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Non-Chemical Treatments for Control of Codling Moth *Cydia pomonella* L. (Lepidoptera: Tortricidae) in Quetta Valley, Balochistan, Pakistan

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Abstract.- Present study was conducted in an apple orchard to evaluate the efficacy of corrugated paper band and pheromone trap as a non-chemical control strategy in relation to degree days against codling moth at Sariab, Quetta, Balochistan. Corrugated paper band (CPBs) were wrapped around the trunk and other main branches of apple trees to collect the larvae and pupae of *Cydia pomonella* during 1997-1999. Number of over-wintering larvae trapped in CPBs was significantly different in 1997 compared with 1999 but was not significantly different from 1998. Pheromone traps with female moth attractants were used for mating disruption to reduce the larval and male moth populations. Overall average percent infestation caused by the larvae of *C. pomonella* was 16.34% in 1998 and 16.23% in 1999. Statistical analysis of data on fruit infestation showed significant differences between generation at P-value <0.001 for 1998 and 1999. During the present investigations larval and pupal parasites of this insect pest were also observed in CPBs. The Ichneomonid wasp, *Diplazon* sp. (Hymenoptera: Ichneomonidae) was recorded for the first time in Balochistan.

Keywords: *Cydia pomonella*, non-chemical treatments, apple, Quetta, Balochistan.

INTRODUCTION

Codling moth, *Cydia pomonella* L. is a major pest of deciduous tree crops in fruit-growing regions throughout the world, infesting pome fruits such as apples, pears and quinces, as well as stone fruits and walnuts. In Quetta valley, codling moth is considered significantly important insect pest of apple. Caterpillar of *C. pomonella* cause heavy losses in unsprayed apple orchards. The loss may rise some times to 80% and the recorded host plant besides apple include pear, quince, plum, peach and cherry (Bajoi, 1994). In Balochistan there are three generations of codling moth and a partial fourth generation depending upon weather condition is also found (Kakar and Hazara, 2002).

The non-chemical method is an important measure to control pests of apple crop in orchard (Berankova *et al*., 1988). This method includes installation of corrugated paper bands (CPBs) or gunny bags around the trunk of apple trees and installation of pheromone traps (containing attractants for male moths) in apple orchard (Madsen *et al.*, 1976; Poswal and Groot, 1995; Charmillot *et al*., 1997; Kakar and Hazara, 2002; Judd *et al*., 2005; Angeli *et al.*, 2007).

Fixation of CPBs or gunny bags on stem of apple trees gives significant results by catching larvae of codling moth, which move down the trees alongside trunks to find suitable shelters for over-wintering are trapped in it (Backer, 1944; Reuveny and Cohen, 2004). These bands should be removed and replaced every month. In this way the natural enemies of pests are saved and the whole tree or orchard does not need spraying (Judd *et al.*, 1997; Suckling *et al.*, 2002).

Protection of apple fruits from codling moth larvae requires a precise data on first emergence and peak moth emergence of this insect. To achieve a monitoring system using pheromone traps is now developed with varying degrees of performance and efficacy. The pests are killed when they enter in these traps and gives some degree of control of this insect (Stelinski *et al.*, 2005). The pheromone traps if efficient also help in providing reliable and valuable information for forecasting pest damage and can determine when to initiate pest management practices.

Utilization of corrugated paper bands in

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chemically unsprayed orchard also seems to be significant to monitor and collect codling moth larval and pupal parasites. Cox and Daniel (1935) and Jaynes and Marucci (1947) recorded parasites from over-wintered larvae of *C. pomonella* in unsprayed orchards.

The aims and objectives of this experiment by wrapping CPBs or gunny bags around tree trunks is to collect, reduce and destroy over-wintered larval populations of codling moth. While installation of pheromone trap in the canopy of apple tree is to suspend egg-laying by mating disruption and to decrease larval and male moth populations of *C. pomonella* in the orchard. By doing so, the fruit trees need no pesticide applications and fruits are saved from chemical contamination, which will have positive impact on pest, beneficial fauna and environment.

