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Chapter

Role of Pheromone Application Technology for the Management of Codling Moth in High Altitude and Cold Arid Region of Ladakh

Barkat Hussain, Faizaan Ahmad, Ejaz Ahmad, Wasim Yousuf and Mohd Mehdi

Abstract

The codling moth is a threat to the apple industries in India. Currently, no solutions are available for the management of codling moth in Ladakh. Therefore, all fresh fruits from Ladakh are still banned due to quarantine regulations. Jammu and Kashmir and Himachal Pradesh and Ladakh are the three main apple producing states of India, both in quality and quantity. The ban on all fresh fruits from Ladakh directly affects the economy of rural populations. These fruits are sold in all the local markets of Kargil and Leh. Apples damaged by the larvae of codling moth are less preferred by inhabitants, tourists, and security forces, a large area of Ladakh is bordered with China and Pakistan. Field demonstration trials revealed significantly less fruit damage in apple orchards in different hamlets of Ladakh using pheromone dispensers, pheromone baited traps, and two applications of insecticides for codling moth management. A demonstration of the use of pheromone and pheromone dispenser technology for area-wide management for high dense populations of the codling moth in Ladakh has revealed successful results in the orchards of the apple growers. Area-wide management of the codling moth in some villages, using dispenser technology has shown promising results. The ban of fresh fruits in Ladakh may not be, therefore, appropriate as management of the codling moth appears to be successful with the use of pheromone dispenser technology. This technology will, surely, boost the apple industry and have a great potential for establishing commercial orchards and quality apples in high altitudes in the second-highest cold arid region of the world.

Keywords: pheromone technology, codling moth, Ladakh, pheromone dispensers, cold arid region

1. Introduction

In India, apple (*Malus domestica* Borkh) are the main dominating fruit crop among all the cultivated fruits grown in Jammu and Kashmir. Annually production is 17.268 lakh metric tons of apple fruits cultivated in an area of 1.629 lakh hectares. The other apple-producing states of India are Himachal Pradesh, Uttarakhand, and some parts of Arunachal Pradesh [1]. Jammu and Kashmir (J&K) account for 60%

of the total apple production among all the cultivated fruits before splitting the state into two Union territories, namely J&K and Ladakh [2, 3]. Ladakh is the second highest, cold arid region of the world. The low precipitation and scarce vegetation over a larger area make Ladakh a high-altitude desert. Ladakh is on the eastern side is connected with China. Pakistan is on the northwest border and to the west is the Kashmir Valley and Himachal Pradesh is on the southern border. Ladakh was extended by the Great Himalaya to the south and the Karakoram mountains to its north. Ladakh is administratively divided into two districts, Leh District and Kargil District. Ladakh was a separate province of Jammu and Kashmir State, constituting the major part of the State until 2019. Recently, in August 2019, the parliament of India passed an act and Ladakh is now being administered as a Union territory of India [4]. Ladakh was considered an important trade link in the past, but border closure with China restricts the movement of all essential commodities and other fresh fruits. The fruit is now being airlifted during the winter which increases the prices of these commodities.

The new Union territory of Ladakh produces annually 3241 metric tonnes of apples from an area of 598 hectares [5]. The dominating fruit crop of Ladakh is apricot grown over an area of 2127 hectares with an annual production of 12686 metric tonnes (**Table 1**). Other important fruit crops (pear, plum, cherry, grapes, and walnut) are grown in areas of 243 ha with an annual production of 319 metric tonnes. The area and production of these fruit crops are detailed in the pie chart (**Figures 1** and **2**). After calculating the area and production of Ladakh under fruit crops, the total fruit crops are grown in an area of 2968 ha with an annual production of 16246 metric tonnes, as reported by the National Horticulture Board of India. In India, the codling moth is found only in Ladakh [6, 7] and, other parts of India are free from this pest. Therefore, the attack of this single pest restricts the movement or transportation of all fresh fruit from Ladakh to other states of India. The monetary losses incurred on the ban on all fresh fruits from Ladakh could be roughly estimated as more than 10,000 Cr INR annually after calculating the prices of these fruit crops in national and international markets by multiplying the huge production of 16246 metric tonnes of fruit crops produced annually [8, 9].

The extent of fruit damage on apples and apricots in Ladakh, caused by the codling moth, is so high that it can enter easily into any neighboring states. Therefore, the Government of India prohibited the export of all fresh fruits from Ladakh within or outside the state under the Law" Destructive Insect Pest Act 1914 (II) before splitting the Jammu and Kashmir state into two union territories. This ban has been strictly imposed by the enforcement agencies to prevent its entry into the neighboring states of Jammu and Kashmir, Himachal Pradesh, Uttar Pradesh, Uttrakhand, and other apple growing areas of India. Such ban on all fresh fruits have prevented also its entry to other parts of the Indian union till to this date. Therefore the ban on the export of all fresh fruits from Ladakh is a good rationale.

Ladakh	**Area (ha)**	**Production (MT)**
Apple	598	3241
Apricot	2127	12686
Other Fruits	243	319
Total Production	2968	16246

Table 1.
Total area and production of main fruit crops in Ladakh during 2018–2019.

