SESSION V

PESTS OF TREE FRUITS: CONTROL OF RED SPIDER MITE, CODLING MOTH AND TORTRICIDS

Chairman: F. R. Tubbs, East Malling Research Station

ASPECTS OF BIOLOGY OF IMPORTANCE IN TIMING SPRAYS AGAINST FRUIT TREE RED SPIDER MITE, CODLING MOTH, AND THE FRUIT TREE TORTRIX MOTHS

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FRUIT TREE RED SPIDER MITE, *Metatetranychus ulmi*

Since few chemicals are highly toxic to the winter eggs, and the performance of these is so intimately related to the efficiency of application, it is almost universal practice to direct control measures against the early summer generations. Recent biological studies have therefore centred on the hatching period and development of the early generations, in an attempt to find a relationship with the blossom period, the last well defined stage of bud development which can be easily recognised and used as a guide to timing sprays.

Hatching period of the winter eggs

From data obtained during the Essex investigations (Blair and Groves, 1952) and subsequently from general orchard observation it had been concluded that hatching began just before the blossom period, about half the eggs had hatched by petal fall, and the remainder hatched over a further period of 3 - 4 weeks.

Whilst this may be representative of most orchards, recent studies have shown that considerable differences in the hatching period can occur. For example, the dates of 50% hatch in two orchards at East Malling (Fig. 1, A and B) where the overall period followed the anticipated course, differed by 9 and 17 days respectively in 1960 and 1961. In a nearby commercial orchard (Fig. 1, C) hatching had only just begun at 10 days after petal fall in 1961, and all stages of the hatching period occurred four weeks later than in the earlier orchard (A) at East Malling.

Although a lack of consistency has thus been shown to exist between orchards in any one season the available data suggests a greater measure of consistency for the same orchard in different seasons. In the East Malling orchard (A), where hatching conformed most closely to the expected pattern, the following stages were reached:-

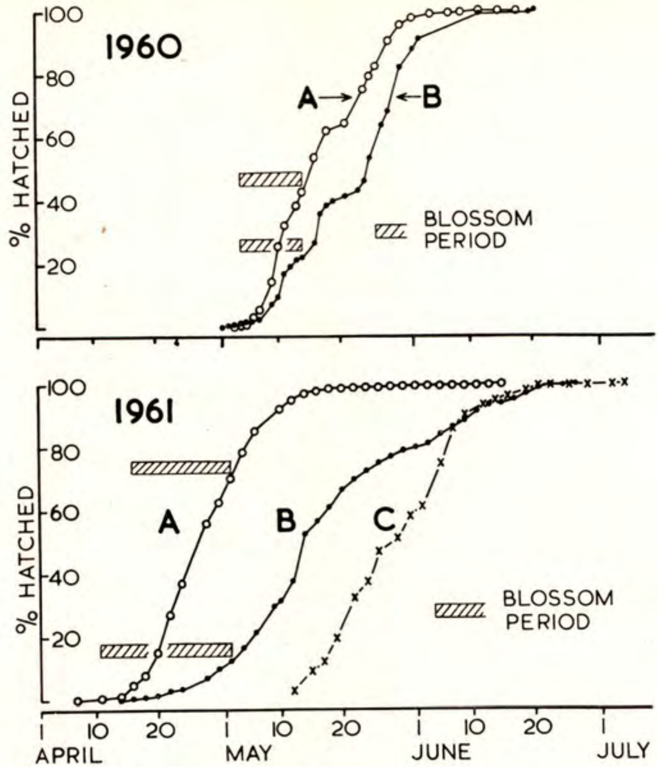

Fig. 1. The hatching period of winter eggs of M. ulmi, at East Malling (A and B) and in a nearby commercial orchard (C).

	1960	1961
Date of, and % hatch at, petal fall	May 14th (42%)	May 2nd (70%)
99% hatch	June 4th	May 18th
100% hatch	June 15th	June 13th

Thus 99% hatch occurred 21 and 16 days respectively after petal fall.

Development of the early generations

Before the hatch of winter eggs is complete the earliest mites have matured and begun to lay summer eggs. The development of this generation has been followed only in orchard A (Fig. 2). Both in 1960 and 1961 the first summer eggs were seen 10 days after petal fall when the hatch of winter eggs had reached 75% and 95% respectively. Production of summer eggs increased rapidly, exceeding the number of mites within two weeks. These eggs began hatching on 9th June 1960 and 3rd June 1961, 16 and 22 days after the first were laid. From this stage onwards the numbers of eggs and mites fluctuate but seldom do the latter exceed more than half of the total population. The period of minimum egg population has occurred about 10 days after petal fall in each year.

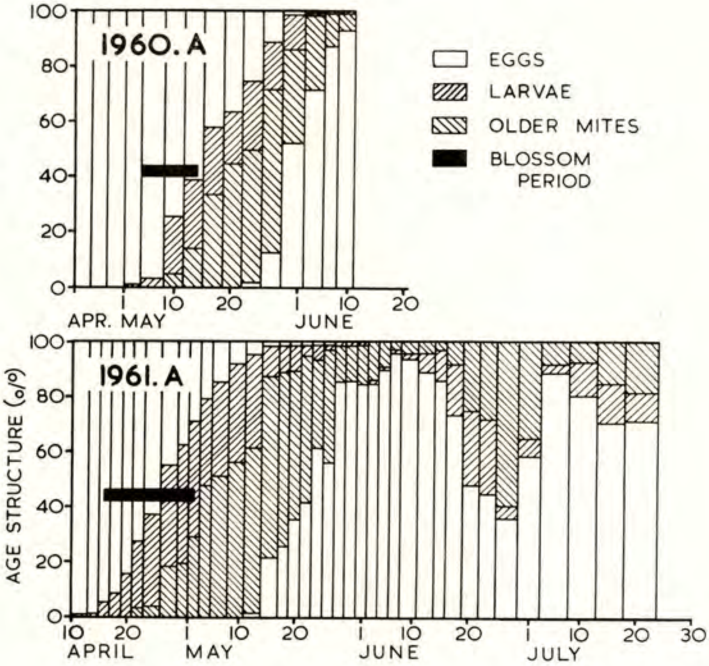

Fig. 2. The relative proportions of eggs, larvae and older mites of M. ulmi during the early generations; orchard A, East Malling.

Duration of various stages in the first generation

From data available, which refer only to laboratory studies, it is clear that temperature is the most important factor controlling the duration of each stage. For example, under constant conditions, the incubation period of summer eggs varies from 23 days at 56° F. to 9 days at 70° F. This emphasises the difficulty in quoting figures for stages exposed to fluctuating temperatures in the orchard. The following times have been estimated from the appearance of the first specimens in recent field studies and probably overestimate the average duration of each stage:-

	1959	1960	1961
Duration of immature stages	20	13	29 days
Preoviposition period of female		about 3 days	
Incubation period of eggs	26	16	22 days

The main point concerning these data is that, if summer eggs are present, a chemical toxic only to active mites will permit survival unless its effective residual period exceeds the incubation period of the eggs, and the surviving mites may in turn be laying more eggs after about two weeks.

Timing of spray applications

Field experience during the past decade has indicated that, in general, two sprays are necessary each year if good control is to be maintained throughout the summer. The actual times at which these are applied will depend on: (1), the population of overwintering eggs; (2), the stages against which the chemical is toxic; (3), the period of residual toxicity.

Where winter egg populations are high the first spray should be applied as near petal fall as possible to avoid foliage injury whilst fruit is setting. With low egg populations and no risk of immediate foliage injury control measures could be directed against the second generation.

CODLING MOTH, *Cydia pomonella*.

Because young larvae tunnel into fruits immediately after hatching it is essential to kill them before any injury has occurred. For this purpose a detailed knowledge of the oviposition period is required but has not been attained because of the difficulty of finding adequate numbers of eggs. As an alternative, studies have centred on the adult which can be caught in light and bait traps, the former being more efficient. But data obtained from such sources are not entirely satisfactory as they reflect adult activity rather than oviposition. For example, the threshold temperature for flight is about 50° F. and that for oviposition a few degrees higher, but the optimum conditions for egg-laying are above 60° F. Furthermore, the light trap only becomes effective when natural light intensity drops to a very low level; it does not therefore give any information on activity during the evening period.

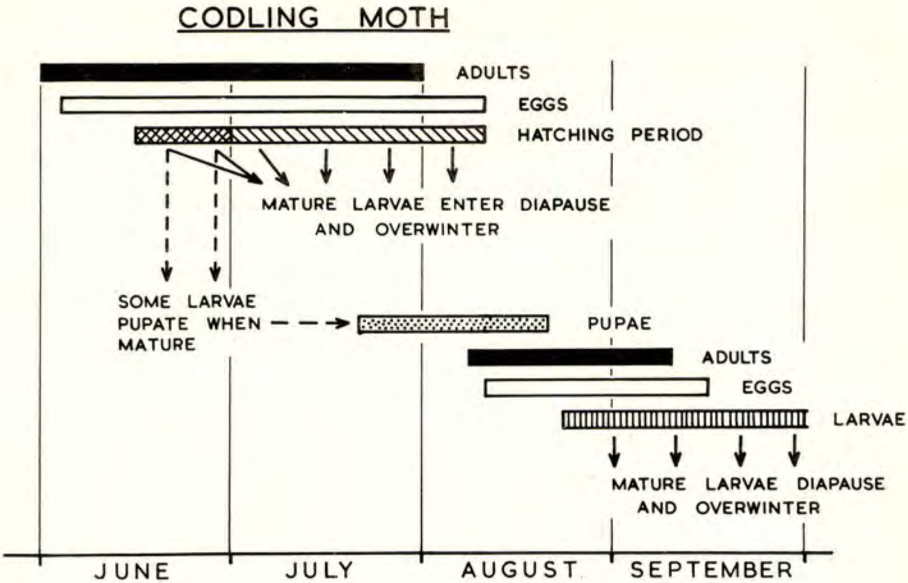

Fig. 3. Diagrammatic representation of life cycle of C. pomonella in south-east England.

A mercury vapour light trap has been in use for the past ten years at East Malling and, whilst the date of the earliest catch has varied from mid-May to mid-June, the composite picture presented by the full records shows that, on average, flight is first noted at the beginning of June (Fig. 3) and moths are present in the orchard until September. These are composed of adults emerging from the overwintered larvae, which occur until early August, and a partial second generation which flies during the rest of the period. Peak flight usually takes place in late June or early July, coinciding with a period of relatively high evening temperatures.

If allowance is made for a preoviposition period of two days, an incubation period of 12 days (varying from 8 days at 70° F. to 15 days at 60° F.) it will be noted that, under average conditions in south-east England, eggs laid by the earliest moths would not normally start hatching until mid-June.

Of the larvae hatching between mid-June and early July a proportion, which is less than half this total, will pupate when fully fed and give rise to the partial second generation. The rest of these larvae and all that hatch later will enter diapause when mature and overwinter in cocoons on the trees or stakes.

