INTEGRATED PEST MANAGEMENT FOR CONTROL OF THE HOUSE FLY *MUSCA DOMESTICA (L.)* (DIPTERA: MUSCIDAE) IN AN URBAN SOLID WASTE TREATMENT PLANT

L. SŰSS[1], S. CASSANI[2], B. SERRA[2], AND M. CAIMI[1]
[1]Istituto di Entomologia Agraria, Université degli Studi di Milano, Italy
[2]Verdeblu S.r.l., Milano, Italy

Abstract - The development of infestations of *Musca domestica* was evaluated in a factory for the treatment of urban solid undifferentiated waste over a period of one year and control strategies were implemented. The waste treatment produces a compost used for the improvement of agricultural soil. The factory, which is situated in an urban environment within Milan, is divided into four closed and covered sheds. Two differing techniques of waste treatment are practised, both based on aerobic biodegradation. One of these techniques, which involves heaping sifted waste for maturation, encourages the development and spread of *M. domestica*. Strong pressure from local residents has resulted in strict control of the hygiene and sanitary risks of this process by the Local Health Authority. Trends in the dynamics of fly populations have been monitored and several parameters have been analysed. Propagation in outside sheds and development patterns of fly populations have been examined to help in the selection of rational and integrated strategies for the control of house fly. The results of integrated fly control strategies using insecticides against both larvae and adults, growth regulators, attractive alimentary baits, chromatotropic panels, phototropic equipment, treated and untreated coverings of the heaps, behaviour of the flies and the use of structures as obstacles to the spread of fly infestations are presented.
Key words - House fly, integrated pest management, control

INTRODUCTION

The common house fly, *Musca domestica*, is the synatropic insect which has always been able to colonise the organic substrata which man has placed at its disposal. The environments in which the fly lives make it a carrier of a large number of micro-organisms which are sometimes pathogens. The fly is considered a successful insect due to its ability to multiply rapidly and to its fecundity. Even if the presence of very high fly populations is constant in rural environments, especially in livestock farms, it is possible to find large populations in food industries. These occur when organic matter is heaped up without due precautions and fermentation starts. It is also possible to observe their presence in towns, where organic waste is gathered irregularly and incompletely. Sacca (1984) refers to having found fly larvae nesting at 20 cm deep inside soil impregnated with liquid manure in a Middle East shanty town.

The capability of insects to shift in order to reach the fittest places for egg laying has been investigated. Schoof *et al.* (1952) state that most insects shift within a mile area, but that in 72 hours they can move up to 4 miles. Contributions on fly behaviour in towns have been recorded by Siverly and Schoof (1955a; 1955b; 1955c) who assessed the practical influence on fly multiplication of the changes in seasons, by increasingly available substrata and by the features of different areas of towns. Zvereva (1990) (in Polyakova and Roslavtseva, 1995) considers the insect as a bio-indicator of the air pollution in industrial areas. Polyakova and Roslavtseva (1995) report a high degree of resistance to organo-phosphorus insecticides in fly lines gathered in the Podolsk industrial area.

There are different ways of treating urban waste; sometimes waste is heaped without differentiating; in other cases waste is selected, using the organic part to produce compost for soil fertilisation. In order to prevent larval colonisation ,waste heaps may be covered with inorganic substances unsuitable for houseflies development, or sometimes with chemicals. Imai (1985) produced positive results in Osaka by covering the waste every week with 15 cm of soil. Figueiredo (1979), on the contrary, observed that a Rio de Janeiro waste deposit needed a covering of over 30 cm of consolidated earth to prevent *M. domestica* emergence, but that this solution was not practical due to its high costs. In Milan the treat-

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ment of waste has included collecting, fragmenting and mixing of undifferentiated waste which is heaped in very large sheds, where, after frequent turning-over of the mass, a progressive selection and blowing with hot air keeps both the humidity and temperature very high and the compost is produced after about 70 days, while the inorganic components are removed into special dumps or incinerators. In these plants, a large colony of *M. domestica* develops almost immediately, making it essential to address the problem of alternative control strategies.

MATERIALS AND METHODS

Plant characteristics

The plant under consideration makes about 600 tonnes of waste every day. The waste, after a first rough mincing, is put into sheds under low light conditions (about 30-35 lux), in heaps about 60 m long, 4 m wide and 2.5 m high; the heap undergoes an initial processing (shifting by mechanical machines) and further mincing after 8 days and this is repeated once a week thereafter. The heaps are blown with air from floor level to induce aerobic fermentation. There are one finished and one developing shaped heap situated side by side in each shed every week. Average temperatures, and relative humidity, recorded in the course of the year are shown in Table 1. Both the temperature and relative humidity show a wide variation from published averages during the seasons; RH reaches almost 100%.

