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POPULATION DYNAMICS, ABUNDANCE AND INFESTATION OF THE RED PALM WEEVIL, *Rhynchophorus ferrugineus* (OLIVIER) IN DIFFERENT GEOGRAPHICAL REGIONS OF DATE PALM IN PAKISTAN

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Date palms are known as the imperious crop producing good quality fruits. Red palm weevil (*Rhynchophorus ferrugineus)* is recognized as the invasive pest of palm trees throughout the world. In Pakistan, date palm is being cultivated in various provinces but infestation and population dynamics of Red palm weevil (RPW) not yet been reported. The objective of the present study was to determine the population abundance and infestation of RPW in Pakistan having a connection with climatic factors (temperature and humidity) by the implementation of (ferrugineol + ferrulure) pheromones and hand picking in palm trees. Regarding the infestation level, a positive relationship was recorded between the populations and temperature while negative effect was observed with relative humidity. The maximum average population of RPW recorded during April, May and June in Punjab, Sindh, KPK and Baluchistan. Adult weevils collected from different provinces were found high during April (Punjab 18.76; Sindh 24.42; KPK 11.26; Baluchistan 8.16 /trap). During survey, In Punjab, the highest 10.75±2.06 weevils were found on Mozawati from Layyah, and 13.00±3.69.5 on Kechnanr from Bahawalpur. The population recorded on Kechanr from D.I Khan and Baluchistan were 17.60 4.74 and 6±1.25, respectively. The highest larval population 11.75±2.12 and 14.18±3.50 was also recorded on same date palms from Layyah and Bahawalpur region, respectively whereas 18.54±3.98 on Kechanr from D.I. Khan and 6.5±1.23 on Mozawati from Baluchistan was documented. Overall minimum weevils were collected from Zeri and Denda (0.09±0.07, 0.25±0.12) in different districts. Maximum % infestation calculated from Layyah was 12%±2.16 on Mozawati, 15.75%±1.70 on Hilawi from Sindh and 17.75%±2.75 and 7%±1.41 on Kechanr from DI Khan and Baluchistan, respectively. This study will be helpful to manage date palm weevil keeping in view its infestation on various date palm varieties and climatic condition.

Keywords: *Rhynchophorus ferrugineus*, ferrugineol, ferrulure, population, date palm infestation.

INTRODUCTION

Red palm weevil (RPW), *Rhynchophorus ferrugineus* is a severe and notorious pest of the date palms in different regions of the ancients as well as the new world in Africa, Asia, Oceania, Caribbean, California and Europe (Kaakeh, 2005; Faleiro, 2006; Ju *et al.,* 2011). Many date palms varieties are being attacked by the RPW, causing serious economic loss (Inghilesi *et al.,* 2013; Manachini *et al.,* 2013; Çıtırıkkaya *et al.,* 2014). Invasion by this notorious pest was preceded by the inadvertent transportation of the palm trees heavily infested with RPW in the Caribbean Islands, North Africa, Europe and Middle East (Fiaboe *et al.,* 2012; Inghilesi *et al.,* 2013). Ecological based Niche modeling was implemented against the area wide dispersal of the RPW and predictions were made for a single occurrence in the Laguna Beach, North Africa, Asia and Middle East (Fiaboe *et al.,* 2012). A basic tool for the population sampling and sustainable management of the RPW is extensive use of aggregation pheromones while synergistic effects are achieved by combining applications of the bait (fermented dates) and kairomone (ethyle acetate) (Hoddle, 2011; Vacas *et al.,* 2013; Hoddle *et al.,* 2013; Vacas *et al.,* 2014). *Rhynchophorus ferrugineus* female show more attraction towards the pheromone traps as compared to the male which will be helpful for the sustainable management of the economic pest (Rochat *et al*., 1991; Oehlschlager *et al*., 1995; Giblin-Davis *et al*., 1996; Hallet *et al.,* 1999; Vidyasagar *et al*., 2000; Faleiro *et al*., 2002; Sorokar *et al*., 2005). The efficacy of the pheromone-based traps not only depends upon

the kairomones but also many other factors play an important role such as environmental conditions, height, color and design of the traps used (Mohamed Abuaglala and Al-Deeb, 2012). Previously, pheromones based collections were done for the identification of these economically important weevils and to determine the infestation status in different date palm growing countries i.e. Saudi Arabia (Vidyasagar *et al.*, 2016; Sadder *et al.*, 2015), Iran (Poorjavad *et al.*, 2009), Canada (Hallett *et al*., 1993), USA (Giblin-Davis *et al*., 1996), Philippine (Abad *et al*., 2014), Egypt (Abdel-Moety *et al.*, 2012). Recently, in Pakistan, molecular study was conducted regarding the characterisation of *R. ferrugineus* (Yasin *et al.*, 2016; Manzoor *et al*., 2018) and insect vectors,entomopathogens and insect resistance for sustainable management (Ahmad *et al.*, 2017; 2018; Sharif *et al.*, 2019; Ahmad *et al.*, 2019). Hallet*et al.* (2004) described five species which were developed in the tropical regions of Asia, for example, *R. ferrugineus, R. bilineatus, R. distinctus, R. lobatus and R. vulneratus*. *R. indostanus*are accounted for male and female specimens of R. *ferrugineus* from Assam and male was reported from Ceylon as *R. signatiellis* on morphological premise (Wattanapongsiri, 1966).

