Chapter 6

Fundamentals of Pests Control in Date Palm

6 Fundamentals of Pests Control in Date Palm

In previous chapters the various methods used in controlling pests of date palm and dates have been described. In this chapter the fundamentals or the modern scientific methods, upon which pest control strategies are built, will be discussed as well as the extent to which they can be used in the future to design more effective control programs for combating pests of date palms and dates. In addition, the development of pest control measures and the elements or the methods that can be used as the basis in designing the pest control program will be identified.

Fundamentals of Pests Control

What does the term "Pest Control" mean? Pest control is defined as "limiting the damage incurred by a certain pest through decreasing the numbers of this pest to its lowest level by killing, expelling or preventing the maximum number possible from reaching their host (crops) or by making the habitat unfavourable for their multiplication."

Here what comes immediately to the minds of many is that pest control is the same as eradication of pests. In fact, this is far from the truth because what it does mean is to decrease the existing levels present in a certain area to its lowest level. As some individuals of the pest survive, they will recover and multiply as soon as the environmental conditions permit whatever the precision and efficiency of control measures.

In some cases the pest was found to multiply and increase significantly after stopping the control programs for a while. This can be attributed to the degree of pest tolerance to the unfavourable conditions, its genetic composition and the emergence of resistant strains, i.e. pest strains that can resist the toxic effects of chemical insecticides, especially when heavily and solely relying on the chemical control of a certain pest.

Before starting to control a certain pest, its life cycle, behaviours and habits should be studied, to identify the suitable environmental conditions for living and multiplying, in other words conducting integrated biological and ecological studies on this pest. Such studies help in denying favourable conditions for the pest in its habitat. The pest control processes should be conducted when the pest is in its weakest and most vulnerable stage. In addition, ecological studies help us to predict the degree of pest infestation in future, so that we can take precautionary measures and prepare to control the pest at the proper time. Generally, pest control measures are divided into two broad categories:

1. Natural Control

It is known that agricultural pests are part of the eco-system and there is a natural balance between these pests and their eco-system. There are several natural factors, which affect and control the regulation of a pest's population. These natural factors help also in preventing the increase of any one pest at the expense of other species in the same environment. This is known as natural control and consists of some biotic and abiotic factors.

The abiotic factors include climatic factors like temperature, humidity, wind, rain, etc., topographical factors like natural obstacles that limit the spread of the pests as in mountains, deserts and seas and soil factors. Biotic factors can be the presence of natural enemies such as predators, parasites, pathogens, resistant plants and the host population, i.e. the extent of host availability and the number of hosts the pest can attack, "host range".

The following is an example for the effects of abiotic factors on the number of pests in nature. It was found that after a period of drought in a certain area, the nitrogen level in the host plant might rise under certain soil conditions for some time after the first rains or irrigation. As a result of this rise in the nitrogen in the plant host, an outbreak of certain insect pests may occur, i.e.: a sudden rise in the population of the insects that feed on these plants. On the other hand, the same kind of drought in another area of a different soil composition may lead to the relative rise in silica in the plant tissues, which helps to protect the host plants against arthropods like insects.

In fact man uses all these previous natural factors, which constitute the natural control in fighting the agricultural pests, whether intentionally or not. In the same context, these can be utilised in date pest control. Once enough agricultural and horticultural data become available, we may be possible to produce date palms, which will be resistant or tolerant to the majority of insect pests. It may also be less susceptible or attracting to low population of pests. Generally, the direction of research should be aimed toward producing date palms, which are resistant to some of the serious pests and diseases and this objective could be achieved through breeding date palm resistance varieties by tissue culture technique, which succeeded in producing resistant varieties against Bayoud disease in Morocco.

In addition, the local natural enemies, whether predators, parasitoids or pathogens, which co-exist in the natural habitat, may work efficiently in controlling numbers of insect pests without any human intervention. Here, the research should encourage such natural enemies to play their roles in controlling these pests and educating and informing the farmers about the importance of preserving such natural enemies. It may be even better to distribute some of these natural enemies by artificial means, will be discussed later under applied control.

2. Applied Control

With the development of the agricultural activity in a certain area and the increased human population, some new crops may be introduced to the area. In addition, agricultural concentration on certain crops to produce large quantities of food may take place whether for local consumption or for export.

Man found himself in a continuous struggle with many agricultural insect pests, which can become disruptive and constitute one of the main problems in agricultural production. Some reports have estimated the average production loss attributed to insect pests as high as 14%, while it is around 10% for diseases and weeds. It was found that natural factors alone are insufficient in eradicating or controlling the number of pests in a certain habitat.

Here, man has to intervene to check the seriousness of these pests by applying many methods and procedures, which help in inhibiting, repelling or killing the insect pests. This is known as applied control, which includes mechanical, biological, legislative and chemical control measures, which will be discussed in detail later in the section about Integrated Pest Management (IPM).

The Development of Pest Control

In the middle of the nineteenth century began the wide spread and successful use of chemicals in combating some insect pests. Farmers in the USA used arsenic compounds especially Paris green (Arsenic Copper Acetate) to combat the Colorado bug on potato. With the increase in areas under different cultivated crops, the problems of pests multiplied and new chemical compounds where discovered that can be used as insecticides.

With the advent of the twentieth century, the use of arsenic, lime, Sulfur, mineral oils and nicotine became common. In the period between the first and second world wars, Pyrethrum, Rotenone and Dinitro- and Thio- cyanates were used.

In mid-twentieth century after the end of the WWII, a new era began in which the production and extensive use of chemical pesticides developed. DDT was discovered by

Swiss scientists and Gammexane (BHS) discovered by British and French scientists. Other compounds followed in the USA like Toxaphen, Chlordane, Aldrin and Dieldrin. In Germany, a group of highly toxic pesticides were discovered known as Organophosphorus compounds or simply OP compounds.

The period between 1950 and 1972 was characterised by the extensive use of chemical pesticides. It became the only method relied upon by farmers to control pests in most of the countries around the world. In the early seventies, some problems and damages due to this extensive use of the chemical pesticides and their harmful effects on man and environment began to surface. No doubt, the continued reliance on the extensive use of chemical pesticides will lead to more and more negative repercussions and the widening of the pesticide treadmill of problems and harms to both man and environment.

The following are the most important problems and harms caused by the extensive use of chemical pesticides and the over-reliance on them as the only method of pest control.

1. Emergence of new strains of insect pests resistant to some pesticide groups. This situation leads to the rise of the density of the pest above its normal levels in what is called "pest resurgence" or the increase in number of the targeted pest to epidemic proportions after the use of the pesticide. This is because of the decrease in the numbers of the natural enemies in rates higher than the pest itself.

2. Disruption of the natural balance as the extensive use of chemical pesticides does not affect the targeted pest only but also its natural enemies.

3. Conversion of some secondary pests to serious pests, because of the resultant disruption in the natural balance and the eradication of the natural enemies of the secondary pests.

4. The toxicity of the pesticides and the health hazards due to accidental poisoning or the long-term effects of these pesticides on the health of the involved persons.

5. Accumulation of pesticides and their residues in various crops and fodders. This problem was more prominent with highly stable pesticides like Organo-chlorinated pesticides, which led to switching to the more toxic but less stable pesticides like the Organophosphorous compounds. Although these have much lower stable residual levels, they caused other problems because of their higher toxicity in mammals.

6. The environmental contamination with the pesticides or their residues and their existence in different levels in the soil, water and air. In addition, there are harms to the basic element of the ecosystem like wildlife and pollinating insects.

In addition to these, because the increased use of the newer, more expensive chemical pesticides by virtue of being less stable in the environment and more toxic on the pests escalated the costs of control and the need to repeating the treatments on shorter intervals. It is noteworthy that the high cost of research and development of pesticide production and manufacturing is behind the increase prices of chemical pesticides. In early 1970's, both Rabb (1972) and Smith (1972) proposed a concept of integrated pest control, which became to be known as Integrated Pest Management (IPM).

Integrated Pest Management (IPM)

As mentioned earlier, the Integrated Pest Management concept to control pests evolved and developed primarily as a result of the problems caused by the over-reliance on synthetic organo-chemicals. However the methods of integrated pest control or management are not entirely new, as many of the elements in this system are well-known since a long time.

The aim of Integrated Pest Management is the combined and coordinated use of the best control measures to decrease the numbers of the pest to a level below the economic threshold. In such a system it is mandatory to obtain the maximum benefits from the natural factors already present in the habitat, because they limit the spread of the pests in addition to using one or more of the applied control measures. This system is characterised by being dynamic, as it is not necessary to use all the different control measures in managing the pest at a given time. Each of such measures has its role, however relatively small, in the overall control effect on the pest. Thus, many of the problems associated with the use of a single control measure can be avoided, especially with chemical pesticides.

Generally, the applied control includes the following measures: cultural control, physical and mechanical control, legislative control, chemical control and biological control. These measures, the modern strategies used and the degree, to which they can be used in controlling the date palm pests, will be discussed in details.

1. Cultural Control

Cultural control is the use of cultural and horticultural methods or measures and developing them to control the pests. It is the cheapest of all control measures and can be relied upon solely in controlling some pests especially in cases of mild infestation. The most important procedures and measures to be used in cultural control purposes are cultural hygiene and the disposal of sources of infestation. Hence, it is important dispose of agricultural waste products that are considered one of the main sources in which many pests grow and later transmit to plants. Equally important is to manage irrigation and drainage particularly in case of pests, which spend a period of their life cycle in the soil. This also helps in decreasing the chances of infection with many plant diseases especially soil born fungi. It was observed as well that adding some organic matter to the soil helps in decreasing the numbers of nematodes due to the formation of some toxic compounds during decomposition, like butyric acid, which is highly toxic to nematodes. Also, the development of varieties resistant to disease and infection is one of the most advanced in cultural pest control. However, this approach requires highly specialized research facilities and specialists to implement.

Generally, culture control measures could include one or more of the following measures: crop rotation, tilling or cultivating the soil, removal of crop residues and weeds, varying the time of planting and harvesting, the use of resistant varieties, regulation of soil moisture and proper pruning and thinning when necessary.

For example, the following are few of the most important measures that should be used in the cultural control of pests of date palms and dates:

1. Taking care in selecting date palm offshoots of known origin and free from insect pests or diseases.
2. Planting date palms with suitable spacing and trying to remove some of the palms in the old crowded Orchards.
3. Trying to develop and plant date palm varieties, which are pest-resistant especially against the most serious plant diseases, which are incurable to date palm like Bayoud disease.
4. Ensuring balanced fertilisation without excess especially with organic fertiliser.
5. Managing irrigation and improving drainage, avoiding irrigation water to rise to the level of the growing point of offshoots.
6. Removing weeds, which are suitable breeding sites for many insect pests.
7. Taking care of the cleanliness of the date palm groves and the disposal of debris regularly. No fermented products should be left in the farm because they are suitable breeding sites for the fruit stalks borers from genus *Oryctes*.

8. Taking care of the cultural measures like pruning and removing the dried or infected leaflets and burning them. The pruning instruments should be disinfected carefully.

9. Harvesting the date varieties at their specific times and avoiding mixing the new dates with the old or dropped ones, in order to prevent infecting the new dates with the stored date pests.

2. Physical and Mechanical Control

Physical and mechanical control are arbitrarily distinguished from cultural control measures in that they involve the use of special equipment or operations, which would not be performed at all, were it not for the insects. They generally give immediate and tangible results. They are in general costly in time and labour, often do not destroy the pest until much damage has been already done and rarely give adequate or economic control. There are two subdivisions: mechanical measures, which involve the operation of machinery or manual methods and physical measures, which employ in a destructive way certain physical properties of the environment. The destruction of insects or their egg masses by hand is sometimes the most practical method to employ in areas where labour is very cheap and where the insects or their eggs are large or conspicuous, not too active, or occur in relatively restricted areas. In addition, it is possible to prevent invasion of a crop by migrating insects through use of physical barriers. The main measures in mechanical pest control that should be put into consideration when designing integrated pest management programmes against dates and palm pests will briefly be discussed.

The following are few of the most important measures that could be used in the physical and mechanical control of pests of date palms and dates:

1. Using different types of insect traps to attract the adult insects including pheromone traps, which are used to attract the adults of red palm weevil and light traps, which attract nocturnally active insects, e.g. longhorn palm trunk borer, rhinoceros beetle and date palm fruit stalk borer.

2. Removing those palms that are heavily infested by trunk borers or red palm weevil, cutting them and then burning and burying them in deep holes.

3. Installing smooth metal sheet bands around the trunks of the palms to thwart rodents from climbing the trees.

4. Burning old palm leaflets and infested fronds to prevent the spread of infestations to healthy palms.

5. Of particular importance is cleaning the date warehouses from the old date's residues before any attempt to store in them. This limits the infestation by many of the stored date pests.

3. Legislative Control

Legislative control is the passing and enactment of laws or decrees by the authorities of a country to protect its agricultural wealth. It is intended to protect the plants from pest attacks and prevent their spread within the country borders and/or prevent the entry of unrecorded pests from other countries.

Agricultural quarantine efforts at the airports, seaports or border checkpoints aid in preventing the entry of new pests or diseases, previously unknown in the area, or at least delaying their entry till they are studied and necessary measures are taken in anticipation of any possible leaks. This is known as external quarantine. In the field of date palm pest control, imported offshoots are examined and diseased offshoots are rejected and burned in the seaports and airports by scientifically qualified quarantine personnel who are trained to identify the different pests and diseases.

Pests cannot be entirely prevented from entry because of the high volumes of trade between the countries, the use of aeroplanes in fast transporting agricultural cargos and the free movement by cars through the borders easing the spread of the pests especially the insect pests. One of the most prominent examples of this is the spread of the red palm weevil into several Middle East countries in the last decade and the failure of agricultural quarantine in averting the spread of such a serious pest.

In the Sultanate of Oman, the Royal Decree number 49/77 was issued on 24th of Rajab 1397 Hj, 11th of July 1977 concerning the agricultural quarantine law. This includes the procedures and legislations necessary to ensure the safety of the agricultural cargos whether imported, exported or in transit and the measures that should be taken in each case. The third article of the Royal Decree includes the necessary steps to be taken with all the imported agricultural consignments and the restraints that should be followed to assure that they are free from different pests in order to prevent their entry to Oman.

Legislations Concerning the Control of Date Palm Pests in Oman

The Ministry of Agriculture and Fisheries in the Sultanate of Oman has issued several ministerial decrees in accordance with the seventh article of the Agricultural Quarantine Law in Oman, in pursuance of the Royal Decree No. 49/77, in order to limit the spread or to prevent the entry of different pests, which attack date palms and dates. What follows is a summary of these ministerial decrees.

1. Ministerial decree number 11/79 issued on 5/2/1979 includes in its Second Article the ban on entry for the palm plants of the genus *Phoenix* and their vegetative products except the fruits. It also banned the entry of coconut palm plants from the genus *Cocus* and their vegetative parts except the fruits into the Sultanate.

2. Ministerial Decree number 26/81 issued on 16/9/1981 concerns the protection of date palm trees from pests. It includes the definitive ban on the date palm offshoots and dates imported or being in transit from Algeria and Morocco or their adjacent countries to enter the Sultanate of Oman, whether through land, air or sea border checkpoints.

3. Ministerial Decree number 5/84 issued on 17/4/1984 concerns the issuance of the executive by- law of the agricultural quarantine law. It has the list of the pests banned from entering the Sultanate of Oman. This list includes some of the pests affecting the dates and date palms, which were:

   a. Date palm soft scale, *Asterolecanium phoenicis*
   b. Longhorn date palm trunk borer, *Jebusea hammerschmidti*
   c. Khapra beetle, *Trogoderma granarium*
   d. Date spider mite, *Oligonychus* sp.
   e. Diplodia rot in palms, *Diplodia phoenicum*
   f. Date palm root rot, *Stomella radicicol*a
   g. Head rot in date and coconut palms, *Phytophthora palmivora*
   h. Lethal Yellowing disease caused by MLO

4. The Ministerial Decree number 10/87 issued on 16/9/1987 added some pests to the list of quarantined agricultural pests into the Sultanate of Oman including;

   a. Coconut beetle, *Oryctes rhinoceros*
   b. Red palm weevil, *Rhynchophorus* spp.

5. Ministerial Decree number 19/88 issued on 12/11/1988 added the carob moth (Meylois moth), *Ectomyelois ceratoniae* Zeller, which infests stored dates, to the list of pest insects quarantined into the Sultanate of Oman.

6. The Ministerial Decree number 23/93 issued on 11/9/1993 prohibits the entry of offshoots of date palms, coconut palms and other ornamental palms species and all their parts into the Sultanate of Oman from any other country.

Following the legislation regarding the red palm weevil, the Ministry of Agriculture and Fisheries has conducted several agricultural seminars and printed pamphlets to educate and inform the farmers about the seriousness of this pest and the dangers in transplanting the palm offshoots from infected areas to other places through the country. These efforts helped in limiting the spread of this serious pest and prevented its transfer from its existing places to new areas in Oman.

