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OCCURRENCE OF NATURAL ENEMIES OF CODLING MOTH (CYDIAPOMONELLA) IN APPLE ORCHARDS IN KUCHLAK, QUETTA, BALOCHISTAN

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ABSTRACT

Codling moth (Cydia pomonella) is the key pest of apple in Balochistan. Natural enemies play a vital role in the regulation of codling moth. This study aimed to monitor the occurrence of natural enemies of codling moth in different apple orchards and fruit infestation by its larvae. Four apple orchards (red delicious-RD, golden delicious-GD, mixed plantation-KRG, KRG (Te)-release of Trichograma evanescens) were selected. Sampling from selected 10 trees was carried out from April to September during 2018 and the data were analyzed through descriptive statistics. The soil surface predators were collected by pitfall trap, other predators and codling moth larvae by corrugate paper fixed around the tree, and parasitic wasps by the yellow sticky trap. The data showed that out of the four orchards, the KRG (Te) presented a higher percent occurrence of parasitic wasps by 61.54% Diplazon sp., 62.14% Dibrachys microgastri, 54.55% Elasmus.sp.nr.johnstoni, and 22.2% Trichograma evanescens respectively. The total parasitized codling moth larvae collected in the band trap was 818 representing 28.36% CM larvae parasitized by Diplazon sp., 49.76% by Dibrachys microgastri, and 21.88% by Elasmus.sp.nr.johnstoni. *While, majority of predators of codling moth were found in KRG (Te) orchard but some predators like carabid beetle, earwig, and green lacewings have shown pesticides tolerance as indicated by their occurrence in RD, GD, and KRG orchards. The release of Trichograma sp. in one orchard with a spray of emamectin benzoate recorded apple fruit damage by 11.0% that might be reduced by using selective pesticides.*

KEYWORDS: Apple varieties, codling moth, natural enemies, occurrence, species.

1. INTRODUCTION

The The codling moth (*Cydia pomonella*) is tremendously a serious pest of agriculture importance the world over (Neven and Hansen, 2010). The larvae of codling moth attack on all deciduous fruits and apple orchards particularly (Chidawanyika and Terblanche, 2011). Effective management of *C. pomonella* is a prerequisite in apple orchards for producing quality fruits and in case of inadequate dealings, a significant fruit loss might occur (Ashraf *et al*., 2007; Asmatullah-Kakar and Hazara, 2009). The notorious nature of this pest is judged by its number of generations produced in a year as reported three generations of *C. pomonella* in the applegrowing region of Balochistan and further the prevailing conducive weather condition to favor partial 4th generation's occurrence (Kakar and Hazara, 2002). In apple orchards, 70% of insecticides used are to control CM (Franck *et al*., 2007). CM control is achieved using various neuroactive products such as organophosphates, carbamates, synthetic pyrethroids, neonicotinoids, and insect growth regulators (IGR). The CM is a very plastic species and easily adapts to different climatic conditions including the development of resistance to various groups of synthetic insecticides (Sauphanor *et al*., 2000; Bouvier *et al*., 2001).

The integration of chemical and biological control is often critical to the success of integrated pest management (IPM) program for arthropod pests (Volkmar *et al*., 2008). Conservation of natural enemies has always been a key element in the theory behind integrated pest management (IPM) (Stern *et al*., 1959). In practice, growers can conserve natural enemies by withholding insecticide applications, using selective insecticide chemistries or application methods, and or providing resources for natural enemies (Morris and Winter, 1999). Unfortunately, codling moth directly damages the crop resulting in a low tolerance for this pest. Thus, in many apples' orchards management of the codling moth still relies largely on suppression of the pest through the use of synthetic or natural toxins that hurt natural enemies (Simon *et al*., 2010). This reliance on insecticides has limited the role of natural enemies in pest management and likely has caused an underestimation of the economic value of the contribution that natural enemies make to pest management in apple orchards (Zhang and Swinton, 2009).

Natural enemies of insect pests feed on different insects belonging to different families (Teixeira *et al.*, 2008; Mooney *et al.*, 2012). Parasitic Hymenoptera is common natural enemies that prey on key apple pests, including codling moth, *Cydia pomonella* (Lacey and Unruh, 2005). Parasitoid wasps offer a potential means of biological control of these orchard pests (Jones *et al*., 2009). Arthropod natural enemies such as parasitoid wasps appear to be more abundant and have higher species richness within organic agroecosystems than conventional ones (Letourneau and Bothwell, 2008). Parasitoid wasps are especially sensitive to pesticides, including fungicides and many insecticides that are less harmful to other beneficial arthropods (Suckling *et al*., 1999; Thomson and Hoffman, 2006). Thus, parasitoid wasp diversity can serve as an indicator of both overall orchard toxicity and the potential for increased biological control after reducing pesticide use.

The potential of a predator usually depends on its voracity (wanting or devouring great quantities of prey or food), behavioral and numerical responses, and spatial heterogeneity (Kratina, 2009). Open field studies revealed that codling moth larvae that have left the trees or fallen fruits seeking suitable pupation sites are actively attacked by carabids and spiders (Bureau de Roincé *et al.*, 2012). According to serological tests, the proportion of *Pterostichus melanarius* (Illig.) adults preying on larvae might be as high as 63% in some apple orchards in Canada (Hagley and Allen, 1988). However, in apple orchards in south-eastern France, where Pterostichus spp. were absent, the most important carabid predator of the codling moth (but also of *G. molesta*) was Harpalus (Pseudophonus) rufipes (Deg.), with 8% of codling moth predation as a maximum (Boreau de Roincé *et al.*, 2012). In addition to that, the most active codling moth predators besides carabids were wolf spiders (Lycosidae, less than 8% preying on codling moth larvae).

