# CHAPTER IV
# DISCUSSION

This three year of intense research work in fields and laboratory gives us an insight vision into diversity of flora and fauna of agricultural and urban community gardens. This covers the economically important crops of the fields as well as some very beautiful large trees and plants of the garden. This survey took us into a chain of thoughts that what nature has given should be sustained and conserved by mankind. Diversity is essential to improve productivity, to enhance ecosystem functions and provide adaptability (Frison et al., 2011).

## Study period

The three year study period shows that overall diversity of insects in these three year time has either remained the same or the insect pest population can said to have been increased.

Some useful insects such as predators and parasitoids were showing declining trend. In the urban areas closer to fields, high raise buildings, multiplexes and urbanization has decreased the green cover and in course of time, affected the population of pollinators (honey bees) apart from a long list of insect pests (Cotton boll worm, Thrips, Whiteflies, etc).

The change in climatic variablities has led to increased frequency and intensity of outbreaks of pests and diseases. Similar type of report has been given by Hoffmann et al., (2008) where numbers of insect pests have increased due to global warming as a result of raise in temperature which ultimately increased pesticide utility and affect the non target insect species like pollinators, predators etc. Pompen et al., (2005) shows the effect of urbanization which includes the discharge of untreated industrial waste in river in Riodas velhas, Brazil, which causes decline in the fish population, benthos richness and diversity.

# Field work

These intense three year study showed persistence of aphids and mealybugs in the fields on an average of 7-8 months. In the month of May and June, there are no crops in the agricultural fields but during these specific months, good ornamental plants showed mealybug infestation. Here I personally found mealybug as major pest of Vadodara having economically important crops in agricultural fields and urban community gardens. The survey conducted by Tanwar et al., (2011) in Haryana, Punjab, Rajasthan, Gujarat indicated mild (10-20%) infestation of mealybug during 2007 which gradually increased to moderate (20-40%) in 2008 and reduced to traces in 2009.

In Vadodara, 31 host plant species were recorded from 17 different families. Similarly, Arif et al., (2009) reported 159 host plant species of mealybug, *Phenacoccus solenopsis* in Pakistan. Major hosts of the mealybugs in agriculture fields of Vadodara are *Gossypium arboretum, Ricinus communis, Abelmoschus esculentus, Lycopersicon esculentum, Solanum tuberosum* and *Solanum melongena*. The *Phenacoccus solenopsis* (Tinsley) is a major pest of *Hibiscus rosa-sinensis* (L.) in the Southern Guinea Savanna of Nigeria (Akintola & Ande, 2008).

Whereas *Hibiscus mutabilis, Tagetes erecta, Nerium indicum, Ziziphus mauritiana, Ficus bengalensis* and certain weeds forming hedges of fields like *Datura metel* and *Xanthium strumarium* that act as alternative hosts of mealybugs throughout the year. Dhawan et al., (2010) recorded *Phenacoccus solenopsis* from 22 plant species of 10 families comprising 7 field and vegetable crops, 3 ornamentals & 12 weeds. Plants from Malvaceae, Solanaceae, Compositae, Amaranthaceae, Asteraceae, Verbenaceae & Zygophyllaceae were generally found as preferred hosts of this mealybug. Among these, *Hibiscus rosa-sinensis* (Malvaceae), *Parthenium hysterophorus* (Compositae) and *Achyvanthes aspra* (Amaranthaceae) harbored this pest round the year and acted as a persistent source of spread of the mealybug to cotton and other crops. In eastern region of Sri Lanka, *Phenacoccus solenopsis* (Tinsley) causes major damage to hibiscus, brinjal, okra, chili, tomato and some other crops, ornamental plants and weeds of families Malvaceae and Solanaceae. Worldwide, the *Phenacoccus solenopsis*

(Tinsley) is known to attack plant species belonging to 31 families (Prishanthini, 2009). It was found to attack large number of plant species including crops, vegetables, ornamental plants and weeds (Abbas et al., 2010).

Damage by insect pest in agricultural fields has been the matter of serious concern in India and abroad. But, in Gujarat this is the first of its kind where the study have not stopped at identification level but has also gone much ahead by showing results of presence of useful insects and also the harmful ones. Unless segregation and classification of harmful and useful insects is done in the fields through exhaustive research, it becomes difficult to adopt biorational alternatives to pesticides for the agricultural crops in the fields.