4. Chemical Control

Chemical control is the method, in which chemical compounds are used in the control process. Such chemical compounds are termed "pesticides", a term composed of two parts; "pest" and "cide", the latter meaning to cut down or to kill. Thus, the main groups of agricultural pesticides are acaricides, bactericides, fungicides, herbicides and insecticides. Generally, a pesticide is a substance or mixture of substances used for preventing, controlling or lessening the damage caused by a pest. A pesticide may be a chemical substance, biological agent (such as a virus or bacteria), antimicrobial, disinfectant or a device used against any pest. Chemical pest control is considered an effective method in the cases of sudden multiplication of an insect pest. Many farmers and growers value this method because they get rapid, direct and obvious results in eradicating the targeted pest. However, as we have discussed earlier, there are many problems that may arise from the extensive use of chemical pesticides.

It is important to stress the mistake of over-reliance on the use of chemical pesticides as a sole method of pest control. It should only be resorted to in cases of extreme necessity. It is imperative that these toxic chemical substances should be used when the natural or applied measures fail, because they cause an imbalance between the pest and its natural enemies of predators and parasitoids. In addition to these complex problems, there are issues with include toxicity on plants, animals and man, not to mention the high costs and the probability of emergence of resistance in some insects. There is also the possibility of converting secondary pests into major ones.

Toxicity and Hazard of Pesticides

Generally, all chemical pesticides are toxic at certain concentrations, because after all they are designed to be extremely toxic to the targeted pest. However, the high toxicity of a chemical pesticide does not automatically mean that it is also hazardous. An insecticide may be extremely toxic but does not carry a hazard unless one is exposed to it.

The toxic effect of the pesticide depends on the amount ingested or absorbed. However, there is a wide range of toxicity level among the different pesticides. Generally, those coming in contact with such pesticides like pest control specialists must take extreme caution in handling them. The person dealing with a certain chemical pesticide should know all its properties and the dangers to its direct or indirect exposure.

Generally, the hazards of any chemical pesticide to those handling it can be minimised, even if it is extremely toxic or highly concentrated, by using diluted preparations or formulations that are not absorbed through the skin or by inhalation. On the contrary, some pesticides of relatively low mammalian toxicity may be dangerous when used in their concentrated forms, which greatly enhance their absorption and inhalation. They may also be dangerous if used by untrained or non-specialised persons who have no prior knowledge about the hazards they may be exposed to. Most of these people believe that chemical pesticides are only dangerous if swallowed by mouth and do not put into consideration the other routes by which pesticides can enter the body, either by inhalation through the respiratory system or absorption through the skin.

The entry of pesticides through one or more of these routes leads to their distribution all over the body via the blood stream. Eventually they reach their site of action, which may be the central nervous system, the kidneys, the liver or the lungs. Therefore, all those dealing with the pesticides should be aware that inhaling the pesticide is the qualitatively same as injecting them into the blood serum, because the cardiovascular system is connected to the pulmonary system. In addition, the skin is one of the most dangerous routes of absorption of pesticides because of the large surface area and the high likelihood of contact with chemicals.

It is worth mentioning that we can determine the different toxicity levels through experiments done on animals especially laboratory mice. Generally, the toxicity is expressed by the value of the Lethal Concentration, LC_{50} or the Lethal Dose, LD_{50}. For example, if the LD_{50} is equal to 50 mg/kg body weight this means that if laboratory animals weighing 1 kg, each is given a quantity of 50 mg of the pesticide, 50% of them would die. However, we should not conclude that the toxicity data based on the LD_{50} values are the actual values applicable to humans, but these figures should serve as an indicator to judge the degree of care to be taken by those handling these pesticides, putting in consideration the following points:

7. The hazards of any given pesticide depend mainly on the method of administration not on its absolute level of toxicity.

8. The LD_{50} values are considered from the statistical point of view some of the most accurate standards available to indicate the level of toxicity of different pesticides.

9. Generally, the LD_{50} values are indicative of the acute toxicity as it describes by definition the acute oral toxicity of the single, orally ingested or swallowed dose. While the acute dermal toxicity describes the effect of a single dose absorbed through the skin. In addition, the pulmonary toxicity describes the exposure to the pesticide through inhalation. It is obvious that these values do not provide information about the effects arising from the accumulation of the pesticides, or their chronic toxicity.

Because of the expected difficulty of keeping abreast of the toxicity doses of all the available pesticides, the US Environmental Protection Agency (EPA) has classified or grouped the different pesticides according to the degree of their acute toxicity. Table 6.1 illustrated the main four groups of pesticides according to acute toxicity levels.

Table 6.1. Environmental Protection Agency (EPA) toxicity classification.

Hazard indicators	EPA Pesticide Categories			
	I	II	III	IV
	Highly hazardous	Moderately hazardous	Slightly hazardous	Relatively nonhazardous
Oral LD_{50}	Up to 50 mg/kg	50 – 500 mg/kg	500 – 5,000 mg/kg	< 5,000 mg/kg
Inhalation LD_{50}	Up to 0.2 mg/liter	0.2 – 2.0 mg/liter	2.0 – 20 mg/liter	< 20 mg/liter
Dermal LD_{50}	Up to 200 mg/kg	200 – 2,000 mg/kg	2,000 – 20,000 mg/kg	< 20,000 mg/kg
Eye effects	Corrosive; corneal opacity not reversible within 7 days	Corneal opacity reversible within 7 days; irritation persists for 7 days	No corneal opacity; irritation reversible within 7 days	No irritation
Skin effects	Corrosive	Sever irritation at 72 hours	Moderate irritation at 72 hours	Mild or slight irritation at 72 hours

The Role of Chemical Pesticides in the IPM Programs

Despite all the problems associated with the use of chemical pesticides in pest control, they are still indispensable. They are the only drastic and effective method currently available to control the pests when their numbers reach a level, at which other methods cannot control or when the pest numbers exceed the economic threshold. Chemical pesticides are relied on as a quick way to decrease the pest population below these thresholds. Thereafter the other measures are employed to control the low levels of the pest. To achieve the objectives of integrated pest management, it should be put into consideration that eradicating the pest, i.e. 100 % pest control is not a necessity to prevent economic damage.

As a result, chemical pest control is considered one of the main components or one of the pillars on which IPM programs are designed. Generally, the proper use of chemical pesticides in pest control programs requires the following:

- Intervening with the use of the chemical pesticides at the appropriate time when the pest is in its weakest stage.
- Intervening with what is called emergency application when other measures failed in decreasing the pest population to satisfactory levels.
- Intervening with what is termed preventive treatments. By the selective use of pesticides and relying on the highly specific pesticides where the lowest possible dose is used. Thus, the least harms or damages are done to the environment. The pesticides are relied upon with physiological selectivity or those applied based upon environmental or behavioral selectivity.

The Selective Use of Pesticides

Physiological Selectivity: Recently a group of compounds have been developed, which are characterized by their specialized target systems.

For example, compounds affecting some of the developmental features in arthropods like insect growth regulators or compounds, which produce biological toxins, which affect the insect like “Living insecticides”. All of these will be explained later when biopesticides are discussed. In addition, there are some compounds, which have selective effects against Acari or Ticks like Dicofol, Offex, Tetradifon and others.

Ecological Selectivity: The aim here is reducing the number of treatments with chemical pesticides as well as using the lowest concentration or dose of the chemical compound. This can be achieved by relying on the life tables of the pest, so that the treatment by pesticide can be undertaken when the pest is at its most vulnerable stage. Undoubtedly, this limits the overuse of pesticides, which often significantly exceeds the actual need for pest control thereby leading to environmental contamination and other ensuing harmful effects. It is believed that 50 to 70% of the applied chemical pesticides are actually without real benefit in pest control. In addition to all the above, lower doses of pesticides generally lead to an increase in selectivity by limiting the damages incurred upon predators and parasitoids.

In this field, we also can apply what is termed selective spraying, i.e. by treating the hot spots only or treating rows of trees without treating the others leaving a chance for natural enemies of predators and parasitoids to multiply. In addition, the use of systemic pesticides shows marked against sap-sucking pest like the sucking insects and the acari. Systemic pesticides, when applied on the vegetative parts, quickly penetrate through the leaf cuticle, travel through the phloem tissues and work as poisons against the sucking insects. This keeps their effects on the parasitoids, predators and pollinators to the minimum or without any effect in most cases.

Behavioural Selectivity: This term means the proper timing of the treatment depending on the behaviour of the pest. These applications have many advantages regarding the efficacy of the control process, the protection of the useful insects especially honey bees and limiting the residual contamination of the crops with the pesticides. Accumulated data on the sensory communication among insects, especially data concerning chemical pheromones involved in regulating mating behaviour and the Kairomones responsible for attracting the insects to the egg laying sites, led to the possibilities of using these chemical messages to attract the insects to certain locations.

In fact, the primary objective of the enlightened pest control lies in treatment with insecticide when needed, instead of the routine chemical control with insecticide. This will lead to a reduction in the number of treatments and the amounts of the pesticide used leading to lowering the costs of control in addition to improving the quality of the environmental system and increasing the degree of safety. Light traps and pheromone traps are considered among other measures, which provide suitable ways to measure and estimate the insect population thereby becoming one of the most important systems to indicate the most suitable time of intervention with the pesticide.

5. Biological Control

Biological control simply means the use of living organisms to suppress pest populations making them less damaging than they would otherwise be. Biological control is one of the main elements in pest control management. The term "biological control" involves encouraging and multiplying the natural enemies of the pests, whether they co-exist in the same environment or by importing these natural enemies, i.e. predators and parasitoids, and trying to accommodate them locally as well as distributing them on a large scale to limit the spread of the pests. The biological control of pests also relies on the use of what are known as bio-pesticides, mainly the microbial pesticide, including entomopathogenic fungi, bacteria, viruses, nematodes or protozoa. It also comprises pesticides produced by the fermentation by actinomycetes naturally present in the soil, insect pheromones, plant-derived pesticides and genetically modified plants resistant to the pests.

Predators and Parasites

Predation and parasitism phenomena can be defined after Tawfik (1997) as follows:

Predation is a type of interaction where one party, called the predator, attacks one or several members of the other party called the prey, which may belong to one or more species, in order to feed upon it. The predator spends with each of its prey members a time less than the complete or incomplete feeding stage.

Parasitism is a kind of biological interaction in which one party, the parasite, lives inside and feeding upon the other party, which called the host, or to live and feed outside the host during one of its feeding stages, i.e. the mature or immature stage or both of them.

Based on the above definition of parasitism some scientists believe that the parasitic insects are lesser developed parasites, and that therefore they should instead be termed as parasitoids. Hence, the parasitoid is defined as the predating parasite, which completes its development by feeding upon a host member, which is nearly its size, then lives freely in the mature stage (the adult insect). This definition relies upon the fact that in the late stages of parasitism, the parasitoid insects usually devours their hosts and feed upon them. However, henceforth the traditional name parasites will be given to such insects.

It is worth mentioning that the predator/parasite insects are considered one of the most important elements in the biological control of pest insects. The Arabs in the pre-Islam era were the first to use biological control when they moved the nests of a species of predator ants living in the desert and released them on the ordinary ants, which attack the date palms. In 1888 the first modern attempt to use this type of insect control was made when USA imported the Vidalia insect (a species of lady beetles) from Australia to control the Australian citrus mealybugs, which attacked citrus trees in California State. The use of predators/parasites in biological control depends upon the following approaches:

A. Classical Biological Control

In this approach, one of the natural enemies for a certain pest (a predator or a parasite) is imported and released in a new area, in which it adapts and settles to multiply and grow. When this is done successfully, the pest population is under control because of the natural balance between the pest and the natural enemy. The number of the pest population lessens to levels below their original levels until they are below the economic threshold.

The classical biological control is usually performed by specialists in the field of biological control and entails active follow-up of these imported predators and parasite species after their introduction to evaluate the degree of adaptation and distribution in their new habitat.

B. Conservation and Enhancement

This approach depends upon facilitating the role of the local natural enemies whether predators or parasites to control the pest population when a sudden outbreak in their numbers occurs reaching damaging levels. The process of conservation of the natural enemies is done by using specific pesticides or low doses of the pesticide to combat the target pest. Alternatively, specific areas of the orchard can be treated by the pesticide leaving other areas or strips without treatment for the natural enemies to grow and spread in. In addition, the choice of the right timing for the use of a pesticide can produce a selective effect on the pest without endangering its natural enemies.

In fact, the majority of the biological control agents in agriculture are naturally occurring, providing excellent regulation of many potential pests with little or no assistance from people. These agents may include native species or exotic species, which once imported have become successfully established as part of a classical biological control programme.

C. Augmentation

Augmentation supplements the numbers of naturally occurring natural enemies with releases of laboratory-reared or field-collected natural enemies. In addition, augmentation of the natural enemies' population could be achieved by providing shelter and protection for the natural enemies, (Flint and Dreistadt, 1998).

For example, preparing hiding places for them on the edges of fields or on trees. Also, by increasing the effectiveness of the natural enemies by using specialized chemical food or introducing alternative feeding materials to the habitat to protect and attract the natural enemies when the populations of their hosts decline. For example, as early as 500 B.C. the Chinese were placing bamboo poles between nests of predaceous ant (*Oncophylla samadina*) and citrus trees to make it easier for ants to prey on scale insects.

In general, the two approaches to augmentation of natural enemies are inoculative release and inundative release.

1. Inoculative Release

Inoculative programmes are used to build-up populations of a natural enemy earlier in the season than usual, or to establish a certain natural enemy in groves or fields where it is not yet present. Thus, the target pest will be under control or eradicated in a shorter period of time because once releases are made the natural enemy will reproduce and increase its populations on its own. Examples of inoculative augmentation include release of the predatory mites, *Metaseiulus occidentalis* (Nesbitt), in almond orchards (Hoy, 1984), *Phytoseiulus persimilis* Athias-Henriot, *Metaseiulus occidentalis* (Nesbitt), and *Neoseiulus californicus* (McGregor) in strawberries fields (Strand 1993) and also releasing the mosquito fish, *Gambusia affinis*, into rice fields and other temporary bodies of water to control mosquitoes (Kramer *et al*. 1988).

2. Inundative Release

In inundative release of the natural enemies of a certain pest, we depend upon the use of far more of these creatures than needed for the desired effective control without relying on their future generations in order to achieve somewhat more rapid effect. This approach in control is similar to the use of chemical pesticides, because the pest members are killed rapidly without depending on long ranging interactions between its population and that of the natural enemy (being a parasite or a predator). Additional releases may be required throughout the season if pest populations approach damaging levels. In this respect, the natural enemies used by the inundative or periodic release programmes are termed biotic insecticides. Many predators and parasitoids have been used in inundative programmes; some of the most well known include the use of egg parasitoid *Trichogramma* spp. wasps, which are released in many countries to control Lepidopterous caterpillars in different crops and the release of leaf-miner and whitefly parasites in greenhouses.

In addition, inundative releases of entomopathogenic nematodes are used to control a number of insect pests. The entomopathogenic activity of Steinernematid and Heterorhabditid species has been documented against a broad range of insect pests in a variety of habitats (Kaya and Gaugler, 1993). These nematodes are called entomopathogenic because they carry a bacterium, (*Xenorhabdus* spp.) in *Steinernema* spp. and *Photorhabdus* spp. in Heterorhabditis, which is pathogenic to insects and these symbiotic bacteria multiply and rapidly kill the insect pest within a day or two.

For example, entomopathogenic nematodes are used against black vine weevil, *Otiorhynchus sulcatus* (F.), and carpenter-worm, *Alcterogystia cadambae* (Moore), and other borers (Gaugler and Kaya, 1990).

It is important to point out some of the difficulties associated with the widespread use or importation of parasites or predators in classical biological control, which include:

1. The application of biological control programmes requires highly qualified experts and specialists.

2. Long time is needed for the effects to show.

3. Occasionally, it is necessary to import more than a single predator or parasites for each pest to ensure successful control.

4. The local conditions may not be as favourable to the activity of the imported predator or parasite as to the activity of the pest.

5. The parasite or predator relies entirely on a single host, while others depend on the presence of other hosts beside the main host. The absence of these hosts limits or reduces the success or adaptation of the predator/parasite in the new locale.

6. The imported predator/parasite may be subject to be a prey itself by other insects normally present in the new habitat.

In Oman several local predators and parasites have been recorded to associate with the date palm pests. Other predators/parasites have been imported to be used in the biological control programmes. Table 6.2 illustrates the general list of these predators and parasites.

Table 6.2. Survey of the natural enemies associated with date palm pests in Oman.