In recent years emphasis has been placed on the control of the earliest hatching larvae as a means of eliminating the partial second generation and thus reducing the overall flight period. Assuming this to be possible, it then becomes necessary to apply sprays which will give protection from mid-June to the end of July. The number of, and time interval between, applications will depend on the period of effective residual toxicity of the chosen chemical. With the most persistent ones an application in mid-June followed by another three weeks later has given excellent control.

There is, at present, no wholly satisfactory method of predicting when the first eggs will be laid. A heat summation formula gives a fairly accurate guide to the emergence of the first moth but has to be considered in relation to prevailing evening temperatures when assessing the possibility of oviposition. Often the earliest captures consist of single moths, separated by intervals of several days, and under conditions of such low density mating may not take place. Until more information on these aspects is available it seems probable that mid-June will become the recognised time for the first spray against codling moth and this will be varied only when trapping records and prevailing climate conditions depart from normal.

THE TORTRIX MOTHS

Of the many species which occur on apples only three are of economic importance, and these can be recognised by the type of injury caused to the fruit.

The fruit tree tortrix, Archips podana, is most widespread and damage, in the form of irregular shallow feeding areas, occurs to mature fruits in September and early October. Injury by the summer fruit tortrix, Adoxophyes orana, is similar but a much larger area of the surface is damaged by the maturing larvae of the first summer generation in July and August. Larvae of the fruitlet mining tortrix, Pammene rhediella, occur in June and make a few discrete feeding holes, about a millimetre in diameter, varying from shallow punctures to tunnels which penetrate deeply into the flesh.

The fruit tree tortrix moth

Overwintered larvae emerge from their cocoons at about the bud burst stage and burrow into the fruit buds where they remain in a protected position until green cluster. The remainder of the larval life, until late May or June, is spent in webbed leaves. Light trap captures of the adult show two discrete flight periods, corresponding to the first and partial second generations, from mid-June to mid-August and again in September and early October. Thus the flight period parallels that of the codling moth but occurs about two weeks later.

There are two periods when control is possible - against the overwintered larvae before the blossom period and against the first summer generation in June and July. Since larvae burrow deeply into the fruit buds between bud burst and green cluster the obvious time to spray is at either the beginning or the end of this period, but experimental data on the relative merits of bud burst and green cluster applications are at present lacking. Whilst a routine preblossom spray may give adequate control on some farms there is also evidence that, on others, this will not prevent injury to the mature fruit. Recent work has therefore concentrated on the control of the first summer generation and, since this follows very closely that of the codling moth, a common spray programme against both species seems possible.

The only results available are for 1960 trials. In these a high degree of control was obtained with azinphos-methyl and 1-naphthyl N-methylcarbamate when applied in mid-June and early July; a further spray in late July did not contribute towards control. If these results are confirmed it would appear that the normal times of application for codling moth should also be suitable for A. podana.

The summer fruit tortrix moth

The life cycle bears a close resemblance to that of A. podana, the main differences being a slightly earlier flight period of first generation moths, which starts in early June, and another complete generation of adults in August and September. Since damage is caused by the maturing larvae arising from the first flight of moths it would be expected that the previous recommendations should also be applicable to this species. The only experimental evidence available is a trial with DDT, toxaphene and parathion (Groves and Tew, 1953) when a marked reduction in damage followed applications on 5th and 23rd June, dates which were subsequently considered by the authors to be too early to give optimum results.

The fruitlet mining tortrix

Information on the life cycle in England rests on evidence gleaned from general orchard observations and the known details are in close agreement with those reported by Vogel, Klingler, and Wildbolz (1956) for Switzerland. Moths are present during the blossom period and probably for a short while afterwards. Eggs, closely resembling those of the codling moth, are laid mainly on the undersides of the rosette leaves and the larvae, on hatching, migrate to the young fruits. Where a fruit cluster is present the larva lives in the centre, protected by copious webbing; single fruits may be entered at the calyx or have a leaf attached to the side. By early July the larvae are mature and spin a cocoon under bark which forms the resting place until a new generation of moths emerges in the following year. This species has only one generation a year.

Once the larvae have reached the fruit and produced some webbing control is probably made difficult by the protection afforded by the webbing. The most susceptible period is at petal fall or shortly afterwards; in Switzerland satisfactory control has been obtained during the ten-day period immediately following petal fall and, in England, similar results have been obtained with DDT.

Acknowledgements

I am greatly indebted to Mrs. Joan Llewelyn (née Groves) and Dr. J.R. Chiswell for the data on codling moth and fruit tree tortrix moths.

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THE CONTROL OF CODLING MOTH, SUMMER FRUIT TORTRICIDS AND FRUIT TREE RED SPIDER MITE, WITH SPECIAL REFERENCE TO AZINPHOS-METHYL

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Summary

Azinphos-methyl is a new insecticide of the organophosphorus group with a wide range of action. It was first introduced into this country for trials purposes in 1958, primarily for use on apples and pears, although it had previously been tested on the Continent and elsewhere. Since, then extensive trials, later borne out by commercial experience, have shown that two or three applications of azinphos-methyl, starting mid- to end June, will control codling and summer tortrix moths and at the same time keep populations of fruit tree red spider mite to a very low level.

Introduction

Most of the insecticides used in the orchard up to the present day have been more or less specific in action necessitating the use of many different materials and a complicated spray programme. During the last five years or so, however, materials with a much wider range have been introduced. The use of such materials, one of which is azinphos-methyl, may simplify the spray programme for the grower and in some cases render timing less critical.

Azinphos-methyl has a somewhat lower vapour pressure than parathion, and is practically unaffected by light. Like other organophosphorus compounds it is a cholinesterase inhibitor. The oral LD50 to male rats is from 10 - 15 mg/kg. The dermal LD50 is in the region of 170 mg/kg. Azinphos-methyl acts as a contact and stomach poison against many insects and mites, and is ovicidal to some species. It is non-systemic, but has some penetrative effect, although not as marked as parathion. Most of the chemical, however, remains as a deposit on the leaf or fruit surface where it persists for ten to fourteen days under field conditions. It does not appear to be so toxic to predators as the chlorinated hydrocarbons. For instance, tests with black kneed capsid (*Blepharidopterus angulatus*) indicate that it is less toxic than DDT, but more toxic than lead arsenate. But any chemical with as wide a range of action as azinphos-methyl may be expected to have some effect on the predator population. Azinphos-methyl is formulated an an emulsifiable concentrate containing 20% w/w active ingredient and as a 25% wettable powder. Only the former is available on a commercial scale in this country.

CODLING MOTH (*Cydia pomonella*)

The codling moth is probably our most important apple pest and, in spite of the recent advances in pest control, is still a problem. Although no cases of resistance have so far been recorded here, some of the conventional materials do not always give a satisfactory control. This could be due to wrong timing or insufficient coverage from changes in spraying technique. Extensive trials with azinphos-methyl against codling moth have shown it to be as good as, and often better than, conventional materials. In a replicated field trial carried out in Norfolk during 1960, a 20% DDT emulsion sprayed on 14th June, 1st and 23rd July at 8 pints/50 gal./acre yielded 3.4% by weight of attacked fruits, whereas the azinphos-methyl 20% emulsion sprayed on the same dates at 3 pints/50 gal./acre gave only 0.9% of attacked fruits.

Although three sprays may be necessary in some seasons where a second generation occurs, two sprays will usually be sufficient, applied at the normal timing, i.e. mid- to end June, and early mid-July. For instance in a trial carried out in 1960 and recorded in the East Malling Research Station for 1960 (p.31), three applications of azinphos-methyl and DDT in mid-June, early and late July gave a 95% control of codling damage. Omission of the last spray had a negligible effect; omission of the June spray, however, reduced the efficiency of the materials by about 25%. Timing, particularly of the first spray, is of great importance and it is usually this spray which causes the greatest reduction in codling moth damage. In fact, a single spray of azinphos-methyl at a rate of three pints per acre in one trial gave a reduction of 75% in the number of attacked apples compared with the unsprayed plot; DDT gave a reduction of 50%.

Emergence of the moths obviously varies from year to year, and the normally accepted spray timings, i.e. 3rd week June and mid-July, whilst giving a perfectly adequate control in many seasons, will, in a few seasons, fail. There are indications that timing is not quite so critical when azinphos-methyl is used. For instance, in a fully replicated trial carried out in 1958 at Rowhill Experimental Farm, where spraying was carried out rather late owing to unsuitable weather conditions, azinphos-methyl reduced the percentage of damaged fruits by 88.6%, whereas DDT reduced it by only 54%. This greater latitude in the use of azinphos-methyl is probably due to its ability to kill codling larvae up to three days after they have entered the fruits, and to its pronounced ovicidal effect.

Codling moth is even more of a problem in other parts of the world where ten or more sprays may have to be applied at 10 to 14 day intervals throughout the season. Azinphos-methyl has proved very effective under these rather more rigorous conditions. The results of a trial carried out in Italy using both formulations are shown in Table 1. Nine sprays at high volume were applied at intervals of 10 to 14 days. Sampling was carried out on the total yield.

Table 1 Results of a trial carried out in Italy against codling moth

Material	Percentage (product)	Percentage attacked apples
Azinphos-methyl 20% Emulsion	0.1%	3.4%
Azinphos-methyl 20% Emulsion	0.2%	1.3%
Azinphos-methyl 25% Wettable Powder	0.1%	5.9%
Azinphos-methyl 25% Wettable Powder	0.2%	3.3%
Control		86.0%

Resistance to lead arsenate and DDT is widespread in many parts of the world and here again azinphos-methyl has proved very effective (See Table 2). This trial was replicated twelve times, using single tree plots and sprays were applied six times at 10 to 14-day intervals. Assessment was made at harvest time on the total yield.

Table 2 Results of a trial carried out in South Africa against DDT resistant codling moth

Material	Percentage (product)	Percentage attacked apples
Azinphos-methyl 25% Wettable Powder	0.1%	10.6%
Azinphos-methyl 25% Wettable Powder	0.2%	3.1%
DDT 50% Wettable Powder	0.2%	28.6%
Control		40.6%

Similar results have been obtained from Australia and the United States.

SUMMER TORTRIX MOTHS

These moths are becoming an increasing problem in some fruit growing areas. Although the damage they cause is largely superficial, it results in downgrading of the fruit and provides an entry for fruit rotting fungi. The two most important species are the surface eating tortrix (Cacoecia oporana) and the summer fruit tortrix (Adoxophyes orana). The former is more widespread and also more difficult to control, since the caterpillars are well-protected by their habit of spinning two leaves together, or a leaf to a fruit. Azinphos-methyl has given outstanding results against this pest with two sprays applied as for codling moth. In a 4x replicated trial in 1958 at the Rowhill Experimental Farm, azinphos-methyl 20% emulsion, sprayed on 30th June and 24th July at 0.1 per cent and about 200 gal/acre, reduced the percentage of damaged fruit from 13.0 on the control trees to 0.1 per cent, whereas a 26/27 per cent DDT emulsion sprayed at 0.3 per cent at the same rate and on the same dates gave 1.1 per cent damaged fruits. In another trial carried out in 1960 different spray timings were used, anda lso gave excellent results (see Table 3).