The many important factors including palm varieties and their metabolites concentration, environmental conditions, play an important role in the spreading of weevils (Abuaglala and Al-Deeb, 2012). Approximately, 26 cultivars of different palms of 16 genera have been damaged by this invasive pest since its entry to the Mediterranean community in 1993 (Malumphy and Moran, 2009). These species infest 1m above ground offshootsand reside inside the stem of infested palms leading to the necrosis and death of the host plant (Manzoor *et al*., 2018). *Rhynchophorus cruentatus* and *R. ferrugineus* rigorously infest the palm trees initiating asymptomatic damage till the apical meristem harmed and have no probabilities of recovery resulting in useless management tactics (Giblin-Davis and Howard, 1989; Hunsberger *et al.*, 2000).

The effect of temperature fluctuation and humidity on the development and growth of *R. ferrugineus* has also been observed by different scientists (Salama and Saker, 2002; Martín and García, 2006; Li *et al.*, 2010; Dembilio *et al.*, 2012; Oehlschlager*et al.*, 1993; Al-Ayedh and Rasool, 2010; Aldryhim and Khalil, 2003).

In the present study, we reported first time, the infestation level of Red Palm Weevil (*Rhynchophorus ferrugineus*) various cultivated date palm varieties in some orchards located in different locations of four provinces of Pakistan. Moreover, an infestation of this invasive pest and populations of larvae and adults were observed regarding abiotic environmental factors such as relative humidity and temperature.

MATERIALS AND METHODS

***Sampling sites*:** A number of trials were implemented to observe the weevil populations in date palm orchards in Pakistan. The study was conducted in different regions of Punjab **(**Bahawalpur, Dera Ghazi Khan, Layyah, Liaqatpur, Kot Addu, Muzaffargarh, RahimYar Khan), Baluchistan (Panjgur and Khuzdar), Sindh (Ghotki, Mirpur Khas, Khairpur, Nathan Shah, Nawab Shah, Rohri, PanoAkil, Sukher) and Khyber Pakhtunkhwa (Dera Ismail Khan) provinces as shown in Fig. 1. The date of all these mentioned sites was given in Table 1.

Table 1. Date palm growing regions inspected for Sampling and field visits in different provinces of Pakistan.

Region	Coordinates	Coordinates
1-Bahawalpur	29°24'N	71°40'E
2-Bhakkar	31°40'N	71°05'E
3-Dera Ghazi Khan	30°05'N	70°43'E
4-Muzaffargarh	30°05'N	71°14'E
5-Rahim Yar Khan	28°30'N	70°25'E
6-Layyah	23°54'S	21°55'E
7-KotAddu	30°30'N	71°00'E
8-Liaqatpur	29°30'N	70°30'E
9-Dera Ismail Khan	31°50'N	70°50'E
10-MirpurKhas	25°30'N	69°0'E
11-Nawabshah	26°15'N	68°25'E
12-PanoAkil	27°51'N	69°07'E
13-Rohri	27°45'N	68°51'E
14-Sukkar	27°0'N	42°0‘E
15-Khairpur Nathan Shah	27°06'N	67°44'E
16-Ghotki	28°05'N	69°21'E
17-Khuzdar	27.81°0'N	66.61°0'E
18-Panjgur	27.00°0'N	64°05'E

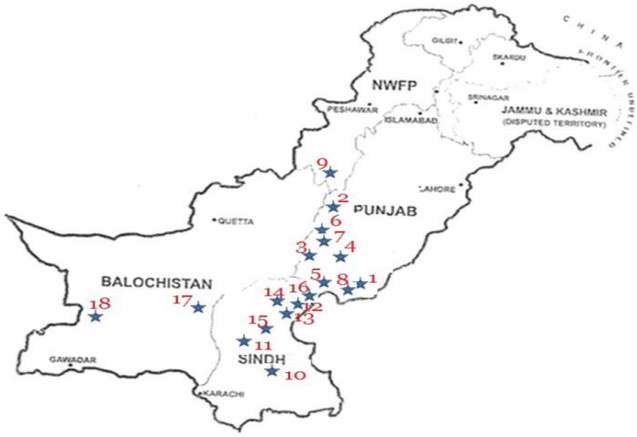

Figure 1. A map showing Sampling locations in different Provinces of Pakistan.

***R. ferrugineus population rise and fall*:**
Rise and fall in the population of weevils (*R. ferrugineus*) were observed in the four orchards of date palms in different districts of the provinces as mentioned above. The study was conductedat the during 2014-18. The work area was divided into three sites based on the positions of the pheromone traps. All these traps retained pheromone aggregation dispensers (ChimTica, Costa Rica) and 250g dates. The present pheromone traps capture only the male weevils. The amount of pheromone implemented in the study was 700 mg. It is available in the market as the product name of Ferrolure PO28. It was composed of 4-mehyl 5 nonanone and 4-methyl 5-nonanol. It was installed at the ratio of 3 to 10 mg/day with 9:1 ratio of pureness including both the constituents. The active ingredient of ethyl acetate was disseminated in gel, transferred in the bucket of 45 L which was lined with kairomone. The kairomones with 95% purity were released (200 to 400 mg/day). The ChemTica International, Costa Rice uses 5 L water and produces these chemicals with a brand name of PO80 45 mL for luring weevils. The traps of 10 mL capacity were made with polypropylene bucket. The other all remaining surfaces were made with a plastic net in rough form for climbing and capture the purpose of the weevils. Traps installed on palm trees were placed at the height of 3 to 4 feet, and out of them, some were buried in soil at the depth of 15 cm for the calm entry of Red Palm Weevil (*Rhynchophorus ferruginous*) into the trapping sites. A part of trap buried in soil was kept safe from birds, animals, wind and flooded water. Space between the palm trees and bucket was maintained about 4m to avoid the adults of Red Palm Weevil (*Rhynchophorus ferruginous*) for the egg purpose as an alternative of entering the bucket. These pheromone traps were placed under the trees to avoid evaporation. The baits in the form of food were exchanged with dates in a fresh form about one or two weeks. Kairomones and pheromones were interchanged relying on the distributing rates facing the direct effect of relative humidity and temperature on dissemination. Data about the weevil were noted every week by observing pheromone traps. The difference between male and female *R. ferrugineus* was done by observing the tuft of brown hairs on half rostrum of males present and absent in females under microscope. The temperature and humidity of the selected regions during sampling were also observed. Coefficients of correlation and regression were determined. Thecollected data was statistically analyzed according to the instructions of Gomez and Ferry (1998).

