
| 130 | 0.279 | 0.690 | 0.031 |
| 140 | 0.310 | 0.674 | 0.016 |
| 150 | 0.232 | 0.752 | 0.017 |

**PROBABILITY OF MAKING EACH OF THREE DECISIONS (NO SPRAY, NO DECISION, SPRAY) FOR SAMPLE SIZES OF 50-150 PLANTS**

**Tolerance (Threshold) = 10%**

**c) At a true infestation level of 10%**

| SAMPLE SIZE | PR (NO SPRAY) | PR (NO DECISION) | PR (SPRAY) |
|---|---|---|---|
| 50 | 0.112 | 0.766 | 0.122 |
| 60 | 0.137 | 0.721 | 0.142 |
| 70 | 0.071 | 0.842 | 0.087 |
| 80 | 0.088 | 0.812 | 0.100 |
| 90 | 0.103 | 0.784 | 0.113 |
| 100 | 0.117 | 0.759 | 0.124 |
| 110 | 0.068 | 0.798 | 0.134 |
| 120 | 0.078 | 0.778 | 0.144 |
| 130 | 0.088 | 0.759 | 0.153 |
| 140 | 0.097 | 0.797 | 0.106 |
| 150 | 0.060 | 0.827 | 0.113 |

**PROBABILITY OF MAKING EACH OF THREE DECISIONS (NO SPRAY, NO DECISION, SPRAY) FOR SAMPLE SIZES OF 50-150 PLANTS**

**Tolerance (Threshold) = 10%**

**d) At a true infestation level of 12%**

| SAMPLE SIZE | PR (NO SPRAY) | PR (NO DECISION) | PR (SPRAY) |
|---|---|---|---|
| 50 | 0.051 | 0.702 | 0.247 |
| 60 | 0.060 | 0.650 | 0.290 |
| 70 | 0.025 | 0.761 | 0.214 |
| 80 | 0.030 | 0.721 | 0.249 |
| 90 | 0.034 | 0.685 | 0.281 |
| 100 | 0.037 | 0.652 | 0.311 |
| 110 | 0.017 | 0.643 | 0.340 |
| 120 | 0.019 | 0.614 | 0.367 |
| 130 | 0.021 | 0.587 | 0.392 |
| 140 | 0.022 | 0.658 | 0.320 |
| 150 | 0.011 | 0.646 | 0.343 |