MATERIALS AND METHODS

Field study was carried out to examine the effects of corrugated paper bands and pheromone trap as control tactics for codling moth during, 1997-1999. For this experiment an apple orchard of five acre block measuring 155.4 x 130.2 m (20234.35 m^2) in Kech Beg at Sariab, Quetta was selected (Fig. 1), which was divided into 12 plots each bearing 25 trees. Each plot was 30.40 x 40.34 m in size. An area of 1.6 m was maintained in the centre of orchard as path. This orchard was poorly maintained and un-managed for several years. No attention was given to protect it from the attack of insect pest of apple. However, the orchard was sprayed during the experiment by the grower with organophosphorous compounds (Lorsban, Neoron, Methyl-Parathion and Omite) once or twice in a season for the control of *C. pomonella* but without considering the proper doses, number of sprays and optimum time of pesticide application.

Installation of corrugated paper bands (CPBs)

Corrugated paper bands were used for collection and removal of larvae (caterpillars) and pupae (*Chrysalis*) of codling moth from the apple orchard to reduce its population in the following season and generation. For this purpose CPBs 15 X 45 cm long (4-5/trees) were wrapped around the tree trunk and other main branches of 300 apple trees every year during 1997-1999. As the present study was initiated in the autumn of 1997, hence CPBs were placed around the limbs of trees to capture the only over-wintering larvae and pupae of moth. While during 1998 and 1999 CPBs were used to collect the larvae and pupae of over-wintering as well as the subsequent three month generations.

In 1997, CPBs were installed on September 13 to collect and remove over-wintering larvae and pupae. The larvae and pupae found in CPBs were counted, removed and killed on October 13. Fresh CPBs were wrapped again on October 17, 1997 and opened on 18th November. Same procedure was repeated again and CPBs were installed on November 20 for collecting hibernating larvae. These CPBs were opened on December 23. Each larva found inside the CPBs was counted and destroyed. Same procedure was adopted for collection of over-wintering larvae and pupae of codling moth during 1998 and 1999.

Corrugated paper bands were also wrapped on tree trunks and main branches for trapping first, second and third generation larvae of codling moth during 1998 and 1999. The larvae and pupae trapped inside the CPBs were counted for record and killed in order to reduce population of codling moth in orchard. Dead over-wintering larvae were frequently found inside CPBs, their numbers were counted for record with other samples during 1997-1999.

During the present investigation in 1998 and 1999, parasitized larvae and pupae of codling moth were also observed in CPBs in the months of July and August. The larvae and pupae of codling moth were counted and dissected under microscope. The larval and pupal forms of parasites were seen. During field observation some adult parasites were also observed and collected from larvae and pupae of the moth by aspirator. The larval and pupal forms of parasite were kept in Petri dishes and reared upto adult stage. Numbers of adult parasites were counted and preserved in 5% alcohol. Permanent mount of larval, pupal and adult parasites was prepared. Slide and wet collections were identified by National Insect Museum, CABI Bio-Sciences Center, Rawalpindi, Pakistan.

