THE MINIMUM EFFECTIVE LEVEL CONCEPT OF PESTICIDE DEPOSITS: AN EVALUATION

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SUMMARY

The minimum effective level of azinphos-methyl deposits on apple foliage, for control of lightbrown apple moth (*Epiphyas postvittana*) larvae was investigated. Azinphos-methyl degradation rates were determined by gas chromatography, and correlated with bioassays of larval mortality, using field-treated leaf samples. Residues and larval mortality declined more rapidly after sprays were applied in November than in February. The minimum effective level of azinphos-methyl was about 0.4 $\mu\text{g}/\text{cm}^2$. The recommended insecticide spray programme for non-export orchards could be modified, with longer intervals between sprays applied after December. The minimum effective level concept offered sufficient potential to warrant further research.

INTRODUCTION

Established methods of horticultural pest control mostly rely on calendar timing of spray programmes, although alternative tactics are becoming more common (Wearing 1982). Reductions in pesticide usage can delay the onset of insecticide resistance, hence prolonging the effective life of whole chemical groups (Georghiou and Mellon 1983), but must not be accompanied by the loss of crop quality. Current spray programmes must ensure that chemical residues on the crop do not exceed either domestic or international limits at harvest (Watts and Holland 1980). Spray recommendations are based on residue and efficacy trials, but these take little account of the precise interaction between a specific pest and the toxicity of pesticide deposits. Monitoring of insect phenology can be used to co-ordinate the timing of spray applications with adult emergence peaks. However, in many New Zealand crops the continuous presence of up to three leafroller species with numerous alternative hosts and overlapping generations offers little hope of improved spray timing.

An alternative tactic to reduce pesticide usage relies on the minimum effect level concept which is based on maintaining insecticide residues on the crop at levels not far above the minimum required to obtain control (Hameed and Allen 1976). This concept is similar to the "toxic carpet" spray strategy recently tested on cotton (Morton *et al* 1982). It is based on bioassays of treated foliage, along with parallel residue analyses, to indicate the change in mortality induced by a certain spray rate with increasing time following application.

To implement this approach, it is necessary to be able to predict insecticide deposition and disappearance from the crop, and to quantify the residue-mortality relationship, so that the insect mortality resulting from a given residue could be estimated. This paper offers a brief examination of this concept and its possible applicability to New Zealand horticulture.

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METHODS

Three trials were carried out on mature 'Red Delicious' apple trees in the Horticultural Research Area at Lincoln College. Each trial comprised four trees treated with azinphos-methyl (Gusathion 50WP) at 150g ai/100 litres using a tractor-mounted airblast sprayer calibrated for 3X concentrate spraying (600 litre/ha). A fifth tree in each trial was protected from spray to provide untreated foliage. Sampling was carried out eight to ten times following spray application, using a parallel grip leaf punch (Smith and Little 1954) to collect 100 20 mm diameter leaf discs from each tree for residue analyses, and 16 leaf discs from each tree for bioassay.

Leaf discs were cut from leaves large enough to permit easy removal of samples, chosen at random from the eastern quadrant of each tree, at the height of 1-2 m, between 9-11 am. The lower regions of the trees were chosen because they are favoured by lightbrown apple moth (LBAM) for oviposition (Collyer and Geldermalsen 1975).

Leaf residues were extracted with solvent and analysed by gas chromatography, with a phosphorus selective detector (Suckling 1983). Residues were calculated as μg azinphos-methyl/ cm^2 of foliage area. Bioassays of the residues on each tree (including the control tree) were carried out by placing two leaf discs inside each of eight size 000 gelatine capsules. Variable numbers of neonate first instar LBAM larvae (normally 20-30) were added to each of four capsules per tree, yielding 16 residue bioassays and four controls per sample date. In addition four 3rd instar LBLAM larvae were added to each of the remaining four capsules per tree, yielding a further 16 residue bioassays and four controls for each sample date. Mortality was assessed in both larval instars after 16 hours, using a binocular microscope for 1st instar larvae only. Mortality was defined as the inability to undertake co-ordinated movement, in response to a blunt probe.

RESULTS AND DISCUSSION

Figure 1 shows the relationship between the decline of azinphos-methyl on the foliage and the concurrent changes in 1st and 3rd instar larval mortality. The residue declined logarithmically with time in all three trials (Table 1). The decline in larval mortality with time was linear after probit-transformation.

This is due to the linearity of the log dose-probit mortality relationship, and the logarithmic decline of residues. Residue-mortality plots were constructed using the residue and bioassay data for each sample date. These compared favourably with standard residue-mortality lines, generated using leaf discs sprayed in a Potter tower (Suckling 1983).

