International Journal for Asian Contemporary Research (2023), Volume 3, Number 2, Page 22-28

ISSN(e): 2789-4231 & ISSN (p): 2789-4223

International Journal for Asian Contemporary Research

www.ijacr.net

H&N Publications INTERNATIONAL

Research Article

Open Access

The Prevalence and Control of Red Palm Weevil, Rhynchophorus ferrugineus Oliver (Coleoptera:Curculionidae) Infestations on Date Palms in Bangladesh

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Article info

Received: 23 April 2023
Accepted: 26 May 2023
Published: 30 May 2023
Available in online:
02 July 2023

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A b s t r a c t

The red palm weevil (RPW), *Rhynchophorus ferrugineus* Oliver (Coleoptera: Curculionidae), is an invasive and destructive insect pest of date palms in many countries of the world, as well as in Bangladesh. The aim of this study was to investigate the prevalence and control technique of RPW at four locations in Bangladesh, viz., (i) BSRI farm, Ishurdi, Pabna; (ii) RSRS farm, Gazipur; (iii) Pirozali, Gazipur; and (iv) Goaspur, Pabna. A total of four integrated pest management (IPM) packages, such as (i) only pheromone trapping in the garen (March, May, July, September) (package 1); (ii) plantation of repellent plant + netting around the garden (February-August) + pheromone trapping (March, May, July, and September) (package 2); (ii) plantation of repellent plant + netting around the garden (February-August) + pheromone trapping (March, May, July, September) + application of Fipronil (Regent 3GR) in soil (March and July) (package 3); and (iv) plantation of repellent plant + netting around the garden (February-August) + pheromone trapping (March, May, July, and September) + spraying chloropyriphos (Dursban 20 EC) (May and September) (package 4) were applied in date palm gardens. The results revealed that the RPW population was 9.66 to 37.66; 16.00 to 38.33; 10.33 to 32.33; and 8.33 to 33.33 weevil garden^{-1} in 2020, and in 2021, it was 7.33 to 39.66; 9.33 to 40.64; 8.00 to 37.33; and 5.33 to 33.33 weevil garden^{-1} during the peak period of infestation in September in the date palm gardens treated with the IPM packages in BSRI Farm, RSRS Farm, Pirozali, and Goaspur locations, respectively. Among the four IPM packages, the significantly lowest population of 9.66, 16.00, 10.33, and 8.33 weevil garden^{-1} was found in 2020, and the population of 7.33, 9.33, 8.00, and 8.33 weevil garden^{-1} was found in 2021 in the gardens treated with package 4 in both locations, respectively. Therefore, IPM package 4 showed more potential against *R. ferrugineus* in field conditions and can be used as an alternative to only chemical pesticides, for the sustainable management of *R. ferrugineus.*

Keywords: Date palm, Red palm weevil, infestation, pheromone trap and control.

Introduction

The date palm tree is a member of the *Arecaceae* family and is well-known and familiar to people all over the world. In Bangladesh, it is well-known for its juice and gur during the winter. There are 14 species of date palm under the genus *Phoenix* in the world, with the most common being *Phoenix sylvestris* (L.) Roxb., which is grown naturally or by growers in the south-northern and central parts of Bangladesh. In the Indian subcontinent, it is known as Indian date palm. The growers nurture date trees for lateral juice production, which is managed for secondary production of molasses and patali. Nowadays, the Saudi date palm, *P. dactylifera* L., is becoming more popular due to its high nutritional and economic value. Every year, a large amount of dates are imported to meet our demand. Bangladesh imported 42,931 tonnes of dates as a popular iftar item in 2018, an increase of 6.32 percent year on year due to increased consumption of the fruit (Barua, 2018).

Insect pests are a major constraint on the production of date palms in Arabian country as well as Bangladesh. The red palm weevil (RPW), *Rhynchophorus ferrugineus* Oliver (Coleoptera: Curculionidae) was first reported in the eastern region of Saudi

Arabia in the mid-1980s (Sallam *et al.,* 2012) and then spread to other areas through infested planting material transported for farming and landscape gardening (Abdel-Raheem *et al.,* 2020; Dembilio and Jaques, 2015; Giblin-Davis, *et al.,* 2013). It has become the most destructive pest affecting date palm trees in several parts of the world, including Saudi Arabia (AlJabr *et al.,* 2017; Haq *et al.,*2018*;* Koubaa, *et al.,*2020). It is a notorious invasive insect pest over 26 species of palm trees belonging to 16 genera globally (Dhouibi *et al.,* 2017). It has emerged as the most damaging global palm tree pest, attacking nearly 40 species from 23 palm genera in over 60 countries (Giblin-Davis *et al.*, 2013; Al-Dosary *et al.*, 2016). The United Nations Food and Agriculture Organization (FAO) has designated RPW as a category 1 pest of date palm in the Middle East region (Faleiro *et al.*, 2011). It is very difficult to detect the infestation of RPW at early stages for its cryptic nature (most part of life stages occurred in the trunk). The RPW infestation in date palm usually occurs in young palms (<20 years old) on the trunk within one meter from the ground (Azam *et al.*, 2001). The mature weevils can fly relatively long distances during the day, up to one kilometer per day, and are active for the most of the year (Oehlschlager, 1998). The RPW infestations are distinguished by symptoms such as oozing from the tree trunk or crown drying. The RPW lays eggs inside the concealed place of trunk or cutting edges of pruned after shaving of older leaves. Then, after the eggs hatch, creamy white larvae emerge, which are the most destructive, feeding on internal succulent tissues and tunneling in palm trunks, which are only visible at the most severe infestation stage. According to FAO recommendations, date palm weevil infestation causes a 30% loss in date palm production every year (Soroker *et al.*, 2005).

