HDC FINAL REPORT

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SF/25

Plum: chemical control of damson-hop aphid

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Plum, damson-hop aphid, chemical control, tar oil, resistance, mites, predators

CONTENTS

PRACTICAL SECTION FOR GROWERS

Background and objectives

Damson-hop aphid is a regular and serious pest of plums in most of the major plum growing areas of the country. Control has become increasing difficult in recent years due to aphids high levels of resistance to most available insecticides. The problem is made worse by the extensive and intensive treatment of hops, the aphids alternative host. The selection pressure imposed by treatment of the aphid at almost all stages of its life cycle has helped make the pest arguably the most resistant pest in the UK. Another complicating factor is the limited number of insecticides approved for use on the crop, which prevents growers from adopting a resistance management strategy of alternating different insecticides. Until the 1960s winter washing of plums with tar oil or DNOC was widely practised, and this did give good control of aphids, but was non-selective and killed many beneficial species as well as pests. The importance of beneficial invertebrates is widely accepted now, and the predatory mites (particularly *Typhlodromus pyri*) are arguably the most important ones in plums.

Part of the work reported was designed to re-evaluate the role of winter washes, when applied at lower water volumes than previously, and to study their impact on beneficial mites. Another part of the work evaluated the effectiveness of a range of experimental insecticides with the aim of applying for approval for use on plums of any that proved effective. The experimental insecticides were provided by manufacturers, but with the proviso that individual products would not be identified, consequently these experimental products are coded in the report. The final part of the work involved a field survey of plum orchards throughout the country to collect background information on the levels of pests, and the distribution of beneficial invertebrates. The aim of this survey was to see what effect the different pesticide regimes used by growers had on the balance of pests and beneficials.

Results and Conclusions

In two replicated experiments on commercial plum orchards in Hereford and Worcester the use of tar oil winter washes gave very good control of damson-hop aphid. This compared to very poor control, which resulted in considerable crop damage, obtained with a programme of summer sprays based on the most effective of the currently approved insecticides. Aphid control was slightly better when tar oil was applied in 2000 litres of water per hectare (200gpa), than where it was applied in 500 litres/hectare (50gpa). The use of tar oil did not eradicate the predatory mites in the orchard. One useful observation made was that tar oil appeared to give a level of control of plum rust mite, which is a significant pest of some varieties, such as Victoria.

In two separate experiments at the same sites as the tar oil studies, two experimental insecticides, applied as summer sprays, showed good aphid control activity and are considered worthy of further studies. Of the insecticides approved at the time of the studies omethoate ('Folimat') gave the best control. Both deltamethrin ('Decis') and a soft soap ('Savona') gave very poor control. Since the studies were started, 'Folimat' has been withdrawn and approval for the use of demeton-S-methyl ('DSM' or 'Metasystox') on plums (and all other top fruit) has been withdrawn.

The survey of plum orchards gave a lot of very useful information about the impact of control measures and highlighted some new potential problems. Where tar oil had been used damson-hop-aphid control was generally good, with the poorest control occurring where water volumes had been reduced too much. Tar oil did not give good control of leaf-curling plum aphid, but mealy plum aphid was well controlled. Growers relying on summer sprays got poor aphid control, although where

chlorpyrifos (eg 'Dursban 4') was used for caterpillar control, reasonable aphid control was reported. The presence of predatory mites in orchards was only really affected by the use of pyrethroid insecticides. Where these had been used predatory mites were absent. One of the most striking types of damage seen was not caused by one of the usual pests, but by leafhoppers. Some orchards showed severe leaf damage due to this pest, and the trees vigour must have been reduced by it. Another pest showing higher than expected numbers was the two-spotted spider mite, which is more normally associated with soft fruit, nursery stock and protected crops. The major disease seen was plum rust, with serious damage and early leaf fall in some orchards was seen.

Action points for growers

Use tar oil routinely for control of damson-hop-aphid, because there are no effective summer treatments.

Apply tar oil in a medium to high water volume, ensuring that most of the wood is thoroughly wetted.

Avoid the use of pyethroid insecticides to preserve beneficial invertebrates.

Monitor the development of minor pests such as leaf hoppers and seek advice on control if a problem appears to be developing.

Plum rust one year will reduce the potential yields for the following year, and treatment is often worthwhile.

Practical and financial benefits from study

The work has clearly identified the method that growers should be using for control of damson-hop-aphid, and has identified two experimental insecticides which are effective as summer treatments. The benefits of good control of this pest are not just seen in gross yield, but also in the reduction of fruit contamination by honeydew, and the associated sooty mould, produced by the aphid. It should not be overlooked that this pest is a very good vector of the plum pox virus, and control of the aphid will minimise spread. The work has provided HDC with the information needed to support the development of particular new insecticides, and has demonstrated that the plum industry will have to rely on tar oil for aphid control in at least the short-term. The results of the work confirm that if the registration of tar oil needs to be supported in the future, HDC can do so on the basis of both biological effectiveness and compatibility with integrated pest control strategies.

EXPERIMENTAL SECTION

A. GENERAL INTRODUCTION

The damson-hop aphid (*Phorodon humuli*) is a regular and serious pest of plums in most of the major plum growing areas of the country. The aphid spends the spring and early summer months feeding on plums (and other *Prunus* spp.) before migrating to hops, particularly in June and July, where it feeds until September. It then migrates back to plums and other *Prunus* spp. and the fertilised females lay overwintering eggs on the woody parts of the plant. The eggs hatch in early spring starting the cycle again.

The aphid is unusual for a native species because it attacks two different horticultural crops during its life cycle and, uncontrolled, causes severe crop damage on both crops every year. Not surprisingly the commercial growers of both plums and hops routinely treat for its control. On hops it is not unusual for 5 or 6 foliar sprays to be applied and on plums 2 or 3 sprays are quite common. In extreme cases, where chemicals fail, some hop crops can be treated with up to 12 sprays and plums with up to 9 sprays.

