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Evaluation of the Efficiency of Certain Attractive Toxic Baits for the Control of the House Fly, *Musca domestica* (Diptera: Muscidac)

Amin AA[1], Soliman MH[1] and Shalaby AA[2]*

[1]*Chemistry Department, Faculty of Science, Helwan University, Cairo, Egypt*
[2]*Research Institute of Medical Entomology, The General Organization for Teaching Hospitals and Institute, Dokki, Giza, Egypt*

Abstract

The efficiency of boric acid, borax and imidacloprid is evaluated for inhibition of adult house fly emergence (IC values) as dry and liquid baits. In the two cases, imidacloprid has the greatest fatal effect at both IC_{50} and IC_{90} levels followed by boric acid and then borax. In the liquid formulation, IC_{50} and IC_{90} values are (0.083 and 2.6%), (0.19 and 2.48%) and (2.6 and 16.9%) for three tested compounds respectively. The relative efficiency for imidacloprid and boric acid compared to borax (the least potent one), imidacloprid and boric acid achieved 31.3 and 13.7 times more suppression of adult emergence than borax. In the solid formulation, IC_{50} and IC_{90} values are (0.083 - 0.67%) followed by boric acid (3.7-11.6%) and borax (5.74-21.1%) respectively. It's clear that imidacloprid 68.8 times and boric acid 1.5 times as toxic as borax. Reasons for differences in manifestation of mortality and possibilities for practical application are discussed. We conclude that the efficiency of tested compounds as liquid baits is higher than it as dry baits.

Keywords: Efficiency; Boric acid; Borax; Imidacloprid; House fly

Introduction

The common house fly (Diptera: *Muscidae*) continues to be a nuisance and acts as an important mechanical vector of pathogenic organism. Flies feeds and breeds in manure, excrement, garbage, sewage sludge and fermenting crop wastes and other sources of filth, where they can pick up and transport various diseases agents amongst humans and animals. Medically important pathogens such as bacteria, fungi, viruses, warms protozoa and nematodes were isolated on the house fly surface [1-5]. Flies have rapid, prolific breeding habits high, mobility and short life cycle, it a difficult control. In order to break the life cycle, control measures should be direct against larvae and adult flies. The traditional and the most extensive control technique used for the suppression of house fly population has been the application of residual contact insecticides. As a result of continuous use of insecticides to control flies, the problem of resistance began to appeal. House fly insecticides resistance is global problem [6-9] and has specifically been documented in Egypt [10-14]. Historically house flies have shown great propensity to develop insecticide resistance, new methods need to be evaluated to prevent future control failures. Toxic baits have been an important tool in fly management program. Localized toxic target technique, like insecticide application through baits is advantageous as not only decrease the risk of resistance developing in flies but also greatly reduce the amount of insecticides released into environment. Also, conservation of predators and parasites of immature stages of house flies [15,16]. Recently, a new promising strategy based on attract and kill for controlling vectors of diseases called attractive toxic sugar bait (ATSB) method. Introduction of ATSB on bait stations have been successful against vectors of diseases in different parts of the world [17-19]. In this method, vectors are attracted to a surface or vegetation that applied with ATSB containing toxins such as organic compound (e.g., imidacloprid, azamethiphos, fipronil, methomyl and chlorpyrifos) or inorganic compound (Boron compounds). Neonicotinoid insecticides are the new class of insecticides and have higher selectivity factor for insect versus mammals [20,21]. Imidacloprid is an insecticide belonging to chloronicoting class compound. It is effective against a wide range of nuisance and public hygiene insect species [22-26]. Insecticides containing boron have a long history of use in pest control [27]. Boron-containing compound, especially boric acid and its sodium salts (e.g., borax, disodium octaborate and sodium metaborate) have been use routinely for fly control before the advent of chlorinated hydrocarbons and DDT, but it was used primarily as laricivid [28]. Boric acid and borax still remains a very safe and useful chemical acting as a contact insecticide and as stomach poison. Recent research had demonstrated efficacy of boron compound against several household pests [29-36]. Sub lethal doses concentrations of insecticides have been shown to cause latent toxicity [37]. Sub lethal effect is expressed as physiological impact on individuals that survive an exposure to an insecticide [38], for example, in changes of biological parameter, longevity, reproduction, fertility of eggs, pupation, adult emergence and development in the life history. Several biological effects are reported in the literature due to the use of sub lethal doses concentrations of insecticides [39-42]. Insecticide mixtures have been proposed as important tools for resistance management in different insect pests. Insecticide mixtures could enhance the toxicity of insecticides in different resistant insects [43-47].