European earwigs are generally beneficial in apple and pear orchards because they can suppress pests and probably do minimal damage to fruits. European earwigs have been reported to eat a variety of pests including apple leaf curling midge (*Dasineura mali* Kieffer) larvae (He *et al.*, 2008), brown marmorated stink bug eggs (Rice *et al.*, 2014), codling moth (*Cydia pomonella* L.) eggs and larvae (Unruh *et al.*, 2016), woolly apple aphid (*Eriosoma lanigerum*, Hausmann) (Orpet *et al.*, 2019). Combining earwigs with relatively specialized natural enemies such as coccinellids or parasitoids may strengthen biological control across the season, as earwigs can suppress low-density pest populations during periods when these other natural enemies are not present (Quarrell *et al.*, 2017).

Apple is grown as a long-term perennial crop, orchard duration being typically 15–30 years (Nix, 2013). The tree canopy is semi-permanent and apple orchards, thus, provide relatively stable ecological habitats that support a rich and diverse fauna of arthropods. Unsprayed apple trees support a large fauna of > 2000 arthropod species. Approximately 20% of the total British Auchenorrhyncha and Heteroptera fauna were collected by foliar sampling in three apple orchards in South-East England (Bleicher *et al.*, 2010; Kondorosy *et al.*, 2010) and more than 2500 arthropod species have been reported from apple orchards in Hungary (Bleicher *et al.*, 2006). About a quarter of the arthropod fauna are pests, a quarter is natural enemies of pests. However, even a small number of sprays of broad-spectrum insecticides are likely to reduce greatly this fauna. Outbreaks are caused by natural enemy disturbance.

Successful IPM in apple orchards needs a range of effective methods to control the pests without harming important natural enemies of pests (Cross and Berrie, 2009). Keeping because of the importance of natural enemies in the regulation of pests and particularly the codling moth in apple orchards, the present study was carried out to achieve the set objectives as i) The main objective of this research work is to inspect the natural enemies of the insect pest (*Cydia pomonella*) on apple varieties in the study area, ii) Identification of natural enemies of *C. pomonella* on apple fruits and iii) to determine the level of fruit infestation caused by the larvae of codling moth in orchards of the study zone.

2. MATERIALS AND METHODS

This study was conducted during 2018 at Tehsil Khuchlak district Quetta to study the occurrence of natural enemies of codling moth in apple orchards of different varieties. In this study, four apple orchards were selected comprising one acre each. These orchards included red delicious (RD), golden delicious (GR), and mix plantation (KRG) having Katja, red delicious and golden delicious. The KRG block orchard consisted of two separate acres where one acre was used for biological control of codling moth i.e. release of Trichograma spp. while the other one acre was maintained by the farmer's practices. From these various apple orchards, natural enemies of codling moth were collected across six months i.e. from April to September 2018.

The apple growers conducted their routine cultural practices such as hoeing, pruning, irrigations, application of chemical fertilizers and farmyard manure, and foliar sprays of pesticides for control of codling moth, aphids, mites, and powdery mildew.

2.1 PESTICIDES SPRAY IN THE SELECTED ORCHARDS

In apple orchards, most of the farmers use 2-3 pesticides sprays for control of codling moth and mites. While some farmers also use fungicides for control of powdery mildew. But very few apple growers use pesticides for control of aphids. In the selected four orchards the use of pesticides by growers is listed in Table 1. In the orchards RD, GR, and KRG, Chlorpyrifos (Lorsoban) was sprayed in May, June, and July while in orchard KRG (Te), one foliar spray of Emamectin benzoate was carried out to control codling moth. Whereas, one of the listed fungicides i.e. Nexter (pyridine) or Omite (propagate) was sprayed in May and June to control mites infestation. However, the fungicide spray was conducted by the farmer in the red delicious orchard at the time of petal fall against diseases like powdery mildew and apple scab as a plant protection measure.

2.2 RELEASE OF TRICHOGRAMMA EVANESCENS

The utilization of *Trichogramma* sp. (Egg parasitoid) for codling moth control has been known around the world for more than 20 years. However, this important egg parasitoid was not reported from Pakistan. The PRMP Quetta team successfully explored this biocontrol agent parasitizing eggs of codling moth from its project site in the Dasht district Mastung of Balochistan province. The specimens were identified as *Trichogramma evanescens* which is the third biocontrol agent of apple codling moth collected and being reared under PRMP in Quetta. The identification also confirms that this is the first-ever record for Pakistani fauna and a major achievement of PRMP project interventions in Quetta.

The reared mass of *Trichogramma evanescens* was obtained from PRMP Biological Control Laboratory at Agriculture Researched Institute Sariab Quetta and released in the KRG (Te) orchard after 15 days of emamectin spray during 2018.

