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Research Paper

Efficacy of Scattering Application and Paint-on Application of Insecticide in Controlling Housefly on a Broiler Farm

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Abstract
The study was performed to determine the efficacy of dinotefuran in controlling housefly (*Musca domestica*) infestation on a commercial broiler farm. The efficacy of the two modes of application of the insecticide was compared to thiamethoxam. The experiment was divided into two groups with five treatments (T) and three replicates per treatment. The first group was scatter application composed of T1: control, T2: dry 20 g dinotefuran, T3: wet 20 g dinotefuran, T4: dry 20 g thiamethoxam, and T5: wet 20 g thiamethoxam. The second group was a paint-on application composed of T1: control, T2: 10 g dinotefuran with 10 g sugar, T3: 20 g dinotefuran, T4: 10 g thiamethoxam with 10 g sugar, and T5: 20 g thiamethoxam. Dead flies were counted after 15, 30, 60, and 120 minutes post-application. In the scatter group, the control was significantly different from dinotefuran and thiamethoxam, but no significant differences were observed between dinotefuran and thiamethoxam. Dinotefuran treatments from paint-on were significantly different from the other three treatments. Lastly, wet dinotefuran from the scattering bait group and dinotefuran treatments from paint were not significantly different. Wet and paint-on treatments of dinotefuran were effective for fly control in broiler farms.

Keywords
Dinotefuran, *Musca domestica*, Paint-on, Scatter Bait, Thiamethoxam

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1. INTRODUCTION

Fly infestation is one of the management problems poultry producers in the Philippines face. A large number of flies causes serious annoyance and public health issues to the farmer and their neighboring rural non-farm communities if not managed properly. This occurrence may lead to poor community relations and possible legal action (Rutz, 1993). The housefly, *Musca domestica L.* (*Diptera: Muscidae*), is a serious nuisance pest and an important mechanical vector for many bacterial and viral pathogens (Wanaratana et al., 2011). They live and breed in animal feces and garbage thus predisposing animals to various viral and bacterial diseases. Their larval stage can ingest worm eggs and bacteria in the manure (Loftin et al., 2003a). They can affect the food intake of animals which can cause poor feed efficiency, decreased weight gain, and lower production. They play a vital role in the epidemiology of diseases because of their breeding and feeding habits which make them ready carriers of various pathogenic microorganisms (Jin et al., 2008)

Accumulation of fly larvae on the manure also has liquefying action which causes a buildup of ammonia gas resulting in a higher incidence of respiratory diseases in chickens. Accelerated deterioration can also be observed in the wire floorings and fixtures due to the fly droppings, which are corrosive. The housefly can adapt physiologically and biologically to environmental changes (Jin et al., 2008). To achieve better production in a farm operation, fly control should be an essential part (Walker, 2015). To control flies, several larvicides and adulticides were tested and formulated. Several methods were used like fly baits (Manrakhan et al., 2013), essential oil (Benelli et al., 2019), chemical sprays (Freeman et al., 2019), fly predators (Achiano and Giliomee, 2006), and ultraviolet lights (Hogsette, 2019). These methods are less stable, less effective in the real world, and affect non-target species (Benelli et al., 2018). Fly bait sprays such as spinosad is expensive insecticides and other insecticides (fipronil, tartar emetic, and imidacloprid) were slower acting compared to Spinosad (Manrakhan et al., 2013). Insecticides permethrin, tetrachlorvinphos, and methomyl resistance are widespread in the USA (Freeman et al., 2019).

The management of houseflies currently uses neonicotinoid insecticides such as dinotefuran and thiamethoxam.

These insecticides are synthetic derivates of alkaloid compounds from leaves (nicotine) and exert their toxic effects via interactions with nicotinic acetylcholine receptors of the insect nervous system (Li et al., 2012). One of the recent preparations contains dinotefuran and thiamethoxam as active ingredients (Berry, 2003). According to reports, enhanced activities of cytochrome P-450 and carboxylesterase enzymes be associated with neonicotinoid insecticide resistance in some insect pests (Li et al., 2012).