Natural Enemy		Host (Insect Pest)	Status of Natural Enemy
Scientific name	Order: Family		
I. Predators			
Cybocephalus rutitrons Rtl.	Coleoptera: Nititulidae	Parlatoria scale insect	Imported 1994
Cheilomenes sexmaculata (Fabricius)	Coleoptera: Coccinellidae	Dubas bug	Local
Chilocorus circumdatus (Gyllenhal)	Coleoptera: Coccinellidae	Oriental yellow scale insect	Imported 1994
Chilocorus baileyii Blackburn	Coleoptera: Coccinellidae	Oriental yellow scale insect	Imported 1994
Cryptolaemus montrouzieri Mulsant	Coleoptera: Coccinellidae	Hibiscus mealybug	Local
Chrysoperla carnea Stephens	Neuroptera: Chrysopidae	Lesser date moth and Dubas bug	Local
Dicrodiplosis manihoti Harris	Diptera: Cecidomyiidae	Citrus mealybugs	Local
Pharoscymnus numidicus Pic.	Coleoptera: Coccinellidae	Date palm mealybug	Local
Pharoscymnus tristiculus Sicard	Coleoptera: Coccinellidae	Parlatoria scale insect	Local
Runcinia sp.	Araneae: Thomisidae	Date palm scale insect	Local
Scymnus levaillanti Mulsant	Coleoptera: Coccinellidae	Dubas bug	Local
Bochartia sp.	Acari: Erythraeidae	Dubas bug	Local
II. Parasites			
Anagyrus agraensis Saraswat	Hymenoptera: Encyrtidae	Date palm mealybug	Local
Anagyrus dactylopii (Howard)	Hymenoptera: Encyrtidae	Date palm mealybug	Local
Anagyrus mirzai Agarwal	Hymenoptera: Encyrtidae	Date palm mealybug	Local
Aphytis lingnanensis Compere	Hymenoptera: Aphelinidae	Oriental yellow scale insect	Imported 1994
Aprostocetus sp.	Hymenoptera: Eulophidae	Dubas bug	Local
Archenomus arabicus Ferriere	Hymenoptera: Aphelinidae	Parlatoria scale insect	Local
Archirileya femorata (Boucek)	Hymenoptera: Eurytomidae	Cicada insect	Local
Pseudoligosita babylonica Viggiani	Hymenoptera: Trichogrammatidae	Eggs of Dubas bug	Local
Comperiella leminscata Compere & Annecke	Hymenoptera: Encyrtidae	Oriental yellow scale insect	Imported 1994
Eupelmus sp. nr. *elongatus* Risbec	Hymenoptera: Eupelmidae	Cicada insect	Local
Euryischia sp.	Hymenoptera: Aphelinidae	Date palm mealybug	Local
Leptomastix dactylopii Howard	Hymenoptera: Encyrtidae	Citrus mealybug	Local
Pseuderimerus sp.	Hymenoptera: Torymidae	Cicada insect	Local
Trichogramma maidis Pintureau & Voegelè (= *Trichogramma brassicae* Bezdenko)	Hymenoptera: Trichogrammatidae	Eggs of Pomegranate mealy-bug	Imported 2003

As mentioned in the previous chapters, there are many predators/parasites, which can be employed in the field of biological control of date palm pests in the framework of the Integrated Pest Management programs. The main predators and parasites, which could be included in the IPM programs of date and date palm pests after conducting the necessary research studies, can be summarized as follows:

I. Predators

Lady Beetles
(Family: Coccinellidae)

Lady beetles (Coleoptera: Coccinellidae), are commonly called "Ladybugs". The adults can be easily recognized by their shiny bright colours and their semi-circular body shape. They have short clubbed antennae, and most of the species are yellow or red-coloured and spotted with black spots or black in colour with white, red or yellow spots. The head of the adult beetle is partially concealed under the pronotum. The terminal segment of maxillary palpus is triangular in shape and is compressed.

The larvae of Coccinellidae are brown in colour, speckled with yellow or red spots or stripes. The maxillae are curved and sickle-shaped. The thoracic legs are developed clearly and the larvae move abundantly. Some larvae have many spines or fleshy outgrowths growing from the sides of the body, while others are covered with waxy covers that resemble those of the mealybugs. Because of this, some may fail to differentiate between the larvae of lady beetles and the mealybugs.

Behaviour of Lady Beetles

Most of lady beetles are predaceous as both adults and larvae, but some species are considered as pests such as the Mexican bean beetle and the squash beetle. Most lady beetles attack and eat soft-bodied insects and mites, but few feed on fungi. The adults of lady beetles can fly for some distance adequate to land on the plants in search for their prey. Many species of lady beetles specialize on certain types of insects or mites making them effective predators. The young lady beetle larvae usually pierce and suck the contents from their prey, while the older larvae and adults chew and consume the entire prey.

About one week after mating the adult females of the lady beetles start to lay their eggs. Usually the eggs are laid in masses of 5-100 eggs according to species. The eggs can be seen attached to plant leaves and stems. In some species the female lays its eggs individually or may hide them under the larval exuviae, under the scales of scale insects or under the ovisacs of the mealybugs.

The oviposition period for most species of lady beetles is relatively long. It may extend up to two months with the total number of eggs ranging between 200 to 400 eggs laid per a single female during its lifetime. There are some species, like *Hippodamia convergens*, which is characterized by high efficiency in oviposition reaching up to 1550 eggs per each female. The eggs hatch within 3-10 days, and the entire egg mass ends up hatching in a few hours. The tiny larvae then gather on the eggs shells for a few more hours.

Later the larvae wander actively looking for a prey. The larvae of most of the Coccinellidae have four instars. The larval instar lasts from two to four weeks, after which the fully grown larva searches for a suitable place to hide and to pupate like the lower surfaces of plant leaves, wrinkled leaves, cracks in tree barks or under insect scales are all suitable places. The larva secretes from its anal opening a sticky substance to fix its posterior end in the place. Then, it moults leaving the exuviae collected at the anal end or rarely surrounding the body of the pupa. Generally, the life cycle takes a period from 3 to 7 weeks while the adult beetle lives usually for 4 months. The lady beetles defend themselves by secreting a repelling, bitter yellow liquid from between the leg femur and tibia to fend off their enemies.

The Different Species of Lady Beetles

Most of the species of the family Coccinellidae are characterized by their high predatory efficiency during the larval and adult stages. They belong to the following genus: *Coccinella*, *Radalia*, *Hippodamia*, *Cryptolaemus*, *Scymnus*, *Stethorus*, *Adalia*, *Chilocorus*, *Harmonia*, *Cycloneda*, *Lindorus*, *Anatis*, *Adonia*, *Neomysia*, *Olla*, *Midas*, *Ceratomegilla*, *Callenida*, *Novius*, *Leis*, *Brumus*, *Curinus*, *Aiolocario*, *Hyperaspis*, *Cryptogonus*, *Exocomus*, *Pseudonycha*, *Proylaea*, *Coleomegilla*. The most important species of lady beetles in the Sultanate of Oman are the following:

1. *Cheilomenes sexmaculata* (Fabricius)
2. *Coccinella septempunctata* L (Seven-spot Ladybird)
3. *Coccinella undecimpunctata* L. (Eleven-spot Ladybird)
4. *Scymnus* sp.

Some other species have been imported and released in different regions in Oman for biological control of several insect pests. The most important species of lady beetles, whether the local or the imported species will be discussed below.

Cheilomenes sexmaculata (Fabricius)

The adult female of *C. sexmaculata* is characterized by the orange colour and each elytron has two black coloured wavy lines and one spot at the end of each elytron. There is also a black line alongside the inner margin of each elytron, as shown in Fig. 6.1. The adult male of *C. sexmaculata* is differentiated by a single line on each elytron and a broad black coloured area at the end of each elytron. This species is the most abundant species of lady beetle in Oman and is found wherever there are aphids being its favourite host. It was also recorded in some regions predating on the nymphs of the Dubas bugs, *Ommatissus lybicus* Bergevin. However, it is not considered highly effective in controlling the spread of Dubas bugs of date palms.

Fig. 6.1. *C. sexmaculata.*

Coccinella septempunctata L. (The seven-spot lady beetle)

Coccinella species are a major group of aphid feeding lady beetles. The adult beetle of *Coccinella septempunctata* has a more rounded shape and their legs are less obvious because the tips of their femoral leg segments are hidden when viewed from above. It is about 4 mm in length and its thorax is black with white along the front margin. There are seven large black spots, three on each elytron and a large one commonly present between the elytra in the front or may be branched, on its red or orangish wing covers, which have some white near the front, as shown in Fig. 6.2.

Fig. 6.2. Adult of *C. septempunctata.*

The egg of *C. septempunctata* is orange in colour and spindle-shaped with sleek cover. It is around 0.9 mm in length and 0.4 mm in width. The eggs are laid to stay perpendicular on pest-infested plant surface. Eggs are laid individually or in compact clusters of up to several dozen, i.e. each egg mass is consist of two to 37 eggs, as shown in Fig. 6.3. The number of eggs laid by a single female beetle during its lifespan differs according to temperature and the type and quantity of food available.

Fig. 6.3. Eggs of *C. septempunctata.*

Fig. 6.4. Newly hatched larvae of *C. septempunctata* L.

The larva of *C. septempunctata* is elongated in shape and pointed toward the posterior end. It has grey colour with yellow spots. The body is covered with short and black spines. The first instar larva is about 1.6 mm long and 0.4 mm wide, while the full grown larva is about 8.1 mm long and 0.9 mm wide, Figs. 6.4 and 6.5. The pupa of *C. septempunctata* is convex in shape and speckled with orange spots. The body is covered with obvious bristles. The pupa is about 4.8 mm long and 3.2 mm wide, Fig. 6.6.

In Oman, the seven-spot lady beetle, *C. septempunctata*, is less abundant than the previous species and was recorded as a predator on Dubas bugs in some regions.

Fig. 6.5. Full grown larvae of *C. septempunctata* L.

***Coccinella undecimpunctata* L.**
(Eleven-spot lady beetle)

The adult beetle of the eleven-spot lady beetle, *Coccinella undecimpunctata*, resembles the seven-spot lady beetle but is differentiated by the number of spots on the two elytra which is eleven, five on each wing cover and a big common one in front and between the two elytra, as in Fig. 6.7. This species was recorded in Oman, but it is somewhat less common than the previous species. The predatory efficiency of the eleven-spot lady beetle, *C. undecimpunctata*, was studied to reveal that the single larva of this species, during its larval stage which lasts from 10-15 days, can devour from 250 to 300 aphids or from 150 to 200 eggs or newly hatched larvae of Lepidopterous, while the adult beetle during its lifespan, which extended to 70-90 days, can daily predates upon around 120 aphids, or 200 eggs or newly hatched larvae of Lepidopterous.

Fig. 6.6. Pupa of *C. septempunctata.*

Fig. 6.7. Adult of, *C. undecimpunctata* L.

It is also noticed that the previous mentioned lady beetle (seven-and eleven- spot lady beetle) was recorded as a predator on the Dubas bugs in some regions. However, it is obvious that both species do not have an effective role in decreasing the population of the Dubas bugs of date palms.

Fig. 6.8. Adult of *C. montrouzieri.*

Fig. 6.9. Larvae of *C. montrouzieri,* predating on the mealybugs.

Cryptolaemus montrouzieri Mulsant (The mealybug Destroyer)

The adult beetle of the mealybug destroyer, *Cryptolaemus montrouzieri*, is an important predator of exposed mealybug species and certain other Homoptera. Flint and Dreistadt (1998) mentioned that both adult and larva of *C. montrouzieri* feed on all mealybug stages, but adult and young larvae prefer mealybug eggs and young nymphs.

The adult beetle of the mealybug destroyer, *C. montrouzieri*, is mostly dark brown or blackish with an orangish head and tail. The body is covered with white thick fluff, as shown in Fig. 6.8. The mealybug destroyer larva is about 7-10 mm long and covered with waxy white curls and resemble mealybugs, except that the lady beetle larva is more active and mature larva grow larger than mealybugs, Fig. 6.9. The wax can be scraped off to reveal the pale, alligator-shaped larva of *C. montrouzieri*.

The mealybug destroyer, *C. montrouzieri*, was imported from the United Kingdom to be deployed in Oman. In April 1997, 3500 adult beetles of mealybug destroyer were released in the Royal Razat Farm in Dhofar province. This predator distributed and established itself in the southern region of Oman, Dhofar province. It is currently highly effective against many species of mealybugs including the Hibiscus mealybug. It can be utilized by transferring some of this predator from Dhofar to any other region in Oman, in which infestations with Hibiscus mealybug or other mealybugs occur on date palms.

Chilocorus circumdatus (Gyllenhal) (The red Chilocorus)

The general shape of the adult beetle of the red Chilocorus, *Chilocorus circumdatus*, resembles a helmet and is dark orange in colour with fine black rim on the elytra base. The adult beetle is 5 mm long, as in Fig. 6.10. The larva is reddish creamy in colour with black appendages like spikes alongside its body, as in Fig. 6.11. The yellow oriental scale insect, *Aonidiella orientalis* is considered the main host of this predator. This species of lady beetle is produced commercially. It was imported and released in many regions in Oman.

Chilocorus nigritus (Fabricius) (The Black Chilocorus)

The adult beetle of *Chilocorus nigritus*, is black in colour as in Fig. 6.12. It is very active in searching for its prey. It preys on different species of scale insect. This predator was imported from India in 1985 and around 680 adult beetles were released in Dhofar province in Oman. Kinawy (1991) mentioned that *Chilocorus nigritus* can completely control the population of the coconut scale insects, *Aspidiotus destructor* Sign., which attack coconut palms in the southern region of Oman, Dhofar province, and that no chemical control is currently needed against this pest.

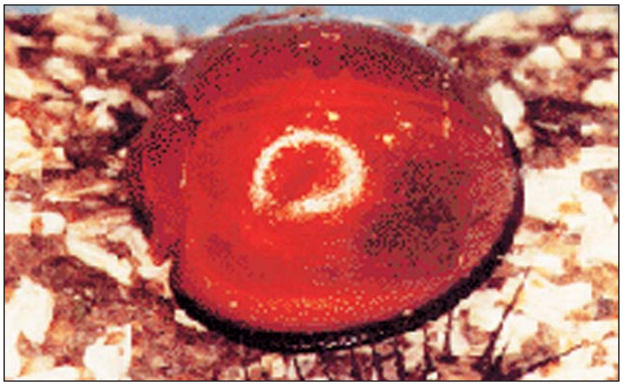


Fig. 6.10. The adult of *Chilocorus circumdatus.*

Fig. 6.11. The larva of *C. circumadatus*.

In addition, the author recorded the presence of *Chilocorus nigritus* devouring with high efficiency both the citrus snow scale, *Unaspis citri* (Comstock), on citrus trees and the wax scale insect, *Ceroplastes floridensis* (Comstock), on Mango trees. The distribution of this predator in the southern region of Oman can be utilized by transferring it in the north of Oman and to carry on some further research to explore the possibility of employing it in the control of several scale insects on date palms.

Fig. 6.12. Adults of *Chilocorus nigritus*.

Species of genus *Stethorus* spp. (Mite-feeding Lady Beetles)

Stethorus spp. lady beetles feed almost exclusively on tetranychid mites, like the red spider mite, dust mite and others. They are called mite-feeding lady beetles or spider-mite destroyer. There are many species identified as under the genus *Stethorus* in many parts of the world. The following are the main species identified under the genus *Stethorus*:

1. *Stethorus gilvifrons* (Mulsant)
2. *Stethorus darwini* (Brèthes)
3. *Stethorus exspectatus* Chazeau
4. *Stethorus histrio* Chazeau
5. *Stethorus keralicus* Kapur
6. *Stethorus loi* Sasaji
7. *Stethorus loxtoni* Britton & Lee
8. *Stethorus pauperculus* (Weise)
9. *Stethorus tridens* Gordon
10. *Stethorus madecassus* Chazeau
11. *Stethorus punctum* (Leconte)
12. *Stethorus punctillum* (Weise)
13. *Stethorus japonicus* Kamiya

The *Stethorus* spp. can hardly be seen because of its tiny size. The adult beetle of the species *Stethorus gilvifrons* is about 1.5 mm long or less. It is shiny black with a very finely punctured surface covered with pale, minute hairs. Females of *Stethorus gilvifrons* lay tiny pale eggs among spider mite colonies. The larva of the spider-mite destroyer, *Stethorus gilvifrons* is dark grey to brownish and covered with numerous fine hairs, as shown in Fig. 6.13.

Some attractive characteristics of *Stethorus* spp. for mite biological control are their prey consumption, longevity and high reproductive capacity. Each adult female may consume 30–60 mites per day. Total fecundity ranges from 123 eggs in *S. tridens* (Fiaboe *et al*. 2007), 184 eggs in *S. madecassus* (Chazeau, 1974a and 1974b), 221 eggs in *S. punctum* (Tanigoshi and McMurtry, 1977), 279 eggs in *S. punctillum* (Roy *et al*. 2003), to a high of 501 eggs in *S. japonicas* (Mori *et al*. 2005).

Ebrahim (2000) mentioned that the spider-mite destroyer *Stethorus gilvifrons* (Mulsant) is successfully produced on commercial scale and large numbers are released to control different species of mites in both greenhouse vegetable and fruit trees. One of the most important features of this predator is that it can tolerate high temperature. It can live and multiply in temperatures above 35°C.

Fig. 6.13. Adult and larva of the spider-mite destroyer, *Stethorus gilvifrons* (Mulsant).

Because of all the above, the spider-mite destroyer *Stethorus gilvifrons* (Mulsant) can be included in the biological control programs against the different species of mites on date palms especially the dust mite. In this respect, further research studies have to be performed to determine the rates of release of this predator on the date palms.

Hippodamia convergens Guérin-Méneville (Convergent Lady Beetle)

The convergent lady beetle, *Hippodamia convergens*, is named for the two converging white marks on its thorax. Although, some forms of *Hippodamia* spp. and some other lady beetles have similar marks, Fig. 6.14. The adult of the convergent lady beetles, *H. convergens*, are mostly orange in colour with usually 13 black spots on the elytra; however many individuals have fewer spots and some have none. A similar wide spread species in USA, *Hippodamia quinquesignata*, is always spotless and may or may not have converging white marks on adult thorax.

