Biological Control: An Important Component in Integrated Management of *Musca domestica* (Diptera: Muscidae) in Caged-Layer Poultry Houses in Buenos Aires, Argentina

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Received May 15, 1997; accepted April 8, 1998

An Integrated Management program to control *Musca domestica* L. was developed by evaluating cultural + chemical control, cultural + biological control + granular bait (IMP 1), and cultural + chemical + biological control + granular bait (IMP 2) in poultry houses in Argentina. Adult fly density was estimated by a modified Scudder-grid method. Percentage of house fly parasitism was estimated by direct and indirect methods. *Spalangia endius* Walker and *Muscidifurax raptor* Girault & Sanders were released at a rate of 10 parasitoids/hen/week. Complete absence of control practices allowed a sustained growth of the fly population. When larvicides and adulticides were used, the number of adult flies decreased but parasitism was adversely affected. When insecticide use was decreased, the number of flies increased. Cultural + biological control + granular bait (IMP 1) produced a reduction of adults from 14 to 3 flies/grid. Where cultural + chemical + biological control + granular bait (IMP 2) was employed, the adult number was reduced from 40 flies/grid to 1 fly/grid. IMP 2 was efficient for reducing the number of larval development sites in the manure. Percentage parasitism exceeded 90% in both IMP 1 and IMP 2 treatments. IMP 1 and IMP 2 treatments both allowed for maximum control of house flies with minimal use of pesticides. With IMP 2, the potential effectiveness of the biological control agents was maximized by reducing adult fly populations with pesticide sprays, then terminating spray applications before parasitoids were released. Thus, IMP 2 would be most suitable for farms which have large adult house fly populations at the initiation of the treatment. The only pesticide used in IMP 1 was a granular bait. Thus, IMP 1 would be most efficient in situations with low initial adult house fly populations and small amounts of manure to ensure the success of the cultural strategy.

Key Words: *Musca domestica*; biological control; augmentative release; *Spalangia endius*; *Muscidifurax raptor*; IMP; poultry houses.

INTRODUCTION

Accumulated manure in commercial caged-layer houses is a potential source of disease organisms harmful both to confined hens and to humans (Anonymous, 1975). Because there are arthropods with a high capacity for dissemination of metaxenic (Del Ponte, 1958) and other types of important diseases, this can pose a potentially serious health problem. Among dipteran species, *Musca domestica* L. has an important role as a disease vector (Aberg-Cobo et al., 1959). The behavior of this pest is typically synanthropic and, because of its high reproductive rate and ability to prosper in a wide range of environments, it pullulates throughout the entire year.

Oliva (personal communication) estimated that in Argentina the annual cost of house fly control on a 50,000-bird poultry farm costs approximately $10,000 U.S. There are 16 million hens in the country (Schang, 1991), half of which are on poultry farms where insecticides are routinely used for house fly control. This represents an annual cost of approximately $1,600,000 U.S.

Besides being costly, insecticidal control of the house fly has many serious drawbacks. If used improperly, insecticides can produce intoxications in animals and humans, contaminate feed and water, and destroy the biological control agents of flies. Likewise, flies possess a strong genetic capability for developing resistance to the insecticides used by farmers (Wang and Plapp, 1980; Roush and Wright, 1986; Meyer and Georgiou, 1987; Shen and Plapp, 1990; Cluck et al., 1990; Kence and Kence, 1992; Oi et al., 1992).

In recent years, Integrated Management Practices (IMP) for house flies have become more widely used. Combinations of different control alternatives, such as biological, cultural, or chemical control, provide interesting options for regulating fly populations without causing environmental damages of any importance (Axtell,
Scientists in several countries, including the U.S. and Canada, have been successful in using parasitoids to control the house fly. Presently, this methodology is applicable at the commercial level (Morgan et al., 1975a,b; Axtell, 1986). In Argentina, research has been done only to identify the natural enemies of *M. domestica*, notably pteromalid (Hymenoptera) parasitoids, which are effective against the pupae of the house fly and other related Diptera (De Santis and De Sureda, 1988).

