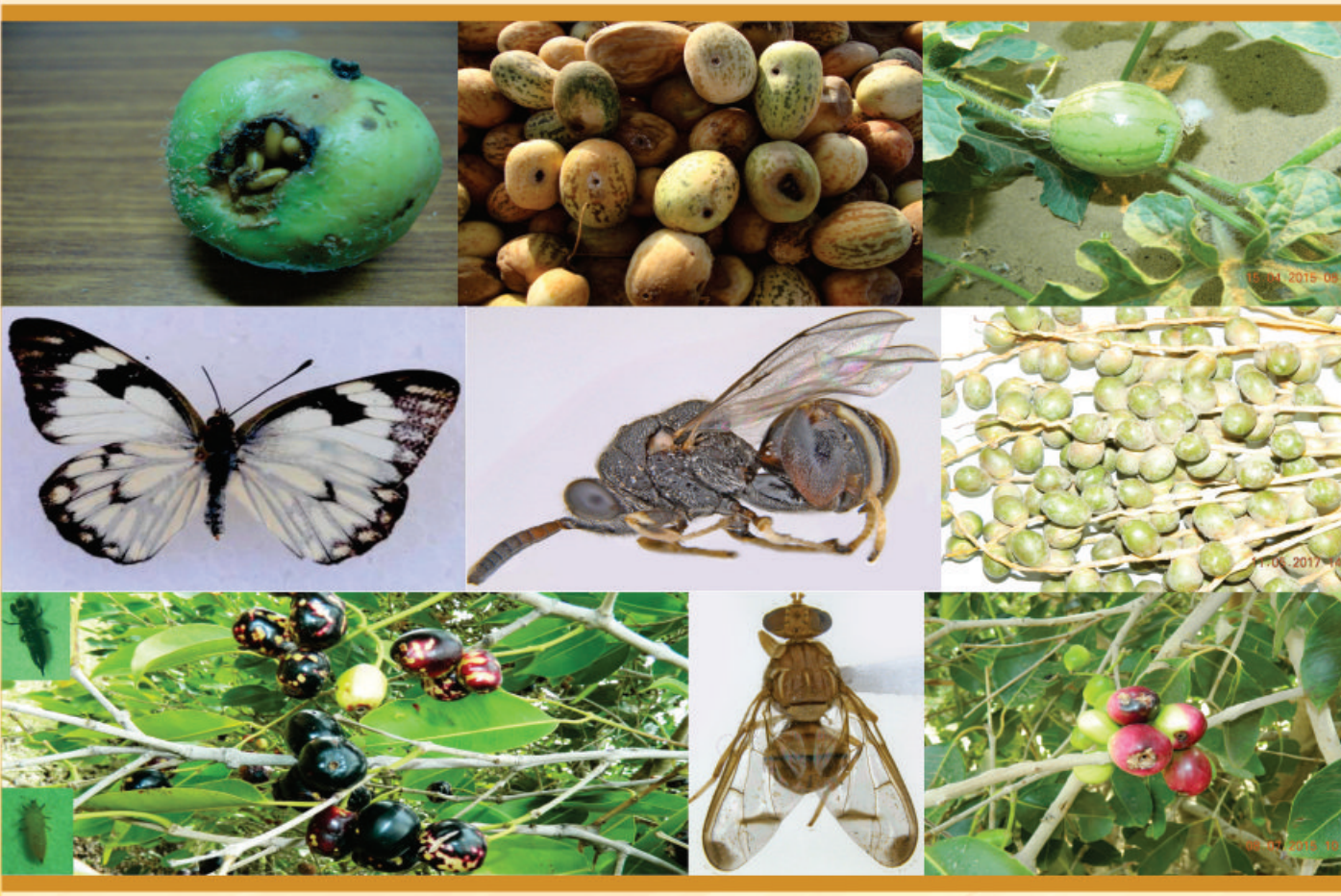
Insect-Pests Management in Arid and Semi-arid Horticultural crops



Shravan M Haldhar | Sushil K Maheshwari

ICAR-CENTRAL INSTITUTE FOR ARID HORTICULTURE
(Indian Council of Agricultural Research)
Bikaner (Rajasthan) - 334006

INSECT-PESTS MANAGEMENT IN ARID AND SEMI-ARID HORTICULTURAL CROPS

Dr. Shravan M Haldhar
Scientist (Agriculture Entomology)
ICAR-Central Institute for Arid Horticulture, Bikaner

Dr. Sushil K Maheshwari
Principal Scientist (Plant Pathology)
ICAR-Central Institute for Arid Horticulture, Bikaner

ICAR-CENTRAL INSTITUTE FOR ARID HORTICULTURE
(Indian Council of Agricultural Research)
Bikaner (Rajasthan) - 334006

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Address : ICAR-Central Institute for Arid Horticulture,
Sri Ganganagar Road, NH-15,
Beechwal, Bikaner (Rajasthan)-334006
Phone: +91 151 2250960, 2250147
Fax: +91 151 2250145
Email: ciah@nic.in
www.ciah.ernet.in

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Preface

Arid and semi-arid horticultural crops are becoming popular for nutritional and health security point of view as they are excellent sources of minerals, vitamins, protein, antioxidants and photochemical. Among the arid and semi-arid horticultural crops ber (*Ziziphus mauritiana*), date palm (*Phoenix dactylifera*), lasora (*Cordia myxa*), aonla (*Emblica officinalis*), bael (*Aegle marmelos*), jamun (*Syzygium cumini*), pomegranate (*Punica granatum*), khejri (*Prosopis cineraria*) and cucurbits are the major crops which can be grown easily in arid and semi-arid eco-system of the country. Date palm provides a wide range of essential nutrients, very good source of dietary potassium and energy. There are many reasons for low productivity of the arid and semi-and horticulture crops. Arid and semi-arid region are marked by abiotic limitations such as high temperature, high potential evapo-transpiration, low erratic rainfall, low soil fertility, poor quality of ground water, *etc.*, which lead to poor crop growth and yield. Apart from the climatic limitations, the biotic factors like insect-pests are also one of the limiting factors for crop production in hot arid ecosystem.

In this endeavour, useful information has been generated on identification, damage symptoms and management of the insect-pests in different horticultural crops at various research institutions and SAUs of the country. Earnest efforts have therefore, been made to compile information on identification, damage symptoms and management of insect-pests in a systematic manner, grouped in different chapters and presented in the form of a bulletin entitled "**Insect-Pests Management in Arid and Semi-Arid Horticultural Crops".** Correct identification of the insect and their damage is the prerequisites for effective control measures. This publication contains excellent colored photographs depicting salient identification characteristics of insect, their damage on plants under natural condition and management in field conditions so as to update the knowledge of extension agencies and farmers.

The authors are grateful to Dr. T. Mohapatra, D. G., ICAR and Secretary, DARE and Dr. A. K. Singh, D. D. G. (Hort.), ICAR, New Delhi for their constant inspiration, encouragement and valuable suggestion to bring out this publication. We are highly thankful to Dr. P. L. Saroj, Director, ICAR-CIAH, Bikaner, who encouraged and provided valuable suggestions and ideas to improve the authenticity and quality of this bulletin.

It is hoped that this publication will be useful for research workers, extension personnel, teachers, students, planners and NGOs.

Place: Bikaner

Date: 11.03.18

Shravan M Haldhar

&

Sushil K Maheshwari

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Introduction

In India, nearly 3, 17,090 sq km area falls under arid region, of which 70, 300 sq km is classified as cold arid and remaining is under hot arid region. About 61% of total hot arid area lies in Rajasthan. Arid and semi-arid horticultural crops are becoming popular for nutritional and health security as they are excellent sources of minerals, vitamins, antioxidants and photochemical. Among the horticultural crops, ber (*Ziziphus mauritiana*), date palm (*Phoenix dactylifera*), lasoda (*Cordia myxa*), aonla (*Emblica officinalis*), bael (*Aegle marmelos*), jamun (*Syzygium cumini*), pomegranate (*Punica granatum*), khejri (*Prosopis cineraria*) and cucurbit are the main crops of arid and semi-arid parts of the country.

There are many reasons for low productivity of the arid and semi-arid horticultural crops. Hot arid region are marked by abiotic limitations such as high temperature, high potential evapo-transpiration, low erratic rainfall, low soil fertility, poor quality of ground water, *etc.*, which lead to poor crop growth and yield. Apart from the climatic limitations, the biotic factors like pests and diseases are also one of the limiting factors for crop production in arid and semi-arid ecosystem. The major pests of this area ber fruit fly, *Carpomyia vesuviana*; ber stone weevil, *Aubeus himalayanus*; fruit borers; aphids; thrips; lemon butter fly; datepalm scale, *Parlatoria blanchardi*; fruity fly, *Bactrocera* cucurbitae; leaf miner, *Liriomyza trifolii*; pod borer, *Helicoverpa armigera*; white flies, *Bemisia tabaci*; thrips, *Frankliniella occidentalis*; shoot and fruit borer, *Leucinodes orbonalis*; Hadda beetle, *Epilachna viginctioctopunctata*; aphids, *Aphis gossypii* and ash weevil, *Myllocerus subfasciatus* are major constraints which causing the considerable economic loss and increasing the cost of arid and semi-arid horticultural crops production of rain fed farmers. Ber fruit fly (*Carpomyia vesuviana*) is the most destructive pest of ber. It contributing towards low yield and poor quality of fruits and it caused yield loss up to 80% under severe infestation. The severe incidence of fruit weevil (*Aubeus himalayanus*) has been recorded in arid region that caused considerable damage to ber fruit on Gola (28.8 %) and Seb (51.8 %) from tree sample and Gola (74.10) and Seb (89.80) in fallen fruits. In date palm, the scales, *Parlatoria blanchardi* and lesser date moth, *Batrachedra amydraula* are an important pests of date palm infesting leaves and fruits. The incidence of scale insect was found 6.46 per cm^2 of leaves and incidence of lesser date moth was around 16 to 20 %. Therefore, the highest fruit damage was recorded in the varieties Medjool (16.01%) followed by Khalas (14.54%) and Nagal (13.78%), whereas, lowest fruit damage was recorded in the varieties Zagloul, Medini and Zahidi as 1.43, 1.51 and 2.30 per cent due to lesser date moth. The cucurbit fruit fly (*B. cucurbitae*) has been the most prominent pest over the last several decades in India. Depending on the environmental conditions and susceptibility of the crop species, the extent of losses varies between 30 to 100%. The field experiments on assessment of losses caused by cucurbit fruit fly in different cucurbits been reported 28.7 - 59.2, 24.7 - 40.0, 27.3 - 49.3, 19.4 - 22.1, and 0 - 26.2% yield losses in pumpkin, bitter gourd, bottle gourd, cucumber, and sponge gourd, respectively. Considering previously reported, it is apparent that >50% of the cucurbits are either partially or totally damaged by fruit flies and are unsuitable for human consumption.

Insect-pests management of horticultural crops in arid and semi-arid region

2.1 Management of insect-pests of ber crop

In India, more than 130 species of insect-pests found to be infest on ber and very few are attained the pest status. However, the pests such as fruit fly, *Carpomyia vesuviana*; stone weevil, *Aubeus himalayanus*; fruit borer, *Meridarchis scyrodes*; ber butterfly, *Tarucus theophrastus* and bark eating caterpillars, *Indarbela tetraonis* are the major pests of *ber* in India.

2.1.1 Fruitfly, *Carpomyia vesuviana* Costa

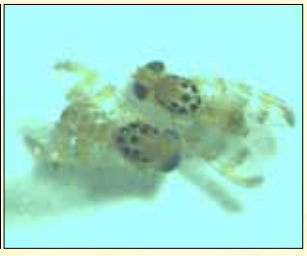
Fruit fly, *C. vesuviana* is the most destructive pest of *ber* in India. It is a monopahagous pest, infests only on *Zizyphus* species and contributes low yield and poor quality fruits. The pest causes the yield loss up to 80% under severe infestation.

Nature of damage

The female fly lays their eggs singly on young developing fruits after 2-5 days after emergence. They lay their eggs inside the epidermis and young maggots feed on fleshy and juicy pulp of fruits. Upon hatching, the maggot starts to feed on the pulp and make galleries with accumulated excreta and resulted to fruit rot. The larva burrow the flesh around the center, leaving excreta that gives fruits a bitter taste. Infested fruits become deformed and their growth is arrested and in severe cases, a large number of such fruits drop off. Mated female preferred to oviposit at central distal part fruit and the oviposition retard the growth of surrounding tissues causing depression in the fruits and deformity is most apparent in young fruits with oviposition holes. Fruit fly incidence was increased with increasing maturation and size of fruits.