Fig. 6.14. The lady beetle *Hippodamia convergens.*

The convergent lady beetle, *H. convergens*, feeds primarily on aphids, but also to some extent consumes whiteflies, other soft-bodied insects, plant bugs, insect eggs as well as different Acari species. There are about 24 species of *Hippodamia* occurring in the United States; they are among the most common orangish and black beetles that prey on aphids. It is found in feral areas and forests in North America where it multiplies. Millions of adult beetles can be collected in their active period to be shipped to different places. There, they can be released in the farms to control many insect pests. This species is considered a general predator as mentioned before.

In Oman, 200,000 beetles of the convergent lady beetle, *H. convergens*, were imported and released during 2002 in Al-Jabal Al-Akhdar (The Green Mountain), in order to control the two common species of aphids, which attack pomegranate trees, i.e. the pomegranate aphid, *Aphis punicae* (Passerini), and the cotton or melon aphid, *Aphis gossypii* (Glover), Fig. 6.15.

It was found that the convergent lady beetle, *H. convergens*, completed its life cycle in about 30 days and the adult

Fig. 6.15. The release process of the Convergent Lady Beetle.

Fig. 6.16. Larva of the Convergent Lady Beetle, *H. convergens.*

beetle lived up to 3 months. The adult beetle devours around 5000 aphids during its life span. While the larva, shown in Fig. 6.16, consumes only 400 aphids during its life. The convergent lady beetle, *H. convergens*, is mostly effective in cool regions. One of its most important drawbacks is that it usually migrates away from its release sites if the host insects are not available.

Lacewings

Family: Chrysopidae

The family Chrysopidae is among the known 19 families of the order Neuroptera. Insects in the order Neuroptera are mostly predaceous including dobsonflies (Corydalidae), alderflies (Sialidae) and antlions (Myrmeleotidae). Adults of the order Neuroptera meaning "nerve-winged" are soft-bodied, have four membranous wings with many-branched veins and have chewing mouthparts and most are predaceous, although adults of some species feed only on pollen and nectar or do not eat at all. Larvae of most species are flattened predators that are 3-20 mm long with prominent jaws as mentioned by Tauber (1991). The Chrysopidae family is commonly called Green Lacewings, which are very common predators in agricultural, garden and landscape habitats. Lacewing larvae are sometimes called aphidlions because they often feed on aphids. However, lacewings also prey on mites and a wide variety of small insects, including small caterpillars, leafhoppers, mealybugs, psyllids, whiteflies and insect eggs.

Green Lacewings (family: Chrysopidae) are one of the most important families under the Neuroptera order utilized in biological pest control, which are commercially available and are among the most common released predators. Generally, all the lacewing larvae are predaceous, but adults of many species of green lacewings are not predaceous. For example, the adults of *Chrysopa* spp. predating on several insects as well as on the honeydew, pollen grains and nectar; while Chrysoperla spp. adults feed only on honeydew, pollen grains and nectar.

Green lacewing, *Chrysoperla carnea* Stephens, is common in Oman and recorded in all agricultural regions and is known as green aphidlions. The larval stage of *Chrysoperla carnea* feeds on the eggs of several insects, small insects likes aphids and thrips as well as the newly hatched larvae of some Lepidopterous. The larvae of *C. carnea* were observed consuming the nymphs and adults of Dubas bugs (*Ommatissus lybicus* Bergevin), lesser date moth larvae (*Batrachedra amydraula* Meyrick), the mealybug nymphs and scale insects on the date palms. The eggs of the green lacewings (green aphid lions) can be easily differentiated because the adult female lays each egg on a minute silken stalk attached to the plant surface, as shown in Fig. 6.17. The egg is white in colour and can be easily seen with the naked eye. The egg hatches after 2- 4 days of oviposition.

The larvae of the green lacewing, *Chrysoperla carnea*, are flattened, tapered at the tail, have distinct legs, and look like tiny alligators. They have reddish brown spotted grey colour, as in Fig. 6.18. They are characterized by their spindle-shaped bodies and the sucking predatory mouth parts. The long and strong upper mandibles can be easily seen. Each upper mandible has a gully or hollow which is covered by the opposing lower mandible. Together, they form a tube through which the fluids are sucked out of their prey. During its life the larva does not defecate because its digestive canal has a closed end as the stomach does not open into the intestines. Therefore, the solid materials remaining from food (the prey) are left inside the stomach of the larva till the pupal stage. The larva has three instars and the larval duration takes from 10 to 15 days. Then, the fully-grown larvae secrete a silky secretion from Malpighi's tubes via the anal opening to form the pupal cocoon. Thus, the larva transforms into a pupa inside a spherical shaped silken cocoon, as in Fig. 6.19. Then the larva also evacuates the faecal mass, which resembles a bean seed. The pupal stage takes from 6 to 10 days.

The adult of green lacewing, *Chrysoperla carnea* Stephens, Fig. 6.20, have golden eyes and slender green bodies and are easily characterized by their attractive yellowish green colouration and the delicate netted lacewings, which are longer than the adult body. They are named for their prominent wings, which have green, netlike or lacy veins. The adults are night-flying insects and are often seen when drawn to lights. During the day, adults can be observed flying if their resting place on foliage is disturbed for example by beating branches to collect specimen samples The adult wings assume the shape of a truss over the insect body during the resting time. The adults of green lacewing, *C. carnea*, are not predaceous, but feed on honeydew and pollen during their lifespan, which ranges from 20 to 30 days. The adult female lays around 300 eggs during its lifespan. The relative predatory effectiveness of the green lacewing, *C. carnea*, was estimated that of a single larva of *C. carnea* can devour around 350 aphids or 300 eggs or newly hatched larvae of Lepidopterous.

Of all the Neuroptera species, the green lacewing, *Chrysoperla carnea* has been the most commonly used species in applied biological control, mainly through augmentation and conservation tactics. It rarely has been involved in classical biological control programs. However, the green lacewings are produced commercially

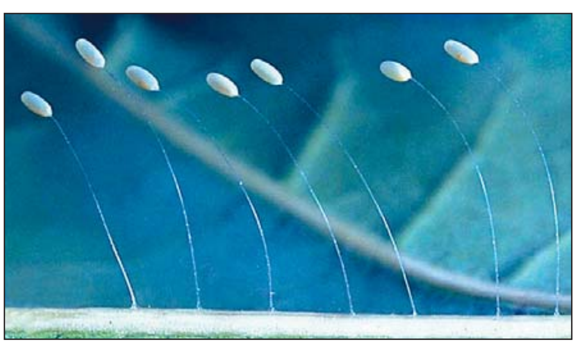


Fig. 6.17. Eggs of *C. carnea.*

Fig. 6.18. Flattened larva of *C. carnea.*

Fig. 6.19. Pupa of *C. carnea*.

Fig. 6.20. Adult of *C. carnea.*

to be released in several places around the world. Large numbers of this predator can be purchased and then released according to the biological control programs through the Integrated Pest Management program of the different date palm pests, especially the Dubas bugs. The larvae of *C. carnea* prey effectively on nymphs and adults of Dubas bugs. This predator can be obtained in the form of adults, larvae or eggs. However, it is preferred to purchase this species in the form of eggs because it is more economical and easier to be released.

Praying Mantids

Family: Mantidae

Family Mantidae (Order: Dictyoptera) is known as praying mantids or mantises. The insects of this family are well-known to be predators of many insect pests. The praying mantids are distributed in several regions around the world especially in the temperate and tropical regions, but are rarely present in cold regions. There are 1800 species of this family were identified around the world to date. Mantids are big in size. The adult is about 5-10 cm long at maturity and is usually yellowish, green, or brown.

The females of praying mantids lay their eggs in masses, cover with secretion and attach them to the plant stalks. Then the egg masses solidify and they look like sponges, thus they are called the spongy sacs, as show in Fig. 6.21. Each female lays four to five spongy sacs of eggs. The sacs act to protect the eggs from birds and natural enemies. Each species of mantids has a distinctive ovisac. The female lays around 400 eggs during its life span.

The adult and immature stages of mantids are considered to be predators of many insects and other arthropods. Mantids young nymphs feed on aphids, leafhoppers and other small insects, while the large nymphs and the adults predate and devour the big flies, mites, ants, wasps, hoppers, beetles and others. Because they feed also on beneficial insects, their beneficial value is limited. They

Fig. 6.21. The spongy ovisac of the praying mantis.

are usually seen on flowers, where they prey on nectar- and pollen-feeding insect species, such as honey bees. In addition, they are highly cannibalistic, as they often eat their siblings when they hatch from the egg case, and sometimes the females attack the males and consume them after mating. Generally, mantids frequently occur naturally in the gardens and fields.

Mantids are easily recognized by their elongate thorax and grasping forelegs, and their ability to elevate their front legs for long period of time. They can stand still on their second and third pair of legs, while the position of the front legs is close to the elevated head and the front thorax. This is their hunting position and because the insect can stand without a move in this position for a long time, it was related to a man praying to God and hence was named "praying mantids". Upon spotting a prey, the insect pushes its front legs suddenly to grasp the prey between the femur and tibia, and then pulls them to the first position, all in less than a second. The insect has very large compound eyes, as in Fig. 6.22, and three simple eyes. The area of the front thorax (pronotum) is modified and much larger than the rest of the thorax. The abdomen ends by in a short pair of segmented urogomphi. There is no visible ovipositor. The male abdomen carries on its end the anal probes.

In Oman, the species known as the spotless big praying mantids, *Mantis religiosa* L., is common in the northern regions. In Oman, Walker and Pittaway (1987) recorded some other species from family Mantidae, these species are: *Blepharopsis mendica* Fabricius (Striped Mantis), *Empusa hedenborgi* Stål (Lappet Mantis), *Hypsicorypha gracillis* Burmeister (Helmeted Mantis), *Eremiaphila braueri* Krauss (Common Ground Mantis), *Sphodromantis trimacula* Saussure, *Empusa spinosa* Krauss and *Microthespis dmitriewi* Werner.

(Source: Flint and Dreistadt, 1998)

Fig. 6.22. Praying Mantids:
Left: Observe the large compound eyes of the adult
Right: Nymph eating a species of flies

Predatory Thrips
(Thysanoptera: Thripidae)

Thrips belong to Order Thysanoptera. They are tiny slender insects with long fringes on the margins of their wings. Although the majority of thrips species are plant feeders, some are important predators of mites and small soft-bodied insects. The adults of thrips are commonly yellowish or black and the nymphs are translucent white to yellows. The majority of thrips predatory species belong to families Thripidae, Aeolothripidae and Phloeothripid. The adults and larvae of the six-spotted thrips, *Scolothrips sexmaculatus* (Pergande), which belong to family Thripidae, are entirely predaceous on mites such as Grass mite, *Oligonychus pratensis* (Banks). The nymphs and adults of this thrips prey on different stages of the spider mites, and can distinguish the adult with six black spots, three on each wing cover of the mostly pale-yellow adult, as shown Fig. 6.23. The life span of the adult of *S. sexmaculatus* is about 47 days at 27°C, and the female lays about 204 eggs during her lifespan. This species can produce many generations per year and one generation takes about 16 days. It is worth mentioning that the predatory thrips, *S. sexmaculatus*, is now produced commercially on a large scale and can be purchased from a production centres and then released in areas affected by spider mite, (Hunter, 1997).

Fig. 6.23. The six-spotted thrips, *Scolothrips sexmaculatus*, prey on mite.

Predatory Mites
(Arthropoda : Acarina)

Mites feed on plants and are therefore considered harmful pests. However, some mites are beneficial and are considered predators of some arthropods such as scale insects, whiteflies, thrips, eggs and larvae of store insects and also spider mites and other harmful plants. In nature the predatory mites play a significant role in controlling some pests, which confirms its importance in the field of biological control of these pests. Mites in the Family Phytoseiidae are the most well-known predators. There are also other predaceous species of mites occur in other families, including Anystidae, Laelapidae and Stigmaeidae.

Mites unlike insects do not have antennae, segmented bodies or wings. Mites pass through an egg stage, a six-legged larval stage and two eight-legged immature stages (nymphal) then adult stage. Most predaceous mites are long-legged and pear-shaped and are shinier than pest mites because they have fewer tiny hairs. They are translucent,

Fig. 6.24. *Galendromus annectens* (De Leon).

Fig. 6.25. *Galendromus helveolus* Chant.

although after feeding they often take on the colour of their host and may be bright white, yellow, red, or green. Eggs of the predaceous mites are more translucent, pearl-colored, and oblong than the eggs of plant-feeding mites, which are commonly spherical and colored or opaque.

In addition, the predaceous mites are much more active than plant-feeding species; they stop moving only to feed. When predaceous mites inconvenience touched they move more quickly than those feeding on plants. Under the stereomicroscope, it is easy to see that predatory mites have mouthparts that extend in front of their bodies to catch and pierce their prey, while the mouthparts of plant feeding mites extend downward to feed on plans. At a moderate temperature, some mite species can complete a generation in one or two weeks, Flint and Dreistadt (1998).

Some predatory mites, especially *Amblyseius* spp. and *Euseius* spp., are not specialized in feeding. Besides feeding on arthropods (mites and plant bugs) they also feed on pollen, fungi, and leaf sap. The predatory mite, *Euseius hibisci* (Chant) completes its life cycle in about 7 days only and a single female lay about 28 eggs during her lifespan, which extends to about 32 days.

On the other hand, *Phytoseiulus* spp. are very specific feeders and prey and feed only on spider mites. While mites in some other genera such as *Galendromus*, *Metaseiulus* and *Neoseiulus* have an intermediate diet, as they prefer feeding on spider mite but also feed on pollen and other food. *Neoseiulus californicus* (McGregor) is used effectively to control the mites that attack many crops and fruit trees such as, strawberries, corn, soybeans, apple trees, plums and ornamental plants. This species completes its life cycle in about 6 days only and a single female lay about 60 eggs during its lifespan, which extended to about 23 days. In nature populations of predatory mites are extremely effective biological control agents against plant-feeder mites. So, outbreaks of plant-feeder mites are frequently associated with the killing of predatory mites by broad-spectrum insecticides applied to control other pests, as most of the pesticides from the Carbamate, Organo-phosphorus or Pyrethroid compounds can be toxic to many of the predatory mites. In addition, plant water stress (drought) and dust are other common causes of plant-feeder mites' outbreaks.

Many species of predatory mites are successfully produced in mass production and can be used in a biological control program against plant-feeder mites. Therefore augmentative release of predatory mites is recommended to control pest mites or other insect pests in some crops. These predatory mites belong to family Phytoseiidae and some species of these predatory mites are shown in Figs. 6.24 - 6.27.

Woets (1973) and Ramakers (1978) mentioned that the first studies for mass production of predaceous mites

(Source: Flint and Dreistadt, 1998)

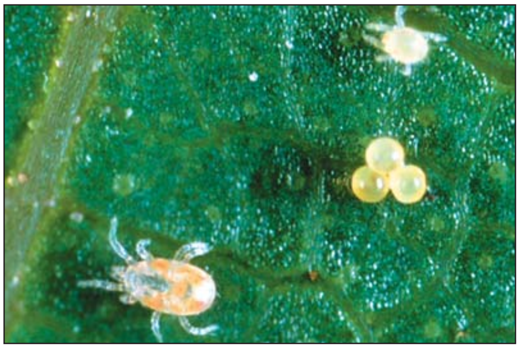


Fig. 6.26. *Neoseiulus californicus* (McGregor).

Fig. 6.27. *Euseius* hibisci (Chant).

to use in biological control was done by producing and release of *Amblyseius mackenziei* Schuster & Pritchard, on cucumber plants and *Amblyseius cucumeris* (Oudemans), on sweet pepper plants in greenhouses to control thrips. In 1979, Koppert company produced predatory mites *Phytoseiulus persimilis* Athias-Henriot, where it was released to control the normal red spider *Tetranychus urticae* Koch on cucumber plants in greenhouses in an area of about 400 hectares, (Koppert, 1980). After that there were many studies for mass production of many species of the predatory mites. Both Hoddle (1998) and Kerguelen and Hoddle (1999) studied these predatory mites. For example, the predatory mites *Galendromus helveolus* Chant, which is used successfully in Florida, where it was released on avocado trees to control certain species of mites. This species complete its life cycle in about 11 days, and a single female lay about 41 eggs during her lifespan, which extends to about 25 days. It was found that this species feeds on all stages of Spider mite, but it prefers to prey on eggs and first instar nymphs. It was also observed that in the absence of food, the females of *G. helveolus* feed on their eggs.