This insect pest is generally controlled by the use of synthetic chemical-based insecticides. However, the widespread use of chemical insecticides has led to the emergence of resistance to a number of currently existing insecticides. Furthermore, the excessive use of insecticides has negative effects on human health as well as the environment (Mukherjee *et al.,* 2020). Now the public demand is to get crops with minimum insecticide residues. In addition to this, the large amount of world trade in agricultural crops requires environmentally friendly pest control methods. These requirements have led to an increasing awareness of finding effective options to control insect pests. Therefore, the objectives of this study were to determine the prevalence of the RPW in date palm gardens as well as effective management practices for controlling this insect pest.

Materials and Methods

Experimental Site

The study was carried out in the cropping year of 2020 and 2021 at four locations of Bangladesh viz., (i) Bangladesh Sugarcrop Research Institute (BSRI) farm, Ishurdi, Pabna, (ii) Regional Sugarcrop Research Station (RSRS) farm, Gazipur, (iii) Pirozali, Gazipur and (iv) Goaspur, Pabna. The climate of the locations is tropical to sub-tropical. The soil had an average sandy loam texture with a pH of 4.5 to 5.0. The soil was low in organic matter, ranging from 1.00 to 1.05%. The individual garden was 20m × 20m in size. Line to line distance was 5m, and plant to plant distance was 5m with a 2.5 m border. A total of 16 date palm plants were established in each garden, and each garden was treated as a treatment garden in which IPM packages were applied. Three gardens were established in each location as a replication. The tissue culture date palm variety Barhi was used as planting material, and planting was done through conventional plant placement in the soil pits.

Maintaining of the Palm Garden

Within 100–150 meters from the palm plantation, piles of rotting sugarcane, dead tree stumps, rotting garbage, rotting dead leaves, etc. were cleaned. Palm trees were usually cleaned and pruned between the months of February and November, and garbage were burned.

Establishment of insect repellent plants

Natural scented repellent plants such as mint, cantaloupe, sunflower, fragrant, lemon, lapa sak, and neem were planted around the base of date palm trees to keep the red palm weevil away from the palm tree due to the smell of these plants, resulting in a reduction in RPW infestation in date palm gardens.

Fertilizer Application

The date palm experimental garden was thoroughly prepared by plowing. Fertilizers such as urea, TSP, MOP, and cowdung were applied twice in equal splits during the final pit preparation and after six months of plantation, in April and September, @ 1.0 kg, 0.5 kg, 1.5 kg, and 20.0 kg per plant. All fertilizers were applied in 10-15 cm depth round the pit.

Agronomic management in palm garden

After cleaning the base of the palm trees, sprinkle 500 grams of Imidacloprid or Sevin powder 85 SP or Regent 50 SC mixed with 2 ml of water, were applied to the soil with irrigation water. Neem seed powder mixed with fine sand (2:1) was sprayed on the upper leaves of palm trees in February and August to prevent the red palm weevil from laying eggs on the plant.

Mechanical management in date palm garden

The dead leaves of palm trees were cut and burnt somewhere far away instead of being left around the garden. Young green leaves were harvested in February and November. The sucker/stem was cut from the root of the date palm tree, leaving 10-12 cm, and the cut sucker was placed in a safe place.

Use of insect-impervious netting

To avoid infestation, an innovative idea integrated with the IPM packages is to cover the base of the stems with an insect-proof net 1-2 meters above the soil's surface that may keep the insects away from the plants, saving them from infestation. From February to August, RPW impervious netting was used at the base of each palm tree for this purpose. The mesh had eight mesh holes to prevent the RPW from entering through the mesh holes. The net wrapped around the plant.

Using pheromone traps

Pheromone trapping is one of the most important components of integrated pest management. In this technique, pheromone trap was placed (one trap/garden) in the following way for mass trapping of RPW from the gardens to reduce the population of insects:

Step-1: A total of four holes (10cm × 2cm) were made laterally and four holes (10cm × 2cm) in the lid. The bucket was surrounded by coconut husks and jute sacks.