## PROBABILITY OF MAKING EACH OF THREE DECISIONS (NO SPRAY, NO DECISION, SPRAY) FOR SAMPLE SIZES OF 50-150 PLANTS

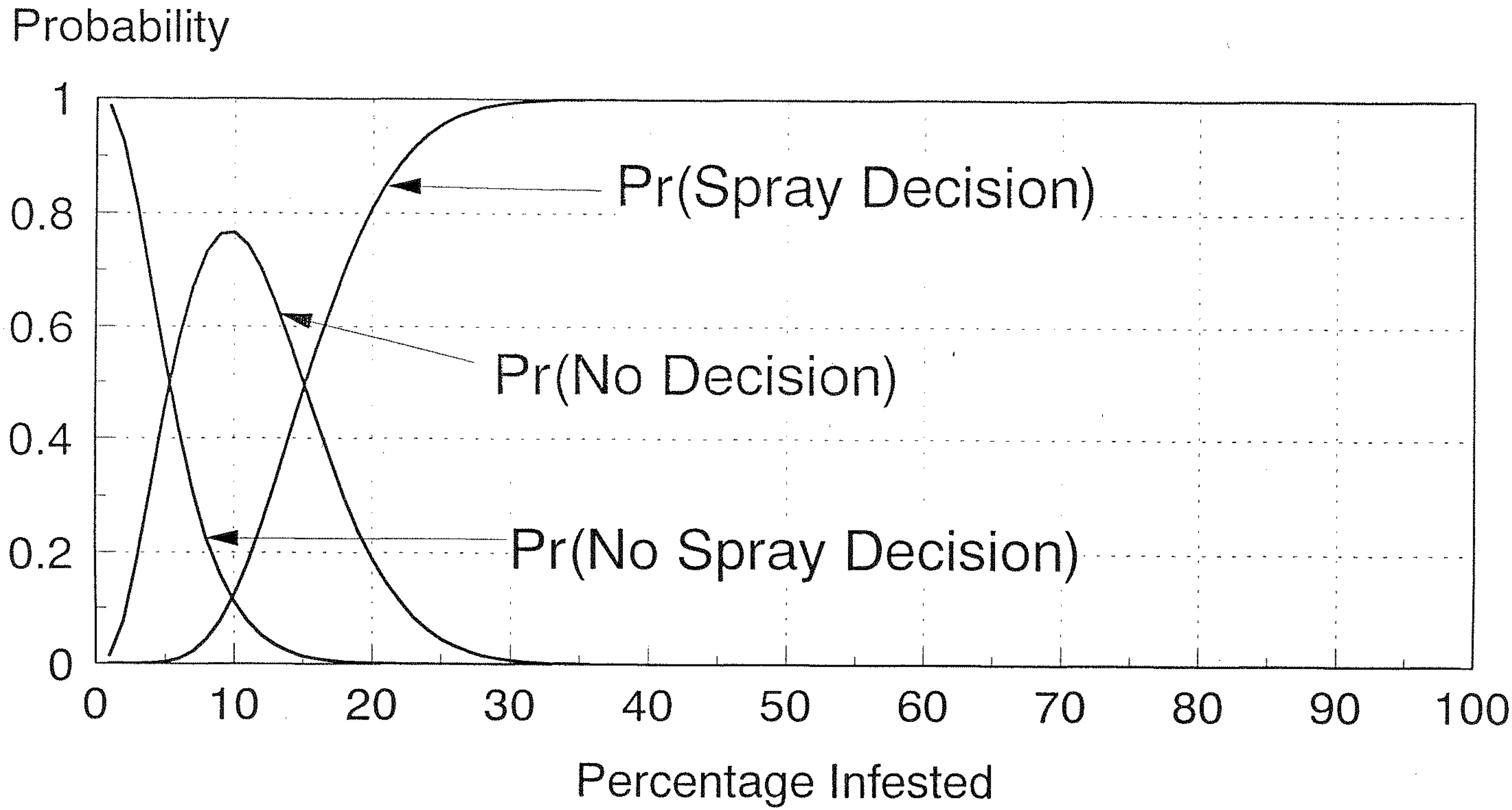
**Tolerance (Threshold) = 10%**

**e) At a true infestation level of 16%**

| SAMPLE SIZE | PR (NO SPRAY) | PR (NO DECISION) | PR (SPRAY) |
|---|---|---|---|
| 50 | 0.009 | 0.432 | 0.559 |
| 60 | 0.009 | 0.354 | 0.637 |
| 70 | 0.002 | 0.422 | 0.576 |
| 80 | 0.002 | 0.355 | 0.643 |
| 90 | 0.002 | 0.299 | 0.699 |
| 100 | 0.002 | 0.251 | 0.747 |
| 110 | 0.001 | 0.212 | 0.787 |
| 120 | 0.001 | 0.179 | 0.820 |
| 130 | 0.001 | 0.150 | 0.849 |
| 140 | 0.001 | 0.185 | 0.814 |
| 150 | 0.000 | 0.158 | 0.842 |