Taxonomic position

Phylum: Arthropoda
Class: Insecta
Order: Diptera
Family: Tephritidae
Subfamily: Trypetinae
Genus: *Carpomyi*a
Species: *vesuviana*



Seasonal incidence

In Northern India infestation occurs during November to April, activity was very high at the time of fruit maturity and there may be a 2 to 3 generation during the active period. In Central India (Gujarat), the fruit fly attack starts around mid-October and increased abruptly during mid-November and continues till December. The pupa hibernates in the soil during April to August shows unusual activity of fly during off season fruits of *Z. Ziziphus* spp. at Punjab.

Management

The fruit fly cause internal damage, preventive measures are essential and synthetic insecticides

are major tools for the successful management. However, integrated approaches would give better control over single control approach with low cost and environmentally safe.

1. Clean cultivation surrounding the orchard through destruction of pruned parts of cultivated as well as the wild bushes.
2. Collection of all fallen, bird damaged and infested fruits at periodical interval and proper destruction and feed such fruits to sheep goats, camels or other farm animals or bury them at least on one meter deep in compact soil can avoid the fly's emergence.
3. Deep and through racking up of soil during hot summer to expose the residual pupa to hot summer it also been destroy the over wintering pupae through mechanical injury during the operations.
4. Use of resistance varieties like Tikadi, Katha and Illaichi for fruit fly management.
5. There is no successful record of parasitoids, predators and pathogens against the *C. vesuviana*. The braconid, *Biostres vandenboschi*, *Bracon fletcheri* and *Omphalia* sp. on *ber* fruitfly were reported. The wasp parasitoid, *Fopius carpomyia* was found at larval stage of fruitfly and the ovipositor is very suitable to parasitize the hidden host in fruits. The rate of parasitization was upto 28.8% under natural condition.
6. The extract of azadiractin 1% and *Ocimum sanctum* 1% were effective up to 10 days after spraying. Application of neem powder and tobacco leaf extracts would also significantly reduce *C. vesuviana* damage and its used for organic cultivation of ber.
7. Bait spray combining molasses or jaggery 10 g/L and one of the insecticides, malathion 50 EC 2 ml/L, dimethoate 30 EC 2ml/L of two rounds at fortnight interval before ripening of the fruits.

2.1.2 Stone weevil, *Aubeus himalayanus* Voss

At first it was recorded as a new pest of *ber* for the first time from Andhra Pradesh state of India. Later, from Rahuri, Maharashtra and Jobner, Rajasthan of India in 1996 and recently in Bikaner district of Rajasthan in 2010. Apart from India, the severe damage of this pest at early stage of fruit development has also been reported from Bangladesh.

Nature of damage

Grubs directly damage the fruits by tunneling inside seeds and adult weevil also blemishes mature fruit by ovi-punctures. The activity of adult beetle could be observed in the field during morning and evening hours. The adult female weevil lays their eggs mostly on the stylar end; rarely on the distal end of fruits and egg laid punctures covered with brown encrustation. Upon hatching, the grubs enter into seed by puncturing endocarp at immature stage and starts feeding on soft seed coat. Later it enters into endosperm moving downward. After entering the seed, it starts feeding on inner content of the seed, and pupates within the seed by making hollow galleries. The weevil completes its life within a single fruit. The developing soft seed was completely eaten away by the pest. At the time of fruit maturity, in the hollowed area, infested fruits had a grub, a pupa or an adult. The infestation occurs in all the fruit stages; however, it is prevalent in pea to pebble size fruits. Infested fruits are abnormal shape and nearly half portion of the fruit towards stalk turns reddish brown with rough surface and the remaining half portion towards stylar region remains greenish colour. Often, infested fruits fail to attain full maturity.

Taxonomic position

Phylum: Arthropoda
Class: Insecta
Order: Coleoptera
Family: Curculionidae
Genus: *Aubeus*
Species: *himalayanus*

Seasonal incidence

The activity of adult weevil starts from month of September and adults starts the egg laying from blooming stage onwards and severe damage could be observed during October month. The incidence could be noticed still at the end of fruiting *i.e.* till February. The incidence was noticed during July to August in Karnataka and maximum damage was observed during July to August months. Correlation with abiotic factors reported negative correlation between infestation and temperature and positive correlation with the relative humidity and rainfall. The incidence and extent of damage also found to be associated with the pruning dates.

Management

1. Collection and destruction of adult weevil immediately after detection can also reduce the population. Infested dropped fruits should be collected and burned to break the generation cycle.
2. Deep and through racking up of soil during hot summer to expose the residual adult to hot summer, it also been destroy the over wintering adult through mechanical injury during the operations.
3. The influence of biophysical factors of ber fruits plays a major role on the intensity of damage by ber stone weevil. The varieties of ber like Kali, Katha, Illaichi and Tikadi were found resistant to stone weevil. The fruit infestation ranged from 9.02 to 49.88 % on retained fruits and 13.57 to 74.16% on drooped fruits. Tannins, phenols, alkaloids and flavonoid contents had significant negative correlations with the percentage fruit infestation on plant fruits and the fallen fruits. The highest pulp: stone ratio was found in variety Mundia and least in variety Tikadi. Most of the resistant varieties were having extremely hardy stones and in susceptible varieties the stones were slightly hard.
4. NSKE 5% and azadirachtin 2000ppm and 1000ppm were also found to be superior over control treatment in minimizing the weevil incidence.
5. Application of spinosad 2.5 SC and indoxacarb 14.5 EC or dimethoate 30 EC just before the fruit setting and repeat the sprays at three weeks interval was found effective and showed significant reduction in weevil incidence.

2.1.3 Fruit borer, *Meridarchis scyrodes* Meyr

The fruit borer, *M. scyrodes* is a serious pest in Southern states like Gujarat, Maharastra, AP, Karnataka etc. of India. The pest causes up to 70% yield loss under severe infestation.

Nature of damage

The moths lay eggs on fruits at peanut stage and upon hatching the newly emerged caterpillars bore

into fruits and feed on the pulp near seed and accumulate fecal. The first and second instar larvae feeds on the fruit superficially but third to fifth instar larvae feeds internally and damages the pulp around the seed. At initial stages of fruit development, the full grown larvae found to feed on soft immature seed.

Taxonomic position

Phylum: Arthropoda
Class: Insecta
Order: Lepidoptera
Family: Carposinidae
Genus: *Meridarchis*
Species: *scyrodes*

Seasonal incidence

The infestation starts during month of November and the peak incidence occurs during end of December. The damage intensity found positively correlated with the temperature and negatively correlated with the relative humidity and wind speed.

Management

1. Removal of wild ber trees around the ber orchard.
2. Rack the soil under the tree or near the trees to destroy the maggots and residual pupae present in the soil.
3. Collection and proper destruction of infested fallen fruits. Harvest of fruits at immediate after maturity (green stage).
4. Growing of resistant cultivars like Safeda, Illaichi and Tikadi to found less incidence of fruit borer.
5. The Neem Seed Kernel Extract (NSKE) at 5% found as effective as like synthetic chemicals. Methanol extracts of *Annona reticulata*, *Azadirachta indica* and *Ocimum sanctum* at 1% concentration recorded 60-70 % mortality after 48h after spray.
6. Sprays of dimethoate 30 EC + jaggery solution (1.0%) at marble stage and one spray at maturation stage resulted in minimum infestation and found to be more economical. Control schedule comprises of malathion at 2 ml or fenvalerate at 1 ml /lit of water first spray at marble stage, second spray at 15 days later and third spray at fruit ripening stage by alternate use of insecticides would be effective against the fruit borer.

2.1.4 Ber butterfly, *Tarucus theophrastus* (Fabricius)

The ber blue butterfly *T. theophrastus* is an important defoliator pest of ber. The infestation occurs on new sprouts and distributed throughout the ber growing region of Karnataka, Rajasthan, Haryana and Punjab.

Nature of damage

Pest causes the leaf damage up to 25-40% during sprouting of new shoots. The larvae also damage the flower buds and tender shoots. Larva feeds on newly sprouting tender shoots, leaves and flower buds. Infested leave gives whitish look due to chlorophyll feeding and leaves remains with long streaks.

Taxonomic position

Phylum: Arthropoda
Class: Insecta
Order: Lepidoptera
Family: Lycaenidae
Genus: *Tarucus*
Species: *theophrastus*

Seasonal incidence

The infestation starts from June and peak incidence occurs during third week of October with a peak population in the first week of August. The population showed positive correlation with maximum and minimum temperatures and negative correlation with relative humidity and rainfall.

Management

1. Spray of dimethoate 0.05%, deltamethrin 0.0014% and fenvalerate 0.0005% would be most effective against 3rd to 6th instar larvae.
2. Quinalphos (0.05%) and triazophos (0.1%) were also effective against larval population and leaves damage.

2.1.5 Bark eating caterpillar, *Indarbela tetraonis* Moore; *Indarbela quadrinotata* Walker

The incidence of pest is found throughout the *ber* growing region of India especially old orchards and trees which are in poor maintenance.

Nature of damage

Bark eating caterpillar attacks on *ber* cause heavy losses if the damage is severe. The presence bark eating caterpillar damages can be easily detected by presence of frassy webs at forks or angle. The moth lays their eggs on bark of the branches, upon hatching they settle at forks or angles of braches and feeds on bark during night, remaining concealed during daytime in tunnel made at junction of branches. Feeding on bark hardly affects plants, it is tunnel made by larva for its shelter, which inflicts the actual loss. The junction point is rendered weak due to tunnel. During bearing period when fruits develop, pressure at forks is greatly increased due to weight of fruits, resulting in cleavage of branch at fork or angle and its drying.

Taxonomic position

Phylum: Arthropoda
Class: Insecta
Order: Lepidoptera
Family: Cossidae
Subfamily: Metarbelinae
Genus: *Indarbela*
Species: *tetaronis; quadrinotata*

Seasonal incidence

The attack of caterpillars starts June onwards and fresh web galleris can be observed till October month.

Management

1. Periodical cleaning of orchard and removal of webs/frassy galleries around affected portion at the time of pruning and destruction of caterpillar using iron spike in hole.
2. The cultivars such as Rothak Gola, Laddu Glory, Chuhhara and Desi Alwar are found to be tolerant to bark eating caterpillar. However no cultivars found to be resistant.
3. Painting of dimethoate 0.05% on the bark would be effective. Application of kerosene mix contains one litre of kerosene and 100g of soap in 9 litre of water to the holes has been found to be effective against caterpillar.
4. Inject the holes with quinalphos at 0.01% or fenvalerate at 0.05% and alternate spray of quinalphos at 2ml per litre water of found to be effective in controlling the caterpillar damage. Cotton swab soaked in petrol or kerosene also can place in the holes and sealed with mud.

2.2 Management of insect-pests of date palm crop

More than 50 species of insects and mites as pests reported on date palms in worldwide. The main pests are *Parlatoria blanchardii*, *Batrachedra amydraula*, *Rhynchophorus ferrugineus* and *Oryctes rhinoceros* and they are well adapted to the oasis environment, have been reported to cause serious losses to date palm.

2.2.1 White scale, *Parlatoria blanchardii* Targioni-Tozzetti

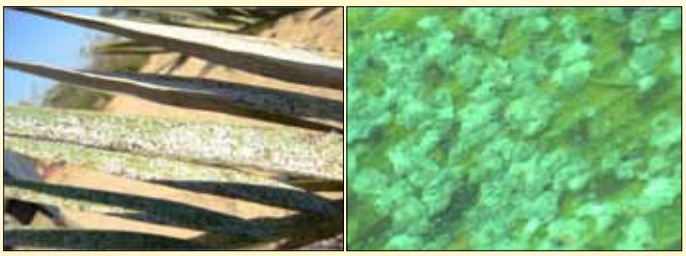
White scale is widely distributed throughout most of the date growing regions of the world. It is generally believed to be native to the Arabian Gulf countries (as is the date palm). Commerce in date offshoots over the centuries paved the way to spread of this pest into India, Central Asia, the Middle East, North Africa and Turkey, and later to Australia and America.

Nature of damage

It mainly infests the leaves and sucking the sap, if full leaf is covered with white scales finally the leaves dry out. In heavy outbreaks, fruits also attacked and fall-off before maturity. Nymphs and adults suck the sap from the leaflet, midribs and the fruits. Under each scale insect, a discoloured area appears on the leaflet. Damage on fruits is easily noticeable and the production is not marketable, especially due to poor acceptability.

