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Sustainable pest management approach against the hog plum leaf beetle, *Podontia 14-punctata* Linn. (Coleoptera: Chrysomelidae)

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Abstract

Background: The hog-plum, locally known as "amra", is a deciduous perennial tree with thick succulent leaves and it grows all over the country, but the quality fruits are produced only in the southern districts of Bangladesh. Its cultivation is seriously hampered by hog-plum leaf beetle or 14 spotted leaf beetle, *Podontia 14-punctata* Linn. (Coleoptera: Chrysomelidae). In most of the cases, insecticidal spray is not effective for controlling this pest as pupation completed in the soil. Therefore, the present study was carried out under both laboratory and field conditions to develop environment friendly sustainable management approaches against the hog-plum beetle.

Results: Laboratory test revealed that spraying with green pesticide spinosad (Success® 2.5% SC) at hog-plum leaflet and drenching with microbial pesticide *Metarhizium anisopliae* + *Trichoderma harzianum* + *Beauveria bassiana* + *Trichoderma viride* (Lycomax, Russell IPM) causes 75.00% larvae, 72.22% adults and 51.85% pupal mortality,, respectively. Some pest management approaches were developed based on the laboratory results, they were verified in field, during the two successive fruiting seasons 2018 and 2019. Field study indicated that approach 1: Hand picking + trunk banding with packaging tape + soil drenching with lycomax, Russell IPM + spraying of spinosad treated trees offered lowest leaf and fruit infestation; even though trunk banding with packaging tape did not show any effect to control this pest. Fruit yield was also increased 39.04–39.66% in approach 1 imposing hog-plum trees compared to control.

Conclusion: The study showed that without banding of the hog-plum trunk, hand picking + soil drenching with microbial pesticides, lycomax, Russell IPM + spraying of spinosad might be sustainable and environment friendly pest management approach against *P. 14-punctata*.

Keywords: Amra, Bio-pesticides, *Metarhizium anisopliae*, *Podontia 14-punctata*, Spinosad

Background

Hog-plum (*Spondias cytherea*), locally known as "amra" is a major fruit in Bangladesh, especially in the southern part of the country (Asaduzzaman et al. 2018). It is one of the popular fruits in all over the country but good quality "amra" is cultivated commercially in southern region. Hog-plum is rich in vitamin C and carotene, can be an alternative source for them (Mondal and Amin 1990). Also hog-plum leaf used as fodder in different parts of India (Singh 1982). The production of hog-plum is greatly hampered by infestation of several insect pests, among the hog-plum leaf beetle or 14 spotted leaf beetle, *Podontia 14-punctata* or *Podontia quaturdecempunctata* L. (Coleoptera: Chrysomelidae:) is an important pest. The larvae and adults of this pest cause damage to the leaves ranging from 50 to 96% depending on the severity of the infestation, and sometimes it causes complete fall of trees (Uddin and Khan 2015; Akata et al. 2021). Average infestation of the leaves about 50% and sometimes

