CHAPTER III

RESULTS

Field work

Identification and assessment of damage by insect pests to the economically important crops of urban community garden and agricultural fields

The present research work has been carried out in Vadodara situated in the central part of West Gujarat having a number of agricultural fields surrounding it. Economically important plants of urban areas were equally prone to insect pest infestation as was the case in the crops within the agricultural fields. It was not possible as a researcher to totally omit the urban areas and begin the work only with the agricultural fields. Hence, a recurring survey of the gardens within Vadodara was also been done. The major crops of these fields are Cotton, Castor, Sugar cane, Pigeon pea, Ladies finger, Brinjal, Radish, Cauliflower, Wheat, Maize, etc. The study revealed that out of 382 insect species 49 species of insects are pests in Vadodara.

The maximum numbers of insect pests are identified from the orders Hemiptera and Lepidoptera having 16 and 13 species respectively. Coleoptera is having 9 insect pest species. Minimum insect pests are from the Orders Orthoptera and Thysanoptera having 2 species each whereas from the order Diptera only 1 insect species has been found damaging the crops (Table 7). The survey also pointed out the status of mealybugs as a major pest of Vadodara fields that prompted the initiation of research on this pest. As a first step information were collected regarding diversity and biology of all insects which are infesting agricultural field crops of Vadodara.

Personal interview with farmers suggested that one of the major insect pests in the fields is mealybug, which is not responding to the chemical control method. Therefore this had motivated me to take mealybug for further studies. The different species were collected and identified in laboratory. In Vadodara, five different species of mealybugs were collected and

identified in the laboratory (keys are given in Annexure V). The identified mealybugs are belonging to three different families. They are Hemipteran *Phenacoccus solenopsis* (Figure 20), *Maconellicoccus hirsutus* Green, 1903 (Figure 18) and *Ferrisia virgata* Cockerell, 1893 (Figure 16 & 17) from the family Pseudococcidae; Homoptera *Ceroplastes ceriferus* Fabricius, 1798 (Figure 19) from the family Coccidae and *Icerya purchasi* Maskell, 1878 (Figure 14 & 15) from the family Monophlebidae. Out of these the *Phenacoccus solenopsis* is a major mealybug species infesting all crop plants during study period.

Mealybug, *Phenacoccus solenopsis*

The present study showed that the population of the mealybug, *Phenacoccus solenopsis* (Tinsley) (Hemiptera: Pseudococcidae) is a major concern for all economically important crops in agriculture fields of Vadodara. It is a major threat to agriculture and horticulture in many tropical and subtropical countries. Mealybugs or pseudococcids comprise the second largest family of scale insect (Downie & Gullan, 2004).

A continuous survey of agricultural fields showed that presence of favorable ecological conditions and alternative hosts causes the increment in the population as well as the areas of infestation of mealybugs. This species is also having multiple advantages of parthenogenesis and presence of ovisacs for population explosion and ability to withstand extremes of environmental temperature from 0^{o} C to 45^{o} C during crop free periods (Bambawale, 2008).

Nature of damage

Infested growing points become stunted and swollen which may vary depending upon the susceptibility of each host species. Heavy clustering of mealybugs can be seen under leaf surface giving the appearance of a thick mat with waxy secretion. They excrete copious amount of honey dew that attracts ants and help in development of black sooty mould which inhibits the plants ability to manufacture food.

Both nymphs and adults suck the sap from leaves causing withering and yellowing of leaves. Fruit of crop plant may drop prematurely. Heavy infestation can cause defoliation and even

death of the plant. Mealybugs also affect the development of flowers and stems (especially in succulents with fleshy stems). Host plants that are affected by mealybugs show curled leaves some times with bunchy tops (Figure 34 & 35). Infested plants can exhibit general symptoms of distorted and bushy shoots, crinkled, twisted bunchy leaves, and stunted plants that may dry completely.

Mode of spread of mealybug

During field survey, it was found that *Phenacoccus solenopsis* dispersed by a number of different biological and physical means. Nymph 'crawlers' (first instar) can play a key role in dispersal over the host plant and can be responsible for spreading the mealybug population to new host plants. Sometimes, these crawlers were seen on the lower part of the host crops just above the soil. During irrigation it was observed that the mealybugs are dispersing with water.

During studies in urban community garden the gardener gave information that sometimes the plants collected from nurseries were already infested by *P. solenopsis.* Therefore, the establishment of proper quarantine lows can prevent the spread of mealybug. Mealybugs can also be transported by machinery, tools, equipment and soil movement during cultivation and repeated transplanting operations conducted at different times. Thus, appropriate hygiene measures applied to these items may also be an effective way of reducing dispersal.

Finally, from personal field observation it was also found that the ants were helpful in dispersal of mealybug, *Phenacoccus solenopsis.* Cotton mealybug, *Phenacoccus solenopsis* secretes honey dew (a sugary solution) which attracts ants and they are having association with the ants. Ants are also act as transporting agents of the mealy bugs. Such type of association is known as trophobiosis (Delabie, 2001). During the study period, it was also observed that the mealybug, *Phenacoccus solenopsis* shared a mutual interaction with *Monomorium pharaonis* (Linnaeus) (Figure 36), *Monomorium minimum* (Buckley); *Camponotus compressus* (Fabricius) (Figure 37) and *Tapinoma melanocephalum* (Fabricius) (Figure 38) of ants (Table 8). 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 (Graph 2).

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 agent gets affected which gives 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 1) gradually decrease. Simultaneously, it was also found that *P. solenopsis* form the major attainders of *Camponotus compressus* on *Hibiscus rosa-sinensis* (Linn.) in urban community gardens of Vadodara.

It was observed that *Camponotus compressus* moves adult mealybugs from one plant to other by holding it in its mouth (Figure 39). Hence, *Camponotus compressus* usually act 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 mealybug which is 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*.