2.3 COLLECTION OF NATURAL ENEMIES OF CODLING MOTH

Natural enemies of codling moth are comprised of predators and parasitoids. The known predators are carabid beetles, plant bugs, earwigs, green lacewings, wolf spiders and daddy longlegs and harvestmen. While the globally known egg parasitoid is Ascogaster quadridentate but here in Balochistan are recorded *Dibrachys microgastri* and *Elasmus* sp. nr. *johnstoni* as well as one recently recognized species of Trichogrammatid *evanescens*. The status of these natural enemies was monitored in the four selected apple orchards of different varieties across six-month period i.e. from April to September 2018. Ten apple trees were randomly selected in each orchard block and collections were performed from these trees. Yellow sticky traps were used for trapping parasitic wasps and were hanged in the middle portion of the apple tree at three different places in each orchard. While Carabid beetles or ground beetles were sampled using pitfall traps small plastic cups (10 cm diameter, 10 cm in depth). Each round of sampling involved one pitfall trap placed under the canopy of selected 10 apple trees. The corrugated paper was used for the collection of codling moth larvae, earwigs adults, and larvae of green lacewings. On the trunk of all 10 apple trees in each orchard block, the corrugated paper was wrapped around the trunk of the tree. Further, the parasitized codling moth larvae collected in corrugated papers were taken to the laboratory of PRMP at Agriculture Research Institute for identification of parasitism causal agent.

2.4 STATISTICAL ANALYSIS

The collected data were analyzed through descriptive statistics. All statistical analysis was computed on the Statistics 8.1 software (MathSoft Inc., Cambridge, MA, USA). The correlation was established among other parameters where possible (Fisher, 1948).

Table 1. Foliar spray of pesticides in the selected orchards at Tehsil Khuchlak district Quetta during 2018

S.No.	Trade name of pesticides	Active ingredients	Spray time
1	**Chlorpyrifos** (also known as Dursban, Lorsban, Whirlwind, Warhawk, and Eraser)	O,O-Diethyl O-3,5,6trichloropyridin-2-yl phosphorothioate	May, June July
2	Emamectin benzoate	Avermectin	May
3	Nexter	pyridaben	May, June
4	Omite	propargite	May, June
5	Cabrio Top	Pyraclostrobin5% + Metiram 55%	Petal fall

3. RESULTS

The natural enemies collected in the four orchards were comprised of predators and parasites. The predators have included carabid beetles, plant bugs, earwigs, wolf spiders, green lacewings, and daddy longlegs while the parasites were Diplazon sp., *Dibrachys microgastri*, *Elasmus.sp.nr.johnstoni*, and *Trichograma evanescens*. The occurrence of these natural enemies was monitored in four different apple orchards across six months extended from April through September during 2018.

3.1 PREDATORS CARABID BEETLE

The monitoring of the carabid beetle population was performed in apple orchards from April to September 2018 with the help of a pitfall trap. In April no carabid beetle was seen in all orchards and the lowest mean population was noted in May with a minimum value of 0.1 per trap in the orchard of mix plantation (KRG) and a higher value of 0.4 per trap in KRG (Te) indicating that all four orchards showed statistically at par differences in carabid beetle population in May (Figure 1a). When the temperature increased i.e. July and August, the carabid beetle population also increased and showed the highest mean population per trap in these two months. In July, the greater mean population of carabid beetle was 7.8 per trap in the red delicious orchard (RD) followed by 7.5 per trap in KRG (Te) with at par differences among apple varieties. But in August, KRG (Te) shown a higher mean population of 8.2 per trap followed by 7.5 per trap in the golden delicious orchard (GD). After the peak period in July and August, the population of carabid beetle started to decline as manifested in September. So, the population dynamics in September indicated a maximum average captured of 4.1 per trap in golden delicious orchard followed by 3.7 per trap in the red delicious orchard (RD) while, KRG and KRG (Te) lower mean captured per trap (Figure 1a). All four orchards showed a similar trend during each month of collection. This demonstrates that the apple cultivars did not affect the population of carabid beetle.

3.2 WOLF SPIDER

The survey of the wolf spider population was made in apple orchards from April to September 2018 as shown in Figure 1b. The collected data showed that in April and May the wolf spider population was low in all orchards but from June to September its population was increased only in a mixed plantation apple orchard (KRG (Te)). The month-wise population dynamics of wolf spider revealed that in all four orchards i.e. RD, GD, KRG, and KRG (Te) mean population was 0.8, 0.7, 0.7, and 0.9 in April; 0.9, 0.9, 0.8, and 1.1 in May; 1.2, 1.4, 1.5, and 4.9 in June; 1.3, 1.5, 1.6, and 5.2 in July; 1.5, 1.7, 1.8, and 4.7 in August while 0.9, 1.1, 1.4 and 3.0 per trap in September respectively (Figure 1b). Except for mixed plantation orchard with trichograma sp. (KRG (Te)), all the orchards were found in similarity trend with at par increase from June to August that demonstrate that there is no significant variation among apple varieties concerning population dynamics of a wolf spider. When the temperature increased i.e. June, July, and August, the wolf spider population also increased and showed the highest mean population per trap in these three months. In July, the greater mean population of wolf spiders was 5.2 per trap in KRG (Te), and also in June and August, KRG (Te) shown a higher mean population of 4.9 and 4.7 per trap followed by 3.0 per trap in September. After the peak period in July and August, the population of wolf spiders started to decline as manifested in September. All four orchards showed a similar trend during each month of collection. This demonstrates that the apple cultivars did not affect the population of wolf spiders (Figure 1b).