## Population dynamics

Once the picture of harmful and useful insects is clear, the percentage population of both should be studied so as to suggest the type of control methods which can be utilized for specific insect pests and their respective host plants.

Even in gardens, where edible crops are less; to know the population of useful insects becomes important because richer the nectar source, better will be the flowering and more beautiful will be the garden. This will directly tell us the percentage population of pollinators, predators and parasitoids. This type of research gives a real picture of population and also if there is a decline then reasons for its declination. If not done than no one will even come to know about it. Sunding & Zivin, (2000) defined the importance of study of population dynamics of insect pests in the agricultural fields. They mentioned that this type of study is helpful for assessing the pesticide productivity and timing of pesticide. In absence of such factors, the decision for pesticide utilization can only be motivated by prevailing conditions at the time of application and thus, misses an important dimension of pesticide problem.

In Vadodara, five different species of mealybugs were collected and identified in the laboratory. They are Hemipteran *Phenacoccus solenopsis* and *Maconellicoccus hirsutus* Green, 1903 from the family Pseudococcidae and Homoptera *Ceroplastes ceriferus* Fabricius, 1798 from the family Coccidae. *Phenacoccus solenopsis* was considered as major pest in

Vadodara. *Phenacoccus solenopsis* infestation started appearing in the month of August which progressively increases with the advancement of crop growth. The highest level of *Phenacoccus solenopsis* population was seen in the month of February. This count appeared around to be 188 adults / 15 cm on apical shoot of host plants. Later, infestation of mealy bug declined gradually and reached around 77 adults/ 15 cm on apical shoot of agricultural crops in the month of April.

In general, predator population was low during cropping season. During 2008-09 and 2009-10 of study period, the average maximum population of Coccinellids and Chrysoperla were 0.24 and 0.16 per host plant, respectively during the season. The percentage presence of parasitoid cocoons ranged between 0.7 to 30.5 per cent per host plant in year 2008-09 whereas in 2009-10 it ranged between 0.5 to 35.4 per cent per host plant. Similarly in 2010-11, the average maximum population of Coccinellids and Chrysoperla were 0.28 and 0.2 per host plant whereas percentage presence of parasitoids cocoons ranged between 0.82 to 32.6 per cent per host plant.

In all three year of studies the activity of parasitoids started during $43^{rd}$ meteorological week and later reached peak during 6th to 8th meteorological week. The highest percentage parasitoid population (30.5 %, 35.4 % and 32.6 %) was recorded during $8^{th}$ meteorological week. From $9^{th}$ week onwards, it started showing gradual decrease in population.

Hanchinal et al., (2010) reported similar type of study on *P. solenopsis* in Agriculture Research Station, UAS, Raichur during 2008-09 recorded on NCS-145 BG-II cotton, grown over an acre in unprotected field, found that mealybug infestation started appearing in the month of September and gradually increased with the advancement of crop growth. The average population reached to 115.42/10 cm apical shoot in the third week of January and thereafter increased suddenly that it reached to an average of 180.42/10cm apical shoot in the $7^{th}$ meteorological week. Later on, infestation of mealybug declined gradually and reached to average of 146.64/10cm apical shoot in the $14^{th}$ meteorological week. They also reported that highest percentage of parasitoid (20.65 %) during $7^{th}$ meteorological week which coincides with the higher population of mealybugs. When they did correlation with weather parameter, they found that mealybug population was significantly and positively correlated with maximum temperature (0.775) and negatively correlated with other parameters.

Dhawan et al., (2009) also reported positive correlation between mealybugs and maximum temperature and negative impact of humidity and rainfall in Punjab which agrees with the present findings. There was positive correlation among the per cent field infestation, number of infested rows by mealybugs and temperature, whereas negative correlation was observed with relative humidity and rainfall. All the meteorological parameters influenced the incidence of mealy bug on cotton in all the districts studied in Faridkot district of Punjab where r-value is 0.71 in per cent infestation by mealy bug and 0.76 in rows infested by mealy bug.

During the study period, it was also observed that the mealybug, *Phenacoccus solenopsis* shared a mutual interaction with *Monomorium Pharaonis* Linnaeus, *Monomorium minimum* Buckley; *Camponotus compressus* Fabricius and *Tapinoma melanocephalum* Fabricius of ants (Table 2). Similar type of research was reported from Pineapple research Institute of Hawaii by Jahn et al., (2003) who recorded 28 different species of ants associated with mealybug of pine apple. In India, seven species of ants were recorded which are associated with *Phenococcus solenopsis* from Haryana (Kedar et al., 2011). These ants showed foraging behaviour on the honey dew secretion of *Phenacoccus solenopsis.* Such type of association is known as trophobiosis (Delabie, 2001).