Figure 14 *Icerya purchasi* Maskell

Figure 15 *Icerya purchasi* Maskell

Figure 16 ***Ferrisia virgata*** **Cockerell**

Figure 17 ***Ferrisia virgata*** **Cockerell**

Figure 18 ***Maconellicoccus hirsutus*** **Green**

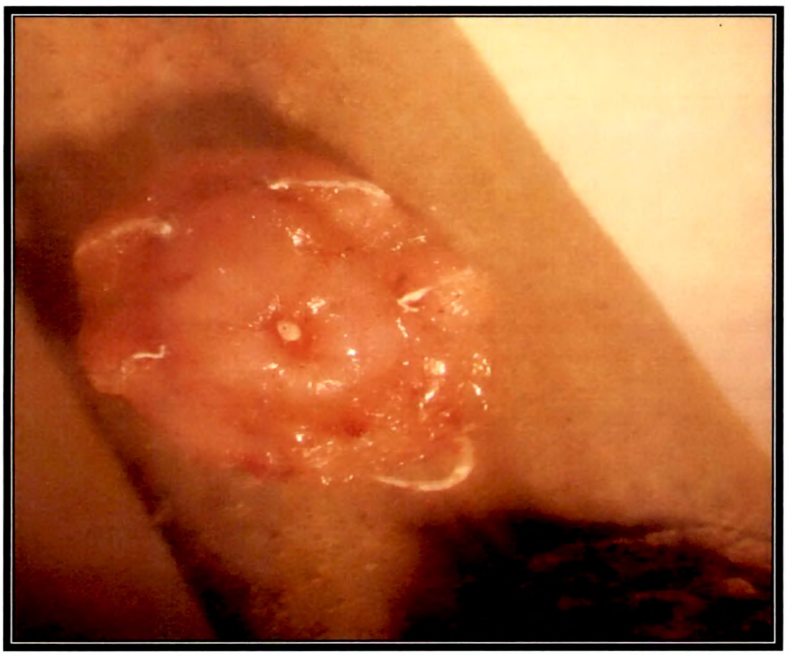


Figure 19 ***Ceroplastes ceriferus*** **Fabricius**

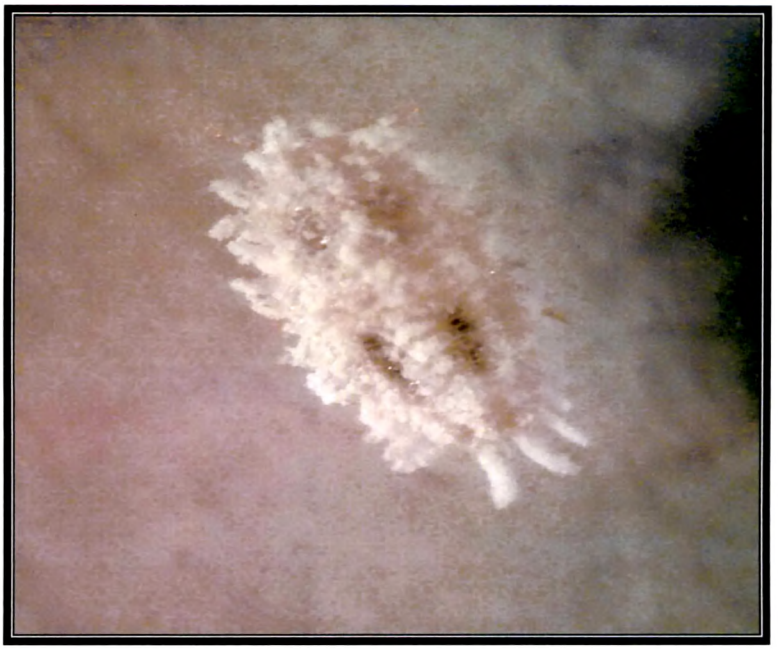


Figure 20 *Phenacoccus solenopsis* Tinsley

Figure 21 Honey dew secreted by *Phenacoccus solenopsis* Tinsley

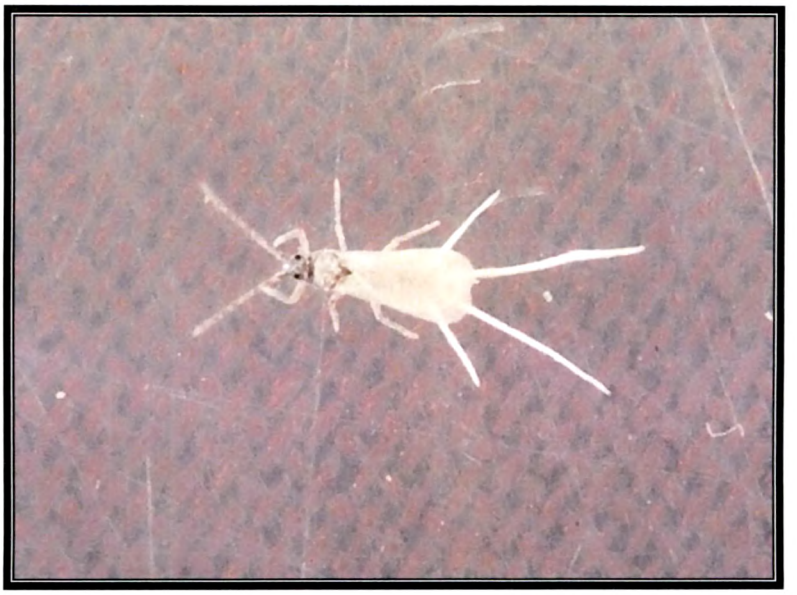


Figure 22 Male of *Phenacoccus solenopsis* Tinsley

Figure 23 Copulating male and female of *Phenacoccus solenopsis* Tinsley

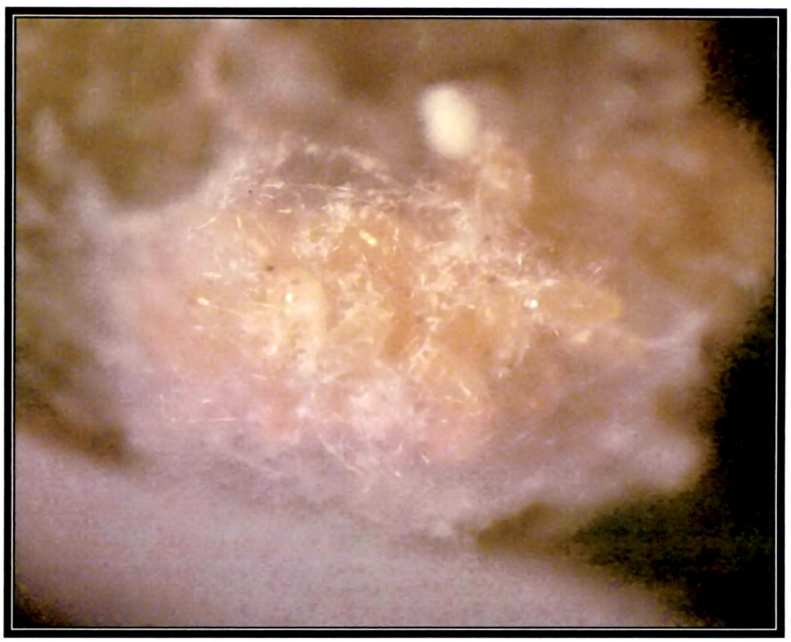
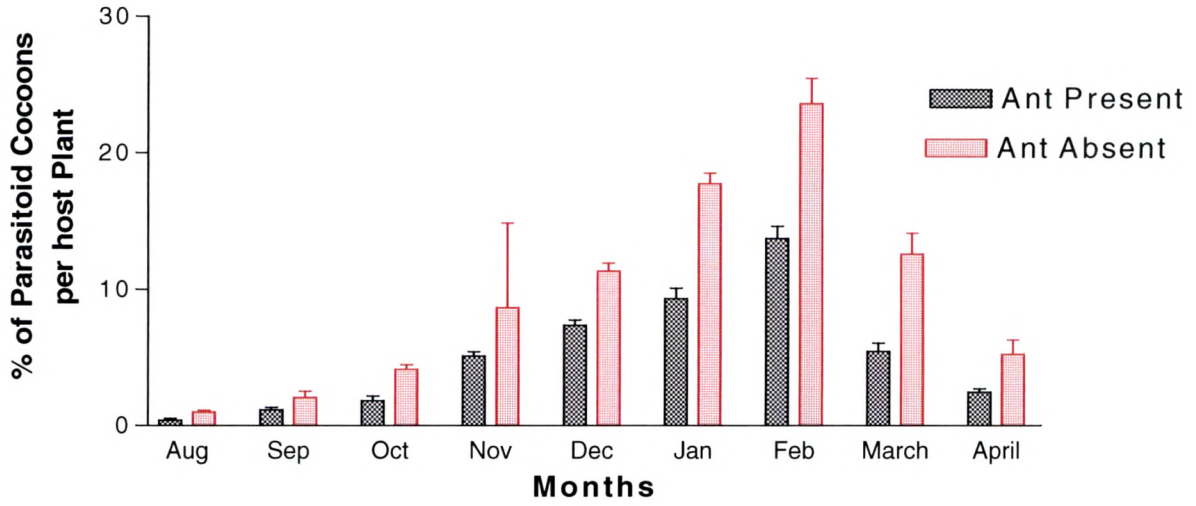


Figure 24 Egg mass of *Phenacoccus solenopsis* Tinsley

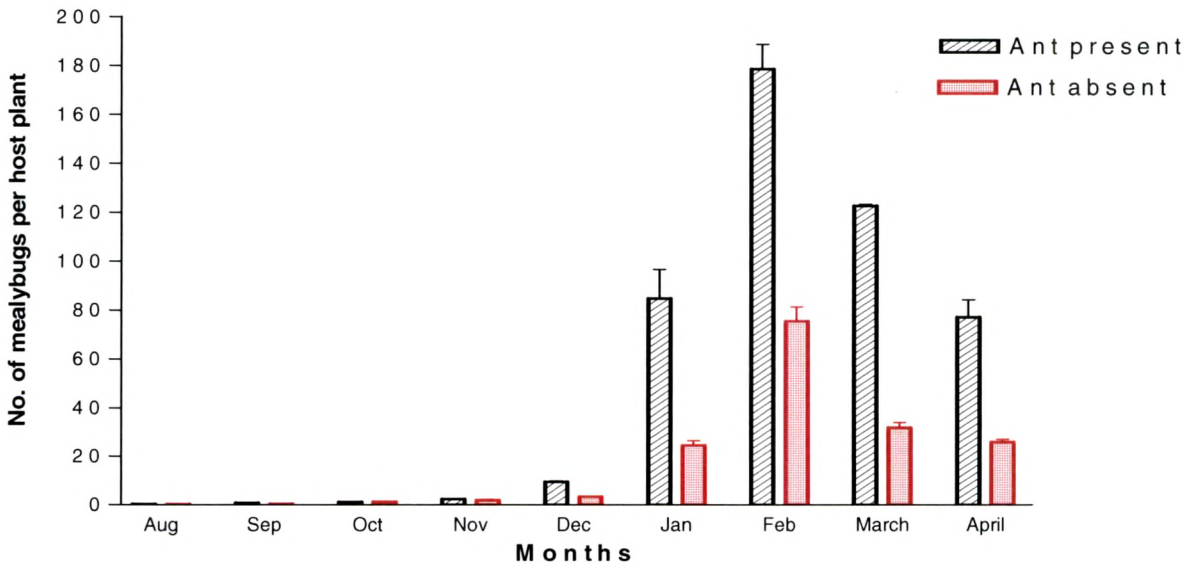
Table 8 Ants (Hymenoptera: Formicidae) associated with *Phenacoccus solenopsis* Tinsley on different host plants in selected sites of Vadodara

Family	Sub family	Scientific name	Host plants
Formicidae	Formicinae	*Camponotus compressus* Fabricius,1787	*Gossypium hirsutum* (L.)
			Abelmoschus esculentus (L.)
			Hibiscus rosa-sinensis (L.)
			Hibiscus mutubilis (L.)
			Ficus bengalensis (L.)
			Lantana camara (L.)
			Xanthium strumarium (L.)
			Parthenium hysterophorus (L.)
			Tagetes erecta (L.)
	Dolichoderinae	*Tapinoma melanocephalum* Fabricius,1793	*Gossypium hirsutum* (L.)
			Abelmoschus esculentus (L.)
			Hibiscus rosa-sinensis (L.)
	Myrmicinae	*Monomorium pharaonis* Linnaeus,1758	*Gossypium hirsutum* (L.)
		Monomorium minimum Buckley,1866	*Abelmoschus esculentus* (L.)
			Hibiscus rosa-sinensis (L.)
			Datura metel (L.)

Graph 1 Percentage of parasitoids *Aenasius bambawalei* Hayat affected by presence of ants in mealybug infested field in Vadodara



Graph 2 Population of *Phenacoccus solenopsis* Tinsley affected by presence of ants in Vadodara



Analyze the population dynamics of insect pests and its correlation with the various environmental parameters and natural enemy population

Population Dynamics

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. The count appeared to be around 188 adults / 15 cm on apical shoot of host plants (Graph 3). 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. Population of mealybug was also affected by the presence of abiotic (Maximum temperature, Minimum temperature, Humidity 8.30 hrs, Humidity 17.30 hrs. (Annexure-I, II & III) and biotic factors (Coccinellids per plant, Chrysoperla per plant, % of Parasitoid per plant).

In general predator population was low during cropping season. During 2008-09 and 2009-10 of study period the average maximum population of Coccinellid and Chrysoperla were 0.24 and 0.16 per host plant, respectively during the season. The percentage presence of parasitoids cocoons ranged between 0.7 to 30.5 per cent per host plant in year 2008-09, whereas in 2009-10, it was ranged between 0.5 to 35.4 per cent per host plant (Table 9 & 10). 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 (Table 11).

In all three year of studies the activity of parasitoids started during 43rd meteorological week and later gradually peak during 6th to 8th meteorological week. The highest percentage population of parasitoids (30.5 %, 35.4 % and 32.6 %) were recorded during 8th meteorological week. from 9th week onwards it start showing gradual decreased in its population (Graph 4).