This study was made to assess the efficacy of dinotefuran and thiamethoxam in the control of flies on a commercial broiler farm. This study will also determine what mode of application will be better and more effective. The use of dinotefuran and thiamethoxam was also compared to one of the leading brands of fly control used in the Philippines since the cost of the leading brand (Spinosad, Tracer 480 SC, Dow Agrosciences) is more expensive costing approximately $200 per 500 mL than dinotefuran (Manrakhan et al., 2013). This study will provide a cheaper and more effective mode of application for controlling flies on a broiler farm.

2. EXPERIMENTAL SECTION

2.1 Broiler House

A commercial broiler farm raising Pilch de Cobb chicks with a population of 9,000 birds under one large broiler house was selected for the study. The broiler house has a floor area of 490 m^2. The manure pit was at least two meters below the floor of the broiler house. The selection of the farm was based on the prevailing extent of the fly problem, the condition of the manure pit, and the willingness of the farm owner to conduct the study on the farm.

2.2 Insecticides

There were two insecticides used in the study. One was composed of dinotefuran, muscamone, and sucrose (Leads Agri Animal Health and Natural Solutions, Philippines). The other insecticide was composed of thiamethoxam and (z)-9-tricosene (Elanco Animal Health, USA).

2.3 Methods

The experiment was divided into two groups with five treatments in each group and three replicates per treatment. The two modes of application of the insecticides were scattering application and paint-on application. They were distributed randomly to different areas in the manure pit using simple random sampling. The treatments were applied in a woven polypropylene bag measuring 52 cm x 30 cm x 10 cm, surrounded by a carton box to allow the dead flies to stay in the bag.

The first group was scattered bait applications. Each drug was applied at a rate of 20 g/10 sqm. For the wet treatment, after the 20 g insecticides were scattered on the woven polypropylene bag, it was sprayed with water using a water sprayer. In the paint-on application group, all treatments were dissolved in 20 mL distilled water before they were painted in the woven polypropylene bag. The drugs used were in Granular Bait (GB) form. The five treatments were described as follows:

The number of dead houseflies within the woven polypropylene bag was counted at 15, 30, 60, and 120 minutes post-application of the treatments for both groups. The data collected were tabulated and statistically analyzed using ANOVA at a 95% confidence interval. Significant differences among treatment groups were determined using the Duncan's Multiple Range Test (DMRT) of the SAS system general linear model procedure.

3. RESULTS AND DISCUSSION

The housefly is the most common fly species found worldwide. It has an effective immune system and powerful antibacterial ability (Tang et al., 2019). Table 2 shows the average number of dead flies after applying scattering insecticides. The control treatment had a mean of 0 dead flies, it could be observed that large numbers of flies approached the polypropylene bag, but no fly died after the experiment. It can also be observed that the groups treated with dinotefuran presented a higher number of dead flies than those treated with thiamethoxam. Wet dinotefuran treatment had the highest mean and the greatest number of dead flies throughout the experiment. Although it presented the highest mean of dead flies, statistically it has no significant difference to dry dinotefuran and thiamethoxam due to the similarity of the number of treatments given.

Dinotefuran has established itself as a third-generation neonicotinoid for controlling sucking pests during agricultural production in more than 20 countries (Chen et al., 2019; Yu et al., 2020). Dinotefuran acts as an agonist of nicotinic acetylcholine receptors (nAChR) in insects, which leads to irreversible binding to receptors and the resultant declining population (Belzunces et al., 2012; Zhang et al., 2022).

Table 3 shows the mean number of dead flies after applying paint-on insecticides. In the paint-on group, the result observed for the control treatment was the same as the control treatment of scattering application. Many flies also approached the polypropylene bag, but no dead fly was present after the experiment. The control treatment differed significantly from the other four treatments ($P<0.05$).

It can also be observed in Table 3 that the groups treated with dinotefuran presented a higher number of dead flies compared to the groups treated with thiamethoxam. The dinotefuran treatments were significantly different compared to the other three treatments ($P<0.05$). It also showed that thiamethoxam treatments were significantly different from the control treatment.

The efficiency of the different treatments as scatter fly and paint-on application were also compared in the experiment. Table 4 represents the mean number of dead flies for scattering and paint-on application after the experiment.

