CHAPTER II

MATERIALS AND METHODS

The study was conducted for a period of three years (April 2008- April 2011).

Study area

Selection of study areas was done on the basis of accessibility and location of eco-regions situated in all the four directions from the city of Vadodara. Preferences were given to those fields having economically important crops that were severely damaged by insect pests. These crops were examined to determine the extent and type of damage to the crops. Various life stages of insect pests were collected from the crops. These collected insect pests were further identified and preserved in the Departmental laboratory. Field surveys include interviews with the farmers and locals, to know the methods employed by them to control the insect pests in the fields. Further surveys were also carried out to make note on the preferences and problems faced by farmers in implementing these pest control measures.

Geological location and climate of Vadodara

Vadodara is located in the eastern part of the Gujarat state in western India. It is located at 22°11N latitude and 73° 07 E longitude. Vadodara District covers an area of 7,794 sq. km.

The climate of Vadodara is semi-arid, characterized by dry and increasingly hot summer from the end of the February to June, warm monsoon from July to September and cold winter from October to early February. The monsoons arrive every year in the latter half of June and continue until September. Usually the months of July and August receive the heaviest downpours.

Vadodara experiences great extremes of temperature. The scorching summer heat (March-June) is intense, with the daytime temperature rising as high as 40.6°C in May. The months from June – September have warm monsoon, while mild winter sets in the month of November and continues till mid of February. The temperature drops in the month of December and January having the mean monthly temperatures for the warmest and coldest

months as 30 °C and 13°C respectively. Relative humidity is at the minimum level during the winter month of December (31%) and at the maximum level during the monsoon, especially in July (92%) (Annexure-I). The data given in annexure-I was utilized to correlate the relationship between the population of insect pests and biotic factors.

In recent years, Vadodara has suffered from increasing air, water and soil pollution from neighboring industrial areas. This has also taken into account the constant increase in average temperatures across all three seasons. Uncontrolled chemical dump from nearby industries has debatably turned the local river Vishwamitri into one big sewer.

Field studies

Agriculture sites (Figure 1)

The agricultural fields selected for this study are located within 25 Km radius of Vadodara district and each of these fields was 2-5 hectares in size. Various herbs, scrubs and trees were located at the hedges of the agricultural fields like Hibiscus, Palm, Asopalav, Mango, Eucalyptus, Bamboo trees, Banyan trees etc. (Table 4 & 5) (Figure 3 &10)

A Site 1 (Channi): This study area is approx. of 2.5 hectares, located within 20 Kms from Vadodara city in the northern direction. The surveyed field had crops of Cotton, Sorghum, Castor, Pigeon pea, Potato, Brinjal, Radish and Cauliflower. Yellow sandy loamy soil is found here.

A Site 2 (Varanama): These fields are spread in an area of 3.23 hectares and located 17 Kms from Vadodara city in southern direction. The surveyed field had crops of Cotton, Castor, Sugar cane, Ladies finger, Pigeon pea, Cauliflower. Black loamy soil was the characteristic of this field.

A Site 3 (Waghodia): Located 20 Kms from Vadodara city and spread across 4.5 hectares. The field surveyed had crops such as Cotton, Castor, Sugarcane and Brinjal.

A Site 4 (Dabhoi): This study area of approx. 4.5 hectares and located 35 Kms from Vadodara city. The field surveyed had crops of Wheat, Paddy, Maize, Sorghum, Cotton, Castor and Pigeon pea.

Urban community gardens (Figure 2)

The economically important crops of urban areas were equally prone to insect pest infestation as it 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 done (Table 6) and (Figure 11, 12 & 13)

U Site A (Sayaji Baug): An extensive park, spread in an area of 113 acres. It has a rich flora of more than 98 species of trees. Palm, Asopalav, Mango, Eucalyptus, Bamboo trees and such various avenues are all planned by horticulturists. The park has deep black as well as yellow sandy loamy soil.

U Site B (Lal baug): It covers an area of 9.31 acres. The soil type is of yellow sandy loam soil. It is the second most popular garden of the city following Sayaji baug.

U Site C (Sardar baug): This has well maintained lawns, play area, swimming pool and much loved spot for children and evening-walker.

U Site D (Akota garden): This garden possesses beautiful lawns; flower beds growing with numerous imported and adapted annuals, hundreds of large and small trees, shrubs, ornamental plants etc.

Collection of insect pests

Sampling Technique

Each of the study site visits were conducted twice a week. Incidence of major insect pests was recorded in each of the field sites which are randomly selected and all consisting of five plants. Equal number of leaves from each plant, representing top, middle and lower regions was observed for the total number of insect pest incidence. Observations were recorded for all selected fields at 20 days interval, after crop emergence in selected location. The sampling was done twice once in morning hrs (7 am to 9 am) and second time in evening hrs. (5 pm to 7 pm) on every day basis. Quadrates of 10x10 m were laid at all the sites, except agriculture fields. Whereas in urban community gardens, 10x 5 m quadrates were laid to decrease sampling error. No sampling was done in the month of May due to extreme temperatures for fieldwork and

also from June to August due to heavy rainfall. The average minimum and maximum temperature was recorded for all sampling periods along with the average rainfall.

