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Codling Moth, *Cydia pomonella* (Lepidoptera: Tortricidae); As a Major Pest of Apple

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Abstract: The article provides a bibliographic review of investigation about *Cydia pomonella* L. (Lepidoptera: Tortricidae); control, through the entire world. It contains different aspects; biology, morphology and different control strategies of the moth in apple, *Pyrus malus* Linn. (Rosaceae: Pomoidea) orchards. It is revealed that the moth is getting resistance to the pesticides thus other control measures like microbial insecticides, *Bacillus thuringiensis,* granulosis virus, biological agent, pheromone, mating disruptant, and selected/alternative use of pesticides are recommended.

Key words: *Cydia pomonella,* biological agent, granulosis virus, *Bacillus thuringiensis,* pheromone, mating disruptant, Balochistan, Pakistan

Introduction

Apple is a major cash crop of Balochistan, Pakistan. It is grown over >129,400 ha which produces about 487,279 tons. The bearing capacity of the province is about 154,50 tons ha^{-1} (Anonymous, 1998-99) which could be increased by batter plant protection activities. Codling moth *(C. pomonella)* is the major pest of the crop and mostly pesticides are being used for it's control (Anonymous, 1999). Isufi and Myrta (1996), also reported *C. pomonella* as key pest of apple among the tortricid. Hashmi (1994), reported that the larvae of the moth cause most of the damage by making tunnels through the calyx tube into the fruit and ended up with eating the seeds. Thus the growth of the affected fruit stops and small, shriveled fruit falls on the ground. The affected part of the fruit could be identified by it's black and rotten damage area. For pupation, the larvae come out and pupate either on fallen leaves or into the mud around the tree trunk.

Biology: The larva is of pinkish white color. Young moth is of lighter gray-brown color with deep golden or bronzed area around the tips. Female moths lay eggs in < 15.5°C during the evening and early night on leaves, twigs and fruits. It takes 5-14 days (depending directly on temperature, temperature has direct relation to the development of codling moth; Marti *et al.*, 1996) for hatching larvae. After 19-21 days the larvae comes out of the fruit and spin cocoons in their hibernation places. Young moth appears after 13-15 days which repeats the cycle. 2-3 generations are reported in a year (Peairs and Davidson, 1956). Pons *et al.* (1994), studied the effect of photoperiod on the diapause of *C. pomonella* in field and laboratory and found that a constant photoperiod does not effect the development of the larvae till 3rd instar. In the laboratory 1-5 h for 15 min. light was recorded as critical photoperiod. In the field conditions 14 hours with 40 min light was reported as critical photoperiod for inducing diapause to the said insect. It was also reported that all larval stages are sensitive to diapause induction. Short photoperiod had greater influence on the 2nd to 5th instar. High temperature (25°C) partially reverse the photoperiod induced diapause. Naven and Rehfield (1995), found that when stored pupae (at 0 °C) of codling moth were exposed to high temperature, high mortality occurred.

Khattak *et al.* (1995), tested radiation on the longevity, mating, fecundity and fertility of moth and found inverse relation between the increase of radiation and all tested factors. Morgan (1996), provided information about the relationship between temperature and biology of moth. He described that 1, 2°C increase in daily minimum and maximum temperatures respectively makes the pest active 10 to 20 days earlier than it would be expected. Such increase in temperature could bring back the life cycle of the pest and as a result a third generation could be obtained. Solomo *et al.* (1996), proved direct relation between temperature and growth/development of the moth through mathematical model. Gottwald (1996), found that 10°C is an appropriate temperature for the development of codling moth. Ravn and Madsen (1995), observed that first moth of Ist generation appears at 10°C (100 day-degrees) while 50% population appears at 300 day-degrees. Karalius and Buda (1995), studied the mating, oviposition and fertility of the females and found that maximum oviposition (116 ± 18 with about 54% fertile eggs) occurred after three days of mating. Mating has indirect relation with oviposition while age and oviposition has direct relations. Delayed mating increases the female longevity.

Forecasting and monitoring: Population forecasting is an important tool in the integrated pest management programme of the moth. The tortricid could be control batter by good forecasting methods (Balazs *et al.*, 1996). Buban *et al.* (1996), emphasize on well pest monitoring for in time control measures. Laurent (1997), reported that the monitoring and forecasting of the pest population is necessary to run any IPM programme for the codling moth.