Taxonomic position

Phylum: Arthropoda
Class: Insecta
Order: Hemiptera
Family: Diaspididae
Genus: *Parlatoria*
Species: *blanchardii*



Seasonal incidence

The infestation of date palms scale, *P. blanchardii* began in December, and peaked in October. The infestation began on the basal tissues of the pinnae and moved upwards. Older leaves and upper leaf surfaces near the pinane were preferred, and the tips remained free of infestation. Infestation of the

pinnae declined in May-June and was concentrated on the floral parts and berries.

Management

1. Varieties Mishrig and Gondaila found as most susceptible varieties and Brakawi and Jaw were moderate, and Tamoda found as tolerant.
2. Use of cultural techniques of providing undergrowth to protect predators of this pest has been effectively used to reduce infestation levels and maintain infestations below the damage level.
3. The removal of infested lower leaves of datepalm was found to be an effective means of decreasing infestation of the insect.
4. Use of indigenous natural enemies such as larvae and adults of a brownish lady bird *Pharosscymnus sp*, (Coccinellidae), *Cybocephalus dudiclri* (Nititulidae), *Crysoperla carnea* (Chrysopidae), *Archenomus arabicus* (Aphelmidae), and some unidentified mites. An introduced predator, lady bird, *Chilocorves bipusrulatus* var. *irpnsis* was applied also to control the pest but with little success due to unsuitability of climatically conditions or some other ecological reasons. The predacious mite, *Hemisarcoptes coccophagus* was also found to control white scale.
5. Establishment of a less toxic environment in date plantations. This is a prerequisite for enhancing the activity and survival of natural enemies of the white scale, and thereby ensuring the successful biological control of white scale.
6. Foliar applications of a variety of oil-based compounds have proven effective against the immature stages of the pest.
7. Spraying with petroleum oil plus Dimethoate (30 EC) also resulted in significant control. Chemical control appears to be conducted occasionally in young plantations. Mineral oils are used for controlling the scales.

2.2.2 Red palm weevil (coconut weevil), *Rhynchophorus ferrugineus* Olivier

The red palm weevil, *R. ferrugineus* also called the Indian palm weevil, is well known in the Middle East where it causes severe damage on date palm. The red palm weevil was first identified in 1790 by Oliver and also noted in the Arabian Peninsula in the mid 1980's and in Egypt in 1992. In India, the serious damage of this pest reported in date growing region of Kachchh, Gujarat.

Nature of damage

Infestation is often not apparent until extensive damage has already been caused and the palms are beyond recovery. In these infested plantations shows wilting symptom with yellow inner leaves and rotting odour could smelt from the damaged tissues. Small round holes at the sites of removed offshoots were also a clear indication of the presence of the weevil. Chewed up date palm fibres were extruded and a brown fluid was oozing out of the holes on the stem. Cocoon, weevil and pupal fibres are frequently found in the palm leaf base. Heavily

infested palms may contain 80 or more simultaneously developing larvae, and more than one generation may develop in the same palm.

Taxonomic position

Phylum: Arthropoda
Class: Insecta
Order: Coleoptera
Family: Curculionidae
Genus: *Rhynchophorus*
Species: *ferrugineus*

Seasonal incidence

It is found throughout the year. It also recorded in Kuchh area of Gujarat.

Management

1. Sanitation measures such as the removal of dead palms or palms beyond recovery are essential as they are the ideal breeding places for the rhinoceros beetles that generally pave the way for entry of the palm weevil into young palms.
2. Wounding of the palms, like cutting steps into the stem to facilitate climbing should be avoided. Soil is to be put around the base of the palm to protect the cut because more than 80 per cent of weevil infestation occurs at the base near the offshoots or where offshoots have been removed.
3. Laboratory tests in India showed that the oil derivative from garlic and its synthetic form diallyl disulphide were toxic to the weevil.
4. Pheromones are increasingly being used as a management tool against *R. ferrugineus*. Pheromone lures for the weevil in date plantations in Saudi Arabia and found that high release lures (Ferrolure and Ferrolure+) obtained from Chem Tica Natural, Costa Rica, attracted twice as many weevils as low release formulations.
5. Preventive and curative measures include: injection of systemic insecticides such as fenthion into the trunk and drenching of the crown of infested palms with insecticides. In India, trunk injections of fenthion, or use of phostoxin tablets (aluminum phosphide, which releases phosphine) were effective.
6. In the prophylactic treatments offshoots and trunk received applications of the organophosphates: azinphos methyl and chlorpyriphos.
7. The curative method involved trunk infusion with dichlorvos and/or soil application of Confidor (imidacloprid).

2.2.3 Lesser date moth, *Batrachedra amydraula* Meyerick

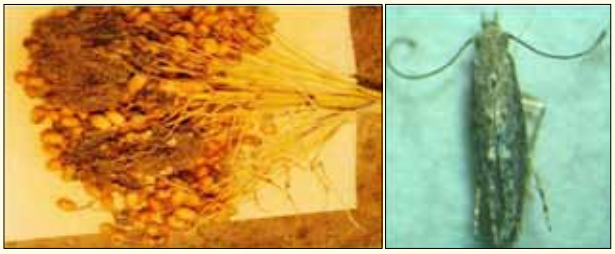
The lesser date moth, *B. amydraula* is a pest that damages fruits in both fields and stores. It is one of the major pests of date palm cause the yield loss upto 50-70%. Larvae found to damage the large number of young fruits from April to June or July. Since1980s, it has gradually spread throughout most of the date growing plantations of the country, where it has become a major pest of newly set and young green date fruits.

Nature of damage

The larvae attack newly formed inflorescences, but the main injury is to the young green fruits. Approximately 80% of the fruits are attacked while between 0.6 and 1.0 cm in diameter. The larva chews a hole near the calyx, through which it penetrates the fruit and feeds on the pulp and the soft immature seed. About 4 weeks of infestation, the fruits become darken, dry and falloff. In severe infestation most of the infested fruits drop to the ground; the bunch ceases to grow, and then dries. Thus lesser date moth injuries to the palms cause considerable fruit drop and losses of upto 75% of the yield.

Taxonomic position

Phylum: Arthropoda
Class: Insecta
Order: Lepidoptera
Family: Batrachedridae
Genus: *Batrachedra*
Species: *amydraula*



Seasonal incidence

It appears in April, while the fruits are in unripe stage and remains till September. The first larvae appear in April to start the damage on the newly formed fruits. The larva has a period of dormancy from August and remains inactive till March of the next year between the bases of the terminal fronds.

Management

1. In Rajasthan, the incidence of this pest was around 16 to 20 %. Therefore, all the thirty four varieties were screened for their per cent fruit damage under field conditions. The highest fruit damage was recorded in the varieties Medjool (16.01%) followed by Khalas (14.54%) and Nagal (13.78%), whereas, lowest fruit damage was recorded in the varieties Zagloul, Medini and Zahidi as 1.43, 1.51 and 2.30 per cent.
2. Inundating release of the egg parasitoid, *T. cacoeciae* at approximately 1000 adults per palm, together with an application of a commercial product of the fungus *B. bassiana*, found to be potential agents against this moth.
3. The use of pheromone traps is a best way to control of the dates moth and it is more accurate and reliable as well as saves much of the annual costs of chemical control. Preparation of the pheromone itself is not a big problem and any sticky trap will do the job properly.
4. Application of dimethoate found to be effective and when the first application was timed with the first detection of infestation and the second 3-4 weeks later with spinosad.

2.2.4 Rhinoceros beetle, *Oryctes rhinoceros* (L.)

Many species of rhinoceros beetles are borers of palms in different regions of the world; the most economically important species are members of the genus *Oryctes*. The rhinoceros beetle, *Oryctes rhinoceros* L. is one of the serious and important pests of date palm in India. This beetle is widespread in all date palm growing areas of India.

Nature of damage

The major injury to the palm is caused by the grubs, which feed on the roots and bore into the underground bases and even the trunks. Severe damage is indicated particularly to offshoots and young palms, in which the mortality rates may be very high. Mature and old palms also infested with grubs, which results in yellowing of the palms and reduction in yield. This rhinoceros species is an opportunistic feeder and easily survives by feeding on roots of grasses also. An attack by rhinoceros beetles may facilitate lethal secondary attacks by palm weevils (*Rhynchophorus* spp.) and by pathogens.

Taxonomic position

Phylum: Arthropoda
Class: Insecta
Order: Coleoptera
Family: Scarabeidae
Genus: *Oryctes*
Species: *rhinoceros*

Seasonal incidence

It is complete one generation per year. Adult activity begins in early May, peaks during June–July and ends in September.

Management

1. Traditional methods of controlling rhinoceros beetles include removal of beetles from feeding holes in young palms and mass capture of adults in light traps.
2. Several arthropod parasitoids, such as scoliid wasps (Hymenoptera: Scoliidae), and predators such as carabid beetles attack rhinoceros beetles but they seem to have little effect on *Oryctes* numbers. In the Philippines the effects of baculoviruses in suppressing populations of *O. rhinoceros* found to give satisfactory control since the mid1980s. Introduction of the baculovirus in to disease free islands lowered the pest population density to10–20% of the pre release levels and over 40% of the adult beetles became infected.
3. Recently a chemical attractant pheromone ethyl-4-methyloctanoate has been used in special traps to attract the beetles which cannot escape and they die due to lack of food.
4. Oil cakes of neem and marotti (*Hydnocarpus wightiana*) have also provided good results for control of *rhinoceros* beetles.
5. Application of naphthalene balls (weighing 3.5 g each) at the rate of three balls per palm, one each to the base of three top most leaf sheaths, at 45 day intervals was found give 100% protection against the pest attacks. The repellant action of naphthalene was significantly superior to that given by conventional insecticides such as Phorate.
6. Application of the organophosphate phorase around the palm trunk at the beginning of August effectively controlled young borer larvae in date plantations in the Arava Valley of Israel.

2.3 Management of insect-pests of aonla crop

2.3.1 Shoot gall maker, *Hypolamprus stylophora* (Swinhoe) (=*Betousa stylophora*)

The gall disease of 'aonla' occurs throughout India, Sri Lanka, Myanmar, Bangladesh, China (Hong

Kong) and Java. Though known to occur widely in India, but it is minor sporadic pest in most of the areas, its occurrence, excepting a few places where it causes considerable economic losses. It is a specific pest of 'aonla' and it is not known to attack any other host so far.

Nature of damage

Inside the gall, the larva feeds on the succulent woody tissues and pushes out reddish frass and excreta through a small hole at one end, kept guarded by a mesh work of silken threads. There is only one larva in each gall which remains confined in an ellipsoidal cavity carved out in gall. The gall is a hollow swelling/localized tumescence of the tender shoot, irregular, roughly, spindles shaped-resembling 'Snake charmer's flute'.

Taxonomic position

Phylum: Arthropoda
Class: Insecta
Order: Lepidoptera
Family: Thyrididae
Genus: *Betousa*
Species: *stylophora*

Seasonal incidence

The infestation of gall forming black caterpillar was found during 4th week of June to 3rd week of January. The significant negative association has been observed between *B. stylophora* and rainfall, wind velocity, minimum temperature, morning and evening vapnur pressure, morning and evening relative humidity, whereas bright sunshine hours, evening vapour pressure deficit and temperature humidity ratio showed significant positive correlation. In the beginning of the infestation terminal shoots swell, which increases in size with the passage of time. Full size galls can be seen in the month of October-November.

Management

1. Galled shoots should be pruned and destroyed along with the pest after harvest.
2. Over-crowding of branches should be removed.
3. A study on screening of genotypes of aonla for their susceptibility to major insect pests revealed that NA-7, Kanchan, Chakaiya, Krishna, LS-2, LS-3 and LS-4 registered lower incidence of *B. stylophora* and proved resistant to this pest.
4. In case of regular occurrence of this insect-pest, spray chloropyriphos 20 EC or dimethoate 30 EC in the beginning of the monsoon season. It may be repeated at fortnightly intervals, if needed.
5. Regarding chemical control Phorate 10G at 10 gm per plant was found more effective.

2.3.2 Mealy bug, *Nipaecoccus vastatar* Newstead

The mealy bug, *N. vastatar* is distributed in Oriental, Palearctic and Ethiopian regions and is a destructive pest of various domesticated plants. Mealybugs once considered as minor pests have assumed the status of major status due to their polyphagous nature coupled with high reproductive capacity with short life cycle which is more favoured due to prolonged drought and quick dispersal through wind, seeds and planting materials.

Nature of damage

High population of nymphs results in drying and dropping of leaves and flowers which affect growth of the tree, flowering and fruiting. The attacked new shoots are found bending and twisting with yellowing of leaves. In case of plants with severe infestation, twigs become leafless and dry. Excessive excretion of honey dew is noticed. Flowers dry up and drop.

