



Contents lists available at ScienceDirect

Saudi Journal of Biological Sciences

journal homepage: www.sciencedirect.com

Original article

The impact of different plant extracts on biological parameters of Housefly [*Musca domestica* (Diptera: Muscidae)]: Implications for management

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ARTICLE INFO

Article history:

Received 13 March 2021

Revised 24 March 2021

Accepted 25 March 2021

Available online 2 April 2021

Keywords:

Musca domestica

Botanical extracts

Biological parameters

Repellency percentage

ABSTRACT

Housefly is a significant domestic pest, which causes nuisance. The use of insecticides is discouraged to manage housefly; therefore, alternative management strategies are inevitable. The current study investigated the impact of different plant extracts, i.e., *Moringa oleifera* (moringa), *Allium sativum* (garlic) and *Piper nigrum* (black pepper) on biological parameters of house fly. Two different concentrations (i.e., 25 and 50%) of the extracts were blended in larval diet made through mixing of wheat bran, yeast and dried milk powder. The results indicated significant differences for larval duration. Maximum larval duration was recorded for garlic followed by black pepper and moringa, respectively. In case of pupal duration, non-significant differences were observed among plant extracts. Increase rate of oviposition was noticed with moringa at 25% concentration, while decreased oviposition rate was noted for garlic with 50% concentration. Egg hatching percentage remained non-significant for the botanical extracts. The highest survival was observed with moringa, while garlic resulted in the lowest survival. The highest repellency was noticed for garlic followed by black pepper, whereas moringa resulted in the lowest repellency after 30, 60 and 90 min. Prolonged developmental time was observed for bot concentrations of garlic, whereas moringa noted the shortest developmental time. Thus moringa was found to be a promoter of housefly development. Minimum adult emergence was found with both concentrations of garlic followed by 50% concentration of black pepper. The 50% concentration of black pepper promoted the population of adult males, while both concentrations of moringa and 25% concentration of black pepper encouraged the population of female adults. Study outcomes depicted that tested botanical extracts had significant potential for disturbing biological parameters of housefly. The garlic extracts can potentially be used to manage housefly. However, further investigations on the larval and adult mortality are needed.

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Peer review under responsibility of King Saud University.



1. Introduction

In recent period, vector borne diseases have increased all over the world and long-term infections are transferred through infection of household pests, mainly houseflies, mosquitoes, ticks, sand flies and black flies (Semiatizki et al., 2020). Housefly [*Musca domestica* (Diptera: Muscidae)] is a major medical and veterinary insect that causes irritation, spoil foods and act as a vector for

<https://doi.org/10.1016/j.sjbs.2021.03.070>

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>100 species of pathogens. It causes serious threat to human health and livestock (Morey and Khandagle, 2012). Housefly is considered as cosmopolitan pest and distributed all over the world (de Jonge et al., 2020).

Housefly could be effectively managed with different insecticides; however, insecticidal resistance in houseflies is being reported abundantly (Kaufman et al., 2001; Shono et al., 2004). Due to this reason, alternative housefly management approaches, like bioinsecticides are being studied (Pavela, 2008; Tarelli et al., 2009). Different botanical species have been utilized worldwide for controlling the dipteran insect populations (Muthukrishnan et al., 1997).

Different plants extracts are primary and secondary chemicals, which are well-known to perform essential roles in plant survival as protection against adverse environmental conditions. *Moringa oleifera* is one of these plants known to possess insecticidal features (de Oliveira et al., 2020). *M. oleifera* is used as an edible plant and has numerous medicinal, agricultural and industrial benefits (Chhikara et al., 2020).

Garlic and its extracts are well known for several years due to their beneficial impact on human health (Wilson and Demmig-Adams, 2007). In the 20th century, the features of one or more compounds present in bulbs of garlic were characterized. In garlic, the bioactive compound is allicin. The toxic influence of formulation prepared by garlic toward insect pests has obtained considerable research focus. Prominent action of garlic has been reported against of hemipteran, lepidoptera (Yang et al., 2012), diptera (Consoli et al., 1988) and coleopteran.

