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Research Article

Development of bio-rational pest management module against hog plum beetle, *Podontia* 14-*punctata* (Coleoptera: Chrysomelidae)

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ABSTRACT: 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 especially in Barishal and Jhalokathi districts. Its cultivation is seriously hampered by hog- hog plum beetle or 14 spotted leaf beetle, *Podontia* 14-*punctata* L. (Chrysomelidae:Coleoptera). In most of the cases, insecticidal spray is not effective for controlling this pest as pupation occurs in the soil. Therefore current study was carried out in both laboratory and field condition to develop environment friendly management approaches against hog plum beetle as well as producing of toxic chemical pesticide free hog-plum. From laboratory test, it is revealed that spraying of spinosad (Success 2.5 SC) at hog plum leaflet and drenching with microbial pesticides, soil recharge namely Lycomax (*Metarhizium anisopliae* + *Trichoderma harzianum* + *Beauveria bassiana* + *Trichoderma viride*) causes 72.22% adults and 51.85% pupal mortality of *P.* 14-*punctata* respectively. Then some pest management modules were developed based on the laboratory result and it's were verified in field during two fruiting season 2018-19 and 2019-20. From field study it is observed that module 1: Hand picking + trunk banding with packaging tape + soil drenching with *lycomax* + 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 module 1 imposing hog plum trees compare to control. Therefore, it is clear that without banding of the hog plum trunk, hand picking + soil drenching with microbial pesticides, *lycomax* + spraying of spinosad might be sustainable and environment friendly pest management module against *P.* 14-*punctata*.

KEY WORDS: *Amra,* bio-pesticides, hand picking, *metarhizium anisopliae,* spinosad

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INTRODUCTION

Hog plum (*Spondias cytherea*), locally known as "*Amra*" is a major fruit in Bangladesh especially in the southern part of the country. It is one of the popular fruits in all over the country and Barishal region is famous for hog plum. Hog plum, is rich in vitamin C and could be a very good alternative source of Vitamin C. In addition to Vitamin C, it has also been reported as a rich source of carotene (Mondal and Amin, 1990). The hog plum fruit generally consumed in green stage and is also used as jam, jelly, pickles etc (Ahmed, 1969). It is reported that hog plum leaf used as fodder in different parts of India like Assam, Madhya Pradesh, Punjab and Uttar Pradesh (Singh, 1982). The production of hog plum is greatly hampered by infestation of several insect pests, among them hog plum beetle or fourteen spotted leaf beetle, *Podontia* 14-*punctata* L. (Chrysomelidae:Coleoptera) is an important pest. Both the larvae and adults feed on the leaf of hog plum and causes up to 96% damage of the leaf (Uddin and Khan, 2015). Average infestation of the leaves is 50% and sometimes causes complete defoliation of trees. This beetle causes serious damage to the crop from March to August with two generations in a year (Mondal, 1975). In Bangladesh, the beetles first appear in the month of April and peak during July to September and disappear in October (Khan, 2016). The peak period of defoliation is found in August and September (Beeson, 1941; Baksha, 1997; Deka and Kalita, 2002). A few studies reveal that in the case of heavy infestation all leaves of the young trees are eaten up except midribs and subsequently cause the trees defoliated. During severe infestation, the larvae cause damage on the old leaves, tender parts of stems and even the green barks of the plants (Howlader, 1993). During off season the insect pupates in the soil in hibernating condition (Plate 1). At present suitable control measures against this pest are not available in the country. Farmers usually spray several toxic insecticides to control this pest which cause health hazard and environmental pollution (Hoffmann et al., 2000; Elzen *et al.,* 2000; Singh *et al.,* 1989). So it is necessary to develop an environment friendly pest management module against this devastating pest which ultimately increases the productivity

of hog plum of the country. Spinosad is a relatively newer insecticide, and has shown good efficacy in field and greenhouse studies against eggplant flea beetle (*Epitrix fuscula*) (McLeod *et al.,* 2002), flower thrips (*Frankliniella occidentalis*) on greenhouse-grown cucumbers (Jones *et al*., 2005), but did not persist on the foliage. (McLeod *et al.,* 2002). Soil recharge namely Lycomax (*Metarhizium anisopliae* + *Trichoderma harzianum* + *Beauveria bassiana* + *Trichoderma viride)* is a commercially available bio-pesticide in Bangladesh. It was reported that soil inoculation of *M. anisopliae* showed significant reduction in *Bactrocera invadens* adult emergence in both laboratory and mango orchard (Ekesi *et al.,* 2011). Therefore, in present study, the efficacy of some bio-pesticides against hog plum beetle was assessed in laboratory followed by field evaluation.