The purpose of our work was to develop an Integrated Management Program for house fly control using pupal parasitoids as a biological control component, optimizing hygienic and economical aspects and minimizing environmental contamination risks. Fly control would be considered acceptable when the population densities were limited to 10 flies/grid when measured with Scudder grids. To this purpose, different control strategies were evaluated in commercial laying houses located near Buenos Aires, Argentina.

**MATERIALS AND METHODS**

The experiments were performed on four caged-layer farms located in Pilar and General Rodriguez, Buenos Aires Province, Argentina, during 1992 and 1993. Except in treatment a, the untreated control, selected pesticides were used to reduce adult fly populations. In treatments that included a biological control component, adulticides were used to give the pupal parasitoids numerical superiority over the house flies and to help reduce the overall fly population. Treatments are described in detail below and summarized in Table 1.

(a) Untreated control. Two houses with about 6,000 hens each served as untreated controls in which no house fly management techniques were performed. When the evaluations began, manure had accumulated under the cages for 2 months. This was similar for treatments b and d as well.

(b) Cultural plus chemical control. This treatment was applied to a house with 10,000 hens where water leaks were eliminated. Initially, manure was treated with quicklime (calcium oxide) and slaked lime (calcium hydroxide) mixed in a proportion of 3:1, respectively. The amount used per m² was dependent upon the size of the larval foci and moisture content of the manure. Localized lime treatments were applied on three occasions to wet spots in the manure, and general repairs were made in various parts of the house. DDVP (Nuvan 100 EC (100 g/liter AI), Ciba-Geigy Buenos Aires, 250 cc/20 liter of water) was applied once and azamethiphos (Alfacron 10% (AI), Ciba-Geigy Buenos Aires, 250 cc/250 liter of water) was applied as a paint-on every 2 weeks for control of adult flies. Larvae were controlled by feeding cyromazine (Larvadex 1% (AI) premix, Ciba-Geigy Buenos Aires, 500 g/per ton of poultry feed) for five consecutive weeks, accompanied by three topical applications of cyromazine (Neporex 50% (AI), Ciba-Geigy Buenos Aires, 1 g/m²) to manure ad libitum. Snip, which contains a sexual attractant and a toxicant (z-9-tricosene with azamethiphos 1% (AI), Ciba Geigy, Buenos Aires), was applied as a granular bait at the rate of 2 kg/house/month as an adulticide. At this farm, all mentioned chemicals were used for the first time during these evaluations.

(c) Cultural plus biological control plus granular bait (IMP 1). This treatment was applied in six houses, each with 10,000 caged-layers. Houses were free of manure when birds were housed, and lime had been applied to the floor in manure collection areas under the cages to help dry the manure. Lime was also applied ad libitum on two occasions to wet spots in the manure. Spalangia endius (Walker) and Muscidifurax raptor (Girault & Sanders) were released weekly at the rate of 10 parasitoids/hen/week (50:50 ratio) starting at the beginning of the evaluation (January). Releases in each house were made by placing approximately 2,500 parasitized fly pupae (30 g) in each of 40 paper bags (18 × 10 cm), which were then suspended from the floors of the cages as close to the aisle as possible. Bags

<table>
<thead>
<tr>
<th>Farm number</th>
<th>Number of houses</th>
<th>Treatment number and type</th>
<th>Components</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2 houses</td>
<td>(a) Control</td>
<td>None</td>
</tr>
<tr>
<td>2</td>
<td>1 house</td>
<td>(b) Cultural plus chemical</td>
<td>Moisture control + lime + nувan + alfacron + Larvadex + neporex + Snip</td>
</tr>
<tr>
<td>3</td>
<td>6 houses</td>
<td>(c) Cultural plus biological control plus granular bait</td>
<td>Moisture control + lime + Snip + parasitic wasps</td>
</tr>
<tr>
<td>4</td>
<td>2 houses</td>
<td>(d) Cultural plus chemical plus biological control plus granular bait</td>
<td>Moisture control + lime + nувan + Snip + parasitic wasps</td>
</tr>
</tbody>
</table>

Note. Larvadex, cyromazine 1% premix; neporex, cyromazine 50% topical; nувan, DDVP 100% AI; alfacron, azamethiphos 10% paint; Snip, azamethiphos 1% AI (with z-9-tricosene) granular bait; parasitic wasps, Spalangia endius (Walker) and Muscidifurax raptor (Girault and Sanders).
were spaced 14 m apart and the tops opened slightly to allow parasitoids to exit. Parasitoid emergence began soon after placement of bags in houses and continued for approximately 1.5 days. Snip granular bait was applied as in treatment b above.