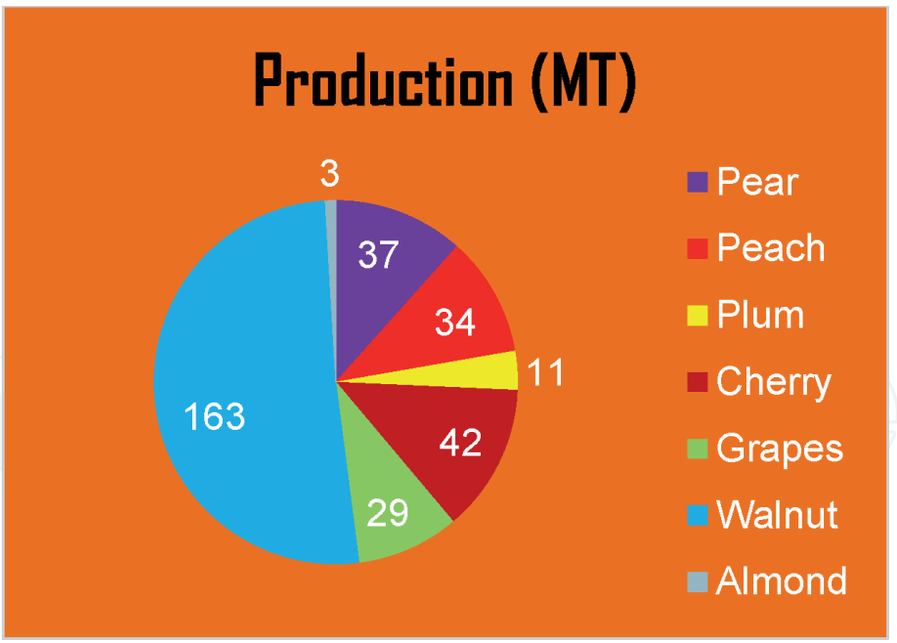


Figure 1.
Detailed production of other fruit crops in Ladakh 2018–2019.

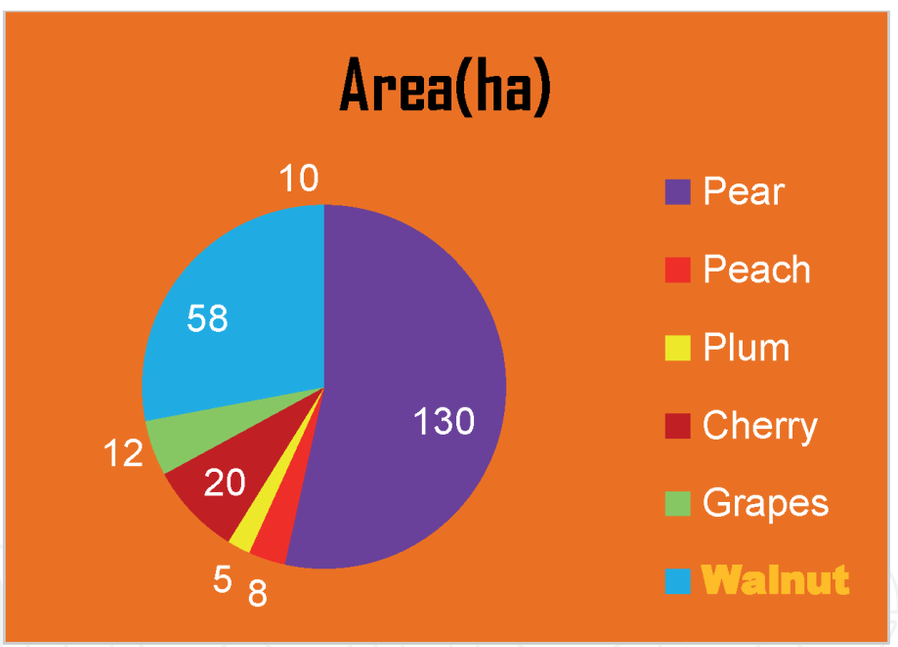


Figure 2.
Detailed area of other fruit crops in Ladakh 2018–2019.

The codling moth, *Cydia pomonella* L, is a well-known notorious pest globally and has been reported from Europe, USA, Canada, South Africa, Australia, New Zealand, Afghanistan, Iran, South Africa, Pakistan, Germany, France, Russia, and other apple-growing regions of the globe [10]. In India, its distribution is restricted to Ladakh [11, 12]. The codling moth is thought to have entered Ladakh through the Northwest Frontier province of Pakistan [12–14]. The infestation level of the codling moth on apple, apricot, pear, and walnut has been observed in all the fruit-growing areas of Ladakh [14]. While, [15] reported that the fruit damage, caused by codling moth, ranged from 42.5 to 49.7 percent in Leh and Kargil, respectively. The codling moth is a single pest on apple in Ladakh and is found to attack all the local and introduced cultivars of apple [14]. Recent surveys conducted in different hamlets of Ladakh revealed

that the level of fruit infestation ranged from 70.0–83.0% (**Table 2**). The extent of fruit damage on other fruit crops caused by the codling moth has not been estimated. Mostly, in all the villages of Ladakh, apple plants are been raised in isolated patches of land. Due to the small size of cultivated land holdings in fruit-producing areas of Ladakh, apple trees are planted along with other fields such as cereals, vegetables, or field crops. The latter field crops act as shelterbelts. Besides, to the cold arid climate and scarcity of water, raising plants in this region is very difficult. Moreover, the apple trees in Ladakh are of the spreading type. These plants are kept untrained, un-pruned, and un-managed due to scarcity of qualified manpower, less awareness, social taboos, and other poor information among the growers [16]. The region falls under Tribal Region. In such circumstances, the insecticides are not effective in the Kargil district, heavily populated by Muslims. In the district of Leh, the majority of the population are Buddhists. In Buddhism, it is a sin to kill insects or any type of pests (boring/sucking/feeding) due to socio-religious constraints. In such situations, the pest populations and the level of fruit damage of all insect pests are increasing at an alarming rate and are being considered a threat to the fruit industry [5, 16].