Taking mealybug as dependent variable and other (Maximum temperature, Minimum temperature, Humidity 8.30 hrs., Humidity 17.30 hrs., Coccinellids per plant, Chrysoperla per plant, % of Parasitoid per plant) as independent variable R square is 0.814, 0.861 and 0.826 in three year of study period respectively. So, this shows that 81.4 %, 86.1 and 82.6 % of mealybug population is dependent on all above independent factors (Table 12, 14 & 16). The regression model is significant (0.000). Mealybug population is positively correlated with maximum temperature, coccinellids and percentage of parasitoids and negatively correlated with other parameters. The present of parasitoid shows strong significant correlation on the population of mealybug (Table 13, 15 & 17). Both simple and partial correlation show almost same value, which recommended it as strong influencing factor on population of mealybug. The positive correlations with population of mealybugs are followed by minimum temperature, evening humidity and chrysoperla. Remaining maximum temperature, coccinellids are less influencing factor for the population of mealybugs.

Table 9 Population dynamics of mealybugs, predators and parasitoids in Agricultural field of Vadodara during 2008-09

Standard weeks	No. of Mealybugs/ Plant	Predator/		% Parasitoid Cocoons per Plant
		Coccinellids	Chrysoperla	
33	0.1200	0.04	0	0
34	0.1200	0	0	0
35	0.2800	0.04	0	0
36	0.3600	0.08	0	0
37	0.4400	0	0	0
38	0.5600	0.04	0	0
39	0.6800	0	0	0
40	0.7200	0.04	0.04	0
41	0.6800	0	0.04	0
42	0.6000	0	0.08	0
43	0.7600	0.04	0	0.7
44	0.8000	0.08	0	1.24
45	0.9600	0	0	2.0
46	1.520	0	0.04	2.6
47	1.800	0	0.16	3.24
48	2.880	0.04	0.2	7.6
49	6.400	0	0.12	9.8
50	9.080	0.08	0.16	10.0
51	11.24	0.12	0	10.4
52	14.96	0.04	0	11.2
1	17.08	0.2	0	11.5
2	32.88	0.24	0.04	12.62
3	56.04	0.16	0.08	13.2
4	74.48	0.12	0.04	13.45
5	108.6	0.08	0	15.62
6	165.2	0.08	0	20.2
7	175.2	0.04	0	22.16
8	148.0	0.12	0	30.5
9	141.9	0	0	24.6
10	133.0	0.04	0	16.42
11	119.9	0.1	0	12.64
12	121.3	0.04	0	10.27
13	106.8	0.12	0	9.6
14	88.72	0.08	0	8.4
15	71.48	0.12	0	3.26

Table 10 Population dynamics of mealybugs, predators and parasitoids in Agricultural field of Vadodara during 2009-10

Standard weeks	No. of Mealybugs/ Plant	Predator/ Plant		% Parasitoid Cocoons per Plant
		Coccinellids	Chrysoperla	
33	0.2000	0	0	0
34	0.3200	0	0	0
35	0.4000	0.04	0	0
36	0.4800	0	0	0
37	0.6400	0	0	0
38	0.7600	0.08	0	0
39	0.9600	0.04	0	0
40	1.160	0	0	0
41	1.280	0	0.08	0
42	1.120	0	0.04	0
43	1.440	0.08	0.04	0
44	1.800	0.1	0	0.5
45	1.760	0	0	1.7
46	2.040	0	0.04	2.04
47	2.320	0.12	0.16	2.1
48	2.880	0	0.08	4.04
49	7.840	0	0.16	6.8
50	11.00	0.04	0.2	8.0
51	12.20	0.16	0	9.25
52	17.40	0.08	0	10.0
1	21.96	0.04	0	11.6
2	40.68	0.1	0.12	12.2
3	59.80	0.24	0.04	14.8
4	78.72	0.2	0.08	19.6
5	114.4	0.1	0	18
6	169.8	0	0	26.4
7	188.6	0	0	28.45
8	152.0	0	0	35.4
9	142.9	0	0	22.8
10	133.0	0	0	18.36
11	120.2	0.2	0	14.46
12	122.3	0.04	0	10.4
13	106.8	0.12	0	9.2
14	95.52	0.16	0	7.6
15	67.72	0.04	0	4.28

Table 11 Population dynamics of mealybugs, predators and parasitoids in Agricultural field of Vadodara during 2010-11

Standard weeks	No. of Mealybugs/ Plant	Predator/ Plant		% Parasitoid Cocoons per Plant
		Coccinellids	Chrysoperla	
33	0.4400	0	0	0
34	0.5200	0.04	0	0
35	0.5600	0	0	0
36	0.7200	0	0	0
37	0.8800	0.08	0	0
38	1.000	0	0	0
39	1.400	0	0	0
40	1.480	0	0	0
41	1.640	0.04	0.04	0
42	2.240	0	0.04	0
43	1.960	0.08	0	0
44	2.280	0.1	0	0.5
45	2.400	0	0	1.7
46	2.840	0	0.08	2.04
47	3.080	0.04	0.12	2.1
48	3.440	0.08	0.16	4.04
49	8.542	0	0.2	6.28
50	11.24	0.12	0.12	8.0
51	11.92	0.2	0.08	9.25
52	17.44	0.08	0	10.3
1	22.00	0.28	0	11.0
2	40.20	0.2	0	14.4
3	59.20	0.12	0.04	16.2
4	77.24	0.08	0.04	14.5
5	113.1	0	0.08	17.25
6	165.9	0.08	0	22.4
7	186.8	0	0	24.5
8	153.0	0.16	0	32.6
9	138.9	0	0	26.3
10	131.9	0.08	0	18.36
11	117.4	0.12	0	16.37
12	121.7	0.04	0	9.76
13	103.9	0.16	0	8.4
14	95.52	0.08	0	7.9
15	74.32	0.2	0	4.27

Table 12 Regression model for population dynamics of mealybug in 2008-09

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	0.940[a]	0.883	0.853	22.70921	0.883	29.098	7	27	.000

a. Predictors: (Constant), Maximum temperature, Minimum temperature, Humidity 5.30 a.m., Humidity 8.30 p.m., Coccinellids per plant, Chrysoperla per plant, % of Parasitoid per plant

Table 13 COEFFICIENTS [a]

Model	**Beta Coefficients**	**t**	**Sig.**	**Correlation**	
				Zero-order	**Partial**
Maximum Temperature	-0.001	-0.007	0.995	0.433	-0.001
Minimum Temperature	0.208	1.622	0.116	-0.187	0.298
Humidity at 5.30 a.m.	-0.041	-0.332	0.743	-0.566	-0.064
Humidity at 8.30 p.m.	-0.294	-1.687	0.103	-0.693	-0.309
Coccinellids / plant	-0.118	-1.571	0.128	0.238	-0.289
Chrysoperla / plant	-0.106	-1.360	0.185	-0.316	-0.253
% of Parasitoid/ plant	0.829	8.861	.000	0.832	0.863

a. Dependent Variable: Mealybug

Table 14 Regression model for population dynamics of mealybug in 2009-10

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	0.960[a]	0.922	0.902	19.01241	0.922	45.517	7	27	.000

a. Predictors: (Constant), Maximum temperature, Minimum temperature, Humidity 5.30 a.m., Humidity 8.30 p.m., Coccinellids per plant, Chrysoperla per plant, % of Parasitoid per plant

Table 15 COEFFICIENTS [a]

Model	**Beta Coefficients**	**t**	**Sig.**	**Correlation**	
				Zero-order	**Partial**
Maximum Temperature	0.308	3.612	0.001	0.166	0.571
Minimum Temperature	0.004	0.051	0.960	-0.173	0.010
Humidity at 5.30 a.m.	0.077	0.582	0.565	-0.715	0.111
Humidity at 8.30 p.m.	-0.160	-1.290	0.208	-0.666	-0.241
Coccinellids / plant	-0.026	-0.451	0.656	0.108	-0.086
Chrysoperla / plant	-0.085	-1.428	0.165	-0.287	-0.265
% of Parasitoid/ plant	0.907	11.106	.000	0.880	0.906

a. Dependent Variable: Mealybug

Table 16 Regression model for population dynamics of mealybug in 2010-11

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	0.954[a]	0.909	0.886	20.18801	0.909	38.646	7	27	.000

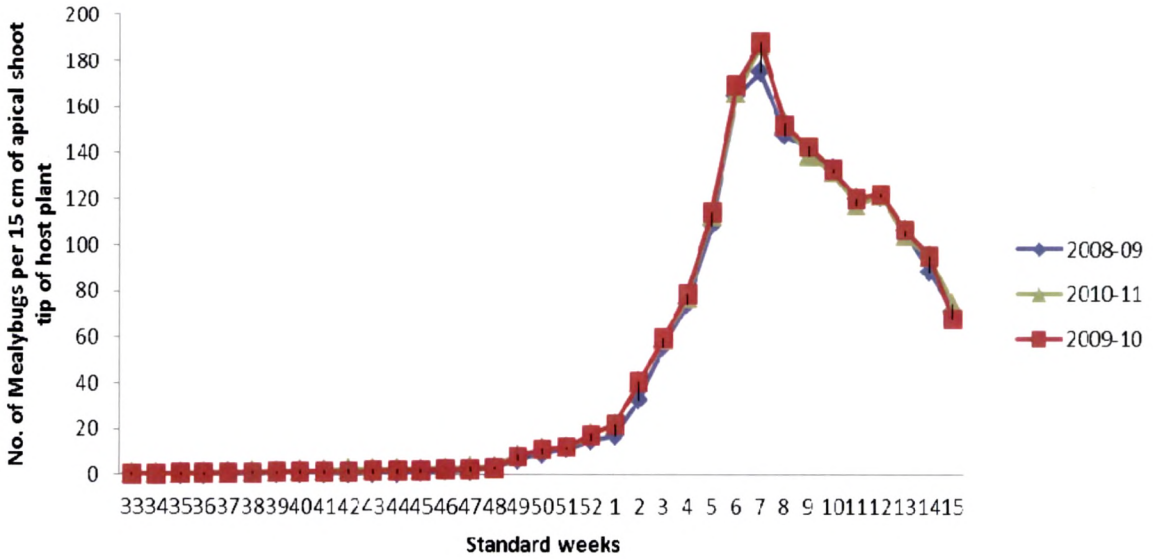
a. Predictors: (Constant), Maximum temperature, Minimum temperature, Humidity 5.30 a.m., Humidity 8.30 p.m., Coccinellids per plant, Chrysoperla per plant, % of Parasitoid per plant

