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Efficacy of some biopesticides for the management of cucurbit fruit fly (*Bactrocera cucurbitae* Coquillett) infesting bottle gourd (*Lagenaria siceraria*) in Barind tract of Bangladesh

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Abstract
An experiment was carried out to evaluate the efficiency of different biopesticides against the fruit fly infestation on bottle gourd. All of the treatments were effective compared to control. Among the treatments, Spinosad (Tracer 45 SC) performed the best based on minimum percent fruit infestation on both number and weight basis (30.71% & 32.64%) & highest percent protection of fruit over control (60.86% & 58.94%). Again, the highest marketable fruit yield (60.43 ton/ha) and percent yield increase of marketable fruit (70.46%) were also observed on Spinosad (Tracer 45 SC) treated plot. Based on the same parameters, Neem oil was inferior to Spinosad (Tracer 45 SC), which was followed by the treatment of Abamectin (Ambush 1.8 EC), Allamanda leaf extract and Mahogany oil. Thereby among all the treatments tested, Spinosad (Tracer 45 SC) may be suggested for cucurbit fruit fly management on bottle gourds.

Keywords: *Bactrocera cucurbitae*, biopesticides, bottle gourd, fruit fly

1. Introduction

Bottle gourd, *Lagenaria siceraria* is one of the cucurbit vegetables, grown widely all over Bangladesh, particularly; Barind tract (Rajshahi & Rangpur division) covers a substantial acreage of cultivation. In Bangladesh, the production of bottle gourd during 2019-20 was 2,50,613 metric tons [1]. In the Barind tract (Rajshahi & Rangpur division), the area under the cultivation of bottle gourd during 2019-20 was 7,974 acres and the production was 39,742 metric tons [1]. Bottle gourd is widely grown in our country during the winter season, although some new types are now being grown in both the summer and winter seasons around the country because it's a high-value profitable crop to farmers.

Fruits are used as a vegetable, a container, a bowl, a decoration, a musical instrument, or fishing floats, among other things. Bottle gourd seeds, tendrils, leaves and immature fruits are also used for a variety of reasons, including various medical treatments [2]. Fruit pulp can be used as an antidote to certain poisons and can help with constipation, night blindness and coughing. For the treatment of jaundice, a leaf decoction is used [3]. Bottle gourds have also been shown to reduce cholesterol, triglycerides, low-density lipoprotein, cholesterol, pain and inflammation [4], oxidation and free radicals [5]. Fruits are utilized in the manufacture of sweets and pickles as well as cooked vegetables. Vitamin C-10.10 mg, Zinc-3.77 mg, Potassium-3320.0 mg, Magnesium-162.33 mg, Energy-63 Kj (15 kcal), Carbohydrates-5.87 gm, Fat-0.02 gm, Protein-0.6 gm, Vitamin C-10.10 mg, Zinc-3.77 mg, Potassium-3320.0 mg, Magnesium-162.33 mg are all present in the edible portion of the bottle gourd fruit [6].

Insect infestations are the primary impediment to increasing the output and productivity of the bottle gourd crop. A prominent pest is *Bactrocera cucurbitae* Coquillett, which causes yield loss in bottle gourds and infests all 15 varieties of cucurbit vegetables grown in Bangladesh. Fruit flies diminish both yield and fruit quality [7]. The degree of losses varies between 30 and 100 percent depending on environmental conditions and host crops [8]. For example, Bitter gourd had about 40% fruit fly infestation, whereas Bottle Gourd had 21%, with an average of

12.8 percent to 25.55 percent infestation in others cucurbits [9]. Adult female fruit flies penetrate soft and tender fruits and lay eggs in a cavity 2-4 mm deep on the fruit. The maggot feeds on the flesh (pulp) after hatching, makes a tunnel and causes damage. The infested fruits may be rotten, dry up, shed up prematurely, sometimes become deformed and ultimately make the fruit unfit for human consumption.

Farmers in Bangladesh solely rely on the use of synthetic insecticides to control fruit fly on bottle gourd. Synthetic insecticides have several disadvantages including the development of resistance in target insects, high pesticide residues in-market products and the environment as well as a resurgence or increased infestation by some insect species due to the destruction of natural enemies. Other important issues include shifting pest status of minor to major insect pests, ecological imbalance and hazard to the pesticide applicator's health [10, 11]. Therefore, bottle gourd farmers require sustainable management of fruit flies. In this regard, biopesticides could play a vital role. Biopesticides are the biological agents or plant-based products used to control the population of injurious organisms in the ecosystem. They are non-toxic substances derived from living organisms or their products (microbial products, phytochemicals) as well as their by-products (semiochemicals). They are considered as minimal risk products safe to humans and their environment [12]. They have moderate residual effects, long-lasting activity and are safe for farmers. Therefore, the present study aimed to develop an environmentally acceptable management strategy for fruit fly using biopesticides.