Step-2: One hundred grams of pineapple, two grams of yeast, and two grams of carbaryl were mixed with one liter of water and placed into the bucket.

Step-3: Pheromone lure (4-methyl-5-monanol 90% and 4-methyl-5-monanone 10%) and ethyl acetate were suspended and hung under the lid of the bucket.

Step-4: The bucket was kept in the palm garden infested with red palm weevil.

Step-5: Mixed detergent water was placed at the bottom of the bucket to increase humidity and drwon RPW in this mixture. Dead RPW were counted and recorded daily.

Step-6: The water was discarded every 7-15 days, and fresh water with detergent was added to the bottom of the bucket.

Step-7: The lure of pheromone trap was changed in every one or two months depending on the weather.

The experiment consisted of following four packages in cropping year 2020 and 2021.

Package 1: Only Pheromone trapping in the garden (March, May, July, September).

Package 2: Plantation of repellent plant + netting around the date palm garden (February-August) + Pheromone trapping (March, May, July, September).

Package 3: Plantation of repellent plant + netting around the date palm garden (February -August) + Pheromone trapping (March, May, July, September) + application of Fipronil (Regent 3GR) in soil (March and July).

Package 4: Plantation of repellent plant + netting around the date palm garden (February -August) + Pheromone trapping (March, May, July, September) + Spraying Chloropyriphos (Dursban 20 EC) (May and September).

Data Collection and Analysis

Field trials were conducted following a randomized complete block design (RCBD) with four treatments (as four packages) and three replicates of each treatment. The population number of adult RPW captured by pheromone trapping was collected and counted daily from the bucket with pheromone. The collected data of adult RPW were analyzed by the analysis of variance (ANOVA) and the means were compared by the least significant difference (LSD) test at 5% significance level using Statistix 10 software (Tallahassee, FL 32312, USA).

Results and Discussion

Prevalence and Effect of the IPM packages against RPW in date palm garden

The prevalence and effect of IPM packages against RPW in date palm gardens located in different places in Bangladesh, as shown by the data presented in Figures 1–8, showed that the IPM packages had a significant effect on the management of RPW, where different effects were found among the packages at different times and at different locations. The incidence of RPW, *Rhynchophorus ferrugineus* throughout the experimental period is presented in the Figures. The population densities per garden were recorded in every month. This study revealed that the population was fluctuated during this duration and different population densities were found among the gardens treated with different packages**.**

Effect at BSRI Location

At the BSRI location in 2020, the data presented in Figure 1 showed that after the application of the IPM packages, the lowest population (1.66 weevil garden^{-1}) of RPW was found on the gardens treated with Package 4 in March (F=12.43; p=0.005). At the same time, the highest population (7.00 adults garden^{-1}) was recorded in package 1 treated gardens. The population increased gradually with time and reached the peak in September (F=260.53; p<0.001), while the lowest population (9.66 weevil garden^{-1}) was observed in the garden treated with package 4,