Collection method

Hand picking method

Handpicking is an excellent method of controlling pests especially when only a few plants are infested. It is the easiest and direct way to kill the visible and slowly moving pests. This method fulfills the objective of recording the number of insect pests species present on major agricultural crops. In this method, different insects were picked up randomly as they were found. Large sized caterpillars and other visible insects were handpicked.

Sweep net

Sweeping is a suitable method for collecting many insects. The sweep net is used to sweep through herbage, grass and bushes. And after few strokes, grasshoppers, bugs and other insects were collected in the net. The net takes a lot of damage from coming into forceful contact with the vegetation so it should be made with a tough netting material and the brim should be well edged with a tough material to prevent wearing. The frame of the sweep net should be big. Both the frame and the bag need to be strong, hence the bag should be of denser material like white calico or heavy muslin. This method was used for collecting insects. In this method, each quadrant was searched until whole quadrate is covered numerous times. This was repeated with a time interval of 10 minutes. 10 sweeps were done each time.

Photography

The photographs have been taken using NICON P80-120 version, 18 megapixel resolution, and 10 X zoom. Some photographs of insects are taken directly at the study site and some are taken in the lab. Photographs were modified using Microsoft picture manager software 2007 and Adobe Photoshop.

Host plants of insect pests and their population dynamics

Host Plants and Assessment of incidence and infestation rate of insect pest

Assessment of infestation by insects on various crops was done as per the scale given by Vennila and his Co- author in National Centre for Integrated Pest Management, New Delhi in year 2010 (Table 7).

0-4 Scale infestation

i. 0 Grade: No insect/ indecently seen

ii. 1 Grade: Scattered appearance of few insect pests on the plants

iii. 2 Grade: Severe incidence of insect pests on only one branch

iv. 3 Grade: Severe incidence of insect pests on more than one branch

v. 4 Grade: Severe incidence of insect pests on whole plants was recorded

Population dynamics

After assessment of insect pests belonging to different orders I came to know that the mealybug is one of the major pest of urban community garden and agricultural fields of Vadodara. Observations on population dynamics of mealybugs and its associated insects were recorded from the selected field sites during sampling period of three years.

The mealybugs were recorded on 15 cm apical shoot length from August 2008 to April 2011 at weekly interval from 25 randomly selected plants. Further correlation and regression were calculated by using SPSS 19 software with the biotic (associated insects) and abiotic factors (weather parameters) which are affecting the population of mealybug. Similar pattern was followed for associated insects.

Current practices of usage of pesticides and the Biorational alternative to these pesticides in the selected agricultural crop

Data was collected through regular visits to agricultural fields. Self-assessment and personal interview with locals and farmers gave sufficient amount of information regarding the type and the pattern of pesticide spray in the agricultural fields of Vadodara. This, in turn, also provides data about popularity and usage of different alternative control measure practice by farmers in agricultural fields of Vadodara.

Laboratory Work

Preservation and Identification of insects collected from the fields

Large insects were killed using killing jars with potassium cyanide powder. The insects, thus, collected, were placed into vials of 75-95% ethanol. Identification and labeling was done using standard taxonomic literature. Collected insects were identified with the help of keys available in Ananthkrishnan & David, (2004), Sharma & Joshi, (2010), Miller et al., (2007). A stereomicroscope Leica MPS 60 Ø 28/8x/MPS was used for identification. The insects were carefully observed for studying the taxonomic characters such as antenna, mouthparts, elytra, epipleura, abdominal sternites and male genitalia by using stereomicroscope.

Based on the characters studied, the species were described and detailed key to the identification of the species were prepared. The identification of all host plants species were done by the Department of Botany of The Maharaja Sayajirao University of Baroda. Collected mealybugs were heated at 60-66°C for 15-30 min in 10 % KOH. Puncture larger specimen with an insect pin before heating in KOH (14 pellet/ 50 ml of distilled water).

A spatula was used to pump out the body contents of the specimen. Then again reheated in KOH and rinsed in distilled water. Followed by, staining with Acid fushin (1% in distilled water or 70 % ethanol) for 15 minutes (Hodges & Hodges, 2005). Rinse it in 70-95% ethanol. Mount with DPX.

Mass Multiplication

From many insect pests, only four insect species were reared and cultured in the laboratory. These are following:

Order: Hemiptera: *Phenacoccus solenopsis* and *Aphis gossypii*

Order: Lepidoptera: *Spodoptera litura* and *Lampides boeticus*

From Order: Hemiptera

a) *Aphis gossypii:*

This Aphis sp. was collected from agricultural fields as well as urban areas. These were reared at 20-25°C under a photoperiod of 16L: 8 D at humidity of 70-75% RH in big plastic containers in laboratory.

b) *Phenacoccus solenopsis:*

This insect pest was reared at 24± 2°C under a photoperiod of 16L: 8D at humidity of 70-75% RH in big plastic containers in laboratory.