Black pepper (*Piper nigrum*), a member of the Piperaceae family, mostly known as 'Spices king' is a widespread table spice applied for flavoring all sorts of foods globally (Mathew et al., 2001). A spicy alkaloid (piperine) exists in black pepper, which is responsible for its spiciness (Tripathi et al., 1996). Piperine promotes the bio-availability of different therapeutical and structural diversified drugs (Khajuria et al., 2002). Black pepper extracts have been reported to have significant insect killing features (Custódio et al., 2016; Maenthaisong et al., 2014; Samuel et al., 2016).

Botanical extracts are a good choice in place of chemical insecticides and are eco-friendly. It is essential to select proper botanical species and their parts for use as bio-insecticides. The application of botanical extracts in the management of specific insect species relies on their inherent substances, which restrict the growth of insects (Kristensen and Jespersen, 2003). This study evaluated the impact of some botanical extracts on the management of housefly. It was hypothesized that the extracts will significantly differ for their potential to impact the biological parameters of housefly. Moreover, different concentrations of the same extract will also differ significantly. The results would help to choose the eco-friendly plant extract for sustainable management of housefly.

2. Materials and methods

This study was conducted Plant Protection Laboratory, Faculty of Agricultural Sciences, Ghazi University, Dera Ghazi Khan, Pakistan during March 2019. House fly mass culture, cages, Petri dishes, rearing containers, muslin cloth, distilled water, botanical materials, aspirators, food products, i.e., sugar, cotton ball, milk powder and wheat bran were the materials used in the study.

2.1. Mass culture of housefly

Houseflies adults were collected from different fruit juices shops near Ghazi University, D. G. Khan and brought to Plant Protection laboratory. The adults were cultured in a specific cage (30 × 30 × 30 cm) by providing open access to sugar and milk

powder + water absorbed cotton bolls in shallow Petri dishes (adult diet). Adult flies were free to mate and lay eggs.

2.2. Larval diet

The larval diet comprised of a mixture of wheat bran, yeast, dried milk powder and water (Ahmad et al., 2013). The mixture was stirred thoroughly to make a loose texture. All rearing containers were filled with the prepared medium and placed in the special cage with flies. After 2–3 days interval, the rearing containers were taken off from the special cages and their mouths were covered by a nylon mesh with the aid of rubber band. In this way larval diet was maintained regularly relying on the larval count. Upon pupal formation, rearing containers were kept in other cages for the emergence of adults.

2.3. Botanical extracts

Fresh leaves of *Moringa oleifera* were taken from different localities in D. G. Khan. Black pepper seeds and garlic cloves were procured from the local market. Moringa leaves were firstly washed with tap water and dried under shade for 2 weeks. The leaves were then crushed into powder with the help of electric grinder. Black pepper seeds were also grinded to fine powder for preparing extracts. Garlic clove juice was extracted and used in the experiment.

The powders were mixed with water in 1:2 ratio, (one part of powder and two parts of water) in plastic bottles. These plastic bottles were labeled with the name of botanical extract. The resulting mixtures were filtered with the aid of Whatman no. 48 filter paper. This filtrate made 100% botanical extract which were diluted with distilled water according to the treatments. The names and concentrations of different plant extracts used in the study are summarized in Table 1.

2.4. Bioassays

The larvae diet having various formulations (25 and 50%) of each extracts were placed in the culturing cages. The control treatment possessed only water as solvent in the larval diet.