***Percentage infestation of RPW weevils on different cultivars of cultivated date palm trees*:** Red Palm Weevil infestation percentage on date palm cultivars planted in different regions was counted (Fig.10). The RPW larvae, pupae and adults were collected manually from the Aseel, Denda, Dhaki, Hillawi, Kobra, Kechanr, Khudravi, Mozawati, Shamrani, Zeri and Zaidi by implying arithmetic mean numbers of larvae and adults. The priority or preference and non-preference of the weevils on palm cultivars were visualized by their number. For percentage infestation, the numbers of RPW infested trees having RPW population or with only significant symptomatic dead trees were also counted.

RESULTS

***R. ferrugineus population dynamics in four provinces of the country*:** The results in Table 2 revealed the comparative magnitude of abiotic environmental factors especially physical factors (temperature and relative humidity) on the populations of *R. ferrugineus.* The coefficient of simple correlation depicts the negative effect by considering the mean of relative humidity on RPW population during 2014. While in contrast the positive correlation between the population dynamics of RPW and temperature was found. In this study, an analysis of variance reveals that an abiotic environmental factor (temperature and relative humidity) induces changeability of 32.4% throughout the year. Thus, we conclude that the populations of RPW were found the maximum in April with an average of 18.76 weevils (5.50 males; 13.26 females) at an average temperature of 38.86°Cand RH (41.93%). We found four peak values in a number of weevils during these months. Next succeeding numbers of weevils were in May, June and March with an average number of RPW (15.34, 14.11 and 13.13) at an average temperature and relative humidity (Ave. temperature 42.73, 43.71 & 36.65; RH 38.32, 39.48 & 40.66) (LSD, 5.13; P=0.05). RPW has infested almost all the provinces of Pakistan with extreme RPW in Sindh 24.42 (10 males and 14.42 females/trap; RH 49; Av. temperature 38.86 °C) province, followed by Punjab 18.76 adults/trap (5.50M & 13.26F; Av. temperature 38.86; RH 41.93), KPK 11.26 Adults/trap (4.50M & 6.36F; av. temperature 33.22; RH 35.12) and Baluchistan 8.16 adults/trap (3M & 5.15F; av. temperature 35.42; RH 23.42). Means of the total captured adults in Punjab indicate minimum numbers of the weevils in December (1.66 Adults/trap) and maximum weevils in April (18.76 adults/trap). In Punjab Province, no. of adult weevils gradually increased in January 2014 from 6.34 (adults/trap) to the peak value 18.76 (adults/trap) during April with a relative humidity (R.H) of 41.93% and declined to 1.66 (adults/trap) in December (LSD 5.13).

In Sindh Province of Pakistan, a gradual increase on the population of RPW adults started from January (2014) (8.33 adults/trap) to April (2014) (24.42 adults/trap) at a relative humidity (49%) and average temperature 38.86 °C. Infestation started to decline at the end of December (3.77 adults/trap) (LSD 6.03) in Sindh Province of Pakistan. There are most probably 3-4 peaks in the in the whole year 2014 in which high infestation has been recorded. In-spite of April, it happened high infestation in May and June with adult weevils 23.44 (9M & 14.44F; ave. temperature 39.73°C; RH 44.22)

and 21.22 (8M & 13.22F; ave. temperature 42.31°C; RH 41.28) (LSD=6.03, P=0.05).

In KPK, there were four population peaks with maximum number of weevils 11.26 adults/trap (4.50M & 6.36F; ave. temperature 33.22°C; RH 35.12) during April and minimum number of weevils 1.19 adults/trap (0.9M & 1F; ave. temperature 14.40°C; RH 28.80) during December (2014) (LSD 5.44). Lowest number of weevils was found in the Baluchistan Province of Pakistan with a maximum number of weevils during April (8.16 adults/trap) and minimum no. of weevils during December (1.32 adults/trap) at R.H. of 23.42% (LSD 5.12).

Table 2. Environmental factors and the population fluctuation of *R. ferruginous* throughout the year in Punjab.

Visits	Average RPW captured adults/traps			Mean Temp. (°C)	R.H (%)
	Overall	Male	Female		
7-Jan	6.34	2.11	4.23	24.11	35.98
6-Feb	6.77	3.00	3.77	29.93	36.76
5-Mar	13.13	7.00	6.13	34.50	40.65
2-Apr	18.76	5.50	13.26	38.86	41.93
7-May	15.34	5.00	10.34	42.73	38.32
6-June	14.11	5.11	14.00	43.71	39.48
6-July	8.44	2.00	6.44	3.57	37.00
7-Aug	6.88	3.88	3.00	36.86	36.88
11-Sep	4.56	1.00	3.56	24.29	36.22
08-Oct	4.12	1.12	3.00	25.07	35.29
06-Nov	3.44	1.22	2.22	24.50	34.29
07-Dec	1.66	0.66	1.00	20.29	35.18
Total	102.54	37.49	70.05		
Mean	14.89	6.31	9.14	21.40	50.24
± SD	±3.20	±2.10	±2.20		

LSD at 5% = 5.13

Table 3. Environmental factors about the population fluctuation of *R. ferrugineus* throughout the year in Sindh.

