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Synchronization of Synthetic Insecticides with Aggregation Pheromone Against *Rhynchophorus ferrugenius* (Oliver).

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Abstract. Aggregation pheromone (ferrolure$^+$) has the potential for successful detection, monitoring and management of Red palm weevil (RPW), *Rhynchophorus ferrugenius.* Therefore, studies were undertaken to evaluate the effectiveness of aggregation pheromone (ferrolure$^+$) along with synthetic insecticides i.e., Karate 0.25 EC (Lambda-cyhlothrin), Coragen 20SC (Chlorantranliprole), Curacron 50 EC (profenophos), Steward 150EC (indoxacarb) and Talstar 10EC (bifenthrin) for the management of RPW. Control treatments with and without ferrolure$^+$ were also maintained. Four traps per acre were applied in each study arranged in a randomized complete block design. Weekly observations were taken till the effectiveness of ferrolure$^+$. Results confirmed that addition of synthetic insecticides showed a negative impact on the mean capture of RPW except for indoxacarb (7.59±0.89 weevils per trap) that attract significantly same but comparatively less RPW attracted towards only ferrolure$^+$ pheromone traps (8.74±0.96 weevils per trap). Overall RPW captured in remaining treatments i.e., chlorantranliprole, lambda-cyhlothrin, profenophos and bifenthrin were 4.56+0.65 weevils per trap; (5.22+0.69) weevils per trap; 5.63+0.71 weevils per trap and 5.48+0.89 weevils per trap, respectively. A gradual rise was recorded in mean capture of RPW in all treatments till week five after installation and then declined rapidly upto week eight. More than double number of females were captured in traps with maximum male to female ratio (1:2.26) captured in lambda-cyhlothrin treatment. Therefore, it is suggested that ferrolure$^+$ traps should be included in the integrated management programs of RPW and indoxacarb pesticide, if required, may be added in trap to get maximum killing of weevils, particularly females that will also help reduce future population growth.

Keywords: aggregation, management, pesticides, pheromone, red palm weevil

Introduction

Red palm weevil (RPW), *Rhynchophorus ferrugenius* (Coleoptera: Dryophthoridae) is a key and highly devastating pests of palms grown in every region of the globe (Abbas *et al*., 2019; Ju *et al*., 2011; Faleiro, 2006). In the history, it is responsible for the worst outbreak of the date (Ali-Bob, 2019; Faleiro, 2006) and urban (Sardaro *et al*., 2018) canary palm trees throughout the world with sustainable losses to palm trees. It is supposed to be native of sub-continent countries but now present in all palms growing areas of the world (Al-Saoud *et al*., 2010). More than twenty-six palms belonging to sixteen genera from various countries of Asia, north Africa, Europe, Oceania and Caribbean countries served as host of RPW (Malumphy and Moran, 2009, 2007; EPPO, 2007). Moreover, during 2008 and 2009 He *R. ferrugineus* started establishing its populations on the islands of the American Caribbean, Curaçao and Aruba, whereas Brazil declared it an A1 quarantine pest in the country with a considerable risk and potential threat for the Brazilian territory invasion (Dalbon *et al*., 2021).

Both adults and nymphs are damaging stages, with latter being the most severe. Moreover, due to its concealed damage nature inside trees, its early detection is very difficult until losses of palms have already been done (Faleiro, 2006). Varying levels of economic losses are reported due to attack of pest with the loss of whole palms in case of severe attack (Çiirikkaya *et al*., 2014; Inghilesi *et al*., 2013; Manachini *et al*., 2013).

The control strategies against RPW throughout the world in general and in Pakistan particularly are based on frequent application of synthetic pesticides (Dembilio and Jaques, 2015; Ferry and Gomez, 2002) but the recent studies suggested the effectiveness of aggregation pheromones (ferrolure$^+$) not only in the monitoring but also in the mass trapping of RPW (Dhouibi *et al*., 2018; Vacas *et al*., 2016; 2014; 2013; Hoddle *et al*., 2013;

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Hoddle and Hoddle, 2011). Moreover, the addition of various food baits *i.e*., pineapple fruit, sago palm stem and sugarcane stem, fermented dates and chemicals like ethyl acetate has been found to have kairomonal effects to increase the effectiveness of the pheromone lures (Azmi *et al.,* 2014; Faleiro, 2005). However, the use of aggregation pheromone ferrolure$^+$ is still in preliminary stage in Pakistan (Arfan *et al*., 2017) as mostly local farmers depend upon systematic chemicals are the best available option to reduce RPW damage once their palms are damaged (Manzoor *et al*., 2020; Llácer *et al*., 2012). But these chemicals are very harmful to humans and their environment. Therefore, considering the importance of aggregation pheromones, food baits and synthetic insecticides in the management of RPW, studies were taken to determine effectiveness of aggregation pheromone ferrolure$^+$ against RPW when applied in mixtures with various insecticides as most of the farmers still rely on them for the management of weevils in the orchards.