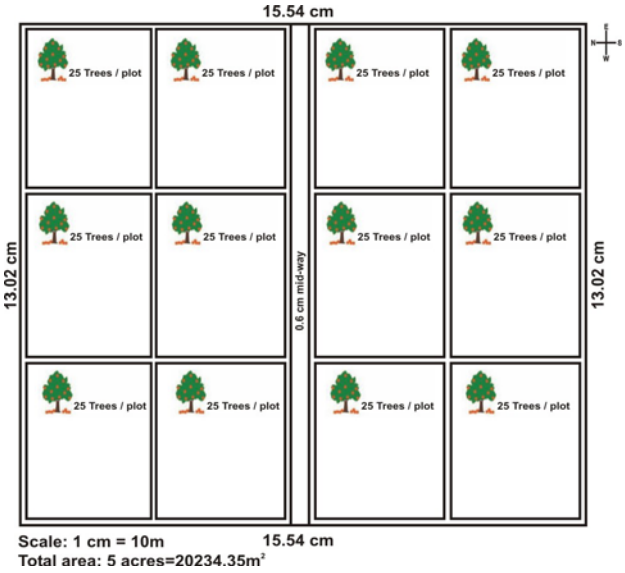

Fig. 1. Layout of the partially non-chemical apple orchard to determine the arrangement of corrugated paper bands and pheromone trap installed for control of codling moth at Sariab, Quetta during 1997-199. Each plot had 25 trees.

Installation of pheromone traps

Pheromone (Tent type) traps with lures of rubber septa (500 µg/trap) loaded with synthetic pheromone (Z-7-dodecenyle acetate, E8E10-120H, symbol Z7-12 AC) were installed inside the canopy of apply trees at a height of 5 feet from the land for all generation of the insect during 1998 and 1999 seasons only, two traps per acre for mating disruption to reduce egg-laying by female moth and to decrease larval population. In total 10 traps were used in the experimental apple orchard. The traps were checked every morning and the adult male moths captured in the traps were recorded daily. The traps with lures were replaced by new ones with an interval of one week and were placed in the same locations in the orchard. Other aims of using pheromone traps were to save the apple fruits from infestation caused by the larvae of *C. pomonella* during 1998-1999.

Fruit sampling

The data regarding fruit infestation 50 trees were selected including 10 each from the east, west, north, south, and centre of orchard. The apple fruits were sampled on five sides (east, west, noth, south and centre) of trees. Maximum number of fruits collected from a single tree were 2348 and 2703 during 1998 and 1999, respectively. Numbers of infested and healthy fruits were counted visually and percent infestation of apple fruits was calculated. Percentage data were transformed (arc-sin) before subjecting them to ANOVA by using statistical software M stat.

Calculation of degree days

For calculation of heat units, daily maximum and minimum temperature was noted from the Agro-Metrological centre of Agriculture Research Centre Sariab, Quetta during 1997-1999. Formula of Bajoi (1994) in calculating degree days was followed as this was found specific and appropriate for codling moth and environmental condition of Balochistan (Kakar and Hazara, 2002). He (1994) mentioned 10ºC as base temperature which is added from the beginning of the year.

If maximum is less than 10 ºC, $A = 0$

If maximum is greater than 10 ºC $A = \frac{\text{maximum+minimum}}{2} - 10$

If maximum is above 10 and minimum is less than 10, then the following is taken:

If $\frac{\text{maximum + minimum}}{2}$ is more than 10 ºC

then $A = \frac{\text{max}}{2} + \frac{\text{min}}{4} - 7.5$

If $\frac{\text{maximum + minimum}}{2}$ is less than 10 ºC

then $A = \frac{\text{maxi}}{4} - 2.5$

Where: A = the daily sum of degrees in Celsius.

The concept of degree days has been successfully used by Beheshti and Seyedoleslami (1987), Berankova *et al.* (1988) and Borchert *et al.* (2004) to predict the population of codling moth.

RESULTS

Corrugated paper bands (CPBs)

The larvae and pupae of codling moth were sampled from 300 apple trees by wrapping CPBs on

tree trunks every year. Table I showed that over-wintering larvae and pupae of *C. pomonella* were observed when degree days were 2350.93, 2535.07 and 2911.86°C during 1997, 1998 and 1999 respectively.

During 1997 a total of 508 over-wintering larvae and 09 pupae were removed and collected from CPBs. Table I also reveals that during the months of June, July and August in 1998, 826 larvae and 384 pupae of the three subsequent generations were observed and removed from corrugated paper bands. At this time sum of mean temperature was between 920.47 to 1969.59 degree days. During the same year a total of 449 over-wintering larvae and 07 pupae were recorded between 2535.07 to 2741.13 degree days from September 4 to December 24 1998 (Table I).