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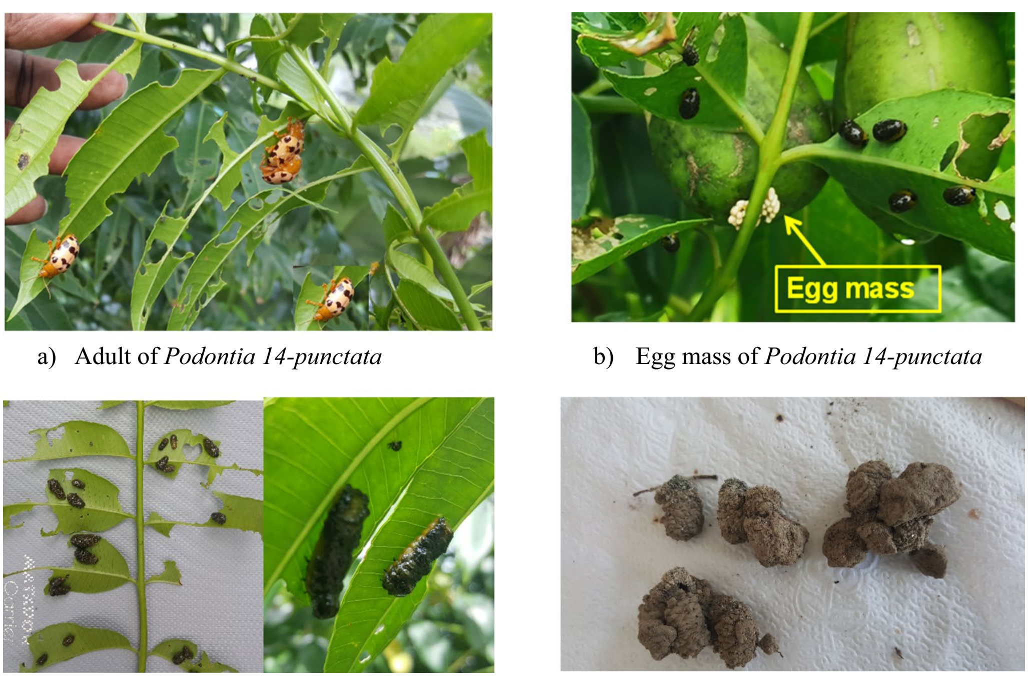
causes complete defoliation of trees (Asaduzzaman et al. 2018). This beetle causes serious damage to the crop from March to August with two generations a year (Mondal 1975). In Bangladesh, the beetles first appear in April, peak during July to September and disappear in October (Khan 2016). The peak period of defoliation is found in August and September. During off season the insect pupates in the soil in hibernating condition (Fig. 1). Recently, suitable control measures against this pest are not available in the country even though some authors tested a few number of chemical insecticides (Khan 2016; Uddin and khan 2015), of them chlorpyripos or cypermethrin was found to be effective against this pest. Farmers usually spray several toxic insecticides to control the pest which cause health hazard and environmental pollution. So, it is necessary to develop an environment friendly sustainable pest management approach against this devastating pest. However, we have some green and bio-pesticides which are very safe to our ecosystem can be used in pest control program. Spraying of a green pesticide spinosad and soil inoculation of bio-pesticide *M. anisopliae* and *B. bassiana* have proven to be the most effective against other beetles, weevils and hemipteran bugs can play an important role in pest's reduction (McLeod et al. 2002; Jones et al. 2005; Ekesi et al. 2011, Amy and Tobin 2020). As this pest is external feeder and pupates in soil (Akata et al. 2021), it is easier to suppress by using soil inoculums and spraying contact or systemic insecticides. But the studies on the development of friendly sustainable management approach were not systematically done in laboratory or in field condition so far. Therefore, the present study aims to search for a friendly sustainable pest management approach against the hog-plum leaf beetle under laboratory and field evaluation.

Methods

Experiments on management of the hog-plum leaf beetle, *P. 14-punctata* were carried out in the laboratory of Entomology Division as well as at the hog-plum orchard of RARS, BARI, Rahmatpur, Barishal, Bangladesh (90° 17′ 29.9.84″ E, 22° 78′ 81.20″ N), during 2 fruiting seasons 2018 and 2019. Laboratory experiment was carried out under the room temperature (31.2 ± 2.1 °C) and relative humidity (78 ± 5%) with a 14 ± 2: 10 ± 2 light and dark cycle (L:D), following a completely randomized design (CRD).

Tested pesticide

The pesticides used in current study obtained from local market which are commercially available. The tested pesticides were: 1. Lycomax, Russell IPM (*M. anisopliae* + *T. harzianum* + *B. bassiana* + *T. viride*) 2. Success® 2.5% SC



a) Adult of *Podontia 14-punctata*
b) Egg mass of *Podontia 14-punctata*
c) Larvae of *Podontia 14-punctata*
d) Pupae of *Podontia 14-punctata*

Fig. 1 Different growth stages of hog plum (*amra*) leaf beetle, *Podontia 14-punctata*

(Spinosad) 3. Bio-neem plus® 1% EC (Azadirachtin) 4. Nitro® 505% EC (Chlorpyripos + cypermethrin).