The present study was carried out with three objectives:

- To evaluate the toxicity of sugar baits containing boric acid, borax and imidacloprid against larvae and adult of house fly in liquid and dry formulations
- Latent effects resulted from treated larvae and adults with sub lethal concentrations of ATSB
- Efficacy of combination of imidacloprid with boric acid or borax.

***Corresponding author:** Shalaby AA, Research Institute of Medical Entomology, The General Organization for Teaching Hospitals and Institute, Dokki, Giza, Egypt, Tel: +20223648073; E-mail: ashraf.yasein@yahoo.com

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Materials and Methods

Insecticides tested

The insecticides tested included two inorganic compounds (boric acid and borax) and one organic compound (imidacloprid).

Inorganic compound

a) Boric acid:

Common name: Boric acid (Orthoboric acid, Boracic acid, Borofax)

Chemical name: Trihydrooxidoboron

Chemical furmula: BH_3O_3 or $B(OH)_3$

b) Borax.

Common name: Borax (Sodium borate, Sodium tetraborate, Disodium tetraborate).

Chemical name: Sodium tetraborate decahydrate

Chemical formula: $Na_2B_4O_7$. $10H_2O$

Organic compound (Imidacloprid)

Common name: Imidacloprid (Admire, confidor, Pravado)

Chemical name: 1-(6-chloro-3-pyridylmethy)-N-nitroimidazliodin-2-ylideneamine.

Chemical formula: $C_9H_{10}CIN_5O_2$

Tested insect

House fly, *Musca domestica*

Family: Muscidae

Order: Diptera

Adult house flies were collected from garbage dumps, Giza Governorate by insect's net as a field strain and transferred to the laboratory. Adults were maintained in cubical cage, 35 cm in each direction. It is constructed of wood frame, covered with Iron network on top and sides. The bottom is made of a movable metallic sheet to facilitate cleaning. The front side was provided with a wooden frame with muslin cloth sleeve, which was used for handling the insects, and introducing the food. The adult flies were provided with cotton ball saturated with 10% milk solution containing 2% sugar held in petri dish for feeding and served as a medium for oviposition. The food was replaced every day.

Eggs were remove from cotton ball and placed on the top of rearing medium in glass jar. The jar top was covered with muslin square held in place by two rubber bands. The breeding medium of larvae consists of wheat bran, yeast, powder milk and water, in the ratios of 20:1:2:20 parts respectively [48-51].

Different larvae instars were reared on larval medium until pupation. The late third instar larvae migrate to the upper layer of the medium to pupate. The dry top layer of media in each jar was removed and transferred to a basin. A stream of air was used for separating the pupae from dried medium. The pupae were transferred to adult breeding cages for emergence. The population was reared at 27 ± 1°C and 65 ± 5% relative humidity (RH).

Preparation of Attractive Toxic Sugar Baits (ATSB)

ATSB solution: Sugar bait solution was made by adding sugar to water at rate of 10%. Boric acid, borax was added directly to sugar solution 10% to obtain serials concentrations. Imidacloprid was dissolve in alcohol before added to sugar solution 10%.