3.3 PLANT BUGS

The population dynamics of plant bugs are depicted in Figure 1c. The collected data showed that in April and May the plant bug population was higher in all orchards but from June to September its population was decreased. The month-wise population dynamics of plant bugs revealed that in all four orchards i.e. RD, GD, KRG and KRG (Te) mean population was 1.4, 1.2, 1.6 and 1.7 in April; 2.2, 2.7, 3.1 and 4.1 in May; 0.6, 0.3, 0.6, and 0.6 in June; 0.4, 0.7, 0.9, and 0.9 in July; 0.6, 0.5, 0.5, and 0.8 in August while 0.7, 0.9, 0.7 and 0.9 per trap in September respectively (Figure 1c). Except for mix plantation orchard with trichogrammatid sp. (KRG (Te)), all the orchards were found in similarity trend with at par variations that demonstrate that there is no significant variation among apple varieties concerning population dynamics of plant bugs. After the peak period in May, the population of plant bugs started to decline as manifested from June to September. All four orchards showed a similar trend during each month of collection. This demonstrates that the apple cultivars did not affect the population of plant bugs.

3.4 EARWIGS

The monitoring of the earwig's population was performed in apple orchards from April to September 2018 with the help of a corrugated paper band wrapping around the tree trunk (Figure 1d). In April earwigs were found only in KRG (Te) by the lowest mean population of 0.3 per sample. The comparison of five months i.e. from May to September, the lowest population mean of earwig was noted in May with a minimum value of 0.3 per trap in the orchard of mix plantation (KRG) and a higher value of 0.6 per trap in GD indicating that all four orchards showed statistically at par differences in earwig population. When the temperature increased i.e. July and August, the earwig population also increased and showed the highest mean population per trap in these two months (Figure 1d). In July, the greater mean population of earwig was 2.4 per trap in KRG (Te). followed by 2.1 per trap in KRG with at par differences among apple varieties. But in August, GD has shown a higher mean population of 2.7 per trap followed by 2.6 per trap in KRG (Te). After the peak period in July and August, the population of earwig started to decline as manifested in September. So, the population dynamics in September indicated a maximum average captured of 1.1 per trap in KRG (Te) followed by 0.9 per trap in KRG (Figure 1d). All four orchards showed a similar trend during each month of collection. This demonstrates that the apple cultivars did not affect the population of earwigs.

3.5 GREEN LACEWINGS

The six months survey for green lacewings revealed that the lowest population was found in April in all orchards followed by the population recorded in September. While the highest mean population per sample in all orchards was noted in July which was the peak period followed by June and August. From May to September, the lowest population mean of green lacewings was noted in May with a minimum value of 2.0 per trap in the orchard of red delicious (RD) and a higher value of 4.9 per trap in KRG (Te) followed by 4.7 and 4.0 per sample in KRG and GD indicating that three apple orchards (i.e. GD, KRG, and KRG (Te)) were significantly higher overpopulation dynamics in RD (2.0 per sample) showed statistically at par differences in earwig population in May. In July, the greater mean population of green lacewing was 14.0 per sample was found in KRG followed by 13.1 per sample in RD with at par differences among apple varieties. But in August maximum mean population of 7.5 per trap was noted in RD followed by 6.3 per sample in GD and KRG which were at par with each other. After the peak period in July, the population of green lacewings started to decline as manifested in August and September (Figure 1e). Out of May, all four orchards showed a similar trend during each month of collection. This demonstrates that the apple cultivars did not affect the population of green lacewings.

3.6 DADDY LONGLEGS

The occurrence of daddy longlegs as given in Figure 1f revealed that the lowest population were found in April and May in all orchards as compared to the other four months. While the highest mean population per sample in KRG (Te) were noted across three months of June to August. The peak period of the population of daddy longlegs covered across June to August and then started to decline in September. When the temperature increased i.e.June-August, the daddy longlegs population also increased and showed the highest mean population per trap in July (Figure 1f).

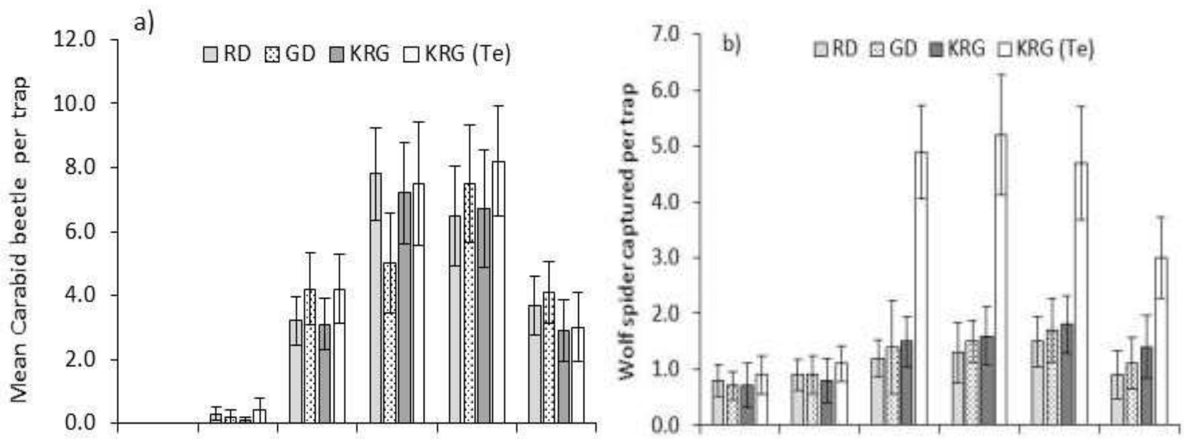

Figure 1. A (wolf spider) b (plant bugs). Shown the abundance of predators in different apple orchards as natural enemies of codling moth, Mean population per sample of carabid beetle.

