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House fly (*Musca domestica*), a challenging pest; biology, management and control strategies

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ABSTRACT

Housefly (*Musca domestica* L.) is considered a key domestic, veterinary and medical pest, causes irritation, spoils food and also an important vector for many pathogenic organisms. A number of social and health problems are caused due to housefly, which emphasize the need to control its population. Hence several control strategies viz., cultural, biological, chemical control and certain technical customs are commonly used. The main purpose of this review is to highlight different house fly control strategies such as ultraviolet machines, through biological control agents, plant sources chemicals (Neem, Wood vinegar and Basel plant). The IPM (integrated pest management) practices, which can offer relatively more reliable field performance, have also been described. However the preservation of the housefly's natural enemies could be an ecologically sustainable method of maintaining the fly populations below threshold level.

Introduction

The housefly (*Musca domestica*) is the synanthropic 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 number of pathogenic organisms. It is a carrier of over 100 different pathogenic organisms including organisms for diseases, viz. typhoid, cholera, bacillary dysentery, tuberculosis, anthrax, ophthalmia neonatorum and infantile diarrhoea as well as parasitic worms (Sasaki *et al.*, 2000; Fotedar *et al.*, 1992). 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 housefly (*Musca domestica* L) has worldwide distribution and is found throughout the country in close association with human activities. In addition to being a nuisance pest, it is a vector of many pathogens. Pathogenic organisms are picked-up by the flies from garbage, sewage and other sources of filth and transferred to human food either mechanically from contaminated external body parts or after consumption by houseflies through vomiting and defecation while feeding on food (Sasaki *et al.*, 2000).

The control of *M. domestica* is thus, vital to human health and comfort. The common control measures are sanitation, use of traps and insecticides. However, in some instances integrated fly control has been implemented and found successful. The development of resistance in houseflies to insecticides and the associated toxicity has necessitated evaluation of safer alternatives for housefly control. The use of safer alternatives like biological control or insect growth regulators (IGR) is thus gaining attention as an important intervention in housefly management programmes (Axtell and Arends, 1990; Tunaz and Uygun, 2004). In this perspective, the present review aims to focus various fly control strategies for the sustainable control of fly population.

Economic importance of house fly (*M. domestica*) control

The house fly, *M. domestica* L., is a worldwide pest of agricultural and public health importance that has plagued humans throughout recorded history (West, 1951). The ability of the fly to develop in a vast array of patchily distributed and ephemeral organic larval substrates has enabled it to exploit virtually any area inhabited by humans and their associated animals (Lietze *et al.*, 2011). Fly populations seem likely to increase with the projected warming of Earth's climate (Goulson *et al.*, 2005). The fly population above threshold level causes nuisance problems to farm workers and neighbouring residents. More importantly, the habit of adult flies to defecate and regurgitate on animal and human food led to the early recognition of their role as vectors of human and animal pathogens, especially those responsible for enteric diseases (Lietze *et al.*, 2011).

Recent concerns about food-borne human illnesses have led to increased documentation of the role of flies in spreading disease-causing organisms, especially *Escherichia coli*, *Shigella* spp., and *Salmonella* spp. (Nayduch and Stuzenberger, 2001; Ahmad *et al.*, 2007; Macovei *et al.*, 2008; Holt *et al.*, 2007). Flies with pathogens can contaminate milk, steak and potato salad (De Jesus *et al.*, 2004; Ahmad *et al.*, 2007; Macovei *et al.*, 2008) Pathogen-carrying flies are commonly found around human and animal waste and landfills, from which they disperse to areas of human habitation and activity (Moriya *et al.*, 1999;

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Sulaiman *et al*., 2000; Mian *et al*., 2002). Greenberg (1971) listed more than 330 different associations between the housefly and pathogenic organisms (Greenberg, 1971). Keiding (1985), listed important diseases which may be transmitted by *M. Domestica* under certain conditions, includes the bacterial infections shigellosis, salmonellosis, cholera and *Campylobacter* infection. Moreover house flies carry the eggs and cysts of many intestinal worms, including *Ascaris* spp., hook worms and tapeworms. *M. Domestica* has been shown to be involved in the spread of trachoma (although in this instance *M. Sorbens*is more important) and epidemic conjunctivitis and, given the attraction of this species to skin infections and wounds, the housefly is also involved in infection of these sites.