The codling moth adults are grayish-brown in color, one inch long, and bear coppery wings that have copper colouration at the tip region. The adult females lay eggs on fruits and leaf surfaces. From the hatched eggs, newly emerged larvae are white with blackheads, while the late instars larvae are light pink in color with blackheads. Codling moth larvae enter the apple fruit at the calyx end and directly bore into the fruit (**Figure 3(A)**) Later on, these larvae feed on fruit pulp and seeds. The fully-grown larvae move out from the apple fruits for pupation. During winter, larvae overwinter under loose or dead bark of apple trees (**Figure 3(B)**). Larvae overwinter in winter, pupates in spring, and emerge as adults from mid-May to mid-June in Ladakh [17]. Adult (egg to adult) emergence synchronized often with the peanut stage of the apple fruit as both the phenological stages of plant and insects require certain amounts of heat requirements [18–20]. Being a direct pest, larvae bore directly inside the fruits, but the early fruit damage is responsible for fruit fall and fruit injury. Larvae inside the fruit feed on the seeds and create exit holes and waste material is pushed out. Sometimes, the waste material remains associated with or inside the fruit that causes fruit rotting.

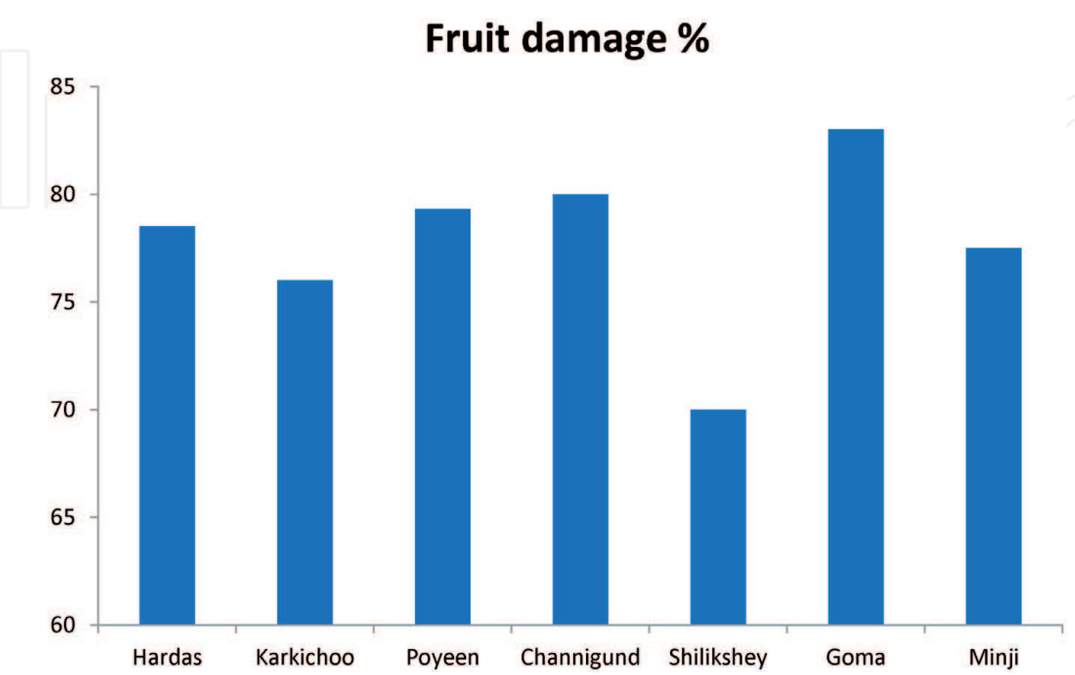


Table 2.
The level of fruit damage (%) in surveyed orchards of Kargil during 2018–2019.