2 Materials and Methods

2.1 Research site

The experiment was carried out at Somaspur village in Godagari Upazila under the district Rajshahi from April to July 2020. Godagari Upazila (24°28'0.12"N & 88°19'50.16"E) is located in the High Barind tract in Bangladesh's northwest. The climate in this Barind area is dry with quite high temperatures and low rainfall.

2.2 Experimental design and layout

The experiment was carried out as a Randomized Complete Block Design (RCBD) with six treatments each replicated thrice. The planting material was the high-yielding BARI Lau-4 variety. The field was ploughed and cross-ploughed multiple times with a power tiller to get good tilth. Laddering was used after each ploughing operation to break up the clods. The field was cleared of weeds and stubbles before being divided into 18 equal plots of 1.5×1.5 m^2 with a 30 cm spacing between them. Finally, the unit plots were prepared as 10 cm raised beds with appropriate fertilizer basal doses and a single pit in each for trials. Three seeds were planted in each pit, with one viable seedling per pit being kept after 7 days of germination through thinning. For optimum germination, seeds were soaked overnight before sowing. Each plant was held in place by a bamboo platform (bamboo macha) for ease creeping and to avoid lodging. When necessary, all cultural practices were carried out to improve the growth and development of the bottle gourd plants.

2.3 Treatments and doses

A total of six treatments were used in the study. Treatments are- i. Spinosad (Tracer 45 SC) @ 0.4ml/L, ii. Abamectin (Ambush 1.8 EC) @ 2ml/L, iii. Neem oil @ 5ml/L, iv. Mahogany oil @ 5ml/L, v. Allamanda leaf extract @ 5ml/L & vi. Untreated Control. Spinosad (Tracer 45 SC manufactured by Auto Crop Care Ltd) and Abamectin (Ambush 1.8 EC manufactured by Haychem Bangladesh Ltd) were collected from a local market. Neem and Mahogany oil were collected from a local dealer of a company situated at Gazipur, Dhaka. Allamanda leaf extract was prepared by crushing the leaves using a hand blender.

2.4 Treatment application and data collection

The first spray was applied as soon as the ovipositor marks of fruit fly were observed on the fruits. Two sprays of Spinosad (Tracer 45 SC) & Abamectin (Ambush 1.8 EC) were applied at ten days intervals [13] and four sprays of Neem oil, Mahogany oil and Allamanda leaf extract were applied at five days intervals [14]. Four countings at five-day intervals were used to collect data. The first counting took place five days after the first spraying and the second, third & fourth counting took place five days after the first, second & third counting, respectively. The following parameters were studied for data: (i) number of infested fruits per plot, (ii) number of healthy or marketable fruits per plot, (iii) weight of infested fruits per plot, (iv) weight of healthy or marketable fruits per plot (v) yield (ton/ha) of healthy or marketable fruit production. Fruit production (gram) in 1.5 m × 1.5 m plots were then translated to ton per hectare. The following equations were used to estimate the percent infestation of fruits on a number and weight basis –

$$\text{Percent fruit infestation on number basis} = \frac{\text{Mean number of infested fruit}}{\text{Mean number of total fruit}} \times 100$$

$$\text{Percent fruit infestation on weight basis} = \frac{\text{Mean weight of infested fruit}}{\text{Mean weight of total fruit}} \times 100$$

Finally, the data were used to compute the percentage protection of fruit infestation over control, the percentage increase of marketable fruit yield over control, and the percentage decrease of infested fruit production over control.

2.5 Data analysis

For statistical analysis, all of the collected data were compiled and tabulated. The MSTAT program was used to analyze variance (ANOVA) [15]. Duncan's Multiple Range Test (DMRT) and Least Significant Difference (LSD) were used to determine treatment mean differences as needed.

3 Results

Based on percent fruit infestation (number and weight basis) and marketable fruit yield (ton/ha), the effects of several biopesticides were assessed.