As house fly causes economic problems to all of farm animals (cattle, camel and sheep) in addition to poultry. House flies reduce milk production because cows must expend extra energy fending off flies; also, it reduce farm worker productivity: flies interfere with work such as feeding and milking as well as house fly increased frequency of animal disease transmission, leading to increased medication veterinary service costs, and increased potential for spread of human diseases (Douglass and Jesse, 2002). The medical and veterinary pest *Musca domestica L*. has developed resistance to most insecticides used against it. For this reason, there is a constant search for new alternative control tools (Douglass and Jesse, 2002, Tarelli *et al*., 2009 and Huang *et al*., 2009).

Life cycle of breeding habits of house flies

The house fly, *Musca domestica* L. (family Muscidae) is the most common fly species (Kettle, 1995). It is diurnal and adult activity consists mostly in seeking food and water, feeding, mating, resting and oviposition (Diether, 1976). House flies are multivoltine and go through 10-12 generations annually in temperate regions with populations peaking in summer. The fly does not migrate with the seasons or go into diapause during winter but survives and continues to breed in refuges. Sites utilized for overwintering include barns and other animal-associated locations that are warm enough and offer sufficient development sites and food to support the flies' lifecycle (Black and Krafsur, 1986; Kettle, 1995).

House fly identification and feeding habits

M. domestica is one of the most abundant insect species and is closely associated with humans (synanthropic). They are abundant in environments such as open markets, fairs, restaurants, refuse dumps, animal pens, confined animal feeding operations and in homes (Echeverria *et al.,* 1983).

Enhanced dissemination of pathogens has led to house flies being termed a "bioenhanced vector" to differentiate this from simple mechanical transmission (Kobayashi *et al.,* 1999). The alimentary canal of the flies includes a highly modified crop that branches from the stomadaeum and extends to the abdomen. The crop of the house fly has been observed as an important site of bacterial accumulation (Kobayashi *et al.,* 1999; Sasaki *et al*., 2000). Further, the crop is important in *M. domestica* because of the fly's method of feeding. Because the fly regurgitates when feeding, any bacteria present in the crop are readily deposited on the flies' food source (Graczyk *et al*., 2001). Flies also frequently defecate on food sources and microbes that have survived to the rectum are passed in this way as well (Kobayashi *et al*., 1999; Sasaki *et al*., 2000; Graczyk *et al*., 2001).

Due to the ability of various microbes/pathogens to proliferate in the house fly digestive tract, a number of studies have focused on tracking the fate of select bacteria in the fly gut in laboratory assays. Kobayashi *et al*. (1999) fed adult house flies trypticase soy broth containing two strains of *E. coli* O157:H7 at a concentration of 109 CFU/ml. Within 1 h of exposure the flies excreted the bacteria and 106-107 CFU/fly were recovered from the alimentary canal. The flies continued to harbor *E. coli* O157:H7 for up to 72 h. additionally, they successfully contaminated their substrates with 107 CFU/fly at 1 h down to 102 at 72 h.

Facility management, sanitation and manure handling

House fly larval development substrates include a variety of rotting organic matter, which is rich in microbial communities. The fly larvae are constantly contacting and consuming the associated microbes/pathogens and are able to carry pathogens from larval substrates through pupation to adult exclusion (Greenburg, 1965; Rochon *et al*., 2005). Further, adult house flies aggregate at sites of larval development as well for breeding, oviposition and feeding and can easily acquire associated pathogens (Blackith and Blackith, 1993).

House flies are known to disperse great distances often with no apparent patterns with regard to wind direction, food/water proximity or suitable mating and larval development sites. A mark and recapture study of wild house flies in rural Georgia resulted in flies captured up to 8 km from the release point in 24 h (Quarterman *et al*., 1954a). The same 9 authors conducted a similar study in an urban area of Georgia (Quarterman *et al*., 1954b).

Animal manure, manure soiled animal bedding, household garbage and other decaying organic substrates provide a suitable habitat for the growth and development of muscoid flies primarily house flies (Zurek *et al*., 2000; Graczyk *et al*., 2001; Moon, 2002). These organic wastes comprise of diverse and active microbial communities (Schmidtmann and Martin, 1992; Zurek *et al.*, 2000; Dillon and Dillon, 2004). Several studies addressing the significance of these microbial communities in the development of immature stages of muscoid flies, including house flies (Schmidtmann and Martin, 1992; Zurek *et al*., 2000).