(d) Cultural plus chemical plus biological control plus granular bait (IMP 2). This treatment was applied in two houses containing 10,000 hens each. The cultural management techniques (lime) were similar to those for treatment b. DDVP was sprayed once for control of adults only in localized places and discontinued after parasitoids were released. Parasitoids were released in the same way as in treatment c, but no releases were made until the 7th week of the evaluation. Snip granular bait was applied as in treatment b above.

Density estimates of house fly adults. The modified Scudder grid method (Murvosh and Thaggard, 1966) was used to estimate adult fly populations in the treated and control houses. Estimates were made weekly from December 12, 1992 to May 15, 1993. Fly counts were made in areas of high fly density throughout the houses by placing a grid (45 x 45 cm) on the manure surface and counting the flies landing on it during a 1-min period. The average number of flies per grid for each treatment was determined by selecting five grids with the greatest number of flies within a variance range of <5%. Fly control was considered to be at an optimal level when the population density in the houses was ≤10 flies/grid.

Rearing of parasitic wasps. Techniques for rearing indigenous S. endius and M. raptor released during the evaluations were similar to those described by Morgan et al. (1978). Rearing rooms were maintained at 27 ± 1°C and 70 ± 10% RH, with a 24-h scotophase. Parasitoids were reared in the pupae of house flies produced in an artificial diet (adapted from Morgan, 1986).

Percentage parasitism. Percentage parasitism of the house fly was estimated by an indirect method using sentinel pupae (Rutz and Axtell, 1981) and a direct method where pupae were extracted from substrates in the poultry houses. For the indirect method, colony-reared house fly pupae <24 h old were placed in open-mesh bags (10 x 10 cm) at the rate of 30 pupae per bag. Bags with pupae were placed in the manure under the cages at the rate of 30 bags per house per week. Pupae were held in the laboratory for 30 days for the emergence of parasitoids, at which time the percentage parasitism was calculated. For the direct method, 500 house fly pupae per house per week were collected at random and held for 30 days at ambient temperature in the laboratory for the emergence of parasitoids. Percentage parasitism was calculated with the intact puparia method of Petersen (1986) using the formula:

\[
\text{percentage parasitism} = \frac{(\text{emerged} + \text{aborted parasitoids})}{\text{intact puparia}} \times 100.
\]

RESULTS AND DISCUSSION

(a) Untreated control. Mean M. domestica population in the controls (a) increased from 44 adults/grid at the beginning of the experiments to 192 adults/grid 15 weeks later (March 18, 1993) (Fig. 1). The trend of increasing house fly populations with the progression

![FIG. 1. Adult house fly density in control treatment a.](image)
of the season can be seen, particularly from December until March. We attributed this population increase to the complete absence of fly control practices.

(b) Cultural plus chemical control. At first, when larvicide (cyromazine) and adulticides (such as baits with sexual lures and DDVP sprays) were used together in the cultural plus chemical control treatment (b) (Fig. 2), fly populations decreased from 41 to 6 flies/grid after 5 weeks. Beginning January 23, 1993, cyromazine was discontinued for 3 weeks and the number of house fly adults increased from 6 to 12 flies/grid. A second application of cyromazine was made, which reduced the number of flies to 2/grid. When cyromazine was again discontinued (March 13, 1993), fly density increased slightly, but stayed <9 flies/grid. This phenomenon, reported also by Morgan et al. (1975a), was observed on both occasions when cyromazine was used and then discontinued.