3.1 Fruit infestation on number basis

At different treatments, the percentage of fruit infestation depending on the number of fruits differed ($p<0.01\%$) (Table 1). Spinosad (Tracer 45 SC), which recorded a minimum infestation of 30.71 percent cumulative mean fruit damage on a numerical basis, outperformed the other treatments significantly. The treatment Neem oil recorded the cumulative mean fruit damage of 39.41% was found next best treatment followed by Abamectin (Ambush 1.8 EC) with the cumulative mean fruit damage of 42.90% on number basis, were statistically similar. The treatment Allamanda leaf extract & Mahogany oil recorded the cumulative mean fruit damage

51.16 & 59.97% on number basis respectively. The untreated control had the most damage, with 78.47 percent cumulative mean fruit damage on number basis, which was much lower than all other treatments. In case of percentage fruit protection over control on number basis, 60.86, 49.78, 45.33, 34.8 & 23.58% were found when plants were treated with Spinosad (Tracer 45 SC), Neem oil, Abamectin (Ambush 1.8 EC), Allamanda leaf extract and Mahogany oil respectively (Fig. 1).

3.2 Fruit infestation on weight basis

Percent fruit infestation based on weight of fruit was varied significantly ($p<0.01\%$) at different treatments (Table 2). The treatment Spinosad treated plots showed a minimum infestation of 32.64% (weight basis) across the season compared to the rest of the treatments. The treatment Neem oil was shown to be the second-best treatment, with cumulative mean fruit damage of 41.16 percent, followed by Abamectin (Ambush 1.8 EC) with cumulative mean fruit damage of 44.61 percent on a weight basis, which was statistically identical. On a weight basis, the treatments Allamanda leaf extract and Mahogany oil resulted in cumulative mean fruit damage of 53.02 and 62.21 percent, respectively. The untreated control showed the most damage, with cumulative mean fruit damage of 79.50 percent on a weight basis, which was much less than the other treatments. When plants were treated with Spinosad (Tracer 45 SC), Neem oil, Abamectin (Ambush 1.8 EC), Allamanda leaf extract and Mahogany oil, percentage fruit protection over control was observed to be 58.94, 48.23, 43.89, 33.31, and 21.75 percent, respectively (Fig. 2).

3.3 Yield and percent yield increase of marketable fruit

Effect of treatments on bottle gourd based on marketable fruit yield (ton/ha) was varied significantly ($p<0.01\%$) at different treatments (Table 3). The treatment Spinosad (Tracer 45 SC) produced the highest marketable fruit production of 60.43 tons per hectare, which was much higher than the other treatments. The treatment Neem oil recorded the second-best treatment with a yield of 51.78 ton/ha followed by Abamectin (Ambush 1.8 EC) with a yield of 48.47 ton/ha, were statistically similar. The treatment Allamanda leaf extract & Mahogany oil recorded yield 40.13 & 32.55 ton/ha. The lowest marketable fruit yield 17.57 ton/ha was found in untreated control, which was significantly inferior to all other treatments. In case of percentage yield increase of marketable fruit, 70.46, 66.07, 63.75, 56.22 & 46.02% were recorded when plants were treated with Spinosad (Tracer 45 SC), Neem oil, Abamectin (Ambush 1.8 EC), Allamanda leaf extract and Mahogany oil respectively (Table 3).

Table 1: Effect of treatments against fruit fly based on number of fruit

Treatments	Mean percent fruit infestation at different pickings				
	1st counting	2nd counting	3rd counting	4th counting	Cumulative mean percentage
Spinosad (Tracer 45 SC)	30.36 d	26.19 d	34.52 d	31.74 c	30.71 e
Abamectin (Ambush 1.8 EC)	43.39 c	34.72 cd	52.38 bc	41.11 c	42.90 d
Neem oil	39.29 c	37.14 c	41.07 cd	40.12 c	39.41 d
Mahogany oil	58.93 b	52.38 b	65.08 b	63.49 b	59.97 b
Allamanda leaf extract	54.17 b	43.33 c	59.52 b	47.62 bc	51.16 c
Untreated Control	72.62 a	68.26 a	89.68 a	83.33 a	78.47 a
$LSD_{0.05}$	8.79	8.62	13.57	16.87	6.84
SE (±)	2.788	2.735	4.305	5.354	2.71
Level of significance	**	**	**	**	**
CV (%)	9.70	10.85	13.07	18.10	7.46