Spider

(Arachnida: Araneae)

Spiders of arthropods frequently deployed in the gardens and orchards. Spiders are classified in the arachnid group along with mites. Spiders belong to Order Araneae, Class Arachnida, and all spiders are predaceous; they prey mainly on insects, other spiders and related arthropods. They hunt their prey in webs, but others stalk insects across the ground or plants and pounce on them. Although there is no doubt that predatory spiders contribute significantly in controlling the numbers of insect pests in nature by devouring large numbers of them, there is little information on how to manipulate spiders to improve pest control, and also non are commercially available for augmentative releases. Spiders seek to avoid people and most of them are harmless to humans. The black widow and recluse spiders can cause painful injuries or systemic illness, but they seldom or ever are fatal to healthy human. Flint and Dreistadt (1998) gave a description of some of the most famous families of predatory spiders, which can be summarized as follows:

Grass Spiders
(Family: Agelenidae)

Spiders in family Agelenidae is known as Grass spiders or Funnel weavers. Funnel weavers feed during the day and night on the ground and in most types of vegetation, including short plants and trees. They spin funnel-shaped webs, often with several-inch-wide, flat extension covering plants or soil. The spider wait motionless in the hole of its web until any insect walked or flew into the web, and accordingly the spider detect the vibrations, the spider run out very fast and captures and bits the prey and then carries it back to the funnel to be eaten. The funnel weavers have six or eight eyes, all about the same size, arranged in two rows, Fig. 6.28.

Fig. 6.28. The funnel weavers, *Hololena nedra.*

Garden Spiders
(Family: Araneidae)

Spiders in family Araneidae is known as Orb weavers or Garden spiders. This type of spiders feed on insects that fly, fall or are blown into their web. Their elaborate silken webs are spun in concentric circles. The spider rests at the center of its web or hides in a shelter near the edge, waiting for prey to become entangled. Orb weavers generally have poor vision and rely on web vibrations to locate and identify prey. Orb-weavers have eight similar eyes, legs hairy or spiny and no stridulating organs. The Araneidae family is cosmopolitan, including many well-known large or brightly colored garden spiders. There are 3,500 species of Orb weavers occur in the world. Figs. 6.29 and 6.30 clarify the Orb weavers, *Araneus* spp.

In Oman, Orb weavers or Garden spiders was seen on date palm trees in many regions. It has seen that the Garden spider weaves a dense web, where they hunt and devour large numbers of insects which settle to rest or fall on the web such as Dubas bugs, as shown in Fig. 6.31.

Sac Spiders
(Family: Clubionidae)

Sac spiders are also known as two-clawed hunting spiders. Species of Sac spiders stalk and capture their prey that is walked or resting on surfaces. They spin silken tubes or sacs under bark, among leaves or on the ground, where they hide during the day or retreat after hunting. Sac spiders commonly are nocturnal, medium sized and pale spiders, as shown in Fig. 6.32.

Fig. 6.32. The Sac spider, *Cheiracanthium inclusum.*

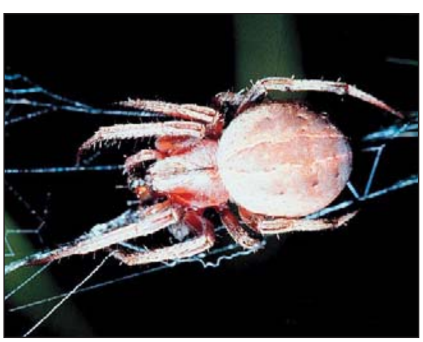


Fig. 6.29 *Araneus* spp.

Fig. 6.30. *Araneus diadematus* Clerch.

Fig. 6.31. Web of Garden spiders, *Araneus* spp. on date palm.

Wolf Spiders
(Family: Lycosidae)

Wolf spiders prey on different type of insects that are walking or resting on the ground. They are active during day and night and hunt their prey in the open. They are often observed on the ground in litter and on low vegetation and also occur in burrows and under debris on soil. They make a small thick web, in which they rest.

(Source: Flint and Dreistadt, 1998)

Fig. 6.33. Wolf spider, *Lycosa* sp.

(Source: Flint and Dreistadt, 1998)

Fig. 6.34. Female of the wolf spider, *Lycosa gulosa.*

Jumping Spiders
(Family: Salticidae)

Jumping spiders are day-active hunters in plants or in the ground. They do not make a web, but they can catch their prey by jumping for distances many times more than their body length. The jumping spiders have a distinctive pattern of eyes in three rows; the first row of four eyes with large and distinctive middle eyes, the second row of two very small to minute eyes and the third one of two medium-sized eyes. Jumping spiders usually have an iridescent, metallic-colored abdomen and black carapace. There are

Wolf spider have a distinctive pattern of eyes; four small eyes in front in a straight row, one middle pair of larger eyes, and one rear pair of widely spaced eyes on top of the head. They have long hairy legs and are usually black and white or strongly contrasting light and dark, which make them difficult to discern unless they are moving. In some species of wolf spider the female carry their young on her stomach after eggs hatching, Fig. 6.33.

Fig. 6.34 shows the female of *Lycosa gulosa*, it can be noted that the bag of eggs, which contains hundreds of eggs, are installed tightly in the female but the female can still catch their prey of insects efficiently in this situation. The frontal view of the wolf spider of *Lycosa aspersa* is shown in Fig. 6.35, which clarifies the thick hair coat on the spider body. It has four small eyes in a straight line in the foreground, a pair of large eyes in the center and the wide range eyes at the top of the head.

Fig. 6.35. Wolf spider, *Lycosa aspersa.*

Fig. 6.36. Female of the jumping spider, *Phiddippus otiosus*.

more than 5,000 species of jumping spiders worldwide. Fig. 6.36 has shown the female of the jumping spider, *Phiddippus otiosus*. The jumping spiders can be easily noticed in date palm groves in many regions in Oman. They prey on many insects including the Dubas bug.

Crab or Flower Spiders (Family: Thomisidae)

Spiders of family Thomisidae are known as Flower or Crab spiders. The crab spiders stalk and capture insects which are walking or resting on surfaces. They are diurnal hunters and do not spin webs. They are called "crab spiders" because their front two pairs of legs are enlarged and extend beyond the side of their flattened body making them look like tiny crabs. Their small eyes occur in two slightly curved rows, with the top row often much wider than the lower one. In addition the crab or flower spiders can change their colour according to the colour of flower they hide in order to be invisible to their prey, as shown in Fig. 6.37. In Oman, a spider species of the genus *Runcinia* has been recorded on date palms, where they prey on Dubas bug and scale insects.

(Source: Flint and Dreistadt, 1998)

Fig. 6.37. The crab or flower spider, *Misumena vatia*, with different colour.

Dwarf Spiders (Family: Linyphiidae)

Dwarf spiders prey on insects that fall, walk or land in their web. They are active during the daytime "diurnal" and occurring in the plant canopy and among litter on the ground. They produce sheetlike webs on the surface of the plants or soil. They are common in vegetable fields, and most species are relatively small in size. The dwarf spider *Linyphia phrygiana* is shown in Fig. 6.38. This species feed on small insects in agricultural fields and orchards.

Fig. 6.38. The dwarf spider, *Linyphia phrygiana*.

Cobweb Spiders (Family: Theridiidae)

Cobweb spiders are also known as "Combfooted spiders". They feed on insects that walk or fly into their webs. These spiders are always found hanging upside down by their claws in irregularly spun, sticky webs waiting for prey. The spider is usually concealed in a corner of the web in a silken tent. Fig. 6.39 shows the cobweb spider, *Theridion dilutum* which is diurnally active and feeds on plant hoppers, flies and mites. This species is common in vine yards in California. Fig. 6.40 shows the cowweb spider, *Theridion fordum,* which prey on many insect pests on different plants and fruit trees. The cowweb spiders produce irregular sticky webs on plants and when the insects fall or walk on webs they cannot escape. The spider immediately attacks and feeds on them. This group includes the black widow spider, which produces relatively thick silk that feels rough and sticky. Cobweb spiders generally have soft, round, bulbous abdomen and slender legs without spines.


(Source: Flint and Dreistadt, 1998)

Fig. 6.39. *Theridion dilutum*.

Fig. 6.40. *Theridion fordum.*

Black Widow Spiders

McCrone and Stone (1965) recorded four species of black widow spiders in Florida in USA. These four species are as follows:

1. *Latrodectus mactans* (Fabricius)
   (The southern black widow)
2. *Latrodectus variolus* Walckenaer
   (The northern black widow)
3. *Latrodectus geometricus* C. L. Koch
   (The brown widow)
4. *Latrodectus bishopi* Kaston
   (The red widow)

As mentioned before the black widow spiders belong to family:Theridiidae. The adult female of black widow spider has a black shiny body, slender legs, and a red hourglass-shaped mark on the underside of her large round abdomen, Fig. 6.41. It occurs indoors and outdoors in fields and orchards. Although its bite can be serious, they tend not to bite people unless somebody actually touches the spider or disturbs its web, especially if egg sacs are present. Her egg sac is roundish to pear-shaped and about 12 mm in diameter. It consists of tough pale-colored silk and contains up to several hundred eggs.

Black widow spiders prefer dark places, where they wait in webs for prey, which include flying insects such as flies and ground dwellers such as crickets and cockroaches. The males of black widow are harmless. They vary from light greenish gray to dark brown or blackish and have cream colored patches and a light to brownish lengthwise band, Fig. 6.42. The male coloring resembles the young female black widows. The hourglass marking on the underside of both immature females and males is yellow to orange.


(Source: Flint and Dreistadt, 1998)

Fig. 6.41. Female of *Latrodectus mactans* with her egg sac.

Fig. 6.42. Male of black widow.

II. Parasitoids

Parasitoids are the group of natural enemies of greatest importance in the biological control of insect pests, and most of them are either wasps belonging to order Hymenoptera, or flies of the order Diptera.

Family: Trichogrammatidae

The Trichogrammatidae is a cosmopolitan family of Chalcidoidea of order Hymenoptera and consists of about 650 wasp species, which belong to 80 genera of insect egg parasitoids. A species catalogue for *Trichogramma* spp. was published by Zerova and Fursov (1989). Members of this group of insects are very small wasps ranging in length from 0.2 to 1.5 mm. The systematics of this group depends for differentiation heavily on male genitalia, Wajnberg and Hassan (1994).

The egg parasitoid tiny wasps *Trichogramma* spp. are the most widely used insect natural enemy in the world, partly because they are easy to mass rear and they attack many important insect eggs, especially eggs of moths and butterflies, Figs. 6.43 and 6.44. In many countries *Trichogramma* species are commercially available and released to control different caterpillar pests attacking corn, rice, sugarcane, cotton, vegetables, sugar beets, fruit trees and pine and spruce trees.

A total area of over 32 million ha of agriculture and forestry in the world has been treated annually with *Trichogramma* for controlling insect pests, Li (1994). The *Trichogramma* species are released against pests in forests (Bai *et al*. 1995), certain field crops (Smith, 1996; Wajnberg and Hassan, 1994). In addition, they are used against some pests of fruit trees such as *Amorbia cuneana* (Walsingham) on Avocado trees (Oatman and Platner, 1985) and *Prays oleae* Bern. on Olive trees (Hegazi *et al*. 2004) and also some insect pests on date palm (Mohammad *et al*. 2004).

For example, the pomegranate butterfly, *Virachola* (*Deudorix*) *livia* (Klug) which is a fruit borer and considered one of the most destructive insect pests attacking pomegranate and date fruits in many countries, e.g. Egypt, India and Oman, was successfully controlled in India by releasing the egg parasitoid *Trichogramma chilotraeae* (Singh *et al*., 2001).

In Oman, during1999 and 2000, preliminary studies were conducted to use the egg parasitic wasp, *Trichogramma brassicae* Bezdenko, against the pomegranate fruit borer, *Virachola livia* Klug (Lepidoptera: Lycaenidae), in Al-Jabal Al-Akhdar. The parasitic wasp, *T. brassicae*,

(Source: Flint and Dreistadt, 1998)

Fig. 6.43. Female of *T. pretiosum*, parasitoid on egg of bollworm.

Fig. 6.44. Parasitized eggs with a *Trichogramma* sp., are typically darken or black.

was imported and released during the activity of the pomegranate fruit borer, from May till August, and it was very effective. From 2005, mass production of the egg parasitic wasps, *Trichogramma* spp., i.e. *Trichogramma evanescens* (Westwood) and *Trichogramma brassicae*, was started in Oman. The grain moth, *Sitotroga cerealella* (Olivier) (Lepidoptera: Gelechiidae), used as a host to rear *Trichogramma* spp. on its eggs. During 2006 and 2007 about 370 million of the egg parasitic wasps, *Trichogramma* spp., were released at weekly intervals in Al-Jabal Al-Akhdar in Oman during the activity season of the pomegranate fruit borer, Fig. 6.45. Now, there was no doubt that the integrated pest management against the pomegranate fruit borer, *Virachola livia*, in Al-Jabal Al-Akhdar, can mainly depend on the classical biological control by releasing the egg parasitic wasp, *Trichogramma* spp.

Fig. 6.45. Release of *Trichogramma* spp. on pomegranate trees in Al-Jabal Al-Akhdar in Oman by Dr. Magdy Kinawy.

Adults of *Trichogramma* spp. are tiny wasps, which can hardly be seen with the naked eye. They measure 1mm or less, are yellow waxy and have red eyes, Fig. 6.46. They also have two pairs of membranous wings and the rear pair is smaller than the front pair, and the majority of species have wing hairs arranged in regular rows, and the antenna have thick hair.

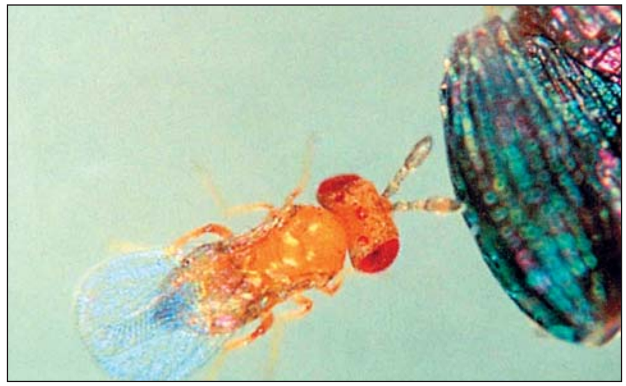


Fig. 6.46. The adult of *Trichogramma* sp.

Li (1984) mentioned that there are more than 70 species of *Trichogramma* that have been used around the world in biological control programs and about 20 species were mass-reared for field release. The following are some species of *Trichogramma*, which are used in large scale around the world to control different insect pests:

1. *Trichogramma evanescens* (Westwood)
2. *Trichogramma maidis* Pintureau & Voegelè
   (= *T. brassicae* Bezdenko)
3. *Trichogramma minutum* Riley
4. *Trichogramma semblidis* (Aurivillius)
5. *Trichogramma cacoeciae* Marchal
6. *Trichogramma platneri* Nagarkatti
7. *Trichogramma oleae* Voegelè & Pointel
8. *Trichogramma ostriniae* Pang & Chan
9. *Trichogramma pretiosum* Riley
10. *Trichogramma dendrolimi* Matsumura
11. *Trichogramma chilonis* Ishii (= *T. confusum* Viggiani)
12. *Trichogramma japonicum* Ashmead

Advantages of Using *Trichogramma* spp. In Biological Control Programs

The egg parasitoid *Trichogramma* spp. is one of the most important parasitoid, which is used widely against many insect pests in many regions of the world. The total area where *Trichogramma* been deployed before 1998 has been estimated in different countries as follows: about 65 million acres in both Russia and China, from 350 to 850 thousand acres in the United States of America, the Philippines and Colombia, from 25 to 100 thousand acres in each of Iran, Egypt, India and France and less than 20 thousand acres in all from Thailand, Canada, Portugal, Germany, Switzerland, Australia, Tunisia and the Netherlands. The main advantages of using the egg parasitoid *Trichogramma* spp. can be summarized as follows:

- It is completely safe for the environment to use the egg parasitoid *Trichogramma* spp. in biological control programs, which gives an opportunity for other natural enemies for multiplication and plays a role in reducing the number of insect pests.
- Since this parasitoid is one of the egg parasitoids it would destroy the host at the egg stage, where the females lay their eggs in eggs of the host (of a pest insect) and complete the life cycle in eggs of the host. It feeds on the contents of the egg and kills it, so that there is no opportunity for the pest (host) to cause damage.
- *Trichogramma* spp. can serve as egg parasitoids in all agricultural environments, where the spread depends on their ability to fly and their ability to search and find host eggs.
- Relative easy of mass-production of *Trichogramma* spp. under laboratory conditions. Millions can thus be produced and then released in the fields against the target insect pest in a timely manner.
- On release the *Trichogramma* parasitoid causes a decrease in the rate of infestation of the target pest in the fields of 80%, even 90%.
- Ease of parasitoid release. It is prepared in the production lab in the form of eggs (for one of the hosts used in rearing technique), where it is a *Trichogramma* parasitoid about to emerge from the eggs of hosts, and have these eggs are installed with adhesive on paper cards. These cards are suspended in the field on the target crop or trees, as shown Fig. 6.47.
- The total life cycle of the *Trichogramma* spp. take from 7 to 10 days, thus doubling the number of the parasitoid generation after generation during the short period of time.

Fig. 6.47. The release cards of *Trichogramma* spp., where they are about to emerge from the eggs of hosts.

Mass Production of *Trichogramma* spp.

In many countries, producing a quantitative mass-production of many species of *Trichogramma* parasitoids met with great success. Mass production of *Trichogramma* spp. now depends on the use of the eggs of three insect species as alternative host. These alternative hosts for the multiplication of *Trichogramma* parasitoids are *Sitotroga cerealella* (Olivier), *Ephestia kuehniella* (Zeller) and *Corcyra cephalonica* (Stainton).