Given this high insecticide use it is not surprising that the aphid has a record second to none for developing resistance to a wide range of insecticides. Resistance has been demonstrated to a wide range of organophosphate, carbamate and pyrethroid insecticides. On plums the only Approved aphicides have all been shown commercially to either be ineffective or to have a very much reduced level of activity. With summer treatments so unreliable it is not surprising that winter treatments for control of aphid eggs with tar oil are being tried again. The main problem with tar oil is its non-selectivity and its direct and indirect impact on the pest complex on plums has never been critically evaluated.

Part of the work described addresses this problem with some detailed orchard experiments, with particular reference to damson-hop aphid. Another part evaluates the impact of commercial practice on the pests and main beneficial insects and mites in orchards. Another part of the work was designed to evaluate the activity of a range of "new" aphicides which could be developed for use in plums. Given the relatively small area of plums nationally it is vital for the industry to support the development of new uses. Once activity has been confirmed progress towards approval is likely to be best achieved by close collaboration between the pesticide manufacturer and the representatives of the growers.

B. PART I

CONTROL OF DAMSON-HOP APHID ON PLUMS WITH TAR OIL WINTER WASHES

Introduction

Winter washes of tar oil or DNOC were widely used in orchards, including plums, until the 1960s when a wide range of summer applied insecticides was introduced. Winter washes are toxic to a range of insect eggs, to most adult stages of invertebrates, to most green plant tissue, to some fungal spores or resting bodies and to mosses, lichen and algae. This broad spectrum of activity means that to avoid plant damage sprays can only be applied in the dormant season.

A high spray volume is normally used to ensure contact with organisms sheltering in the cracks and old bark of the wood. Traditionally sprays were applied with hand lances at volumes of over 5,000 l/ha, but with air-assisted sprayers 2,000 l/ha was more usual.

Aphid eggs are relatively large and are laid on fairly exposed parts of the plant and winter washes are known to be very effective against them. The main predator of mites in plums is *Typhlodromus pyri* (Typhs) and it overwinters on the tree. Typhs are killed by contact with winter washes but the overwintering eggs of its main prey, the fruit tree red spider mite, (FTRSM) are tolerant. Winter washes are therefore likely to interfere with predator control of FTRSM. One possible means of overcoming this potential problem is to reduce the winter wash spray volume to prevent penetration into the deeper bark cracks etc where the Typhs overwinter. The use of lower spray volumes for some treatments was to see if an element of selectivity could be introduced, the lower volumes should contact the aphid eggs (exposed) but be less likely to contact the Typhs (sheltered). As winter washes are not toxic to FTRSM eggs some treatments included a standard application of 'Apollo' (clofentezine).

Although plums were more commonly treated in the 1950s and 1960s with DNOC than tar oil, DNOC is no longer available and therefore tar oil was used throughout the study.

Materials and Methods

Two experiments were done, one in 1993 and one in 1994. Both were done on established commercial orchards of the cultivar Victoria grown on St Julian rootstock.

Sites

1993 — Much Marcle, Herefordshire

Planted: 1988/89
Spacing: 4.8 (row) x 3.6 m
Layout: 3 tree plots
4 replicates
Randomised block design

1994 — Tenbury Wells, Worcestershire

Planted: 1987
Spacing: 5.5 (row) x 2.7 m

Layout: Single tree plots (separated by one guard tree)
4 replicates
Randomised block design

Treatments

1. Untreated
2. Sterilite Tar Oil (80%) at 160 l (product) in 2000 l/ha of water
3. As 2, plus Apollo at 400 ml in 500 l/ha of water
4. Sterilite Tar Oil at 64 l in 800 l/ha of water
5. As 4, plus Apollo at 400 ml in 500 l/ha of water
6. Standard summer aphid control programme (see below)

1993	Tar oil was applied to treatments 2 to 5 on	21 Jan 1993
	Apollo was applied to treatments 3 and 5 on	11 Mar 1993
	Decis plus Folimat applied to treatment 6 on	22 Apr 1993
		7 May 1993
		3 June 1993
	(Decis applied at 800 ml/ha, Folimat at 1000 ml/ha in 1000 l/ha of water)	
1994	Tar oil applied to treatments 2 to 5 on	2 Feb 1994
	Apollo applied to treatments 3 and 5 on	20 Mar 1994
	Decis plus Folimat applied to treatment 6 on	6 Jun 1994
		24 Jun 1994

Sprays were applied with a knapsack sprayer using a medium quality spray for Apollo, Decis plus Folimat and tar oil at 800 l/ha, and a coarse quality spray for tar oil at 2000 l/ha.

No other insecticides or acaricides, nor any fungicides were applied to the experimental areas.

Assessments

A range of different assessments were done, at each date the exact assessment method was selected according to the level of infestation and/or crop damage present at the time.The range of assessments done included:

1. Pre-treatment count of aphid and FTRSM eggs, number of eggs present on 10 two year old shoots per tree.
2. Number of shoots infested with aphids, 10 shoots per tree.
3. Number of blossom trusses infested by aphids, 20 trusses per tree.
4. Blossom phytotoxicity - 1994 only (11 Apr 1994), overall whole tree qualitative assessment, see 'Results' for scale.
5. Counts of adult female aphids on leaves in early summer, counts of 25 leaves per tree.
6. Assessment of level of infestation and contamination with aphid honeydew and sooty mould, whole tree assessment.
7. Counts of mites on detached leaves, 50 leaves per tree collected and assessed in laboratory.
8. Qualitative assessment of rust mite damage (whole tree) - 1993 only, see 'Results' for scale.

Results

The results are presented in the sequence of assessment for each year. Tables 1 to 5 deal with 1993.