Taxonomic position

Phylum: Arthropoda
Class: Insecta
Order: Hemiptera
Family: Pseudococcidae
Genus: *Nipaecoccus*
Species: *vastatar*

Seasonal incidence

Incidence of these mealy bugs has been noticed from March to July with the peak population in April-May. Delayed rainfall dry and humid climate causes rapid spread of this pest.

Management

1. Clean cultivation and maintenance of health and vigour of the tree.
2. Prune affected parts and destroy them at early stage of infestation.
3. The entomogenous fungus *Beauveria bassiana* is found to be an effective bioagent in controlling the nymphs of this pest. Different species of predatory spiders, *Neoscona* sp., *Peucetia* sp., *Argiope* sp. and *Oxyopes* sp. feeds on mealy bugs.
4. Spray with neem oil or insecticidal soap frequently (every couple of weeks) until insect population declines.
5. In case of severe infestation, spray chlorpyriphos 20 EC at 2 ml/l or imdaclorprid 70WS at 0.4 ml/l or profenophos 50EC at 2 ml/l or Spinosad 45 SC at the rate of 0.25 ml/l water. Care should be taken that the spray shall reach the base and also the sides of the plant

2.3.3 Aonla aphids, *Schoutedonia* (=*Cerciaphis*) *emblica* (Patel & Kulkarny)

The incidence of this pest is mainly seen from July to October with the peak period in September. The new shoots are infested at growing points. The nymphs and adult females suck the sap. Heavy attack of this pest affects the growth and vigour of the tree and ultimately affecting the flowering and fruiting.

Nature of damage

The infested leaves turn yellow and dry up. Infested shoots appear bended and twisted at the growing points. Presence of ants also indicates the infestation of aphids. The new shoots are infested at growing points. The nymphs and adult females suck the sap. Heavy attack affects the growth and vigour of the tree, ultimately affecting the flowering and fruiting. Aphids were observed to congregate on the new flush at the growing points of aonla. The infested leaflets turned yellow and dried up.

Taxonomic position

Phylum: Arthropoda
Class: Insecta
Order: Hemiptera
Family: Aphididae
Genus: *Schoutedonia* (=*Cerciaphis*)
Species: *emblica*

Seasonal incidence

The population of aphids initiated from second fortnight of April, then increased gradually during May and June and showed peak activity during second fortnight of June. Its population declined during July and then disappeared from end of October. It is also reported the peak incidence of this pest during first fortnight of September, where its population was maximum.

Management

1. Clipping off and destruction of affected leaf and shoot.
2. NA-20 was found to be the most and NA-6 the least susceptible on the basis of number of aphids. Based on mean population, the ascending order of cultivars/genotypes for aphid population/ branches was NA-6 (6.34) and Francis (6.40), Banarasi (7.03), Kanchan (9.60) and NA-8 (10.16), Krishna (12.89), Chakaiya (14.64), NA-10 (20.52), NA-7 (21.33), NA-9 (21.68), Anand (25.17), Sitapur selection (33.79) and NA-20 (41.83).
3. Two species of Coccinellid beetles, *Menochilus sexmaculatus* and *Coccinella septempunctata* were fond feeding on the aphids.
4. Crop spray with Neem oil at the rate of 0.5% (50 ml neem oil+ 10 gm detergent in 10 litres of water).
5. Spray Dimethoate30 EC at the rate of 0.06% or Spinosad 45 SC at the rate of 0.25 ml/l or Imidacloprid 17.8 SL @ 0.40ml/l at the appearance of aphid.

2.4 Management of insect-pests of pomegranate crop

Pomegranate (*Punica granatum* L.) is one of the important fruit crops in India and being cultivated in the states of Gujarat, Maharashtra, Karnataka, Uttar Pradesh, Andhra Pradesh and Tamil Nadu. Pomegranate trees are attacked by about of 91 insects, 6 mites and 1 snail pest feeding on crops in India.

2.4.1 Anar Butterfly, *Deudorix* (=*Virachola*) *isocrates* F.

It is a polyphagous pest having a very wide range of host plants, including, aonla, apple, ber, citrus, guava, litchi, loquat, mulberry, peach, pear, plum, pomegranate, sapota and tamarind. *D. isocrates* is widely distributed all over India and is found wherever pomegranates are grown, while *D. epijarbas* is a serious pest in Himachal Pradesh and Jammu and Kashmir.

Nature of damage

On hatching, the caterpillars bore inside the developing fruits and are usually found feeding on pulp

and seeds just below the rind. As many as eight caterpillars may be found in a single fruit. The conspicuous symptoms of damage are offensive smell and excreta of the caterpillars coming out of entry holes, the excreta are found stuck around the holes. Sometimes the holes may also be seen plugged with the anal end of a caterpillar. The affected fruits ultimately fall down and are of no use.

Taxonomic position

Phylum: Arthropoda

Class: Insecta

Order: Lepidoptera

Family: Lycaenidae

Genus: *Deudorix* (=*Virachola*)

Species: *isocrates*

Seasonal incidence

The incidence of fruit borer throughout the year in Bombay and Karnataka but observed this pest more active during summer in North India. It reported that the extent of damage caused by fruit borer ranged from 40 to 90 % in different parts of the country.

Management

1. Remove and destroy the affected fruits.
2. Before maturity, bag the fruits with butter paper.
3. Clip off calyx cup immediately after pollination followed by two applications of neem oil @ 3 %.
4. Release *T. chilonis* at 2.5 lakh/ha, four times at ten days interval has been recommended.
5. At flowering stage, spray NSKE 5% or neem formulations 2 ml/1.
6. Spray deltamethrin 2.8 EC (1.5 ml/litre of water) at fortnightly interval from the stage of flowering to fruit development.
7. Spray malathion 50 EC 0.1% or azadirachtin 1500ppm @ 3.0 ml/l at 15 days intervals commencing from initiation of flowering up to the harvesting subjected to the presence of fruit borer.

2.4.2 Fruit sucking moths, *Eudocima* (=*Othreis*) *fullonia* (Clerk); *E. materna* (Linn.)

This pest is distributed in Australia, China, Japan, Korea, Philippines, Hawai, Thailand, India *etc*. The caterpillars of these are leaf defoliators on weed hosts *viz*., *Tinospora cardifolia*, *Cocculus pendulus* and *C. hirsutus*.

Nature of damage

The caterpillars of these feed and survive on the weed hosts viz., *Tinospora cordifolia*, *T. sinensis*, *Cocculus hirsutus*, *C. pendulus*. All the species of moths attack the fruits during night hours especially during the rainy season. The moths are distinguished by having particularly well developed proboscis with dentate tips with which they are able to pierce the ripening fruits. They pierce through the rind and suck the juice with their long proboscis. The damaged fruits soon start rotting as the punctured regions are easily infected with bacteria and fungi and ultimately the fruits drop prematurely. The

feeding preference of *E. homaena* in the descending order is guava>tomato>banana>pomegranate >orange> mosambi>brinjal.

Taxonomic position

Phylum: Arthropoda
Class: Insecta
Order: Lepidoptera
Family: Noctuidae
Genus: *Eudocima* (=*Othreis*)
Species: *fullonia, materna*

Seasonal incidence

The moths are nocturnal in habit and may be seen flying about in orchards after dusk especially during rainy season.

Management

1. Systematic destruction of weed host plants on which the caterpillars feed in the vicinity of orchards helps to check the pest population.
2. Bagging of fruits has been suggested in small scale.
3. Creating smoke in the orchards after sunset may keep the pest at bay.
4. Covering the entire orchard with nylon net followed by spray with contact insecticide has been recommended.
5. Spraying oil emulsions once in 10 days to act as a deterrent.
6. Poison baiting (20 g malathion 50% W.P. + 200 g jaggery or molasses in 2 L of water) has been found quite affective.

2.4.3 Pomegranate aphid, *Aphis punicae* Passerini

Aphis punicae is one among the serious pests attacking pomegranate orchards. Small yellowish-green aphids typically colonizing the upper sides of leaves of pomegranate, winged and wingless aphids.

Nature of damage

Both adults and nymphs lives in colonies and suck the sap by penetrating their styles leaves, stem and even reproductive parts. They feed by sucking the cell sap from leaves and tender twigs. The affected parts get discoloured and disfigured. These insects also secrete a copious amount of honeydew on which sooty mould develops, hindering the photosynthetic activity of the plant. Under severe infestations they also infest and suck the sap resulting in sooty mould development on fruits.

Taxonomic position

Phylum: Arthropoda
Class: Insecta
Order: Hemiptera
Family: Aphididae
Genus: *Aphis*
Species: *punicae*

Seasonal incidence

Young pomegranate leaves are highly susceptible to aphid attacks and distributed throughout the Mediterranean region peak during June- August. High humidity favours the multiplication of aphid.

Management:

1. Collect and destroy the damaged plant parts.
2. Use yellow sticky trap.
3. Release first instar larva of *Chrysoperla carnea* @ 15 per flowering branch (four times) at 10 days interval from flower initiation during April.
4. The botanicals like neem oil, azadirachatin, neem alkaloid and neem seed karnal extract were so effective in bringing about a quick knock-down effect.
5. Spray application of Imidacloprid 17.5 SL @ 0.4-0.6 ml/lit or dimethoate 30 EC at 2ml/lit for effective management this pest.

2.4.4 Thrips, *Scirtothrips dorsalis* and *Rhipiphorothrips cruentatus*

Thrips, *Rhiphiphorothrips cruentatus* (Hood) and *Scirtothrips dorsalis* (Hood) are widely distributed polyphagous pests. Generally of minor importance but occasionally become serious.

Nature of damage

Both nymphs and adults feed on the underside of the leaves by rasping the surface and sucking the oozing cell-sap. Leaf tip turn brown and get curled**,** drying and shedding of flowers and scab on fruits which will reduce the market value.

Taxonomic position

Phylum: Arthropoda

Class: Insecta

Order: Thysanoptera

Family: Thripidae

Genus: *Rhiphiphorothrips* and *Scirtothrips*

Species: *cruentatus* and *dorsalis*

Seasonal incidence

The incidence of thrips on pomgranate was significantly positively correlated with maximum temperature and negatively correlated with mean relative humidity.

Management

1. Remove and destroy affected plant parts.
2. Use of blue sticky traps @ 1trap / 10 plants.
3. Do not intercultivate crops like chilli and onion.
4. Spray chloropyriphos @ 0.02% or imidacloprid @ 0.04% or deltamethrin @ 0.15 or dichlorovos @ 0.05% as prophylactic or on observing the symptoms.

5. Spray with acetamiprid 20 sp @ 0.005% to 0.01% i.e. 25 to 50 g /100 L or spinosad 45 SC @ 0.25 ml/L i.e. 25 ml/100 L or NSKE 5% or *Verticillium lecani (2x108 cfu/g)* @ 200 g / 100 L starting from prior to flowering at the interval of 10 days.

2.4.5 Pomegranate mite, *Tenuipalpus punicae* Pritchard & Baker

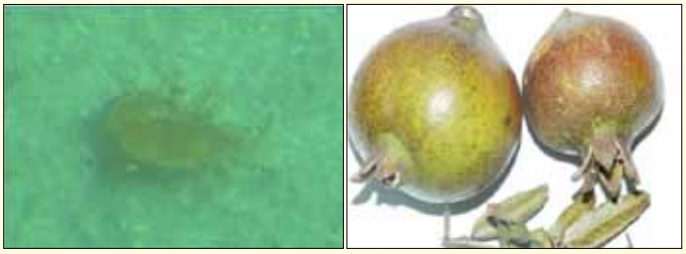
The pomegranate mite, *Tenuipalpus punicae* is reported as pest in Punjab, Haryana and Rajasthan.

Nature of damage

This mite is effected all part of pomegranate plant like leaves, stem, fruit and flowers. The mite inhabited only the underside of pomegranate leaves on either side of the mid-rib, and was concentrated around the petiole. Continued feeding (sap-sucking) by mites resulted in the defoliation of plant leaves. The mite was present on pomegranate stem throughout the year with peak numbers occurring during May-August.

Taxonomic position

Phylum: Arthropoda
Class: Arachnida
Order: Acarina
Family: Tenuipalpidae
Genus: *Tenuipalpus*
Species: *punicae*



Seasonal incidence

The relationships between the pomegranate false spider mite, *Tenuipalpus punicae* population dynamics and optimum temperatures for *T. punicae* were 30°C and 33°C. The optimum conditions for the shortest pre-oviposition period and higher egg-laying and immature development were noted at 33°C followed by 30°C.

Management

1. Regular monitoring is also mandatory for mite management in pomegranate field.
2. Frequent irrigation during summer season reduces the mite infestation.
3. Spray dicofol 18EC 2 ml/lit or ethion 50 EC 2 ml/lit.
4. Application of wettable sulphur 80 WP 2g/lit using hand operated sprayer.
5. Spray of Spiromesifen 240 SC @ 0.4-0.7 ml per litre of water.