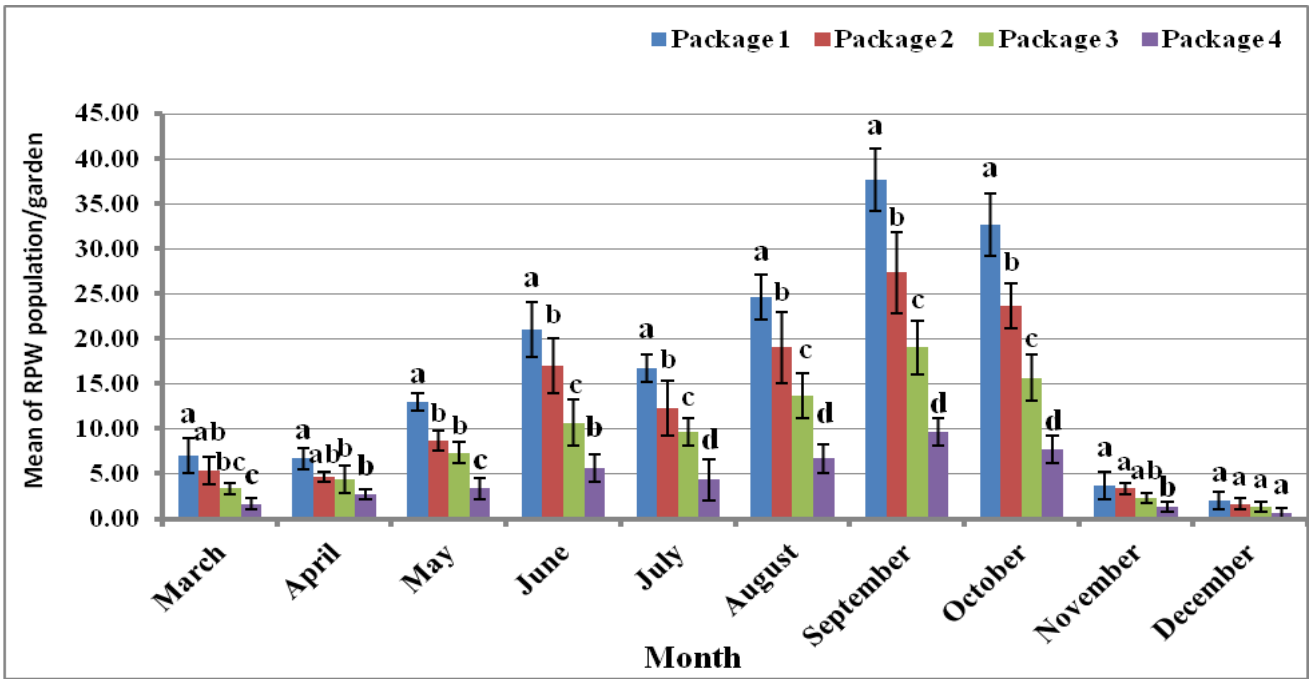

Figure 1. Polpulation of RPW per garden after treated with different IPM packages recorded at different time (every month) intervals at BSRI 2020. Different letters indicate significant differences (P ≤ 0.05) among the packages. Columns represent the mean ± SD (n = 3). SD=standard deviation. Package 1=Only Pheromone trapping in the garden (March, May, July, and September). Package 2=Plantation of repellent plant + netting around the date palm garden (February-August) + Pheromone trapping (March, May, July, and September). Package 3=Plantation of repellent plant + netting around the date palm garden (February -August) + Pheromone trapping (March, May, July, and September) + application of Fipronil (Regent 3GR) in soil (March and July). Package 4= Plantation of repellent plant + netting around the date palm garden (February-August) + Pheromone trapping (March, May, July, and September) + Spraying chloropyriphos (Dursban 20 EC) (May and September).

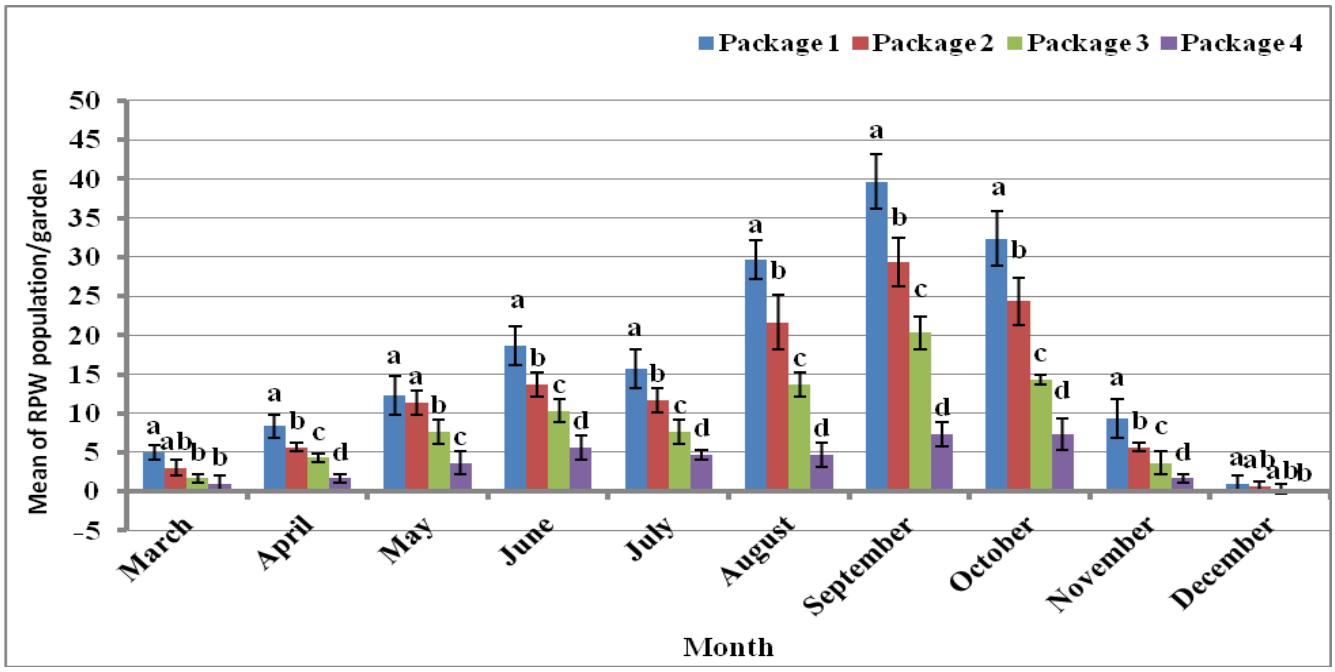

Figure 2. Polpulation of RPW per garden after treated with different IPM packages recorded at different time (every month) intervals at BSRI 2021. Columns represent the mean ± SD (*n* = 3). SD= standard deviation. Package 1= Only Pheromone trapping in the garden (March, May, July, and September). Package 2= Plantation of repellent plant + netting around the date palm garden (February-August) + Pheromone trapping (March, May, July, and September). Package 3=Plantation of repellent plant + netting around the date palm garden (February -August) + Pheromone trapping (March, May, July, and September) + application of Fipronil (Regent 3GR) in soil (March and July). Package 4= Plantation of repellent plant + netting around the date palm garden (February-August) + Pheromone trapping (March, May, July, and September) + chloropyriphos (Dursban 20 EC) (May and September).