Laboratory bio-assay

Laboratory bio-assay was carried out to find out an effective treatment can verify under field conditions. The treatment modules were T_1: soil drenching with *M. anisopliae* + *T. harzianum* + *B. bassiana* + *T. viride* (Lycomax, Russell IPM) at 5 g/L of water, T_2: spraying with spinosad (Success® 2.5% SC) at 1.2 mL/L of water on hog-plum leaflet, $T_{3:}$ spraying of azadirachtin (Bio-neem plus® 1% EC) at 1.0 ml/liter on hog-plum leaflet, $T_{4:}$ spraying of chlorpyripos + cypermethrin (Nitro® 505% EC) at 0.75 ml/L of water on hog-plum leaflet, T_5: spraying with water as a control. The potential fungal isolate lycomax was sprayed at 5 g/L of water in the soil. Spray volume of soil recharge (lycomax, Russell IPM) was 100 mL/kg soil. After spraying in soil, it was air dried for 6 h. then placed bottom of acrylic cage for pupation. Before applying the rest of the treatments, the petiole of fresh succulent mid-aged hog-plum leaflet was placed inside the acrylic cage. Then 12 larvae (2nd–3rd instar) and 12 adult (7–10 days old) beetles were released in each acrylic cage containing 3 kg treated soil at the bottom of the cage. The same process was replicated 3 times. When the released larvae and adult beetles started normal movement then the treatments were applied by a hand sprayer as cover spray. After leaflet treatment, the mouth of the acrylic cage was covered by a mosquito net. After application of the treatments, the covered acrylic cage was placed on the laboratory table near opened window. Mortality data of larvae and adults were recorded at 24 h. interval after treatment up to 72 h. Rates of pupation and adult emergence were also noted at 24 h. interval after treatment up to 30 days.

Field trial

The experiments were conducted at the hog-plum orchard of RARS, BARI, Rahmatpur, Barishal (90° 17′ 29.9.84″ E, 22° 78′ 81.20″ N) during the 2 fruiting seasons 2018 and 2019 as a randomized complete block design (RCBD) with 5 treatments and 4 replicates. A total of 20 trees around 9 years' old were used at this study. Each hog plum tree was counted as a single iteration and the distance between each plant and another was 8 × 8 meter. The treatments were assigned as follows: T_1 = Module 1: Hand picking (removal of infested leaves with egg mass and larvae) + soil drenching with microbial pesticides, *lycomax,* Russell IPM + trunk banding with packaging tape + spraying with spinosad (Success® 2.5% SC) at 1.2 mL/L of water, T_2 = Module 2: Hand picking (removal of infested leaves with egg mass and larvae) + soil drenching with microbial pesticides, *Lycomax* + spraying of azadirachtin (Bio-neem plus® 1% EC) at 1.0 ml/liter of water, T_3 = Module 3: Hand picking (removal of infested leaves with egg mass and larvae) + soil drenching with microbial pesticides, lycomax, Russell IPM. T_4 = Module 4: Farmers practice: spraying of chlorpyripos + cypermethrin (Nitro® 505% EC) at 0.75 ml/liter, T_5 = Module 5: Untreated control (water spray). The potential fungal isolates lycomax was sprayed at 5 g/L of water in the soil at onset of fruiting. Hand picking was carried out twice a week. Trunk of hog-plum tree banding with packaging tape was done on 7 April 2018 and 2019 before fruit setting. A total of 3 sprays/treatment applications were made at 10 days intervals. Each spray was applied by manually driven foot pump sprayer as a full cover spray for the hog-plum tree. The leaves, branches and the main trunk of each tree were sprayed with spray mixture through the outlet of the nozzle. Application was made in such a way that the spray pressure would not knock down the pest from the tree. The pre-treatment data were recorded on the number of 1st, 2nd, 3rd and 4th instars larvae and adults. One square meter (1 m^2) quadrat was placed in the central position of the east side canopy structure. The number of adults and larvae, as well as healthy and infected leaves from inside each quadrant under different treatments, was counted one day before the first spray and a week after each spray.