Table 1 shows the level of aphid and FTRSM eggs present before the first treatment was applied, and Table 2 gives the percentage of fruit/flower trusses infested with damson-hop aphids in two assessments of 20 trusses per tree. Table 3 shows the percentage of shoots infested with damson-hop aphids in late May (10 shoots per tree assessed). Table 4 gives the results of detailed mite counts done on detached leaves in the laboratory. This assessment was based on 50 leaves taken from each tree in mid June. Subsequent to this assessment rust mite numbers continued to rise and Table 5 gives the results of a qualitative assessment (in August) of the level of rust mite damage. The scale of the assessment was from 0 (no damage) to 10 (every leaf severely affected). The feeding damage appears as a distinct dull bronzing of the leaves compared to the healthy leaves which are shiny with a rich deep green colour.

TABLE 1 MEAN NUMBER OF APHID AND SPIDER MITE EGGS ON 1ST AND 2ND YEAR NODES JANUARY 1993

Treatment	Eggs per 10 nodes			
	Aphid		Mite	
	1st year node	2nd year node	1st year node	2nd year node
1. Untreated	0.2	1.0	0.5	13.2
2. High volume tar oil	0.7	3.2	10.2	32.0
3. High volume tar oil, plus Apollo	0.2	1.0	0.25	41.5
4. Medium volume tar oil	1.7	0.2	0.5	24.0
5. Medium volume tar oil, plus Apollo	0.2	4.2	6.0	32.5
6. Summer sprays only	1.0	1.7	6.2	80.0

TABLE 2 PERCENTAGE OF TRUSSES INFESTED WITH APHIDS, 1993

Treatment	Percentage of trusses infested	
	21 April	11 May
1. Untreated	15.0	20.0
2. High volume tar oil	0	0
3. High volume tar oil, plus Apollo	0	0
4. Medium volume tar oil	2.5	2.5
5. Medium volume tar oil, plus Apollo	0	0
6. Summer sprays only	20.0*	10.0

(* = pre-treatment)

TABLE 3 PERCENTAGE OF SHOOTS INFESTED WITH APHIDS 25 MAY 1993

Treatment	Percentage of shoots infested
1. Untreated	90
2. High volume tar oil	0
3. High volume tar oil, plus Apollo	0
4. Medium volume tar oil	10
5. Medium volume tar oil, plus Apollo	5
6. Summer sprays only	40

TABLE 4 MEAN NUMBER OF MITES PER LEAF 15 JUNE 1993

Treatment	Spider mites	Rust Mites	Typhs
1. Untreated	0	309	0.02
2. High volume tar oil	0	63	0
3. High volume tar oil, plus Apollo	<0.1	113	0.02
4. Medium volume tar oil	0	64	0
5. Medium volume tar oil, plus Apollo	0	78	0.01
6. Summer sprays only	0	285	0.01

TABLE 5 QUALITATIVE ASSESSMENT OF RUST MITE DAMAGE 17 AUGUST 1993

Treatment	Damage level*
1. Untreated	9.2
2. High volume tar oil	8.0
3. High volume tar oil, plus Apollo	8.7
4. Medium volume tar oil	9.0
5. Medium volume tar oil, plus Apollo	8.7
6. Summer sprays only	9.5

(* 0 = no damage
10 = every leaf severely bronzed)

Tables 6 to 11 give results from 1994. Table 6 gives the aphid and mite egg numbers recorded pre-treatment. The blocks were laid out to allow for the obvious variation in spider mite egg numbers seen in the trial area. The results are given by block rather than by treatment to confirm this observation.

Table 7 gives the mean numbers of adult female wingless aphids for three assessment dates and Table 8 shows the percentage of leaves infested with damson-hop aphid (any stage) on the same dates. Table 9 gives a qualitative measure of the amount of sooty mould seen on the trees in each plot. In this qualitative assessment the level of sooty mould was scaled from severe (most or all fruit contaminated), moderate (20-60% fruit contaminated), low (5-15% of fruit contaminated), very low (difficult to find contaminated fruit) and nil.

Table 10 gives the results of mite counts done in July. These assessments were done in the laboratory on 50 detached leaves per plot.

Table 11 shows the level of damage seen on plum blossom at the start of flowering in April. Severe relates to virtually no blossom and moderate to noticeably less blossom.

TABLE 6 MEAN NUMBER OF APHID AND SPIDER MITE EGGS ON 1ST AND 2ND YEAR NODES, JANUARY 1994

Block	Eggs per 10 nodes			
	Aphid		Spider Mite	
	1st year node	2nd year node	1st year node	2nd year node
1	1.4	0	0	4.4
2	1.6	0.2	0	1.0
3	2.3	0.3	0	0.2
4	1.3	0.3	8.5	53.0

TABLE 7 MEAN NUMBERS OF ADULT APHIDS PER LEAF, 1994

Treatment	6 June	23 June	19 July
1. Untreated	25.2	12.1	<0.1
2. High volume tar oil	0.4	2.3	0
3. High volume tar oil, plus Apollo	0.2	1.0	<0.1
4. Medium volume tar oil	0.4	0.2	0
5. Medium volume tar oil, plus Apollo	0.5	0.8	<0.1
6. Summer sprays only	11.0	5.4	<0.1

TABLE 8 PERCENTAGE OF LEAVES INFESTED WITH APHIDS, 1994

Treatment	6 June	23 June	19 July
1. Untreated	92	80	2
2. High volume tar oil	12	29	0
3. High volume tar oil, plus Apollo	11	18	1
4. Medium volume tar oil	14	8	0
5. Medium volume tar oil, plus Apollo	18	15	2
6. Summer sprays only	80	49	2

TABLE 9 QUALITATIVE ASSESSMENT OF SOOTY MOULD ON FRUIT 19 JULY 1994

	Sooty mould level (number of plots)				
Treatment	**Severe**	**Moderate**	**Low**	**Very low**	**Nil**
1. Untreated	1	1	2	0	0
2. High volume tar oil	0	0	0	1	3
3. High volume tar oil, plus Apollo	0	0	1	0	3
4. Medium volume tar oil	0	0	1	0	3
5. Medium volume tar oil, plus Apollo	0	0	1	0	3
6. Summer sprays only	2	0	1	0	0