Likewise, during the first, second and third generations in 1999 a total number of 635 larvae and 262 pupae were observed and removed from corrugated paper bands, when heat units (degree days) was 1000.30 to 2209.55^{o}C from 18 May 1999 to 30 August 1999. In addition to this 335 over-wintering larvae and 04 pupae were collected in 1999. During this period 2911.86 to 3169.55 degree days were accumulated. A gross total of 1235 larvae and 391 pupae were collected in 1998, similarly 970 larvae and 266 pupae were removed from CPBs during 1999. A small number of 20 pupae were sampled in the months of October during 1997-1999 because of favorable conditions (Table I).

Significant differences were observed in number of over-wintering larvae in 1997 against 1999 but was not significantly different against 1998 (Table I). The same table also indicates that the numbers of larvae and pupae trapped in CPBs reduced on each subsequent sampling date and generation. Differences were also found significant between number of larvae and pupae of 1998 against 1999.

Overall average percent infestation caused by the larvae of *C. pomonella* was 16.34% in 1998 and 16.23% in 1999 (Table I). Statistical analysis of data on fruit infestation showed significant differences between generation at P-value < 0.001 for 1998 and 1999.

Analysis of average percent fruit infestation during 1998 and 1999 revealed that significant difference was not found between sides itself, however, some significant differences of fruit infestation were observed in the first, second and third generation in the year 1998 and 1999 (Table III).

As a result of present investigations using corrugated paper bands for trapping codling moth larvae and pupae, some natural enemies of *C. pomonella* were also recorded. These natural enemies were identified by CABI International Bioscience Centre, Rawalpindi as *Dibrachys* sp. (Pteromalidae: Hymenoptera) a larval and pupal parasite. Another parasite was *Diplazon laetatorius* Fab. (Ichneomonidae: Hymenoptera). *Diplazon* sp. was recorded for the first time during 1998 in Sariab, Balochistan. These parasites were observed in August, 1998, July and August, 1999. Number of adult parasites recorded during field observation were 56 *Dibrachys* sp. and those reared in laboratory were 34 *D. laetatorius*. Total number of parasitized larvae and pupae observed in CPBs were 37 and 14, respectively.

Pheromone traps

Using of pheromone trap was the purpose for mating disruption and to reduce larval and male moth population of codling moth in the orchard. Secondly, it was aimed for protection of apple fruits from infestation by larvae of *C. pomonella.*

Table II indicated that during 1998 emergence and peak of first generation moth was observed on March 27 and April 8, at 90.34 and 179.04 degree days respectively. Last moth emergence was recorded on April 16 at 222.64 degree days. During second generation, appearance, peak and last moth emergence was noted on June 2nd, July 4 and July 21st, 1998 at 723.82, 1148.72 and 1415.62 degree days respectively. Similarly emergence, peak and last moth flight of the third generation was observed on August 3, 6 and 17 respectively. On these dates effective mean temperature was 1606.12, 1650.54 and 1808.59 computed heat units (degree days). A period of 15 days was observed between first and last moth appearance of the third generation.

During 1999, first generation moth was emerged on March 27th at 89.43 degree days. Peak and last moth activity was noted on April 5 and

Table I.- Trapping of codling moth larvae and pupae by corrugated paper bands (CPBs) wrapped on trees in partially non-chemical apple orchard in relation to temperature and cumulative degree days at Sariab, Quetta during 1997-1999.