Visits	Average RPW captured adults/traps			Mean Temp. (°C)	R.H (%)
	Overall	Male	Female		
06-Jan	8.33	2.00	6.33	18.24	34.24
05-Feb	11.12	3.12	8.00	23.93	37.36
04-Mar	15.88	7.00	8.88	36.50	40.65
01-Apr	24.42	10.00	14.42	38.86	49.00
06-May	23.44	9.00	14.44	39.73	44.22
05-Jun	21.22	8.00	13.22	42.31	41.28
05-Jul	18.18	8.18	10.00	41.57	36.00
06-Aug	14.98	4.98	10.00	34.46	35.78
10-Sep	12.44	5.22	7.22	30.29	34.66
07-Oct	10.22	4.12	6.10	25.07	34.29
05-Nov	8.52	3.52	5.00	21.50	33.79
06-Dec	3.77	1.77	2.00	16.29	32.20
Total	172.52	66.91	105.61		
Mean	15.49	7.12	10.33	22.36	52.14
± SD	±3.30	±2.00	±2.10		

LSD at 5% = 6.03

Table 4. Environmental factors and the population fluctuation of *R. ferrugineus* throughout the year in KPK.

Visits	Average RPW captured adults/traps			Mean Temp. (°C)	R.H (%)
	Overall	Male	Female		
08-Jan	3.24	1.00	2.24	20.02	31.02
07-Feb	4.72	1.00	3.72	22.93	32.26
07-Mar	6.53	3.00	3.52	29.50	34.35
04-Apr	11.26	4.50	6.36	33.22	35.12
10-May	9.24	3.24	6.00	34.12	34.78
09-Jun	7.31	2.31	5.00	33.42	34.42
09-Jul	5.24	2.24	3.24	28.78	30.32
10-Aug	4.18	1.18	3.00	28.92	30.18
11-Sep	3.54	1.00	3.54	28.13	29.87
11-Oct	3.42	1.12	2.30	26.27	29.67
08-Nov	2.44	1.22	1.22	24.40	28.94
09-Dec	1.19	0.19	1.00	19.40	28.80
Total	61.40	22.00	39.40		
Mean	12.43	5.11	8.32	18.20	46.24
± SD	±2.50	±1.40	±1.60		

LSD at 5% = 5.44

Table 5. Environmental factors and population fluctuation of *R. ferrugineus* throughout the year in Baluchistan.

Visits	Average RPW captured adults/traps			Mean Temp. (°C)	R.H (%)
	Overall	Male	Female		
03-Jan	2.12	1.00	1.12	21.40	20.40
02-Feb	1.66	1.00	0.66	28.43	22.48
02-Mar	4.43	3.00	1.43	33.60	22.98
01-Apr	8.16	3.00	5.16	35.42	23.42
07-May	5.14	2.14	3.00	34.62	23.02
05-Jun	5.08	2.08	3.00	33.72	21.30
05-Jul	4.14	1.14	3.00	33.70	20.50
07-Aug	3.48	1.24	2.24	32.29	20.26
06-Sep	2.94	1.00	1.94	31.80	19.80
06-Oct	2.82	1.12	1.70	25.70	18.00
04-Nov	2.74	1.22	1.52	23.10	17.20
05-Dec	1.32	0.32	1.00	20.90	17.00
Total	44.03	18.26	25.77		
Mean	10.30	4.88	7.96	17.40	45.45
± SD					

LSD at 5% = 5.12

In Baluchistan, four population peaks occurred with maximum number of weevils 8.16 adults/trap (3M & 5.16F; ave. temperature 35.42°C; RH 23.42) during April and minimum number of weevils 1.32 adults/trap (0.32M & 1F; ave. temperature 29.90°C; RH 17) during December. Lowest weevils' number was found in the Baluchistan Province of Pakistan with a maximum number of weevils during April

Table 6. Influence of environmental factors on the population profusion of the *R. ferrugineus.*

(Factors)	(r)	(b)	R^2	SE	Equations (Predictions)
Average daily temp.	0.274	0.894	6.9%	0.280	y^ = a+b x
P	0.003	0.004			x= Temp. degree
					y^=No. of adults (RPW) at this degree
Average daily humidity	-0.487	-1.462	19.8%	0.256	Y^=a + (-) b x
P	0.000	0.000			X= relative humidity
					Y^= No. of adults (RPW) at this degree
R.H and Temperature	-0.178		23.4%		Y^= a+b 1x1+b 2 x 2

b = simple regression coefficient, r = simple correlation coefficient, R^2 = relative humidity and SE = standard error.

(8.16 adults/trap) and minimum no. of weevils during December (1.32 adults/trap) at R.H. of 23.42% (LSD 5.12).

The simple correlation coefficient (r) presents a positive correlation in the results achieved between temperature and population of RPW while the negative relationship was obtained with relative humidity scrutinized through Analysis of covariance.

***Population dynamics and Percentage infestation of R. ferrugineus in palm cultivars commercially grown in Layyah, Punjab*:** Populace abundance was determined by putting the study in the form of surveys done to the highly infested areas and picking of the RPW live specimens for further study from palm orchards. We also collected the fallen dead infested palms on ground and counted the empty puparium along with the larval instars and adults alive in the palm trees. Minimum ten (n=10) infested trees were considered for samples collection from each palm orchard in Layyah City (Coordinates: 23°54'S, 21°55'E). Three to four orchards were visited on an average from each district for data collection and evaluation related to population dynamics. The data about a collection like a number of larvae and the number of an adult were calculated independently for each cultivar. The results of an experiment conducted in district Layyah shows that maximum population of adult (10.0±1.80) and larvae (11.75±2.08) of RPW on Mozawati. RPW population on Hillawi with 11.25±2.08 adult weevils and 10.90±2.0 larvae was observed. Other varieties such as Aseel, Khudravi, Shamrani and Zaidi had mimimum adults (2.6±0.91, 2.6±0.85, 1.57±2.18 & 1.25±0.26) and larval population (2.3±0.98, 2.7±2.88, 1.60±0.58 & 1.18±2.55) respectively as shown in Fig. 2. While lowest or no infestation was examined on Zeri variety probably constituting 0.09±0.08 adults and no larval population. Out of all mentioned varieties, some produce volatiles which act as an attractant for RPW to damage the palm varieties. Moreover, the palm cultivars with high sugar content were found more susceptible to the attack of RPW.