** = Significant at 1% level of probability

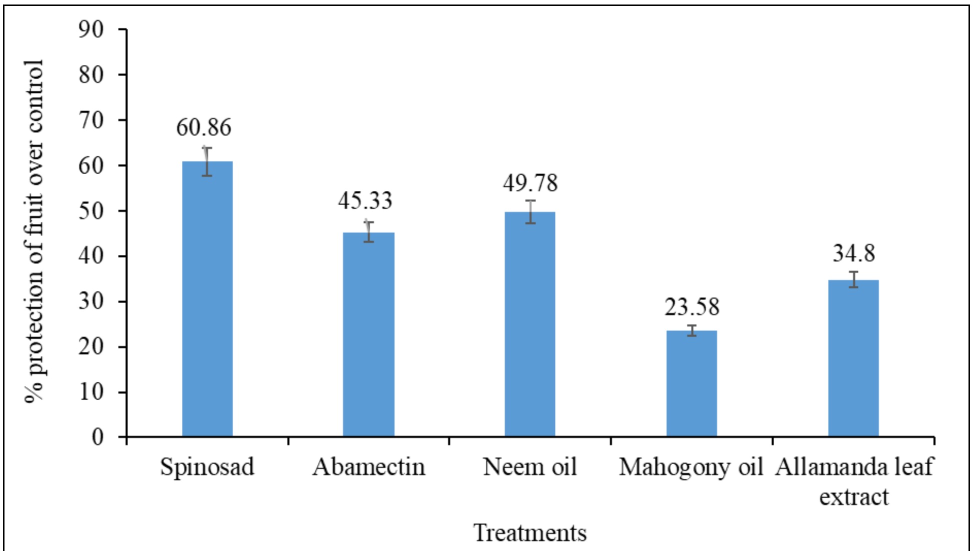

Fig 1: Protection of fruit (%) over control on number basis resulted from different treatments

Table 2: Effect of treatments against fruit fly based on weight of fruit

Treatments	Mean percent fruit infestation at different pickings				
	1st counting	2nd counting	3rd counting	4th counting	Cumulative mean percentage
Spinosad (Tracer 45 SC)	29.78 d	27.22 e	39.86 e	33.71 c	32.64 e
Abamectin (Ambush 1.8 EC)	46.29 c	35.21 de	54.76 cd	42.17 c	44.61 d
Neem oil	41.26 c	38.42 cd	43.06 de	41.90 c	41.16 d
Mahogany oil	62.92 b	53.03 b	68.36 b	64.51 ab	62.21 b
Allamanda leaf extract	56.52 b	44.04 c	62.55 bc	48.97 bc	53.02 c
Untreated Control	74.43 a	70.01 a	91.34 a	82.24 a	79.50 a
$LSD_{0.05}$	9.54	8.45	12.98	17.92	5.65
SE (±)	3.025	2.680	4.120	5.688	2.79
Level of significance	**	**	**	**	**
CV (%)	10.10	10.40	11.90	18.86	5.95

** = Significant at 1% level of probability

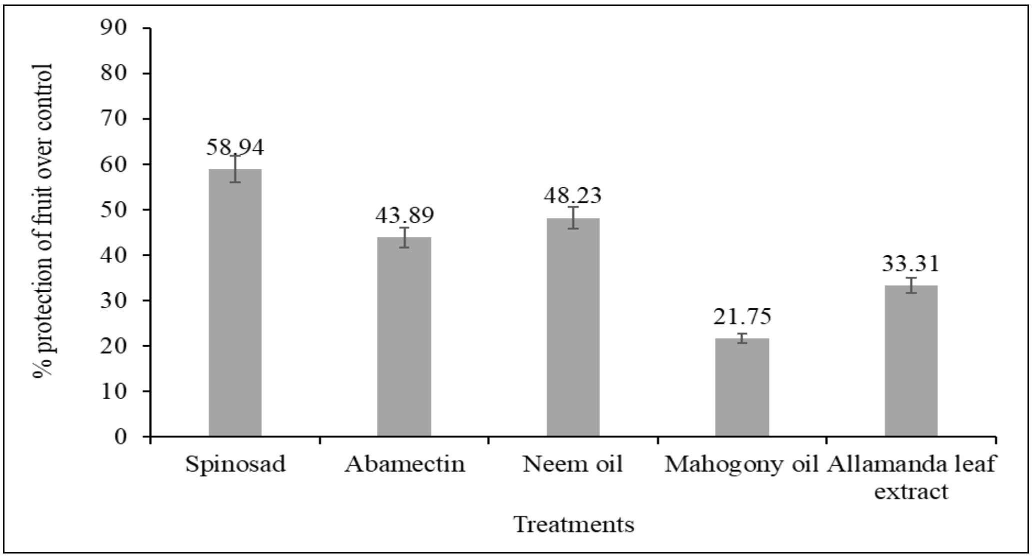

Fig 2: Protection of fruit (%) over control on weight basis resulted from different treatments