In our research on the ant association with mealybug, *Phenacoccus solenopsis,* it was found that in the presence of ant population, the density of mealybug was found high. Helm & Vinson, (2007) in the Southeast of United States also reported that the increase in the population of ants *Solenopsis invicta* causes an increase in the population of mealybug, *Antonina graminis.* Population of mealybug was also affected by the presence and absence of biocontol agents. But due to the presence of ants, the population of biocontrol agents get affected which causes an inverse positive impact on mealybug population.

In Channi fields, when mealybug *P. solenopsis* were attended by population of *Tapinoma melanocephalum* and *Monomorium pharaonis,* it was found that the population of predatory larvae, *Scymnobius sordidus* belonging to Coccinellidae family and the number of parasitoid cocoons of *Aenasius bambawalei* (Graph 3) gradually decrease. Simultaneously, it was also found that *P. solenopsis* form the major attenders of *Camponotus compressus* on *Hibiscus rosa-sinensis* (Linn.) in urban community gardens of Vadodara.

Similarly, Styrsky & Eubanks, (2007) reported 76% increase in the activity of predators against hemipterans due to removal of ant species, *Formica propinqua.* Daane et al., (2007) in California reported the increase in the population of obscure mealybug, *Pseudococcus viburni* and lowered densities of its parasitoids, *Pseudophycus flavidules* and *Leptomastix epona.* It was also observed that *C. compressus* move adult mealybugs from one plant to other by holding it in its mouth. Hence, *Camponotus compressus* usually acts as one of the reason of *Phenacoccus solenopsis* dispersion from one plant to other in cotton, okra and ornamental plants in Vadodara. Hence, ants build good shelter for the mealybugs which is inturn helpful for its prolonged persistence. Therefore the effective removal of weeds or alternative plants and proper management of ants will be highly significant for the management of mealybug *Phenacoccus solenopsis.*

## Biorational alternatives

In Vadodara, following fields located in different direction were visited i.e. in Channi (North), Varanama (Southwest), Waghodia (East) and Dabhoi (Southwest). The importance of field visits has become the prime need for such type of survey and research not only in Vadodara or entire Gujarat but also for entire India. These visits gave present scenario of utilization of biorational alternatives used in Vadodara. We found that in Vadodara, these biorational alternatives are used in very less quantity. But, even with the minimum consumption, it gives certain extent of positive result which minimizes the load of pesticides in the agricultural fields.

Vadodara markets have Spodo lure, Heli lure, Earis lure, Scripo lure, Pectino lure and Bacu lure but, unfortunately their field consumption is very less and it is limited to the fields where only the Heli and Spodo lures are used.

Heli lure are used in Dabhoi fields, on cotton crops during flowering season and which are showing good result by trapping > 1000/ trap.

Spodo lure which is used in Waghodia field on cotton and castor fields during flowering season shows similar type of result by trapping 700-800 insect pest/ traps.

But remaining lures such as pectino lure, scripo lure and bacu lure was rarely seen to use in agricultural fields of Vadodara during three year of study period.

Some of vital information on the less popularity of pheromone used by farmers of Vadodara was collected personally, through discussions, literatures and field visits. This information is so vital that if they are rectified/ improved, the use of pheromone as commercial product will go a long way not only in Vadodara but all throughout India in the field of agricultural science.

1. Proper fixing facilities are not provided in the trap itself for farmers to use it properly in the fields.
2. Poor quality rubber band which is tied around the neck and bottom of the sleeve of the trap creating difficulty in fixing the trap.
3. Improper fixing of trap and improper tieing of rubber band at bottom of sleeve causes tilting of trap to one side allowing visiting insects to escape easily.
4. Poor quality plastic sleeve which has to work for one month becoming brittle and tear off early.
5. Improper fixing of lures in the trap and also use of very thin or damaged bamboo sticks which cannot even withstand heavy winds have been one of the prime reason for less utility of pheromones.
6. Some times, proper quality of materials are not used for the manufacturing of the traps and so fails to work for longer period in the field conditions.
7. The quality of pheromone component also varies which donot give marked result. This may be due to lack of high purity of the pheromone components used for actual blend of the pheromone (above 97%).