MATERIALS AND METHODS

Experiments on management of hog plum beetle, *Podontia 14-punctata* were carried out in the laboratory of Entomology Division as well as at the hog plum orchard of Regional Agricultural Research Station (RARS), Bangladesh Agricultural Research Institute (BARI), Rahmatpur, Barishal, Bangladesh (90°17˙29.9.84˝ E, 22˚78˙81.20˝ N), during two fruiting season 2018-19 and 2019-20. The laboratory experiment was carried out under normal room temperature (31.2 ± 2.1^0 C) and relative humidity (78 ± 5%) with a 14 ± 2: 10 ± 2 light and dark cycle (L:D) following Completely Randomized Design (CRD).

Bio-assay studies in laboratory

Laboratory bio-assay was carried out to find out the effective treatment which will be verified in field condition. The treatment modules were T_1 : soil drenching with *Metarhizium anisopliae* + *Trichoderma harzianum* + *Beauveria bassiana* + *Trichoderma viride* (Lycomax) @ 5 g/L of water, T_2: spraying with spinosad (Success 2.5 SC) @ 1.2 ml/L of water at hog plum leaflet, $T_{3:}$ spraying of azadirachtin (Bio-neem plus 1 EC) @ 1.0 ml/liter at hog plum leaflet, $T_{4:}$ spraying of chlorpyripos + cypermethrin (Nitro 505 EC) @ 0.75 ml/L of water at hog plum leaflet, T_5 : untreated control (water spray). The potential fungal isolate lycomax was sprayed @ 5 g/L of water in the soil. Spray volume of soil recharge (lycomax) was 100 ml/kg soil. After spraying in soil it was air dried for 6 hours then placed bottom of acrylic cage for pupation. Before applying 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 beetles were released in each acrylic cage containing 3 kg treated soil at the bottom of the cage. When the released larvae and adult beetles started normal movement then the treatments were applied by a hand sprayer as cover spray. After treating the leaflet, the mouth of the acrylic cage was covered with 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 noted at 24 hours interval after treatment up to 72 hours. Rate of pupation and adult emergence were also noted at 24 hours interval after treatment up to 30 days.

Field experiments

The experiment was conducted at the hog plum orchard of RARS, Rahmatpur, Barishal (90°17˙29.9.84˝ E, 22˚78˙81.20˝ N) during two fruiting season 2018-19 and 2019-20 in a Randomized Complete Block Design (RCBD) with five treatments and four replications. A total of 20 trees of around nine years old were used for this study. One hog plum tree was considered as one replication. Plant to plant distance was 20 ft × 20 ft. 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* + trunk banding with packaging tape + spraying with spinosad (Success 2.5 SC) @ 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) @ 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. T_4 = Farmers practice: spraying of chlorpyripos + cypermethrin (Nitro 505 EC) @ 0.75 ml/liter, T_5 = Untreated control (water spray). The potential fungal isolates lycomax was sprayed @ 5 g/L of water in the soil at onset of fruiting. Hand picking was done twice in a week. Trunk of hog plum tree banding with packaging tape was done at 7 April 2018 and 2019 before fruit setting. A total of three sprays/treatment applications were made at 10 days intervals. Each spray was done 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 was counted from inside each quadrat under different treatments at one day before the first spray and 1 week after each spray. The number of healthy and infested leaves was counted from inside each quadrat under different treatments at one day before the first spray and one week after each spray.

Statistical analysis

The experimental data were analyzed by SAS software. The mortality, pupation, adult emergence, infestation rate

a) Adult beetles of *Podontia* 14-*punctata*

b) Adult beetles + egg mass of *Podontia* 14-*punctata*

c) Larvae of *Podontia* 14-*punctata*

d) Pupae of *Podontia* 14-*punctata*

Plate 1. Different growth stages of hog plum beetle, *Podontia 14-punctata*

of *P. 14-punctata* was 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 *Podontia* 14-*punctata* were subjected to square root transformation before the Analysis of Variance (ANOVA) and Tukey's multiple range tests. (SAS Institute, 2012).