Table 3: Effect of treatments on bottle gourd based on marketable fruit yield

Treatments	Marketable fruit yield (ton/ha)	Percentage yield increase of marketable fruit
Spinosad (Tracer 45 SC)	60.43 a	70.46
Abamectin (Ambush 1.8 EC)	48.47 b	63.75
Neem oil	51.78 b	66.07
Mahogany oil	32.55 d	46.02
Allamanda leaf extract	40.13 c	56.22
Untreated Control	17.57 e	
$LSD_{0.05}$	7.14	
SE (±)	2.264	
Level of significance	**	
CV (%)	9.38	

** = Significant at 1% level of probability

4. Discussions

According to the number of fruits, plots treated with Spinosad (Tracer 45 SC) had the lowest mean percent fruit infestation (30.71%), followed by Neem oil (39.41%), Abamectin (Ambush 1.8 EC) (42.90%), Allamanda leaf extract (51.16%) and Mahogany oil (59.97%). The Spinosad (Tracer 45 SC) treated plots had the highest percentage of fruit protection (60.86%), followed by Neem oil-treated plots (49.78%). It was reported that Spinosad (200ml/ha) had the lowest fruit infestation (27.29%) in bottle gourds on a numerical basis [16]. Cucumber plots treated with Spinosad (200 ml/ha) showed the least mean percent fruit damage against fruit fly invasion [17]. In terms of the efficacy of Neem oil, it was found that Neem oil and Neem seed extract reduced fruit fly infestation considerably [18].

Plots treated with Spinosad (Tracer 45 SC) had the lowest mean percent fruit infestation (32.64%) based on fruit weight, followed by plots treated with Neem oil (41.16), Abamectin (Ambush 1.8 EC) (44.61%), Allamanda leaf extract (53.02%) and Mahogany oil (62.21%). The Spinosad (Tracer 45 SC) treated plots had the highest percentage of fruit protection (58.94%), followed by Neem oil-treated plots (48.23%). Spinosad (200 ml/ha) had the lowest fruit infestation (25.90%) in bottle gourds on a weight basis [16]. Similarly, fruit fly attacks on round gourds resulted in the least mean percent fruit damage in Spinosad @ 0.4ml/L treated plots [19].

Spinosad (Tracer 45 SC) treated plots produced the highest marketable fruit production (60.43 ton/ha), followed by Neem oil (51.78 ton/ha), Abamectin (Ambush 1.8 EC) (48.47 ton/ha), Allamanda leaf extract (40.13 ton/ha), and Mahogany oil (32.55 ton/ha). Spinosad (Tracer 45 SC) treated plots had the largest percentage yield increase of marketable fruit

(70.46%), followed by Neem oil (66.07%), Abamectin (Ambush 1.8 EC) (63.75%), Allamanda leaf extract (56.22%) and Mahogany oil (46.02%). It was observed that Spinosad (60 g/ha) worked best against fruit fly infestation in the bitter gourd in terms of marketable fruit yield [20]. They also reported that in the pre-Kharif season, the Spinosad (60 g/ha) treated plot had the highest percent yield increase of marketable fruit (86.83 percent) over the control plot. The Spinosad (200 ml/ha) treated plot against fruit fly infestation on cucumber produced the highest mean marketable fruit production [17].

5. Conclusion

In bottle gourd, the Cucurbit Fruit Fly (*Bactrocera cucurbitae*) causes considerable yield loss. All the tested bio-pesticides were significantly effective against fruit fly infestation in bottle gourd. Spinosad (Tracer 45 SC) outperformed Neem oil in terms of reducing fruit infestation and increasing marketable fruit production. The ranking of the bio-pesticide was Spinosad (Tracer 45 SC)>Neem oil>Abamectin (Ambush 1.8 EC)>Allamanda leaf extract>Mahogany oil to control fruit fly infestation on bottle gourd in Barind tract. As a result, growers may be encouraged to use Spinosad (Tracer 45 SC) @ 0.4ml/L for eco-friendly management of cucurbit fruit fly to increase yields.

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7. Conflict of Interest

The authors declare that the publishing of this paper does not include any conflicts of interest.

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