followed by package 3 (19.00 adults garden^{-1}), and a significant difference was found among the packages (Figure 1). The population then decreased with increasing time, reaching a minimum in December (*F=2.06; p=0.20*), with a very small population (0.66 weevil garden^{-1}) found in package 4-treated gardens.

In the same location in 2021, a population of 1 weevil garden^{-1} was found in package 4 treated gardens, and a highest population of 5.00 weevil garden^{-1} was observed in package 1 treated gardens in March (*F*=1.89; *p*=0.22) (Figure 2). In the peak period of infestation in September 2021 (*F*=68.98; *p*<0.001), the lowest population (7.33 weevil garden^{-1}) was found in the garden treated with IPM package 4, compared to a population of 20.33 weevil garden^{-1}, 29.33 weevil garden^{-1}, and 39.66 weevil garden^{-1} found in package 3, package 2, and package 1-treated gardens, respectively (Figure 2).

Effect at RSRS farm, Gazipur Location

The data presented in Figure 3 showed the application effects of the IPM packages at the RSRS farm, Gazipur location in 2020. Among the four packages applied in the date palm gardens, package 4 showed the lowest population (5.00 weevil garden^{-1}) of RPW, while package 1 showed the highest population (9.00 weevil garden^{-1}) in March (*F*=2.77; *p*=0.133).

In the treated gardens, the population ranged from 5.00 to 10.00 weevil garden^{-1}, 4.00 to 10.33 weevil garden^{-1}, 8.00 to 16.66 weevil garden^{-1}, 10.00 to 17.33 weevil garden^{-1}, and 15.00 to 25.66 weevil garden^{-1} was recorded in April (*F=2.77; p=0.133*), May (*F=2.77; p = 0.133*), June (*F=2.77; p=0.13*), July (*F*=2.77; *p*=0.133) and August (*F*=2.77; *p*=0.133) 2020,, respectively. In September 2020 (*F=17.46; p=0.002*), package 4 treated gardens had the highest population range of 16.00 to 38.33 weevil garden^{-1} compared to other packages (Figure 3).

In 2021, the highest population ranged from 9.33 to 40.64 weevil garden^{-1}; this was also found in September (*F=71.22; p<0.001*), where package 4 treated gardens showed the lowest population of 9.33 weevil garden^{-1} (Figure 4).

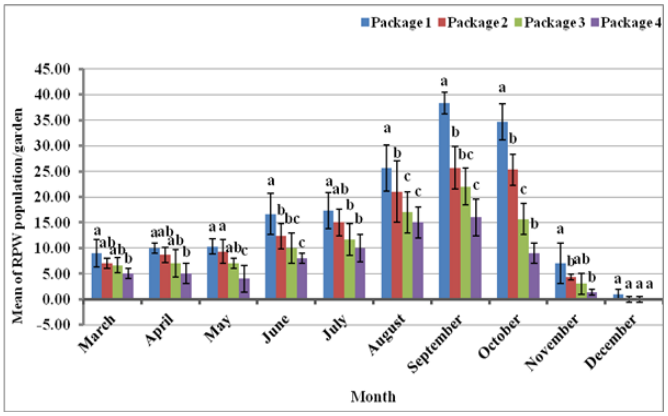

Figure 3. Polpulation of RPW per garden after treated with different IPM packages recorded at different time (every month) intervals at RSRS Gazipur 2020. Columns represent the mean ± SD (*n* = 3). SD= standard deviation. Package 1=Only Pheromone trapping in the garden (March, May, July, and September). Package 2=Plantation of repellent plant + netting around the date palm garden (February-August) + Pheromone trapping (March, May, July, and September). Package 3= Plantation of repellent plant + netting around the date palm garden (February -August) + Pheromone trapping (March, May, July, and September) + application of Fipronil (Regent 3GR) in soil (March and July).Package 4=Plantation of repellent plant + netting around the date palm garden (February-August) + Pheromone trapping (March, May,

July, and September) + Spraying chloropyriphos (Dursban 20 EC) (May and September).