TABLE 10 MEAN NUMBER OF MITES PER LEAF 28 JULY 1994

Treatment	Spider mites	Rust Mites	Typhs
1. Untreated	1.6	19.0	0.21
2. High volume tar oil	1.0	20.5	0.15
3. High volume tar oil, plus Apollo	0.9	11.0	0.12
4. Medium volume tar oil	1.6	21.7	0.20
5. Medium volume tar oil, plus Apollo	1.5	12.2	0.08

6. Summer sprays only	1.2	16.2	0.02

TABLE 11 BLOSSOM DAMAGE, NUMBER OF PLOTS AFFECTED, 11 APRIL 1994

Treatment	Severe damage (95% +)	Moderate damage	No damage
1. Untreated	0	0	4
2. High volume tar oil	4	0	0
3. High volume tar oil, plus Apollo	4	0	0
4. Medium volume tar oil	1	3	0
5. Medium volume tar oil, plus Apollo	3	1	0
6. Summer sprays only	0	0	4

Discussion

In both years, despite relatively low overwintering egg numbers, damson-hop aphid infestations built up to damaging levels in untreated plots in mid summer. Apart from fruit contamination with honeydew, and the resultant sooty mould, the vigour of the trees was undoubtedly reduced. The two experiments therefore gave a good test of the treatments applied. The results clearly demonstrated the effectiveness of tar oil in controlling the overwintering eggs and the resulting aphid infestation. Results were apparently slightly better in 1993 than in 1994 but this probably reflects the size of tree. In 1993 the trees were discrete and not touching in the rows whereas the 1994 experiment had more mature trees with extensive foliage contact up the row. This resulted in aphids being able to walk from one tree to another. Thus same previously clean trees were infested from adjacent trees. (NB Any winged damson-hop aphids in plums in the summer will not re-infest plums but move off to hops).

The results also indicated that tar oil can be equally effective in controlling aphid eggs at medium volume as at high volume. The effectiveness of the medium volume spray will however be more dependent on thorough and even spray application than with higher volumes.

Despite moderately high fruit tree red spider mite egg numbers in 1993 an infestation did not develop. Given the very low Typh numbers recorded in June it is unlikely that they were the reason for the low mite numbers. No other obvious reason for the low spider mite numbers was apparent. Rust mite numbers were very high in June, particularly on treatments 1 and 6. This indicates that tar oil was giving a 60-80 per cent control of these mites. Given the high breeding rate of rust mites and the very low Typh numbers it was not surprising to see such severe rust mite damage in August in all plots. Although Typh numbers were very low, their presence in tar oil treated plots does indicate that they can survive tar oil sprays, probably by overwintering in places inaccessible to the spray.

Mite egg numbers in 1994 were very variable but no major infestation developed even where egg numbers were high. Typh numbers in July were quite reasonable and given the spider mite and rust mite numbers were not far from ideal. There was no evidence that either tar oil treatment had a lasting effect on Typh numbers. Rust mite numbers were low and were not damaging. Apollo treatment had no consistent lasting effect on mite numbers in 1994.

One interesting point of confirmation which emerged in 1994 was the phytotoxic effect of tar oil on plum buds. At the time tar oil was applied the buds were apparently still closed as there was no visible evidence of bud scales separating. However it is obvious that bud swelling had started and the loss of blossom where tar oil had been used was dramatic. Severe crop loss would undoubtedly have resulted but this could not be measured due to the very poor (almost nil) fruit set in the rest of the orchard. Slightly less damage occurred where medium volume sprays were used, reflecting the reduced penetration compared to high volumes.

Conclusions

1. Tar oil gives better damson-hop aphid control than approved summer sprays.

2. Tar oil can be applied at medium spray volume to control damson-hop aphid.

3. Tar oil does not necessarily eradicate Typhs.

4. Tar oil appears to give some control of plum rust mite.

5. Tar oil must be applied well before bud swelling to avoid flower loss.

B. PART II

CONTROL OF DAMSON-HOP APHID ON PLUMS WITH SUMMER SPRAYS

Introduction

In 1993 a range of organophosphate aphicides, including demeton-S-methyl (eg Campbells DSM), dimethoate (various products) and omethoate (Folimat), and the synthetic pyrethroids cypermethrin (eg Ambush C) and deltamethrin (Decis) were the only approved pesticides for summer aphid control. Commercial experience, in some cases confirmed by laboratory studies, showed the aphid to be resistant to all of the approved products. The most effective treatment was a mixture of Decis and Folimat. During 1993 the approval of Folimat was revoked, but with a two year "use-up" period which finishes in May 1995. No new supplies of Folimat were available from mid 1993. The loss of Folimat reinforced the need for new aphicides for use in plums for damson-hop aphid control. For over 10 years previous to the start of this work no new aphicides had been introduced but in the early 1990s several manufacturers started to develop novel aphicides. Most manufacturers agreed that their new products could be included in a screening experiment on plums (and also on hops under the National Hops Association levy fund).

The experiments reported below were designed to identify activity against established damson-hop aphid infestations. Whilst willing to collaborate some manufacturers asked that their product should not be identified and consequently experimental compounds reported below are coded to fulfil the secrecy agreement. This avoids the possibility of identification by elimination. In order to fully test the materials treatments were not applied until a heavy infestation was present on the trees. Therefore, given the difficulty of obtaining complete spray cover at medium volumes on mature trees with hand-held applicators, full aphid control was not expected.

Materials and Methods

Two experiments were done, one in 1993 and one in 1994. Both were done on established commercial orchards of the cultivar Victoria, grown on St Julian rootstock.