It is worthy to note that genetic resistance to cyromazine and the adulticides was not observed in these house fly populations, possibly because this was the first time these products were used on this poultry farm. The combined use of both strategies (cultural plus chemical) succeeded in maintaining the adult fly population at tolerable levels (Fig. 2).

(c) Cultural plus biological control plus granular bait (IMP 1). The cultural plus biological control treatment plus granular bait (c) began with an initial adult population of 14 flies/grid. However, adult fly populations decreased from 14 to 4 flies/grid after the first 2 weeks of parasitoid releases and were maintained at about 3 flies/grid for the next 8 weeks (Fig. 3). The overall lime application provided a dry base for the initial layers of manure, and the two localized applications eliminated fly breeding in wet spots.

Treatments were discontinued at the beginning of April because hens had become infected with fowl typhoid (Salmonella gallinarum), which causes extremely wet droppings. This stresses the importance of monitoring the health and sanitary condition of confined animals, especially for diseases which cause diarrhea. With the combined strategy of cultural plus biological control plus granular bait, the pest population was maintained within acceptable levels (<10 flies/grid) until treatments were discontinued. However, the effectiveness of the last parasitoids released was probably reduced because of the increase in manure moisture caused by the diarrhea of the hens.

(d) Cultural plus biological plus chemical control (IMP 2). In houses receiving the IMP treatment (d), the mean number of adult flies was reduced from 40 to 17/grid during the first 7 weeks (Fig. 4). Lime and adulticide reduced the number of larval foci, substantially improving the general condition of the houses. Weekly releases of S. endius and M. raptor began on January 30, 1993 (Fig. 4), and in 5 weeks adult house fly population density was reduced from 17 to 1/grid. Good control was maintained throughout the study, with adult populations never exceeding 4 flies/grid.

Percentage parasitism. Percentage parasitism of house fly pupae scored either by the direct or the indirect method was very similar in the controls (a) and

![FIG. 2. Adult house fly density in cultural plus chemical treatment b.](image-url)
the cultural plus chemical treatment (b); but, weekly average values were lower when estimated by the direct method compared with the indirect method (Figs. 5 and 6). In contrast, the percentage parasitism and the weekly average values calculated by either of the two sampling methods were similar in both the IMP 1 (c) and the IMP 2 (d) treatments (Figs. 7 and 8).

When percentage parasitism is low, as it was in treatments a and b, indirect sampling methods tend to yield higher parasitism values than direct methods. Direct methods are based on making collections of mixed-age, naturally occurring, and possibly parasitized, house fly pupae that may be clustered or scattered throughout the study site. Finding enough pupae to
sample can at times be difficult (Rutz, 1986). Indirect methods are based on exposing concentrations of known-age, laboratory-reared house fly pupae in selected sampling sites to attack by parasitoids; but this may result in a high rate of parasitism produced by a small number of wasps. In treatments c and d, where there was little or no pesticide used for larval control, background larval populations were developing to the pupal stage and being heavily parasitized by the large parasitoid populations being maintained during the study.
Thus, results from direct and indirect methods were very similar. However, when a percentage parasitism >90% was observed 5 to 6 weeks after the initial release, superparasitism was observed (dudding effect) and direct sampling was difficult to perform because of the scarce number of host pupae. Both the direct and indirect method of pupal sampling have advantages and disadvantages (Rutz, 1986), but Petersen and Watson (1992) recommend that both methods be used together when possible. Percentage parasitism was almost 100% for several weeks in treatments c and d (Figs. 7 and 8), and both

FIG. 7. Comparison of percentage parasitism of house fly pupae in the cultural plus biological treatment (c) using the indirect and direct sampling methods.

FIG. 8. Comparison of percentage parasitism of house fly pupae in the IMP treatment (d) using the indirect and direct sampling methods.
parasitoid species were recovered in almost equal numbers. Morgan et al. (1981) recorded similar parasitism levels when releasing S. endius and M. raptor together; however, they recovered very few M. raptor. Their parasitoids were released from 15 stations outside the poultry houses or from eight stations inside the poultry houses. M. raptor apparently did not disperse from these stations to fly breeding sites in the manure (Morgan et al., 1981). In our study, parasitoids were released at 14-meter intervals inside the houses, which provided a very uniform distribution of parasitoids as they emerged.