2.4.6 Root-Knot Nematode, *Meloidogyne incognita*, Race-II

The root-knot nematode, *Meloidogyne incognita* is one of them causing considerable yield losses in pomegranate.

Nature of damage

Recently pomegranate growers are encountering problem of yellowing of leaves, stunting and less productivity of trees. Such trees were found to be severely infested with root knot nematodes on assaying of soil and root samples. Besides, the direct damage caused to the plant, the root-knot nematodes are notorious for disease complexes involving fungi, bacteria, virus, mycoplasma, insects

and other nematodes. Owing to its polyphagous nature and endoparasitic feeding habit, it is very difficult to control especially on established crops.

Taxonomic position

Class: Secernentea
Order: Tylenchida
Family: Meloidogynidae
Genus: Meloidogyne
Species: *incognita*

Seasonal incidence

It is found throughout the year after incidence of nematode. The average initial root-knot nematode population in the field ranged from 360 to 640 12/200 cm^3 of soil.

Management

1. Avoid introduction of infected soil or plants or plantlet to your plot and avoid dumping any soil having nematodes or infected roots with plants.
2. Provision of adequate light and water drainage
3. Use of resistant root stock.
4. Planting stocks certified free of infection.
5. Applying farmyard manure @ 20 tonnes/ha, neemcake @ 250 g/tree followed by bioagent *Paecilomyces lilacinus* @ 25g/plant are suggested to manage nematode problem.
6. Use of *Paecilomyces lilacinus* @ 20 kg/tree + Castor cake @ 2 ton/ha in root zone of pomegranate at regular interval of six months reduced the root-knot nematode population below economic threshold level.
7. Several nematicide have been very effective against the root-knot nematode in pomegranate. Examples are Nemagon, Mocap, Dasanit, Nemacur, Vydate.

2.5 Management of insect-pests of bael crop

One of the reasons for it is attack of insect-pests on the vegetative stage as well as on developing fruits which ultimately leads to significant yield loss and reduction in quality attributes of the fruits. About 30 species of insect and mites have been reported feeding on bael in India.

2.5.1 Lemon butter fly, *Papilio demoleus* Linnaeus

It is a serious pest of citrus throughout India. Various types of insect-pests are found to be infesting bael in which *P. demoleus* is major one which defoliate the plant.

Nature of damage

The larvae damage is serious problem in citrus nursery stock (trees 1-2 ft. in height) and other young citrus trees and are capable of defoliating entire nursery groves. Larvae may utilize young foliage on more mature trees. It may cause complete (100%) defoliation of infested young plants.

Taxonomic position

Phylum: Arthropoda
Class: Insecta
Order: Lepidoptera
Family: Papilionidae
Genus: *Papilio*
Species: *demoleus*

Seasonal incidence

It observed in bael that population and infestation of *P. demoleus* appeared from August to February. The highest egg, larval population and plant infestation were observed 12.75, 6.15/ 10 branches and 65.0 %, respectively.

Management

1. Larvae can be easily hand-picked from nursery plants; however this practice is labour intensive if infestation is high.
2. The young caterpillars of lemon butter fly were attacked by the yellow wasp (*Polistes hebreus* F.), preying mantis (*Creobrator gemmatus*) and spiders.
3. The pupae were parasitised by *Pteromalus* sp. and eggs by another unknown hymenopteran parasite. *Trichogramma chilonis* and *Telenomus sp*. are egg parasitoids on lemon butterfly and as high as 75.9% egg parasitism was recorded on both *P. demoleus* and *P. polytes* species.
4. Some plant extracts like Pipal (*Ficus religiosa*), Beshram (*Manchoria hastaefolia*), *Parthenium histerophorus*, Neem (*Azadirachta indica*) and Datura (*Datura stramoneum*) significantly (52.8%) reduced *P. demoleus* larval population. Similarly the plant products allitin, replin, margosol and neem guard @ 1% aqueous extract gave >75% pest control in citrus. The leaf extracts of *Eucalyptus globulus* and *Ageratum conyzoides*, clove extracts of *Allium sativum* cause morphological abnormalities in 5th instar larvae and thus are useful botanicals in the pest management.
5. The spray of *Bacillus thuringiensis* @ 1 gram/l with water for managing citrus butterfly.
6. Use of novaluron indicated 94.8 per cent mortality followed by emamectin benzoate (84.5%), chlorpyriphos (59.4%) and neem (59.4%).

2.5.2 Bael fruit fly, *Bactrocera zonata* (Saunders)

Bactrocera zonata originates from South and South-East Asia (India, Indonesia, Laos, Sri Lanka, Thailand, and Vietnam) and has been introduced into Bangladesh, Myanmar, Nepal, Pakistan, Saudi Arabia, Oman, Mauritius and Reunion Island. This fruit fly was found to damage severely to fruits of bael during 2009-10 in all important cultivars growing in the farm at CIAH, Bikaner.

Nature of damage

Attacked fruits usually show signs of oviposition punctures. Fruits with a high sugar content, such as peaches, exude a sugary liquid, which usually solidifies adjacent to the oviposition site. The infested fruits drop-off before to mature. The fruit cracking and rotting also observed in the infested fruits. About 40 to 50 larva has been observed from the single fruit. The active maggot comes out from the dropped fruit through split puncture after the crack for pupation.

Taxonomic position

Phylum: Arthropoda

Class: Insecta

Order: Diptera

Family: Tephritidae

Genus: *Bactrocera*

Species: *zonata*

Seasonal incidence

B. zonata is a tropical species and unable to survive in extreme cold. The maximum fly population was observed during the third week of June. The fly population was positively correlated with temperature and rainfall whereas negative correlation was observed between the fly population and relative humidity. Abundance of larval host is also an important factor regulating its population. More flies were available during the second to fourth weeks of June, which synchronized with the peak fruiting period of its preferred hosts.

Management

1. In cultural control different measures were taken such as ploughing, sanitation hoeing, and weeding. In these practices a large number of insects were killed by the farmers unconsciously. In cultural most important and effectiveness was field sanitation. This practice reduced re-infestation pressure.
2. All unmarketable and infested fruits were destroyed. Wrapping or bagging individual fruit to prevent oviposition by females is also effective.
3. The infestation (fruit drop) was noticed in the cultivars such as NB 5, NB 7, NB 9, Pant Aparna, Pant Urvashi, Pant Shivani, Pant Sujatha. The more fruit drop was noticed in the late season cultivars.
4. In areas where containment or eradication is envisaged, *B. zonata* should be continually monitored using insecticide traps baited with methyl eugenol. The male annihilation technique is the most suitable method available to date for the eradication and control of *B. zonata*. This technique relies on the combined use of sexual attractants (methyl eugenol in the case of *B. zonata*) and insecticide to eliminate male flies, thus stopping mating.
5. Malathion is the usual choice of insecticide for fruit-fly control and this is usually combined with protein hydrolysate to form a bait spray. Yeast hydrolysate or autolysate is used commonly as the protein source.

2.6 Management of insect-pests of cucurbitaceous crop

The main pests of cucurbit crops are leaf eating caterpillar, *Diaphania indica*; fruity fly, *Bactrocera* cucurbitae; leaf miner, *Liriomyza trifolii*; white flies, *Bemisia tabaci*; Hadda beetle, *Epilachna viginctioctopunctata*; aphids, *Aphis gossypii* and ash weevil, *Myllocerus subfasciatus*. The cucurbit fruit fly (*B. cucurbitae*) has been the most prominent pest over the last several decades in India. Depending on the environmental conditions and susceptibility of the crop species, the extent of losses varies from 30 to 100%.

2.6.1 Melon fruit fly, *Bactrocera cucurbitae* Coquillett

It is commonly called melon fruit fly. Originally from the Indo-Malayan region, the fly was introduced into Hawaii from Japan in 1895. It is widely distributed and has been recorded from East Africa, some parts of USA, northern Australia, Taiwan, Okinowa in Japan, South China, South-east Asia and the Indian sub-continent.

Nature of damage

The female flies puncture the soft and tender fruits with their stout and hard ovipositor and lay eggs below the epidermis. On hatching the maggots feed inside on the pulp of fruits and the infested fruits can be identified by the presence of brown resinous juice which oozes out of the punctures made by the flies for oviposition. These punctures also serve as an entry for various bacteria and fungi; as a result, the infested fruits start rotting, get distorted and malformed in shape and fall off from the plants pre-maturely.

Taxonomic position

Phylum: Arthropoda
Class: Insecta
Order: Diptera
Family: Tephritidae
Genus: *Bactrocera*
Species: *cucurbitae*

Seasonal incidence

The melon fruit fly remains active throughout the year on one or the other host. During the severe winter months, they hide and huddle together under dried leaves of bushes and trees. During the hot and dry season, the flies take shelter under humid and shady places and feed on honeydew of aphids infesting the fruit trees. The lower and upper developmental thresholds for eggs were 11.4 and 36.4° C. The accumulative day degrees required for egg, larvae, and pre-egg laying adults were recorded as 21.2, 101.7, and 274.9 day degrees, respectively. This species actively breeds when the temperature falls below 32.2° C and the relative humidity ranges between 60 to 70%.

Management

1. The most effective cultural management technique is the destruction of all infested and unmarketable fruit and the disposal of crop residues immediately after harvest.
2. To break the reproduction cycle and population increase, growers need to remove all unharvested fruits or vegetables from a field by completely burying them deep into the soil.
3. Bagging of fruits on the tree (3 to 4 cm long) with 2 layers of paper bags at 2 to 3 day intervals minimizes fruit fly infestation and increases the net returns by 40 to 58%.
4. An extract of *Acorus calamus* (0.15%) reduced the adult longevity from 119.2 days to 26.6 days when fed continuously with sugar mixed with extract (at 1 ml/g sugar). Neem oil (1.2 %) and neem cake (4.0 %) have also been reported to be as effective as dichlorvos (0.2 %).
5. It reported *Opius fletcheri* to be a dominant parasitoid of *B. cucurbitae*, but the efficacy of this parasitoid has not been tested under field conditions in India. More recently, a new parasitoid, *Fopius arisanus* has also been included in the IPM program of *B. cucurbitae*.

6. Methyl eugenol and cue-lure traps have been reported to attract *B. cucurbitae* adults from mid-July to mid-November.
7. The application of molasses + malathion 50 EC and water in the ratio of 1: 0.1: 100 provides good control of melon fly. Application of spinosad @ 0.4ml/litre of water at 50% appearance of male flowers, and again at 3 days after fertilization is helpful in reducing the melon fly damage.

2.6.2 Hadda beetle, *Epilachna vigintioctopunctata* (Fabricius, 1775)

This species originated in the far east of Russia and has been expanding its range in the second half of the 20th century and is now found over most of Russia, North-East China, Northern Korea, Australia and Japan. It is found in different parts of South East Asia.

Nature of damage

The grubs and adults scrape the leaves in a characteristic manner and feed. They feed on the epidermal layers of leaves which get skeletonized and gradually dry away. They affect the crop in all the stages.

Taxonomic position

Phylum: Arthropoda
Class: Insecta
Order: Coleoptera
Family: Coccinellidae
Genus: *Epilachna*
Species: *vigintioctopunctata*

Seasonal incidence

Incidence of this pest is recorded in both the summer as well as rainy season. The peak period of infestation varies with' the region, but the peak is in April-June in summer and September-November in rainy season.

Management

1. Plough the fields just after harvesting destroy the adults.
2. In the initial stage, collection and destruction of affected leaves along with the eggs, grubs and adults.

3. The various natural insect control agents and two disease-causing organisms (*Aspergillus flavus* and *Bacillus thuringiensis*) which were sometimes able to control populations.
4. The aqueous extract sprays of the castor oil plant *Ricinus communis* (Family: Euphorbiaceae) reduced *Epilachna* attack on foliage and capitulum of sunflower *Helianthus annulus* and consequently increased the oilseed crop.
5. Spray application of cypermethrin 0.025% or profenofos 0.05%.

2.6.3 Leaf eating caterpillar, *Diaphania indica* (Saunders, 1851)

This moth occurs in many tropical and subtropical regions, though it is native to southern Asia; it is occasionally a significant pest of cucurbits and some other plants.

Nature of damage

The caterpillars do the damage after hatching; they roll the leaves with silken threads and eat the leaves between the veins. They also attack the flowers and reduce the number of fruits set. Young fruits are also attacked by this pest. The caterpillars damage the skin and cause the fruits to rot.