To keep house flies awaypoultry operations need to keep manure dry. Dairy farms should remove accumulated manure especially if it is wet. Homeowners and restaurants should remove garbage at least twice a week and keep the area clean (Michael and DuPonte, 2003).

How can we keep ourselves safe from keeping the breeding sites of house flies is very important to avoid economic and other losses caused by them. The present study concerns about the methods of sanitation and manure handling etc. to the flies aside. The public health risks and annoyance associated with large housefly populations are therefore substantial and efforts to control the species have been the focus of considerable research for several decades (Wiesmann, 1962; Mitchell *et al.*, 1975; Carlson and Leibold, 1981; Chapman *et al.*, 1999; Hanley *et al.*, 2004).

Cultural Control

The cultural control can be used to control house fly in the poultry farms by maintaining animal manure. Jacobs (2013) reported that good sanitation, exclusion, and some cultural controls may reduce the flies in more appropriate way. Further keeping the form house dry is another aspect to control this disease causing pest (Axtell, 1986). According to Barth, (1986) cultural control of house flies in the farm houses is the only convincing option in the future. He elaborated that manure management should be taken out. The manure management includes both manure handling system and manure utilizing capacity. Moon (2004) stated that the filth flies can be govern by baits, chemicals (pyrethrum), pasticides wasps, and by some other known cultural controls (wreckage management). These practices can be done for the regulation of flies near the horses. Furthermore Tomberlin, (2006) illustrated that the proper drainage and garbage management along with the keeping your house holds neat and clean is more perfect way to control flies. More over ultraviolet lights should be installed in dark area in house and 5 feet away from kitchen essentials. Lights should be cleaned regularly as dead flies are food source for other flies too.

Powell *et al*. (1995) stated that the manure management can allow the eradication of house flies in the poultries. A house fly can be restricted to grow by cleaning manure twice a week, as life cycle of fly is 7 days. Baits should be applied in the form of sticky odor strips. Mixture of syrup, scraps and milk can be applied as baiting material. *Muscidafurax raptor* is found to be much more effective parasite for the house flies. Author recommended to use parasitic wasps along with baits is more efficient practice to control houseflies.

Windows fittings to restrict or block the passageway for the flies, removing the garbage and drainage of the water should be examined at the priority bases for the house fly control was recommended. Use of sticky papers was suggested as a healthy practice too. Commercially available chemical may be used, but it should be kept in view that more powerful insecticides are harmful for the health too, so should be sprayed outside the close buildings (pests note, 2004). Kaufman *et al*. (2005) used techniques for the cultural control of the house fly in the farms. Large sticky traps were used to capture house flies in farms. Effective results were found to control adult *Musca domestica.*

Chemical Control

Several chemical methods are used to control fly, dieldrin is considered as the cheap method for the control of the flies (Chow *et al*., 1953). John *et al*. (1956) and Hertz *et al*. (2011) used chemical cords both natural (e.g. cotton and manila) and synthetic (e.g. nylon), that were treated with a small amount of insecticide (fipronil or indoxacarb). House flies like to rest on attractive cords. It was noticed that the natural cords attract more flies than synthetic cords. Therefore plant manufactured cords attracted more flies. Insecticide on wool cord was examined as most efficient control of house flies, as median lethal time for it was lowest. For urban, field fly control purposes fipronil and indoxacarb found to be a better option in market. Tilak *et al*. (2010) reported that both the Dichlorvos EC and Diflubenzuron granule formulation are effective housefly larvicides under labortary and field conditions.

Pospischil *et al*. (2005) inspires the use of the baits and treated chemical control of the house fly by oral action. Fly attractant (z-9 tricosene) along with imidacloprid as insecticide. There was a little resistance was shown by the flies for the particular insecticide treated with. Baits of different colours also have variable impact on the fly attraction. Black and white colours are more attractive for fly, while white colour is least effective, that were used by using with blood, sugars and honey applying on baits (Ahmed *et al*. 2005). Vartak *et al*. (1995) used K-otherine on bait viz., dry milk, dog cookies, and jiggery and suggested that the persistence of the k-otherin is quite impressive and effective way to control fly population.