Based on local conditions, we determined that a successful fly control program should maintain average fly densities at ≤10 flies/Scudder grid inside the poultry houses. Other fly control programs have been based on fly density estimates derived from Scudder grids (Morgan et al., 1981), spot cards (Rutz and Axtell, 1979), sticky tapes (Turner et al., 1992), and baited jug traps (Burg and Axtell, 1984). These devices provide visible estimates which can be used by poultry producers to make subsequent control decisions.

Eventually, treatments b, c, and d all reduced density estimates to ≤10 flies/grid (Figs. 2–4). However, our treatment of choice was the cultural plus chemical plus biological control (d). With this treatment, attempts were made to eliminate wet spots in the manure with lime and reduce adult fly populations with nuvan before parasitoids were released. Control of wet spots continued during the parasitoid release program, and Snip provided additional adult fly control without adversely affecting the parasitoids. The cultural plus biological control treatment (c) looked very promising, despite the hens’ disease problems, and employed Snip as the only pesticide component. Percentage parasitism peaked earlier with this treatment (Fig. 7) than it did with treatment d (Fig. 8); however, initial fly populations were considerably lower in the houses used for treatment c (Fig. 3) compared with those used for treatment d (Fig. 4). The cultural plus chemical treatment (b) stabilized fly populations below the optimal level after 9 to 10 weeks (Fig. 2), but alfacron and snip were routinely applied for adult control until the end of the study.

In the cultural plus chemical treatment (b), each time chemical products were applied inside the poultry houses to reduce the adult fly population, the percentage parasitism was adversely affected. The DDVP application abruptly reduced the percentage parasitism from 34% on the application date to 10% 2 weeks later (Fig. 6). This was not surprising, because DDVP has proved to be moderately to extremely toxic to some strains of Spalanga and Muscidifurax (Rutz and Scott, 1990). Also, immediately after the larvicide application the percentage of parasitism underwent a second decrease from 38 to 18% in 4 weeks. This could be ascribed to the cyromazine, but under our working conditions these reductions were impossible to explain.

An important first component of treatments b, c, and d was moisture control, which included drying wet manure areas with lime, and repair and maintenance of watering systems and poultry housing. House flies develop well in poultry manure with a moisture range of 60 to 75% (Miller et al., 1974), but they have been recovered in manure with moisture levels from 37 to 80% (Stafford and Bay, 1987). Dry manure is not only important for the control of flies and odors, but it is critical for maximum performance of parasitoids and other natural enemies (Morgan et al., 1981).

CONCLUSIONS

The cultural plus biological plus chemical control (IMP 2) (d) and cultural plus biological control plus granular bait (IMP 1) (c) treatments were the most appropriate strategies for successfully reducing house fly populations to low levels and maintaining them at low levels over time.

The IMP 2 treatment (d) would be better for those cases in which initial house fly populations per house are high, because the cultural and chemical strategies used in the IMP treatment permit the number of adult flies to be reduced before the biological control component is used.

The IMP 1 treatment (c) would be better for those situations with a low initial number of adult flies because no pesticide sprays are used to reduce adult fly populations. IMP 1 would also be better in situations with a low initial quantity of manure to ensure the success of the cultural strategy.

In all cases, it is important to be aware of the hens’ level of health and the structural condition of the poultry houses. Neglect of these factors can result in increased manure moisture, the development of larval foci and the subsequent increase of the population density of adult flies. In both treatments where parasitic wasps were used, the biological control potential was maximized by using selected pesticides to reduce adult fly populations without contaminating areas occupied by pupal parasitoids.

ACKNOWLEDGMENTS

We thank Dr. Renato Ripa S. (INIA, La Cruz, Chile) for many valuable suggestions and for his critical reading of the manuscript. We also are grateful to Dr. Pascual Franzone and Mrs. Estela Favret for their help with the translation.
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