From Order: Lepidoptera

a) *Spodoptera litura:*

Spodoptera litura were obtained from the laboratory stock culture from the insectary. The larvae were reared on cabbage leaves as their prime artificial diet. The entire insect culture was maintained in the insectary at 25°C, 70% RH and 16:8 (L: D) photoperiod.

b) *Lampides boeticus:*

Lampides boeticus were obtained from the laboratory stock culture from the insectary. The larvae were reared on legume pods as their artificial diet. The entire insect culture was maintained in the insectary at 25°C, 70% RH and 16:8 (L: D) photoperiod.

Control of one of the insect pest (mealybug) without the use of insecticides

Through periodic field visits, I found that mealybug is major threat in Vadodara agricultural fields. Mealybug is severely damaging almost all major crops of Vadodara. The field surveys also showed that farmers are mainly dependent on chemicals for control of mealybugs. Intensive literature survey and regular visits to agricultural fields shows that these chemicals are harmful for non-target organisms. This was the main driving force to carry out research work to find the alternative control methods for control of these mealybugs.

Biology and control methods of Mealybugs in the laboratory

Biology of mealybug

The Biology of *Phenacoccus solenopsis* was studied on hibiscus twigs at room temperature (24.3-31.2°C, 48.9-71.7% R.H.) in the laboratory. The cotton twigs, harbouring *Phenococcus solenopsis* colonies, were collected from the fields and brought to the laboratory. The mealybugs present on these cotton twigs were gently removed with the help of soft camel hair brush and were released on the hibiscus twigs (Twigs end was rapped with wet cotton) kept in plastic box (20 x 15 cm^2) in laboratory.

Newly hatched crawlers were collected from the ovipositing female of laboratory culture and were placed onto the hibiscus twigs. 25 replicates were used for this experiment. Daily observations were made on molting of nymphs to determine the instar and its duration.

Pupal period (in case of male): pre-oviposition, oviposition and post-oviposition period in case of females and longevity of female and male were recorded.

Isolation and identification of pheromones from mealybugs

Collection of volatile chemicals

Though many methods are available, the following methods were used in isolating the pheromones (volatiles) from mealybugs:

Confinement and wash method

More than 1000 of virgin adult female mealybugs were kept in the plastic petri dishes of 9 cm diameter and depth of 2 cm, having Whatmann filter paper at the base and covered by the lid.

After 24 hrs, the females were removed and entire surface of the petri dish was washed and rinsed with little quantities of the solvent n-hexane. The crude extract obtained from female mealy bug was used for fractionation using gas chromatographic analysis. The crude extract was also used for simple bioassay.

Adsorbent method

This method involves placing of virgin adult female mealybugs into an airborne volatile collection apparatus (Sugie et al., 2008), through which filtered air is passing on to a narrow glass tube with inside diameter of 11.5mm, length of 125 mm which is packed with an adsorbent (2g Tenax-TA 60-80 mesh, Sigma-Aldrich, Bangalore) for 4-5 days (Figure 25). Exposure period of insects was of 24hrs with equal light and dark regimes at 24± 2°C. The trapped volatiles were extracted from adsorbent using an appropriate solvent n-hexane. This solution was then used for chemical fractionation (gas chromatography, GC-MS analysis) and bioassay studies.

Purchase of chemicals and apparatus

Chemicals: All chemicals were purchased from Sigma-Aldrich, India.

Apparatus: Airborne volatile collection apparatus was constructed by JANCOS, Vadodara.

Identification of Pheromones

Gas Chromatography – Mass Spectrometry (GC – MS)

This was helpful to analyze the complex multi component blend of the semiochemicals present in minute quantities. GC – MS used is one of the so-called hyphenated analytical techniques. A gas chromatography- mass spectrometry (Perkin Elmer, Auto system XL GC+, Turbo mass 4.1- software, in SICART, India) was used (Figure 26).

The temperatures of the GC- oven and ion source were 210-220°C, respectively. Silica base capillary column (250 micrometer diameter x 100m length, 0.25 µm thickness of cp- silica 8) was used under a programmed oven temperature condition of 50°C for 1 min with increase to 250 at 5°C / min. Helium was used as carrier gas at a flow rate of 1.2 ml/min.

Behavioral Bioassays

Effect of volatile extract of female mealybug on female as well as on male mealybug

Simple bioassay was conducted by using petri plate having two small filter papers one having control solution n-hexane and other having volatile solution extracted by using confinement and adsorbent methods. The volatile which was collected from the female mealybugs by confinement and adsorbent method 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. Females and Males which were collected during rearing and breeding were release on to it.

The above experiment was also conducted by using female volatile obtained by using 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 and adsorbent method. Observations were taken as per Arai, (2000).