Table 3 Replicated trial against surface eating tortrix

Spraying dates: 16th June and 3rd August
Volume: Low volume, 25 gallons per acre

Material	Damaged apples out of 100 September 19th				
	1	2	3	4	Total
Azinphos-methyl 20% Emulsion at 3 pints/acre	0	0	0	0	0
Control	9	0	9	3	21

Two sprays would appear to give a perfectly adequate control in most seasons. In the East Malling trial previously referred to, three sprays applied mid-June, early and late July gave a 97% control of damage (69% for DDT). Two early sprays applied to a different site gave a 92% control. In both cases the application rate was 100 gallons per acre. Although lower volumes have given good results, they are not generally recommended as good coverage is essential against this pest.

The summer fruit tortrix (Adoxophyes orana) occurs locally in some places in Kent and, although figures are not available from trials conducted in this country, azinphos-methyl has given good results in Holland where this pest is widespread. A single spray applied during the third week of June reduced the number of damaged leaves by about 95% compared with the unsprayed control; DDT gave a reduction of 82%. Besides being effective against the larvae of tortrix moths, azinphos-methyl is ovicidal to both species.

FRUIT TREE RED SPIDER MITE (Metatetranychus ulmi)

The fruit tree red spider mite is becoming an increasingly important pest, particularly where lead arsenate for codling moth has been replaced by insecticides which are damaging to predators and yet do not control red spider mite. Azinphos-methyl, on the other hand, is a good acaricide as well as being effective against codling moth, and though not harmless to predators, is less damaging than some of the currently used insecticides. In the early trials with azinphos-methyl it was used specifically against red spider mite and its performance tested alongside a number of other acaricides. In a fully replicated trial carried out at Rowhill Experimental Farm in 1959, when infestations were generally severe, three sprays applied on 29th May, 22nd June and 20th July, using 0.2% formulated product, kept the population at a very low level and seven weeks after the last application, was still giving over a 95% control. This corresponded to a figure of 10 mites per 30 leaves on the azinphos-methyl plots and 1135 mites per 30 leaves on the unsprayed control, and compared favourably with two sprays of demeton-methyl applied on 29th May and 22nd July.

The results of a similar trial also carried out at Rowhill Experimental Farm, but using a lower rate (0.1% formulated product) are given in Table 4.

Table 4 A 4 x replicated trial against fruit tree red spider mite

Spraying dates: 3rd and 30th June, 24th July.
Volume: Approximately 200 gallons per acre.
Results (expressed as the mean number of mites per 25 leaves)

Material	10th June	24th June	8th July	15th July	20th Sept.
Azinphos-methyl 20% Emulsion (0.1% product)	1.5	5.0	0.25	4.5	94
Control	75.0	83.0	373.0	325.0	4382

Further trials were carried out in 1960 on the effect of a single spray of azinphos-methyl on red spider populations. In one of these a spray applied on 30th June, using a rate of 3 pints in 20 gallons per acre, kept the population at a low level for the rest of the season, and on 9th September there were only 49 mites per 100 leaves on the treated plots; on the unsprayed plots there were 513 mites per 100 leaves. 1960 was not, generally speaking, a year when red spider was particularly troublesome, and normally one would not rely on a single spray, even where a petal fall acaricide has been applied.

However, azinphos-methyl is normally recommended specifically against Codling moth, and its function against red spider is regarded as secondary. Usually an acaricide such as demeton-methyl would be applied where necessary for the petal fall spray, followed by azinphos-methyl at the normal codling timing, which has been found to give an adequate control of red spider under most conditions. For instance, in a field trial carried out in Kent during 1960, where azinphos-methyl was applied at the normal timing for codling moth control, using a rate of 0.15% formulated product, a count taken at the end of August showed a population of only six mites per 100 leaves. This compared favourably with a demeton-methyl/DDT mixture applied at the same timing.

Azinphos-methyl is primarily effective against the active stages of red spider mite and whilst having a slight ovicidal effect against the summer eggs, is ineffective against the resting stages. This should be borne in mind when spraying against codling because the correct timing for codling may not always coincide with maximum red spider activity.

THE PROBLEM OF RESIDUES

The fact that the penetration of azinphos-methyl into plant tissues is limited would indicate that the risk of toxic residues at harvest is slight, which is supported by the residue analyses given in Table 5.

Table 5 Results of residue tests using azinphos-methyl at 0.05% active ingredient

	Date of Spraying	Date of Harvest	Date of Analysis	Residue p.p.m.
Worcester Pearmain	22.6 and 14.7.59	20.8.59		0.18
Newton Wonder	22.6 and 14.7.59	18.9.59		0.05
Worcester Pearmain	13.5, 9.6, 30.6 and 22.7.59	22.7.59 29.7.59 5.8.59	28.7.59 4.8.59 12.8.59	0.74 0.18 0.12
Cox's Orange Pippin	13.5, 9.6, 30.6 and 22.7.59	22.7.59 29.7.59 5.8.59	28.7.59 4.8.59 12.8.59	0.57 0.28 0.19

On the basis of these and other residue data, azinphos-methyl has been approved by the Ministry of Agriculture's Notification Scheme for use on apples and pears provided that an interval of three weeks is allowed between the last spray and harvesting. On apples up to five applications may be made and on pears three applications, each not exceeding $7\frac{1}{2}$ oz per 100 gallons of the active ingredient high volume (0.05%).

If applied medium or low volume the quantity of active ingredient used per acre should not exceed that which would have been applied high volume. Azinphos-methyl is included in the Agriculture (Poisonous Substances) Regulations as a Second Schedule, Part III Substance.

RECOMMENDATIONS FOR THE USE OF AZINPHOS-METHYL

From experience both in trials and commercial practice the following recommendations are made for the use of azinphos-methyl.

Two applications at a rate of 0.04% active ingredient ($1\frac{1}{4}$ pints per 100 gallons water high volume or $2\frac{1}{2}$ pints per acre low or medium volume) should be made, the first made about mid-June, followed by a second in early July. A third spray may be applied towards the end of July or the beginning of August to control late attacks of codling and tortrix but whether or not this last spray is necessary can only be determined by local observation. Although this programme is directed specifically against codling and tortrix moths, it will also keep red spider populations at a low level in most seasons, following a petal-fall acaricide where necessary.

It has been said that 'a chemical is as good as its coverage' which is particularly true of non-systemic materials such as azinphos-methyl. Good coverage is, of course, important for the control of codling and even more so for tortrix, but is probably most important in the case of red spider mite where isolated colonies which have been missed during spraying can be responsible for reinfesting a whole orchard.

Azinphos-methyl is suitable for high and low volume application and good results have been obtained with both, although volumes below 20 gallons per acre are not recommended for the margin of error is much greater with this rate of application.

Acknowledgements

Acknowledgement is made to Plant Protection Limited, who kindly allowed us to use come of their trial results; also to the growers, without whose co-operation it would have been impossible to carry out field scale trials.

OBSERVATIONS ON THE PERIOD AND DENSITY OF OVIPOSITION AND APPLE ENTRY BY CODLING MOTH IN RELATION TO TIMING AND APPLICATION OF PHOSPHAMIDON, ETHION AND DDT

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Introduction

Codling moth has always been a pest of sporadic importance in England. To some extent this variability has made it more difficult to control adequately than if it were as continually serious as it is in many countries with warmer climates. The English grower has never been convinced that a continuous routine spray programme to cover the whole flight period is necessary or economically sound, and for this reason the timing of such sprays as he has used have been the more important. Nevertheless, very little quantitative information has been published on the factors relevant in this country. When experiments were started at Ongar on the control of codling moth, firstly with phosphamidon, and later with ethion, considerable emphasis was therefore placed on obtaining basic information on emergence, flight periods, and oviposition of this pest and how these were related to the progress of the actual damage on the tree. One of the aims was to determine the importance of the early flights of moths in relation to the total level of the attack, but it was soon apparent that the known techniques of studying the progress of the attack on the apples were unsatisfactory. Not the least of the difficulties was the relatively low incidence of the attack at any one time. For example, even in an orchard where almost 50% of the apples were eventually attacked, the incidence of eggs on the apples at any one time was in the order of 2 - 3%. In the course of the insecticide experiments it was therefore necessary to explore various evaluation techniques for measuring the time and density of codling moth attack, and this paper is a progress report of the results obtained so far in this part of the investigations.

Experimental methods

Plot layouts and spray applications

Experiments were confined to the apple varieties Worcester Pearmain and Cox's Orange Pippin. Plot sizes varied from year to year depending on the number of treatments to be tested and the size of experimental plots available. On all sites randomised block layouts were used, usually with 2 or 3 trees per treatment plot with 3 or 4 replicate plots per treatment. All sprays were applied at high volume (200 - 250 gal/acre) with hand lances.

Observations and Assessments

a) Moth trapping. In 1960 a light trap was used at Ongar only and was examined daily over the period 17th May to 3rd August 1960. In 1961, in addition, two other traps were operated, at Beltring in Kent and at Boreham in Essex. The trap at Ongar was emptied daily, and the others three times weekly over the period 1st June to 26th October 1961.

b) Observations on the emergence and oviposition of captive moths

Hibernating larvae were collected from the 1960 experiments and kept in gauze covered tins in a sheltered place on the boundary of one of the orchards at Ongar. These tins were observed daily from the beginning of June and when the moths emerged they were placed in sleeves on trees to observe the oviposition times and subsequent hatching.

c) Observations on egg deposition and hatching

In an endeavour to find out more about the periods of incubation of codling eggs, specific fruits or fruit clusters were marked on selected trees on each experimental site. These trees were known as 'Pilot trees'. 20 fruits on each of 8 trees were tagged on the 1960 site and 30 fruits on each of 8 to 12 trees on both sites of the 1961 experiments. These fruits were selected well in advance of the onset of egg laying and examined every other day over the period of attack. As soon as eggs were seen on these apples they were recorded and marked, and kept under observation, until they had hatched. The appearance of 'stings' on the fruits, whether associated with specific eggs or not was also recorded.

d) Observations on the progress of codling attack

As soon as eggs were observed on pilot trees, routine assessments were begun on all treatment plots. This involved examining 50 fruits per tree, taken at random, and recording the number of eggs, hatched and unhatched, and the number of stings present on this 50-fruit sample. The intention was to carry out this assessment weekly until harvest. Some counts were missed but there were sufficient on each site to enable us to deduce the periods of attack.

e) Counts of fallen fruit

Many fruits fail to reach maturity and fall before harvest. As some of these may be damaged by codling moth larvae, all fallen fruits were picked up from under each tree each week and examined for codling damage.

f) Harvest records

All fruits remaining on the tree at harvest were picked and the weight of the total yield recorded. A half bushel sub-sample was then taken from each tree and each fruit examined for codling damage and the number of fruits counted to determine the total number of fruits at harvest and the number and percentage of fruit attacked by codling.