Chemical control: Different control methods are introduced for the control of the pest. The use of chemicals is very famous among the farmers but it may deteriorate the nutritional quality of the product (Niemezyk *et al.*, 1996). Prokopy *et al.* (1995), ran an IPM programme for the pest and found chemical control methods cheeper and affective than other control measures. Sahib and Abdul (1995), reported that increase in the number of spray applications has no significant effect on percent infestation of fruits but increases economic losses to the farmer. Stamenkovic *et al.* (1994), reported that Esfenvalerate (formulation) @ 0.0025% provided 100% control of the moth. Penrose (1996), described an Integrated Programme for the moth with minimal use of pesticides. Grodskii (1995), reported that Anthio (formulation) @ 1.5 L ha^{-1} provided significant control of 1st instar codling moth. Wearing and Popay (1995), ran chemical control program in apples against leafroller and codling moth. They observed that three application of organophosphate sprays for leafroller could control codling moth. Trimble *et al.* (1996), found border sprays an affected tool for the control of codling moth and apple maggot. Cadei (1995), introduced Cyfluthrin (Baythroid), Onevos and Orafon (Pirimiphos-methyl) against *Carpocapsa pomonella* (*C. pomonella*), *Lyonetia clerkella*, *Lithocolletis blancardella* (*Phyllonorycter blancarella*), *Nepticula malella* (*Stigmella malella*) and *Quadraspidiotus perniciosus*. Except *C. pomonella* and *Q. perniciosus* the chemical did not worked significantly. Trimble and Solymar (1997), reported that the old colonies of the moth could be eradicated by organophosphorus (OP) border spray followed by the cover spray. Sauphanor and Bouvier(1995), reported cross resistance of *C. pomonella* against chemicals (Benzoylureas and benzoylhydrazines) and confirms that the regular use of the pesticides could produce natural resistance in the insects. Stamenkovic *et al.* (1994), reported that pesticides are a lethal challenge for beneficial arthropods. Chemical control should be limited by using microbial insecticides and mating disruptants (Sauphanor and Delorme, 1996).

Resistance against pesticides: Malezieux *et al.* (1995), reported resistance of codling moth against diflubenzuron. Speich (1996) reported resistance against OP group. Decoin *et al.* (1996), found that the pest got resistance to the pesticides due to the continuous use on the other hand the pesticides are badly affecting to the natural enemies thus they must be used with a define schedule for a short period of time. Sauphanor *et al*. (1996), reported that the moth has a lot of abilities to create resistance against the pesticides than other arthropods. The resistance may cause a dynamic increase in the population (Martinet, 1996). To avoid the resistance in the moth the strategies of alternation of insecticides is not enough. The use of microbial insecticides and mating disruptants may also be offered (Sauphanor and Delorme, 1996). Bylemans (1997), noted that the pesticide application at the time of first oviposition could avoid the resistance in the moth. To avoid the resistance and destruction to the ecosystem other methods to control the pest should be used (Baudry *et al*., 1996).

Biological control: Kutsryavtseva and Teshler (1994), released *Trichogramma* spp. against *C. pomonella* in apple orchard. They observed that not only distance between the parasitoid and the host but also temperature and density per parasitoid over number of moths are the major factors in biological control programme. They reported highest parasitization at 21-23 °C with 10:1 ratio of parasitoid/host. That proves *Trichogramma* spp., a good biological control agent for the said moth. Zhang and Cossentine (1995), used *T. platneri* against codling moth and found good results against viable eggs. Hassan and Wuhrer (1997), made four to five releases per season of *T. dendrolimi* and *T. cacaeciae* to establish the parasitoid in the apple fields and found encouraging results. Cossentine *et al*. (1996), found that *T. platneri* prefers *C. pomonella* than *Choristoneura rosaceana* in apple orchard. Riddick and Mills (1996), studied activities of predator beetle (*Pterostichus* spp.) in soil and found increased activities of the said beetle in rich organic matter soils. They suggested that the predator could be better utilized if their population is synchronized with the growth stage of the moth (5th instar). Vogt (1995), found that beneficial arthropods or microorganisms provided good results if used on specific targets.