8. The availability and supply of the pheromone traps and lures is not easy to the farmers as compared to insecticide shops.
9. Moreover, there are some illiterate farmers who are not able to read the instruction given for installation of the traps, lure and also lack of proper instructions with flow diagrams for proper installation of the traps and lures along with the pheromone traps makes it more difficult for its utility.
10. Their lack of regular training at the extension agencies on the installation and the methods adopted on the monitoring, mass trapping and communication disruption of the insects using the pheromones. Thus, the farmers remain unaware about the proper installations of the traps and the actual number of traps /unit area.
11. Hence due to the above mentioned, problems farmers are not willing to purchase the fresh lures every time as this method becomes expensive for farmers.

Although it is having following advantages and disadvantages the lures are less popular among farmers of Vadodara.

**Lure advantages**

- They are economical, effective and eco friendly.
- Easy to use.
- Can also work simultaneously with other control methods.
- Not hazardous / no adverse effects on health and environment.
- Insects are not showing resistance towards pheromones

**Lure disadvantages**

- Limited no. of lures present in market for different insect pests. This work is still new in India.
- Dependence on environmental conditions.
- Its less popularities / lack of awareness among farmers of India.

The disadvantage of species specific lures can be covered by focused research in Tradition University on isolation and characterization of biolures, their synthesis in R & D section and their field trials by agricultural university. This type of coordinated and collaborated work can do wonders which can change the present agriculture scenario of India.

Isolation of insect pheromone is very less popular among Tradition University of India. But, there are few institutes and research foundations that focus on isolation and identification of pheromones like Indian Institute of Chemical Technology, Hyderabad and Asthagiri herbal research foundation, Chennai, Tamilnadu institutes.

For synthesis of the components of pheromones of all the major insects, the following centers of excellence and commercial establishments can be approached:

1) Indian Institute of Chemical Technology (CSIR), Hyderabad
2) Central Coffee Research Institute Coffee Research Station, Karnataka
3) Bhabha Atomic Research Centre, Mumbai.
4) Indian Lac Research Institute (ICAR), Ranchi

For field trials, in India, monitoring of the key insect-pests such as *H. armigera, S. litura, P. gossypiella*, were undertaken in the 1980s. Intensive work has been done on these insects spreading over Karnataka, Haryana, Madhya Pradesh, Tamil Nadu, Andhra Pradesh, Maharashtra, Himachal Pradesh, Punjab and Gujarat. Pant University, Punjab Agricultural University, Banashkantha University, Anand Agricultural University, ICAR institutes carry out frequent field trials for knowing the effect of lures.

In our research, isolation and identification of mealybug lures are giving positive result. This result motivates us to collaborate with chemistry department of our university for synthesis work. Hence, the collaboration is needed.

Like our research, if each university picked up one insect model studies its biology by rearing and breeding them in the laboratory and tend to isolate the lure, then it can change the presence status of number of lure production in India which is at present 13 but can be made 31 soon.

## Laboratory work

Once it comes to biorational alternatives for minimizing insecticides utility, the field work alone is not sufficient. Since last 15 years, Entomology Division of the Department of Zoology, Faculty of Science, The M.S. University of Baroda, Vadodara has extensively done the field studies on diversity of insects with special emphasis on excellent research on ants and termites. Pardeshi et al., (2010) identified 15 species belonging to 2 families and 7 genera of termite from the agricultural fields of Vadodara. Mishra & Kumar, (2009) found 13 families of ants.

Work has also been done on the role of spiders as bio control agents in agriculture fields as well as the role of social spider in agro ecosystem. Siliwal, (2000) identified 20 families, 62 genera and 114 species of Spiders and emphasized the role of Spiders as biological control agent of insect pests. Spiders research is continued by Kumar & Shivakumar, (2004) working on the recent status of IPM in agricultural fields of Gujarat. Kumar, (2007) worked on role of spiders as bio-control agents to minimize the use of pesticides in the agricultural fields of Vadodara. But extending this research in lab was equally important hence to initiate, the Entomology Division carried out lab studies. Kumar & Yashkamal, (2011) studied the prey spectrum of social spiders *Stegodyphus sarasinorum* (Karsch) (Araeneae: Eresidae) and its potentialty as biological control agents.