Generation	Date when CPBs		No. of larvae trapped	No. of pupae observed	Temperature (°C) when CPBs opened		Cumulative °DDs when CPBs opened	Av: % infested fruits
	Wrapped	Opened			Minimum	Maximum		
1997								
Collection of	13-9	13-10	260	9	7.4	24.2	2350.93	
over-wintering	14-10	18-11	130	0	0.2	13.2	2372.38	No infestation
larvae	20-11	23-12	118	0	-0.8	8.4	2390.58	due to off season
Total			508	9				
1998								
1st generation	21-5	18-6	345	231	16.2	32.4	920.47	
2nd generation	21-6	23-7	292	89	19.6	34.0	1444.12	16.34
3rd generation	25-7	28-8	189	64	19.4	33.8	1969.59	
Total			826	384			2535.07	
Collection of	4-9	21-10	188	7	2.4	23.8	2650.32	No infestation
over-wintering	23-10	19-11	154	0	0.8	17.5	2741.13	due to off season
larvae	21-11	24-12	107	0	-0.6	18.2		
Total			449	391				
Grand total			1235					
1999								
1st generation	18-5	16-6	235	118	19.0	36.8	1000.30	
2nd generation	18-6	18-7	207	74	20.6	38.6	1578.40	16.23
3rd generation	21-7	30-8	193	70	18.4	34.6	2209.85	
Total			635	262				
Collection of	7-9	20-10	137	4	10.6	24.6	2911.86	
over-wintering	22-10	24-11	109	0	7.5	16.5	3026.15	No infestation
larvae	25-11	25-12	89	0	-4.5	13.8	3169.55	due to off season
Total			335	4				
Grand total			970	266				

Table II.- Effect of pheromone traps on trapping and monitoring emergence of codling moth in partially non-chemical apple orchard at Sariab, Quetta during 1998 and 1999.

Generation with date of trap installation	Date of emergence with °DDs		Date of peak emergence with °DDs		Date of last moth recorded with °DDs		Total No. of moth trapped	
	1998	1999	1998	1999	1998	1999	1998	1999
1st generation	27-3	27-3	8-4 179.04	5-4 148.41	19-4	14-4	32	27
24-3-1998	90.34	89.43 °DDs	°DDs	°DDs	251.74	225.16		
24-3-1999	°DDs				°DDs	°DDs		
2nd generation	2-6	24-5	4-7	28-6	21-7	11-7	54	43
27-5-1998	723.82	675.03	1148.72	874.80	1415.62	1455.60		
23-5-1999	°DDs	°DDs	°DDs	°DDs	°DDs	°DDs		
3rd generation	3-8	30-7	6-8	5-8	17-8	31-8	39	24
1-8-1998	1606.1	1786.5	1650.54	1883.4	1808.59	2303.85		
28-7-1999	2	°DDs	°DDs	°DDs	°DDs	°DDs		
	°DDs							

Table III.- Average % infested apple fruit sampled from different sides of tree in partially non-chemical orchard at Sariab, Quetta during 1998 and 1999.

Side	1998			1999		
	1st generation	2nd generation	3rd generation	1st generation	2nd generation	3rd generation
	Av % infestation ± SD	Av % infestation ± SD	Av % infestation ± SD	Av % infestation ± SD	Av % infestation ± SD	Av % infestation ± SD
East	12.92±2.49	19.09±0.75	10.46±1.44	14.31±0.54	18.05±0.96	8.17±2.04
West	12.89±0.87	18.97±1.93	9.59±0.79	14.12±0.44	16.89±2.74	7.98±0.93
North	14.34±1.17	19.83±2.93	11.47±1.66	14.86±1.95	19.14±0.93	9.64±1.33
South	13.82±1.70	18.62±2.81	11.17±1.11	14.75±1.16	18.85±1.12	8.97±0.74
Centre	13.17±1.65	18.71±2.07	10.32±1.44	13.95±0.96	18.41±0.27	7.36±1.16

K/values	Source	n	Analysis of variance – 1998				Analysis of variance – 1999			
			S.S.	M.S.	F value	Prob.	S.S.	M.S.	F value	Prob.
1	Replication	4	18.22	4.55	1.189	0.332	9.56	2.39	1.455	0.236
2	Between sides	4	9.51	2.37	0.621		13.92	3.48	2.117	0.098
4	Between generations	1	393.90	393.90	102.855	0.001	187.32	187.32	113.947	0.001
6	AB	4	3.00	0.75			4.44	1.11	0.673	
-7	Error	36	137.87	3.83			59.18	1.64		
	Total	49	562.51				24.44			