Statistical analysis

Experimental data were analyzed by SAS software. The mortality, pupation, adult emergence, infestation rate of *P. 14-punctata* were subjected to arcsine transformation before the analysis of variance (ANOVA) and Tukey's multiple range tests. (SAS Institute 2012). The adult and larval population per quadrat of *P. 14-punctata* were subjected to square root transformation before the analysis of variance (ANOVA) and Tukey's multiple range tests. (SAS Institute 2012).

Results

Laboratory evaluation

Larval mortality

The mean larval (2nd–3rd instar) mortality at the laboratory treatments ranged from 36.11 to 75.00% (Table 1). Laboratory bioassay shows that spinosad (T_2) caused the highest larval mortality (75.00%), followed by spraying of (T_4) chlorpyripos + cypermethrin (61.11%) and spraying of azadirachtin (52.78%). On the other hand, soil drenching with microbial pesticide, lycomax, Russell IPM (T_1) do not cause significant larval mortality.

Pupal mortality

The highest pupal mortality rate (51.85%) is recorded at the soil treatment drenched with microbial pesticides,

Table 1 Effect of different treatments against *P. 14-punctata* under laboratory conditions

Treatments	Mortality (%)		
	Larva	Pupa	Adult
T_1	36.11[c]	51.85[a]	25.00[c]
T_2	75.00[a]	19.44[b]	72.22[a]
T3	52.78[b]	17.78[b]	55.56[b]
T_4	61.11[b]	13.89[b]	58.33[b]
T_5 = untreated control	36.11[c]	13.10[b]	22.22[c]

All means followed by same letters at each column are not significantly different by Tukey's multiple range tests, ANOVA ($P < 0.05$)

T_1 = soil drenching with microbial pesticides, Lycomax, Russell IPM; T_2 = spraying spinosad at hog-plum leaflet; T3 = spraying azadirachtin at hog-plum leaflet; T_4 = spraying of chlorpyripos + cypermethrin at hog-plum leaflet

Lycomax, Russell IPM (T_1). But other treatments do not show detrimental effect on pupal mortality compare to control (Table 1).

Adult mortality

The mean adult mortality at the laboratory treatments ranged from 22.22 to 72.22% (Table 1). Among treatments, there were significant differences, spinosad (T_2) causes the highest adult mortality rate (72.22%), followed by spraying of (T_4) chlorpyripos + cypermethrin (58.33%) and spraying of (T_3) azadirachtin (55.56%). While, adult mortality of hog-plum beetle is not affected by soil drenching with microbial pesticides naming lycomax, Russell IPM (T_1).

Pupation rate and adult emergence

Significant effects on the pupation and adult emergence are recorded. Spraying with spinosad offered very detrimental effects on both pupation and adult emergence but soil drenching with microbial pesticides, lycomax, Russell IPM (T_1) shows negative effects on adult emergence than rest of the treatments (Fig. 2). Laboratory trials revealed that spraying of spinosad (T_2) on hog-plum leaflet has a significant mortality rate on *P.14-punctata* larvae and adults than other treatments. Soil drenching with a microbial pesticide, lycomax, Russell IPM (T_1) causes a higher pupal mortality (69.44%) and significant effect on adults' emergence of *P. 14-punctata.*