ATSB dry: The baits were prepared by mechanically mixing technical insecticide with granulated sugar or prepared by mixing alcohol solutions of technical grad insecticides with granulated sugar and allow the solvent to evaporate. Tested application treatments:

Larval bioassay: The breeding medium of larvae was prepared as described above. ATSB solution mix with larval medium to produce a serial concentration as follows:

-For imidacloprid (0.02 - 0.32%)

-For boric acid (0.125 - 4%)

-For borax (1-12%).

Another experiment for ATSB dry formulation, the range of concentration tested was as follows:

(0.024 to 0.38%) for imidacloprid, (2 to 12%) for boric acid and (2 to 16%) for borax. Small plastic cups were filled with five grams of larval medium. Twenty-five third instar larvae were used per treatment. Control groups provided with untreated medium (rearing medium plus sugar solution 10% or granules sugar). Each insecticides concentration and sugar control for each insecticide were replicated four times. Mortality of larvae was observed daily until pupation. The number of pupae and adults emerging were recorded.

Results and Discussion

Effects of ATSB on the development of house fly larvae

ATSB as liquid baits: The development of third instar larvae of house fly *Musca domestica* was affected by imidacloprid, boric acid and borax treatment of larval medium as ATSB liquid baits (Tables 1-3 and Figures 1-3), and the effects were concentration dependent.

Concentration (%)	Pupation (% ± SD)	Emergence (% ± SD)	Inhibition of Adult Emergence (%)
0.0	100 ± 0.0	97 ± 0.58	3
0.02	97 ± 0.58	88 ± 0.58	12
0.04	93 ± 0.58	83 ± 0.58	17
0.06	75 ± 1.0	65 ± 1.0	35
0.12	47 ± 0.58	33 ± 0.58	67
0.16	30 ± 1.0	20 ± 1.0	80
0.32	18 ± 0.58	8 ± 0.58	92

Table 1: Effect of imidacloprid on the development of the house fly in a treated medium containing third instar larvae (liquid baits).

Concentration (%)	Pupation (% ± SD)	Emergence (% ± SD)	Inhibition of Adult Emergence (%)
0	100 ± 0.0	85 ± 0.58	15
0.125	97 ± 0.58	60 ± 0.58	40
0.25	75 ± 1.0	42 ± 0.58	58
0.5	63 ± 1.0	25 ± 1.0	75
1	60 ± 0.58	23 ± 0.58	77
2	48 ± 0.58	18 ± 1.0	82
4	35 ± 1.0	0.0 ± 0.58	100

Table 2: Effect of boric acid on the development of the house fly in a treated medium containing third instar larvae (liquid baits).

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From data shown in Table 1 and Figure 4, it clears that the pupation rate was reduce at imidacloprid concentration as 0.32%, only 18% of treated larvae reached the pupal state. Additional 0.92% reduction in emergence of adult was observed for the same treatment.

Observation of the effect of boric acid (Table 2 and Figure 5) on the development of larvae showed that application of 4% resulting in 65% larvae mortality and 35% pupation. This treatment prevented all exclusion of flies.

Concentration (%)	Pupation (% ± SD)	Emergence (% ± SD)	Inhibition of Adult Emergence (%)
0.0	100 ± 0.0	98 ± 0.58	2
1.0	90 ± 0.58	70 ± 0.58	30
2.0	75 ± 1.0	55 ± 0.58	45
4.0	65 ± 1.0	43 ± 1.0	57
8.0	45 ± 0.58	23 ± 0.58	77
10.0	40 ± 0.58	15 ± 1.0	85
12.0	30 ± 1.0	8 ± 0.58	92

Table 3: Effect of borax on the development of the house fly in a treated medium containing third instar larvae (liquid baits).

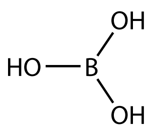

Figure 1: Chemical Structure: Technical grade contains 99% active ingredient.

