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Efficacy of three biopesticides against cucurbit fruit fly, *Bactrocera cucurbitae* Coquillett (Diptera: Tephritidae) and yield of bitter gourd

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ABSTRACT

The cucurbit fruit fly, *Bactrocera cucurbitae* (Diptera: Tephritidae)) is a significant threat to different cucurbits. The efficacies of three biopesticides viz. Spinosad, Abamectin and *Lecanicillium muscarium* either by an individual or their combined application were evaluated against the insect attack and yield of bitter gourd (*Momordica charantia* L). Two sprays at 10-day interval were applied, and data were collected at 3, 5, 7 and 10 days after treatments (DATs), and finally, the cumulative means were calculated based on following parameters: percent fruit infestation and healthy fruits, number of healthy and infested fruits per sq. meter and yield of marketable and infested fruits (ton/ha). All the biopesticides both in individual and combined forms significantly reduced the infestation of the fly at variable levels compared to control. The individual application of Spinosad had provided moderate efficacy. The combination of Spinosad and *L. muscarium* was the most effective approach to produce the highest percent of healthy fruits (83.32) and the lowest fruit infestation (16.68) protecting the most top percent (54.21) of fruits from infestation. The maximum number of marketable fruits per m^2 were (13.67), the highest marketable yield (5.15 ton/ha) and the lowest infested yield (0.17 ton/ha) also were obtained from this combined treatment. The fruit yield increased almost twice over control. These suggest that there might be an additive or synergistic action between Spinosad and *L. muscarium* admixture. However, the Abamectin with *L. muscarium* treatment did not increase yield, and other parameters significantly suggesting the incompatibility or an antagonistic effect between them. Therefore, based on the findings of the present study, the combination of Spinosad and *L. muscarium* could be suggested for the management of the cucurbit fruit fly infesting bitter gourd fruits and increasing the yield.

Introduction

Bitter gourd (*Momordica charantia* L.) is one of the most popular summer vegetables to all classes of peoples of Bangladesh as well as in Asia (Khan *et al.*, 2019; Beloin *et al.*, 2005). It is rich in ascorbic acid, iron, Vitamin A, Vitamin B, Vitamin C and carbohydrates (Ashrafuzzaman *et al.*, 2010). The chemical 'Charantin' present in the bitter gourd is known to reduce blood sugar for the diabetic patient (Dhillon *et al.*, 2005).

Prevalence of different insect pests is higher in the summer crops. The Cucurbit fruit fly, *B. cucurbitae* Coquillett is considered as a significant threat to yield loss of different cucurbits. In case of bitter gourd, it is reported to cause 30-100% yield loss when favorable environmental condition as well as susceptible varieties prevails (Dhillon *et al.*, 2005; Rakshit *et al.*, 2011). The vegetable growers in Bangladesh and other countries are adopted with the use of synthetic chemical insecticides of different groups like organophosphate, organocarbamate, pyrethroids, nicotinoids to control this pest (Khatun *et al.*, 2016; Khatun *et al.*, 2015; Waseem *et al.*, 2009). However, use of synthetic insecticides has many drawbacks such as development of resistance by the target insects, high pesticide residues in market produce and environment, resurgence or increased infestation by some insect species due to the destruction of natural enemies, changing pest status of minor to major insect pests, ecological imbalance and risk to health of the

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pesticide applicator (Akram *et al.*, 2010; Saxena, 2008; Kodandaram *et al.*, 2010; Tahir *et al.*, 2011).

Uses of biopesticide products have many potentialities to overcome the situations. The "biorational" or "reduced risk" insecticides are synthetic or natural compounds that effectively control insect pests, but have low toxicity to non-target organisms (such as humans, animals, and natural enemies and the environment (Horowitz and Ishaaya, 2004). They have moderate residual effects, long-lasting activity and are safe for farmers (Srinivasan *et al.*, 2014). Most of the Asian countries like China, Japan, and Korea are intensively using bio-pesticides, but there are very low uses in Bangladesh (Srinivasan and Ying, 2014). Currently, several microbial derivative based biopesticides products such as Spinosad and Abamectin are available in the local market of Bangladesh (Alam, 2013). The *Leanicillium muscarium* is a fungal biopesticide also possesses high potentialities (Marshall *et al.*, 2003).