Field trial

Effect of weather parameters on incidence of Podontia 14-punctata population

Incidence of *P. 14-punctata* population with weather parameters is presented in Table 2. The incidence of *P. 14-punctata* larvae is started from the third week of March and reached its peak of 18.0/(1 m^2) quadrat during May and 20.21 during August. Adult population is also started from the fourth week of March and reached its peak of 19.33/(1 m^2) quadrat during June and 21.50 during September. Its population disappeared after the month of October. Multiple linear regression models, along with coefficients of determination (R^2) regarding the impact of weather parameters on the seasonal abundance of both adult and larva *P. 14-punctata* population, are presented in Table 3. The data show that the temperature individually contributed positively to buildup pest abundance, and its effect is significant (adult: t value = 2.77, $P = 0.024$; larva: t value = 2.66, $P = 0.029$). But relative humidity and rainfall do not show significant relation with pest abundance. The combined effect of temperature, relative humidity and rainfall is also

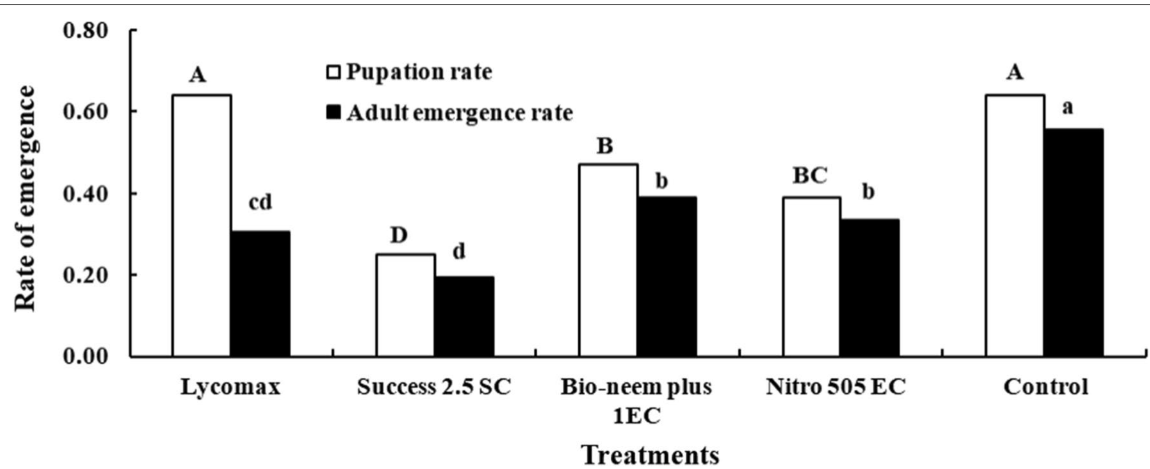


Fig. 2 Efficacy of different treatments on pupa and adult emergence of *P. 14-punctata* under laboratory condition (all means followed by same letters at each bar are not significantly different by Tukey's multiple range tests, ANOVA ($P < 0.05$)

Table 2 Monthly distributions of meteorological parameters and *P. 14-punctata* population buildup in hog plum during 2019

Observation month	Temperature (°C)	Rainfall (mm)	Relative humidity (%)	No. of *P. punctata*/(1 m^2) quadrat	
				larvae	adult
January	18.99	0.00	72.51	0.00	0.00
February	21.84	0.00	68.65	0.00	0.00
March	26.07	0.00	71.59	1.20	1.24
April	28.00	0.00	71.59	4.34	7.25
May	30.38	0.00	70.85	18.00	12.90
June	29.88	25.40	73.77	11.10	19.33
July	28.58	147.60	86.46	10.24	12.50
August	34.57	260.10	85.60	20.21	16.50
September	29.21	161.50	84.41	8.33	21.50
October	30.30	192.65	84.06	1.24	1.20
November	16.31	0.00	73.73	0.00	0.00
December	19.15	0.00	72.10	0.00	0.00

Source: Meteorological station, Regional Station, BRRI, Barishal

Table 3 Multiple linear regression models along with coefficients of determination (R^2) regarding the impact of weather parameters on the seasonal abundance of *P. 14-punctata* population in hog plum