There was good correlation between the bioassay and chemical assay results for both larval instars in all three trials, although a much slower rate of decline in azinphos-methyl residues and larval mortality was noted in February, compared with the two November trials, as can be seen from the half lives in Table 1. Tree growth was quantified during the third trial, and both leaf expansion and the appearance of new apple leaves became asymptotic during late December 1982 (Suckling 1983). Rapid leaf growth may account for the faster residue decline in the November trials, compared with the February 1982 trial, by which time total leaf growth was minimal. Residue samples were taken at random, so that the rates of residue decline were effectively averaged over all leaves within the sample zone. The preference of first instar larvae for young foliage (W.P. Thomas pers comm) would tend to increase the diluting aspects of growth on residues in the early part of the season. Growth of the vertical shoot tips outside the sampling zone may continue throughout the season, and leafrollers can sometimes be found in the upper portion of apple trees, away from the fruit.

Field control of LBAM is aimed at 1st instars, which are the most susceptible larval stage (King 1972; Suckling 1983) although eggs are also susceptible to azinphos-methyl, as are *Planotortrix excessana* (Suckling 1983) and *Ctenopseustis obliquana* larvae (Suckling unpublished results). The rolling of leaves to form a protective niche helps to protect the later stages, in addition to withstanding a 15x increase in the median lethal residue of azinphos-methyl from 1st - final instars of LBAM (Suckling 1983).

TABLE 1: Decline in azinphos-methyl residues and lightbrown apple moth mortality after the application of azinphos-methyl (150g ai/100 litres, 600 litres/ha) to 'Red Delicious' trees at Lincoln College.

Chemical assays					
Trial	Spray date	No. Sample dates	Decay Rate	R ²	Half life
1	11/11/81	8	log Y = 0.28 – 0.051t*	95.8%	5.5 days
2	4/ 2/82	10	log Y = 0.34 – 0.025t	88.3%	12.5 days
3	3/11/83	9	log Y = 0.39 – 0.063t	95.5%	5.0 days

Bioassays						
Trial	Instar	Spray date	No. sample dates†	Time-probit regression	R ²	Days to 50% mortality
1	1st	11/11/81	5	P = 6.76 – 0.076t*	86.2%	23.1 days
	3rd	11/11/81	4	P = 6.05 – 0.082t	96.1%	12.8 days
2	1st	4/ 2/82	3	P = 9.10 – 0.097t	99.5%	42.3 days
	3rd	4/ 2/82	5	P = 6.85 – 0.056t	97.3%	33.0 days
3	1st	3/11/82	5	P = 7.37 – 0.099t	98.3%	23.9 days
	3rd	3/11/82	7	P = 6.19 – 0.080t	89.5%	14.9 days

* t = time in days, Y = leaf residue in $\mu\text{g}/\text{cm}^2$, P = probit

† samples with 100% mortality

Fig. 1: The decline in azinphos-methyl residues following application on day 0 (11.11.81) from foliage of 'Red Delicious' trees (Trial 1). Residues are mean values from four trees, with 95% confidence limits. The simultaneous decline in mortality of 1st and 3rd instar lightbrown apple moth larvae is also shown.

On the basis of these data, and information of the susceptibility of other stages (Suckling 1983), an estimate of the minimum effective level of azinphos-methyl needed to control LBAM in the field is approximately $0.4 \mu\text{g}/\text{cm}^2$. This level of residue was exceeded for approximately 13 days in Trial 1 (Table 1). This period corresponds to more than 75% 1st instar mortality and 50% 3rd instar mortality in the 16 h bioassays (Fig. 1). These bioassays probably underestimate field mortality due to the short assessment interval which was necessary to minimise 1st instar control mortality. In the field, mortality of both instars would probably continue to rise after the 16 h period, although newly hatched larvae would be more likely to show this trend (Suckling (1983). During Trial 2, this residue level was exceeded for the first 30 days (Table 1), at a time when leaf growth was liable to be much slower. Based on the decline in azinphos-methyl residues, the recommended spray programme on apples is approximately fortnightly applications until vigorous leaf growth finishes in mid-late December, and then monthly applications until 2 weeks prior to harvest.

This is not radically different from the programme currently advocated by the MAF, who have established these guidelines with the experience of many seasons. Trials by the DSIR suggest that the insecticide programme used for export apples has little potential for reduction in Hawkes Bay or Nelson (C.H. Wearing pers comm). Larger intervals between sprays after December may be warranted for non-export orchards, as some growers in Canterbury successfully follow this pattern now (W.P. Thomas pers comm).

Many factors are likely to affect the application of the minimum effective level concept in the field, and with current spray application techniques, a certain spray rate does not equate with a certain pesticide deposition. This is particularly true in view of the wide range of equipment and rates of application in use. Apart from differences in deposition, weather factors may also contribute to variability in residues. Rainfall was a significant ($P < 0.05$) second factor after time in a multiple correlation analysis of weather variables on azinphos-methyl residues in two of the three trials, and nearly significant ($P < 0.10$) in the other trials. More work is needed on the relationship between the amount and timing of rainfall and azinphos-methyl disappearance (Suckling 1983).

The bioassays and chemical assay principles used here could be applied to other districts, new crops, or new insecticides. Improvements in evenness of coverage through controlled droplet application and more open crop training systems could lead to greater precision in predicting pesticide deposits, in addition to making control more reliable.

The minimum effective level concept offers sufficient potential to warrant further research, with the aims of reducing spray costs and delaying resistance.

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