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Susceptibility of house flies (Diptera: Muscidae) exposed to commercial insecticides on painted and unpainted plywood panels

Phillip E Kaufman* and Donald A Rutz
Department of Entomology, Cornell University, Ithaca, New York 14853-0999, USA

Abstract: House flies were collected from dairies in New York state and the levels of resistance to commercially available insecticide formulations were measured on painted and unpainted plywood panels. Dimethoate was ineffective on all surfaces. The wettable powder permethrin formulation was more toxic than the emulsifiable concentrate formulation. The wettable powder cyfluthrin formulation was also more toxic than the recently developed liquid formulation. In general, the best house fly control was obtained on flat latex painted plywood panels and the poorest control on gloss latex painted panels. It is highly unlikely that producers obtain adequate control with dimethoate and permethrin.

Keywords: resistance; insecticides; dairy; organophosphate; pyrethroid; *Musca domestica*

1 INTRODUCTION

House flies, *Musca domestica* L, are major pests in and around dairy housing systems. The role of house flies in transmission of pathogens found on livestock farms has long been suspected. Recently, enterohemorrhagic *Escherichia coli* O157:H7 has been confirmed in house flies collected from cattle farms.[1] Insecticides used for house fly control continue to be an important pest management component on dairy farms.[2] However, as resistance continues to increase in house fly populations, farmers are finding management of these pests extremely difficult.[2–7]

In a 1987 survey of flies from New York dairies,[5] the frequency of resistance was high for crotoxyphos, dimethoate and tetrachlorvinphos, moderate for permethrin and low for dichlorvos. A 1999 survey of house fly resistance on New York dairies reported an even higher frequency of resistance to permethrin and tetrachlorvinphos, but lower resistance to dimethoate than observed in 1987.[7]

House flies can commonly be observed on the walls and ceilings of livestock facilities. To control house flies, farmers spray these areas with residual insecticides. For sanitary reasons and appearance, dairy facilities are commonly covered with one of several types of paint. These often include gloss or flat exterior grade latex paint or whitewash (lime and water solution). With advances in milking equipment and building design and materials, newer facilities may not be painted at all.

On-farm studies of the efficacy of commercially available insecticides in dairy facilities have not been published. The problems associated with controlling and assessing mortality, and other factors, make such studies extremely difficult to perform. However, studies examining commercial formulations applied to metal, concrete and plywood used in commercial facilities have been conducted.[7–12] Many dairy facilities are lined with painted and unpainted plywood and comparisons between these two have not been reported. Examination of house fly susceptibility to commercially available insecticides on painted and unpainted plywood in controlled laboratory settings provides an excellent simulation of conditions in dairy facilities.[7,11,12]

Most dairy farmers practice some form of integrated pest management, but pesticides still play a major role in fly management on New York farms. As the Food Quality Protection Act of 1996 moves toward full implementation, fewer and fewer pesticides remain available to producers. It is highly likely that dairy farmers in the very near future will be left without any effective registered pesticides. To this end, we must determine those materials that are most efficacious and work to maximize their effectiveness and to preserve their registrations.

This study was conducted to simulate conditions in dairy facilities using field-collected populations of house flies placed on insecticide-treated plywood panels that had been either painted or left unpainted. Our goal was to confirm the presence of insecticide resistance at New York dairies and to determine

* Correspondence to: Phillip E Kaufman, Department of Entomology, Comstock Hall, Cornell University, Ithaca, New York 14853, USA
E-mail: pek4@CORNELL.edu
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whether the presence or absence of latex paint influenced insecticide efficacy.

2 MATERIALS AND METHODS

2.1 Insects, farms and chemicals

House flies were collected from within dairy barns in and around calf housing in central New York state during August 2000. Laboratory colonies of each strain were established from flies free of pathogens and ectoparasites. Flies were reared as previously described.[6] Flies were bioassayed beginning with the second generation of adults produced by the field-collected flies. The Cornell susceptible (CS) strain served as the standard laboratory strain with which all field strains were compared.[13]

Farms in Schuyler and Tompkins counties served as collecting sites for insecticide-treated fly populations. The Schuyler county farm was included in previous house fly resistance surveys.[5,13]

Five commercially available formulated insecticides were examined: dimethoate 234 g liter^{-1} EC (Bonide Cygon, Bonide Products, Yorkville, NY), permethrin 57 g liter^{-1} EC (Ectiban EC, Universal Cooperatives, Minneapolis, MN), permethrin 250 g kg^{-1} WP (Ectiban WP, Durvet, Blue Springs, MO), cyfluthrin 200 g kg^{-1} WP (Tempo 20, Bayer, Kansas City, MO) and cyfluthrin 118 g liter^{-1} SC (Tempo SC Ultra, Bayer, Kansas City, MO).