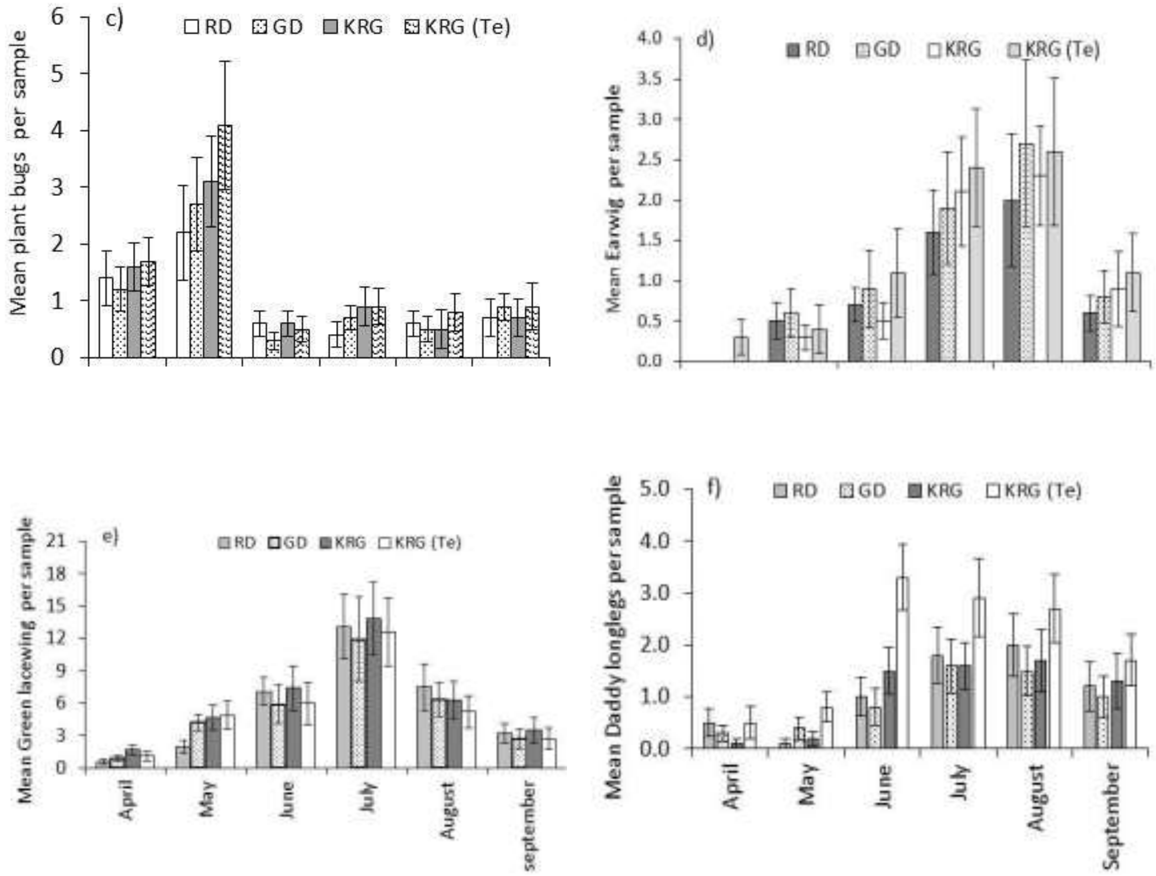

Figure 1. c (earwigs), d (green lacewings), e (daddy longlegs), and f showed Error bar represent standard error of means abundance of predators in different apple orchards as natural enemies of codling moth, Mean population per sample of carabid beetle

3.7 PARASITIZED CODLING MOTH LARVAE

The parasitized codling moth larvae were collected in the corrugated paper wrapped around the trunk of an apple tree in the selected ten trees in each orchard across six months extending from April through September during 2018. The collected larvae were taken to the PRMP laboratory at Agriculture Research Institute Sariab road Quetta for identification of parasitism. Figure 2a depicts the parasitized codling moth larvae caused by the Diplazon sp. The parasitized CM larvae collected during six months were 818 in total representing 232 parasitized CM larvae by Diplazon sp which make 28.36% of the total. No larvae were found in April in two orchards of RD and GD and lower mean parasitized CM larvae of 0.1 in-band trap per sample was observed in KRG and KRG (Te) orchards in April. While the highest mean population per sample in KRG (Te) were noted in June to July. Concerning orchards, KRG (Te) manifested the highest mean parasitized CM larvae of 3.0 in-band trap per sample followed by 2.4 in GD in July. While, in June, the KRG (Te) significantly expressed higher parasitized CM larvae of 3 in-band traps per sample over other orchards (Figure 2a).