These alternative hosts were selected because they are able to host the parasitoids such that high quantities of production are achieved. The main features of these alternative hosts are that they are of high reproductive efficiency, that their adult stages have reduced mouthparts and therefore do not require a supply of special diet and that their females lay the majority of eggs during the first week of their lifespan, thereby leading to a short production cycle. Also, the alternative hosts do not pose any risk to the crops in any way when released in the field, because they are store pests only. In case they are used in storage in association with the parasitoid, then the eggs can be sterilized before using as host and the fetus killed thereby. In addition, it is possible to develop the technique of mass-production of both host and parasite semi-mechanical means, i.e. by using artificial host eggs.

Possibility of Using *Trichogramma* spp. to Control Date Palm Pests

Some studies have shown that *Trichogramma* spp. can be used successfully by releasing them in date palm orchards to reduce the numbers of some date palm pests. In Egypt, Mohammad *et al*. (2004), reported that the release of the egg parasitoid, *Trichogramma evanescens* (West.) (Hymenoptera: Trichogrammatidae) in date palm orchards at El-Bahria Oases was evaluated as an eco-biological agent for suppression of date infestation with date palm insect pests. Results revealed a significant efficacy of this parasitoid in controlling insect pests of date palms. He mentioned, that fronds infestation with the greater date moth, *Arenipses sabella* Hampson, was reduced by 35.6-62.4% while date infested with the lesser date moth, *Batrachedra amydraula* Meyer, was reduced by 58.2%. Infestation rates of dates infested with the date stone beetle, *Coccotrypes dactyliperda* (Fabricius), the pomegranate butterfly, *Virachola* (*Deudoris*) *livia* Klug, and the currant moth, *Cadra* (*Ephestia*) *calidella* (Guenee), were also diminished by 51.3, 80 and 45%, respectively. He also added that time of parasitoid release; parasitoid density and number of releases are of great importance as factors influencing the efficacy of the parasitoid action against the insect pests of date palms at El-Bahria oases, Giza, Egypt.

Based on the above the egg parasitoid *Trichogramma* spp. can be used in the system of Integrated Pest Management of date palm pests in Oman. In addition, it is better to mass-produce the local strain of *Trichogramma* spp., because it is certain that this local strain would establish and adapt better to different environmental conditions in the region than imported strains. It has been also shown that the selection of the appropriate species and strain of *Trichogramma* is an influential factor in the success of the *Trichogramma* spp. to parasitize on the eggs of the target pest.

Family: Encyrtidae

Species of family Encyrtidae (Order: Hymenoptera) are internal parasitoids of ticks and various insect eggs, larvae, or pupae, including beetles, bugs, moths, mealybugs and scales. Adults of family Encyrtidae are tiny wasps and are usually less than 2 mm long, Fig. 6.48. Wasps of this family feed on honeydew and plant secretions, but many of them may depend on the host secretions to get their food. Reproduction of this family can be sexually or parthenogenetically in the absence of males, in which case the offspring will be all males. Genera of family Encyrtidae include *Anagyrus*, *Comperiella*, *Copidosoma*, *Encyrtus*, *Leptomastix*, *Metaphycus*, *Pentalitomastix* and *Psyllaephagus*. Over 3,000 species of family Encyrtidae have been identified.

Fig. 6.48. *Anagyrus* sp.

In Oman, four species of family Encyrtidae were recorded; three of them belong to genus *Anagyrus* (*Anagyrus agraensis* Saraswat, *A. dactylopii* (Howard) and *A. mirzai* Agarwal), which were recorded as parasitoids of a date palm mealybug species, and the fourth species belong to genus *Leptomasti* (*Leptomastix dactylopii* Howard), which was recorded on citrus mealybug, *Planococcus citri* Risso. In addition, *Comperiella leminscata* Compere & Annecke was imported on 1994 and released to control oriental yellow scale, *Aonidiella orientalis* (Newstead).

Family: Aphelinidae

Species of family Aphelinidae (Order Hymenoptera) are a diverse group of external or internal and primary or secondary parasitoids. Family Aphelinidae is one of the most important groups, and about 1,000 species are known all over the world. Their hosts include aphids, mealybugs, psyllids whiteflies and scales. Some species of family Aphelinidae are parasitoid on eggs of insects of the orders Orthoptera and Lepidoptera. Adults of the family Encyrtidae are tiny wasps and are usually one mm long or less.

Adults of this family often feed on copious honeydew produces by their hosts. In some cases adults may feed on the liquid full proceeds from the host injured. Females of this family lay their eggs through inserting their ovipositor in the rear part of body of aphids or whiteflies. If the hosts are scale insects, then the females often lay their eggs under the body of the host and sometimes on its back. The internal parasitoids of this family can pupate inside the host body, while some species pupate inside cocoon beside the host. Many species of this family are hyperparasites. The most important genera of this family include, *Aphytis*, *Aphelinus*, *Archenomus*, *Euxanthellus*, *Euryischia*, *Marietta*, *Physcus*, *Ertmocerus* and *Encarsia*.

In Oman, two species of family Aphelinidae are recorded; *Archenomus arabicus* Ferriere and *Euryischia* sp. The first species is recorded on the Parlatoria date palm scale, *Parlatoria blanchardi*, while the second one is recorded on the giant mealybug or the date palm mealybug, *Pseudaspidioproctus hyphaeniacus*. In addition, during 1994 the parasitoid wasp *Aphytis lingnanensis* Compere was imported to Oman and released in date palm orchards to control date palm scale insects, e.g. the oriental yellow scale, *Aonidiella orientalis*.

III. Biopesticides

The definition of biopesticides as given by FAO is "a compound that kills organisms by virtue of specific biological effects rather than as a broader chemical poison". They differ from biocontrol agents in being passive agents, whereas Biocontrol agents actively seek the pest. The rationale behind replacing conventional pesticides with biopesticides is that the latter are more likely to be selective and biodegradable. In addition, CABI's definition is "Biopesticides use naturally occurring organisms, such as fungi, bacteria, viruses and nematodes to control plant diseases and arthropod pests".

It worth to mentioned that the definition of biopesticides by the United States Environmental Protection Agency (EPA) is "Biopesticides are certain types of pesticides derived from such natural materials as animals, plants, bacteria, and certain minerals". For example, canola oil and baking soda have pesticides applications and are considered biopesticides. EPA also added that "Biopesticides fall into two major classes":

1. Microbial pesticides consist of a microorganism (e.g. a bacterium, fungus, virus or protozoan) as the active ingredient. Microbial pesticides can control many different kinds of pests, although each separate active ingredient is relatively specific for its target pests.
2. Plant-Incorporated-Protectants (PIPs) are pesticides substances that plants produce from genetic material that has been added to the plant.

In general, the term biopesticides is used for microbial biological pest control agents that are applied in a similar manner to chemical pesticides. Commonly these are bacterial, but there are also examples of fungal control agents, including *Trichoderma* spp. and *Ampelomyces quisqualis* (a control agent for grape powdery mildew). *Bacillus subtilis* are used to control plant pathogens. Weeds and rodents have also been controlled with microbial agents. The most well-known insecticide example is *Bacillus thuringiensis*, a bacterial disease organism of Lepidoptera, Coleoptera and Diptera. Because it has little effect on other organisms, it is considered more environmentally friendly than synthetic pesticides. The toxin from *Bacillus thuringiensis* (Bt toxin) has been incorporated directly into plants through the use of genetic engineering. Other biological insecticides include products based on entomopathogenic fungi (e.g. *Beauveria bassiana*, *Lecanicillium lecanii*, *Metarhizium anisopliae*), entomopathogenic nematodes (e.g. *Steinernema feltiae*) and entomopathogenic viruses (e.g. *Cydia pomonella* granulovirus).

Another addition to the group of biopesticides are pesticides derived or extracted from plants as well as different types of insect pheromones which change or alter behavior. Finally plants have been genetically modified for pest control. In general, Biopesticides can be divided as follows:

1. Living Systems

These include microbial pesticides, which consist of a microorganism (e.g. a bacterium, fungus, virus or protozoan) as the active ingredient. Microbial pesticides can control many different kinds of pests, although each separate active ingredient is relatively specific for its target pest. Some of the microbial pesticides can be commercially produced and packaged for use as pesticides, by spraying on plants or used in any other way to reach the pest to be eliminated.

In fact, microbial control is considered one of the biological control methods that use micro-organisms to control pest population to reduce the damage caused by them. Thus the micro-organisms used to control insects are known as biological insecticides, while those used to control fungi are known as biological fungicides.

There are many viruses killing insects, but these viruses cannot be multiplied outside of the living organisms.

There was a type of virus infecting the larvae of *Anticarsia gemmatalis*, which is an important pest on soybeans in North and South America. It was possible to get this virus through the collection of infected larvae. These were crushed and then filtered to get an extract, which was diluted and then sprayed on plants in order to infect larvae of the pest with the virus and to eliminate them. This virus and many other viruses can be produced commercially in the form of dry powder to use against specific pest when needed.

Data in Table 6.3 give some information about the most important microbial pesticides, which are produced commercially. It should be noted that there are some difficulties facing the use of microbial pesticides in Integrated Pest Management, and these difficulties can be summarized as follows:

1. Some of the microbial pesticides need special weather conditions in order to multiply and impact occur, such as fungi that require moisture of more than 90% in the atmosphere.

2. Many microbial pesticides are highly specialized; therefore they are used to control limited species of pests at the same time, unlike chemical pesticides that may be used to control more than one species at the same time.

3. Since the microbial pesticides are formulations from living microorganisms, they need to be stored under special circumstances, so as not to lose their viability.

4. It is relatively difficult to produce some microbial pesticides, especially those characterized by specialization. The production costs are very high when compared with the production costs of chemical pesticides.

5. Microbial pesticides need time to kill the target pest. During the period of time between application and death of the target pest much damage may be caused despite the fact that infected larvae often stop feeding.

6. When spraying a microbial pesticide, its application should completely cover the surfaces of the plant, so that it can touch the larvae of the target pest causing the disease. So, in the case of non-ambulatory pests such as borers, it will be difficult to deliver the microbial pesticide to the immature stages of the target pest.

Table 6.3. Examples about the most important microbial pesticides, which are produced commercially and used to control agricultural pests.

Microbial Pesticides	Commercial Name	Target Pest
1. Viruses		
(Insecticidal baculovirus)		
Adoxophyes orana granulovirus	Capex 2	Larvae of *Adoxophyes orana* Fischer von Roesl.
Anagrapha falcifera nucleopolyhedrovirus	*Anagrapha falcifera* NPV	Lepidopterous larvae
Anticarsia gemmatalis nucleopolyhedrovirus	Polygen, Multigen	*Diatreae saccharalis* *Anticarsia gemmatalis*
Autographa californica nucleopolyhedrovirus	VPN 80, Gusano	Lepidopterous larvae
Cydia pomonella granulovirus	Madex 3, Granupom, Carposin,Carpovirusine	*Cydia pomonella*
Helicoverpa zea nucleopolyhedrovirus	GemStar	*Helicoverpa zea* (Boddie) *Helicoverpa virescens* (Fabricius)
Lymantria dispar nucleopolyhedrovirus	Gypcheck	*Lymantria dispar* L.
Mamestra brassicae nucleopolyhedrovirus	Mamestrin	*Mamestra brassicae* L.
Spodoptera exigua nucleopolyhedrovirus	Spod-X, Ness-A	*Spodoptera exigua* (Hubner)
2. Bacteria		
(Biological Insecticides)		
Bacillus thuringiensis subsp. *kurstaki* (Btk)	Bactospeine, Biobit, Foray DiPel, Thuricide, Delfin, Troy-BT, Biobest BT	*Lepidopterous* larvae *Leptinotarsa decemlineata* Say
B. t. subsp. *aizawai*	XenTari, Florbac, Agree, Design	Lepidopterous larvae
B. t. subsp. *tenebrionis*	Novodor	Coleopterous larvae, especially Colorado potato beetle (*Leptinotarsa decemlineata*)
B. t. subsp. *japonensis* strain *buibui*	M-Press	Coleopterous larvae, especially those live in the soil.
B. t. subsp. *aizawai* encapsulated deltaendotoxins	Maatch (kurstaki + aizawai)	Lepidopterous larvae (*Spodoptera* spp., *Heliothis*, *Helicoverpa*, *Pieris* and *Plutella xylostella*).

Microbial Pesticides	Commercial Name	Target Pest
B. sphaericus	VectoLex CG	Mosquitos larvae, especially *Culex* spp.
(Biological Fungicides)		
Bacillus subtilis	Kodiak, Quantum 4000, System 3, Rotor	Seed treatment against soil-borne fungi, i.e. *Fusarium* spp., *Pythium* spp., *Rhizoctonia* spp.
Burkholderia cepacia	Deny, Intercept	Against soil-borne fungi and Nematodes.
Pseudomonas chloraphis	Cedoman	Against soil-borne fungi.
Pseudomonas fluorescens	Dagger, Biocure, BlightBan	Against soil-borne fungi and the bacteria causing fire blight in apple and pear, *Erwinia amylovora*.
Pseudomonas syringae	BioBlast	Fungi that attack stored materials.
Streptomyces griseoviridis	Mycostop	Against soil-borne fungi such as: *Fusarium*, *Alternaria*, *Pythium* and *Phomopsis* spp.
(Microbial bactericide)		
Erwinia carotovora (Non-pathogenic strain)	Biokeeper	Against the soft rot caused by *Erwinia carotovora*
(Bacterial herbicide)		
Pseudomonas gladioli	AM 301, Camperico	*Poa annua* L. in lawn.
3. Fungi		
(Biological Insecticides)		
Beauveria bassiana (Bolis.)	Naturalis-L, Naturalis-T, Mycotrol, CornGuard	**Strain (Bb 147)** against *Ostrinia* spp. **Strain (GHA)** against sucking insects, i.e. Aphids, Thrips, Whiteflies and Mealybugs. **Strain (ATCC 74040)** against soft insects of Coleoptera and Homoptera.
Beauveria brongniartii	Engerlingspilz, Betel	White grubs, *Hoplochelis marginalis* and Cockchafers, *Melolontha melolontha*
Metarhizium anisopliae	Ago Biocontrol Metarhizium 50, Bio-Blast	Many Coleopterous and Lepidopterous insects and Termites.
Metarhizium flavoviride	Green Muscle	Against locust and grasshoppers.
Paecilomyces fumosoroseus	PreFeRal	Whiteflies, e.g. *Trialeurodes vaporariorum* and *Bemisia tabaci*, and Aphids, Thrips and Mites.
Verticillium lecanii	Mycotal (whiteflt strain), Vertalec (aphid strain)	Whiteflies, Thrips and Aphids.
(Biological Fungicide)		
Candida oleophila	Aspire	Post-harvest diseases in citrus, apple, pear and quince.

Microbial Pesticides	Commercial Name	Target Pest
Coniothyrium minitans	Contans	Fungi of genus *Sclerotinia*.
Endothia parasitica (Non-pathogenic strain)	*Endothia parasitica*	Against the fungus, *Endothia parasitica* in Chestnut trees.
Fusarium oxysporum (strain Fo 47)	Fusaclean L, Fusaclean G	Against vascular wilt diseases, e.g. *Fusarium oxysporum* and *Fusarium moniliforme*
Gliocladium catenulatum	Primastop	Against soil-borne fungi (*Pythium* and *Rhizoctonia* spp.) and Post-harvest diseases, e.g. *Botrytis*, *Didymella* and *Helminthosporium* spp.
Gliocladium virens	SoilGard	Root rot and seedling diseases, e.g. *Rhizoctonia*, *Pythium*, *Fusarium*, *Thielaviopsis*, *Sclerotinia* and *Sclerotium* spp.
Pythium oligandrum	Polyversum	Against soil-borne fungi.
Trichoderma harzianum	Harzan, Trichodex, Ago Biocontrol Trichoderma50	Against *Botrytis* and *Sclerotinia* spp.
(Biological herbicide)		
Chondostereum purpureum	Biochon	Used in the forest to prevent the growth of some unwanted plants.
(Biological nematicide)		
Myrothecium verrucaria	DiTera	Against plant pathogenic nematodes.
4. Nematodes		
(Entomopathogenic Nematodes)		
Heterorhabditis bacteriophora	Heteromask, Cruiser, Lawn Patrol, Nema-green	Many insects, especially the Japanese beetles.
Heterorhabditis megidis	Larvanem, Nemasys	Soil insects such as: *Otiorhynchus sulcatus*
Steinernema carpocapsae (weiser)	Exhibit SC-WDG, Bio Safe WG, BioVector WG	Against many type of soil insects.
Steinernema feltiae	Nemasys, Entonem, Traunem, X-Gnat	Many species of Sciarid flies, i.e. (*Bradysia*, *Lycoriella* and *Sciara* spp.)
Steinernema glaseri	*Steinernema glaseri*	Larvae of family Scarabaeidae (White Grubs).
Steinernema riobravae	Biovector 355 WG, Devour WG, Vector MC	Nymphs and adults of Mole crickets in lawns, citrus weevil (*Pachnaeus litus*)and sugarcane stem borer (*Diaprepes abbreviates*)
Steinernema scapterisci	Otinem S	Mole crickets (*Scapteriscus vicinus* and *Gryllotalpa* spp.)
5. Protozoa		
Nosema locustae	Nolo Bait	Grasshoppers

2. Fermentation Products

The active ingredients in some pesticides are in fact the by-product of some fermentation processes of certain soil microorganisms. Since the eighties of the twentieth century many such pesticides have been produced widely for commercial purposes through the fermentation processes of some bacteria which are naturally occurring in the soils. Examples are the insecticide/acaricide Abamectin® and the insecticide Spinosad®.