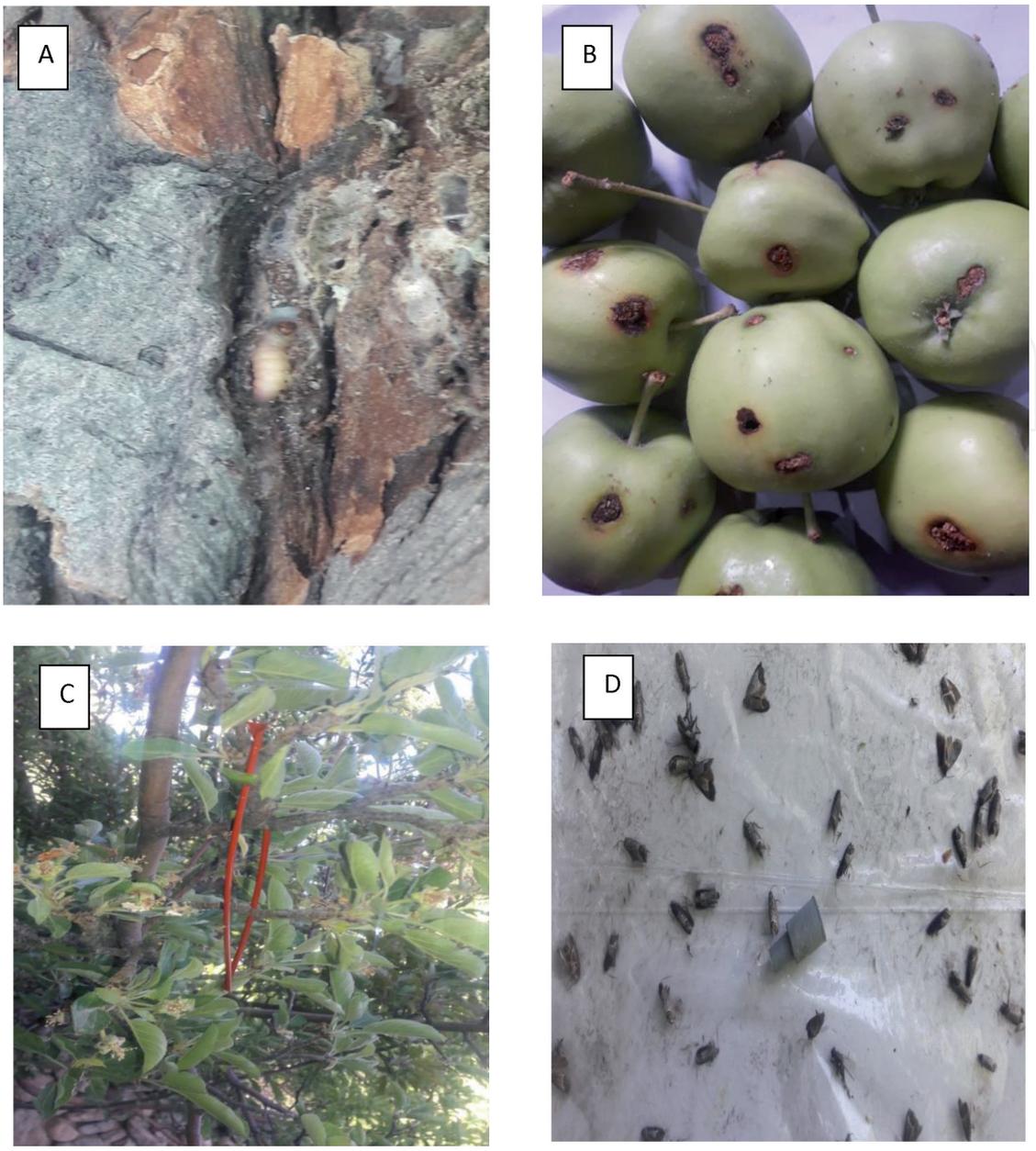


Figure 3.
(A) Overwintering larvae exposed on loose bark, (B) bored fruits by codling moth, (C) pheromone dispenser inserted on apple branch, (D) trap catch of codling moth.

The boring habit of the larvae inside the fruits is not fit for consumption and is disliked by consumers and discarded for marketing purposes. Therefore, the economic thresh hold level (ETL) for this pest is very low. The codling moth is a quarantine pest and is of great importance concerning its quarantine requirement for trade purposes. To export apple fruits to any part of the world, stringent phytosanitary and other quarantine measures are warranted for exporting from reporting countries (presence of codling moth) to non-reporting (absence of codling Moth) countries. Sometimes trade is declined due to incursion of this pest where it has not been reported.

2. Pheromones for the management of codling moth

Insecticides are considered as entomological weapons against a wide group of insect pests. The insecticides are cheaper, wide spectrum, hazardous to consumers, and responsible for the quick kill to both codling moth and its natural enemies [21, 22]. The application of insecticides on fruit orchards lead to poisoning of the

environment, eliminating the non-target organisms, insecticidal resistance, resurgence and secondary pest outbreaks [21, 22]. Indiscriminate application of insecticides, like organophosphates and carbamates against codling moth, has to lead to insecticidal resistance, death of natural enemies [21, 23]. Insects release specific chemical odors to attract their partners known as sex pheromones. Besides, pheromones are naturally produced, environmentally acceptable, species-specific chemical compounds and are considered a good choice for pest management [24, 25]

Pheromones are considered as the essential components for monitoring, mass trapping, mating disruption, attract and kill and also combined with other non-chemical strategies for the management of codling moth using pheromone technology. Pheromone disruption technology employs different application methods (Puffers, metered backpack sprayers, caulking guns, dosing guns, aircraft, rings, and SPLAT) to disrupt mating of codling moth [26–29] in various countries. Pheromone for the codling moth was identified as (E, E)-8,10-dodecadien-1-ol [30]. The other minor compounds as (E, Z)-8,10-dodecadien-1-ol, and 1-tetradecanol) increase the efficacy and also the behavior of the codling moth [31]. These chemicals have now been synthesized and used for lure making and monitoring the adult population of the codling moth. Pheromone dispensers have been widely used for the management of codling moth across the world [32, 33]. The estimated area in hectares (77,000) for North America, 38,000 for European Union, 19,000 for South Africa and 28,000 for Argentina, Chile, Australia, New Zealand, and Israel), employed for mating disruption for codling moth [27, 34]

Pheromone-driven technology is an important method for the management of the codling moth [27, 35]. The learning of sex communication in insects, mostly through chemicals has been utilized for the management of the codling moth [27] and other insects [36, 37]. Using the mating disruption technique, species-specific chemicals are released in greater quantities in the environment to disrupt mating [38–40] of the target pest. Pheromone dispenser technology has been demonstrated in more than 7000 hectares in the world [27], and is more powerful than male annihilation technique and mass trapping [17, 38]. Male annihilation technique (MAT) is an insect control method to reduce the male population using sext attractants or sex pheromones from a large area to disrupt sexual communication. Mass trapping is an acceptable method, when both male and female partners are trapped from a large area using both sex pheromones and plant volatiles and mostly adopted for eradication programmes. To our knowledge, SKUAST-K is the only university to fabricate and prepare the lures for codling moth and other insect pests in India. In addition, pheromone dispensers has not been registered against any insect pests in India to cut down the pesticide usage, safe environment, reduce health hazards, pollution in the environment and shall be helpful for the management of various insect pests on apple or other crops. The various management options already available in making integrated pest management programme safer and sustainable for our future generations has been fully documented through the use of mating dispenser technology for the codling moth in all developed countries [27, 39].