Table 1. Experimental Design for the Treatment of Controlling Housefly

Treatment Group	Scattered Bait Application	Paint-on Application
Treatment 1	Control (dry sugar)	Control (sugar)
Treatment 2	20 g dry 0.5 GB dinotefuran	10 g 0.5 GB dinotefuran with 10 g of sugar
Treatment 3	20 g wet 0.5 GB dinotefuran	20 g 0.5 GB dinotefuran
Treatment 4	20 g dry 1 GB thiamethoxam	10 g 1 WG thiamethoxam with 10 g of sugar
Treatment 5	20 g wet 1 GB thiamethoxam	20 g 1 WG thiamethoxam

Table 2. The Mean Number of Dead Flies After the Application of Scattering Treatments

Time (Minutes)	Control (Sugar)	Dry DN*	Wet DN*	Dry TMX**	Wet TMX**
15	0	21.67±21.96	43.00±22.27	20.67±15.04	6.00±4.36
30	0	17.33±6.35	30.67±18.01	13.67±3.05	7.67±6.43
60	0	43.00±13.00	69.67±28.31	30.00±27.18	32.33±22.37
120	0	51.00±25.63	121.33±68.98	35.67±13.05	17.00±16.00
Mean	0^b	33.25 ± 21.51^a	66.17 ± 49.83^a	25.00 ± 16.92^a	15.75 ± 16.36^a

^{abc} means with different letters within rows are significantly different at P-value <0.05
*DN – dinotefuran
**TMX – thiamethoxam

Table 3. The Mean Numbers of Dead Flies Present After the Application of Paint-on Treatments

Time (Minutes)	Control (Sugar)	10 g DN* + 10 g Sugar	20 g DN*	10 g TMX** + 10 g Sugar	20 g TMX**
15	0	50.33±14.74	54.67±38.89	7.67±2.51	4.00±2.65
30	0	50.33±30.07	86.00±15.10	16.00±7.55	5.33±4.04
60	0	106.00±6.24	151.67±61.01	31.00±15.72	29.00±9.54
120	0	128.00±12.49	184.33±53.90	45.33±6.66	44.33±21.94
Mean	0^c	83.67 ± 38.95^a	119.17 ± 66.35^a	25.00 ± 17.06^b	20.67 ± 20.49^b

^{abc} means with different letters within rows are significantly different at P-value <0.05
*DN – dinotefuran
**TMX – thiamethoxam

Table 4. The Mean Numbers of Dead Flies After the Application of Scattering and Paint-on Treatments

Mode of Application	T1	T2	T3	T4	T5
Scatter Bait	0^d	33.25 ± 21.51^c	66.17 ± 49.83^b	25.00 ± 16.92^c	15.75 ± 16.36^c
Paint-on	0^d	83.67 ± 38.95^a	119.17 ± 66.35^a	25.00 ± 17.06^c	20.67 ± 20.49^c

^{abc} means with different letters within the column are significantly different at P-value <0.05
T = Treatment (Table 1)

The results in Table 4 showed that paint-on dinotefuran application presented a higher number of dead flies than scattering applications. However, statistically shown that paint-on dinotefuran treatments were not significantly different from the wet dinotefuran treatment of the scattered group based on their efficacy in controlling houseflies (P<0.05). On the other hand, thiamethoxam treatments from scattering bait and paint-on application were not significantly different. This result contrast to Yee (2011) the neonicotinoid thiamethoxam in a sucrose solution causes faster or higher mortality and is supported study by Kessler et al. (2015) and Liu et al. (2017) neonicotinoids in sugar might be more attractive and consumed by an insect that is first exposed to the toxicant.

The result observed for the control group for scatter bait and paint-on application was the same. Many flies approached the polypropylene bag, but no dead fly was found after the experiment. This was because sugar serves only as an attractant to flies and draws the flies into the sack due to its sweet smell (Li et al., 2015). Even though many flies approached the sack, no flies died because sugar has no insecticidal effect on them. In the scatter bait application, generally, the groups treated with dinotefuran presented a higher number of dead flies than those treated with thiamethoxam. Wet dinotefuran treatment resulted in the highest mean and the greatest number of dead flies throughout the experiment. This might indicate that the wet treatment of dinotefuran made the flies stick to the sack until they died (Rutz, 1993).