Table 1. T (ºC) and relative humidity, r.h. (%) recorded in the sheds during the reference period.

Reference period	T	rh%
(months)	(ºC)	(%)
Apr-June	20-37	30,5-100
July-Oct	22-39,5	33,5-99
Nov-Jan	12-25	94-100

Table 2. Insecticide dosages applied to heaps and internal and external shed walls

	Average dose of a.i. applied per 1000 m^2 of surface and per application		
Active ingredients	Heap treatments g/1000 m^2	Internal shed wall treatment g/1000 m^2	External shed wall treatment g/1000 m^2
malathion	1300	350	1600
chlorpyrifos	1300	240	-
dimethoate	1300	240	-
cypermethrin	50	50	200
permethrin	400	-	-
diazinon	800	-	-
azamethiphos	-	-	5000*

* spot treatment

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Instrumentation

The studies have been made by means of an inspection and monitoring, depending on the season (every week from April to May, every fifteen days from June to September); compost and environmental temperatures have been recorded by probe thermometer and the humidity by hygrometer. Organic matter has been gathered to check larval density in the laboratory either by means of pitfall-traps or after storage in conditioned rooms. The development of *M. domestica* collected have been studied in the laboratory at different temperatures (16 º, 25 º, 35 º, 40 º, 45 ºC). Attractive food traps have been positioned along the external periphery of the waste plant, to evaluate potential fly entry and exit movements. Combined treatments on the walls of the fermentation shed and on the heaps have been made on the basis of monitored results; sometimes, the external walls of the sheds have been treated also, using active ingredients with a persistent efficacy, in order to reduce the fly population from the external environment (Table 2). Insecticide treatments with active ingredients characterised by a knock down or residual effect have been made against both adults and larvae, using atomisers.

RESULTS

Temperatures of substrate and house fly development

The temperatures which influence insect development have been recorded by many Authors, who often quote contrasting data. Derbeneva-Ukhova (1973) (in Busvine 1966), record a high death-rate of pupae at about 40 ºC, while larvae are often found in waste at temperatures of 45-50 ºC.

Lystyk and Axtell (1987) observed pupae develop up to 41ºC, but at temperatures higher than 38 ºC the adult emergence is not checked. Tiwari *et al.* (1997) studied *M. domestica* behavior in the laboratory, where they bred flies at increasing temperatures and they recorded that a strong emergence of adults is possible if pupae are maintained at 44 - 46 ºC.

In our study, compost temperature has been recorded at a height of 50 cm from the floor and at depths of 10 cm and 50 cm from the surface; environmental temperature and relative humidity have been recorded at a height of 2 m (Table 3). The cycle, at the different temperatures considered in these investigations, was completed in periods varying from 51 days at 16 ºC to 9 days at 40 ºC (Tab. 4).On the contrary, constant temperature does not allow to gain maturity. The best temperatures for fly development are between 35 ºC and 40 ºC, which are temperatures recorded frequently in the fermenting organic substrata a very little time after heaping. Table 3 shows the number of larvae and pupae found in 5 litre samples of compost taken from the top10 cm of heaps, after removing the roughest debris from the samples. The presence of *M. domestica* larvae was recorded in the waste heaps from the beginning of fermentation, even where conditions very similar to those noticed in the presence of large populations of housefly were recorded; therefore, the development of *M. domestica* seems to be connected with the formation of niches with particularly favourable micro-climates and quality of food within the fermenting mass.

Use of attractive panels treated with triflumuron

M. domestica auto-sterilisation was obtained by feeding the insects with sweet baits treated with triflumuron, an inhibitor of chitin synthesis (Howard and Wall 1996a; 1996b ; Morgan *et al*., 1975 and Smith and Wall, 1998). The efficacy of the active ingredients had already been described (Hamman and Sirrenberg, 1980; Miller, 1982; Beck *et al*., 1983; Kostina, 1989). When swallowed by *M. domestica*, low doses of triflumuron cause a diminution of fertility, or interfere with post-embryonic development, with such a high reduction of population that it may be considered as auto-sterilisation. Based on this knowledge, a control strategy was developed to utilise and integrate different techniques.

First, using 30 cm x 20 cm PVC chromotropic panels, of differing colour but always activated with sugar diluted to 50%, it has been observed that the black panels attract up to 20 times more flies then the white, yellow or blue coloured panels. The attraction of colours to *M. domestica,* independent of bait

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Table 3. T (ºC) and r.h. (%) recorded in the environment and in the heaps and number of larvae and pupas found in 5.0 l of compost.