Table 1 Relation between flight, oviposition and egg hatch of Codling Moth, 1961

Observation	Site	June week commencing:-				July			
		4 M.W.F.	11 M.W.F.	18 M.W.F.	25 M.W.F.	2 M.W.F.	9 M.W.F.	16 M.W.F.	23 M.W.F.
Emergence of captive moths	Ongar, Essex.	1	5	6	8. 8. 6.	20			
Nos. of moths trapped	Beltring, Kent.	3	1	2		3. 2.	7. 4.	4	1
	Boreham, Essex.					1	1	3	1
	Ongar, Essex.				2	6	2. 3.		
Nos. of newly laid eggs per observation	Southfleet* Kent.		2	1	2 3		3	3	
	Boreham** Essex.				5	3.2.			
Nos. of newly hatched eggs per observation	Southfleet Kent.				2	1	5. 3.5.	1. 1. 3.	3. 2. 1.
	Boreham, Essex.				1	1.2.7.	2. 2.1.	1	

Codling moths were also trapped 2nd August (one), 16th August (one).
One 'second generation' captive moth emerged - September 7th.
Observations on eggs stopped on the 31st July.

* from 360 apples
** from 240 apples

Table 2 Incubation period of Codling Moth eggs in the field (1961)

Site:- Southfleet, Kent. Variety:- Worcester Pearmain

Egg No.	Date found	Incubation period in days
1	19 June	10 - 13
2	30 "	6 - 12
3	30 "	10 - 13
4	30 "	6 - 12
5	3 July	11 - 16
6	3 "	9 - 13
7	10 "	14
8	10 "	12 - 13
9	10 "	14
10	10 "	15
11	21 "	12 - 13
12	21 "	12 - 13
13	21 "	9 - 12

In 1960 of 15 eggs observed at weekly intervals, none took less than 7 days or more than 15 days to hatch.

In 1961, in daily observations on a batch of 15 eggs laid on the night of 17th June at Ongar, one hatched after 11 days, 6 after 12 days, 8 after 13 days.

Table 3 Relation between oviposition, egg hatch and progress of attack on the fruit

Site, Pearsons Green, 1960. Variety: Cox.

	Records from** 'pilot' trees		Increase in % of infected apples at each count. Underlining indicates spray dates		
Week ending	eggs laid	eggs hatched	Control	DDT	Phosphamidon 0.02%
June 18th	-	-	-	-	-
June 25th	5	-	-	-	-
July 2nd	4	2	1.6	0	0.2
July 9th	4	5	-1.1	0	-0.2
July 16th	4	4	0.2	0.4	0.8
July 23rd	3	2	1.9	0.4	1.0
July 30th	10	2	2.4	-0.4	0.8
Aug. 6th	1	12	1.8	1.2	0
Aug. 13th	0	8	4.6	0.5	1.2
Aug. 20th	0	0	2.3	0	5.7
Aug. 27th	0	0	7.5	2.1	0.7
Sept. 3rd	(2)*	-	2.1	1.8	0.3
Sept. 10th	-	-	10.3	1.1	1.7
Harvest date - 15th	-	-	13.3	2.4	10.6
		Total at harvest	47.8	9.5	19.1

* This figure from random counts on control plots. There was clear evidence of egg laying at this level on all plots this week.

** From 160 apples.

Table 4 Relation between oviposition, egg hatch and progress of attack on the fruit

Site, Southfleet, 1961. Variety: Worcester Pearmain

	Records from* 'pilot' trees		Increase in % of infected apples at each count. Underlining indicates spray dates		
Week ending	eggs laid	eggs hatched	Control	DDT	Phosphamidon 0.02%
June 16th	2	0	-	-	-
June 23rd	1	0	-	-	-
June 30th	5	2	-	-	-
July 7th	3	1	0.8	1.5	0.3
July 14th	3	13	4.3	0.9	1.4
July 21st	3	5	-0.9	0.5	-0.7
July 28th	0	6	7.0	-0.4	2.7
Aug. 4th	0	0	5.7	1.6	0.6
Aug. 11th	-	-	7.0	1.1	0.5
Aug. 18th	-	-	1.2	0.2	0
Harvest date - 25th	-	-	0.7	1.6	0.6
		Total at harvest	28.1	7.0	4.9

* From 360 apples

Table 5 Relation between oviposition, egg hatch and progress of attack on the fruit

Site. Boreham, Essex, 1961. Variety: Worcester Pearmain

	Records from* 'pilot' trees		Increase in % of infected apples at each count. Underlining indicates spray dates		
Week ending	eggs laid	eggs hatched	Control	DDT	Phosphamidon 0.02%
June 16th	0	0	-	-	-
June 23rd	0	0	-	-	-
June 30th	5	1	0	0	0
July 7th	5	10	0.5	0.5	1.1
July 14th	0	5	0.3	-0.5	-1.1
July 21st	0	1	0.9	0	0
July 28th	0	0	2.4	0	1.1
Aug. 4th	0	0	3.8	0.6	0
Aug. 11th	0	0	0	0.4	0
Aug. 18th	0	0	0.5	0	0
Harvest date - 28th	0	0	2.2	0.5	0
		Total at harvest	9.9	1.6	1.1

* From 240 apples

Table 6 Proportion of codling infected apples falling before harvest 1959-61 on control plots

Site & Year	Variety	Infected apples dropped before harvest as % of total	Overall % infection
Beltring 1959	Cox Worcester	3 6	18 9
Pearson's Green 1959 1960	Cox Cox	23 11	47 42
Southfleet 1960 1961	Worcester Worcester	10 25	19 28
Boreham 1961	Worcester	7	11

Discussion

a. Flight periods, oviposition and egg-hatch

Full data on the relationship between these are only available from the 1961 experiments. It was unfortunately not possible to obtain comparisons between moth trap records and egg counts on the tree within particular orchards. On one of the two sites where moth traps were placed, there was no visible codling moth attack, even though there was a relatively high catch of moths in the trap, and in the other the yield of moths was relatively low. However, when the frequencies of moth catch from all the traps are compared side by side, as in Table 1, a similar pattern is shown throughout, and this is in itself in close relation to the oviposition data and the observations on the emergence of moths from captivity at Ongar. The egg hatch observations were a more reliable measure of egg oviposition than the oviposition observations, as several eggs were first recorded some days after they had been laid. This is because changes in the eggs in the later stages of development make them much more conspicuous on the apple surface. One obvious weakness of the oviposition observations is that they relate to eggs laid on the apples only. This limitation was deliberate, as it was thought that it would be difficult to follow the subsequent history of eggs laid on the leaves, but in practice it was found that this difficulty also applied to eggs laid on the apples, and a very small proportion of the larvae hatched from them actually entered the apples on which the eggs were laid. There is some evidence that the natural tendency of the larvae to wander before entering was increased by the handling that the marked apples inevitably suffered. There was a closer quantitative correlation between density of eggs and stings on the random samples, but in this case there is no way of relating individual 'stings' and eggs. It is also not possible from these counts to say what proportion of the stings arose from eggs laid on the apples, and what proportion from eggs laid elsewhere, as the random egg counts at each time included eggs from the previous count. As taken in the field, random egg-counts can only give crude estimates of peak egg population, and have been omitted from the tables. Methods of extracting more precise information from such counts are under investigation and it seems that they could be made to yield valuable data on the effect of treatments on oviposition, egg hatch, and larval entry in orchards with a sufficiently high incidence of codling moth.

b. The incubation period

One of the objects of the observations on marked eggs on the pilot trees was to obtain an estimate of the average hatching period in the field. Results for 1960 and 1961 are given in Table 2. The range given for the incubation period in this Table represents the interval between successive observations on each egg. For the later observations in 1961 it was possible to reach a more precise estimate by studying the development stages. In general the incubation period was 10 - 24 days.

c. Relation between oviposition egg hatch and progress of the damage on the apples

Although the dates of oviposition are the best measure of the beginning of the attack, the hatching date is most relevant to spray timing. If the incubation interval is 10 - 14 days, sprays which are applied at flight time or oviposition time are likely to be well diluted, perhaps by weather and certainly by apple growth, by the time the eggs actually hatch. The observations in 1961 suggest that the earlier part of the June attack was making a very small contribution to the total attack and that the main onset of egg hatching was 2 - 3 weeks after the very first moths were trapped. On this basis sprays applied too early in June would not only have a small effect on subsequent attack, but if normal spray intervals were adhered to, would result in minimum protection being available at the most important time. However, the egg counts can only give a qualitative picture. The next essential step is to estimate what proportion of the damage can be associated with any particular flight or hatch period. To do this the progress of the attack on the apples themselves has been estimated from the following data:- (a) the level of infection on the tree by sample counts at weekly intervals; (b) the numbers of dropped apples per week; (c) the numbers of dropped infected apples per wee; and (d) the numbers of clean and infected apples at harvest.

From these the level of infection in terms of total apples produced can be calculated.

These calculations for those experiments where all this information is available are given in Tables 3, 4, and 5. These experiments have been primarily concerned with ethion in various spray combinations, but there is not the space to give all the details of this work here. Instead, the results of the controls and standard treatments are given to show how this approach indicates clearly where a particular treatment is failing to give complete control. In these tables the oviposition and egg-hatch data are included to show how these are correlated. In all these there is a lag of about one week between peak egg-hatch on the pilot tree and peaks of apple entry on the main plots. This is because 'Stings' are generally not detected under conditions of large-scale random sampling until they are a few days old. The results from all three sites are in agreement in that the proportion of attack taking place before the end of June is negligible. On the 1961 sites, both on Worcester, the greater part of the fruit entry was observed in the last week of July and the first week of August, which, allowing for the time lag in detecting stings, coincides with the peak of egg hatch on the 10th - 21st July, and of oviposition from the 26th June to the 7th July, shown in the observations on the pilot trees. On the 1960 site the pattern was very different; the oviposition egg hatch show three peaks, one from the 26th June to the 3rd July, one from the 17th July to the 31st August, and another very late peak at the end of August. The peaks of damage detection each follow at about three-week intervals after these oviposition peaks. The increases in infestation close to harvest may partly be due to second entry. Attempts were made to distinguish between this and primary attack but were not successful on a routine basis. The very late attack on the 1960 site is, however, almost certainly due to the partial second generation as eggs were known to be laid at this time. It accounted for 20 to 30% of the total final infestation. In two of the sites there is a slight fall in the percentage infection at the end of June; this is known to have been associated with 'June drop'.

d. Timing and efficiency of the treatments

In 1960, both of the standards in these experiments, DDT and phosphamidon, were applied as conventional three application programmes at three intervals of three weeks from the 15th June to the end of July. In 1961 the number of phosphamidon applications was increased to four but covered the same spray period. From Table 3 - 5 it is clear that although the degree of control was satisfactory, a better result might have been obtained by delaying the programme by about a fortnight throughout, i.e., delaying the first spray until the last week in June. As it was, the last spray was not applied late enough to catch the most important phase of the attack, i.e., from mid-July to mid-August. In terms of proportion of crop saved, the first application was largely wasted. DDT and phosphamidon were similar in efficiency. Another point of practical importance is that most of the apples attacked early on drop before harvest. Although they represent a loss of crop they are less costly to the growers than those apples which contain codling at harvest and have to be picked out on the grading table. Most of these latter will have arisen from the August attack. Table 4 shows the proportion of infected apples that dropped before harvest on a number of sites from 1959-61. The proportion is very high - frequently more than half - and demonstrates that the considerable labour of gathering the dropped apples week by week cannot be avoided.