RPW percentage infestation rate was also observed high on Mozawati (12%±2.16) showing a close relationship with Hillawi with an 11.7%±1.77 infestation. The low infestation was also found on other varieties such as Aseel, Khudravi, Shamrani and Zaidi (4±1.29, 3.25±1.50, 1.825±0.85 & 1.4±0.52) respectively. Minimum or no infestation was shown by Zeri approximately 0.175±0.17 as indicated in Fig. 3. Most susceptible varieties emit volatile compounds which attract the palm weevils and cause more infestation as compared to other varieties having lower infestation level.

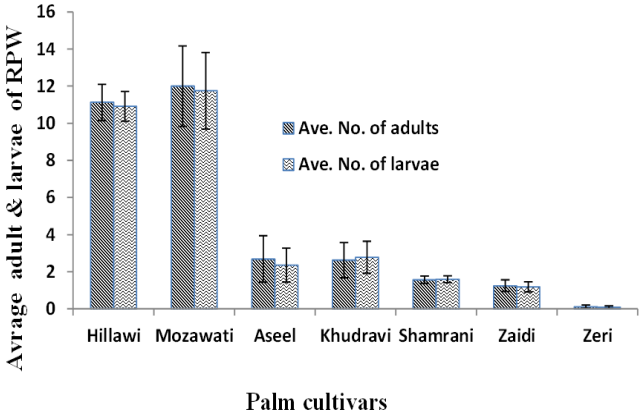

Figure 2. Average No of *R. ferrugineus* (larvae and adults) found in different infested date palm cultivars grown in Layyah district, Punjab, Pakistan. (n=10 plants/date palm field).

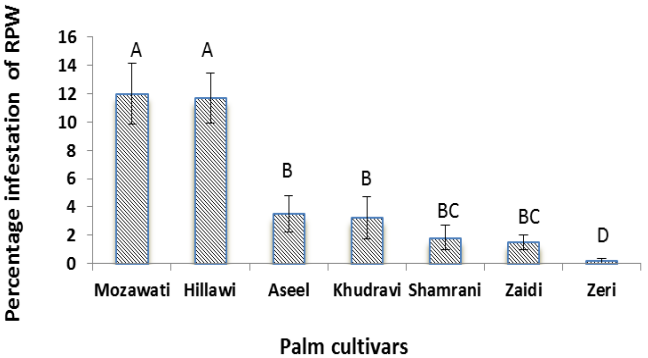

Figure 3. Infestation (%) of *R. ferrugineus* in Layyah district, Punjab, Pakistan. Different Letters shows significant level (0.05%).

***Population fluctuation and Infestation percentage of R. ferrugineus on date palm cultivars were grown in Bahawalpur* (Punjab):** Population fluctuation was studied by

making a collection of adults and larvae dead as well as alive from fallen dead infested palms on the ground and counted the empty puparium. Minimum ten (n=10) infested trees were considered for samples collection from each palm orchard in Bahawalpur (Coordinates: 29°24'N, 71°40'E). Four orchards were visited on an average from each district for data collection and evaluation related to population dynamics. The data about a collection like some larvae and the number of an adult were calculated independently for each cultivar. The results of the experiment conducted in district Bahawalpur show that maximum population of adult (10.43±1.47) and larvae (14.18±3.69) of RPW on Aseel and Kechanr, respectively. While in contrast Denda and Kobrawas found resistant cultivars against the RPW showing 0.0% and 0.28%±0.58 infestation, respectively. Numbers of adults on Kechanrwere found statistically similar toa number of larvae on Aseel as shown in Fig. 4.

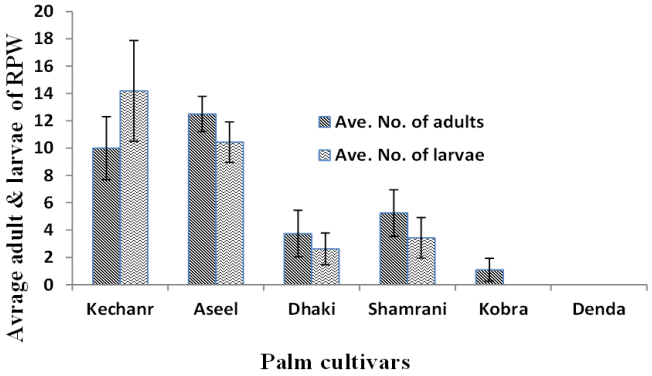

Figure 4. Average No of *R. ferrugineus* (larvae and adults) found in different infested date palm cultivars grown in Bahawalpur district, Punjab, Pakistan. (n=10 plants/date palm field).

Highest % infestation was recorded on Kechanr (13.75%±2.58) which was very close to the infestation in the Aseel variety upto 10.25%±0.82. Other varieties have also shown a little infestation of 3.2±0.95, 2.75±0.87 and 1.62%±0.94 (Dhaki, Shamrani & Kobra, respectively). Minimum or no infestation was shown by Dendaupto 0.5% ±0.57as indicated in Fig. 5. Percent infestation was done in the infested date palms including dead fallen trees and empty cocoons as well. Most susceptible varieties emit volatile compounds which attract the palm weevils and cause more infestation as compared to other varieties having low infestation level.