Stage of insect	Parameters	Coefficients	Standard error	*t*-value	*P* value	R^2	*F*-statistics
Adult	Intercept	− 103.497	64.979	− 1.593	0.150	0.617	$F_{3,11}=4.299, P=0.044$
	Temperature	1.240	0.447	2.777	0.024		
	Rainfall	− 0.079	0.066	− 1.199	0.265		
	Relative Humidity	1.101	0.853	1.290	0.233		
Larva	Intercept	− 22.877	57.432	− 0.398	0.701	0.606	$F_{3,11}=4.093, P=0.049$
	Temperature	1.050	0.395	2.661	0.029		
	Rainfall	− 0.006	0.058	− 0.104	0.919		
	Relative Humidity	0.027	0.754	0.036	0.972		

Y = insect population/(1 m^2) quadrat; X_1 = average temperature (°C); X_2 = average rainfall (mm); X_3 = relative humidity (%)

significant to buildup pest abundance of hog plum (adult: $F_{3,11}=4.29$, $P=0.044$; larva: $F_{3,11}=4.09$, $P=0.049$).

Effectiveness of different pest management approches on the population of Podontia 14-punctata

Two years field study shows that different pest management approaches have significant mortality effects on the population of *P. 14-punctata.* The highest larval and adult populations' reduction (82.40–82.58 and 78.50–80.88%) over control is observed in T_1, which consisted of hand picking + soil drenching with microbial pesticides, lycomax + trunk banding with packaging tape + spinosad treated trees, followed by T_2 (hand picking + soil drenching with microbial pesticides, lycomax + azadirachtin and Farmers practice T_4 (Tables 4, 6). The percent leaflet and fruit infestation is also significantly reduced (80.80–88.40 and 78.41–81.74%) when hog-plum plants are treated with T_1 followed by T_2. Even though adults of *P. 14-punctata* easily crossed hog-plum trunk which is banding with packaging tape (Tables 5, 7). Therefore, it is clear that without banding the hog-plum trunk, hand picking + soil drenching with microbial pesticides, lycomax, Russell IPM + spinosad is the sustainable and environment friendly toxic chemical free safe pest management module against *P. 14-punctata.*

Yield production

Yield of hog-plum varied significantly with the level of fruits' infestation by hog-plum beetle depending on the efficacy of different management modules during both 2018 and 2019 fruiting seasons (Tables 5, 7). The highest yield production (17.61–18.36 ton/ha) is obtained from T_1, followed by T_2 imposing tree (15.38–16.48 ton/ha). The lowest yield production (12.61–13.21 ton/ha) is recorded from untreated control tree (T_5). Yield reached 39.04–39.66%, increased in T_1 imposing tree compare to the control.

Table 4 Efficacy of different pest management modules in controlling hog-plum beetle, *P. 14-punctata* under field condition during 2018

Treatments	No. of larvae/(1 m^2) quadrat		No. of adults/(1 m^2) quadrat		% reduction of larvae over control	% reduction of adults over control
	Before treatment	After treatment	Before treatment	After treatment		
T_1	11.35^a	3.37^d	12.45^a	3.35^d	82.58	78.50
T_2	12.36^a	5.38^{bc}	10.34^a	5.58^c	72.20	64.18
T_3	14.34^a	9.35^b	11.33^a	7.34^b	51.68	52.89
T_4	13.55^a	7.58^b	11.52^a	8.59^b	60.83	44.87
T_5 (control)	12.33^a	19.35^a	10.32^a	15.58^a	–	–

All means followed by same letters at each column are not significantly different by Tukey's multiple range tests, ANOVA ($P < 0.05$)

T_1: Hand picking + soil drenching with microbial pesticides, Lycomax, Russell IPM + trunk banding with packaging tape + spraying of spinosad; T_2 = Hand picking + soil drenching with microbial pesticides, Lycomax, Russell IPM + spraying of azadirachtin; T_3 = Hand picking + soil drenching with microbial pesticides, Lycomax, Russell IPM*;* T_4: spraying of chlorpyripos + cypermethrin