Based on the data collected as described above, the attractive index (AI) was worked out as below:

AI= (No. of insects responded to test material - No. of insects responded to control) / (No. of insects released -No. of insects responded to control)

Effect of botanicals on female mealybug

Selection of plant species and preparation of leaf extracts

The leaf extracts were obtained from the selected 3 plant species because of their repellent properties already reported against other insects. These plants were abundantly available in the study areas. The selected plants and leaf parts were: Neem leaf extract (*Azadirachta indica*), Tulsi leaf extract (*Ocimum sanctum*) and Nilgiri leaf extract (*Eucalyptus globules*).

Methanol leaf extract was prepared using Soxhlet extraction method. The freshly collected leaves were washed thoroughly under tap water. The washed leaves were again rewashed with distilled water. The excess water was drained off. The excess moisture was removed by using muslin cloth and later subjected to air or shade dry. The completely dried leaves without any trace of moisture were collected and made into fine powder by means of a blender or a mixer grinder. Each leaf sample was extracted separately at 50°C for 8 hours in 300 ml of the above solvent.

Later on, the crude extract was then evaporated to obtain concentrated slurry of about 10ml. The concentrated extract, thus obtained, was filtered through a sterilized Whatmann No.1 filter paper. The obtained filtrate was a pure leaf extract from which different required dose levels were prepared.

Repellency bioassays

Bioassays were conducted under ambient laboratory condition of 28±2°C and relative humidity of 80±20 %. The repellent action of the extracts against the mealybug adult females was evaluated by following method.

In this study, large petri plates were used. The test areas consisted of No. 1 Whatmann filter papers which were cut in triangular shape. Different test extracts and concentrations were applied to these triangular strips with possible uniformity with the help of pipette. The treated strips were air dried. On the other side of petri plates, the water dip strip was used as control. These are placed in a petri plates and 15 insects (mealybugs) were placed at the centre of the petri plate and covered with lid.

Each treatment was replicated three times. The number of insects (mealybugs) on control and treated (extract treated) strip was recorded after 12 and 24 hours. Percentage Repellency (PR) values were computed using the formula:

PR= [(NC-NT)/ (NC+NT)] x 100

PR= percentage repellency

NC= insect no. present on control

NT= insect number present on strip treated with extract

Effect of insecticides on predators and parasitoids of mealybugs

Insecticides: The insecticides for toxicity studies were chosen, taking into consideration the broad spectrum of chemical, that are exposed to the popular usage of chemical by the farmers.

The insects were exposed to four main pesticides namely

1. Dursban- Chlorpyrifos 20 % EC: Manufacture by Dow AgroSciences. It is a broad-spectrum contact, stomach poison, with fumigating action and affects more than 280 insect pests, including Chinch bugs, Lepidoptera, Aphids and other Sap-sucking insects. It is based on the active ingredient chlorpyrifos, which belongs to the phosphorothioate group of organophosphorus pesticides. Chlorpyrifos is a broad spectrum insecticide, which inhibits the ACh esterase enzyme in the synaptic gap of the insect nervous system acting as a nerve excitatory poison.

2. Imidacloprid- Media*: Manufactured by Dhanuka Agritech Limited. It's a systemic insecticide. It belongs to class neonicotinoid which is an acetylcholine receptor agonist/antagonist. It is used for control of aphids, Colorado potato beetle, rice hoppers, Thrips, Whiteflies and Soil insects in cereal, corn, cotton, sorghum, fruit, maize, potatoes, rice, sugar beets and vegetables.

3. Folidon 50 FC- Methyl parathion 50 % EC: Manufacture by Chemet Chemical Limited. It is a broad-spectrum contact and stomach poison. It belongs to group of

organophosphorus pesticides. It is used for control of pest like Leaf hopper, Cut worm, Aphids, Caterpillar of Paddy, Wheat, Cotton and Mustard.

All the above mention chemicals were tested at recommended dosage after converting them to ppm (part per million); the dose were increased or decreased geometrically in relation to dose dependent mortality obtained for each chemical. This was done to obtain the LC_{50} estimates for each chemical against mealybug, predator and parasitoid by using probit analysis from SPSS- 19.

On mealybug

Adult female mealybug was separated from stock culture which was cultured on hibiscus twigs at 24.3-31.2° C temperature and at 48.9-71.7% R.H. in the laboratory. Around 15 mealybugs were separated in individual petri plate for experiment work. The experiment was replicated thrice for all three insecticides. The pesticide was applied dorsally on the abdomen of the mealybug. 2 micro litre of pesticide was applied using micropipette. The mealybugs were allowed to acclimatize for 15 minutes before the application. Observation were taken daily till 72 hour; then it was observed for cumulative mortality.

