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

Muhammad Faheem Malik, 1Arshad Ghani Khan, 2Abdul Karim Jafer, Liaquat Ali, Sohail Anwar and 3Akhtar Munir

Agriculture Training Institute, Sariab, Quetta, Balochistan, Pakistan
1Balochistan Agriculture College, Belali, Quetta, Balochistan, Pakistan
2Department of Agriculture Extension, Government of Balochistan, Quetta, Pakistan,
3Agriculture Research Institute (Horticulture), Sariab, Quetta, Pakistan

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: Pomiceae) 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 better plant protection activities. Coding moth (*C. pomonella*) is the major pest of the crop and mostly pesticides are being used for its control (Anonymous, 1999). Isuf and Mytra (1996), also reported *C. pomonella* as key pest of apple among the torticid. 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 coding moth; Marti et al., 1998) for hatching larvae. After 19-21 days the larva 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 (Pears and Davidson, 1966). 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 hr 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 Reithfeld (1989), found that when stored pupae (at 0°C) of coding 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 temperature 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 (1998), found that 10°C is an appropriate temperature for the development of coding moth. Ravn and Madsen (1995), observed that first moth of 1st generation appears at 10°C (100 day-degrees) while 50% population appears at 300 day-degrees.

Karaslu and Buda (1995), studied the mating, oviposition and fertility of the females and found that maximum oviposition (116 ± 18 with about 64% 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 torticid could be control better by good forecasting methods (Balazes 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 coding 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 (Niemczyk et al., 1996). Prokop et al. (1996), ran an IPM programme for the pest and found chemical control methods cheaper and effective than other control measures. Sahib and Abdul (1996), reported that increase in the number of spray applications has no significant effect on percent infestation of fruits but increases economic losses to the farmers. Stamenkovic et al. (1984), reported that Esfenvalerate (formulation) @ 0.002% provided 100% control of the moth. Panrose (1996), described an Integrated Programme for the moth with minimal use of pesticides. Gerdtski (1996), reported that Anthio (formulation) @ 1.5 L ha⁻¹ provided significant control of 1st instar coding moth. Wearing and Popay (1996), ran chemical control program in apples against leaf roller and coding moth. They observed that three application of organophosphate sprays for leafroller could control coding moth. Trimble et al. (1996), found border sprays affected tool for the control of coding moth and apple maggot. Cadiel (1996), introduced Cyfluthrin (Baythridiet), Oenvos and Orafon (Primophos-methyl) against *Capocapsa pomonella* (*C. pomonella*), *Lycentia clarkella,* Lithocolletis blancardella (*Phyllocyrtis blancardella*), *Nepticula malaeae* (*Stigmella malaeae*) and Dicladisporis punctifer. Except *C. pomonella* and *O. punctifer* 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. Sauphon and Bouvier (1996), reported cross resistance of *C. pomonella* against chemicals (Benzoylurea and benzoyldihydrazines) and confirms that the regular use of the pesticides could produce natural resistance in the insects. Stamenkovic et al. (1984), reported that pesticides are a lethal challenge for beneficial arthropods. Chemical control should be limited by using microbial insecticides and mating disruptants (Sauphon and Delorme, 1996).

Resistance against pesticides: Malezka et al. (1996), reported resistance of coding moth against diflubenzuron. Speich (1986) reported resistance against OP group. Decin 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 of the moth. 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). Beyerlans (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., 1998).

Biological control: Kutsyraytsveva and Tesniier (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. Zang and Cossentine (1995), used T. platenii against codling moth and found good results against viable eggs. Hassan and Wuhrer (1997), made four to five releases per season of T. dendralimensi and T. cacaeesiae to establish the parasitoid in the apple fields and found encouraging results. Cossentine et al. (1996), found that T. platenii prefers C. pomonella than Choristoneura rosae 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 (6th instar). Vogt (1986), 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 (lasperone) 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. Skirkevičius et al. (1995), described BE, 10E-8, 10-dodeca-dien-1-ol as a new sex pheromone for codling moth. Knight (1995b), tried three sex pheromone disrupting components; [BE; 10E-8, 10-dodeca-dien-1-ol (Codlemone); 1-dodecanol and 1-tetradecanol] for C. pomonella. 1000 Polyethylene tube dispensers ha⁻¹ were hung in 9 orchards. All trials showed significant performance in disrupting the sexual communication of the moth. Wittigall et al. (1995), used E8, E10-12H4 (Codlemone) and E8, E10-12Ac (Codlemone Acetate) in apple orchards and observed behavior of the moth. For E8, E10-12H4 (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. (1995), used a combination of granules virus (Medax 3 0 3 x 1012 granules ha⁻¹) and mating dispensers (Check Mate-CM, 105 mg Codlemone, E-E-8, 10-dodeca-dien-1-ol @ 31.6 g ha⁻¹). The technique provided good results of the control of codling moth. Judd et al. (1996), used Codlemone (BE-E-10E-8, 10-dodeca-dien-1-ol @ 14.9, 15.2, 16.6 and 17.8 g ha⁻¹ (1000 dispensers ha⁻¹). They found inverse relation between the activity of the pheromone and the use of pesticides. Charnillot et al. (1995), used a formulation, Sirene (combination of Codlemone and Pemetrin, 1:3,625 respectively) against the said pest. They could control the pest below a threshold of 1%. Meni et al. (1998), used pheromone 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. Weisssing and Knight (1995), studied the distribution of coding 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 et al. (1996), tested the pheromone trap 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 levels of the trees in a treated orchard and controlled the pest 100%. Miller (1995), reported that the components of the pheromone of C. pomonella is adversely affected by sunlight. Hilson 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 pheromone in apple orchards against coding 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 up to 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 pheromone 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. Ostermacher (1996), found Wageningen type pheromone traps, the best method to trap the moths. Cross (1995), 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 pheromone. Deventer et al. (1997) found BASP (RAK-3) as an effective disrupter 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 up to 6 m high while the down wind at the edge of the orchard could spread the chemical up to 80 m. Deschanell 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: Buballa et al. (1996), got high mortality rate by using extracts of 4 neem varieties (Sukrina Nerv, Rajthak, 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 antifeedant effect.

Other controls: - Growth regulator (Tebufurine and Fenoxycarb) provided good control of C. pomonella with out disturbing the population of biological agents like Tattersayrius urticae (Two Spotted Mitte), Panonychus ulmi (European Red Mitte), Aerespe spp. (spiders), Stethorus spp. (coccinellids) and Campyloptoma liebknechtii (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 coding installed components of the granules virus (Alvistin @ 25 cc ha⁻¹) of Trifumuron (Alvistin @ 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% Quinalpho (Ekulax @ 160 ha⁻¹) and granulosis virus (Carpoovirus 6.7x1012 GV⁻¹ @ 160 cc ha⁻¹ or 25% Azinphose 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. Guillen and Biache (1996), successfully used coding 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 Carpoovirusina (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 (CgMv-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 leucotraeata granulovirus with 98% amino acid identity for the granulin and 98% for the putative polypeptides encoded by the upstream ORFs which means that they have low degree of homology to MESS3 from Autographa californica nucleopolyhedrovirus (AcMNPV). The

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hybridization between CqGv and AcMNVP 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 (1998), introduced a new method for the control of the moth in quarantine. They used 1.0% CO2 with 15% CO2 in high temperature 45 and 47°C up to 54 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 Codemone 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 coding moth using this review as a guideline.

References

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