***Population dynamics and Infestation of R. ferrugineus (larvae and adult) on date palm cultivars grown in Sukhur* (Sindh):** Palm cultivars mostly were grown in district Sukher (Sindh) is Aseel, Dhaki, Denda, Hillawi, Kobra, Khudravi, Kechanr, Shamrani, Zeri and Zaidi. In Sukkur district increased number of RPW was noticed on Hillawi having average number of larvae and adult (16.48±1.70 and 16.18±±2.58, respectively). Second highest infestation in the Sindh was recorded on Kechanr with adult's population of 14.68%±2.48 and 15.35%±2.38 larvae attack. On Aseel variety, the larval population was found 9.7%±0.58. Less infested varieties were Dhaki, Shamrani, Khudravi and Zaidi with % infestation of 4.6±1.25, 2.78±0.85, 2.78±2.88 and 1.18±0.28, respectively as shown in Fig. 6. Minimum or no weevils were recorded on Zeri, Kobra and Denda because these three varieties were found resistant to weevil's attack. Varieties with high sugar contents are prune to RPW attack.

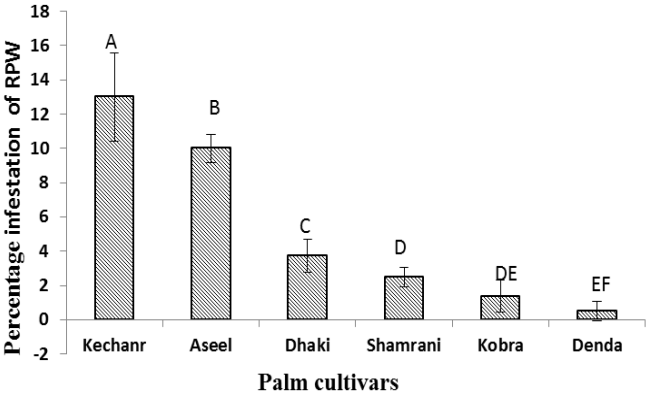

Figure 5. Infestation (%) of *R. ferrugineus* in Bahawalpur district, Punjab, Pakistan. Different Letters shows significant level (0.05%)

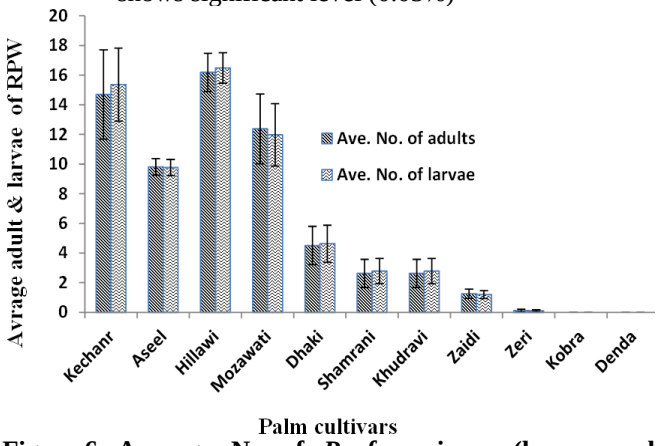

Figure 6. Average No of *R. ferrugineus* (larvae and adults) found in different infested date palm cultivars grown in Sukher district, Sindh, Pakistan. (n=10 plants/date palm field

However, the highest % infestation was recorded on Hillawi (15.75%±1.70) which was very close to the plague with Kechanr, Mozawati and Aseel (12.5±±1.91, 9.75±±2.21 &9.75±±1.70) upto 10.25%±1.16. Other varieties such as Dhaki, Shamrani, Khudravi and Zaidi have also shown a modest invasion of 6±2.16, 3.07±0.89, 2.9±0.82 and 1.9%±0.94, respectively. Minimum or no infestation was

shown by Dendaupto 0.41%±0.49 as indicated in Fig. 7. Percent infestation was done in the infested date palms including dead fallen trees and empty cocoons as well. Varieties such as Hilawi and Mozawati containing high sugar contents are prune to weevil's attack while those having less, or no volatiles emitted in them provide the rare chances for infestation against insect pest entities. Denda and Kobra were found resistant against RPW attack in the Sukher region of Pakistan.

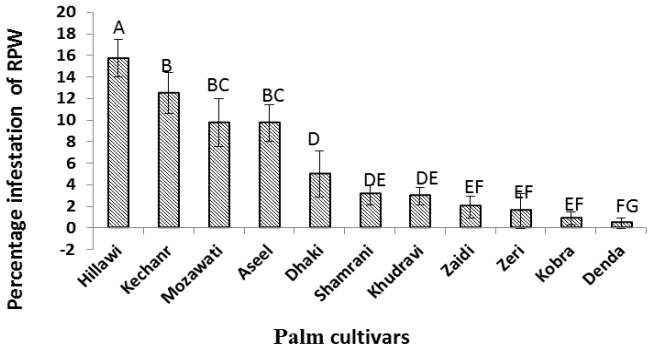

Figure 7. Infestation (%) of *R. ferrugineus* in Sukhar district, Sindh, Pakistan. Different Letters shows significant level (0.05%)

***Populace dynamics and Infestation percentage of R. ferrugineus (larvae and adult) on date palm cultivars were grown in D. I. Khan* (KPK):** Cultivated varieties of date palms in D. I. Khan are Aseel, Dhaki, Hillawi, Khudravi, Kechanr, Mozawati and Shamrani. Population fluctuation was studied by making a collection of adults and larvae dead as well as alive from fallen infested palms on the ground and counted the empty puparium. Minimum ten (n=10) infested trees were considered for samples collection from each palm orchard in D. I. Khan. Four orchards were visited on an average for data collection and evaluation related to population dynamics. The data about a collection like a number of larvae and the number of an adult were calculated independently for each cultivar. The results of an experiment conducted in D. I. Khan show that maximum population of adult RPW (18.43±4.78, 11.81±0.58& 10.61±0.91) and larvae (18.00±3.51, 12.26±0.83& 10.35±0.78) were recorded on Kechanr, Aseel and Mozawati respectively. Minimum adult's percent infestation noticed was (3.25, 2.6 & 1.31) on Denda, Shamrani and Khudravi respectively as indicated in Fig. 8.