Previously, we evaluated the efficacy of Abamectin alone and in combination with the other biopesticides (e.g. emamectin benzoate, lambda-cyhalothrin and lufenuron) and found that it could serve as an effective strategy for the management of the cucurbit fruit fly (Khatun *et al.*, 2016; Khatun *et al.*, 2015). Like Abamectin, Spinosad is a biopesticide derived from naturally occurring soil actinomycete, *Saccharopolyspora spinosa* Mertz and Yao (Bacteria: Actinobacteridae) (Sparks *et al.*,1998) is gaining popularity in Bangladesh. However, the Spinosad or any fungal biopesticide was not included for their efficacy or compatibility against cucurbit fruit fly in our previous work. In this work, we have evaluated Spinosad and a fungal biopesticide, *L. muscarium*, along with Abamectin for their efficacy against cucurbit fruit fly and their effect on yield of bitter gourd.

Materials and Methods

Experimental design and layout

The experiment was conducted in the Entomology Field Laboratory of Bangladesh Agricultural University (BAU), (24°43'03.9"N, 90°25'29.0"E) from March to July 2017. The treatments were laid out in a Randomized Complete Block Design (RCBD) with three replications. Each plot was 1.5 x 1.5 m^2 with a distance of 30cm between the plots. The recommended horticultural practices were conducted properly for better growth and development of the bitter gourd plants (Palada and Chang, 2003). The high yielding variety, Taj Korola-88 (Lal Teer Seed Company, Bangladesh, https://www.lalteer.com), was used as plant materials.

Test insect

The Cucurbit flies collected from the experimental field were brought to the Insect Biotechnology and Biopesticide Laboratory, Department of Entomology, BAU, Mymensingh and identified as *Bactrocera cucurbitae*. The adult fruit flies are 6 to 8 mm in length, distinctive wing Pattern, long third antennal segment, the dorsum of the thorax reddish yellow with light yellow markings and without black markings, and the head yellowish with black spots are the identifying characters (Plant Health Australia, 2018; Divya *et al.*, 2019).

Treatments and doses

Three biopesticides viz. Ambush 1.8 EC (Abamectin) Tracer 45 SC (Spinosad), and Mycotal (*L. muscarium*) were selected for this study. The detailed specifications (doses, group, etc.) of different individual and combined treatments are presented in Table 1. The combined treatments were prepared by mixing the individual treatments and doses as mentioned in Table 1 according to previous reports (Khatun *et al.*, 2016; Khatun *et al.*, 2015).

Treatments application and data collection

After flowering and fruit initiation, the plants were monitored regularly to confirm the infestation level caused by fruit fly. Treatments were prepared and applied according to the experimental specifications stated above. The treatments were applied in two sprays of 10 days. Data were collected on 3, 5, 7 and 10 days after each spray by observing all the fruits present per plot through naked eye. The fruits were harvested after 10 days of treatments of each spray and a total of two pickings were done during the experimental period. The yield of the fruits (gram) in 1.5m × 1.5m plots were then converted into ton per hectare.

Data collecting parameters

Data were collected on the following parameters: (i) total and infested number of fruits, (ii) number of healthy or marketable fruits per square meter, and (iii) yield (ton/ha) of healthy fruit production and infested fruits. The fruits of bitter gourd are the fruits having no hole, no deformation or no pseudo-puncture present on the healthy or marketable fruits while deformed, yellowish and fruits with these signs are considered as infested fruits (Khatun *et al.*, 2015). The percent of infested fruits and fruit protection was also calculated later as per the procedures previously reported (Khatun *et al.*, 2016; Khatun *et al.*, 2015).

Statistical analysis

All the recorded data were compiled and tabulated for statistical analysis. The Analysis of Variance (ANOVA) was done with the MSTAT program (Nissen, 1990). The treatment means differences were adjudged with Duncan's Multiple Range Test (DMRT) and Least Significant Difference (LSD) when necessary.

Results

Fruit infestation

The performance of the biopesticides on the reduction of percent fruit infestation of bitter gourd by cucurbit fruit fly presented in Table 2. It was found that the individual and combined application of biopesticides showed significant ($P < 0.01$) reduction of percent fruit infestation compared to control (Table 2).