For paint-on application, the groups treated with dinotefuran presented a higher number of dead flies than those treated with thiamethoxam. Dinotefuran 20 g treatment also presented the highest average of dead flies after the experiment. This had occurred since the drug used was in full concentration. All neonicotinoid insecticides act with nanomolar affinity against houseflies and other insect nAChR, except thiamethoxam, which exhibits a comparatively low affinity for the [^{3}H]imidacloprid binding site (Wiesner and Kayser, 2000). Dinotefuran paint-on treatments also presented a higher number of dead flies than scatter bait since the paint-on mode of application affects locomotion (Arthur and Fontenot, 2013). More flies from the paint-on application will be stuck and will eventually die in the polypropylene bag because they will have a lesser chance to escape.

In the paint-on application of thiamethoxam, treatments mixed with sugar produced a lower number of dead flies compared to scatter and paint-on treatments not mixed with sugar. Even though sugar helped in attracting flies to go in the polypropylene bag, lower efficacy was observed since the concentration of the drug used was decreased (Matsuda et al., 2001). All the treatments from scattering bait and paint-on application with dinotefuran and thiamethoxam contain (z)-9-tricosene. This specific pheromone helped in attracting male houseflies to go into the polypropylene bag. They were trapped and eventually died in the polypropylene bag. As a result, female houseflies lose the opportunity to be mated (Loftin et al., 2003b).

Neonicotinoid insecticides are compounds acting agonistically on insect nicotinic acetylcholine receptors (nAChR). Neonicotinoids show good activity against pest insects resistant to other classes of insecticides such as organophosphates, carbamates, pyrethroids, chlorinated hydrocarbons, and several other classes of compounds (Jeschke and Naeun, 2006). They act selectively on insect nicotinic acetylcholine receptors and their ability to displace tritiated imidacloprid from its binding site correlates well with their insecticidal efficacy (Tomizawa and Casida, 2003). [^{3}H]imidacloprid binds with nanomolar affinity to nAChR preparations from insect tissues, and it is next to the less specific α-bungarotoxin the preferred compound in radioligand competition studies (Nauen et al., 2003). Nevertheless, the biological efficacy of thiamethoxam is in most cases comparable to other neonicotinoid insecticides. It was shown earlier that N-demethylated thiamethoxam exhibited a 1000-fold greater affinity to insect nAChR than thiamethoxam itself (Yamamoto et al., 1998).

Treatments under the thiamethoxam group presented a lower number of dead flies compared to treatments under dinotefuran. This may be because houseflies resisted thiamethoxam since it is the most common drug used for fly control in the country (Klaassen, 2013; Mohamed et al., 2015). Another reason revealed that thiamethoxam was an easy-to-cleave precursor of clothianidin, a highly active open-chain neonicotinoid. This suggests that thiamethoxam has a pro-drug principle in the mode of action rather than binding to the receptor (Nauen et al., 2003). Dinotefuran act agonistically on nicotinic acetylcholine receptor (nAChR) which makes it a potential treatment for fly infestation, unlike thiamethoxam which exhibits a low activity for the binding site and does not act directly on the nAChR of insects (Nauen et al., 2003; Gupta, 2011). Dinotefuran is also a full agonist which causes a high insecticidal activity. Dinotefuran when ingested by flies, has a faster speed of uptake compared to thiamethoxam thus, a faster rate of death in houseflies can be observed (Cranshaw, 2014).

Strategies to develop low-risk pesticides with better utilization and reduced toxicity cannot be ignored because the widespread application of pesticides has detrimental effects on human health and the survival of non-targeted organisms (Raine, 2018). Uncontrolled distribution and application resulted in many pesticides entering the soil and water environment (Pascoli et al., 2019).

4. CONCLUSIONS

New and effective insecticides are urgently needed for controlling houseflies. Dinotefuran presented a higher number of dead flies compared to the groups treated with thiamethoxam. The paint-on application presented a higher number of dead flies compared to scattering applications. Dinotefuran with the paint-on application is the best combination for controlling house flies in broiler farms. It is recommended that the exposure of treatments should be extended for a longer time to determine the best time for application and need to make sure the application of insecticides used on farms does not affect the chicken farm.

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