The parasitized codling moth larvae by *Dibrachys microgastri* as given in Figure 2b, that from total 818 parasitized CM larvae, 407 CM larvae were parasitized by *Dibrachys microgastri* which makes 49.76% of the total. The data further showed that no larvae were found in April in any orchard and during May to July only KRG (Te) orchard indicated parasitized CM larvae with a mean population of 0.4, 0.9, and 1.9 in-band trap per sample. While the highest mean population per sample in KRG (Te) were noted in August and September. Concerning orchards in these two months, KRG (Te) manifested the highest mean parasitized CM larvae of 5.9 in-band trap per sample in September followed by 5 in August.

While, other three orchards such as RD, GD, and KRG manifested mean parasitized CM larvae of 0.4, 1.1, 1.6 in-band trap per sample in September. But in August, this orchard expressed 0.2, 0.2, and 0.3 mean parasitized CM larvae in-band trap per sample which were significantly lower than that in September. The peak period was August and September (Figure 2b).

The total parasitized codling moth larvae collected in the corrugated paper wrapped around the trunk of the apple tree in the selected apple orchards was 818. After identification at PRMP laboratory at Agriculture Research Institute Sariab road Quetta, 179 parasitized CM larvae was found to be caused by parasite *Elasmus.sp.nr.johnstoni* as the mean parasitized CM larvae in-band trap per sample is given in Figure 2c. During six month period extending from April through September, *Elasmus.sp.nr.johnstoni* makes 21.88% parasitized CM larvae among the total collected larvae.

The data showed no larvae in April in any orchard and in May all the orchards registered the lowest mean values of parasitized CM larvae which were 0.1, 0.1, 0.3, and 0.5 mean parasitized CM larvae in-band trap per sample in RD, GD, KRG, and KRG (Te) respectively. While, from June to September, the KRG (Te) orchard showed a linear increase in mean parasitized CM larvae with the highest value of 7.4 in September followed by 6.2 in August. Except in May, KRG (Te) showed a statistically significant increase over the other three orchards from June to September. While all three orchards were at par from July to September. In August the three orchards expressed comparatively higher mean parasitized CM larvae than July and September which were noted as 2.4, 2.2, and 2.3 mean parasitized CM larvae in RD, GD, and KRG respectively (Figure 2c).

3.8 ABUNDANCE AND SPECIES OF PARASITIC WASPS

The natural enemies of codling moth play an important role in the regulation of the population of this pest which is damaging the apple orchards and decreasing its market value. The abundance and species richness of parasitic wasps were studied in four different orchards with one have restricted pesticide spray (KRG (Te)) while resting orchards (RD, GD, and KRG) were sprayed two or three times by the grower. Using a yellow sticky trap, the parasitic wasps were collected and evaluated for abundance and species variation. The data given in Figure 2d indicated a higher mean population of parasitic wasps in the orchard KRG (Te) as compared to the other three orchards. Four different species were found in these orchards including *Diplazon* sp., *Dibrachys microgastri*, *Elasmus.sp.nr.johnstoni* and *Trichograma evanesces*. In the orchard RD, the lowest abundance of parasitic wasps was observed indicating 1.0,2.0 and

3.0 mean parasitic wasps per tree of *Diplazon* sp., *Dibrachys microgastri*,

Elasmus.sp.nr.johnstoni respectively while, the higher abundance of *Diplazon* sp., *Dibrachys microgastri*, *Elasmus.sp.nr.johnstoni* and *Trichograma evanesces* were found in KRG (Te) and manifested 16., 21.33, 12.0 and 3.33 mean parasitic wasps per tree (Figure 4.14). The total number of wasps collected through the yellow sticky trap was 292 representing 35.3% *Dibrachys microgastri* as the dominant one followed by 26.7% Diplazon sp. and the lowest one *Trichograma evanescens* (15.4%). Out of the four orchards, the KRG (Te) showed a higher percentage of occurrence of parasitic wasps by 61.54% Diplazon sp., 62.14% *Dibrachys microgastri*, 54.55% *Elasmus.sp.nr.johstoni*, and 22.2% *Trichograma evanescens* respectively (Figure 2d).

3.9 APPLE FRUITS DAMAGED BY CODLING MOTH IN FOUR APPLE ORCHARDS

Percent damaged apple fruits were examined at the time of harvesting where 50 fruits were randomly selected from ten trees in each orchard and observed for the presence or absence of damage symptoms of codling moth (Figure 3). The results showed that the apple orchard with release Trichograma sp. (KRG (Te)) where the only emamectin was sprayed manifested a higher number of damaged fruit (11.0%). But the golden delicious orchard (GD) recorded the lowest number of fruit damage (1.7%) by codling moth. While the other two orchards also expressed the fruit damage percentage as red delicious noted 3.0% fruit damage by codling moth and mix plantation orchard (KRG) recorded 4.8%.