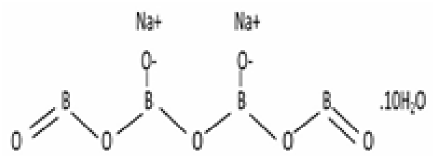

Figure 2: Technical grade contains 99% active ingredient.

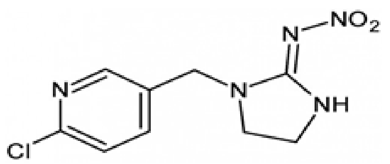

Figure 3: Chemical Structure: Technical grade contains 95% active ingredient.

Borax also had some effects on the larval-to- pupal stage of development; however, compared with that of imidacloprid and boric acid, the effect of borax was relatively weak. The effect of borax on larvae to pupae development at high concentration of 12%, the formulation of pupae was 30%. Similarly, a reduction in adult emergence from the pupal stage was also observed; borax achieved 92% suppression of adult emergence (Table 3 and Figure 6). The efficiency of tested compounds is evaluated for inhibition of adult emergence (IC values). Data in Table 4 and Figure 7 revealed that, imidacloprid has the greatest fatal effect at both IC_{50} and IC_{90} levels followed by boric acid and then borax. This was represented by IC_{50} and IC_{90} values, (0.083 and 0.27%), (0.19 and 2.48%) and (2.6 and 16.9%) for three tested compounds respectively. The relative efficiency for imidacloprid and boric acid compared to borax (the least potent one), imidacloprid and boric acid achieved 31.3 and 13.7 times more suppression of adult emergence than borax (Figure 7).

ATSB as dry baits: Data on the effectiveness of dry formulation baits of tested compounds on development of third instar larvae of housefly are shown in Tables 5-7 there was a concentration dependent relationship in the rate of pupation and adult emergence with three compounds.

The mortality of larvae reached to 73% (27% pupation) when the larvae were reared in media containing 0.38% imidacloprid. Also, the number of flies was reduced by 85% (Table 5 and Figure 4).

Data in Table 6 and Figure 5 indicated that the mortality of larvae, as reflected by percentage of larvae forming pupa was 70% (pupation 30%) when third instar larvae fed at concentration level of 12% boric acid. At the same concentration, boric acid was able to suppress emergence of adult by 95%.

Treatment of larvae medium containing third larvae with borax at the rate of 12%, only 33% of larvae able to form pupae. At 16% more effective, the mortality increases to 85% (15% pupation) and the flies emerged reduced by 90% (Table 7 and Figure 6).

Comparisons among IC_{50} and IC_{90} values showed that imidacloprid exhibited the highest effect on the inhibition of adult emergence when applied as dry formulation bait. From the probit analysis with respect of IC_{50} and IC_{90} values, imidacloprid gave (0.083-0.67%) followed by boric acid (3.7-11.6%) and borax (5.74 - 21.1%) respectively. Regarding to the relative toxicity, it's clear that imidacloprid 68.8 times and boric acid 1.5 times as toxic as borax (Table 8 and Figure 8).

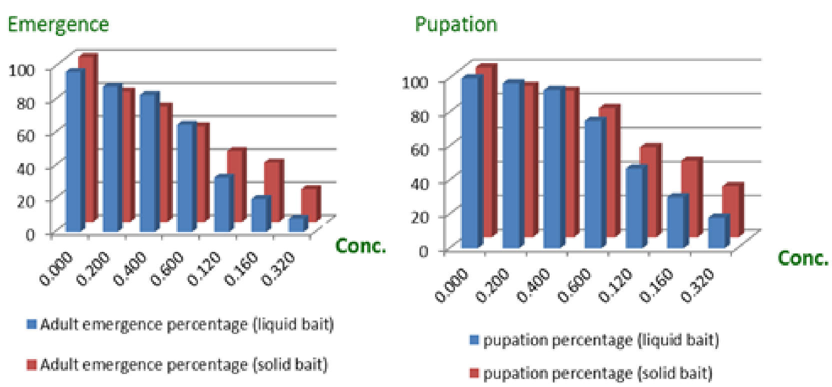

Figure 4: Effects of imidacloprid on the development of the house fly in a treated medium containing third instar larvae (liquid and solid baits).