This research also emphasized that *Phenacoccus solenopsis* (Tinsley) (Hemiptera: Pseudococcidae) has been the current topic of research for insect taxonomists and applied entomologists in India due to its invasiveness, rapid spread, morphological and biological variations and the need for establishing an effective control strategy.

One component of the earlier research has already shown the effect of insecticides in the fields. It shows that the mealybugs are not controlled by pesticides. The high dose of insecticides is affecting the non target insects. But, to give biorational alternatives to chemicals are another important research work. Hence, biology, effect of biological control agents, use of botanicals and chemical ecology of mealybugs has been taken up for laboratory experiment work.

The exercise is extensively difficult as the size of insect was very tiny (Male of 1.49-1.5mm and female of 2.0-3.0 mm) and equally difficult was to rear and breed but was worth to conduct the experiment as it gives fruitful result in biorational way.

To learn its biology, field collected adult female mealybug were reared in insect house of Zoology Department at 20-25°C under a photoperiod of 16L: 8D at humidity of 70-75% RH condition on the hibiscus twigs (Twigs end was rapped with wet cotton) kept in plastic box (20 x 15 cm2) in laboratory. Narai & Murail, (2002) reared other species of mealybug, *Planococcus kraunhiae* on germinated broad bean seeds as an alternative food source at approximately 70% relative humidity and 25°C. This was further use for learning its biology.

## Biology

During our study, we found that male of *Phenacoccus solenopsis* had two nymphal instars, pupal and adult stage (winged) while the female had three nymphal instars and the adult stage (wingless). The adult female of *Phenacoccus solenopsis* had pre-oviposition, oviposition and post oviposition period of 7.120 ± 0.7810, 14.04 ± 0.9781 and 3.560 ± 0.7118 days, respectively. The male was short lived with an adult life of 1.960 ± 0.8406 days, while female lived longer (24.44 ± 2.329 days). In the present studies, the total life duration of female ranged from days (39.88 ± 3.127 days) and that of male from days (19.20±1.756 days). The female formed 3.520±0.7141 ovisacs during its life span in which around 540.8 ± 107.2 eggs were deposited that hatched within few minutes (3.634 ± 0.7342 minutes).

Similarly, Kedar et al., (2011) studied the biology of mealybug *Phenacoccus solenopsis* under laboratory condition on potato sprouts at CCS Haryana Agricultural University, Hisar. Total Life span was 39.12+ 2.85 and 18.60+1.5 days in case of female and male respectively. The female had three nymphal instars and adult stage while male had two nymphal instars, pupal and adult stage. The pre-ovipostion, oviposition, post oviposition, fecundity and incubation period of eggs were 7.52+1.12, 14.36+2.53, 3.72+1.14 days, 746.08+ 141.1 crawlers/female and incubation period is 3.21+0.93 minutes, respectively.

Nikam et al., (2010) studied the biology of *Phenacoccus solenopsis* Tinsley in Biocontrol Research Laboratory, Anand Agricultural University, Anand during the year 2006-07 at temperature and relative humidity range from 25 to 30°C and 75 to 80%, respectively on pumpkin. They found that longevity of female ranged from 32 to 35 days with an average of 33.67 ± 1.19 days. Total life cycle lasted for 55 to 60 days with an average of 58.00 ± 3.72 days. Whereas longevity of males ranged from 7 to 10 days with an average of 8.70 ± 0.79 days and total life cycle ranged from 25 to 30 days with an average of 26.73 ± 2.20 days. The further observations on pre-oviposition, oviposition, and post oviposition periods of *P. solenopsis* revealed that it varied from 8 to 9, 16 to 18 and 9 to 10 days with an average of 8.56 ± 0.61, 16.73 ± 0.57 and 9.33 ± 0.47 days, respectively. Total number of eggs laid by a single female during its entire life period ranged from 400 to 700 eggs with an average of 572 ± 102 eggs.

## Biological control

During the present study, 6 natural enemies of the pest were spotted which belong to order Coleoptera, Neuroptera and Hymenoptera from Vadodara fields. Similarly, in Egypt, natural enemies reported against Citrus mealybug, *Planococcus citri* (Risso) are *Sympherobius amicus* (Navas), *Scymnus syriacus* (Mars), *Chrysoperla carnea* (Stephens) and parasitic species *Coccidoxenoides perminutus* (Timberlake). The infestation of *Planococcus citri* (Risso) on the ornamental plant Croton, *Codiaeum variegatum* (L.) was controlled by using coccinellid predators, *Cryptolaemus montrouzieri* (Muls) (Afifi et al., 2010). Similarly Jose et al., (2011) found seven species of predatory coccinellid beetles belonging to sub family Scymninae from vegetable field of Kerala associated with sucking pest.