Table 17 COEFFICIENTS [a]

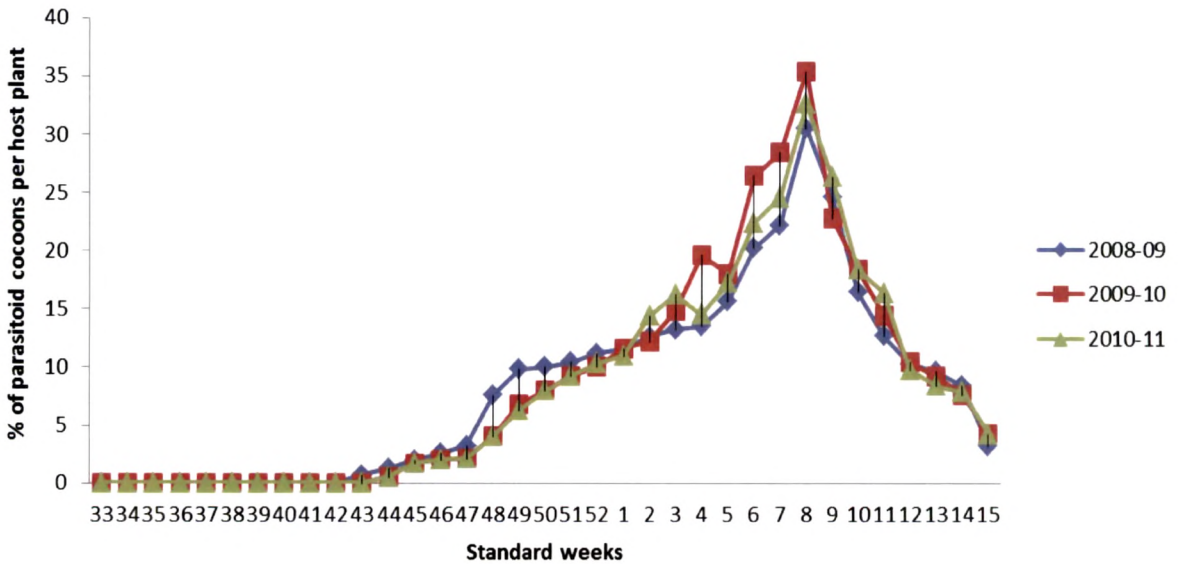
Model	Beta Coefficients	t	Sig.	Correlation	
				Zero-order	Partial
Maximum Temperature	0.321	1.956	0.061	0.324	0.352
Minimum Temperature	0.114	0.609	0.547	-0.313	0.116
Humidity at 5.30 a.m.	0.184	1.245	0.224	-0.551	0.233
Humidity at 8.30 p.m.	-0.165	-0.799	0.431	-0.683	-0.152
Coccinellids / plant	-0.025	-0.304	0.764	0.146	-0.058
Chrysoperla / plant	0.018	0.238	0.813	-0.267	0.046
% of Parasitoid/ plant	0.963	9.715	.000	0.871	0.882

a. Dependent Variable: Mealybug

Graph 3 Population dynamics of mealybug, *Phenacoccus solenopsis* Tinsley



Graph 4 Percentage of *Aenasius bambawalei* Hayat cocoons per host plant



Biorational alternative used in Vadodara

Cultural control

Vadodara farmers are generally preferred crop rotation and removing crop residues as cultural control. For example, cauliflower and cabbage crops are rotated by non-cruciferous crops (chick pea and potato) to divert insect pests like Diamond Back Moth, Cabbage looper, Cabbage aphid, Whitefly etc. The use of intercropping is also popular amongst farmer of Varanama. For example, in the chick pea agricultural fields, the wheat crop is used as inter-crop for protecting it from *Helicoverpa armigera* and *Lampidus boiticus.* At the hedges of cotton plantation the row of chickpea is also used as the trap-crop. Singh et al., (2011) mentioned the used Napies grasses as trap crop in management of *Chilo partellus* on maize in Punjab.

In case of mealybug very few farmers are using cultural control methods in the field of Vadodara. The first resort for mealybug control is the use/production of clean planting material. Farmer awareness regarding mealybug damage symptoms, their management and control options is the key to a successful eradication of this important pest. Farmers also need to be trainned in clean planting material production. Therefore, extension programmes on mealybug managements and control strategies should be reinforced so that large numbers of farmers can control the insects in established plantations. Hence, they can start with clean planting materials and stop the distribution of this pest to new cultivated areas.

The proper quarantine measures could be designed to prevent further spread of the insect to different parts of the region. In practical, a clean sucker certification scheme could be developed, in which farmers who produce planting materials would be monitored. Localities with a high incidence and severity of the insect should be delineated. The concerte effort should be made to stop the distribution of infested seedlings/planting materials to neighboring areas. Farmers should get support to eradicate infested plants/plots and to start new plantations using clean seedlings/transplants.

Preparatory hygiene measures also include exploiting the fact that adult female mealybugs are unable to survive for more than three weeks in the soil without any plant material/food supply. Therefore, crop rotation (during one or two cropping seasons) or removal of grasses and weeds in agricultural fields will also helpful to control this pest. Infested host plants need to be properly disposed of so that all the plant debris decays and no re-growth occur. Repeated ploughing and removal of weeds and grasses in field is believed to eradicate the mealybug.

Physical barriers such as ant fences can be applied parallel to the field periphery to keep ants away from field, and subsequently help in controlling mealybug populations. All crop residues in previously infested fields should be removed and burnt. Crop residues and grass left in the field may harbor mealybug populations which may invade the new crop. Field borders should be free from weeds and debris because it provids alternative host for ant populations between periods where mealybug infestations are small. Remove alternate host plants like hibiscus, okra, custard apple and guava. Equipment should be sanitized before moving to uninfected portions in a crop.

Mechanical control

Mechanical control such as hand picking where eggs and caterpillars of *Earias insulana*, *Helicoverpa armigera* and *Spodoptera litura* are handpicked and removed. Biolures which are having a potential of trapping large (around 1000/trap) number of insects are less frequently used.

Moreover there are only 5 biolures which are commercially available in the market of Vadodara. This is negligible compared to the availability of wide variety of insecticides. In the field of Vadodara the use of pheromone traps are less popular. The heli lures are used for controlling *Helicoverpa armegera* in Dabhoi and Varanama fields. But, for mealybugs no mechanical controls are used in the agricultural fields of Vadodara.

Biological control

Amongst biological control methods the use of Trichocards is popular amongst Vadodara farmers for controlling pests such as *Helicoverpa armigera* and *Spodoptera litura*. Farmers are releasing this card in small pieces which are stapled on inner-side of leaf in the morning to avoid direct sunlight. It is released in the fields of cotton, cauliflower, castor etc. where *Trichogramma* sp. will parasitize on the Lepidopteran eggs and finally kill them controlling large population of insect pests. 5-8 cards/ha are released, each card having around 1000 eggs. The time when cards are released insecticides are not sprayed.

Biological control is considered the most effective long-term solution to the mealybug infestation because the parasites and predators are self-perpetuating, persist even when the mealybug is at low population densities, and they continue to attack the mealybugs, keeping populations below economic injury levels. Scale insects are difficult to control even with insecticides. As many as 6 species of biological control agents have been recorded feeding on cotton mealybugs in the survey conducted in agricultural fields of Vadodara (Figure 40, 41, 42, 43 & 46). These predators were present throughout the cropping season. *Aenasius bambawalei* (Hayat) has been reported as excellent capability of parasitism. The use of these biological control agents are economical and ecofriendly in nature. The present value of accrued benefits is estimated at U.S. $ 531 million over a period of 20 years (Bokonon-Ganta et al., 2002).

Malleshaiah et al., (2000a) studied the feeding potential of *Chrysoperla carnea* on the eggs, nymphs and adult females of *Phenococcus citri* under laboratory conditions for the first time. The grubs were found active predators on mealy bugs and the predatory grub preyed on all the stages of the mealy bug. Since the number of available natural enemies for biological control is limited and the technical development of the use of other natural enemies is still at preliminary stage, integrated use of natural enemies and other control measures is essential for commercial application.

Botanical management

The farmers of Vadodara are aware about the use of botanicals but, their uses are less popular. Although, farmer in Channi, Dabhoi and Varanama agricultural fields were using eco-neem product for the controlling of major insect pests.

Gupta, (2010) at agricultural research station, Tikamgarh, Madhya Pradesh found the reduction in incidence of mustard aphids, *Lipaphis erysimi* Kalt after the treatment of neem leaf and kernel extract in cow urine against it which increase the yield of mustard.

Oparaeke et al., (2005) found that the treatment of mixtures of neem and eucalyptus leaf extract with extract of lemongrass, African curry, tomato, Bitter leaf and African Bush tea on *Maruca vitrata* Fab. the pod borers and *Clavigralla tomentosicollis* Stal caused great reduction in pod damage / plant and ensure higher yield compared to untreated plats in the Research Farm of the Institute for Agricultural Research, Ahmadu Bello University , Zaria, Nigeria. Through survey of agricultural fields it was also found that there is no proper botanical use for mealybug control.

Chemical control

The use of chemical pesticides has been dominating the plant protection since1950s. In spite of the presence of other alternative control methods farmers are mainly depend dependent on popular pesticides in the fields of Vadodara. Growers often apply synthetic chemical insecticides such as Organophosphates, Carbomates, Synthetic pyrethroids and Nicotonoids in mixture of two with fertilizers. The use of these pesticides was reported to be not very satisfactory in controlling the mealybugs but it also leads toward decrease in the population of biological control agents. The presence of fertilizer which is rich in nitrogen also increased the population of insects.

In case of mealybug the use of pesticides are not much effective. Mealybugs are lived in protected areas of the host plants such as cracks, crevices of bark, at the base of leaf petioles, on the underside of the leaves and also inside the host plant bunches. Eggs of the mealy bugs,

protected by waxy filaments, are almost impossible to be penetrated with insecticidal sprays. Late nymphs and adult female mealy bugs are not affected by foliar application of insecticides since they are covered with waxy coating.