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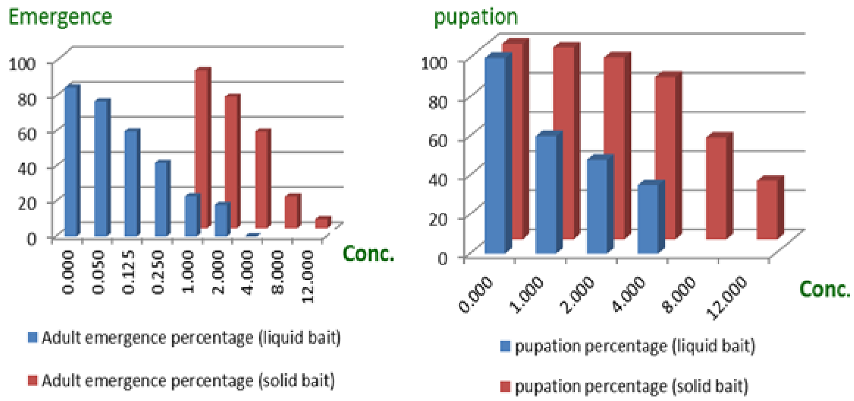

Figure 5: Effect of boric acid on the development of the house fly in a treated medium containing third instar larvae (liquid and solid baits).

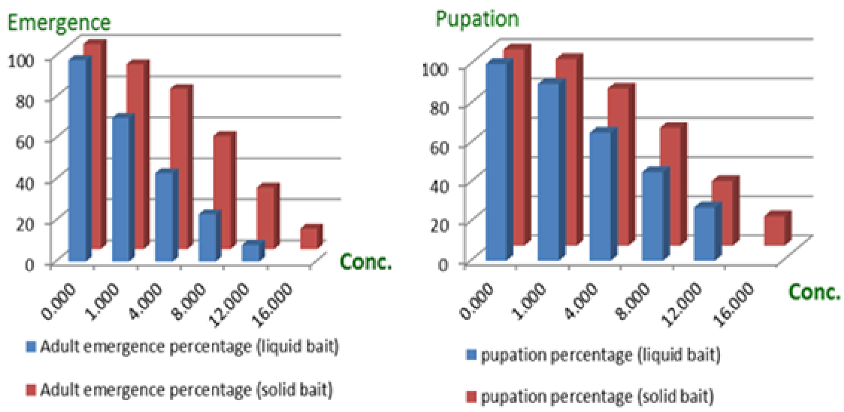

Figure 6: Effect of borax on the development of the house fly in a treated medium containing third instar larvae (liquid and solid baits).

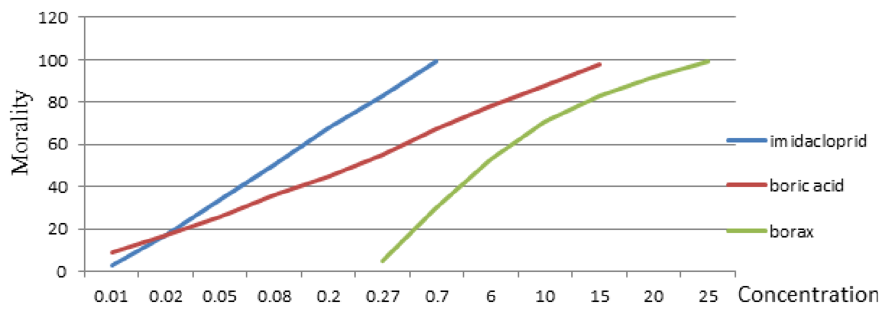

Figure 7: Imidacloprid has the greatest fatal effect at both IC_{50} and IC_{90} levels followed by boric acid and then borax.