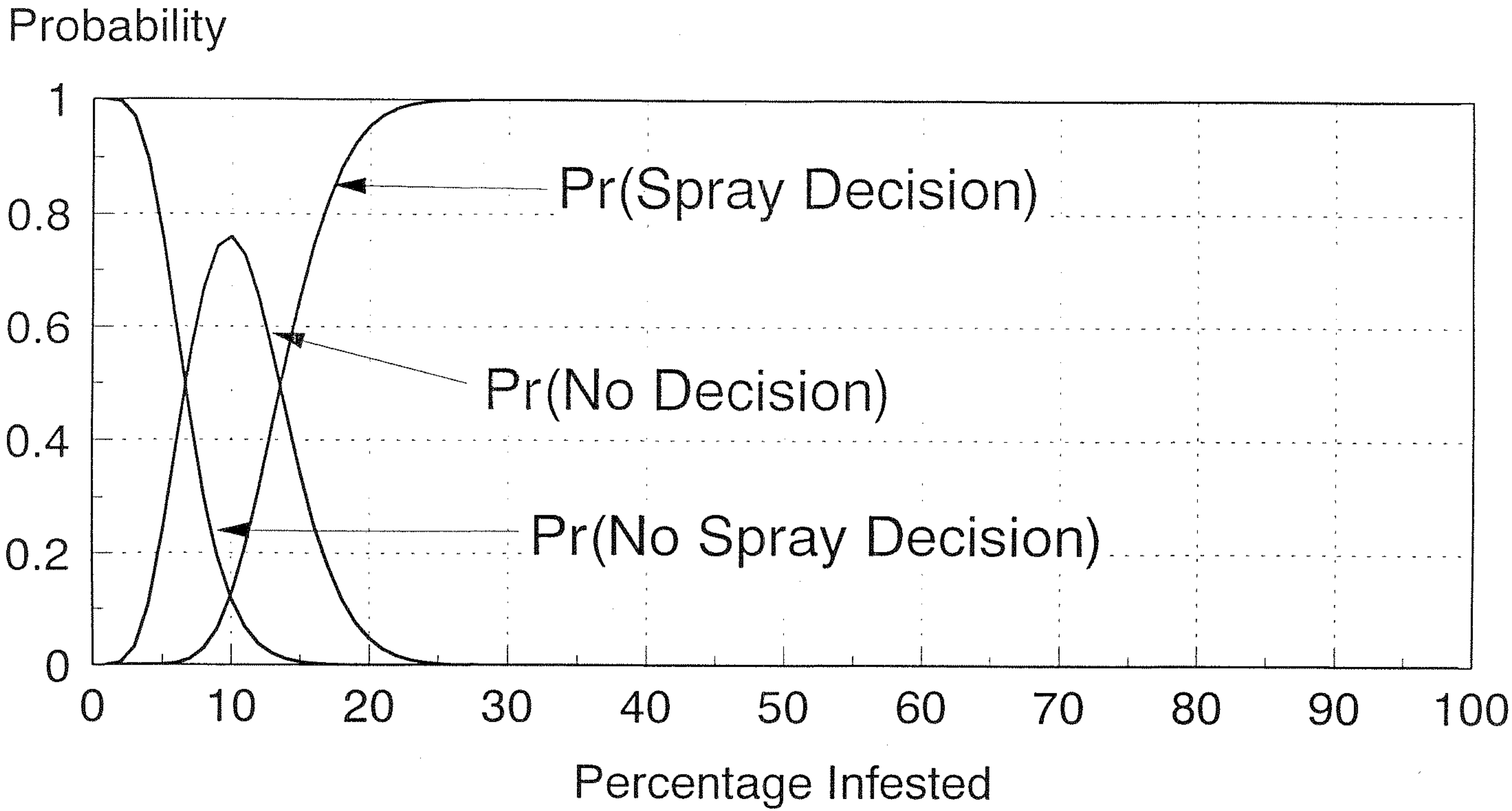
# Appendix 23

## Sample size = 50 ; Tolerance = 10%



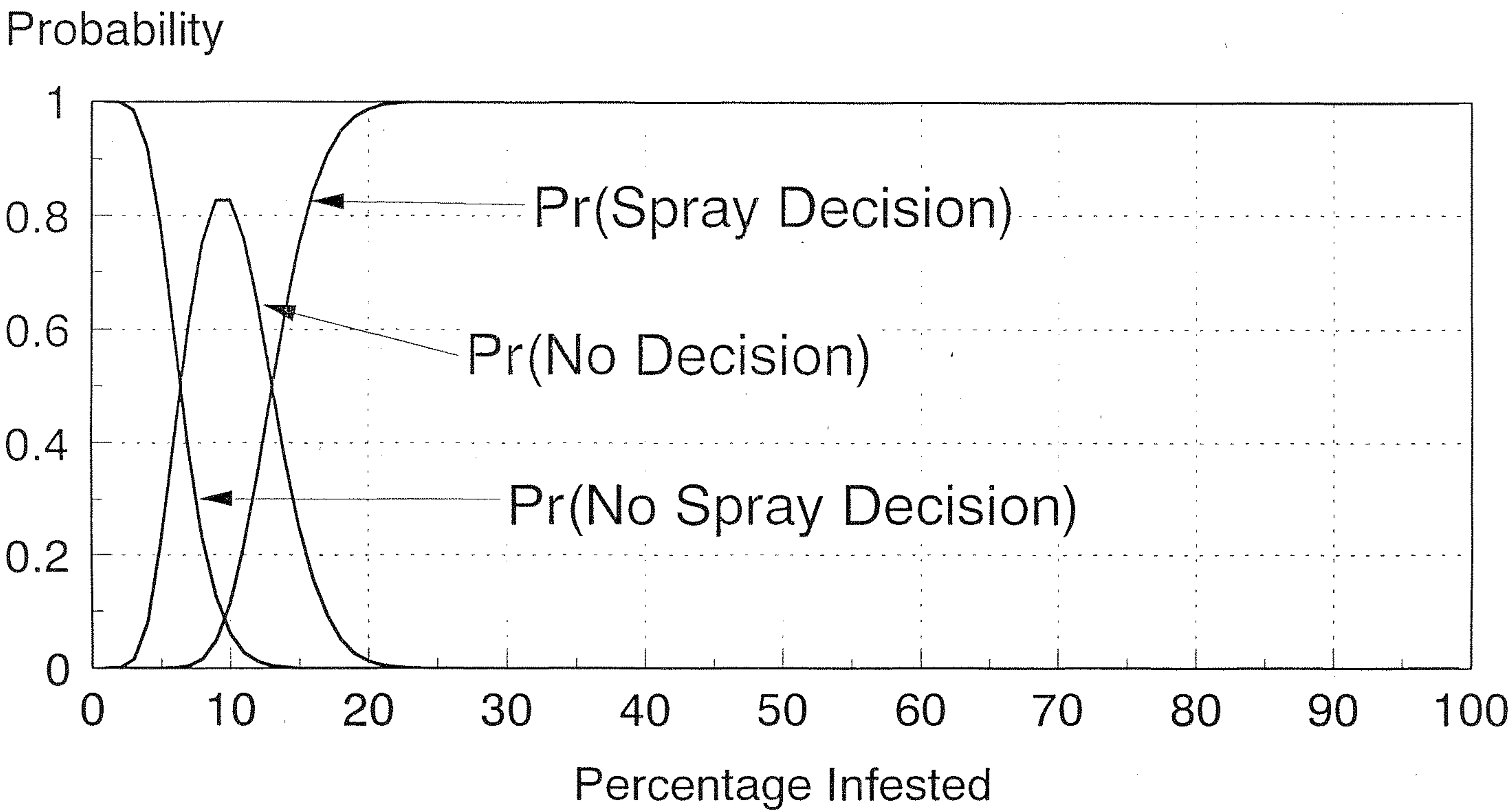
# Appendix 24

## Sample size = 100 ; Tolerance = 10%



# Appendix 25

## Sample size = 150 ; Tolerance = 10%



Contract between ADAS and HRI (hereinafter called the "Contractors") and the Horticultural Development Council (hereinafter called the "Council") for research/development project.

1. **TITLE OF PROJECT**

**Contract No: FV/119**
**(Modified contract for second year)**
**Contract date: 13.8.93**

INTEGRATED PEST MANAGEMENT OF INSECT PESTS IN BRASSICA CROPS

2. **BACKGROUND AND COMMERCIAL OBJECTIVE**

As for FV119.

A simplified version of the supervised control experiment currently funded by MAFF Pesticide Safety Division as F05D, is intended to establish over 2 years, on commercial holdings, a cost-effective pest monitoring system for use by farmers and consultants. A systematic sampling method and treatment thresholds have been tested in year 1 for control of caterpillars and cabbage aphid on Brussels sprouts. For 1993, these procedures and assessments will be tested with as few changes as possible. Additional funding and changes in pricing structure have resulted in a 30% increase in resource input to test an extra supervised treatment (pirimicarb in addition to DSM) and obtain baseline information on aphid parasitoids.

3. **POTENTIAL FINANCIAL BENEFIT TO THE INDUSTRY**

As for FV119.

4. **SCIENTIFIC/TECHNICAL TARGET OF THE WORK**

As for FV119.

5. **CLOSELY RELATED WORK - COMPLETED OR IN PROGRESS**

As for FV119.

6. **DESCRIPTION OF THE WORK IN YEAR 2 (1993/4)**

<u>CROP</u>

Brussels sprouts, planted preferably mid-late May at 51 cm spacing. This crop is studied in project F05D, is grown in most regions of the UK and suffers pests problems in most years.

**SAMPLING METHOD**

A systematic method will be used to assess pest numbers in the crop (N.B. the headland will not be separately assessed or treated this year because the work in 1992 proved too time consuming and impractical for consultants and growers alike. Also the "Zoning" system for harvest assessments indicated a more even distribution of caterpillar and cabbage aphid infestation than expected, with little merit in headland spraying. The "zones" will again test this point).

Walk into the crop (starting from the first plant), assess every fourth plant until 25 plants are checked; then move across 4 rows (and up one plant), assessing every fourth plant on the return traverse to the headland. Repeat this process with a third and fourth traverse (starting at the third plant and ending with the fourth plant in from the headland): total = 100 plants.