Co-efficient of Variation =12.05% Co-efficient of Variation =7.85

April 14 when sum of temperature was 148.41 and 225.16 degree days. Similarly emergence, peak and last moth appearance of the second generation was observed on May 24, June 8 and July 11 respectively. At these dates effective mean temperature was 675.03, 874.80 and 1455.30 computed heat units (degree days). While emergence, peak and last moth activity of third generation was noted on July 30, August 5 and August 31, respectively at 1786.5, 1883.4 and 2303.85 degree days. An interval of 33 days was noted between first and last moth emergence of the third generation.

A total of 125 moths were captured in pheromone traps in 1998, while the number of moths trapped in 1999 was 94 (Table II).

DISCUSSION

Under natural conditions the presence of larvae or pupae of codling moth depend on the variation in temperature during the post-diapause development period. The scattered emergence of *C. pomonella* after over-wintering period is due to the fluctuation in temperature. In the present investigation temperature dependence was observed as the main cause of scattered emergence of moth. Some authors (Riedl, 1983) observed that the first individual of over-wintering larvae entering diapause, were also the first ones emerging in the following season. Other workers (Jermy, 1967; Russ, 1966; Saringer, 1977) however, did not confirm this relationship.

The objective of present study was to control or reduce codling moth infestation by trapping and killing the larvae. We made sufficient control of codling moth larvae and pupae trapped in corrugated paper bands and their population was decreased year by year from autumn 1997 to autumn 1999 (Table I). Table I also indicated that in 1997 a relatively more over-wintering larvae (508) were collected against 449 and 335 over-wintering larvae of 1998 and 1999 respectively.

A cumulative numbers of 1292 over-wintering larvae sampled from CPBs on apple trees during the subsequent years, whereas, a total number of 20 pupae (chrysalis) were obtained only in the months of September of 1997, 1998 and 1999. Because suitable temperature conditions were available in the months of September which

influenced the development of larvae to change into pupae. In the subsequent 1st, 2nd and 3rd generation of *C. pomonella* during 1998 a gross total of 1235 larvae and 391 pupae were sampled against 970 larvae and 266 pupae in 1999.

Berankova *et al*. (1988) reared over-wintering larvae directly in cages captured from CPBs in a non-chemical orchard and recorded the mortality of larvae and daily moth emergence. Bajoi (1994) also observed rearing of over-wintering larvae in orchard trapped in corrugated bands, is feasible for the determination of peak moth activity under environmental conditions of Balochistan.

Researchers like Steiner and Ackerman (1936), Baker (1944), Jaynes and Marucci (1947), Yothers and Carlson (1949), Saeb (1994) and Judd *et al*. (1997) have highlighted the significance of corrugated paper bands for cocooning larvae of *C. pomonella* and promoted non-chemical control of codling moth.

Result of pesticide treatment by the grower in the experimental orchard during 1998 and 1999 is given in Table IV.

Table IV.- Data of pesticide treatment by the grower's in partially non-chemical apple orchard at Sariab, Quetta during 1998 and 1999.

Treatments	Date of pesticide application	Date of cover spray
1998		
Lorsban	22-4-98	09-5-98
Neoron	20-6-98	Nil
Applied water only	31-7-98	Nil
1999		
Methyl-parathion	26-4-99	Nil
Omite	18-6-99	Nil
Applied water only	19-7-99	Nil

The data of pheromone trap has demonstrated that mating disruption has potential as a practical control method for codling moth. A total of 125 and 94 male codling moths were caught in pheromone traps during 1998 and 1999. However, our experimental design was a partially non- chemical orchard, therefore, levels of overall average percent infestation in CPBs and pheromone treated apple orchard is consistently extended to 16.34% and 16.23% in 1998 and 1999 compared with fruit damage 43.5 - 56.7%, recorded by Judd *et al*. (1997) in tree banded experimental orchard.