Too many generalisations on spray timing should not be made from the results from three sites in two years, and it must be remembered that the first larvae to enter the apples are especially important in that they are the source of the second generation attack in late varieties of apples. A substantial second generation did occur at one site, but this experiment could not detect any treatment effects, as there were always sufficient early-maturing larvae from the untreated plots to provide enough second generation moths to give rise to a high level of infection on all treatment plots.

Conclusions

Several points have arisen from the work so far which might be considered in evaluating the efficiency of insecticides against this pest. These are:-

1. That harvest data alone cannot provide an adequate method for comparing the efficiency of different spray timings.
2. That it is possible to follow the progress of the attack quantitatively and so to estimate the direct effect of a particular application.
3. That using such methods it could be shown on these three sites that:-
    a. less than 2% of the final attack could be attributed to eggs hatching before the end of June.
    b. At least 50% of the attack arose from eggs hatching between mid-July and mid-August.
    c. The one example of second generation attack arose from eggs hatching in early September.

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LEAF BRONZING IN APPLES AS A MEASURE OF EFFICIENCY OF ACARICIDES AND ITS RELATION TO LEAF POPULATION OF FRUIT TREE RED SPIDER

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Introduction

Dr. Massee in his survey of the red spider problem in 1949 (Groves and Massee 1949) said that one of the difficulties of experiments on the control of red spider was the measurement of the degree of control. This was perhaps more acute at that time when the control of summer infestation depended on the use of pre-blossom treatments. Since then the widespread use of summer acaricides has made it possible to obtain immediate control of the summer population but it is still not easy to get an accurate quantitative picture of the overall effect of an acaricide throughout the season. The chief reasons for this are:- (a), the population of red spider throughout the summer period fluctuates because of the succession of generations, but the effect on any one of these generations cannot be measured very clearly because, as shown by Blair and Groves (1952), two are normally present at any one time. Furthermore, one of these generations may be present at the egg stage and the immediate effect of the acaricide on the population is not necessarily a good measure of the subsequent effect on the build-up. (b), Red spider does not have any direct effect on the yield of crop nor on the appearance of the fruit itself, so that neither can serve as a measure of the degree of control. The magnitude of the indirect effects on yield, resulting from the characteristic leaf damage is inevitably influenced by environmental conditions, tree vigour and variety so that it is hardly surprising that results from different sources have often been conflicting.

Of course, it is quite possible to follow the fluctuations of population accurately as Blair and Groves did by sample counting at intervals on both treated and untreated trees, but apart from the labour involved in doing this on a large number of treatments, it is not easy to express the differences in population fluctuations in a simple comparative way. Even if one is able to detect differences in the population density over a given time one may not know what these mean in terms of damage to the tree and therefore it becomes difficult to put treatment differences in perspective. Many attempts have been made to establish the relationship between red spider attack and yield, but, apart from the general failure so far to establish a clear relationship, the majority of summer insecticide programmes designed to control red spider mite will also be affecting other pests and diseases, and so influencing yield. This was certainly true of two of the insecticides we were interested in, phosphamidon and ethion, both of which were being tested primarily for their effect on codling moth. The only visible damage which is a characteristic of red spider is the 'bronzing' effect caused by the feeding punctures on the leaf. In the course of our work on red spider we have attempted to relate the intensity of damage with the population density throughout the season and by this means establish the practical importance of observed treatment differences.

Methods

A. Population Counts

The population levels have been estimated from leaf samples taken at intervals through the summer. The distribution of red spider changes progressively through the season and the attempt has been made to overcome this by a partially systematic sampling technique. Pairs of leaves are taken from 5 random trusses on each of three branches, each pair of leaves consisting of one of the small older leaves, and one of the later full sized leaves. This is because the attack normally starts on the older and smaller leaves and eventually spreads to the younger leaves. Extension shoots are avoided, partly because the red spider often does not reach these until very much later in the season, and partly because it is much more difficult to operate a routine sampling method which includes both extention shoots and leaf trusses without taking inordinately large samples of leaves. In most of the experiments described here, 30 leaves were taken per tree, usually from 2 trees per plot, the replicates varying from 3 to 6. In all experiments but one in this paper the total leaf sample per treatment was 180.

Extraction of the mites has not been by the classic East Malling method (Austin and Massee, 1947) but by a method derived from a technique described by Melvin and Earle (1948) for another purpose. Briefly, the leaf samples are picked directly into conical flasks, and a band of softened petroleum jelly smeared around the inside of the neck of the flask immediately after collection. The flasks are, as soon as convenient, placed on a warming mat under fluorescent light and as the leaves dry out the mites leave them, climb the sides of the flask and become embedded in the band. They can easily be counted in this position, and different stages of the active mites are easily distinguished. The main advantage of this method over the leaf-pressing method is that it is easier to operate when examining a large number of treatments and replicates on a number of sites, with relatively unskilled or inexperienced operators. The main disadvantage is, of course, that it only extracts the active stages although there is some evidence that some egg hatching does take place during the extraction process. The extraction efficiency has been checked by comparison with a formalin washing method.

On the whole, flask extraction has given a rather higher count of newly hatched nymphs than the formalin method, mainly due to hatching after collection, but a lower count (50 - 60%) of adult mites. However, as the major population surges seem to be chiefly due to the egg-hatching of young nymphs, these weaknesses do not prevent the method from giving a reasonably accurate assessment of the population fluctuations.

Ideally, counts should be carried out weekly from petal-fall until

October but this has been rarely practicable and a much longer interval has been used in the early part of the season, when population levels are generally low.

B. 'Bronzing' assessment

A simple five grade (0-4) scoring system was used, but as two or more observers independently graded each tree in each replicate, the mean treatment score was derived from 12 - 24 observations and a finer gradation of means was possible. The grades used were:-

Grade of damage	Score	Range of means	Description
V. severe	4	3.5 - 4.0	Bronzing complete - no green colour visible.
Severe	3	2.5 - 3.5	Nearly complete but a significant proportion of green leaves visible from a distance.
Moderate	2	1.5 - 2.5	General effect green but some bronzing can be seen from a distance without difficulty.
Slight	3	0.5 - 1.5	Leaf damage not at the bronzing stage and can only be detected by closer examination.
Negligible	0	0 - 0.5	No damage visible.

It is essential that the damage score should be made while the leaves are still green and vigorous on unattacked trees. Immediately after picking has been found to be a suitable time for the common commercial varieties. This has the advantage that differences in fruit density and colouring do not influence the assessment.

Results

A. Population fluctuations as a measure of control

Figure 1 gives typical population curves for the controls and treatments on one site in a series of experiments in 1959. (This is part of the experiment given in more detail in the tables). These curves exhibit the same sort of fluctuations due to the overlap of the generations as shown in Blair and Groves' work, and illustrate how a severe late summer attack can build up even from a low petal-fall population. The relation between the control and treatment curves in these figures reveals the difficulty of estimating the degree of control obtained for the comparison of the effects of treatments. The possibility of expressing the intensity of mite attack by an estimate of the area under the population curve has therefore been examined. This gives a measure of the 'mite-days' to which a particular leaf sample is exposed to attack. The measure of intensity of attack obtained by this method is illustrated in Table 2. One of the drawbacks of a method of this type is that treatment differences are apparently exaggerated and it becomes more difficult to judge the practical significance of the values obtained.

B. Comparison of 'mite-days' and 'bronzing' methods

Although both methods have been used in all our acaricide work since 1958, the comparison of these two methods is best illustrated by an experiment carried out in 1959 on four sites, two each of two varieties, and in which the treatments, the times, and methods of application, and the times and methods of assessment were exactly the same on each site. This experiment was primarily designed to give information on the control of codling moth, but the control of red spider mite was an important secondary issue. The results obtained by the two methods are compared in Tables 1 and 2.

Table 1 Comparison of treatment ranking by population counts and by 'bronzing' score

Experiment No. 59/18/16

(a) By Mite days

Variety	Site	Treatments in descending order of effectiveness							
Worcester	Horsmonden	5	6	3	1	4	2	7	8
	Beltring	5	3	6	4	1	2	7	8
Cox	Matfield	5	6	3	1	4	2	7	8
	Pearson's Green	5	6	1	3	4	2	7	8

(b) By 'Bronzing' Score

Variety	Site	Treatments in descending order of effectiveness							
Worcester	Horsmonden	1,5,6.			3	2,4		7	8
	Beltring	1,5		3,6		4	2	7	8
Cox	Matfield	5	1,3		6	4	2	7	8
	Pearson's Green	1,5		3	6	4	2	7	8

Table 2 Actual values of Mite days and 'bronzing' score for four treatments of practical interest from Table 1

(a) Mite days

Site	Mean log mite days per 30 leaf sample (Mean of 6 samples) Figures in brackets are actual mite days per leaf				S.E.* of a treatment mean (log mite days)
	5 Ethion 2 x 0.05%	1 Phosphamidon 4 x 0.02%	7 DDT + chlorbenside	8 Control	
Horsmonden	1.91 (2.7)	2.92 (27)	4.02 (352)	4.09 (414)	± .168
Beltring	1.11 (0.4)	3.23 (57)	3.57 (127)	4.23 (566)	± .171
Matfield	1.10 (0.4)	2.85 (24)	3.49 (103)	3.80 (211)	± .167
Pearson's Green	0.92 (0.3)	1.82 (2.2)	3.21 (193)	3.80 (211)	± .248

(b) 'Bronzing' score

Site	Mean 'bronzing' score (Max = 4) Mean of x 3 replicates x 2 observers				
	5 Ethion 2 x 0.05%	1 Phosphamidon 4 x 0.02%	7 DDT + chlorbenside	8 Control	S.E.* of a treatment mean
Horsmonden	0	0	1.83	2.33	± .137
Beltring	0	0	1.25	2.33	± .314
Matfield	0	0.17	1.50	2.25	± .256
Pearson's Green	0	0	1.58	2.42	± .314

* S.E. calculated from all eight treatments in Table 1

Table 3 Relationship between 'mite days' and level of 'bronzing'

Variety & Site & Year	Mite days per leaf causing damage at a particular level of 'bronzing'			Mean mite days per leaf*	Max. mite Nos. per leaf	Bronzing score
	Slight	Moderate	Severe			
Worcester Pearmain						
Horsmonden 1959	224	490	1096	414	9.4	2.3
Beltring 1959	182	490	1349	566	21.6	2.3
" 1958	78	219	549	410	30.5	3.3
Cox Orange Pippin						
Matfield 1959	97	281	871	211	11.7	2.3
Pearson's Green 1959	35	218	1148	211	8.3	2.4
Ongar 1958	39	87	229	430	35.1	3.7

* Geometric means

The first aim of this comparison was to see whether bronzing score would place treatments in the same order as the more time-consuming mite counts, and with a sufficient degree of precision. In Table 1 is seen the ranking of the eight treatments in the experiment as given by the two methods on the four sites; the order of ranking by the two methods is in close agreement. In order to show the practical significance of the order of ranking, Table 2 gives the actual values obtained for phosphamidon, ethion, DDT and the controls. In these two Tables one can see that the 'bronzing' method has given the same practical answer as the count method and although the precision is less it is in fact sufficient to enable one to assign a practical value to the treatment differences with some degree of confidence. The complete analysis shows that, as would be expected from a log transformation, the 'mite-days' method tends to give a better separation of the more successful treatments than the less successful. On the other hand, the 'bronzing' method is less able to distinguish between low levels of damage, and is more effective when the treatments are less successful.