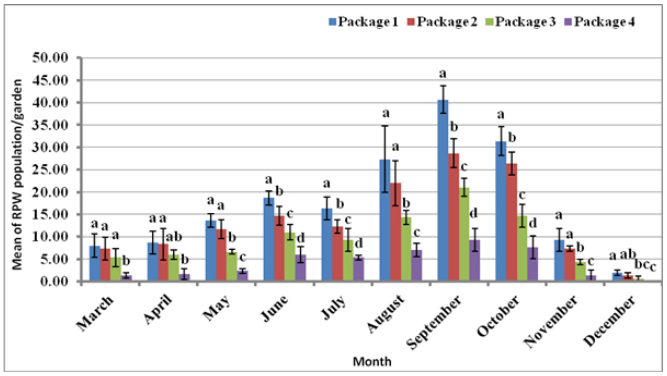

Figure 4. Polpulation of RPW per garden after treated with different IPM packages recorded at different time (every month) intervals at RSRS Gazipur 2021. Different letters indicate significant differences ($P \leq 0.05$) among the packages. Columns represent the mean ± SD (n = 3). SD= standard deviation. Package 1=Only Pheromone trapping in the garden (March, May, July, September). Package 2=Plantation of repellent plant + netting around the date palm garden (February-August) + Pheromone trapping (March, May, July, September). Package 3= Plantation of repellent plant + netting around the date palm garden (February -August) + Pheromone trapping (March, May, July, September) + application of Fipronil (Regent 3GR) in soil (March and July). Package 4= Plantation of repellent plant + netting around the date palm garden (February -August) + Pheromone trapping (March, May, July, September) + Spraying chloropyriphos (Dursban 20 EC) (May and September).

Effect at Pirojali, Gazipur Location

The *R. ferrugineus* population observed at Pirojali, Gazipur location from March to December 2020 after the application of the IPM packages is presented in Figure 5. The population ranges from 1.33 to 6.00 weevil garden^{-1}, 2.33 to 6.00 weevil garden^{-1}, 3.33 to 11.66 weevil garden^{-1}, 5.00 to 19.66 weevil garden^{-1}, 5.00 to 16.00 weevil garden^{-1}, 5.66 to 23.00 weevil garden^{-1}, 10.33 to 32.33 weevil garden^{-1}, 7.33 to 31.00 weevil garden^{-1}, 7.00 to 30.66 weevil garden^{-1}, and 1.33 to 3.00 weevil garden^{-1}, were found in the treated gardens at March (*F=5.01; p=0.045*), April (*F=6.23; p=0.028*), May (*F=16.43; p=0.002*), June (*F=47.16; p<0.001*), July (*F=20.92; p=0.001*), August (*F=93.76; p<0.001*) , September (*F=54.28; p<0.001*), October (*F=110.46; p<0.001*), November (*F=1004.64; p<0.001*) and December (*F=1.69; p=0.268*), respectively. Throughout the study period, the lowest population was found in package 4 treated gardens (Figure 5).

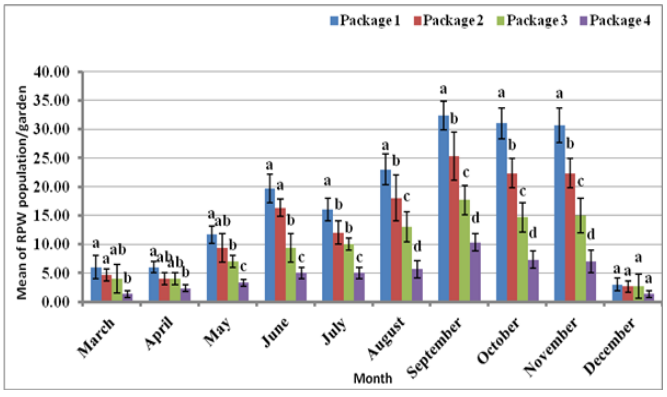

Figure 5. Polpulation of RPW per garden after treated with different IPM packages recorded at different time (every month) intervals at Pirojali, Gazipur 2020. Columns represent the mean ± SD (n = 3). SD= standard deviation. Package 1= Only Pheromone trapping in the garden (March, May, July, and September). Package 2= Plantation of repellent plant + netting around the date palm garden (February-August) + Pheromone trapping (March, May, July, and September). Package 3=Plantation of repellent plant + netting around the date palm garden (February -August) + Pheromone trapping (March, May, July, and September) + application of Fipronil (Regent 3GR) in soil (March and July). Package 4= Plantation of repellent plant + netting around the date palm garden (February-August) + Pheromone trapping (March, May, July, and September) + Spraying chloropyriphos (Dursban 20 EC) (May and September).

The highest population range from 8.00 to 37.33 weevil garden^{-1} at Pirojali, Gazipur Location in 2021; this was also observed in September, when package 4 treated gardens had the lowest population of 8.00 weevil garden^{-1} (Figure 6).