The presence of *Aenasius bambawalei* (Hayat) shows 60-70% parasitization percentage in the Vadodara fields. This shows it is most effective biocontrol agent against *Phenacoccus solenopsis*. Similar type of research was found at research sites in the Dominican Republic and

Puerto Rico where the release of the four genera of parasitoid wasps has brought 99.7% and 97% reduction in the density of mealybug populations, with parasitism levels between 35.5% and 58.3% (Meyerdirk & Kauffman, 2001).

In Palau, during 2006, there was a reduction in the population of *Paracoccus marginatus* within six months after introduction of parasitoids and it was considered to be reducing the possibility of mealybugs to spread to the other areas of the field (Muniappan et al., 2006). Lacewing *Sympherobius fallax* (Navas) larvae are known to feed on the second instars of *Pseudococcus longispinus* (Targioni-Tozzetti) which are major pest of fruit, crop plants, vegetables, ornamental and greenhouse plants (Gillani et al., 2009).

For control of this pest, the farmers of Vadodara heavily depend upon the chemical methods and use of various insecticides (mainly organophosphates). Such extensive use of pesticides is reducing the predator's population. Mansour et al., (2011) found that the organophosphate (chloropyrifos-methyl) which is used for control of *Planococcus ficus* in vineyards is most toxic insecticide which shows 100% mortality of *Aenasius sp.* within 24 hrs of spray.

Present study shows that the use of pesticides resulted in delay emergence of biocontrol agent. The insecticides tested against *Phenacoccus solenopsis* showed that the imidacloprid is most effective at very low dose when applied topically under laboratory condition as compared to the dose used for control of mealybug. Golmohammadi et al., (2009) also found that the imidacloprid is most toxic against fifth instar larvae of *Chrysoperla carnea* under laboratory condition.

The use of the systemic insecticide imidacloprid showed limited efficacy due to its improper mode of application in the field. In Tunisia Mansour et al., (2010) who reported the use of imidacloprid through drip irrigation system, found it more effective in the vineyards for the control of vine mealybug and considered it as a promising option for its control.

The farmers at study area mostly expressed their concern that by relying only on the pesticides for management of the cotton field infestation by mealybugs did not give desired results. The infestation of mealybugs causes the major yield loss in agriculture fields. This is a worldwide occurrence. During 2007 in Pakistan due to the emergence of a new cotton pest, the mealybug *Phenacoccus solenopsis* (Tinsley) caused a damage which was estimated around 3.1 million bales of cotton. Apart from yield loss, the cost of insecticides application increased by Rs. 11,265- 16,891 / acre in both India and Pakistan (Nagrare et al., 2009). Many farmers as a result, incurred a heavy yield loss due to mealybug infestation in this area too.

The farmers were driven to extensive use of insecticides against mealybug in Vadodara and this practice was showing adverse effect on natural enemies (non-target effects) of the pest. This was apart from the undesirable effects of the insecticide resistance shown by the pest and on natural enemies. The chemical control has become a less desirable option to combat the mealybug. Use of broad spectrum insecticides like chloropyrifos also caused adverse effect on the natural enemies such as *Coccidoxenoides peregrinus* (Timberlake) (Hymenoptera: Encyrtidae) of *Planococcus ficus* (Signoret) (Walton & Pringle, 1999). In South Africa too, use of contact insecticides like Synthetic pyrethrin (Cypermethrine), Carbamate (Mancozeb) against Vine mealybugs showed adverse effect on the development of parasitoids *Anagyrus* sp. and *Coccidoxenoides perminutus* (Mgocheki & Addison, 2009). There is an urgent need for the development of proper strategies to control the *Phenacoccus solenopsis* (Tinsley) by slowly weaning away the farmers from the tendencies that heavily depend on the use of pesticides to a more ecofriendly biocontrol agent mediated pest management.