2.5. Data collection

Larval duration was taken as the time between first emerged to larvae and first pupae development. The pupal duration was counted from first pupal development to first adult emergence. Four pairs of freshly emerged male and female adults moved toward ovipositional cages possessing adult diet (sugar and cotton balls) in plastic bottles of 250 ml with various formulations of extracts for feeding and egg laying. The cotton balls were changed on regular basis. In this way, total egg count and egg laying by single female (fecundity) was recorded. Egg hatching percentage was calculated by following formula;

$$\text{Egg hatching (\%)} = \frac{\text{Number of eggs hatched}}{\text{Number of eggs laid}} \times 100$$

Similarly, fecundity percentage was calculated by the formula given below;

$$\text{Fecundity (\%)} = \frac{\text{Mean fecundity in the treatment}}{\text{Mean fecundity in control}} \times 100$$

Hundred eggs were kept in Petri dishes having larval diet comprising of various botanical extracts (25 and 50%). Then, survived larvae and pupae were counted. Repellency percentage was observed by applying repellency percentage formula. This repellency percentage was observed after 30, 60 and 90 min.

Table 1
The names and concentrations of different plant extracts used in the study.

SR. No.	Common Name	Botanical Name	Part Used	Concentration
1	Moringa	<i>Moringa oleifera</i>	Leaves	50% 25%
2	Garlic	<i>Allium sativum</i>	Clove	50% 25%
3	Black pepper	<i>Piper nigrum</i>	Seeds	50% 25%

$$\text{Repellency}(\%) = \frac{\text{Larvae on control part} - \text{larvae on treated part}}{\text{Larvae on control part} + \text{larvae on treated part}} \times 100$$

The repellency test was based on area preference technique by employing Whitman no. 1 filter paper (9 cm diameter). First half of the filter paper was reacted with treatment formulation, whereas second half was dipped in water (control). The reacted filter paper halves dried for 15 min. Furthermore, both halves were rejoined by thin tape and maintained in Petri dishes of 9 cm diameter. Ten larvae were released in the middle of filter paper in all Petri dishes and then covered. Along this, little amount of diet was kept in each Petri dish to avoid mortality.

The duration of egg to first adult emergence was assumed as developmental time. Total number of emerged adults were counted for total adult emergence. The newly emerging adults were distinguished into male and female count for recording male and female population.

2.6. Statistical analysis

The recorded data were subjected to one-way analysis of variance (ANOVA) appropriate to completely randomized design with factorial arrangements in three repeats and means separation was done by using 0.05% Duncan's multiple range test (Steel et al., 1980).

3. Results

3.1. Larval duration

Statistically significant differences were recorded among tested plant extracts (Table 2). The maximum larval duration was observed for garlic (50% and 25%), while minimum duration of larvae was found in control treatment. Statistically same outcomes were observed for garlic (25%), black pepper (50%) and moringa (50%) concentrations.

3.2. Pupal duration

Non-significant differences were recorded for pupal duration among tested plant extracts. Table 1 for mean comparison exhibited that highest pupal duration was observed for garlic, black pepper and moringa, whereas the lowest duration was observed for control treatment.

3.3. Developmental time

The longest development time was taken recorded with 50% concentration of garlic followed by its 25% concentration. The shortest development time was observed for control treatment. The remaining concentrations of all tested extracts were statistically similar.

Table 2
The impact of different plant extracts on larval duration, pupal duration and developmental time of housefly.

Treatments	Larval duration (Days)	Pupal duration (Days)	Developmental time (Days)
<i>Moringa oleifera</i> 50%	6.67 c	4.00 ^{N.S}	10.67 b
<i>Moringa oleifera</i> 25%	4.33 e	3.00 ^{N.S}	7.33 cd
<i>Allium sativum</i> 50%	10.00 a	5.67 ^{N.S}	15.67 a
<i>Allium sativum</i> 25%	7.67 b	4.33 ^{N.S}	12.00 b
<i>Piper nigrum</i> 50%	7.00 bc	4.33 ^{N.S}	11.33 b
<i>Piper nigrum</i> 25%	5.33 d	3.33 ^{N.S}	8.67 c
Control 0%	3.33 f	2.67 ^{N.S}	6.00 d

The means sharing the similar letters within a column are statistically non-significant, while N.S represents that the means were non-significant.