Taxonomic position

Phylum: Arthropoda
Class: Insecta
Order: Lepidoptera
Family: Pyralidae
Genus: *Diaphania*
Species: *indica*

Seasonal incidence

Incidence of this pest is recorded in both the summer as well as rainy season. The larval incidence and climatic factors indicated significant negative correlation between incidence and morning relative humidity. However, among non significant factors with minimum temperature was positively influencing the infection of this pest.

Management

1. Make regular inspections of the crop, at least once a week. Check the young leaves, looking for those that are stuck together and those where only the veins are left. Look for faeces on the leaves. They are the signs that the caterpillars are present.
2. Hand picking should be the first method of control. Look for rolled leaves: remove them, or squeeze the caterpillars inside. Check the flowers and the fruits for damage. If it is severe, consider using chemicals. But consider carefully which ones to use.
3. The survey for the natural enemies associated with the caterpillar, *Diaphania indica* revealed the presence of 20 species of parasitoids, predators and pathogens. Of these, 16 were parasitoids belonging to the families Braconidae, Ichneumonidae, ethylidae, Elasmidae and Chalcididae. Except for 3 species the remaining parasitoids were new records for *D. indica*. The predators recorded were ants and spiders. A microsporidia also was recorded for the first time on *D. indica*.
4. Spray any following insecticides like malathion 50 EC @ 500 ml, dimethoate 30 EC 500 ml / ha *etc*.

2.6.4 Melon aphid, *Aphis gossypii* Glover

It has a worldwide distribution. However on cotton, often it causes appreciable damage during severe drought conditions.

Nature of damage

It infest the tender shoots and the under surface of leaves in very large numbers and suck the sap. Severe infestation results in curling of leaves, stunted growth and gradual drying and death of young plants. Black sooty mould develops on the honey dew of the aphids which falls on the lower leaves affecting photosynthetic activity.

Taxonomic position

Phylum: Arthropoda
Class: Insecta
Order: Hemiptera
Family: Aphididae
Genus: *Aphis*
Species: *gossypii*

Seasonal incidence

Incidence of *A. gossypii* was observed from last week of February to first week of April. Peak population was recorded in mid-March. Aphid population exhibited positive non-significant correlation with temperature whereas it exhibited significant negative correlation with minimum humidity and non-significant negative correlation with maximum humidity.

Management

1. The wide host range of melon aphid makes crop rotation a difficult tactic to implement successfully. Also, crops grown down-wind from infested fields are especially susceptible because aphids are weak fliers and tend to be blown about.
2. Infested crops should be destroyed immediately after harvest to prevent excessive dispersal, and it may be possible to destroy overwintering hosts if they are weeds. Time of planting may influence potential aphid population increase potential.
3. Protective covers will also prevent transmission of aphid-transmitted viruses. Check transplants for aphids and remove them before planting or destroy infested plants by dropping the plant or infested plant part in a bucket of soapy water, and dispose of them away from the field.
4. Many of the natural enemies known to be effective against melon aphid like lady bird beetles, syrphid flies and braconid wasps. Ants are commonly found associated with melon aphid but they are there to collect honeydew, and may even hinder predation by other insects. The wasp *Lysiphlebus testaceipes* is especially effective, sometimes causing up to 99% parasitism.
5. Spray application of dimethoate 0.03 % or imidacloprid 0.01 % affords protection. Include also imidacloprid seed treatment for sucking pests @ 3 – 5g /kg seed that protects the crop around 30 – 45 days

2.6.5 Whitefly, *Bemisia tabaci* (Gennadius, 1889)

It is distributed in all cotton growing regions of the world. It is known to infest about 50 different

species of plants but it becomes quite a serious pest of cotton in certain regions of the country. The infestation by this pest adversely affects the physiology of the plant at all its stages of growth.

Nature of damage

The nymphs are found in large numbers on the under surface of leaves and drain of sap due to sucking. Severe infestation results in premature defoliation, development of sooty mould on honey dew excreted, and shedding of buds and bolls and bad boll opening.

Taxonomic position

Phylum: Arthropoda
Class: Insecta
Order: Hemiptera
Family: Aleyrodidae
Genus: *Bemisia*
Species: *tabaci*

Seasonal incidence

As regards the role of abiotic factors on seasonal incidence of white fly, the rainfall played a negative role in incidence. While maximum and minimum temperature manifested positive and significant impact on incidence of white fly. Contrary relative humidity demonstrated negative and significant role in build up of population. Considering the combined impact, rainfall decidedly non-significant with maximum and minimum temperature. But it was positive and significantly associated with relative humidity. The maximum temperature was positive and significant in association with minimum temperature while, it was negatively correlated with relative humidity.

Management

1. Intercropping practices using non-hosts have been used in many countries aiming to reduce numbers of whiteflies on specific crops. However, intercropping with susceptible crops can promote whitefly populations, by offering more leaf area for feeding. Weed species play an important role in harbouring whiteflies between crop plantings and attention should be paid to removing these in advance of planting susceptible crops. Weeds also often harbour whitefly-transmitted viruses and may be a major source of crop virus epidemics.
2. Monitor whitefly populations by using sticky traps and weekly inspections to detect early infestations.
3. Three species of entomopathogenic fungi active against *B. tabaci* are available commercially, *Paecilomyces fumosoroseus*,*Verticillium lecanii* and *Beauveria bassiana*. The first two are naturally found infecting whiteflies whereas *B. bassiana* is only seen infecting white flies when applied as part of a formulation.
4. The development of transgenic resistant plant and crop species through genetic engineering must be considered and accepted as a future method of control where whitefly-transmitted viruses are already endemic and causing severe crop losses.
5. White fly is difficult to control with insecticides for two reasons; adults and immatures infest the lower surfaces of leaves which are difficult to reach with insecticide sprays and they have developed resistance to many insecticide chemistries. Homeowners would be best advised to treat populations before they reach outbreak levels and to spray immature whiteflies with

imidacloprid 0.01 % or acetamaprid 0.01% or thiomethoxam 0.02% *etc.*

2.7 Management of insect-pests of khejri crop

2.7.1 Gall forming insects

Four distinct types of galls were identified on *P. cineraria* in western Rajasthan. Galls reduce vegetative growth and seed formation in *P. cineraria*. The genesis of these growths is a result of a nutritional dependence of the causal organisms on plant tissues.

Nature of damage

Galls on branches

Galls are solid, hard, woody brown structures, caused by a chalcid, *Pediobopsis* sp. Galls measured 11.2-45.2 mm in length and 11-42 mm in breadth. Each gall has an oval larval chamber in the centre which opened externally through a small pore in the periphery through which the adults ultimately escaped. These galls were formed throughout the growing season.

Galls on rachis of leaflets

Galls are globose, indehiscent and hard and measured 3.4-10.2 mm in length and 2.0-3.4 mm in breadth. Galls were prevalent throughout the growing season. The causal insect was found to be a cecidomyid, *Contarinia prosopidis*. The larval development took place in the gall cavity where they sucked sap from the tissues.

Galls on leaflets

Galls are variable size and developed on leaflets mostly during the rainy season. The causal organism was found to be *Eriophyes prosopidis*, a mite. The mites bred parthenogenetically, giving rise to large number of galls on the leaflets.

Management

One spray of insecticide Thiomethoxam 25 WG @ 0.4 ml per litre of water at penical emergence and second spray of Dimethoate 30 EC @ 1.5 ml per litre of water at flowering stage for management of gall midges in Khejri.

2.7.2. Seed Beetle, *Caryedon serratus*

This beetle, *C. serratus* was recorded on khejri pod with seed in the month of July to November, 2014 at Entomology laboratory of Central Institute for Arid Horticulture, Bikaner.

Nature of damage

The adults lay eggs on pods or seeds of Khejri.The emerging grub was penetrate into the pods ad reach into seeds and make hole in the seeds. The complete seeds were damaged not used in any purpose. The grub development and moulting remain in the seed upto fourth instar and pupate inside seeds or near the seed hole in their silk cocoon.

Taxonomic position

Phylum: Arthropoda
Class: Insecta
Order: Coleoptera
Family: Bruchidae
Genus: *Caryedon*
Species: *serratus*

Management

1. Use of cow dung dust mixed with seed of khejri for controlling the seed beetle.
2. Use of resistance germplasm against insects.
3. Dusting of insecticides malathion 5D at 2.5 g/kg and quinalphos 1.5D at 2.5 g/kg of khejri pods were found to be most effective in minimizing per cent pod damage and weight loss.
4. Surface treatment for gunny bags, beta-cyfluthrin 2.5EC at 0.5 ml/ litre,lambda – cyhalothrin 5EC and deltamethrin 10EC at 0.5 ml/ litre were found to be most effective in minimizing per cent pod damage and weight loss.

2.7.3. Khejri moth, *Anarsia triaenota*

This moth, *A. triaenota* was recorded on khejri in the month of April to September, 2013 at experimental farm of Central Institute for Arid Horticulture, Bikaner.

Nature of damage

This moth is looking new threat to arid ecosystem and it was a severe problem during new leaves new leaves. The larvae damages to new leaves and make the gallery inside the leaves of the khejri plant. Due to attack of this pest, the growth of khejri plant is suppressed and dry of the new leaves. Larval and pupal development took place inside gallery of leaves.

Taxonomic position

Phylum: Arthropoda
Class: Insecta
Order: Lepidoptera
Family: Gelechiidae
Genus: *Anarsia*
Species: *triaenota*

Seasonal incidence

The incidence of moth was recorded from 14.67 % to 80.33 %. The incidence was started from the month of April to end of September and highest intensity was recorded in the month of June to July.

Management

1. Mechanical collection of grown up larva and pupa of the moth.
2. Apply any one of the following insectcides: Azadirachtin 0.03 % WSP 2.5-4.0 L/ ha or Dimethoate 30% EC 1-1.5 L/ha or Emamectin benzoate 5% SG 220 g/ha or Neem oil 2%.

2.8. Management of insect-pests of jamun crop

2.8.1. Fruit borer, *Dudua aprobola* (Meyrick)

The jamun leaf roller, *D. aprobola* has been reported as one of the serious pests of jamun where its grown.

Nature of damage

The larvae roll or web the leaves of the food plant together, feeding on them within this shelter. They are also damaging the fruit and flower of jamun. Pupation takes place inside a rolled leaf, which is lined by a thin layer of silk. The pupation period lasts one to two weeks. The symptoms of leaf injury by the larvae are manifested through rolling of tender leaves and feeding inside. As a result of larval injuries, the infested twigs distort and wither.

Taxonomic position

Phylum: Arthropoda
Class: Insecta
Order: Lepidoptera
Family: Tortricidae
Genus: *Dudua*
Species: *aprobola*

Seasonal incidence

The incidence of leaf roller was found on jamun trees during April to October when new leaf flush, flowering and fruiting were available and restricted breeding took place during off season (November to March) on alternate hosts such as litchi and chhota amaltas growing around jamun field.

Management

1. Systematic collection of larvae of leaf roller and their destruction.
2. Spray application of spinosad 0.5 ml and dimethoate 2.0 ml per liter of water affords protection.

3. New pests information with climate change

The study of plant insect often begins with a discussion of the "plant pest triangle". The three legs of the triangle *i.e.* host, pest and environment must be present and interact appropriately for plant pests to result. If any of the three factors is altered, changes in the progression of a pests epidemic can occur. Insect habitats and survival strategies are strongly dependent on patterns of climate. Therefore, it is highly expected that, the major drivers of climate change *i.e.* elevated CO2, increased temperature and depleted soil moisture can impact population dynamics of insect-pests and the extent of crop losses, significantly. It has been reported that, global climate warming may lead to altitude wise expansion of the geographic range of insect-pests, increased abundance of tropical insect species, decrease in the relative proportion of temperature sensitive insect population, more incidence of insect transmitted plant diseases through range expansion and rapid multiplication of insect vectors. Thus, with changing climate it is expected that the growers of crops have to face new and intense pest problems in the years to come.

3.1 Tingid bug, *Dictyla cheriani* Drake

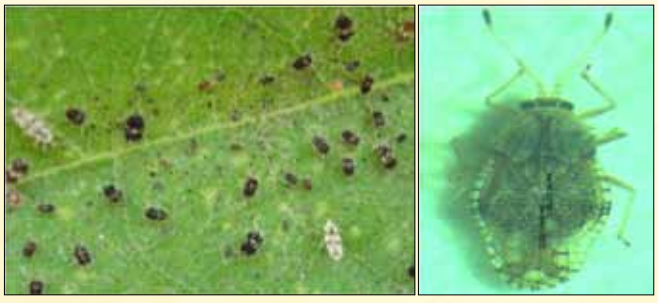
Few studies were made on the bug, *D. cheriani* infestation on *Cordia sp.* (India) and bug, *D. monotropidia* infestation on *Cordia verbenacea* (Brazil). It reported that infestation of *Dictyla cheriani* on Indian cherry was first noticed in 2010 at Bikaner, Rajasthan.