2.2 Bioassays and analysis

Flies were assayed using commercially available, formulated materials as residual contact applications as described previously.[7] Plywood panels were split into three groups. The first group was left unpainted, while the remaining panels were painted with two coats of either gloss (Accolade, exterior gloss acrylic latex, Pratt and Lambert Paints, Cleveland, OH) or flat (Pro-Hide Gold, exterior flat latex, Pratt and Lambert Paints, Cleveland, OH) latex paint. After painting, all plywood panels were exposed to natural summer weather conditions for 10 days before the insecticides were applied. Dispersions of the formulated insecticides in water were prepared according to label directions and applied to the plywood panels at a uniform rate of 5 ml per 929 cm^2 (= 1 gal per 750 ft^2). Calibrated trigger-pump hand sprayers were used to apply insecticides and a water-treated control to individual 929-cm^2 plywood panels. All panels were allowed to dry for 1 h before test flies were placed on them.

Flies were exposed to treated panels by anesthetizing them with carbon dioxide and transferring 25 flies to each panel. Flies were confined to panels by placing wooden embroidery hoops (14.5 cm inner diameter, 1 cm thick) that had been covered with coarse mesh screen cloth (14 squares per cm^2) (Fig 1). Prior to fly transfer, a strip of duct tape (3 cm × 9 cm) was affixed near the bottom of the hoop for the duration of the exposure and this prevented fly contact with the treated panel while the insects were anesthetized or immobilized. Hoops were secured to the plywood panels with two rubber bands stretched across the hoop and fastened to push pins. After the hoop was secured, panels were hung vertically for a 6-h holding period at 25 °C under constant fluorescent lighting. This design was an attempt to replicate the conditions presented to flies in dairies, including the choice of resting on a treated surface or moving to untreated areas. Throughout the holding period, flies were observed walking on the surface of the panels.

Following exposure on the panels, flies were again anesthetized and transferred to 118-ml plastic cups with screened lids. Flies were provided a dental wick soaked in 10% sugar water and held at 25 °C under constant fluorescent lighting. Mortality was assessed after 48 h and flies were considered dead if they were ataxic. The assays were replicated three times (75 insects per replication), with three panels per farm (including the CS strain) and insecticide at each replication.

For all studies we calculated the percentage mortality and corrected the data for control mortality.[14] To normalize the data, prior to statistical analysis a log $(x+0.5)$ transformation was performed; however, non-transformed data are presented in the Figures. Data from each chemical examined were examined using a multi-factorial analysis of variance.[15] The statistical model contained the fixed effects of study replication, panel treatment, fly strain, within-study replication and three interaction terms: study * panel treatment, study * fly strain, and panel treatment * fly strain. Data within each chemical were tested for treatment differences using a Tukey's mean separation.

3 RESULTS AND DISCUSSION

Main effects in the dimethoate EC model were significant, indicating that differences exist with individual terms in the model ($F = 6.30$; $df = 20, 57$; $P < 0.001$). Dimethoate efficacy was not impacted by painting ($F = 1.31$; $df = 2$; $P < 0.2768$) (Fig 2). Greater than 80% of the field-collected strains and nearly 70% of CS strain flies survived a 6-h exposure to dimethoate EC. These results emulate survival reported using pteromalid parasitoids exposed to dimethoate-treated plywood panels.[9] However, treating glass jars with the same rate of technical dimethoate[7] and with dimethoate EC (Kaufman, PE, unpublished data) resulted in rapid morbidity of CS strain house flies, indicating that dimethoate is toxic to flies. It has been suggested that both cardboard and plasterboard bind insecticides, thereby reducing efficacy.[16–18] This growing body of evidence suggests that dimethoate EC interacts with properties of the plywood, resulting in reduced insecticidal activity, and that painted surfaces did not enhance efficacy. Furthermore, it is highly unlikely that producers are actually achieving house fly