3.4. Oviposition, egg hatching and fecundity

Significant variations were observed among tested extracts for oviposition (Table 3). The decreases oviposition was recorded with 50% garlic extracts. The oviposition in moringa (25%), black pepper (25 and 50%) and control (0%) was statistically dissimilar. Egg hatching percentage was not altered by the tested extracts. Overall, maximum hatching was recorded with 25% concentration of moringa, whereas at 50% concentration of garlic resulted in the lowest egg hatching (Table 3). The lowest number of eggs per female were laid with 50% concentrations of garlic, while highest fecundity was found in control treatment of the study. Significant variations were recorded among tested extracts for fecundity percentage (Table 3). Mean values displayed that similar result was reported among garlic (25%) and black pepper (50%) while remaining treatments were significantly different from each other.

3.5. Survival and emergence

Larval and pupal survival were significantly affected by different plant extracts used in the study (Table 4). The highest larval and pupal survival was recorded for control treatment. Nonetheless, 50% concentration of garlic resulted in the lowest larval and pupal survival (Table 4). Similar to the larval and pupal survival, control treatment had the highest number of adults emerged and male and female adults. Likewise, 50% concentration of garlic observed the lowest values of these traits.

3.6. Repellency

The repellency was significantly affected by tested extracts at 30 and 60 min, while non-significant impacts were noted for 90 min (Table 5). Data regarding repellency after 30 min revealed that garlic (25 and 50%), and black pepper (50%) resulted in 100% repellence. Both concentrations of garlic extracts resulted in the highest repellence at 60 min indicating its potential to manage the housefly.

Table 3
The impact of different plant extracts on oviposition, egg hatching percentage and fecundity of housefly.

Treatments	Oviposition	Hatching % age	Fecundity	Fecundity %age
<i>Moringa oleifera</i> 50%	175.00 cd	87.45 ^{N.S}	43.75 cd	56.63 c
<i>Moringa oleifera</i> 25%	216.67 b	92.02 ^{N.S}	54.17 b	70.11 b
<i>Allium sativum</i> 50%	98.33 f	81.87 ^{N.S}	24.58 f	31.82 e
<i>Allium sativum</i> 25%	152.33 de	88.64 ^{N.S}	38.08 de	49.29 d
<i>Piper nigrum</i> 50%	133.33 e	85.91 ^{N.S}	33.33 e	43.15 d
<i>Piper nigrum</i> 25%	182.67 c	90.47 ^{N.S}	45.67 c	59.11 c
Control 0%	309.00 a	95.84 ^{N.S}	77.25 a	100.0 a

The means sharing the similar letters within a column are statistically non-significant, while N.S represents that the means were non-significant.

Table 4
The impact of different plant extracts on larval and pupal survival, adult emergence and number of male and female adults of housefly.

Treatments	Survived larvae	Survived pupae	Adult emerged	Male	Female
<i>Moringa oleifera</i> 50%	64.00 c	40.33 d	37.33 d	17.33 d	20.00 d
<i>Moringa oleifera</i> 25%	79.33 b	68.00 b	63.33 b	31.00 b	32.33 b
<i>Allium sativum</i> 50%	13.33 f	7.33 f	4.00 f	2.67 f	1.33 g
<i>Allium sativum</i> 25%	30.00 e	13.67 e	10.67 e	6.00 e	4.67 f
<i>Piper nigrum</i> 50%	50.00 d	38.67 d	36.00 d	18.67 d	17.33 e
<i>Piper nigrum</i> 25%	70.00 c	62.00 c	56.67 c	27.67 c	29.00 c
Control 0%	90.67a	85.00 a	82.00 a	39.00 a	43.00 a

The means sharing the similar letters within a column are statistically non-significant, while N.S represents that the means were non-significant.

4. Discussion

The results of current experiment exhibited that various botanical extracts significantly differed for larval duration, oviposition, fecundity, fecundity percentage, larval and pupal survival, developmental time, adult emergence (male and female population) and repellency after 30 and 60 min. All tested extracts had non-significant impact on pupal duration, egg-hatching percentage and repellency after 90 min.