Mealybugs (Hemiptera: Pseudococcidae) causes major economic losses in many Tunisian grape growing areas. In an attempt to improve management strategies for the Vine Mealybug, *Planococcus ficus* (Signoret), three insecticides, imidacloprid, Prev-Am® and spirotetramat, were evaluated for their effect on this insect on vine, with reference to methidathion (Mansour et al., 2010). The systemic insecticides are more effective against the mealybug.

Laboratory work

Rearing and breeding of the selected Insect pests in the laboratory

Breeding was done in insect animal house of the Zoology for the four major insect pests namely from order: Hemiptera: *Phenacoccus* solenopsis and *Aphis gossypii* and order: Lepidoptera: *Spodoptera litura* and *Lampides boeticus* on artificial food diet. These insect pests were selected on the bases of their polyphagous nature which causes damage to all economically important crops in Vadodara. The rearing and breeding was in general done at 20-25°C under a photoperiod of 16L: 8D at humidity of 70-75% RH.

Study of the biology of one of the major insect pest severely damaging the crops (polyphagous in nature) under laboratory condition- Mealybugs

It was found that the mealybug, *Phenacoccus solenopsis* is polyphagous and caused severe damage to many host plants (Table 18). In Vadodara, 31 host plant species were recorded from 17 different families which were infested by *Phenacoccus solenopsis*. Major hosts of the mealybugs in agriculture fields of Vadodara *are Gossypium arboretum* (Figure 33), *Ricinus communis, Ameranthus sp.* (Figure 30), Abelmoschus *esculentus* (Figure 32), *Lycopersicon esculentum* (Figure 31), *Solanum tuberosum* and *Solanum melongena.* Whereas *Hibiscus mutabilis, Hibiscus rosa-sinensis* (Figure 29), *Tagetes erecta* (Figure 27), *Nerium indicum* (Figure 28), *Ziziphus mauritiana, Ficus bengalensis* and certain weeds around the hedges of

fields like *Datura metel* and *Xanthium strumarium* act as alternative host of mealybugs throughout the year. Host plant species belonging to family Malvaceae (16%), Solanaceae (13%) and Asteraceae (10%) were found as preferred hosts of mealybugs in Vadodara (Graph 5). Therefore biology of *Phenacoccus solenopsis* was studied on *Hibiscus rosa-sinensis* belonging to family Malvaceae; which was one of the major host in Vadodara.

Data recorded for biological parameters are present in (Table 19). 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) (Figure 22). It is evident from the table that the mean duration was 4.320 ± 0.8524, 4.840 ± 0.8000 and 5.120 ± 0.8327 days for the first instar (crawler), second and third instar nymph female, respectively. For male, it was 5.160 ± 0.8000, 5.080 ± 0.7594 and 7.440 ± 1.083 days for first, second instar nymph and pupa, respectively.

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 which hatched within few minutes (3.634 ± 0.7342 minutes) (Figure 24). The results indicated that the pest reported both sexually (Figure 23) and parthenogenetically.

Table 18 Host plants of *Phenacoccus solenopsis* Tinsley with its infestation level in Vadodara

Host category	Botanical Name	Common Name	Family	Infestation
Field crops	*Gossypium hirsutum*(L.)	Cotton	Malvaceae	4 Grade
	Ricinus communis (L.)	Castor	Euphorbiaceae	1 Grade
Vegetables	*Solanum melongea* (L.)	Brinjal	Solanaceae	3 Grade
	Solanum tuberosum (L.)	Potato	Solanaceae	3 Grade
	Lycopersicon esculentum(L.)	Tomato	Solanaceae	4 Grade
	Abelmoschus esculentus(L.)	Lady's finger	Malvaceae	4 Grade
	Momordica charantia(L.)	Bitter gourd	Cucurbitaceae	1 Grade
	Lufa cyclindrica (L.)	Sponge gourd	Cucurbitaceae	0 Grade
Ornamental crops/ Fruit trees /trees and shrubs	*Nerium indicum* (Mill.)	Oleander	Apocynaceae	0 Grade
	Tagetes erecta (L.)	Marigold	Asteraceae	4 Grade
	Hibiscus mutubilis (L.)	Cotton rose-mallow	Malvaceae	4 Grade
	Hibiscus rosa-sinensis (L.)	China rose	Malvaceae	4 Grade
	Tabernaemontana coronaria (L.)	Crape jasmine	Apocynaceae	1 Grade
	Tabernaemontana divaricata (L.)	Pinwheel flower	Apocynaceae	1 Grade
	Jatropha integerrima (Jacq.)	Peregrina	Euphorbiaceae	0 Grade
	Rosa indica (L.)	Rose	Rosaceae	1 Grade
	Bougainvillea glabra(Chois)	Paper flower	Nyctaginaceae	1 Grade
	Annona squamosa (L.)	Custard apple	Annonaceae	4 Grade
	Punica granatum (L.)	Pomegranate	Lythraceae	2 Grade
	Ziziphus mauritiana (Lam.)	Chinee apple	Rhamnaceae	1 Grade
	Ficus bengalensis (L.)	Fig	Moraceae	2 Grade
	Areca catechu (L.)	Nut palm	Arecaceae	0 Grade
	Mangifera indica (L.)	Mango	Anacardiaceae	0 Grade
	Lantana camara (L.)	Red sage	Verbenaceae	0 Grade
	Clerodendron inerme (Gaert.)	Gardenia	Verbenaceae	0 Grade
Weeds	*Datura metel* (L.)	Angel's trumpet	Solanaceae	4 Grade
	Xanthium strumarium (L.)	Common cocklebur	Asteraceae	4 Grade
	Parthenium hysterophorus (L.)	Whitetop weed	Asteraceae	4 Grade

	Calotropis procera (W.T.Aiton)	Apple of sodom	Asclepiadaceae	2 Grade
	Achyranthes aspera (L.)	Prickly chaff flower	Amaranthaceae	2 Grade
	Malvastrum coromandelianum (L.)	Malvastrum	Malvaceae	2 Grade

Graph 5 Percentage infestation of different host plants by *Phenacoccus solenopsis* Tinsley

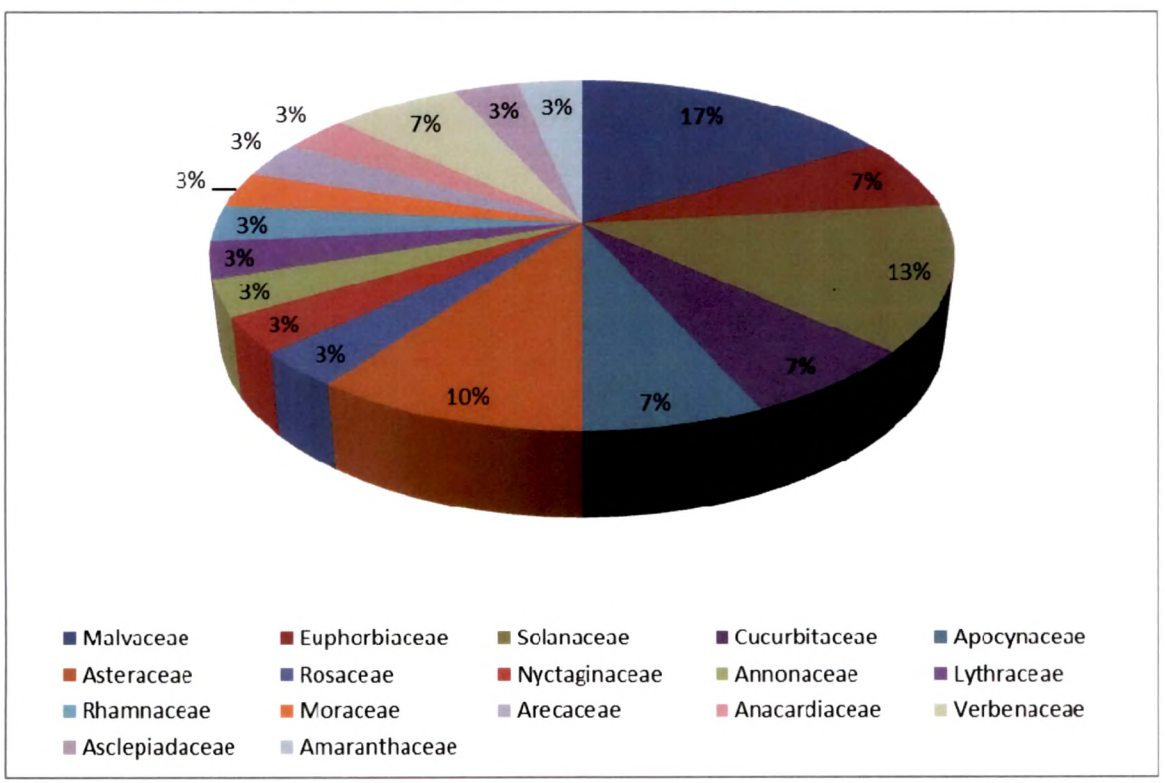


Table 19 Biological parameters of *Phenacoccus solenopsis* Tinsley on *Hibiscus rosa-sinensis* (L.) under laboratory conditions

Biological Parameters	Mean ± SD	Range
Incubation period (minutes)	3.634 ± 0.7342 minutes	2.45 - 4.8
FEMALE		
Nymphal duration (days)		
First instar	4.320±0.8524	3 - 6
Second instar	4.840± 0.8000	4 - 6
Third instar	5.120± 0.8327	4 - 6
Pre-oviposition period (days)	7.120± 0.7810	6 - 9
Oviposition period (days)	14.04± 0.9781	12 - 15
Post-oviposition period (days)	3.560± 0.7118	2 - 5
Fecundity(no. of eggs laid/ female)	540.8± 107.2	300 - 750
Ovisacs (no. of ovisacs/ female)	3.520±0.7141	2 - 5
Adult longevity (days)	24.44±2.329	21- 30
Total life cycle (days)	39.88±3.127	33 - 44
MALE		
Nymphal duration (days)		
First instar	5.160±0.8000	4-6
Second instar	5.080±0.7594	4-6
Pupal period (days)	7.440±1.083	6-9
Adult longevity(Days)	1.960±0.8406	1-3
Total life cycle (Days)	19.20±1.756	17-22

Bio semiotic studies- To observe the effect of volatile extracts from *Phenacoccus solenopsis* on its own species

Mealybug, *Phenacoccus solenopsis* spread more easily than of many other insect species. Since, they possess a waxy coating on the dorsal side that protect them from insecticides and natural enemies, have a high reproductive rate, their ability to hid in soil, cracks and crevices of plants and propensity to spread quickly proved that mealybug have immense potential to emerge as crop pest and thus pose great threat to agriculture in the Vadodara. Therefore it is necessary to develop appropriate area wise ecofriendly strategies for management along with other insect pests.