RESULTS AND DISCUSSION

Laboratory evaluation

Mortality of larva

The results (Table 1) showed that the mean larval mortality due to treatments ranged from 36.11 to 75.00%. From laboratory bio assay, it was shown that spinosad caused highest larval mortality (75.00%) which was followed by spraying of chlorpyripos + cypermethrin (61.11%) and spraying of azadirachtin (52.78%). The efficacy of spinosad, against hog plum beetle was also reported in previous studies (Khatun *et al.,* 2016). Soil drenching with microbial pesticide, lycomax did not cause significant larval mortality.

Mortality of pupa

The highest pupal mortality (51.85%) was recorded with soil drenching with microbial pesticides, *Metarhizium anisopliae* + *Trichoderma harzianum* + *Beauveria bassiana* + *Trichoderma viride* (Lycomax). But other treatments didn't show detrimental effect on pupal mortality compare to control (Table 1).

Mortality of adult

The results (Table 1) showed that the mean adult mortality after treatments application ranged from 22.22 to 72.22%. Among treatments, spinosad caused highest adult mortality (72.22%) which was followed by spraying of chlorpyripos + cypermethrin (58.33%) and spraying of azadirachtin (55.56%). Similarly, Khatun et al*.,* (2016) found that spinosad showed effect on adult hog plum beetle in laboratory condition. Adult mortality of hog plum beetle was not affected by soil drenching with microbial pesticides, lycomax.

Pupation and adult emergence

The treatments (Figure 1) showed significant effect on pupation and adult emergence. Spraying with spinosad offered very detrimental effects on both pupation and adult emergence but soil drenching with microbial pesticides, lycomax showed negative effects on adult emergence than rest of the treatments (Figure 1). Previous study (Ekesi *et al.,* 2011) revealed that soil inoculation of *M. anisopliae* showed significant reduction in *Bactrocera invadens* adult emergence in both laboratory and mango orchard.

From the laboratory trial it is clear that spraying of spinosad on hog plum leaflet had significant mortality on *P.* 14-*punctata* larva and adult compare to other treatments. Soil drenching with a microbial pesticide, lycomax cause higher pupal mortality causes significant effect on adult emergence of *P.* 14-*punctata.* Therefore, the pest management module soil drenching with microbial pesticides, lycomax + spraying with spinosad (Success 2.5 SC) at hog plum leaflet should be verified in filed condition.

Effectiveness of different pest management modules on *Podontia* 14-*punctata*

Two years field study showed that different pest management modules had significant mortality effect on the population of *P. 14-punctata.* The highest larval and adult population reduction, 82.40-82.58 and 78.50-80.88% over control was observed in Module 1 consisting of hand picking + soil drenching with microbial pesticides, lycomax + trunk banding with packaging tape + spinosad treated trees followed by Module 2 (hand picking + soil drenching with microbial pesticides, lycomax + azadirachtin and Farmers practice (Tables 2 and 4). The percent leaflet and fruit infestation was also significantly reduced, 80.80-88.40 and 78.41-81.74% when hog plum plants were treated with module 1 followed by Module 2, even though adults of *P. 14-punctata* easily cross hog plum trunk which was banding with packaging tape. Therefore, it is clear that without banding of the hog plum trunk, Hand picking + soil drenching with microbial pesticides, lycomax + spinosad (Success 2.5 SC) is the sustainable and environment friendly toxic chemical free safe pest management module against *P.* 14-*punctata* (Tables 3 and 5).

Yield

Yield of hog plum varied significantly with the level of fruit infestation by hog plum beetle depending on the efficacy of different management modules during both 2018-19 and 2019-20 fruiting season (Tables 3 and 5). The highest yield (17.61-18.36 t/ha) was obtained from Module 1: Hand picking + soil drenching with microbial pesticides, lycomax + trunk banding with packaging tape + spinosad imposing trees which was followed by to Module 2 tree (15.38-16.48 t/ha). The lowest yield (12.61-13.21 t/ha) was recorded from untreated control tree. Yield was 39.04-39.66% increased in Module 1 imposing tree compare to control.