It was found that the combined treatments were more effective than the individual treatments in reducing percent fruit infestation of bitter gourd. The combined application of Spinosad and *L. muscarium* (T5) performed the best, having the lowest cumulative mean percent of fruit infestation (16.68) ranged from 10.83 to 23.80% which is statistically significant ($P < 0.01$) than that of other treatments. On the other hand, the highest percent of fruit infestation was found in control which is ranged from 39.04 to 42.13% and the cumulative mean of infestation was 36.43%. The second-lowest infestation (cumulative mean 19.10%) recorded in the three biopesticide combined treatment (T7). The combined application of Abamectin and *L. muscarium* results 26.89% cumulative mean of percent fruit infestation. Application of Spinosad (T3, Tracer 45 SC) showed the best efficacy (21.25% fruit infestation) among the individual treatments.

Besides, percent protections of fruits over control were also calculated and the results are shown in Figure 1. It was found that the highest percent (54.21) of fruits protected from the combined use of Spinosad and *L. muscarium* (T5). The use of Spinosad, Abamectin and *L. muscarium* (T7) resulted the second highest (47.57%) fruit protection over control. The individual use of Spinosad (T3), *L. muscarium* (T4) and Abamectin (T2) resulted 41.67, 36.37 and 11.75, respectively percent protection of bitter gourd fruits over control. Thus, Spinosad and *L. muscarium* combination provides the highest protection of fruits.

Healthy fruits production

All biopesticides significantly ($P < 0.01$) had reduced percent fruit infestation, and the percent of healthy fruit increased (Table 3). The highest percent (83.32) of healthy fruits obtained from the plants treated with Spinosad and *L. muscarium* (T5) combination treatment followed by the treatment of the combined application of Spinosad, Abamectin and *L. muscarium* (80.90) which were statistically similar. The lowest healthy fruit percent was obtained from control (64.24). The single application of Spinosad (T3) and *L. muscarium* (T4) showed statistically similar results. On the other hand, single application of Abamectin (T2) and combined application of Abamectin plus *L. muscarium* (T6) also showed statistically identical results suggesting that admixture of *L. muscarium* with Abamectin did not bring additional benefits (Table 3).

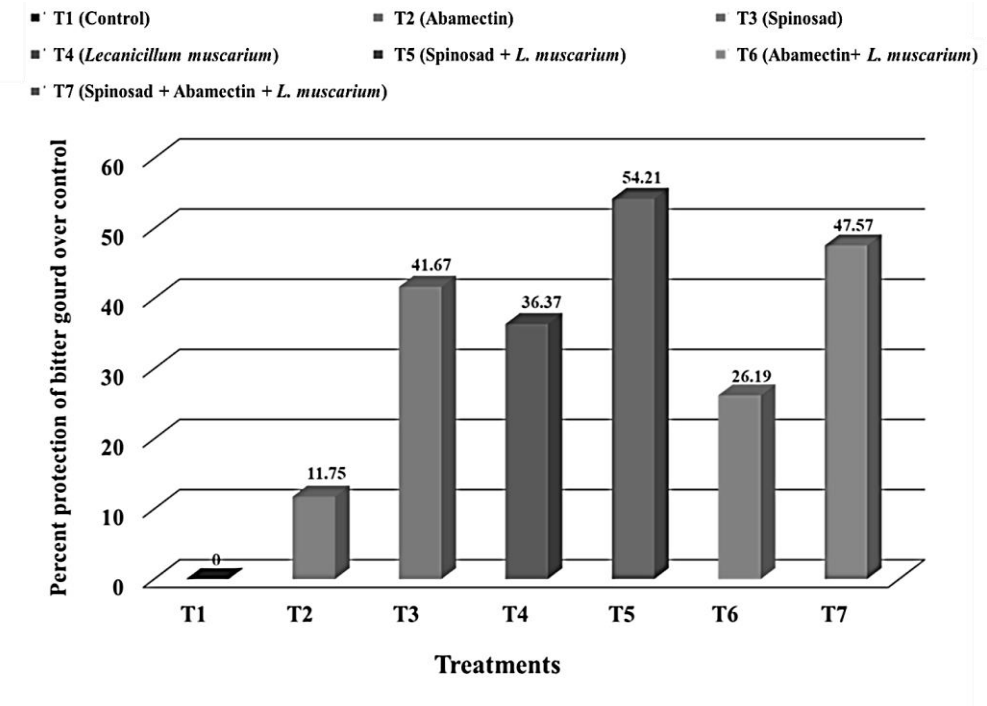

Fig. 1 Percent protection of bitter gourd fruits over control resulted from different treatments