In addition it was discovered that some antibiotics are effective against some plant diseases and have been used commercially for that purposes. As an example, Streptomycin and Tetracycline are used to treat some plant diseases like fire blight disease in apples and pears. They are used also to control Phytoplasma-caused diseases especially in peaches and cherries by injecting the trees at concentration of 100 parts per million. Al-Wijam disease in the date palms is also treated by the above-mentioned antibiotics at a rate of 20 grams in each tree, three times per year during the period in which the temperature is between 20-30°C, with 2 months intervals between treatments. In this context, antibiotics are considered as pesticides to control the plant diseases.

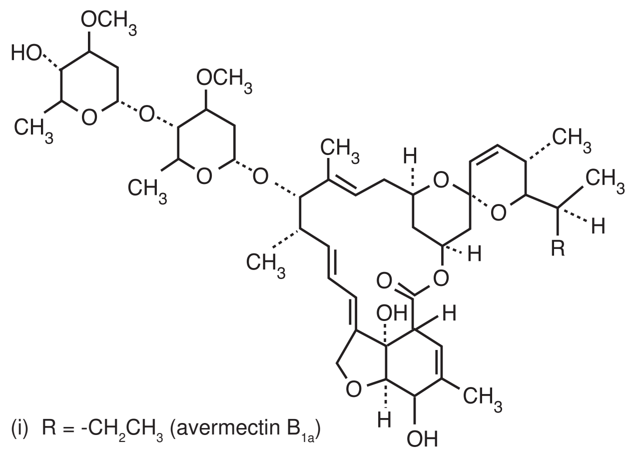
This group of pesticides is used effectively to control different pests on several crops and some are used successfully against some date palm pests. In this respect, we recommend further research on this group of pesticides in order to use them against different date palm pests. This group of pesticides is among the reduced risk products, and it is registered among the green chemicals according to the classification of the US Environmental Protection Agency (EPA).

Such pesticides are safer on the environment in all aspects if compared to other conventional pesticides. They are also compatible with the use of beneficial predators or parasites deployed in biological control programs, because they are harmless to the natural enemies. They can be successfully included in the Integrated Pest Management (IPM) programs of the date palm pests, especially with the classical biological control programs, when importing predators and parasites for releasing in date palm orchards.

The following are some examples of this group of pesticides, which are produced commercially on a large scale:

a. Abamectin

Microbial Acaricide / Insecticide



(i) R = $-CH_2CH_3$ (avermectin B_{1a})

(ii) R = $-CH_3$ (avermectin B_{1b})

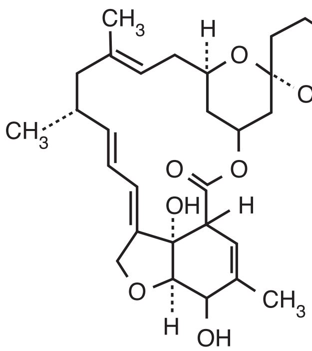
This pesticide is the product of the fermentation processes of the actinomycete species *Streptomyces avermitilis*, which is naturally occurring in the soil. It is used effectively against the motile stages of a wide range of mites, leafminers, suckers, beetles and other insects. It is also used to control the fire ants, *Solenopsis* spp.

Abamectin is produced commercially in the form of emulsifiable concentrate (EC) or ready-for-use bait (RB) under many trade names like; Abacid®, Agri-Mek®, Avid ®, Dynamec® or Vertimec®. Abamectin works as contact and stomach action without any systemic effects. According to the EPA classification, it is in the fourth group and its mammalian toxicity is estimated as:

Acute oral LD_{50}: rats 10, mice 13.6 mg / kg.
Acute dermal LD_{50}: rabbits > 2,000 mg / kg.

b. Milbemectin

Microbial Acaricide / Insecticide



Milbemycin A_3 : R = CH_3

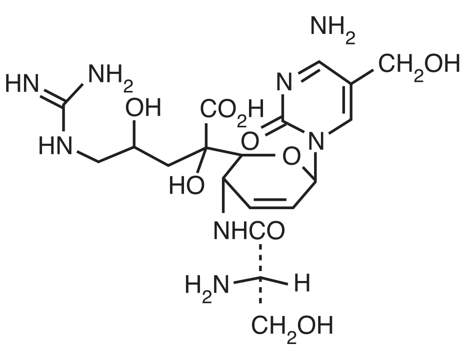
Milbemycin A_4 : R = CH_2CH_3

Milbemectin has been isolated from the fermentation products of the soil actinomycete, *Streptomyces hygroscopicus* subsp. *aureolacrimosus*. It is used to control citrus red mites, pink citrus rust mites, Kanzawa spider mites and other spider mites. It is produced commercially under the trade name Milbeknock® and is available as emulsifiable concentrate (EC). Its mammalian toxicity is as follows:

Acute oral LD_{50}: male rats 762, female rats 456 mg / kg.
Acute dermal LD_{50}: male and female > 5,000 mg / kg.

c. Mildiomycin

A microbial fungicide



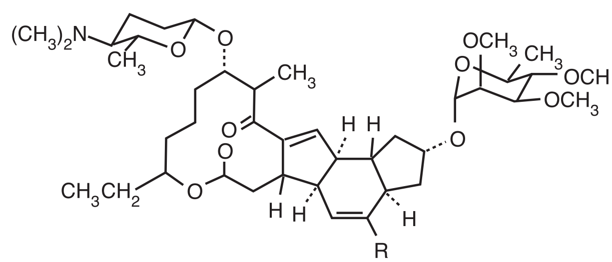
This fungicide is produced from the fermentation processes of the soil actinomycete; *Streptoverticillium rimofaciens* strain B-98891. It is used to control the powdery mildews fungi, i.e. *Erysiphe* spp., *Uncinula necator* Burr., *Podosphaera* spp. and *Sphaerotheca* spp. through spraying the plants in the rate of 5 to 10 grams per 100 litres of water. Mildiomycin is believed to inhibit protein biosynthesis in fungi by blocking peptidyl-transferase. It is effective as an eradicating agent with some systemic activity.

This fungicide is sold as a wettable powder (WP) formulation under the trade name: Mildiomycin®. Its mammalian toxicity is as follows:

Acute oral LD_{50}: male rats 4,300
female rats 4,120 mg / kg.
Acute dermal LD_{50}: male and female > 5,000 mg / kg.

d. Spinosad

Microbial insecticide



Spinosyn A, R = H-

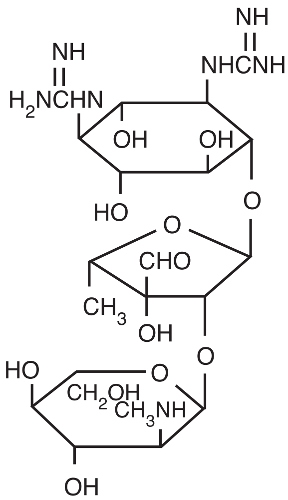
Spinosyn D, R = CH_3-

The commercial product of this insecticide is a mixture of spinosyn A and spinosyn D. Both compounds are secondary metabolites of the soil actinomycete *Saccharopolyspora spinosa*. It is recommended to use it for the control of Lepidopterous larvae, leafminers, thrips and foliage-feeding beetles. In addition, it can be used against several date palm pests like; date palm frond borer, lesser date moth, moths of *Ephestia* spp. and the pomegranate butterfly. This insecticide is produced commercially as suspension concentrate (SC) and is marketed under the trade names of Conserve® or Tracer®. Its mammalian toxicity is estimated as follows:

Acute oral LD_{50}: male rats 3,783
female rats > 5,000 mg / kg.
Acute dermal LD_{50}: rabbits > 5,000 mg / kg.

e. Streptomycin

Microbial bactericide



This antibiotic was isolated from the soil actinomycete *Streptomyces griseus* and is used as a microbial bactericide to control of bacterial shot-hole, bacterial rots, bacterial canker, bacterial wilt and many other bacterial diseases, especially those caused by gram-positive species. This antibiotic is also used to control AL-Wijam disease on the date palms by injecting the infected palm trees at a rate of 20 grams per tree. Streptomycin is particularly effective against the following bacteria: *Xanthomonas oryzae* Dows., *X. citri* Dows., *Pseudomonas tabaci* Stevens and *Pseudomonas lachrymans* Carsner.

This antibiotic is commercially available in the forms of either wettable powder (WP) or soluble concentrate (SL), and it is sold under different trade names such as; Agrimycin 17, AS-50, Plantomycin or Paushamycin. Streptomycin is very safe for humans and lies in the fourth group according to the classification of the US Environmental Protection Agency (EPA). The mammalian toxicity is estimated as follows:

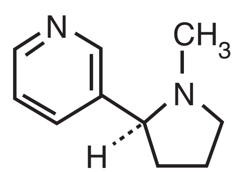
Acute oral LD_{50}: mice > 10,000 mg / kg.
Acute dermal LD_{50}: male mice 400
female mice 325 mg / kg.

3. Botanical Pesticides

This group contains pesticides derived from plants which have been shown to have insecticidal properties, i.e. pesticides of plant origin are called botanical pesticides. The botanical pesticides are also called plant-derived insecticides. They were used widely until the 1940’s; these natural pesticides were displaced by modern synthetic pesticides that at the time seemed cheaper, easier and longer lasting. As awareness of the health and environmental hazards of chemical pesticides increases, however, and as pests become more resistant to synthetic compounds, the popularity of botanical insecticides is once again increasing. They are natural products and safer to the user and the environment because they break down into harmless compounds within hours or days in the presence of sunlight. They are also very close chemically to those plants from which they are derived, so they are easily decomposed by a variety of microbes common in most soils.

The following are some examples of the plant-derived insecticides:

a. Nicotine



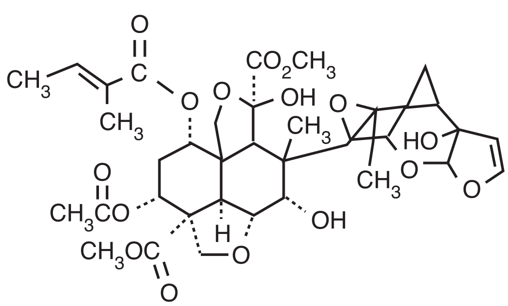
The source of this insecticide is the tobacco plants of the genus *Nicotiana*, and particularly the species *Nicotiana rustica* L. The name nicotine and the genus *Nicotiana* are attributed to Jean Nicot, the French consul of France in Lisbon who is credited for the transfer of the tobacco plant from Spain and Portugal to Italy and France. The nicotine insecticide is used for the control of a wide range of insects including aphids, thrips and whiteflies on the different crops like vegetables and fruits and ornamental plants as well. However, it must be tested on each plant species to determine its phytotoxicity.

Nicotine is produced commercially as dispersible powder (DP), soluble concentrate (SL) or as fumigant formulations. From the several trade names of Nicotine are; Nico Soap, XL-All Nicotine and Nicotine 40% Shreds.

This insecticide is considered as non-systemic insecticide that binds to the cholinergic acetylcholine nicotinic receptor in the nerve cells of insects, leading to a continuous firing of this neuroreceptor. In addition, active predominantly through the vapour phase, but also have slight contact and stomach action. There are no toxic effects on humans in the normal concentration of nicotine. Nevertheless, high concentrations are rapidly and highly toxic to humans and animals. Nicotine insecticide is toxic to man whether through inhalation or upon dermal contact. The oral lethal dose in man is from 40 to 60 mg. The mammalian toxicity of Nicotine is estimated as:

Acute oral LD_{50}: rats 50 – 60 mg / kg.
Acute dermal LD_{50}: rabbits 50 mg / kg.

b. Azadirachtin



This insecticide is primarily extracted from neem tree seeds, *Azadirachta indica* A Juss. It is believed that the origin of this tree is Burma but currently it grows in several parts of the world. It is cultivated abundantly and successfully as shade and ornamental tree all over the Sultanate of Oman.

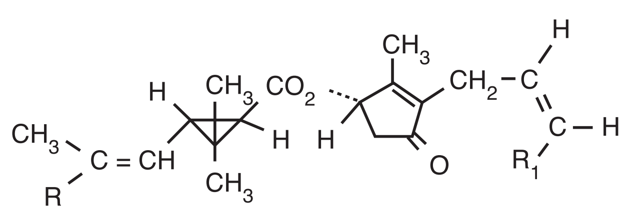
The Azadirachtin insecticide is used against insects on different crops like vegetables (tomato, potato and cabbage) as well as cotton, tea, coffee and other crops. Azadirachtin has several effects on phytophagous insects. It has a dramatic anti-feedant and repellent effect with many insects avoiding treated plants. It is thought that Azadirachtin disrupts insect moulting by antagonising ecdysone and this leads to morphological defects in insects coming into contact with sprayed crops, and in some cases the larval period is extended. This effect is independent of feeding inhibition. In addition, it is believed that Azadirachtin reduce the reproductive capabilities of phytophagous insects by disrupting normal mating behaviour and thereby reducing fecundity.

Azadirachtin insecticide is produced commercially either as emulsifiable concentrate (EC) or as technical material (TC). It is sold under a number of trade names such as: Neemix 90 EC, Neemazid, Trilogy 90 EC (neem oil for disease control), Azatin, Bio-neem, Nimbecidine, Neemachtin, Proneem and NeemAzal. It is important to know that this insecticide can be mixed with several other compounds. It is apply at rates of 100 to 500 g active ingredient per hectare, and frequent applications are more effective than a single one.

Azadirachtin has extremely low toxicity in humans and other mammals, so it is placed in group four of the EPA classification. Its toxicity is estimated as;

Acute oral LD_{50}: rats > 5,000 mg / kg.
Acute dermal LD_{50}: rabbits > 2,000 mg / kg.

c. Pyrethrins (Pyrethrum)



R = - CH_3 or - CO_2CH_3
R_1 = - $CH{=}CH_2$ or - CH_3 or - CH_2CH_3

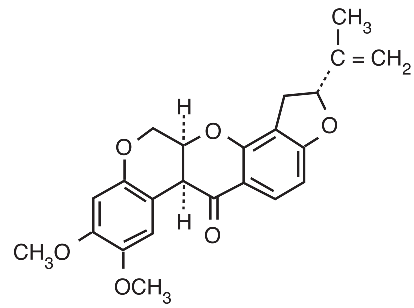
The powder of the dried flowers of pyrethrum, *Chrysanthemum cinerariaefolium* Vis. has been used as an insecticide since antiquity. According to modern plant taxonomy this species is moved from the genus *Chrysanthemum* to the genus *Tanacetum*. This flower species was known in the ancient ages of China and was transferred to Iran (Persia) via the Silk Road. Because of that the dried, powdered flower heads were known as "Persian Insect Powder". In the 19th Century, this species was brought to the Adriatic coastal areas in the Western part of the Balkan from there to France then to the United States of America and subsequently to Japan. At the present time, this species is cultivated extensively in East Africa (mostly in Kenya), Ecuador, New Guinea islands and Australia.

Pyrethrums are extracted from the flowers of *Tanacetum cinerariaefolium* and are used to control a wide range of insects and acari on several fruit trees, vegetables and other crops. Pyrethrums have been shown to bind to sodium channels in insects, prolonging their opening and thereby causing knockdown and death. They are non-systemic insecticides with contact action. The commercial preparations of these insecticides are in the form of Aerosol dispensers (AE), dispersible powders (DP), fogging concentrates, pressurised liquid CO2, ultra-low volume liquids (UL) or emulsifiable concentrate (EC). They are marketed under several tradenames including Alfadex, Pyrocide, Evergreen, Milon, CheckOut, Pycon, ExciteR. Pyrethrums are considered of relatively low toxicity to humans and mammals. As a result, they are placed in the third group of the EPA classification. Its toxicity is expressed in the following;

Acute oral LD_{50}: rats 2,370 mg / kg.
Acute dermal LD_{50}: rabbits 5,000 mg / kg.

d. Rotenone

The source of this pesticide is some plants of the Leguminosae family which grow in the Far East (The Philippines and Malaya) and the Amazon Valley in South America as well. The rotenone insecticide is extracted from the roots of some species of the genera *Derris*, *Lonchocarpus* and *Tephrosia*. The primary commercial source of rotenone is the species *Derris elliptica*.



Rotenone is a non-systemic insecticide with contact and stomach action. It is used to control a wide range of arthropod pests including aphids, thrips, moths, beetles and spider mites. It is also used for the control of fire ants and of mosquito larvae when applied to pond water. In addition, it is recommended for the control of ticks, lice and warble flies on animals. It is harmless to humans and animals when used in the recommended dose for pest control. However, it is toxic to fish and has been used in Asia and South America to control fish populations.

This insecticide is commercial sold as dispersible powder (DP), emulsifiable concentrate (EC) and wettable powder (WP) formulations. It should be applied as an overall spray to give good cover of the foliage. In addition, when dusted, the fine powder of the roots is used after dilution by a carrier like talcum, gypsum or sulfur. These powder preparations usually contain from 4-5% of active ingredient.