3. What are the gaps in the management of codling moth in Ladakh?

3.1 Pruning and training

Pruning and training are not practiced in Ladakh and emphasis should be given to pruning and training in apple orchards. Such practices do not allow the insecticidal spray to provide the best coverage on the fruit and the whole plant canopy. Moths, larvae, and eggs are less likely to come into contact with poisoned

fruit surfaces. The unpruned plants are not managed properly to perform various orchard management operations. Such practices are responsible for bushy and alternate fruit bearing plants, and poor harvest. Due to no fruit thinning, the fruits that developed are small in size and poor in quality and quantity. Being, an arid climate, no fungal diseases have been reported on apple orchards as fungal diseases perpetuate and perform well in humid climatic conditions. In both the districts of Ladakh, the plants are kept untrained and the heights of these plants are so high and are very difficult for the power-driven motor sprayers to cover the whole plant. The scarcity of skilled pruners is being felt in Ladakh and efforts should be made to introduce the course certification for training and pruning, leading to employment benefits to local populations.

4. Orchard types

Very few commercial apple orchards were observed during our surveys in Ladakh. Besides, more than 90% of apple trees are grown as backyard orchards, and very difficult to use the insecticidal application. Under the canopy of backyard orchards of apple, different types of vegetables and fruit crops are being cultivated. It is very difficult and tricky to use insecticides under such circumstances. The reason for raising mixed farming is due to the scarcity and non-availability of water in cold arid climates. The plant to plant and row to row distance between apple plants is improper in Ladakh. The apple orchards are scattered and are not connected with roads. It is very difficult for the growers to perform various intercultural operations. Mostly apple orchards in Ladakh, established as backyard orchards. The other fruit crops (pear, walnut, and apricot) are preferred hosts for codling moth. The future strategy for the management of codling moth in these backyard orchards should be directed to all fruit crops which shelter codling moth population. The demarcation line or walls between the houses are erected of stones provide shelter for the colding moth immatures (summer and overwintered larvae). So the overwintered larvae of the codling moth get easy access for overwintering inside the crevices and gaps among the stone walls. The levels of infestation of the codling moth remain high. Besides, the awareness campaigns should be launched for the management of codling moth, orchard management and quality plants with deep rooted, root stocks of apple.

4.1 Orchard sanitation

Due to the high population density of the codling moth, infested fruits drop prematurely from the apple trees before maturity. Picking and removing these infested fruits is not carried out to break the cycle of codling moth infestation. It has been observed that due to the huge infestation of the codling moth, fruits are not being harvested and the larvae mostly overwinter in such apple fruits and also in the fallen fruits. The targeted burlapping for trapping the overwintering larvae without impregnating the wrapping material with insecticides is not effective. It is therefore recommended to use the insecticide impregnated materials for trapping and killing the overwintered larvae. It was observed during the surveys that the larvae of the codling moth still like to overwinter on the loose bark, stone bunds raised around the houses rather than on the burlapping materials wrapped around the stems and limbs of the old trees. Therefore, it is recommended to remove the old bark from the old apple trees.

4.2 Social sentiment and social taboos

Ladakh has been divided into two districts and the distance between the two districts is 220 km^2. Leh is dominated by Buddhists and Kargil by Muslims. Leh is

well known for mixed ethnicity, culture, and traditions, and before performing any operations for the management for codling moth or any field operations, they mostly avoid any management strategies for codling moth during various festivals. As the codling moth is a boring pest, when it enters into the fruit, then it is very difficult to control. Leh district is dominated by the Buddhist population, as the sentiment of killing insects or even pests is considered a sin in major parts of Leh. In Nurla village, we performed all management practices for the management of codling moth. To perform these practices possible in the village, scientific diplomacy was employed to make aware the tribal leaders about the importance of fresh fruit industry, fresh fruit trade, issues pertaining to fruit ban and its prospects on growth and economy. In Kargil district, the sentiment of killing insects is not being observed because no social taboo is related to it but even the population density of codling moth in this region is not below ETL because of various factors (no pruning, training, no proper protection measures and other factors).