C. Relation between 'mite-days' and bronzing

Similar close agreement between treatment ranking by the two methods had been obtained on two independent sites in 1958 (the first on which the 'bronzing' method was used), and suggested that a quantitative relationship between the two rankings might be found. Figure II shows a straightforward plot of mite-days against bronzing score. The agreement between these two curves encouraged fuller study of the method, mainly to see whether it would serve for measuring treatment differences on a large number of sites, but also to see whether a quantitative relationship could be established between the intensity of mite attack and the characteristic symptoms by which the grower normally judges the efficiency of these control measures. The 1959 curves differed to a certain extent from those for 1958 and various transformations were tried to make the data easier to analyse. The most satisfactory method so far found has been to express 'bronzing' score as a percentage of the maximum possible score, transform to probits and plot against the log of mite days.

The chief requirement for an examination of relationship between these two methods is that the experiment should contain sufficient treatments of only moderate success to give a wide range of 'bronzing' responses. Probit regression lines for three crops of Cox and three crops of Worcester, on which there was sufficient variation in 'bronzing' are given in Figure II. It will be seen that the form of the relationship is similar in each case, but that there are pronounced quantitative differences from site to site and year to year. These differences are shown more clearly in Table 2 where they are expressed as the level of 'mite-days' per leaf which has resulted in damage equivalent to the means of the three damage categories, slight, moderate, and severe damage. The fiducial limits of the lines have not been calculated, but there is sufficient agreement between them to suggest the following points: (1), it required a higher intensity of mite attack per leaf to produce the same degree of bronzing on Worcester as on Cox; (2), the same level of mites produced a much higher degree of bronzing in 1958 than in 1959. The actual values for the control plots in each year are given, and these show marked differences from the relationships measured from the whole of the experiments. They also show, however, that there was a tendency for a higher level of attack to be maintained on the Worcester than on Cox so that the final damage was similar in the two varieties. A possible explanation lies in the very high August levels of population in 1958, and there are undoubtedly considerable climatic differences between the two years which could account for different levels of damage. One must admit, however, that there are differences in interval between scoring and counting which might also provide some of the answers. The effect of high late season levels illustrates one of the weaknesses of the bronzing method as an absolute method of intensity of mite attack throughout the season. In this past year only one experiment has been carried out to which these methods could be applied. Red spider attack developed exceptionally early in high numbers, and in order to avoid complete defoliation of the trees the controls and DDT plots had to be sprayed with an acaricide in the middle of July. All plots remained free after that date; this means that in contrast to the experiments so far described, the major part of the mite attack on this site was before mid July instead of after it. It is perhaps significant that on this site low levels of bronzing were obtained even with relatively high mite counts. Probably the leaf bronzing in June or in early July, which was very apparent this year, was considerably masked later by new growth.

More work is needed to establish the relative parts played by late and early attack. The effect of growing conditions and variety are also important. In 1958 one crop of Laxtons Superb was examined by this method and gave a regression line of markedly different slope from that reported for Cox and Worcester. However, it does seem that 'bronzing' assessment can be a rapid and effective means of comparing the efficiency of acaricide treatments quantitatively. If one did not wish to rely upon it entirely, much counting could be avoided by using the counts from controls and one or two of the less efficient treatments, to establish the 'bronzing'-mite days relationship for each site.

Acknowledgements

My thanks are due to numerous colleagues who have assisted in assembling data on which this paper is based.

I would especially like to mention Mr. D C. Twinn and the members of his unit who carried out the mite counts, and Mrs. B. A. Bryant who undertook most of the statistical analysis.

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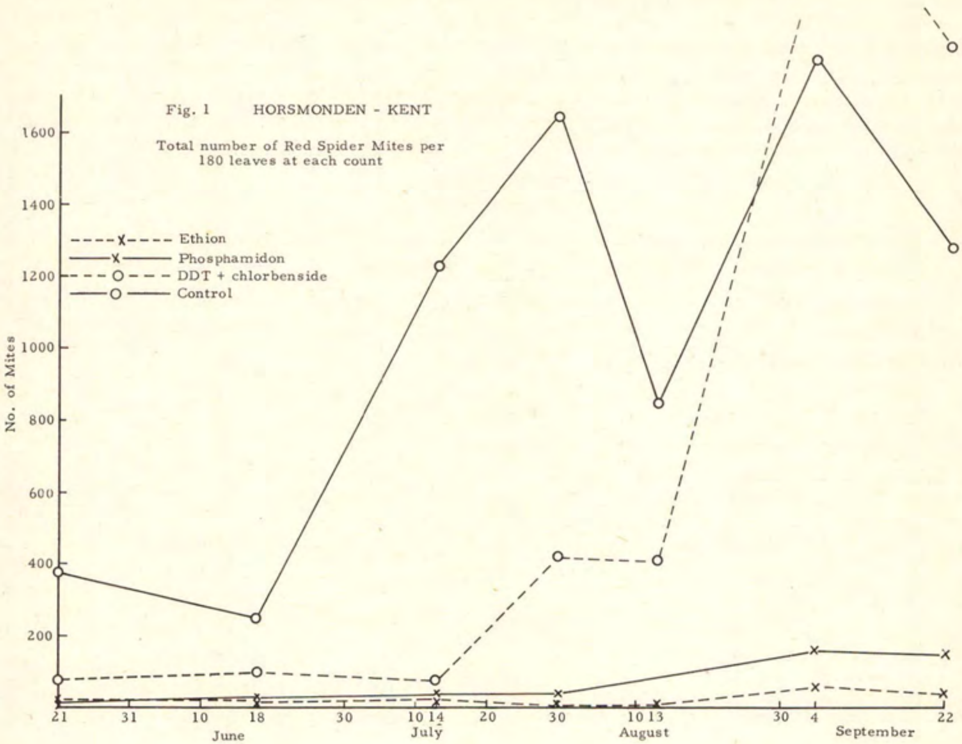


Fig. 1 HORSMONDEN - KENT
Total number of Red Spider Mites per 180 leaves at each count
Ethion
Phosphamidon
DDT + chlorbenside
Control
No. of Mites
1600
1400
1200
1000
800
600
400
200
21
31
10
18
30
10 14
20
30
10 13
30
4
22
June
July
August
September

Fig. 2 RELATION BETWEEN MITE DAYS AND BRONZING SCORE

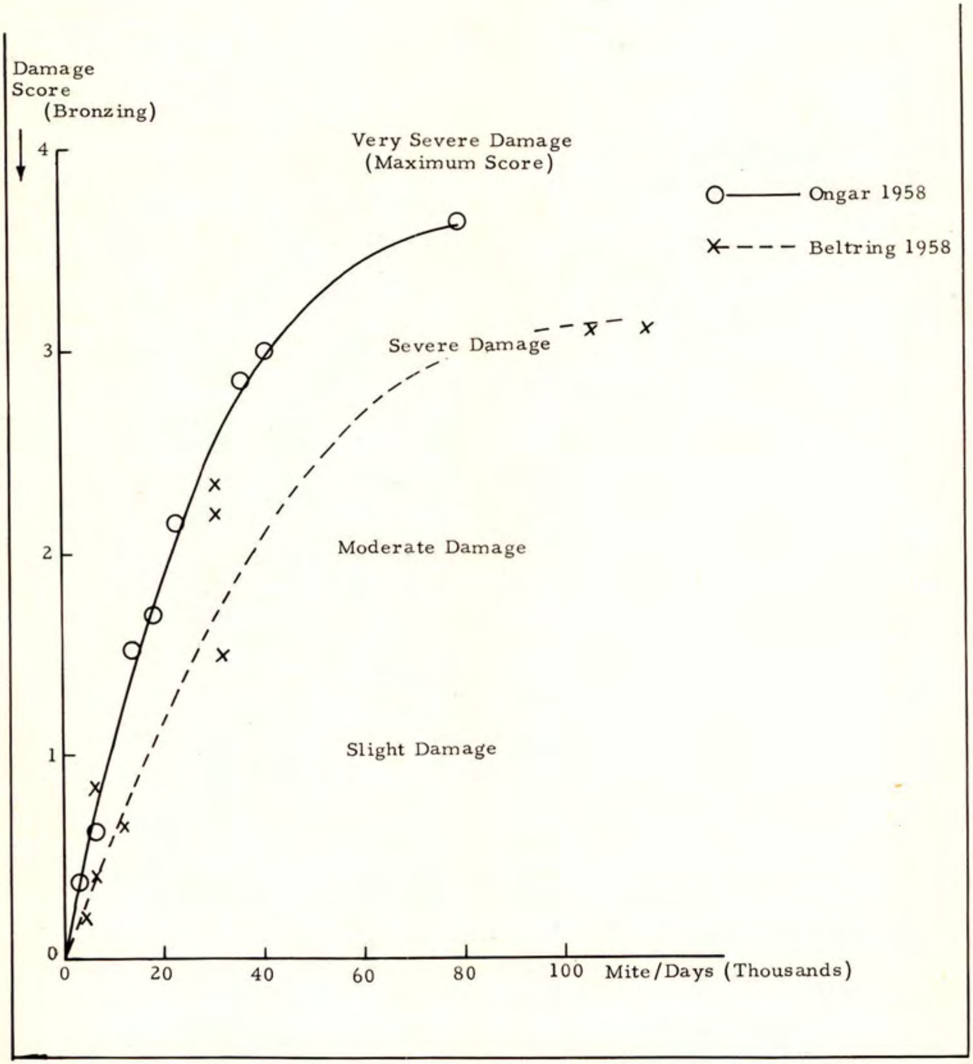
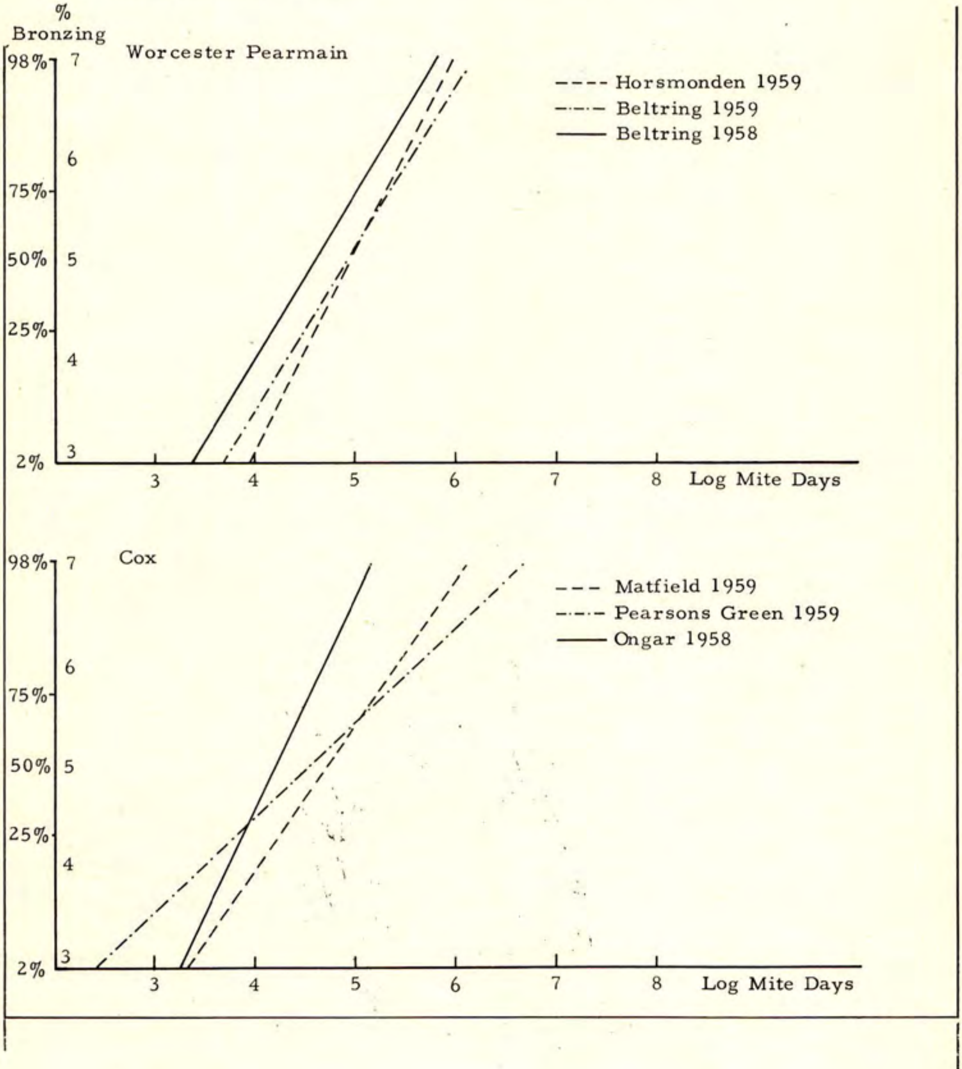