Table 5 Efficacy of different pest management modules on leaf and fruit infestation by hog-plum beetle, *P. 14-punctata* under field condition during 2018

Treatments	Leaf infestation (%)	Fruit infestation (%)	Reduction of leaf infestation over control (%)	Reduction of fruit infestation over control (%)	Yield (ton/ha)	Yield increased over control (%)
T_1	2.37^d	2.84^d	88.40	81.74	18.36^a	39.04
T_2	5.38^c	5.16^{bc}	73.67	66.82	16.48^b	24.76
T_3	7.35^{bc}	7.39^b	64.02	52.48	15.80^{bc}	19.63
T_4	9.56^b	8.56^b	53.21	44.95	14.95^c	13.21
T_5 (control)	20.43^a	15.55^a	–	–	13.21^d	–

All means followed by same letters at each column are not significantly different by Tukey's multiple range tests, ANOVA ($P < 0.05$)

T_1: Hand picking + soil drenching with microbial pesticides, Lycomax, Russell IPM + trunk banding with packaging tape + spraying of spinosad; T_2 = Hand picking + soil drenching with microbial pesticides, Lycomax, Russell IPM + spraying of azadirachtin; T_3 = Hand picking + soil drenching with microbial pesticides, Lycomax, Russell IPM*;* T_4: spraying of chlorpyripos + cypermethrin

Table 6 Efficacy of different pest management modules in controlling hog-plum beetle, *Podontia 14-punctata* under field conditions during 2019

Treatments	No. of larvae/(1 m^2) quadrat		No. of adults/(1 m^2) quadrat		% reduction of larvae over control	% reduction of adults over control
	Before treatment	After treatment	Before treatment	After treatment		
T_1	9.61^a	2.59^d	10.90^a	3.10^d	82.40	80.88
T_2	9.24^a	5.71^b	10.27^a	4.88^c	61.20	69.87
T_3	9.58^a	7.27^{bc}	10.57^a	6.08^b	50.58	62.49
T_4	9.58^a	5.54^b	9.92^a	7.68^b	62.38	52.62
T_5 (control)	9.30^a	14.72^a	11.55^a	16.21^a	–	–

All means followed by same letters at each column are not significantly different by Tukey's multiple range tests, ANOVA ($P < 0.05$)

T_1: Hand picking + soil drenching with microbial pesticides, Lycomax, Russell IPM + trunk banding with packaging tape + spraying of spinosad; T_2 = Hand picking + soil drenching with microbial pesticides, Lycomax, Russell IPM + spraying of azadirachtin; T_3 = Hand picking + soil drenching with microbial pesticides, Lycomax, Russell IPM*;* T_4: spraying of chlorpyripos + cypermethrin

Discussion

Environment friendly green or bio-pesticides can play a significant role in sustainable crop production by providing successful pest management. The main objective of this study was to determine whether the commercial green and bio-pesticides [spinosad (Success® 2.5% SC) and *M. anisopliae* + *T. harzianum* + *B. bassiana* + *T. viride* (Lycomax, Russell IPM)] could be used as an alternative to chemical insecticides in hog plum production. Our results showed that a green pesticide spinosad

Table 7 Efficacy of different pest management modules on leaf and fruit infestation by hog-plum beetle, *P. 14-punctata* under field condition during 2019

Treatments	Leaf infestation (%)	Fruit infestation (%)	Reduction of leaf infestation over control (%)	Reduction of fruit infestation over control (%)	Yield (ton/ha)	Yield increased over control (%)
T_1	3.57^{d}	3.87^{d}	80.80	78.41	17.61^{a}	39.66
T_2	5.67^{c}	6.33^{bc}	69.55	64.70	15.38^{b}	21.97
T_3	5.91^{c}	8.24^{b}	68.26	54.08	14.27^{bc}	13.22
T_4	7.40^{b}	8.73^{b}	60.25	51.35	13.98^{c}	10.87
T_5 (control)	18.61^{a}	17.94^{a}			12.61^{d}	–