On biological control agents

a) **Predator source**

A predator stock culture was obtained from *Phenacoccus solenopsis* collected from cotton and okra fields in Vadodara. The predatory larva was reared on *Phenacoccus solenopsis* grown on hibiscus leaves and twigs in plastic cages as described above for rearing of mealybugs. 5 pairs of male and female were transferred into a small plastic cage containing 3 instars and virgin females of mealybug. Culture were maintained at 28 ± 1°C, 60 ± 5% RH, under a photoperiod of 16:8 L: D.

Treatment of insecticides

The bio-efficacy of selected insecticides against predator *Scymnobius sordidus* (Horn) was recorded. Topical application on fourth instar of predator was done to know the mortality rate. The petri plates were coated with recommended dose of all the three pesticides. After

treatment, the petri plates are air dried. The 10 predators were released in the treated petri plates. Post release mortality of all stages of both predators was recorded at 72 hours. The mortality data, thus obtained, were corrected with respect to control mortality analysis applying Abbott's formula.

b) Culture of parasitoid

A parasitoid, *Aenasius bambawalei* (Hayat) stock culture obtained from *Phenococcus solenopsis*, was collected from a cotton and okra fields in Vadodara. The parasitoid was reared on *Phenococcus solenopsis* grown on hibiscus leaves and twigs in plastic cages as described above for rearing of mealybugs. 15 pairs of male and female were transferred into a small plastic cage (5 x 5 x 3 cm) containing 3 instars and virgin females of mealybug. Colonies were maintained at 28 ± 1°C, 60 ± 5% RH, under a photoperiod of 16:8 L: D.

Treatment of insecticides

Aenasius bambawalei (Hayat) parasitoid mummies were exposed to insecticides residues to measure their susceptibility to pesticides. 25 mummies of this parasitoid were placed on a sticky tape. The tapes were placed on glass plates, which were sprayed with the recommended field dose of the pesticide using a standard sprayer. The sticky tapes were air dried for one hour and then sprinkled with fine soil to prevent the emerging parasitoids from coming in contact with the pesticide residues and get stuck on the adhesive. The tape was placed in ventilated petri dishes (9.6 cm diameter) and kept under controlled conditions (70 ± 5% RH, 25 ± 0.5°C with a 12:12 (L: D) photoperiod). This experiment was replicated thrice for each pesticide and parasitoid species.

Parasitoid emergence was checked daily between 14:00 and 15:00 hours. Emerged parasitoids were placed in ventilated vials supplied with 50% honey-water solution. Abbott's correction formula was used to adjust for control mortality (Mgocheki & Addision, 2009).

Statistical Analysis

The raw data of all the sampled sites from the field diary of the three consecutive years was transferred in an electronic format in spreadsheet layout (Microsoft Excel). Data so obtained

were analyzed statistically using the ANOVA and SPSS using statistical software prism 3.0 version and graphs were produced accordingly.

Table 4: Description of study sites

Site Code	Site Name	Distance from Vadodara	Area in hectare	Soil Type	Description of the site
Agricultural fields					
A Site1	Channi	25 Kms. towards North	3	Yellow sandy loam	Cultivated fields with large trees and hedges
A Site 2	Varanama	15 Kms. in the Southwest	3	Yellow sandy loam	
A Site 3	Waghodia	15 Kms. on the East	4	Medium black clay	
A Site 4	Dabhoi	30 Kms. in the Southeast	5	Medium black clay	
Urban Community gardens					
U Site A	Sayaji Baug	Within Vadodara	40	Deep black , yellow sandy loam	Garden with river Vishwamitri passing through it
U Site B	Lal baug		4	Yellow sandy loam	Garden with pond & swimming pool
U Site C	Sardar baug		5	Yellow sandy loam	Garden
U Site D	Akota garden		4	Yellow sandy loam	Garden with pond & swimming pool

Table 5: Flora of Agricultural Sites

Site Code	Site Name	Flora
A Site 1	Channi	**Commercial crop:** Cotton (*Gossypium hirsutum*) **Oil seed crop:** Castor (*Ricinus communis*) **Pulses:** Pigeon pea (*Cajanus cajan*) **Cereals:** Maize (*Zea mays*), Sorghum (*Sorghum sp.*) **Vegetable crops:** Spinach (*Spinacia olerecea*), Potato (*Solanum tuberosum*), Tomato (*Solanum lycopersicum*), Brinjal (*Solanum melongena*), Fenugreek (*Trigonella foenum-graecum*), Coriander (*Coriandrum sativum*), Raddish (*Raphanus sativus*), Cauliflower (*Brassica olerasea var. campestris*)
A Site 2	Varanama	**Commercial crop:** Cotton (*Gossypium hirsutum*), Sugarcane (*Saccharum sp.*) **Oil seed crop:** Castor (*Ricinus communis*) **Pulses:** Pigeon pea (*Cajanus cajan*) **Cereals:** Maize (*Zea mays*), Sorghum (*Sorghum sp.*), Pearl millet (*Pennisetum glaucum*) **Vegetable crops:** Tomato (*Solanum lycopersicum*), Brinjal (*Solanum melongena*), Ladies finger (*Abelmosches esculentus*), Cauliflower and Cabbage (*Brassica olerasea var. campestris*), Bean (*Phaseolus vulgaris*)
A Site 3	Waghodia	**Commercial crop:** Cotton (*Gossypium hirsutum*) **Oil seed crop:** Castor (*Ricinus communis*) **Pulses:** Pigeon pea (*Cajanus cajan*), Chickpea (*Cicer orietinum*) **Cereals:** Maize (*Zea mays*), Sorghum (*Sorghum sp.*), Pearl millet (*Pennisetum glaucum*) **Vegetable crops:** Potato (*Solanum tuberosum*), Tomato (*Solanum lycopersicum*), Brinjal (*Solanum melongena*), Fenugreek