Table 1. Specifications of different individual and combined treatments

Treatments	Recommended dose	Active ingredients	Group	Registration holder
Individual treatments				
T1 (Control)	-	-	-	-
T2 (Ambush 1.8 EC)	2 ml/L	Abamectin	Avermectin	Haychem (Bangladesh) Ltd
T3 (Tracer 45 SC)	1 ml/L	Spinosad	Microbial	Auto Crop Care Ltd
T4 (Mycotal, *Lecanicillium muscarium*)	3 g/L	Fungus	Microbial	Koppert Biological Systems
Combined treatments				
T5 (Tracer 45 SC + Mycotal)	1 ml/L + 3 g/L	Spinosad + Fungus	Spinosad +Microbial	-
T6 (Ambush 1.8 EC + Mycotal)	2 ml/L + 3 g/L	Abamectin + Fungus	Avermectin + Microbial	-
T7 (Tracer 45 SC + Ambush 1.8 EC + Mycotal)	1 ml/L + 2 ml/L + 3 g/L	Spinosad + Abamectin + Fungus	Spinosad + Avermactin + Microbial	-

Table 2. Efficacy of biopesticides on percent fruit infestation by *Bactrocera cucurbitae* of bitter gourd

Treatments	Mean percent fruit infestation at different sprayings								Cumulative mean percentage
	Day after 1st spray				Day after 2nd spray				
	3 DAT	5 DAT	7 DAT	10 DAT	3 DAT	5 DAT	7 DAT	10 DAT	
Individual treatments									
T1 (Control)	42.13^{a}	41.45^{a}	39.20^{a}	37.78^{a}	31.39^{a}	30.26^{a}	30.16^{a}	39.04^{a}	36.43^{a}
T2 (Ambush 1.8 EC)	32.36^{b}	31.94^{b}	36.11^{a}	34.52^{a}	30.84^{a}	30.16^{a}	27.50^{ab}	33.73^{b}	32.15^{b}
T3 (Tracer 45 SC*)	20.21^{cd}	21.67^{cd}	26.17^{bc}	25.56^{bc}	12.94^{b}	19.31^{bc}	20.95^{d}	23.18^{cd}	21.25^{e}
T4 (Mycotal*, *L. muscarium*)	22.02^{c}	24.45^{c}	27.17^{bc}	27.17^{bc}	15.25^{b}	22.22^{b}	22.22^{cd}	24.90^{c}	23.18^{d}
Combined treatments									
T5 (Tracer 45 SC + Mycotal)	16.67^{d}	16.67^{d}	19.52^{d}	23.80^{c}	10.83^{b}	14.39^{d}	14.39^{e}	17.17^{e}	16.68^{g}
T6 (Ambush 1.8 EC + Mycotal)	22.27^{c}	26.17^{bc}	27.78^{b}	31.82^{ab}	27.54^{a}	27.85^{a}	25.32^{bc}	26.39^{c}	26.89^{c}
T7 (Tracer 45 SC + Ambush 1.8 EC + Mycotal)	17.78^{cd}	21.11^{cd}	22.82^{cd}	25.00^{c}	12.79^{b}	16.19^{cd}	18.57^{d}	18.57^{de}	19.10^{f}
LSD $_{(0.05)}$	4.31	6.95	4.28	6.17	4.54	4.26	3.90	5.11	1.84
Level of significance	**	**	**	**	**	**	**	**	**
CV (%)	9.79	14.90	8.43	11.80	12.62	10.45	9.66	10.99	4.13

In a column, means of similar letter(s) do not differ significantly. ** = Significant at 1% level, * = Significant at 5% level, CV = Co-efficient of Variation.

Number of healthy or marketable and infested fruits

The competences of the tested biopesticides on the number of marketable and infested fruits are presented in Table 4. Statistically significant differences were observed among the treatments ($P < 0.01$). It was observed that the tested biopesticides both in individual or combined treatments significantly increase the number of healthy or marketable gourd fruits and reduced the number of infested fruits over control.