The rotenone is marketed under several tradenames like; Cube Root, Rotenone Extract, Noxfire, Rotenone FX-11 and Prentox. The lethal dose of rotenone in humans is estimated to 300-500 mg per kilogram of body weight. It is actually more toxic if inhaled than when swallowed. The rotenone is extremely poisonous to the pigs. The LD_{50} in rats and mice are;

Acute oral LD_{50}: white rats 132 – 1,500 mg / kg.
Acute dermal LD_{50}: white mice 350 mg / kg.

e. Ryania extracts

Ryania is alkaloids from the stem of the **Ryania** species, particularly *Ryania speciosa* Vahl. The plant contains about 0.1– 0.2% of the active ingredient, ryanodine. Ryanodine and related alkaloids affect muscles by binding to the calcium channels in the sarcoplasmic reticulum. This causes calcium ion flow into the cells and death follows very rapidly. Because of its rapid effect, it is used against borers like; European corn borer, *Ostrinia nubilalis* (Hubner), codling moth, *Cydia pomonella* Linnaeus, sugarcane borer, cabbage moth and citrus thrips. This insecticide is commercially marketed under different tradenames such as; Natur-Gro R-50, Natur-Gro Triple Plus, Natur-Gro R-50 and Ryan 50. Ryania is considered of relatively low toxicity to humans and other mammals. As a result of this, it is placed in group three of EPA classification. Its toxicity is expressed as; acute oral LD_{50}: rats 1,200 mg / kg.

4. Insect Pheromones

Insects secretes some chemical compounds to direct and organize some of the behavioural traits in insects like mating or searching for food, shelter and egg depositing sites. These chemicals work on transferring the behavioural messages between the members of the same species. They are called the intra-specific semiochemicals or simply pheromones. The communication chemicals between the members of different species are called allomones when indicating the sender of the message, i.e. chemical substances that benefit the emitter but not the receiver (e.g. venom secreted by social wasps), or kairomones when indicating the receiver of the message, i.e. chemical substances that benefit the receiver but not the emitter (e.g. host location by beneficial insects). Pheromones are classified into several subcategories on the basis of the type of interaction they mediate as follows:

- **Sex pheromones:** Chemicals that bring both sexes together (e.g. sex pheromone in moths).
- **Aggregation pheromones:** Chemicals that cause an increase in the density of the animals in the vicinity of the pheromone source.
- **Trail pheromones:** Chemicals secreted by workers of social insect to recruit other individuals to food source or to a new colony site.
- **Alarm pheromones:** Chemicals that stimulate escape or defence behaviour.

In addition, there are other types of pheromones, including; dispersal pheromones, maturation pheromones and others.

The term "Behaviour Control" is applied when chemicals are used to attract insects in a certain direction in order to eradicate them. During this, a disturbance in the sexual activity, attracting insect members away from the opposite sex members just before mating or a misdirection of the insect from its normal path may occur. The entomologist Wilson has divided the pheromones into two major divisions the releaser pheromones and the primer pheromones.

The releaser pheromones

Releaser pheromones elicit rapid behavioural responses within seconds or minutes in the receiving insects. They are primarily effectors related to smell and their effects are limited on the central nervous system of the receiving insects, e.g. sex pheromones (aphrodisiacs), alarm pheromones, trail and following pheromones, dispersal pheromones, and aggregation pheromones. The aggregation pheromones include the sex lures (mating pheromones), food lures and oviposition lures.

The Primer Pheromones

They are pheromones which trigger long-term responses in the receiving living animal. Primer pheromones produce long-term physiological changes which may take days to manifest. They are not important in our present field of interest.

The sex pheromones have stimulated interest and in-depth research since it became known in the beginnings of the 20^{th} century that some insects could be lured from long distances. It was observed that the females of Chinese silk butterfly can attract their males for mating from as far as eleven kilometres and the gypsy moth females can attract males from about three kilometres.

Recently with the sophistication in chemical analytical techniques, it became possible to determine the exact chemical composition of the pheromones secreted by several insects, whatever small in quantity. Up till now, more than 170 types of sex pheromones are identified for insects from order Lepidoptera besides some from order Coleoptera and others.

Nowadays, the identified pheromones are utilized in the field of Integrated Pest Management. The main advantages of the use of pheromones are that they are highly specific, low toxicity to mammalian and they are biodegradable quickly thus they do not accumulate in the environment. Several pheromones have been produced commercially to be used in the field of insect pest control. The following are the most important areas where pheromones can be used in IPM programs:

1. The measurement of pest population densities to help in choosing, organizing and directing control programs. This is of great importance in making the decision to control when reaching the economic threshold. Now pheromone traps are used in the IPM programs to monitor and control several pest insects such as the almond weevil, American almond moth, the red scale insect and the red date palm weevil.

2. The use of pheromone traps equipped with toxic baits to attract large numbers of the pest insects and eradicating them, i.e. mass trapping.

3. The use of pheromones for aggregating the pests in a certain location where they can be controlled with suitable insecticides or to eradicate them by any other way.

4. The use of pheromones in the sterilization programs of endemic insects by luring the pest to the chemical sterilization sources.

5. The use of pheromones in the behaviour control programs by causing mating disruption or confusion to the male insects in order to prevent or stop the mating.

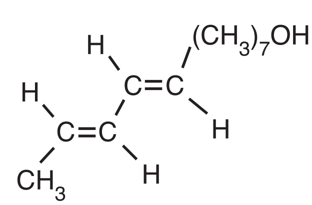
6. Using the pheromone traps to catch some of the mature stages of the insect pest when they emerge before their time as an early method to control the low levels of pest population.

7. To preserve the low levels of pest population achieved after the use of conventional insecticides by using the pheromone traps containing one of the highly effective insecticide.

8. The pheromones, which elicit excitation in the insects, making them thereby more exposed to the pesticides. For example, the effectiveness of contact insecticides against the aphids is increased when the pheromone Farnesene is applied on treated plants. This pheromone excites the aphids and forces them to move from the lower surface of the leaves, thus increasing their chances of being exposed to the insecticide.

The following are some examples of the commercially produced pheromones which are used in control programs of insect pests:

a. Codlemone (Codling moth sex pheromone)



Codlemone is the sex pheromone of the codling moth, *Cydia pomonella*. In nature, the sex pheromone of the Codling moth was originally isolated from the terminal abdominal segments of virgin females.

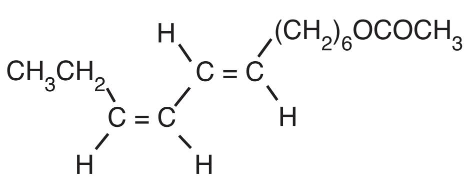
The commercially produced pheromone is used in pome fruits such as apples, pears and walnuts orchards to control codling moth. The male moths locate and subsequently mate with female moths by following the trail or pheromone plume emitted by virgin females. The application of Codlemone applied indiscriminately interferes with this process as a constant exposure to high levels of pheromone makes trail following impossible. Alternatively, the use of discrete sources of pheromone released over time presents the male with a false trail to follow, i.e. mating confusion or disruption. Control is subsequently achieved through the prevention of mating process and subsequently the laying eggs by the females are unfertile.

The pheromone can also be used as a means of monitoring the incidence of the codling moth so that insecticidal sprays can be applied at the most susceptible stages of the insect. The use of the pheromone to attract the moths to a contact insecticide, i.e. mass trapping of moths and kill them is also successful in controlling the codling moth.

Codlemone is sold as a coil or as polyethylene ampoules that release the pheromone slowly as a vapour. There are several trade names for this pheromone such as; Isomate-C (mixture), NoMate CM, RAK 3, Sirene-CM (plus permethrin), Hercon Disrupt CM (laminated plastic) and Codlemone (plastic barrier film).

b. (E,Z)-7,9-dodecadien-1-yl acetate

European Grapevine Moth Sex Pheromone

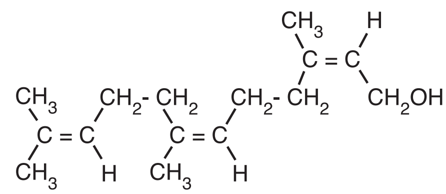


(7E,9Z)- isomer

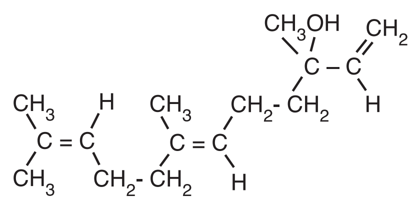
This compound is the sex pheromone of the European grapevine moth, *Lobesia botrana* Denis and Schiffermüller. It was originally isolated from the female pheromone glands. It works like other sex pheromones by confusing the males and thus preventing the mating process. The application of pheromone makes trail following impossible (camouflage, competition between artificial and female plume, false trail following). Very low rates are required to cause mating disruption. Trade names of this pheromone are: RAK 2 and Quant L.b.

c. Farnesol and Nerolidol

Spider Mite Alarm Pheromone



fernesol (27,6E)- isomer



nerolidol *trans*- isomer

This is an example of the alarm pheromone, which is isolated from the female of the two-spotted spider, *Tetranychus urticae* Koch. It is isolated from the crude extracts of homogenised female deutonymphs. It is released under natural conditions when the population of the mite is threatened or is being attacked by a mite predator. As a result, the mites become restless and increase their activity and movement. Thus, they are more susceptible to the contact acaricides applied at the same time leading to a more lethal effect. In addition the alarmed spider mites feed less than undisturbed mites. This pheromone is formulated as a controlled-release liquid concentrate. It is commercially sold under the tradenames of Stirrup M and Stirrup Mylox (plus Sulfur).

d. Ferrolure+

Red palm weevil aggregation pheromone

$$CH_3(CH_2)_2CH(CH_3)CH(OH)(CH_2)_3CH_3$$

4-methylnonan-5-ol

$$CH_3(CH_2)_2CH(CH_3)C(O)(CH_2)_3CH_3$$

4-methylnonan-5-one

Ferrolure + (4-methyl-5-nonanol plus 4-methyl-5-nonanone) is the aggregation pheromone secreted by the males of the red palm weevil, *Rhynchophorus ferrugineus* (Olivier). It is used with high effectiveness in pheromone traps to attract adults of both sexes (males and females) of the red palm weevil. Evaporation of pheromone vapours from traps containing date fruits or sugarcane stalks attracts male and female weevils to the traps. The pheromone traps was already described in details in chapter one. Ferrolure+ is sold as a slow-release formulation from plastic bags containing liquid pheromone. The trade names of the commercial preparations of this pheromone are Red Date palm Weevil Attract, Ferrolure+ and Kill Dispensers.

5. Transgenic Plant Pesticides

Around 1983, the development of the science and methods to produce "transgenic crops" began as part of a broader technological movement to genetically modify organisms (GMOs) for economic, medical, military, and other general human ends. The major genetically engineered (GE) crop varieties commercialized since 1996 in the United States have been designed to help control a damaging class of insects and simplify herbicide based weed management systems.

Crops engineered to tolerate applications of herbicides, or so-called "herbicide-tolerant" (HT) crops, account for the largest share of GE acres. About 487 million acres have been planted since 1996, or 73 percent of total GE crop acres. Herbicide-tolerant soybeans are the most widely planted GE crop technology and account for more than half the total acres planted to GE varieties since 1996.

Corn and cotton have been genetically engineered to express the bacterial toxin *Bacillus thuringiensis*, or Bt. This transgenic trait allows plants to manufacture within their cells a crystalline protein that is toxic to most Lepidopteran insects (moths and butterflies). Some 183 million acres of Bt transgenic corn and cotton have been planted since 1996, representing 27% of total GE crop acreage, (Benbrook, 2004).

The European Union is debating the question of permitting transgenic crop production alongside its well-established organic production in order to avoid World Trade Organization (WTO) sanctions against trade barriers. There is also a social resistance to the use of such crops in the United States of America. The following are some examples of these transgenic plants to control pests, which have been produced or granted license to be produced commercially.

a. *Bacillus thuringiensis* gene

Bacillus thuringiensis genes or Bt genes introduce resistance to insects. *Bacillus thuringiensis* produces parasporal, proteinaceous, crystal inclusion bodies during sporulation. Upon ingestion these are insecticidal. Different endotoxins have different biological spectra and different toxin genes are used in different crops to afford protection from attack by different insects.

The gene isolated from *Bacillus thuringiensis* is often truncated and introduced into the crop associated with promoter, usually cauliflower mosaic virus (CaMV)35S promoter. The plants are produced by insertion of the Bt nuclei acid using transformed and disabled *Agrobacterium tumefasciens*, bombardment using a particular gun or other accepted transformation technique. The target crops are maize, potatoes and cotton. Such genetically modified crops become resistant to the following insect pest; Colorado potato beetle, *Leptinotarsa decemlineata* (Say), European corn borer, *Ostrinia nubilalis* Hübner, Pink corn borer, *Sesamia cretica* and noctuid's, *Heliothis* spp. and *Helicoverpa* spp.

Several companies are producing these crops on a commercial scale under different tradenames like; BollGard Cotton, NewLeaf Potatoes, YieldGard Corn, Maximizer Corn and Bt plus Buctril BXN System Cotton.

b. Class II EPSP Synthase Gene

The Class II EPSP synthase gene was extracted from *Agrobacterium tumefasciens* strain CP4 isolated from the glyphosate production facilities and cloned into *Escherichia coli*. Being resistant to its toxic effect, the genetically modified crops are not affected when glyphosate is sprayed unlike the targeted weeds. The promoter was isolated from the cauliflower mosaic virus (CaMV) 355S and found to be very effective at enhancing transcription levels of foreign genes in plants. Several crops have been genetically modified by introducing the gene through the Cauliflower mosaic virus under the following tradenames; Roundup Ready Cotton, Roundup Ready Corn and Roundup Ready Canola.

c. Papaya Ring-spot Potyvirus Coat Protein Gene

The coat protein gene was isolated from mild Papaya Ring-spot Potyvirus (PRSV) strain 5-1 that had been shown to protect papaya plants from severe attacks if used as an inoculant for each plant each season. This gene has been used to produce papaya plants, which are resistant to attack from the aphid transmitted the PRSV and genetically modified papaya plants were produced commercially in Hawaii Island in the USA in 1996 under the brand name SunUp 551 and SunUp 63-1.

Integrated Pest Management of Date Palm Pests

From all that proceeded, we can state that an intelligent or enlightened control of date palm pests should be based upon following the Integrated Pest Management (IPM) strategy, which is the most advance and scientific strategy to deal with such pests. IPM encompasses the selection and integration of pest control measures while keeping the social and ecological dimensions in mind. Such a strategy does not only seek the immediate goals of the pest control measures employed, but also puts into consideration the long-term goals related to the economy, the society and the environment. Thus, Integrated Pest Management or Integrated Pest Control is based on using the different combinations of the control measures which enables us in the end to achieve the desired outcome of pest control. So, we must utilise the natural measures to the maximum extent while using more than one measure of the applied control methods. It is imperative to put the following points into consideration when we design Integrated Peat Management programe for date palm pests:

- Estimating the economic thresholds of infestations of the main pests of date palms and dates. Economic threshold represents the density of pests, at which the control measures should be undertaken, to prevent pest multiplication to the economic injury level. This indicates a pest population density leading to a level of damage equal to the costs of preventing this damage. The Economic threshold is usually lower than the economic injury level to warrant enough time to prepare and implement necessary control operations.

- Relying as much as possible on cultural control measures to control date palm pests because they are simple to apply and low in cost.

- Using appropriate legislation, “Legislative Control” to limit the spread and transfer of date palm pests from one area to another and to prevent the invasion of pests currently not present in the environment, but found in neighbouring countries.

- Attempting to find varieties of date palms resistant to pest infestations and other palm diseases.

- Relying as much as possible on obtaining different palm varieties by tissue culture because it ensures that the offshoots are free from various diseases especially phytoplasma.

- Relying on the use of selective pesticides or Bio-pesticides in chemical control, because we have to resort to corrective measures which cause the least imbalance in the environment. In addition, these pesticides must be applied according to accurate concentration at the right time to preserve any natural enemies present in the environment.

- Avoiding extremely toxic chemical pesticides except when necessary and avoiding repeated spraying of these pesticides. When used, these chemicals should be applied cautiously and in such a way that permits the natural enemies to survive in order to perform their role in pest controlling after pesticide application. Here, we should remember that there are many insects living in our environment which have not developed into pests, because of parasitoids and predators coexisting in the habitat.

- Implementing programs for early detection of pest infestation by using innovative measures like pheromone traps and light traps. It is also recommended that these measures could be used in eradicating large numbers of pests, e.g. the red palm weevil, where large numbers of weevils are collected by pheromone traps and exterminated.

- Considering the possibility of applying several of the aforementioned Bio-pesticides when designing the date palms and dates pest control programs. Most of such pesticides are considered selective and environmentally friendly.

- Maximizing the role of biological control by relying upon predators and parasitoids in designing Integrated Pest Management Programmes of date palms and dates, as it is one of the most important elements in IPM. This can be done either through the classical biological control by importing some parasitoids and predators and releasing them in various areas to control many palm and date pests or through the mass production of predators and parasitoids already available in the local habitat and releasing them at the right time to control date palm pests.