		(*Trigonella foenum-graecum*), Coriander (*Coriandrum sativum*)
A Site 4	Dabhoi	**Commercial crop:** Cotton (*Gossypium hirsutum*) **Oil seed crop:** Castor (*Ricinus communis*) **Pulses:** Pigeon pea (*Cajanus cajan*) **Cereals:** Paddy (*Oryza sativa*), Maize (*Zea mays*) **Vegetable crops:** Brinjal (*Solanum melongena*), Ladies finger (*Abelmosches esculentus*)
Common in all fields		**Big trees:** *Azadirachta indica, Ficus bengalensis, Mangifera indica, Glycine abrus, Tamarindus indicus, Moringa oleifera, Citrus limon* **Hedges:** *Euphorbia nerifolia, E. Triucalli, Capparis decidua, C. Zeylacnica, Lawsonia inermis, Nerium indicum, Tagetes erecta, Hibiscus mutubilis, H. Rosa-sinensia, Baugainvillea glabra, Lanatna camara, Annona squamosa, Clerodendrum inermis, Zizyphus mauritiana, Z. Oenoplia, Caeselpenia crista, Calotropis peocera, Capparis cepiaria, Salvadora persica, Opuntia elatior, Ipomea obscura, Coccinea cordifolia, Tinospora cordifolia* **Weeds:** *Melochia corchorifolia, Ammania baccifera, Jussiaea perennis, Eclipta prostrate, Oryza rufipogon, Portulaca oleracea, Sida alba, Solanum nigrum, Boerhavia diffusa, Amaranthus spinosus, Chenopodum album, Cuscuta chinensis, Setaria tomentosa, Euphorbia geniculata, Xanthium strumarium, parthenium hysterophorus, Malvastrum coromandelianum*

Table 6: Flora of Urban Community Gardens

Site Code	Site Name	Flora
U Site A	Sayaji Baug	**Trees:** *Ficus bengalensis, Azadirachta indica, Terminalia catappa, Feronia limonia, Aegle marmelos, Butea monosperma, Casuarina equistifolia, Tamarindus indicus, Dalbergia latifolia, Mangifera indica, Syzygium cumine, Tabebuia spectabilis* **Herbs, Shrubs, Creepers:** *Caeselpenia pulcherrima, Commelina nudiflora, Tephrosia purpurea, Hibiscus lobatus, Abutilon indicum, Bougainvillea spectablis, Ixora, Coccinea, Tephrosia strigosa, Andropogon annulatus, Zomia gibbosa, Vinca rosea, Rosa chinensis, Lantana camara, Canna indica, Nerium odorum, Oxalis comiculata, Giaillardia pinnatifida*, etc.
U Site B	Sardar Baug	**Herbs, Shrubs, Creepers:** *Canna indica, Tecoma stans, Ixora, Hibiscus, Cymbopogon martini, Cynodon dactylon, Helianthus annus, Rosa chinensis, Lantana camara*
U Site C	Lal Baug	**Trees:** *Butea monosperma* **Herbs: Shrubs, Creepers:** *Canna indica, Nerium odorum, Tecoma stans, Ixora rubiacea, Hibiscus syriacus, Ipomoea palmata, Cymbopogon martini, Cynodon dactylon, Helianthus annus, Rosa chinensis* **Aquatic plants:** *Hydrilla verticilla, Typha augustata, Vallisnaria spiralis*
U Site D	Akota Garden	**Trees:** *Casuarina equisetifolia, Butea monosperma* **Herbs, Shrubs, Creepers:** *Canna indica, Nerium odorum, Tecoma stans, Ixora rubiacea, Hibiscus syriacus, Oxalis corniculata, Cynodon dactylon, Helianthus annus, Lantana camara, Vinca rosa, Giaillardia pinnaifa,*
Common in all fields		**Trees:** *Polualthia longifolia, Saraca indica, Oreodoxa regia, Cassia tora*

Table 7: Insect pests and the crops they damage in the agricultural fields of Vadodara