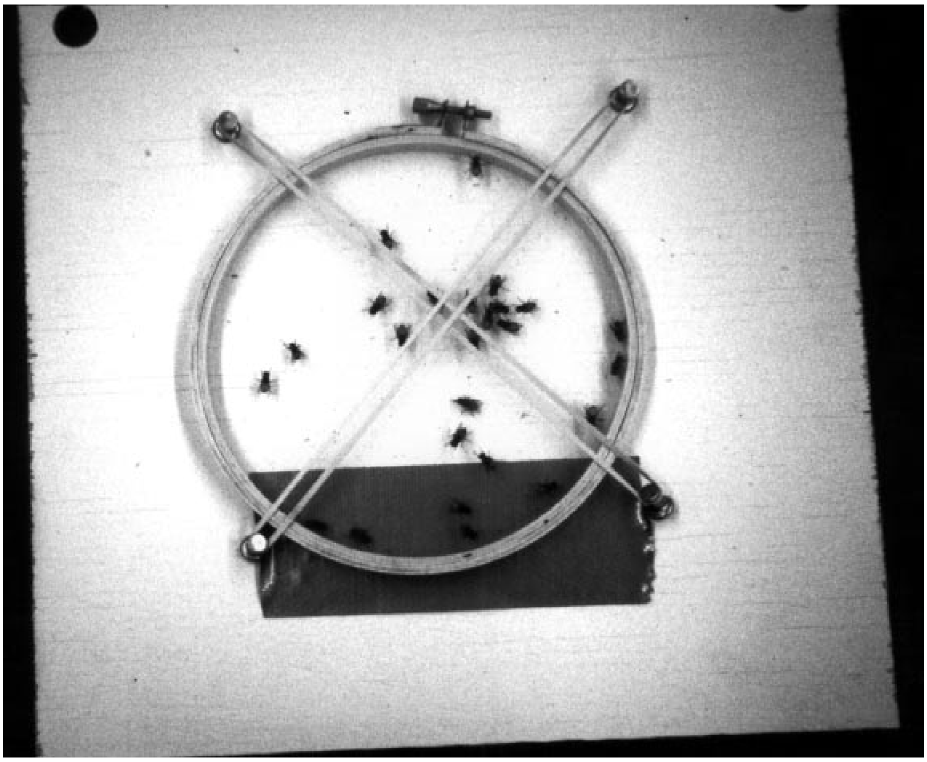

Figure 1. House flies confined to treated plywood panel (ie simulated field bioassay).

control with dimethoate EC applied as a surface spray treatment.

Significant differences were observed in the permethrin EC main effects model ($F = 20.91$; $df = 20, 60$; $P < 0.0001$). Permethrin EC killed more flies on the gloss latex and unpainted panels than on the flat latex panels ($F = 10.43$; $df = 2$; $P < 0.0001$) (Fig 3A). The interaction term fly strain * panel type was significant ($F = 4.49$; $df = 4$; $P < 0.0031$), suggesting that, although the trends between panel types were similar, efficacy among fly strains varied across the panel types. This is best illustrated as in Fig 3A where permethrin EC efficacy was highest on gloss latex panels.

Results for permethrin WP documented a significant difference in the main effects model ($F = 48.72$; $df = 20, 60$; $P < 0.0001$). Unlike the permethrin EC results, efficacy of the WP was greatest on flat latex and unpainted panels ($F = 5.34$; $df = 2$; $P < 0.0074$) (Fig 3B). As observed with permethrin EC, a significant interaction was observed in the WP treatment between the panel type and fly strain ($F = 3.00$; $df = 4$; $P < 0.0251$).

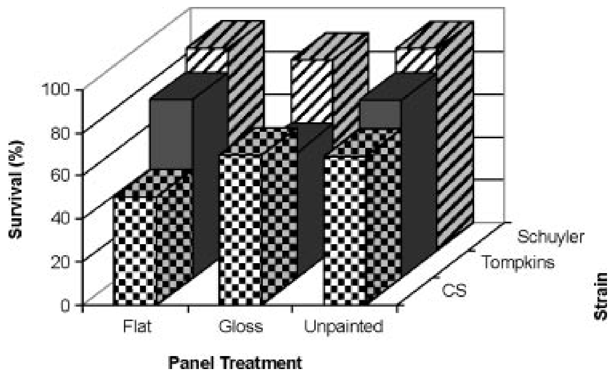

Figure 2. Percentage survival of house flies from two New York state dairy farms and a laboratory-susceptible strain (CS) exposed to the labeled rate of dimethoate EC on treated painted and unpainted plywood panels.