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. Following the hatching of eggs, the neonates nymphs were reared on the hibiscus twigs (Twigs end was rapped with wet cotton) kept in plastic box (20x 15 cm2) in laboratory to get virgin male and female to study the biology and sex communication of this insect.

After knowing biology of mealybug it was found that mating activities were predominant during early morning (4-7 am). Through literature survey it was also found that female mealybug secrete pheromones from pygidial glands which released through rectum. These volatile was collected from the female mealybugs by using confinement and adsorbent method. These collected volatile were further used for behavior bioassay. The studies conducted in dark room with live male and female to avoid any visual contact, indicated the presence of pheromonal attraction between sexes. The response of each sex to the collected volatile by different method was studied by counting the number of adults attracted towards it. The solvent n-Hexane was used as control for volatiles.

In the first trial, 30 females were released in experiment set consisting of female volatile extracted by using confinement method. In this six female get attracted towards the volatile but, it was only for few second. So, it was concluded that the volatile collected from female

did not attract females. The above experiment was also conducted by using female volatile obtained by using adsorbent method. During this only two female was attracted towards the volatile which indicate that female was not get attracted towards the volatile obtained by adsorbent method.

In the next set of experiments, 30 males were released in the experimental pertriplate consist of female volatile extract obtained by using confinement method. In this 22 males easily get attracted towards the female volatile extract. The same experiment was also conducted by using female volatile obtained by using adsorbent method. During this 26 males get attracted towards the female volatile. Therefore this shows that the males get attracted towards the volatile obtained from females using confinement and adsorbent method.

The responsiveness of the mealybug was converted to AI (Attractive index). The maximum value of 0.86 was recorded for the volatile extract collected from female by adsorbent method which attracted the males (Table 20). The Attractive index value obtained by using confinement method was equivalent or similar to the adsorbent method. Therefore, this indicated the female released the sex pheromone.

Table 20 Bioassay study using volatiles for pheromone communication in mealybug

Adult released in experiment setup			Responsiveness percentage	Type of volatile	Attractive index
Sex	**Number of released insect**	**Number of insect respond**			
Female	30	6	17.24	Confinement method	0.17
Control		1		n- Hexane	
Female	30	2	6.66	Adsorbent method	0.07
Control		0		n- Hexane	
Male	30	22	71.42	Confinement method	0.71
Control		2		n- Hexane	
Male	30	26	86.20	Adsorbent method	0.86
Control		1		n-Hexane	

Isolation and identification of a pheromone lure from Mealybug, *Phenacoccus solenopsis* Tinsley as an alternative to insecticide

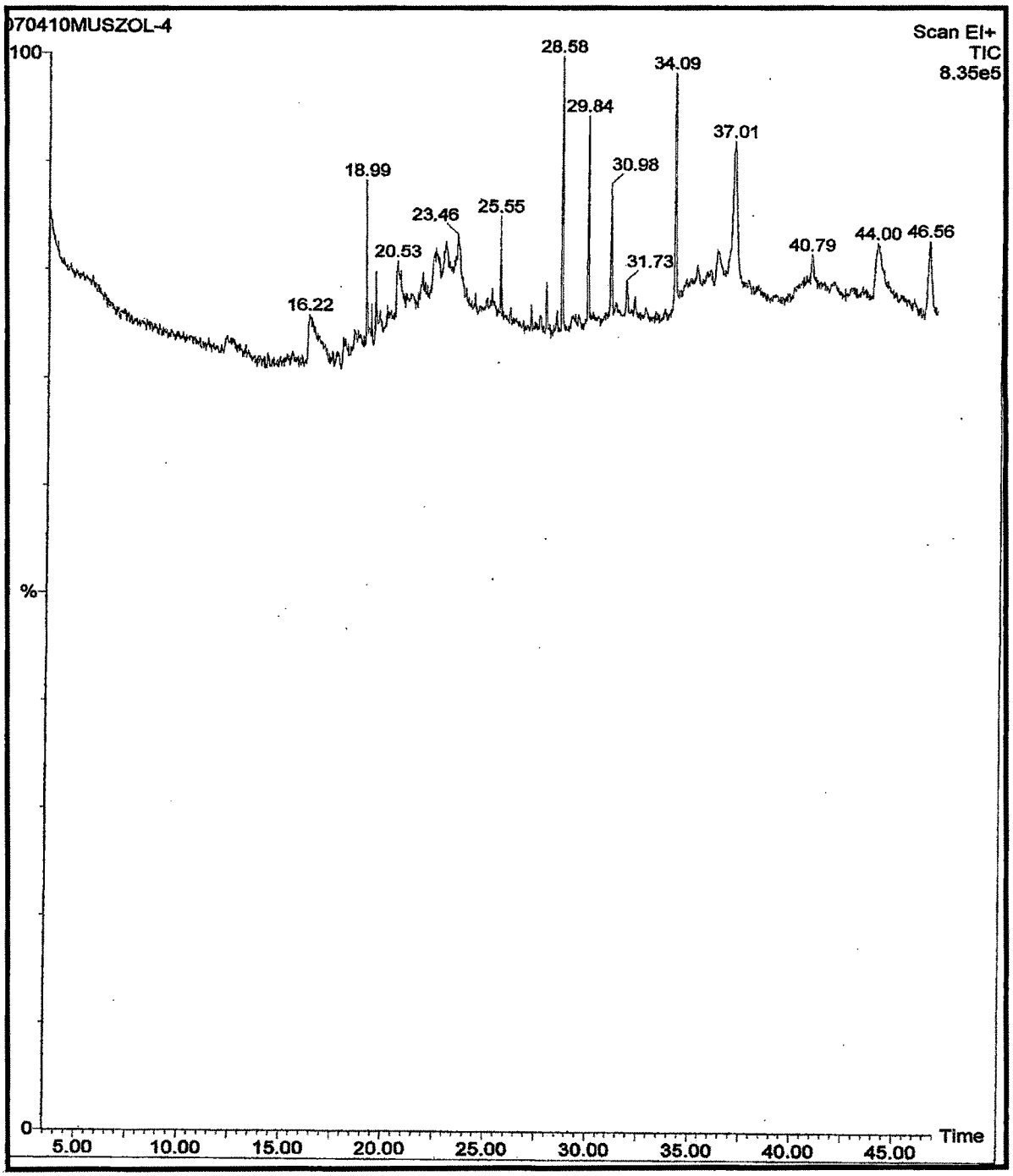
The result of behaviour studies is an encouragement for further fractionation and identification of volatile from n hexane solvent extract by using GC-MS (Graph 6 & 7)The collected air born volatiles in n-hexane were identified as ester and terpenes.

In which the major volatiles which are identified from both confinement and adsorbent methods are:

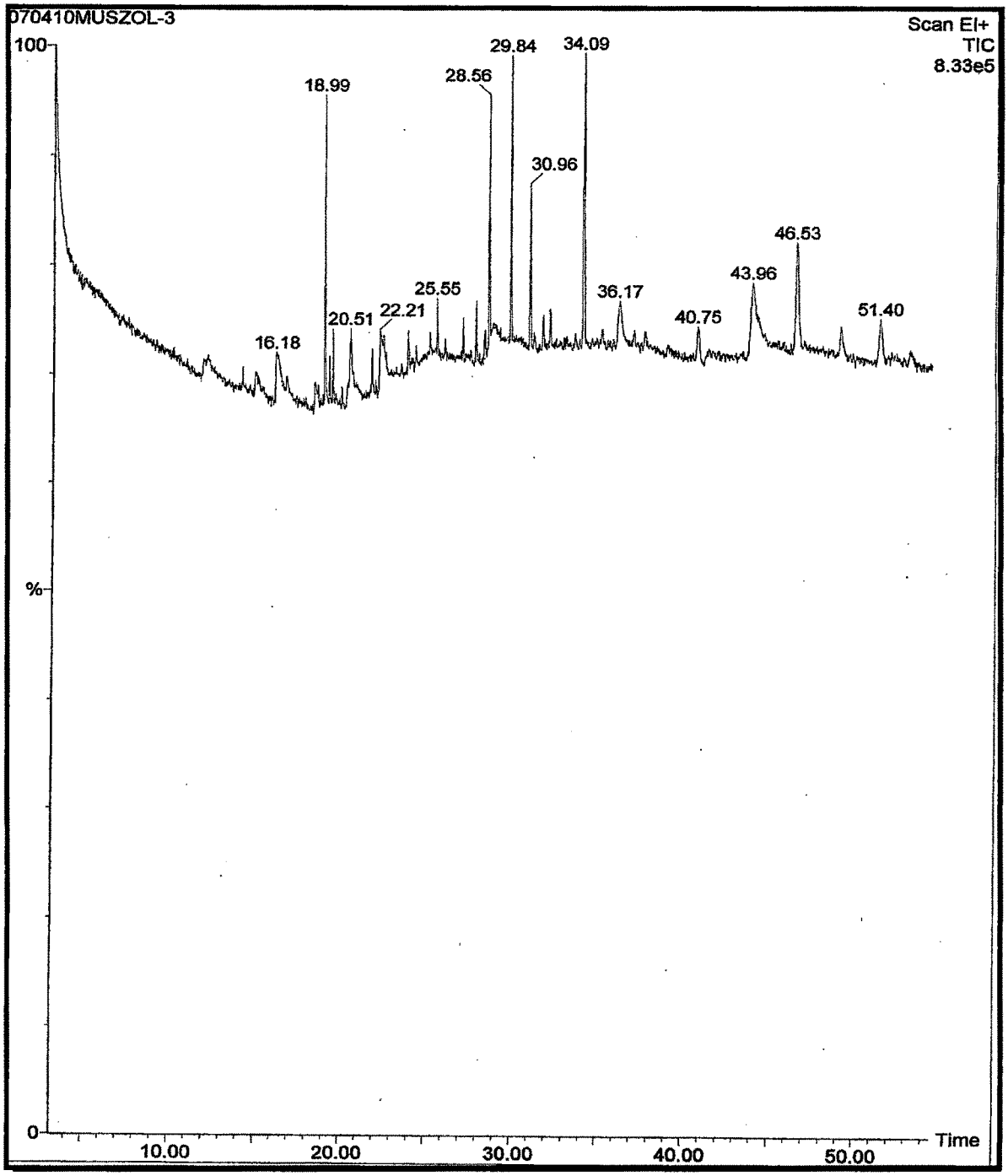
2, 2, Dimethyl-isopropenyl cyclobutane methyl ester
3,7,11,15-Tetramethyl-2-hexadecen-1-ol (Diterpenes)
2,6,10,15,19,23-Hexamethyltetracosa-2,6,10,14,18,22-hexaene (Triterpenes)
Carotene (Tetraterpenes)
Hexadeconoic acid
2- Cyclohexane-1-ol