Increased larval duration was recorded with garlic extract followed by black pepper and moringa. (Prowse et al. (2006) determined the insecticidal potential of garlic juice against *Delia radicum* and *M. domestica* and revealed that garlic juice induced mortality at increased which are parallel to our results. In present investigation less larval survival and increased developmental time were observed with garlic extract at both concentrations. Scott et al. (2004) investigated the toxicological effectiveness of extracts of *Piper tuberculatum*, *P. nigrum* and *P. guineense* against five insect orders and found that pepper possess secondary metabolites and amides of isobutyl which treat to insects as neurotoxins. Hence, extracts of pepper may provide an adequate management (feeding barrier and repellency) toward European pine sawfly and lepidopteran (larvae). Samuel et al. (2016) determined the larvicidal influences of piperine and *P. nigrum* (grounded form) toward *Anopheles* (3rd & 4th larval instar) and reported that *P. nigrum*

Table 5
The impact of different plant extracts on repellency of housefly after 30, 60 and 90 min.

Treatments	Repellency After 30 min.	Repellency After 60 min.	Repellency After 90 min.
<i>Moringa oleifera</i> 50%	86.67 bc	73.33 bc	66.67 ^{N.S}
<i>Moringa oleifera</i> 25%	80.00 c	60.00 c	60.00 ^{N.S}
<i>Allium sativum</i> 50%	100.00 a	100.00 a	86.67 ^{N.S}
<i>Allium sativum</i> 25%	100.00 a	93.33 a	80.00 ^{N.S}
<i>Piper nigrum</i> 50%	100.00 a	86.67 ab	73.33 ^{N.S}
<i>Piper nigrum</i> 25%	93.33 ab	73.33 bc	66.67 ^{N.S}
Control 0%	0.00 d	0.00 d	0.00

The means sharing the similar letters within a column are statistically non-significant, while N.S represents that the means were non-significant.

demonstrating considerable potency in comparison to piperine. Rashad et al. (2019) analyzed *M. oleifera* (crude seed extract) toward mosquito (*Culex pipiens* of third larval stage) and reported its influence as larvicide.

Non-significant results were observed in case of pupal duration among tested extracts. Maximum pupae survived with moring and black pepper extracts, whereas minimum pupae recorded with garlic extract. Elkattan et al. (2011) determined the effectiveness of various plants viz. seeds of *Acacia nilotica*, leaves of *Cupressus macrocarpa*, *Lantana camara*, *Pelargonium zonale* and *Cyperus rotundus* (whole plant) materials against *M. domestica* oviposition, larval time, pupal %, weighed of pupae, pupal time, % emerged adult, adult longevity and sex ratio by treating with 3 lethal formulations (LC₂₅, LC₅₀ and LC₇₅). The outcomes suggested that botanicals might be employed in management practices of insect due to its potential effects. Aktar and Saiful-Islam (2015) studied the botanical toxic influence against *M. domestica* by using 3 indigenous botanical species, i.e., *Polygonum hydropiper*, *Piper longum* and *Calotropis procera* in the form of whole-botanical boiled extracts. The extract of *C. procera* showed deformed pupae (21.54%) and deformed adults (11.76%) that failed to survive at increase doses. In bio-assays of pupal mortality, peppermint and blue gum crude oils inhibited (100%) adult flies emergence (Kumar et al., 2011).

In the current study, minimum oviposition, hatching percentage, fecundity and fecundity percentage was observed by all extracts at 50% and 25% concentrations, respectively. Ovicidal potential of different garlic concentrations has been stated for many other insect species comprising moths and beetles related to stored grains (Ho et al., 1996; Işıkber et al., 2009). Bell et al. (2016) reported that allicin could cease females *M. domestica* from egg laying. Elkattan et al. (2011) stated that the extract of *Lantana camara* induced great decrease in *M. domestica* eggs count.