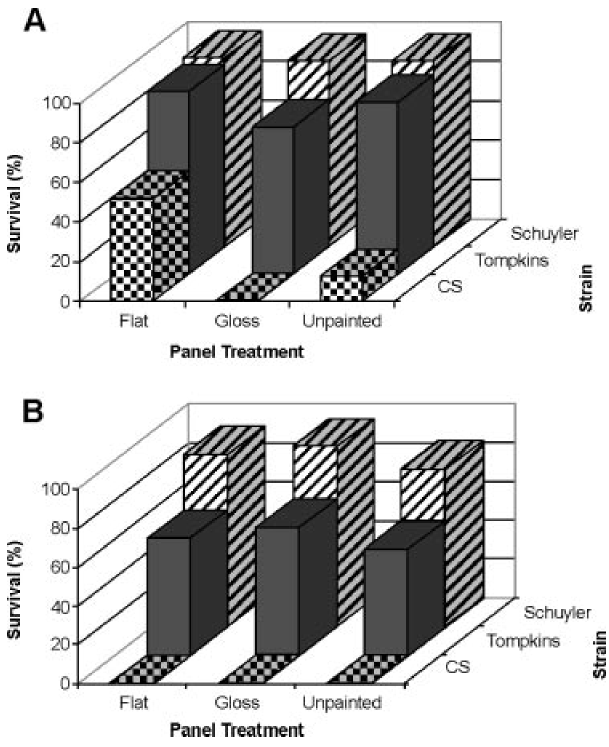

Figure 3. Percentage survival of house flies from two New York state dairy farms and a laboratory-susceptible strain (CS) exposed to the labeled rate of (A) permethrin EC and (B) permethrin WP on treated painted and unpainted plywood panels.

Over 40% of susceptible CS strain house flies and >80% of wild collected house flies survived permethrin EC exposure on flat latex painted panels, suggesting that this formulation is completely ineffective against house flies in dairies. Permethrin WP efficacy was considerably higher than that of the EC formulation; however, the application of this formulation in dairies will not provide adequate control of house flies. In an earlier study with house flies collected from New York dairies, permethrin was ineffective against all field-collected strains, suggesting this insecticide would not be efficacious at these dairies.[7] Our results support this conclusion.

Both cyfluthrin formulations were more effective than the permethrin and dimethoate formulations; however, resistance is now emerging with both cyfluthrin-based products. Significant differences were observed in the main effects model of the cyfluthrin SC treatment ($F = 27.48$; $df = 20, 60$; $P < 0.0001$). The panel treatments were significantly different from each other, with the highest survival observed on the gloss latex treatment and the greatest efficacy on the flat latex panels ($F = 49.82$; $df = 2$; $P < 0.0001$) (Fig 4A). A significant interaction was observed between panel type and fly strain ($F = 12.57$; $df = 4$; $P < 0.0001$).

The main effects in the model for the cyfluthrin WP treatment were significant ($F = 30.12$; $df = 20, 60$; $P < 0.0001$). The efficacy of the WP was lower on panels painted with the gloss latex than with the flat latex and unpainted surfaces ($F = 25.38$; $df = 2$; $P < 0.0001$) (Fig 4B). A significant interaction was again observed between panel type and fly strain ($F = 7.42$; $df = 4$; $P < 0.0001$).

To date, comparisons of insecticide formulations have not revealed differences in efficacy between wettable powders and EC formulations of the same AI.; however, the resistance status of the arthropods was not discussed.[13,14] Our results document that efficacy of dimethoate and permethrin is influenced not only by insect biochemical factors,[19–24] but by environmental conditions such as the type of surface on which the materials are applied. The labor intensity required to conduct these studies precludes its use as an inexpensive monitoring technology. However, this method does provide an effective technique for future controlled comparisons of insecticide responses under simulated field conditions.

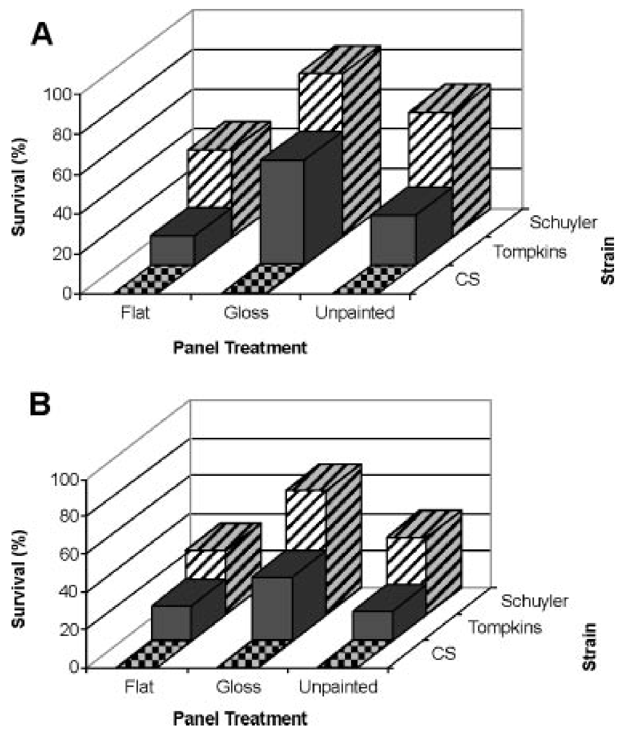

Figure 4. Percentage survival of house flies from two New York state dairy farms and a laboratory-susceptible strain (CS) exposed to the labeled rate of (A) cyfluthrin SC and (B) cyfluthrin WP on treated painted and unpainted plywood panels.

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