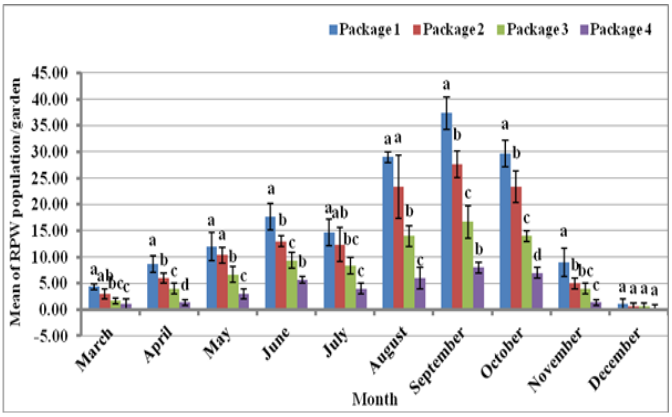

Figure 6. Polpulation of RPW per garden after treated with different IPM packages recorded at different time (every month) intervals at Pirojali, Gazipur 2021. Columns represent the mean ± SD (n = 3). SD= standard deviation. Package 1= Only Pheromone trapping in the garden (March, May, July, and September). Package 2= Plantation of repellent plant + netting around the date palm garden (February-August) + Pheromone trapping (March, May, July, and September). Package 3= Plantation of repellent plant + netting around the date palm garden (February -August) + Pheromone trapping (March, May, July, and September) + application of Fipronil (Regent 3GR) in soil (March and July). Package 4= Plantation of repellent plant + netting around the date palm garden (February-August) + Pheromone trapping (March, May, July, and September) + Spraying chloropyriphos (Dursban 20 EC) (May and September).

Effect at Goaspur, Pabna Location

Figure 7 depicts statistically analyzed data on the population of *R. ferrugineus* collected from March to December 2020 in Goaspur, Pabna Location, following the application of the IPM packages. A population of 1.00 to 5.66 weevil garden^{-1} was found in March (*F=10.10; p=0.009*), 2.33 to 5.00 weevil garden^{-1} in April (*F=11.91; p=0.06*), 3.00 to 11.66 weevil garden^{-1} in May (*F=12.90; p=0.005*), 5.00 to 20.00 weevil garden^{-1} in June (*F=22.16; p=0.001*), 5.33 to 16.66 weevil garden^{-1} in July (*F=61.28; p<0.001*), 4.00 to 20.33 weevil garden^{-1} in August (*F=30.30; p<0.001*), 8.33 to 33.33 weevil garden^{-1} in September (*F=318.15; p<0.001*), 7.33 to 31.00 weevil garden^{-1} in October (*F=92.11; p<0.001*), 5.66 to 30.33 weevil garden^{-1} in November (*F=71.18; p<0.001*) and 1.00 to 2.33 weevil garden^{-1} in December (*F=2.06; p=0.207*) in the treated gardens. All through the observation period, package 4 treated gardens had also the lowest population in this location (Figure 7). In the same location in 2021, during the peak period of infestation in September 2021 (F=91.60; p<0.001), a population of 5.33 to 33.33 weevil garden^{-1} was found in the treated gardens, while the lowest population was found in package 4 treated garden compared to a

population of the gardens treated with other packages (Figure 8). Thus, package 4 was found to be the best among all the packages, showing a reduction in the population of *R. ferrugineus* in the date palm gardens in all the locations both in 2020 and 2021.

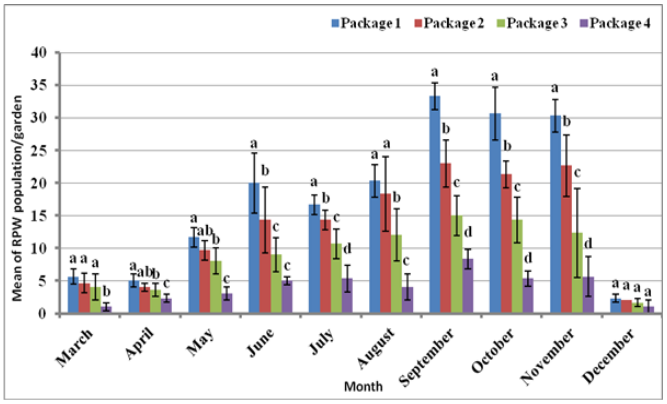

Figure 7. Polpulation of RPW per garden after treated with different IPM packages recorded at different time (every month) intervals at Goaspur 2020. Columns represent the mean ± SD (*n* = 3). SD= standard deviation. Package 1= Only Pheromone trapping in the garden (March, May, July, and September). Package 2= Plantation of repellent plant + netting around the date palm garden (February-August) + Pheromone trapping (March, May, July, and September). Package 3= Plantation of repellent plant + netting around the date palm garden (February -August) + Pheromone trapping (March, May, July, and September) + application of Fipronil (Regent 3GR) in soil (March and July). Package 4= Plantation of repellent plant + netting around the date palm garden (February-August) + Pheromone trapping (March, May, July, and September) + Spraying chloropyriphos (Dursban 20 EC) (May and September).