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

Treatments	Mortality (%)		
	Larva	Pupa	Adult
T_1 = Soil drenching with microbial pesticides, *Metarhizium anisopliae* + *Trichoderma harzianum* + *Beauveria bassiana* + *Trichoderma viride* (Lycomax)	36.11^{c}	51.85^{a}	25.00^{c}
T_2 = Spraying spinosad (Success 2.5 SC) at hog plum leaflet	75.00^{a}	19.44^{b}	72.22^{a}
T_3 = Spraying azadirachtin (Bio-neem plus 1 EC) at hog plum leaflet	52.78^{b}	17.78^{b}	55.56^{b}
T_4 =Spraying of chlorpyripos + cypermethrin (Nitro 505 EC) at hog plum leaflet	61.11^{b}	13.89^{b}	58.33^{b}
T_5 = Untreated Control	36.11^{c}	13.10^{b}	22.22^{c}

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

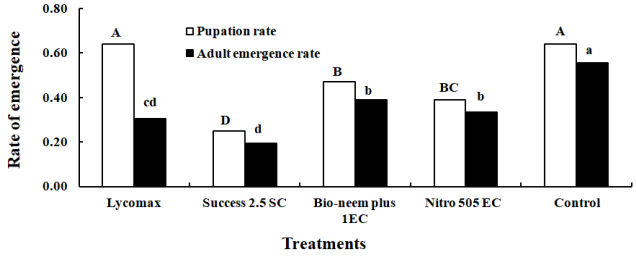

Fig. 1. Efficacy of different treatments on pupa and adult emergence of *Podontia* 14-*punctata* under laboratory condition (All means followed by same letters at each bar were not significantly different by Tukey's multiple range tests, ANOVA ($P < 0.05$).

Table 2. Efficacy of different pest management modules in controlling hog plum beetle, *Podontia* 14-*punctata* under field condition at Rahamatpur, Barishal hog plum orchard during 2018-19

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		
Module 1	11.35 ^{a}	3.37 ^{d}	12.45 ^{a}	3.35 ^{d}	82.58	78.50
Module 2	12.36 ^{a}	5.38 ^{bc}	10.34 ^{a}	5.58 ^{c}	72.20	64.18
Module 3	14.34 ^{a}	9.35 ^{b}	11.33 ^{a}	7.34 ^{b}	51.68	52.89
Farmers practice	13.55 ^{a}	7.58 ^{b}	11.52 ^{a}	8.59 ^{b}	60.83	44.87
Untreated Control	12.33 ^{a}	19.35 ^{a}	10.32 ^{a}	15.58 ^{a}	-	-

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

Note: Module 1: Hand picking + soil drenching with microbial pesticides, *Metarhizium anisopliae* + *Trichoderma harzianum* + *Beauveria bassiana* + *Trichoderma viride* (Lycomax) + trunk banding with packaging tape + Spinosad (Success 2.5 SC); Module 2= Hand picking + soil drenching with microbial pesticides, Lycomax + Azadirachtin (Bio-neem plus 1 EC); Module 3= Hand picking + soil drenching with microbial pesticides, Lycomax*;* Farmers practice: spraying of Chlorpyripos + Cypermethrin (Nitro 505 EC)

Table 3. Efficacy of different pest management modules on leaf and fruit infestation by hog plum beetle, *Podontia* 14-*punctata* under field condition at Rahamatpur, Barishal hog plum orchard during 2018-19

Treatments	Leaf infestation (%)	Fruit infestation (%)	Reduction of leaf infestation over control (%)	Reduction of fruit infestation over control (%)	Yield (ton/ ha)	Yield increased over control (%)
Module 1	2.37 ^{d}	2.84 ^{d}	88.40	81.74	18.36 ^{a}	39.04
Module 2	5.38 ^{c}	5.16 ^{bc}	73.67	66.82	16.48 ^{b}	24.76
Module 3	7.35 ^{bc}	7.39 ^{b}	64.02	52.48	15.80 ^{bc}	19.63
Farmers practice	9.56 ^{b}	8.56 ^{b}	53.21	44.95	14.95^{c}	13.21
Untreated Control	20.43 ^{a}	15.55 ^{a}	-	-	13.21^{d}	-