Sites

1993 — Much Marcle, Herefordshire

Planted: 1988/89
Spacing: 4.8 (row) x 3.6 m
Layout: Single tree plots (discrete trees)
3 replicates
Randomised block design

1994 — Tenbury Wells, Worcestershire

Planted: 1982/3
Spacing: 5.5 (row) x 2.7 m
Layout: Single tree plot (separated by one guard tree)
4 replicates
Randomised block design

1993 Treatments

1. Untreated
2. Decis 800 ml/ha
3. Folimat 1 l/ha
4. Decis (800 ml) plus Folimat (1 l)
5. Savona
6. Product A 400 g/ha
7. Product B 1.25 kg/ha
8. Product C 500 ml/ha
9. Product C 1 l/ha
10. Product C 2 l/ha

Sprays were applied on 7 May 1993 and 3 June 1993 at 1000 l/ha using a knapsack sprayer giving a medium spray quality.

1994 Treatments

1. Untreated
2. Decis 800 ml/ha
3. Campbells DSM 380 ml/ha
4. Decis (800 ml) plus DSM (380 ml)
5. Product A 100 g/ha
6. Product A 200 g/ha
7. Product A 400 g/ha
8. Product B 1.25 kg/ha

Sprays were applied on 6 and 24 June 1994, method as 1993.

Product coding (A and B) was the same in the two seasons. Product C was only used in 1993. No other product with aphicidal activity was applied to the experimental area during the experiment, tar oil had not been applied to the experimental area in the previous winter.

Assessments

Aphid numbers on 20 leaves per plot or the overall level of infestation were recorded three times during each season.

Crop destruction

All the fruit on the trees in treatments 6 to 10 (inclusive) in 1993 inclusive and in treatments 5 to 8 (inclusive) in 1994 were removed from the trees in early August.

Results

The results of the two years are presented separately below. Table 12 gives aphid numbers in early May 1993 4 days after the first spray application with Table 13 showing the level of infestation 18 days after the first treatment. Table 14 shows the level of aphid infestation 11 days after the second spray in 1993.

TABLE 12 NUMBER OF ADULT APHIDS PER LEAF AND PERCENTAGE OF LEAVES INFESTED 11 MAY 1993

Treatment	Aphids per leaf	Percentage of leaves infested
1. Untreated	16.7	80
2. Decis	10.3	87
3. Folimat	3.7	93
4. Decis plus Folimat	5.3	93
5. Savona	14.2	100
6. Product A	3.3	80
7. Product B	9.3	47
8. Product C (low)	14.6	87
9. Product C (medium)	2.2	73
10. Product C (high)	7.9	67

TABLE 13 LEVEL OF APHID INFESTATION, 25 MAY 1993

	Mean frequency of colonies per tree				
Treatment	All shoots	Most shoots	Some shoots	Few shoots	None
1. Untreated	2	1	0	0	0
2. Decis	2	1	0	0	0
3. Folimat	1	0	1	0	1
4. Decis plus Folimat	0	1	1	0	1
5. Savona	3	0	0	0	0
6. Product A	0	1	0	1	1
7. Product B	1	0	1	0	1
8. Product C (low)	3	0	0	0	0
9. Product C (medium)	0	2	1	0	0
10. Product C (high)	0	1	0	1	1

TABLE 14 LEVEL OF APHID INFESTATION 14 JUNE 1993

Treatment	Frequency of aphid colonies				
	All shoots	Most shoots	Some shoots	Few shoots	None
1. Untreated	3	0	0	0	0
2. Decis	3	0	0	0	0
3. Folimat	0	0	1	1	2
4. Decis plus Folimat	0	0	0	1	2
5. Savona	1	2	0	0	0
6. Product A	0	0	0	1	2
7. Product B	0	1	1	0	1
8. Product C (low)	3	0	0	0	0
9. Product C (medium)	3	0	0	0	0
10. Product C (high)	3	0	0	1	1

Results from 1994 in Table 15 shows the level of infestation by block pre-treatment and Tables 16 and 17 give aphid numbers 13 days and 25 days after the first and second treatments respectively. Table 18 gives a qualitative assessment of the level of foliage contamination with sooty mould in mid July. (Fruit contamination could not be measured because of the exceptionally low crop). The assessment recorded in Table 18 are based on the mean proportion of foliage contaminated, the contamination was sometimes very patchy on individual trees.

Tables 16-18 include results from treatments of the tar oil experiment for comparison. Although tar oil treatments were not replicated in the summer spray experiment, the tar oil experiment was in adjacent rows in the same orchard.

TABLE 15 PRE-TREATMENT LEVEL OF APHID INFESTATION 6 JUNE 1994

Block	Adult aphids per leaf	Percentage of leaves infested
1	2.7	75
2	10.8	80
3	7.8	95
4	20.1	100
Mean	10.4	87.5

TABLE 16 LEVEL OF APHID INFESTATION 23 JUNE 1994

Treatment	Adult aphids per leaf	Percentage of leaves infested
1. Untreated	2.7	75
2. Decis	10.8	80
3. DSM	7.8	95
4. Decis + DSM	4.7	42
5. Product A (low)	5.8	54
6. Product A (medium)	2.0	48
7. Product A (high)	1.2	32
8. Product B	3.4	59
(* Tar oil	2.3	29)

* See text - figures for comparison from other experiment.

TABLE 17 LEVEL OF APHID INFESTATION 19 JULY 1994

Treatment	Number of adult aphids per leaf	Percentage of leaves infested
1. Untreated	0.12	6
2. Decis	0.20	10
3. DSM	0.02	1
4. Decis + DSM	0.05	2
5. Product A (low)	0.08	4
6. Product A (medium)	0.01	2
7. Product A (high)	0.05	2
8. Product B	0.15	8
(* Tar oil	0	0)

TABLE 18 QUALITATIVE ASSESSMENT OF CONTAMINATION WITH SOOTY MOULD 19 JULY 1994

	Sooty mould level (number of plots)				
Treatment	Severe	Moderate	Low	Very low	Nil
1. Untreated	0	1	2	1	0
2. Decis	0	0	0	4	0
3. DSM	0	1	1	1	1
4. Decis plus DSM	1	0	1	1	1
5. Product A (low)	0	1	1	1	1
6. Product A (medium)	0	0	0	3	1
7. Product A (high)	0	0	0	2	2
8. Product B	0	1	0	3	0
(* Tar oil	0	0	0	1	4)

Discussion

In both years damson-hop aphid infestations were severe and significant fruit and crop damage resulted. Where results above are expressed as mean number of adult aphids per leaf it should be noted that for every adult aphid there are probably between 50 and 100 young aphids also present and all of these are feeding and producing honeydew.