ORDER	FAMILY	PEST NAME	CROP	STATUS
Orthoptera	Gryllotalpidae	*Gryllotalpa fossor* (Mole cricket)	Paddy	1 Grade
	Acrididae	*Schistocerca gregaria* (Desert locust)	Cotton, Wheat	2 Grade
Isoptera	Termitidae	*Microtermes obesi*	Cotton, Sugarcane & Wheat	0 Grade
		Microtermes mycophagus	Castor, Cotton & Sugarcane	2 Grade
		Odontotermes redemanni	Sugarcane & Wheat	0 Grade
		Odontotermes obesus	Sugarcane, Cotton, Wheat & Castor	1 Grade
		Odontotermes guptai	Sugarcane, Cotton, Wheat & Castor	1 Grade
		Odontotermes bhagwathi	Sugarcane, Cotton, Wheat & Castor	1 Grade
Hemiptera	Aphididae	*Leptocentrus taurus* (Horned treehopper)	Brinjal	0 Grade
		Nephotettix nigropictus (Green rice leafhopper)	Paddy	0 Grade
		Aphis gossypii (Cotton aphids)	Cotton, Brinjal	4 Grade
		Aphis crassivora (Cow pea aphids)	Chick pea, Bean	4 Grade
		Rhopalosiphum maidis (Maize aphid)	Maize, Wheat	4 Grade
		Myzus persicae (Green peach aphids)	Cotton, Spinach, Cabbage, Radish, Brinjal	4 Grade
	Aleyrodidae	*Bemisia tabaci* (Whitefly)	Cotton, Tobacco, Spinach, Cabbage, Radish, Brinjal	4 Grade
	Lophopidae	*Pyrilla perpusilla* (Sugarcane leaf hopper)	Sugar cane, Maize, Wheat, Pea.	2 Grade
	Pseudococcidae	*Maconellicoccus hirsutus* (Hibiscus mealy bug)	Cotton, Tomato, Ladies finger	3 Grade

ORDER	FAMILY	PEST NAME	CROP	STATUS
	Lygaeidae	*Blissus gibbus*	Sugar cane	0 Grade
		Lygaeus militaris (Plant bug)	Cotton	0 Grade
		Lygaeus hospes (Lygaeid bug)	Cotton	2 Grade
	Coreidae	*Riptortus linearis* (Spined legume bug/ Sap sucking bug)	Chick pea, Bean, Gram	0 Grade
		Anoplocnemis phasiana (Coreid bug)	Chick pea, Brinjal	0 Grade
		Clavigralla gibbosa (Pod sucking bug)	Chick pea	1 Grade
	Pentatomidae	*Nezara gramineae* (Green plant bug)	Wheat, Paddy, Castor	2 Grade
	Psychidae	*Bagrada picta* (Bagrada bug/ Colourful bug)	Cabbage	0 Grade
Thysanoptera	Thripidae	*Caliothrips indicus* (Groundnut thrips)	Brinjal, Wheat	4 Grade
		Scirtothrips dorsalis (Chilli thrips)	Cotton, Brinjal, Radish	2 Grade
Coleoptera	Dynastidae	*Oryctes rhinoceros* (Coconut rhinoceros beetle)	Sugarcane	2 Grade
	Melolonthidae	*Holotrichia insularis* (White Grub)	Sugarcane, Paddy	2 Grade
		Holotrichia tuberculipennis (Bomboo beetle)	Sugarcane, Paddy	1 Grade
		Autoserica insanabilis (Scarab beetle)	Sugarcane, Paddy	1 Grade
	Bruchidae	*Callosobruchus maculates* (Bruchid beetle)	Gram	1 Grade
	Bostrychidae	*Rhyzopertha dominica* (Lesser grain borer)	Rice , Wheat	1 Grade
	Coccinellidae	*Henosepilachna vigintioctopunctata* (Twenty- eight spot lady bird beetle)	Brinjal	0 Grade
	Meloidae	*Psaldolytta menoni* (Blister beetle)	Bean	0 Grade
		Mylabris pustulata (Orange Blister Beetle)	Bean	1 Grade

ORDER	FAMILY	PEST NAME	CROP	STATUS
Diptera	Agromyzidae	*Melanagromyza obtuse* (Pigeonpea pod fly)	Chick pea, Bean	2 Grade
Lepidoptera	Yponomeutidae	*Plutella xylostella* (Diamondback Moth)	Cabbage	4 Grade
	Pyralidae	*Scirpophaga auriflua* (Sugarcane top shoot borer)	Sugarcane	4 Grade
	Gelechiidae	*Platyedra gossypiella* (Pink bollworm)	Cotton	4 Grade
	Nymphalidae	*Melanitis leda* (Common Evening Brown)	Paddy, Wheat	0 Grade
	Lycaenidae	*Lampides boeticus* (Long-tailed Blue)	Gram, Chick pea	4 Grade
	Noctuidae	*Earias insulana* (Spiny bollworm)	Cotton	4 Grade
		Trichoplusia ni (Cabbage looper)	Cabbage	2 Grade
		Achaea janata (Castor Semi-looper)	Castor	3 Grade
		Helicoverpa armigera (American bollworm)	Cotton, Cabbage, Radish	4 Grade
		Spodoptera littoralis (African Cotton Leaf worm)	Cotton, Cabbage, Radish	4 Grade
		Pericallia ricini (Darth Maul Moth)	Maize, Brinjal	2 Grade
	Tipulidae	*Creatonotus gangis* (Hong Kong Tiger Moth)	Paddy, Sugarcane	2 Grade
	Arctiidae	*Estigmene lactinea* (Cram hairy caterpillar)	Cotton	2 Grade