In present studies, Ichneomonid wasp, *Diplazon* sp. (Ichneomonidae) was recorded for the first time in Balochistan. Another parasite was *Diplazon laetalorius* Fab. (Ichneomonidae: Hymenoptera). In addition, *Dibrachys* sp. (Pteromalidae) a larval and pupal parasite was recorded (Junjua and Chaudry, 1964). Collection of these parasites from larvae and pupae trapped in CPBs suggest that parasitism by insects is of minor importance. Some dead larvae were recorded which appear to have been killed by the fungus, but it may be doubtful that such natural enemies ever exist in effective numbers. Suckling *et al*. (2002) reported 7-12% larval parasitism of *C. pomonella* from the banded apple trees suggested that tree banding for insect biological control agents is a valuable tool that can help to determine and improve parasitoid success.

Dean (1989) demonstrated that fungus diseases destroy a significant number of hibernating larvae, but insect predators and parasites are not important. He further mentioned that great mortality to over-wintering larvae is caused by birds, especially small of wood-pickers feeding on larvae in cocoon. But if an orchard chemically-untreated is to be maintained for five to six years constantly, then the parasites may have capacity to control pests effectively.

REFERENCES

ANGELI, G., ANFORA, G., BALDESSARI, M., GERMINARA, G.S., RAMA, F., CRISTOFARO, A. AND LORIATTI, C., 2007. Mating disruption of codling moth, *Cydia pomonella* with high densities of Ecodian sex pheromone dispensers. *J. appl. Ent*., **131:** 311-318.

BAJOI, A.H., 1994. Insect pests of hill fruits. In: *Horticultural and forest crops*. Vol. 2 (ed. A. A. Hashmi), pp. 449-476, PARC, Islamabad.

BAKER, H., 1944. Effect of scraping and banding trees upon the number of transforming and hibernating codling moth larvae. *J. econ. Ent*., **37:** 624-628.

BEHESHTI, N.D. AND SEYEDOLESLAMI, H., 1987. Forecasting codling moth phenology based on the degree day summation in the apple orchard in west of Esfahan. *Ent. Phyt. Appliq*., **54:** 2 5-45.

BERANKOVA, J., BARTAK, M. AND KOCOUREK, F., 1988. Variability in spring emergence of the over-wintering generation of codling moth, *Cydia pomonella* (L.). *Acta ent. Bohemoslov*., **35:** 274-282.

BORCHERT, D.M., WALGENBACH, J.F., KENNEDY, G.G. AND LONG, J.W., 2004. Toxicity and residual activity of Methoxyfenozide and Tebufenozide to codling moth (Lepidoptera: Tortricidae) and oriental fruit moth (Lepidoptera: Tortricidae). *J. econ. Ent*., **7:** 1342-1352.

CHARMILLOT, P. J., PASQUIER, D., DORSAZ, L. KEIMER, C., HERMINJARD, P., OLIVIER, R. AND ZUBER, M., 1997. Mating disruption of codling moth, *Cydia pomonella* L. with Isomate-C plus distributors in Switzerland in 1996. *Rev. Suisse. Vatic. Arboric. Hortic*., **29:** 91-96.

COX, J.A. AND DENIEL, M.D., 1935. *Ascogaster carpocapcae* Vierack. In relation to arsenicals sprays. *J. econ. Ent*., **28:** 113-120

DEAN, R.W., 1989. Biology of the codling moth in Hudson Valley Orchards. *Search Agric.*, **36**: 1-28.

JANJUA, N.A. AND CHAUDHRY, G.U., 1964. *Biology and control of hill fruit insect of West Pakistan.* pp. 158. Government of Pakistan Press, Karachi.

JAYNES, H.A. AND MARUCCI, P.A., 1947. Effects of artificial control practices on the parasites and predators of the codling moth. *J. econ. Ent*., **40**: 9-25.