In 1993 the standard treatment with Folimat worked particularly well in the experiment which contrasted with control obtained with it in some other local commercial crops. This variability in effectiveness has long been a feature of Folimat but, despite this, its loss to the plum industry will cause problems. Of the experimental treatments Product C failed to give adequate control, even at the highest rate, which is well in excess of the proposed rate for other crops. Product A gave results equivalent to or slightly better than Folimat. This product used for damson-hop aphid control on hops gave outstanding control in 1993, and was certainly worthy of further work. Product B gave reasonable control of damson-hop aphid in a very testing situation, and combined with good results from hops also justified further study.

Both Decis and Savona gave very poor control in 1993. Overall control with all products was poorer in 1994 but this partly reflects the much larger trees and difficulty of obtaining thorough spray cover with a knapsack sprayer. Despite this products A and B showed sufficient activity in such a difficult situation to justify further experimentation. The lower aphid numbers seen in mid July reflect the migration of aphids back to hops rather than any control effect.

Further work in damson-hop aphid control on plums is needed but it should be done using farm sprayer and treatments should be applied before the infestation reaches the levels seen in these experiments.

Conclusions

Products A and B showed sufficient activity to justify further study. The ultimate aim should be to work with the pesticide manufacturer to seek approval for one or both products on plums.

B. PART III

GROWER SURVEY OF PEST INCIDENCE IN ORCHARDS

Introduction

The damson-hop aphid is only one of the major pests of plums and control measures are regularly needed for other pests. Two other aphid species occur, the leaf-curling plum aphid (*Brachycaudus helichrysi*) is common and widespread whilst the mealy plum aphid (*Hyalopterus pruni*) can cause serious damage, but tends to be less common. Of the foliage caterpillars, winter moth (*Operophtera brumata*) is the most common and control treatments are often needed. The main fruit damage is caused by the plum fruit moth (*Cydia funebrana*), it is sometimes also referred to as the red plum maggot. Plum sawfly (*Hoplocampa flava*) also attacks the fruit. Two major mite pests are common, the fruit tree red spider mite (*Panonychus ulmi*) and the plum rust mite (*Aculus fockeui*). The main plum variety, Victoria, is particularly susceptible to rust mite damage. There are also a number of gall mites (various species) which cause damage on some varieties, although Victoria is not normally attacked.

In common with commercial apple orchards, the mite pests on plums can be controlled naturally without the need for acaricides by predators, particularly *Typhlodromus piri* (Typhs). However Typhs are susceptible to some of the pesticides used on plums and Typh populations may consequently be inadequate to keep mites under control. Tar oil, being non-selective, will kill Typhs that it contacts.

The impact of pesticides on the total invertebrate population cannot be predicted with any degree of accuracy. This is because the balance between different species is very delicate. By relating pesticide usage to the actual pest and beneficial levels in commercial orchards it should be possible to identify major effects of pesticides. This would enable us to suggest ways of minimising the impact of necessary pest control treatments on non-target, and particularly beneficial, species.

Method

Twenty five plum growers in England were visited by the author in the autumn of 1993. Growers were selected at random from the 3 major plum growing areas, ie East Anglia (mainly Cambridge), Kent and the West Midlands.

A single plum orchard (variety Victoria), typical of those on the farm, was selected, and details of the orchard history were recorded. Particular note was made of pesticide treatments. The orchard was then inspected for the presence, and indications, of pest, beneficial and neutral invertebrates. Level of the various species were recorded on a scale from zero (not present) to 5 (present on all trees in high numbers).

At the time of the inspection it was possible to identify damage caused by most pests even when this occurred earlier in the season. The only exceptions to this were the fruit damaging pests, plum fruit moth and plum sawfly.

Results

Pesticide usage

Tar oil was used by 36% of growers with the highest usage in Kent (57%) and the lowest in East Anglia (17%). Several growers, particularly in the West Midlands, said they had planned to use tar oil but had been unable to. Seventy five per cent of tar oil applications were at 1000 l/ha and the remainder at 500 l/ha. Chlorpyrifos (eg Dursban) was the most widely used insecticide used, 68% of growers used it with a mean of just over 2 applications per orchard (maximum 4).

Omethoate (Folimat) was used by nearly a quarter of growers and demeton-S-methyl (DSM) by nearly 40%.

Diflubenzuron (Dimilin), fenitrothion (eg Dicofen), phosalone (Zolone) and pirimiphos-methyl (Blex) were each used by 2 or 3 growers.

Pyrethroid insecticides (cypermethrin - Ambush (1) and deltamethrin-Decis (4)) were only used by growers in Kent and the West Midlands.

Somewhat surprisingly only 2 growers applied any specific mite control treatments, only clofentezine (Apollo) was used. However 3 growers used Blex, which although a general insecticide, was recommended and is very effective against rust mite. Four growers used pirimicarb (eg Aphox) and one used gamma-HCH (eg Gamma-col), neither of these insecticides are approved for use on plums. Fungicide usage was minimal with one grower using non-approved benomyl (eg Benlate) and two using carbendazim (eg Bavistin) for blossom wilt (brown rot).