Data	Fermenting environment T (ºC)	Fermenting environment r.h. (%)	Compost 10cm depth T (ºC)	Larvae (N)	Pupae (N)	Compost 70cm depth T (ºC)
15 April '98	19.1	98.5	58.8	0	0	71
25 April '98	25.3	88.9	48.8	0	0	59
13 May '98	30.2	51.3	49.5	0	0	69
27 May'98	28.6	68.4	62	2	22	64
24 June'98	36.3	50	34.3	18	1	63
1 July'98	35.7	64.3	59.1	0	0	58
15 July'98	29.9	57.4	48.6	3	17	68
22 July '98	36	49.7	47.2	0	0	70
5 August '98	35.1	58.8	35.9	14	45	63
19 August '98	31.6	56.1	38.1	0	0	64
26 August '98	35.7	40.2	42.4	2	0	48
2 September '98	33.7	62.1	44.7	2	0	68
9 September '98	32.8	54.8	33.1	4	32	58
7 October'98	26	86.3	42.7	669	540	59
21 October '98	22.5	90.6	36.4	1232	2	58
4 November '98	24.4	100	31.9	0	2	61
18 November '98	17.8	98.8	37.4	0	0	63
2 December '98	14.7	100	24.2	0	11	69
16 December '98	14.4	100	21.8	35	593	70
30 December '98	15.7	100	35.2	6	632	66
13 January '99	18.9	100	56.8	898	7	65
27 January '99	15.1	100	44.2	201	71	69

Table 4. Days for the development of different stages of *M. domestica* in relation to temperature.

	16 ºC	25 ºC	35 ºC	40 ºC	45 ºC
Pre-oviposition period	9	3	1.8	*	*
Egg hatching	1.7	0.66	0.33	*	*
Larvae development	17-19	3-6	3.4	5	6-7
Pupae hatch	17-19	6-7	3.4	4	no hatch
Complete cycle	45-51	14-16	8-10	9	-

Table 5 - Fertility reduction of *M. domestica* gained after a 24 h treatment with triflumuron at 3%, starting from 200 eggs gathered at 2,4 and 6 days after treatment.

		Trial					Control					
Days after treatment	Stage	R1	R2	R3	R4	Mean	R1	R2	R3	R4	Mean	% Mort
2	Egg	200	200	200	200	200	200	200	200	200	200	-
	Larva	13	4	8	10	11.5	179	187	168	183	181	93.65
	Pupa	6	0	3	4	5	182	153	125	144	138	96.38
	Adult	6	0	2	2	4	126	153	117	138	132	96.97
4	Egg	200	200	200	200	200	200	200	200	200	200	-
	Larva	10	25	12	17	13.5	182	194	179	185	183.5	92.64
	Pupa	4	10	6	11	7.5	154	170	145	147	150.5	95.02
	Adult	1	3	1	4	2.5	150	159	136	142	146	98.29
6	Egg	200	200	200	200	200	200	200	200	200	200	-
	Larva	20	18	11	15	17.5	183	169	173	180	181.5	90.36
	Pupa	11	9	6	10	10.5	151	149	160	148	149.5	92.98
	Adult	9	5	4	7	8	145	140	153	141	143	94.41

1 (We used a lamp Insect-O-Cutor, model P25)

usage was reported by Hecht (1970). Flies used for experiments, 24 hours after emergence, have been fed once a day on panels on which triflumuron at 3% concentration has been spread with a solution of sugar at 50%. Each test consisted of 200 eggs laid 2, 4 and 6 days after exposure to the product, with the result that the emergence of adults was reduced (Table 5). All the tests were repeated 4 times.

In reference to these results, the per cent reduction of emergence was similar, whether for eggs laid two days after treatment or for those laid 6 days after treatment; the reduction of eggs hatching was greater than 90% and the final number of adults were no more than 5%. An high sterilisation of eggs was obtained in that way and larvae hatching from the eggs were not able to mature.

Use of insecticide-treated nets

The use of black coloured nets made of synthetic material has been assessed firstly in the laboratory and then in the waste treatment plants, after having treated the nets with a 15% formulation of azamethiphos at 25g/m² product or with a 2.5% formulation of deltamethrin at 3g/m² product. The technique has been suggested by the experiences of tse-tse fly control with nets treated with deltamethrin (Green, 1991). A commercial application was made to the organic waste heaps during the heap formation phase and for 8 days of fermentation; in that period it was observed that the micro-climatic conditions of the waste and the sensory attraction resulted in a highly attractive fly habitat most favourable for egg laying and larval development. After having covered the heaps with nets, one was treated with insecticide solution. The real efficacy of this control method was recorded as the flies, attracted by the smell of the waste, alighted on the net and died.