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

Note: Module 1: Hand picking + soil drenching with microbial pesticides, *Metarhizium anisopliae* + *Trichoderma harzianum* + *Beauveria bassiana* + *Trichoderma viride* (Lycomax) + trunk banding with packaging tape + Spinosad (Success 2.5 SC); Module 2= Hand picking + soil drenching with microbial pesticide, Lycomax + Azadirachtin (Bio-neem plus 1 EC); Module 3= Hand picking + soil drenching with microbial pesticide, Lycomax*;* Farmers practice: spraying of Chlorpyripos + Cypermethrin (Nitro 505 EC)

Table 4. Efficacy of different pest management modules in controlling hog plum beetle, *Podontia* 14-*punctata* under field conditions at Rahamatpur, Barishal hog plum orchard during 2019-20

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		
Module 1	9.61 ^{a}	2.59 ^{d}	10.90 ^{a}	3.10 ^{d}	82.40	80.88
Module 2	9.24 ^{a}	5.71 ^{b}	10.27 ^{a}	4.88 ^{c}	61.20	69.87
Module 3	9.58 ^{a}	7.27 ^{bc}	10.57 ^{a}	6.08 ^{b}	50.58	62.49
Farmers practice	9.58 ^{a}	5.54 ^{b}	9.92 ^{a}	7.68 ^{b}	62.38	52.62
Untreated Control	9.30 ^{a}	14.72 ^{a}	11.55 ^{a}	16.21 ^{a}	-	-

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

Note: Module 1: Hand picking + soil drenching with microbial pesticides, *Metarhizium anisopliae* + *Trichoderma harzianum* + *Beauveria bassiana* + *Trichoderma viride* (Lycomax) + trunk banding with packaging tape + Spinosad (Success 2.5 SC); Module 2= Hand picking + soil drenching with microbial pesticides, Lycomax + Azadirachtin (Bio-neem plus 1 EC); Module 3= Hand picking + soil drenching with microbial pesticides, Lycomax*;* Farmers practice: spraying of Chlorpyripos + Cypermethrin (Nitro 505 EC)

Table 5. Efficacy of different pest management modules on leaf and fruit infestation by hog plum beetle, *Podontia* 14-*punctata* under field condition at Rahamatpur, Barishal hog plum orchard during 2019-20

Treatments	Leaf infestation (%)	Fruit infestation (%)	Reduction of leaf infestation over control (%)	Reduction of fruit infestation over control (%)	Yield (ton/ha)	Yield increased over control (%)
Module 1	3.57 [d]	3.87 [d]	80.80	78.41	17.61 [a]	39.66
Module 2	5.67 [c]	6.33 [bc]	69.55	64.70	15.38 [b]	21.97
Module 3	5.91 [c]	8.24 [b]	68.26	54.08	14.27 [bc]	13.22
Farmers practice	7.40 [b]	8.73 [b]	60.25	51.35	13.98 [c]	10.87
Untreated Control	18.61 [a]	17.94 [a]			12.61 [d]	-

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

Note: Module 1: Hand picking + soil drenching with microbial pesticides, *Metarhizium anisopliae* + *Trichoderma harzianum* + *Beauveria bassiana* + *Trichoderma viride* (Lycomax) + trunk banding with packaging tape + Spinosad (Success 2.5 SC); Module 2 = Hand picking + soil drenching with microbial pesticides, Lycomax + Azadirachtin (Bio-neem plus 1 EC); Module 3 = Hand picking + soil drenching with microbial pesticides, Lycomax*;* Farmers practice: spraying of Chlorpyripos + Cypermethrin (Nitro 505 EC)

CONCLUSION

From the study it can be concluded that the pest management module comprising Hand picking of infested leaves with egg mass and larvae + soil drenching with microbial pesticides, [*Metarhizium anisopliae* + *Trichoderma harzianum* + *Beauveria bassiana* + *Trichoderma viride*] (Lycomax) + spraying of spinosad (Success 2.5 SC) effectively suppressed *Podontia* 14-*punctata* population which resulted in higher yield. Therefore, this toxic chemical pesticide free pest management module can be recommended for the production of safe hog plum in Bangladesh which might be helpful to ensure food security of the country.

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