Materials and Methods

Study location. The experiment was carried out at in a densely populated and highly RPW infested date palm orchards in district Khairpur, Sindh, Pakistan. The size of Orchard was ten acres containing more than 200 trees of date palm of different varieties and mixed ages. The experiment was set up on 1st June 2018 considering the active period of RPW owing to favourable conditions because of the plantation of suckers for new propagation.

Preparation of pheromone traps. The pheromone traps were prepared accordance with the (Soomro *et al*., 2020). Red-coloured plastic buckets (36 cm L and 26, 20 cm diameter at the top and bottom, respectively) were used for traps. For the entrance of RPW, sides and top of each trap has rough surface along with four equidistant rectangular (3 x 7 cm). Red palm weevil aggregation pheromone (P028 ferrolure$^{+®}$ ChemTica International, Costa Rica) was attached to the lower surface of the lid with iron wire.

Synthetic insecticides used in the study. The insecticides used in the study are given with their recommended dose applied in ferrolure$^+$ pheromone traps against RPW *i.e*., Karate 0.25 EC (lambda-cyhlothrin) 250 mL /acre or 2.50 mL/L of water; Coragen 20SC (chlorantranliprole) 200 mL/acre 2.00 mL/ L of water; Curacron 50 EC (profenophos) 500 mL/acre 5.00 mL/L of water; Steward 150EC (indoxacarb) 150 mL/acre 1.50 mL/L of water; Talstar 10EC (bifenthrin) 200-250 mL/acre 2.50 mL/L of water; Control (pheromone trap without insecticide)

Each pesticide was applied at its recommended dose mixed with water in individual traps. Four replications were maintained for each treatment in a randomized complete block design. Each treatment trap was placed at a minimum distance of 1000 meters from each other to avoid the interference among various treatments.

Data collection and analysis. Data collection was started with installation of pheromone traps in the orchards and then continued weekly until effectiveness of the traps. All the attracted weevils in the traps were counted and separated as males and females based on their distinguished morphological features as suggested by (Dembilio and Jacas, 2011; Menon and Pandalai, 1960). Apical dorsal half of the male's snout is generally covered with a patch of brownish short hairs. However, no such hairs are present on snout of females and it is bare, slenderer, curved and a little longer than the males. Analysis of variance and the least significant difference test were applied at 5% probability to analyze the data and separate means with significant differences, respectively. All analysis was done using STATISTIX 8.3 computer software.

Results and Discussion

Although, installation of ferrolure$^+$ aggregation pheromone with insecticides showed their effectiveness to attract RPW but a highly significant reduction ($F = 15.02$, $P < 0.001$) was observed in the mean capture of RPW in traps supplied with insecticides (Fig. 1). The results indicated that the maximum attraction of weevils attracted to pheromonal traps containing only ferrolure$^+$ (8.74±0.96 weevils per trap) but not significantly different from RPW captured in traps containing Indoxacarb (7.59±0.89 weevils per trap). Moreover, the attraction of weevils recorded in the remaining significantly lower from above treatments but similar to each other. Thus, the overall, mean capture recorded in the pheromone traps containing chlorantranliprole, lambda-cyhlothrin, profenophos and bifenthrin was 4.56+0.65 weevils per trap; 5.22+0.69 weevils per trap; 5.63+0.71 weevils per trap and 5.48+0.89 weevils per trap, respectively. The observation wise data revealed that the mean per week attraction of RPW showed an increasing trend up to week five *i.e*., 6th July 2018 and then declined drastically as no weevil was captured

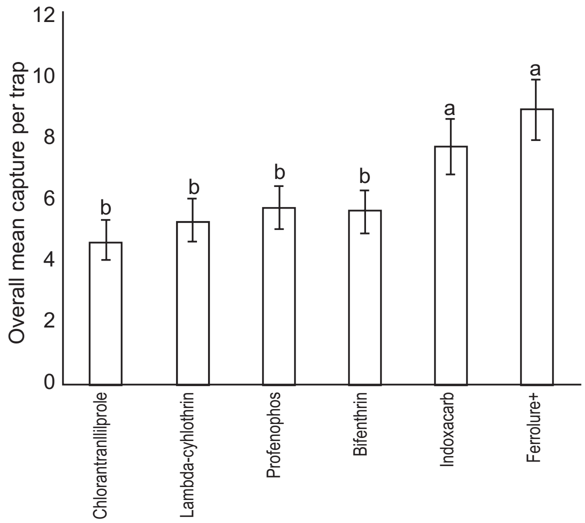

Fig. 1. Mean capture of *Rhynchophorus ferrugineus* (RPW) using ferrolure+ mixed with synthetic pesticides *Means followed by same letters are not significantly different (LSD = 1.9227, P < 0.05)