JERMY, T., 1967. Experiments on the factors governing diapause in the codling moth, *Cydia pomonella* L. (Lepidoptera: Tortricidae). *Acta Phyt. Acad. Sci*., **2**: 49-60.

JUDD, G.J.R., GARDINER, M.G.T. AND THOMSON, D.R., 1997. Control of codling moth in organically managed apple orchard by combing pheromone mediated mating disruption, post harvest fruit removal and tree banding. *Ent. exp. Applic*., **83**: 137-146.

JUDD, G.J.R., GARDINER, M.G.T., DELURY, N.C. AND CARG, G., 2005. Reduce antennal sensitivity, behavioural response and attraction of male codling moth *Cydia pomonella* to their pheromone (E,E)-8,10-dodecadien-1-01 following various pre-exposure regimens. The Netherlands Entomological Society. *Ent. exp. Applic*., **114**: 65-78.

KAKAR, A.U. AND HAZARA, A.H., 2002. Population dynamics of codling moth, *Cydia pomonella* L. (Lepidoptera: Thortricidae) with special reference to degree day technique in apple orchard of Balochistan. *Balochistan J. agric. Sci*., **3**: 26-34.

MADSEN, H.F., VAKENTI, J.M. AND PETERS, F.E., 1976. Codling moth suppression by male removal with sex pheromone traps in the isolated apple orchard. *J. econ. Ent*., **69**: 597-599.

POSWAL, M.A. AND DE GROOT, J.M., 1995. In: *The grower's guide for moderating use of chemical sprays in apple orchards in Balochistan* (eds. M.A. Poswal and J.M. De Groot), pp. 10. Department of Agriculture and Co-operatives, Government of Balochistan, Food and Agriculture Organization, UNDP.

RIEDL, H., 1983. Analysis of codling moth phenology in relation to latitude, climate and availability. In: *Diapause and life cycle strategies in insects* (eds. V.K. Brown and I. Hodek.). Dr. W. Junk Publishers, The Hague, pp. 233-252.

RUNEURY, H. AND COHEN, E., 2004. Resistance of the codling moth *Cydia pomonella* (L.) (Lepidoptera: Tortricidae) to pesticides in Israel. *J. appl. Ent*., **128:** 645-651.

RUSS, K., 1966. Der Einfluss Phitoperiodizitat auf die Biologie des Apfelwicklers (*Carpocapsa pomonella* L.). *Pflanzensch, Ber*., **33:** 27-92.

SAEB, H., 1994. Bio-ecological investigation on codling moth (Lepidoptera: Olethreutidae) in the Rasht region. *J. entomol. Soc. Iran*, **14:** 17-18.

SARINGER, G., 1977. Diapause–Untersuchungen an ungarischen und americanischen Apfel wickler-Populationen , *Laspeyresia pomonella* L. (Lepidoptera: Tortricidae). *Z. angew. Ent.*, **33:** 62-79.

STEINER, L.F. AND ACKERMAN, A.J., 1936. Large scale test of orchard sanitation on control of codling moth. Progress Report. *J. econ. Ent.*, **29:** 648-653.

STELINSKI, L.L., GUT, L., KETNER, K.C. AND MILLER, J.R., 2005. Orientational disruption of codling moth, *Cydia pomonella* (L.) (Lepidoptera: Tortricidae) by concentrated formulations of microencapsulated pheromone in flight tunnel assays. *J. appl. Ent*., **129:** 481-488.

SUCKLING, D.M., GIBB, A.R., BURNIP. G.M. AND DELURY, N.C., 2002. Can parasitoid sex pheromones help in insect bio-control ?. A case study of codling moth (Lepidoptera: Tortricidae) and its parasitoid *Ascogaster quadridentata* (Hymenoptera: Braconidae). *Environ. Ent.*, **31:** 947-952.

YOTHERS, M. A. AND CARLSON, F. W., 1949. Scraping and banding apple trees as a supplementary codling moth control measurer in the Pacific Northwest. USDA. *Circ*., 828.

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