However, we examined the highest infestation on Hillawi which was 17.75%±2.75. Other two varieties having maximum infestation were Aseel and Mozawati with an infestation of 12.25±1.60 & 10.75%±1.23. The minimum infestation was shown by Khudraviupto 1.25%±0.50 as indicated in Fig. 9. Population dynamics were studied by collecting weevil's larvae and adults from each orchard. We collected samples from ten trees from each garden and calculated the percentages.

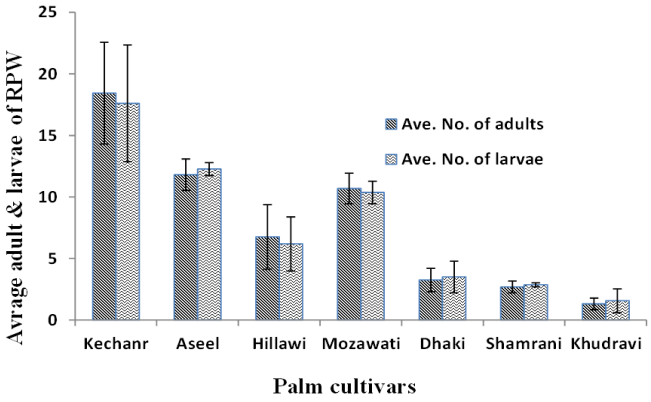

Figure 8. Average No of *R. ferrugineus* (larvae and adults) found in different infested date palm cultivars grown in DI Khan district, KPK, Pakistan. (n=10 plants/date palm field

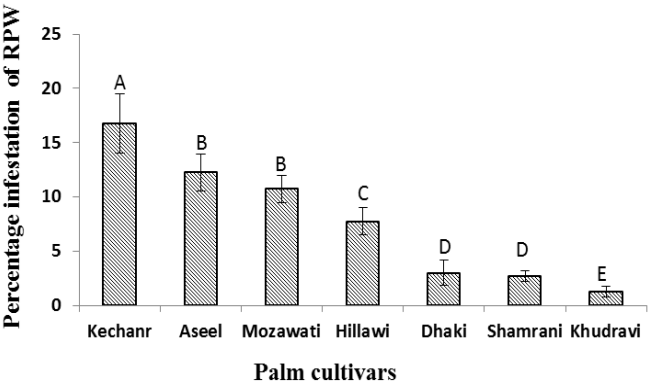

Figure 9. Infestation (%) of *R. ferrugineus*in DI Khan district, KPK, Pakistan. Different Letters shows **significant** level (0.05%)

***Populace dynamics and Infestation percentage and of R. ferrugineus (larvae and adult) on date palm cultivars grown in district Punjgur* (Baluchistan):** The mostly grown cultivars of date palms in Punjgur district of Baluchistan are Aseel, Dhaki, Hillawi, Khudravi, Kechanr, Shamrani and Mozawati. The highest numbers of RPW larvae (5.81±0.98, 7±1.18 and 6.5±1.59) were collected from Mozawati, Kechnr and Aseel varieties, respectively. A number of weevils calculated on Katonwas statistically at par with Aseel showing equal infestation by the larval population. While maximum adult population (6adults/trap) was estimated on Hillawi and Kechanr and minimum (1.75± 0.47adult/trap) was captured on Dhaki and Shamrani showing a similar infestation for larval and adult population individually. However, increased infestation percentage was on Aseel

(6.75%±1.58) as indicated in Fig. 10.We examined the highest infestation on Aseel (7.75%±1.29). Other two varieties having maximum infestation were Kechanr and Mozawati with an infestation of 5.5±1.20 & 3.25% ±0.95 (P=0.05, n=10). The minimum infestation was shown by Dhaki and Shamrani which were statically similar with each while Khudravi was little more infested (2.5%±0.58) as illustrated in Fig. 11.

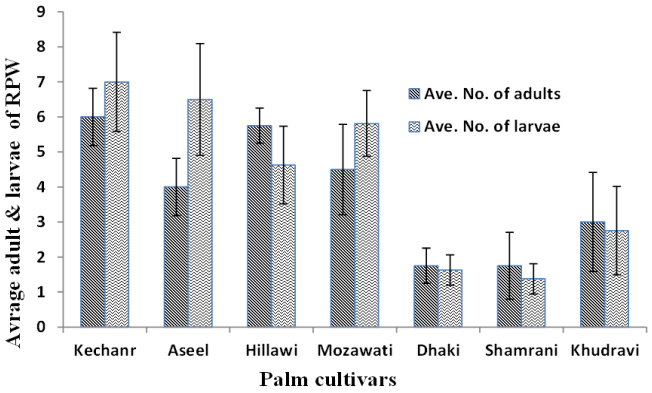

Figure 10. Average No of *R. ferrugineus* (larvae and adults) found in different infested date palm cultivars grown in Punjgur district, Baluchistan, Pakistan. (n=10 plants/date palm field