4.3 Shops for agriculture implements and products

The dearth of vendors and shops to sell different items (pruning saw, secateurs, foot sprayers, fertilizers, pesticides, pheromone traps and light trap to tribal growers. They are also deficient in to supply the seeds and quality planting material to the growers. The reason for the absence of these implements and planting materials in the private market is discouraged by government policies. These items are partially or fully provided by the government free to the growers under tribal plans. Besides, being a remote area, the season for performing various activities in different ecosystems (horticulture, agriculture) lasts for a few months as the harsh and killing temperatures are prevailing in the region. Tribal growers are unaware and lack knowledge about the importance of orchard management. The tradition or custom of pruning and plant canopy management of apple plants are not being practiced by the tribal growers because of this reason, the height as well as the canopy of the apple plants are not being maintained. The wrong policy and faulty practice of the government is to supply the foot sprayers and insecticides at subsidized rates to the growers is of no use in these situations. Besides, it is beyond the capacity of the foot sprayers to spray the insecticide solution on such untrained and unmanaged apple plants for the management of codling moth in Ladakh. The use of chemical fertilizers and pesticides is not gaining momentum in Ladakh as the government of Ladakh has declared the whole region as an organic belt without any proper guidelines. The ground transport to other states of the Indian union remains cut off for more than six months due to heavy snowfall on Zojilla Pass connecting Ladakh to Jammu and Kashmir. The quality apple plant material/rootstocks which are being produced in bulk in Jammu and Kashmir could not be transported at the proper time in Ladakh. The border of Himachal Pradesh state is connected with Ladakh on another side. This side too remains cut off due to heavy snowfall at different Passes. Therefore, the transportation charges for lifting the planting material or other plant protection products are very costly and not possible to use Cargo flights. In these situations, the government is emphasizing more on to supply the essential commodities to the people of Ladakh, foreign tourists, military, and paramilitary persons during winter. The long hostile borders with China and Pakistan guarded by these troops made the essential commodities more important for their survival and to meet their needs. To summarize it, and the priority of the policymakers is the supply of essential commodities for the survival of the Ladakh populace and

military establishments either stored before the winter months or airlifted by cargo flights such as meat, vegetables, and other needs.

4.4 Policies for lifting the ban and way forward

The policies for lifting the ban on all fresh fruits from Ladakh and the ways and methods with the timeline is needed to monitor the population densities of the codling moth and subsequently to reduce the fruit damage on all host trees which harbor pest populations. The scientific advisors and experts are not being consulted on how to move forward for lifting the ban on all fresh fruits from Ladakh. It is not out of place to mention that most of the areas of Ladakh are bordered by Pakistan. Insects have wings and these adults can fly and cross the borders easily (trans-boundary movement). How to reduce such incursions by the codling moth or monitor the population is lacking or both the countries should adopt strict management guidelines for codling moth management, as the hosts for codling moth survival are available on both sides. Recently, the new incursions of browntail moth in Ladakh created havoc on the horticulture crops as this invasive pest is neither reported from India and nor from other bordering states/countries [1]. The flow of tourists without any plant bio-security guidelines are not in place in India or Ladakh. Ladakh is having a very important place with unique biodiversity in the Trans Himalayan region and may be a threat to insect and plant biodiversity due to the introduction of invasive pests (browntail moth, apricot aphid, poplar leaf miner, fruit flies, and locusts) from the last five years [1, 41]. Currently, the unavailability of plant protection measures for this single pest (codling moth) on apple, restricts the movement of all fresh fruits from Ladakh to other states of the Indian Union. To boost fresh fruit trade, it is necessary for the policy makers to adopt and consult codling moth experts and researchers for the management of codling moth in Ladakh. Plant bio-security for the endangered areas which has a monopoly in producing walnuts, apple and other temperature fruits that contribute a major share to the national economy of about 6000 cr and providing employability to a large population of India and also reduce the inflow of these fruits in India to meet out the demand and supply of consumers throughout the year.

4.5 Scientific interventions and awareness campaigns

Timing and use of insecticidal applications are very important for huge infested areas to bring down the population of codling moth below economic threshold levels (ETL). Biofix and degree-day calculations are essential for detecting the first emergence of codling moth adults from the overwintered larvae, monitor the adult activities and egg-laying periods of different generations of codling moth. Though, All India Coordinated Research Project on biological control (AICRP) tried mass production of egg parasitoids viz.; Trichogramma embroyphagum and Trichogramma cacociae could not survive in the cold arid climate of Ladakh. They advocated the use of biocontrol agents and insecticides for the codling moth from the last one decade but desirable results and adoption rate of this technology could not be established as both biocontrol agents and insecticides are antagonistic to each other. The various components of IPM viz., insecticides, botanicals, egg parasitoids, burlapping to target the overwintering population, pheromone baited traps have not been evaluated individually to determine their efficacy against codling moth. Such field trials were laid in small pockets and the benefits of such technologies could not deliver desirable results. The application of these technologies never coincide with the different stage of the target organisms

4.6 Climatic conditions

The climate of Ladakh is cold arid and annually 10 cm of rainfall has been recorded. The huge temperature variations from -30^0 C in winter and + 40^0 C in summers are very challenging for raising plants in such harsh climatic conditions. The gusty winds blowing during summers cause more evapotranspiration from plants and also from the soil surface. Besides, the scarcity of water resources needed for apple plants is not being timed or applied as per the scientific requirements for these plantations. The high tourist flow from the last decade in Ladakh prompted the urban population to establish a maximum number of bore wells in hotels, restaurants, and guest houses for the basic requirement for their comfortable stay and other basic needs. It has been felt that such activities are a threat to the environment and surroundings of Ladakh as the scarcity of water has been felt from the already water-starved region of India. Consequently, the rural people are not very interested to perform various horticultural operations needed from time to time but are being hired by the hotel owners for the maintenance and care for the national and international tourists. A good number of the rural population are fully satisfied to act as guides and transportation facilitators for tourists rather than in the horticulture sector as the avenues for the growth of the horticulture sector are still not opened up due to the ban on all fresh fruits from Ladakh. The scarcity of skilled and semi-skilled persons required to perform various horticulture operations are not being performed. Also, a good number of the local population of Ladakh are migrating to other parts of India to escape from these harsh climatic conditions for more than six months in winter, The big winters are prevailing in the region, and the temperature from October goes beyond sub-zero temperatures till the end of March. Therefore, nurturing and caring for these apple plants and planting material is being left at the mercy of nature.