Nature of damage

The lace bugs were found to be aggregated on the leaves of the plants. During a survey of the natural vegetation, the population of this pest was found to be higher on small seeded plants than the bold seeded plants. The lace bugs sucked the sap from newly emerging leaves and young branches, which led to the leaves turned yellow and suppression of growth of the tree through drying of leaves and young branches. Nymphal instars of the summer species of Tingidae possess body out growths which are morphologically different from those of the winter forms. The peak population of the summer species coincides with the onset and progress of monsoon.

Taxonomic position

Phylum: Arthropoda
Class: Insecta
Order: Hemiptera
Family: Tingidae
Genus: *Dictyla*
Species: *cheriani*



Seasonal incidence

The maximum incidence was observed in October (51.67% on bold & 76.67% on small seeded plants) and minimum in January (11.67% on bold & 21.67% on small seeded plants). The number of this lace bug ranged between (0.5 to 8.8 on bold & 4.5 to 25.97 on small seeded plants) nymphs and adults per leaves.

Management

1. Provide proper cultural practices, so plants are vigorous. If damage has previously been intolerable, monitor plants early during subsequent seasons. Take action when populations begin to increase and before damage become extensive.
2. Provide adequate irrigation and other care to improve plant vigor. Prune out damaged foliage if the discoloring is intolerable and relatively localized.
3. Do not remove more than a small percent of a plant's branches during one season and use good techniques so that pruning does not injure plants, such as by exposing inner branches to sunburn.
4. Almost any insecticide will control tingid bugs if it is sprayed directly onto the insects. Azadirachtin (BioNeem), insecticidal soap (Safer), narrow-range oil (Green Light, Volck) and neem oil sprays temporarily control tingid bugs if insecticide thoroughly covers the underside of leaves where adults and nymphs occur. Imidacloprid 17.5 SL can be applied as a foliar spray for controlling of this pest.

3.2 Ker butter fly, *Anaphaeis aurota* Fabricius

A. aurota is found throughout tropical Africa, Arabia and Indian subcontinent. It is migratory and regularly penetrates the Middle East and Egypt. Actual migrations recorded from Arabia have been of modest proportions, but in East Africa several million butterflies may cross a narrow front in a single day.

Nature of damage

Capparis decidua was found to be heavily infested with *Anaphaeis aurota* commonly known as the Pioneer or Caper white, in various parts of Rajasthan. The species is so abundant that the caterpillars completely strip trees and bushes; bare twigs may literally be festooned with the pupae of those caterpillars which did not starve to death. The regular occurrence of dwarf specimens is almost certainly linked to this type of overcrowding. During the investigation it is found that the grown caterpillars of *A. aurota* easily strip off the branches, devouring leaf after leaf causing great damage in Rajasthan.

Taxonomic position

Phylum: Arthropoda
Class: Insecta
Order: Lepidoptera
Family: Pieridae
Genus: *Anaphaeis*
Species: *aurota*

Seasonal incidence

The maximum incidence (86.67%) was observed in first fortnight of December and it was reduced to 11.67% in first fortnight of September in subsequent year. The average numbers of insects ranged between 1.33 to 10.33 larvae per branch of plant.

Management

1. Systematic collection of egg masses of butter fly and their destruction.
2. Pest can be checked by handpicking and mechanical destruction of caterpillars during early stage of attack when the caterpillars feed gregariously.
3. The pupae of *A. aurota* are parasitized with *Brachymeria albicrus*. The mean per cent parasitization of pioneer butterfly by *B. albicrus* at CIAH farm and at Desnok, Bikaner was 49.5 and 47.5 respectively and the mean per cent emergence of the mature adult parasitoids from the parasitized pupae was 15.5 and 14.0 respectively.
4. Spray application of cypermethrin 1.5 ml, spinosad 0.5 ml and dimethoate 2.0 ml per liter of water affords protection.

3.3 Coreid bug, *Homoeocerus variabilis* Dallas

It is newly recorded on Khejri that are found in arid and semi-arid region of India. The sucking type mouth part is found in coreid bug.

Nature of damage

It damages the new flowering/ leaves/ stem of the khejri plant. Due to attack of this pest, the growth of khejri plant was suppressed and dry of the new branches/ leaves. In winter season, the coreid bug was found on stem/ branches of plant in gregarious stage.

Taxonomic position

Phylum: Arthropoda
Class: Insecta
Order: Hemiptera
Family: Coreidae
Genus: *Homoeocerus*
Species: *variabilis*

Seasonal incidence

The maximum incidence was observed in December (66.7%) and minimum in June (16.7%). The number of this bug ranged between 27.3 and 222.9 adults per plant.

Management

1. Shaking the infested plants over the vessels of oil and water or oily cloth gives most effective.
2. Spray of dimethoate 30 EC 1-1.5L or imidacloprid 17.8 SL 300-500 ml/ha.

3.4 Pilu butter fly, *Colotis amata* (F.)

An infestation of *C. amata* on pilu (*Salvadora persica*) plants was first noticed in 2012 at the Experimental Farm of the Central Institute for Arid Horticulture and other fields of Bikaner District, Rajasthan, India.

Nature of damage

The larvae were found to be aggregated on the leaves of the plants. The newly sprouting tender shoots and leaves are attacked by larvae of butterfly. Due to its attack, the leaves dried up and tender

shoots do not grow properly. Larvae feed on sprouting tender shoots, leaves and flower buds. An infested leaf gives whitish look due to chlorophyll feeding.

Taxonomic position

Phylum: Arthropoda
Class: Insecta
Order: Lepidoptera
Family: Pieridae
Genus: *Colotis*
Species: *amata*

Seasonal incidence

The average incidence of larvae on plant ranged between 16.67 to 80.00 per cent. The incidence and the numbers were higher in the month of December than during other months and the minimum in September. Thus the highest mean number of this butterfly species per 3 leaves was recorded in December (22.30) followed by January (16.77) and the lowest was in September (7.63).

Management

1. Collect and destroy caterpillars in the early stage of attack.
2. Conserve parasitoids and predators of butter fly.
3. Spray insecticides like quinalphos 25EC or malathion 50 EC @ 1.5 ml per litre of water.

3.5 Karonda moth, *Digama hearseyana* Moore, 1859

An infestation of *D. hearseyana* on karonda, *Carissa carandus,* was first noticed in 2014 at the experimental farm of ICAR-Central Institute for Arid Horticulture at Bikaner in Rajasthan, India.

Nature of damage

During a survey of the natural vegetation, the population of this pest was found to be higher on young trees than the old trees. The larvae damage the fresh emerging leaves and flowers which led to the suppression of growth of the karonda tree through scraping of leaves and flowers.

Taxonomic position

Phylum: Arthropoda
Class: Insecta
Order: Lepidoptera
Family: Noctuidae
Genus: *Digama*
Species: *hearseyana*

Seasonal incidence

The average incidence of karonda moth on trees ranged between 10.00 to 63.33 percent during throughout the year. The incidence of moth were higher in July to September and the maximum incidence 63.33 per cent was recorded in August and the minimum in October (16.67%). Thus the highest number of this moth per tree was recorded in August (5.77/ plant) followed by August (4.8/

plant) and the lowest was in October (10.67/ plant).

Management

1. Collect and destroy larvae to the extent possible.
2. Spray application of spinosad 0.5 ml and dimethoate 2.0 ml per liter of water affords protection.

3.6 Ridge gourd armyworm, *Spodoptera exigua* (Hubner)

For the first time, beet armyworm was observed on ridge gourd, *Luffa acutangula* in the hot arid region of north-western India, (*i.e.*, Thar Desert) and identified as *Spodoptera exigua*. Beet armyworm is a polyphagous pest and serious pest of ridge gourd cause to leaves, flowers and fruits of plants.

Nature of damage

Smaller larvae devour the parenchyma of leaves, so all that remains is the thin epidermis and veins. Larger larvae tend to burrow holes through thick areas of plants. Ridge gourd fruits are most susceptible to injury, starting from young fruit to maturity of fruits. The beet armyworm is damage to summer as well as rainy season but more incidences was recorded in the rainy season crop.

Taxonomic position

Phylum: Arthropoda
Class: Insecta
Order: Lepidoptera
Family: Noctuidae
Genus: *Spodoptera*
Species: *exigua*

Seasonal incidence

The incidence of beet armyworm started 20 days after sowing of crops and continued till ending of the crops. Eggs are laid in clusters of 50 to 150 eggs per mass. Eggs are usually deposited on the lower surface of the leaf, and often near blossoms and the tip of the branch. Pupation takes place in soil.

Management

1. Collection and destruction of larvae by hand in the field.
2. Plough the soil to expose and kill the pupae.
3. The chemical indoxacarb or spinosad or thiodicarb were most effective in reducing larval population of beet worm.

4. Biochemical mechanism of plant-pest interaction in arid horticulture crops

In natural systems, plants face a plethora of antagonists and thus posses a myriad of defense and have evolved multiple defense mechanisms by which they are able to cope with various kinds of biotic stress. Plants produce a large and diverse array of organic compounds that appear to have no direct functions in growth and development *i.e.* they have no generally recognized roles in the process of photosynthesis, respiration, solute transport, translocation, nutrient assimilation and differentiation. High concentrations of secondary metabolites might result in a more resistant plant. Therefore, defense metabolites can be divided in to constitutive substances, also called prohibitins or phytoanticipins and induced metabolites formed in response to an infection involving de novo enzyme synthesis, known as phytoalexins. Phytoanticipins are high energy and carbon consuming and exhibit fitness cost under natural conditions but recognized as the first line of chemical defense that potential pathogens have to overcome. In contrast, phytoalexin production may take two or three days, as by definition first the enzyme system needs to be synthesized. Plant secondary metabolites can be divided into three chemically distinct groups viz: Terpenes, Phenolics, N and S containing compounds. On the basis of secondary metabolites, we have identified the some genetic material having resistance to insect pests in arid horticulture crops.

Muskmelon: AHMM/BR-1, RM-50 and AHMM/BR-8 were the most resistant; MHY-5, Durgapura Madhu and Pusa Sarabati were moderately resistant genotypes to fruit fly in arid region. Total sugar, reducing sugar, non-reducing sugar and pH were lowest in resistant and highest in susceptible genotypes whereas tannins, phenols, alkaloids and flavinoid contents were highest in resistant and lowest in susceptible genotypes. Total alkaloid and pH contents explained 97.96% of the total variation in fruit fly infestation and 92.83% of the total variation in larval density per fruit due to alkaloids and total sugar contents.

Watermelon: The genotypes Asahi Yamato, AHW/BR-16 and Thar Manak were found to be resistant to fruit fly infestation. Free amino acid content was lowest in the resistant 'Asahi Yamato' and highest in the susceptible 'BSM-1', whereas the contents of phenols, tannins, total alkaloids, and flavonoids were highest in resistant and lowest in susceptible genotypes. Flavonoid and total alkaloid contents explained 88.4% and 92.0%, respectively, of the total variation in fruit fly infestation and in larval density per fruit.

Kachri: The genotypes IC-350933and IC-373479 were found to be highly resistant; IC-351005, IC-351088, IC-258131 and DKS 2011/01 were found to be resistant to fruit fly. The phenols (r = -0.90), tannin (r = -0.89), total alkaloids (r = -0.80) and flavonoid (r = -0.96) contents had significant negative correlations with percent fruit fly infestation. Flavinoid and tannin contents explained (91.2 and 92.1 %, respectively) of the total variation in fruit fly infestation and in larval density per fruit. Based on the Kaiser Normalization method, two principal components (PCs) were extracted explaining the cumulative variation of 88.2% in melon fruit fly infestation. PC1 explained 71.6 % of the variation while PC2 explained 16.6 % of the variation.

Ber: Growers can adopt the potential resistant cultivars of ber (Tikadi, Katha and Illaichi cultivars) with minimal financial investment to obtain higher yields. Hence, a benefit of resistance cultivars for yield potential is apparent and resistance cultivars can be used as an important component of sustainable management. The phenol, tannin and flavonoid contents had significant negative correlations with percent fruit infestation. Flavonoid and phenols content explained (89 %) of the total variation in fruit fly infestation. Two principal components (PCs) were extracted which explained the cumulative variation of 84.7% in fruit fly infestation. PC1 explained 59.9 % of the variation while PC2 explained 24.9 % of the variation.