Fig. 3 CALCULATED PROBIT REGRESSION LINES

Excluding 0% Bronzing, as scoring system was such that small percentages (≏>2%) were counted as 0%.



THE PRESENT POSITION REGARDING THE INCIDENCE AND CONTROL OF APPLE APHIDS, FRUIT TREE RED SPIDER, FRUITLET MINING TORTRIX AND PEAR SUCKER

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The pattern of behaviour of insects and mites of economic importance in fruit growing is both complicated and unpredictable, a consequence of a combination of biological and ecological factors. Among the biological factors are the number of generations a year, the inherent capacity for varying resistance to toxic chemicals, and the ability to exist on several alternative host plants may decide whether or not a pest is easy to control. The ecological factors include the availability of alternative hosts, the disturbance in the balance of predator and parasite populations often caused by the use of spray chemicals, weather condition and its effect upon birds and other wild life, and various cultural practices will all effect the issue for good or ill.

Experience shows that certain pests are easy to control, and that where routine spray applications are carried out they may be regarded as nonexistent. Among these are Apple Blossom Weevil, Apple Sawfly, Apple Sucker and Apple Capsid Bug. Conversely, certain other pests must always be regarded as a serious menace in spite of the fact that they have been subjected down the years to a wide range of spray chemicals. Among these are Fruit Tree Red Spider mite, Aphids, and some species of caterpillars.

A third category will include insects which have been known to entomologists for many years, but which for reasons difficult to explain, have become more numerous, or have changed their hosts and have now become pests requiring control measures.

The writers have selected two subjects from the 'difficult to control' category viz:- Aphids and Fruit Tree Red Spider, and two from the 'new pest' category viz:- Fruitlet Mining Tortrix Caterpillars and Pear Sucker.

APPLE APHIDS

The four main species of aphids which are of economic importance are: (a) Apple-grass Aphid (Rhopalosiphum insertum), (b) Rosy Apple Aphid (Sappaphis mali), (c) Woolly Aphid (Eriosoma lanigerum) and (d) Rosy Leaf Curling Aphid (Sappaphis devecta).

Apple-grass Aphid

This aphid occurs little or much every year, the incidence varying from one or two eggs per branch to hundreds of eggs on a spur. This variation in population from year to year is no doubt due to the effect of weather and other conditions on the well being of the alternative host plants. Often the fruit buds of apple trees are completely covered with the newly hatched aphids during the 'burst' stage in March or April, Before the introduction of winter washes control was often very difficult, but with the introduction of tar oil and DNC/Petroleum Oil winter washes, complete control was invariably obtained. During the late 1940's there was a trend among fruit growers to discontinue the regular use of winter washes in favour of BHC and combined BHC/DDT sprays. These could be applied following the hatching period at bud burst, and afforded a cheaper and more convenient method of control than the winter washes.

Given ideal timing and good weather conditions, control of aphids by spring spraying has generally been good, but where the timing has been delayed, often through adverse weather conditions, the control obtained has been disappointing, particularly when low volume methods of application have been used. In recent years growers have said that control of aphids by spring spraying with BHC and DDT has been so poor that two or three applications have been found necessary. Some growers have suggested that aphids have become resistant to these chemicals but there is no evidence, apart from grower experience, to support this. It is more likely that low-volume application techniques, which have become almost universal in recent years, are not as effective as high volume drenching sprays under conditions where the aphids have been able to penetrate deeply into the bud clusters.

Economics and labour shortages prevent a return to high volume spraying and the question arises as to whether it is not better to use a more effective insecticide immediately before the blossoms open in order to obtain a complete control and avoid a carry-over of aphid populations through the blossoming period and on to subsequent growth stages. The question raises the following points: (1), optimum timing between bud burst and blossom period; (2), the need to add another chemical for the control of other pests at the pre-blossom stages (e.g. DDT for caterpillar); (3), the effect on predators and parasites and the possible results of this upon the incidence and control of Red Spider at later stages, and (4), the comparative cost in relation to BHC or BHC/DDT.

In reviewing the possible alternatives to BHC and DDT the choice will probably rest with one of the following:- diazinon, phosphamidon, malathion, demeton-methyl, mecarbam and dimethoate.

In making a choice it should be noted that some of these alternatives are true systemics, and the question of whether there is sufficient leaf area in the tree before blossoming to take advantage of systemic properties will be of first importance.

Rosy Apple Aphid

This is the most damaging of all the apple aphids. Like the Apple-grass Aphid, control by winter washing is usually good, but often spring spraying is unsatisfactory. Complaints have been made by many growers in recent years of successive (if sporadic) infestations throughout the summer months, too obvious to ignore yet hardly worth a separate spray application for their control. These local colonies of aphids breeding in curled clusters of leaves are difficult to control, and in some cases applications of some of the most recent systemic chemicals have failed to give complete control. The reason for these persistent colonies throughout the summer is most likely an incomplete control of the aphids during the pre-blossom stages. Further attention should be directed toward both choice of chemical and method of application during the early stages of growth to obtain a complete kill and to avoid further occurrences of Rosy Apple Aphid (Blue Bug) in the post-blossom period.

Woolly Aphid

While Rosy Apple Aphid is judged to be the most destructive species because of the direct damage it does in stunting and distorting the growth and fruitlets, Woolly Aphid might well be the most costly aphid to the fruit grower because of the indirect damage it causes. This damage includes the obvious stunting of growth, disfigurement of fruits and the general sticky and dirty staining effects on the clothes and bodies of workers. In addition there are the indirect results of Nectria apple cankers and a higher incidence of Gloeosporium cankers giving rise to storage rots.

Woolly Aphid has always been a difficult pest to master. While it may be given a setback and the trees appear almost entirely free, it quickly becomes re-established given favourable weather conditions. Winter washing gives some measure of control, but the present method of medium volume application by automatic spraying machines is hardly likely to be as effective as the drenching formerly given by hand application. Like the two previously mentioned species the control obtained by thorough spray application in the pre-blossom period is likely to have a profound effect upon the incidence of this pest late in the year. It should not be assumed that because no 'woolliness' is seen during the early growth stages, that Woolly Aphid is absent. High populations may be in the trees at pink-bud stage with little or no sign of 'woolliness'. Thorough spraying at this stage with a good phosphorus insecticide will hold the pest in check for a long period.

Often apple trees are found to be heavily infested with woolly aphid during the fruit harvesting time. An application of a good insecticide immediately the fruit is harvested will reduce the infestation the following spring.

Rosy Leaf Curling Aphid

This aphid often called the Red Leaf Aphid because of the bright colour taken on by infested leaves, occurs regularly in well defined localities. It is slow to spread and its occurrence is often limited to certain trees where it may re-appear year after year. The reason is that it has no migrating phase, and that its period of activity is short compared with other species. The eggs are laid by the fourth generation in early July and are deposited in well protected positions often under the bark which makes control by winter washing almost impossible.

Rosy Leaf Curling Aphid is not easy to control by spring spraying for the leaves curl at an early stage and the aphids are well protected. A systemic insecticide is necessary for a good control and both dimethoate and demeton-methyl have proved effective.

FRUIT TREE RED SPIDER MITE (*Metatetranychus ulmi*)

It is now evident that there is an ever increasing number of apple orchards in England where the Fruit Tree Red Spider mite are becoming resistant to the organophosphorus compounds in general and the big question is where do we go now?

This mite started to become a minor pest in the late 1920's after the introduction of Tar Oil winter washes which killed off some of its predators. However, with the introduction of DDT into orchards at the end of the war, the mite assumed the role of a major pest. When DDT is applied post blossom, the population of Black-Kneed Capsids (*Blepharidopterus angulatus*) is almost annihilated. Since this insect is the chief predator of the Fruit Tree Red Spider mite, it follows that the mite can build up to high numbers in a short time given suitable weather conditions.

It was known, however, that a D.N.C. petroleum wash, if properly applied just before bud burst, will give a high percentage kill of the winter eggs of the mite, and if derris was applied during the growing season, the mites which did emerge could be reasonably well controlled.