Each of the supervised plots will be assessed fortnightly. If "no decision" is made on one or more plots, ie nearly a threshold (see Table 1) then these plots only will be rechecked one week later; the remaining plots being assessed two weeks later.

**NB All plots are treated as separate units so that it may be necessary to assess and/or treat some parts of the trial in every week.**

<u>ASSESSMENTS</u>

1. <u>Aphids</u>

On each selected plant, the presence or absence of cabbage aphid will be assessed. The threshold is applicable to live wingless cabbage aphid only. However, a general comment on other species seen, such as potato aphid and peach potato aphid will be made. These are illustrated on identification cards (IC) IC nos 125 and 127 respectively.

2. <u>Cabbage Aphid Parasitoids.</u>

On each selected plant, presence or absence of "Mummies" of the parasitic wasps *Diaeretiella rapae* and/or *Aphidius* species will be recorded. The aphid colonies in each plot (up to 10 per plot) with no obvious "mummies" will be tagged. At the next visit, the presence or absence of "mummies" will be recorded ie whether any parasitoids have developed over the 1-2 week period. On one occasion during the season, Ben Emmett at Leeds will examine a sample of unemerged "mummies" for adult parasitoid identification.

3. <u>Caterpillars</u>

The presence or absence of cabbage caterpillars will be assessed on each selected plant. The threshold is applicable to the major cabbage caterpillars:

| | |
|---|---|
| Small white butterfly | - *Pieris rapae* (IC 41) |
| Green - veined white butterfly | - *Pieris napi* (IC 42) |

| | |
|---|---|
| Cabbage moth | - *Mamestra brassicae* (IC 47) |
| Diamond-back moth | - *Plutella xylostella* (IC 43) |

If other species occur, an attempt will to be made to identify them. They may be sent to Ben Emmett at Leeds as necessary.

**THRESHOLDS - PERCENT PLANTS INFESTED**

| PEST | PERIOD FROM PLANTING/FOUR TRUE LEAVES ~~GROWTH STAGE OF BRUSSELS SPROUT PLANTS~~ | | |
|---|---|---|---|
| | ~~INITIAL~~ 0-10 weeks | ~~LEAVES TOUCHING~~ 11-15 weeks | ~~FROM BUTTON INITIATION~~ 16 weeks onwards |
| APHID | ~~20~~ 10 | ~~10~~ 5 | ~~5~~ 0 |
| CATERPILLAR (all species) | 40 | ~~40~~ 5 | ~~5~~ 0 |

Whitefly will not be assessed this year.

**TREATMENTS:**

Each replicate will be considered separately eg plots that achieve threshold numbers will be sprayed; those that do not, will remain unsprayed on that occasion.

1. Routine Treatment (R)

A tank-mix application of demeton-S-methyl at 325 g ai per hectare (560 ml per hectare of eg Campbell's DSM and deltamethrin at 3.75 g ai per hectare (150 ml per hectare of Decis), to protect the crop against aphids and caterpillars respectively, should be applied in 600 litres of water per hectare from the standard farm spraying apparatus, every two weeks from three weeks after transplanting until two weeks before the plots are harvested. This treatment or similar, is regarded as standard for most Brussels sprout crops grown in Bedfordshire, West Midlands, Lincolnshire and Yorkshire. There may be a tendency for fewer sprays than these to be used in the Thames Valley.

2. Supervised Treatment (S1)

Insecticides as above applied singly or in tank-mix according to monitoring results, DSM only, if aphid threshold exceeded. Deltamethrin at 7.5 g ai per hectare 300 ml per hectare of Decis only, if caterpillar threshold exceeded. Both insecticides if both thresholds exceeded.

3. Supervised Treatment (S2)

Insecticides applied singly or in tank-mix according to monitoring results, ie pirimicarb at 210 g ai per hectare (420g of product) only, if aphid threshold exceeded.

Deltamethrin at 7.5g ai per hectare (300 ml per hectare of Decis) only, if caterpillar threshold exceeded. Both insecticides if both thresholds exceeded.

**DESIGN AND LAYOUT**

Three treatments:

- R = Routine
- S1 = Supervised Control (DSM)
- S2 = Supervised Control (Pirimicarb)

No untreated control is required. The three treatments will be replicated three times. Nine plots of minimum size 26 x 52 m (5,000 plants); preferably divided into nine randomised plots.