The combined treatment of Spinosad and *L. muscarium* (T5) returned the highest number of marketable fruits from two harvests, about 13.67/m^2 (6.67 and 7.00/m^2 for 1st and 2nd pickings, respectively) and simultaneously, the lowest number of infested fruits were also counted (0.67/m^2). Among the individual treatments, the Spinosad was proved to produce the maximum number of marketable fruits (10.66/m^2) (Table 4). Total infested fruit numbers in case of Spinosad application (T3) (3.00/m^2) was found statistically insignificant with the use of *L. muscarium* alone (T4) and the combined application of Abamectin and *L. muscarium* (T6). When the plants treated with Abamectin alone (T2), it was observed that the cumulative number of marketable fruit (7.67/m^2) was statistically insignificant with the marketable fruit number of control (7.34/m^2). The control treatment provided the highest number of infested (4.66/m^2) bitter gourd fruits.

Table 3. Efficacy of biopesticides on the percent healthy fruits of bitter gourd at two different sprayings

Treatments	Mean per cent of healthy fruits at different sprayings								Cumulative mean percentage
	Day after 1st spray				Day after 2nd spray				
	3 DAT	5 DAT	7 DAT	10 DAT	3 DAT	5 DAT	7 DAT	10 DAT	
Individual treatments									
T1 (Control)	57.87^{c}	58.55^{d}	60.80^{d}	62.22^{c}	68.61^{b}	69.74^{c}	69.84^{c}	66.27^{d}	64.24^{e}
T2 (Ambush 1.8 EC)	67.64^{bc}	68.06^{c}	72.22^{bc}	65.48^{bc}	69.16^{b}	69.84^{c}	72.50b^{c}	72.07^{c}	69.62^{d}
T3 (Tracer 45 SC)	79.79^{ab}	78.33^{ab}	73.83^{bc}	74.44^{ab}	87.06^{a}	80.69^{ab}	79.05^{abc}	76.82^{b}	78.75^{b}
T4 (Mycotal, *L. muscarium*)	77.98^{ab}	75.55^{b}	72.83^{bc}	72.83^{ab}	84.75^{a}	77.78^{abc}	77.78^{abc}	75.10^{bc}	76.83^{bc}
Combined treatments									
T5 (Tracer 45 SC + Mycotal)	83.33^{a}	83.33^{a}	80.48^{a}	76.20^{a}	89.17^{a}	85.61^{a}	85.61^{a}	82.83^{a}	83.32^{a}
T6 (Ambush 1.8 EC + Mycotal)	77.73^{ab}	73.83^{bc}	72.22^{c}	68.18^{abc}	72.46^{b}	72.15^{bc}	74.68^{bc}	73.61^{bc}	73.11^{cd}
T7 (Tracer 45 SC + Ambush 1.8 EC + Mycotal)	82.22^{a}	78.89^{ab}	77.18^{ab}	75.00^{ab}	87.21^{a}	83.81^{a}	81.43^{ab}	81.43^{a}	80.90^{ab}
$LSD_{0.05}$	12.57	6.69	4.55	9.00	7.15	8.91	8.66	4.40	4.18
Level of significance	**	**	**	*	**	**	*	**	**
CV (%)	9.39	5.10	3.52	7.17	5.04	6.50	6.30	3.28	3.12

In a column, means of similar letter(s) do not differ significantly. ** = Significant at 1% level, * = Significant at 5% level, CV = Co-efficient of Variation.

Table 4. Efficacy of biopesticides on the mean number of marketable and infested fruits of bitter gourd