4.7 Removal of old apple plants and establishing new orchards

More than 30–50% of apple plants in Ladakh are kept untrained and the limbs or branches of apple trees are more robust. The use of burlapping on the main stem to intercept the overwintered larvae of the codling moth is not providing satisfactory results. Our survey team observed that the overwintered larvae of codling moth even overwintered on the adjacent limbs of apple trees. To target, these larvae on these branches could not be achieved because it is very difficult for the person to burlap the whole branches or limbs which harbor these larvae. Mostly these apple trees have developed dead bark, under which it is easier for the codling moth larvae to overwinter during winters. In these circumstances, such apple plants are to be removed and burnt, because such plants have a long history of codling moth infestation. Such apple plants have developed more vegetative growth and to train these plants at this stage is very difficult. These apple plants are so close to each other and it is very difficult for sun rays to reach the ground surface or in the center of these plants which is necessary for growth and the development of quality apple fruits. There is a need to establish new apple orchards on scientific lines by planting elite apple cultivars with deep root stocks which develop fruiting with two years and the quality and quantity of these apple varieties are more than the traditional varieties with fewer inputs with maximum returns.

5. Pheromone dispensers for the management of codling moth in Ladakh and way forward in India

A lot of research work has been carried out using pheromones and mating disruption for the management of codling moth in developed countries [42–44]. Mass

trapping is a method to capture enough male insects to get a significant reduction in fruit damage against various pests of economic importance [1]. In codling moth, capturing both partners (male and female) are being targeted using different pheromone traps/dispensers to reduce the high population densities of codling moth [27, 45, 46]. There is scanty information about the number of traps recommended on area basis to target both males and females followed by pheromone dispensers in the world at high population densities. Pheromone baited traps are also being used for monitoring the adult population densities [15, 45, 47]. Mass trapping of codling moth adults has been done in some pockets of Ladakh and trapped a significant number of male adults and also monitoring the adult population to establish the biofix, actually when the adults are flying after winters in Ladakh [15, 26].

6. Demonstration and dissemination of pheromone technology in Ladakh

From 2012 to 2018, demonstrations and dissemination of pheromone technology were conducted in few hamlets of Ladakh during 2012–2018 to observe the efficacy of these treatments as compared to control plots of apple orchards, having a history of codling moth infestation (**Table 3**). All apple plants were installed with a single pheromone trap and the lures were changed three times till harvesting of fruits and pheromone dispensers were installed just after petal fall once in a fruit season. The treatments include, two insecticide applications were sprayed, one at the fruitlet stage and another after thirty days after the first insecticidal spray. The apple plots in Mangbore, Poyeen, and Shilikchey villages were selected for the dissemination and demonstration of pheromone traps and pheromone dispensers and insecticides against codling moth infestation. The treatment with pheromone dispensers +pheromone traps + two insecticidal applications observed an 85% reduction in fruit damage. While dispensers alone recorded 55% fruit damage. While in those treatments, where traps + dispensers were installed, the fruit damage of 69.00% was recorded. All the treatments were compared with control plots. The control plots were two kilometers away from the treated plots.

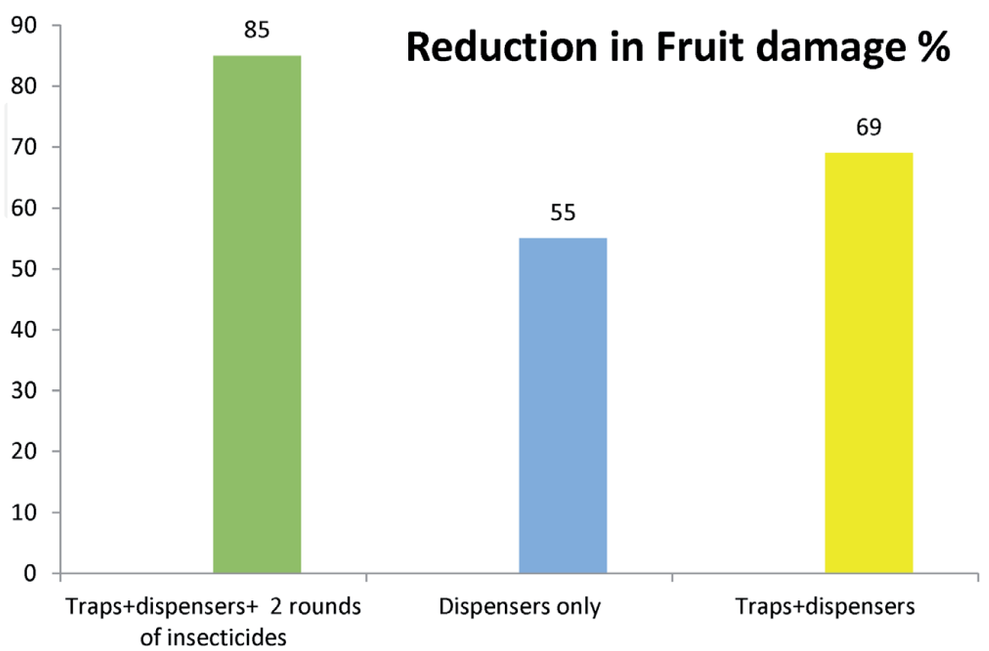


Table 3.
The demonstration of pheromone traps + dispensers in combination and alone for the management of codling moth in Ladakh in selected villages from 2012–2018.