Summer treatments were applied in a wide range of different spray volumes on different farms:-

Volume (l/ha)	1000	500	300	200	150	50	No spray
Percentage of farms	16	24	8	28	8	8	8

Pest incidence

a. Damson-hop aphid

All orchards inspected in Kent had evidence of damson-hop aphid damage with moderate levels of damage in one orchard where tar oil at 500 l/ha had been used and one where no tar oil had been used. Aphid damage was lowest where tar oil had been used.

In East Anglia only a third of orchards had damage. These orchards had not received tar oil and Aphox had been used for aphid control.

In the West Midlands 33% of orchards showed no damage from damson-hop aphid and these had all received tar oil at 1000 l/ha. Damage in other orchards varied from slight to severe (in one orchard).

b. Leaf-curling plum aphid

Damage was widespread with this species and only two orchards (in Kent) were free of damage. Damage levels were generally low to moderate, with only one severe attack in the West Midlands. The presence of this species in all but one orchard treated with tar oil confirms the commonly expressed opinion that tar oil does not give complete control of leaf-curling plum aphid.

c. Mealy plum aphid

No evidence of this species was found in the West Midlands and only one orchard was infested in Kent. In East Anglia all except one orchard were infested.

d. Caterpillar

Eighty eight per cent of orchards were infested but damage had been slight, even in the orchards where no early season insecticides had been used.

e. Leafhoppers

A number of different species of leaf hoppers attack plums and it was not possible to identify which were involved in the infestations and damage seen. All orchards in Kent and the West Midlands were infested and 66% of those in East Anglia. Damage levels were generally low but Kent had the highest levels with one orchard severely affected. This orchard had received tar oil (1000 l/ha) and 2 ultra low volume Dursban sprays.

f. Leaf weevils

Several species of *Phyllobius* attack a wide range of deciduous trees and shrubs, including plums. Seventy percent of orchards were damaged but in only 2 cases was damage severe and even then it was patchy in the orchard.

g. Scale insects

Only one orchard was infested with scale insects. The orchard, in Kent, was infested with the mussel scale (*Lepidosaphes ulmi*) and scale numbers were very low.

h. Fruit tree red spider mite

Over 70% of orchards were infested, mostly with very low levels of fruit tree red spider mite. Three orchards in the West Midlands and one in East Anglia had moderate damage. All orchards free of this pest had good populations of Typhs but there was no consistency in the pesticides used or their frequency.

i. Two-spotted spider mite

This pest (*Tetranychus urticae*) is not normally associated with tree fruit but it was present in just under half of the orchards checked. In two orchards (one in Kent and one in the West Midlands) this pest was present at very high levels and was causing severe leaf bronzing. At both of these sites Typhs were absent but there was no apparent link to pesticide use.

j. Rust mite

Nearly 90% of orchards were infested with rust mite with severe, but patchy, damage in 12% of orchards. Where damage was absent Typh numbers were moderate to high but there was no link with pesticide use.

Beneficials/neutrals incidence

a. Typhs

Seventy five per cent of orchards had a population of Typhs with nearly half having moderate or high numbers. In all cases where a pyrethroid insecticide had been used (4) typhs were absent. Where tar oil had been used (total 8) typhs were present in all except two orchards, and their numbers were usually moderately high. In one case the absence of typhs following tar oil could be attributed to the use of Decis, but the other case could not be explained.

b. Tydeids

Tydeids are small neutral mites which can form an alternative prey for Typhs. They feed on a range of fungi, algi and possibly some dead plant tissue. Tydeids were present in all orchards, occasionally at very high numbers. Lowest populations were seen in two orchards treated with Decis and one other orchard where Typhs were absent and the only pesticides used were tar oil and Dursban. Apart from the above example, Tydeid numbers were moderate to high where tar oil had been used.

c. Predatory midges

The predatory midge *Therodiplosis persicae* was seen associated with spider mite infestations in two orchards. One of these orchards had received Decis in June.

d. Psocids

Psocids are primitive invertebrates which feed as scavengers. They often are found feeding on fungi in damp situations and are particularly associated with the sooty moulds (*Cladosporium*) which form on aphid honeydew. They were present in two orchards in moderate numbers on leaves which had been infested earlier in the season with aphids. Tar oil had been used in of these orchards.

Diseases

Although the survey was aimed at invertebrates note was made of the level of disease present in the orchard. Tar oil is known to have a controlling influence on the brown rot/blossom wilt fungus (*Monolinia* spp.).

a. Rust

Rust was present in all orchards at moderate to severe levels in East Anglia and Kent, and at low to moderate levels in the West Midlands. There were no effects from any treatments applied, including tar oil.

b. Bacterial canker

Canker was present in all except one orchard, levels were low and were not affected by the fungicide treatments used in the orchard.

c. Silver leaf

Levels of silver leaf were extremely variable with no treatment effect. The levels were higher in Kent than other areas. Only one orchard was free of the disease.

d. Brown rot

Brown rot was recorded in all except two orchards. Three orchards had high to severe levels and a further 4 moderate levels. With one exception with a moderate level, orchards treated with tar oil had nil or very low levels of brown rot.

Discussion

In view of the problems of controlling damson-hop aphid with summer sprays it was somewhat surprising that only just over a third of growers used tar oil. However most growers in East Anglia did not normally expect a problem with the pest and this was confirmed by the orchard inspections. In addition a few of the West Midland growers were unable to treat with tar oil as planned due to the weather.

Where tar oil was used damson-hop aphid control was generally very good. The only exception was were a reduced spray volume had been used on well-grown, dense mature trees. Grower's comments and advisory experience indicated that 1993 had not been a particularly difficult year for damson-hop aphid on plums and that populations on plums were low naturally in most orchards.

The impact of tar oil on pests other than aphids was minimal. This was at least in part because some of the pests were not present in the orchard at the time of spraying. With other pests, such as mites the reason is that the overwintering stages are either tolerant of tar oil (fruit tree red spider mite eggs) or overwinter in places inaccessible to the spray (ie behind bud scales for rust mite, or deep in crevices for the two-spotted spider mite).