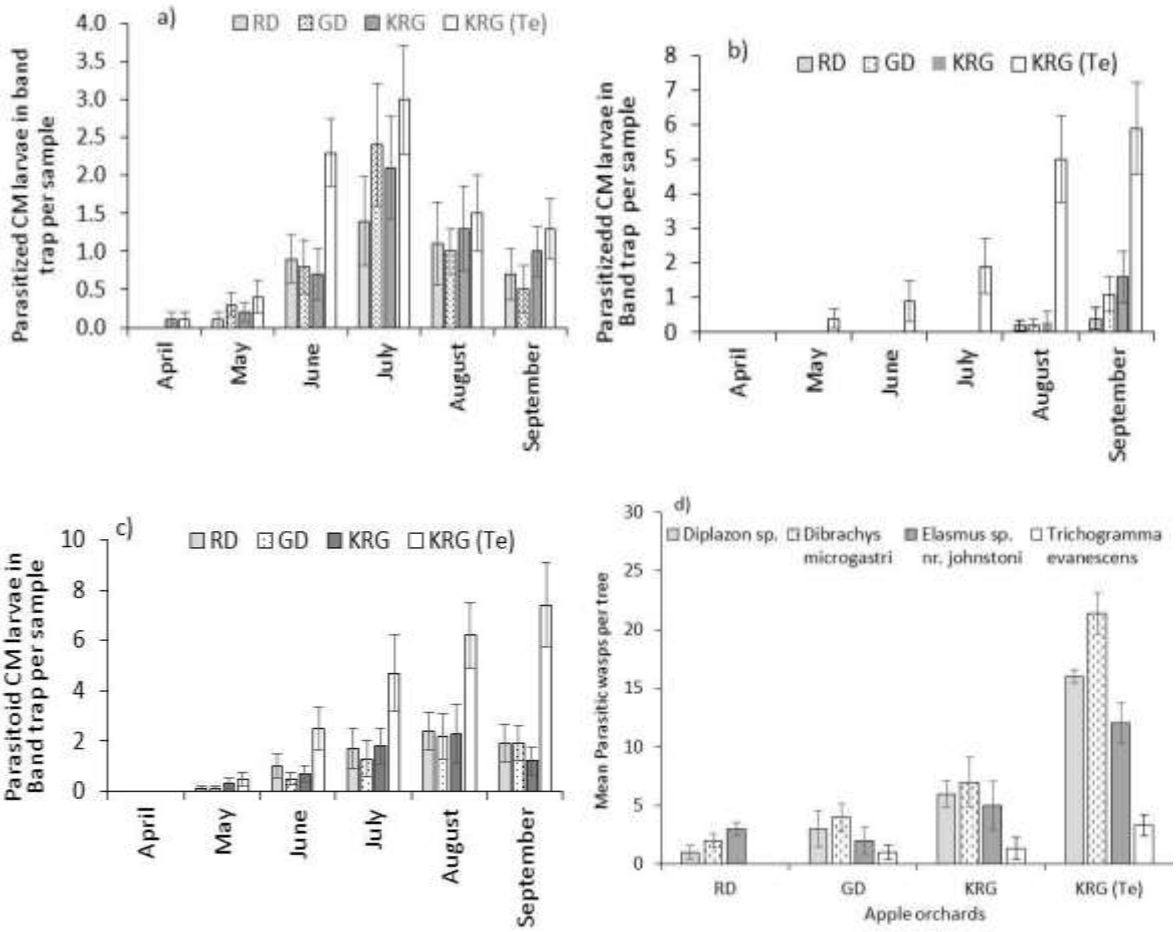

Figure 2. Represents the abundance of mean parasitoid codling moth larvae in-band trap per sample collected from ten trees in each apple orchards across six months i.e. from April to September 2018. Parasitism was identified by *diplazon* sp. (a), *Dibrachys microgastri* (b), *Elasmus*.sp.nr. *johnstoni* (c), While mean parasitic wasps per tree collected in four orchards and (d) Error bar represents standard error of means

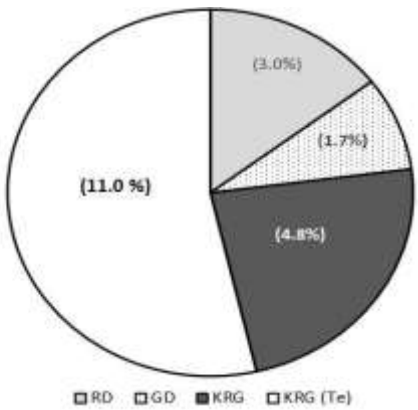

Figure 3. Percent damaged apple fruits by codling moth in four different apple orchards in Tehsil Kuchlak district Quetta

4. DISCUSSION

Natural enemies of codling moth play an important role in the regulation of the population of codling moth in apple orchards to less damage level. But, in the present era, codling moth infestation in apple orchards is tremendously controlled by the intensive application of pesticides spray that has now resulted in the eradication of natural enemies and severe emergence of codling moth with the creation of pesticides resistance issues. In the present study, the occurrence of natural enemies of the codling month was studied in four different orchards where farmers used different pesticides. But one orchard (KRG (Te)) was sprayed with emamectin at the request of a researcher at the time of petal fall and after 15 days of spray Trichograma sp. was released as a biological control agent for control of codling moth.

From this study, the higher carabid beetle population was recorded in July and August and lowest in May with no presence in June indicate that the foliar spray of pesticides less affected the surface predator as carabid beetle or another ground beetle. This might be due to the behavior of the carabid beetle that protects himself from the direct contract of pesticide by taking refuge in hidden places where spray particles can't drift to those places. Another reason is at the time of spray these beetles migrate to the boundary area where the intensity of spray less. There is great variability between apple-producing regions of the world in the average number of insecticide applications per season. A survey of pesticide use in commercial apple orchards in the UK in 2012 showed that, on average, apple orchards receive five insecticide sprays per annum (Garthwaite *et al*., 2012). Open field studies revealed that codling moth larvae which have left the trees or fallen fruits seeking for suitable pupation sites are actively attacked by carabids and spiders (Hagley and Allen, 1988; Boreau de Roincé *et al*., 2012).