In this the 2, 2, dimethyl-isopropenyl cyclobutane methyl ester is belonging to sex pheromone in other species of mealybug like *Macollinecoccus hirsutus*. 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 are mainly act as kairomones. The role of Hexadeconoic acid and 2- Cyclohexane-1-ol are also identified which act as attractant in *Agelastica coerulea* and *Alnus glutinosa* (Jung et al., 2000a). Both also act as precursor for the formation of pheromone. These kariomones can be used for attraction of female mealybugs which can reduce the population in the fields.

Graph 6 Representation of gas chromatography of female sex pheromone isolated from *Phenacoccus solenopsis* Tinsley using n-Hexane as solvent by using Confinement method



Graph 7 Representation of gas chromatography of female sex pheromone isolated from *Phenacoccus solenopsis* Tinsley using n-Hexane as solvent by using Adsorbent method



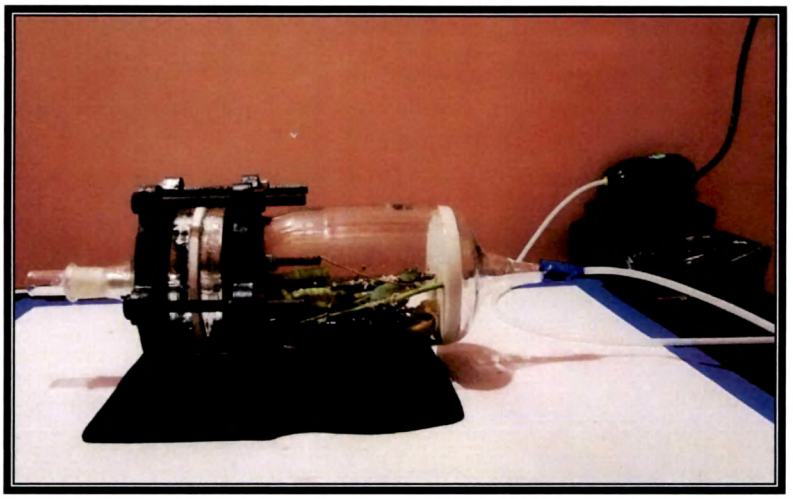


Figure 25 Volatile collectors used during adsorbent method

Figure 26 GC-MS at SICART for isolation of pheromone from mealybug

Experiments with Insecticides on Mealybug, *Phenacoccus solenopsis* Tinsley, *Scymnobius sordidus* Horn (Predator) and *Aenasius bambawalei* (parasitoid) bio-control agent of *Phenacoccus solenopsis*

The visit to the study sites shows that the farmers are mainly dependent on chemical control for management of mealybug. The major insecticides which were belonging to organophosphate group are more popular among farmer in Vadodara. The field study shows that the despite of use of chemical the population of mealybug are not come under control. It also affects the non target insects which are beneficial for us. The laboratory studies on knowing the effect of insecticides on mealybug shows that the LC_{50} for chlorpyrifos is 151.101 which is less then the folidon and imidacloprid (Table 23). This shows that the most effective or toxic insecticide is chloropyrifos followed by folidon and imidacloprid when applied by using topical method.

In Vadodara the mealybug *Phenacoccus solenopsis* is controlled by various biocontrol agents (Table 21). The major predators of *Phenacoccus solenopsis* is *Scymnobius sordidus*. It is small yellowish brown with mouth parts dark brown; prothorax yellowish brown with dark brown patch at the median dorsal region; scutellum brown; elytra yellowish brown with characteristically arranged dark brown marking (Figure 42). It is around 1.5 mm in size. The larvae are feeding on the mealybugs. The fully grown larvae are larger than adults and consist of waxy filaments (Figure 43). Through personal observation I found that the larvae and pupae are consistently found under bark. It was not found on expose leaf even if the mealybug number is more. Although, adult, *Scymnobius sordidus* are seen on all parts of host plant. The appearance was recorded from early September. While observation it was also found that the waxy filaments on the larvae give them protection from ants. It also acts as camouflage among mealybug.

The major predators of *Phenacoccus solenopsis* is *Scymnobius sordidus*. It's having four larval stages. The fourth instar larvae voracious feeder. This stage feeding 36.20 ± 3.0 number of mealybug nymph. Larvae are mainly preferred nymph then adult of mealybug. The total number of *Phenacoccus solenopsis* nymph eaten by the larvae of *Scymnobius sordidus* is

61.6±5.81 during its life cycle. 2.8±0.84 adults of *Phenacoccus solenopsis* were consumed during its life cycle (Table 22). The effect of insecticides which was used for control of mealybug in the laboratory agent the fourth instar of predatory larva. In both folidon and chlorpyrifos total mortality of forth instar larvae was seen at 200 ppm, where as in imidacloprid the total mortality were noted at 100 ppm (Graph 8). Therefore, imidacloprid is having higher toxic effect which is followed by chlorpyrifos and folidon on *Scymnobius sordidus*. The dose which kills the total population of predatory larva is much less then the dose required for control of mealybug.

The personal observation of the fields shows that the most effective biocontrol agent is *Aenasius bambawalei* (Figure 47). The body of parasitized mealybug can be easily recognized by absence of wax from its thoracic region as well as the disappearance of two characteristic strips from its abdominal region. The parasitoid lays its egg in 2nd and 3rd nymphal instar and adult female mealybug. In field the parasitization percentage recorded range between 60-70%. But the population of this biocontrol agent is affected by the uncontrollable use of broad spectrum pesticides in the field of Vadodara. Therefore experiment with three major insecticides which were used for control of mealybug in Vadodara was conducted on *Aenasius bambawalei*. The parasitoid was treated with different concentration and the total number of days taken for emergence of the parasitoids was recorded.

The result shows that day for parasitoid emergence after treatment with insecticide significantly different between treatments ($P \leq 0.0001$). In which folidon causing a significantly delay in emergence by almost 20 days relative to other treatment at higher concentration. Where as, in other two insecticides delay in emergence of parasitoids were seen when compared with control respectively (Table 24). Hence, the use of insecticides in the field is harmful for the biocontrol agents.

Table 21 Natural enemies of *Phenacoccus solenopsis* Tinsley recorded from field of Vadodara

Order	Family	Natural control agents
Coleoptera	Coccinellidae	*Cheilomenes sexmaculata* Fabricius *Anegleis cordoni* Weise *Scymnobius sordidus* Horn
Neuroptera	Chrysopidae	*Chrysoperla zastrowi Arabica* Henry et. al. *Sympherobius fallax* Banks
Hymenoptera	Encyrtidae	*Aenasius bambawalei* Hayat

Table 22 Consumption of different stages of *Phenacoccus solenopsis* Tinsley by different instars of *Scymnobius sordidus*

Larval stage	Nymph	Adult
I	5.8±0.84	1.4±0.5
II	7.2±0.83	1.6±0.54
III	12.4±1.14	1.8±0.44
IV	36.2±3.0	2.8±0.84
Total	61.60±5.81	7.6±2.42

Table 23 Showing toxic effect of insecticides against mealybug in laboratory condition

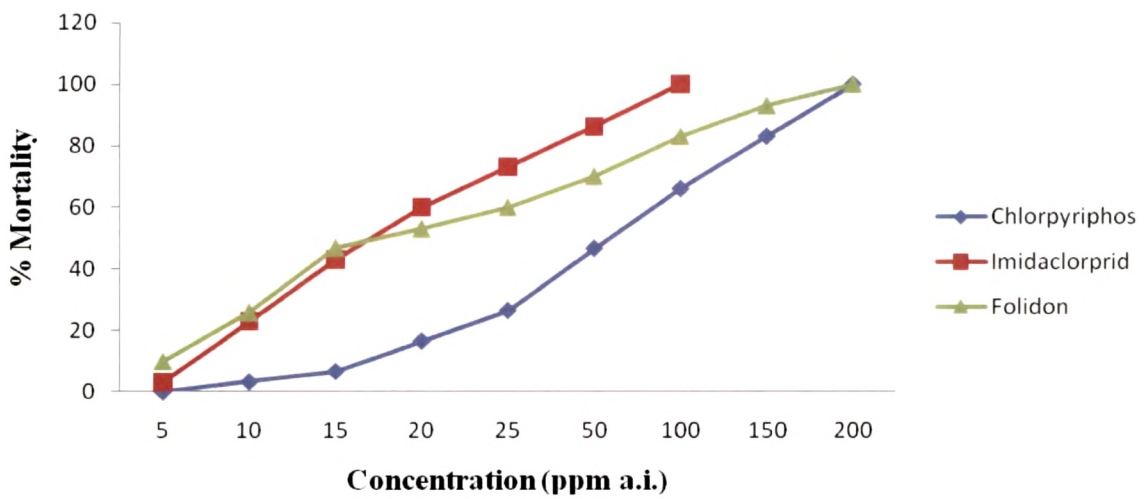
Route of Exposure	Topical application		
Chemical	**LC50**	**95% Confidence Interval**	
		Lower Limit	**Upper Limit**
Imidacloprid	1574.301	950.443	9215.198
Folidon	217.492	146.383	311.181
Chlorpyrifos	151.101	97.840	220.715