after 27th July 2018 in all the treatment traps. Accordingly, the highest per week mean attraction of RPW was recorded in control with only ferrolure+ (14.33±2.03 weevils per trap) followed by Indoxacarb (13.00±1.86 weevils per trap). Moreover, the maximum mean attraction recorded in chlorantranliprole, lambda-cyhlothrin, profenophos and bifenthrin treatments was 8.67±1.76 weevils per trap; 9.00±1.15 weevils per trap; 9.67±1.76 weevils per trap and 9.67±1.67 weevils per trap, respectively.

The weekly observation data also indicated that overall, the highest weekly mean population of RPW captured was recorded during week five *i.e.*, 5th July 2020 (10.72±0.96 weevils per week) followed by week four *i.e.*, 28th June 2020 (9.67±0.74 weevils per week), The lowest weekly mean attraction of RPW in various treatments was recorded during eighth week of study *i.e.*, 26th July 2020 (1.44±0.29 weevils per week) (Table 1).

Results also confirmed higher female attraction in the ferrolure+ traps mixed with different insecticides (Table 2) as more than double females were captured in traps than males. The maximum male to female ration attracted to traps was observed in Lambda-cyhlothrin (1:2.26), whereas overall male to female ration in different treatments was 1:2.17

Since the discovery of aggregation pheromone of *R. ferrugineus* by Hallett *et al.* (1993), it is widely used and considered as a basic and key element for its integrated management in almost all date palm growing areas of the world (Manzoor *et al*., 2020; Hashim and Ali, 2019; Vacas *et al*., 2014, 2013 ; Hoddle *et al*., 2013). However, it has been reported that addition of synthetic pesticides in pheromone traps capture a smaller number of weevils as El-Shafie *et al.* (2011) noticed comparatively less but significantly same mean attraction of RPW towards Hook RPW (containing pheromone and cypermethrin) and food baited pheromone traps (FBPT-treated) plots throughout the three month duration of their experiment.

Although, aggregation pheromones are used in various parts of the globe but still, most of the farmers depend on the use of synthetic pesticides, either as protectants or through trunk injection to control various stages of RPW (Ahmad, 2021). In coconut Orchards of south Asia, initial control programs against RPW were based on the use of organo phosphate and carbamate insecticides, as both group of pesticides were used either as preventive or curative purposes (Faleiro, 2006). However, with the advancement in the development of pesticides due to less effectiveness and more hazards of above mentioned pesticides, recently new generation insecticides *i.e*., neonicotinoid (imidacloprid) and phenyl pyrazole (fipronil) are practiced widely against RPW in date palms with variable control operations (Al-Shawaf *et al*., 2010). In a study, repeated application of large quantities of synthetic insecticides *i.e*., emamectin benzoate, imidacloprid, fiprol (cyclodines), dureracide (organophosphate) and *Steinernema carpocapsae* with chitosan (Biorend R® Palmeras) formulation have been evaluated against *R. ferrugineus* in the field, with Fiprol being the most effective (Chihaoui-Meridja *et al*., 2020; Mohammed *et al*., 2020; Dembilio and Jaques, 2011).

However, in this study, addition of synthetic insecticides mostly showed a detrimental impact on the mean capture of RPW in the pheromone traps as comparatively less number was attracted in traps containing insecticides plus ferrolure+. Only, the treatment containing Indoxacarb with ferrolure+ capture significantly same but a smaller number of RWP as compared to traps containing only ferrolure+. The reason for less low level of attraction of RPW in pesticides containing pheromone traps may be

Table 1. Impact of different synthetic insecticides on performance of ferrolure+ traps to capture *Rhynchophorus ferrugineus*