According to serological tests, the proportion of Pterostichus melanarius (Illig.) adults preying on larvae might be as high as 63% in some apple orchards in Canada (Hagley and Allen, 1988). Another predator of codling moth larvae is the wolf spider in apple orchards. The collected data showed that in April and May the wolf spider population was low in all orchards but from June to September its population was increased only in a mixed plantation apple orchard (KRG (Te)). The low population of wolf spiders in other orchards is might be due to pesticide application particularly Chlorpyrifos which is highly toxic to spiders. A decrease in spider populations as a result of pesticide use can result in an outbreak of pest populations (Marc *et al*., 1999; Maloney *et al*., 2003). Like Spiders, the plant bugs are also bugs are highly susceptible to pesticides that is why in June September its population was lower as the results of severe pesticide applications. Except for the mixed plantation orchard with Trichograma sp. (KRG (Te)), all the orchards were found in similarity trend with at par variations.

The data regarding earwigs mean population in four apple orchards showed that augmentation of average monthly temperature resulted in an increase in earwig population linearly with a peak period in July and August and then decline in September. According to this survey, pesticides have been sprayed thrice in RD, GD, and KRG and once spray of emamentic in KRG (Te) but the population of earwigs not affected. This demonstrates that earwigs possess tolerance to pesticides to some extent. The potential earwig impact on codling moth (C. Pomonella) will be minor, as only eggs and recently hatched larvae are exposed (Carroll *et al*., 1985). Similarly, green lacewing is another important predator and, in this study, out of May, all four orchards showed a similar trend during each month of collection.

Christopher (2018) also recorded the highest adult abundance in June, July, and August in Wenatchee valley pear orchards. This demonstrates that the apple varieties did not affect the population of green lacewings. Instead of 2-3 sprays of chlorpyrifos in the study orchards, the population of green lacewing increased that evidence some degree of its tolerance to pesticides. Similar reports in the scientific literature have also indicated pesticide tolerance of green lacewings (Tauber *et al.*, 2000; McEwen *et al.*, 2001). As reported by Ashfaq *et al.* (2002) and Syed *et al.* (2008) that green lacewing can rear in the laboratory on large scale and can successfully be used against pests of different crops including pome fruits. The ability to tolerate pesticides has made them quite important in research and field application as well as easily adapt to various environmental factors (Nasreen *et al.,* 2003; Ulhaq *et al.,* 2006).

As regard parasitized codling moth larvae and parasitic wasps, from this study it was observed that the orchard with mixed plantation such as KRG (Te) exhibited the maximum number of parasitized codling moth larvae and the higher number of parasitic wasps because this orchard received restricted pesticide spray while in the other orchard various pesticides were sprayed. This demonstrates that parasitoids cannot tolerate the toxic effect of pesticides and that is why most of the natural enemies of codling moth as well as of other secondary pests are diminished resulting in the outbreak of pest. Arthropod natural enemies such as parasitoid wasps appear to be more abundant and have higher species richness within organic agroecosystems than conventional ones (Bengtsson *et al*., 2005; Hole *et al*., 2005; Letourneau and Bothwell, 2008). Parasitoid wasps are especially sensitive to pesticides, including fungicides and many insecticides that are less harmful to other beneficial arthropods (Suckling *et al*., 1999; Thomson and Hoffman, 2006). Thus, parasitoid wasp diversity can serve as an indicator of both overall orchard toxicity and the potential for increased biological control after reducing pesticide use.

Apple fruit damage by codling moth can be minimized through integrated pest management in which the use of a biological agent is one of its components. The influence of released Trichograma sp. (*Trichograma evanescens*) in mixed plantation orchard (KRG (Te)) on egg parasitism of codling moth was observed in terms of damage fruit percentage. The results showed that the apple orchard with release Trichograma sp. (KRG (Te)) where the only emamectin was sprayed manifested a higher number of damaged fruit (11.0%) as compared to orchards where codling moth was controlled by a repeated spray of pesticides. From these results, it is evidenced that the use of a biological agent can help in reducing pesticide pressure if a proper combination with chemical pesticides is exercised to effectively control codling moth.

A reduction of 53–84% of CM was achieved by the experimental release of two Trichogramma species (*T. dendrolimi* and *T. embryophagum*) in apple orchards in Germany (Sauer *et al.*, 2017). An additional benefit of the release of parasitoids is the simultaneous control of other pest species in apple orchards. The beneficial organisms alone can play an effective role in IPM but in general, the effect on codling moth control in economically productive orchards is considered insufficient (Thorpe *et al*., 2016).

5. CONCLUSION

The occurrence of natural enemies of codling moth in different apple orchards across six months period extended from April through September was studied. It is inferred that the indiscriminate use of pesticides affected natural enemies of codling moth particularly parasitoids, spiders, daddy longlegs, and plant bugs while some predators like carabid beetle, earwig, and green lacewings have shown tolerance. Single species of each predator and four species of parasitic wasps were recorded in the study area. The release of Trichograma sp. in one orchard with a spray of emamectin benzoate recorded apple fruit damage by 11.0% that might be reduced by using selective pesticides. Consequently, the time of Trichograma sp. release and use of selective pesticides along with other control measures can be effectively used for formulating integrated pest management program. It is suggested that the current status of natural enemies of codling moth in apple orchard may be investigated in all apple growing districts of Balochistan and make inventories of natural enemies to species level.

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