A random series of samplings of those individual flies was taken and weighed (the weight of 100 flies dehydrated at 70°C for one hour is 0.3g), and this has allowed us to quantify that more than 3,000,000 individuals died in a week on one heap only. The application of this technique has given the most successful results during the experimentation: the efficacy of the active ingredient persisting for two months. As soon as the heaps of organic waste are formed, they must be covered with the net during 8 days; after this period it is possible to shift the net on to another newly formed waste.

Use of larvicides

The most used larvicidal products are IGR (Miller, 1970; Jespersen, 1993). El-Khodary *et al.* (1979) recorded a mortality of 50-100% of *M. domestica* larvae using diflubenzuron at 0.056-0.56 mg/g concentration in the substrata and observed a higher sensitivity of first aged larvae. Positive results have been recorded with the use of triflumuron in laboratory tests simulating a larvicidal treatment in a poultry house (Fukase *et al.*,1988).

Motoyama (1999) refers to a 94% mortality of *M. domestica* larvae treated with pyriproxyfen and 100% mortality for those treated with cyromazine or diflubenzuron.

According to these experiments, a larvicidal treatment on fermenting waste heaps was made with diflubenzuron, using 2 g of a 25% wp product /m^2 of the exposed surface of a newly formed heap. The initial part of the heap, identified as T1 and 4 days old, and the final part of the heap, identified as T2 and 1 day old, have been treated at the same moment, while the middle part of the heap (C) has been chosen as the untreated control. Four days after application, a high increase in the population of the untreated control (larvae and pupae) was recorded, whilst the treated plots produced a population reduction of 38% on T1 and 98% on T2; this result confirms the efficacy of the method when the application of the product is made on the heaps after fermenting for a maximum of 1 or 2 days.

The physical nature of the compost does not allow a regular penetration of the product into the mass, whilst the addition of the larvicide during the mincing stage of heaps has to be avoided: the biological behaviour of larvae that are able to reach the heap surface in less than 24h after being put into the deep layers by the turnover of the mass has been observed.

DISCUSSION AND CONCLUSION

It is well known that a balanced pest management is based on prevention, followed by infestation monitoring and, as the least important part only, by the application of direct control techniques. That is also true for *M. domestica*. Within a closed plant of waste recycling, prevention practices can not stop the daily arrival of flies which come, especially as eggs and larvae, with the waste collected in the town. The problem is, therefore, to prevent fly populations exiting the plant to colonise the surrounding environments and spreading micro-organisms. Within the Milan plant, prevention has been established by the use of double doors at the staff entrance, automatic doors with fast-lock for the transit of vehicles and a continuous control of window glass to avoid casual exit through broken panes or holes in the walls. The space between the double-doors must be darkened to avoid luminosity higher than the interior, as such high luminosity is very attractive to the flies. Outside, the squares have to be strictly cleaned. Infestation monitoring must be made with periodic records of the flies present on pre-arranged surfaces, checking population dynamics to permit timely control measures.

The following method of direct control of larvae and adults, using chemicals, is recommended: covering the heaps of organic materials at the beginning of the fermentation process for 8 days with black nets, treated with azamethiphos at 15%, or, as an alternative, with deltamethrin at 1%. The treatments must be repeated every two months; installation of black chromotropic panels, of dimension 1 m^2, activated with triflumuron at 3% spread with a 50% sugar solution ; this treatment must be repeated monthly; larvicidal treatments with diflubenzuron (2 g 25wp/m^2 exposed surface) on heaps during their formation, when there are good conditions for high infestations of the compost (large population of adults, ideal temperature and relative humidity conditions). Application of larvicidal products on the shed floors along the walk-ways amongst the heaps, where there are often mature larvae near the metamorphosis stage of pupation; treatment of fast-lock doors and of all windows with azamethiphos at 15%, as these are the places where high outside luminosity attracts *M. domestica*; adulticidae treatments with a knock-down effect or persistent activity, such as malathion, chlorpyrifos, dimethoate, cypermethrin, diazinon or azamethiphos applied by atomisers, during the occurrence of sporadic, heavy infestations of flies, provoked by the introduction of organic waste already highly infested, particularly during the summer season.

One further addition is the use of attractive lamps at less illuminated areas of the plant and the treatment with 15% azamethiphos of the space between the double-doors of the staff entrance.

This integrated pest management programme requires prevention techniques, different direct control strategies and the use of chemicals.

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