The increased development time was observed with 50% concentration of garlic extract and decrease time was noted in 25% concentration of moringa. Minimum adult emergence was found with both concentrations of garlic followed by 50% concentrations of moringa and black pepper. Bell et al. (2016) assessed allicin concentration (a material taken from garlic cloves) against the *M. domestica* eggs, larvae and adults and reported that allicin represents potency for employing toward filth *M. domestica* with inclusion into their growth medium and capacity for the management

of other major dipteran pests. Various abnormalities like single wing, smaller size, reduced body and elongated abdomen were caused by the application of flufenoxuron (IGR), and plant extracts (*C. intybus*, *Piper nigrum* and *C. aegyptiaca*). Fan et al. (2011) studied the essential oils and extracts of *Piper nigrum* (fruit) to *Spodoptera litura* (tobacco army worm) by topical application on homogeneous weighed larvae (2nd instar) under laboratory circumstances and stated that hexane contained anti-feedant features causing extreme development suppression of tobacco army worm. Singh and Kaur (2016) conducted a study to measure the efficacy of the *Ricinus communis* castor plant crude extracts against *Musca domestica* using dipping and thin film technique and findings suggest that the plant extracts contain some active principles that interfere with hormonal developmental regulation influencing the fly's life cycle.

Both garlic extract concentrations and 50% concentration of black pepper extracts promoted population of adult female, while both concentrations of moringa and 25% concentration of black pepper extract encouraged the population of female adult. Shaalan et al. (2005) observed the variation in sex ratio of *Aedes aegypti* with more female population after the application of *Calitris glaucophylla* (LC₂₅).

Garlic extract (50% concentration) represented maximum repellency 100%, 100% and 86.67% followed by black pepper extract (50% concentration) repellency was 100%, 86.67% and 73.33%, while moringa extract (50% concentration) repellency was 86.67%, 73.33% and 66.67% after 30, 60 and 90 min, respectively. The highest repellency at 25% concentration of garlic extract was 100%, 93.33% and 80% subsequently black pepper extract was 93.33%, 73.33% and 66.67% and moringa extract was 80%, 60% and 60% after 30, 60 and 90 min application. Inyang and Emosairue (2005) reported that extracts of garlic have been extensively used for their repelling effects against many species of invertebrates. Kemabonta et al. (2018) stated that methanolic and water based black pepper (*Piper nigrum*) and turmeric (*Curcuma longa*) extracts may be utilized toward *A. gambiae* as repellents and also employed in vector control practices. Scott et al. (2007) investigated the black pepper (*Piper nigrum*) toxic influence toward insect pests of Canadian forest viz. forest tent caterpillar (*Malacosoma disstria*), spruce budworm (*Choristoneura fumiferana*), gypsy moth (*Lymantria dispar*) and pine sawfly (*Diprion similis*). Black pepper extract (0.2%) application represented repellent influence because *Lymantria dispar* larvae (70%) left branching within one hour of extract application. Such findings encourage to our results. Abdel-Gawad (2018) studied the efficacy of *Moringa oleifera* leaf extracts as repellent toward *M. domestica* on *Mangifera indica* fruit and said that extracts in the form of crude liquid and powder both repelled *Musca domestica* at various time intervals with various doses for three days but crude powder demonstrated increase repellency in comparison to crude liquid. This work also favor to our findings because in present study water based extract of moringa showed less repelling impact as compared to Agarlic and black pepper. Kumar et al. (2011) stated that for repellency peppermint was recorded as highly effective subsequently blue gum and lemongrass to *M. domestica*.

5. Conclusion

The current investigation concluded that extracts' application hindered the natural development of the various growth phases of housefly. All tested extracts showed their toxic potential toward life parameters of housefly. Both concentrations of tested extracts proved detrimental to housefly with increase developmental time and reduce reproductive potential. The extracts demonstrated repelling potential against housefly. Garlic extract with 50% con-

centration had highest toxicity; thus, it must be explored further in toxicity assays.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgement

The authors would like to express their gratitude to the Research Center of Advanced Materials–King Khalid University, Saudi Arabia for support by grant number (RCAMS/KKU/0020/20).

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