Pheromone Control: Sazonov *et al*. (1994), worked on male disorientation of codling moth in apples. They used Codlemone (*Iasperone*) and found it quite affected to control the population of the pest in the said crop. In such a way a significant decline in the infestation of codling moth could possible with out using pesticides. Skirkevicius *et al*. (1995), described 8E, 10E-8, 10-dodecadien-1-ol as a new sex pheromone for codling moth. Knight (1995b), tried three sex pheromone disrupting components; {(8E, 10E)-8,10-dodeca dien-1-ol (Codlemone); 1-dodecanol and 1-tertadecanol} for *C. pomonella*. 1000 Polyethylene tube dispensers ha^{-1} were hanged in 9 orchards. All trials showed significant performance in disrupting the sexual communication of the moth. Witzgall *et al*. (1996), used E8, E10-120H (Codlemone) and E8, E10-12Ac (Codlemone Acetate) in apple orchards and observed behavior of the moth. For E8, E10-120H (Codlemone) the moths were not only attracted to the traps but also flying on the tree crown while in case of E8, E10-12Ac only towards the traps.In both the cases good results were obtained. Trematerra *et al*. (1996), used a combination of granules virus (Madex 3 @ 3 x 1012 granules ha^{-1}) and mating dispensers (Check Mate-CM, 105 mg Codlemone, E. E.-8, 10-dodecadien-1-ol @ 31.5 g ha^{-1}). The technique provided good results of the control of codling moth. Judd *et al*. (1996), used Codlemone {(8E-10E)-8, 10-dodecadien-1-ol @ 14.9. 15.2. 16.6 and 17.5 g ha^{-1} (1000 dispensers ha^{-1}). They found inverse relation between the activity of the pheromone and the use of pesticides.

Charmillot *et al*. (1996), used a formulation, Sirene (combination of Codlemone and Permethrin, 1:3.625 respectively) against the said pest. They could control the pest below a threshold of 1%. Mani *et al*. (1995), used pharomone traps in the canopy of host and non host plants and as well as in the open fields near the apple orchards at a distance of 10-40 m. The apple orchards had mix plantation of large and dwarf varieties of apples and the non crop vegetation, shrubs. The study revealed that in the large trees of apples the catch of *C. pomonella* was greater than the small varieties while in the open field the response of the moths was very low. Weissling and Knight (1995), studied the distribution of codling moth in the treated and untreated apple and pear orchards. They observed that the dispensers hanged at 2 to 4 m above the ground were very affected while greatest capture of males and females unbaited sticky traps occurred at mid and upper canopy heights. There was no significant difference found between pheromone treated and untreated orchards. It was also observed by the fluorescent powder marked moths that the male moths shift to the lower canopy where pheromone dispensers were placed 2.1 m above the ground. The study suggests that the pheromone dispensers should be placed in the middle to upper canopy of apple and pear orchards. Barrett (1995), studied the pharomone tape at different heights and also suggested that the traps should be in the upper canopy area of the orchards. Chouinard *et al*. (1996), installed pheromone traps @ 1000 dispensers ha^{-1} at the lower canopy of the trees in a treated orchard and controlled the pest 100%. Millar (1995), reported that the components of the pheromone of *C. pomonella* is adversely effected by sunlight. Hilton *et al*. (1994), used a combination of mating disruptant with horticultural spray oil and found that the combination not only suppress the moth population but also useful for beneficial insects and the control of secondary pests. Knight (1995a), found that the use of pheromones in apple orchards against codling moth not only reduce the pest but also the labor cost to control the pest as compared to the other controlling techniques.