The survey confirmed the findings from the experiment reported above (Part I) which indicated that Typhs were not necessarily affected by tar oil applied by modern air-assisted sprayers. The presence of Tydeids in all orchards reinforced this, because they also overwinter on the tree.

Sprays applied in the summer generally had no specific effect on beneficial invertebrates. The notable exception was the use of Decis and Ambush C which apparently eradicated Typhs in the orchard. Where summer sprays alone were used for damson-hop aphid growers normally applied two or three specific sprays of a systemic organophosphate (with or without a pyrethroid). However in addition the widespread use of chloryrifos (Dursban) undoubtedly had some controlling effect on the damson-hop aphid because it has been clearly demonstrated to give moderate control of this species on hops. Although Aphox does not control damson-hop aphid, its use in East Anglia has some logic because it is effective against the other two aphid species which are relatively far more important in the area.

Of the two recognised major mite pests, rust mite was considerably more common and damaging than the fruit tree red spider mite. This may in part be due to the preference of Typhs for the spider mite which means rust mites may increase in a mixed population of spider and rust mites where Typhs are present.

Apart from the recognised major pests the survey identified some newer problems. The widespread damage seen by leaf hoppers was particularly striking. The effect of the leafhopper damage is difficult to quantify because it tends to become more serious late in the year. It therefore may not affect the current year's crop. Its, effect on subsequent crops however needs to be evaluated. The presence of two-spotted spider mite has previously been reported from plums but the extent of infestations seen in the survey was unexpected. Given the widespread presence of Typhs in orchards the threat posed by two-spotted spider mite may not seem that important. However Typhs do not seem to be quite so effective in controlling this species. Growers will need to be aware of this different species and monitor its levels carefully in case control measures are needed. This is particularly relevant because of the lack of acaricides approved on plums which are effective against this species. Because this species overwinters as an adult, the use of the acaricide Apollo is ineffective, this leaves only tetradifon (Tedion) as an approval acaricide

Although outside the terms of reference of this work note should be made of the widespread and sometimes severe incidence of plum rust.

C. OVERALL DISCUSSION

The initial aim of the work to study the control of damson-hop aphid and the impact of control measures on non-target species was successfully achieved. The three parts of the work have meshed together well and have identified the best method of control currently available and given indications of good activity with some of the novel insecticides being developed. The grower survey was particularly revealing in that it not only reinforced some of the experimental results, but it also gave very consistent results on the effect of pesticide usage on mite predators as well as highlighting some new but potentially pests in plums.

The work clearly demonstrated the effectiveness of tar oil in controlling damson-hop aphid, even at medium spray volumes. There is obviously a limit to the amount the spray volume can be reduced, as illustrated in one commercial orchard where 500 l/ha did not give adequate control. Although Typh numbers in the two experiments were low, the grower survey clearly showed that tar oil, applied at 1000 l/ha, does not eradicate Typhs and concerns over a mite population flare or surge after tar oil were largely unfounded. This may have implications for other orchard crops where pests such as apple sucker are becoming more important.

In the tar oil experiment in 1993 the suppression of rust mite numbers was quite striking but the grower survey did not support this finding.

Until more effective aphicides become available for summer use, plum growers in the high risk areas (ie the South East, and the West Midlands) should plan to apply tar oil as a routine for damson-hop aphid control.

The loss of omethoate (Folimat) from the UK market in 1995, and the withdrawal of approval of demeton-S-methyl (Campbell's DSM) for use on all orchard crops (effective from 31 January 1994 but with a two-year use-up period for appropriately labelled stocks) means that only dimethoate, 2 pyrethroids and 3 contact organophosphates are currently approved for summer aphid control on plums. Given the well proven high level of resistance to theses aphicides plum growers have no effective aphicides available to them for summer use. The results of the new aphicide screening experiments give some hope for the future with two products showing promising activity. Although the level of control obtained with the new aphicides was not as good as would be needed commercially, it must be remembered that the aphicides were applied to an already high aphid population and that some cross-plot contamination (movement) occurred in 1994.

The grower survey provided a realistic appraisal of commercial experience in all aspects of pest control in plums. Without doubt, with the exception of frost/poor pollination, pests are the main limiting factor in successful commercial plum production. Every orchard surveyed received at least one insecticide spray, with over half receiving four or more different treatments (maximum 7).

Apart from the expected major pests, the survey identified several "minor" pests and of these two were widespread and locally severe. Leafhoppers have been reported as attacking plums but the extent, and the severity of some attacks, was unexpected. Given the increase in leaf hopper damage on other fruit crops, and their ability to transmit viruses in other crops, the level of damage and their distribution gives cause for concern. Their impact on cropping needs to be evaluated and the species involved need to be identified. Two-spotted spider mite is normally associated with soft fruit crops but the wide overall distribution of infestations and severity of some attacks on plums was surprising

and of concern. Given the background population seen the potential for damage in hot dry seasons must be significant.

D. OVERALL CONCLUSIONS

1. Tar oil applied in medium to high spray volumes gives very good control of damson-hop aphid.

2. Tar oil applied in medium to high volumes does not have a detrimental effect on predatory mites.

3. Two new coded aphicides were active against damson-hop aphid in the summer.

4. Despite relatively high insecticide use, pest damage is easy to find in commercial plum orchards.

5. Leafhopper and two-spotted spider mite both pose a threat to plums and their levels have increased.

6. Plum rust was the major disease seen with severe leaf damage in some orchards.

E. RECOMMENDATIONS

1. HDC should, if necessary, support the renewal of approval of tar oil on plums.

2. New work should be started, in conjunction with the relevant pesticide manufacturers, to develop the use of new aphicides (Products A and B) with the aim of obtaining approval for use on plums.

3. Studies should be done on the impact of leafhoppers on crop yields.

4. Work should be started on identifying and obtaining approval for fungicides for rust control.

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