Table 24 Effect of different concentration of insecticides on emergence of parasitoid

Concentration (ppm)	No. Of days for Emergence		
	Chlorpyrifos	Folidon	Imidacloprid
5	10.67±0.33	11.0±0.58	10.67±0.33
10	11.67±0.33	11.33±0.33	11.0±0.58
15	13.67±0.33	14.33±0.33	11.67±0.33
20	15.0±0.33	15.67±0.33	13.67±0.33
25	15.33±0.33	17.67±0.33	15.33±0.89
50	16.67±0.67	20.67±0.33	17.33±0.33
100	17.67±0.67	24.67±0.33	18.67±0.33
150	17.33±0.67	27.33±0.33	20.67±0.33
200	19.67±0.33	31.67±0.67	22.67±0.33
Control	11.0	11.0	11.0

Mean of three set with ± SE

Graph 8 Impact of Topical application of three agrochemicals at various doses on the mortality of forth larval stage of *Scymnobius sordidus* (Horn)



To study the bio efficacy of botanicals against *Phenacoccus solenopsis* Tinsley

The laboratory assays was carried out to evaluate the repellent property of leaf extracts of various indigenous native botanical such as *Azadirachta indica* A. Juss; *Eucalyptus globules* L. and *Ocimum basilicum* L. against mealybug, *Phenacoccus solenopsis*. This was evaluated by using large petri plates which was further divided into test area and control area. Test area was treated with different botanical leaf methanol extracts (extracted by using soxhlet method) against *Phenacoccus solenopsis* at different dose levels viz., 1, 2, 4, 8 and 10 per cent respectively. On the other side of petri plates, the water dip strip was used as control. After this 15 insects (mealybugs) were placed at the centre of the petri plate and covered with lids. These repellent bioassays were conducted under ambient laboratory condition of 28±2° C and relative humidity of 80±20 %.

The result was seen at 12 and 24 hours. At one percent concentration, mealybugs among the treatments the botanical extracts of *Azadirachta indica* A. Juss (16.67%) showed higher repellency. *Eucalyptus globules* L. extract stands the next position (19.67%).The least repellency was recorded from *Ocimum basilicum* leaf extract (11.33%) against mealybug during 12 hours of release. At same level of concentration after 24 hours of insect release the highest repellency was noticed from *Azadirachta indica* A. Juss leaf extract (55.0%), followed by *Eucalyptus globules* L leaf extract (44.0%) and *Ocimum basilicum* L. (33.0 %) against mealybugs (Table 25).

Among the botanical extracts there was not a marked or significant difference between 12 hours and 24 hours of release. Similar trend as like 1% concentration was noticed in case of 2%, 4%, and 8% concentration both at 12 hours and at 24 hours of release. Repellency was recorded by methanol leaf extract was in following order *Azadirachta indica* A. Juss > *Eucalyptus globules* L >*Ocimum basilicum* L. against mealybugs.

After 24 hours of release of 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 repulsion was seen in *Ocimum basilicum* L. leaf extract (88.0%) at 10% concentration. 12 hours of release there were no marked difference in repellent effect

between these three native botanicals. No significant effect was noticed in case of time duration between treatments i.e. 12 and 24 hours of release. During 24 hours of release all the native botanical extracts reported highest repellency effect without any deviation from the earlier dose levels.

Thus, as the time increases the repellency property also increased. Irrespective of the all three botanical extract treatments, as the concentration level increases the repellency property was also increased.

Table 25 Mean percentage repellency values shown by mealybug against botanical at 12 and 24 hours

Plant extracts	Hours	Mean Percentage* repellency value after different concentration				
		1%	2%	4%	8%	10%
Azadirachta indica	12 hrs	16.67 ± 0.8819^{j}	34.33 ± 1.202^{g}	44 ± 0.5774^{e}	61.33 ± 0.333^{c}	70.33 ± 0.8819^{a}
	24 hrs	55 ± 0.5774^{g}	62.33 ± 0.8819^{f}	79.67 ± 0.8819^{d}	86 ± 0.8819^{c}	97 ± 0.5774^{a}
Eucalyptus globules	12 hrs	19.67 ± 0.8819^{i}	27 ± 0.5774^{h}	40.3 ± 0.8819^{f}	54.33 ± 0.333^{d}	64.67 ± 0.8819^{b}
	24 hrs	44 ± 1.155^{h}	55 ± 0.577^{g}	71 ± 0.5774^{e}	77.3 ± 0.6667^{d}	93 ± 1.155^{b}
Ocimum basilicum	12 hrs	11.33 ± 0.6667^{k}	22.33 ± 1.202^{i}	34 ± 1.155^{g}	45 ± 1.000^{e}	54 ± 1.155^{d}
	24 hrs	34.33 ± 0.6667^{i}	41.67 ± 1.202^{h}	55.67 ± 0.881^{g}	70 ± 0.5774^{e}	88 ± 1.155^{c}
Control (Aqueous)		0	0	0	0	0

Figure 27 ***Phenacoccus solenopsis*** **infesting** ***Tagetes erecta*** **(L.)**

Figure 28 ***Phenacoccus solenopsis*** **infesting** ***Nerium indicum*** **(Mill.)**

Figure 29 ***Phenacoccus solenopsis*** **infesting** ***Hibiscus rosa-sinensis*** **(L.)**

Figure 30 ***Phenacoccus solenopsis*** **infesting** ***Amaranthus sp.***

Figure 31 ***Phenacoccus solenopsis*** **infesting** ***Lycopersicon esculentum*** **(L.)**

Figure 32 ***Phenacoccus solenopsis*** **infesting** ***Abelmoschus esculentus*** **(L.)**

Figure 33 *Phenacoccus solenopsis* infesting *Gossypium hirsutum* (L.)

Figure 34 *Phenacoccus solenopsis* infesting cotton boll

Figure 35 Symptom of *Phenacoccus solenopsis* infestation in *Hibiscus rosa-sinensis* (L.)

Figure 36 *Phenacoccus solenopsis* associated with *Monomorium pharaonis* (L.)

Figure 37 *Phenacoccus solenopsis* associated with *Camponotus compressus* (Fab.)

Figure 38 ***Phenacoccus solenopsis*** **associated with** ***Tapinoma melanocephalum*** **(Fab.)**

Figure 39 ***Phenacoccus solenopsis*** **carried by** ***Camponotus compressus*** **(Fab.)**

Figure 40 ***Anegleis cordoni*** **(Weise)**

Figure 41 ***Cheilomenes sexmaculata*** **(Fab.)**

Figure 42 *Sympherobius fallax* (Banks)

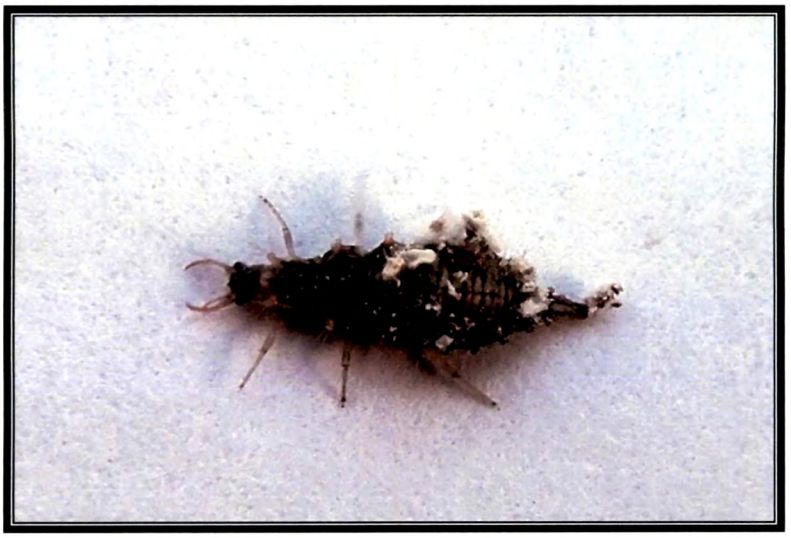


Figure 43 Larva of *Sympherobius fallax* (Banks)

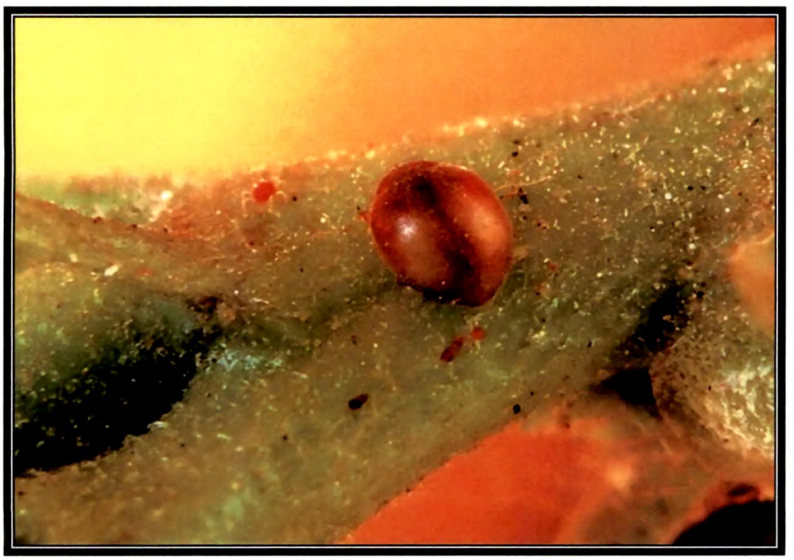


Figure 44 *Scymnobius sordidus* (Horn)

Figure 45 Larvae of *Scymnobius sordidus* (Horn)

Figure 46 ***Chrysoperla zastrowi Arabica*** **(Henry)**

Figure 47 ***Aenasius bambawalei*** **Hayat and its cocoons**