Compounds	IC values %			IC_{90}/IC_{25}	Slope	Relative Efficiency
	25	50	90			
Imidacloprid	0.046	0.083	0.27	3.3	2.52	31.3
Boric acid	0.047	0.19	2.48	13.2	1.14	13.7
Borax	1	2.6	16.9	44.9	1.59	1

Table 4: Relative efficiency and IC values of tested compounds in liquid formulation against third instar larvae of the house fly *M. domestica*.

Attractive toxic sugar baits (ATSB) methods are new form of vector control. ATSB are highly effective method which targets flies based on their sugar foraging behavior by presenting baits of attractive compound. It is low cost and circumvents traditional problems associated with the indiscriminate effects of contact insecticides by narrowing the attraction to sugar and by using environmentally safe. Such as boron compounds that are considered to be only slightly toxic to humans [51-60]. At as a promising new tool for vector control, although imidacloprid is considered to have low oral toxicity to mammals [61-66]. Fly baits are usually applied as either dry insecticidal granular baits or as sprayable baits.

The data obtained from the present study indicate that both of solution or dry formulation baits could be used in the control of house fly. The lower concentration IC_{50} (0.083%) was observed for larvae treated rearing medium with imidacloprid in liquid and dry

Concentration (%)	Pupation (% ± SD)	Emergence (% ± SD)	Inhibition of Adult Emergence (%)
0.0	100 ± 0.0	100 ± 0.0	0
0.024	85 ± 1.0	70 ± 0.0	30
0.048	80 ± 1.0	65 ± 1.0	35
0.072	70 ± 1.0	50 ± 1.0	50
0.096	55 ± 1.0	45 ± 1.0	55
0.192	40 ± 1.0	30 ± 1.0	70
0.38	27 ± 0.58	15 ± 0.0	85

Table 5: Effect of imidacloprid on the development of the house fly in a treated medium containing third instar larvae (solid baits).

Concentration (%)	Pupation (% ± SD)	Emergence (% ± SD)	Inhibition of Adult Emergence (%)
0.0	100 ± 0.0	93 ± 0.58	7
2	93 ± 0.58	75 ± 1.0	25
4	83 ± 0.58	55 ± 1.0	45
6	62 ± 0.58	35 ± 0.0	65
8	52 ± 0.58	18 ± 0.58	82
10	33 ± 0.58	10 ± 0.0	90
12	30 ± 1.0	5 ± 0.0	95

Table 6: Effect of boric acid on the development of the house fly in a treated medium containing third instar larvae (solid baits).

Concentration (%)	Pupation (% ± SD)	Emergence (% ± SD)	Inhibition of Adult Emergence (%)
0.0	100 ± 0.0	100 ± 0.0	0
2	90 ± 0.58	88 ± 1.0	12
4	80 ± 0.58	78 ± 0.58	22
8	60 ± 0.58	55 ± 0.58	45
10	45 ± 0.58	43 ± 0.58	57
12	33 ± 0.58	30 ± 1.0	70
16	15 ± 1.0	10 ± 0.58	90

Table 7: Effect of borax acid on the development of the house fly in a treated medium containing third instar larvae (solid baits).

Compounds	IC values %	Pupation (% ± SD)	Emergence (% ± SD)	IC_{90}/IC_{25}	Slope	Relative Efficiency
	25	50	90			
Imidacloprid	0.027	0.083	0.67	8.1	1.41	68.8
Boric acid	2.1	3.7	11.6	3.1	2.6	1.5
Borax	2.8	5.74	21.1	3.7	2.26	1

Table 8: Relative efficiency and IC values of tested compounds in solid formulation against third instar larvae of the house fly *M. domestica*.