It is interesting to recall that in California's extensive grape-growing regions, although organophosphate, nicotinoids (imidacloprid) and insect growth regulators (buprofezin) were used for controlling vine mealybug *Planococcus ficus* (Signoret), the use of biological control and mating disrupter was providing promising results and could be considered as an alternative to standard organophosphate insecticide controls (Daane et al., 2006). Even Armenta et al., (2003) in Southern Mexico found that the use of synthetic insecticides i.e. carbamate (carbaryl), pyrethroid (cypermethrin), and organophosphate (chloropyrifos, methamidophos) insecticides cause reduced abundance of insect natural enemies when compared with nucleopolyhedrovirus on *Spodoptera frugiperda.*

## Botanical control

Plant extracts selected for the studies have been reported to cause or inhibit the bioactivity of several insects. The three plant leaf extracts cause the repulsion of mealybugs under laboratory condition. Repellency was recorded by using methanol leaf extract showed repellence activity in following order *Azadirachta indica* (A. Juss.) > *Eucalyptus globules* (L.) > *Ocimum basilicum* (L.) against mealybugs.

The highest repellency was recorded in case of *Azadirachta indica* (A. Juss.) leaf extract (97.0%) followed by *Eucalyptus globules* (L.) leaf extract (93.0%). Minimum repellance activity was seen in *Ocimum basilicum* (L.) leaf extract (88.0%) at 10% concentration against mealybug. In Tamil Naidu agricultural university, Sathyaseelan & Bhaskaran, (2010) found the highest repellency by *Azadirachta indica* (A. Juss.) (99%), kernal extracts (99%) then *Ocimum basilicum* (L.) (90.1%) leaf extract after 48 hours of release against *Maconellicoccus hirsutus* (Green) which was major pest of mulberry crop.

The repellent property of the plant extracts was due to presence of active compounds. The plant extract of *Azadirachta indica* which is globally accepted as good green insecticides having bio-active alkaloid, Azadirachtin and other tetranortriterpenoids compounds are responsible for the repellency (Jeyasanker, 2005). Neem products have been reported to reduce the infestation of various insect pests. Jaglan et al in 2011 found that the neem is good ovicidal for *Helicoverpa armigera.*

In Zambia, Mukanga et al., (2010) tested leaf powder of *Eucalyptus globules* and *Azadirachta indica* for its insecticidal activity against larva and adult of *Prostephanus truncatus* Horn found neem as good anti-feedent and repellent than eucalyptus.

Okigbo et al., (2010) found that *Azadirachta indica* (A. Juss.) leaf extract caused 100% mortality to *Culex* larva species after 24 hour at concentration of 40% where as 100% mortality was seen at 50% concentration of *Ocimum gratissimum* L. after 24 hours.

Tandon & Sirohi, (2009) found that ethanol extract of *Azadirachta indica* was showing good repellent activity against *Raphidopalpa foveicollis* (Lucas.) which is major pest of cucurbits crops. *A. indica* comes under repellency of Class IV (60.1-80%).

Asogwa et al., (2010) emphasized on the use of *Azadirachta indica* A. Juss which is biodegradable pesticide for the control of brown coca mirids, *Sahlbergella singularis* Haglund which cause major damage to coca in Nigeria.

Lekshmi et al., (2011) conducted field experiment by using neem product (neemol, neem azal, neem baon and econeem) in brinjal fields of Punjab and found the reduction of *Leucinodes orbonalis* population as well as whiteflies population.

The mealybug *Planococcoides njalensis* (Dist.) and its attendant ants, *Pheidole megcephala* and *Camponotus* sp. and some minor pests, including the mirid *Helopeltis* sp. and the psyllid *Tyora tessmanni* (Aulm.), were also adversely affected by the crude neem extract and the commercial neem formulations, especially Neem Azal (Padi et al., 2000).

Much work on the selected plants were done on different agricultural as well as store insect pests. Results obtained from the laboratory bioassay studies demonstrated the good potential of these plants in field trials. These plants are consumed and also utilized by human beings. Thus, it is safe for environment and non target organisms like human. These plants are found in abundance at study area which can easily utilized by local farmers. Therefore, these plants can be utilized for preparing phytochemical products which are good alternatives to synthetic insecticides as they are safe, economical and readily available in many areas of world.