Observation	Insecticides						
Dates	Chlorantran-liprole	Lambda-cyhlothrin	Profenophos	Bifenthrin	Indoxacarb	Ferrolure+	Overall weekly mean population
07-Jun-2020	4.33±0.88g-o	4.67±1.20g-o	6.00±0.58e-n	6.33±0.67d-n	7.33±0.58b-l	8.33±0.88a-j	6.17±0.63d
14-Jun-2020	5.33±1.20f-o	6.33±0.88d-n	6.67±1.20c-m	7.33±0.88b-l	10.00±0.88a-f	11.33±0.88a-d	7.83±0.95c
21-Jun-2020	6.33±1.45d-n	8.00±0.58a-k	8.67±1.20a-i	8.00±1.53a-k	10.67±2.03a-e	11.67±2.03abc	8.89±0.80bc
28-Jun-2020	7.67±1.45b-l	8.33±2.33a-j	9.33±1.76a-h	9.00±1.15a-h	11.33±1.20a-d	12.33±1.76ab	9.67±0.74ab
05-Jul-2020	8.67±1.76a-i	9.00±1.15a-h	9.67±1.76a-g	9.67±1.67a-g	13.00±1.86ab	14.33±2.03a	10.72±0.96a
12-Jul-2020	5.67±1.76e-o	6.67±1.45c-m	6.00±0.58e-n	5.67±0.33e-o	8.67±0.88a-i	10.67±0.88a-e	7.22±0.83cd
19-Jul-2020	2.67±0.33k-o	2.67±0.88k-o	2.67±0.33l-o	2.33±0.67l-o	5.00±0.88f-o	6.67±0.33c-m	3.67±0.72e
26-Jul-2020	0.33±0.33o	1.33±0.88no	1.67±0.88mno	1.00±0.58	2.00±1.20l-o	2.33±1.20l-o	1.44±0.29f

*Means followed by same letters are not significantly different (LSD = 5.4381, P < 0.05)

Table 2. Sex ratio of *Rhynchophorus ferrugineus* attracted to different ferrolure+ traps with various synthetic insecticides

Food bait	Males	Females	Sex ratio Male: Female
Chlorantranliprole	18	36	1: 2.00
Profenophos	52	104	1: 2.00
Lambda-cyhlothrin	31	70	1:2.26
Indoxacarb	72	161	1: 2.24
Bifenthrin	61	131	1: 2.15
Control (ferrolure+)	81	182	1: 2.25
Overall	315	684	1:2.17

due to strong odour of pesticides. Therefore, most of the studies on use of aggregation pheromones used various food baits and kairomone materials to enhance to mean capture of RPW (Manzoor *et al.*, 2020; Hashim and Ali, 2019; Mohammadpour *et al.*, 2018; Azmi *et al.*, 2014; Vacas *et al.*, 2014). However, some researchers suggested to use of non-repellent insecticides such as deltamethrin, carbaryl or chlorpyrifos can help to retain and kill the adult weevils captured in the traps (Hoddle and Hoddle, 2011; Faleiro, 2006). Moreover, the use of synthetic pesticides in pheromone traps is also discouraged because of the death of beneficials insects and vertebrates that may be attracted to these traps supplied with food baits such as parasitoids (Dalbon *et al*., 2021; Lhor *et al*., 2019; Sumano *et al*., 2012; Moura *et al*., 2006; Osorio-Osorio *et al*., 2003). In some instances, rainwater may enter the traps, causing pesticides to pour out of traps and absorbed in soil, thus causing soil and environmental pollution (Murguía-González *et al*., 2018; Sumano *et al*., 2012).

The use of ferrolure+ aggregation pheromone against RPW in various studies has confirmed that it attracts both males and females but mostly a female dominant capture has been reported (Al-Saoud *et al.*, 2010; Al-Saoud, 2009a,b, 2007). In continuation of these studies, a females based RPW capture was recorded in all the treatments that ranges between 1.00:2.00 to 1.00:2.26 ration in favour of females. The higher capture of females *R. ferrugineus* in pheromone traps may be attributed to their higher activity in the field than males (Avand-Faghih, 2004). Moreover, the number of basioconic sensillae is supposed to more on the antennae of female weevils than males (Avand-Faghih, 2004), thus responding more towards the aggregation pheromone as reported in *R. palmarum* (Said *et al*., 2003). Therefore, use of aggregation pheromone as a key component of integrated programs is also gaining more importance as most of the captured females are found to gravid and fertile, thus, can help to significantly reduce their future population too in any area (Faleiro and Satarkar, 2003).

Conclusion

Although ferrolure+ aggregation found to be effective to attract significant number of RPW, but addition of synthetic pesticides except Indoxacarb, was found detrimental for RPW. Therefore, it is suggested that addition of pesticides may be avoided in pheromone traps but if required according to the need of growers, Indoxacarb or other less odour pesticides may be included for the rapid killing of RPW in traps.

Conflict of Interest. The authors declare that they have no conflict of interest.

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