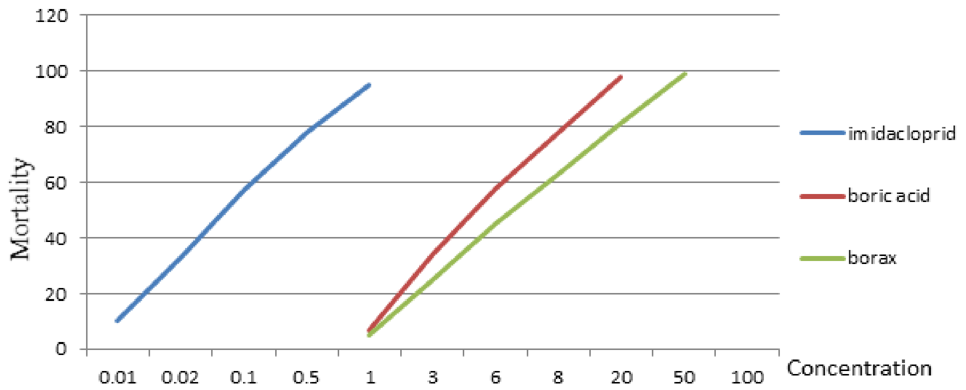

Figure 8: IC-P-lines for the effect of tested compounds on the inhibition of adult emergence after treated of third instar larvae (solid formulation).

formulation. For boron compounds, the inhibition of adult emergence was generally greater in those larvae treated by ATSB as liquid baits compared to dry formulation. Form probit analyses the IC_{50} were 0.19% and 2.6% in liquid baits and 3.7 and 5.7 for dry baits when larvae treated with boric acid and borax respectively. Also, data demonstrated that the effects of tested compound on both pupation (larval-to-pupal development) and emergence were significantly reduced at the high concentration of boron compounds. Concentrations needed were considerably greater than the effective concentration for imidacloprid. The relative efficiency revealed that, imidacloprid and boric acid 31.3 and 13.7 times more suppression of adult emergence than borax when larvae treated as liquid baits. In dry formulation baits, it is clear that imidacloprid 68.8 times and boric acid 1.5 times as to toxic as borax.

In a previous studies using imidacloprid, as Larvicidal activity was observed in the direct surrounding of treated animals [67,68]. Arther et al. concluded that monthly imidacloprid application of 7.5 to 10 mg/kg will rapidly kill existing and reinvesting flea infestation in dog and break the flea life cycle by killing adult fleas before egg production begins [69-74]. Previous works mentioned that the ability of imidacloprid to suppress the yield of adult fleas on carpate (6-hours exposure) steadily declined from 82% (Day +2) to 12% (Day +43) [75-81]. Previous works mentioned that LC_{50} (84 Nano-gram/L) of imidacloprid to larvae of *Aedes aegypti*. Uragayala et al. evaluated the Larvicidal effect of neonicotinoid insecticides against susceptible and resistant mosquito's strains [82-96].

Boron compounds were the standard chemical use for control of larval moscoid fly population in manure [97-105], sewage ludge [106-111] and compost [112]. Recently, Hinkle et al. [113,114] mentioned borate compounds varied in efficiency against larval of cat fleas. The LC_{50} values of larvae exposed in treated carpet for 96 h were 23 μg/cm² for powder boric acid, 40 μg/cm² for granular boric acid and 47 μg/cm² for granular polybor. Shahiduzzaman [115-119] suggested that boric showed highest Larvicidal effect (78.9%) followed by borax (68.9%) against larva.

Conclusion

Imidacloprid has the greatest fatal effect at both IC_{50} and IC_{90} levels followed by boric acid and then borax. In the liquid formulation, the relative efficiency for imidacloprid and boric acid compared to borax (the least potent one), imidacloprid and boric acid achieved 31.3 and 13.7 times more suppression of adult emergence than borax. In the solid formulation, it's clear that imidacloprid 68.8 times and boric acid 1.5 times as toxic as borax. The efficiency of tested compounds as liquid baits is higher than it as dry baits.

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