Treatments	Mean number of marketable fruits/m^2			Mean number of infested fruits/m^2		
	1st picking	2nd picking	Total	1st picking	2nd picking	Total
T1 (Control)	2.67^{c}	4.67^{c}	7.34^{d}	2.33^{a}	2.33^{a}	4.66^{a}
T2 (Ambush 1.8 EC*)	3.00^{c}	4.67^{c}	7.67^{d}	2.33^{a}	1.37^{b}	3.70^{b}
T3 (Tracer 45 SC*)	4.33^{b}	6.33^{ab}	10.66^{b}	2.00^{a}	1.00^{c}	3.00^{bc}
T4 (Mycotal*, *L. muscarium*)	4.33^{b}	5.33^{bc}	9.66^{bc}	2.00^{a}	1.00^{c}	3.00^{bc}
T5 (Tracer 45 SC + Mycotal)	6.67^{a}	7.00^{a}	13.67^{a}	0.00^{c}	0.67^{d}	0.67^{d}
T6 (Ambush 1.8 EC + Mycotal)	3.67^{bc}	5.00^{c}	8.67^{cd}	2.00^{a}	1.00^{c}	3.00^{bc}
T7 (Tracer 45 SC + Ambush 1.8 EC + Mycotal)	5.67^{a}	6.67^{a}	12.34^{a}	1.33^{b}	1.00^{c}	2.33^{c}
$LSD_{0.05}$	1.15	1.18	1.40	0.417	0.126	0.684
Level of significance	**	**	**	**	**	**
CV (%)	14.97	11.66	7.86	13.65	6.08	13.23

In a column, means of similar letter(s) do not differ significantly. ** = Significant at 1% level, * = Significant at 5% level, CV = Co-efficient of Variation; Ambush 1.8 EC @2 ml/L, Tracer 45 SC @1 ml/L and Mycotal @3 g/L was selected from Abamectin, Spinosad and *L. muscarium* group, respectively.

Table 5. Efficacy of biopesticides on yield (ton/ha) of marketable and infested fruits

Treatments	Yield (ton/ ha) of marketable fruits				Yield (ton/ ha) of infested fruits		
	1st picking	2nd picking	Cumulative yield	Increase (times)	1st picking	2nd picking	Total
T1 (Control)	1.09^{c}	1.59^{c}	2.68^{d}	-	0.54^{a}	0.53^{a}	1.06^{a}
T2 (Ambush 1.8 EC*)	1.13^{c}	1.70^{bc}	2.83^{d}	1.06	0.52^{a}	0.34^{b}	0.86^{b}
T3 (Tracer 45 SC*)	1.89^{b}	2.28^{abc}	4.17^{b}	1.56	0.42^{a}	0.23^{c}	0.66^{d}
T4 (Mycotal*, *L. muscarium*)	1.42^{bc}	2.03^{abc}	3.45^{c}	1.29	0.43^{a}	0.24^{c}	0.67^{d}
T5 (Tracer 45 SC + Mycotal)	2.49^{a}	2.66^{a}	5.15^{a}	1.92	0.00^{b}	0.17^{c}	0.17^{e}
T6 (Ambush 1.8 EC + Mycotal)	1.16^{c}	1.77^{bc}	2.93^{d}	1.09	0.49^{a}	0.25^{c}	0.74^{c}
T7 (Tracer 45 SC + Ambush 1.8 EC+ Mycotal)	1.91^{b}	2.34^{ab}	4.25^{b}	1.59	0.39^{a}	0.23^{c}	0.63^{d}
$LSD_{0.05}$	0.56	0.65	0.29	-	0.15	0.08	0.06
Level of significance	**	*	**	-	**	**	**
CV (%)	19.74	17.87	4.47	-	20.27	15.22	5.66

In a column, means of similar letter(s) do not differ significantly. ** = Significant at 1% level, * = Significant at 5% level, CV = Co-efficient of Variation

Yield of healthy or marketable and infested fruits

The healthy or marketable and infested fruits separated carefully and weights were measured regarding the treatment specification. The results presented in Table 4.4 and found that the tested treatments significantly ($P < 0.01$) increase the yield of healthy bitter gourd fruits and gradually reduced the infested yield (Table 5).

A statistically significant ($P < 0.01$) maximum yield of marketable bitter gourd fruits recorded from the use of Spinosad and *L. muscarium* (T5) (5.15 ton/ha) which also produced the lowest infested fruit yield (0.17 ton/ha) (Table 5). This followed by the second highest yield of marketable fruits from the combined treatment of Spinosad, Abamectin and *L. muscarium* (T7) which is statistically the same with the application of individual spray of Spinosad (T3). The yield of marketable and infested fruits was 4.25 and 0.63 ton/ ha, respectively and *L. muscarium* (T4) provided 4.17 ton/ ha and 3.45 ton/ ha yield of marketable fruits respectively. Statistically, insignificant observation was recorded on marketable fruit yield from the treatments with Abamectin (T2) (2.83 ton/ha) and Abamectin + *L. muscarium* (T6) (2.93 ton/ ha) and control (T1) (2.68 ton/ ha) suggested that admixture of *L. muscarium* with Abamectin did not bring any additive effects. About 0.86 and 0.74 ton/ha yield of infested fruits recorded when Abamectin (T2) (2.83 ton/ ha) and Abamectin + *L. muscarium* (T6) were applied, respectively. The highest infested yield (1.06 ton/ha) was observed in control (Table 5).