In this study, the results obtained showed that the adult RPW population in the date palm gardens treated with IPM packages was minimum in March. The population gradually increased and provided the highest value in September. After September, the population declined and reached a minimum in December (Figures 1 to 8). Similarly, Shar *et al.* (2012) observed that RPW infestation was significantly higher in the month of June, July and August during the study period. In another study, Soroker *et al.* (2005) reported that the use of pheromone traps contributed to a reduction in the RPW population attacking date palm plantations in Israel. They also found that the application of systematic insecticides to the soil and tops of plants serves as a curative and preventive measure in IPM activities for controlling RPW. According to Shukla *et al.*(2017), the stump trap is more effective than the tree trap. Soroker *et al.* (2005) also examined the effects of spraying alone and of spraying combined with pheromone trapping. They mentioned that about 30% less infestation was derived from the combined use of spray and pheromone traps compared with spray alone.

Researchers throughout the world used different types of biopesticides in controlling the insect pests and diseases of date plants with no or limited work with RPW in Bangladesh. In a new integrated approach, insect repellent trees, herbs, and shrubs such as Marigold, Mint, Tulshi, and Neem should be planted in between the plants to prevent RPW insects from coming into contact with date palm plants. The insect-repellent plants not only provide protection against harmful insects but also provide leaf biomass through shredded leaves in the soil. Some of the insect-repellent plants also act as mulch crops and weed-suppressive plants. The component of IPM, chemical insecticide such as chlorpyrifos is a broad-spectrum insecticide which kills insects upon contact by affecting the normal function of the nervous system.

However, our results showed that the IPM package 4 was the most potential package in field conditions in reducing the infestation of RPW. Therefore, this package could be applied as an IPM package in date palm cultivation.

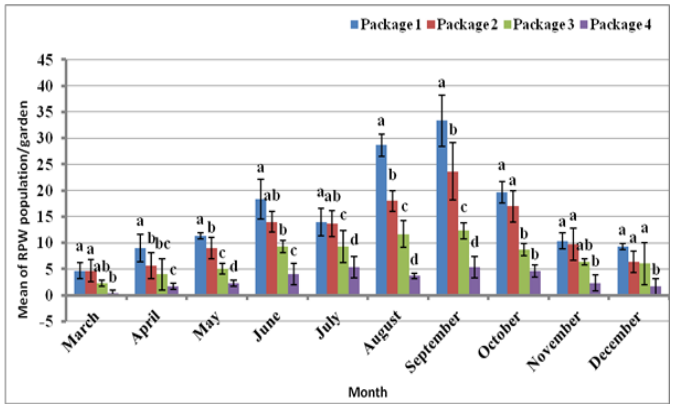

Figure 8. Polpulation of RPW per garden after treated with different IPM packages recorded at different time (every month) intervals at Goaspur 2021. Columns represent the mean ± SD (*n* = 3). SD= standard deviation. Package 1= Only Pheromone trapping in the garden (March, May, July, and September). Package 2= Plantation of repellent plant + netting around the date palm garden (February-August) + Pheromone trapping (March, May, July, and September). Package 3= Plantation of repellent plant + netting around the date palm garden (February -August) + Pheromone trapping (March, May, July, and September) + application of Fipronil (Regent 3GR) in soil (March and July). Package 4= Plantation of repellent plant + netting around the date palm garden (February-August) + Pheromone trapping (March, May, July, and September) + Spraying chloropyriphos (Dursban 20 EC) (May and September).

Conclusion

According to the findings of the study, *R. ferrugineus* infestation varies from location to location, with some showing higher infestation and others showing lower infestation. The beetle was found all year, but the population was highest from August to October. Package 4 (Plantation of repellent plant + netting around the date palm garden (February-August) + Pheromone trapping (March, May, July, and September) + Spraying chloropyriphos (Dursban 20 EC) (May and September) was found to be a potential and most effective package for the management of *R. ferrugineus* in field conditions, when compared to other packages. To the best of our knowledge, this package is the first to be reported as a potential IPM package against *R. ferrugineus*, and it is expected to be an alternative to only chemical-based insecticides for *R. ferrugineus* management.

Conflict of interest

The authors state that they did not have any commercial or financial associations that could be interpreted as a possible conflict of interest during the research work.

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To cite this article: Rahman, M.A., Alam, M.N., Siddiquee, M.N.A., Reza, M.E., and Islam, M.S. (2023). The Prevalence and Control of Red Palm Weevil, *Rhynchophorus ferrugineus* Oliver (Coleoptera:Curculionidae) Infestations on Date Palms in Bangladesh. *International Journal for Asian Contemporary Research,* 3 (2): 22-28.