All means followed by same letters at each column are not significantly different by Tukey's multiple range tests, ANOVA ($P < 0.05$)

T_1: Hand picking + soil drenching with microbial pesticides, Lycomax, Russell IPM + trunk banding with packaging tape + spraying of spinosad; T_2 = Hand picking + soil drenching with microbial pesticides, Lycomax, Russell IPM + spraying of azadirachtin; T_3 = Hand picking + soil drenching with microbial pesticides, Lycomax, Russell IPM; T_4: spraying of chlorpyripos + cypermethrin

caused significant larval and adult mortalities under laboratory condition, similar to the previous study (Khatun et al. 2016). The highest pupal mortality was recorded at the soil drenched with microbial biopesticide, lycomax, Russell IPM. Adult and larval mortalities of hog-plum beetle were not affected by soil drenching with microbial pesticide lycomax, Russell IPM but showed negative effects on both pupation and adult emergence; it may be due to pupation occur in soil. A microbial pesticide, lycomax, Russell IPM used in this study consists of four soil microbes (*M. anisopliae* + *T. harzianum* + *B. bassiana* + *T. viride*). Among the two entomopathogenic fungal species, *B. bassiana* and *M. anisopliae* have proven to be the most effective against wide range of pests like beetles, weevils and hemipteran bugs (Castrillo et al. 2010; Migiro et al. 2010; Singha et al. 2010; Ekesi et al. 2011; Skinner et al. 2012; Akmal et al. 2013; Wraight et al. 2016; Amy and Tobin 2020). Similarly, laboratory trial revealed that soil drenching with a microbial pesticide, lycomax, Russell IPM caused a higher pupal mortality which reflexed as a significant effect on adult emergence of *P.14-punctata.*

Therefore, some pest management approach were developed based on the laboratory results, should be verified under field conditions. The 2 years field study showed that the highest larval and adult population reductions were recorded in T_1 (hand picking of infested leaves with egg mass and larvae) + soil drenching with lycomax, Russell IPM + trunk banding with packaging tape + spraying with spinosad).The percent leaflet and fruit infestation was also significantly reduced, with T_1 treated trees. Soil microbes (Lycomax, Russell IPM) can greatly enhance the effectiveness of integrated pest management programmes and is compatible with many bio-rational control tools. It is particularly successful when utilized in combination with green or biopesticides i.e., spinosad providing vital background protection to the crop against devastating pests. Previous study (Hossain et al. 2019) reported that soil inoculation of lycomax, Russell IPM combined with a biopesticide showed significant reduction of tomato leaf miner, *Tuta absoluta* infestation which can be supported current study. Therefore, it is clear that by banding of the hog-plum trunk, T_1 (hand picking of infested leaves with egg mass and larvae) + soil drenching with lycomax, Russell IPM + trunk banding with packaging tape + spraying with spinosad) was the sustainable and environment friendly toxic chemical free safe pest management module against *P. 14-punctata*.

Conclusions

The present study concluded that the sustainable pest management approach comprising hand picking of infested leaves with egg mass and larvae + soil drenching with microbial pesticides, [*M. anisopliae* + *T. harzianum* + *B. bassiana* + *T. viride*] (Lycomax, Russell IPM) + spraying of spinosad (Success® 2.5% SC) effectively suppressed *Podontia 14-punctata* population and gained a higher yield. Further studies are still needed, particularly under field conditions.

Abbreviations

RARS: Regional Agricultural Research Station; BARI: Bangladesh Agricultural Research Institute; BRRI: Bangladesh Rice Research Institute.

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Authors' contributions

MMR designed, carried out the experiments, recorded the data, interpreted the results and wrote the manuscript. MRI and NKD supervised the experiments, provided technical guidance and edited the manuscript. All authors read and approved the final manuscript during the present study.

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Competing interests
All authors declare that they have no competing interests.

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