## Pheromone

A perusal of literature published in last 12 years shows that around 120 papers were published in the field of pheromones from India. Pheromone research endeavor persisted throughout the 1980s with the identification of numerous pheromones of pests of economic importance in South Asia (Cork and Hall, 1998). Cork et al., (1985) were the first to identify the chemical nature of the sex pheromone from *Scirpophaga incertulas*, a major pest of rice and now in market as Scirpo-lure. Later Cork et al., (2001 and 2003), made considerable efforts to develop a pheromone-based system for the control of *Leucinodes ordonalis*, brinjal fruit and shoot borer. In Cork et al., (2005) developed pheromone trap system for mass trapping Brinjal borer, *Leucinodes ordonalis* in South Asia.

During the years Nesbitt et al., (1975, 1978, 1979 and 1980) worked in Sudan, Malawi and India on identification of the female sex pheromones of *Spodoptera litura, Helicoverpa armigera, Chilo suppressalis* and used it for mating disruption. This came as a blessing for the farmers and the environment which minimized the large amount of insecticide consumption for controlling these economically important pests.

In India, Narasimhan, (1995) of Asthagiri herbal research foundation, Chennai, Tamilnadu, identified the pheromones of the early shoot borer, *Chilo infuscatellus*, and internode borer, *Chilo sacchariphagus* pests of sugarcane. Krishnaiah et al., (1998) in Gunter district, Andhra Pradesh, worked on pheromone monitoring of yellow stem borer, *Scirpophaga incertulas* for mating disruption. Jhala, (2005a,b) explored the various modified traps for their trapping efficiency against *Leucinodes orbonalis* male moth in Anand Agriculture University, Anand, Gujarat. Kumar, (2008) at ICAR Research Complex, Goa, developed rapid decision sampling plan for the management of red palm weevil *Rhynchophorus ferrugineus* in coconut plantation of India. Arivudainami & Chandar, (2009) in Nagapattinam, Tamilnadu consider *Lampidus boeticus* as major pest and tried different bio product for its management through field trials.

During my research, the isolation and identification of volatile of *Phenacoccus solenopsis* from crude n-Hexane solvent extract was done by using GC-MS. The collected air born volatiles in n-hexane were identified as ester and terpenes. In this, the 2, 2, dimethyl-isopropenyl cyclobutane methyl ester is belonging to sex pheromone in other species of mealybug like *Macollinecoccus hirsutus* (Zhang et al., 2005). Terpenes such as 3,7,11,15-Tetramethyl-2-hexadecen-1-ol and 2,6,10,15,19,23-Hexamethyltetracosa-2,6,10,14,18,22-hexaene are identified from volatile extracts that mainly act as kariomones. The role of Hexadeconoic acid and 2- Cyclohexane-1-ol are also identified which act as attractance in *Agelastica coerulea* and *Alnus Glutinosa* (Jung et al., 2000a). Both also act as precursors for the formation of pheromone. These kairomones can be used for attracting female mealybugs which can reduce its population in the fields.

Arai, (2003) from Japan identified ester compound from *Pseudococcus cryptus* female. This pest was a serious problem to the highly valued cultivated greenhouses of Japan. Similarly, Sugie et al., (2008) from Japan identified ester as sex attractant component from *Planococcus kraunhiae* which is known to be euryphagous pest of fruit trees, such as pear, citrus, grapes and persimmon. Millar et al., (2005) identified monoterpene from sex pheromone of the obscure mealybugs. In U.S. El-Sayed et al., (2010) identified 2- acetoxy, 3-methylbutanoate as sex pheromone from *Pseudococcus calceolariae* which is a major pest of citrus, grapes, sugarcane and apple.

With these findings on biodiversity, biology, effect of insecticides and botanicals on the mealybug *Phenacoccus solenopsis* as well as a major result of extracting the lure from the important field insect pest was done. The use of all above mentioned biorational alternatives in the integrated way will increase the yield and reduce the pesticide spray in the fields of Vadodara. Dhawan et al., (2011) emphasized on the use of IPM in Punjab in wheat and rice fields which reduce the 49.25%, 37.74% and 49.23% in number of spray. The use of IPM reduces the incidences of stem borers, leaf folders and plant hoppers and increased the natural enemies. There is reduction in number of spray, spray cost and increased yield. Similarly Grewal et al., (2011) showed that 36% increase in income of the farmers adopting IPM in cotton belt of Punjab agricultural fields. We expect that this piece of research will contribute very significantly in the field of integrated pest management.

## Future plane of work

Insects like aphids, *lampidus boiticus*, etc. also need to have their lure for its control.