MAP OF THE STUDY SITES

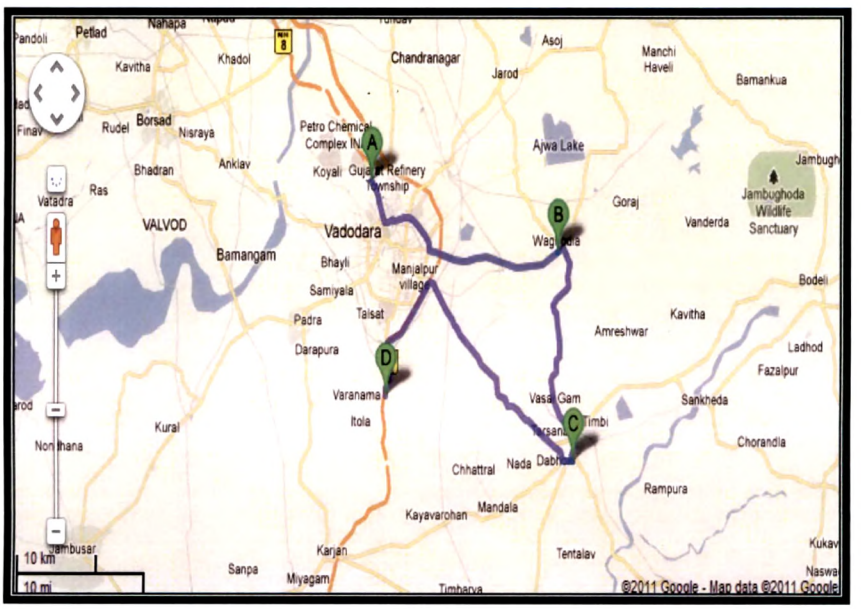

Figure 1 Map of Vadodara showing agricultral field sites

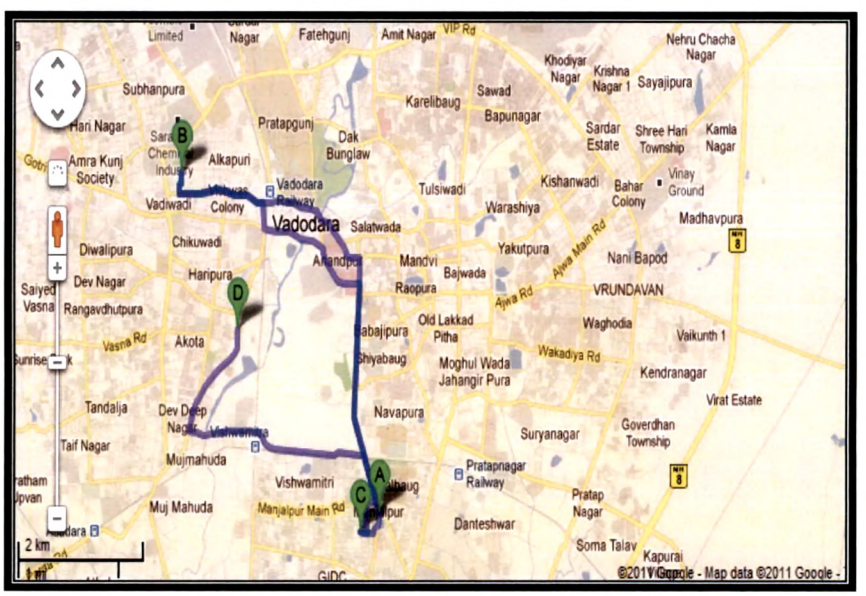

Figure 2 Map of vadodara showing urban community garden sites

PLATE 1 AGRICULTURAL FIELDS

Figure 3 Bajra field in Varanama

Figure 4 Brinjal field in Varanama

PLATE 2 AGRICULTURAL FIELDS

Figure 5 Fields of cotton in Channi

Figure 6 Cauliflower fields in Channi

PLATE 3 AGRICULTURAL FIELDS

Figure 7 Wheat field in Dabhoi

Figure 8 Potato field in Dabhoi

PLATE 4 AGRICULTURAL FIELDS

Figure 9 Fields of Castor in Waghodia

Figure 10 Beans field in Waghodia

PLATE 5 COMMUNITY GARDENS

Figure 11 Lal baug

Figure 12 Sayajirao Garden

PLATE 6 COMMUNITY GARDENS

Figure 13 Sardar baug