7. Pheromone and mating dispenser technology save water in Ladakh and also in world

After perusing a lot of literature across the globe for the management of the codling moth and other pests using pheromone dispensers and mating dispenser technologies [27, 34]. It has not been reflected that pheromone traps and various mating dispenser technologies can save water. Ladakh is a cold arid region and the scarcity of water is already there in the region. The apple orchards in the different hamlets of Ladakh are without road connectivity and have to travel by foot through small hill slopes between the apple blocks. The availability or the connectivity of water in these apple blocks is not being observed due to natural climatic conditions prevailing in the region. Though for the survival of apple plants, watering for these plants is being carried out by melting of snow on the naked mountains during summer months which precipitates from these hills to lower reaches. Such water is being diverted by the orchardists of Ladakh during the summer months for the survival of these plants. Keeping in view the water scarcity and the factors already detailed above in the Ladakh region. The experts on codling moth in India are emphasizing more on pheromone dispensers and pheromone baited traps for the management of codling moth in Ladakh. The proven technology of pheromone dispensers are easy to apply, no health hazards, easy in application, easy to teach farmers and can be easily adopted by these tribal growers. On average, 15 liters of spray fluid is required for spraying a single apple plant till runoff. Three hundred apple plants are planted

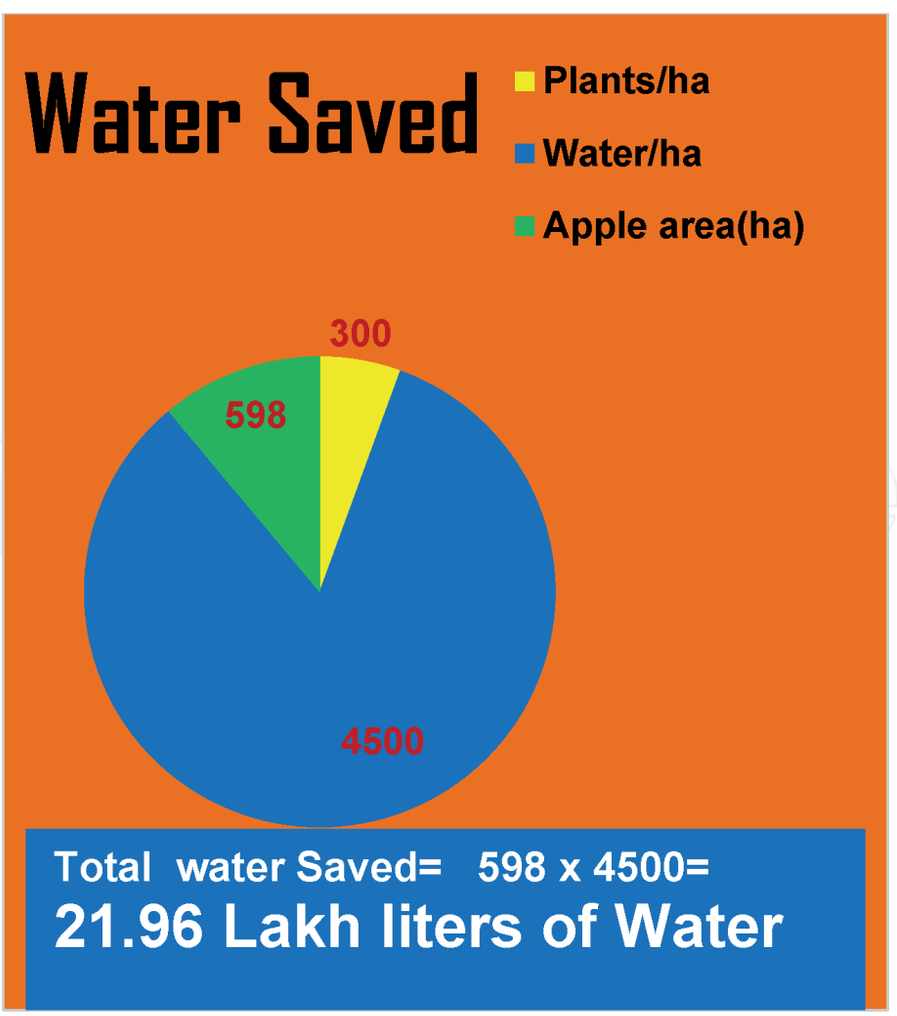


Figure 4.
Pheromone traps and pheromone dispenser technology save water.

in one hectare. As per the estimated (**Figure 4**) of National Horticulture Boards of India, the area under apple cultivation is about 598 hectares. It has been estimated that 4500 liters of water can be saved by using pheromone traps and pheromone dispenser technology for the management of codling moth in Ladakh in a one-hectare area. The application of pheromone traps and pheromone dispensers in Ladakh could save 21.96 Lakh liters of water (total under apple x water requirement for one ha). The pheromone dispenser technology should be adopted in those regions where water scarcity and crisis is more for the management of various insect pests across the globe and environmentally friendly solutions and sustainable agriculture.

To the best of my knowledge, pheromone dispensers are still not registered in India but are used to control various insect pests in the world to their management [48] Therefore, it is important to include pheromone dispensers in India for the management of the codling moth and other insect pests [26] to have safe fruit production without pesticide residues, less fruit damage, safe to the environment and other health issues. Also, this paper may act as a base for policymakers, political advisors on horticulture, researchers, organic growers, and agricultural advisors/commentators of India to use non-chemical management for codling moth [47] and other important pests of India [49] for sustainable and safe agriculture in Ladakh. Pheromone dispenser technology has a huge potential for commercial marketing in India. Besides, reduction of insecticidal usage, reduction of fruit damage, and new employment opportunities in India and Ladakh and subsequently as a safe platform to lift the ban on all fresh fruits from Ladakh.

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