**HARVEST ASSESSMENTS**

In each of the nine plots, 40 plants will be assessed. For pest assessments, three buttons per stem; one top, one middle and one bottom will be recorded. For yield assessments all buttons from the 40 plants will be harvested, graded and weighed.

Harvest sampling method

For each plot at harvest, five rows into the crop, eg headland rows 8, 16, 24, 32 and 40 will be selected. Moving into the crop, every 12th plant in these rows, moving up one plant in each successive row, ie plant 1, 12, 24, 36, 48, 60, 72 and 84 in row 8; 2, 13, 25, 37 etc. in row 16; 3, 14, 26 etc in row 24 will be taken. Three buttons per stem, will be cut open and examined for presence or absence of pest damage ie aphid, caterpillar, slug - and also the pest itself. The pests under the wing leaves will be checked and recorded separately. The buttons in separate categories ie top, middle and bottom will be graded as <12.5mm, 12.5-20mm, 21-30mm, 31-40mm and >40mm. As in 1992, the pest numbers at increasing distances into the crop will be assessed and the results will be recorded in separate "zones" (ie. 5 top, 5 middle and 5 bottom sprouts). The plants will be assessed progressingly further into the crop.

**NB** **If growers field insecticide treatment for control of the two main pests is different from the experimental treatments, then one extra harvest assessment must be taken from the field crop in addition to those from each of the three replicates in the routine and two supervised treatments. To avoid this complication we should try to persuade the growers to use Decis and DSM or Aphox.**

**RESULTS**

1. Fortnightly pest assessments for all supervised plots, with comments on decisions taken ie "no decision - repeated one week later".

Plot Summaries

2. Grading of marketable produce - numbers per category ie sprout buttons < 12.5, 12.5-20mm, 21-30mm, 31-40mm and > 40mm.

3. Pest damaged buttons - recorded separately for each of the 8 zones.

   a. Internal and external:

   i. Total pest damage.

   ii. Total aphid damage, (distorted, marked or discoloured).

   iii. Total caterpillar damage.

   iv. Other (eg whitefly contaminated with honeydew/sooty moulds).

   v. Slug (particularly important after severe damage in 1992).

   b. Plot summaries using the same 5 categories (as in 3a. above) - zones 1-8 separately recorded:

   i. External pest damage.

   ii. Internal pest damage (in cut buttons).

   iii. Damage under wing leaves (removable with trimming).

   c. Plot summaries for the pest presence for cabbage aphid (and cabbage caterpillars and/or CRF if seen):

   i. External pest presence.

   ii. Internal pest presence.

   iii. Pests under wing leaves.

   d. Plot summaries for upper, middle and lower in zones 1 - 8 separately:

   i. External pest damage.

   ii. Internal pest damage

iii. External pest presence.

iv. Internal pest presence.

4. Yields

Plot weights for the 5 size grades separately .

**ANALYSIS AND REPORTING**

The statistical analysis will be carried out by HRI-W and all the data will be compiled into one final report by Mr B Emmett.

## 7. COMMENCEMENT DATE AND DURATION

As for FV119.

The final report detailing the results of year 2 together with a comprehensive summary of the work in year 1 will be produced by 01.05.94. It is hoped that it may be possible to organise grower walks on one or more of the sites if the experiments are successful.

## 8. STAFF RESPONSIBILITIES

Project Leader: Mr B J Emmett (ADAS-Leeds)
Site Managers:
a) Dr W E Parker (ADAS-Wolverhampton)
b) Mr J Oakley (ADAS-Reading)
c) Dr J A Blood-Smyth (ADAS-March)
d) Mr B J Emmett & Dr S A Ellis (ADAS-Leeds)
e) Mr M Holliday (ADAS-Kirton)

Consultant HRI Staff: Mr A Mead - Biometrics (HRI-W)
Project Co-ordinator: Mr A Whitlock

## 9. LOCATION OF THE WORK IN YEAR 2

One farm in each of the following regions:

a) Vale of Evesham
b) Thames Valley
c) Bedfordshire
d) N Yorkshire
e) Lincolnshire

Contract No: FV/119-MOD

## TERMS AND CONDITIONS

The Council's standard terms and conditions of contract shall apply.

Signed for the Contractor(s)

Signature.......................................... 
Position Head of Horticultural Crops Development Centre
Date 25/8/93

Signed for the Contractor(s)

Signature..........................................
Position..........................................
Date..........................................

Signed for the Council

Signature..........................................
Position CHIEF EXECUTIVE
Date 13.8.93.