After World War II, agricultural labour was at a premium and the chlorinated hydrocarbon compounds, chlorbenside, chlorfenson and chlorobenzilate and the first organo-phosphorus compounds were found to be effective against this pest. This resulted in a swing from winter washes of any sort, and reliance on sprays applied during the growing season for control of all pests.

The use of parathion at about the petal fall stage appealed to many growers as an economic spray since it would control red spider, aphids including Woolly Aphid, and Apple Sawfly in one application. Some growers continued this for many years, often using sub-lethal doses of toxicant per acre. Other growers did not like the use of such a poisonous material and began using non-poisonous summer ovicides. This stage of affairs continued with the introduction of several alternative phosphorus compounds, such as demeton-methyl and malathion, which were used as a petal fall spray followed in late June with an ovicide spray.

Until 1958 this procedure seemed to work well, but then suspicions of resistance to the summer ovicides arose, and were confirmed in 1959. However, other organo-phosphorus compounds were discovered, some more effective than those already in use, and so the control of this pest seemed to be well in hand. But in 1960 and 1961, the mite populations in many orchards seemed to have developed resistance to the latest phosphorus compounds.

Fortunately for English fruitgrowers, this development has already occurred in parts of Europe, the U.S.A., Australia and New Zealand in the control of closely related mites (Maelzer and Loehmeyer, 1960). In these countries, resistance to the organo-phosphorus compounds, chlorinated hydrocarbons and the sulphones was known. As early as 1946, forecasts were made as to the possibility of insecticide-resistant mites (Steiner *et al*. 1946) but the warnings were largely unheeded.

One of the most disturbing features of the development of resistance is that it usually seems to develop slowly at first and then more rapidly. Hence a chemical which has given good control for a decade or so, may quite suddenly seem not to give economic control and a year later be quite valueless.

In these countries, it has been found that it is much better to alternate the use of insecticides, rather than to use one exclusively until resistance to it appears and then to change to another. Where possible, it is advantageous to alternate between compounds from different chemical groups.

Unfortunately in England, no sooner has one basic chemical grouping been found to be effective against Fruit Tree Red Spider mite than many slight 'variations on the theme' have quickly followed, such as in the summer ovicides and organo-phosphorus compounds. As a consequence many orchards have been sprayed at the same time with the same type of material.

Not only have these sprays been introduced for mite control but some have been found effective against and recommended for, the control of Codling Moth and various Tortrix species, necessitating the application of two or three sprays of the same material in one season.

Fortunately, we have two compounds in the non phosphorus groups which can be used as alternatives:- (1) in the sulphone group, there is tetradifon which has only been used for two or three years and which is giving a good control; (2) recent large scale trial work in England suggests that 1,1,1-trichloro-2,2-bis (p-chlorophenyl) ethanol will give good control of phosphorus resistant strains of the Fruit Tree Red Spider mite, and provides further chemical group with which to alternate.

The number of years elapsing before one can return to a particular chemical group in an orchard where the mite population has previously developed resistance to this group is not known.

Instances have occurred where the summer ovicides have been retried in orchards where they have not been used for three years and successful control has not been obtained.

How can we then use the materials available to us at the present time to the best advantage? We have five groups of materials known to be effective against the mite at some time or other:-

(1) Summer ovicides - chlorbenzide, chlorfenson, chlorobenzilate.
(2) Organo-phosphorus compounds - azinphos-methyl, demeton methyl, diazinon, dimethoate, ethion, malathion, mecarbam, mevinphos, morphothion, phenkapton, phosphamidon and parathion.
(3) Ethanol grouping - 1,1,1-trichloro-2,2-bis (p-chlorophenyl) ethanol.
(4) Sulphone grouping - tetradifon.
(5) D.N.C. petroleum washes.

The use of dinocap, another chemical group, in the fungicide programme of a dessert orchard, also gives a useful alternative.

Two suggested programmes for the next two or three years are listed below:-

1. For the majority of orchards where phosphorus resistance is not yet apparent: D.N.C. petroleum just before bud burst or a phosphorus insecticide at petal fall, and alternating with materials from groups 3 and 4 in June or July as required.
2. For the orchards in which the mite population already show resistance to organo-phosphorus compounds: D.N.C. petroleum wash just before bud burst and alternating with materials from groups 3 and 4 in June or July as required.

In further years, alternative programmes and materials can be used to make all possible trends to resistance impossible.

The programmes suggested above do not preclude the use of various organo-phosphorus materials pre-blossom for the control of aphids, which must be recommended in many years for these sprays will rarely affect the red spider mite problem. The use of phosphorus compounds after picking, say in late September - early October for Woolly Aphid control will also not greatly affect the mite population. But again, the use of alternative materials over a period of three or four years is advisable. The control of codling moth and surface eating tortrix species with phosphorus insecticides is now unnecessary with chlorinated hydrocarbon and carbamate group compounds available, and in any event phosphorus compounds should not be used more than once every five years.

By observing these simple precautions and following the suggestions outlined it should be relatively easy for English fruit growers to overcome any possibility of selecting resistant Fruit Tree Red Spider mite populations.

FRUITLET MINING TORTRIX (*Pammene rhediella*)

During the years 1955-58 specimens of apple fruits mainly Bramley and Laxton Superb were received showing damage indicative of feeding by caterpillars, accompanied by boring into the apple. No living insects were present on these fruits and the reason for this damage remained unsolved until the summer of 1959.

During July 1959 Mr. K. Chandler of the Land Settlement Association, Foxash, Essex, with Mr. J. Brakefield, Murphy Chemical Co. Ltd., discovered a number of lepidopterous larvae hibernating in a sacking tree band in an orchard where apples with this distinctive damage had been found. A tall hawthorn hedge surrounding the orchard carried a high population of *Pammene rhediella* and the larvae were suspected of the apple damage. In 1960 investigations carried out in the weald of Kent, East Sussex and Wisbech areas, showed that *P. rhediella* had become established in apples some distance from hawthorn, and were found damaging pears, plums and cherries. During 1961 severe infestation has been noted in orchards around Wisbech, in Somerset, Essex, Kent and Sussex. In the Isle of Grain, Czar plums were damaged. It is now safe to say that local infestations occur over most of the fruit growing areas of England and that these can often cause financial loss to the grower.

The larvae, after feeding on the surface of the fruit and tunnelling beneath the skin, become fully fed at the end of June. They find suitable hibernating sites and spin a cocoon where they remain until the following April. From the middle of April until the end of May they are in the pupal stage and emerge as moths from the third week in May until mid June. Eggs are laid on leaves and the receptacles of the flowers of apples at about petal fall stage, and caterpillars may be found all through June until they go into hibernation early in July. The caterpillar, when fully fed, is about $\frac{1}{2}$" in length, of a greenish white colour. The head is black and anal plate brown, and there are seven black spots on each segment.

Attacks are most severe in orchards surrounded by hawthorn bushes or hedges which do not receive an annual trim. The population in hawthorn where the bushes carry a crop of haws.

Control measures in fruit trees consist of an application of DDT immediately at petal fall. The timing for sawfly sprays would be ideal for P. rhediella. For pears and plums the time to spray will approximate to the petal fall stage in apples.

PEAR SUCKER (Psylla pyricola)

Pear Sucker is without doubt the most serious pest of pear orchards in England today. It has been known for many years and sporadic outbreaks in particular orchards have been recorded. However, in the last five or six years the pest has come into real prominence. In many orchards where it had rarely been seen previously big populations soon became established. Where this menace was either not seen or else left unchecked, the insidious type of damage caused led to a marked reduction in the crop.

Pear Sucker overwinters in the adult stage, which may be found on the spurs or shoots of the tree itself, in rubbish at the base of the tree, in hedgerows, dry ditches or any situation in or near the orchard which offers the type of protection needed. The adults do not seem to be affected by cold temperatures of winter except that they remain stationary, while on bright sunny days they can often be seen flitting about the trees.

The females normally lay their eggs between mid March and the petal fall stage. The eggs are at first almost colourless, but they soon turn to a clear lemon yellow and become deep yellow as they approach maturity. Hatching usually begins at the White Bud stage but may vary somewhat from season to season, depending on weather conditions.

The emerging nymphs are very delicate being almost colourless with large pinkish-red eyes, but after a few days the body colour changes to amber. Each is enveloped in a protective drop of transparent liquid. They feed in the developing leaves and flower trusses, and some of the blossoms may be actually killed. The honey dew secreted by the nymphs allows the growth of black sooty moulds and the presence of these gives the trees a very sickly appearance. Later in the season, serious downgrading of the fruits results if these black moulds are present on them.

The honey dew also attracts ants, flies and other insects, so that if these are found in large numbers on the tree one can be pretty sure that Pear Sucker is present.

Several instars occur before the nymphs become mature with the possession of wing buds. At the final moult, the young adult emerges.

There are normally three generations per year and occasionally a fourth generation.

Several observers have reported an apparent migration of some of the first generation adults. In some orchards where there has been a large first generation of nymphs, one can find reallv few individuals some time after the fruitlet stage has been reached. However, later in July, large numbers suddenly appear back in the orchard. This is thought to be more than just good concealment, but no alternative host plant has so far been found.

Serious damage to the trees is done late in the season by the nymphs of the third or fourth generations moving to the following years blossom buds. They seek shelter in the leaf stalk axils surrounding these buds, the tissues of which they feed upon. This feeding results in the appearance of many 'blind' buds the following season and over the years, if left unchecked, the cropping potential of an orchard goes down and down and down.

Now why has this pest suddenly come into prominence in practically all pear orchards within a short period?

One of the main contributory causes is no doubt the swing away from winter washes. While tar oil spraying does not give a complete control, it certainly keeps the population in any one orchard down to a low level by killing off any adults overwintering on the trees and providing an oily film over the surface of the spurs and shoots, which deters the females from laying their eggs. Of course, winter spraying did not control adults overwintering away from the trees, and so the pest was always present although often in small numbers.

Nicotine was formerly recommended for use at the white bud stage but this has now been superseded by the organo-phosphorus materials, for nicotine is a contact insecticide requiring a fairly high temperature (i.e. around 70° F.) to be really effective, whereas some of the organo phosphorus sprays have systemic as well as contact action which is not so dependent on temperature.

Good control may be obtained by using a material such as dimethoate, malathion or demeton methyl at the white bud stage and again at petal fall or, in seasons such as 1961 when virtually no eggs had hatched by the white bud stage, a first spray at petal fall and a second 14 days later. Where these early season sprays have not been applied and a build up of the pest occurs later in the season, the grower should apply an organo-phosphorus spray immediately after picking during a fine, warm period rather than wait until the following spring.

Little experience has been recorded with low volume sprays against this pest, but several instances have occurred where an organo-phosphorus material at the recommended dosage in 50 gallons of water per acre has given excellent control.

Another advantage of the organo-phosphorus materials over nicotine is that they also control Red Spider mites on pear, at least temporarily.

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