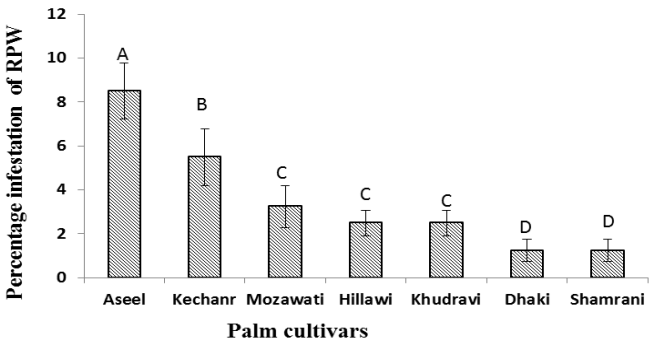

Figure 11. Infestation (%) of *R. ferrugineus* in Punjgur district, Baluchistan, Pakistan. Different Letters shows significant level (0.05%)

DISCUSSION

The red palm weevil, *Rhynchophorus ferrugineus* important date palm pest, is being spread worldwide. Recently, it has been reported from Pakistan infesting different date palm cultivars in different provinces of Pakistan. Maximum % infestation observed from Layyah, was 12%±2.16 on Mozawati, 15.75%±1.70 on Hilawi from Sindh and 17.75%±2.75 and 7%±1.41 on Kechanr from DI Khan and Baluchistan, respectively. The results of the present work indicated that few date palm varieties in the country are found to be susceptible and favorable host plants for the infestation of Red Palm Weevil (Rh. The previous work done by Giblin-Davis and Howard (1989) also showed similar infestation pattern for various palms infested by different palm weevils. Our research findings illustrated that the maximum population of Red Palm Weevil was recorded during April, May and June with adults weevils collected (18.76, 15.34 & 14.11, respectively) in Punjab, (24.42, 23.44 & 21.22, respectively), Sindh, (11.26, 9.24 & 7.31, respectively), KPK and (8.16, 5.14 & 5.08, respectively) Baluchistan showing a positive correlation with temperature and negative correlation with relative humidity. Various species of the RPW with Palmetto weevil shows harborage activity in the soft tissues of the palm cultivars showing a direct relation of infestation with moisture for the placement of the eggs (Giblin-Davis and Weissling, 1993). Weevils infestation could be inclined with the previous work done in which the RPW attack the tree within minutes if any tissues is cut off (during transplanting, pruning) drought or previous damage instigated by the *Metamasius hemipterus* occurs (Giblin-Davis *et al*., 1996). In the same way, *Rhynchophorus ferrugineus* and Palmetto Weevil indicate the hygro-positive reply to temperature and humidity. The life spans of the weevils were shortened under low humidity conditions and increased under high humidity conditions. It was found that longevity of the weevils extends to 39.3 days when placed inside the moist peat (Aldryhim and Khalil, 2003). The outcomes of our study were parallel to the results of Faleiro and Satarkar (2005) in which they acknowledged the positave relationship of temperature and negative relationship in the capturing weevils.

Few reports also revealed that the development and growth of *R. ferrugineus* are affected by the changes in temperature as indicated by the minimum tolerance range of 17.4 to -2^{0}C by various researchers (Salama and Saker, 2002; Martín and García, 2006; Li *et al.*, 2010; Dembilio *et al.*, 2012). The relative humidity was found directly proportional to the R. *ferrugineus* infestation. The population started dying in dry environmental conditions living for only 4 to 6 days (Oehlschlager *et al.*, 1993; Al-Ayedh and Rasool, 2010; Nirula, 1956; Aldryhim and Khalil, 2003). The aggregated and contagious populations of *R. ferrugineus* were found high during August 1999 - July 2000 (Faleiro *et al.*, 2002). In Egypt, about 21 generations were reported in one year (Salama and Saker, 2002)

In contrast, El-Sebay and El-Wahab (2003) observed no correlation between the seasonal fuluctuation of RPW with abiotic environmental factors. Percent infestation was measured in the most commercially grown cultivars in the four provinces (Punjab, Sindh, KPK and Baluchistan) of Pakistan for studying the percent infestation and population dynamics. In Punjab, maximum infestation by RPW was recorded on Muzafati (12%) and minimum on Zeri (0.175%) while two varieties 'Kobra' and 'Deenda' were found resistant with minimum or no infestation. Overall damage by

RPW was maximum in Sindh (24.42 adults at 38.86°C and RH 49%), Punjab (18.76 adults at 38.86 and RH 41.93%) and KPK (11.26 adults at 33.22 °C and RH 35.12%) provinces while minimum infestation was in Baluchistan due to high temperature and low relative humidity which shortens the life of the insect pest. Our findings resembled with those of Huang *et al.* (2008) belonging from Chinawho reported the impact of abiotic environmental factors on the collection of RPW by installing pheromone traps. Their results showreduced trapping of the RPW during rainfall and low temperature. The RPW population was harmfully affected by the environmental condition, especially temperature and relative humidity (Al-Deeb and Khalaf, 2015). Our result correlates with the findings formerly documented in Saudi Arabia showing the susceptibility of the Shahl and Khasan populations. Pakistani date palm cultivars (Aseel, Hillawi, Kechanr and Mozawati) depicted susceptibility and decreased the ratio of antixenosis which leads to oviposition of RPW and high infestation. This study is the first investigation of RPW infestation on various date palm cultivars in 4 provinces of Pakistan and its association with climatic factors. This study will be very helpful for developing better management and control strategy of RPW in Pakistan.

***Conclusion*:** It is concluded from the present studies that resistant varieties should be launched in areas of high red palm weevil's infestation in Pakistan. Farmers are not aware of management practices and control measures for this notorious weevils. So, training workshops should be conducted and palm growers should be invited throughout the country. If this pest can be controlled, then production of dates will be increased many folds.

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