Insecticides are effective agents for the suppression of fly population, however with the passage of time flies develop resistance against chemicals used to control them. Acevedo, *et al*. (2009) noticed the development of resistance among house fly against insecticide particularly two commercial insecticides, that are 2,2-dicholovinyl dimethyl phosphate (DDVP), and permithrin. Axtell (1967) applied 12 types of insecticides on the manure and found that insecticides did not kill fly predator mites were showing little effect for control of house fly. By increasing the dose of the insecticide killed mites so indirectly larval population of the house fly increased at a massive rate. Furthermore these chemicals are not environment friendly.

Researcher strived to develop new environment friendly chemicals as well as better fly pest control agents. The plant based chemicals are considered environment friendly and better pest suppressive agents. Panhwar (2005) found neem plant as a good insecticide. It was also noticed that neem plant is a good repellent too. In addition it showed results as pesticide, and the more important thing was it was found less harmful and environmental friendly. Pangnakorn *et al*. (2011) used Wood Vinegar for fly control. He documented that the mortality rate of the flies is directly proportional to dose concentration and time interval for exposure to wood vinegar as well as feeding method is more efficient than contact method. Ojianwuna *et al*. (2011) found oil of basil plant as good and cheap factor for house fly control.

Biological Control

Biological control is a effective method to controll pests such as insects, mites, weeds and plant diseases by using other living organisms. Several biological control agents are used to for the control of house fly. Axtell (1986) used two species of mites viz., *Macrocheles muscae domesticae* and *Fuscuro podavegetans*gave and one beetle species *Carcinops pumilo* found more effective against fly pests. Peterson *et al*., (1991) used six species of Pteromalid wasps and Tomberlin (2006) three species of wasps (*Spalangia nigroaenea, Muscidifurax raptor*, *Muscidifurax zaraptor and Spalangia cameroni*) for fly control. The wasp laid eggs in the pupa of the house fly, after the emergence of new born inside the pupa, the wasp larvae feed inside the fly, and grow there up to the death of the host house fly.

Biopesticides are also a good option to get rid from fly and the peoples all over the world preferring to apply this method of fly control, because it has little impact on the environment. Geden (2012) compared the bio-insecticides viz., Steinernema, Heterorhabditis, entomophthora, *Beauveria bassiana*, and *Bacillus thuringiensis*. He found Beauveriabassiana more efficient and effective biopesticide to control fly population. Further he documented that the chemicals such as Cryl B, 1,8-cineole, pulegone, limonene, menthol, certain active oils are good biopesticides in the field.

Hodgman *et al*. (1993) found *Bacillus thuringiensis*is to be the toxic in nature for the housefly. This species of bacteria is found naturally in the gut of the moth and butterflies caterpillar. Crystal endotoxins are produced by this species of bacteria. *B. thuringiensis* introduced medium showed positive results by killing 50% of flies' larvae. Latter Merdan (2012) introduced a bioinsecticide *Bacillus thuringiensis* in the food of poultry. It reduced house fly pupal and adult strength.

Control By Radiation

Described the house fly as human pathogenic source and irritation causing agent. The control of fly is seemed to be declined in its approaches because of insecticide resistance, ecological limitations and inefficient results by biological control. Ultra violet lights can kill the house flies upto some extent but can never decline their population as the key sources to growth of the flies are not controlled in this way. Certain electronic baits were considered to be the best choice for houseflies' control (Smallegange, 2004).

Gouge *et al*. (2009) quantified that the garbage outside the houses should be positioned far from house entrance. Dumpster should steam clean and lid closed. External doors should be shut and windows should be properly shut. Installments of light traps such as ultraviolet lights could be the benefit measures to control house flies.

The population monitoring by the use of simple fly sticky taps should be the primary measure in poultries. A moist humid environment is suitable medium for the growth of the house fly morphs, so proper drainage and manure management should be carried out. The 3rd control strategy is by help of parasites and predators of houseflies. If there is more threatening condition or high mass of the flies in a particular area, chemical control should be introduced (Day, 2013).

Integrated pest management approach

Nicoletti *et al*. (2012) showed some advance researches in the integrated pest management. The key source for the control of insects and pests was through neem. Experimental studies revealed that neem cake can be used as best insecticide in the future.

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 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 involve 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 (Sûss *et al.,* 1999).

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