Discussion

It is found that the biopesticides exerted variable efficacy in reducing fruit infestation over the check. The admixing of Spinosad with *L. muscarium* was the most effective treatment against the cucurbit fly on bitter gourd fruits based on the parameters analyzed. Among the single biopesticide sprays, the application of Spinosad provided the highest fruit yield about 1.5 times higher than control. The fruit yield was practically two times increased by the combined use of Spinosad with *L. muscarium* (Table 5). This suggested that there might be an additive or synergistic effect present between Sipnosad and *L. muscarium* admixture. Many authors also reported the efficacies of Spinosad against *B. cucurbitae* (Shivangi *et al.*, 2017; Gazit and Akiva, 2017; Kakani *et al.*, 2010). Shivangi *et al.*, (2017) shown that three sprays of Spinosad 45 SC @ 200 ml/ha alone at an interval of 12 days was most effective against fruit fly, (*Bactrocera cucurbitae* Coquillett) infesting cucumber. Gazit and Akiva (2017) measured the toxicity by contact and feeding with the bait of Spinosad to *Bactrocera zonata* (Saunders) and found that the toxicity of spinosad to *B. zonata* (Saunders) was high with LC_{80}, LC_{90}, and LC_{99} values of 12.28, 17.67, and 33.62 ppm, respectively. Kakani *et al.*, (2010) reported that Spinosad had used since 2004 for control of olive fruit fly, *B. oleae* (Rossi) in California and Hawaii for the control of both *B. cucurbitae* and *B. dorsalis* (Hendel) since 2000.

Considering the efficacy of Abamectin, previously, Khatun *et al.*, (2016) and Khatun *et al.*, (2015) found that Abamectin (Ambush 1.8 EC) was found as the most effective one followed by Emamectin benzoate (Suspend 5 SG) and Abamectin plus Lambda-cyhalothrin against the *B. cucurbitae*. They reported that the efficacy of Abamectin was significantly better in comparison with that of the others. In this study, the Abamectin was also found effective against *B. cucurbitae*, but its effectiveness was comparatively lower than the other treatments such as Spinsoad. The difference was possibly due to the dose of the Abamectin used. It was found that Khatun *et al.*, (2015) studied the effect of Abamectin using 2.5 ml/L dose and in this study it was 2.0 ml/L.

Besides, the admixing of Abamectin with the fungal biopesticides, *L. muscarium* results statistically same yield with the individual yield of Abamectin and control, i.e., did not enhance the yield (Table 5). These results suggested that there might be an antagonistic effect or incompatible present between Abamectin and *L. muscarium* admixture. The present results also agreed to the findings of Krishnamoorthy *et al.*, (2007) who reported that use of abamectin, thiophanate-methyl and dinocarp resulted in very low production of conidia of *L. lecanii* (*L. muscarium*) when studied the influence of some pesticides on it and hence, they concluded that the admixtures of these insecticides considered to be incompatible.

Conclusion

The application of three biopesticides viz Spinosad, Abamectin and *L. muscarium* both alone and their different combinations were found significantly useful against the cucurbit fruit fly infesting bitter gourd. The individual application of Spinosad had provided moderate efficacy. However, when, it was applied by admixing with *L. muscarium*, the combination was recorded as the most effective treatment considering the reduction of percent fruit infestation, increasing the fruit yield and decreasing the infested fruit yield. There might be an additive or synergistic effect present between Spinosad and *L. muscarium* admixture. On the other hand, these results have shown that the admixture of Abamectin and *L. muscarium* did not enhance yield and other parameters tested significantly suggesting the incompatibility of them. Therefore, based on this study, the combined use of Spinosad and *L. muscarium* could be recommended to the bitter gourd growers for effective management of cucurbit fruit fly, *B. cucurbitae*

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