Lasora: The analysis showed 3 germplasms (AHCM-22-1, AHCM-25 and AHCM-34) as resistant and AHCM-14, AHCM-30 and AHCM-31 as moderately resistant to tingid bug in lasora crop. Free amino acid had positive correlation with infestation, whereas phenols, tannin, alkaloid and flavonoid contents had significant negative correlation with infestation. Phenols and flavinoid contents explained (96.9 and 96.1%, respectively) of the total variation in bug infestation and bug density per leaf. The one principal component was extracted explaining cumulative variation of 90.07% in infestation. The flavonoid, alkaloid, tannins, phenols content, roughness and hairyness were the novel antibiosis and antixenotic characters found in Indian cherry accessions, which were resistant to *D. cheriani*.

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Appendices

Appendix: 1. List of insect –pests of fruit and vegetable crops in arid region

S. No.	Insect-pests of fruit crops	Family	order
1. Ber pests			
	Ber fruit fly (*Carpomyia vesuviana*)	Tephrididae	Diptera
	Ber stone weevil (*Aubeus himalayanus*)	Curculionidae	Coleoptera
	Ber butter fly (*Tarucus theophrastus*)	Lycaenidae	Lepidoptera
	Ber fruit borer (*Meridarchis scyrodes*)	Carposinidae	Lepidoptera
	Bark eating caterpillar (*Indarbela quadrinotata*)	Cossidae	Lepidoptera
	Ber leaf webber (*Synclera univocolis*)	Pyraustidae	Lepidoptera
	Ber weevil (*Myllocerus dentifer*)	Curculionidae	Coleoptera
	Ber weevil (*Myllocerus blandus*)	Curculionidae	Coleoptera
	Ber weevil (*Amblyrrhinus poricollis*)	Curculionidae	Coleoptera
	Ber lygaeid bug (*Nysius* sp.)	Lygaeidae	Hemiptera
	Termite (*Odontotermes obesus*)	Termitidae	Isoptera
2. Date palm pests			
	Date palm scale (*Parlatoria blanchardi*)	Diaspididae	Hemiptera
	Lesser date moth (*Batrachedra amydraula*)	Batrachedridae	Lepidoptera
	Greater date moth *(Arinipses sabella)*	Pyralidol	Lepidoptera
	Termite (*Microtermus diversus*)	Termitidae	Isoptera
	Date palm flour beetle (*Tribolium castaneum*)	Tenebrionidae	Coleoptera
	Date palm weevil (*Rhynchophorus ferrugineus*)	Curculionidae	Coleoptera
3. Aonla pests			
	Aonla shoot gall maker (*Betousa stylophora*)	Thyrididae	Lepidoptera
	Aonla aphids (*Schoutedenia* (=*Cerciaphis) emblica*)	Aphididae	Hemiptera
	Aonla bark-eating caterpillar (*Indarbela tetraonis*)	Cossidae	Lepidoptera
	Aonla mealy bug (*Nipaecoccus viridis*)	Pseudococcidae	Hemiptera
	Aonla leaf rollers (*Gracilaria acidula*)	Gracillariidae	Lepidoptera
4. Pomegranate pests			
	Pomegranate butterfly (*Deudorix isocrates*)	Lycaenidae	Lepidoptera
	Fruit sucking moths (*Eudocima fullonica* & *E. materna*)	Noctuidae	Lepidoptera

S. No.	Insect-pests of fruit crops	Family	order
	Pomegranate aphids (*Aphis punicae*)	Aphididae	Hemiptera
	Pomegranate whitefly (*Siphoninus phyllyreae*)	Aleyrodidae	Hemiptera
	Pomegranate thrips (*Scirtothrips dorsalis*)	Thripidae	Thysanoptera
	Pomegranate mealy bugs (*Ferrisia virgata*)	Pseudococcidae	Hemiptera
	Pomegranate mite (*Tenuipalpus punicae*)	Tenuipalpidae	Acarina
5. Bael pests			
	Bael fruit fly (*Bactrocera zonata*)	Tephrididae	Diptera
	Lemon butter fly (*Papilio demoleus*)	Papilionidae	Lepidoptera
	Red scale (*Aonidiella aurantii*)	Diaspididae	Hemiptera
	Citrus leaf minor (*Phyllocnistis citrella*)	Gracillariidae	Lepidoptera
6. Citrus pests			
	Citrus leaf miner (*Phyllocnistis citrella*)	Gracillariidae	Lepidoptera
	Lemon butter fly (*Papilio demoleus*)	Papilionidae	Lepidoptera
	Citrus psylla (*Diaphorina citri)*	Psyllidae	Hemiptera
	Fruit sucking moths (*Eudocima fullonica* & *E. maternal*))	Noctuidae	Lepidoptera
7. Kinnow pests			
	Kinnow fruit fly (*Bactrocera dorsalis*)	Tephrididae	Diptera
	Kinnow psylla (*Diaphorina citri)*	Psyllidae	Hemiptera
	Kinnow mite (*Eutetranychus orientalis*)	Tetranychidae	Acarina
	Kinnow leaf-folder (*Psorosticha zizyphi*)	Oecophoridae	Lepidoptera
	Kinnow whitefly (*Dialeurodes citri*)	Aleurodidae	Hemiptera
8. Lasora pests			
	Lasora tingid bug (*Dictyla cheriani*)	Tingidae	Hemiptera
	Lasora mirid bug (*Nesidiocoris tenuis*)	Miridae	Hemiptera
9. Ker pest			
	Ker butter fly (*Anaphaeis aurota*)	Pieridae	Lepidoptera
	Ker pentatomid bug (*Stenozygum speciosum*)	Pentatomidae	Hemiptera
10. Phalsa pests			
	Phalsa bug (*Gargara mixta*)	Membracidae	Hemiptera
	Phalsa psyllid (*Psylla sp.*)	Psyllidae	Hemiptera
	Bark-eating caterpillar (*Indarbela tetraonis*)	Cossidae	Lepidoptera
	Chaffer beetle (*Oxycetonia sp.*)	Scarabaeidae	Coleoptera

S. No.	Insect-pests of fruit crops	Family	order
11. Cucurbits pests			
	Melon fruit fly (*Bactrocera cucurbitae*)	Tephritidae	Diptera
	Hadda beetle (*Epilachna vigintioctopunctata*)	Coccinellidae	Coleoptera
	Melon aphid (*Aphis gossypii*)	Aphididae	Hemiptera
	Leaf eating caterpillar (*Diaphania indica*)	Pyralidae	Lepidoptera
	Red pumpkin beetle (*Aulacophora foveicolis*)	Chrysomelidae	Coleoptera
	Thrips (*Thrips tabaci*)	Thripidae	Thysanoptera
	White fly (*Bemisia tabaci*)	Aleyrodidae	Hemiptera
	Leaf minor (*Liriomyza trifolii*)	Agromyzidae	Diptera
	Two-spotted spider mites (*Tetranychus urticae*)	Tetranychidae	Acarina
12. Brinjal pests			
	Brinjal fruit and shoot borer (*Leucinodes orbonalis*)	Pyraustidae	Lepidoptera
	Brinjal thrips (*Scirtothrips dorsalis*)	Thripide	Thysanoptera
	Brinjal bollworm (*Helicoverpa armigera*)	Noctuidae	Lepidoptera
	Brinjal jassids (*Amrasca devastans*)	Cicadellidae	Hemiptera
	Brinjal lace wing bug (*Urentius hystricellus*)	Tingidae	Hemiptera
	Brinjal leaf roller (*Eublemma olivacea*)	Noctuidae	Lepidoptera
	Brinjal stem borer (*Euzophera perticella*)	Pyralidae	Lepidoptera
	Brinjal blister beetle (*Mylabris pustulata*)	Meloidae	Coleoptera
13. Tomato pests			
	Tomato pod borer (*Helicoverpa armigera*)	Noctuidae	Lepidoptera
	Tobacco caterpillar (*Spodoptera litura*)	Noctuidae	Lepidoptera
	Tomato serpentine leaf miner (*Liriomyza trifolii*)	Agromyzidae	Diptera
	White fly (*Bemisia tabaci*)	Aleyrodidae	Hemiptera
	Cotton aphid (*Aphis gossypii*)	Aphididae	Hemiptera
14. Khejri pests			
	Coreid bug (*Homoeocerus variabilis*)	Coreidae	Hemiptera
	Galls on rachis of leaflets (*Contarinia prosopidis*)	Cecidomycidae	Diptera
	Induce galls on branches (*Pediobopsis* sp.)	Chalcididae	Hymenoptera
	Galls on leaflets (*Eriophyes prosopidis*)	Eriophyidae	Acarina
	Termite (*Odontotermes obesus*)	Termitidae	Isoptera
15. Beans pests			

S. No.	Insect-pests of fruit crops	Family	order
	Gram pod borer (*Helicoverpa armigera*)	Noctuidae	Lepidoptera
	Leaf minor (*Chromatomyia horticola*)	Agromyzidae	Diptera
	Whitefly (*Bemisia tabaci*)	Aleyrodidae	Hemiptera
	Leaf hopper (*Empoasca kerri*)	Cicadellidae	Hemiptera
	Aphid (*Aphis craccivora*)	Aphididae	Hemiptera
	Pod borer (*Maruca vitrata*)	Pyralidae	Lepidoptera
	Red spider mites (*Tetranychus urticae*)	Tetranychidae	Acarina
	Pod borer (*Etiella zinckenella*)	Pyralidae	Lepidoptera
16. Jamun			
	Jamun weevil (*Curculio c-album*)	Curculionidae	Coleoptera
	Jamun fruit borer (*Meridarchis scyrodes*)	Carposinidae	Lepidoptera
	Jamun leaf roller (*Dudua aprobola*)	Tortricidae	Lepidoptera
17. Karonda			
	Karonda moth (*Digama hearseyana*)	Noctuidae	Lepidoptera
18. Pilu			
	Small salmon Arab or pilu butter fly (*Colotis amata*)	Pieridae	Lepidoptera

Appendix: 2. Pesticides banned/ withdrawn/ refused registration and restricted use in India

S. No.	Name of pesticides	S. No.	Name of pesticides
(a) Pesticides banned for manufacture, import and use			
1.	Aldrin	15.	Pentachlorophenol
2.	Benzene Hexachloride	16.	Phenyl Mercury Acetate
3.	Calcium Cyanide	17.	Sodium Methane Arsonate
4.	Chlordane	18.	Tetradifon
5.	Copper Acetoarsenite	19.	Toxafen
6.	Cibromochloropropane	20.	Aldicarb
7.	Endrin	21.	Chlorobenzilate
8.	Ethyl Mercury Chloride	22.	Dieldrine
9.	Ethyl Parathion	23.	Maleic Hydrazide
10.	Heptachlor	24.	Ethylene Dibromide
11.	Menazone	25.	TCA (Trichloro acetic acid)

S. No.	Name of pesticides	S. No.	Name of pesticides
12.	Nitrofen	26.	Metoxuron
13.	Paraquat Dimethyl Sulphate	27.	Chlorofenvinphos
14.	Pentachloro Nitrobenzene	28.	Lindane banned dated 25/03/2011
(b) Pesticide banned for use but their manufacture is allowed for export			
1.	Nicotin Sulfate	2.	Captafol 80% Powder
(c) Pesticide formulations banned for import, manufacture and use			
1.	Methomyl 24% L	3.	Phosphamidon 85% SL
2.	Methomyl 12.5% L	4.	Carbofuron 50% SP
(d) Pesticide withdrawn			
1.	Dalapon	5.	Paradichlorobenzene (PDCB)
2.	Ferbam	6.	Simazine
3.	Formothion	7.	Warfarin
4.	Nickel Chloride	8.	Sirmate
(e) Pesticides refused registration			
1.	Calcium Arsonate	10.	Azinphos Ethyl
2.	EPM	11.	Binapacryl
3.	Azinphos Methyl	12.	Dicrotophos
4.	Lead Arsonate	13.	Thiodemeton / Disulfoton
5.	Mevinphos (Phosdrin)	14.	Fentin Acetate
6.	2,4, 5-T	15.	Fentin Hydroxide
7.	Carbophenothion	16.	Chinomethionate (Morestan)
8.	Vamidothion	17.	Ammonium Sulphamate
9.	Mephosfolan	18.	Leptophos (Phosvel)
(f) Pesticides restricted use in India			
1.	Aluminium Phosphide	8.	Monocrotophos
2.	DDT	9.	Endosulfan
3.	Lindane	10.	Fenitrothion
4.	Methyl Bromide	11.	Diazinon
5.	Methyl Parathion	12.	Fenthion
6.	Sodium Cyanide	13.	Dazomet
7.	Methoxy Ethyl Mercuric Chloride (MEMC)