Navarro *et al*. (1995), used pheromone (ECOPOM) against codling moth in apple and pear orchards and found the technique with batter results. He found that the said pheromone was well affected upto 30 days in the field thus for batter results the application must be repeated three times which is a costly procedure thus is not recommended for professional farmers but good for experimental plots. Williamson *et al*. (1996), reported phermone traps more expensive than chemical control but the said technique is best for low pest population. The technique provided good results to control codling moth. Osterreicher (1996), found Wagening type pheromone traps, the best method to trap the moths. Cross (1996), surveyed ten different orchards for codling moth with the help of pheromone traps and captured >500 moths in those orchards where least pesticides were used. Which means that the pesticides affects the performance of the pheromones. Deventer *et al*. (1997) found BASF (RAK-3) as an effective dispenser against the moths of apple. Milli *et al*. (1997), found that wind has direct relation with the dispersal of pheromones but a mild wind could take the chemical upto 6 m high while the down wind at the edge of the orchard could spread the chemical upto 60 m. Deschanel and Florac (1996), claimed that the pheromone or mating disruptant alone, are not enough to control the moth.Other control measures should also be utilized with them.

Inorganic control: Burballa *et al*. (1995), got high mortality rate by using extracts of 4 neem varieties (Sukrina New, Rakshak, Margosano and Azatin) in the diet of the larvae of moth in laboratory. No alteration in the feeding behavior was found except Azatin extract that repelled larvae and caused antifeedent effect.

Other controls : Growth regulator (Tebufenozide and Fenoxycarb) provided good control of *C. pomonella* with out disturbing the population of biological agents like *Tetranychus urticae* (Two Spotted Mite), *Panonychus ulmi* (European Red Mite), *Araneae* spp. (spiders), *Stethorus* spp. (coccinellids) and *Campylomma iiebknechti* (dimpling bug) as compared to the applications of chemicals like Azinphose Methyl and Organophosphate (Valentine *et al*., 1996). Forti *et al*. (1996), tried different schemes of chemicals against codling moth; 4 treatments of 15% Teflubenzuron (Nomolt @ 33 cc ha^{-1}) or Triflumuron (Alvstin @ 25 cc ha^{-1}) repeated at 30 days intervals, 2 treatments of growth regulators at 250 day-degrees in the first generation followed by 2 treatments of 25% Quinalphos (Ekalux @ 150 ha^{-1} each) and granulosis virus (Carpovirusine 6.7x1012 GV l^{-1} @ 150 cc ha^{-1} or 25% Azinphos Methyl (Gusathion @ 200 g ha^{-1} in the 2n generation but did not find any significant difference among the treatments regarding the damage of the pest. Guillon and Biache (1995), successfully used codling moth granulosis virus (CmGv) in apples. Though the agent was found good and economical for the larvae but is slow. Speich (1996), used *Bacillus thuringiensis* or granulosis virus to avoid resistance in the moth. Biache *et al*. (1996), reported good susceptibility of the moth to granulosis virus. Baudry *et al*. (1996), reported Carpovirusine (a microbial pesticide contain granulosis virus) as a good microbial agent to control the moth. Crook *et al*. (1997), used a cloned strain of *C. pomonella* granulovirus (CpGv-M1) by vivo dilution method. Using different kinds of enzymes, a genom map was constructed. The map showed a high degree of homology to the equivalent region from *Cryptophlebia leucotreta* granulovirus with 98% amino acid identity for the granulins and 68% for the putative polypeptides encoded by the upstream ORFs which means that they have low degree of homology to ME53 from *Autographa californica* nucleopolyhedrovirus (AcMNPV). The

hybridization between CpGv and AcMNPV was just 15%, which means that very few genes are highly conserved between GVs and NPVs. The studies could help to get the sequence of genome to evaluate the resistance strain of *C. pomonella*. Neven and Mitcham (1996), introduced a new method for the control of the moth in quarantine. They used 1.0% O_2 with 15% CO_2 at high temperature 45 and 47^{0}C upto 64 and 44 minutes respectively and got positive results applicable to closed environment only. It is revealed through the review that the moth is getting resistance to the pesticides specially against the frequent use of OP group pesticides.
Therefore other control measures like microbial insecticides, *Bacillus thuringiensis*, granulosis virus, biological agent, pheromone, mating disruptant and selected/ alternative use of pesticides are recommended. Though biological agents like *Trichogramma* spp. is working good against the moth but is not easily available to all the farmers and is tedious. Pheromones like Codlemone has encouraging results but are expensive and scarce in the area like Balochistan. The farmers which have large holdings could run a comprehensive IPM Programme for codling moth using this review as a guideline.

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